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

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

### Types
- 70-W212NMA600NB04-M200P60

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### VINcoMNPC X4
1200 V / 600 A

#### Maximum Ratings

**Tj=25°C, unless otherwise specified**

<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 breakdown voltage</td>
<td>V_{CE}</td>
<td>T_1=T_{j,max} T_h=80°C</td>
<td>1200</td>
<td>V</td>
</tr>
<tr>
<td>DC collector current</td>
<td>I_{C}</td>
<td>T_1=T_{j,max}</td>
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<tr>
<td>Repetitive peak collector current</td>
<td>I_{CPulse}</td>
<td>t_p limited by T_{j,max}</td>
<td>1200</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>P_{tot}</td>
<td>T_1=T_{j,max}</td>
<td>1051</td>
<td>W</td>
</tr>
<tr>
<td>Gate-emitter peak voltage</td>
<td>V_{CE}</td>
<td>T_{j}</td>
<td>-20</td>
<td>V</td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>t_{SC}</td>
<td>T_1≤150°C V_{CE}=15V</td>
<td>10</td>
<td>µs</td>
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<tr>
<td></td>
<td>V_{CC}</td>
<td></td>
<td>850</td>
<td>V</td>
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<tr>
<td>Maximum Junction Temperature</td>
<td>T_{j,max}</td>
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<td>175</td>
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#### Neutral point FWD (D2, D3)

<table>
<thead>
<tr>
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<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
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<tr>
<td>Peak Repetitive Reverse Voltage</td>
<td>V_{RRM}</td>
<td>T_1=T_{j,max} T_{h}=80°C</td>
<td>650</td>
<td>V</td>
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<td>DC forward current</td>
<td>I_{F}</td>
<td>T_1=T_{j,max}</td>
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<td>Repetitive peak forward current</td>
<td>I_{FPM}</td>
<td>t_p = 1 ms T_{a} &lt; 150°C</td>
<td>800</td>
<td>A</td>
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<td>Power dissipation</td>
<td>P_{tot}</td>
<td>T_1=T_{j,max}</td>
<td>354</td>
<td>W</td>
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<tr>
<td>Maximum Junction Temperature</td>
<td>T_{j,max}</td>
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Maximum Ratings

<table>
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<tr>
<td>Neutral point IGBT (T2, T3)</td>
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<tr>
<td>Collector-emitter breakdown voltage</td>
<td>V_{CE}</td>
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<td>650</td>
<td>V</td>
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<tr>
<td>DC collector current</td>
<td>I_c</td>
<td>T_j=T_{j,max}</td>
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<tr>
<td>Repetitive peak collector current</td>
<td>I_{paks}</td>
<td>t_p limited by T_{j,max}</td>
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<td>Gate-emitter peak voltage</td>
<td>V_{ce}</td>
<td></td>
<td>±20</td>
<td>V</td>
</tr>
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<td>Short circuit ratings</td>
<td>t_{sc}</td>
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<td></td>
<td>μs</td>
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<tr>
<td>Turn off safe operating area (RBSOA)</td>
<td>I_{max}</td>
<td>V_{CE,max} = 1200V</td>
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<td></td>
<td></td>
<td>T_{j,max} = 150°C</td>
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<tr>
<td>Maximum Junction Temperature</td>
<td>T_{j,max}</td>
<td></td>
<td>175</td>
<td>°C</td>
</tr>
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| Half bridge FWD (D1, D4)                       |        |                            |       |      |
| Peak Repetitive Reverse Voltage               | V_{esm} |                             | 1200  | V    |
| DC forward current                            | I_r    | T_j=T_{j,max}               |       | A    |
| Surge forward current                         | I_{esm} |                             | 1100  | A    |
| I2t-value                                     | t_{p}  |                             | 3026  | A²s  |
| Repetitive peak forward current               | I_{paks} |                             | 1200  | A    |
| Power dissipation                             | P_{tot} | T_j=T_{j,max}               | 596   | W    |
| Maximum Junction Temperature                  | T_{j,max} |                             | 175   | °C   |
# Maximum Ratings

T\(_j\) = 25°C, unless otherwise specified

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<thead>
<tr>
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<td>DC link Capacitor</td>
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<tr>
<td>Max. DC voltage</td>
<td>( V_{\text{MAX}} )</td>
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<td>630</td>
<td>V</td>
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<tr>
<td>Operation Temperature</td>
<td>( T_{\text{OP}} )</td>
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<td>-40...+105</td>
<td>°C</td>
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<tr>
<td>RMS Current</td>
<td>( I_{\text{RMS}} )</td>
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<td>General Module Properties</td>
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<td>Material of module baseplate</td>
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<td>Cu</td>
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<tr>
<td>Material of internal isolation</td>
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<td></td>
<td>Al2O3</td>
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</tr>
<tr>
<td>Thermal Properties</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Storage temperature</td>
<td>( T_{\text{stab}} )</td>
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<td>-40...+125</td>
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<tr>
<td>Operation temperature under switching condition</td>
<td>( T_{\text{op}} )</td>
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<td>-40...+(Tjmax - 25)</td>
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<td>Isolation Properties</td>
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<tr>
<td>Isolation voltage</td>
<td>( V_{\text{a}} )</td>
<td>( t=2s ) DC voltage</td>
<td>4000</td>
<td>V</td>
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<td>Creepage distance</td>
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<td></td>
<td>min 12,7</td>
<td>mm</td>
</tr>
<tr>
<td>Clearance</td>
<td></td>
<td></td>
<td>min 12,7</td>
<td>mm</td>
</tr>
<tr>
<td>Comparative tracking index</td>
<td>( \text{CTI} )</td>
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<td>&gt;200</td>
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## Characteristic Values

<table>
<thead>
<tr>
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<th>Value</th>
<th>Unit</th>
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<tbody>
<tr>
<td><strong>Half bridge IGBT (T1, T4)</strong></td>
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<tr>
<td>Gate-emitter threshold voltage</td>
<td>V_{th}</td>
<td>Y_{th}=Y_{th}</td>
<td>0.03</td>
<td>V</td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>V_{ce}</td>
<td>Y_{ce}=Y_{ce}</td>
<td>15, 600</td>
<td>V</td>
</tr>
<tr>
<td>Collector-emitter cut-off current, incl. FWD</td>
<td>I_{cso}</td>
<td>0, 1200</td>
<td>nA</td>
<td>mA</td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>I_{le}</td>
<td>20, 0</td>
<td>1500</td>
<td>nA</td>
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<tr>
<td>Integrated Gate resistor</td>
<td>R_{gin}</td>
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<td>Ω</td>
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<tr>
<td>Turn-on delay time</td>
<td>t_{on}</td>
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<td>15, 350, 600</td>
<td>ns</td>
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<tr>
<td>Rise time</td>
<td>t_{r}</td>
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<tr>
<td>Turn-off delay time</td>
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<td>Fall time</td>
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<td>Turn-on energy loss</td>
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<td>Turn-off energy loss</td>
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<td>Input capacitance</td>
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<td>Output capacitance</td>
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<td>Reverse transfer capacitance</td>
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<td><strong>Neutral point FWD (D2, D3)</strong></td>
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<td>PWD forward voltage</td>
<td>V_{FWD}</td>
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<td>Peak reverse recovery current</td>
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<td>Reverse recovery time</td>
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<td>ns</td>
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<td>Reverse recovered charge</td>
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<td>μC</td>
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<td>Peak rate of fall of recovery current</td>
<td>E_{r}</td>
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<td>A/μs</td>
</tr>
<tr>
<td>Reverse recovered energy</td>
<td>E_{rr}</td>
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<td>3</td>
<td>mWs</td>
</tr>
<tr>
<td><strong>Neutral point IGBT (T2, T3)</strong></td>
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<td></td>
</tr>
<tr>
<td>Gate-emitter threshold voltage</td>
<td>V_{th}</td>
<td>Y_{th}=Y_{th}</td>
<td>0.0032</td>
<td>V</td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>V_{ce}</td>
<td>Y_{ce}=Y_{ce}</td>
<td>15, 400</td>
<td>V</td>
</tr>
<tr>
<td>Collector-emitter cut-off incl. FWD</td>
<td>I_{cso}</td>
<td>0, 650</td>
<td>nA</td>
<td>mA</td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>I_{le}</td>
<td>20, 0</td>
<td>1500</td>
<td>nA</td>
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<tr>
<td>Rise time</td>
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<td>Turn-off delay time</td>
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<tr>
<td>Fall time</td>
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<tr>
<td>Turn-off energy loss</td>
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<td>pF</td>
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<td>Output capacitance</td>
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<td>Reverse transfer capacitance</td>
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<td>732</td>
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<tr>
<td>Gate charge</td>
<td>Q_{in}</td>
<td>15, 480, 600</td>
<td>2507</td>
<td>nC</td>
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<tr>
<td><strong>Thermal resistance junction to sink</strong></td>
<td>R_{jcs}</td>
<td>100μm preapplied PCM</td>
<td>0.09</td>
<td>K/W</td>
</tr>
<tr>
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<td>K/W</td>
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<td><strong>Neutral point IGBT (T2, T3)</strong></td>
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<tr>
<td>Gate-emitter threshold voltage</td>
<td>V_{th}</td>
<td>Y_{th}=Y_{th}</td>
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<td>V</td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>V_{ce}</td>
<td>Y_{ce}=Y_{ce}</td>
<td>15, 400</td>
<td>V</td>
</tr>
<tr>
<td>Collector-emitter cut-off incl. FWD</td>
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<td>nA</td>
<td>mA</td>
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<tr>
<td>Gate-emitter leakage current</td>
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<td>1500</td>
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<td>Integrated Gate resistor</td>
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<td>Ω</td>
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<tr>
<td>Turn-on delay time</td>
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<td>ns</td>
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<td>Rise time</td>
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<td>Turn-off delay time</td>
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<td>Fall time</td>
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<td>Turn-on energy loss</td>
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<td>Turn-off energy loss</td>
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<tr>
<td>Input capacitance</td>
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<td>pF</td>
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<td>Output capacitance</td>
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<td>Reverse transfer capacitance</td>
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<td>Gate charge</td>
<td>Q_{in}</td>
<td>15, 480, 600</td>
<td>2507</td>
<td>nC</td>
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<tr>
<td><strong>Thermal resistance junction to sink</strong></td>
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<td>100μm preapplied PCM</td>
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<td>K/W</td>
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### Characteristic Values

<table>
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<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
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<tbody>
<tr>
<td>Peak reverse recovery current</td>
<td>(i_{	ext{comm}})</td>
<td>Tj=25°C, Tj=125°C</td>
<td>≤600</td>
<td>µA</td>
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<td>Reverse recovery time (t_{	ext{rec}})</td>
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<td>≤9</td>
<td>µC</td>
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<td>Peak rate of fall of recovery current (dV/dt)</td>
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<td>Tj=25°C, Tj=125°C</td>
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### DC link Capacitor

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<td>Tolerance</td>
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### Thermistor

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<td>Rated resistance</td>
<td>(R)</td>
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<td>Ω</td>
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<tr>
<td>Deviation of (R_{25})</td>
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<td>Power dissipation constant</td>
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<td>B-value (R_{25})</td>
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### Module Properties

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<td>Module inductance (from chips to PCB)</td>
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<td>Module inductance (from PCB to PCB using Intercon board)</td>
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<tr>
<td>Mounting torque</td>
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<td>Nm</td>
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<td>Mounting torque</td>
<td></td>
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<td>Terminal connection torque</td>
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<tr>
<td>Weight</td>
<td></td>
<td>710</td>
<td>g</td>
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</table>
Buck operation

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

Figure 1  IGBT
Typical output characteristics Vge=15V
$I_C = f(V_{CE})$

At $t_p = 350 \mu s$
$T_j = 25/125/150 ^\circ C$
$V_{GE} = 15 \text{ V}$

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

At $t_p = 350 \mu s$
$T_j = 150 ^\circ C$
$V_{GE}$ from 7 V to 17 V in steps of 1 V

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

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

At $t_p = 350 \mu s$
$V_{CE} = 350 \text{ V}$
$T_j = 25/125/150 ^\circ C$
Buck operation
Half Bridge IGBT (T1,T4) and Neutral Point FWD (D2,D3)

**Figure 5**
Typical switching energy losses as a function of collector current

\[ E = f(I_C) \]

With an inductive load at

- \( T_J = 25/125/150 ^\circ C \)
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 0.5 \) Ω
- \( R_{goff} = 0.5 \) Ω

**Figure 6**
Typical switching energy losses as a function of gate resistor

\[ E = f(R_G) \]

With an inductive load at

- \( T_J = 25/125/150 ^\circ C \)
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_C = 601 \) A

**Figure 7**
Typical reverse recovery energy loss as a function of collector current

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

With an inductive load at

- \( T_J = 25/125/150 ^\circ C \)
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 0.5 \) Ω

**Figure 8**
Typical reverse recovery energy loss as a function of gate resistor

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

With an inductive load at

- \( T_J = 25/125/150 ^\circ C \)
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_C = 601 \) A
Buck operation

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

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

With an inductive load at  
\[ T_j = 125 \, ^\circ C \]  
\[ V_{CE} = 350 \, V \]  
\[ V_{GE} = \pm 15 \, V \]  
\[ R_{gon} = 0,5 \, \Omega \]  
\[ R_{goff} = 0,5 \, \Omega \]

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

With an inductive load at  
\[ T_j = 125 \, ^\circ C \]  
\[ V_{CE} = 350 \, V \]  
\[ V_{GE} = \pm 15 \, V \]  
\[ I_C = 601 \, A \]

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

At  
\[ T_j = 25/125/150 \, ^\circ C \]  
\[ V_{CE} = 350 \, V \]  
\[ V_{GE} = \pm 15 \, V \]  
\[ R_{gon} = 0,5 \, \Omega \]

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

At  
\[ T_j = 25/125/150 \, ^\circ C \]  
\[ V_{RA} = 350 \, V \]  
\[ I_T = 601 \, A \]  
\[ V_{GE} = \pm 15 \, V \]
Buck operation
Half Bridge IGBT (T1,T4) and Neutral Point FWD (D2,D3)

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

![Graph showing \( Q_{rr} \) vs. \( I_C \)]

At
\[ T_J = 25/125/150 \, ^\circ C \]
\[ V_{CE} = 350 \, V \]
\[ V_{GE} = \pm 15 \, V \]
\[ R_{gon} = 0.5 \, \Omega \]

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

![Graph showing \( Q_{rr} \) vs. \( R_{gon} \)]

At
\[ T_J = 25/125/150 \, ^\circ C \]
\[ V_R = 350 \, V \]
\[ I_F = 601 \, A \]
\[ V_{GE} = \pm 15 \, V \]

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

![Graph showing \( I_{RRM} \) vs. \( I_C \)]

At
\[ T_J = 25/125/150 \, ^\circ C \]
\[ V_{CE} = 350 \, V \]
\[ V_{GE} = \pm 15 \, V \]
\[ R_{gon} = 0.5 \, \Omega \]

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

![Graph showing \( I_{RRM} \) vs. \( R_{gon} \)]

At
\[ T_J = 25/125/150 \, ^\circ C \]
\[ V_R = 350 \, V \]
\[ I_F = 601 \, A \]
\[ V_{GE} = \pm 15 \, V \]
Buck operation
Half Bridge IGBT (T1,T4) and Neutral Point FWD (D2,D3)

**Figure 17**
Typical rate of fall of forward and reverse recovery current as a function of collector current
\[ \frac{dI_0}{dt}, \frac{dI_{rec}}{dt} = f(I_{c}) \]

\[ \begin{align*}
&\text{At} \\
&T_j = 25/125/150 \, ^\circ C \\
&V_{CE} = 350 \, V \\
&V_{GE} = \pm 15 \, V \\
&R_{gon} = 1,0 \, \Omega \\
\end{align*} \]

**Figure 18**
Typical rate of fall of forward and reverse recovery current as a function of IGBT turn on gate resistor
\[ \frac{dI_0}{dt}, \frac{dI_{rec}}{dt} = f(R_{gon}) \]

\[ \begin{align*}
&\text{At} \\
&T_j = 25/125/150 \, ^\circ C \\
&V_R = 350 \, V \\
&I_F = 601 \, A \\
&V_{GE} = \pm 15 \, V \\
\end{align*} \]

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

\[ \begin{align*}
&\text{At} \\
&D = t_p / T \\
&\text{Preapplied PCM} \\
&R_{th} = 0,09 \, K/W & R_{th} = 0,11 \, K/W \\
\end{align*} \]

100um preapplied PCM
100um grease 1W/mK (P12)
R (K/W) Tau (s) R (K/W) Tau (s)
4,16E-02 1,92E+00 5,06E-02 1,92E+00
2,44E-02 2,34E-01 2,97E-02 2,34E-01
2,28E-02 3,53E-02 2,77E-02 3,53E-02
1,69E-03 5,94E-03 2,06E-03 5,94E-03

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

\[ \begin{align*}
&\text{At} \\
&D = t_p / T \\
&\text{Preapplied PCM} \\
&R_{th} = 0,09 \, K/W & R_{th} = 0,11 \, K/W \\
\end{align*} \]

100um preapplied PCM
100um grease 1W/mK (P12)
R (K/W) Tau (s) R (K/W) Tau (s)
4,04E-02 5,63E+00 4,67E-02 5,63E+00
4,43E-02 1,07E+00 5,12E-02 1,07E+00
4,38E-02 2,02E-01 5,07E-02 2,02E-01
3,79E-02 4,11E-02 1,00E-01 4,11E-02
1,49E-02 1,48E-03 1,72E-02 1,48E-03
**Buck operation**

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

**Figure 21**

IGBT

Power dissipation as a function of heatsink temperature

\[ P_{\text{tot}} = f(T_h) \]

At

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

**Figure 22**

IGBT

Collector current as a function of heatsink temperature

\[ I_C = f(T_h) \]

At

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

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

**Figure 23**

FWD

Power dissipation as a function of heatsink temperature

\[ P_{\text{tot}} = f(T_h) \]

At

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

**Figure 24**

FWD

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) and Neutral Point FWD (D2,D3)

Figure 21
IGBT
Reverse bias safe operating area

At
\[ T_j = 25,150 \, ^\circ C \]
\[ U_{cc\text{minus}} = U_{cc\text{plus}} = U_{cc}/2 \]
\[ V_{GE} = \pm 15 \, V \]
\[ R_{\text{gon}} = 1 \, \Omega \]
Switching mode: 3 level cont 2 level dashed
Boost operation
Neutral point IGBT (T2,T3) and Half bridge FWD (D1,D4)

**Figure 1**
Typical output characteristics $V_{ge}=15\text{V}$
$I_C = f(V_{ce})$

At
$\tau_r = 350 \ \mu\text{s}$
$T_j = 25/125/150 \ ^\circ\text{C}$
$V_{ce} = 15 \ \text{V}$

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

At
$\tau_r = 350 \ \mu\text{s}$
$T_j = 151 \ ^\circ\text{C}$
$V_{ce}$ from 7 V to 17 V in steps of 1 V

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

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

At
$\tau_r = 350 \ \mu\text{s}$
$T_j = 25/125/150 \ ^\circ\text{C}$
Boost operation

Neutral point IGBT (T2, T3) and 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
- \( T_j = 25/125/150 \, ^\circ\text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( R_{gon} = 1.0 \, \Omega \)
- \( R_{goff} = 1 \, \Omega \)

**Figure 6**
Typical switching energy losses as a function of gate resistor

\[ E = f(R_G) \]

With an inductive load at
- \( T_j = 25/125/150 \, ^\circ\text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( I_C = 600 \, \text{A} \)

**Figure 7**
Typical reverse recovery energy loss as a function of collector current

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

With an inductive load at
- \( T_j = 25/125/150 \, ^\circ\text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( R_{gon} = 1 \, \Omega \)

**Figure 8**
Typical reverse recovery energy loss as a function of gate resistor

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

With an inductive load at
- \( T_j = 25/125/150 \, ^\circ\text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( I_C = 600 \, \text{A} \)
Boost operation
Neutral point IGBT (T2,T3) and 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
- \( T_j = 126 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 1 \) Ω
- \( R_{goff} = 1 \) Ω

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

With an inductive load at
- \( T_j = 126 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_C = 600 \) A

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

At
- \( T_j = 25/125/150 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 1 \) Ω

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

At
- \( T_j = 25/125/150 \) °C
- \( V_A = 350 \) V
- \( I_F = 600 \) A
- \( V_{GE} = \pm 15 \) V
Boost operation
Neutral point IGBT (T2,T3) and Half bridge FWD (D1,D4)

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

At
\[ T_J = 25/125/150 \, ^\circ C \]
\[ V_{CE} = 350 \, V \]
\[ V_{GE} = \pm 15 \, V \]
\[ R_{gon} = 1 \, \Omega \]

**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
\[ T_J = 25/125/150 \, ^\circ C \]
\[ V_R = 350 \, V \]
\[ I_F = 600 \, A \]
\[ V_{GE} = \pm 15 \, V \]
**Boost operation**

Neutral point IGBT (T2,T3) and Half bridge FWD (D1,D4)

![Figure 17](image1.png)

**Figure 17**

Typical rate of fall of forward and reverse recovery current as a function of collector current

\[
\frac{dI}{dt}, \frac{dI_{rec}}{dt} = f(I_C)
\]

At

- \( T_j = 25/125/150 \, ^\circ C \)
- \( V_{GE} = 350 \, V \)
- \( V_{GE} = \pm 15 \, V \)
- \( R_{gon} = 1 \, \Omega \)

![Figure 18](image2.png)

**Figure 18**

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

\[
\frac{dI}{dt}, \frac{dI_{rec}}{dt} = f(R_{gon})
\]

At

- \( T_j = 25/125/150 \, ^\circ C \)
- \( V_R = 350 \, V \)
- \( I_F = 600 \, A \)
- \( V_{GE} = \pm 15 \, V \)

![Figure 19](image3.png)

**Figure 19**

IGBT transient thermal impedance as a function of pulse width

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

At

- \( D = tp / T \)

Preapplied PCM

- Thermal grease

<table>
<thead>
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<th>( R_{thJH} ) (K/W)</th>
<th>( R_{thJH} ) (K/W)</th>
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<td>0,15</td>
<td>0,17</td>
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100um preapplied PCM 100um grease 1W/mK (P12)

IGBT thermal model values

- 100um preapplied PCM
- 100um grease 1W/mK (P12)

![Figure 20](image4.png)

**Figure 20**

FWD transient thermal impedance as a function of pulse width

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

At

- \( D = tp / T \)

Preapplied PCM

- Thermal grease

<table>
<thead>
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<th>( R_{thJH} ) (K/W)</th>
<th>( R_{thJH} ) (K/W)</th>
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100um preapplied PCM 100um grease 1W/mK (P12)

FWD thermal model values

- 100um preapplied PCM
- 100um grease 1W/mK (P12)
Boost operation
Neutral point IGBT (T2,T3) and Half bridge FWD (D1,D4)

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

\[ I_C = f(T_h) \]

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
\[ T_j = 175 \ ^\circ\text{C} \]
Boost operation
Neutral point IGBT (T2,T3) and Half bridge FWD (D1,D4)

**Figure 25**
Reverse bias safe operating area

**Figure 22**
Gate voltage vs Gate charge

At
\[ T_j = 25\text{°C} \]
\[ U_{\text{dominu}} = U_{\text{uplus}} + U_c/2 \]
\[ VGE = \pm 15 \text{ V} \]
\[ R_{\text{gon}} = 1 \text{ Ω} \]

At
\[ I_C = 400 \text{ A} \]
Figure 1

Thermistor

Typical NTC characteristic as a function of temperature

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

General conditions

- $T_J = 125 \, ^\circ C$
- $R_{on} = 0.5 \, \Omega$
- $R_{off} = 0.5 \, \Omega$

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

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

**Figure 3**
Half Bridge IGBT
Turn-off Switching Waveforms & definition of $t_i$

**Figure 4**
Half Bridge IGBT
Turn-on Switching Waveforms & definition of $t_r$

### Switching Definitions Half Bridge

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<th>Condition</th>
<th>Value</th>
<th>Condition</th>
<th>Value</th>
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<td>$V_{CE}$ (0%)</td>
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<td>$V_{CE}$ (100%)</td>
<td>350 V</td>
<td>$V_{CE}$ (100%)</td>
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<tr>
<td>$I_C$ (100%)</td>
<td>599 A</td>
<td>$I_C$ (100%)</td>
<td>599 A</td>
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<tr>
<td>$t_{doff}$</td>
<td>0.27 $\mu$s</td>
<td>$t_{don}$</td>
<td>0.34 $\mu$s</td>
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<td>$t_{Eoff}$</td>
<td>0.97 $\mu$s</td>
<td>$t_{Eon}$</td>
<td>0.80 $\mu$s</td>
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<td>$t_i$</td>
<td>0.07 $\mu$s</td>
<td>$t_r$</td>
<td>0.09 $\mu$s</td>
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</table>
Switching Definitions Half Bridge

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

- $P_{\text{off}} (100\%) = 209.70$ kW
- $E_{\text{off}} (100\%) = 26.34$ mJ
- $t_{\text{off}} = 0.97$ μs

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

- $P_{\text{on}} (100\%) = 209.70$ kW
- $E_{\text{on}} (100\%) = 33.64$ mJ
- $t_{\text{on}} = 0.80$ μs

**Figure 7**  
Gate voltage vs Gate charge (measured)

- $V_{\text{Goff}} = -15$ V
- $V_{\text{Coff}} = 15$ V
- $V_{\text{C}} (100\%) = 350$ V
- $I_{\text{C}} (100\%) = 599$ A
- $Q_g = 2710.20$ nC

**Figure 8**  
Turn-off Switching Waveforms & definition of $t_{\text{rr}}$

- $V_{\text{G}} (100\%) = 350$ V
- $I_{\text{d}} (100\%) = 599$ A
- $I_{\text{RRM}} (100\%) = -192$ A
- $t_{\text{rr}} = 0.42$ μs
Switching Definitions Half Bridge

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

**Figure 10**  
Neutral Point FWD  
Turn-on Switching Waveforms & definition of $t_{Erec}$  
($t_{Erec} =$ integrating time for $E_{rec}$)

- $I_d (100\%) = 599$ A
- $Q_{rr} (100\%) = 34.86$ μC
- $t_{Qrr} = 0.85$ μs

- $P_{rec} (100\%) = 209.70$ kW
- $E_{rec} (100\%) = 6.58$ mJ
- $t_{Erec} = 0.85$ μs
Figure 11

Half Bridge switching measurement circuit
Switching Definitions Neutral Point

General conditions

- $T_J = 125 \, ^\circ C$
- $R_{on} = 1 \, \Omega$
- $R_{off} = 1 \, \Omega$

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

- $V_{GE}(0\%) = -15 \, V$
- $V_{GE}(100\%) = 15 \, V$
- $V_C(100\%) = 350 \, V$
- $I_C(100\%) = 601 \, A$
- $t_{doff} = 0,23 \, \mu s$
- $t_{Eoff} = 0,58 \, \mu s$

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

- $V_{GE}(0\%) = -15 \, V$
- $V_{GE}(100\%) = 15 \, V$
- $V_C(100\%) = 350 \, V$
- $I_C(100\%) = 601 \, A$
- $t_{don} = 0,21 \, \mu s$
- $t_{Eon} = 0,38 \, \mu s$

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

- $V_C(100\%) = 350 \, V$
- $I_C(100\%) = 601 \, A$
- $t_f = 0,106 \, \mu s$

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

- $V_C(100\%) = 350 \, V$
- $I_C(100\%) = 601 \, A$
- $t_r = 0,049 \, \mu s$
Switching Definitions Neutral Point

**Figure 5** Neutral Point IGBT
Turn-off Switching Waveforms & definition of $t_{Eoff}$

- $P_{off} (100\%) = 210,20\ kW$
- $E_{off} (100\%) = 27,94\ mJ$
- $t_{Eoff} = 0,58\ \mu s$

**Figure 6** Neutral Point IGBT
Turn-on Switching Waveforms & definition of $t_{Eon}$

- $P_{on} (100\%) = 210,204\ kW$
- $E_{on} (100\%) = 13,39\ mJ$
- $t_{Eon} = 0,38\ \mu s$

**Figure 7** Neutral Point IGBT
Gate voltage vs Gate charge (measured)

- $V_{GEoff} = -15\ V$
- $V_{GEon} = 15\ V$
- $V_{CE} (100\%) = 350\ V$
- $I_{CE} (100\%) = 601\ A$
- $Q_g = 3441,54\ nC$

**Figure 8** Half Bridge FWD
Turn-off Switching Waveforms & definition of $t_{rr}$

- $V_{ GE } (100\%) = 350\ V$
- $I_2 (100\%) = 601\ A$
- $I_{RRM} (100\%) = -540\ A$
- $t_{rr} = 0,14\ \mu s$
Switching Definitions Neutral Point

**Figure 9**
Half Bridge FWD
Turn-on Switching Waveforms & definition of \( t_{Qrr} \)
(\( t_{Qrr} \) = integrating time for \( Q_{rr} \))

\[
\begin{align*}
I_d (100\%) &= 601 \text{ A} \\
Q_{rr} (100\%) &= 51,60 \text{ } \mu\text{C} \\
t_{Qrr} &= 0,33 \text{ } \mu\text{s}
\end{align*}
\]

**Figure 10**
Half Bridge FWD
Turn-on Switching Waveforms & definition of \( t_{Erec} \)
(\( t_{Erec} \) = integrating time for \( E_{rec} \))

\[
\begin{align*}
P_{rec} (100\%) &= 210,20 \text{ kW} \\
E_{rec} (100\%) &= 12,97 \text{ mJ} \\
t_{Erec} &= 0,33 \text{ } \mu\text{s}
\end{align*}
\]
Neutral Point switching measurement circuit

Figure 11
Ordering Code and Marking - Outline - Pinout

### Ordering Code & Marking

<table>
<thead>
<tr>
<th>Version</th>
<th>Ordering Code</th>
<th>in DataMatrix as</th>
<th>in packaging barcode as</th>
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</thead>
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<td>70-W212NMA600NB04-M200P60</td>
<td>M200P60</td>
<td>M200P60</td>
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<td>with PCM</td>
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<td>M200P60</td>
<td>M200P60/-3/</td>
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### Driver pins

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<tr>
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<th>Y1</th>
<th>Function</th>
<th>G1-1</th>
<th>T1</th>
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### Low current connections

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<th>Function</th>
<th>M6 screw</th>
<th>X2</th>
<th>Y2</th>
<th>Function</th>
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### Power connections

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<th>Function</th>
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<th>Function</th>
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### Outline

*Centerline of press-fit pinhead*

- Low current connections with PCM
- Power connections without PCM

---

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29 15 Jan. 2018 / Revision 2
### Ordering Code and Marking - Outline - Pinout

**Identification**

<table>
<thead>
<tr>
<th>ID</th>
<th>Component</th>
<th>Voltage</th>
<th>Current</th>
<th>Function</th>
<th>Comment</th>
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<td>600 A</td>
<td>Buck Switch</td>
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<td>400 A</td>
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</tbody>
</table>

**NOTE:** Driver pins for parallel devices are not connected inside the module! Gx-1 to Gx-2 and Ex-1 to Ex2 shall be connected on customer PCB! Where x = 1 to 4
As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, or (c) whose failure to perform when properly used in accordance with instructions for use provided in labelling can be reasonably expected to result in significant injury to the user.

2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.