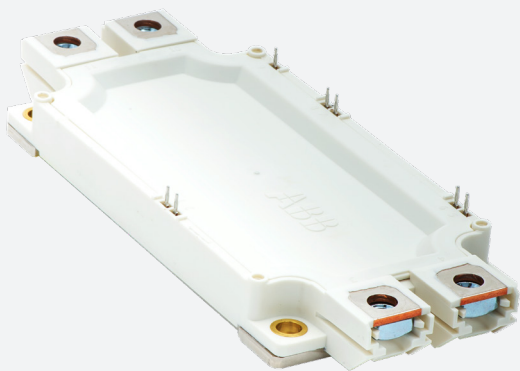


Use and installation instructions for LoPak1 modules - Thermal paste



This application note provides some basic guidelines for installing and using the LoPak1 modules in a range of environments. Following these guidelines ensures safe mechanical, electrical and thermal connections that are crucial for reliable operation of these power modules.

1. General

The descriptions and recommendations in this document cannot replace an accurate assessment and evaluation of all aspects of the application related to the intended use of the device. All LoPak1 modules undergo a final test according to IEC60747-9 and IEC60747-15 before delivery.

2. ESD considerations

IGBTs are sensitive to electrostatic discharge (ESD). All LoPak1 modules are ESD protected during transportation and storage. When handling the modules, the gate and auxiliary terminals of both switches should be short-circuited with the ESD protection cap provided or with a metal strip to prevent damage by static charges (IEC60747-1, chap. VIII). A conductive-grounded wrist strap and a conductive-grounded work station are strongly recommended during assembly.

3. Climatic conditions, storage and transportation

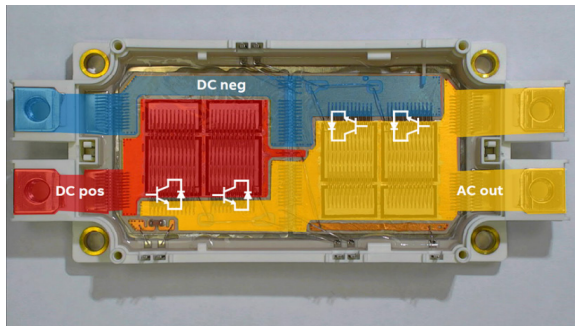
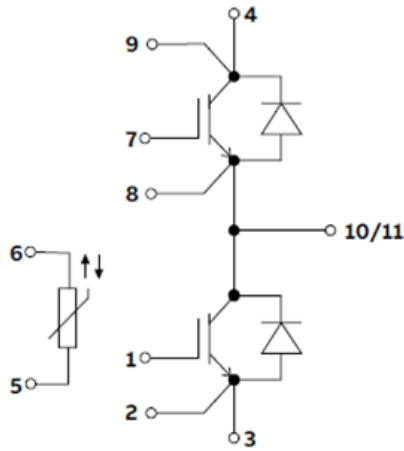
During transportation and storage of the modules, extreme forces such as shock or vibration should be avoided as well as environmental conditions exceeding the recommended limits.

4. Climatic conditions during active, current carrying operation of LoPak1 modules

The LoPak1 modules are not hermetically sealed. The housings and the molding compound, used for the electrical isolation within the housing, are permeable by humidity and gases in both directions. Humidity differences will therefore be equalized. The climate conditions for LoPak1 modules in active, current carrying operation are specified according to Environmental Specification 5SZK 9118. In the case of a humid atmosphere that causes condensation, or operation in climatic conditions surpassing class 3K3 of EN60721-3-3, appropriate measures must be taken to avoid liquid droplet depositions under all circumstances.

5. Terminals

The connection between gate-drive circuit and the control terminals of the LoPak1 module should be as short as possible. Coaxial cables, twisted wires or mounting of the gate-drive PCB directly on the auxil-



01 Device circuit diagram with all internal and external connections in the phase-leg configuration

ary terminals are highly recommended to prevent any electro-magnetic interference (EMI) from the power circuitry to the gate signals. Figure 1 shows the circuit diagram of the device with all internal and external connections in the phase-leg configuration. A low inductance symmetrical copper busbar, mounted directly on top of the module, is highly recommended for all LoPak1 modules.

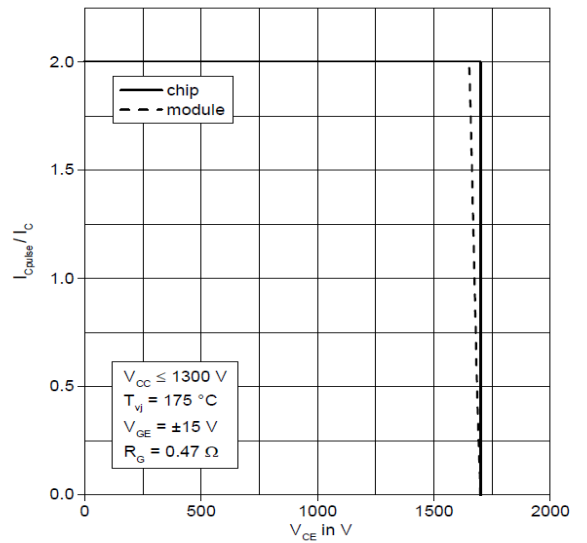
6. Safe operating area / Voltage rating

The peak turn-off over-voltage (V_{CEM}) must be kept below the maximum rated collector-emitter voltage (V_{CES}) for each switch in the LoPak1 module. Therefore, it is important to use a busbar with low inductance L_{σ} . Please refer to the module data sheet for the internal module stray inductance ($L_{\sigma CE}$).

$$V_{CEM} = |di/dt| \cdot (L_{\delta CE} + L_{\sigma}) + V_{DC} \leq V_{CES} \quad \text{Eq. 1}$$

The “Turn-off safe operating area (RBSOA)” graph in the module data sheet shows the maximum allowed operating conditions with the peak turn-off over-voltage measured at the module power terminals and at the chip (figure 2).

There are several factors limiting the voltage class and operating range of the device when used at altitudes higher than 2000 m above sea level. The lower air pressure will affect the cooling performance, the changed dielectric strength of the air will reduce the clearance distance of the device and the statistical failure rate due to higher cosmic radiation levels will also impact the maximum operating voltage. All

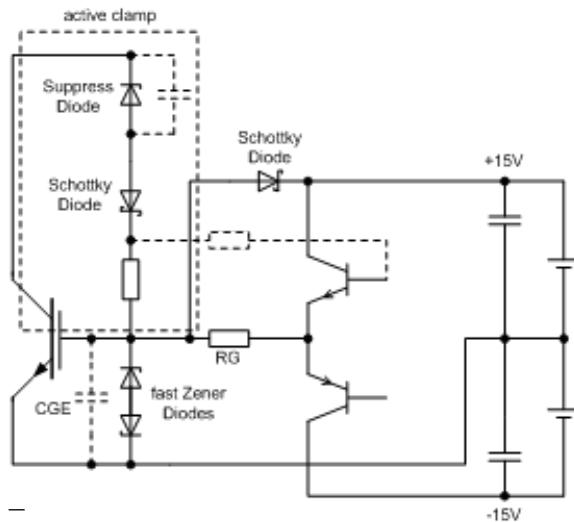


02 Turn-off safe operating area (RBSOA)

these factors should be carefully analyzed in the design phase. The LoPak1 application notes provide data to optimize use of the device for the application conditions (see also application support).

7. Gate drive

It is recommended the LoPak1 modules are operated with a turn-on gate voltage of +15 volts (V) for low on-state losses and good short-circuit ruggedness. Turn-on gate-voltages of more than +15 V result in slightly lower on-state losses but reduce short-circuit ruggedness. A turn-off gate voltage of -5 to -15 V is recommended for low turn-off losses and high dv/dt immunity. The gate driver can be mounted or fixed either by using the press fit pins or soldering pins.



03 Gate-drive recommendations

Clamping the gate voltage to 15 V for protection against high inductive short-circuit events is also recommended. This can be achieved by either clamping the gate-voltage as close as possible to the gate-emitter auxiliary terminals of the module with anti-series fast Zener diodes, or by feedback from the gate to the +15 V supply capacitor using a fast Schottky barrier diode (figure 3).

If, due to high stray inductance or DC-link voltage, the turn-off over-voltage of the module cannot be kept below V_{CES} (equation 1), an active clamp circuit as shown in figure 3 can be used.

If the data sheet specifies a gate-emitter capacitor (C_{GE}), it is recommended to mount C_{GE} as close as possible to the module, preferably on the gate-emitter terminals. Otherwise the effect of C_{GE} will be considerably reduced, especially when long gate wires are used.

8. Heat sink specification

The mounting area on the heat sink and the module must be clean and free of particles to obtain the maximum thermal conductivity between the module and the heat sink. In addition, ridges with more than 10 μm height, or particles, can lead to deformation of the Cu baseplate and cracks in the ceramic and must be avoided. The mechanical specification of the mounting surface is:

- Flatness: 30 micrometer (μm) over entire contact area
- Roughness: Rz - 15 μm , no ridge larger than 10 μm

9. Application of thermal paste

In order to avoid air gaps at the interface between the module and the heat sink, thermal paste must be applied. The function of the grease is to minimize the thermal interface resistance by filling any voids and allowing a metal-to-metal contact wherever possible.

Possible paste types include Wacker P12, Electrolube HTC(P) and Dow Corning TC-5121. Please ensure the application recommendations of the paste manufacturers are considered.

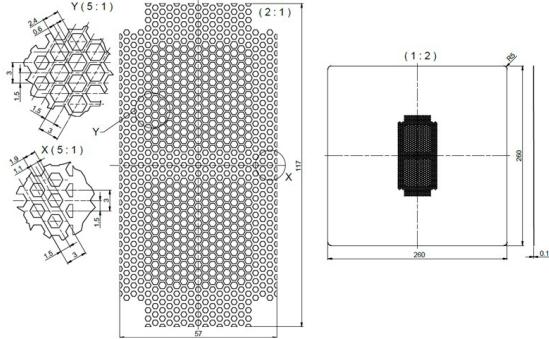
- It is vital that the paste is applied as a homogeneous, even and reproducible layer. An uneven layer of paste can lead to cracks in the ceramic insulator inside the module.
- Prior to application of the paste, both heat sink and baseplate area of the module must be cleaned (e.g. with ethylene glycol). Both surfaces must be completely clean and free from damage. The thermal paste can be applied either to the mounting area of the heat sink or to the base area of the module. A rubber roller, or preferably a stencil or screen print, is recommended to ensure an even distribution of the grease.
- For manual application a paste layer of 50 μm or 100 μm , depending on stencil thickness, paste type and viscosity, is recommended. The thickness can be checked with a measuring gauge (for example Wet Film Comb, www.elcometer.com).

An advanced method for paste application is stencil-printing. ABB provides a CAD drawing for a suitable stencil (5SZK 8101). The stencil, shown in figure 4, takes the topology of the ABB module baseplate into account. The thickness of the stencil plate depends on the type of thermal paste used. Typically, 50 μm or 100 μm grease layer thickness is used, but it is strongly recommended this is verified with optical assessment of the paste layer (figure 9/10) or with R_{th} measurements.

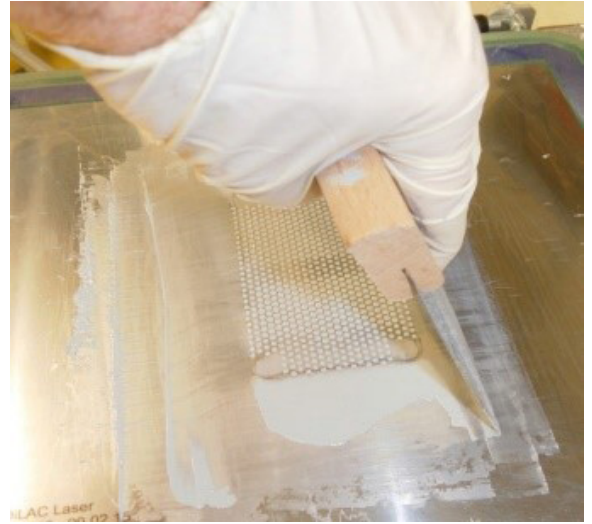
We recommend the following procedure for thermal paste application:

1. Using a stencil print equipment as shown in figure 5.
2. For low viscosity pastes (e.g. Wacker P12, Electrolube HTC(P)) the paste can be applied using a rubber roller (figure 6). Surplus paste must be removed with a scraper. The final paste thickness can depend on whether the scraper is pushed or pulled.

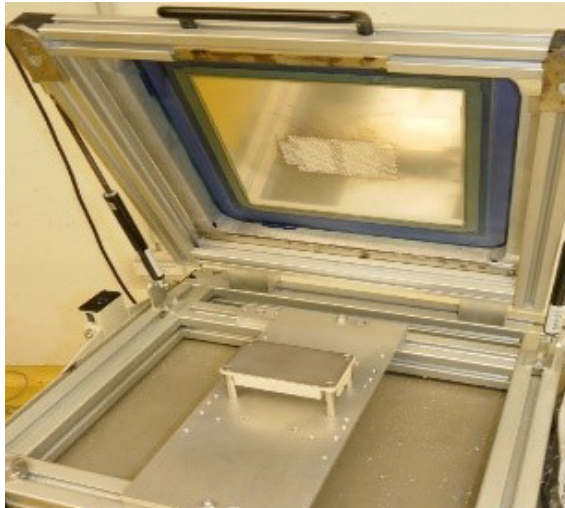
3. For high viscosity or stickier pastes (e.g. Dow Corning (TC-5121), application with a rubber roller is difficult as the paste might stick to the roller. In this case the paste can be applied directly with the scraper (figure 7). The final paste thickness can depend whether the scraper is pushed or pulled.



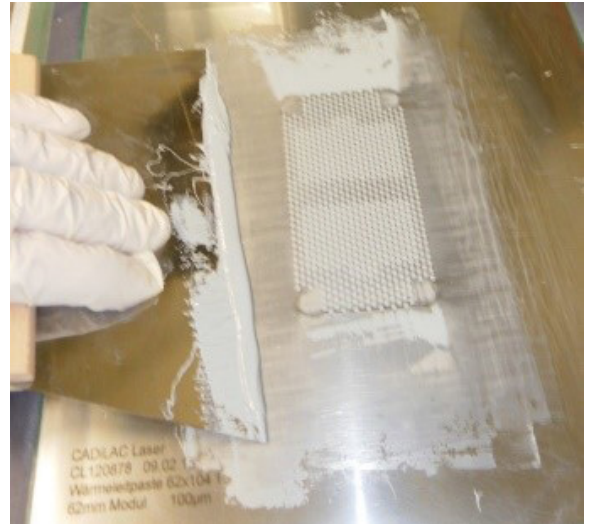
04 Stencil drawing for LoPak1 type modules



06b Applying the paste onto the stencil using a scraper (low viscosity pastes)



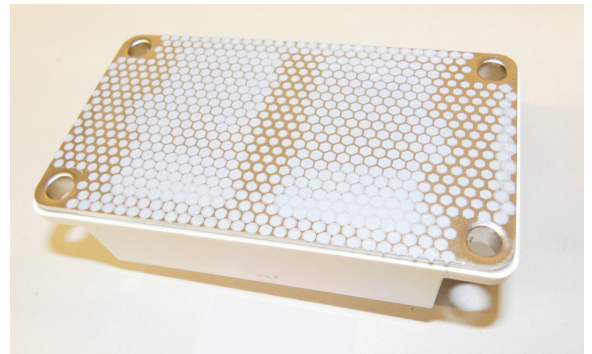
05 Stencil print tooling



07 Applying the paste onto the stencil using a scraper (high viscosity pastes)



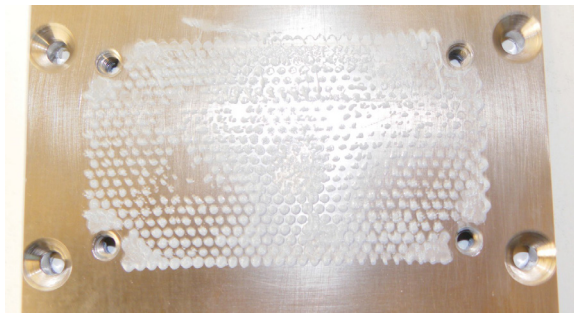
06a Applying the paste onto the stencil using a rubber roller



08 Example of a module after stencil print



09 Example of good paste coverage



10 Example insufficient paste coverage

Figure 8 shows an example of a module baseplate after stencil printing with high viscosity paste. It is crucial to make a visual assessment of the paste layer quality for a couple of samples after mounting the module onto the heat sink. Sufficient grease layer thickness can be assumed if the complete module surface is covered with paste and a small stripe of surplus grease is visible along the baseplate edges.

Figure 9 shows a good example with the complete surface covered with paste after its removal. Figure 10 shows an example of insufficient paste coverage. The reason for this could be either an insufficient paste layer thickness when using manual application or an insufficient thickness of the stencil plate.

10. Mounting the module onto the heat sink

After applying the thermal grease, the module is placed on the heat sink. Any movement of the module should be avoided after it is positioned on the heat sink. The fixing screws are inserted and evenly

tightened by hand (~6 Nm) or by electric or pneumatic screwdrivers with a torque limit of 6 Newton meter (Nm) according to the sequence given in figure 11.

The screws are then tightened again to the final torque (per table 1 and figures 11 and 12), following the same sequence. The use of torque wrenches with automatic release is recommended.

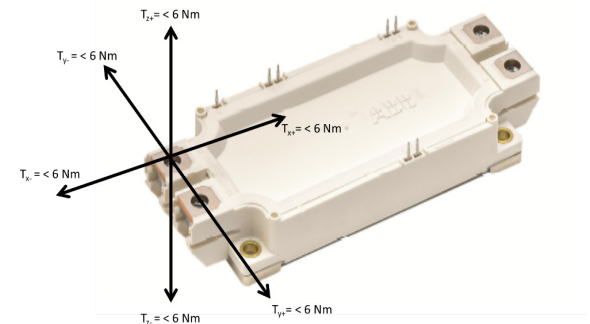
The two-step procedure must be followed to allow the module baseplate to relax and conform to the heat sink. Depending on the viscosity of the thermal grease, or in case of phase change material, it is

Mounting screws	Type	Torque values (Nm)	
		Minimum	Maximum
Base to heat sink	M5	3	6
Main terminal	M6	3	6
Auxiliary terminals	Plug		

Table 01 Recommended mounting torques



11 Tightening sequence to mount the module to the heat sink



12 Maximum permissible mounting torques at 25 °C

strongly recommended to recheck the torque after 15 - 30 minutes and retorquing to the final torque value if necessary, following the sequence shown in figure 11.

11. Mounting of the busbar and auxiliary connections

The busbars must be mounted onto the collector and emitter power terminals with the recommended torque given in table 1. It is important that the mounting torque is above the minimum requirement, and it is better close to the maximum recommended value to allow good electrical and thermal contact. The cross sections of the busbars must be sufficiently large to avoid heating of the module by busbar resistive losses. Permanent mechanical stress to the power and auxiliary terminals, for example by rotating forces, must be avoided. Special attention must be paid to avoiding forces caused by shock and vibration as well as forces due to thermal expansion of the busbar during operation. Supporting the busbar could be done using fixing posts close to the modules on each side, an example of which is shown in figure 13).

If soldering pins are used, the auxiliary pins must be connected by plugs according to an appropriate standard such as DIN 46245, while observing the ESD guidelines. If an external driver board is used, it is recommended that the contact areas be mechanically relieved after soldering by mounting the PCB onto the module using the four PCB mounting stand-offs.

If press fit pins are used, a reasonable amount of contact area between the PCB hole and press fit pin should be left in the PCB design and the appropriate mounting tools should be used. Also note that the auxiliary emitter and collector terminals are not designed to carry any load current.

Maximum forces at the terminals during the assembly process are shown in figures 11 and 12. Connecting parts, such as the busbar and gate-unit, must be designed and assembled in a way that those forces are not exceeded.

Important notes:

- Impact wrenches can damage the module or cause jamming of the screw and are not recommended.
- Do not use too fast screwing speed as this might result in excessive torque values or jamming of the screw.
- The use of washers and lock- or spring washers is recommended.
- To avoid the screws jamming, always use screw material that matches the material of the thread: for example, threads in the heat sink or the terminal nuts. The module's terminal nuts are made from 10B21 carbon steel.
- The screw lengths must be selected to ensure the maximum tightening depth of the main connections is not exceeded.

12. Cleaning during replacement

The heat sink must be cleaned to remove any remaining debris when replacing the power semiconductor module. Removing the paste creates no special industrial safety demands. A lint free cloth can be used for cleaning, and the surface of the heat sink must not be damaged during this process.

Step 1: Remove module from the heat sink

Step 2: Clean off coarse particles

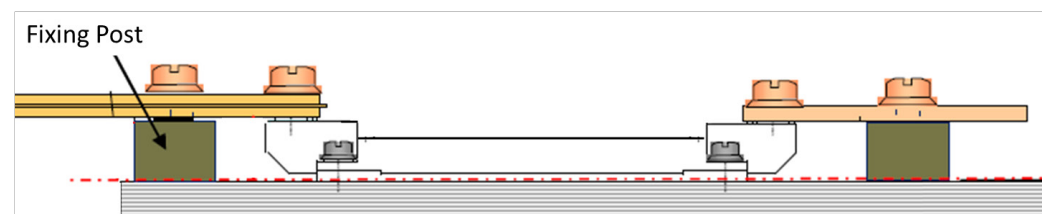
Step 3: Complete a final wipe-down

13. Revision history

Version	Change	Authors
01	May 2020	Roc Blumenthal

14. Related documents

- 5SYA 1451 Data sheet 5SNG 0450R170300 LoPak1 phase leg IGBT module
- 5SYA 2045 Thermal runaway during blocking
- 5SYA 2053 Applying IGBT
- 5SYA 2058 Surge currents for IGBT diodes
- 5SYA 2093 Thermal design and temperature ratings of IGBT modules
- 5SYA 2098 Paralleling of IGBT modules



13 Device circuit with all internal and external connections for the phase-leg configuration