
Chapter 3

IGBT Module Selection and Application

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This section explains relevant IGBT module selection and application.

1 Selection of IGBT module ratings

When using IGBT modules, it is important to select modules which having the voltage and current ratings most suited for the intended application.

1.1 Voltage rating

The IGBT voltage rating closely depends on the input voltage of the equipment in which it will be installed. Table 3-1 lists IGBT voltage ratings and applicable input voltages. Use this table as a reference when selecting modules for a particular voltage application.

Table 3-1 IGBT rated voltage and applicable input voltage

	Area		IGBT rated voltage V_{CES}		
			600V	1200V	1700V
Line voltage (Input voltage AC)	Asia	Japan	200V	400V, 440V	690V (High voltage supply for Industry, wind-power generation etc.)
		South Korea	200V, 220V	380V	
		China	220V	380V	
	North America	U.S.A	120V, 208V, 240V	460V, 480V	
		Canada	120V, 208V, 240V	575V	
	Europe	U.K	230V	400V	
		France	230V	400V	
		Germany	230V	400V	
		Russia	220V	380V	

1.2 Current rating

When the IGBT module's collector current increases, consequently so will the $V_{CE(sat)}$ and the power dissipation losses.

Simultaneously, there will be an increase in the switching energy, resulting in an increase in the chip and module temperature.

It is necessary to control the collector current in order to keep the junction temperature below maximum junction temperature (T_{jmax}), taking into account of the heat generation of both conduction and switching energy dissipation. When designing a power conversion equipment, it should be noted the fact that as the switching frequency increases, so will the switching loss and the amount of heat generated. It is recommended to keep the collector current at or below the maximum rating for the reasons stated above. This also provides a more economical design.

2 Static electricity countermeasures

The V_{GE} of an IGBT is rated $\pm 20V$. If an IGBT is subjected to a V_{GES} that exceeds this rated value, then there is a danger that the module might be destroyed. Therefore, ensure that the voltage between the gate and emitter is never greater than the maximum allowable value.

When an IGBT is installed and voltage is applied between the collector and emitter while the gate emitter connection is open as shown in Fig. 3-1, depending on changes in the electric potential of the collector, the current (i) will flow, causing the gate's voltage to rise turning the IGBT on.

Under these circumstance, since the voltage potential between the collector and emitter is high, the IGBT could overheat and be destroyed.

On an installed IGBT, if the gate circuit is faulty or completely inoperative (while the gate is open), the IGBT may be destroyed when a voltage is applied to the main circuit. In order to prevent this destruction, it is recommended that a $10K\Omega$ resistor (R_{GE}) be connected between the gate and the emitter.

Furthermore, since IGBT modules have a MOS structure that is easily destroyed by static electricity, observe the following points of caution.

- 1) When handling IGBTs, hold them by the case and do not touch the terminals.
- 2) If the terminals are connected by some conductive material, do not remove the material until immediately before wiring.
- 3) It is recommended that any handling of IGBTs be done while standing on a grounded mat.
- 4) Before touching a module's terminal, discharge any static electricity from your body or clothes by grounding through a high capacity resistor ($1M\Omega$) i.e. ESD grounding strap.

When soldering, in order to protect the module from static electricity, ground the soldering iron through a low capacity resistor.

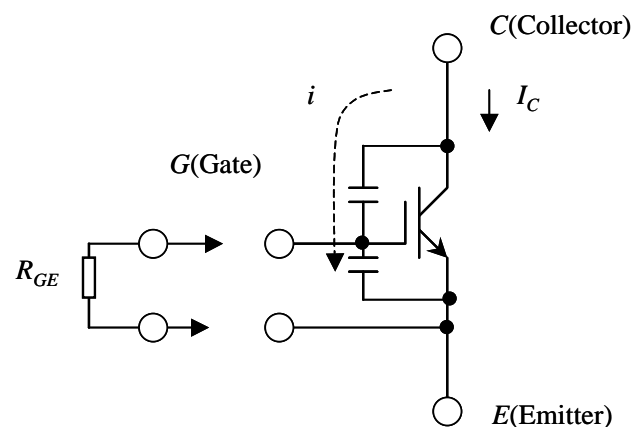


Fig. 3-1 Gate charging from electric potential of collector.

3 Designing protection circuits

Since IGBT modules may be destroyed by overcurrent, overvoltage or other abnormality, it is necessary to design protection circuits.

It is important when designing this circuits that module's characteristics are fully taken into consideration, since an inappropriate circuit will allow the module to be destroyed. For example, the overcurrent cut-off time may be too long or the capacitance of the snubber circuit's capacitor may be too small.

For more details on overcurrent and overvoltage protection methods, refer to chapter 5 of this manual.

4 Designing heat sinks

As the maximum allowable junction temperature ($T_{j(max)}$) of an IGBT modules is fixed, an appropriate heat sink must be selected to keep them at or below these values.

When designing appropriate cooling, first calculate the loss of a single IGBT module, then based on that loss, select a heat sink that will keep junction temperature (T_j) within the required limits.

If the IGBT module is not sufficiently cooled, the temperature may exceed $T_{j(max)}$ during operation and destroy the module. For more information on IGBT power loss calculation and heat sink selection methods, refer to chapter 6 of this manual.

5 Designing drive circuits

It cannot be emphasized enough, that it is the design of the drive circuit that ultimately determines the performance of an IGBT. It is important that drive circuit design is also closely linked to protection circuit design.

Drive circuits consists of a forward bias voltage section to turn the IGBT on, and a reverse bias voltage section to accelerate and maintain turn-off. Remember that the characteristics of the IGBT change in accordance with the conditions of the circuit. Also, if the circuit is wired improperly, it may cause the module to malfunction. For more information on how to design the best drive circuits, refer to Chapter 7 of this manual.

6 Parallel connection

In high capacity converters/inverters and other equipment that needs to control large currents, it may be necessary to connect IGBT modules in parallel.

When connected in parallel, it is important that the circuit design allows for an equal flow of current to each of the modules. If the current is not balanced among the IGBTs, a higher current may build up in just one device and destroy it.

The electrical characteristics of the module as well as the wiring design, change the balance of the current between parallel connected IGBTs. In order to help maintain current balance it may be necessary to match the $V_{CE(sat)}$ values of all devices.

For more detailed information on parallel connections, refer to Chapter 8 of this manual.

7 Mounting notes

When mounting IGBT modules on designated equipment, note the following:

1. When mounting an IGBT module on a heat sink, first apply a thermal grease or equivalent material to the module's base and then secure it properly to the heat sink by tightening the specified screws using the recommended torque. Use a heat sink with a mounting surface finished to a roughness of $10\mu\text{m}$ or less and a flatness of $50\mu\text{m}$ or less between screw mounting pitches. For more details, refer to Chapter 6 of this manual.
2. Avoid wiring designs that places too much mechanical stress on the module's electrical terminals.

8 Storage and transportation notes

8.1 Storage

- 1) The IGBT modules should be stored at an ambient temperature of 5 to 35°C and humidity of 45 – 75%. If the storage area is very dry, a humidifier may be required. In such a case, use only deionized water or boiled water, since the chlorine in tap water may corrode the module terminals.
- 2) Avoid exposure to corrosive gases and dust.
- 3) Rapid temperature changes may cause condensation on the module surface. Therefore, store modules in a place with minimal temperature changes.
- 4) During storage, it is important that nothing be placed on top of the modules, since this may cause excessive external force on the case.
- 5) Store modules with unprocessed terminals. Corrosion may form causing presoldered connections to have high contact resistance or potential solder problems in later processing.
- 6) Use only antistatic containers for storing IGBT modules in order to prevent ESD damage.

8.2 Transportation

- 1) Do not drop or jar modules which could otherwise cause mechanical stress.
- 2) When transporting several modules in the same box or container, provide sufficient ESD padding between IGBTs to protect the terminals and to keep the modules from shifting.

9 Reliability notes

Generally, when the power converters such as inverters are in operation, the temperature rises and falls repeatedly in the IGBT module installed in the system. Accordingly, the IGBT module is exposed to the thermal stress caused by this temperature swing and so its life span depends on the operating conditions. Therefore, the expected thermal cycling lifetime of IGBT module must be designed to be longer than system lifetime design.

In general, the temperature swing of the IGBT module has to be checked and the expected IGBT module lifetime should be predicted based on the power cycle capability. If the life design is not well investigated, the life span of the IGBT module may result shorter than expectation which may cause long-term reliability issue of system. Therefore, it is strongly recommended to investigate the the IGBT module temperature cycling design to match the required reliability criteria.

For more detailed information on reliability notes, refer to Chapter 11 of this manual.

10 Additional notes

- 1) The gate drive voltage (V_{GE}) should be measured at the terminals of the module to verify that a predetermined voltage is being applied. (Measurement at the output stage of the drive circuit may lead to a voltage that is unaffected by the voltage drops across the transistors and other components used at the output stage of the drive circuit. Consequently, if the predetermined voltage (V_{GE}) is not being applied to the IGBT gate, this lower (V_{GE}) voltage could pass unnoticed, leading to device destruction.
- 2) Measure the surge and other voltages appearing during turn-on and turn-off at the module terminals. If measured terminals are defined on the specification, measure the voltages at defined terminals.
- 3) Use the product within the tolerances of the absolute maximum ratings (voltage, current, temperature etc). Particularly, if a voltage higher than V_{CES} is applied to the module, an avalanche breakdown could occur, resulting in device destruction.
- 4) As a precaution against the possible accidental destruction of the device, insert a fuse or breaker of the appropriate rating between the commercial power source and the semiconductor device.
- 5) Before using the IGBT, acquire a full understanding of its operating environment to verify that its matched long term reliability requirement. If the product is used exceeding its product lifetime, the device could be destroyed before the intended useful life of the equipment expires.
- 6) Use this IGBT within its power-cycle life capability. Power cycle capability is classified to delta-Tj mode, which is stated as above, and delta-Tc mode. Delta-Tc mode is due to rise and down of case temperature (Tc), and depends on cooling design of equipment, which use this product. In application, which has such frequent rise and down of Tc, well consideration of product lifetime is necessary.
- 7) Avoid using the product in locations where corrosive gases are present. The warranty covering the functionality, appearance and other aspects of the product will be voided if it is used in environments where acids, organic substances or corrosive gases (such as hydrogen sulfide and sulfur dioxide) are present.
- 8) Do not allow the primary and control terminals of the product IGBT to be deformed by stress. A deformed terminal could cause a defective contact or other fault.
- 9) Select the correct terminal screws for the module according to the outline drawing. Using longer screws could damage the device.
- 10) If only a FWD is used and an IGBT is not used (as in a chopper circuit application), apply a reverse bias voltage of -5V or higher (-15V recommended, -20V maximum) between G and E of the IGBT out of service. An insufficient reverse bias voltage could cause the IGBT to false triggered due to dV/dt during reverse recovery of the FWD, resulting in device destruction.
- 11) A high turn-on voltage (dv/dt) could cause the IGBT in the opposing arm to turn on falsely. Use the product under optimal gate drive conditions (such as $+V_{GE}$, $-V_{GE}$, and R_G , C_{GE}) to prevent false turn-on.

- 12) Do not apply excessive stress to the primary and control terminals of the product when installing it in equipment. The terminal structure could be damaged.
- 13) Use this product with keeping the cooling fin's flatness between screw holes within 50 μ m at 100mm and the roughness within 10 μ m. Also keep the tightening torque within the limits of this specification. Too large convex of cooling fin may cause isolation breakdown and this may lead to a critical accident. On the other hand, too large concave of cooling fin makes gap between this product and the fin bigger, then, thermal conductivity will be worse and over heat destruction may occur.
- 14) If excessive static electricity is applied to the control terminals, the devices may be broken. Implement some countermeasures against static electricity.
- 15) In case of mounting this product on cooling fin, use thermal grease or equivalent cooling methods to secure thermal conductivity. If the thermal grease amount was not enough or greasing method was not suitable, its spreading will not be enough, then, thermal contact resistance between IGBT module base and heatsink may have an issue which results thermal run away destruction in worst case. Experimental confirmation of grease spreading state at the thermal contact is recommended before applying to the actual product. (Spreading state of the thermal compound can be confirmed by removing this product after mounting.)
- 16) The gate resistance R_G described in the specification sheet is one of example values to achieve the highest performance of minimized switching energy. In practical application, the optimum R_G depends on the circuit setup and/or system environment. Therefore, the gate resistance R_G should be selected with consideration of switching losses, EMC/EMI, spike voltage, spike current and unexpected oscillation and so on based on system requirement and IGBT module specification.
- 17) More references of notes, cautions and warnings in detail can be found in each specification provided for specific products. Following these contents is also recommended to take into account of system design because information in this section describes a part of important notifications.

WARNING

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