**Features**
- neutral point clamped inverter
- reactive power capability
- clip-in pcb mounting
- low inductance layout

**Target Applications**
- solar inverter
- UPS

**Types**
- 10-FZ12NMA040SH-M267F
- 10-PZ12NMA040SH-M267FY
- 10-F012NMA040SH-M267F09

---

**Maximum Ratings**

**Half Bridge IGBT**

<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=T_{j,max} )</td>
<td>1200</td>
<td>V</td>
</tr>
<tr>
<td>DC collector current</td>
<td>( I_C )</td>
<td>( T_j=T_{j,\text{max}} )</td>
<td>41</td>
<td>A</td>
</tr>
<tr>
<td>Repetitive peak collector current</td>
<td>( I_{\text{pulse}} )</td>
<td>( I_u ) limited by ( T_j=80^\circ \text{C} )</td>
<td>53</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per IGBT</td>
<td>( P_{\text{tot}} )</td>
<td>( T_j=T_{j,\text{max}} )</td>
<td>107</td>
<td>W</td>
</tr>
<tr>
<td>Gate-emitter peak voltage</td>
<td>( V_{GE} )</td>
<td>( T_j\leq 150^\circ \text{C} )</td>
<td>±20</td>
<td>V</td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>( I_{\text{SC}} )</td>
<td>( V_{DD}=15V )</td>
<td>10</td>
<td>A</td>
</tr>
<tr>
<td>Turn off safe operating area (RBSOA)</td>
<td>( I_{\text{FWD}} )</td>
<td>( V_{CE, \text{max}}=1200V ) ( T_{j,\text{max}}=150^\circ \text{C} )</td>
<td>80</td>
<td>A</td>
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<tr>
<td>Maximum Junction Temperature</td>
<td>( T_j=80^\circ \text{C} )</td>
<td>( T_j=T_{j,\text{max}} )</td>
<td>175</td>
<td>°C</td>
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**Neutral Point FWD**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
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<th>Unit</th>
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<tr>
<td>Peak Repetitive Reverse Voltage</td>
<td>( V_{\text{RRM}} )</td>
<td>( T_j=T_{j,\text{max}} )</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>21</td>
<td>A</td>
</tr>
<tr>
<td>Surge forward current</td>
<td>( I_{\text{FMS}} )</td>
<td>( T_j=80^\circ \text{C} )</td>
<td>41</td>
<td>A</td>
</tr>
<tr>
<td>( I_2t )-value</td>
<td>( f_t )</td>
<td>( I_u=8.3\text{ms, sin} 180^\circ )</td>
<td>300</td>
<td>A</td>
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<tr>
<td>Repetitive peak forward current</td>
<td>( I_{\text{FRM}} )</td>
<td>( I_u ) limited by ( T_j=80^\circ \text{C} )</td>
<td>60</td>
<td>A</td>
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<tr>
<td>Power dissipation per Diode</td>
<td>( P_{\text{tot}} )</td>
<td>( T_j=T_{j,\text{max}} )</td>
<td>48</td>
<td>W</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>( T_j=80^\circ \text{C} )</td>
<td>( T_j=T_{j,\text{max}} )</td>
<td>175</td>
<td>°C</td>
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### 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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<tr>
<td><strong>Neutral Point IGBT</strong></td>
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</tr>
<tr>
<td>Collector-emitter break down voltage</td>
<td>(V_{CE})</td>
<td>(T_j=T_{max}) (T_h=80°C)</td>
<td>600</td>
<td>V</td>
</tr>
<tr>
<td>DC collector current</td>
<td>(I_C)</td>
<td>(T_j=T_{max}) (T_h=80°C)</td>
<td>31</td>
<td>A</td>
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<tr>
<td>Repetitive peak collector current</td>
<td>(I_{CP RM})</td>
<td>(I_p) limited by (T_j)</td>
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<tr>
<td>Power dissipation per IGBT</td>
<td>(P_{tot})</td>
<td>(T_j=T_{max}) (T_h=80°C)</td>
<td>57</td>
<td>W</td>
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<tr>
<td>Gate-emitter peak voltage</td>
<td>(V_{GE})</td>
<td>(\pm 20) (V)</td>
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<td></td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>(I_{SC})</td>
<td>(V_{CC}=15V)</td>
<td>6</td>
<td>µs</td>
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<td>Turn off safe operating area (RBSOA)</td>
<td>(I_{FSM})</td>
<td>(V_{CC}=600V) (T_{j}=150°C)</td>
<td>60</td>
<td>A</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>(T_{jmax})</td>
<td></td>
<td>175</td>
<td>°C</td>
</tr>
<tr>
<td><strong>Half Bridge FWD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Repetitive Reverse Voltage</td>
<td>(V_{RRM})</td>
<td></td>
<td>600</td>
<td>V</td>
</tr>
<tr>
<td>DC forward current</td>
<td>(I_F)</td>
<td>(T_j=T_{max}) (T_h=80°C)</td>
<td>13</td>
<td>A</td>
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<tr>
<td>Surge forward current</td>
<td>(I_{SOV})</td>
<td>(I_p=10ms \cdot \sin 180°)</td>
<td>65</td>
<td>A</td>
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<td>(I_2t)-value</td>
<td>(P_t)</td>
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<td>A²s</td>
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<td>Repetitive peak forward current</td>
<td>(I_{FRM})</td>
<td>(I_p) limited by (T_j)</td>
<td>45</td>
<td>A</td>
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<td>Power dissipation per Diode</td>
<td>(P_{tot})</td>
<td>(T_j=T_{max}) (T_h=80°C)</td>
<td>31</td>
<td>W</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>(T_{jmax})</td>
<td></td>
<td>150</td>
<td>°C</td>
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<tr>
<td><strong>Thermal Properties</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Storage temperature</td>
<td>(T_{stg})</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…+((T_{jmax}) - 25)</td>
<td>°C</td>
</tr>
<tr>
<td><strong>Insulation Properties</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Insulation voltage</td>
<td>(V_{in})</td>
<td>(t=2s) DC voltage</td>
<td>4000</td>
<td>V</td>
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<tr>
<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>
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## Characteristic Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate-emitter threshold voltage</td>
<td>$V_{GE(th)}$</td>
<td>$T_j=25^\circ C$</td>
<td>5.2 V</td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>$V_{CE(sat)}$</td>
<td>$T_j=150^\circ C$</td>
<td>6.4 V</td>
</tr>
<tr>
<td>Collector-emitter cut-off current incl. Diode</td>
<td>$I_{CEO}$</td>
<td>$T_j=150^\circ C$</td>
<td>0.02 mA</td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>$I_{DSS}$</td>
<td>$T_j=150^\circ C$</td>
<td>120 nA</td>
</tr>
<tr>
<td>Integrated Gate resistor</td>
<td>$R_{int}$</td>
<td>none</td>
<td>$\Omega$</td>
</tr>
<tr>
<td>Turn-on delay time</td>
<td>$t_{on}$</td>
<td>$T_j=25^\circ C$</td>
<td>70 ns</td>
</tr>
<tr>
<td>Rise time</td>
<td>$t_r$</td>
<td>$T_j=150^\circ C$</td>
<td>0.52 mWs</td>
</tr>
<tr>
<td>Turn-off delay time</td>
<td>$t_{off}$</td>
<td>$T_j=25^\circ C$</td>
<td>166 ns</td>
</tr>
<tr>
<td>Fall time</td>
<td>$t_f$</td>
<td>$T_j=150^\circ C$</td>
<td>1.16 mWs</td>
</tr>
<tr>
<td>Turn-on energy loss per pulse</td>
<td>$E_{on}$</td>
<td>$T_j=25^\circ C$</td>
<td>0.67 mWs</td>
</tr>
<tr>
<td>Turn-off energy loss per pulse</td>
<td>$E_{off}$</td>
<td>$T_j=150^\circ C$</td>
<td>1.16 mWs</td>
</tr>
<tr>
<td>Input capacitance</td>
<td>$C_{iss}$</td>
<td>$f=1\text{MHz}$</td>
<td>2300 pF</td>
</tr>
<tr>
<td>Output capacitance</td>
<td>$C_{oss}$</td>
<td>$f=1\text{MHz}$</td>
<td>160 pF</td>
</tr>
<tr>
<td>Reverse transfer capacitance</td>
<td>$C_{rss}$</td>
<td>$T_j=25^\circ C$</td>
<td>135 pF</td>
</tr>
<tr>
<td>Gate charge</td>
<td>$Q_{Gsat}$</td>
<td>$T_j=25^\circ C$</td>
<td>203 nC</td>
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<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>$R_{thJH}$</td>
<td>Thermal grease thickness 50um $A = 1 \text{ W/mK}$</td>
<td>0.89 K/W</td>
</tr>
<tr>
<td>Diode forward voltage</td>
<td>$V_D$</td>
<td>30 ns</td>
<td>2.28 V</td>
</tr>
<tr>
<td>Reverse leakage current</td>
<td>$I_L$</td>
<td>$T_j=25^\circ C$</td>
<td>2.71 V</td>
</tr>
<tr>
<td>Peak reverse recovery current</td>
<td>$I_{DSS}$</td>
<td>$T_j=150^\circ C$</td>
<td>100 µA</td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>$t_{rr}$</td>
<td>$T_j=25^\circ C$</td>
<td>1.74 A</td>
</tr>
<tr>
<td>Reverse recovered charge</td>
<td>$Q_{rec}$</td>
<td>$T_j=150^\circ C$</td>
<td>41 A/µs</td>
</tr>
<tr>
<td>Peak rate of fall of recovery current</td>
<td>$di/dt$</td>
<td>$T_j=25^\circ C$</td>
<td>0.92 µC</td>
</tr>
<tr>
<td>Reverse recovered energy</td>
<td>$E_{rec}$</td>
<td>$T_j=150^\circ C$</td>
<td>0.03 mWs</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>$R_{thJH}$</td>
<td>Thermal grease thickness 50um $A = 1 \text{ W/mK}$</td>
<td>1.98 K/W</td>
</tr>
</tbody>
</table>
### Characteristic Values

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<tr>
<td><strong>Neutral Point IGBT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gate emitter threshold voltage</td>
<td>$V_{GE(th)}$</td>
<td>V</td>
<td>$0,002$</td>
<td>$T_j=25°C$</td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>$V_{CE(sat)}$</td>
<td>V</td>
<td>$1,1$</td>
<td>$T_j=25°C$</td>
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<tr>
<td>Collector-emitter cut-off incl diode</td>
<td>$I_{GS}$</td>
<td>mA</td>
<td>$0,0016$</td>
<td>$T_j=25°C$</td>
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<tr>
<td>Gate-emitter leakage current</td>
<td>$I_{GEE}$</td>
<td>mA</td>
<td>$200$</td>
<td>$T_j=150°C$</td>
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<td>Integrated Gate resistor</td>
<td>$R_{pp}$</td>
<td>Ω</td>
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<td>Turn-on delay time</td>
<td>$t_{tr}$</td>
<td>ns</td>
<td>$15$</td>
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<td>Rise time</td>
<td>$t_{r}$</td>
<td>ns</td>
<td>$350$</td>
<td>$T_j=150°C$</td>
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<td>Turn-off delay time</td>
<td>$t_{off}$</td>
<td>ns</td>
<td>$28$</td>
<td>$T_j=25°C$</td>
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<tr>
<td>Fall time</td>
<td>$t_{f}$</td>
<td>ns</td>
<td>$50$</td>
<td>$T_j=150°C$</td>
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<tr>
<td>Turn-on energy loss per pulse</td>
<td>$E_{on}$</td>
<td>mWs</td>
<td>$1,66$</td>
<td>$T_j=25°C$</td>
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<td>Turn-off energy loss per pulse</td>
<td>$E_{off}$</td>
<td>mWs</td>
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<td>Input capacitance</td>
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<td>pF</td>
<td>$1630$</td>
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<td>Output capacitance</td>
<td>$C_{oss}$</td>
<td>pF</td>
<td>$50$</td>
<td></td>
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<tr>
<td>Gate charge</td>
<td>$Q_{ge}$</td>
<td>nC</td>
<td>$165$</td>
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<td>Thermal resistance chip to heatsink per chip</td>
<td>$R_{thJH}$</td>
<td>K/W</td>
<td>$1,68$</td>
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<tr>
<td><strong>Half Bridge FWD</strong></td>
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</tr>
<tr>
<td>Diode forward voltage</td>
<td>$V_d$</td>
<td>V</td>
<td>$15$</td>
<td>$T_j=25°C$</td>
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<tr>
<td>Reverse leakage current</td>
<td>$I_d$</td>
<td>mA</td>
<td>$1200$</td>
<td>$T_j=125°C$</td>
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<tr>
<td>Peak reverse recovery current</td>
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<td>mA</td>
<td>$47$</td>
<td>$T_j=25°C$</td>
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<tr>
<td>Reverse recovery time</td>
<td>$t_{rr}$</td>
<td>ns</td>
<td>$44$</td>
<td>$T_j=125°C$</td>
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<tr>
<td>Reverse recovered charge</td>
<td>$Q_{r}$</td>
<td>μC</td>
<td>$1,47$</td>
<td>$T_j=125°C$</td>
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<tr>
<td>Peak rate of fall of recovery current</td>
<td>$di/dt_{max}$</td>
<td>A/μs</td>
<td>$3534$</td>
<td>$T_j=125°C$</td>
</tr>
<tr>
<td>Reverse recovery energy</td>
<td>$E_{off}$</td>
<td>mWs</td>
<td>$0,71$</td>
<td>$T_j=125°C$</td>
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<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>$R_{thJH}$</td>
<td>K/W</td>
<td>$2,27$</td>
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<td><strong>Thermistor</strong></td>
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<td>Rated resistance</td>
<td>$R$</td>
<td>Ω</td>
<td>$22000$</td>
<td>$T_j=25°C$</td>
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<td>Deviation of $R_{100}$</td>
<td>$\Delta R/R$</td>
<td>%</td>
<td>$-5$</td>
<td>$T_j=100°C$</td>
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<td>Power dissipation</td>
<td>$P$</td>
<td>mW</td>
<td>$200$</td>
<td>$T_j=25°C$</td>
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<td>Power dissipation constant</td>
<td>$B_{(P0)}$</td>
<td>mW/K</td>
<td>$2$</td>
<td>$T_j=25°C$</td>
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<tr>
<td>B-value</td>
<td>$B_{(IS=8)}$</td>
<td>K</td>
<td>$3950$</td>
<td>$T_j=25°C$</td>
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<tr>
<td>B-value</td>
<td>$B_{(IS=10)}$</td>
<td>K</td>
<td>$3996$</td>
<td>$T_j=25°C$</td>
</tr>
</tbody>
</table>

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Figure 1

Typical output characteristics

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

- \( t_p = 250 \ \mu s \)
- \( T_j = 25 ^\circ C \)
- \( V_{CE} \) from 7 V to 17 V in steps of 1 V

Figure 2

Typical output characteristics

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

- \( t_p = 250 \ \mu s \)
- \( T_j = 125 ^\circ C \)
- \( V_{CE} \) from 7 V to 17 V in steps of 1 V

Figure 3

Typical transfer characteristics

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

- \( \tau_p = 250 \ \mu s \)
- \( T_j = 25 ^\circ C \)

Figure 4

Typical diode forward current as a function of forward voltage

\[ I_F = f(V_F) \]

- \( \tau_p = 250 \ \mu s \)
- \( T_j = 25 ^\circ C \)
Figure 5  IGBT
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
- \( V_{GE} = \pm15 \) V
- \( R_{on} = 8 \) Ω
- \( R_{off} = 8 \) Ω

Figure 6  IGBT
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
- \( V_{GE} = \pm15 \) V
- \( R_{on} = 8 \) Ω
- \( R_{off} = 8 \) Ω

Figure 7  FWD
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
- \( V_{GE} = \pm15 \) V
- \( R_{on} = 8 \) Ω
- \( R_{off} = 8 \) Ω

Figure 8  FWD
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
- \( V_{GE} = \pm15 \) V
- \( R_{on} = 8 \) Ω
- \( R_{off} = 8 \) Ω
Half Bridge

IGBT

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

![Graph showing typical switching times as a function of collector current.]

With an inductive load at
- \( T_j = 125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 8 \) Ω
- \( R_{goff} = 8 \) Ω

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

![Graph showing typical switching times as a function of gate resistor.]

With an inductive load at
- \( T_j = 125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_C = 28 \) A

FWD

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

![Graph showing typical reverse recovery time as a function of collector current.]

At
- \( T_j = 25/125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 8 \) Ω

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

![Graph showing typical reverse recovery time as a function of IGBT turn on gate resistor.]

At
- \( T_j = 25/125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_V = 28 \) A
Half Bridge
Half Bridge IGBT and Neutral Point FWD

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

\[ Q_{rr} \text{ (mC)} \]
\[ 0 \rightarrow 1.2 \]
\[ 0 \rightarrow 1.2 \]
\[ 0 \rightarrow 0.6 \]
\[ 0 \rightarrow 0.6 \]
\[ 0 \rightarrow 0.3 \]
\[ 0 \rightarrow 0.3 \]
\[ 0 \rightarrow 0 \]
\[ 0 \rightarrow 0 \]
\[ I_C \text{ (A)} \]
\[ 0 \rightarrow 60 \]
\[ 0 \rightarrow 60 \]

At
\[ T_j = 25/125 \degree C \]
\[ V_{CE} = 350 \text{ V} \]
\[ V_{GE} = \pm 15 \text{ V} \]
\[ R_{gon} = 8 \Omega \]

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

\[ Q_{rr} \text{ (mC)} \]
\[ 0 \rightarrow 1.2 \]
\[ 0 \rightarrow 0.9 \]
\[ 0 \rightarrow 0.6 \]
\[ 0 \rightarrow 0.3 \]
\[ R_{gon} \text{ (Ω)} \]
\[ 0 \rightarrow 40 \]
\[ 0 \rightarrow 40 \]

At
\[ T_j = 25/125 \degree C \]
\[ V_{TH} = 350 \text{ V} \]
\[ I_F = 28 \text{ A} \]
\[ V_{GE} = \pm 15 \text{ V} \]

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

\[ I_{\text{RRM}} \text{ (A)} \]
\[ 0 \rightarrow 60 \]
\[ 0 \rightarrow 60 \]
\[ 0 \rightarrow 30 \]
\[ 0 \rightarrow 30 \]
\[ 0 \rightarrow 15 \]
\[ 0 \rightarrow 15 \]
\[ 0 \rightarrow 0 \]
\[ 0 \rightarrow 0 \]
\[ I_C \text{ (A)} \]
\[ 0 \rightarrow 60 \]
\[ 0 \rightarrow 60 \]

At
\[ T_j = 25/125 \degree C \]
\[ V_{CE} = 350 \text{ V} \]
\[ V_{GE} = \pm 15 \text{ V} \]
\[ R_{gon} = 8 \Omega \]

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

\[ I_{\text{RRM}} \text{ (A)} \]
\[ 0 \rightarrow 60 \]
\[ 0 \rightarrow 45 \]
\[ 0 \rightarrow 30 \]
\[ 0 \rightarrow 15 \]
\[ 0 \rightarrow 0 \]
\[ R_{gon} \text{ (Ω)} \]
\[ 0 \rightarrow 40 \]
\[ 0 \rightarrow 40 \]

At
\[ T_j = 25/125 \degree C \]
\[ V_{TH} = 350 \text{ V} \]
\[ I_F = 28 \text{ A} \]
\[ V_{GE} = \pm 15 \text{ V} \]
Typical rate of fall of forward and reverse recovery current as a function of collector current
\[ \frac{dI}{dt}, \frac{dI_{\text{rec}}}{dt} = f(I_c) \]

<table>
<thead>
<tr>
<th>( I_c ) (A)</th>
<th>( \frac{dI_{\text{rec}}}{dt} ) (A/ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3300</td>
<td>0</td>
</tr>
<tr>
<td>6000</td>
<td>0.1</td>
</tr>
<tr>
<td>9000</td>
<td>0.2</td>
</tr>
<tr>
<td>12000</td>
<td>0.3</td>
</tr>
<tr>
<td>15000</td>
<td>0.4</td>
</tr>
</tbody>
</table>

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<td>2.0</td>
</tr>
<tr>
<td>15000</td>
<td>2.5</td>
</tr>
</tbody>
</table>

At:
\[ T_j = 25/125 \; ^\circ\text{C} \]
\[ V_{GE} = 350 \; \text{V} \]
\[ V_{CE} = \pm 15 \; \text{V} \]
\[ R_{gon} = 8 \; \Omega \]

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

<table>
<thead>
<tr>
<th>( D )</th>
<th>( t_p/T )</th>
<th>( Z_{\text{thJH}} ) (K/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.005</td>
<td>0.1</td>
<td>0.01</td>
</tr>
<tr>
<td>0.01</td>
<td>0.2</td>
<td>0.02</td>
</tr>
<tr>
<td>0.05</td>
<td>0.3</td>
<td>0.05</td>
</tr>
<tr>
<td>0.001</td>
<td>0.4</td>
<td>0.01</td>
</tr>
</tbody>
</table>

IGBT thermal model values

<table>
<thead>
<tr>
<th>( R ) (C/W)</th>
<th>( \text{Tau} ) (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.09</td>
<td>1.1E+00</td>
</tr>
<tr>
<td>0.17</td>
<td>2.9E-01</td>
</tr>
<tr>
<td>0.47</td>
<td>9.1E-02</td>
</tr>
<tr>
<td>0.12</td>
<td>1.4E-02</td>
</tr>
<tr>
<td>0.04</td>
<td>9.2E-04</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>( D )</th>
<th>( t_p/T )</th>
<th>( Z_{\text{thJH}} ) (K/W)</th>
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<td>0.05</td>
</tr>
<tr>
<td>0.001</td>
<td>0.4</td>
<td>0.01</td>
</tr>
</tbody>
</table>

FWD thermal model values

<table>
<thead>
<tr>
<th>( R ) (C/W)</th>
<th>( \text{Tau} ) (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.07</td>
<td>5.6E+00</td>
</tr>
<tr>
<td>0.17</td>
<td>1.2E+00</td>
</tr>
<tr>
<td>0.52</td>
<td>2.2E-01</td>
</tr>
<tr>
<td>0.75</td>
<td>7.6E-02</td>
</tr>
<tr>
<td>0.25</td>
<td>1.5E-02</td>
</tr>
<tr>
<td>0.13</td>
<td>2.8E-03</td>
</tr>
</tbody>
</table>
Power dissipation as a function of heatsink temperature

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

Collector current as a function of heatsink temperature

\[ I_C = f(T_h) \]

At

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

Forward current as a function of heatsink temperature

\[ I_F = f(T_h) \]

At

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

\[ V_{GE} = 15 \quad \text{V} \]
**Half Bridge**

**Half Bridge IGBT and Neutral Point FWD**

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

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

**Figure 26**
Gate voltage vs Gate charge

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

At
- \( D = \) single pulse
- \( T_h = \) 80 \(^\circ\)C
- \( V_{GE} = \) ±15 V
- \( T_j = T_{j\text{max}} \) \(^\circ\)C

**Figure 27**
Reverse bias safe operating area

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

At
- \( T_j = T_{j\text{max}} - 25 \) \(^\circ\)C
- DC link\_minus = DC link\_plus
- Switching mode: 3 level switching

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Neutral point
Neutral Point IGBT and Half Bridge FWD

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

![IGBT Figure 1](image1)

At
- $t_p = 250 \mu s$
- $T_j = 25^\circ C$
- $V_{CE}$ from 7 V to 17 V in steps of 1 V

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

![IGBT Figure 2](image2)

At
- $t_p = 250 \mu s$
- $T_j = 125^\circ C$
- $V_{CE}$ from 7 V to 17 V in steps of 1 V

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

![IGBT Figure 3](image3)

At
- $t_p = 250 \mu s$
- $V_{CE} = 10 V$
- $T_j = 25^\circ C$

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

![FWD Figure 4](image4)

At
- $t_p = 250 \mu s$
- $T_j = T_{j,\text{max}}$
- $T_j = 25^\circ C$
- $T_j = T_{j,\text{max}} - 25^\circ C$
Neutral point
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
- \( T_J = 25/125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gON} = 16 \) Ω
- \( I_C = 28 \) A

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
- \( I_C = 28 \) 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
- \( R_{gON} = 16 \) 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
- \( I_C = 28 \) A
Neutral point
Neutral Point IGBT and Half Bridge FWD

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

With an inductive load at
- \( T_j = 125 \, ^\circ \text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( R_{gon} = 16 \, \Omega \)
- \( R_{goff} = 16 \, \Omega \)

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

With an inductive load at
- \( T_j = 125 \, ^\circ \text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( I_C = 28 \, \text{A} \)

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

At
- \( T_j = 25/125 \, ^\circ \text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( R_{gon} = 16 \, \Omega \)

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

At
- \( T_j = 25/125 \, ^\circ \text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( I_F = 28 \, \text{A} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
Neutral point

Neutral Point IGBT and Half Bridge FWD

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

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

- \( T_j = 25/125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 16 \) Ω

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

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

- \( T_j = 25/125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_F = 28 \) A

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

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

- \( T_j = 25/125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 16 \) Ω

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

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

- \( T_j = 25/125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_F = 28 \) A
Neutral point
Neutral Point IGBT and Half Bridge FWD

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

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

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

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

IGBT thermal model values
\[
\begin{array}{c|c|c|c|c|c|c|c|c}
\text{R (C/W)} & \text{0.07} & \text{0.17} & \text{0.47} & \text{0.56} & \text{0.32} & \text{0.09} \\
\text{R (C/W)} & 4.8E+00 & 1.0E+00 & 1.9E-01 & 6.8E-02 & 1.2E-02 & 2.5E-03 \\
\text{R (C/W)} & 0.05 & 0.01 & 0.005 & 0.000 & & & \\
\end{array}
\]

FWD thermal model values
\[
\begin{array}{c|c|c|c|c|c|c|c|c}
\text{R (C/W)} & \text{0.04} & \text{0.13} & \text{0.53} & \text{0.66} & \text{0.42} & \text{0.29} & \text{0.19} \\
\text{R (C/W)} & 9.1E+00 & 9.0E-01 & 1.5E-01 & 5.1E-02 & 1.1E-02 & 2.5E-03 & 5.8E-04 \\
\text{R (C/W)} & & & & & & & \\
\end{array}
\]

**Notes:**
- \( T_j = 25/125 \ ^\circ\text{C} \)
- \( V_{GE} = \pm 15 \ \text{V} \)
- \( I_F = 28 \ \text{A} \)
- \( V_{GE} = \pm 15 \ \text{V} \)
- \( R_{gon} = 1.6 \ \Omega \)
- \( R_{thJH} = 1.68 \ \text{K/W} \)
- \( R_{thJH} = 2.27 \ \text{K/W} \)

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Neutral point
Neutral Point IGBT and Half Bridge FWD

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

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

At
\[ T_j = 150 \, ^\circ\text{C} \]

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

At
\[ T_j = 150 \, ^\circ\text{C} \]
Neutral point
Neutral Point IGBT and Half Bridge FWD

**Figure 25**
Safe operating area as a function of collector-emitter voltage
\[ I_C = f(V_{CE}) \]

- **At**
  - \( D = \) single pulse
  - \( T_h = 80 \) °C
  - \( V_{GE} = 15 \) V
  - \( T_j = T_{\text{max}} \) °C

**Figure 26**
Gate voltage vs Gate charge
\[ V_{GE} = f(Q) \]

- **At**
  - \( I_C = 30 \) A

**Figure 27**
Reverse bias safe operating area
\[ I_C = f(V_{CE}) \]

- **At**
  - \( T_j = T_{\text{max}}-25 \) °C
  - DC link minus\( =\)DC link plus
  - Switching mode: 3 level switching
Thermistor

Figure 1

Typical NTC characteristic
as a function of temperature

\[ R_T = f(T) \]
Switching Definitions Neutral point IGBT

General conditions

- $T_J = 125 \degree C$
- $R_{son} = 16 \Omega$
- $R_{popt} = 16 \Omega$

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

- $V_{GE}(0\%) = -15$ V
- $V_{GE}(100\%) = 15$ V
- $V_C(100\%) = 350$ V
- $I_C(100\%) = 28$ A
- $t_{off} = 0.19 \mu s$
- $t_{Eoff} = 0.39 \mu s$

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

- $V_{GE}(0\%) = -15$ V
- $V_{GE}(100\%) = 15$ V
- $V_C(100\%) = 350$ V
- $I_C(100\%) = 28$ A
- $t_{on} = 0.11 \mu s$
- $t_{Eon} = 0.26 \mu s$

Figure 3
Turn-off Switching Waveforms & definition of $t_f$

- $V_C(100\%) = 350$ V
- $I_C(100\%) = 28$ A
- $t_f = 0.09 \mu s$

Figure 4
Turn-on Switching Waveforms & definition of $t_r$

- $V_C(100\%) = 350$ V
- $I_C(100\%) = 28$ A
- $t_r = 0.02 \mu s$
Switching Definitions Neutral point IGBT

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

![Graph showing turn-off switching waveforms with definitions of $P_{off}$, $E_{off}$, and $t_{E_{off}}$.]

- $P_{off} (100\%) = 9.70 \text{ kW}$
- $E_{off} (100\%) = 0.98 \text{ mJ}$
- $t_{E_{off}} = 0.39 \mu\text{s}$

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

![Graph showing turn-on switching waveforms with definitions of $P_{on}$, $E_{on}$, and $t_{E_{on}}$.]

- $P_{on} (100\%) = 9.70 \text{ kW}$
- $E_{on} (100\%) = 0.66 \text{ mJ}$
- $t_{E_{on}} = 0.26 \mu\text{s}$

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

![Graph showing gate voltage vs gate charge with values $V_{G_{off}}$, $V_{G_{on}}$, $V_{CE_{3\%}}$, $V_{CE_{3\%}}$, $I_{C_{1\%}}$, and $Q_g$.]

- $V_{G_{off}} = -15 \text{ V}$
- $V_{G_{on}} = 15 \text{ V}$
- $V_{CE_{3\%}} = 350 \text{ V}$
- $I_{C_{1\%}} = 28 \text{ A}$
- $Q_g = 277 \text{ nC}$

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

![Graph showing turn-off switching waveforms with definitions of $V_d$, $i_d$, and $t_{rr}$.]

- $V_d (100\%) = 350 \text{ V}$
- $i_d (100\%) = 28 \text{ A}$
- $t_{rr} (100\%) = -44 \text{ A}$
- $t_{rr} = 0.11 \mu\text{s}$
Switching Definitions Neutral point IGBT

**Figure 9**
**Neutral point IGBT**

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

(t$_{Q_{rr}}$ = integrating time for Q$_{rr}$)

- $I_d(100%) = 28$ A
- $Q_{rr}(100%) = 2.73$ µC
- $t_{Q_{rr}} = 1.00$ µs

**Figure 10**
**Neutral point FWD**

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

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

- $P_{rec}(100%) = 9.70$ kW
- $E_{rec}(100%) = 0.71$ mJ
- $t_{E_{rec}} = 1.00$ µs

**Measurement circuits**

**Figure 11**
**BOOST stage switching measurement circuit**
Switching Definitions Half Bridge IGBT

General conditions

- $T_J = 125^\circ C$
- $R_{on} = 8 \Omega$
- $R_{off} = 8 \Omega$

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

- $V_{CE} (0\%) = -15$ V
- $V_{CE} (100\%) = 15$ V
- $I_C (100\%) = 28$ A
- $t_{off} = 0.22 \mu s$
- $t_{on} = 0.61 \mu s$

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

- $V_{CE} (0\%) = -15$ V
- $V_{CE} (100\%) = 15$ V
- $V_C (100\%) = 700$ V
- $I_C (100\%) = 28$ A
- $t_{on} = 0.07 \mu s$
- $t_{on} = 0.16 \mu s$

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

- $V_C (100\%) = 700$ V
- $I_C (100\%) = 28$ A
- $t_r = 0.08 \mu s$

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

- $V_C (100\%) = 700$ V
- $I_C (100\%) = 28$ A
- $t_r = 0.02 \mu s$
Switching Definitions Half Bridge IGBT

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

- $P_{off} (100\%) = 19.50$ kW
- $E_{off} (100\%) = 1.16$ mJ
- $t_{Eoff} = 0.61$ µs

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

- $P_{on} (100\%) = 19.50$ kW
- $E_{on} (100\%) = 0.52$ mJ
- $t_{Eon} = 0.16$ µs

**Figure 7**
Half Bridge IGBT
Gate voltage vs Gate charge (measured)

- $V_{GEoff} = -15$ V
- $V_{GEon} = 15$ V
- $V_C (100\%) = 700$ V
- $I_C (100\%) = 28$ A
- $Q_g = 299.41$ nC

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

- $V_4 (100\%) = 700$ V
- $I_4 (100\%) = 28$ A
- $I_{RRM} (100\%) = -41$ A
- $t_{rr} = 0.04$ µs
Switching Definitions Half Bridge IGBT

Figure 9
Half Bridge IGBT
Turn-on Switching Waveforms & definition of t_Qrr
(t_Qrr = integrating time for Qrr)

I_d (100%) = 28 A
Qrr (100%) = 0.92 µC
t_Qrr = 0.08 µs

Figure 10
Half Bridge FWD
Turn-on Switching Waveforms & definition of t_Erec
(t_Erec = integrating time for Erec)

P_rec (100%) = 19.50 kW
E_rec (100%) = 0.12 mJ
t_Erec = 0.08 µs

Measurement circuits

Figure 11
BUCK stage switching measurement circuit
Ordering Code and Marking - Outline - Pinout

Ordering Code & Marking

<table>
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<tr>
<th>Version</th>
<th>Ordering Code</th>
<th>in DataMatrix as</th>
<th>in packaging barcode as</th>
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<tr>
<td>w/o thermal paste 12mm housing solder pin</td>
<td>10-FZ12NMA040SH-M267F</td>
<td>M267F</td>
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<tr>
<td>w/o thermal paste 12mm housing Press-fit pin</td>
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<td>w/o thermal paste 17mm housing solder pin</td>
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Outline

Pinout
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