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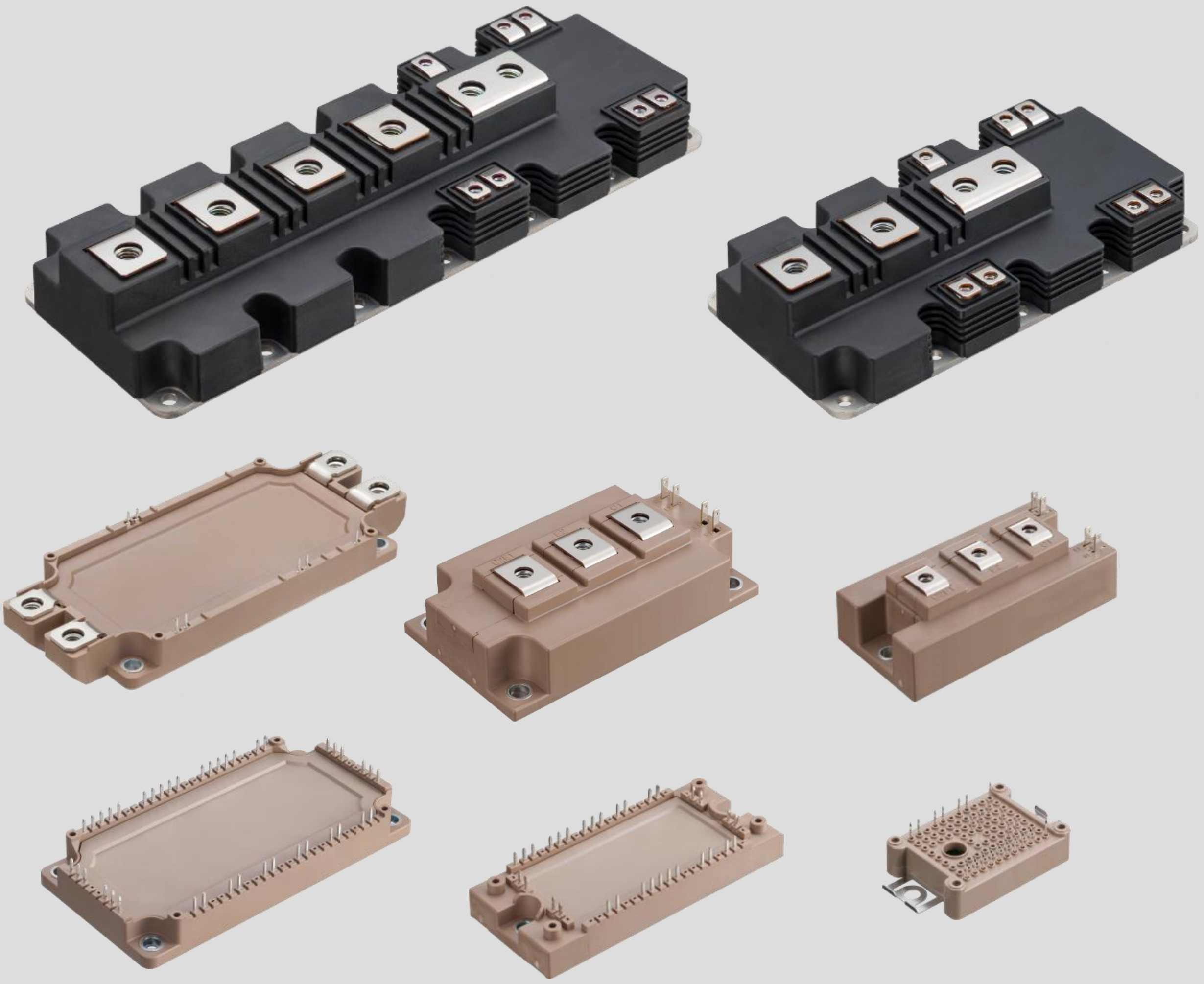

Fuji IGBT Module

Application Manual

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Fuji Electric Co.,Ltd.

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⚠ Cautions

This manual contains the product specifications, characteristics, data, materials, and structures as of March 2023.
The contents are subject to change without notice for specification changes or other reasons. When using a product listed in this manual, be sure to obtain the latest specifications.

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Chapter 3 IGBT Module Selection and Application Notes

This chapter describes the precautions when using IGBT module and application.

1. Selection of IGBT Module Ratings

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

1.1 Voltage rating

The IGBT must have voltage rating that is suitable with the input voltage of the system in which it will be installed. Table 3-1 shows the 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 application input voltage

	Area		IGBT rated voltage		
			600V	1200V	1700V
Commercial power supply voltage (input voltage)	Asia	Japan	200VAC	400VAC, 440VAC	690VAC (Industry high voltage power supply, wind power generation, etc.)
		South Korea	200VAC, 220VAC	380VAC	
		China	220VAC	380VAC	
	North America	U.S.A	120VAC, 208V, 240VAC	460VAC, 480VAC	
	Europe	U.K.	230VAC	480VAC	
		France	230VAC	400VAC	
		Germany	230VAC	400VAC	
		Russia	220VAC	380VAC	

1.2 Current rating

When the collector current I_C of the IGBT module increases, the conduction loss and switching loss increase, resulting in an increase in the module temperature. Since the IGBT module must be used with the virtual junction temperature T_{vj} of IGBT and FWD below the maximum virtual junction temperature $T_{vj(max)}$, I_C must be set in order not to exceed $T_{vj(max)}$.

Incorrect selection of current rating may lead to module destruction or deterioration of reliability. Note that in high frequency switching applications, switching loss increases, which increases the module temperature.

As a basic selection criteria, it is common to select a module with current rating higher than √2 times of the AC output current RMS value of the inverter circuit. However, the selection of the current rating depends on the operating conditions and heat dissipation conditions of the equipment, thus it is important to select the current rating after checking the power loss and temperature rise in the equipment.

1.3 Maximum rating

Use the product within the maximum ratings (voltage, current, temperature, etc.) described in the specifications. Using the product beyond the maximum rating may destroy the product. Also, the value described in each item of the absolute maximum rating is specified for that item, not for combination of more than one item.

1.4 RBSOA

Make sure that the IGBT turn-off voltage and current operating trajectories are within the RBSOA specifications. Using the IGBT beyond the RBSOA region may destroy the product.

1.5 Diode inrush current

When using the rectifier diode or FWD for rectifier application, a large inrush current will flow to charge the DC smoothing capacitor when the power is turned on. The guaranteed values for this inrush current are expressed as I_{FSM} (non-repetitive) and I^2t (non-repetitive). However, if inrush current flows frequently into the product, the product may be destroyed due to power cycle destruction by the repetitive current. For applications where such inrush current flows frequently, take measures to suppress the inrush current to prevent power cycle destruction.

Note that inrush current may flow to charge the capacitor too when an instantaneous voltage drop occurs in the power supply system.

On the other hand, if transient surge voltage due to lightning strike, etc. that exceeds the voltage rating of the product is applied to the product, the product might be destroyed. Thus, if surge voltage is expected, insert surge protection devices to suppress the voltage to within the product specifications.

2. Static Electricity Countermeasures

Generally, the absolute maximum rating of $V_{GE,}$ V_{GES} is ±20V. If voltage exceeding V_{GES} is applied to G-E, the IGBT gate may be destroyed. Therefore, ensure that V_{GE} value does not exceed V_{GES}.

If voltage is applied between C-E of IGBT while G-E is open as shown in Fig. 3-1, the IGBT may be destroyed. This is because the current *i* flows from the collector to the gate due to changes in the collector voltage, causing the gate voltage to rise and turn-on the IGBT. As a result, collector current will flow and the IGBT could overheat and be destroyed.

For this reason, after installing an IGBT module, if the gate circuit is malfunctioning or completely inoperative (gate is open), the IGBT may be destroyed when voltage is applied to the main circuit. In order to prevent this, it is recommended to connect a 10kΩ resistor (R_{GE}) between G-E.

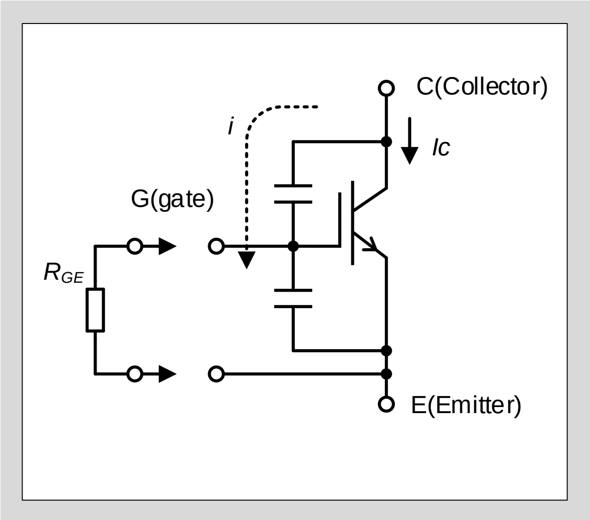

Fig. 3-1 IGBT behavior when G-E is open

Furthermore, the IGBT gate is very sensitive to static electricity. Observe the following precautions when handling the product.

(1) When handling IGBT modules after unpacking, discharge any static electricity from your body and clothes by grounding through a high resistance (1MΩ). Then, any handling of IGBTs should be done while standing on a grounded conductive mat.

(2) The terminals of IGBT modules are not protected against static electricity. When handling, hold them by the module case and do not touch the terminals (especially the control terminals).

(3) When soldering the terminals, ground the tip of the soldering iron through a low resistance to protect the module from static electricity .

3. Protection Circuits Design

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

It is important to fully understand the IGBT modules characteristics when designing these circuits. An inappropriate circuit will not be able to protect the module. For example, the overcurrent cut-off time may be too long, or the capacitance of the snubber capacitor may be too small.

For more details on overcurrent and overvoltage protection methods, refer to Chapter 5 ‘Protection Circuit Design’ of this manual.

4. Cooling Design

IGBT modules have a maximum virtual junction temperature ($T_{vj(max)}$). An appropriate heat sink must be selected to keep the temperature below this value. When designing heat sink, the operating conditions of the IGBT module has to be fully considered.

First, calculate the loss of the IGBT module. Based on that loss, select a heat sink that will keep T_{vj} below the limit. If the heat sink design is insufficient, the temperature may exceed $T_{vj(max)}$ during operation and destroy the module. For more information on IGBT power loss calculation and heat sink selection methods, refer to Chapter 6 ‘Cooling Design’ of this manual.

5. Gate Drive Circuits Design

It is no exaggeration to say that the design of the gate drive circuits ultimately determines the performance of the IGBT. It is also closely related to the protection circuits design.

Gate drive circuits consists of a forward bias circuit to turn-on the IGBT, and a reverse bias circuit to turn-off and keep the IGBT in a stable off state. The characteristics of the IGBT change in accordance with each bias condition.

Insufficient reverse bias gate voltage $-V_{GE}$ may cause false turn-on. Set a sufficient $-V_{GE}$ value to prevent false turn-on. If the dv/dt is high, false turn-on of the opposing arm IGBT, gate overvoltage, or noise propagation to the power supply line may occur. Set the optimum drive conditions ($+V_{GE}$, $-V_{GE}$, R_G, C_{GE}) to avoid these problems.

Also, if the wiring length between the IGBT module and the gate drive circuit is long, the gate voltage at the product terminal may fluctuate and the product may be destroyed by overvoltage.

For more information on how to design the best gate drive circuits, refer to Chapter 7 ‘Gate Drive Circuit Design’ 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.

In parallel connection, it is important that the circuit design allows an equal flow of current to each of the modules. If the current is not balanced among the IGBTs, a higher current may concentrate in one IGBT and destroy it.

The electrical characteristics of each module as well as the wiring design determines the current balance between parallel modules. Thus, it is necessary to design such that the C-E saturation voltage $V_{CE(sat)}$ of each parallel modules is matched and the main circuit wiring is symmetrical.

For a detailed explanation, refer to Chapter 8 "Parallel Connections“ of this manual.

Note that the 6-Pack, PIM, IPM, and Small IPM are not designed on the premise of using in parallel connections, thus application of these modules in parallel connections are not guaranteed.

7. Mounting Notes

7.1 Mounting to heat sink

When mounting the product to heat sink, it is recommended to apply thermal grease to the module’s base plate to ensure heat dissipation. In order to spread the thermal grease evenly, the flatness and surface roughness of the heat sink should be within the range of the recommended values described in the specifications.

If the amount and application method of the thermal grease are not appropriate, it may prevent the thermal grease from spreading over the entire module’s base plate, resulting in poor heat dissipation and lead to thermal failure. To determine whether the amount of thermal grease applied and the method of application is appropriate, confirm that the thermal grease has spread over the entire base plate of the product. (You can check the extent of spreading by removing the module after mounting)

If the amount of thermal grease near the product mounting hole is excessive, the thermal grease will act as a spacer, hindering the spread of the thermal grease and causing deterioration in heat dissipation.

Also, depending on the properties of the thermal grease and application method, the thermal grease may deteriorate or deplete during high temperature operation and temperature cycles, shortening the product lifetime. Thus, pay attention to the selection and application method of thermal grease.

The surface flatness of the heat sink between the screw mounting holes should be 50µm or less per 100mm, and the surface roughness should be 10µm or less. Excessive convex warpage may cause insulation failure of the product, leading to serious accidents. On the other hand, excessive concave warpage or distortion will create gaps between the IGBT module and the heat sink, which will result in poor heat dissipation and may lead to thermal failure.

Refer to the mounting instruction of each package for details on how to select and apply thermal grease, and how to mount the product to heat sink.

Note that the surface flatness and roughness requirements for heat sinks of PrimePACK^{TM}* differ from other products. Refer to the mounting instruction for details.

*PrimePACK^{TM} is a registered trademark of Infineon Technologies

7.2 Terminal connections

During soldering of the IGBT module terminals, note that soldering at an excessively high temperatures may cause deterioration of the package. If reflow soldering method is used, the solder inside the IGBT module may remelt and affect its reliability. In this case, Fuji Electric Co., Ltd. is not responsible for the product performance and appearance.

If the applied bus bars are not suitable, the temperature of the main terminals may rise above the storage temperature. Use the main terminals within the storage temperature range.

Applying excessive stress (tensile, pushing, bending) to the main terminals and control terminals may deform the terminals and crack the case resin, resulting in poor contact and poor insulation. Refer to the mounting instructions of each package for the maximum allowable stress on the main and control terminals.

For screw type terminals, tighten the screws with the specified tightening torque. If the tightening torque is excessive, insulation failure may occur due to cracking of the case. If the tightening torque is small, the contact resistance may increase, resulting in increased heat generation at the terminals. In addition, it is expected that the screws may loosen due to vibration, etc., thus select and use screws that are difficult to loosen, tighten with the appropriate torque, and perform retightening to suppress the occurrence.

Refer to the outline drawing in the specifications and select screws with the appropriate length. If the screw length is longer than the allowable value, the product may be damaged, resulting in ground fault or insulation failure. In such cases, Fuji Electric will not be held responsible.

If the printed circuit board is not suitable, the temperature of the main terminal pins may rise above the storage temperature. Use the main terminal pins within the storage temperature range.

Applying excessive stress (tensile, pushing, bending) to the main terminals and control terminals may deform the terminals and crack the case resin, resulting in poor contact and poor insulation. Refer to the mounting instructions of each package for the maximum allowable stress on the main and control terminals.

Do not apply stress that causes the lid to deform. The internal circuit of the product may be damaged in the pushing direction. In addition, the lid may come off in the pulling direction.

8. Storage and Transportation Notes

8.1 Storage

(1) The products should be stored at an ambient temperature of 5 to 35ºC and humidity of 45 to 75%. If the storage area is very dry, a humidifier may be required. In such case, use only deionized water or boiled water, since the chlorine in tap water may corrode the product terminals.
(2) Avoid exposure to corrosive gases and dust.
(3) Rapid temperature changes may cause condensation on the product surface. Avoid such environment and store products in a place with minimal temperature changes.
(4) Do not apply external force to the products during storage. Unexpected force may be applied to the products when stacked. Do not place heavy objects on the products.
(5) Store the products with unprocessed terminals. Storing after the terminals are processed may cause soldering defects later during product mounting due to rust.
(6) Use only antistatic containers or the same container as shipped for storing the products in order to prevent ESD damage.
(7) Use grounded metal storage shelves.

8.2 Transportation

(1) Avoid extreme forces such as dropping or shock when transporting the products .
(2) When transporting several products in the same box or container, insert padding between the products to protect the terminals and to keep the products from shifting.
(3) Take measures against static electricity from being applied to the gate terminals, such as using antistatic bag or shorting the gate and emitter with aluminum foil when transporting the product.

9. Reliability Notes (Lifetime Design)

Generally, during the operation of power converters such as inverters, the temperature of the IGBT module T_{vj} rises and falls repeatedly. This temperature change ΔT_{vj} causes the IGBT module to be exposed to thermal stress, which may shorten its lifetime depending on the operating conditions. Therefore, it is necessary to design the lifetime of the IGBT module to be longer than that of the power converters.

In most cases, the temperature change of the IGBT module is checked and the lifetime design is performed based on the power cycling (P/C) capability. If the lifetime design is insufficient, the lifetime of the IGBT module may be shorter than the required lifetime, and the module reliability may not be ensured. Therefore, it is important to design the IGBT module lifetime so that it meets the required reliability. For more detailed information on reliability notes, refer to Chapter 11 ‘Reliability of Power Modules’ of this manual.

Please use the IGBT module within the ΔT_{vj} P/C lifetime shown in Fig. 11-5. However, Fig. 11-5 shows the ΔT_{vj} P/C lifetime of the V series IGBT modules. The ΔT_{vj} P/C lifetime of the X series is different. Please refer to the technical data for details. In addition to this ΔT_{vj} P/C, there is another P/C based on the case temperature change of the module, ΔT_C P/C. Since the ΔT_C P/C lifetime depends on the thermal stress caused by the rise and fall of the case temperature, the lifetime of the IGBT module is greatly affected by the cooling design of the equipment. If the case temperature rises and falls frequently, pay sufficient attention to the product lifetime.

If the IGBT module is used beyond its lifetime, product quality deterioration may occur. In the worst case, the IGBT module may be destroyed. Please fully understand the usage environment of the equipment in which the IGBT module is to be installed, and apply the IGBT module after considering whether the target lifetime can be satisfied.

10. Other Precautions

Be sure to install an adequate fuse or circuit breaker between the power supply and the product in case the product is destroyed by an unexpected accident to prevent secondary destruction such as fire, explosion, and spread of fire.

In environments containing acids, alkalis, organic substances, corrosive gases (hydrogen sulfide, sulfurous acid gas, etc.), and corrosive liquids (cutting fluid, etc.), the product may oxidize or corrode, resulting in poor contact, disconnection, short circuit, ground fault, etc. In such cases, do not use the product as it may cause malfunctions. Should a short circuit or ground fault occurs, there is a secondary risk of smoke, fire, or explosion. If the product is used under conditions containing these corrosive substances, Fuji Electric Co., Ltd. is not responsible regardless of the conditions (temperature, humidity, concentration, etc.).

If the product is to be operated after being stored or assembled in a high humidity environment, operate the equipment after removing the moisture sufficiently. If the product is operated in a moisture-absorbed state, it may cause electrical wiring defects or insulation failures inside the product, in which case Fuji Electric Co., Ltd. is not responsible.

The products are not designed for use in dusty environments. If it is used in an environment where dust is generated, heat dissipation may deteriorate due to the heat sink may become clogged, and short circuits or ground faults may occur due to leaks between terminals or creeping discharge. (Even if the dust is an insulating material such as fiber, it may leak due to moisture absorption.)

In general, semiconductor devices have random failure modes due to high-speed particles (cosmic rays) originating from space and radiation. The failure rate in this failure mode varies depending on the installation location (latitude, longitude, altitude), installation environment, and operating conditions (voltage). Please contact Fuji Electric Co., Ltd. when using the product under high altitude or high voltage conditions.

Clearance distance and creepage distance of the products are designed for usage in an environment of 2000m or less above sea level. Fuji Electric Co., Ltd. is not responsible if the product is used in an environment exceeding this or in an environment with low atmospheric pressure.