# 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

An IGBT must have a voltage rating that is suitable for dealing with the input voltage of the unit in which it will be installed. Table 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 | 1400V | 1700V |
| Line voltage (Input voltage AC) | U.S.A. | 208V<br>230V<br>240V<br>246V | 460V<br>480V | 575V | 575V |
| | Europe | 200V<br>220V<br>230V<br>240V | 346V<br>350V<br>380V<br>400V<br>415V<br>440V | | 690V |
| | Japan | 200V<br>220V | 400V<br>440V | | |

## 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 loss, resulting in an increase in the modules temperature.
It is necessary to control the collector current in order to keep the junction temperature well below 150°C (below 125°C is recommended for safety reasons), despite the heat generated by static loss and switching loss. When designing a circuit, be careful of 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 ± 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 10KΩ 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 (1MΩ) 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.

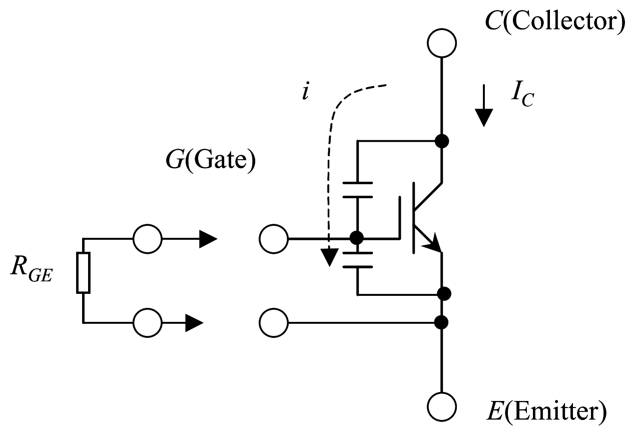


**Fig. 3-1 Gate charging from electric potential of collector.**

## 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 a 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 ($T_j$) of an IGBT module is fixed, an appropriate heat sink must be selected to keep it at or below this value.
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 the $T_j$ 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.

**Table 3-2 Selection of IGBT module ratings**

| | Motor capacity [kW] | Inverter capacity [kVA] | IGBT module type | | |
|---|---|---|---|---|---|
| | | | N series (3rd gen.) | S series (4th gen.) | U series (5th gen.) |
| Input voltage 220V AC | 1.5 | 3 | | 7MBR30SA060 | 6MBI20UE-060 |
| | 2.2 | 4 | | 7MBR30SA060 | 6MBI30UE-060 |
| | 3.7 | 6 | | 7MBR50SA060 | 6MBI50UF-060 |
| | 5.5 | 9 | 7MBI75N-060 | 7MBR75SB060 | 6MBI75U2A-060 |
| | 7.5 | 13 | 7MBI100N-060 | 7MBR100SB060 | 6MBI100U2A-060 |
| | 11 | 17 | 2MBI150N-060 | | 2MBI150U2A-060 |
| | 15 | 22 | | | |
| | 18.5 | 28 | 2MBI200N-060 | | 2MBI200U2A-060 |
| | 22 | 33 | | | |
| | 30 | 44 | 2MBI300N-060 | 2MBI300S-060 | 2MBI300U2B-060 |
| | 37 | 55 | | | 2MBI400U2B-060 |
| | 45 | 67 | | | |
| Input voltage 440V AC | 0.75 | 2 | | 7MBR10SA120 | 6MBI10UF-120 |
| | 1.5 | 3 | | | |
| | 2.2 | 4 | | 7MBR15SA120 | 6MBI15UF-120 |
| | 3.7 | 6 | | 7MBR25SA120 | 6MBI25UF-120 |
| | 5.5 | 9 | 7MBI50N-120 | 7MBR50SB120 | 6MBI50UA-120 |
| | 7.5 | 13 | | | |
| | 11 | 17 | 2MBI75N-120 | 6MBI75S-120 | 6MBI75UB-120 |
| | 15 | 22 | | | |
| | 18.5 | 28 | 2MBI100N-120 | 6MBI100S-120 | 6MBI100UB-120 |
| | 22 | 33 | | | |
| | 30 | 44 | 2MBI150N-120 | 2MBI150S-120 | 6MBI150UB-120 |
| | 37 | 55 | 2MBI200N-120 | 2MBI200S-120 | 6MBI225U-120 |
| | 45 | 67 | | | |
| | 55 | 84 | 2MBI300N-120 | 2MBI300S-120 | 6MBI300U-120 |

## 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 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 in designated equipment, note the following:

1) When mounting an IGBT module on a heat sink, first apply a thermal compound 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 10μm or less and a flatness of 100μm 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 Additional points

1) 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 fire falsely due to dV/dt during reverse recovery of the FWD, resulting in device destruction.

2) Measure the gate drive voltage ($V_{GE}$) at the terminals of the module to verify that a predetermined voltage is being applied. (Measurement at the end of the drive circuit will lead to a voltage that is unaffected by the voltage drops across the transistors and other components used at the end 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.

3) Measure the surge and other voltages appearing during turn-on and turn-off at the module terminals.

4) Avoid using the product in locations where corrosive gases are present.

5) 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 could occur, resulting in device destruction.

6) 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.

7) Before using the IGBT, acquire a full understanding of its operating environment to verify that its reliability life can be met. If the product is used past its reliability life, the device could be destroyed before the intended useful life of the equipment expires.

8) Use this IGBT within its power-cycle life capability.

9) 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.

10) 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.

11) Select the correct terminal screws for the module according to the outline drawing. Using longer screws could damage the device.

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) Apply sufficient reverse bias gate voltage, improper ($-V_{GE}$) could cause the IGBT to turn on when not intended. Set $-V_{GE}$ at -15V (recommended) to prevent false turn-on.

14) 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 $R_{G)}$ to prevent false turn-on.

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