Vincotech

VINcoMNPC X4 1200 V/400 A

Features
- Mixed voltage NPC
- Low inductive
- High power screw interface

Target Applications
- Solar inverter
- UPS
- High speed motor drive

Types
- 70-W212NMA400NB02-M209P62

Maximum Ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>half bridge IGBT (T1, T4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collector-emitter break down voltage</td>
<td>V_CES</td>
<td></td>
<td>1200</td>
<td>V</td>
</tr>
<tr>
<td>DC collector current</td>
<td>I_C</td>
<td>T_{j=25°C}</td>
<td>358</td>
<td>A</td>
</tr>
<tr>
<td>Pulsed collector current</td>
<td>I_{pul}</td>
<td>T_{j=25°C} limited by T_{j,max}</td>
<td>800</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per IGBT</td>
<td>P_{tot}</td>
<td>T_{j=25°C}</td>
<td>864</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>V_{SC}</td>
<td>T_{j=150°C}, V_{GE}=15V</td>
<td>10</td>
<td>μs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>800</td>
<td>V</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>T_{j,max}</td>
<td></td>
<td>175</td>
<td>°C</td>
</tr>
</tbody>
</table>

neutral point FWD (D2, D3)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Repetitive Reverse Voltage</td>
<td>V_{max}</td>
<td>T_{j=25°C}</td>
<td>650</td>
<td>V</td>
</tr>
<tr>
<td>DC forward current</td>
<td>I_{Fmax}</td>
<td>T_{j=25°C}</td>
<td>232</td>
<td>A</td>
</tr>
<tr>
<td>Repetitive peak forward current</td>
<td>I_{Rmax}</td>
<td>T_{j=25°C} limited by T_{j,max}</td>
<td>600</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per FWD</td>
<td>P_{tot}</td>
<td>T_{j=25°C}</td>
<td>306</td>
<td>W</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>T_{j,max}</td>
<td></td>
<td>175</td>
<td>°C</td>
</tr>
</tbody>
</table>

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1  Revision: 1.2
### Maximum Ratings

T\(_{j}\) = 25°C, unless otherwise specified

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral point IGBT (T2, T3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collector-emitter break down voltage</td>
<td>(V_{CES})</td>
<td></td>
<td>650</td>
<td>V</td>
</tr>
<tr>
<td>DC collector current</td>
<td>(i_c)</td>
<td>(T_i = T_{j,\text{max}}) (T_i = T_{j,\text{max}})</td>
<td>260</td>
<td>A</td>
</tr>
<tr>
<td>Pulsed collector current</td>
<td>(i_{\text{pulse}})</td>
<td>(i_p) limited by (T_{j,\text{max}})</td>
<td>900</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per IGBT</td>
<td>(P_{\text{tot}})</td>
<td>(T_i = T_{j,\text{max}}) (T_i = T_{j,\text{max}})</td>
<td>500</td>
<td>W</td>
</tr>
<tr>
<td>Gate-emitter peak voltage</td>
<td>(V_{GE})</td>
<td></td>
<td>(\leq 20)</td>
<td>V</td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>(t_{SC}) (V_{CC}) (V_{GE} = 15)</td>
<td></td>
<td>10 (\mu)s</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>360</td>
<td>V</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>(T_{j,\text{max}})</td>
<td></td>
<td>175</td>
<td>°C</td>
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</table>

### Half Bridge FWD (D1, D4)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Repetitive Reverse Voltage</td>
<td>(V_{\text{RMM}})</td>
<td>(T_i = 25°C)</td>
<td>1200</td>
<td>V</td>
</tr>
<tr>
<td>DC forward current</td>
<td>(i_{FAM})</td>
<td>(T_i = T_{j,\text{max}}) (T_i = T_{j,\text{max}})</td>
<td>252</td>
<td>A</td>
</tr>
<tr>
<td>Surge forward current</td>
<td>(i_{\text{SM}}) (i_p = 10) ms, (\sin 180°)</td>
<td>(T_i = 25°C)</td>
<td>1720</td>
<td>A</td>
</tr>
<tr>
<td>(\mu)T-value</td>
<td>(\mu T)</td>
<td>(T_i = 150°C)</td>
<td>3700</td>
<td>A²s</td>
</tr>
<tr>
<td>Power dissipation per FWD</td>
<td>(P_{\text{tot}})</td>
<td>(T_i = T_{j,\text{max}}) (T_i = T_{j,\text{max}})</td>
<td>528</td>
<td>W</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>(T_{j,\text{max}})</td>
<td></td>
<td>175</td>
<td>°C</td>
</tr>
</tbody>
</table>

### General Module Properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material of module baseplate</td>
<td>Cu</td>
</tr>
<tr>
<td>Material of internal isolation</td>
<td>Al2O3</td>
</tr>
</tbody>
</table>

### Thermal Properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage temperature</td>
<td>(T_{\text{stg}}) (-40...+125) °C</td>
</tr>
<tr>
<td>Operation temperature under switching condition</td>
<td>(T_{\text{op}}) (-40...+(T_{j,\text{max}} - 25)) °C</td>
</tr>
</tbody>
</table>

### Insulation Properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulation voltage (V_i) (i = 2)</td>
<td>4000 V</td>
</tr>
<tr>
<td>Creepage distance</td>
<td>min 12.7 mm</td>
</tr>
<tr>
<td>Clearance</td>
<td>min 12.7 mm</td>
</tr>
<tr>
<td>Comparative tracking index</td>
<td>CTI &gt; 200</td>
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</tbody>
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### Characteristic Values

#### half bridge IGBT (T1, T4)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate emitter threshold voltage</td>
<td>V_{GE(th)} [V]</td>
<td>V_{GE} = V_{GE(th)}</td>
<td>0,04</td>
<td>5,5</td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>V_{CE(sat)} [V]</td>
<td>V_{CE} = V_{CE(sat)}</td>
<td>2,21</td>
<td>3,5</td>
</tr>
<tr>
<td>Collector-emitter cut-off current incl. FWD</td>
<td>I_{CES} [mA]</td>
<td>I_{CES}</td>
<td>1200</td>
<td>2</td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>I_{GED} [mA]</td>
<td>I_{GED}</td>
<td>3000</td>
<td>nA</td>
</tr>
<tr>
<td>Integrated Gate resistor</td>
<td>R_{Integrated resistors} [Ω]</td>
<td>R_{Integrated resistors}</td>
<td>none</td>
<td>Ω</td>
</tr>
<tr>
<td>Turn-on delay time</td>
<td>t_{on} [ns]</td>
<td>t_{on}</td>
<td>±15</td>
<td>350</td>
</tr>
<tr>
<td>Rise time</td>
<td>t_{Rise} [ns]</td>
<td>t_{Rise}</td>
<td>±15</td>
<td>350</td>
</tr>
<tr>
<td>Turn-off delay time</td>
<td>t_{off} [ns]</td>
<td>t_{off}</td>
<td>±15</td>
<td>350</td>
</tr>
<tr>
<td>Fall time</td>
<td>t_{Fall} [ns]</td>
<td>t_{Fall}</td>
<td>±15</td>
<td>350</td>
</tr>
<tr>
<td>Turn-on energy loss per pulse</td>
<td>E_{on} [mWs]</td>
<td>E_{on}</td>
<td>12,25</td>
<td>17,66</td>
</tr>
<tr>
<td>Turn-off energy loss per pulse</td>
<td>E_{off} [mWs]</td>
<td>E_{off}</td>
<td>2,98</td>
<td>5,40</td>
</tr>
<tr>
<td>Input capacitance</td>
<td>C_{in} [pF]</td>
<td>C_{in}</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>Output capacitance</td>
<td>C_{out} [pF]</td>
<td>C_{out}</td>
<td>1MHz</td>
<td>8000</td>
</tr>
<tr>
<td>Reverse transfer capacitance</td>
<td>C_{RSS} [pF]</td>
<td>C_{RSS}</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>Gate charge</td>
<td>Q_{Gate} [nC]</td>
<td>Q_{Gate}</td>
<td>±15</td>
<td>600</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>R_{JH} [K/W]</td>
<td>R_{JH}</td>
<td>0,11</td>
<td></td>
</tr>
<tr>
<td>Thermal resistance chip to case per chip</td>
<td>R_{JC} [K/W]</td>
<td>R_{JC}</td>
<td>0,13</td>
<td></td>
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</tbody>
</table>

#### neutral point FWD (D2, D3)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>FWD forward voltage</td>
<td>V_{DF} [V]</td>
<td>V_{DF}</td>
<td>300</td>
<td>1,2</td>
</tr>
<tr>
<td>Peak reverse recovery current</td>
<td>I_{RR} [A]</td>
<td>I_{RR}</td>
<td>±15</td>
<td>350</td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>t_{RR} [ns]</td>
<td>t_{RR}</td>
<td>±15</td>
<td>350</td>
</tr>
<tr>
<td>Reverse recovered charge</td>
<td>Q_{r} [µC]</td>
<td>Q_{r}</td>
<td>±15</td>
<td>350</td>
</tr>
<tr>
<td>Peak rate of fall of recovery current</td>
<td>dI_{d(rec)} [A]</td>
<td>dI_{d(rec)}</td>
<td>±15</td>
<td>350</td>
</tr>
<tr>
<td>Reverse recovered energy</td>
<td>E_{rec} [mWs]</td>
<td>E_{rec}</td>
<td>±15</td>
<td>350</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>R_{JH} [K/W]</td>
<td>R_{JH}</td>
<td>0,31</td>
<td></td>
</tr>
<tr>
<td>Thermal resistance chip to case per chip</td>
<td>R_{JC} [K/W]</td>
<td>R_{JC}</td>
<td>0,36</td>
<td></td>
</tr>
</tbody>
</table>
### Characteristic Values

<table>
<thead>
<tr>
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<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>neutral point IGBT (T2, T3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gate emitter threshold voltage</td>
<td>V&lt;sub&gt;GE(th)&lt;/sub&gt;</td>
<td>V&lt;sub&gt;GE&lt;/sub&gt; or V&lt;sub&gt;GS&lt;/sub&gt;</td>
<td>0.0048</td>
<td>V</td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>V&lt;sub&gt;CE(sat)&lt;/sub&gt;</td>
<td>V&lt;sub&gt;CE&lt;/sub&gt; or V&lt;sub&gt;DS&lt;/sub&gt;</td>
<td>5.1</td>
<td>V</td>
</tr>
<tr>
<td>Collector-emitter cut-off incl FWD</td>
<td>I&lt;sub&gt;CES&lt;/sub&gt;</td>
<td>650</td>
<td>1.85</td>
<td>mA</td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>I&lt;sub&gt;CES&lt;/sub&gt;</td>
<td>300</td>
<td>2.2</td>
<td>mA</td>
</tr>
<tr>
<td>Integrated Gate resistor</td>
<td>R&lt;sub&gt;int&lt;/sub&gt;</td>
<td>T&lt;sub&gt;j=25°C&lt;/sub&gt;</td>
<td>191</td>
<td>Ω</td>
</tr>
<tr>
<td>Turn-on delay time</td>
<td>t&lt;sub&gt;on&lt;/sub&gt;</td>
<td>T&lt;sub&gt;j=25°C&lt;/sub&gt;</td>
<td>192</td>
<td>ns</td>
</tr>
<tr>
<td>Rise time</td>
<td>t&lt;sub&gt;r&lt;/sub&gt;</td>
<td>T&lt;sub&gt;j=25°C&lt;/sub&gt;</td>
<td>32</td>
<td>ns</td>
</tr>
<tr>
<td>Turn-off delay time</td>
<td>t&lt;sub&gt;off&lt;/sub&gt;</td>
<td>R&lt;sub&gt;goff=2 Ω&lt;/sub&gt;</td>
<td>34</td>
<td>ns</td>
</tr>
<tr>
<td>Fall time</td>
<td>t&lt;sub&gt;f&lt;/sub&gt;</td>
<td>T&lt;sub&gt;j=25°C&lt;/sub&gt;</td>
<td>239</td>
<td>ns</td>
</tr>
<tr>
<td>Turn-on energy loss per pulse</td>
<td>E&lt;sub&gt;on&lt;/sub&gt;</td>
<td>T&lt;sub&gt;j=25°C&lt;/sub&gt;</td>
<td>4.29</td>
<td>mWs</td>
</tr>
<tr>
<td>Turn-off energy loss per pulse</td>
<td>E&lt;sub&gt;off&lt;/sub&gt;</td>
<td>T&lt;sub&gt;j=25°C&lt;/sub&gt;</td>
<td>6.19</td>
<td>mWs</td>
</tr>
<tr>
<td>Input capacitance</td>
<td>C&lt;sub&gt;in&lt;/sub&gt;</td>
<td>f=1MHz</td>
<td>10.19</td>
<td>µF</td>
</tr>
<tr>
<td>Reverse transfer capacitance</td>
<td>C&lt;sub&gt;rss&lt;/sub&gt;</td>
<td>T&lt;sub&gt;j=25°C&lt;/sub&gt;</td>
<td>14.03</td>
<td>µF</td>
</tr>
<tr>
<td>Gate charge</td>
<td>Q&lt;sub&gt;gmax&lt;/sub&gt;</td>
<td>15</td>
<td>548</td>
<td>nC</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>R&lt;sub&gt;thJH&lt;/sub&gt;</td>
<td>100µm preapplied PCM</td>
<td>0.19</td>
<td>K/W</td>
</tr>
<tr>
<td>Thermal resistance chip to case per chip</td>
<td>R&lt;sub&gt;thJC&lt;/sub&gt;</td>
<td>1W/mK</td>
<td>0.22</td>
<td>K/W</td>
</tr>
</tbody>
</table>
### Characteristic Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>FWD forward voltage</td>
<td>$V_{F}$</td>
<td>$T_j=25^\circ C$</td>
<td>2.21</td>
<td>$V$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_j=125^\circ C$</td>
<td>2.76</td>
<td>$V$</td>
</tr>
<tr>
<td>Reverse leakage current</td>
<td>$I_{R}$</td>
<td>$T_j=25^\circ C$</td>
<td>0.048</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_j=125^\circ C$</td>
<td>0.56</td>
<td>mA</td>
</tr>
<tr>
<td>Peak reverse recovery current</td>
<td>$I_{RMS}$</td>
<td>$T_j=25^\circ C$</td>
<td>309</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_j=125^\circ C$</td>
<td>441</td>
<td>A</td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>$t_{rr}$</td>
<td>$T_j=25^\circ C$</td>
<td>66</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_j=125^\circ C$</td>
<td>136</td>
<td>ns</td>
</tr>
<tr>
<td>Reverse recovered charge</td>
<td>$Q_{rr}$</td>
<td>$T_j=25^\circ C$</td>
<td>19</td>
<td>µC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_j=125^\circ C$</td>
<td>38</td>
<td>µC</td>
</tr>
<tr>
<td>Peak rate of fall of recovery current</td>
<td>$d(i_{rec})/dt$</td>
<td>$T_j=25^\circ C$</td>
<td>14653</td>
<td>A/μs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_j=125^\circ C$</td>
<td>14438</td>
<td>A/μs</td>
</tr>
<tr>
<td>Reverse recovery energy</td>
<td>$E_{rec}$</td>
<td>$T_j=25^\circ C$</td>
<td>4.36</td>
<td>mWs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_j=125^\circ C$</td>
<td>9.72</td>
<td>mWs</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>$R_{thJH}$</td>
<td>$T_j=100^\circ C$</td>
<td>22000</td>
<td>Ω</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$R_{thJH}=1000 \Omega$</td>
<td>$R_{thJH}=1486 \Omega$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$T_j=25^\circ C$</td>
<td>+14</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$T_j=125^\circ C$</td>
<td>+14</td>
</tr>
<tr>
<td>Power dissipation constant</td>
<td>$P$</td>
<td>$T_j=25^\circ C$</td>
<td>200</td>
<td>mW</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$T_j=125^\circ C$</td>
<td>2</td>
</tr>
<tr>
<td>B-value</td>
<td>$B(25/50)$</td>
<td>$T_j=25^\circ C$</td>
<td>3950</td>
<td>K</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_j=125^\circ C$</td>
<td>3996</td>
<td>K</td>
</tr>
<tr>
<td>Vincotech NTC Reference</td>
<td></td>
<td></td>
<td></td>
<td>B</td>
</tr>
</tbody>
</table>

### Thermistor

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
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<tr>
<td>Rated resistance</td>
<td>$R$</td>
<td>$T_j=25^\circ C$</td>
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<td>Deviation of $R_{100}$</td>
<td>$\Delta R/R$</td>
<td>$R_{100}=1486 \Omega$</td>
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<tr>
<td>Power dissipation</td>
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<td>B-value</td>
<td>$B(25/50)$</td>
<td>$T_j=25^\circ C$</td>
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<td>Vincotech NTC Reference</td>
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## Characteristic Values

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<td>Parameter</td>
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<tr>
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<td>V_{GE} [V] or V_{GS} [V]</td>
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<td></td>
<td>V_{r} [V] or V_{CE} [V] or V_{DS} [V]</td>
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<td>I_{C} [A] or I_{F} [A] or I_{D} [A]</td>
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<tr>
<td></td>
<td>T_{j}</td>
<td>Min</td>
<td>Typ</td>
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<table>
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<tr>
<th>Module Properties</th>
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<tr>
<td>Module inductance (from chip to PCB)</td>
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<tr>
<td>Module inductance (from PCB to PCB using Intercon board)</td>
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<tr>
<td>Resistance of Intercon boards (from PCB to PCB using Intercon board)</td>
</tr>
<tr>
<td>Mounting torque</td>
</tr>
<tr>
<td>Mounting torque</td>
</tr>
<tr>
<td>Terminal connection torque</td>
</tr>
<tr>
<td>Weight</td>
</tr>
</tbody>
</table>

*Module inductance (from chip to PCB):* $L_{CE}$

*Module inductance (from PCB to PCB using Intercon board):* $L_{CE,PCB}$

*Resistance of Intercon boards (from PCB to PCB using Intercon board):* $R_{CE,PCB}$

*Mounting torque (M):* Screw M4 and M5

*Terminal connection torque (M):* Screw M6

*Weight (G):* 710 g
**Buck operation**

Half Bridge IGBT (T1, T4) & Neutral Point FWD (D2, D3)

**Figure 1**

Typical output characteristics

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

At

\[ t_{p} = 350 \ \mu s \]
\[ T_j = 25 \ ^\circ C \]

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

**Figure 2**

Typical output characteristics

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

At

\[ t_{p} = 350 \ \mu s \]
\[ T_j = 125 \ ^\circ C \]

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

**Figure 3**

Typical transfer characteristics

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

**Figure 4**

Typical diode forward current as a function of forward voltage

\[ I_F = f(V_F) \]

At

\[ t_{p} = 350 \ \mu s \]
\[ V_{CE} = 10 \ \text{V} \]

**Typical output characteristics**

- **IGBT**: 
  - \[ I_C = f(V_{CE}) \]
  - At
    - \[ t_{p} = 350 \ \mu s \]
    - \[ T_j = 25 \ ^\circ C \]
    - \[ V_{CE} \text{ from } 7 \text{ V to } 17 \text{ V in steps of } 1 \text{ V} \]

- **FWD**: 
  - \[ I_C = f(V_{GE}) \]
  - At
    - \[ t_{p} = 350 \ \mu s \]
    - \[ V_{CE} = 10 \ \text{V} \]
**Figure 5**

Typical switching energy losses as a function of collector current

\[ E = f(I_C) \]

With an inductive load at

- \( T_j = 25 / 125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{goln} = 1 \) Ω
- \( R_{goff} = 1 \) Ω

**Figure 6**

Typical switching energy losses as a function of gate resistor

\[ E = f(R_G) \]

With an inductive load at

- \( T_j = 25 / 125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_c = 400 \) A

**Figure 7**

Typical reverse recovery energy loss as a function of collector current

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

With an inductive load at

- \( T_j = 25 / 125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{goln} = 1 \) Ω

**Figure 8**

Typical reverse recovery energy loss as a function of gate resistor

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

With an inductive load at

- \( T_j = 25 / 125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_c = 400 \) A
Buck operation
Half Bridge IGBT (T1, T4) & Neutral Point FWD (D2, D3)

Figure 9
Typical switching times as a function of collector current

With an inductive load at

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

\[ V_{CE} = 350 \, \text{V} \]

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

\[ R_{gon} = 1 \, \Omega \]

\[ R_{goff} = 1 \, \Omega \]

Figure 10
Typical switching times as a function of gate resistor

With an inductive load at

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

\[ V_{CE} = 350 \, \text{V} \]

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

\[ I_C = 400 \, \text{A} \]

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

At

\[ T_J = 25 / 125 \, ^\circ\text{C} \]

\[ V_{CE} = 350 \, \text{V} \]

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

\[ R_{gon} = 1 \, \Omega \]

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

At

\[ T_J = 25 / 125 \, ^\circ\text{C} \]

\[ V_{B} = 350 \, \text{V} \]

\[ I_B = 400 \, \text{A} \]

\[ V_{GE} = \pm 15 \, \text{V} \]
Buck operation
Half Bridge IGBT (T1, T4) & Neutral Point FWD (D2, D3)

**Figure 13**
Typical reverse recovery charge as a function of collector current
\[ Q_{rr} = f(I_C) \]

**Figure 14**
Typical reverse recovery charge as a function of IGBT turn on gate resistor
\[ Q_{rr} = f(R_{gon}) \]

**Figure 15**
Typical reverse recovery current as a function of collector current
\[ I_{RRM} = f(I_C) \]

**Figure 16**
Typical reverse recovery current as a function of IGBT turn on gate resistor
\[ I_{RRM} = f(R_{gon}) \]

**At**
- \( T_j = 25 / 125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 1 \) Ω

**At**
- \( T_j = 25 / 125 \) °C
- \( V_{BE} = 350 \) V
- \( I_F = 400 \) A
- \( V_{GE} = \pm 15 \) V

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Buck operation
Half Bridge IGBT (T1, T4) & Neutral Point FWD (D2, D3)

**Figure 17**
Typical rate of fall of forward and reverse recovery current as a function of collector current $\frac{dI}{dt},\frac{dI}{dt}$ as $f(Ic)$

![Graph showing typical rate of fall of forward and reverse recovery current as a function of collector current.]

**Figure 18**
Typical rate of fall of forward and reverse recovery current as a function of IGBT turn on gate resistor $\frac{dI}{dt},\frac{dI}{dt}$ as $f(R_{gon})$

![Graph showing typical rate of fall of forward and reverse recovery current as a function of IGBT turn on gate resistor.]

**Figure 19**
IGBT transient thermal impedance as a function of pulse width $Z_{thJH} = f(t_p)$

![Graph showing IGBT transient thermal impedance as a function of pulse width.]

**Figure 20**
FWD transient thermal impedance as a function of pulse width $Z_{thJH} = f(t_p)$

![Graph showing FWD transient thermal impedance as a function of pulse width.]

**IGBT thermal model values**

<table>
<thead>
<tr>
<th>$R$ (C/W)</th>
<th>$\tau$ (s)</th>
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</thead>
<tbody>
<tr>
<td>0.02</td>
<td>2.9E+00</td>
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<tr>
<td>0.02</td>
<td>6.6E-01</td>
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<td>1.3E-01</td>
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<td>5.0E-03</td>
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<td>0.01</td>
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**FWD thermal model values**

<table>
<thead>
<tr>
<th>$R$ (C/W)</th>
<th>$\tau$ (s)</th>
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<tr>
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<td>0.04</td>
<td>1.1E-02</td>
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<td>0.02</td>
<td>1.8E-03</td>
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</tbody>
</table>
Buck operation
Half Bridge IGBT (T1, T4) & Neutral Point FWD (D2, D3)

Figure 21
Power dissipation as a function of heatsink temperature
\[ P_{\text{tot}} = f(T_h) \]

At
\[ T_j = 175 \, ^\circ\text{C} \]

Figure 22
Collector current as a function of heatsink temperature
\[ I_C = f(T_h) \]

At
\[ T_j = 175 \, ^\circ\text{C} \]
\[ V_{GE} = 15 \, \text{V} \]

Figure 23
Power dissipation as a function of heatsink temperature
\[ P_{\text{tot}} = f(T_h) \]

At
\[ T_j = 175 \, ^\circ\text{C} \]

Figure 24
Forward current as a function of heatsink temperature
\[ I_F = f(T_h) \]

At
\[ T_j = 175 \, ^\circ\text{C} \]
Buck operation
Half Bridge IGBT (T1, T4) & Neutral Point FWD (D2, D3)

Figure 29
Reverse bias safe operating area

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

At
\[ T_j = 125 \, ^\circ C \]
\[ R_{g_{on}} = 1 \, \Omega \]
\[ R_{goff} = 1 \, \Omega \]
Boost operation
Neutral Point IGBT (T2, T3) & Half Bridge FWD (D1, D4)

Figure 1
Typical output characteristics
$I_C = f(V_{CE})$

![Graph of $I_C$ vs $V_{CE}$](graph1)

At
$t_p = 350 \mu s$
$T_j = 25 ^\circ C$
$V_{CE}$ from 7 V to 17 V in steps of 1 V

Figure 2
Typical output characteristics
$I_C = f(V_{GE})$

![Graph of $I_C$ vs $V_{GE}$](graph2)

At
$t_p = 350 \mu s$
$T_j = 125 ^\circ C$
$V_{CE}$ from 7 V to 17 V in steps of 1 V

Figure 3
Typical transfer characteristics
$I_C = f(V_{CE})$

![Graph of $I_C$ vs $V_{CE}$](graph3)

At
$t_p = 350 \mu s$
$V_{CE} = 10 V$

Figure 4
Typical diode forward current as a function of forward voltage
$I_F = f(V_F)$

![Graph of $I_F$ vs $V_F$](graph4)

At
$t_p = 350 \mu s$

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Neutral Point IGBT (T2, T3) & Half Bridge FWD ((D1, D4))

**Figure 5**
Typical switching energy losses as a function of collector current
\[ E = f(I_C) \]

With an inductive load at
\[ T_j = 25 \text{ / } 125 \, ^\circ \text{C} \]
\[ V_{CE} = 350 \, \text{V} \]
\[ V_{GE} = \pm 15 \, \text{V} \]
\[ R_{gon} = 2 \, \Omega \]
\[ R_{goff} = 2 \, \Omega \]

**Figure 6**
Typical switching energy losses as a function of gate resistor
\[ E = f(R_G) \]

With an inductive load at
\[ T_j = 25 \text{ / } 125 \, ^\circ \text{C} \]
\[ V_{CE} = 350 \, \text{V} \]
\[ V_{GE} = \pm 15 \, \text{V} \]
\[ I_C = 300 \, \text{A} \]

**Figure 7**
Typical reverse recovery energy loss as a function of collector current
\[ E_{rec} = f(I_C) \]

**Figure 8**
Typical reverse recovery energy loss as a function of gate resistor
\[ E_{rec} = f(R_G) \]

With an inductive load at
\[ T_j = 25 \text{ / } 125 \, ^\circ \text{C} \]
\[ V_{CE} = 350 \, \text{V} \]
\[ V_{GE} = \pm 15 \, \text{V} \]
\[ I_C = 300 \, \text{A} \]
Neutral Point IGBT (T2, T3) & Half Bridge FWD ((D1, D4)

**Figure 9**
Typical switching times as a function of collector current
\[ t = f(I_C) \]

With an inductive load at
- \( T_J = 125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{CE} = \pm 15 \) V
- \( R_{gon} = 2 \) Ω
- \( R_{goff} = 2 \) Ω

**Figure 10**
Typical switching times as a function of gate resistor
\[ t = f(R_G) \]

With an inductive load at
- \( T_J = 125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{CE} = \pm 15 \) V
- \( I_C = 300 \) A

**Figure 11**
Typical reverse recovery time as a function of collector current
\[ t_{rr} = f(I_C) \]

At
- \( T_J = 25 / 125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{CE} = \pm 15 \) V
- \( R_{gon} = 2 \) Ω

**Figure 12**
Typical reverse recovery time as a function of IGBT turn on gate resistor
\[ t_{rr} = f(R_{gon}) \]

At
- \( T_J = 25 / 125 \) °C
- \( V_{CE} = 350 \) V
- \( I_T = 300 \) A
- \( V_{GE} = \pm 15 \) V
**Boost operation**

Neutral Point IGBT (T2, T3) & Half Bridge FWD ((D1, D4)

**Figure 13**
Typical reverse recovery charge as a function of collector current

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

![Graph showing typical reverse recovery charge as a function of collector current.](image)

**At**
- \( T_j = 25 / 125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 2 \) Ω

**Figure 14**
Typical reverse recovery charge as a function of IGBT turn on gate resistor

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

![Graph showing typical reverse recovery charge as a function of IGBT turn on gate resistor.](image)

**At**
- \( T_j = 25 / 125 \) °C
- \( V_{GE} = 350 \) V
- \( I_F = 300 \) A
- \( V_{GE} = \pm 15 \) V

**Figure 15**
Typical reverse recovery current as a function of collector current

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

![Graph showing typical reverse recovery current as a function of collector current.](image)

**At**
- \( T_j = 25 / 125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 2 \) Ω

**Figure 16**
Typical reverse recovery current as a function of IGBT turn on gate resistor

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

![Graph showing typical reverse recovery current as a function of IGBT turn on gate resistor.](image)

**At**
- \( T_j = 25 / 125 \) °C
- \( V_{GE} = 350 \) V
- \( I_F = 300 \) A
- \( V_{GE} = \pm 15 \) V

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Revision: 1.2
Boost operation
Neutral Point IGBT (T2, T3) & Half Bridge FWD ((D1, D4)

Figure 17
Typical rate of fall of forward and reverse recovery current as a function of collector current $\frac{dI}{dt}, \frac{dI_{rec}}{dt} = f(Ic)$

At
$Tj = 25 / 125 ^\circ C$
$VGE = 350 V$
$VGE = \pm 15 V$
$R_{gon} = 2 \Omega$

Figure 18
Typical rate of fall of forward and reverse recovery current as a function of IGBT turn on gate resistor $\frac{dI}{dt}, \frac{dI_{rec}}{dt} = f(I_{ton})$

At
$Tj = 25 / 125 ^\circ C$
$VGE = 350 V$
$Ir = 300 A$
$VGE = \pm 15 V$

Figure 19
IGBT transient thermal impedance as a function of pulse width $Z_{thJH} = f(t_p)$

$D = \frac{tp}{T}$
$R_{thJH} = 0.19 KW$

IGBT thermal model values
$R (C/W)$ $\tau (s)$
0.02 5.05
0.03 1.19
0.03 0.24
0.06 0.05
0.04 0.02
0.01 0.00

Figure 20
FWD transient thermal impedance as a function of pulse width $Z_{thJH} = f(t_p)$

$D = \frac{tp}{T}$
$R_{thJH} = 0.18 KW$

FWD thermal model values
$R (C/W)$ $\tau (s)$
0.02 4.17
0.03 0.86
0.05 0.15
0.06 0.03
0.01 0.01
0.01 0.00
Boost operation
Neutral Point IGBT (T2, T3) & Half Bridge FWD ((D1, D4)

Figure 21  IGBT
Power dissipation as a function of heatsink temperature
$P_{\text{tot}} = f(T_h)$

At
$T_j = 175 \degree C$

Figure 22  IGBT
Collector current as a function of heatsink temperature
$I_C = f(T_h)$

At
$T_j = 175 \degree C$
$V_{GE} = 15 \ V$

Figure 23  FWD
Power dissipation as a function of heatsink temperature
$P_{\text{tot}} = f(T_h)$

At
$T_j = 175 \degree C$

Figure 24  FWD
Forward current as a function of heatsink temperature
$I_F = f(T_h)$

At
$T_j = 175 \degree C$
Figure 1

Thermistor

Typical NTC characteristic
as a function of temperature

\[ R_T = f(T) \]
Switching Definitions Half Bridge

General conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>$T_J$</td>
<td>125 °C</td>
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<tr>
<td>$R_{Jth}$</td>
<td>1 Ω</td>
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</table>

Turn-off Switching Waveforms & definition of $t_{off}$, $t_{Eoff}$

- $V_{GE}(0\%) = -15$ V
- $V_{GE}(100\%) = 15$ V
- $V_{C}(100\%) = 700$ V
- $I_{C}(100\%) = 400$ A
- $t_{off} = 0.19$ µs
- $t_{Eoff} = 0.86$ µs

Turn-on Switching Waveforms & definition of $t_{on}$, $t_{Eon}$

- $V_{GE}(0\%) = -15$ V
- $V_{GE}(100\%) = 15$ V
- $V_{C}(100\%) = 700$ V
- $I_{C}(100\%) = 400$ A
- $t_{on} = 0.12$ µs
- $t_{Eon} = 0.24$ µs

Turn-off Switching Waveforms & definition of $t_{f}$

- $V_{C}(100\%) = 700$ V
- $I_{C}(100\%) = 400$ A
- $t_{f} = 0.07$ µs

Turn-on Switching Waveforms & definition of $t_{r}$

- $V_{C}(100\%) = 700$ V
- $I_{C}(100\%) = 400$ A
- $t_{r} = 0.02$ µs
Switching Definitions Half Bridge

Figure 5
Turn-off Switching Waveforms & definition of $t_{\text{Eoff}}$

- $P_{\text{off}}(100\%) = 280$ kW
- $E_{\text{off}}(100\%) = 17.66$ mJ
- $t_{\text{Eoff}} = 0.86$ µs

Figure 6
Turn-on Switching Waveforms & definition of $t_{\text{Eon}}$

- $P_{\text{on}}(100\%) = 280$ kW
- $E_{\text{on}}(100\%) = 5.40$ mJ
- $t_{\text{Eon}} = 0.24$ µs

Figure 7
Turn-off Switching Waveforms & definition of $t_{\text{rr}}$

- $V_d(100\%) = 700$ V
- $I_d(100\%) = 400$ A
- $I_{\text{fmax}}(100\%) = -320$ A
- $t_{\text{rr}} = 0.27$ µs

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Switching Definitions Half Bridge

**Figure 6** Neutral Point FWD
Turn-on Switching Waveforms & definition of $t_{Qrr}$
($t_{Qrr}$ = integrating time for $Q_{rr}$)

![Waveform diagram](image)

$I_d (100\%) = 400 \text{ A}$
$E_{rec} (100\%) = 30.81 \mu \text{C}$
$t_{Qrr} = 0.54 \mu \text{s}$

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

![Waveform diagram](image)

$P_{rec} (100\%) = 280 \text{ kW}$
$E_{rec} (100\%) = 7.81 \text{ mJ}$
$t_{Erec} = 0.54 \mu \text{s}$

**Measurement circuits**

**Figure 10**
Half Bridge stage switching measurement circuit

![Circuit diagram](image)
Switching Definitions Neutral Point

General conditions

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_J$</td>
<td>125 °C</td>
</tr>
<tr>
<td>$R_{on}$</td>
<td>2 Ω</td>
</tr>
<tr>
<td>$R_{off}$</td>
<td>2 Ω</td>
</tr>
</tbody>
</table>

Figure 1: Neutral Point IGBT
Turn-off Switching Waveforms & definition of $t_{doff}$, $t_{Eoff}$
($t_{Eoff}$ = integrating time for $E_{off}$)

- $V_{CE} (0\%) = -15$ V
- $V_{CE} (100\%) = 15$ V
- $V_C (100\%) = 700$ V
- $I_C (100\%) = 300$ A
- $t_{doff} = 0.26$ μs
- $t_{Eoff} = 0.77$ μs

Figure 2: Neutral Point IGBT
Turn-on Switching Waveforms & definition of $t_{don}$, $t_{Eon}$
($t_{Eon}$ = integrating time for $E_{on}$)

- $V_{CE} (0\%) = -15$ V
- $V_{CE} (100\%) = 15$ V
- $V_C (100\%) = 700$ V
- $I_C (100\%) = 300$ A
- $t_{don} = 0.19$ μs
- $t_{Eon} = 0.28$ μs

Figure 3: Neutral Point IGBT
Turn-off Switching Waveforms & definition of $t_f$

- $V_C (100\%) = 700$ V
- $I_C (100\%) = 300$ A
- $t_f = 0.12$ μs

Figure 4: Neutral Point IGBT
Turn-on Switching Waveforms & definition of $t_r$

- $V_C (100\%) = 700$ V
- $I_C (100\%) = 300$ A
- $t_r = 0.03$ μs
Switching Definitions Neutral Point

**Figure 5**
Neutral Point IGBT

Turn-off Switching Waveforms & definition of $t_{Eoff}$

- $P_{off}(100\%) = 210$ kW
- $E_{off}(100\%) = 14.03$ mJ
- $t_{Eoff} = 0.77$ µs

**Figure 6**
Neutral Point IGBT

Turn-on Switching Waveforms & definition of $t_{Eon}$

- $P_{on}(100\%) = 210$ kW
- $E_{on}(100\%) = 6.19$ mJ
- $t_{Eon} = 0.28$ µs

**Figure 7**
Neutral Point IGBT

Turn-off Switching Waveforms & definition of $t_{rr}$

- $V_d(100\%) = 700$ V
- $I_d(100\%) = 300$ A
- $I_{rr max}(100\%) = -385$ A
- $t_{rr} = 0.15$ µs
Switching Definitions Neutral Point

**Figure 6** Half Bridge FWD

Turn-on Switching Waveforms & definition of $t_{Qrr}$

($t_{Qrr}$ = integrating time for $Q_{rr}$)

![Waveform graph showing $I_d$, $Q_{rr}$, and $t_{Qrr}$](image)

- $I_d(100\%) = 300$ A
- $Q_{rr}(100\%) = 38.18$ µC
- $t_{Qrr} = 1.00$ µs

**Figure 9** Half Bridge FWD

Turn-on Switching Waveforms & definition of $t_{Erec}$

($t_{Erec}$ = integrating time for $E_{rec}$)

![Waveform graph showing $P_{rec}$, $E_{rec}$, and $t_{Erec}$](image)

- $P_{rec}(100\%) = 210$ kW
- $E_{rec}(100\%) = 9.72$ mJ
- $t_{Erec} = 1.00$ µs

**Measurement circuits**

**Figure 10**

Neutral Point stage switching measurement circuit

![Circuit diagram](image)
Ordering Code and Marking - Outline - Pinout
Ordering Code and Marking - Outline - Pinout

Outline

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Power connections

*Low current connections*

Centerline of press-fit pinhead

convexity for each baseplate

only convex 0.25±0.15mm

Screw depth from PCB top

min. 7
max. 10
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