Chapter 2 Terms and Characteristics

This chapter describes the terms related to the automotive IGBT module and its characteristics.

1. Description of Terms

Various terms used in the specification, etc. are described below.

Table 2-1 Maximum ratings

Term	Symbol	Definition explanation (See specifications for test conditions)
Collector-emitter voltage	V_{CES}	Maximum collector-emitter voltage with gate-emitter shorted
Gate-emitter voltage	V_{GES}	Maximum gate-emitter voltage with collector-emitter shorted
Implemented collector current	I_{CN}	Ratings current
Collector current	I_{Cnom}	Maximum forward DC collector current
	I_C	
	$-I_{Cnom}$	Maximum reverse DC collector current
	$-I_C$	
Collector power dissipation	P_C	Maximum power dissipation per element
Junction temperature	T_{vj}	Maximum chip temperature, at which normal operation is possible. You must not exceed this temperature in the worst condition.
Operating junction temperature	T_{vjop}	Maximum chip temperature during continuous operation
Cooling water temperature	T_{win}	Cooling water temperature on the inlet side of the cooling water channel
Storage temperature	T_{stg}	Temperature range for storage or transportation, when there is no electrical load on the terminals
Isolation voltage	V_{iso}	Maximum effective value of the sine-wave voltage between the terminals and the heat sink, when all terminals are shorted simultaneously
Screw torque	Mounting	Maximum torque for specified screws when mounting the IGBT on customer's system
	Main Terminal	Maximum torque for terminal screws when connecting external wires/bus bars to the main terminals
	PCB Mounting	Maximum torque for tightening screws when PCB install on the IGBT module
Control terminal soldering	Number of times	Maximum number of times
	Soldering temperature	Maximum soldering temperature
	Soldering time	Maximum soldering time

Caution: The maximum ratings must not be exceeded under any circumstances.

Table 2-2 Electrical characteristics

	Term	Symbol	Definition explanation (See specifications for test conditions)
Static characteristics	Zero gate voltage collector current	I_{CES}	Collector leakage current when a specific voltage is applied between the collector and emitter with gate-emitter shorted
	Gate-emitter leakage current	I_{GES}	Gate leakage current when a specific voltage is applied between the gate and emitter with collector-emitter shorted
	Gate-emitter threshold voltage	$V_{GE(th)}$	Gate-emitter voltage at a specified collector current and collector-emitter voltage (gate-emitter voltage which start to flow a low collector current)
	Collector-emitter saturation voltage	$V_{CE(sat)}$	Collector-emitter voltage at a specified collector current and gate-emitter voltage (Usually V_{GE}=15V)
	Input capacitance	C_{ies}	Gate-emitter capacitance, when a specified voltage is applied between the gate and emitter as well as between the collector and emitter, with the collector and emitter shorted in AC
	Output capacitance	C_{oes}	Gate-emitter capacitance, when a specified voltage is applied between the gate and emitter as well as between the collector and emitter, with gate-emitter shorted in AC
	Reverse transfer capacitance	C_{res}	Collector-gate capacitance, when a specified voltage is applied between the gate and emitter, while the emitter is grounded
	Diode forward on voltage	V_F	Forward voltage when the specified forward current is applied to the internal diode
Dynamic characteristics	Turn-on time	$t_{d(on)}$	The time interval between when the gate-emitter voltage rises to 10% of the maximum value and when the collector current rises to 10% of the maximum value during IGBT turn on
	Rise time	t_r	Time required for collector current to rise from 10% to 90% of the maximum value
	Turn-off time	$t_{d(off)}$	The time interval between when the gate-emitter voltage drops to 90% of the maximum value and when the collector current drops to 90% of the maximum value during IGBT turn off
	Fall time	t_f	Time required for collector current to drop from 90% to 10% of the maximum value
	Reverse recovery time	t_{rr}	Time required for reverse recovery current in the internal diode to decay
	Reverse recovery current	I_{rrm}	Peak reverse current during reverse recovery
Reverse bias safe operating area		RBSOA	Current and voltage area when IGBT can be turned off under specified conditions
Gate resistance		R_G	Series gate resistance (See switching time test conditions for standard values)

Table 2-3 Electrical characteristics (cont’d)

Term	Symbol	Definition explanation (See specifications for test conditions)
Gate charge capacity	Q_g	Turn on gate charge between gate and emitter
Electro Static Discharge	HBM	Static electricity tolerance on human body model
	MM	Static electricity tolerance on machine model
Sense emitter voltage	V_{SE}	Sense emitter voltage between specified shunt resistance under ratings collector current by specified V_{GE}
Temperature sense diode forward on voltage	V_{AK}	Temperature sense diode forward voltage between Anode and Kathode

Table 2-4 Thermal resistance characteristics

Term	Symbol	Definition explanation (See specifications for test conditions)
Thermal resistance	$R_{th(j\text{-}win)}$	Thermal resistance between the junction and cooling water

2. Cooling Performance of the Automotive IGBT Module

2.1 Cooler (liquid-cooling jacket)

The automotive IGBT module has a direct liquid-cooling structure which has a aluminum base and fins with aluminum water jacket. The cooling efficiency is enhanced by eliminating clearance at the bottom of the cooler in 1st. generation cooling system. Although the 1st. generation direct cooling structure requires a cooler (liquid-cooling jacket) which has a flow path of coolant, it is not necessary to design the liquid-cooling jacket because of integrated both of base fin and water jacket in 3rd. generation cooling system any more.

2.2 Transient thermal resistance characteristics

Fig. 2-1 shows the transient thermal resistance characteristics which is used to calculate temperature increase. (This characteristics curve represents the value of one element of IGBT)

The thermal resistance characteristics are often used for thermal analysis, and defined by a formula similar to the one representing the Ohm's law for electrical resistance.

Temperature difference ΔT [°C] = Thermal resistance R_{th} [°C/W] × Energy (loss) [W]

The thermal resistance is used for calculation of T_{vj} of IGBT and FWD in the automotive IGBT module. (See Chapter 3 Heat dissipation design method for details.)

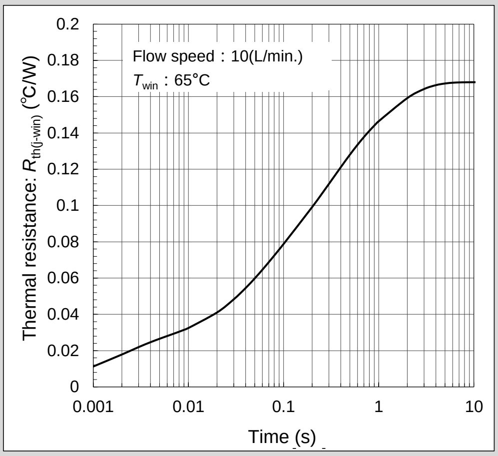

Fig. 2-1 Transient thermal resistance (max.)

2.3 Cooling performance dependence of cooling liquid temperature

The temperature of the cooling liquid (coolant) which is used to cool the automotive IGBT module affect the thermal resistance. Further, the higher the cooling water temperature, the lower the pressure loss, but higher the junction temperature. Due attention should therefore be paid to the above when designing the module.

2.4 Cooling performance and pressure loss dependence of flow rate of cooling liquid

As well as the cooling liquid temperature, the flow rate of the cooling liquid also affects the cooling performance. The cooling performance increases with an increase of flow rate, but the pressure loss between the inlet and outlet of the flow path also increases. If the pressure loss increases, the variation of chip temperature in the module becomes wide. Therefore it is necessary to optimize the performance of the pump in the system and flow path design.

As a typical example, Fig. 2-2 shows the pressure loss and thermal resistance on the flow rate of coolant. Refer to this figure when designing a module.

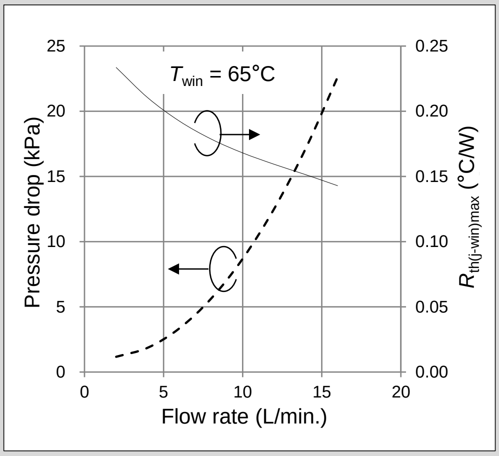

Fig. 2-2 Pressure drop and R_{th} dependence of flow rate