

MOUNTING INSTRUCTION / 安装说明

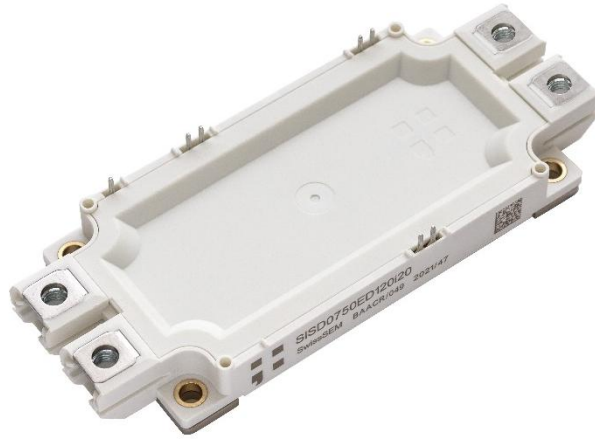
SEM AN 22-0001

Application note for ED-Type modules

ED 封装模块应用说明

swiss
semicon
ductors.

MOUNTING INSTRUCTION 安装说明



Basic guidelines for the application, environmental conditions and installation of ED-type product platform are provided within this application note. Obeying these guidelines ensures safe mechanical, electrical and thermal connections which are crucial for a reliable operation of such power modules.

本应用说明提供了有关 ED 封装产品平台的应用、环境条件和安装的基本指导原则。遵守这些准则可确保安全的机械、电气和热连接，这对于此类功率模块的可靠运行至关重要。

1 GENERAL REMARKS AND PRECAUTIONS 一般性说明和注意事项

The recommendations and guidelines provided here cannot replace a detailed assessment and evaluation of all aspects of the application related to the intended use of the power-module. All ED-type modules pass a final production test-sequence according to IEC60747-9 and IEC0747-15 prior shipment.

此处提供的建议和指导不能取代对与功率模块预期用途相关应用的所有方面进行的详细评估和评价。所有 ED 封装模块在出厂前都要通过符合 IEC60747-9 和 IEC0747-15 标准的一系列最终生产测试。

1.1 ESD

IGBT power modules are sensitive to electrostatic discharge (ESD). All ED-type power modules are protected during transportation and storage in the provided packings. A short circuit with ESD-protection between the gate and the auxiliary terminals of high-side and low-side switch should be guaranteed, when handling the modules, to prevent ESD related damages by static charges (IEC60747-1, chapter VIII). A conductive-grounded wrist strap and a conductive-grounded workstation are strongly recommended during the assembly process.

IGBT 功率模块对静电放电 (ESD) 非常敏感。所有 ED 封装功率模块在运输和储存过程中都会包装好，都会被完好保护。在搬运模块时，应确保上桥和下桥的栅极和辅助端子之间有静电放电保护，以防止静电放电造成的损坏 (IEC60747-1, 第八章)。在装配过程中，强烈建议使用导电接地腕带和导电接地工作台。

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S. M. COO and PL	R. S. VP Product Management & Application	C. T. VP Supply and Quality

1.2 Climatic conditions 气候条件

During transportation and storage of the ED-type modules, extreme forces such as shock and vibration should be avoided as well as environmental conditions exceeding the recommended limits. The ED-type modules are not hermetically sealed. The housings and the silicone gel used for the electrical isolation within the housing, are permeable by humidity and gases in both directions. Humidity differences will therefore be equalized.

在 ED 封装模块的运输和储存过程中，应避免冲击和振动等极端外力，以及超出建议限值的环境条件。ED封装模块并非密封。外壳和壳内用于电气隔离的硅凝胶可被湿气和气体双向渗透。因此，湿度差异将被均衡。

1.2.1 Storage 存储

Storing the modules at the specified temperature limits stated in the datasheet is possible, however not recommended. The recommended storage conditions according to Table 1-1 should be assured for the recommended storage time of maximum two years.

可以在数据表中规定的温度限制下存放模块，但不建议这样做。在建议的最长两年储存时间内，应确保表 1 1 所列的建议储存条件。

Table 1-1 Climatic conditions for storage 储存的气候条件

POS 位置	PARAMETER 参数	VALUE 值
1	Temperature 温度	5 °C to 40 °C
2	Relative humidity 相对湿度	20 % to 75 %
3	Precipitation, condensation, ice, frost and similar 降水、凝露、结冰、结霜及类似现象	Not allowed at any time 任何时候都不允许

1.2.2 Operation 运行

The climate conditions for the non-hermetically sealed ED-type power modules in active, current carrying operation are specified as EN60721-3-3 class 3K3. 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 on the module in all circumstances. Corrosive gases must be avoided during operation and storage of the devices.

非密封 ED封装功率模块在有源、带电运行时的气候条件规定为 EN60721-3-3 级 3K3。在导致凝露的潮湿环境下，或在超过 EN60721-3-3 3K3 级的气候条件下运行时，必须采取适当措施，在任何情况下都要避免液滴沉积在模块上。在设备运行和存放期间必须避免腐蚀性气体。

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2 ELECTRICAL 电气

2.1 Terminals and circuitry 接线端子和电路

The connection between gate-drive circuit and the control terminals of the ED-type module should be as short as possible. Coaxial cables, twisted wires or mounting of the gate-drive PCB directly on the auxiliary terminals are recommended to prevent any electromagnetic interference (EMI) from the power circuitry to the gate signals.

栅极驱动电路与ED封装模块控制端子之间的连接应尽可能短.建议使用同轴电缆、双绞线或将栅极驱动电路板直接安装在辅助端子上,以防止电源电路对栅极信号产生电磁干扰(EMI)。

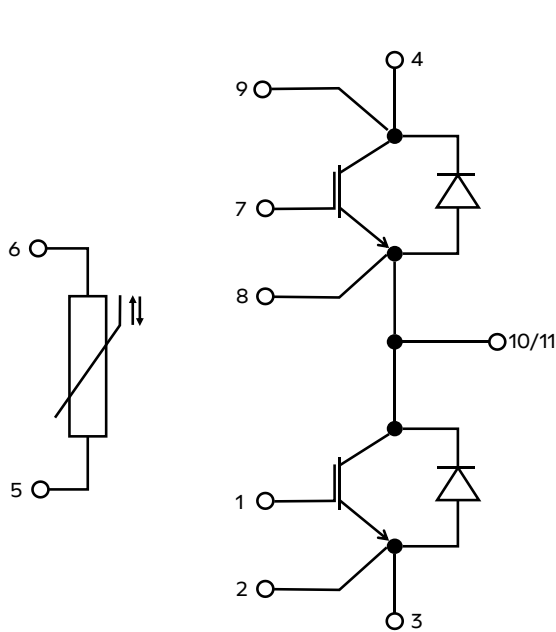


Figure 2-1 Schematic circuit diagram 电路框原理图

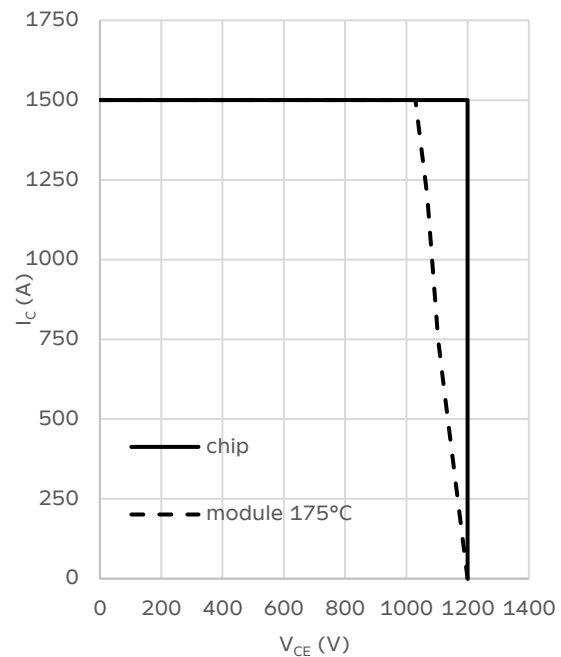


Figure 2-2 IGBT RBSOA $I_c = f(V_{CEM})$, $R_{Goff} = 1.5 \Omega$, $V_{GE} = \pm 15 V$, highest current rating variant. 最高额定电流变量.

A low inductance symmetrical copper busbar, mounted directly on top of the module, is recommended for all ED-type power modules.

建议所有ED封装功率模块都采用直接安装在模块顶部的低电感对称铜母线。

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2.2 Safe operating area / Voltage rating 安全工作区 / 额定电压

It is imperative to keep the peak turn-off over-voltage V_{CEM} below the maximum rated collector-emitter voltage V_{CES} for each switch in the ED-type power module. Hence, it is recommended to apply a busbar with low inductance L_s . Please, refer to the datasheet for the internal module stray inductance L_{SCE} .

ED 封装功率模块中，每个开关的关断电压峰值 V_{CEM} 必须低于最大额定集电极-发射极电压 V_{CES} 。因此，建议使用低电感 L_s 的母线。有关内部模块杂散电感 L_{SCE} ，请参阅数据手册。

The safe operating area (RBSOA) turn-off graph in the datasheet (Figure 2-2) indicates the maximum allowed operating conditions with the peak turn-off over-voltage measured at the module power terminals and at the chip that is considered equivalent to values measured between auxiliary Collector and auxiliary Emitter of the HS-switch and HS-auxiliary Emitter and LS-auxiliary Emitter for the LS-switch (Figure 2-1). Several factors limit the voltage and operating range of the power module in applications running 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.

数据表中的安全工作区 (RBSOA) 关断图 (图 2 2) 显示了最大允许工作条件，在模块电源端子和芯片上测得的关断过电压峰值相当于 HS 开关的辅助集电极和辅助发射极之间以及 LS 开关的 HS 辅助发射极和 LS 辅助发射极之间测得的数值 (图 2 1)。在海拔高于 2000 米的应用中，有几个因素限制了电源模块的电压和工作范围。较低的气压会影响冷却性能，空气介电强度的变化会减小设备的间隙距离，较高的宇宙辐射水平导致的统计故障率也会影响最大工作电压。

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S. M. COO and PL	R. S. VP Product Management & Application	C. T. VP Supply and Quality

3 INSTALLATION 安装

3.1 Heatsink 散热器

Maximum thermal conductivity between the power module bottom-side and the heatsink must be ensured by using a clean heatsink, being free of any particles or ridges of more than 10 µm. There is a risk that such objects deform the Cu-baseplate and result in cracks of the ceramic layers inside the power module. The following conditions must be obeyed in the application:

- Roughness: $R_z \sim 15 \mu\text{m}$
- Flatness: 30 µm (valid for entire contact area)

必须使用干净的散热片，确保功率模块底面和散热片之间的热传导率最大，散热片上不得有超过 10 µm 的颗粒或棱角。这些物体有可能使铜底板变形，导致功率模块内部的陶瓷层出现裂缝。在应用中必须遵守以下条件：

- 粗糙度: $R_z \sim 15 \mu\text{m}$
- 平面度: 30 µm (对整个接触区域有效)

3.2 Applying thermal paste 涂抹导热硅脂

The application of thermal paste is a must to ensure good thermal conductivity between the power module and the heat sink and will prevent "dry" contact and enables a metal-to-metal contact wherever possible. Typical thermal pastes include but are not exclusively limited to: Honeywell PTM6000HV-SP, Wacker P12, Electrolube HTC(P), Dow Corning TC-5121. Please obey the guidelines provided by the manufacturers.

必须使用导热硅脂，以确保功率模块和散热器之间良好的导热性，防止 "干" 接触，并尽可能实现金属与金属之间的接触。典型的导热硅脂包括但不限于以下几种：霍尼韦尔 PTM6000HV-SP、瓦克 P12、Electrolube HTC(P)、道康宁 TC-5121。请遵守制造商提供的指南。

Please ensure the following by applying thermal paste:

- Generate a reproducible, homogeneous, and even layer. Inhomogeneities might result either in dry contacts or act like particles and result in a cracked ceramic.
- Clean all interfaces the thermal paste will be in contact with prior applying thermal paste (e.g. IPA ethylene glycol etc.)
- A stencil or screen printer is recommended to ensure an even distribution of the grease
- In case of a manual application of the grease a thickness of 50 µm to 100 µm is recommended depending on paste type, its viscosity and stencil thickness.
- A subsequent process control (e.g. concerning thickness, volume, pattern etc.) is recommended.

请在涂抹导热硅脂时确保以下几点：

- 形成可重复的、均匀一致的涂层。不均匀可能导致干接触或像颗粒一样导致陶瓷破裂。
- 在涂抹导热硅脂之前，要清洁导热硅脂接触的所有界面（如 IPA 乙二醇等）。
- 建议使用钢网或丝网印刷机，以确保导热硅脂均匀分布。
- 在手动涂抹导热硅脂的情况下，建议厚度为 50 µm 至 100 µm，具体取决于膏体类型、粘度和钢网厚度。
- 建议随后进行工艺控制（如厚度、体积、图案等）。

SwissSEM provides a stencil mask design Figure 3-1. SwissSEM 提供模板掩膜设计图 31。

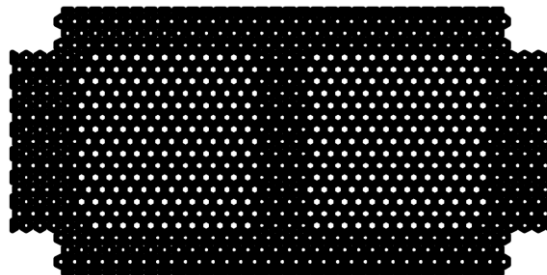
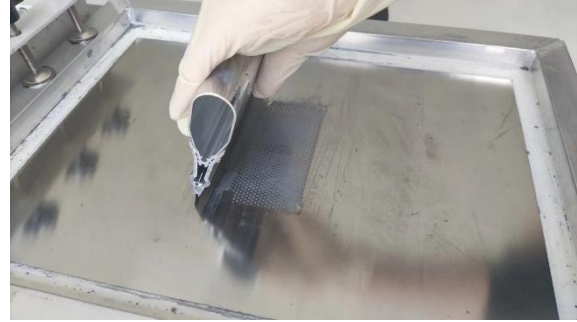


Figure 3-1 Stencil mask drawing provided by SwissSEM (available on request); 模板掩膜图由 SwissSEM 提供 (可应要求提供)

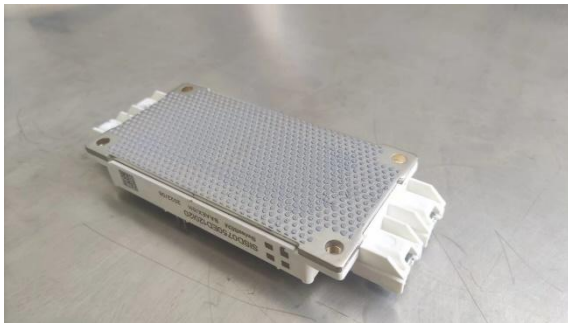
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Stencil printing tooling 钢网印刷工具



Thermal grease application onto the stencil using a scraper (suitable for low viscosity pastes) 使用刮刀在钢网上涂抹导热硅脂 (适用于低粘度硅脂)



Example of an ED-type module after stencil printing 经过钢网印刷的ED封装模块示例



Example of good thermal grease coverage (module removed after mounting) 导热硅脂覆盖良好的示例 (模块安装后拆除)

Figure 3-2 ED-type power module and typical grease application; ED封装功率模块和典型的导热硅脂应用

3.3 Power module mounting 功率模块安装

It is assumed that the ED-type power module has an even, homogeneous, and reproducible layer of thermal grease attached. Avoid any lateral movement of the module after the module got placed on the heat sink. The screws for fixing the module to the heat sink are inserted and evenly tightened by hand or by electric or pneumatic screwdrivers with a torque of 0.5 Nm according to the sequence provided in Figure 3-3. Depending on grease viscosity introduce some waiting time to let the grease and module conform to each other (higher viscosity needs longer time).

Afterwards the screws are tightened again to the final torque provided in the datasheet, following the same procedure. It is recommended to limit the maximum torque to the datasheet values by using torque wrenches with automatic release.

假定ED封装功率模块上附有一层均匀、一致且可重复的导热硅脂，模块安装到散热器上后，应避免模块横向移动。按照图 3 3 提供的顺序，用手或电动或气动螺丝刀插入用于将模块固定到散热器上的螺钉，并以 0.5 牛米的扭矩均匀拧紧。根据导热硅脂的粘度，需要等待一段时间，使导热硅脂和模块相互贴合（粘度较高的需要更长的时间）。然后，按照同样的步骤将螺丝再次拧紧至数据表中规定的最终扭矩。建议使用带自动释放功能的扭矩扳手，将最大扭矩限制在数据表规定的数值内。

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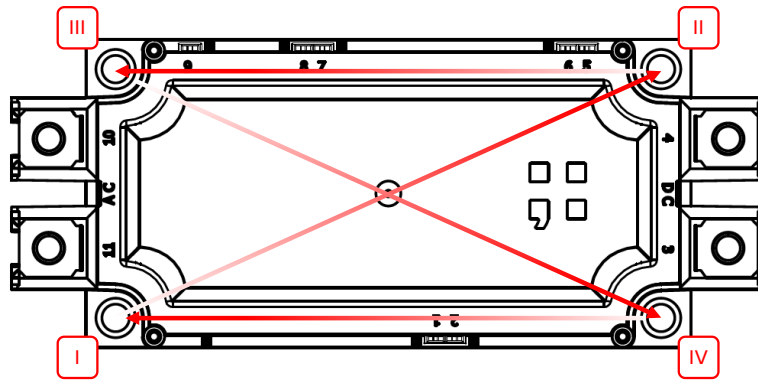


Figure 3-3 Sequence for tightening the ED-type power module to the heatsink; 将ED封装功率模块紧固到散热器上的顺序

3.4 Gate drive 门极驱动

ED-type modules should be operated with a turn-on gate voltage of +15 V for low on-state and good short-circuit ruggedness. Although higher turn-on voltages provide lower conduction losses the downside is a resulting reduced short-circuit ruggedness. A turn-off gate voltage of -5 to -15 V is recommended for low turn-off losses and high dv/dt capability. The gate drive can be connected by soldering the auxiliary pins. For modules operated in vibrating environment it is strongly advised to additionally fix the gate-driver PCB with four screws (e.g.: EJOT PT WN 1451 K25x10). The self-tapping screws must be torqued to 0.41 Nm to 0.49 Nm. The effective screw thread length in the module case must be between 4 and 10 mm.

ED 型模块的栅极开启电压应为 +15 V，以实现低导通和良好的短路耐用性。虽然较高的导通电压可降低通态损耗，但缺点是会降低短路稳定性。建议使用 -5 至 -15 V 的关断栅极电压，以实现低关断损耗和高 dv/dt 能力。栅极驱动可通过焊接辅助引脚连接。对于在振动环境中运行的模块，强烈建议使用四个螺钉（例如：EJOT PT WN 1451 K25x10）额外固定栅极驱动 PCB。自攻螺丝的扭矩必须在 0.41 牛米至 0.49 牛米之间。模块外壳内的有效螺纹长度必须在 4 至 10 毫米之间。

A schematic of a typical Gate Unit output stage is depicted in figure Figure 3-4. It is recommended to clamp the gate voltage to 15 V for protection against high inductive short-circuit events or short-circuit type II events, with a suppressor diode (D3) mounted close to the module Gate and auxiliary Emitter as well as with fast Schottky diodes (D1 & D2) connected low inductive to the gate-voltage supply Figure 3-4. An optional gate-emitter capacitor mounted low inductive to the module can improve the controllability of the IGBT. In case the turn-off overvoltage of the IGBT can't be kept below the allowed V_{CEM} of the IGBT, for instance due to too high stray inductance, an active clamp circuit comprising of suppressor diodes (D4 to Dx) a Schottky Diode D7 and a damping resistor R3 is needed. The total clamp voltage of the suppressor diodes (D4 to Dx) and the value of the damping resistor needs to be optimized to the effective power circuit and stray inductance. The clamp circuit must be low inductive connected to the module to be effective. In any case the sum of the V_{BR} of the clamp diodes needs to be above the maximum expected V_{DC} to avoid damage to the IGBT and inverter.

典型栅极单元输出级的原理图如图 3 4 所示。建议将栅极电压箝位至 15 V，以防止大电感短路失效或 II 类短路失效，并在模块栅极和辅助发射极附近安装一个瞬态抑制二极管 (D3)，以及将快速肖特基二极管 (D1 和 D2) 低电感连接至栅极电压电源 (图 3 4)。可选的栅极发射极电容器安装在模块上，电感值较低，可提高 IGBT 的可控性。如果由于杂散电感过高而导致 IGBT 的关断过电压无法保持在允许 V_{CEM} 以下，则需要一个由瞬态抑制二极管 (D4 至 Dx)、肖特基二极管 D7 和阻尼电阻 R3 组成的有源箝位电路。抑制二极管 (D4 至 Dx) 的总箝位电压和阻尼电阻的值需要根据有效功率电路和杂散电感进行优化。与模块相连的箝位电路必须是低电感的，这样才能有效。在任何情况下，箝位二极管的 V_{BR} 总和必须高于预期的最大 V_{DC} ，以避免损坏 IGBT 和逆变器。

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S. M. COO and PL	R. S. VP Product Management & Application	C. T. VP Supply and Quality

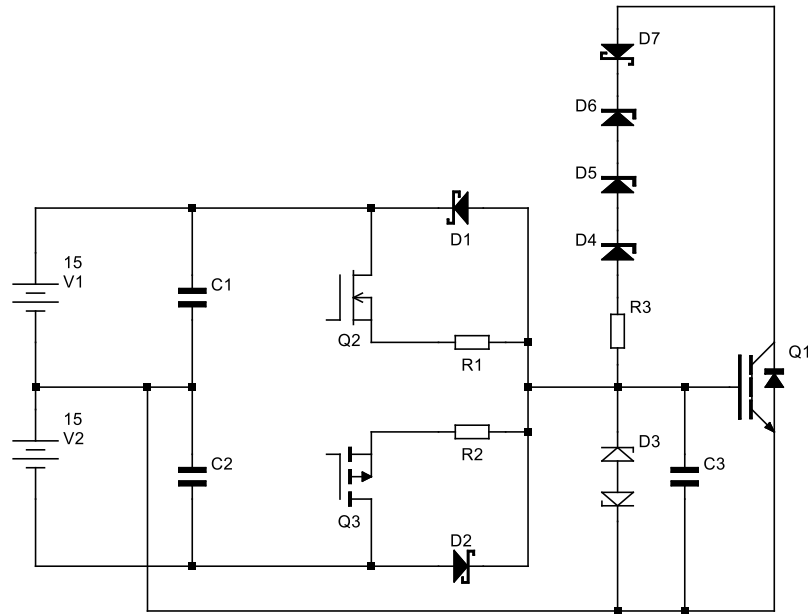


Figure 3-4 Typical Gate-drive output stage; 典型栅极驱动输出级

3.5 Mounting of busbars to the module 将母排安装到模块上

The busbars must be mounted onto the collector and emitter terminals with the recommended torques provided in the datasheet. It is important that the torque is within the specified limits, to enable good electrical and thermal contact. The cross-section of the busbar should be tailored to the power terminal contacts to avoid heating of the power-terminals by resistive losses resulting from the busbar.

母排必须按照数据表中提供的建议扭矩安装到集电极和发射极上。扭矩必须在规定范围内，以确保良好的电气和热接触。汇流条的横截面应与功率端子的触点相匹配，以避免母排电阻损耗导致功率端子发热。

The auxiliary pins are intended to be soldered to a printed circuit board (PCB) in through hole technology (THT). ESD guidelines must be obeyed during the hole assembly/soldering process. It is recommended that mechanical stress due to shocks and vibrations to the auxiliary pins is relieved by mounting the PCB on to the module utilizing the four PCB mounting fixing posts.

辅助引脚用于以通孔技术（THT）焊接到印刷电路板（PCB）上。在孔装配/焊接过程中必须遵守 ESD 指导原则。建议利用四个 PCB 安装固定柱将 PCB 安装到模块上，以减轻冲击和振动对辅助引脚造成的机械应力。

Continuous mechanical stress to power and auxiliary terminals must be avoided. Forces caused by shock and vibration or resulting from thermal expansion of the system in operation require special attention and care e.g., supporting the busbar by fixing posts close to the module at each side.

必须避免功率和辅助端子受到持续的机械应力。冲击和振动造成的力或系统在运行中热膨胀造成的力需要特别注意和小心，例如，在靠近模块的两侧用固定柱支撑母线。

The maximum forces acting at power-terminals should not exceed 150N (in any direction). Connecting parts such as busbars and gate-drives must be designed and assembled in a way that limits are kept.

功率端子上的最大作用力不应超过 150N（任何方向）。母排和门极驱动器等连接部件的设计和装配必须符合要求。

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3.6 General mounting remarks 一般安装说明

Table 3-1 The industry standards apply for this product as shown in the table below; 该产品适用的行业标准如下表所示

POS 位置	DO 做	DON'T 不要	RISK 风险
1	Apply wrenches with automatic release in case maximum torque is reached 达到最大扭矩时，扳手会自动松开	Use impact wrenches 使用冲击扳手	Damage to power module Jamming of screw 功率模块损坏 螺丝卡住
2	Limit screw speed to manageable values 将拧紧转速限制在可控范围内	Maximize screw speed 最大限度地提高拧紧速度	Damage to power module Jamming of screw 功率模块损坏 螺丝卡住
3	Use carbon steel screws for power terminal mounting 使用碳钢螺钉安装功率端子	Compromise 妥协	
4	Use screws for module mounting that are tailored to heat sink material 使用适合散热器材料的螺钉安装模块	Compromise 妥协	
5	Length of screws must be tailored to application 螺钉长度必须根据应用而定	Compromise 妥协	Damage to power module 功率模块损坏

4 REVISION HISTORY

DATE	AUTHOR	REMARK
May, 2022	S. M.	Initial version
July, 2022	S. M.	Update RBSOA: 25°C curve removed
June, 2024	S. M. & R. S.	Update mounting procedure
December, 2024	C. Y., B. M. & S. M	Introduction and proofing of Chinese text

AUTHOR	CHECKED	RELEASED
S. M. COO and PL	R. S. VP Product Management & Application	C. T. VP Supply and Quality