
Chapter 3

IGBT Module Selection and Application

CONTENTS		Page
1	Selection of IGBT module ratings	3-2
2	Static electricity countermeasures	3-3
3	Designing protection circuits	3-3
4	Designing heat sinks	3-4
5	Designing drive circuits	3-4
6	Parallel connection	3-4
7	Mounting notes	3-4
8	Storage and transportation notes	3-5
9	Reliability notes	3-5
10	Additional points	3-6

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 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 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 maximum junction temperature (T_j), 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 $\pm 20V$. 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 IGBT modules after unpacking, discharge any static electricity from your body or clothes by grounding through a high capacity resistor ($1M\Omega$) i.e. ESD grounding strap. Then, any handling of IGBTs should be done while standing on a grounded mat.
- 2) IGBT modules does not have anti-static electricity treatment after unpacking. Hold them by the module case and do not touch the terminals directly (especially control terminals)
- 3) When soldering to terminals, in order to protect the module from static electricity, ground the soldering iron through a low capacity resistor.

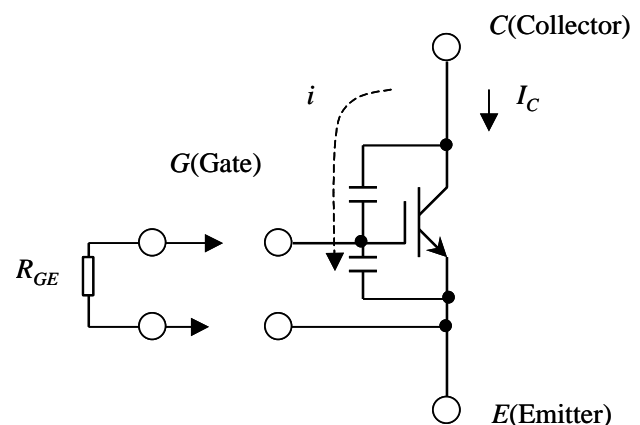


Fig. 3-1 Gate charging from electric potential of collector.

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 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 $10\mu\text{m}$ 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 driven, the temperature rises and falls repeatedly in the IGBT module built into them. Accordingly, the IGBT module is exposed to the heat stress caused by this heat change and so its life span depends on the operating conditions. Therefore, the design life of the IGBT module must be longer than that of the power converters.

In most cases, the temperature change of the IGBT module is checked and the life design is performed based on the power cycle capability. If the life design is not good enough, the life span of the IGBT module may become shorter than the required life span and the module may not have sufficient reliability. Therefore, it is important to design the IGBT module so that it meets the required reliability.

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

10 Additional points

- 1) 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.
- 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 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 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.
- 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 (T_c), and depends on cooling design of equipment, which use this product. In application, which has such frequent rise and down of T_c , 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 fire falsely 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 50um at 100mm and the roughness within 10um. 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 compound to secure thermal conductivity. If the thermal compound amount was not enough or its applying method was not suitable, its spreading will not be enough, then, thermal conductivity will be worse and thermal runaway destruction may occur. Confirm spreading state of the thermal compound when its applying to this product. (Spreading state of the thermal compound can be confirmed by removing this product after mounting.)
- 16) Gate resistance R_G , by which switching losses is minimized, is drawn on the specification. However, optimum R_G is varied for the circuit setup and/or system environment. So, Gate resistance R_G should be selected so as to keep the contents on the specification in consideration of switching losses, EMC/EMI, spike voltage, spike current and unexpected oscillation and so on.
- 17) IGBT modules have random failure mode by primary or secondary cosmic ray in general. In this failure mode, products have chance of failure due to the radiation by primary cosmic ray which comes from cosmic space and secondary cosmic ray which is generated when the primary cosmic ray strikes to the atmosphere. The failure rate in this failure mode is higher in higher altitude condition because the amount of primary cosmic ray is higher in case the altitude is higher. The amount of primary cosmic ray also depends on latitude and longitude. The high voltage also triggers high failure rate in this failure mode. In case the product is used under high altitude and/or voltage condition, please contact to Fuji Electric Co.,Ltd.
- 18) More details of cautions and warnings are referred to each specification and keep them because in this section, only some of important notifications are described.

WARNING

1. This Catalog contains the product specifications, characteristics, data, materials, and structures as of January 2017. The contents are subject to change without notice for specification changes or other reasons. When using a product listed in this Catalog, be sure to obtain the latest specifications.
2. All applications described in this Catalog exemplify the use of Fuji's products for your reference only. No right or license, either express or implied, under any patent, copyright, trade secret or other intellectual property right owned by Fuji Electric Co., Ltd. is (or shall be deemed) granted. Fuji Electric Co., Ltd. makes no representation or warranty, whether express or implied, relating to the infringement or alleged infringement of other's intellectual property rights which may arise from the use of the applications described herein.
3. Although Fuji Electric Co., Ltd. is enhancing product quality and reliability, a small percentage of semiconductor products may become faulty. When using Fuji Electric semiconductor products in your equipment, you are requested to take adequate safety measures to prevent the equipment from causing a physical injury, fire, or other problem if any of the products become faulty. It is recommended to make your design failsafe, flame retardant, and free of malfunction.
4. The products introduced in this Catalog are intended for use in the following electronic and electrical equipment which has normal reliability requirements.
 - Computers
 - OA equipment
 - Communications equipment (terminal devices)
 - Measurement equipment
 - Machine tools
 - Audiovisual equipment
 - Electrical home appliances
 - Personal equipment
 - Industrial robots etc.
5. If you need to use a product in this Catalog for equipment requiring higher reliability than normal, such as for the equipment listed below, it is imperative to contact Fuji Electric Co., Ltd. to obtain prior approval. When using these products for such equipment, take adequate measures such as a backup system to prevent the equipment from malfunctioning even if a Fuji's product incorporated in the equipment becomes faulty.
 - Transportation equipment (mounted on cars and ships)
 - Trunk communications equipment
 - Traffic-signal control equipment
 - Gas leakage detectors with an auto-shut-off feature
 - Emergency equipment for responding to disasters and anti-burglary devices
 - Safety devices
 - Medical equipment
6. Do not use products in this Catalog for the equipment requiring strict reliability such as the following and equivalents to strategic equipment (without limitation).
 - Space equipment
 - Aeronautic equipment
 - Nuclear control equipment
 - Submarine repeater equipment
7. Copyright ©1996-2011 by Fuji Electric Co., Ltd. All rights reserved.
No part of this Catalog may be reproduced in any form or by any means without the express permission of Fuji Electric Co., Ltd.
8. If you have any question about any portion in this Catalog, ask Fuji Electric Co., Ltd. or its sales agents before using the product. Neither Fuji Electric Co., Ltd. nor its agents shall be liable for any injury caused by any use of the products not in accordance with instructions set forth herein.