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# Chapter 1 – Features and structure

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<td>2</td>
<td>Features of the V-IPM by package</td>
<td>1-3</td>
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<td>3</td>
<td>Description of nomenclature and lot code</td>
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<td>6</td>
<td>Structure</td>
<td>1-12</td>
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</table>
1 Features of the V-IPM

An IPM (intelligent power module) is an intelligent IGBT module combining a built-in control IC which includes a drive circuit and a protection circuit. The V-IPM (V-series IPM) has the following features:

1.1 VR-IGBT chip
• Trade-off characteristic between the turn-off switching energy ($E_{off}$) and the saturation voltage ($V_{ce(sat)}$) is improved by applying the 6th generation IGBT (V-series), so that the total loss is reduced.

1.2 Built-in drive circuit
• Drives the IGBT under the optimized gate control conditions.
• No negative power supply is needed since it has minimum gate impedance between the drive circuit and the IGBT devices.
• Four isolated power supply units are required: one (1) on the lower arm side, three (3) on the upper arm side.

1.3 Built-in protection circuit
• Overcurrent protection (OC), short-circuit protection (SC), controlled power supply under voltage protection (UV), overheat protection (TjOH) and an external alarm output (ALM) are integrated.
• OC and SC are functions to protect the IGBT against breakdown caused by an over current or a load short-circuit. Each IGBT has an on-chip current sensor which can detect the collector current of each IGBT. This feature can protect the IPM module against an over current and a short circuit that may occur in any IGBT.
• UV is the protective function that works against a drive power supply voltage drop. Every control IC has this function.
• TjOH provides a high-speed over temperature protection by using an on-chip temperature sensor.
• ALM sends an alarm signal to the outer peripheral control unit of the IPM when an OC, SC, UV and/or TjOH occur. Additionally the IPM initiates a safe soft stop of the system. *1
*1 See [Chapter 3 Description of functions] for details of protective functions of each IPM.

1.4 Built-in brake circuit (7in1 IPM)
• A brake circuit can be configured by adding an external resistor that consumes electric power during regeneration.
• The brake circuit has a drive circuit and protection circuit, same as the inverter unit.

1.5 RoHS compliant
• All products of the V-IPM series are compliant with the RoHS directive.
Chapter 1  Features and structure

2 Features of the V-IPM by package

2.1 Low power type (P629: 6in1 with lower arm alarm output)

20 A to 50 A for 600V and 10 A to 25 A for 1200V are lined up as the low power type V-IPM. (P629 package)

- P629 package has a copper base plate with excellent heat dissipation performance.
- Terminal pitch of the control terminals is a standard 2.54 mm (0.1 inch).
- Main terminals are flat type solder pin and the height is the same as the control terminals. Therefore, it enables to solder the main terminals and control terminals to the same PCB.

- The IGBT is protected against abnormal overheating by an on-chip temperature sensor. *1
- Over current protection is realized by the on-chip sense IGBT current sensor. *1
- Compatible mounting dimensions with the R-IPM-series P619 package.

*1 Although the protective function is applied to the upper arm side, but no alarm output function is available for the upper arm.

2.2 Medium-power small-package type (P626: 6in1 with upper and lower arm alarm output)

50A to 75A for 600V and 25A to 50A for 1200V are lined up as the medium-power small-size package type. (P626 package)

- Terminal pitch of the control input terminals is a 2.54mm (0.1inch) standard pitch.
- Main terminals are flat type solder pin and the height is the same as the control terminals. Therefore it enables the main and control terminals to be soldered to the same PCB
- The IGBT is protected against abnormal overheating by an on-chip temperature sensor
- Over current protection is realized by the on-chip sense IGBT current sensor.

2.3 Medium-power thinner package type (P630: 6in1 / 7in1 with upper and lower arm alarm output function)

50A to 200A for 600V and 25A to 100A for 1200V are lined up as the medium-power thinner package type. Additionally, there is a low thermal impedance type for 100A ~ 200A/600V and 50A ~ 100A/1200V. (P630 package)

- Terminal pitch of the control input terminals is a 2.54mm (0.1inch) standard pitch that can be connected by using a general-purpose connector or by soldering.
- Guide pins assist insertion of a PCB to the IPM.
- Screw size for the main terminals is M4.
• The screw size for mounting to the heat sink is M4, which is the same as the main terminals.
• Solder less connection is also possible for electrical connection (main terminals and control terminals), which facilitates easy disconnection.
• The IGBT is protected against abnormal overheating by an on-chip temperature sensor.
• Over current protection is realized by the on-chip sense IGBT.

2.4 High power type (6in1 / 7in1 with upper and lower arm alarm output function)
200A to 400A for 600V and 100A to 200A for 1200V are lined up as the high power type (P631 package)
• Main DC bus input terminals (P1, P2, N1, N2), brake terminal (B) and output terminals (U, V, W) are located in proximity to each other and the package structure permits easy main wiring. Terminals P1, P2 and terminals N1, N2 are electrically connected to each other respectively.
• Screw size for the main terminals is M5 which allows large current.
• The screw size for mounting to a heat sink is M5, which is the same size as the main terminals.
• Solder less electrical connection is also possible and it can realize easy disconnection.
• The IGBT is protected against abnormal overheating by an on-chip temperature sensor.
• This package has two different boss heights. The PCB height from the base of the IPM can be set to 17.0 mm or 18.5 mm by changing the boss height (See Figure 1-12).
• Over current protection is realized by the on-chip sense IGBT.
• Mounting dimensions are compatible with the R-IPM-series P612 package products (excluding control terminal positions).

2.5 Medium power small package type (6in1 / 7in1 with upper and lower arm alarm output)
50A to 100A for 600V and 25A to 50A for 1200V are lined up as the medium power type (P636 package)
• Terminal pitch of the control input terminals is a 2.54mm (0.1inch) standard pitch.
• Main terminals are flat type solder pin and the height is the same as the control terminals. It enables the main and control terminals to be soldered to the same PCB
• The IGBT is protected against abnormal overheating by an on-chip temperature sensor.
• Over current protection is realized by the on-chip sense IGBT current sensor.
3 Description nomenclature and lot code

- **Type**

  - **Model sequential number** (< 50: Non-RoHS, >=50: RoHS)
  - **Voltage rating**
    - 060: 600 V
    - 120: 1200 V
  - **Series sequential number**
  - **Package**
    - A: P629
    - B: P626
    - D: P630
    - E: P631
    - F: P636
  - **Series name**
  - **Current rating**
  - **Represents “IGBT-IPM”**
  - **Number of the main IGBT elements**
    - 7: 6 IGBTs with built-in brake
    - 6: 6 IGBTs without brake

- **Label**

  ![Label Diagram]

  - **Lot No.**
  - **Country of production and place of production**
  - **Data matrix**
## 4 Line-up

### 800V Series

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<th>Package</th>
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<th>P626</th>
<th>P630</th>
<th>P631</th>
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Note) 7/6MBP***VDN060-50 is low thermal resistance version

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<th>P630</th>
<th>P631</th>
<th>P636</th>
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<td>7/6MBP150VDFN120-50</td>
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</tr>
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</table>

Note) 7/6MBP***VDFN120-50 is low thermal resistance version
5 Package outlines

Target type: 6MBP20VAA060-50, 6MBP30VAA060-50, 6MBP50VAA060-50,
6MBP10VAA120-50, 6MBP15VAA120-50, 6MBP25VAA120-50

Note: 1. The dimensions shown in fig. 1-1 represent the theoretical dimension.
2. The terminal pitch is the value at the root of the terminal.
3. Dimensions in brackets are given only for reference.
4. Terminal plating: Sn (for soldering)

[Unit of dimensions: mm]
Figure 1-2  Package outline drawing for P626

Target type:  6MBP50VBA060-50, 6MBP75VBA060-50, 6MBP25VBA120-50, 6MBP35VBA120-50, 6MBP50VBA120-50

Note: 1. The dimensions shown in fig. 1-2 represent the theoretical dimension.
2. The terminal pitch is the value at the root of the terminal.
3. Terminal plating: Sn (for soldering use)

[Unit of dimensions: mm]
Chapter 1  Features and structure

Figure 1-3 Package outline drawing for P630

Target type:
- 7/6MBP50VDA060-50, 7/6MBP75VDA060-50, 7/6MBP100VDA060-50, 7/6MBP150VDA060-50,
- 7/6MBP150VDN060-50, 7/6MBP200VDA060-50, 7/6MBP200VDN060-50, 7/6MBP25VDA120-50, 7/6MBP25VDA120-50,
- 7/6MBP35VDA120-50, 7/6MBP50VDA120-50, 7/6MBP50VDN120-50, 7/6MBP75VDA120-50, 7/6MBP75VDN120-50, 7/6MBP100VDA120-50,
- 7/6MBP100VDN120-50

Note:
1. The dimensions shown in fig. 1-3 represent the theoretical dimension.
2. The terminal pitch is the value at the root of the terminal.
3. Dimensions given in brackets are for reference.
4. Main terminal plating: Ni
   Control terminal plating: Ni plating on the ground, Au plating on the surface.
   (for connector and soldering use)
5. The guide pins located on both sides of a control terminal are made of brass.
   (They are insulated internally and are not connected to any object.)

[Unit of dimensions: mm]
Figure 1-4 Package outline drawing for P631

Target type: 7/6MBP200VEA060-50, 7/6MBP300VEA060-50, 7/6MBP400VEA060-50, 7/6MBP100VEA120-50, 7/6MBP150VEA120-50, 7/6MBP200VEA120-50

Note: 1. The dimensions shown in fig. 1-4 represent the theoretical dimension.
2. The terminal pitch is the dimension measured at the root.
3. Dimensions given in brackets are for reference only.
4. Main terminal plating: Ni
Control terminal plating: Ni plating on the ground, Au plating on the surface.
(for connector and soldering use)
5. The guide pins located on both sides of a control terminal are made of brass.
(They are insulated internally and are not connected to any object.)

[Unit of dimensions: mm]
Figure 1-5  Package outline drawing for P636

Target type: 7/6MBP50VFN060-50, 7/6MBP75VFN060-50, 7/6MBP100VFN060-50, 7/6MBP25VFN120-50, 7/6MBP35VFN120-50, 7/6MBP50VFN120-50

Note: 1. The dimensions shown in fig. 1-5 represent the theoretical dimension.
2. The terminal pitch is the value at the root of the terminal.
3. Terminal plating: Sn (for soldering use)

[Unit of dimensions: mm]
Structure

* This drawing is prepared for explanation of the material. It does not represent accurate chip size or layout.

<table>
<thead>
<tr>
<th>No.</th>
<th>Component</th>
<th>Material (main)</th>
<th>Remarks</th>
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<td>Isolation substrate</td>
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<tr>
<td>2</td>
<td>IGBT chip</td>
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</tr>
<tr>
<td>3</td>
<td>FWD chip</td>
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<tr>
<td>4</td>
<td>Printed Circuit Board (PCB)</td>
<td>Glass reinforced Epoxy resin</td>
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</tr>
<tr>
<td>5</td>
<td>IC chip</td>
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</tr>
<tr>
<td>6</td>
<td>Base Plate</td>
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<td>Ni plating</td>
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<td>7</td>
<td>Main Terminal</td>
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<td>Sn plating</td>
</tr>
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<td>Lid</td>
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<td>Case</td>
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Figure 1-6  Structure and material list (P629)
This drawing is prepared for explanation of the material. It does not represent accurate chip size or layout.

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<td>Main Terminal</td>
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Figure 1-7  Structure and material list (P626)
* This drawing is prepared for explanation of the material. It does not represent accurate chip size or layout.

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Figure 1-8  Structure and material list (P630)
* This drawing is prepared for explanation of the material. It does not represent accurate chip size or layout.

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<td>3</td>
<td>FWD chip</td>
<td>Silicon</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Printed Circuit Board (PCB)</td>
<td>Glass reinforced Epoxy resin</td>
<td>Halogen Free</td>
</tr>
<tr>
<td>5</td>
<td>IC chip</td>
<td>Silicon</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Base Plate</td>
<td>Cu</td>
<td>Nickel plating</td>
</tr>
<tr>
<td>7</td>
<td>Main Terminal</td>
<td>Cu</td>
<td>Surface: Ni plating</td>
</tr>
<tr>
<td>8</td>
<td>Lid</td>
<td>PPS resin</td>
<td>UL 94V-0</td>
</tr>
<tr>
<td>9</td>
<td>Case</td>
<td>PPS resin</td>
<td>UL 94V-0</td>
</tr>
<tr>
<td>10</td>
<td>Wiring</td>
<td>Aluminum</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Silicone Gel</td>
<td>Silicone resin</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Ring</td>
<td>SUS</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Nut</td>
<td>Fe</td>
<td>Trivalent chromate treatment</td>
</tr>
<tr>
<td>14</td>
<td>Control terminal</td>
<td>Brass</td>
<td>Au plating on Ni plating</td>
</tr>
<tr>
<td>15</td>
<td>Guide pin</td>
<td>Brass</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1-9  Structure and material list (P631)
This drawing is prepared for explanation of the material. It does not represent accurate chip size or layout.

<table>
<thead>
<tr>
<th>No.</th>
<th>Component</th>
<th>Material (main)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Isolation substrate</td>
<td>Ceramic</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>IGBT chip</td>
<td>Silicon</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>FWD chip</td>
<td>Silicon</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Printed Circuit Board (PCB)</td>
<td>Glass reinforced Epoxy resin</td>
<td>Halogen Free</td>
</tr>
<tr>
<td>5</td>
<td>IC chip</td>
<td>Silicon</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Base Plate</td>
<td>Cu</td>
<td>Ni plating</td>
</tr>
<tr>
<td>7</td>
<td>Main Terminal</td>
<td>Cu</td>
<td>Sn plating</td>
</tr>
<tr>
<td>8</td>
<td>Lid</td>
<td>PPS resin</td>
<td>UL 94V-0</td>
</tr>
<tr>
<td>9</td>
<td>Case</td>
<td>PPS resin</td>
<td>UL 94V-0</td>
</tr>
<tr>
<td>10</td>
<td>Wiring</td>
<td>Aluminum</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Silicone Gel</td>
<td>Silicone resin</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Ring</td>
<td>SUS</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Control Terminal</td>
<td>Brass</td>
<td>Sn plating</td>
</tr>
</tbody>
</table>

Figure 1-10  Structure and material list (P636)
• **Main terminals of IPM (screw type)**
The structure of the main terminal is shown in Figure 1-9:

![Figure 1-9](image)

**Table 1-1  Specification for IPM main terminal unit**

<table>
<thead>
<tr>
<th>PKG</th>
<th>Screw standard</th>
<th>Terminal tab thickness (B)</th>
<th>Nut depth (C)</th>
<th>Screw hole depth (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P630</td>
<td>M4</td>
<td>0.8</td>
<td>3.5</td>
<td>8.5±0.5</td>
</tr>
<tr>
<td>P631</td>
<td>M5</td>
<td>1.0</td>
<td>4.0</td>
<td>9.0±0.5</td>
</tr>
</tbody>
</table>

(Unit: mm)

• **Guide pins of IPM**
The guide pins located on both sides of control terminal portions of P630 and P631 are made of brass. They are insulated in the interior and are not connected to any circuits.
• **Height of boss on lid of P636**

  P636 package has two different boss heights (2.5 mm and 1.0 mm) on the lid. The PCB height can be set to 18.5 mm or 17.0 mm by changing the boss height.

  ![Diagram of P636 package showing boss heights](image)

  **Figure 1-12** Selecting from two different boss heights
## Chapter 2

Description of terminal marking and terms

<table>
<thead>
<tr>
<th>Table of Contents</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Description of terminal marking</td>
<td>2-2</td>
</tr>
<tr>
<td>2 Description of terms</td>
<td>2-3</td>
</tr>
</tbody>
</table>
# Descriptions of the I/O terminals

## Main terminals

<table>
<thead>
<tr>
<th>Terminal Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P (P1, P2)</td>
<td>DC-bus terminals after smoothing capacitor</td>
</tr>
<tr>
<td>N (N1, N2)</td>
<td>P: + side, N: - side</td>
</tr>
<tr>
<td>B</td>
<td>Collector terminal of the Brake IGBT. Connect a brake resistor for dissipating regenerated energy</td>
</tr>
<tr>
<td>U</td>
<td>3-phase output terminals</td>
</tr>
<tr>
<td>V</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td></td>
</tr>
</tbody>
</table>

* P1, P2, N1 and N2 terminals are P631 package only.

## Control terminals

<table>
<thead>
<tr>
<th>Terminal Name</th>
<th>P629 Pin#</th>
<th>P626, P630, P631 Pin#</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GND U</td>
<td>1</td>
<td>1</td>
<td>Ground reference for the U-arm control power supply</td>
</tr>
<tr>
<td>Vcc U</td>
<td>3</td>
<td>4</td>
<td>U-arm control power supply positive terminal</td>
</tr>
<tr>
<td>Vin U</td>
<td>2</td>
<td>3</td>
<td>U-arm control signal input</td>
</tr>
<tr>
<td>ALM U</td>
<td>-</td>
<td>2</td>
<td>U-arm alarm signal output</td>
</tr>
<tr>
<td>GND V</td>
<td>4</td>
<td>5</td>
<td>Ground reference for the V-phase control power supply</td>
</tr>
<tr>
<td>Vcc V</td>
<td>6</td>
<td>8</td>
<td>V-arm control power supply positive terminal</td>
</tr>
<tr>
<td>Vin V</td>
<td>5</td>
<td>7</td>
<td>V-arm control signal input</td>
</tr>
<tr>
<td>ALM V</td>
<td>-</td>
<td>6</td>
<td>V-arm alarm signal output</td>
</tr>
<tr>
<td>GND W</td>
<td>7</td>
<td>9</td>
<td>Ground reference for the W-phase control power supply</td>
</tr>
<tr>
<td>Vcc W</td>
<td>9</td>
<td>12</td>
<td>W-arm control power supply positive terminal</td>
</tr>
<tr>
<td>Vin W</td>
<td>8</td>
<td>11</td>
<td>W-arm control signal input</td>
</tr>
<tr>
<td>ALM W</td>
<td>-</td>
<td>10</td>
<td>W-arm alarm signal output</td>
</tr>
<tr>
<td>GND</td>
<td>10</td>
<td>13</td>
<td>Ground reference for the lower arm control power supply</td>
</tr>
<tr>
<td>Vcc</td>
<td>11</td>
<td>14</td>
<td>Control power supply positive terminal for the lower arm</td>
</tr>
<tr>
<td>Vin X</td>
<td>12</td>
<td>16</td>
<td>X-arm control signal input</td>
</tr>
<tr>
<td>Vin Y</td>
<td>13</td>
<td>17</td>
<td>Y-arm control signal input</td>
</tr>
<tr>
<td>Vin Z</td>
<td>14</td>
<td>18</td>
<td>Z-arm control signal input</td>
</tr>
<tr>
<td>Vin DB</td>
<td>-</td>
<td>15</td>
<td>DB-arm control signal input</td>
</tr>
<tr>
<td>ALM</td>
<td>15</td>
<td>19</td>
<td>Lower-arm alarm signal output</td>
</tr>
</tbody>
</table>

* Pin (15) of P626 is of no contact.

* Pin (15) of each of P631 (6in1), P630 (6in1) is of no contact.
2 Description of terms

2.1 Absolute maximum rating

<table>
<thead>
<tr>
<th>Term</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC power supply voltage</td>
<td>$V_{DC}$</td>
<td>Maximum DC bus voltage between the P and N terminal</td>
</tr>
<tr>
<td>DC power supply voltage at short circuit</td>
<td>$V_{DC}$</td>
<td>Maximum DC bus voltage between the P and N terminal during short-circuit protection and over current protection</td>
</tr>
<tr>
<td>Collector-Emitter blocking voltage</td>
<td>$V_{CES}$</td>
<td>Maximum voltage between the collector and emitter terminal of the built-in IGBT, and peak inverse voltage of the FWD.</td>
</tr>
<tr>
<td>Collector current</td>
<td>$I_C$</td>
<td>Maximum DC collector current for each IGBT</td>
</tr>
<tr>
<td>Diode forward current for DB</td>
<td>$I_F$</td>
<td>Maximum DC forward current for FWD in brake circuit</td>
</tr>
<tr>
<td>Diode forward current for DB</td>
<td>$I_{CP}$</td>
<td>Maximum peak collector current for each IGBT</td>
</tr>
<tr>
<td>Collector loss</td>
<td>$P_C$</td>
<td>Maximum power dissipation for each IGBT at $T_{jc}=25^\circ C$, $T_{j}\leq 150^\circ C$</td>
</tr>
<tr>
<td>Control power supply voltage</td>
<td>$V_{CC}$</td>
<td>Maximum voltage between the $V_{CC}$ and GND terminal</td>
</tr>
<tr>
<td>Input voltage</td>
<td>$V_{in}$</td>
<td>Maximum voltage between the $V_{in}$ and GND terminal</td>
</tr>
<tr>
<td>Alarm voltage</td>
<td>$V_{ALM}$</td>
<td>Maximum voltage between the ALM and GND terminal</td>
</tr>
<tr>
<td>Chip junction temperature</td>
<td>$T_{j}$</td>
<td>Maximum IGBT/FWD chip junction temperature during continuous operation</td>
</tr>
<tr>
<td>Case temperature during operation</td>
<td>$T_{op}$</td>
<td>Allowable case temperature range during operation (measured point of the case temperature $T_{c}$ is shown in Figure 5-4)</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>$T_{stg}$</td>
<td>Allowable ambient temperature during storage or transportation without being subject to electrical load.</td>
</tr>
<tr>
<td>Soldering temperature</td>
<td>$T_{sld}$</td>
<td>Maximum temperature for soldering the terminals to a PCB</td>
</tr>
<tr>
<td>Isolation voltage</td>
<td>$V_{iso}$</td>
<td>Maximum RMS isolation of sinusoidal voltage between all the terminals and heat sink (all terminals are shorted)</td>
</tr>
<tr>
<td>Screw torque</td>
<td>Terminal</td>
<td>Maximum screw torque for the main terminal with specified screw</td>
</tr>
<tr>
<td>Screw torque</td>
<td>Mounting</td>
<td>Maximum screw torque for mounting the IPM on heat sink with specified screw</td>
</tr>
</tbody>
</table>

2.2 Electrical characteristics

2.2.1 Main circuit

<table>
<thead>
<tr>
<th>Term</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector-Emitter leakage current</td>
<td>$I_{CES}$</td>
<td>Leakage current when specified voltage is applied between the collector and emitter and all input signals are &quot;H&quot; (=all IGBTs are turned-off).</td>
</tr>
<tr>
<td>Collector-Emitter saturation voltage</td>
<td>$V_{CE(sat)}$</td>
<td>Voltage drop between the collector and emitter when gate input signal is &quot;L&quot; (=IGBT is turned-on)</td>
</tr>
<tr>
<td>Diode forward voltage</td>
<td>$V_{f}$</td>
<td>Voltage drop across the diode at defined forward current at input signal is &quot;H&quot; (=IGBT is turned-off)</td>
</tr>
<tr>
<td>Turn-on time</td>
<td>$t_{on}$</td>
<td>Time interval between the moment when gate input voltage has exceed $V_{inth(on)}$ and the collector current has increased to 90% of the load current. (see Figure 2-1)</td>
</tr>
<tr>
<td>Turn-off time</td>
<td>$t_{off}$</td>
<td>Time interval between the moment when the gate input voltage has dropped less than $V_{inth(off)}$ and the corrector current drops to 10% of the load current. If the collector dropping waveform is not a straight line, a tangential line is used as the substitute (see Figure 2-1)</td>
</tr>
<tr>
<td>Fall time</td>
<td>$t_{f}$</td>
<td>Time interval the collector current decreased from 90% to 10% of the load current</td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>$t_r$</td>
<td>Time interval between the moment when the collector current exceeds 100% of the load current and the reverse recovery current disappears</td>
</tr>
<tr>
<td>Dead time</td>
<td>$t_{dead}$</td>
<td>Time delay of the turn-on signal from the alternate IGBT turn-off signal.</td>
</tr>
</tbody>
</table>
### 2.2.2 Control circuit

<table>
<thead>
<tr>
<th>Term</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control power supply consumption current</td>
<td>$I_{CCP}$</td>
<td>Current flows into VCC terminal of upper arm control power supply</td>
</tr>
<tr>
<td></td>
<td>$I_{CCN}$</td>
<td>Current flows into VCC terminal of lower arm control power supply</td>
</tr>
<tr>
<td>Input threshold voltage</td>
<td>$V_{in\text{th(on)}}$</td>
<td>Voltage above which considerable the control IC can detect the input signal as ON</td>
</tr>
<tr>
<td></td>
<td>$V_{in\text{th(off)}}$</td>
<td>Voltage below which considerable the control IC can detect the input signal as OFF</td>
</tr>
</tbody>
</table>

### 2.2.3 Protection circuit

<table>
<thead>
<tr>
<th>Term</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over current protection current</td>
<td>$I_{CCP}$</td>
<td>Current flows into the VCC terminal of upper arm control power supply</td>
</tr>
<tr>
<td>Over current interruption lag time</td>
<td>$t_{doc}$</td>
<td>Lag time since the over current reaches the trip level until the protection start. See Figure 2-3</td>
</tr>
<tr>
<td>Short-circuit protection current</td>
<td>$I_{SC}$</td>
<td>Threshold current for short-circuit protection</td>
</tr>
<tr>
<td>Short-circuit protection lag time</td>
<td>$t_{SC}$</td>
<td>Lag time since the short circuit current reaches the trip level until the protection start. See Figure 2-4</td>
</tr>
<tr>
<td>Chip over heat protection temperature</td>
<td>$T_{jOH}$</td>
<td>Threshold junction temperature for overheat protection</td>
</tr>
<tr>
<td>Chip over heat protection hysteresis</td>
<td>$T_{jH}$</td>
<td>Lower hysteresis offset temperature to reactivate after the over temperature protection</td>
</tr>
<tr>
<td>Control power supply under voltage protection</td>
<td>$V_{UV}$</td>
<td>Trip voltage to start under-voltage protection</td>
</tr>
<tr>
<td>Control power supply under voltage protection hysteresis</td>
<td>$V_{H}$</td>
<td>Higher threshold offset voltage to reactivate after the low voltage protection</td>
</tr>
<tr>
<td>Alarm output hold time</td>
<td>$t_{ALM(OC)}$</td>
<td>Alarm signal pulse width of the overcurrent protection (OC)</td>
</tr>
<tr>
<td></td>
<td>$t_{ALM(UV)}$</td>
<td>Alarm signal pulse width of under the voltage protection (UV)</td>
</tr>
<tr>
<td></td>
<td>$t_{ALM(TjOH)}$</td>
<td>Alarm signal pulse width of the overheat protection (TjOH)</td>
</tr>
<tr>
<td>Alarm output resistance</td>
<td>$R_{ALM}$</td>
<td>Value of the built-in resistance that is connected in series to alarm terminals. It limits the primary forward current of opto-coupler.</td>
</tr>
</tbody>
</table>

### 2.3 Thermal characteristics

<table>
<thead>
<tr>
<th>Term</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal resistance between chip and case</td>
<td>$R_{h(j-o)}$</td>
<td>Thermal resistance between the case and IGBT chip</td>
</tr>
<tr>
<td></td>
<td>$R_{h(j-c)}$</td>
<td>Thermal resistance between the case and FWD chip</td>
</tr>
<tr>
<td>Thermal resistance between case and heat sink</td>
<td>$R_{h(c-f)}$</td>
<td>Thermal resistance between the case and heat sink at the condition</td>
</tr>
<tr>
<td>Case temperature</td>
<td>$T_{C}$</td>
<td>IPM case temperature (bottom surface of the copper base plate directly under the chip)</td>
</tr>
</tbody>
</table>

### 2.4 Noise tolerance

<table>
<thead>
<tr>
<th>Term</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common mode</td>
<td>-</td>
<td>Common mode noise tolerance in our test circuit</td>
</tr>
</tbody>
</table>
### 2.5 Others

<table>
<thead>
<tr>
<th>Term</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>Wt</td>
<td>Mass of the IPM</td>
</tr>
<tr>
<td>Switching frequency</td>
<td>$f_{SW}$</td>
<td>Allowable switching frequency for the control signals to the input terminals.</td>
</tr>
<tr>
<td>Reverse recovery current</td>
<td>$I_{rr}$</td>
<td>Peak value of the reverse recovery current. See Figure 2-1.</td>
</tr>
<tr>
<td>Reverse bias safe operating area</td>
<td>RBSOA</td>
<td>The area of the voltage and current which the device can operate without self-damage during turn-off switching. There is a possibility to brake down when voltage or current exceed the area.</td>
</tr>
<tr>
<td>Switching loss</td>
<td>$E_{on}$</td>
<td>Dissipated switching energy of the IGBT during turn-on</td>
</tr>
<tr>
<td></td>
<td>$E_{off}$</td>
<td>Dissipated switching energy of the IGBT during turn-off</td>
</tr>
<tr>
<td></td>
<td>$E_{orr}$</td>
<td>Dissipated switching energy of the FWD during reverse recovery</td>
</tr>
<tr>
<td>Inverse voltage</td>
<td>$V_{R}$</td>
<td>Repetitive reverse peak voltage of the FRD chip in the brake unit</td>
</tr>
<tr>
<td>Input current</td>
<td>$I_{in}$</td>
<td>Maximum current into the Vin terminals</td>
</tr>
</tbody>
</table>
Chapter 2  Description of terminal marking and terms

Figure 2-1  Switching times

Figure 2-2  Input/output timing diagram
Figure 2-3  Overcurrent interruption lag time ($t_{doc}$)

Figure 2-4  Short-circuit protection lag time ($t_{sc}$)
Figure 2-5  Dead time ($t_{\text{dead}}$)
– Chapter 3 –

Description of functions

<table>
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<th>Page</th>
</tr>
</thead>
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<tr>
<td>2 Description of functions</td>
<td>3-4</td>
</tr>
<tr>
<td>3 Truth table</td>
<td>3-10</td>
</tr>
<tr>
<td>4 Block diagram</td>
<td>3-12</td>
</tr>
<tr>
<td>5 Timing chart</td>
<td>3-20</td>
</tr>
</tbody>
</table>
## List of functions

The built-in protection functions in the V-IPM are shown in Tables 3-1 and 3-2.

### Table 3-1  IPM built-in functions, 600 V-series

<table>
<thead>
<tr>
<th>Number of Switch</th>
<th>Type Name</th>
<th>Built-in Function</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Upper and Lower arms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drive</td>
<td>UV</td>
</tr>
<tr>
<td>6 in 1</td>
<td>6MBP20VAA060-50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6MBP30VAA060-50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6MBP50VAA060-50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6MBP50VBA060-50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6MBP75VBA060-50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6MBP50VDA060-50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6MBP75VDA060-50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6MBP100VDA060-50</td>
<td></td>
<td></td>
</tr>
<tr>
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</table>

Drive: IGBT drive circuit, UV: Control power supply under voltage protection, TjOH: Chip temperature overheat protection, OC: Overcurrent protection, SC: Short-circuit protection, ALM: Alarm signal output
Table 3-2  IPM built-in functions, 1200 V-series

<table>
<thead>
<tr>
<th>Number of Switch</th>
<th>Type Name</th>
<th>Drive</th>
<th>UV</th>
<th>TjOH</th>
<th>OC / SC</th>
<th>Upper arm ALM</th>
<th>Lower arm ALM</th>
<th>Package</th>
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</table>

Drive: IGBT drive circuit, UV: Control power supply under voltage protection, TjOH: Chip temperature overheat protection, OC: Overcurrent protection, SC: Short-circuit protection, ALM: Alarm signal output
## Description of functions

### 2.1 IGBT and FWD for 3-phase inverter

The V-IPM has a 3-phase bridge circuit which consists of six IGBTs and six FWDs as shown in Figure 3-1. The main circuit is completed when the main DC bus power supply line is connected to the P and N terminals and the 3-phase output line is connected to the terminals U, V and W. Connect a snubber circuit to suppress the surge voltage.

### 2.2 IGBT and FWD for brake

IGBT and FWD for brake circuit are integrated in the V-IPM (7in1 of P630 and P631 series). The collector terminal of the IGBT is connected to the output terminal B as shown in Figure 3-1. The regenerative energy during deceleration is consumed by the resistor which is connected between terminal P and B. Voltage rise between terminals P and N can be suppressed by switching the brake IGBT.

![Figure 3-1 Typical application of 3-phase inverter](image-url)
2.3 IGBT drive function

Figure 3-2 shows a block diagram of the Pre-Driver. The V-IPM has a built-in gate drive circuit for the IGBT and it is possible to drive the IGBT by inputting an opto-isolated control signal to the V-IPM without designing the gate resistance value.

The features of this drive function are introduced below:

- **Independent turn-on and turn-off control**
  The V-IPM has an independent gate drive circuits for turn-on and turn-off of the IGBT instead of a single gate resistance. The drive circuits control the dv/dt of turn-on and turn-off independently and maximize the performance of the device.

- **Soft shutoff**
  The gate voltage is gradually reduced at the occasion of the IGBT shutoff when the protection function is activated in various kinds of abnormal modes. The soft shutoff suppresses the surge voltage during the turn-off and prevents the breakdown of the device.

- **Prevention of false turn-on**
  The gate electrode of the IGBT is connected to the grounded emitter with low impedance. It prevents false turn-on of the IGBT due to the increase of the V_{GE} due to noise or other cause.

- **No reverse bias power supply is necessary**
  The wiring length between the control IC and the IGBT in the V-IPM are short and the wiring impedance is small, therefore the V-IPM can be driven without reverse bias.
2.4 Protective functions

The V-IPM has protection circuits which prevent failures of the IPM caused by an abnormal mode. The V-IPM has four kind of protective functions; OC (overcurrent protection), SC (short-circuit protection), UV (control power supply under voltage protection) and TjOH (chip temperature overheat protection).

When a protective function is activated, the MOSFET for alarm output is turned on and the alarm output terminal voltage changes from High to Low. The alarm output terminal becomes conductive to GND. Furthermore, since a 1.3 kΩ resistance is connected in series between the control IC and the alarm output terminal, an opto-coupler that is connected between the ALM terminal and the Vcc terminal can be driven directly.

- **Alarm signal output function**

  When the protected operation is activated, the IGBT is not turned on even when an ON signal is input. The failure mode is identified and the IGBT goes through soft shutdown. The alarm signal can be output from the phase that detected the failure mode individually.

  - After the elapse of \( t_{\text{ALM}} \) from the alarm signal output the input signal will be OFF then the protection operation is stopped and normal operation is restarts.
• Even in case the alarm factor is dissolved within the alarm signal output period ($t_{ALM}$), the protected operation continues during the alarm signal output period ($t_{ALM}$), and accordingly, the IGBT is not turned on.

Furthermore, the alarm circuits for the lower arm devices including brake circuit are connected mutually. If protection operation occurs on the lower arm side, all the IGBTs of the lower arms are turned off during the protection operation.

* P629 package has protective functions on both of the upper arm and the lower arm devices, but the upper arm devices do not have an alarm signal output function. The lower arm devices have both, the protective functions and alarm signal output function.

□ Alarm factor identification function

As the alarm signal output period ($t_{ALM}$) varies in correspondence to the failure mode, the failure mode can be identified by measuring the alarm signal pulse width.

<table>
<thead>
<tr>
<th>Alarm factor</th>
<th>Alarm signal output period ($t_{ALM}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overcurrent protection (OC)</td>
<td>2 ms (typ.)</td>
</tr>
<tr>
<td>Short-circuit protection (SC)</td>
<td></td>
</tr>
<tr>
<td>Control power supply under voltage protection (UV)</td>
<td>4 ms (typ.)</td>
</tr>
<tr>
<td>Chip temperature overheat protection (TjOH)</td>
<td>8 ms (typ.)</td>
</tr>
</tbody>
</table>

However, the pulse width of the alarm signal output through an optocoupler varies by the influence of a time delay of the optocoupler and other peripheral circuits. It is necessary to take these influences into account in your design.
2.5 Overcurrent protection function: Over Current (OC)

The IGBT's forward collector current is measured by the current sense IGBT built in the IGBT chip. When the forward collector current exceeds the protection level ($I_{OC}$) and continues longer than $t_{doc}$ (typ. 5 µs), it is judged as being in the OC status and the IGBT is turned off to prevent occurrence of breakdown by the overcurrent. At the same time, an alarm signal is provided. The OC status alarm signal period ($t_{ALM}$) is 2 ms.

- Protection operation is stopped and normal operation is restarted if the current level is lower than the $I_{OC}$ level and the input signal is OFF after 2 ms ($t_{ALM}$) of the alarm signal output.
- Even in case the current level goes back to below the $I_{OC}$ within the 2 ms ($t_{ALM}$), the protection operation continues until the end of the period of 2 ms ($t_{ALM}$) elapses and accordingly the IGBT is not turned on.

2.6 Short-circuit protective function: Short Circuit (SC)

The SC protective function prevents the IPM form being damaged by the peak current during load short-circuit and arm short-circuit. When the IGBT’s forward collector current exceeds the protection level ($I_{SC}$) and continues longer than $t_{dsc}$, it is judged as being in the SC status and the protective function is activated then the IGBT is softly turned off to prevent occurrence of breakdown by short-circuit. At the same time an alarm signal is output. The SC status alarm signal output period ($t_{ALM}$) is 2 ms.

- Protection operation is stopped and normal operation is resumed if the current level is lower than the $I_{SC}$ level and the input signal is OFF after 2 ms ($t_{ALM}$) of the alarm signal output.
- Even in case that the short circuit disappears within 2 ms ($t_{ALM}$), the protective operation continues until the period of 2 ms ($t_{ALM}$) elapses and accordingly the IGBT is not turned on.

2.7 Control power supply under voltage protection function (UV)

The UV protective function prevents malfunction of the control IC caused by a voltage drop of the control power supply voltage ($V_{CC}$) and thermal breakdown of the IGBT caused by increase of the $V_{CE}$ (sat) loss. When $V_{CC}$ is continuously below the voltage protection trip level ($V_{UV}$) for a period of 20 µs, it is judged as being in the UV status and the IGBTs are softly turned off to prevent malfunction and breakdown caused by the control power supply voltage drop. When it is judged as being in the UV status, the protective function is activated and the alarm signal is generated. The alarm signal output period ($t_{ALM}$) of the UV protection is 4 ms.
• As hysteresis $V_H$ is provided, protection operation is stopped and normal operation is resumed, if $V_{CC}$ is higher than $(V_{UV} + V_H)$ and the input signal is OFF. A 4 ms ($t_{ALM}$) alarm signal will be sent to the output.
• Even in case the supply voltage exceeds $(V_{UV} + V_H)$ within 4 ms ($t_{ALM}$), the protective operation continues until the period of 4 ms ($t_{ALM}$) elapses, and accordingly, the IGBT is not turned on. Furthermore, an alarm signal for judgment of the UV status is provided at the time of startup and shutdown of the control power supply.

2.8 Chip temperature overheat protective function: IGBT chip Over Heat protection ($T_{JOH}$)

The $T_{JOH}$ protective function includes the direct IGBT chip temperature detected by a built-in on-chip temperature sensor on each IGBT chip. If the IGBT chip temperature is continuously higher than protection trip level ($T_{JOH}$) for 1.0 ms, it is judged as being in the overheat status, the $T_{JOH}$ protective function is activated then the IGBTs are softly turned off to prevent a failure of the IGBT. At the same time an alarm signal output is generated. The UV status alarm signal output period ($t_{ALM}$) is 8 ms.

• There is a hysteresis offset $T_{JH}$, the protective operation is stopped and normal operation is resumed, if $T_j$ is below $(T_{JOH} - T_{JH})$ and the input signal is OFF after 8 ms ($t_{ALM}$) of the alarm signal output.
• Even in case the alarm signal disappears within 8 ms ($t_{ALM}$), the protected operation continues until the period of 8 ms ($t_{ALM}$) elapses, and accordingly, the IGBT is not turned on.

A case temperature overheat protective function ($T_{COH}$), which is built in the former IPM series, is not built in the V-IPM series. The IGBT chip overheat status is protected by the $T_{JOH}$ protective function.
### Chapter 3  Description of functions

#### 3 Truth table

The truth tables of the V-IPM series when protective function is activated are shown in Tables 3-3 to 3-5.

**Table 3-3  Truth table (P629)**

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<th>IGBT</th>
<th>Alarm signal output</th>
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<td>V-phase</td>
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<tr>
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</tr>
<tr>
<td>UV</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>TJ OH</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

* Dependent on the input signal.

**Table 3-4  Truth table (P626)**

<table>
<thead>
<tr>
<th>Alarm factor</th>
<th>IGBT</th>
<th>Alarm signal output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U-phase</td>
<td>V-phase</td>
</tr>
<tr>
<td><strong>U-phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OC</td>
<td>OFF</td>
<td>*</td>
</tr>
<tr>
<td>SC</td>
<td>OFF</td>
<td>*</td>
</tr>
<tr>
<td>UV</td>
<td>OFF</td>
<td>*</td>
</tr>
<tr>
<td>TJ OH</td>
<td>OFF</td>
<td>*</td>
</tr>
<tr>
<td><strong>V-phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OC</td>
<td>*</td>
<td>OFF</td>
</tr>
<tr>
<td>SC</td>
<td>*</td>
<td>OFF</td>
</tr>
<tr>
<td>UV</td>
<td>*</td>
<td>OFF</td>
</tr>
<tr>
<td>TJ OH</td>
<td>*</td>
<td>OFF</td>
</tr>
<tr>
<td><strong>W-phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OC</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>SC</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>UV</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>TJ OH</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Lower arm side X, Y and Z-phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OC</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>SC</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>UV</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>TJ OH</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

* Dependent on the input signal.
### Table 3-5  Truth table (P630, P631 and P636)

<table>
<thead>
<tr>
<th>Alarm factor</th>
<th>IGBT</th>
<th>Alarm signal output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U-phase</td>
<td>V-phase</td>
</tr>
<tr>
<td><strong>U-phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OC</td>
<td>OFF</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>SC</td>
<td>OFF</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>UV</td>
<td>OFF</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>TjOH</td>
<td>OFF</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>V-phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OC</td>
<td>*</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>SC</td>
<td>*</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>UV</td>
<td>*</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>TjOH</td>
<td>*</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td><strong>W-phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OC</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>SC</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>UV</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>TjOH</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

* Dependent on the input signal.
V-IPM block diagrams are shown in Figures 3-3 to 3-8.
Figure 3-4  IPM block diagram (P626)
Figure 3-5  IPM block diagram (P630 without break)
Figure 3-6  IPM block diagram  (P630 with built-in brake)
Figure 3-7  IPM block diagram (P631 without brake)
Figure 3-8  IPM block diagram (P631 with built-in brake)
Figure 3-9  IPM block diagram (P636 without built-in brake)
Figure 3-10  IPM block diagram (P636 with built-in brake)
### 5 Timing chart

#### 5.1 Control power supply under voltage protection (UV): Case 1

1. At the period of the VCC ramp-up, alarm output begins when the VCC exceeds 5 V and less than VUV. (See 5.3 for details.)
2. Protective function is not activated if the length of time during which VCC is lower than VUV is shorter than 20 µs. (While Vin is off)
3. While Vin is off, an alarm is generated 20 µs after the VCC drop below VUV, and the IGBT is kept in the off status.
4. UV protected operation continues during the tALM (UV) period even if the VCC returns to over (VUV + VH) and Vin is off. Normal operation is restarted from protected operation after the elapse of the tALM (UV) period.
5. Protection operation is not activated if the length of time during which VCC is lower than VUV is shorter...
than 20 µs. (While Vin is on)

(6) While Vin is on, an alarm output signal is generated 20 µs after VCC drops below VUV, and the IGBT is softly turned off.

(7) In case VCC returns to over VUV + VH before the elapse of tALM (UV) period and Vin remains on state, an alarm is output during the tALM (UV) period, but the protective function continues operating until Vin is changed to off-state.

(8) An alarm output is generated when VCC is below VUV during shutoff. (See 5.3 for details.)

5.2 Control power supply under voltage protection (UV): Case 2

(1) At the period of the Vcc ramp-up, an alarm is generated and Vin is kept in the on status. Therefore, UV protected operation is held regardless of the Vcc voltage drop.

(2) Reset from protected operation occurs at the timing when the Vin is off in the state where VCC is VUV+VH or higher.

(3) The protective function continues because the VCC is lower than VUV. Then Vin signal is ignored and then the IGBT is not turned on. In addition, even if the duration of the protective operation is much longer than the tALM (UV), the alarm output is generated only once.

*1: tALM (UV) is 4 ms, typical.
*2: Dead time 20 µs is a typical
5.3 Control power supply under voltage protection (UV) during startup and shutdown of power supply

V-IPM has control power supply under voltage protection (UV) function. Because of this function, an alarm output is generated during the startup and shutdown of the power supply. Its details are described below:

5.3.1 During startup

When VCC exceeds 5 V, an alarm output is generated after the elapse of 20 μs in both of Case 1 and Case 2. In Case 1, the VCC voltage reaches (VUV + VH) and the Vin becomes off-state within the t_ALM(UV) and the protective operation is stopped after the elapse of t_ALM (UV). In Case 2, protective operation continues even after the elapse of t_ALM(UV) because the VCC is still below (VUV+VH). The protected operation is stopped when VCC exceeds VUV + VH and Vin is off-state.

5.3.2 During Shutdown

When the VCC becomes less than the VUV, an alarm signal is generated after the elapse of 20 μs in both of Case 3 and Case 4. In Case 3, the alarm is stopped before the t_ALM(UV) because the VCC becomes less than 5V before the elapse of the t_ALM (UV) and the IPM operation becomes unstable. In Case 4, protected operation continues after the elapse of the t_ALM(UV) because the VCC is still higher than 5 V. When the VCC becomes less than 5 V, the protected operation of the control IC is stopped and the VALM changes to VCC equivalent.
5.4 Overcurrent protection (OC)

(1) When the Ic exceeds the overcurrent trip level Ioc, an alarm signal is generated after the elapse of the tdOC, and the IGBT is softly turned off.

(2) The protected operation continues during the tALM (OC) period even if the Vin becomes off-state, and resumes to normal operation after the elapse of the tALM (OC) and Vin is in the off-state.

(3) OC protected operation continues if the Vin is on-state after the elapse of the tALM (OC), and resumes to normal operation when the Vin becomes off-state. In addition, even if duration of the protection operation is much longer than the tALM (OC), alarm signal output is generated only once.

(4) When the Vin is off-state before the elapse of the tdOC since the Ic exceeds the Ioc, protection operation is not activated and the IGBT is softly turned off by the Vin off-state input.

(5) If Ic is higher than Ioc when Vin becomes on-state and if Vin becomes on-state before the elapse of tdOC, protection operation is not activated and the IGBT is softly turned-off normally.

*1: tALM (OC) is 2 ms, typical.
*2: tdOC is 5 μs, typical.
5.5 Short-circuit protection (SC)

<table>
<thead>
<tr>
<th></th>
<th>High (OFF)</th>
<th>Low (ON)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_in</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I_c</td>
<td>ISC</td>
<td>IOC</td>
</tr>
<tr>
<td>Protected</td>
<td></td>
<td></td>
</tr>
<tr>
<td>operation</td>
<td>In operation</td>
<td>Cancelled</td>
</tr>
<tr>
<td>VALM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>t_ALM (OC)</td>
<td>t_SC</td>
</tr>
<tr>
<td>High</td>
<td>t_ALM (OC)</td>
<td>t_SC &gt;</td>
</tr>
</tbody>
</table>

(1) If a load short-circuit occurs when normal I_c is flowing and if the I_c exceeds I_SC the peak current of the I_c is suppressed momentarily. After the elapse of t_SC, an alarm signal is generated and the IGBT is softly turned off.

(2) SC protected operation is stopped if the V_in is off-state after the elapse of the t_ALM (OC).

(3) When a load short-circuit occurs immediately after the I_c is flowing and if the I_c exceeds I_SC the peak current is suppressed momentarily. After the elapse of t_SC an alarm is generated and the IGBT is softly turned off.

(4) SC protection operation continues if the V_in is on-state even after the elapse of the t_ALM (OC). SC protection operation is stopped when a V_in signal becomes off-state. In addition, even if duration of the protection operation is much longer than the t_ALM (OC), alarm output is generated only once.

(5) When a load short-circuit occurs immediately after the I_c began to flow and the I_c peak is suppressed momentarily as soon as the I_c exceeds the I_SC. If the V_in becomes off-state before the elapse of the t_SC the SC protection operation is not activated and the IGBT is softly turned off normally.

(6) When a load short-circuit occurs immediately after the I_c began to flow, and the I_c peak is suppressed momentarily when the I_c exceeds the I_SC. If the V_in becomes off-state before the elapse of the t_SC, the SC protection operation is not activated and the IGBT is softly turned off normally.

*1: t_ALM (OC) is 2 ms, typical.
*2: t_SC is 2 μs, typical.
5.6 Chip temperature heating protection (TjOH): Case 1

(1) If chip junction temperature $T_j$ is higher than $T_{jOH}$ for a period exceeding 1 ms, an alarm is generated and the IGBT is softly turned off.

(2) Protection operation continues during the $t_{ALM}(TjOH)$ period even if the IGBT chip temperature $T_j$ drops below $T_{jOH}-T_{jH}$ before the elapse of the $t_{ALM}(TjOH)$ period. Normal operation resumes if the $V_{in}$ is off-state after the elapse of $t_{ALM}(TjOH)$ period.

(3) Protection operation continues if $V_{in}$ is on-state, even if the chip temperature $T_j$ drops lower than the $T_{jOH}-T_{jH}$ after the elapse of $t_{ALM}(TjOH)$ period.

(4) Protection operation continues after the elapse of the $t_{ALM}(TjOH)$ period if the chip temperature $T_j$ is higher than $T_{jOH}-T_{jH}$ even when $V_{in}$ is off-state. In addition, even if duration of the protection operation is much longer than the $t_{ALM}(TjOH)$, alarm output is generated only once.

*1: $t_{ALM}(TjOH)$ is 8 ms, typical.

*2: Dead time 1 ms is a typical value.
5.7 Chip temperature heating protection (TjOH): Case 2

(1) Protection operation is not activated if the Tj drops lower than the TjOH within 1 ms since Tj exceeds TjOH, regardless of whether the Vin is on or off.

(2) The TjOH detection timer of which duration is 1 ms is reset if Tj has been kept lower than the TjOH-TjH for longer than 2.5 µs after the Tj exceeds the TjOH.

*1: tALM (TjOH) is 8 ms, typical.
*2: Dead time 1 ms is a typical value.
5.8 Case where protective functions operated compositely

(1) When an IGBT junction temperature $T_j$ exceeds the $T_{JOH}$ for 1 ms continuously, an alarm is generated and the IGBT is softly turned off.

(2) If the $V_{CC}$ drops lower than the $V_{UV}$ before the elapse of the $t_{ALM (T_{JOH})}$ period, an alarm output of UV protection is cancelled because protected operation of the $T_{JOH}$ is continuing.

(3) Protection operation stops after the elapse of $t_{ALM (T_{JOH})}$ period if $V_{in}$ is off-state and chip temperature $T_j$ drops less than $T_{JOH-H}$.

(4) An alarm signal is generated and the IGBT is softly turned off if the IGBT chip temperature $T_j$ continuously exceeds of $T_{JOH}$ for 1 ms.

(5) Similar to the case (2), alarm output by $V_{UV}$ is stopped while protection operation of the $t_{ALM (T_{JOH})}$ is continued.
(6) Protected operation stops after the elapse of $t_{\text{ALM}} (T_{\text{JOH}})$ period if $V_{\text{in}}$ is off-state and the chip temperature $T_{j}$ drops lower than the $T_{\text{JOH}} - T_{jH}$. At this time $V_{CC}$ is kept lower than the $V_{\text{UV}}$ for 20 $\mu$s after the stop of protective functions by $T_{\text{JOH}}$, an alarm is generated by the $V_{\text{UV}}$ again and the UV protected operation is activated.

(7) Protected operation stops after the elapse of $t_{\text{ALM}} (UV)$ period if $V_{\text{in}}$ is off-state and $V_{CC}$ is higher than $V_{\text{UV}} + V_{H}$.

5.9 Multiple alarm outputs from lower arm by control power supply under voltage protection (UV) (excluding P629)

Each of three (or four for brake built-in type) IGBTs have independent control ICs, but the alarm outputs is a common output for lower arm control ICs. Therefore, there are some cases when several alarm outputs are generated because of distribution of protected operation level of the control ICs. If $dv/dt$ of $V_{\text{UV}}$ is less than 0.5 V/ms in the vicinity of $V_{CC}$, there is a possibility of alarm output such as shown in the figure right. (This is not an abnormal phenomenon.)

\[ V_{CC} < V_{UV} + V_{H} \]

\[ V_{UV} (IC_A) \]

\[ V_{UV} (IC_B) \]

\[ V_{UV} (IC_C) \]

\[ V_{UV} + V_{H} \]

*1: $t_{\text{ALM}} (UV)$ is 4 ms, typical.
## Chapter 4

### Typical application circuits

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<th>Page</th>
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</thead>
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<td>2 Important remarks</td>
<td>4-6</td>
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<td>3 Optocoupler peripheral circuits</td>
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<td>4 Connector</td>
<td>4-11</td>
</tr>
</tbody>
</table>
Chapter 4  Typical application circuits

## 1 Typical application circuits

Figure 4-1 shows typical application circuits of P629.

![Typical application circuits of P629](image)

**Figure 4-1  Typical application circuits of P629**
Figure 4-2 shows typical application circuits of P626.

(a) Where upper phase alarm is used  
(b) Where upper phase alarm is not used

Figure 4-2  Typical application circuits of P626
Figure 4.3 shows typical application circuits of P630, P631 and P636 with built-in brake type.

(a) Where upper phase alarm is used  
(b) Where upper phase alarm is not used

Figure 4-3  Typical application circuits of P630, P631 and P636 with brake circuit
Figure 4-4 shows typical application circuits of P630, P631 and P636 of no brake type.

(a) Where upper phase alarm is used

(b) Where upper phase alarm is not used

Figure 4-4 Typical application circuits of P630, P631 and P636 without brake circuit
2 Important remarks

2.1 Control power supply units

Four isolated power supply units; three for the upper arm and one for the lower arm are needed as shown in the application circuit examples. If a readymade power supply unit is used, do not connect the output GND terminals of the power supply unit. If the GND of the output side is connected to the + or − terminals, it may cause a failure of the system because each power supply unit is connected to the ground of input side of the power supply unit. Furthermore, reduce stray capacitance (floating capacitance) between the power supply units and the Earth ground as much as possible.

Furthermore, please use a power supply unit which has enough capability to supply Icc with low output power fluctuation.

2.2 Structural insulation between four power supply units (input portion connector and PCB)

The four power units and the main power supply unit have to be insulated from each other. A sufficient insulation air gap distance is required (2 mm or longer is recommended) because a high dv/dt is applied to the insulation distance during IGBT switching.

2.3 GND connection

Do not connect the control terminal GND U to the main terminals U, control terminal GND V to main terminals V, control terminal GND W to main terminal W, control terminal GND to main terminal N (N1 and N2 in case of P631). If these terminals are connected, it might cause a malfunction.

2.4 External capacitors for control power supply

Capacitors of 10 μF (47 μF) and 0.1 μF, which are connected to each power supply unit shown in typical application circuits are not used for smoothing the output voltage of the control power supply units but are used for reduction of the wiring impedance from the power supply unit to the IPM. Additional capacitors for smoothing the voltage are required.

Furthermore, these external capacitors should be connected to the IPM terminals or optocoupler terminals as short as possible because transient variation occurs by the wiring impedance between the capacitors and control circuits.

Also, an electrolytic capacitor which has a low impedance and good frequency characteristics is recommended. In addition, it is recommended to connect a film capacitor which has good frequency characteristics in parallel.
2.5 Alarm circuit

The alarm terminal has a 1.3 kΩ internal resistor in series, so that an optocoupler can be connected to the terminal directly without an external resistor. The wiring distance between the optocoupler and the IPM should be as short as possible. Also the pattern layout should be designed to minimize the floating capacitance between the primary side and the secondary side of the optocoupler. Because of the potential of the secondary side of the optocoupler it may fluctuate due to high dv/dt. It is recommended that a 10nF capacitor is connected to the output terminal of the secondary side of the optocoupler as shown in Figure 4-4.

Furthermore, if upper side alarm outputs are not used, please connect the alarm output terminal to Vcc as shown in Figure 4-4 (b).

2.6 Pull-up of signal input terminal

Connect the control signal input terminals to Vcc through a 20 kΩ pull-up resistor. Furthermore, unused input terminals also have to be pulled up through a 20 kΩ resistor. If these terminals are not pulled up, an under voltage protection is activated during the starting up so that no ON operation is possible.

2.7 Connection in case there is an unused phase

If there is an unused phase such as the case when a 6in1 IPM (no brake type) is used in single phase or a 7in1 IPM (brake built-in type) is used without using B-phase, please supply a control voltage to these unused phase and connect the input/alarm terminals of the phase to Vcc so that it will stabilize the potential of these terminals.

2.8 Handling of unconnected terminals (no contact terminals)

Unconnected terminals (no contact terminals) are not connected to the internal of the IPM. These terminals are insulated from other terminals. There is no need of special treatment such as potential stabilization.

Furthermore, guide pins should also not be connected to the internal of the IPM.

2.9 Snubbers

Connect snubber circuits between P and N terminals directly and as short as possible.

For P631 package which has two P/N terminals, it is effective for surge voltage reduction to connect snubber circuits to the P1-N1 and P2-N2 terminals. Do not connect snubber circuits across the two terminals such as P1-N2 and P2-N1 because it may cause a malfunction.

2.10 Grounding capacitor

Please connect about 4500 pF capacitors between each AC input line and Earth ground to prevent a noise from the AC input line to the system.
2.11 Input circuit of IPM

There is a constant current circuit in the input part of the IPM as shown in Figure 4-5 and constant current of \( I_{\text{in}} = 0.15 \, \text{mA} \) or \( I_{\text{in}} = 0.65 \, \text{mA} \) flows at that timing shown in Figure 4-5. The current of the secondary side of optocoupler is the sum of the constant current \( I_{\text{in}} \) and the current through a pull-up resistor \( R \). Therefore it is necessary to decide the current of primary side of optocoupler \( I_{\text{P}} \) so that enough current flows in the secondary side of optocoupler. If the \( I_{\text{P}} \) is insufficient, there is a possibility that a malfunction arises on the secondary side.

* The operation duration of constant current circuit (0.65 mA) is the length of time until \( V_{\text{in}} \) reaches \( V_{\text{CC}} \), and the maximum length about 5 \( \mu \text{s} \).

Figure 4-5  IPM input circuit and constant current operation timing
3 Optocoupler peripheral circuits

3.1 Control input Optocoupler

3.1.1 Optocoupler rating

Use an optocoupler that satisfies the characteristics indicated below:

- \( \text{CMH} = \text{CML} > 15 \text{ kV/μs} \) or \( 10 \text{ kV/μs} \)
- \( \text{tpHL} = \text{tpLH} < 0.8 \ \text{μs} \)
- \( \text{tpLH} - \text{tpHL} = -0.4 \) to \( 0.9 \ \text{μs} \)
- \( \text{CTR} > 15\% \)

Example: HCPL-4504 made by Avago Technologies
TLP759 (IGM) made by Toshiba

Pay attention to safety standards such as UL and VDE.

The reliability and characteristics of these optocouplers are not guaranteed by Fuji Electric.

3.1.2 Primary side limit resistance

The current limiting resistor on the primary side should be selected to have an ability to flow a sufficient current on the secondary side. Also, an age-related deterioration of CTR of the optocoupler should be considered in the design of the current limiting resistor.

3.1.3 Wiring between optocoupler and IPM

The wiring distance between the optocoupler and the IPM should be short as much as possible to reduce the impedance of the line. The primary line and secondary line of the optocoupler should be kept away from each other to reduce the floating capacitance. High \( \text{dv/dt} \) is applied between the primary side and the secondary side.
3.1.4 Optocoupler drive circuit

A noise current flows through the floating capacitance between the primary side and the secondary side of the optocoupler due to the high dv/dt that is generated inside or outside of the IPM. The dv/dt tolerance also varies by the optocoupler drive circuit. Good/bad examples of the optocoupler driving circuits are shown in Figures 4-6. As the optocoupler input is connected in low impedance in these good examples, malfunction caused by noise current hardly occurs. Please contact to the optocoupler manufacturer regarding details of the optocouplers.

Good example: Totem pole output IC
Current limit resistance on cathode side of photodiode

Bad example: Open collector

Good example: Diodes A and K are shorted between transistors C and E
(Case that is particularly strong against photocoupler off)

Bad example: Current limit resistance on anode side of photodiode

Figure 4-6 Optocoupler input circuits
3.2 Alarm output optocoupler

3.2.1 Optocoupler ratings
A general-purpose optocoupler can be used, but an optocoupler of the following characteristics is recommended:

- $100\% < \text{CTR} < 300\%$
- Single channel type

Example: TLP781-1-GR rank or TLP785-1-GR rank made by Toshiba
Pay attention to safety standards such as UL and VDE also.

The reliability and characteristics of the optocouplers indicated above are not guaranteed by Fuji Electric.

3.2.2 Input current limiting resistance
A current limiting resistor for the input side diode of optocoupler is built in the IPM. The resistance $R_{\text{ALM}} = 1.3 \, \text{k}\Omega$, and $I_F$ is about 10 mA when the optocoupler is connected to $V_{\text{CC}} = 15 \, \text{V}$. An external current limiting resistor is not required.

If large current $I_{\text{out}} > 10 \, \text{mA}$ is required for the optocoupler output side, it is necessary to increase the optocoupler's CTR value to achieve the required level.

3.2.3 Wiring between optocoupler and IPM
Note that high $dv/dt$ is applied to the optocoupler for alarm output, please take care as same as to Section 3.1.3.

4 Connector
Connectors that conform to the shape of control terminals of V-IPM are available on the market.
For P630: MA49-19S-2.54DSA and MA49-19S-2.54DSA (01) made by Hirose Electric
For P631: MDF7-25S-2.54DSA made by Hirose Electric

Furthermore, please contact the connector manufacturer for the details of reliability and use of these connectors.

Please note that the reliability and the characteristics of these connectors are not guaranteed by Fuji Electric.
Chapter 5

Cooling Design

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</table>
1 Guidelines for heat sink selection

- To safely operate the IGBT, it is necessary that the junction temperature $T_j$ should not exceed $T_{j\text{max}}$. Carry out thermal design having sufficient margins so that the junction temperature $T_j$ never exceeds the $T_{j\text{max}}$ also on occurrence of disorder such as overload.
- There is a risk of thermal breakdown, if the IGBT is operated at temperature above the $T_{j\text{max}}$. Although the $T_{j\text{OH}}$ protected function in the IPM activates when the junction temperature exceeds the $T_{j\text{max}}$, however, there is a possibility that the protection cannot work if the temperature rises rapidly. Also pay attention to the FWD so that the $T_{j\text{max}}$ should not be exceeded, same case for the IGBT.
- The heat sink temperature should be measured just below the center of the chip.

Please refer to the IPM specification sheet for the chip layout drawing.

In addition, please consider the following documents regarding to the design for your reference.

[IGBT Module Application Manual RH984b]

- How to calculate the occurred loss
- How to select a heat sink
- How to mount IPM to a heat sink
- Troubleshooting

2 Notice for heat sink selection

Although a guideline for heat sink selection is described in the IGBT Module Application Manual (RH984b), please pay attention to the following recommendations as well.

2.1 Flatness of the heat sink surface

It is recommended that flatness of the heat sink surface is less than 50 $\mu$m per 100 mm between screw mounting points and the surface roughness is less than 10 $\mu$m.

If the heat sink surface is concave or convex, the contact thermal resistance ($R_{\text{th}(c-f)}$) will be increased.

[Reason]

- Concave: A gap appears between the heat sink surface and the bottom of the IPM, and the heat transfer performance becomes worse (contact thermal resistance $R_{\text{th}(c-f)}$ increases).
- Convex (larger than +50 $\mu$m): The copper base of the IPM is deformed and there is a possibility of a generation of cracks on the internal insulated board by the mechanical stress.

![Figure 5-1  Flatness of heat sink surface](image)
3 Mounting instruction of the IPM

3.1 Layout of IPMs on a heat sink

The thermal resistance varies depending on the IPM mounting position. Please note the following matters:

- When an IPM is mounted to a heat sink, it is recommended to place the IPM on the center of the heat sink to maximize the usage of the heat sink.
- When multiple IPMs are mounted to a single heat sink, the IPMs location and layout should be designed with their generated losses. Allocate the largest area to the IPM which generates largest loss.

3.2 Application of thermal grease

To reduce the contact thermal resistance, apply thermal grease between the IPM and heat sink mounting surface.

Use of a stencil mask and use of a roller are available in general as methods for application of thermal grease.

The purpose of the thermal grease is to promote heat transmission to the heat sink, but the grease has a limited thermal capacity. If the thickness of thermal grease is larger than the appropriate thickness, the grease layer prevents the heat transfer from the IPM to the heat sink and the junction temperature will be increased. On the other hand, if the thermal grease thickness is less than the appropriate thickness, such as a void area, a gap or space may be caused between the heat sink and the IPM. This may cause an increase of the contact thermal resistance. Therefore thermal grease should be applied in appropriate thickness.

If the thermal grease thickness is inadequate, the thermal dissipation of heat becomes worse, and there is a possibility of breakdown in the worst case due to the excess of the junction temperature $T_{j\text{max}}$.

Application of thermal grease using a stencil mask is recommended so that uniform thickness can be achieved.

Figure 5-2 shows an example of a thermal grease application using a stencil mask. The basis of this method is applying specified weight of thermal grease to the metallic base of the IPM using a stencil mask. It is possible to achieve a uniform thickness of thermal grease by mounting the IPM with thermal grease to the heat sink and tightening screws with recommended torque for each product. Fuji Electric can provide recommended stencil mask designs upon request of customers.
Figure 5-2  Outline of a thermal grease application method
The required thermal grease weight is given by the following equation by assuming uniform thermal grease thickness:

\[
\text{Thermal grease weight (g)} \times 10^{-4} = \text{Thermal grease thickness (μm)} \times \text{IPM base area (cm}^2) \times \text{Thermal grease density (g/cm}^3)\]

Calculate the thermal grease weight that corresponds to the required thermal grease thickness from this equation, and apply the thermal grease. The recommended thermal grease thickness after spreading of thermal grease is 100 μm. Also please note that the optimum thermal grease thickness varies by the characteristics of the used thermal grease and application method.

Table 5-1 shows the footprint area of IPMs.

<table>
<thead>
<tr>
<th>Package</th>
<th>Back side base area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P629</td>
<td>21.71</td>
</tr>
<tr>
<td>P626</td>
<td>22.77</td>
</tr>
<tr>
<td>P630</td>
<td>55.67</td>
</tr>
<tr>
<td>P631</td>
<td>141.24</td>
</tr>
<tr>
<td>P636</td>
<td>41.17</td>
</tr>
</tbody>
</table>

Table 5-2 Shows recommended thermal greases (typical)

<table>
<thead>
<tr>
<th>Type</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>G746</td>
<td>Shin-Etsu Chemical Co., Ltd.</td>
</tr>
<tr>
<td>TG221</td>
<td>Nippon Data Material Co., Ltd.</td>
</tr>
<tr>
<td>SC102</td>
<td>Dow Corning Toray Co., Ltd.</td>
</tr>
<tr>
<td>YG6260</td>
<td>Momentive Performance Materials Inc.</td>
</tr>
<tr>
<td>P12</td>
<td>Wacker Chemie</td>
</tr>
<tr>
<td>HTC</td>
<td>ELECTROLUBE</td>
</tr>
</tbody>
</table>

The list of thermal greases shown above is based on the information at the time of issuance of this Application Manual. Please contact these manufacturers for details of these thermal greases.
3.4 Screw tightening

Figure 5-3 shows screw-tightening procedures for mounting an IPM to a heat sink. It is recommended to tighten all screws with specified tightening torque.

The specified tightening torque is described in the specification. If the screw tightening torque is insufficient, there is a possibility of increasing the contact thermal resistance or loosing screws during operation. If the tightening torque is excessive, on the other hand, the case would be damaged.

<table>
<thead>
<tr>
<th>Torque</th>
<th>Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st time (initial tightening)</td>
<td>1/3 of specified torque</td>
</tr>
<tr>
<td>2nd time (permanent tightening)</td>
<td>100% of specified torque</td>
</tr>
</tbody>
</table>

(1) Case of IPM of 2-point mounting type

<table>
<thead>
<tr>
<th>Torque</th>
<th>Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st time (initial tightening)</td>
<td>1/3 of specified torque</td>
</tr>
<tr>
<td>2nd time (permanent tightening)</td>
<td>100% of specified torque</td>
</tr>
</tbody>
</table>

(2) Case of IPM of 4-point mounting type

Figure 5-3  IPM mounting method
3.5 IPM mounting direction

When an IPM is mounted on an extruded heat sink, it is recommended that the IPM is mounted in parallel to the extrusion direction as shown in Figure 5-3. This purpose is to reduce the influence of heat sink deformation.

3.6 Verification of chip temperature

After selecting a heat sink and IPM mounting position is decided, measure the temperature at various points on case (Tc), heat sink (Tf) and junction temperature (Tj).

Figure 5-4 shows an example of measuring method for an accurate measurement of case temperature (Tc). Please measure the case temperature just below the chip center. The chip location is described in the specification.

Please verify that the chip junction temperature does not exceed Tjmax and the thermal design meets required life time of the system.

 ![Figure 5-4 Measuring the case temperature](image-url)
– Chapter 6 –

Precautions for use

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<td>4 Power Cycling Capability</td>
<td>6-5</td>
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<tr>
<td>5 Others</td>
<td>6-6</td>
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</tbody>
</table>
1 Main power supply

1.1 Voltage range

- The collector and emitter terminal voltage (=\(V_{\text{CES}}\)) should never exceed the absolute maximum rated voltage (600 V-series = 600 V, 1200 V-series = 1200 V).
- In order to keep the maximum surge voltage between all terminals within the rated voltage during the switching, connect the IPM and other components as short as possible to each other and connect a snubber capacitor between P and N terminals.

Between all terminals means as follows:

- P629, P626, P630 (6in1), P636 (6in1): \([P-(U, V, W), (U, V, W)-N]\)
- P630 (7in1), P636 (7in1): \([P-(U, V, W, B), (U, V, W, B)-N]\)
- In case of P631, connect the dc bus power supply between the P1 and N1 or between the P2 and N2. Don’t connect cross-multiply connections such as between the P1 and N2 and between the P2 and N1. It might cause a false operation. It is effective to connect snubber capacitors to both terminals between the P1/N1 and between the P2 / N2 terminals to suppress the surge voltage.

1.2 Noise protection

- The V-IPM series has a tolerance against exogenous noise. However, there is a possibility of false operation or breakdown of the V-IPM by exogenous noise depending on the kind and intensity of the noise. It is recommended to implement other protections against the noise applied to the IPM.

1.2.1 Protection against external noise

- Take countermeasures such as installing a noise filter along the AC line and strengthening of insulating grounding.
- Add a capacitor of <100 pF between signal input line and signal GND of every phase, as necessary.
- When the excessive noise voltage increases on the alarm terminal, it may become a false output of the alarm signal. Please connect 0.2 kΩ to 1 kΩ resistor in series to the alarm terminal as needed. Please choose a most suitable resistance level in consideration of CTR of the optocoupler on this occasion.
- Connect a grounding capacitor of about 4700 pF between each line of 3 phases of AC input and ground, for preventing entry of noise through the AC line.
- Insert an arrester against lightning surge.

1.2.2 Protection against the internal noise from the IPM

- Outside of rectifier: Apply the same countermeasures as Section 1.2.1.
- Inside of rectifier: Add snubber capacitors or similar circuit to the P/N line. (Particularly in case multiple inverters are connected to one rectifying converter)
1.2.3 Protection against the noise from output terminals
- Apply countermeasures outside of the module to block contactor switching surge or others from entering the device.

2 Control power supply

2.1 Voltage range
- The control power supply voltage range including ripple should not exceed the spec value.

<table>
<thead>
<tr>
<th>Control power supply voltage (Vcc) (V)</th>
<th>IPM operation</th>
<th>Control power supply under voltage protection (UV)</th>
<th>IPM input signal voltage</th>
<th>IGBT operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 &lt; Vcc ≤ 12.5</td>
<td>Control IC does not work correctly and the gate signal output is unstable. However, the IGBT does not turn on if the Vcc applied to the IGBT directly because VCC is lower than gate threshold voltage Vth. The UV protection does not work and no alarm output.</td>
<td>-</td>
<td>Hi</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lo</td>
</tr>
<tr>
<td>5.0 &lt; Vcc ≤ 11.0</td>
<td>Control IC is working normally and IGBT is kept OFF state because UV protection is activated. UV alarm output is generated.</td>
<td>Activated</td>
<td>Hi</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lo</td>
</tr>
<tr>
<td>11.0 &lt; Vcc ≤ 12.5</td>
<td>(1) When UV protection is activated: IGBT is kept OFF state and alarm signal output is generated. (2) When UV protection is not activated: The IGBT status follows the input signal, no alarm output is generated.</td>
<td>(1) Activated</td>
<td>Hi</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2) Cancelled or before action</td>
<td></td>
<td>Hi</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lo</td>
</tr>
<tr>
<td>12.5 &lt; Vcc &lt; 13.5</td>
<td>UV protection is not activated. The IGBT switching follows the input signal, but the losses would be increased and the emission noise relatively small. The protection function does not work sufficiently and the IGBT might be damaged because protection characteristics are shifted.</td>
<td>Cancelled</td>
<td>Hi</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lo</td>
</tr>
<tr>
<td>13.5 &lt; Vcc ≤ 16.5</td>
<td>Recommended voltage range. Drive circuit works stably. The IGBT switching follows input signal.</td>
<td>Cancelled</td>
<td>Hi</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lo</td>
</tr>
<tr>
<td>16.5 &lt; Vcc ≤ 20</td>
<td>The switching losses are decreased but emission noise tend to be increased. The protection function does not work sufficiently and the IGBT might be damaged because protection characteristics are shifted.</td>
<td>Cancelled</td>
<td>Hi</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lo</td>
</tr>
<tr>
<td>Vcc &lt; 0, Vcc &gt; 20</td>
<td>If the Vcc is &lt;0V or &gt;20V, the drive circuit and main chip may be damaged. Never apply such voltage to the device.</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

2.2 Voltage ripple
- A voltage range of Vcc is 13.5 to 16.5 V that includes voltage ripple is recommended. The control power supply should be designed to guarantee sufficient low voltage ripple. Also, the noise on the power supply voltage should be as low as possible.
- If the control power supply voltage exceeds the recommended voltage range, there is a possibility of a malfunction or breakdown of the IPM.
- Design the control power supply so that dv/dt will not exceed 5 V/μs.
Additionally, it is recommended that variation of the power supply voltage does not exceed ±10%.

2.3 **Power supply startup/shutdown sequence**

- Make sure that the main power supply voltage Vcc is within the recommended voltage range, before applying this voltage to the main power supply terminals (P-N terminal).

- Shutdown the voltage supply (Vcc) and disconnect the P-N terminals of the IPM then.

  If VCC is applied to the P-N terminals before the voltage reaches the recommended voltage range there may happen a malfunction due to exogenous noise and the chip might be damaged. Same case occurs if low voltage of VCC remains before disconnecting P-N terminals.

2.4 **Alarm output during startup/shutdown of power supply**

- An alarm signal (typ = 4 ms) is generated when the power supply voltage is lower than UV protection level during startup of the power supply.

  The alarm signal is stopped after typ = 4 ms but the input signal is ignored unless the root cause of the protection is settled. An input signal is accepted when all the protection operation functions are not activated (dissolving of protection factor, elapse of tALM and input signal OFF). The drive control circuit should be designed to output gate signals after the period of alarm signal output.

- Also note that an alarm signal is generated during VCC shutdown.

- See Chapter 3, section 5 [Timing chart] for considering the timing chart.

2.5 **Notes for the design of control circuit**

- The control circuit should be well-designed to have enough capability to provide a specified consumption current (Icc).

- Minimize the length of the wiring between the optocoupler and the IPM as well as the pattern layout should be designed to minimize the floating capacitance between the primary side and the secondary side of the optocoupler.

- Add a capacitor between Vcc and GND for high-speed optocouplers.

- Use a high-speed optocoupler of tpHL, tpLH ≤ 0.8 µs and of high CMR type for the control signal input circuit.

- Use a low-speed optocoupler of CTR ≥ 100% for the alarm output circuit.

- The four power supply units for the power supply control Vcc have to be isolated. Also, it is recommended to connect a capacitor which has a good frequency response characteristic on the output terminal of each power supply unit to suppress transient voltage variation.

- Note that if a capacitor is connected between an input terminal and GND, the response time of the optocoupler becomes slow.

- The optocoupler primary side current IF should have enough capability in consideration of CTR of the used optocoupler. To reduce the influence of noise, the pull-up resistance on the optocoupler secondary
side should be small.

As described in Chapter 4 [Typical application circuits], it is necessary to design the IF on the optocoupler primary side so that the constant current through the pull-up resistance IR can flow to the secondary side. If the IF is insufficient, there is a possibility of a malfunction on the secondary side circuit. Also, the resistance of current limiting resistor on the primary side of the optocoupler should be designed in consideration of a lifetime of the optocoupler.

3 Protective functions

- An alarm output function varies depending on the package. Check protective functions of your IPM by referring to Chapter 3.1 [List of functions].

3.1 Protected operation in general

3.1.1 Range of protection

- The protective functions of the IPM deal with non-repeated abnormal phenomena. Avoid a situation of repetitive occurrence of abnormal phenomena.
- Overcurrent and short-circuit protections are guaranteed under the condition of control power supply voltage 13.5 to 16.5 V and main power supply voltage 200 to 400 V (600 V-series) or 400 to 800 V (1200 V-series).

3.1.2 Action on occurrence of alarm output

- When an alarm signal is generated the input signal to the IPM stops and shutdown the system immediately.
- The IPM protective functions protect the IPM against abnormal phenomena but they are not able to eliminate the causes. Please dissolve the abnormal phenomena by finding the root cause and then restart the system.
- When an abnormal phenomenon is detected in the upper arm, the IGBT of the detected phase is only turned off and an alarm output is generated from the same phase (excluding P629). Switching of other phases is permitted at this time. On the other hand, when an abnormal phenomenon is detected in the lower arm all the IGBTs of the lower arm (+ brake unit) is turned off regardless of the phase and an alarm is generated from the lower arm. Switching of all phases of the upper arm is permitted at this time.

3.2 Precautions for protected operation

3.2.1 Overcurrent (OC)

- When overcurrent continues longer than 5 µs (tdoc), it is judged as being in the OC condition and the IGBT is turned off softly. An alarm output signal is generated.

If current descend below the trip level within the tdoc period the OC protection is not activated and the
IGBT is turned-off normally (hard turn-off).

- P629 does not have an alarm output on the upper side arms but the OC protection does work and the IGBT is turned off softly.

### 3.2.2 Short-circuit (SC)

- When short-circuit current continues longer than 2 µs (tdsc) it is judged as being in the SC condition and the IGBT is turned off softly. An alarm signal output is generated.
  
  If short-circuit current descends below the trip level within the tdsc period, the SC protection does not work and soft turn-off is not applied to the IGBT.

- P629 does not have an alarm output on the upper arms but the SC protection does work and soft turn-off is applied to the IGBT.

### 3.2.3 Ground short circuit

- When ground-fault current flows to the IGBT of the lower arm longer than the dead time tdoc or tdsc the OC (SC) protection is activated and an alarm signal is generated.

- When the ground-fault current flows to the IGBT of the upper arm longer than tdoc or tdsc the OC (SC) protection is activated but the alarm signal output varies by the package.
  
  P629: The upper arm is protected by the OC (SC) function without alarm output.

  P626, P630, P631, P636: The upper arm is protected by the OC (SC) function and an alarm signal is generated.

### 3.2.4 Booting under short-circuit or ground-fault status

- Because the OC or SC protection involves a dead time (tdoc or tdsc), the protected operation is not activated when the input signal pulse width is shorter than the dead time. Especially when the IPM is booted under the load short-circuit condition the input signal pulse width is shorter than the dead time for a long time (tens of milliseconds). The chip temperature rapidly increases because the protection function doesn’t work. In this case, even though the chip over heat protection (TjOH) works against the increase of the chip temperature, the response time of TjOH is about 1ms. Therefore, there is a possibility of damaging the chip by over temperature since the protection is not on time.

### 3.3 Chip overheat protection

- Chip overheat protection (TjOH) is built in every IGBT including brake unit. The TjOH interacts when a chip is abnormally heated up. Since the V-IPM does not have a case overheat protection, TjOH protection does not activate when Tj is lower than the trip level even if Tc reveals an abnormal temperature. Please implement another protection for Tc overheating as required.

### 3.4 Protection of FWD

- FWDs don’t have protective functions (overcurrent, overheat protection).
4 Power Cycling Capability

- The lifetime of semiconductor products is not unlimited. Note that thermal fatigue caused by temperature rise/drop due to self-heating restricts the lifetime. If temperature rise and drop occur continuously, the reduction of the temperature variation amplitude is mandatory.

  1. **$\Delta T_j$ power cycle capability**: lifetime determined by junction temperature ($T_j$) change that arises in a relatively short period and consequently a deterioration of wire connection on the chip surface is possible.
     Please refer to MT5Z02525 (P629, P626, P630, P631, P636) for the $\Delta T_j$ power cycling capability curves.

  2. **$\Delta T_c$ power cycle capability**: lifetime determined by copper base plate temperature ($T_c$) change that arises in a relatively long period and consequently a deterioration of solder layer between the DCB and copper base can occur, which is the main cause of the lifetime reduction.
     Please refer to MT5Z02509 (P629, P626, P630) and MT5Z02569 (P630 low thermal resistance version, P631, P636) for $\Delta T_c$ power cycling capability curves.

- Please refer to chapter 11 [Reliability of power modules] of Fuji IGBT Module Application Manual (RH984b) in addition.

5 Others

5.1 Precautions for use and mounting procedure

  1. Please refer to the IPM specification in addition to this manual for usage and mounting procedure of the IPM.

  2. Please install a fuse or circuit breaker of an adequate capacity between the input AC power line and the system for stopping the spreading of damage when the IPM is failed.

  3. Designing a turn-off operation of the IGBT chip, please confirm that the turn-off current-voltage operation track does not exceed the RBSOA specification.

  4. Please understand the product usage environment and check if the reliability of the IPM satisfies the demand, before using the product. If the IPM is used beyond the spec, there is a possibility of failure before the designed lifetime of the system.

  5. Please reduce the contact thermal resistance as much as possible between the IPM and the heat sink by applying thermal compound. (See Chapter 5, Section 3.)

  6. Please use appropriate length of screws. The package may be damaged if the screw length is longer than the screw hole depth. (See Chapter 1, Section 6.)

  7. Tightening torque and heat sink flatness should be within the range of specified values.
Wrong handling may cause an insulation breakdown. (See Chapter 5, Section 2.)

8. Do not apply excessive weight to the IPM.
   Don’t apply deforming forces to the lid. If pushing force was applied to the lid, the internal circuit might be damaged. If pull force was applied, the lid might get off. Don’t bend the control terminals.
   Pay attention not to bend control terminals.

9. Do not apply reflow soldering to the main terminals or control terminals. In addition, be careful so that heat, flux and cleaners for other products do not affect the IPM.

10. Avoid a place where corrosive gases are generated and locations of excessive dust.
11. Avoid any applied static electricity to main terminals and control terminals of the IPM.
12. Please confirm that the Vcc is 0V before mounting/dismounting of control circuits to/from the IPM.
13. Do not make the following connections outside of the IPM:
   - Control terminal GNDU and Main terminal U
   - Control terminal GNDV and Main terminal V
   - Control terminal GNDW and Main terminal W
   - Control terminal GND and Main terminal N (N1, N2 in case of P631)
   Malfunction may cause if these terminals are connected.
14. If there is an unused phase or built-in brake circuit the control power supply voltage should be applied to these unused phases and pull-up both of input terminal voltage (VIN). Connect the alarm output terminal (ALM) to the Vcc line. Otherwise the IPM generates an alarm output if the control power supply voltage is applied to the IPM.
15. Please pull-up alarm terminal to control power supply Vcc if the alarm is not used.
16. Regarding the alarm factor identification function, the alarm signal pulse width shown in this manual or specification indicates the output width from the IPM. The time delays of optocouplers and other circuits should be considered when using the alarm output functions.
17. The IPMs are not allowed to use in parallel. Each individual IPM has its own drive circuits and protection circuits. If multiple IPMs are operated in parallel, there is a possibility of current imbalance and current constriction due to the difference of switching speed and protection timing.
18. The case and epoxy resin is not a non-flammable material even though the materials meet the standard UL 94V-0. Also, the surface temperature of the lid shouldn't exceed glass-transition temperature during soldering. At a certain temperature the terminals deform, melt or solder material remains on the case material of the package.
## Chapter 7 – Troubleshooting

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</table>
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 Tree Analysis Chart](image)

Figure 7-1 (a) IPM failure tree analysis chart

(Codes A to F are linked with those indicated in separate FTA pages.)
Chapter 7  Troubleshooting

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

- Increased steady-state loss
- Increased saturation voltage VCE (sat)
- Insufficient control power supply voltage
- Gate drive circuit disorder
- Control power supply circuit disorder
- Control PCB disorder
- Insufficient dead time
- Control PCB disorder
- Increased carrier frequency
- Input signal malfunction (oscillation)
- Control PCB disorder
- Increased turn-on loss
- Increased turn-on time
- Insufficient control power supply voltage
- Control PCB disorder
- Increased turn-off loss
- Increased surge voltage
- Excessive turn-off current
- Insufficient thermal compound weight
- Insufficient compound weight adjustment
- Insufficient tightening torque
- Insufficient tightening force
- Faulty fin warpage
- Insufficient contact thermal resistance
- Excessive fin warpage
- Clogged heat sink
- Insufficient cooling capacity
- Dropped cooling capacity
- Dropped or stopped cooling fan revolution
- Abnormal rise of ambient temperature
- Stack local overheating
- Cooling fan disorder
- Cooling system disorder
- Stack local overheating
- Faulty anti-shot measures
- Faulty anti-shot measures
- Ground short circuit (repeated short-circuit current)
- Increased carrier frequency
- Input signal malfunction
- Insufficient dead time
- Control PCB disorder
- Control PCB disorder
- Increased carrier frequency
- Increased turn-on loss
- Increased turn-on time
- Insufficient control power supply voltage
- Control PCB disorder
- Increased turn-off loss
- Increased surge voltage
- Excessive turn-off current
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- Insufficient compound weight adjustment
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- Insufficient compound weight adjustment
- Insufficient tightening torque
- Insufficient tightening force
- Faulty fin warpage
- Insufficient contact thermal resistance
- Excessive fin warpage
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- Stack local overheating
- Cooling fan disorder
- Cooling system disorder
- Stack local overheating
- Faulty anti-shot measures
- Faulty anti-shot measures
- Ground short circuit (repeated short-circuit current)
- Increased carrier frequency
- Input signal malfunction
- Insufficient dead time
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- Control PCB disorder
- Increased carrier frequency
- Increased turn-on loss
- Increased turn-on time
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- Insufficient compound weight adjustment
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- Excessive fin warpage
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- Increased carrier frequency
- Input signal malfunction
- Insufficient dead time
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- Control PCB disorder
- Increased carrier frequency
- Increased turn-on loss
- Increased turn-on time
- Insufficient control power supply voltage
- Control PCB disorder
- Increased turn-off loss
- Increased surge voltage
- Excessive turn-off current
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- Insufficient compound weight adjustment
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- Insufficient tightening force
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- Insufficient contact thermal resistance
- Excessive fin warpage
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- Dropped cooling capacity
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- Cooling system disorder
- Stack local overheating
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- Faulty anti-shot measures
- Ground short circuit (repeated short-circuit current)
- Increased carrier frequency
- Input signal malfunction
- Insufficient dead time
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- Control PCB disorder
- Increased carrier frequency
- Increased turn-on loss
- Increased turn-on time
- Insufficient control power supply voltage
- Control PCB disorder
- Increased turn-off loss
- Increased surge voltage
- Excessive turn-off current
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- Insufficient compound weight adjustment
- Insufficient tightening torque
- Insufficient tightening force
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- Stack local overheating
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- Faulty anti-shot measures
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- Increased carrier frequency
- Input signal malfunction
- Insufficient dead time
- Control PCB disorder
- Control PCB disorder
- Increased carrier frequency
- Increased turn-on loss
- Increased turn-on time
- Insufficient control power supply voltage
- Control PCB disorder
- Increased turn-off loss
- Increased surge voltage
- Excessive turn-off current
- Insufficient thermal compound weight
- Insufficient compound weight adjustment
- Insufficient tightening torque
- Insufficient tightening force
- Faulty fin warpage
- Insufficient contact thermal resistance
- Excessive fin warpage
- Clogged heat sink
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- Insufficient dead time
- Control PCB disorder
- Control PCB disorder
- Increased carrier frequency
- Increased turn-on loss
- Increased turn-on time
- Insufficient control power supply voltage
- Control PCB disorder
- Increased turn-off loss
- Increased surge voltage
- Excessive turn-off current
- Insufficient thermal compound weight
- Insufficient compound weight adjustment
- Insufficient tightening torque
- Insufficient tightening force
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Figure 7-1 (e)  Mode D: FWD breakdown

- Excessive junction temperature rise
- Increased steady-state loss
  - Overload
  - [Estimated point of disorder]
    - Dropped power factor
    - Load disorder
    - Control PCB disorder

- Increased switching loss
  - Increased switching count
  - Input signal malfunction
  - Control PCB disorder
  - Insufficient carrier frequency
  - Control PCB disorder

- Increased contact thermal resistance
  - Insufficient element tightening force
    - Faulty fin warpage
    - Insufficient compound weight
      - Faulty anti-dust measures
      - Insufficient compound weight adjustment

- Case temperature rise
  - Dropped cooling capacity
    - Clogged heat sink
    - Cooling fan disorder
    - Cooling system disorder
    - Snubber circuit disorder
  - Abnormal rise of ambient temperature
    - Stack local overheating
    - Control power supply circuit disorder
  - Overvoltage
    - Increased dV/dt at the time of turn-on
      - Increased control power supply voltage
      - Control power supply circuit disorder
    - Minor pulse reverse recovery phenomenon
      - Gate signal cracking caused by noise or similar
      - Control PCB disorder
    - Excessive surge voltage at the time of IGBT turn-off
      - Charging circuit disorder
    - Excessive surge voltage at the time of reverse recovery

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Control circuit breakdown

- Overvoltage
- Excessive control power supply voltage
  - Spike voltage
  - [Estimated point of disorder]
    - Control power supply circuit disorder
    - Power supply instability
    - Capacitor disorder
    - Excessive control power supply voltage
    - Excessive power supply wiring length
    - ON/OFF of control voltage impression
    - External noise

- Excessive minus voltage
  - Capacitor disorder
  - External noise

- Excessive input unit voltage
  - Control circuit disorder

- Excessive static electricity
  - Insufficient static electricity measures

Figure 7-1 (f)  Mode E: Control circuit breakdown
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#### Breakdown related to reliability and product handling

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- **Excessive tightening torque**
- **Insufficient main terminal tightening torque**
- **Vibration**
  - Excessive vibration during transportation (products, devices)
- **Impact**
  - Falling, impact, etc. during transportation
- **Heat resistance of soldered terminals**
  - Excessive heating during terminal soldering
- **Storage in inferior environment**
  - Storage in corrosive gas atmosphere
  - Storage in condensable environment
  - Storage in dusty environment

**Reliability (service life) breakdown**

- Storage in high temperature conditions
  - Long-term storage in high temperature conditions
  - Long-term storage in high temperature and high humidity conditions
  - Long-term storage in high temperature and high humidity and high temperature conditions

**Conditions for storage**

**Matching of applied conditions with product service life**

- **Thermal stress fatigue generated by repeating of gradual up-down of product temperature (temperature cycle, \( \Delta T_c \) power cycle)**
  - Thermal stress breakdown generated by rapid rise or fall of product temperature (thermal impact)

**Conditions for transportation**

- **Storage in low temperature conditions**
  - Long-term storage in low temperature conditions
- **Storage in high temperature and high humidity conditions**
  - Long-term storage in high temperature and high humidity conditions
- **Excessive contact resistance**

**Conditions for transportation**

- **Incorrect fixing of components at the time of product mounting**
- **Main terminal screw tightening**

**Conditions for assembly during product mounting**

- **Excessive loading during product storage**
- **Excessive stress applied to terminals and case at the time of IPM mounting**
- **Excessive stress applied to terminals and case at the time of IPM dismounting**
- **Excessive screw length used for main terminals**

**Conditions for transportation**

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

**Conditions for transportation**

- **Excessive tightening torque**
- **Insufficient main terminal tightening torque**
- **Vibration**
  - Excessive vibration during transportation (products, devices)
- **Impact**
  - Falling, impact, etc. during transportation
- **Heat resistance of soldered terminals**
  - Excessive heating during terminal soldering
- **Storage in inferior environment**
  - Storage in corrosive gas atmosphere
  - Storage in condensable environment
  - Storage in dusty environment

**Conditions for transportation**

- **Excessive loading during product storage**
- **Excessive stress applied to terminals and case at the time of IPM mounting**
- **Excessive stress applied to terminals and case at the time of IPM dismounting**
- **Excessive screw length used for main terminals**

**Conditions for transportation**

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

**Conditions for transportation**

- **Excessive tightening torque**
- **Insufficient main terminal tightening torque**
- **Vibration**
  - Excessive vibration during transportation (products, devices)
- **Impact**
  - Falling, impact, etc. during transportation
- **Heat resistance of soldered terminals**
  - Excessive heating during terminal soldering
- **Storage in inferior environment**
  - Storage in corrosive gas atmosphere
  - Storage in condensable environment
  - Storage in dusty environment

**Conditions for transportation**

- **Excessive loading during product storage**
- **Excessive stress applied to terminals and case at the time of IPM mounting**
- **Excessive stress applied to terminals and case at the time of IPM dismounting**
- **Excessive screw length used for main terminals**

**Conditions for transportation**

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