**Features**
- Mixed voltage NPC
- Low inductive
- High power screw interface
- Integrated DC-snubber capacitors

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

**Types**
- 70-W212NMA400SC-M209P

---

**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>Collector-emitter break down voltage</td>
<td>$V_{CE}$</td>
<td>$T_{j}$=max, $T_{C}$=80°C</td>
<td>1200 V</td>
<td></td>
</tr>
<tr>
<td>DC collector current</td>
<td>$I_{C}$</td>
<td>$T_{j}$=max, $T_{C}$=80°C</td>
<td>338 A</td>
<td></td>
</tr>
<tr>
<td>Repetitive peak collector current</td>
<td>$I_{p}$, limited by $I_{j}$</td>
<td></td>
<td>1200 A</td>
<td></td>
</tr>
<tr>
<td>Power dissipation per IGBT</td>
<td>$P_{D}$</td>
<td>$T_{j}$=max, $T_{C}$=80°C</td>
<td>729 W</td>
<td></td>
</tr>
<tr>
<td>Gate-emitter peak voltage</td>
<td>$V_{GE}$</td>
<td>$T_{j}$=max</td>
<td>±20 V</td>
<td></td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>$I_{SC}$</td>
<td>$V_{CC}$=15V</td>
<td>10 A</td>
<td></td>
</tr>
<tr>
<td>Turn off safe operating area (RBSOA)</td>
<td>$I_{FSM}$</td>
<td>$V_{CE}$ max = 1200V, $T_{j}$ max = 150°C</td>
<td>800 A</td>
<td></td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{j}$</td>
<td></td>
<td>175 °C</td>
<td></td>
</tr>
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</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>$V_{RMS}$</td>
<td>$T_{j}$=25°C</td>
<td>600 V</td>
<td></td>
</tr>
<tr>
<td>DC forward current</td>
<td>$I_{F}$</td>
<td>$T_{j}$=max, $T_{C}$=80°C</td>
<td>309 A</td>
<td></td>
</tr>
<tr>
<td>Surge forward current</td>
<td>$I_{S}$</td>
<td>$T_{j}$=10 ms, sine halfwave</td>
<td>890 A</td>
<td></td>
</tr>
<tr>
<td>$I_{2t}$-value</td>
<td>$I_{2t}$</td>
<td></td>
<td>3960 A²s</td>
<td></td>
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<tr>
<td>Repetitive peak forward current</td>
<td>$I_{F}$</td>
<td>$T_{j}$=1 ms</td>
<td>800 A</td>
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<tr>
<td>Power dissipation per FWD</td>
<td>$P_{D}$</td>
<td>$T_{j}$=max, $T_{C}$=80°C</td>
<td>421 W</td>
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<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{j}$</td>
<td></td>
<td>175 °C</td>
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</table>
## 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><strong>neutral point IGBT (T2, T3)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collector-emitter break down voltage</td>
<td>$V_{CE}$</td>
<td>$T_{j}=T_{j\text{max}}$</td>
<td>600</td>
<td>V</td>
</tr>
<tr>
<td>DC collector current</td>
<td>$I_{C}$</td>
<td>$T_{j}=T_{j\text{max}}$</td>
<td>329</td>
<td>A</td>
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<tr>
<td></td>
<td></td>
<td>$T_{j}=80°C$</td>
<td>430</td>
<td>A</td>
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<tr>
<td>Repetitive peak collector current</td>
<td>$I_{CPUL}$</td>
<td>$I_{p}$ limited by $T_{j\text{max}}$</td>
<td>1200</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per IGBT</td>
<td>$P_{tot}$</td>
<td>$T_{j}=T_{j\text{max}}$</td>
<td>574</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_{j}=80°C$</td>
<td>870</td>
<td>W</td>
</tr>
<tr>
<td>Gate-emitter peak voltage</td>
<td>$V_{GE}$</td>
<td>$T_{j}=T_{j\text{max}}$</td>
<td>±20</td>
<td>V</td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>$I_{SC}$</td>
<td>$T_{j}=150°C$</td>
<td>6</td>
<td>A</td>
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<tr>
<td></td>
<td></td>
<td>$V_{CC}=15V$</td>
<td>360</td>
<td>µs</td>
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<tr>
<td>Turn off safe operating area (RBSOA)</td>
<td>$I_{t\text{max}}$</td>
<td>$V_{CE\text{max}}=1200V$</td>
<td>800</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_{j\text{max}}=150°C$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{j\text{max}}$</td>
<td></td>
<td>175</td>
<td>°C</td>
</tr>
<tr>
<td><strong>half bridge FWD (D1, D4)</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Peak Repetitive Reverse Voltage</td>
<td>$V_{RMM}$</td>
<td>$T_{j}=25°C$</td>
<td>1200</td>
<td>V</td>
</tr>
<tr>
<td>DC forward current</td>
<td>$I_{F}$</td>
<td>$T_{j}=T_{j\text{max}}$</td>
<td>270</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_{j}=80°C$</td>
<td>356</td>
<td>A</td>
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<tr>
<td>Surge forward current</td>
<td>$I_{SM}$</td>
<td>$I_{p}=10ms \cdot \sin 180°$</td>
<td>2200</td>
<td>A</td>
</tr>
<tr>
<td>$I_{2t}$-value</td>
<td>$P_{1}$</td>
<td>$T_{j}=150°C$</td>
<td>6052</td>
<td>A²s</td>
</tr>
<tr>
<td>Repetitive peak forward current</td>
<td>$I_{RMM}$</td>
<td>$I_{p}$ limited by $T_{j\text{max}}$</td>
<td>1200</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per FWD</td>
<td>$P_{tot}$</td>
<td>$T_{j}=T_{j\text{max}}$</td>
<td>540</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_{j}=80°C$</td>
<td>818</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>
<tr>
<td><strong>DC link Capacitor</strong></td>
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<td></td>
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</tr>
<tr>
<td>Max.DC voltage</td>
<td>$V_{MAX}$</td>
<td>$T_{c}=100°C$</td>
<td>630</td>
<td>V</td>
</tr>
<tr>
<td><strong>General Module Properties</strong></td>
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<tr>
<td>Material of module baseplate</td>
<td></td>
<td></td>
<td>Cu</td>
<td></td>
</tr>
<tr>
<td>Material of internal isolation</td>
<td></td>
<td></td>
<td>Al₂O₃</td>
<td></td>
</tr>
<tr>
<td><strong>Thermal Properties</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage temperature</td>
<td>$T_{\text{el}}$</td>
<td></td>
<td>-40...+125</td>
<td>°C</td>
</tr>
<tr>
<td>Operation temperature under switching condition</td>
<td>$T_{op}$</td>
<td></td>
<td>-40...+(Tjmax - 25)</td>
<td>°C</td>
</tr>
<tr>
<td><strong>Insulation Properties</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insulation voltage</td>
<td>$V_{is}$</td>
<td>$t=2s$</td>
<td>DC voltage</td>
<td>4000</td>
</tr>
<tr>
<td>Creepage distance</td>
<td></td>
<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>CTI</td>
<td></td>
<td>&gt;200</td>
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</tbody>
</table>

---

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 Revision: 7
### Characteristic Values

**Parameter** | **Symbol** | **Conditions** | **Value** | **Unit**
--- | --- | --- | --- | ---
Gate emitter threshold voltage | $V_{GE(th)}$ | $V_{CE(sat)}$ | Min | Typ | Max
Collector-emitter saturation voltage | $V_{CE(sat)}$ | $V_{CE(sat)}$ | 5 | 5,8 | 8,5 | V
Collector-emitter cut-off current incl. FWD | $I_{CEO}$ | $I_{CEO}$ | 1,8 | 1,97 | 2,23 | mA
Gate-emitter leakage current | $I_{GE}$ | $I_{GE}$ | 20 | 2000 | nA
Integrated Gate resistor | $R_gint$ | $R_gint$ | 1,88 | 1,88 | 1,88 | Ω
Turn-on delay time | $\tau_{on}$ | $\tau_{on}$ | 200 | 247 | ns
Rise time | $\tau_1$ | $\tau_1$ | 55 | 55 | 55 | ns
Turn-off delay time | $\tau_{off}$ | $\tau_{off}$ | 202 | 202 | 202 | ns
Fall time | $\tau_f$ | $\tau_f$ | 354 | 354 | 354 | ns
Turn-on energy loss per pulse | $E_{on}$ | $E_{on}$ | 7,36 | 7,36 | 7,36 | mWs
Turn-off energy loss per pulse | $E_{off}$ | $E_{off}$ | 13,25 | 13,25 | 13,25 | mWs
Input capacitance | $C_{iss}$ | $C_{iss}$ | 24600 | 24600 | 24600 | pF
Output capacitance | $C_{oss}$ | $C_{oss}$ | 1620 | 1620 | 1620 | pF
Reverse transfer capacitance | $C_{rss}$ | $C_{rss}$ | 1380 | 1380 | 1380 | pF
Gate charge | $Q_{gss}$ | $Q_{gss}$ | 2030 | 2030 | 2030 | nC
Thermal resistance chip to heatsink per chip | $R_{goff}$ | $R_{goff}$ | 0,13 | 0,13 | 0,13 | kW
Thermal resistance chip to case per chip | $R_{goff}$ | $R_{goff}$ | 0,09 | 0,09 | 0,09 | kW

### neutral point FWD (D2, D3)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>FWD forward voltage</td>
<td>$V_F$</td>
<td>$V_F$</td>
<td>600</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Peak reverse recovery current</td>
<td>$I_{RRM}$</td>
<td>$I_{RRM}$</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>$\tau_{rec}$</td>
<td>$\tau_{rec}$</td>
<td>285</td>
<td>285</td>
<td>285</td>
</tr>
<tr>
<td>Reverse recovered charge</td>
<td>$Q_{rec}$</td>
<td>$Q_{rec}$</td>
<td>163</td>
<td>163</td>
<td>163</td>
</tr>
<tr>
<td>Peak rate of fall of recovery current</td>
<td>$I_{RMS}$</td>
<td>$I_{RMS}$</td>
<td>7,44</td>
<td>7,44</td>
<td>7,44</td>
</tr>
<tr>
<td>Reverse recovered energy</td>
<td>$E_{rec}$</td>
<td>$E_{rec}$</td>
<td>1,27</td>
<td>1,27</td>
<td>1,27</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>$R_{RMS}$</td>
<td>$R_{RMS}$</td>
<td>0,23</td>
<td>0,23</td>
<td>0,23</td>
</tr>
<tr>
<td>Thermal resistance chip to case per chip</td>
<td>$R_{RMS}$</td>
<td>$R_{RMS}$</td>
<td>0,15</td>
<td>0,15</td>
<td>0,15</td>
</tr>
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</table>

### neutral point IGBT (T2, T3)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate emitter threshold voltage</td>
<td>$V_{GE(th)}$</td>
<td>$V_{GE(th)}$</td>
<td>0,0064</td>
<td>0,0064</td>
<td>0,0064</td>
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<tr>
<td>Collector-emitter saturation voltage</td>
<td>$V_{CE(sat)}$</td>
<td>$V_{CE(sat)}$</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Collector-emitter cut-off incl. FWD</td>
<td>$I_{CEO}$</td>
<td>$I_{CEO}$</td>
<td>1,06</td>
<td>1,06</td>
<td>1,06</td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>$I_{GE}$</td>
<td>$I_{GE}$</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Integrated Gate resistor</td>
<td>$R_gint$</td>
<td>$R_gint$</td>
<td>0,5</td>
<td>0,5</td>
<td>0,5</td>
</tr>
<tr>
<td>Turn-on delay time</td>
<td>$\tau_{on}$</td>
<td>$\tau_{on}$</td>
<td>201</td>
<td>201</td>
<td>201</td>
</tr>
<tr>
<td>Rise time</td>
<td>$\tau_1$</td>
<td>$\tau_1$</td>
<td>224</td>
<td>224</td>
<td>224</td>
</tr>
<tr>
<td>Turn-off delay time</td>
<td>$\tau_{off}$</td>
<td>$\tau_{off}$</td>
<td>248</td>
<td>248</td>
<td>248</td>
</tr>
<tr>
<td>Fall time</td>
<td>$\tau_f$</td>
<td>$\tau_f$</td>
<td>272</td>
<td>272</td>
<td>272</td>
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<tr>
<td>Turn-on energy loss per pulse</td>
<td>$E_{on}$</td>
<td>$E_{on}$</td>
<td>3,93</td>
<td>3,93</td>
<td>3,93</td>
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<tr>
<td>Turn-off energy loss per pulse</td>
<td>$E_{off}$</td>
<td>$E_{off}$</td>
<td>14,07</td>
<td>14,07</td>
<td>14,07</td>
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<tr>
<td>Input capacitance</td>
<td>$C_{iss}$</td>
<td>$C_{iss}$</td>
<td>732</td>
<td>732</td>
<td>732</td>
</tr>
<tr>
<td>Output capacitance</td>
<td>$C_{oss}$</td>
<td>$C_{oss}$</td>
<td>1536</td>
<td>1536</td>
<td>1536</td>
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<tr>
<td>Reverse transfer capacitance</td>
<td>$C_{rss}$</td>
<td>$C_{rss}$</td>
<td>732</td>
<td>732</td>
<td>732</td>
</tr>
<tr>
<td>Gate charge</td>
<td>$Q_{gss}$</td>
<td>$Q_{gss}$</td>
<td>2480</td>
<td>2480</td>
<td>2480</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>$R_{RMS}$</td>
<td>$R_{RMS}$</td>
<td>0,17</td>
<td>0,17</td>
<td>0,17</td>
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<tr>
<td>Thermal resistance chip to case per chip</td>
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<td>$R_{RMS}$</td>
<td>0,11</td>
<td>0,11</td>
<td>0,11</td>
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</table>
## Characteristic Values

### half bridge FWD (D1, D4)

<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_{FWD}</td>
<td>Tj=25°C, T=150°C,</td>
<td>400</td>
<td>V</td>
</tr>
<tr>
<td>Reverse leakage current</td>
<td>I_{R}</td>
<td>Tj=25°C, T=150°C,</td>
<td>102</td>
<td>μA</td>
</tr>
<tr>
<td>Peak reverse recovery current</td>
<td>I_{RRM}</td>
<td>Tj=25°C, T=150°C,</td>
<td>410</td>
<td>A</td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>T_{RR}</td>
<td>Tj=25°C, T=150°C,</td>
<td>149</td>
<td>ns</td>
</tr>
<tr>
<td>Reverse recovered charge</td>
<td>Q_{m}</td>
<td>Tj=25°C, T=150°C,</td>
<td>24</td>
<td>μC</td>
</tr>
<tr>
<td>Peak rate of fall of recovery current</td>
<td>f_{rec}</td>
<td>Tj=25°C, T=150°C,</td>
<td>16910</td>
<td>A/μs</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>E_{thJH}</td>
<td>Tj=25°C, T=150°C,</td>
<td>12.71</td>
<td>mW/K</td>
</tr>
<tr>
<td>Thermal resistance chip to case per chip</td>
<td>E_{thJC}</td>
<td>Tj=25°C, T=150°C,</td>
<td>0.18</td>
<td>kW</td>
</tr>
</tbody>
</table>

### DC link Capacitor

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>C value</td>
<td>C</td>
<td></td>
<td>2 * 0.68</td>
<td>μF</td>
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<tr>
<td>Stray inductance of on board capacitors</td>
<td>ESL</td>
<td></td>
<td>26/2</td>
<td>nH</td>
</tr>
<tr>
<td>Series resistance of on board capacitors</td>
<td>ESR</td>
<td></td>
<td>14/2</td>
<td>mΩ</td>
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</tbody>
</table>

### Thermistor

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated resistance</td>
<td>R_{T25}</td>
<td>Tj=25°C,</td>
<td>20000</td>
<td>Ω</td>
</tr>
<tr>
<td>Deviation of R_{T25}</td>
<td>δR_{T25}</td>
<td>Tj=100°C,</td>
<td>5</td>
<td>%</td>
</tr>
<tr>
<td>Power dissipation constant</td>
<td>P_{T25}</td>
<td>Tj=25°C,</td>
<td>200</td>
<td>mW</td>
</tr>
<tr>
<td>Power dissipation constant</td>
<td>P_{T25}</td>
<td>Tj=25°C,</td>
<td>2</td>
<td>mW/K</td>
</tr>
<tr>
<td>B-value</td>
<td>B_{B25}</td>
<td>Tj=25°C,</td>
<td>3500</td>
<td>K</td>
</tr>
<tr>
<td>B-value</td>
<td>B_{B25}</td>
<td>Tj=25°C,</td>
<td>3996</td>
<td>K</td>
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### Module Properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module inductance (from chips to PCB)</td>
<td>L_{mcb}</td>
<td>T=25°C,</td>
<td>5</td>
<td>nH</td>
</tr>
<tr>
<td>Module inductance (from PCB to PCB using Intercon board)</td>
<td>L_{mc1b}</td>
<td>T=25°C,</td>
<td>3</td>
<td>nH</td>
</tr>
<tr>
<td>Resistance of Intercon boards (from PCB to PCB using Intercon board)</td>
<td>R_{ocmcb}</td>
<td>T=25°C, per switch</td>
<td>1.5</td>
<td>mΩ</td>
</tr>
<tr>
<td>Mounting torque (Source Mn - mounting according to valid application note FSWB1-4TY-M-*10)</td>
<td>M</td>
<td>T=25°C,</td>
<td>2,2</td>
<td>Nm</td>
</tr>
<tr>
<td>Mounting torque (Source Mn - mounting according to valid application note FSWB1-4TY-M-*10)</td>
<td>M</td>
<td>T=25°C,</td>
<td>6</td>
<td>Nm</td>
</tr>
<tr>
<td>Terminal connection torque (Source Mn - mounting according to valid application note FSWB1-4TY-M-*10)</td>
<td>M</td>
<td>T=25°C,</td>
<td>2,5</td>
<td>Nm</td>
</tr>
<tr>
<td>Weight</td>
<td>G</td>
<td></td>
<td>710</td>
<td>g</td>
</tr>
</tbody>
</table>
**Buck**

half bridge IGBT and neutral point FWD

---

**Figure 1**

**IGBT**

**Typical output characteristics**

$I_C = f(V_{CE})$

At

- $t_p = 350 \, \mu s$
- $T_j = 25 \, ^\circ C$
- $V_{GE}$ from 8 V to 17 V in steps of 1 V

---

**Figure 2**

**IGBT**

**Typical output characteristics**

$I_C = f(V_{CE})$

At

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

---

**Figure 3**

**IGBT**

**Typical transfer characteristics**

$I_C = f(V_{CE})$

---

**Figure 4**

**FWD**

**Typical FWD forward current as a function of forward voltage**

$I_F = f(V_F)$

At

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

---

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Buck

half bridge IGBT and neutral point FWD

**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
- \( R_{gon} = 1 \) 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
- \( R_{gon} = 1 \) 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

half bridge IGBT and neutral point FWD

Figure 9

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

With an inductive load at
\[ T_j = 125 \, ^\circ \text{C} \]
\[ V_{CE} = 350 \, \text{V} \]
\[ V_{GE} = \pm 15 \, \text{V} \]
\[ R_{gon} = 1.0 \, \Omega \]
\[ R_{goff} = 1.0 \, \Omega \]

Figure 10

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

With an inductive load at
\[ T_j = 125 \, ^\circ \text{C} \]
\[ V_{CE} = 350 \, \text{V} \]
\[ V_{GE} = \pm 15 \, \text{V} \]
\[ I_C = 400 \, \text{A} \]

Figure 11

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

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

Figure 12

Typical reverse recovery time as a function of IGBT turn on gate resistor
\[ t_{rr} = f(I_{pox}) \]

At
\[ T_j = 25/125 \, ^\circ \text{C} \]
\[ V_{CE} = 350 \, \text{V} \]
\[ V_{GE} = \pm 15 \, \text{V} \]
\[ I_V = 400 \, \text{A} \]
Typical reverse recovery charge as a function of collector current

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

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

Typical reverse recovery current as a function of collector current

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

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

- \( T_j = 25/125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_F = 400 \) A
- \( R_{gon} = 1 \) Ω

IGBT transient thermal impedance as a function of pulse width:

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

At

- \( D = t_p / T \)
- \( R_{thJH} = 0,13 \) K/W

Thermal grease

<table>
<thead>
<tr>
<th>R (C/W)</th>
<th>Tau (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,06</td>
<td>2,5E+00</td>
</tr>
<tr>
<td>0,03</td>
<td>4,7E-01</td>
</tr>
<tr>
<td>0,03</td>
<td>3,9E-02</td>
</tr>
<tr>
<td>0,01</td>
<td>1,2E-02</td>
</tr>
<tr>
<td>0,00</td>
<td>1,2E-03</td>
</tr>
</tbody>
</table>

IGBT thermal model values

FWD transient thermal impedance as a function of pulse width:

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

At

- \( D = t_p / T \)
- \( R_{thJH} = 0,23 \) K/W

Thermal grease

<table>
<thead>
<tr>
<th>R (C/W)</th>
<th>Tau (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,05</td>
<td>5,2E+00</td>
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<tr>
<td>0,07</td>
<td>1,1E+00</td>
</tr>
<tr>
<td>0,02</td>
<td>2,0E-01</td>
</tr>
<tr>
<td>0,06</td>
<td>4,6E-02</td>
</tr>
<tr>
<td>0,02</td>
<td>1,7E-02</td>
</tr>
</tbody>
</table>
Power dissipation as a function of heatsink temperature

$P_{\text{tot}} = f(T_h)$

At $T_j = 175 \, ^\circ C$

Collector current as a function of heatsink temperature

$I_c = f(T_h)$

At $T_j = 175 \, ^\circ C, \ V_{GE} = 15 \, V$

Forward current as a function of heatsink temperature

$I_f = f(T_h)$

At $T_j = 175 \, ^\circ C$
Buck

half bridge IGBT and neutral point FWD

Figure 25
Safe operating area as a function of collector-emitter voltage

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

<table>
<thead>
<tr>
<th>V_{CE} (V)</th>
<th>10^{-1}</th>
<th>10^{0}</th>
<th>10^{1}</th>
<th>10^{2}</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_{GE} (V)</td>
<td>0</td>
<td>400</td>
<td>800</td>
<td>1200</td>
</tr>
<tr>
<td>Q_g (nC)</td>
<td>0</td>
<td>20</td>
<td>40</td>
<td>60</td>
</tr>
</tbody>
</table>

At
D = single pulse
T_h = 80 °C
V_{GE} = ±15 V
T_j = T_{jmax} °C

Figure 26
Gate voltage vs Gate charge

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

At
I_C = 400 A

Figure 27
Reverse bias safe operating area

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

At
T_j = T_{jmax} - 25 °C
U_{continuous} = U_{replus}

Switching mode: 3 level switching
Boost
neutral point IGBT and half bridge FWD

**Figure 1**
Typical output characteristics

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

At
- \( t_p = 350 \ \mu s \)
- \( T_j = 25^\circ C \)
- \( V_{CE} \) from 8 V to 17 V in steps of 1 V

**Figure 2**
Typical output characteristics

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

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

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

At
- \( t_p = 350 \ \mu s \)
- \( T_j = 25^\circ C \), \( T_j = T_{j\max} - 25^\circ C \)
- \( V_{CE} = 0 \ \text{V} \)

**Figure 4**
Typical FWD forward current as a function of forward voltage

\[ I_F = f(V_F) \]

At
- \( t_p = 350 \ \mu s \)
Boost
neutral point IGBT and half bridge FWD

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

With an inductive load at
\[ T_J = 25/125 \, ^\circ \text{C} \]
\[ V_{CE} = 350 \, \text{V} \]
\[ V_{GE} = \pm 15 \, \text{V} \]
\[ R_{gon} = 1 \, \Omega \]
\[ R_{goff} = 1 \, \Omega \]

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

With an inductive load at
\[ T_J = 25/125 \, ^\circ \text{C} \]
\[ V_{CE} = 350 \, \text{V} \]
\[ V_{GE} = \pm 15 \, \text{V} \]
\[ I_C = 400 \, \text{A} \]

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

With an inductive load at
\[ T_J = 25/125 \, ^\circ \text{C} \]
\[ V_{CE} = 350 \, \text{V} \]
\[ V_{GE} = \pm 15 \, \text{V} \]
\[ R_{gon} = 1 \, \Omega \]

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

With an inductive load at
\[ T_J = 25/125 \, ^\circ \text{C} \]
\[ V_{CE} = 350 \, \text{V} \]
\[ V_{GE} = \pm 15 \, \text{V} \]
\[ I_C = 400 \, \text{A} \]
Figure 9
Typical switching times as a function of collector current
\( t = f(I_C) \)

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

Figure 10
Typical switching times as a function of gate resistor
\( t = f(R_g) \)

With an inductive load at
- \( T_j = 125 \, ^\circ C \)
- \( V_{CE} = 350 \, V \)
- \( V_{GE} = \pm 15 \, V \)
- \( I_C = 400 \, A \)

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

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

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

At
- \( T_j = 25/125 \, ^\circ C \)
- \( V_{GE} = 350 \, V \)
- \( I_C = 400 \, A \)
- \( V_{GE} = \pm 15 \, V \)
**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
\( T_j = 25/125 \degree C \)
\( V_{CE} = 350 \) V
\( V_{GE} = \pm 15 \) V
\( R_{gon} = 1 \) 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
\( T_j = 25/125 \degree C \)
\( V_I = 350 \) V
\( I_F = 400 \) 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
\( T_j = 25/125 \degree C \)
\( V_{CE} = 350 \) V
\( V_{GE} = \pm 15 \) V
\( R_{gon} = 1 \) 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
\( T_j = 25/125 \degree C \)
\( V_I = 350 \) V
\( I_F = 400 \) A
\( V_{GE} = \pm 15 \) V
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

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

Figure 18  
Typical rate of fall of forward and reverse recovery current as a function of IGBT turn on gate resistor

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

At

- \( T_J = 25/125 \, ^\circ \text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( I_F = 400 \, \text{A} \)

Figure 19  
IGBT transient thermal impedance as a function of pulse width

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

At

- \( D = \frac{tp}{T} \)
- \( R_{thJH} = 0.17 \, \text{K/W} \)

IGBT thermal model values

<table>
<thead>
<tr>
<th>R (C/W)</th>
<th>Tau (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.03</td>
<td>8.9E+00</td>
</tr>
<tr>
<td>0.07</td>
<td>2.2E+00</td>
</tr>
<tr>
<td>0.02</td>
<td>3.7E-01</td>
</tr>
<tr>
<td>0.04</td>
<td>4.3E-02</td>
</tr>
<tr>
<td>0.01</td>
<td>1.1E-02</td>
</tr>
<tr>
<td>0.00</td>
<td>1.9E-03</td>
</tr>
</tbody>
</table>

Figure 20  
FWD transient thermal impedance as a function of pulse width

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

At

- \( D = \frac{tp}{T} \)
- \( R_{thJH} = 0.18 \, \text{K/W} \)

FWD thermal model values

<table>
<thead>
<tr>
<th>R (C/W)</th>
<th>Tau (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.02</td>
<td>9.8E+00</td>
</tr>
<tr>
<td>0.05</td>
<td>2.5E+00</td>
</tr>
<tr>
<td>0.03</td>
<td>6.5E-01</td>
</tr>
<tr>
<td>0.03</td>
<td>8.1E-02</td>
</tr>
<tr>
<td>0.03</td>
<td>2.7E-02</td>
</tr>
<tr>
<td>0.01</td>
<td>4.1E-03</td>
</tr>
</tbody>
</table>
Boost
neutral point IGBT and half bridge FWD

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

At
\[ T_j = 175 \degree C \]

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

At
\[ T_j = 175 \degree C \]

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

At
\[ T_j = 175 \degree C \]

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

At
\[ T_j = 175 \degree C \]

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17 Revision: 7
Figure 25
Reverse bias safe operating area

$I_C = f(V_{CE})$ at $T_j = T_{j\text{max}} - 25 \degree C$

$U_{C-} = U_{C+}$

Switching mode: 3 level switching
Thermistor

Figure 1

Typical NTC characteristic as a function of temperature

\[ R_T = f(T) \]
Switching Definitions half bridge IGBT

General conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_J$</td>
<td>125 $^\circ$C</td>
</tr>
<tr>
<td>$R_{son}$</td>
<td>1 $\Omega$</td>
</tr>
<tr>
<td>$R_{goff}$</td>
<td>1 $\Omega$</td>
</tr>
</tbody>
</table>

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

- $V_{CE}$ ($0\%) = -15$ V
- $V_{CE}$ ($100\%) = 15$ V
- $I_C$ ($100\%) = 400$ A
- $t_{doff} = 0.35$ $\mu$s
- $t_{Eoff} = 1.12$ $\mu$s

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

- $V_{CE}$ ($0\%) = -15$ V
- $V_{CE}$ ($100\%) = 15$ V
- $V_C$ ($100\%) = 350$ V
- $I_C$ ($100\%) = 400$ A
- $t_{don} = 0.25$ $\mu$s
- $t_{Eon} = 0.56$ $\mu$s

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Switching Definitions half bridge IGBT

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

![Graph](image)

\[ P_{\text{off}} \ (100\%) = 140.00 \ kW \]
\[ E_{\text{off}} \ (100\%) = 22.08 \ mJ \]
\[ t_{\text{Eoff}} = 1.12 \ \mu s \]

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

![Graph](image)

\[ P_{\text{on}} \ (100\%) = 140.00 \ kW \]
\[ E_{\text{on}} \ (100\%) = 12.30 \ mJ \]
\[ t_{\text{Eon}} = 0.56 \ \mu s \]

Figure 7
Gate voltage vs Gate charge (measured)

![Graph](image)

\[ V_{\text{Goff}} = -15 \ V \]
\[ V_{\text{Gon}} = 15 \ V \]
\[ V_{\text{G}} \ (100\%) = 350 \ V \]
\[ I_{\text{d}} \ (100\%) = 400 \ A \]
\[ Q_{g} = 3059 \ nC \]

Figure 8
Turn-off Switching Waveforms & definition of \( t_{rr} \)

![Graph](image)

\[ V_{d} \ (100\%) = 350 \ V \]
\[ I_{d} \ (100\%) = 400 \ A \]
\[ I_{\text{fmax}} \ (100\%) = -262 \ A \]
\[ Q_{g} = 0.30 \ \mu s \]
Switching Definitions half bridge IGBT

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

$\begin{align*}
I_q \text{(100\%)} &= 400 \text{ A} \\
Q_{rr} \text{(100\%)} &= 33.04 \mu \text{C} \\
t_{Q_{rr}} &= 0.64 \mu \text{s}
\end{align*}$

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

$\begin{align*}
P_{rec} \text{(100\%)} &= 140.00 \text{ kW} \\
E_{rec} \text{(100\%)} &= 7.44 \text{ mJ} \\
t_{E_{rec}} &= 0.64 \mu \text{s}
\end{align*}$

**Figure 11**
Half bridge IGBT switching measurement circuit

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Switching Definitions neutral point IGBT

**General conditions**

- $T_J = 125 \degree C$
- $R_{on} = 1 \Omega$
- $R_{off} = 1 \Omega$

**Figure 1** neutral point IGBT

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

($t_{off}$ = integrating time for $E_{off}$)

- $V_G(0\%) = -15$ V
- $V_G(100\%) = 15$ V
- $V_C(100\%) = 700$ V
- $I_C(100\%) = 400$ A
- $t_{off} = 0.23 \mu s$
- $t_{f_{off}} = 0.58 \mu s$

**Figure 2** neutral point IGBT

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

($t_{on}$ = integrating time for $E_{on}$)

- $V_G(0\%) = -15$ V
- $V_G(100\%) = 15$ V
- $V_C(100\%) = 700$ V
- $I_C(100\%) = 400$ A
- $t_{on} = 0.20 \mu s$
- $t_{f_{on}} = 0.38 \mu s$

**Figure 3** neutral point IGBT

Turn-off Switching Waveforms & definition of $t_f$

- $V_C(100\%) = 700$ V
- $I_C(100\%) = 400$ A
- $t_f = 0.088 \mu s$

**Figure 4** neutral point IGBT

Turn-on Switching Waveforms & definition of $t_r$

- $V_C(100\%) = 700$ V
- $I_C(100\%) = 400$ A
- $t_r = 0.032 \mu s$
Switching Definitions neutral point IGBT

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

$P_{\text{off}}$ (100%) = 280.22 kW
$E_{\text{off}}$ (100%) = 14.07 mJ
$t_{\text{Eoff}}$ = 0.58 $\mu$s

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

$P_{\text{on}}$ (100%) = 280.2184 kW
$E_{\text{on}}$ (100%) = 13.39 mJ
$t_{\text{Eon}}$ = 0.38 $\mu$s

Figure 7
Gate voltage vs Gate charge (measured)

$V_{\text{GEoff}}$ = -15 V
$V_{\text{GEon}}$ = 15 V
$I_{\text{off}}$ (100%) = 700 V
$I_{\text{on}}$ (100%) = 400 A
$Q_{\text{g}}$ = 3442 nC

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

$V_{\text{d}}$ (100%) = 700 V
$i_{\text{b}}$ (100%) = 400 A
$i_{\text{rrmax}}$ (100%) = -521 A
$t_{\text{rr}}$ = 0.15 $\mu$s
Switching Definitions neutral point IGBT

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

- $I_D(100\%) = 400$ A
- $Q_{rr}(100\%) = 49.18$ µC
- $t_{Qrr} = 0.33$ µs

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

- $P_{rec}(100\%) = 280.22$ kW
- $E_{rec}(100\%) = 12.71$ mJ
- $t_{Erec} = 0.33$ µs

**neutral point IGBT switching measurement circuit**

**Figure 11**

Ordering Code and Marking - Outline - Pinout

Outline

<table>
<thead>
<tr>
<th>Driver pins</th>
<th>Power connections</th>
<th>Low current connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin</td>
<td>X1</td>
<td>Y1</td>
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<tr>
<td>1.1</td>
<td>4.5</td>
<td>78.0</td>
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<td>1.2</td>
<td>4.5</td>
<td>81.5</td>
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<tr>
<td>1.3</td>
<td>38.5</td>
<td>78.0</td>
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<tr>
<td>1.4</td>
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<td>1.5</td>
<td>1.95</td>
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<td>4.05</td>
<td>66.4</td>
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<td>1.7</td>
<td>38.5</td>
<td>66.4</td>
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<tr>
<td>1.22</td>
<td>67.6</td>
<td>69.8</td>
</tr>
</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
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