– Chapter 7 –

Troubleshooting

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1 Troubleshooting

An IPM has various integrated protective functions (such as overcurrent protection and overheat protection) unlike a standard module. It shuts down safely in the case of an abnormal condition. However, it may breakdown depending on the abnormality of the failure that occurred. When the IPM has failed, it is necessary to take countermeasures upon clarification of the situation and find the root cause of the breakdown.

Failure tree analysis charts are shown in Figure 7-1. Carry out the investigation of the failure mode by using these charts. For the failure criteria, see chapter 4, section 2 [IGBT test procedures] of the IGBT Module Application Manual (RH984b).

Furthermore, when an alarm signal is generated from the IPM investigation of the root cause by reference of the alarm factor analysis chart can be done as shown in Figure 7-2.

2 Failure analysis tree charts

![Failure Analysis Tree Chart]

Figure 7-1 (a) IPM failure tree analysis chart
(Codes A to F are linked with those indicated in separate FTA pages.)
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Figure 7-1 (b)  Mode A: Deviation from RBSOA specification

Figure 7-1 (c)  Mode B: Gate overvoltage
Figure 7-1 (d) Mode C: Excessive junction temperature rise
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**D  FWD breakdown**

- Excessive junction temperature rise
  - Increased steady-state loss
    - Overload
      - [Estimated point of disorder]
        - Dropped power factor
        - Load disorder
        - Control PCB disorder
      - Control PCB disorder
        - Input signal circuit disorder
          - Control PCB disorder
          - Insufficient tightening torque
      - Faulty anti-dust measures
      - Increased contact thermal resistance
    - Increased switching loss
      - Increased switching count
        - Input signal malfunction
          - Control PCB disorder
        - Increased carrier frequency
          - Control PCB disorder
          - Insufficient tightening torque
      - Faulty fin warpage
      - Insufficient element tightening force
    - Insufficient thermal compound weight
    - Case temperature rise
      - Dropped cooling capacity
        - Clogged heat sink
          - Faulty anti-dust measures
        - Cooling fan disorder
          - Faulty fin warpage
          - Insufficient compound weight adjustment
      - Dropped or stopped cooling fan revolution
      - Cooling system disorder
    - Abnormal rise of ambient temperature
      - Stack local overheating
      - Insufficient tightening torque
      - Faulty fin warpage
      - Insufficient compound weight adjustment
      - Snubber circuit disorder
    - Overvoltage
      - Excessive surge voltage at the time of reverse recovery
        - Increased dV/dt at the time of turn-on
          - Increased control power supply voltage
            - Control power supply circuit disorder
          - Control power supply circuit disorder
          - Control PCB disorder
        - Increased di/dt at the time of turn-on
          - Gate signal cracking caused by noise or similar
            - Control PCB disorder
            - Charging circuit disorder
      - Minor pulse reverse recovery phenomenon
    - Overcurrent
      - Excessive charge current at the time of application to converter unit

**Figure 7-1 (e)  Mode D: FWD breakdown**
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Figure 7-1 (f)  Mode E: Control circuit breakdown

[Diagram showing control circuit breakdown with nodes for overvoltage, excessive control power supply voltage, spike voltage, excessive minus voltage, excessive input unit voltage, excessive static electricity, and estimated points of disorder such as control power supply circuit disorder, power supply instability, capacitor disorder, excessive control power supply voltage, ON/OFF of control voltage impression, and external noise.]
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#### Breakdown related to reliability and product handling

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<th>Breakdown</th>
<th>Loading conditions</th>
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<td>Excessive loading during product storage</td>
<td>Mounting work</td>
</tr>
<tr>
<td>Insufficient main terminal tightening torque</td>
<td>Excessive stress applied to terminals and case at the time of IPM mounting</td>
<td>Forceful dismounting</td>
</tr>
<tr>
<td>Insufficient main terminal tightening torque</td>
<td>Excessive stress applied to terminals and case at the time of IPM dismounting</td>
<td>Screw length</td>
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<tr>
<td>Insufficient main terminal tightening torque</td>
<td>Excessive screw length used for main terminals</td>
<td></td>
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<tr>
<td>Vibration</td>
<td>Excessive vibration during transportation (products, devices)</td>
<td>Conditions for transportation</td>
</tr>
<tr>
<td>Impact</td>
<td>Falling, impact, etc. during transportation</td>
<td>Conditions for transportation</td>
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<tr>
<td>Heat resistance of soldered terminals</td>
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<td>Conditions for storage</td>
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<tr>
<td>Storage in inferior environment</td>
<td>Storage in condensable environment</td>
<td></td>
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<tr>
<td>Storage in inferior environment</td>
<td>Storage in dusty environment</td>
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</tr>
<tr>
<td>Storage in low temperature conditions (shelving under low temperature)</td>
<td>Long-term storage in low temperature conditions</td>
<td></td>
</tr>
<tr>
<td>Storage in high temperature and high humidity conditions (shelving under high temperature and high humidity)</td>
<td>Long-term storage in high temperature and high humidity conditions</td>
<td></td>
</tr>
<tr>
<td>Storage in high temperature conditions (shelving under high temperature)</td>
<td>Long-term storage in high temperature conditions</td>
<td></td>
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<tr>
<td>Thermal stress breakdown generated by repeating of gradual up-down of product temperature (temperature cycle, (\Delta T_c) power cycle)</td>
<td></td>
<td></td>
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<tr>
<td>Thermal stress breakdown generated by rapid rise or fall of product temperature (thermal impact)</td>
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<tr>
<td>Thermal stress fatigue breakdown to product internal wiring, etc. generated by changes in semiconductor ship temperature caused by rapid load change ((\Delta T_c) power cycle)</td>
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<tr>
<td>Excessive tightening torque</td>
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<tr>
<td>Insufficient main terminal tightening torque</td>
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<tr>
<td>Excessive contact resistance</td>
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#### Reliability (service life) breakdown

* For results of reliability tests conducted by Fuji Electric, see the specification or reliability test report.

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Figure 7-1 (g)  Mode F: Breakdown related to reliability and product handling
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3  Alarm factor analysis tree chart

When the system equipped with the IPM has stopped and an alarm signal is generated, first carry out investigations to identify where the alarm signal was generated from. Possible locations are the IPM or the device control circuit.

If the alarm was sent from the IPM, then identify the factor in accordance with the factor tree chart indicated below. V-IPM is easy to identify which protective function is activated by checking the alarm pulse width. Therefore, you can shorten the factor analysis time.

In addition, the alarm output voltage can be easily measured by connecting a 1.3 KΩ resistor in series between the IPM alarm terminal and the cathode terminal of the alarming photodiode.

<table>
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<tr>
<th>Phenomenon</th>
<th>Alarm factor and method for identification</th>
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<td>Occurrence of an IPM alarm</td>
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</table>
| Normal alarm | Overcurrent  
\(t_{\text{ALM Typ}} = 2 \text{ ms}\) | The collector current is detected by checking the current that flows to the current sense IGBT that is built in every IGBT chip. The IGBT is OFF for protection, if the overcurrent trip level was continuously exceeded for about 5 μs.  
**[Method for identification of alarm factor]**  
- Observe the alarm and output current (U, V, W) using an oscilloscope.  
- Observe the alarm and DC input current (P, N) using an oscilloscope.  
- Observe the change in the current 5 μs before occurrence of alarm output.  
- Where a CT or similar is used for current detection, check the trip level and point of detection. |
| Low control power supply voltage | Overcurrent  
\(t_{\text{ALM Typ}} = 4 \text{ ms}\) | The IGBT is OFF for protection, if control power supply voltage Vcc was of undervoltage trip level or less continuously for 20 μs.  
**[Method for identification of alarm factor]**  
- Observe the alarm and Vcc using an oscilloscope.  
- Observe the change in the current 20 μs before occurrence of alarm output. |
| Chip overheat | Overcurrent  
\(t_{\text{ALM Typ}} = 8 \text{ ms}\) | The chip temperature is detected by the temperature detection element (diode) that is built in every IGBT chip. The IGBT is OFF for protection, if the \(T_{\text{jOH}}\) trip level was exceeded continuously for 1 ms.  
**[Method for identification of alarm factor]**  
- Measure control power supply voltage Vcc, DC input voltage Vdc and output current Io.  
- Measure case temperature \(T_c\) just below the chip, calculate \(\Delta T_{j-c}\) and estimate the value of \(T_j\).  
- Check the IPM mounting method.  
(Fin flatness, thermal compound, etc.) |
| Erroneous alarm  
Unstable \(t_{\text{ALM}}\) | If control power supply voltage Vcc exceeds absolute maximum rating, which is 20 V, or if excessive \(dv/dt\) or ripple was impressed, there is a possibility where the drive IC is broken and an erroneous alarm is output. Furthermore, also in case noise current flows to the IPM control circuit, there is a possibility where the IC voltage becomes unstable and an erroneous alarm is output.  
**[Method for identification of alarm factor]**  
- A short-pulse alarm of an us is produced. \(\rightarrow\)See chapter 6 section 1.2.1  
- Observe the Vcc waveform using an oscilloscope while the motor is running. It is desirable that the point of observation is located nearest to an IPM control terminal.  
- Confirm that Vcc < 20 V, \(\text{dv/dt} \leq 5 \text{ V/μs}\), ripple voltage \(\leq 10\%\) (with every one of four power supply unit).  
- Confirm that no external wiring connection is made between IPM control GND and main terminal GND. If wiring is made, noise current flows through IPM control circuit.  
- If the drive IC was broken, there is a large possibility where the value \(I_{cc}\) rises to an abnormal level.  
Example: It is abnormal, if \(I_{ccp} \geq 10 \text{ mA}, I_{ccn} \geq 20 \text{ mA}, \text{ and } @V_{in} = \text{OFF}.)