<IGBT MODULES>

7th Generation T-Series Industrial LV100-type Application Note

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1 Features of the Industrial LV100 Module

1.1 Features of the 7th Generation IGBT and Diode chip

In order to realize the reduction of the on-state loss and the switching loss leading to the improvement of the energy saving performance of the product, the 7th generation charge storage type IGBT (CSTBT™) and MOS (Metal Oxide Semiconductor) chip structure has been optimized using thinner wafers. The 7th generation diode chip has been made with thinner wafer and has applied the RFC (Relaxed Field of Cathode) structure using backside diffusion layer formation technology.

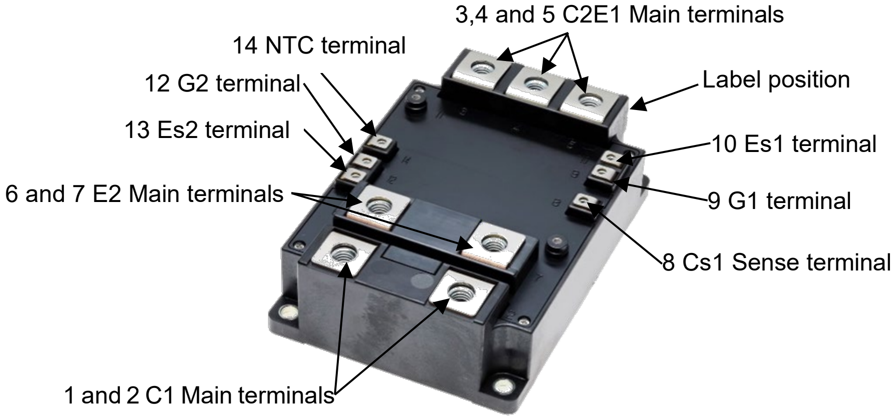
*CSTBT™: Our proprietary IGBT utilizing carrier accumulation effect
*RFC diode: P layer is partially added on the cathode side, holes are injected at the time of recovery, and by making the recovery waveform soft the diode can suppress the rise of steep voltage

1.2 Line Up

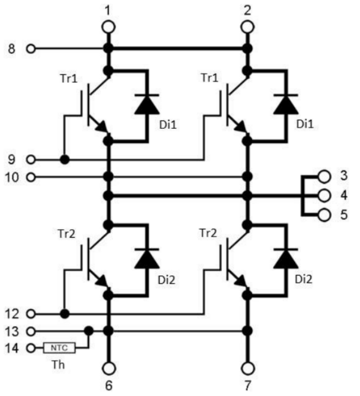
V_{CES} [V]	Type name	Number of elements	Package size [mm]
1200	CM800DW-24T	2	99.8 x 140
	CM1200DW-24T		
1700	CM800DW-34T		
	*CM800DW-34TA		
	CM1200DW-34T		

*Large diode

1.3 Module Nomenclature

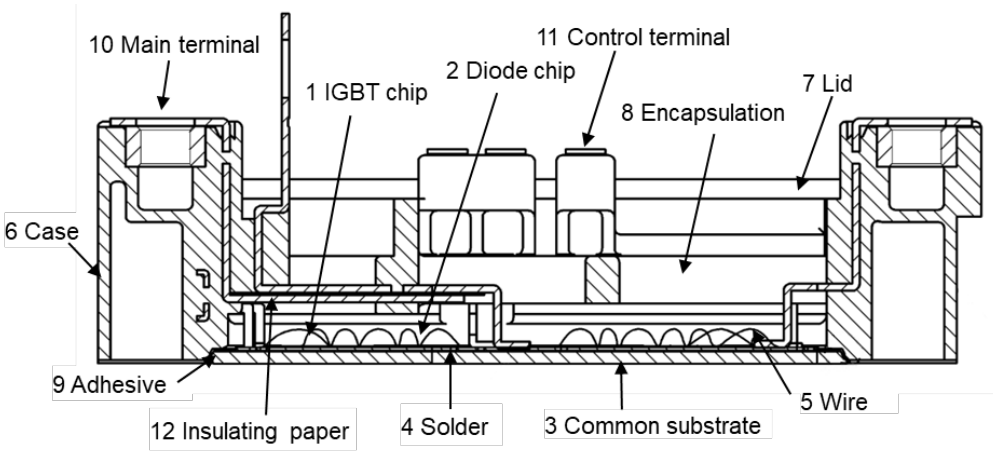


Connection



1.4 Structure (Parts and Materials)

The structure of industrial LV100 is shown.



*This figure shows the structural diagram of a typical example for the material explanation. It does not indicate the exact package size and chip size layout.

	Parts	Material	Flame Retardance
1	IGBT chip	Silicon	
2	Diode chip	Silicon	
3	Common substrate (Insulating metal baseplate)	Insulating part: Resin	UL 94V-0
		Baseplate: Copper	
4	Solder	Tin	
5	Wire	Aluminum	
6	Case	PPS	UL 94V-0
7	Lid	PPS	UL 94V-0
8	Encapsulation	Epoxy resin	UL 94HB
9	Adhesive	Epoxy resin	
10	Main terminal	Main terminal: Copper Plating: Nickel	
11	Control terminal	Main terminal: Copper Plating: Nickel	
12	Insulating paper	Nomex®	
-	Bushing	Steel	

2 Glossary

2.1 Common

Item		Description
IGBT	Insulated Gate Bipolar Transistor	Insulated gate bipolar transistor
FWD	Free Wheeling Diode	Free wheel (flywheel) diode
t_{dead}	Dead time	Pause (no signal) time provided in the ON signal between the upper and lower arm transistors
UL	Underwriters Laboratories	One of the safety standards in the United States. American Insurer Safety Test Laboratory power module conform to UL 1557.
RoHS Directive	Restriction of Hazardous Substances (Original) DIRECTIVE 2002/95 / EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.	Regulations prohibiting the use of four heavy metals and two types of brominated flame retardants in electrical products. "The basic concept is to make the use of heavy metals of lead, mercury, cadmium, hexavalent chromium and new products of electrical equipment as a rule not to contain by July 1, 2006." WEEE: waste electrical and electronic equipment
PC-TIM	Phase Change - Thermal Interface Material	High thermal conductivity grease. Solid phase at normal temperature and softening with temperature rise.
DP resin	Direct Potting Resin	A specially prepared resin material with enhanced coefficient of thermal expansion and adhesion.
RFC diode	Relaxed Field of Cathode Diode	It can suppress transient voltage rise as a hole is injected at the recovery time by adding a P layer to the cathode partially.
CSTBT™		Our proprietary IGBT utilizing carrier accumulation effect

2.2 Maximum Ratings

Symbol	Item	Definition or description
V_{CES}	Collector-emitter voltage	Maximum voltage that can be applied for a short time between collector and emitter with gate and emitter short-circuited.
V_{GES}	Gate-emitter voltage	Maximum voltage that can be applied for a short time between gate and emitter with collector and emitter short-circuited.
V_{CC}	Power-supply voltage	DC supply voltage that can be applied between collector and emitter.
I_C	Collector current	Maximum current that can flow continuously from collector to emitter within the rated junction temperature range.
I_{CRM}	Collector current (Maximum)	Maximum current that can be repeatedly flowed for a short time from collector to emitter within the rated junction temperature range. Normally it is twice the I_C.
I_E	Emitter current	Maximum current that can flow continuously from emitter to collector (freewheel diode) within the rated junction temperature range.
I_{ERM}	Emitter current (Maximum)	Maximum current that can be repeatedly flowed for a short time from emitter to collector (freewheel diode) within the rated junction temperature range. Normally it is twice the I_E.
P_{tot}	Collector loss	The maximum allowable power loss of the IGBT at the specified case temperature.
T_{stg}	Storage temperature	Maximum allowable temperature and minimum allowable temperature in the ambient temperature range when storing without applying power.
V_{isol}	Insulation withstand voltage	The maximum voltage that can be applied between terminal and the base plate with all main terminals and all auxiliary terminals short-circuited. It is usually expressed as an effective value.
M_t	Tightening torque	Tightening torque range of terminal screws.
M_s	Tightening torque	Tightening torque range of the mounting screws.
T_{vjop}	Continuous operating junction temperature	Allowable temperature range of chip in continuous operation. The ripple caused by the output frequency also must be taken into account within this rating.
T_{vjmax}	Maximum junction temperature	The maximum temperature that the chip can tolerate in instantaneous operation such as overload. The ripple caused by the output frequency also must be taken into account within this rating.

2.3 Temperature Ratings

Symbol	Item	Definition or description
T_a	Ambient temperature	When self-cooling or air cooling, the air temperature of a point which is not influenced by the heating element.
T_c	Case temperature	Temperature at a defined point on the enclosure (baseplate) of the device.
T_s	Heatsink temperature	Temperature at a defined point on the heatsink.

2.4 Thermal Ratings and Characteristics

Symbol	Item	Definition or description
R_{th}	Thermal resistance	A value that indicates how many degrees K per unit electric power the junction temperature will rise over the externally specified point when the heat flow due to the power consumption of the junction is in equilibrium.
$R_{th(j-c)}$	Thermal resistance	Thermal resistance from junction (chip) to the surface of the case (baseplate).
$R_{th(c-s)}$	Contact thermal resistance	Thermal resistance from the surface of the case (base plate) to the surface of the heatsink. Normally, it is the value when thermal conductive grease is applied.

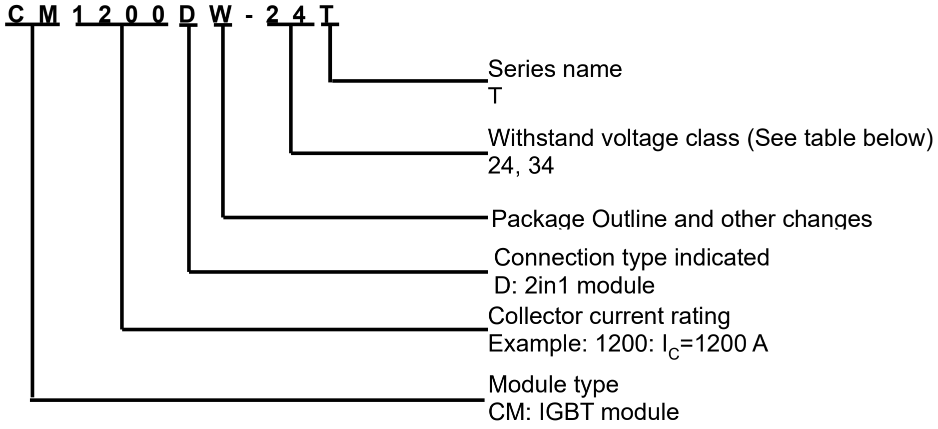
2.5 Electrical Characteristics

Symbol	Item	Definition or description
I_{CES}	Collector-emitter cutoff current	The leakage current when applying specified collector-emitter voltage with gate and emitter short-circuited.
I_{GES}	Gate-emitter leakage current	The leakage current when applying specified gate-emitter voltage with collector and emitter short-circuited.
$V_{GE(th)}$	Gate-emitter threshold voltage	The required gate-emitter voltage for the specified collector to flow under the specified collector-emitter voltage.
V_{CEsat}	Collector – emitter saturation voltage	The collector-emitter voltage when the specified collector current flows under the specified conditions.
C_{ies}	Input capacitance	Capacitance between gate and emitter terminal with collector to emitter short-circuited for a.c. under the specified conditions.
C_{oes}	Output capacitance	Capacitance between collector and emitter terminal with gate to emitter short-circuited for a.c. under the specified conditions.
C_{res}	Feedback capacitance	Capacitance between collector and gate terminal with collector to emitter short-circuited for a.c. under the specified conditions.
$t_{d(on)}$	Turn-on delay time	Time interval between 0 % of gate voltage during switching IGBT from off-state to on-state and 10 % of output collector current.
t_r	Rise time	Time interval between 10 % to 90 % of output collector current during switching IGBT from off-state to on-state.
$t_{d(off)}$	Turn-off delay time	Time interval between 90 % of gate voltage during switching IGBT from on-state to off-state and 90 % of output collector current.
t_f	Fall time	Time interval between 90 % to 10 % of output collector current during switching IGBT from on-state to off-state.
t_{rr}	Reverse recovery time	Time interval during flowing reverse recovery current when the current of the built-in freewheeling diode is switched from the forward direction to the reverse direction under the specified conditions.
Q_{rr}	Reverse recovery charge	The charge accumulated in the internal elements when the current of the built-in freewheeling diode is switched from the forward direction to the reverse direction under the specified conditions. Time integral of the reverse recovery current that flows in the reverse direction.
V_{EC}	Emitter to collector voltage	Voltage drop when the specified current flows to the built-in free wheel diode.
R_G	External gate resistance	The recommended range of the gate resistance connected between the element and the drive circuit.
E_{on}	Turn-on energy (Turn-on loss)	Integral of V_{CE} × I_C × dt during switching IGBT from off-state to on-state. Integral time is from 10 % rise point of I_C to 10 % drop point of V_{CC}.
E_{off}	Turn-off energy (Turn-off loss)	Integral of V_{CE} × I_C × dt during switching IGBT from on-state to off-state. Integral time is from 10 % rise point of V_{CC} to 2 % drop point of I_C.
E_{rr}	Reverse recovery energy (Reverse recovery loss)	Integrall of V_{EC} × I_E × dt during switching IGBT from off-state to on-state. Integral time is from forward current of the diode reaches 0 A until reverse recovery current reaches 0 A.

*The symbols and definitions are subject to change due to revision of the reference standard (IEC, JEC).

3 Product Label Information

3.1 Configuration of the Part Number

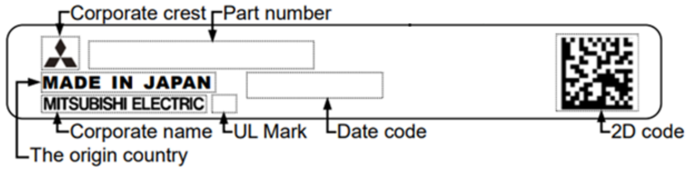


Withstand voltage class (50 times the number rated V_{CES})

Withstand voltage class	V_{CES} [V]
24	1200
34	1700

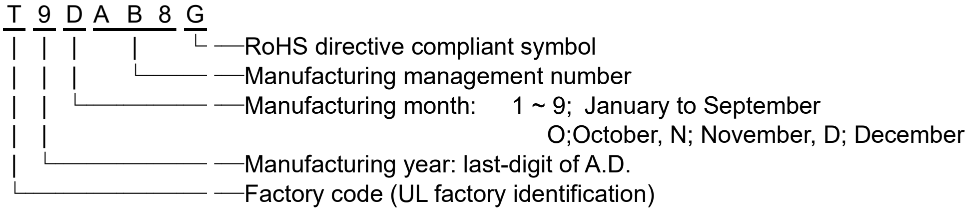
3.2 Labeling

1 Label printing example



- This product complies with the RoHS Directive (2011/65 EU, 2015/863/EU).
- Restriction of the use of certain hazardous substance in electrical and ecteronic equipment.

2 Date code formation



3.3 Two-Dimensional Barcode Configuration

Two-dimensional code specifications

Specification

Item	Specification
Symbology	Data Matrix (ECC200)
Data type	Alphanumeric (ASCII) characters
Error correction ability	20 – 35 %
Symbol size	6.0 mm x 6.0 mm
Code size	24 cell x 24 cell
Cell size	0.25 mm
Data size	39 letters

Data contents

Data item	Letter size
Part number	20
Space (Blank)	2
Data code	8
Space (Blank)	1
Parallel spec. symbol	3
Space (Blank)	1
Serial number	3
Space (Blank)	1
total	39

Data contents example: “SP” means space, equivalent to ASCII code number 32

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
C	**M**	**1**	**2**	**0**	**0**	**D**	**W**	**-**	**2**	**4**	**T**	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	**T**	**9**	**D**	**A**	**B**	**8**	**G**	SP	SP	SP	SP	SP	SP	**0**	**0**	**1**	SP
20																				2		8								1	3			1	**3**			1

4 Safety Standard (UL Standard)

Mitsubishi Power Modules are UL certified (Recognized) for UL Standard 1557 and Category Code QQQX2.
(Except for some special items, File No. E 323585)

Power modules are not certified for other safety standards (TUV, VDE, CSA etc).
(Reinforcement of CE marking is not made considering correspondence to insulation.)
Regarding European CE and China CCC, as of September 2021, the target regulation as a power module has not been confirmed.

5 Handling Precautions

Elements of a power module may be damaged depending on usage conditions (electrical/mechanical stress, handling etc.). In order to use our power module safely, observe the following precautions and use correctly.

5.1 Handling Precautions

⚠ Caution	
Transportation method	- During transportation, please keep the shipping box in the correct orientation. If it is inverted or excessive force is applied, the terminals may be deformed or the resin case may be broken. - Throwing or dropping may cause the device to break. - Care should be taken when transporting during rainfall or snowfall to not expose the device to water. Do not use the device if it is exposed to water as it may malfunction at the time of use.
Storage method	- The temperature and humidity of the storage location is desirably within the normal temperature and humidity range of 5 – 35 °C and 45 – 75 %. If stored in a more extreme environment than this temperature and humidity, the performance and reliability of the device may decrease.
Long-term storage	- When storing the product for a long term (over 1 year), please take measures for dehumidification. In addition, please confirm that there is no scratch, dirt, rust etc. on the device when using after long term storage.
Usage environment	- Use in environments where high humidity (including condensation), organic solvents directly adhere, where corrosive gas is generated, or in places where explosive gas, dust, salt, etc. are present may cause serious accidents. Please avoid usages in these environments.
Flame retardance	- For the epoxy filled resin, UL standard 94V-0 and for the case material, UL standard 94HB certified products are used. It is not incombustible, so please use caution.
Countermeasure against static electricity	- observe the following items in order to prevent damage due to static electricity. (1) Precautions to prevent static electricity destruction If static electricity charged on the human body and packing materials becomes an excessive voltage (±20V or more) and is applied between the gate and the emitter, the device may be damaged. The basic principle of static electricity countermeasure is to minimize the generation of static electricity and to avoid application of the voltage to the device * Do not use containers that are susceptible to static electricity for transportation and storage. * It is recommended to short-circuit the gate and emitter with carbon cloth/foam etc. until just before using the module. Also, please wear gloves so as not to touch the terminals with bare hands. Avoid gloves and work clothes that are easy to charge, such as nylon. * During assembly, ground the equipment to be used and the person performing work. It is also recommended to ground a conductive mat on the surface of the work table and the floor around the work table. Assembly refers to the point in time when the product is removed from the packing box. * Please note that when the gate-emitter is open on the printed circuit board on which the element is mounted, it may be destroyed by the static electricity charged on the printed circuit board. * When using a soldering iron, use a low voltage (12 V to 24 V) soldering iron for semiconductors, Ground the tip. (2) Open Gate-emitter Guidelines * Do not apply voltage between the collector and the emitter while the gate and emitter are open. * Please remove the element after checking gate and emitter short-circuited. (3) Interior shipping container Conductive plastic is used for the interior box, so the conductive foam used for short circuiting between gate and emitter is not necessary. As with the conventional conductive foam, this conductive plastic tray is not an electrostatic component that completely shorts the gate and emitter or clamps the overvoltage. Please take adequate measures against static electricity during the process of taking out the module out of the packing box to mounting in the equipment, by using a conductive mat grounded to earth with a band to the operator. If you take out the module out of the interior box and store it in another container etc, please implement electrostatic measures such as using a conductive container for the storage container. Also, since the module main body is not fixed to the interior tray, please be careful about handling so as not to drop the module while taking out or unpacking the interior tray.

Antistatic measures	- When performing an acceptance test (saturation voltage test etc.) such as applying a voltage between the gate and the emitter, discharge between the gate and the emitter before returning to the packing tray or storage (conductive) container after the test is completed. Please discharge the electric charge with a high resistance (about 10 kΩ).
Connection Method	- When mounting the module in the product, do not apply excessive stress to the screw terminal (structure). The terminal structure itself and the joint of the terminal structure case may be damaged. - During connecting to the module pins by using printed circuit board etc, please be careful not to deform with excessive stress. - During fixing the printed circuit board to the module case with tapping screws, please pay attention to the size of the screws and mounting method. If you mistake the screw size and installation method, the case of the module may be damaged.

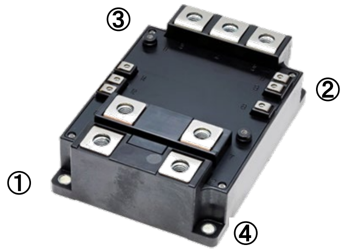
5.2 Flame Retardance

The case/encapsulation material PPS/resin and insulating substrate material used in the IGBT module have a flame retardance. If the module is cut off from the combustion source, there is no danger of spreading fire. Other components such as the silicon chip, copper baseplate, etc. do not have applicable UL flame retardance standards.

6 Precautions on Actual Use

6.1 Method of Attaching the Module to the Heatsink

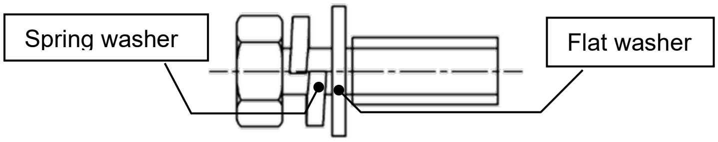
When mounting the module to a heatsink, if a one-sided tightening torque is applied extremely, the power module could get damage or degrade due to stress on the insulating substrate or silicon chip inside the module. An example of tightening sequence is shown in Fig. 6-1.



Pre-tightening ①→②→③→④ Final tightening ④→③→②→①

*Temporary tightening torque should be set to 20 to 30 % of maximum rating as a guideline
*Please use spring washer and flat washer.

Fig. 6-1: Mounting screw tightening order



*It is recommended using spring washer and flat washer.

Fig. 6-2: Example of Washer embedded screw (Spring and flat washers)

1. In order to maximize heat dissipation, it is necessary to minimize the contact thermal resistance by maximizing the contact area as much as possible.
2. The flatness of the heatsink should be -50 μm ~ +50 μm (for a length of 100 mm) on the module mounting surface (see Fig. 6-3). Also, the surface roughness should be within 10 μm for a length of 100 mm. Sufficient flatness must be provided on the surface of the heatsink. Excessive minus (concave) flatness will increase the contact thermal resistance $R_{th(C-S)}$ and affect the heat dissipation of the module. Excessive plus (convex) flatness may cause stress to be applied to the inside of the module during installation, which may cause damage to the module.
3. 7th generation IGBT modules are offered to optionally be pre-applied with PC-TIM (Phase change - Thermal Interface Material) on the baseplate. For details on handling, please refer to the “PC-TIM Application Note”.
4. It is also possible to apply heat conductive grease (herein referred to as grease) to the contact surface between the module and the heatsink. In this case, please apply so that it becomes uniform with thickness of 50 μm to 100 μm.
5. Use a torque wrench for tightening and tighten to the required torque. If the tightening torque is too large, there is a danger of breakage or deterioration of the element as well as the tightening components.

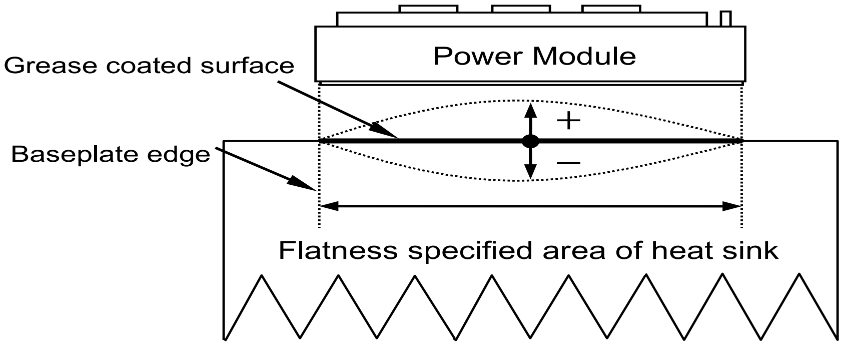


Fig. 6-3: Flatness of the heatsink

Required shape of the module mounting heatsink hole

The recommended maximum outermost diameter dimension of the threaded hole (φA) in Fig. 6-4 is 7 mm for securing the axial force of the mounting screw (to prevent screw looseness) and preventing stress concentration on the case resin material.

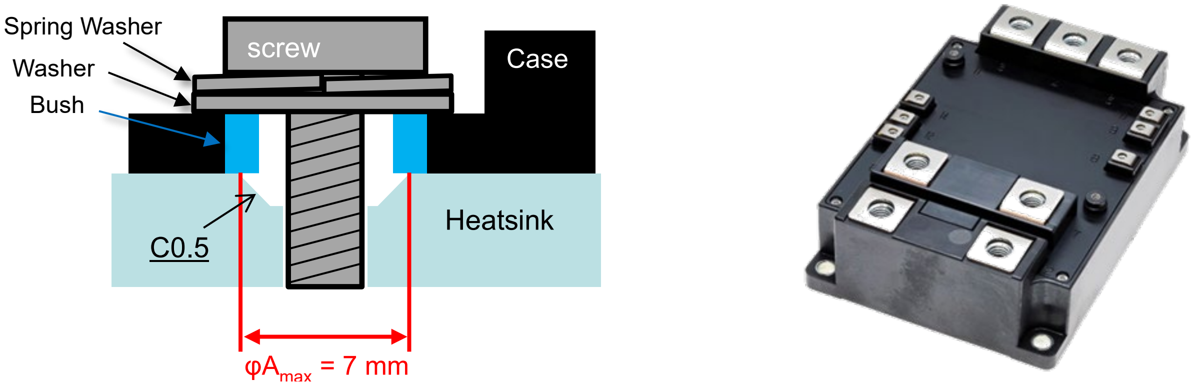


Fig. 6-4: Schematic of module mounting heatsink hole

6.2 Mechanical Strength of Main Terminal

To prevent deformation or damage to the main terminals, please keep the stress on the main terminals from the connected busbar or so on under the value indicated Fig. 6-5. The value which indicated in Fig. 6-5 assumes the condition which is all the main terminals for the same potential (two or three terminals) are connected with a common busbar.

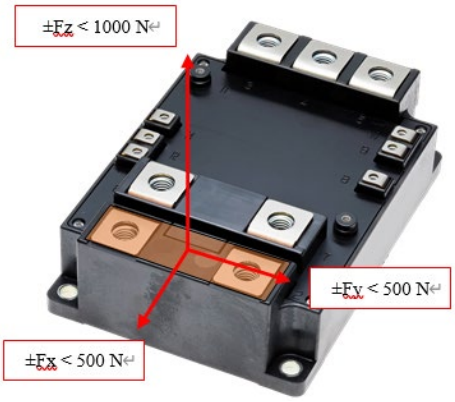


Fig. 6-5: Mechanical strength of main terminal

6.3 Power Module Implementation

Capacitor Connection

During switching, high voltage is induced in power circuit stray inductance by the high di/dt of the main current in case the stray inductance is large. This voltage can appear on the IGBT module and cause IGBT or diode destruction. In order to avoid this problem, guidelines that should be followed in designing the circuit layout are:

1. Reduce the L1 inductance by bringing the connection of the smoothing capacitor close to that of the module and arranging the return connection in a laminated plate structure to cancel the magnetic field.
2. The smoothing capacitor itself should be of low impedance type.
3. Decrease the di/dt by slowing the switching speed of the element (increase the gate resistance, etc.).
4. If possible, connect the snubber capacitor close to the module terminal in order to bypass the high frequency current and absorb the surge voltage.

It is a general measure to suppress the wiring inductance (L1) of the main circuit as much as possible by 1 or 2 and still suppress surge voltage using 3 or 4 when the surge voltage is large. Regarding 4, if the wiring inductance (L1) is large, the voltage oscillation may increase due to the resonance between C and L1. At that time, oscillation can be suppressed by changing the value of C.

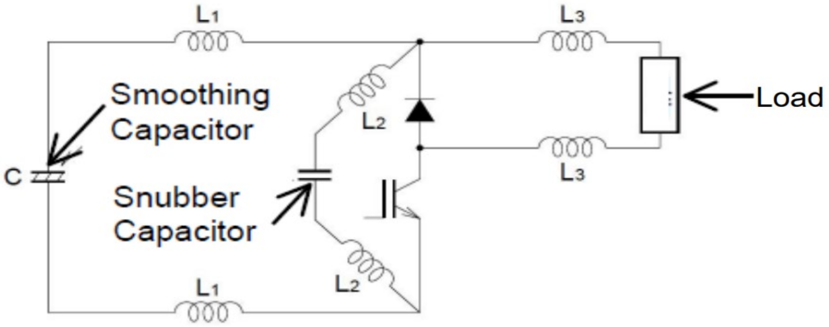


Fig. 6-6: Power Module application circuit

L1: Inductance of the wiring connecting the smoothing capacitor and the IGBT module. Since it is a round-trip line, it is necessary to use laminated conductors made of parallel flat metal plates sandwiching an insulator so that mutual magnetic fields are canceled.
L2: Inductance of the snubber capacitor lead wire. If this inductance is large, it will not be an effective bypass.
L3: Inductance of the wiring connecting the load.

Precautions for mounting/installation

Please install using hand tightening method if possible. When tightening with an electric screwdriver or similar, the excess thermally conductive grease should be squeezed out by pushing the module against the heatsink, etc. before tightening. Also, it is necessary to sufficiently lower the tightening speed or to apply a low viscosity grease. If tightening at high speed with a high viscosity thermally conductive grease, the module may deform and be damaged.

Please use mounting screws and washers that match the module mounting hole size. If screws with a size smaller than the recommended screw size (with flat washer) are used, there is a possibility that a misalignment of the center line of the screw occurs, a shearing force is applied to the flat washer, and the clamping force is not evenly applied to the module mounting hole. This will cause loosening of the mounting screws. An attaching method that makes axial force uniform and that the head end face of the screw can be held within the center line deviation in order to cover the whole mounting hole is ideal.

When using iron screws for module installation and screw terminal connection, the tightening torque is limited by the strength of the resin case etc. of the module body. Please note that tightening with the standard tightening torque of the iron screw specified in JIS etc. may cause damage to the case.

Note)

Please note the screw length. If screws longer than necessary are used, it may cause resin breakage at the terminal.
Please refer to the following dimensions and use the screw of the optimum length.
Please tight the screw with equivalent torque in the two main terminals. In particular, the tightening difference of the C1/E2 terminals affects current imbalance.

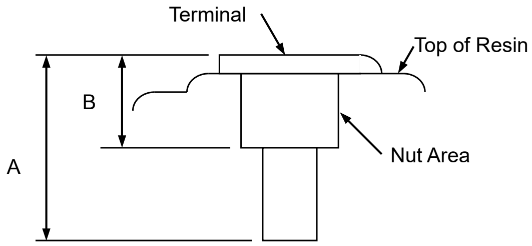


Fig. 6-7: Terminal screw hole depth

Terminal screw hole depth (Unit: mm)

Screw and size		Model	A	B	Terminal thickness
Main terminals	M8	CM800DW-24T, CM1200DW-24T, CM800DW-34T, CM800DW-34TA, CM1200DW-34T	14.5 mm	7.7 mm	1.2 mm
Auxiliary terminals	M3		8 mm	3.2 mm	0.8 mm

*Dimensions A and B do not include floating of the terminal.

Please use the screws which is appropriate length for the main terminals and auxiliary terminals.
Industrial LV100 series products have 2 terminals each for P-side and N-side terminal and have 3 terminals in AC terminal. Each external terminal is internally connected, but please be sure to use all terminals for external connection.

6.4 Thermally Conductive (Heat Dissipating) Grease Application Example

Method of applying the thermally conductive grease to the power module:

1. Required materials: Power module, thermally conductive grease, screen, electronic mass meter, gloves
   What is called a thermal compound basically performs the same function as the thermally conductive grease. When using a highly viscous compound, thoroughly stir before spreading so that it spreads over the entire baseplate.

2. The relationship between the amount and the thickness of the thermally conductive grease to be applied is as follows:

$$\text{Thickness of thermally conductive grease} = \frac{\text{Amount of grease [g]}}{\text{Baseplate area of module } [cm^2] \times \text{ density of grease } [\text{g}/cm^3]}$$

Our recommended thermal conductivity grease thickness is 50 µm to 100 µm.
Note, this thickness is the initial value at the time of coating, it changes depending on the flatness of the base plate and heatsink after installation.

Calculate the amount of thermal conductive grease required for the power module. Calculation example:
Mounting area 103 mm × 95.5 mm, for case of G-747 made by Shin-Etsu Chemical Co., Ltd. for heat conductive grease

$$50\mu\text{m} = \frac{Amount\ of\ grease\ [g]}{98.37\ [cm^2] \times 2.65\ [g/cm^3]}$$

∴ Thermally conductive grease amount will be 1.30 [g].

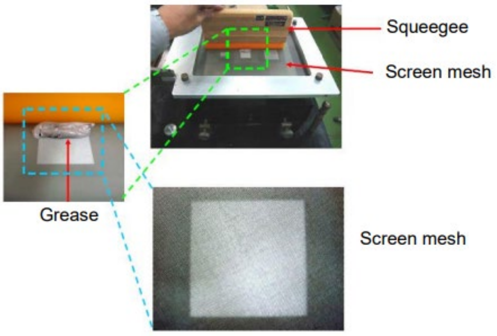
3. Measure the mass of the power module without grease applied.

4. Add the amount of thermally conductive grease calculated in 2 to the base plate of the power module using an electronic mass meter. There is no specific and required method for applying the grease.

5. Apply the added thermal conductive grease to the entire surface of the base plate so as to be uniform. There is no particular limitation on the application method as long as the target thickness is nearly uniform over the entire surface of the baseplate of the power module.

Please be careful not to contaminate with foreign matter and bubbles when applying the grease. When coating with a roller etc., please be careful that bubbles do not get mixed in the grease. When using metal spatula, please be careful not to scratch the baseplate surface. It is possible to reduce the aging effect of the thermally conductive grease on the baseplate by not wiping off the excess grease after installing to the heatsink.

Example of using a squeegee and mesh screen (mask)
(Application example: Shin-Etsu Chemical Co., Ltd.)



Grease for aluminum conductor connections is mainly aimed at improving the contact properties of the aluminum surface and lowering electrical contact resistance by preventing corrosion. Although there seems to be a long-term use record, it is not intended to improve the heat conduction of the contact part, so it cannot be expected to make much reduction in contact thermal resistance. If this grease is adopted, sufficient heat dissipation design/study is required.

The optimum thermal conductivity grease varies depending on the application and usage, so please contact directly to the grease maker at the time of selection/specification.

6.5 Concept of Thermal Resistance

The datasheet defines the thermal resistance $R_{th(j-c)}$ between the chip junction and case (baseplate), and the contact thermal resistance $R_{th(c-s)}$ between case (baseplate) and heatsink. The reference point of thermal resistance (case temperature) is just under the chip. Chip positions of each product is described in the datasheet. An example of that is described below.

Tr** indicates the center position of the IGBT chip, Di** indicates the center position of the FWD chip. For 2 elements, Tr1/Di1 indicates the upper arm and Tr2/Di2 indicates the lower arm.

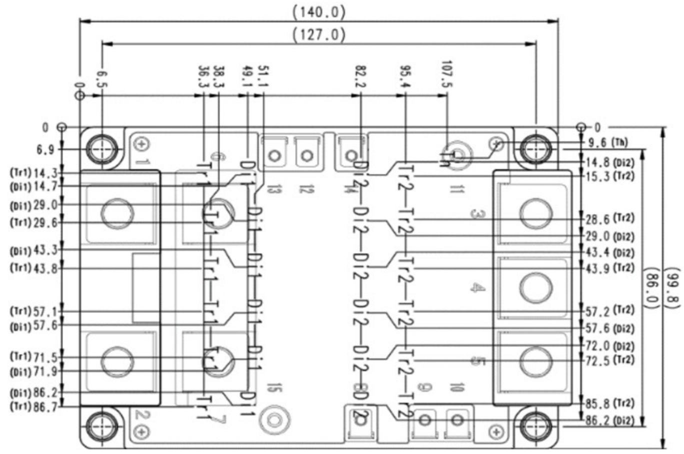


Fig. 6-8: Chip location (CM1200DW-24T)

Please measure the case and heatsink temperature by attaching the thermocouple at the position (directly under the chip) based on this Fig. 6-8.

Notes

1. The thermal resistance of the heatsink will change depending on the material, area, and thickness used. Generally, with heatsinks of the same material, the smaller the area and the thinner the heatsink, the higher the thermal resistance.

2. The indicated contact thermal resistance $R_{th(c-s)}$ value in the datasheet is the typical value under noted application conditions of thermal conductive grease. The thermal conductivity conditions of the grease are $\lambda = 0.9$ W/(m・K) and $D_{(c-s)} = 50$ μm. Actual contact thermal resistance depends on the type of grease, the applied amount and the heat generation conditions and so on. Please confirm the thermal resistance $R_{th(c-s)}$ in actual operating conditions.

3. Water-cooled heatsink:
   The general industrial power module is assumed to be used in a cooling system using a natural convection heatsink or air-cooling heatsink. If you use a water-cooled heatsink, thermal resistance $R_{th(j-c)}$ and contact thermal resistance $R_{th(c-s)}$ may change significantly due to the nature of heat spreading. Further, if condensation occurs, discharge may occur between the main electrodes. Destruction due to dew condensation is possible due to overvoltage breakdown due to the surge voltage generated by the discharge. Since there is no dew condensation countermeasure as part of the module, it is necessary to take dew condensation measures in the unit using the module when it is used with water cooling. The encapsulation material (DP resin) filled in the module has moisture permeability.

4. Package for general industrial power module is not airtight structure, so liquid can be absorbed into the module. Both the package materials and semiconductor chips are not designed assuming long-term contact with any material which is entered from outside. Therefore, characteristics and reliability cannot be guaranteed when the module is immersed in silicone oil or similar.

6.6 Example of Thermocouple Attachment

Example of thermocouple attachment for case temperature measurement just under the chip are shown below.

1. Case temperature measurement

Case temperature just under chip is used for estimation of junction temperature.
(Please see “10. Power loss and heat dissipation design” for the detail estimation procedure.)
Thermocouple attachment examples are shown below.

<Step 1>
Drill into the IGBT module as shown in Fig. 6-9.
(The depth of the groove is 0.8 mm and the width is 1 mm as a guideline when a thermocouple with a wire diameter of 0.3 mm (recommended value) is used.)
Please be careful that the base of the thermocouple tip (dashed blue line) comes to the point you want to measure (just under the chip).

<Step 2>
Insert a thermocouple into the groove drilled in Step 1, place it on the module baseplate, and seal with a high thermal conductivity filler from the top so that the thermocouple does not move.

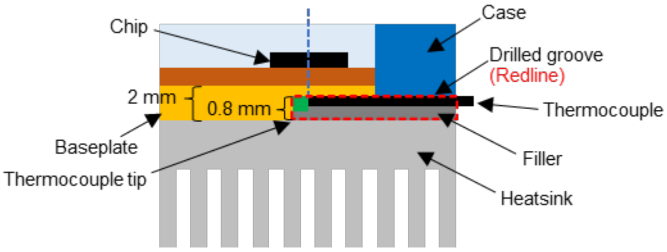


Fig. 6-9: Example of thermocouple attachment

Fig. 6-10 shows an example of groove drilling on the back of the module. Please be careful not to impact the flatness of the module by burs and filling materials after the groove processing.

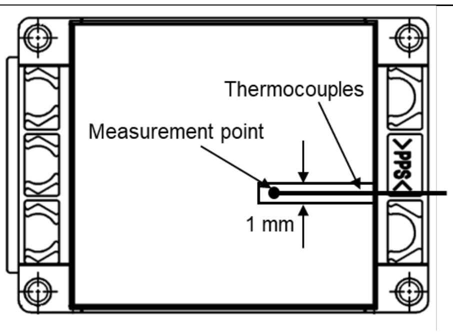


Fig. 6-10: Drilling example

Note: For the junction temperature estimation, it is recommended to measure the case temperature with an actual cooling system on your application.

2. Heatsink temperature measurement

<Step 1>
Drill into the heatsink as shown in Fig. 6-11.
(The depth of the groove is 1 mm and the width is 1 mm as a guideline when a thermocouple with a wire diameter of 0.3 mm (recommended value) is used.
Please be careful that the base of the thermocouple tip (dashed blue line) comes to the point you want to measure (just under the chip).

<Step 2>
Insert a thermocouple into the groove drilled in Step 1, place it on the heatsink, and seal it with a high thermal conductivity filler from the top so that the thermocouple does not move. It is no problem even if the thermocouple is caulked to the heatsink.

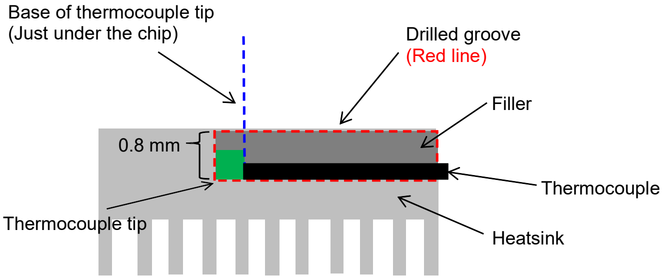


Fig. 6-11: Example of heatsink thermocouple mounting

Fig. 6-12 shows an example of groove processing on a heatsink.
Be careful not to impact the flatness of the heatsink by burrs and filling materials after the groove processing.

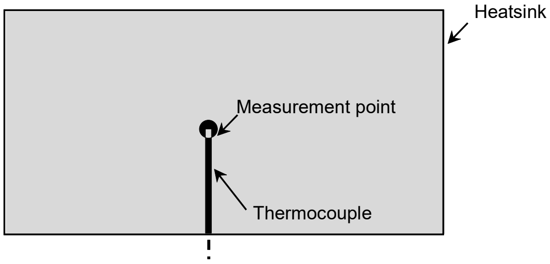


Fig. 6-12: Drilling example of heatsink

Wiring example of the power module

It is suggested to layout by using two DC bus conductor plates (P layer, N layer) which are sandwiching an insulating layer. The stacking order has no effect on wiring inductance. An example of how to connect this multilayer bus to the module is shown below.

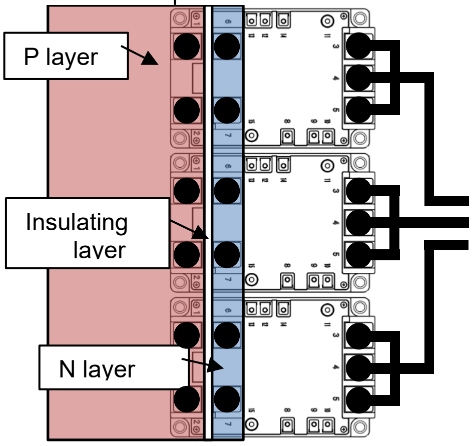


Fig. 6-13: Layout example when a three-phase full-bridge is used as one unit

Low inductance laminated bus bar manufacturer example: Ryoden Kasei Co., Ltd.: "Laminated bus bar" https://www.ryoka.co.jp/ For details, please contact directly to the manufacturer.

6.7 Use of Thermistor

(1) Basic characteristics of NTC thermistor

A thermistor is a resistor whose resistance depends on temperature, and thus has a function as a temperature sensor. The thermistor installed in industrial LV100 is NTC (Negative Temperature Coefficient) thermistor and then is resistance decreases with increase in temperature. The resistance R is defined as the following equation.

R_{25} is the resistance at T_{25}(25 °C) = 298.15 [K]. B is called B-constant which means the slope of temperature dependence. Each thermistor has its own B-constant and is defined in the datasheet of IGBT modules as the following table. Two temperature points must be defined for B-constant. We define $B_{(25/50)}$ as the B-constant with 25 °C and 50 °C.

Symbol	Item	Conditions	Limits			Unit
			Min	Typ	Max	
R_{25}	Zero-power resistance	T=25 °C	-	5.00	-	kΩ
$B_{(25/50)}$	B-constant	Approximate by equation	-	3375	-	K

To be precise, B-constant has a temperature dependence. Thus, more precise resistance value is given in the thermistor characteristics curve in the datasheet as Fig. 6-14.

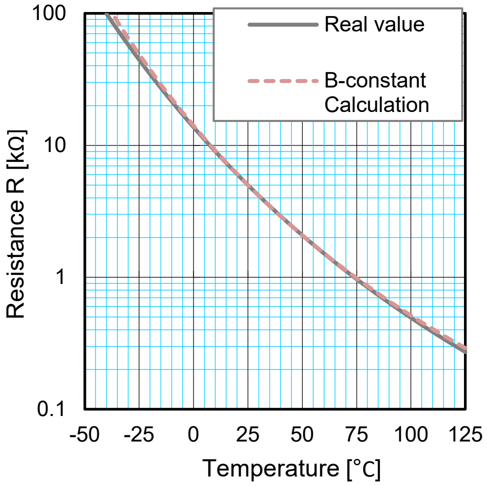


Fig. 6-14: Thermistor characteristics curve

In Fig. 6-14, the calculation result with $B_{(25/50)}$ is shown with red dashed line in addition to the thermistor characteristics curve. The calculation result matches the actual thermistor resistance very well. Then it is confirmed that the equation with $B_{(25/50)}$ is enough accurate in the range of operation temperature of power semiconductors. Also, calculation result with B-constant is even higher than real temperature and then it is safer side estimation.

$$R = R_{25} exp\left\{B\left(\frac{1}{T}-\frac{1}{T_{25}}\right)\right\}$$

(2) NTC thermistor position

NTC thermistor is located on the substrate in industrial LV100. Heat from power semiconductor chips is transferred to the thermistor via the substrate. Therefore, the thermistor temperature is lower than the chip temperature and rather closer to the case temperature.

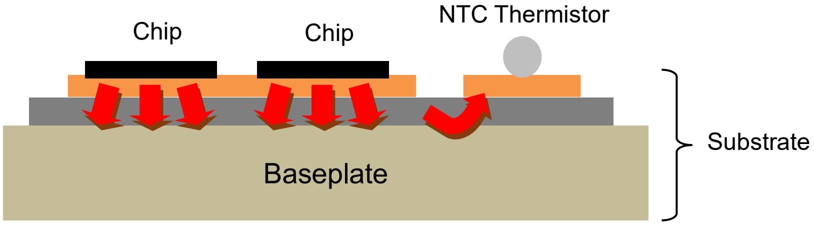


Fig. 6-15: NTC thermistor position and heat dissipation path

NTC thermistor is connected with the auxiliary emitter terminal (No. 13 in Fig. 6-16). The thermistor temperature can be calculated with the measurement of the resistance between the thermistor terminal (No. 14) and the auxiliary emitter terminal.

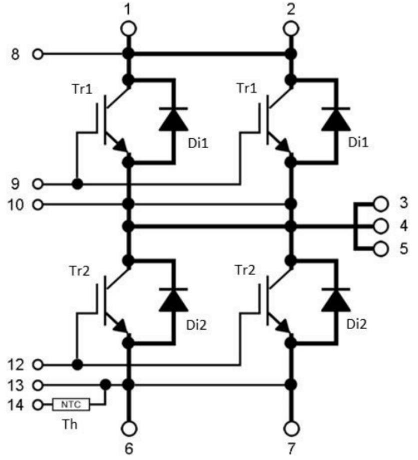


Fig. 6-16: Circuit diagram

Please take care that the one of NTC terminal is connected internally to the main emitter terminal of the power module (No. 6 and 7 terminals in Fig. 6-16). If necessary, please isolate your detection circuit by using device such as isolation amplifier. Some supplier lines up the driver board to match Mitsubishi power devices and offers the isolation type for the thermistor signal line.

(3) Measurement method of NTC thermistor resistance

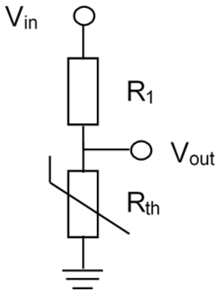
For thermistor temperature measurement, its resistance needs to be measured. A voltage divider is applicable for the resistance measurement. The resistance for series connection with the thermistor needs to be chosen to have precise measurement at the target temperature.

The thermistor resistance is calculated with the divided voltage of the thermistor by the following equation.

$$R = \frac{V_{out}}{V_{in} - V_{out}} \cdot R_1$$

The thermistor temperature is estimated with the calculated thermistor resistance by the following equation.

$$T = \frac{1}{\frac{1}{B} \ln\left(\frac{R}{R_{25}}\right) + \frac{1}{T_{25}}}$$



$$V_{out} = \frac{R}{R + R_1} \cdot V_{in}$$

Fig. 6-17: Temperature measurement circuit

6.8 Others

In the IGBT module, the insulation distance is designed to UL 840 as a reference standard, but there is a risk that the clearance might become insufficient at high altitude. Due to decreased air pressure, the withstand voltage for the same spatial distance decreases and the insulation capability decreases in general.

Also, as the altitude increases, the cosmic radiation will increase rapidly. It is known that as more cosmic radiation hits a semiconductor, the possibility of random failure increases. Please refer to application notes "About Isolation Voltage and LTDS".

7 How to Use the IGBT Module

7.1 IGBT Module Selection

(1) Voltage rating

The voltage rating of the IGBT module is determined by the input supply voltage of the applicable device or the bus voltage applied between P and N of the module. Generally, Table 7-1 shows the input power supply voltage, bus voltage, and rating of module.

Table 7-1: Application example of input power supply voltage and device rating

	Voltage rating of input power supply voltage and device rating	
	1200 V	1700 V
Input supply voltage (AC)	~480 Vrms	~690 Vrms
P-N bus voltage (DC)	~850 V	~1200 V

(2) Current rating

It is a current value that can flow as a DC current. For switching operation (pulse), up to twice the rated current can be tolerated. However, in actual use, it is necessary to consider junction temperature, case temperature, life (lifetime of power cycle, thermal cycle etc) etc.

7.2 Switching Loss

Selection of gate resistance

As for the gate resistance R_G, maximum and minimum values are indicated as recommended values in the datasheet. The recommended minimum R_G value is the condition that regulates the electrical characteristic switching time of the IGBT module, and it is assumed can be applied in actual operating conditions. The gate resistance R_G greatly affects switching time and switching loss. Below is a graph of R_G vs Switching time and R_G vs Switching loss of CM1200DW-24T.

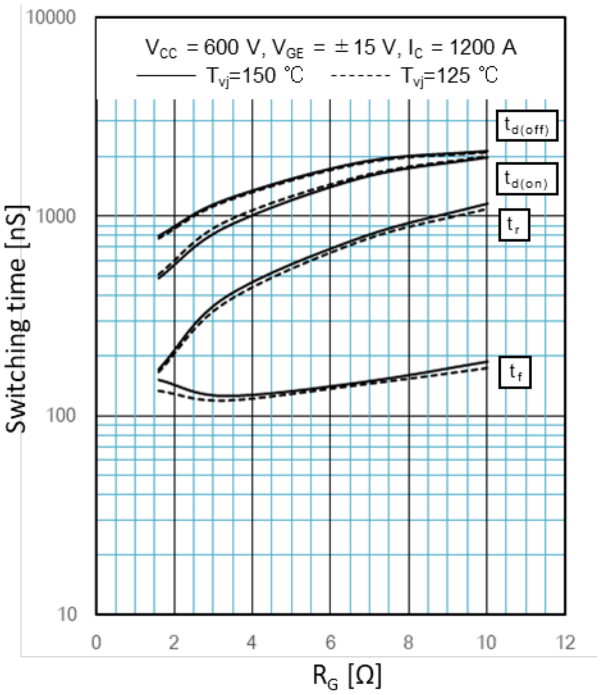


Fig. 7-1: R_G - Switching time

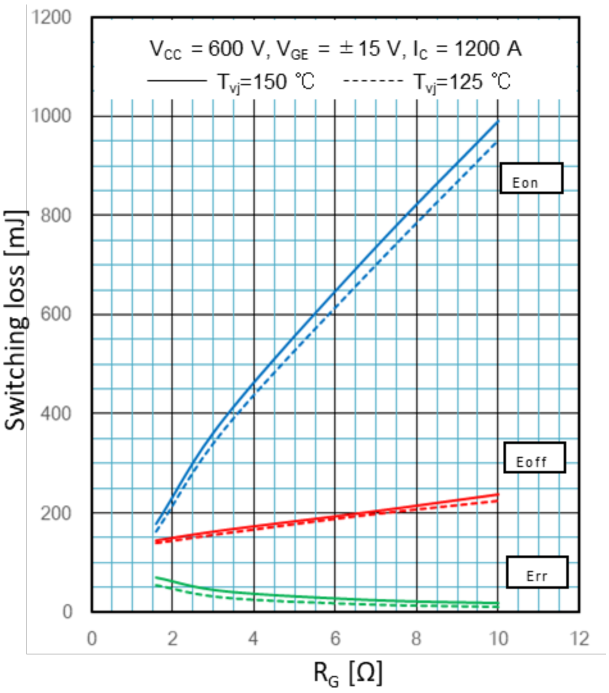


Fig. 7-2: R_G - Switching losses

It is necessary to select the optimum R_G value for the characteristics of switching time, switching loss, surge voltage and so on. Since the surge voltage may change depending on the wiring inductance of the equipment and the snubber circuit etc. The optimum value varies depending on the main circuit. In order to apply maximize performance, it is recommended to set the gate resistance on turn-on side and turn-off individually.

7.3 Parallel Connection of IGBT Modules

(1) Parallel operation

The following sub-sections outline the basic requirements and considerations for parallel operation of industrial LV100 of dual switch configuration with ratings. Industrial LV100 lineups paralleling-specification type which is specially designated for parallel use.

I_C vs V_{CEsat} characteristics of Industrial LV100 have a positive with temperature coefficient. This feature (positive temperature coefficient) facilitates the reduction in the imbalance of the collector current between paralleled devices. When the junction temperature of IGBT get to be high, the V_{CEsat} is increased and the collector current reduces accordingly.

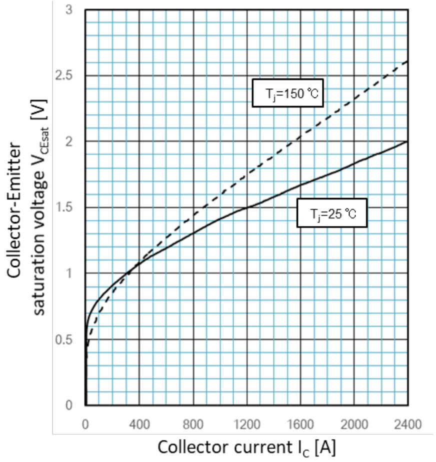


Fig. 7-4: V_{CEsat} characteristics of CM1200DW-24T

When two 7th generation IGBT modules with parallel specification are paralleled, the ratio of the maximum static current imbalance will be restricted to ±15 % for both 1200 V and 1700 V class. Using modules from the same lot number in parallel is recommended since a smaller deviation in the V_{CEsat} results in a smaller ratio of the static current imbalance between two modules. (Please inquire of your sales contact the detail of the parallel specification)

As the number of modules connected in parallel increases, there is a possibility for any one single module to experience a high collector current. When modules are paralleled, calculate the derating current with formula shown below:

$$\left\{1-\frac{(n-1)\times\frac{1-x}{1+x}+1}{n}\right\}\times 100\,\%$$

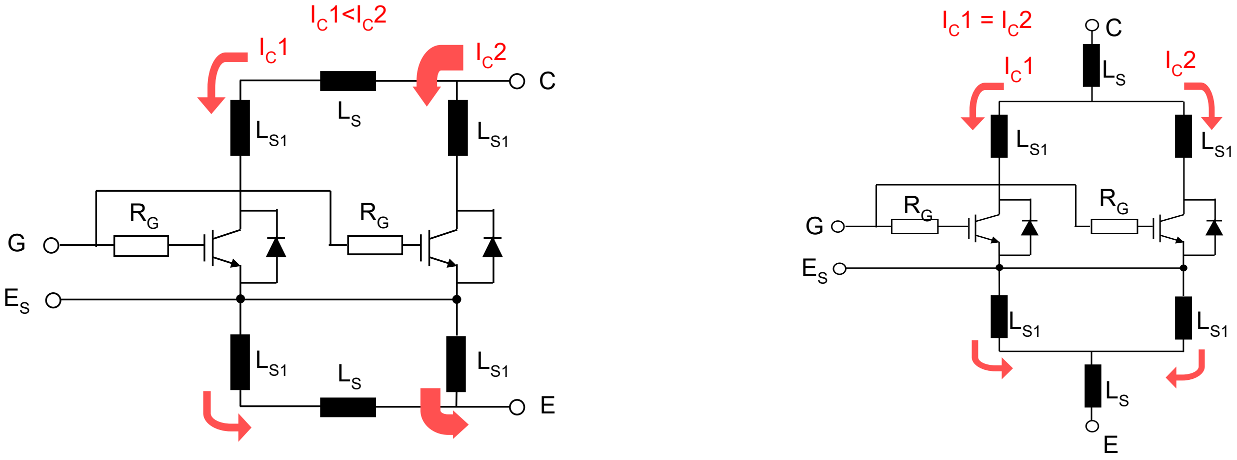
n: Number of paralleled modules

x: Ratio of static current imbalance

Matching V_{CEsat} is effective for maintaining good static steady state current balance. Gate drive conditions and power circuit layout have the significantly impact on dynamic current balance between paralleled devices. Please connect IGBT modules to the application circuit symmetrically and shortly in order to minimize the current imbalance.

(2) Layout of main circuit

1. Circuit connections should be low inductance and laid out symmetrically for balanced inductance. Difference in the circuit inductance between each device may cause current imbalance and thermal destruction (Fig. 7-5).
2. Use snubber circuit for each module individually and reduce circuit inductance in order to minimize surge voltage.



<Example of imbalanced current>
Collector current through each device has a large deviation due to an imbalance in the circuit inductance between devices.

<Example of balanced current>
Collector current flows symmetrically due to balanced circuit inductance between devices.

Fig. 7-5: Current imbalance caused by an asymmetric main circuit inductance

(3) Gate drive circuit

1. Uniform impedance of each gate drive circuit. In case the difference in the impedance consisting of gate resistance and stray inductance is high, current imbalance may occur.
2. Use short and tightly, twisted wires of equal length.
3. Gate resistance should not be too high.
4. Avoid running the wiring of drive circuit in parallel to main circuit.
5. Use gate resistor for each device individually to prevent gate oscillation. (Fig. 7-6)
6. Insert a low value resistance (e.g. 0.1 Ω) or ferrite core in the emitter wiring of the gate drivers in case an inductive current flow in the loop of the main emitter wiring and the gate wiring. This loop current may cause a difference in the switching speeds between paralleled devices by influencing the instantaneous gate voltage. (Fig. 7-6)

<Example of imbalanced current>
Only a single gate resistor is employed to connected the gates of the paralleled devices.

<Example of balanced current>
Use gate resistors for each device individually to prevent gate oscillations.

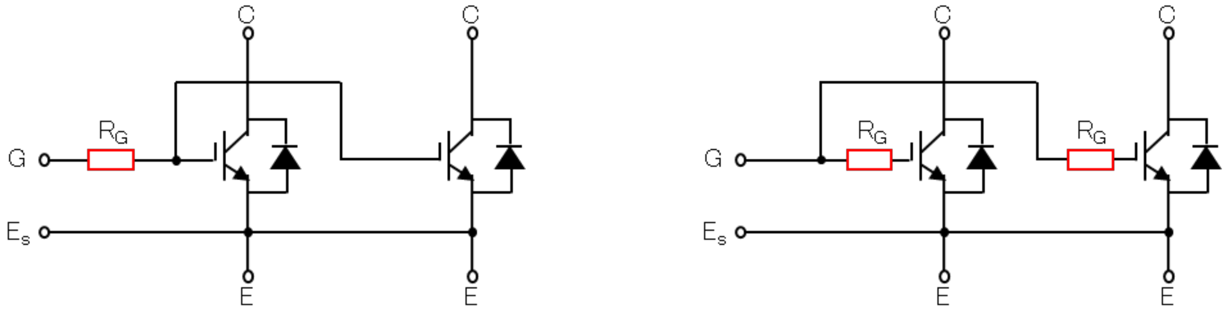


Fig. 7-6. Measures to limit gate oscillation

<Example of imbalanced current>
Inductive current flows through the drive circuit via emitter connection due to a difference in the value of the inductances L_{S1} and L_{S2}.

<Example of balanced current>
Insert resistors (R_S = 0.1 Ω) or ferrite core in emitter wiring of the gate drive circuit to limit the inductive current flow.

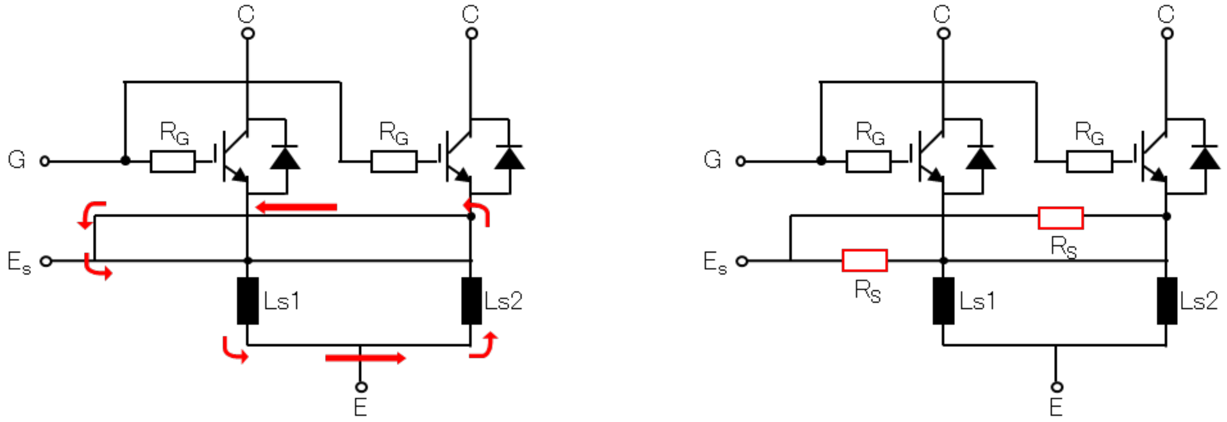


Fig. 7-7: Measures to limit inductive current in emitter wiring

8 Power Loss and Heat Dissipation Design

8.1 How to Calculate the Power Loss

(1) Loss calculation of the power module

In order to use the power module safely, it is necessary to calculate the power loss and the junction temperature under the conditions to be used, and to use the module within the absolute ratings. When selecting a power module, you can download and use simulation software from our website.

Download site: https://www.mitsubishielectric.com/semiconductors/simulator/index.html

Please click "Register" on the page, and after entering the necessary information, the download page will be displayed.
*Supported OS is Windows® 98SE or later only.
For the usage of the software, please download the manual “POWER LOSS SIMULATION Ver. * User’s Manual”

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