This chapter describes how to deal with troubles that may occur while the automotive IGBT module is handled.

1. Troubleshooting

When the IGBT module is installed in an inverter circuit, etc., a failure of the IGBT module might be occurred due to improper wiring or mounting. Once a failure is occurred, it is important to identify the root cause of the failure. Table 4-1 illustrates how to determine a failure mode as well as the original causes of the failure by observing irregularities outside of the device. First of all, estimate a failure mode of the module by using the table when a failure is happened. If the root cause cannot be identified by using Table 4-1, see Fig. 4-1 as detailed analysis chart for helping your further investigation.

<table>
<thead>
<tr>
<th>External abnormalities</th>
<th>Cause</th>
<th>Device failure mode</th>
<th>Further checkpoints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short circuit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm short-circuit</td>
<td>After short-circuit detection, surge voltage excess SCSEO</td>
<td>Outside SCSEO</td>
<td>Integrity waveform of locus and device ruggedness</td>
</tr>
<tr>
<td>Series arm short-circuit</td>
<td>Insufficient dead time</td>
<td>Large ( t_{off} ) due to reverse gate bias dead time setting mistakes</td>
<td>Over heating</td>
</tr>
<tr>
<td></td>
<td>d/dt malfunction</td>
<td>less reverse gate bias too long gate wiring</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Noise induced</td>
<td>Gate circuit malfunction Logic circuit malfunction</td>
<td></td>
</tr>
<tr>
<td>Output short-circuit</td>
<td>Faulty wiring, abnormal wire contact, load short-circuit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground short</td>
<td>Faulty wiring, abnormal wire contact</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overload</td>
<td>Overcurrent</td>
<td>Logic circuit malfunction protection function setting fault</td>
<td>Overheating</td>
</tr>
<tr>
<td></td>
<td>Overvoltage larger than device breakdown voltage apply between Corrector and Emitter</td>
<td>Excessive input voltage</td>
<td>Redesign of protection condition</td>
</tr>
<tr>
<td>Overvoltage</td>
<td>Excessive spike voltage</td>
<td>RBSOA</td>
<td>Overvoltage protection</td>
</tr>
<tr>
<td></td>
<td>Destruction due to excessive surge voltage larger than RBSOA at turn-off</td>
<td>RBSOA and operating locus at turn-off</td>
<td>Integrity confirmation RBSOA and operating locus at turn-off Redesign of snubber circuit</td>
</tr>
<tr>
<td></td>
<td>Destruction due to excessive surge voltage larger than device breakdown voltage at reverse recovery</td>
<td></td>
<td>Integrity spike voltage and device breakdown voltage snubber circuit</td>
</tr>
<tr>
<td></td>
<td>Reverse recovery phenomenon at operating with very narrow gate pulse *1)</td>
<td>logic circuit or gate circuit malfunction due to noise Electromagnetic induction noise from main circuit to gate wiring</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Destruction by the main circuit wiring is too long, the surge voltage at the time of the turn-off to reach the dynamic avalanche voltage</td>
<td></td>
<td>Redesign of main circuit inductance</td>
</tr>
</tbody>
</table>

*1) Excessive reverse recovery voltage over device breakdown voltage is produced, if gate pulse width is less than few hundred nano second.
### Table 4-1(b) causes of device failure modes

<table>
<thead>
<tr>
<th>External abnormalities</th>
<th>Cause</th>
<th>Device failure mode</th>
<th>Further checkpoints</th>
</tr>
</thead>
<tbody>
<tr>
<td>driver supply voltage drop</td>
<td>$V_{GE}$ is increased by $V_{GE}$ lower than specified value. As a result, power consumption and Joule head are increased.</td>
<td>Overheat</td>
<td>Each circuit design</td>
</tr>
<tr>
<td></td>
<td>DC/DC converter malfunction</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Too much time constant of power supply settling</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gate wiring break</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excessive gate voltage</td>
<td>Electro static discharge on $V_{GE}$</td>
<td>Excessive $V_{GES}$</td>
<td>Assembly area environment against ESD</td>
</tr>
<tr>
<td></td>
<td>Spike voltage larger than $V_{GES}$ is produced by too long gate wiring</td>
<td></td>
<td>Gate voltage</td>
</tr>
<tr>
<td>Operation under opened gate circuit</td>
<td>Voltage apply to Corrector and Emitter while gate is opened.</td>
<td>Overheat</td>
<td>Gate voltage</td>
</tr>
<tr>
<td>Overvoltage on temperature diode, sense IGBT</td>
<td>Temperature diode and/or sense IGBT destruction due to ESD</td>
<td>ESD</td>
<td>Assembly area environment against ESD</td>
</tr>
<tr>
<td>Overheat</td>
<td>Lack of heat dissipation capacity</td>
<td></td>
<td>Radiation condition or radiation design</td>
</tr>
<tr>
<td></td>
<td>Anomalous heating due to lack of heat dissipation capacity</td>
<td></td>
<td>Logic circuit on gate</td>
</tr>
<tr>
<td>Thermal runaway</td>
<td>Total dissipation is increased by carrier frequency increased due to logic circuit malfunction.</td>
<td>Overheat</td>
<td></td>
</tr>
<tr>
<td>Stress</td>
<td>Stress</td>
<td></td>
<td>Disconnection of circuit</td>
</tr>
<tr>
<td></td>
<td>Soldered portion is broken by stress fatigue</td>
<td></td>
<td>Mechanical stress due to mounting condition</td>
</tr>
<tr>
<td></td>
<td>Stress from external wiring</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stress induced vibration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reliability (Life time)</td>
<td>The application condition exceeds the reliability of the module.</td>
<td></td>
<td>Destruction is different in each case.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Refer to Fig. 4-1 (a-f)</td>
</tr>
</tbody>
</table>
Fig. 4-1(a) IGBT module failure analysis

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

- Faulty control PCB
- Faulty gate drive circuit
- Over current protection failure
- Excessive turn-on current
- Over voltage
- Excessive supply voltage
- Motor regeneration
- Over voltage protection circuit failure
- Insufficient snubber discharge
- Excessive surge voltage at FWD reverse recovery

- Faulty control PCB
- Faulty gate drive circuit
- Insufficient dead time
- Gate drive circuit malfunction
- Series arm short-circuit
- Output short-circuit
- Ground fault

- Faulty input voltage
- Faulty regeneration circuit
- Faulty control PCB
- Disconnected snubber resistor
- Faulty snubber circuit
- Fault time too short

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

- Gate overvoltage
  - Static electricity
  - Spike voltage
  - L-di/dt voltage
  - Still no static protection

[Origine of failure]
- Manufacturing fault
- Gate wire too long

Fig. 4-1(d) Mode C: Junction overheating

- Junction overheating
  - Saturation voltage increase $V_{CE(sat)}$
  - Collector current increase
  - Over current
  - Over current protection circuit failure
  - Gate drive circuit malfunction

[Origine of failure]
- Faulty gate drive circuit
- Faulty power supply control circuit
- Faulty control PCB
- Abnormal load
- Abnormal load
- Faulty control PCB
- Faulty control PCB
- Faulty control PCB
- Faulty control PCB
- Faulty control PCB
- Faulty control PCB
- Faulty control PCB
- Faulty control PCB
- Faulty control PCB
- Faulty control PCB
- Faulty control PCB
- Faulty control PCB
- Faulty control PCB
- Faulty control PCB
- Pump failure
- Clogging of pipe
- Cooling system failure (Water leakage)
- Degradation of water quality
- Cooling system failure (Foreign matter)
- Module installation direction
- Lower flow rate
- Cooling system failure (Radiator)
Fig. 4-1(e) Mode D: FWD destruction
Destruction due to reliability or product handling

- **Destruction due to handling**
  - **External force or load**
    - Stress produced in the terminals when mounted
    - Excessively long screws used in the main and control terminal
  - **Excessive tightening torque**
    - Increase contact resistance
  - **Insufficient tightening torque for main terminal screws**
    - Excessive vibration during transport
  - **Vibration**
    - Loose component clamping during product mounting
  - **Impact**
    - Dropping, collision during transport
  - **Soldered terminal heat resistance**
    - Overheating at terminal soldering
  - **Storage in abnormal conditions**
    - Storage in corrosive gas environment
    - Storage in condensation-friendly environment
    - Storage in dusty environment
  - **Electric static discharge**
    - Assembly at easily charged environment
    - Abnormal at the flange seal
  - **Cooling water leakage**
    - Abnormal at the cover of the cooler
    - Abnormal mounting conditions
    - Corrosion
  - **Reliability induced destruction**
    - Soaking in high temperature
    - Long term storage in high temperature
    - Long term storage in low temperature
    - Soaking in high temperature and high humidity
    - Long term storage in high temperature and high humidity
    - Thermal stress fatigue in temperature cycle
    - Long term bias on G-E or C-E under high temperature conditions
    - Long term usage on high temperature
    - Voltage applied for long term under hot and humid conditions
    - Long term usage on high temperature and humidity

**[Origine of failure]**

- **Loading conditions**
  - Stress in the terminal section
  - Screw length
  - Clamped section
  - Terminal section
  - Main terminal section
  - Transport conditions
  - Product terminal section
  - Transport conditions
  - Assembly condition at the installation
  - Storage condition

**ESD control condition at the installation**

- **Product handling**
  - Excessive water pressure
  - Excessive vibration and shock
  - Insufficient torque
  - Broken screw
  - Unsuitable sealing design
  - Unsuitable coolant
  - Excessive flow rate
  - Air bubble in the coolant
  - Storage conditions

**Storage conditions**

**Matching between product life time and operation conditions**

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*Fig. 4-1(f) Mode E: FWD destruction*