flow PIM 0B + PFC

Features
- Converter, PFC, inverter in one housing
- New high speed IGBT for PFC
- One screw heatsink mounting

Target applications
- Embedded drives

Types
- 10-OB06PPA004RC-L022A09

Maximum Ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>Collector-emitter break down voltage</td>
<td>$V_{CES}$</td>
<td></td>
<td>600</td>
<td>V</td>
</tr>
<tr>
<td>DC collector current</td>
<td>$I_C$</td>
<td>$T=\max$</td>
<td>8</td>
<td>A</td>
</tr>
<tr>
<td>Pulsed collector current</td>
<td>$I_{Pulse}$</td>
<td>$T_p$ $\leq T_{\max}$</td>
<td>12</td>
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</tr>
<tr>
<td>Turn off safe operating area</td>
<td>$I_T$</td>
<td>$\leq 150^\circ$C, $V_{CE}=900V$</td>
<td>0</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>$P_{M}$</td>
<td>$T=\max$</td>
<td>37</td>
<td>W</td>
</tr>
<tr>
<td>Gate-emitter peak voltage</td>
<td>$V_{GE}$</td>
<td></td>
<td>±20</td>
<td>V</td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>$t_{SC}$, $V_{CC}$</td>
<td>$T=150^\circ$C, $V_{GE}=15V$</td>
<td>5, 400</td>
<td>μs, V</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{\max}$</td>
<td></td>
<td>175</td>
<td>°C</td>
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07 Feb. 2017 / Revision 4
### PFC Switch Protection Diode

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Peak Repetitive Reverse Voltage</td>
<td>$V_{fsm}$</td>
<td></td>
<td>650</td>
<td>V</td>
</tr>
<tr>
<td>DC forward current</td>
<td>$I_{f}$</td>
<td>$T_J= T_{max}$, $T_i=85^\circ C$</td>
<td>12</td>
<td>A</td>
</tr>
<tr>
<td>Repetitive peak forward current</td>
<td>$I_{f RMS}$</td>
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<td>12</td>
<td>A</td>
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<tr>
<td>Non-repetitive peak surge current</td>
<td>$I_{f RMS}$</td>
<td>60Hz Single Half Sine Wave</td>
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<td>A</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>$P_{f}$</td>
<td>$T_J= T_{max}$, $T_i=85^\circ C$</td>
<td>32</td>
<td>W</td>
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<td>Maximum Junction Temperature</td>
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### Rectifier Diode

<table>
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<tr>
<td>Peak Repetitive Reverse Voltage</td>
<td>$V_{fsm}$</td>
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<td>1600</td>
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<td>DC forward current</td>
<td>$I_{f AV}$</td>
<td>$T_J= T_{max}$, $T_i=85^\circ C$</td>
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<tr>
<td>Non-repetitive peak surge current</td>
<td>$I_{f RMS}$</td>
<td>60Hz Single Half Sine Wave</td>
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<td>A</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>$P_{f}$</td>
<td>$T_J= T_{max}$, $T_i=85^\circ C$</td>
<td>34</td>
<td>W</td>
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<td>Maximum Junction Temperature</td>
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<td>$T_{max}$</td>
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<td>°C</td>
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## Characteristic Values

### Inverter Switch

<table>
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<tr>
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<th>Symbol</th>
<th>Conditions</th>
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<tbody>
<tr>
<td><strong>Static</strong></td>
<td></td>
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<td></td>
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<tr>
<td>Gate-emitter threshold voltage</td>
<td>$V_{GE(th)}$</td>
<td>$V_{ce}=V_{ce}$</td>
<td>0.090075</td>
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<tr>
<td></td>
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<td>25</td>
<td>4.4</td>
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<td>125</td>
<td>5</td>
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<tr>
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<td></td>
<td>150</td>
<td>5.6</td>
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<tr>
<td>Collector-emitter saturation voltage</td>
<td>$V_{CE(sat)}$</td>
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<td>15</td>
<td>2.02</td>
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<tr>
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<td>25</td>
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<td>2.20</td>
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<tr>
<td>Collector-emitter cut-off</td>
<td>$I_{ZS}$</td>
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<tr>
<td></td>
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<tr>
<td>Gate-emitter leakage current</td>
<td>$I_{ZSS}$</td>
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<tr>
<td>Integrated Gate resistor</td>
<td>$R_{Gate}$</td>
<td>none</td>
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<tr>
<td>Input capacitance</td>
<td>$C_{in}$</td>
<td>f=1 MHz</td>
<td>0</td>
<td>18</td>
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<tr>
<td>Output capacitance</td>
<td>$C_{oss}$</td>
<td>f=1 MHz</td>
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<td>16</td>
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<tr>
<td>Reverse transfer capacitance</td>
<td>$C_{Refr}$</td>
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<tr>
<td>Gate charge</td>
<td>$Q_{gate}$</td>
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<tr>
<td><strong>Thermal</strong></td>
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<tr>
<td>Thermal resistance to heatsink</td>
<td>$R_{Thm}$</td>
<td>Phase-Change Material X=3.4W/mK</td>
<td>2.60</td>
<td>K/W</td>
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<tr>
<td><strong>IGBT Switching</strong></td>
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<tr>
<td>Turn-on delay time</td>
<td>$t_{on}$</td>
<td>Rgs=64Ω Rgds=64Ω</td>
<td>±15</td>
<td>400</td>
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<tr>
<td>Rise time</td>
<td>$t_r$</td>
<td>Rgs=64Ω Rgds=64Ω</td>
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</tr>
<tr>
<td>Turn-off delay time</td>
<td>$t_{off}$</td>
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<td>25</td>
<td>88</td>
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<td>125</td>
<td>81</td>
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<tr>
<td>Fall time</td>
<td>$t_f$</td>
<td>Rgs=64Ω Rgds=64Ω</td>
<td>400</td>
<td>4</td>
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<tr>
<td>Turn-on energy loss per pulse</td>
<td>$E_{on}$</td>
<td>QhFV=0.2μC QhFV=0.4μC</td>
<td>25</td>
<td>0.049</td>
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<tr>
<td>Turn-off energy loss per pulse</td>
<td>$E_{off}$</td>
<td>QhFV=0.2μC QhFV=0.4μC</td>
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<td>0.073</td>
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<td><strong>FVID Switching</strong></td>
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<tr>
<td>Peak recovery current</td>
<td>$I_{recover}$</td>
<td>dI/dt=447A/μs</td>
<td>±15</td>
<td>400</td>
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<tr>
<td>Reverse recovery time</td>
<td>$t_{recover}$</td>
<td>dI/dt=196A/μs</td>
<td>±15</td>
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<td>Reverse recovery charge</td>
<td>$Q_{recover}$</td>
<td>dI/dt=196A/μs</td>
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<tr>
<td>Reverse recovered energy</td>
<td>$E_{recover}$</td>
<td>dI/dt=196A/μs</td>
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<td>0.086</td>
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<td>Peak rate of fall of recovery current</td>
<td>$dI/dt$</td>
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# PFC Switch

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<th>Symbol</th>
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<th>Value</th>
<th>Unit</th>
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<tr>
<td><strong>Static</strong></td>
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<td></td>
</tr>
<tr>
<td>Gate-emitter threshold voltage</td>
<td>VGE</td>
<td>0.6004</td>
<td>25</td>
<td>V</td>
</tr>
<tr>
<td>Collector-emitter saturation</td>
<td>VCE</td>
<td>15</td>
<td>25</td>
<td>V</td>
</tr>
<tr>
<td>Collector-emitter cut-off</td>
<td>ICE</td>
<td>0</td>
<td>25</td>
<td>µA</td>
</tr>
<tr>
<td>GTO-emitter leakage current</td>
<td>IGTO</td>
<td>20</td>
<td>25</td>
<td>nA</td>
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<td>Integrated Gate resistor</td>
<td>Rint</td>
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<td>24</td>
<td>pF</td>
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<tr>
<td>Input capacitance</td>
<td>Cin</td>
<td>930</td>
<td>25</td>
<td>pF</td>
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<tr>
<td>Output capacitance</td>
<td>Coss</td>
<td>0</td>
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<td>pF</td>
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<tr>
<td>Reverse transfer capacitance</td>
<td>Ciss</td>
<td>4</td>
<td>25</td>
<td>pF</td>
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<tr>
<td>Gate charge</td>
<td>Qg</td>
<td>15</td>
<td>25</td>
<td>nC</td>
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<tr>
<td><strong>Thermal</strong></td>
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<tr>
<td>Thermal resistance chip to heatsink</td>
<td>Rth</td>
<td>2.14</td>
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<td>K/W</td>
</tr>
<tr>
<td><strong>IGBT Switching</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Turn-on delay time</td>
<td>τon</td>
<td>15/0</td>
<td>63</td>
<td>ns</td>
</tr>
<tr>
<td>Rise time</td>
<td>tR</td>
<td>Rg=320Ω</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn-off delay time</td>
<td>τoff</td>
<td>Rg=320Ω</td>
<td></td>
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</tr>
<tr>
<td>Fall time</td>
<td>tf</td>
<td></td>
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<tr>
<td>Turn-on energy loss per pulse</td>
<td>Eon</td>
<td>≈0.3µC</td>
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<td>mW/s</td>
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<tr>
<td>Turn-off energy loss per pulse</td>
<td>Eoff</td>
<td>≈0.5µC</td>
<td></td>
<td>mW/s</td>
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# PFC Diode

<table>
<thead>
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<th>Conditions</th>
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<th>Unit</th>
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<tr>
<td>PFC Diode</td>
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</tr>
<tr>
<td>Voltage</td>
<td>( V _\text{F} )</td>
<td>15, 25°C, 125°C, 150°C</td>
<td>1.44, 1.33, 1.29</td>
<td>V</td>
</tr>
<tr>
<td>Reverse leakage current</td>
<td>( \text{I}_{\text{R}} )</td>
<td>550, 25°C, 150°C</td>
<td>0.94</td>
<td>( \text{A} )</td>
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## Static

### Thermal

<table>
<thead>
<tr>
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<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal resistance chip to heatsink</td>
<td>( R_{\text{Th,JC}} )</td>
<td>Phase Change Material ( \lambda = 0.4 \text{W/mK} )</td>
<td>2.19</td>
<td>K/W</td>
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## FWD Switching

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<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak recovery current</td>
<td>( \text{I}_{\text{R}} )</td>
<td>15/0, 400, 6</td>
<td>25, 125</td>
<td>9, 13</td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>( \text{t}_{\text{R}} )</td>
<td>696/46, 46/43</td>
<td>25, 125</td>
<td>47, 64</td>
</tr>
<tr>
<td>Reverse recovery charge</td>
<td>( \text{Q}_{\text{R}} )</td>
<td>696/46, 46/43</td>
<td>25, 125</td>
<td>0.026, 0.009</td>
</tr>
<tr>
<td>Reverse recovered energy</td>
<td>( \text{E}_{\text{R}} )</td>
<td>696/46, 46/43</td>
<td>25, 125</td>
<td>0.040, 0.005</td>
</tr>
<tr>
<td>Peak rate of fall of recovery current</td>
<td>( \text{d} \text{I}_{\text{R}}/\text{d} \text{t} )</td>
<td>696/46, 46/43</td>
<td>25, 125</td>
<td>408, 917</td>
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# PFC Protection Diode

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<tr>
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<th>Conditions</th>
<th>Value</th>
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<tbody>
<tr>
<td>PFC Protection Diode</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage</td>
<td>( V _\text{F} )</td>
<td>6</td>
<td>25°C, 125°C, 150°C</td>
<td>1.73, 1.59, 1.54</td>
</tr>
<tr>
<td>Reverse leakage current</td>
<td>( \text{I}_{\text{L}} )</td>
<td>650, 25°C, 150°C</td>
<td>0.1</td>
<td>( \text{mA} )</td>
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</table>

## Static

### Thermal

<table>
<thead>
<tr>
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<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal resistance chip to heatsink</td>
<td>( R_{\text{Th,JC}} )</td>
<td>Phase Change Material ( \lambda = 0.4 \text{W/mK} )</td>
<td>3.01</td>
<td>K/W</td>
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</table>

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### Rectifier Diode

<table>
<thead>
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<th>Symbol</th>
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<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Forward voltage</td>
<td>$V_F$</td>
<td>7</td>
<td>1.04</td>
<td>V</td>
</tr>
<tr>
<td>Reverse leakage current</td>
<td>$I_R$</td>
<td>1000</td>
<td>20</td>
<td>μA</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>$R_{h,s,t}$</td>
<td>Phase-Change Material $\lambda=3.4,\text{W/mK}$</td>
<td>2.09</td>
<td>kW/°C</td>
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### Thermistor

<table>
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<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>Rated resistance</td>
<td>$R$</td>
<td>25</td>
<td>21.5</td>
<td>kΩ</td>
</tr>
<tr>
<td>Deviation of $R_{100}$</td>
<td>$\Delta R/R$</td>
<td>$R_{100}=1488,\Omega$</td>
<td>100</td>
<td>%</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>$P$</td>
<td>25</td>
<td>210</td>
<td>mW</td>
</tr>
<tr>
<td>Power dissipation constant</td>
<td>$B(25/50)$</td>
<td>25</td>
<td>3.5</td>
<td>mW/K</td>
</tr>
<tr>
<td>$B$-value</td>
<td>$B(25/100)$</td>
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<td>3984</td>
<td>K</td>
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<tr>
<td>Vincotech NTC Reference</td>
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### Module Properties

#### Thermal Properties

<table>
<thead>
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<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>Storage temperature</td>
<td>$T_{stg}$</td>
<td></td>
<td>-40...+125</td>
<td>°C</td>
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<tr>
<td>Operation temperature under switching condition</td>
<td>$T_{op}$</td>
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<td>-40...+(Tmax - 25)</td>
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#### Insulation Properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>DC voltage</th>
<th>t=2s</th>
<th>Value</th>
<th>Unit</th>
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<tr>
<td>Insulation voltage</td>
<td>$V_{ui}$</td>
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<td>V</td>
</tr>
<tr>
<td>Creepage distance</td>
<td></td>
<td></td>
<td></td>
<td>min 12.7</td>
<td>mm</td>
</tr>
<tr>
<td>Clearance</td>
<td></td>
<td></td>
<td></td>
<td>min 12.7</td>
<td>mm</td>
</tr>
<tr>
<td>Comparative tracking index</td>
<td>$CTI$</td>
<td></td>
<td></td>
<td>&gt;200</td>
<td></td>
</tr>
</tbody>
</table>
Inverter Switch Characteristics

Typical output characteristics

\[ I_{C} = f(V_{CE}) \]

\[ t_{p} = 250 \ \mu s \quad T_{j}: \ 25 \ ^{\circ}C \]

\[ V_{CE} = 15 \ V \]

\[ t_{p} = 250 \ \mu s \quad T_{j}: \ 125 \ ^{\circ}C, \ 150 \ ^{\circ}C \]

\[ V_{CE} \text{ from } 7 \ V \text{ to } 17 \ V \text{ in steps of } 1 \ V \]

Typical transfer characteristics

\[ I_{C} = f(V_{CE}) \]

\[ t_{p} = 100 \ \mu s \quad T_{j}: \ 25 \ ^{\circ}C \]

\[ V_{CE} = 10 \ V \]

\[ t_{p} = 250 \ \mu s \quad T_{j}: \ 25 \ ^{\circ}C, \ 125 \ ^{\circ}C, \ 150 \ ^{\circ}C \]

Transient thermal impedance as a function of pulse width

\[ Z_{thJH} = f(t_{p}) \]

\[ D = t_{p} / T \]

\[ R_{th} = 2.60 \ K/W \]

IGBT thermal model values

- \( R \) (K/W)
- Tau (s)
- 7.48E-02, 2.66E-00, 1.91E-01, 1.40E+00, 4.54E-01, 4.75E-01
Inverter Switch Characteristics

**Gate voltage vs Gate charge**  
IGBT

\[ V_{GE} = f(Q_G) \]

**Safe operating area**  
IGBT

\[ I_C = f(V_{CE}) \]

- **At**
  - \( I_C = 4 \) A
  - Single pulse
  - \( T_s = 80 \) °C
  - \( V_{GE} = \pm 15 \) V
  - \( T_j = T_{j_{max}} \) °C

**Short circuit duration as a function of \( V_{GE} \)**  
IGBT

\[ t_{pS C} = f(V_{GE}) \]

- **At**
  - \( V_{CE} \leq 400 \) V
  - \( V_{CE} \leq 400 \) V
  - Start at \( T_j \leq 150 \) °C
  - Start at \( T_j \leq 25 \) °C

**Typical short circuit current as a function of \( V_{GE} \)**  
IGBT

\[ I_{SC} = f(V_{GE}) \]
PFC Switch Characteristics

**Typical output characteristics**

\[ I_C = f(V_{CE}) \]

- \( t_p = 250 \mu s \)
- \( V_{CE} = 15 \text{ V} \)
- \( T_j: 25^\circ C \)
- \( 125^\circ C \)
- \( 150^\circ C \)

- \( V_{GE} \) from 7 V to 17 V in steps of 1 V

**Typical transfer characteristics**

\[ I_C = f(V_{GE}) \]

- \( t_p = 100 \mu s \)
- \( V_{CE} = 10 \text{ V} \)
- \( T_j: 25^\circ C \)
- \( 125^\circ C \)
- \( 150^\circ C \)

**Transient thermal impedance as a function of pulse width**

\[ Z_{thJH} = f(t_p) \]

- \( D = \frac{t_p}{T} \)
- \( R_{thJH} = 2.14 \text{ K/W} \)

IGBT thermal model values

<table>
<thead>
<tr>
<th>( R ) (K/W)</th>
<th>( \tau ) (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.10E-01</td>
<td>1.85E+00</td>
</tr>
<tr>
<td>3.05E-01</td>
<td>2.58E-01</td>
</tr>
<tr>
<td>8.44E-01</td>
<td>6.42E-02</td>
</tr>
<tr>
<td>4.55E-01</td>
<td>1.26E-02</td>
</tr>
<tr>
<td>2.79E-01</td>
<td>3.05E-03</td>
</tr>
<tr>
<td>1.45E-01</td>
<td>4.84E-04</td>
</tr>
</tbody>
</table>

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**PFC Switch Characteristics**

**Gate voltage vs Gate charge**

*IGBT*

\[ V_G = f(Q_g) \]

*At*  
\[ I_C = 15 \text{ A} \]

**PFC Diode Characteristics**

**Typical forward characteristics**

\[ I_F = f(V_F) \]

\[ t_p = 250 \mu s \]

**Transient thermal impedance as a function of pulse width**

\[ Z_{th}(j\omega) = f(t_p) \]

\[ D = \frac{t_p}{T} \]

\[ R_{th}(0) = 2.19 \text{ K/W} \]

**FWD thermal model values**

<table>
<thead>
<tr>
<th>R (K/W)</th>
<th>T (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.49E-02</td>
<td>4.22E-00</td>
</tr>
<tr>
<td>1.67E-01</td>
<td>4.66E-01</td>
</tr>
<tr>
<td>9.76E-01</td>
<td>5.57E-02</td>
</tr>
<tr>
<td>5.62E-01</td>
<td>1.45E-02</td>
</tr>
<tr>
<td>3.00E-01</td>
<td>2.81E-03</td>
</tr>
<tr>
<td>1.17E-01</td>
<td>5.62E-04</td>
</tr>
</tbody>
</table>
PFC Protection Diode characteristics

Typical forward characteristics

\[ I_F = f(V_F) \]

\[ Z_{th(j-s)} = f(t_p) \]

\[ t_p = 250 \mu s \]

25 °C

125 °C

150 °C

\[ \text{FWD thermal model values} \]

\[ R (K/W) \]

5.15E-02 9.38E+00

9.53E-02 8.91E-01

3.22E-01 1.25E-01

1.35E+00 2.97E-02

8.32E-01 8.19E-03

3.58E-01 1.78E-03

Transient thermal impedance as a function of pulse width

\[ Z_{th(j-s)} = f(t_p) \]

\[ D = \frac{t_p}{T} \]

\[ R_{adj} = 3.01 \text{ K/W} \]
**Rectifier characteristics**

**Typical forward characteristics**

I_F = f(V_F)

<table>
<thead>
<tr>
<th>V_F (V)</th>
<th>0</th>
<th>0.5</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>I_F (A)</td>
<td>0</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>15</td>
<td>21</td>
</tr>
</tbody>
</table>

- t_p = 250 µs
- 25 °C
- 125 °C
- 150 °C

**Diode thermal model values**

<table>
<thead>
<tr>
<th>R_th(j-W) (K/W)</th>
<th>τ_S (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.86E-02</td>
<td>1.03E+01</td>
</tr>
<tr>
<td>1.45E-01</td>
<td>6.91E-01</td>
</tr>
<tr>
<td>1.18E+00</td>
<td>6.09E-02</td>
</tr>
<tr>
<td>5.46E-01</td>
<td>1.88E-02</td>
</tr>
<tr>
<td>1.74E-01</td>
<td>1.96E-03</td>
</tr>
</tbody>
</table>

**Transient thermal impedance as a function of pulse width**

Z_th(j-s) = f(t_p)

- D = t_p / T
- R_θ(j-W) = 2.09 K/W

**Thermistor Characteristics**

**Typical NTC characteristic**

R_T = f(T)

<table>
<thead>
<tr>
<th>T (°C)</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>100</th>
<th>125</th>
</tr>
</thead>
<tbody>
<tr>
<td>R (Ω)</td>
<td>25000</td>
<td>20000</td>
<td>15000</td>
<td>10000</td>
<td>5000</td>
</tr>
</tbody>
</table>

- NT4-typical temperature characteristic

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Inverter Switching Definitions

Figure 1.
Typical switching energy losses as a function of collector current

\[ E = f(I_C) \]

\[ E_{\text{on}} \]

With an inductive load at 25 °C
- \( V_{ds} = 400 \) V
- \( T_j = 125 \) °C
- \( R_{gon} = 64 \Omega \)
- \( I_C = 4 \) A

\[ E_{\text{off}} \]

Figure 2.
Typical switching energy losses as a function of gate resistor

\[ E = f(R_G) \]

\[ E_{\text{on}} \]

With an inductive load at 25 °C
- \( V_{ds} = 400 \) V
- \( T_j = 125 \) °C
- \( V_{gs} = \pm 15 \) V
- \( l_I = 4 \) A

\[ E_{\text{off}} \]

Figure 3.
Typical reverse recovery energy loss as a function of collector current

\[ E_{\text{rec}} = f(I_C) \]

\[ E_{\text{rec}} \]

With an inductive load at 25 °C
- \( V_{ds} = 400 \) V
- \( T_j = 125 \) °C
- \( V_{gs} = \pm 15 \) V
- \( R_{goff} = 64 \Omega \)

\[ E_{\text{rec}} \]

Figure 4.
Typical reverse recovery energy loss as a function of gate resistor

\[ E_{\text{rec}} = f(R_G) \]

\[ E_{\text{rec}} \]

With an inductive load at 25 °C
- \( V_{ds} = 400 \) V
- \( T_j = 125 \) °C
- \( V_{gs} = \pm 15 \) V
- \( l_I = 4 \) A
Inverter Switching Definitions

**Figure 5.** Typical switching times as a function of collector current

\[ t = f(I_C) \]

With an inductive load at

- \( T_j = 125 \, ^\circ\text{C} \)
- \( V_{CE} = 400 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( R_{on} = 64 \, \Omega \)
- \( I_C = 4 \, \text{A} \)

**Figure 6.** Typical switching times as a function of gate resistor

\[ t = f(R_{on}) \]

With an inductive load at

- \( T_j = 125 \, ^\circ\text{C} \)
- \( V_{CE} = 400 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( i_C = 4 \, \text{A} \)

**Figure 7.** Typical reverse recovery time as a function of collector current

\[ t_{rr} = f(I_C) \]

At

- \( V_{CE} = 400 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( T_j = 125 \, ^\circ\text{C} \)
- \( T_j = 150 \, ^\circ\text{C} \)
- \( R_{on} = 64 \, \Omega \)

**Figure 8.** Typical reverse recovery time as a function of IGBT turn on gate resistor

\[ t_{rr} = f(R_{on}) \]

At

- \( V_{CE} = 400 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( T_j = 125 \, ^\circ\text{C} \)
- \( i_C = 4 \, \text{A} \)
- \( T_j = 150 \, ^\circ\text{C} \)
Inverter Switching Definitions

Figure 9. Typical reverse recovery charge as a function of collector current

\[ Q_{rr} = f(I_C) \]

At

\( V_{CE} = 400 \text{ V} \)
\( T_j = 25 ^\circ \text{C} \)
\( R_{gon} = 64 \Omega \)

\( V_{CE} = 815 \text{ V} \)
\( T_j = 125 ^\circ \text{C} \)
\( R_{gon} = 64 \Omega \)

\( V_{CE} = 400 \text{ V} \)
\( T_j = 150 ^\circ \text{C} \)

Figure 10. Typical reverse recovery charge as a function of IGBT turn on gate resistor

\[ Q_{rr} = f(R_{gon}) \]

At

\( V_{CE} = 400 \text{ V} \)
\( T_j = 25 ^\circ \text{C} \)
\( R_{gon} = 64 \Omega \)

\( V_{CE} = 815 \text{ V} \)
\( T_j = 125 ^\circ \text{C} \)
\( R_{gon} = 64 \Omega \)

\( V_{CE} = 400 \text{ V} \)
\( T_j = 150 ^\circ \text{C} \)

Figure 11. Typical reverse recovery current as a function of collector current

\[ I_{RRM} = f(I_C) \]

Figure 12. Typical reverse recovery current as a function of IGBT turn on gate resistor

\[ I_{RRM} = f(R_{gon}) \]
Inverter Switching Definitions

Figure 13. FWD
Typical rate of fall of forward and reverse recovery current as a function of collector current
\[
d\frac{dI}{dt},d\frac{dI}{dt}=f(I_c)
\]
At
\[
V_{CE}=400\ \text{V}
\]
\[
V_{GE}=\pm15\ \text{V}
\]
\[
R_{gan}=64\ \Omega
\]

Figure 14. FWD
Typical rate of fall of forward and reverse recovery current as a function of
IGBT turn-on gate resistor
At
\[
V_{CE}=400\ \text{V}
\]
\[
V_{GE}=\pm15\ \text{V}
\]
\[
I_c=4\ \text{A}
\]

Figure 15. IGBT
Reverse bias safe operating area
At
\[
T_{j}=175\ ^\circ\text{C}
\]
\[
R_{pm}=64\ \Omega
\]
\[
R_{pmt}=64,015\ \Omega
\]
Inverter Switching Definitions

General conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tj</td>
<td>125 °C</td>
</tr>
<tr>
<td>Rgs</td>
<td>64 Ω</td>
</tr>
<tr>
<td>Rgoff</td>
<td>64 Ω</td>
</tr>
</tbody>
</table>

Figure 1. Turn-off Switching Waveforms & definition of \( t_{\text{doff}} \) \( t_{\text{off}} \) (integrating time for \( E_{\text{off}} \))

\[ V_{\text{GE}} (0\%) = -15 \text{ V} \]
\[ V_{\text{CE}} (100\%) = 400 \text{ V} \]
\[ I_{\text{C}} (100\%) = 4 \text{ A} \]
\[ I_{\text{C}} = 0.098 \mu\text{s} \]
\[ t_{\text{doff}} = 0.098 \mu\text{s} \]
\[ t_{\text{off}} = 0.293 \mu\text{s} \]

Figure 2. Turn-on Switching Waveforms & definition of \( t_{\text{don}} \) \( t_{\text{on}} \) (integrating time for \( E_{\text{on}} \))

\[ V_{\text{GE}} (0\%) = -15 \text{ V} \]
\[ V_{\text{CE}} (100\%) = 400 \text{ V} \]
\[ I_{\text{C}} (100\%) = 4 \text{ A} \]
\[ I_{\text{C}} = 0.081 \mu\text{s} \]
\[ t_{\text{don}} = 0.081 \mu\text{s} \]
\[ t_{\text{on}} = 0.220 \mu\text{s} \]

Figure 3. Turn-off Switching Waveforms & definition of \( f \)

\[ V_{\text{CE}} (100\%) = 400 \text{ V} \]
\[ I_{\text{C}} (100\%) = 4 \text{ A} \]
\[ I_{\text{C}} = 0.293 \mu\text{s} \]
\[ t_{\text{f}} = 0.047 \mu\text{s} \]

Figure 4. Turn-on Switching Waveforms & definition of \( r \)

\[ V_{\text{CE}} (100\%) = 400 \text{ V} \]
\[ I_{\text{C}} (100\%) = 4 \text{ A} \]
\[ I_{\text{C}} = 0.220 \mu\text{s} \]
**Inverter Switching Definitions**

**Figure 5.** IGBT

- $P_{on} (100\%) = 1.59$ kW
- $E_{on} (100\%) = 0.16$ mJ
- $t_{Eon} = 0.22 \mu$s

**Figure 6.** IGBT

- $P_{off} (100\%) = 1.59$ kW
- $E_{off} (100\%) = 0.08$ mJ
- $t_{Eoff} = 0.29 \mu$s

**Figure 7.** FWD

- $V_d (100\%) = 400$ V
- $I_d (100\%) = 4$ A
- $I_{fused} (100\%) = -4$ A
- $t_{rr} = 0.219 \mu$s
Inverter Switching Definitions

Figure 8. Turn-on Switching Waveforms & definition of $t_{Qrr}$ ($t_{Qrr}$ = integrating time for $Q_{rr}$)

- $I_{d}$ (100%) = 4 A
- $Q_{rr}$ (100%) = 0.38 µC
- $t_{Qrr}$ = 0.44 µs

Figure 9. Turn-on Switching Waveforms & definition of $t_{Erec}$ ($t_{Erec}$ = integrating time for $E_{rec}$)

- $P_{rec}$ (100%) = 1.59 kW
- $E_{rec}$ (100%) = 0.10 mJ
- $t_{Erec}$ = 0.44 µs
PFC Switching Definitions

**Figure 1.**
Typical switching energy losses as a function of collector current

\[ E = f(I_C) \]

*With an inductive load at 25 °C*

- \( V_{CE} = 400 \text{ V} \)
- \( T_J = 125 \text{ °C} \)
- \( R_{gon} = 32 \Omega \)
- \( R_{goff} = 32 \Omega \)

**Figure 2.**
Typical switching energy losses as a function of gate resistor

\[ E = f(R_G) \]

*With an inductive load at 25 °C*

- \( V_{CE} = 400 \text{ V} \)
- \( T_J = 125 \text{ °C} \)
- \( R_{gon} = 32 \Omega \)
- \( R_{goff} = 32 \Omega \)

**Figure 3.**
Typical reverse recovery energy loss as a function of collector current

\[ E_{rec} = f(I_C) \]

*With an inductive load at 25 °C*

- \( V_{CE} = 400 \text{ V} \)
- \( T_J = 125 \text{ °C} \)
- \( R_{gon} = 32 \Omega \)
- \( R_{goff} = 32 \Omega \)

**Figure 4.**
Typical reverse recovery energy loss as a function of gate resistor

\[ E_{rec} = f(R_G) \]

*With an inductive load at 25 °C*

- \( V_{CE} = 400 \text{ V} \)
- \( T_J = 125 \text{ °C} \)
- \( R_{gon} = 32 \Omega \)
- \( R_{goff} = 32 \Omega \)
PFC Switching Definitions

Typical switching times as a function of collector current

\[ t = f(I_C) \]

With an inductive load at

- \( V_{CE} = 400 \, \text{V} \)
- \( V_{DS} = 15/0 \, \text{V} \)
- \( R_{GON} = 32 \, \Omega \)
- \( R_{GOFF} = 32 \, \Omega \)

\[ T_j = 125 \, ^\circ\text{C} \]

\[ V_{GE} = 15/0 \, \text{V} \]

Typical reverse recovery time as a function of collector current

\[ t_{rr} = f(I_C) \]

At

- \( V_{CE} = 400 \, \text{V} \)
- \( V_{DS} = 15/0 \, \text{V} \)
- \( R_{GON} = 32 \, \Omega \)

\[ T_j = 125 \, ^\circ\text{C} \]

\[ V_{GE} = 15/0 \, \text{V} \]

\[ R_{GOFF} = 32 \, \Omega \]

\[ T_j = 125 \, ^\circ\text{C} \]

\[ R_{GON} = 32 \, \Omega \]

\[ I_C = 6 \, \text{A} \]

\[ V_{CE} = 400 \, \text{V} \]

\[ V_{DS} = 15/0 \, \text{V} \]

\[ R_{GOFF} = 32 \, \Omega \]

\[ T_j = 125 \, ^\circ\text{C} \]

\[ V_{GE} = 15/0 \, \text{V} \]

\[ R_{GON} = 32 \, \Omega \]

\[ T_j = 125 \, ^\circ\text{C} \]

\[ I_C = 6 \, \text{A} \]

\[ V_{CE} = 400 \, \text{V} \]

\[ V_{DS} = 15/0 \, \text{V} \]

\[ R_{GOFF} = 32 \, \Omega \]

\[ T_j = 125 \, ^\circ\text{C} \]

\[ V_{GE} = 15/0 \, \text{V} \]

\[ R_{GON} = 32 \, \Omega \]

\[ T_j = 125 \, ^\circ\text{C} \]

\[ I_C = 6 \, \text{A} \]
PFC Switching Definitions

Figure 9. Typical reverse recovery charge as a function of collector current

\[ Q_{rr} = f(I_C) \]

- At \( V_{CE} = 400 \text{ V} \), \( 25 \degree C \)
- \( V_{IN} = 15/0 \text{ V} \), \( T_J = 125 \degree C \)
- \( R_{gon} = 32 \text{ Ω} \), \( 150 \degree C \)

Figure 10. Typical reverse recovery charge as a function of IGBT turn on gate resistor

\[ Q_{rr} = f(R_{gon}) \]

- At \( V_{CE} = 400 \text{ V} \), \( 25 \degree C \)
- \( V_{IN} = 15/0 \text{ V} \), \( T_J = 125 \degree C \)
- \( i_n = 6 \text{ A} \), \( 150 \degree C \)

Figure 11. Typical reverse recovery current as a function of collector current

\[ I_{RRM} = f(I_C) \]

- At \( V_{CE} = 400 \text{ V} \), \( 25 \degree C \)
- \( V_{IN} = 15/0 \text{ V} \), \( T_J = 125 \degree C \)
- \( R_{gon} = 32 \text{ Ω} \), \( 150 \degree C \)

Figure 12. Typical reverse recovery current as a function of IGBT turn on gate resistor

\[ I_{RRM} = f(R_{gon}) \]

- At \( V_{CE} = 400 \text{ V} \), \( 25 \degree C \)
- \( V_{IN} = 15/0 \text{ V} \), \( T_J = 125 \degree C \)
- \( i_n = 6 \text{ A} \), \( 150 \degree C \)
PFC Switching Definitions

Figure 13. FWD
Typical rate of fall of forward and reverse recovery current as a function of collector current
\[
\frac{dI_0}{dt}, \frac{dI_{rec}}{dt} = f(I_c)
\]

At
- \( V_{GE} = 15/0 \) V
- \( I_C = 6 \) A
- \( \Delta V_{CE} = 400 \) V
- \( \Delta R_{gon} = 32 \) Ω

Figure 14. FWD
Typical rate of fall of forward and reverse recovery current as a function of IGBT turn on gate resistor

At
- \( V_{GE} = 15/0 \) V
- \( I_C = 6 \) A
- \( \Delta V_{CE} = 400 \) V
- \( \Delta R_{gon} = 32 \) Ω

Figure 15. IGBT
Reverse bias safe operating area

At
- \( T_J = 175 \) °C
- \( \Delta R_{gon} = 32 \) Ω
- \( \Delta R_{goff} = 32 \) Ω

\( I_c = f(V_{GE}) \)
PFC Switching Definitions

General conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_J$</td>
<td>125 °C</td>
</tr>
<tr>
<td>$R_{ESR}$</td>
<td>32 Ω</td>
</tr>
<tr>
<td>$R_{DOff}$</td>
<td>32 Ω</td>
</tr>
</tbody>
</table>

Figure 1. IGBT

Turn-off Switching Waveforms & definition of $t_{doff}$, $t_{Eoff}$ ($t_{Eoff}$ = integrating time for $E_{off}$)

- $V_{CE} (0\%) = 0$ V
- $V_{CE} (100\%) = 15$ V
- $V_C (100\%) = 400$ V
- $I_C (100\%) = 6$ A
- $t_{doff} = 0.191 \mu s$
- $t_{Eoff} = 0.235 \mu s$

Figure 2. IGBT

Turn-on Switching Waveforms & definition of $t_{don}$, $t_{Eon}$ ($t_{Eon}$ = integrating time for $E_{on}$)

- $V_{CE} (0\%) = 0$ V
- $V_{CE} (100\%) = 15$ V
- $V_C (100\%) = 400$ V
- $I_C (100\%) = 6$ A
- $t_{don} = 0.017 \mu s$
- $t_{Eon} = 0.108 \mu s$

Figure 3. IGBT

Turn-off Switching Waveforms & definition of $t_f$

- $V_C (100\%) = 400$ V
- $I_C (10\%) = 6$ A
- $t_f = 0.004 \mu s$

Figure 4. IGBT

Turn-on Switching Waveforms & definition of $t_r$

- $V_C (100\%) = 400$ V
- $I_C (10\%) = 6$ A
- $t_r = 0.011 \mu s$
PFC Switching Definitions

**Figure 5.**
*IGBT*
**Turn-off Switching Waveforms & definition of t\textsubscript{Eoff}**

- \(P_{\text{off}}\) (100%) = 2.37 kW
- \(E_{\text{off}}\) (100%) = 0.06 mJ
- \(t_{\text{Eoff}}\) = 0.24 µs

**Figure 6.**
*IGBT*
**Turn-on Switching Waveforms & definition of t\textsubscript{Eon}**

- \(P_{\text{on}}\) (100%) = 2.37 kW
- \(E_{\text{on}}\) (100%) = 0.21 mJ
- \(t_{\text{Eon}}\) = 0.11 µs

**Figure 7.**
*FWD*
**Turn-off Switching Waveforms & definition of t\textsubscript{rr}**

- \(V_{\text{d}}\) (100%) = 400 V
- \(I_{\text{d}}\) (100%) = 6 A
- \(I_{\text{RRM}}\) (100%) = -13 A
- \(t_{\text{rr}}\) = 0.064 µs
PFC Switching Definitions

Figure 8. Turn-on Switching Waveforms & definition of $t_{Q_{rr}}$ ($t_{Q_{rr}}$ = integrating time for $Q_{rr}$)

$I_d (100\%) = 6$ A  
$Q_{rr} (100\%) = 0.51$ µC  
$t_{Q_{rr}} = 0.16$ µs

Figure 9. Turn-on Switching Waveforms & definition of $t_{E_{rec}}$ ($t_{E_{rec}}$ = integrating time for $E_{rec}$)

$P_{rec} (100\%) = 2.37$ kW  
$E_{rec} (100\%) = 0.10$ mJ  
$t_{E_{rec}} = 0.16$ µs
Ordering Code & Marking

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Outline

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## Pinout

![Pinout Diagram](image)

## Identification

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Handling instruction
Handling instructions for flow 0 B packages see vincotech.com website.

Package data
Package data for flow 0 B packages see vincotech.com website.

UL recognition and file number
This device is certified according to UL 1557 standard, UL file number E192116. For more information see vincotech.com website.

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