

Discrete IGBT

Application Manual

Cautions

This manual contains the product specifications, characteristics, data, materials, and structures as of December 2025.

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 4 Typical Troubles and Troubleshooting

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This chapter describes typical troubles and how to deal with them.

1. Troubleshooting

Abnormality such as incorrect wiring or mounting of discrete IGBTs in inverter circuit, etc., could cause device destruction. Because there are many failure modes, it is important to first determine the cause of the problem and take the necessary countermeasures. Table 4-1 shows how to determine a device failure modes as well as the causes by observing the device external abnormalities. First of all, check the estimated failure mode from Table 4-1. If the cause cannot be determined using this table, use the detailed analysis charts in Fig. 4-1. In addition, method to determine whether the device is broken is described in section 4.2, and typical troubles and their countermeasures are described in section 4.3. These can be used to assist in finding the cause.

Table 4-1 Estimation of failure modes and causes of elements

External abnormalities		Cause		Failure mode	Checkpoints
Short circuit	Arm short circuit	Surge voltage during short circuit protection exceeds SCSOA.		SCSOA (surge voltage)	Check that short circuit waveform (locus) and device ruggedness match.
	Series arm short circuit	Insufficient dead time	Insufficient $-V_{GE}$ Dead time setting error	Overheating	Check that device t_{off} and dead time match.
		dv/dt malfunction	Insufficient $-V_{GE}$ Gate wiring too long	SCSOA and overheating	Check for false turn-on caused by dv/dt.
			Noise, etc.		
	Output short circuit	Miswiring, abnormal wire contact, or load short circuit.		SCSOA and overheating	Check conditions at time of failure. Check that device ruggedness and protection circuit match. Check wiring condition.
Ground fault	Miswiring, abnormal wire contact		Check logic circuit.		
Overload (overcurrent)		Logic circuit malfunction Overcurrent protection circuit setting error		Overheating	Adjust overcurrent protection level.
Overvoltage	Excessive DC voltage	C-E voltage exceeds voltage rating	Excessive input voltage Overvoltage protection setting error	C-E overvoltage	Adjust overvoltage protection level.
	Excessive surge voltage	Surge voltage during turn-off exceeds RBSOA		RBSOA	Check that turn-off waveform (locus) and RBSOA match. Review snubber circuit.
		Surge voltage during FWD reverse recovery exceeds voltage rating		C-E overvoltage	Check that surge voltage and voltage rating match. Review snubber circuit.
		Short on-pulse reverse recovery	Logic or gate drive circuit malfunction due to noise		
			Interference to gate signal from the main circuit, etc.	Check gate signal. Use twisted pair wire. Check distance between main circuit and signal wire.	
Drive supply voltage drop		V_{GE} drops resulting in increased heat (loss) generation	DC-DC converter malfunction Drive voltage rise is too slow. Disconnected wire	Overheating	Check for circuit malfunction.
Gate overvoltage		Static electricity applied to gate Surge voltage due to excessive length of gate wiring		G-E overvoltage	Check operating conditions (anti-static protection). Check gate voltage.
Driving IGBT with gate open		Applying voltage at C-E with the gate open		Overheating	Check gate voltage.
Overheating	Insufficient heat dissipation	T_{vj} exceeds maximum value	Loose screws Insufficient thermal grease Cooling fan stopped	Overheating	Check cooling conditions.
	Increased loss	Logic circuit malfunction			Check logic circuits.
Stress	Stress	Soldering inside the module disconnected due to stress fatigue	Stress from external wiring	Disconnection of internal circuit (open)	Check the generated stress. Check the mounting condition of the module and other mounting parts.
	Vibration		Stress from vibration of other mounting parts		
Reliability (Lifetime)		The application conditions do not match the reliability of the module		Failure mode is different for each case	Refer to Fig. 4-1.

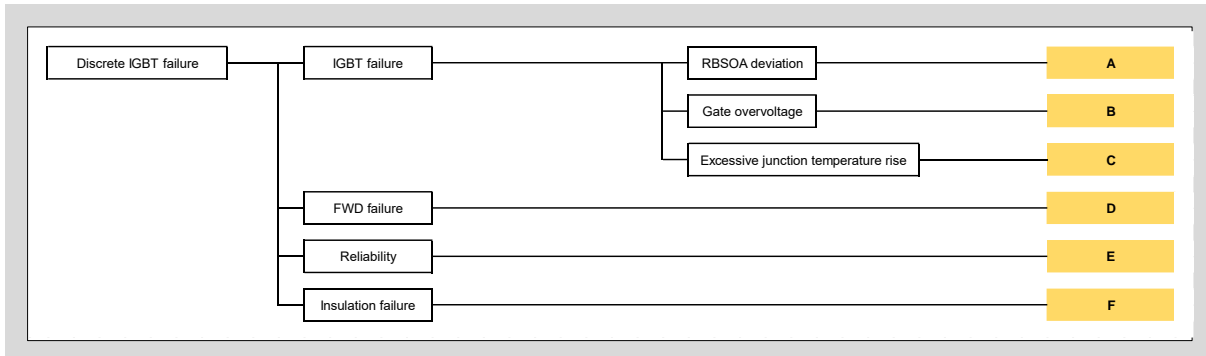


Fig. 4-1(a) Discrete IGBT failure analysis chart (* Symbols A to E are linked to the charts below)

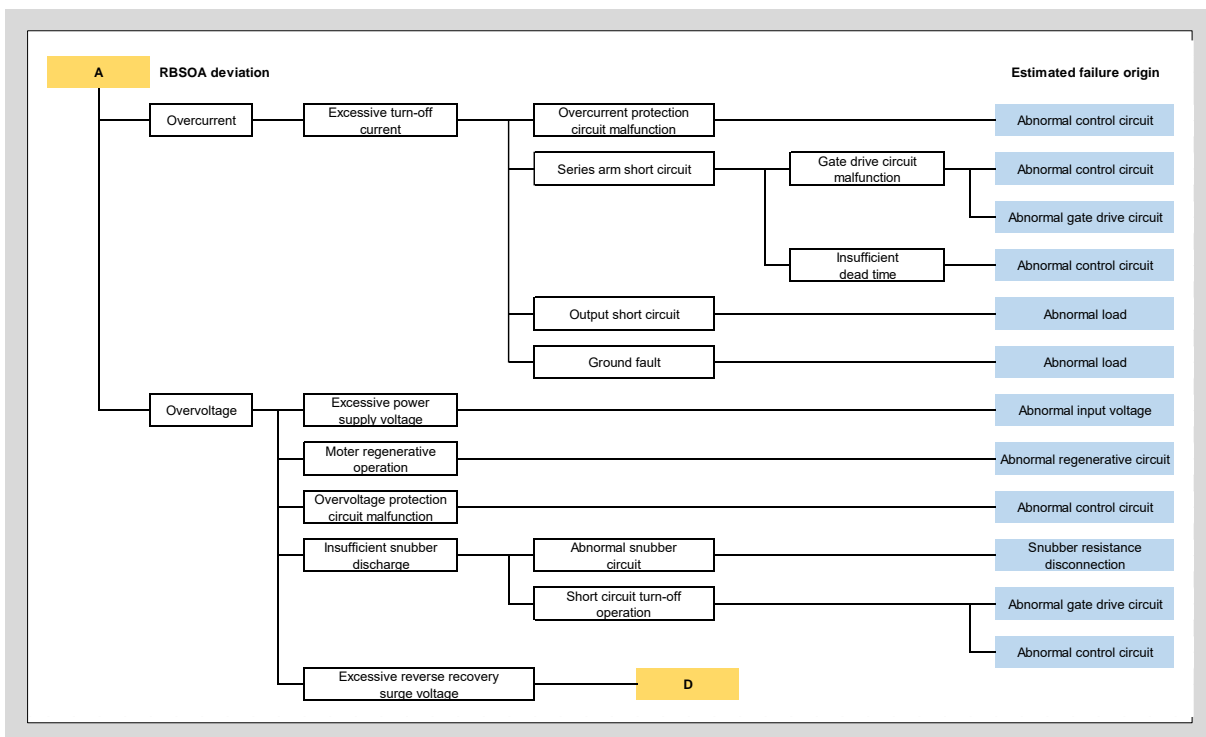


Fig. 4-1(b) Mode A: RBSOA deviation

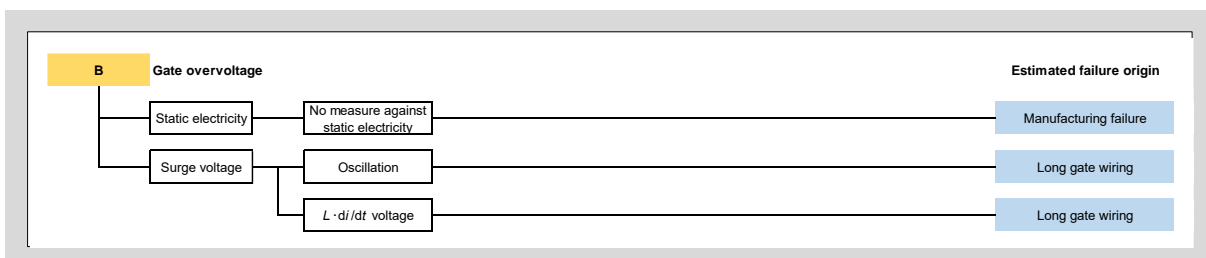


Fig. 4-1(c) Mode B: Gate overvoltage

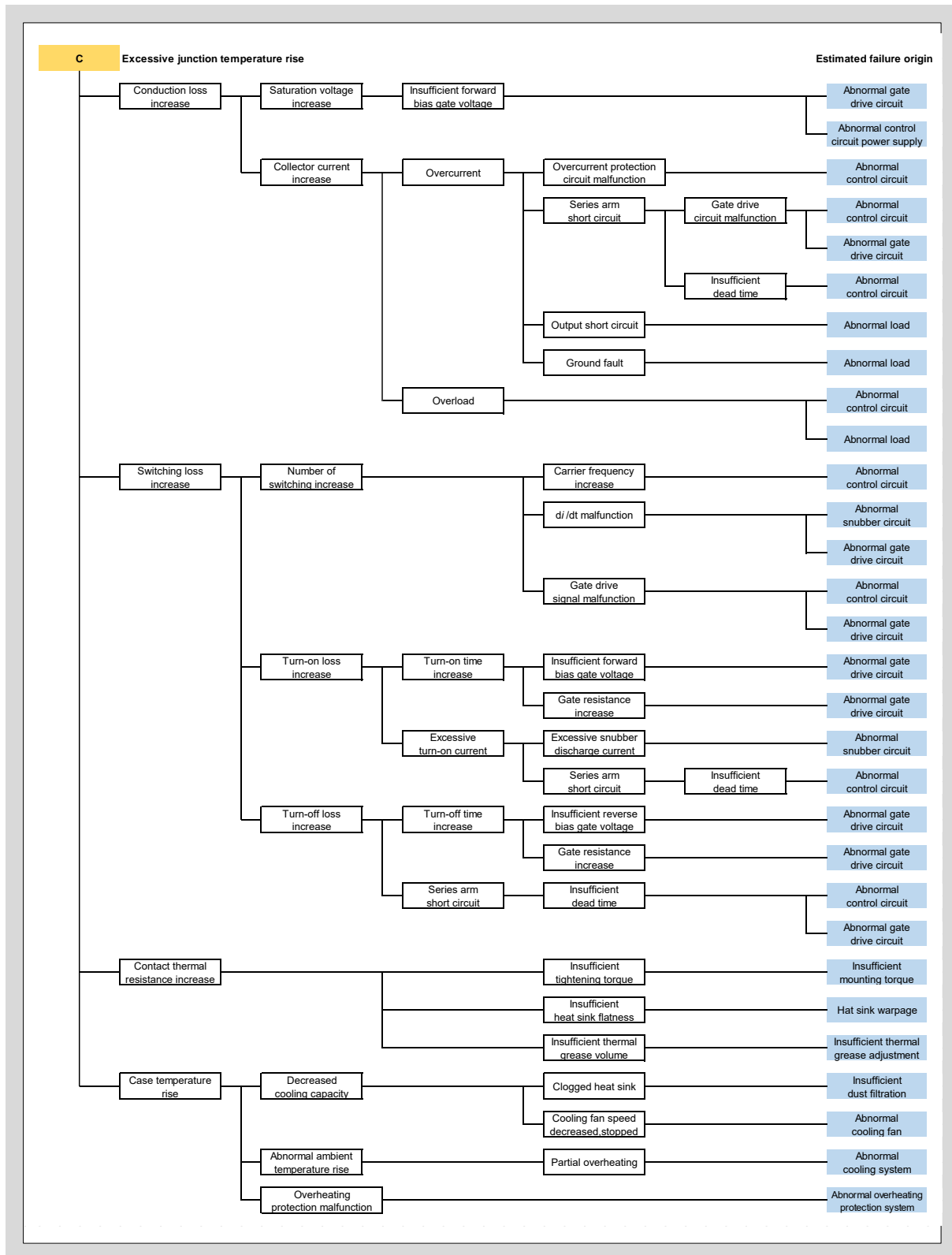


Fig. 4-1(d) Mode C: Excessive junction temperature rise

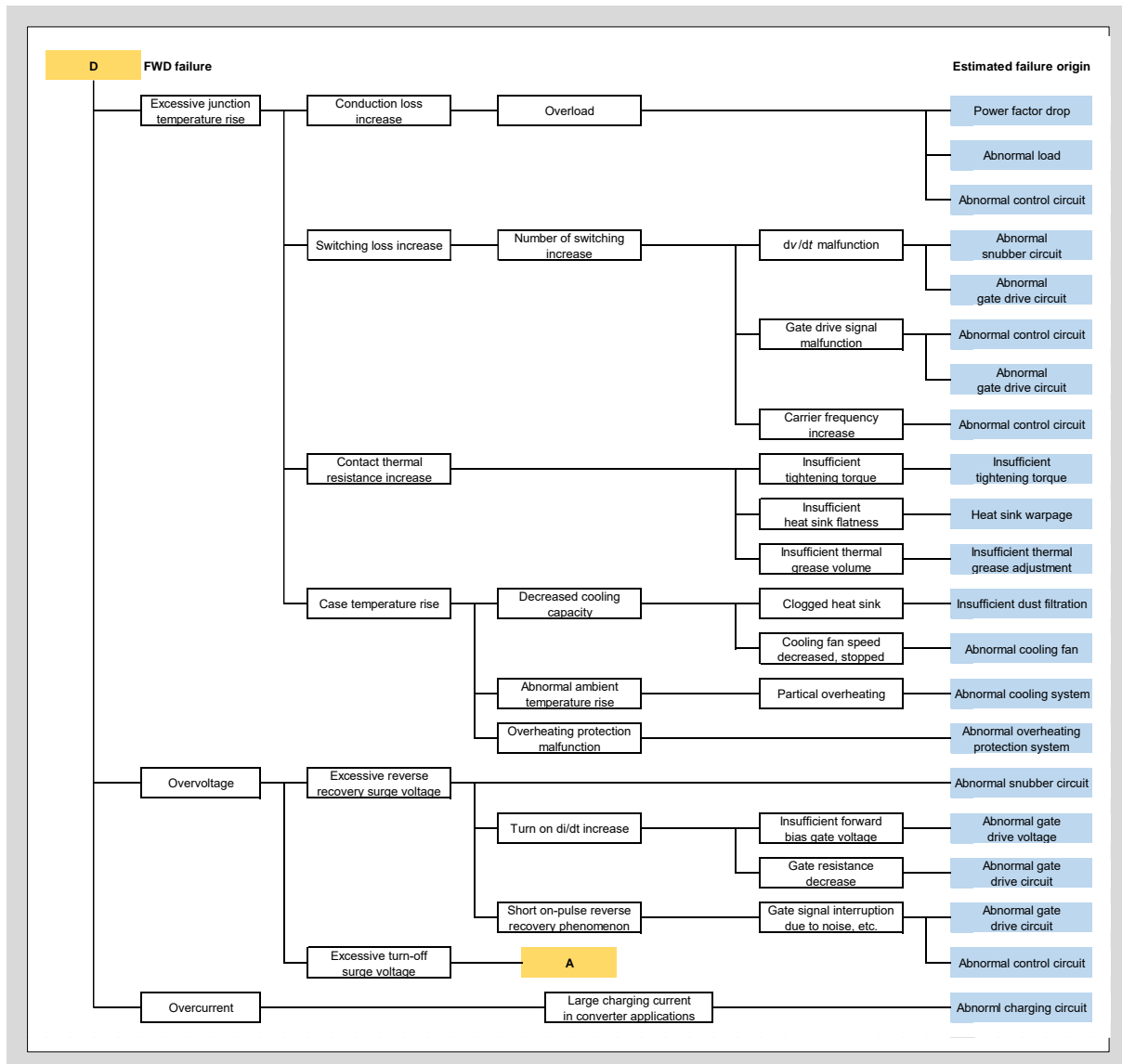


Fig. 4-1(e) Mode D: FWD failure

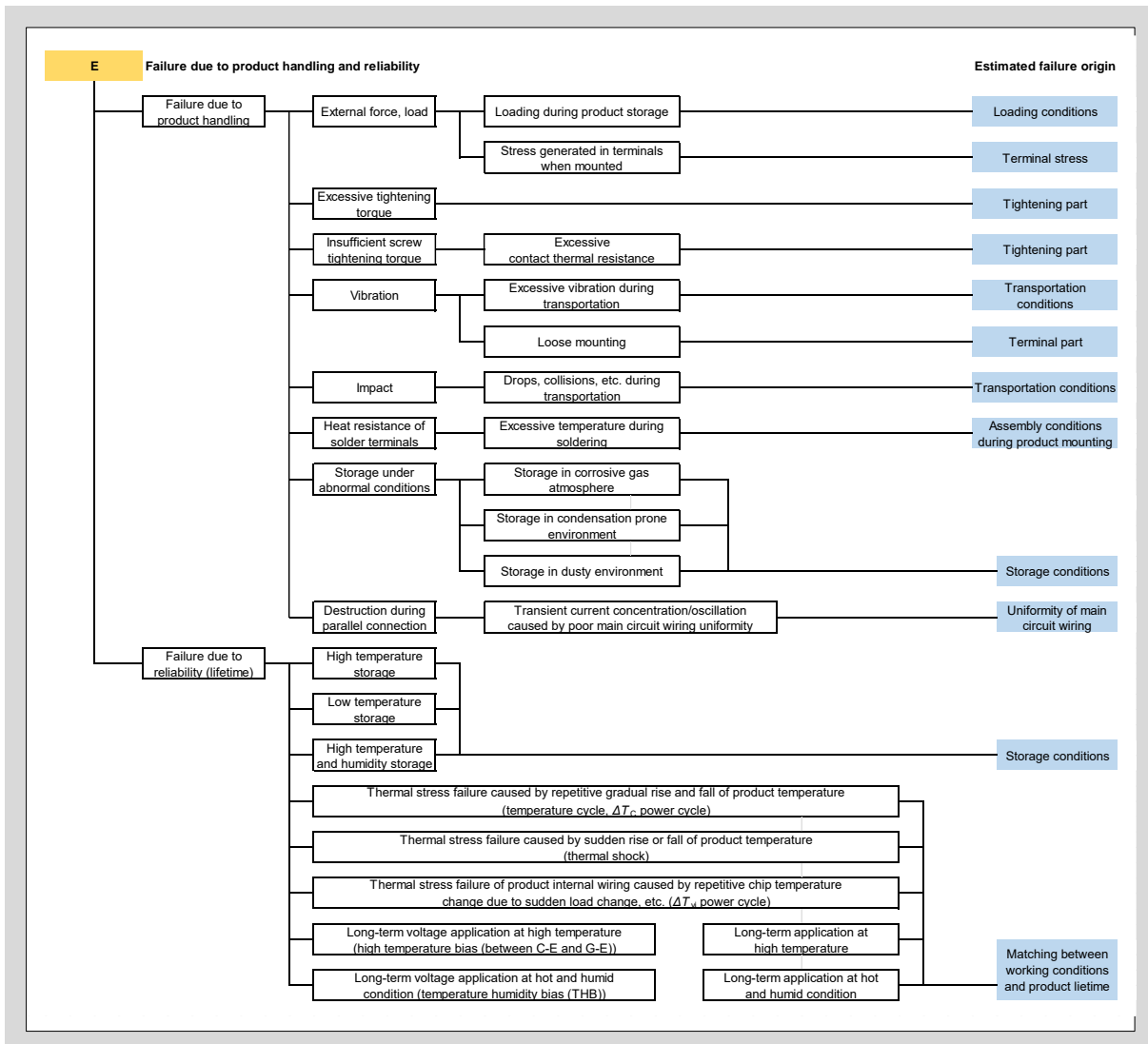


Fig. 4-1(f) Mode E: Failure due to product handling and reliability

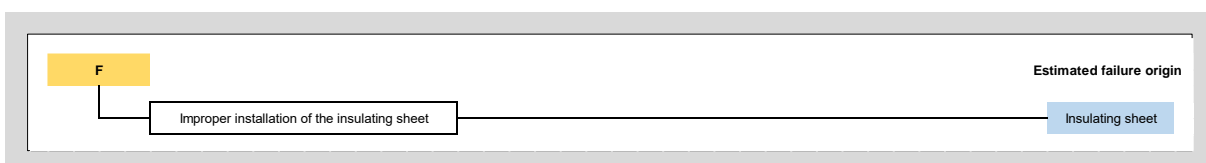


Fig. 4-1(g) Mode F: Improper installation of the insulating sheet

2. IGBT Test Procedures

An IGBT device that has been found to be faulty can be checked by using a transistor characteristics measuring device called a 'transistor curve tracer (CT)'.

- (1) G-E leakage current
- (2) C-E leakage current (short G-E)

If a CT is not available, other test equipment such as a tester that is capable of measuring voltage/resistance can be used to help to diagnose the module.

2.1 G-E leakage current check

As shown in Fig.4-2, measure the leakage current or resistance between G-E, with C-E shorted. (Do not apply a voltage in excess of 20V between G-E. If a tester is used, make sure that the internal battery voltage is less than 20V.)

If the module is normal, the leakage current reading will be on the order of several 100nA (if a tester is used, the resistance reading will be on the order of 10M Ω to infinity). Otherwise, the device has most likely destroyed (generally, if a device is destroyed, G-E will be short-circuited).

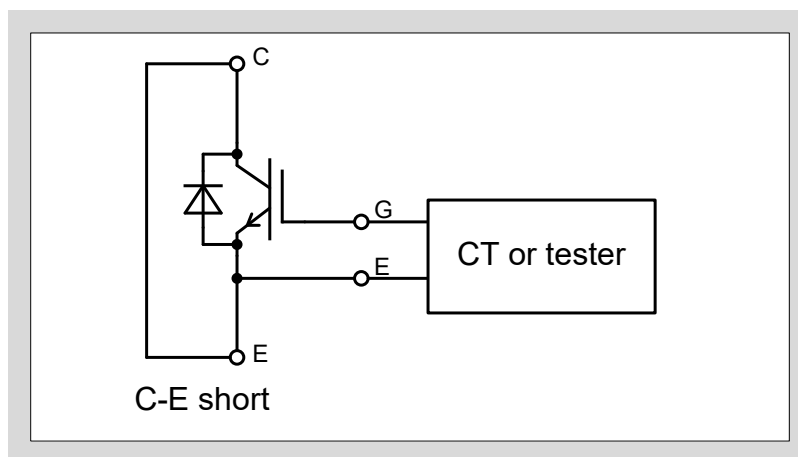


Fig. 4-2 G-E check

2.2 C-E leakage current check

As shown in Fig.4-3, measure the leakage current or resistance between C-E, with G-E shorted. Be sure to connect C to (+) and E to (-). If the polarity is reversed, the FWD will conduct and shorts C-E.

If the module is normal, the leakage current reading should read below the I_{CES} maximum value specified in the datasheet (if a tester is used, the resistance reading will be on the order of 10M Ω to infinity). Otherwise, the device has most likely destroyed (generally, if a device is destroyed, C-E will be short-circuited).

Caution: Never perform withstand voltage measurement between C-G. It might cause the dielectric breakdown of the oxide layer due to excessive voltage.

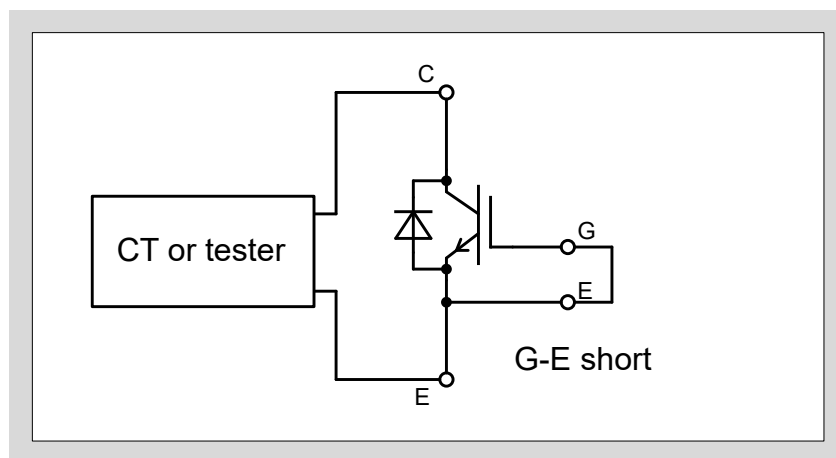


Fig. 4-3 C-E check

3. Typical Troubles and Troubleshooting

3.1 Main circuit voltage application with G-E open

If main circuit voltage is applied with G-E open, the IGBT would be turned on autonomously, triggering a large current flow and cause device destruction. This phenomenon occurs when the G-E capacitance is charged through the feedback capacitance C_{res} of the IGBT, raising the gate potential and causing the IGBT to be turned on. Take measures such as connecting a resistor of about 10k Ω to G-E to prevent G-E from being opened (refer to Chapter 3, section 2).

If the gate signal line is switched using a mechanical switch, such as a rotary switch during product acceptance testing or on similar occasions, the G-E may open instantaneously at the time of switching, which could cause device destruction if voltage is applied to C-E.

When the mechanical switch chatters, a similar period is generated, leading to device destruction. To prevent this, be sure to discharge the main circuit voltage to 0V before switching the gate signal. Furthermore, when conducting characteristics test, such as acceptance test on a product comprising multiple devices (two or more), be sure to short G-E of the devices other than the one under test.

Fig. 4-4 shows an example of an on-voltage measurement circuit. The measurement procedure is described using this circuit. First, turn off the gate drive unit (GDU) ($V_{GE} \leq 0V$), then turn on SW_1 to apply voltage to C-E. Next, apply a predefined forward bias voltage to G-E from the GDU to turn-on the IGBT and measure the on voltage. Finally, turn off the gate circuit and then turn off SW_1 . This sequence allows for safe measurement of device characteristics without risking destruction.

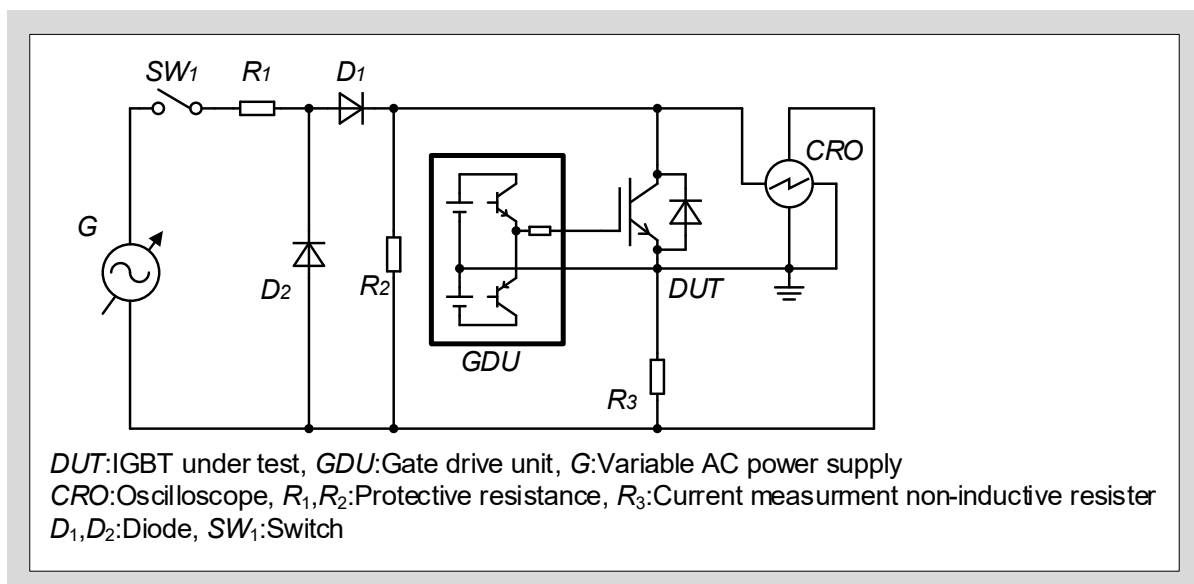


Fig. 4-4 On voltage measurement circuit

3.2 False turn-on of the IGBT caused by insufficient $-V_{GE}$

Insufficient reverse bias gate voltage $-V_{GE}$ induces false turn-on of the IGBT, resulting in short circuit of both the upper and lower arm IGBTs. The product may be destroyed by the surge voltage or loss generated when the short circuit current is cut off. Therefore, make sure that false turn-on does not happen when designing the equipment (recommended $-V_{GE}=15V$). In addition, please refer to Chapter 7, section 1.4 for the details of the malfunction occurrence mechanism due to the dv/dt when $-V_{GE}$ is insufficient.

Fig. 4-5 shows an example of how to check the presence of short circuit current in the upper and lower arms. First, disconnect the output terminals (U, V, W) of the inverter (open, no load). Next, start the inverter and drive each IGBT. At this time, if the current flowing from the power supply line is detected as shown in the figure., the presence of short circuit current can be checked. If $-V_{GE}$ is sufficient, only a very small pulse current (about 5% of the rated current) that charges the junction capacitance of the device will be observed. However, if $-V_{GE}$ is insufficient and short circuit occurs, this current will increase. To make an accurate judgment, it is recommended to perform this current measurement with $-V_{GE}=15V$ first, and then measure the current again with the specified $-V_{GE}$. If the current of both cases have the same value, it means that there is no false turn-on.

If false turn-on is confirmed by the above method, countermeasures include increasing $-V_{GE}$ until the short circuit current disappears, or connect a capacitor (C_{GE}) with capacitance of about twice the value of C_{ies} described in the specifications between G-E. Is recommended to connect C_{GE} close to the gate terminals.

However, simply adding C_{GE} will increase the switching time and loss. In order to have equivalent switching time and loss before C_{GE} addition, it is recommended to decrease the R_G value to about half of that before C_{GE} addition.

Another cause of short circuit through the upper and lower arms is insufficient dead time. When this happens, short circuit current will be observed in the test. If the short circuit current does not decrease even when $-V_{GE}$ is increased, increasing the dead time is necessary. Please refer to Chapter 7, section 3 for a detailed explanation of dead time.

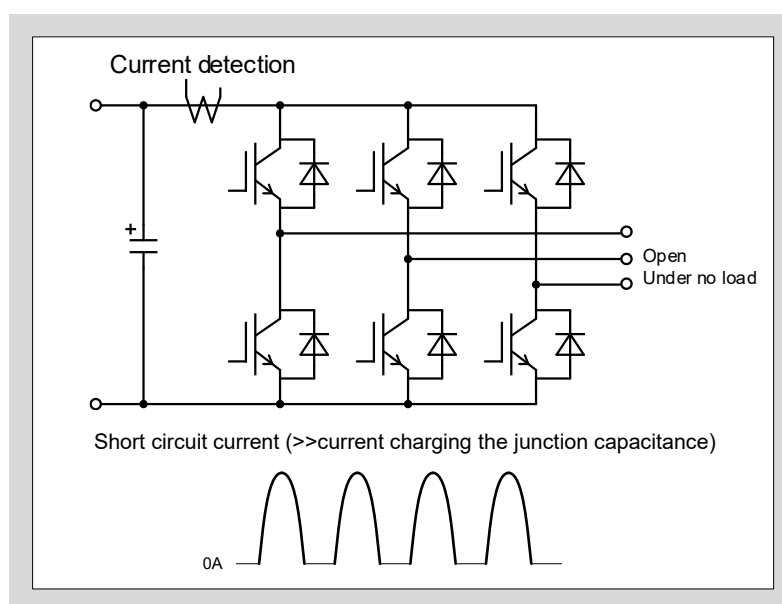


Fig. 4-5 Short circuit current measuring circuit

3.3 Diode reverse recovery from a transient on state (short on-pulse reverse recovery)

Some discrete IGBT contains built-in FWD. Paying close attention to the behavior of this FWD is very important for designing a reliable equipment. This section describes the short on-pulse reverse recovery phenomenon, which is likely to lead to device failure.

The short on-pulse reverse recovery phenomenon is a phenomenon in which the gate signal is interrupted due to noise, etc. when driving the IGBT, resulting in a very large reverse recovery surge voltage. Fig. 4-6 shows the waveforms of short on-pulse reverse recovery. If a very short off-pulse (T_w) with respect to the on period (T_{ON}) of IGBT is generated, the FWD on the opposite arm will enter reverse recovery in a very short time after it is turned on. Normally, reverse recovery starts after sufficient carriers are accumulated in the FWD, whereas in the short on-pulse reverse recovery, reverse recovery starts without sufficient carrier accumulation in the FWD. As a result, the depletion layer of FWD expands at a rapid speed, causing steep di/dt and dv/dt . This causes a very large reverse recovery surge voltage to occur between C-E (K-A). If the surge voltage exceeds the device rated voltage, it may lead to device failure.

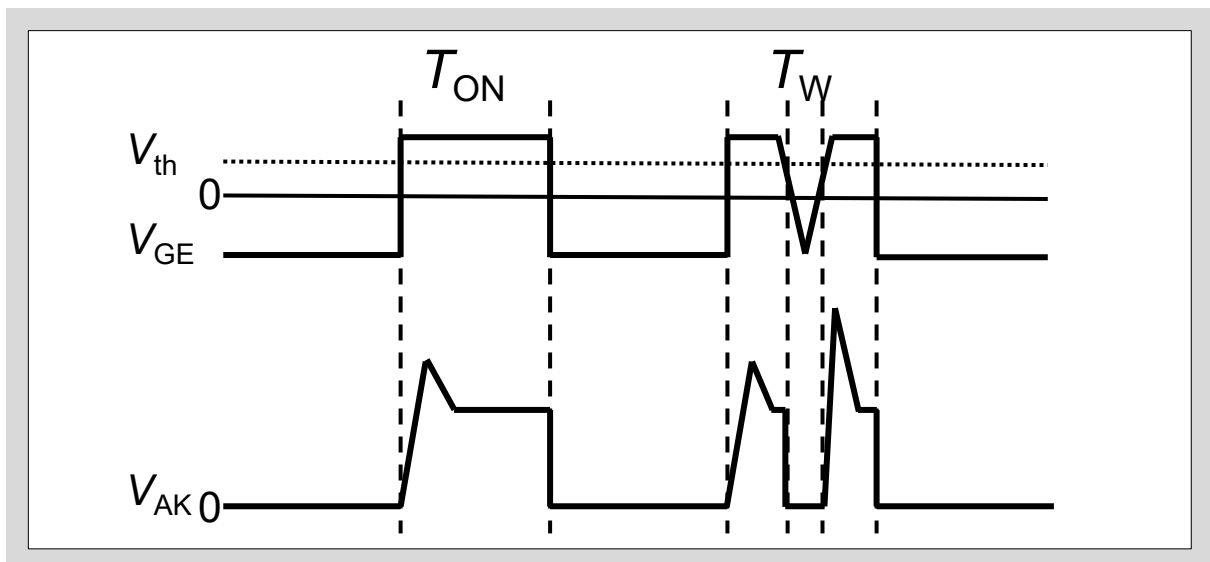


Fig. 4-6 Waveforms of short on-pulse reverse recovery

When designing your equipment, verify that the surge voltage at minimum T_w does not exceed the device rated voltage. If the surge voltage exceeds the device rated voltage, implement one or more of the following countermeasures.

- Increase R_G
- Reduce circuit inductance
- Enhance snubber circuit
- Add C_{GE}
- Add active clamping circuit

3.4 EMC noise countermeasures

Power converters often need to comply with Europe's CE-marking requirements or Japan's VCCI standards. Suppressing EMI noise, both conducted and radiated below the regulatory limits is therefore a critical design task.

Discrete IGBTs have been pushed toward ever faster switching and lower loss. As a result, the high dv/dt and di/dt generated when switching IGBTs increasingly become a source of radiated noise. In particular, the steep transitions at turn-on, when the FWD in the opposite arm undergoes reverse recovery, can excite high-frequency LC resonances between the semiconductor's junction capacitances and the wiring inductances, leading to significant radiated emissions.

To reduce radiated noise from discrete IGBTs, it is effective to "soften" the switching waveforms, especially the turn-on edge, by revising the gate drive conditions. Refer to Chapter 7 for guidelines on selecting appropriate gate drive parameters. Note, however, that slowing the switching transitions will tend to increase switching loss. Therefore, it is important to balance noise reduction against efficiency, taking into account the converter's operating conditions and the IGBT's cooling conditions.

Table 4-2 lists the common measures for reducing radiated noise. Because the actual noise sources and levels depend heavily on each system's wiring layout, materials, and circuit topology, you should validate the effectiveness of these countermeasures in your own design.

Table 4-2 Countermeasures of radiation noise

Countermeasure	Description	Remarks
Review gate drive conditions (reduce dv/dt and di/dt)	Increase the R_G (particularly, turn-on side).	Switching time and switching loss increase.
	Connect a capacitor between G-E (C_{GE}).	Switching time and switching loss increase.
Connect the snubber capacitor as near as possible to the discrete IGBT	Minimize the wiring between the snubber capacitor and the discrete IGBT.	Effective in suppressing surge voltage and dv/dt during switching.
Reduce wiring inductances	Use laminated bus bars to reduce inductances.	Effective in suppressing surge voltage and dv/dt during switching.
Filtering	Connect noise filters to the input and output of the equipment.	Various filters are commercially available
Cable shielding	Shield the input/output cables to reduce radiation noise from the cables.	
Metalize the equipment case	Metalize the equipment housing to suppress noise emitted from the device	