### 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>
</tr>
</thead>
<tbody>
<tr>
<td>Collector-emitter break down voltage</td>
<td>$V_{CE}$</td>
<td></td>
<td>1200</td>
<td>V</td>
</tr>
<tr>
<td>DC collector current</td>
<td>$I_C$</td>
<td>$T_J=80°C$</td>
<td>66</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_J=80°C$</td>
<td>84</td>
<td>A</td>
</tr>
<tr>
<td>Repetitive peak collector current</td>
<td>$I_{C pulse}$</td>
<td>$I_t$ limited by $T_J$ max</td>
<td>320</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per IGBT</td>
<td>$P_{tot}$</td>
<td>$T_J=80°C$</td>
<td>158</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_J=80°C$</td>
<td>240</td>
<td>W</td>
</tr>
<tr>
<td>Gate-emitter peak voltage</td>
<td>$V_{GE}$</td>
<td></td>
<td>±20</td>
<td>V</td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>$t_{SC}$</td>
<td>$T_J≤150°C$</td>
<td>6</td>
<td>µs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{GE}=15V$</td>
<td>360</td>
<td>V</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_J$ max</td>
<td></td>
<td>175</td>
<td>°C</td>
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</table>

### Neutral Point FWD

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Repetitive Reverse Voltage</td>
<td>$V_{max}$</td>
<td>$T_J=25°C$</td>
<td>600</td>
<td>V</td>
</tr>
<tr>
<td>DC forward current</td>
<td>$I_F$</td>
<td>$T_J=80°C$</td>
<td>26</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_J=80°C$</td>
<td>36</td>
<td>A</td>
</tr>
<tr>
<td>Surge forward current</td>
<td>$I_{F SM}$</td>
<td>$I_p=8,3ms \text{, sin } 180°$</td>
<td>300</td>
<td>A</td>
</tr>
<tr>
<td>I2t-value</td>
<td>$f_I$</td>
<td></td>
<td>370</td>
<td>A *s</td>
</tr>
<tr>
<td>Repetitive peak forward current</td>
<td>$I_{R RM}$</td>
<td>$I_t$ limited by $T_J$ max</td>
<td>60</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per Diode</td>
<td>$P_{tot}$</td>
<td>$T_J=80°C$</td>
<td>44</td>
<td>W</td>
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<td></td>
<td></td>
<td>$T_J=80°C$</td>
<td>66</td>
<td>W</td>
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<tr>
<td>Maximum Junction Temperature</td>
<td>$T_J$ max</td>
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<td>150</td>
<td>°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</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collector-emitter break down voltage</td>
<td>$V_{CE}$</td>
<td></td>
<td>600</td>
<td>V</td>
</tr>
<tr>
<td>DC collector current</td>
<td>$I_C$</td>
<td>$T_j=T_{max}$ $T_h=80°C$ $T_c=80°C$</td>
<td>36</td>
<td>A</td>
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<tr>
<td></td>
<td></td>
<td>$T_j=T_{max}$ $T_h=80°C$ $T_c=80°C$</td>
<td>46</td>
<td>A</td>
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<tr>
<td>Repetitive peak collector current</td>
<td>$I_{CPmax}$</td>
<td>$I_i$ limited by $T_{max}$</td>
<td>150</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per IGBT</td>
<td>$P_{tot}$</td>
<td>$T_j=T_{max}$ $T_h=80°C$ $T_c=80°C$</td>
<td>56</td>
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<tr>
<td></td>
<td></td>
<td>$T_h=80°C$ $T_c=80°C$</td>
<td>85</td>
<td>W</td>
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<tr>
<td>Gate-emitter peak voltage</td>
<td>$V_{GE}$</td>
<td></td>
<td>≤20</td>
<td>V</td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>$t_{SC}$</td>
<td>$T_i=150°C$ $V_{CC}=15V$</td>
<td>6</td>
<td>µs</td>
</tr>
<tr>
<td></td>
<td>$V_{CC}$</td>
<td></td>
<td>360</td>
<td>V</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_j$</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>$T_j=25°C$</td>
<td>1200</td>
<td>V</td>
</tr>
<tr>
<td>DC forward current</td>
<td>$I_f$</td>
<td>$T_j=T_{max}$ $T_h=80°C$ $T_c=80°C$</td>
<td>25</td>
<td>A</td>
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<tr>
<td></td>
<td></td>
<td>$T_h=80°C$ $T_c=80°C$</td>
<td>35</td>
<td>A</td>
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<tr>
<td>Surge forward current</td>
<td>$I_{FSM}$</td>
<td>$I_L=8.3ms$, sin 180° $T_j=25°C$</td>
<td>325</td>
<td>A</td>
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<tr>
<td>$I_2t$-value</td>
<td>$I_2t$</td>
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<td>440</td>
<td>A²s</td>
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<tr>
<td>Repetitive peak forward current</td>
<td>$I_{PRM}$</td>
<td>20kHz Square Wave</td>
<td>70</td>
<td>A</td>
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<tr>
<td>Power dissipation per Diode</td>
<td>$P_{tot}$</td>
<td>$T_j=T_{max}$ $T_h=80°C$ $T_c=80°C$</td>
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<td>$T_h=80°C$ $T_c=80°C$</td>
<td>68</td>
<td>W</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_j$</td>
<td></td>
<td>150</td>
<td>°C</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>$T_{stg}$</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...+(Tj$_{max}$ - 25)</td>
<td>°C</td>
</tr>
<tr>
<td><strong>Insulation Properties</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Insulation voltage</td>
<td>$V_{in}$</td>
<td>$I=2s$ DC voltage</td>
<td>4000</td>
<td>V</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>
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### Characteristic Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate-emitter threshold voltage</td>
<td>V_{GE(th)}</td>
<td>V_{CE}=V_{GE}</td>
<td>0.002</td>
<td>5.80</td>
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<tr>
<td>Collector-emitter saturation voltage</td>
<td>V_{CE(sat)}</td>
<td></td>
<td>15</td>
<td>100</td>
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<tr>
<td>Collector-emitter cut-off current incl. Diode</td>
<td>I_{FSS}</td>
<td></td>
<td>8</td>
<td>1200</td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>I_{GSS}</td>
<td></td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Integrated Gate resistor</td>
<td>R_{int}</td>
<td></td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>Turn-on delay time</td>
<td>t_{f_{on}}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rise time</td>
<td>t_{r}</td>
<td>R_{goff}=8Ω</td>
<td>±15</td>
<td>350</td>
</tr>
<tr>
<td>Turn-off delay time</td>
<td>t_{f_{off}}</td>
<td>R_{gon}=8Ω</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall time</td>
<td>t_{f}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn-on energy loss per pulse</td>
<td>E_{on}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn-off energy loss per pulse</td>
<td>E_{off}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input capacitance</td>
<td>C_{iss}</td>
<td>f=1MHz</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>Output capacitance</td>
<td>C_{oss}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reverse transfer capacitance</td>
<td>C_{rss}</td>
<td></td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>Gate charge</td>
<td>Q_{ge}</td>
<td></td>
<td>15</td>
<td>960</td>
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<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>R_{thJH}</td>
<td></td>
<td>0.60</td>
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</table>

### Neutral Point FWD

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diode forward voltage</td>
<td>V_{F}</td>
<td></td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Peak reverse recovery current</td>
<td>I_{RHM}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>t_{r}</td>
<td>R_{gon}=8Ω</td>
<td>±15</td>
<td>350</td>
</tr>
<tr>
<td>Reverse recovered charge</td>
<td>Q_{r}</td>
<td>R_{goff}=8Ω</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak rate of fall of recovery current</td>
<td>dE_{rec}/dt</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reverse recovered energy</td>
<td>E_{rec}</td>
<td></td>
<td>0.02</td>
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<td>Thermal resistance chip to heatsink per chip</td>
<td>R_{thJH}</td>
<td></td>
<td>1.61</td>
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</table>

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### Characteristic Values

<table>
<thead>
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<th>Symbol</th>
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<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>Neutral Point IGBT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gate emitter threshold voltage</td>
<td>$V_{GE(th)}$</td>
<td>$V_{CE}=V_{GE}$</td>
<td>$0.0008$</td>
<td>$T=25°C$</td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>$V_{CE(sat)}$</td>
<td></td>
<td>$15$</td>
<td>$T=25°C$</td>
</tr>
<tr>
<td>Collector-emitter cut-off incl diode</td>
<td>$I_{oss}$</td>
<td></td>
<td>$50$</td>
<td>$T=25°C$</td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>$I_{GE}$</td>
<td></td>
<td>$20$</td>
<td>$T=25°C$</td>
</tr>
<tr>
<td>Integrated Gate resistor</td>
<td>$R_{gint}$</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Turn-on delay time</td>
<td>$t_{on}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rise time</td>
<td>$t_{r}$</td>
<td>$R_{gon}=8 \Omega$</td>
<td>$\pm15$</td>
<td>$0.0008$</td>
</tr>
<tr>
<td>Turn-off delay time</td>
<td>$t_{off}$</td>
<td>$R_{goff}=8 \Omega$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall time</td>
<td>$t_{f}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn-on energy loss per pulse</td>
<td>$E_{on}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn-off energy loss per pulse</td>
<td>$E_{off}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input capacitance</td>
<td>$C_{in}$</td>
<td>$f=1MHz$</td>
<td>$0$</td>
<td>$T=25°C$</td>
</tr>
<tr>
<td>Output capacitance</td>
<td>$C_{oss}$</td>
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<td>$25$</td>
<td>$T=25°C$</td>
</tr>
<tr>
<td>Reverse transfer capacitance</td>
<td>$C_{rss}$</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Gate charge</td>
<td>$Q_{gate}$</td>
<td></td>
<td>$15$</td>
<td>$T=25°C$</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>$R_{thJH}$</td>
<td>Thermal grease thickness=50um $\lambda=1$ W/mK</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Half Bridge FWD | | | | |
| Diode forward voltage | $V_{F}$ | $30$ | $T=25°C$ | $1.5$ | $2.23$ | $3.4$ | V |
| Reverse leakage current | $I_{r}$ | $1200$ | $T=25°C$ | $100$ | | | µA |
| Peak reverse recovery current | $I_{rr(max)}$ | | | | | | A |
| Reverse recovery time | $t_{rr}$ | $R_{gon}=8 \Omega$ | $\pm15$ | $0.0008$ | $350$ | $41$ | | |
| Reverse recovered charge | $Q_{rr}$ | $R_{goff}=8 \Omega$ | | | | | | µC |
| Peak rate of fall of recovery current | $d_{di/dc(max)}$ | $di/dc(max)$ | | | | | | A/µs |
| Reverse recovery energy | $E_{rec}$ | | | | | | | mWs |
| Thermal resistance chip to heatsink per chip | $R_{thJH}$ | Thermal grease thickness=50um $\lambda=1$ W/mK | | | | | | K/W |

| Thermistor | | | | |
| Rated resistance | $R$ | $T=25°C$ | $22000$ | | Ω |
| Deviation of R100 | $\Delta R/R$ | $R100=1486 \Omega$ | | | % |
| Power dissipation | $P$ | $T=25°C$ | $200$ | | mW |
| Power dissipation constant | | $T=25°C$ | $2$ | | mW/K |
| B-value | | | | | | K |
| Vincotech NTC Reference | | | | | | B |
Buck
half bridge IGBT and neutral point FRED

**Figure 1**
Typical output characteristics

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

At

- \( t_p = 250 \ \mu s \)
- \( T_j = 25 \ \degree C \)
- \( V_{CE} \) from 6 V to 16 V in steps of 1 V

**Figure 2**
Typical output characteristics

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

At

- \( t_p = 250 \ \mu s \)
- \( T_j = 125 \ \degree C \)
- \( V_{CE} \) from 6 V to 16 V in steps of 1 V

**Figure 3**
Typical transfer characteristics

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

At

- \( t_p = 250 \ \mu s \)
- \( V_{CE} = 10 \ \text{V} \)
- \( T_j = 25 \ \degree C \)
- \( T_j = T_{jmax} - 25 \ \degree C \)

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

\[ I_F = f(V_F) \]

At

- \( t_p = 250 \ \mu s \)
**Figure 5**

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

\[ E = f(I_c) \]

With an inductive load at

- \( T_j = 25/125 \, ^\circ \text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( R_{Son} = 2 \, \Omega \)
- \( R_{Goff} = 2 \, \Omega \)

**Figure 6**

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

\[ E = f(R_G) \]

With an inductive load at

- \( T_j = 25/125 \, ^\circ \text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( I_c = 40 \, \text{A} \)

**Figure 7**

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

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

With an inductive load at

- \( T_j = 25/125 \, ^\circ \text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( R_{Son} = 2 \, \Omega \)

**Figure 8**

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

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

With an inductive load at

- \( T_j = 25/125 \, ^\circ \text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( I_c = 40 \, \text{A} \)
Figure 9
Typical switching times as a function of collector current
\[ t = f(I_C) \]

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

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

With an inductive load at
- \( T_j = 125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_c = 40 \) A

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

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

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

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half bridge IGBT and neutral point FRED
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**Figure 13**
Typical reverse recovery charge as a function of collector current
\[ Q_{rr} = f(I_C) \]

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

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

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

---

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

half bridge IGBT and neutral point FRED

**Figure 17**

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

![Graph](image1.png)

**At**

- $T_j = 25/125^\circ C$
- $V_{CE} = 350 \text{ V}$
- $V_{GE} = \pm 15 \text{ V}$
- $I_F = 40 \text{ A}$
- $R_{gon} = 2 \text{ \Omega}$

**Figure 18**

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

![Graph](image2.png)

**At**

- $T_j = 25/125^\circ C$
- $V_{GE} = \pm 15 \text{ V}$
- $I_F = 40 \text{ A}$
- $V_{GE} = 350 \text{ V}$

**Figure 19**

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

![Graph](image3.png)

**At**

- $D = 0.5$
- $R_{\text{shJH}} = 0.60 \text{ KW}$

**Figure 20**

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

![Graph](image4.png)

**At**

- $D = 0.5$
- $R_{\text{shJH}} = 1.61 \text{ KW}$

**IGBT thermal model values**

<table>
<thead>
<tr>
<th>$R$ (C/W)</th>
<th>Tau (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10</td>
<td>1.7E+00</td>
</tr>
<tr>
<td>0.28</td>
<td>2.4E-01</td>
</tr>
<tr>
<td>0.16</td>
<td>6.7E-02</td>
</tr>
<tr>
<td>0.04</td>
<td>8.5E-03</td>
</tr>
<tr>
<td>0.02</td>
<td>5.6E-04</td>
</tr>
</tbody>
</table>

**FRED thermal model values**

<table>
<thead>
<tr>
<th>$R$ (C/W)</th>
<th>Tau (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.06</td>
<td>9.8E+00</td>
</tr>
<tr>
<td>0.30</td>
<td>1.1E+00</td>
</tr>
<tr>
<td>0.80</td>
<td>1.8E-01</td>
</tr>
<tr>
<td>0.28</td>
<td>3.3E-02</td>
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<tr>
<td>0.11</td>
<td>5.6E-03</td>
</tr>
<tr>
<td>0.07</td>
<td>3.8E-04</td>
</tr>
</tbody>
</table>
Power dissipation as a function of heatsink temperature

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

At
\[ T_j = 175 \degree C \]

Collector current as a function of heatsink temperature

\[ I_C = f(T_h) \]

At
\[ T_j = 175 \degree C \]
\[ V_{GE} = 15 \text{ V} \]

Power dissipation as a function of heatsink temperature

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

At
\[ T_j = 150 \degree C \]

Forward current as a function of heatsink temperature

\[ I_F = f(T_h) \]

At
\[ T_j = 150 \degree C \]
Buck

half bridge IGBT and neutral point FRED

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

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

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

At

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

Figure 26
Gate voltage vs Gate charge

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

At

\( I_C = 40 \) A

240V

960V
**Boost**

neutral point IGBT and half bridge FRED

---

**Figure 1**
Typical output characteristics

$I_C = f(V_{CE})$

<table>
<thead>
<tr>
<th>$V_{CE}$ (V)</th>
<th>$I_C$ (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
</tr>
<tr>
<td>9</td>
<td>40</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
</tr>
</tbody>
</table>

At

$\tau_p = 250 \mu$s

$T_j = 25^\circ C$

$V_{GE}$ from 7 V to 17 V in steps of 1 V

---

**Figure 2**
Typical output characteristics

$I_C = f(V_{CE})$

<table>
<thead>
<tr>
<th>$V_{CE}$ (V)</th>
<th>$I_C$ (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
</tr>
<tr>
<td>9</td>
<td>40</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
</tr>
</tbody>
</table>

At

$\tau_p = 250 \mu$s

$T_j = 125^\circ C$

$V_{GE}$ from 7 V to 17 V in steps of 1 V

---

**Figure 3**
Typical transfer characteristics

$I_C = f(V_{CE})$

<table>
<thead>
<tr>
<th>$V_{CE}$ (V)</th>
<th>$I_C$ (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
</tr>
<tr>
<td>9</td>
<td>40</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
</tr>
</tbody>
</table>

At

$\tau_p = 250 \mu$s

$V_{CE} = 10$ V

---

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

$I_F = f(V_F)$

<table>
<thead>
<tr>
<th>$V_F$ (V)</th>
<th>$I_F$ (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
</tr>
</tbody>
</table>

At

$\tau_p = 250 \mu$s

$T_j = T_{jmax} - 25^\circ C$

$V_{CE} = 10$ V
**Figure 5**
Typical switching energy losses as a function of collector current

\[ E = f(I_C) \]

With an inductive load at

- \( T_J = 25/125 \, ^\circ C \)
- \( V_{CE} = 350 \, V \)
- \( V_{GE} = \pm 15 \, V \)
- \( R_{gon} = 8 \, \Omega \)
- \( I_C = 41 \, A \)

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

\[ E = f(R_G) \]

With an inductive load at

- \( T_J = 25/125 \, ^\circ C \)
- \( V_{CE} = 350 \, V \)
- \( V_{GE} = \pm 15 \, V \)
- \( I_C = 41 \, A \)

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

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

With an inductive load at

- \( T_J = 25/125 \, ^\circ C \)
- \( V_{CE} = 350 \, V \)
- \( V_{GE} = \pm 15 \, V \)
- \( R_{gon} = 8 \, \Omega \)

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

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

With an inductive load at

- \( T_J = 25/125 \, ^\circ C \)
- \( V_{CE} = 350 \, V \)
- \( V_{GE} = \pm 15 \, V \)
- \( I_C = 41 \, A \)
Figure 9  
Typical switching times as a function of collector current
$t = f(I_C)$

With an inductive load at
- $T_J = 125 \degree C$
- $V_{CE} = 350 \, V$
- $V_{GE} = \pm 15 \, V$
- $R_{gon} = 8 \, \Omega$
- $R_{goff} = 8 \, \Omega$

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

With an inductive load at
- $T_J = 125 \degree C$
- $V_{CE} = 350 \, V$
- $V_{GE} = \pm 15 \, V$
- $I_C = 41 \, A$

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

At
- $T_J = 25/125 \degree C$
- $V_{CE} = 350 \, V$
- $V_{GE} = \pm 15 \, V$
- $R_{gon} = 8 \, \Omega$

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

At
- $T_J = 25/125 \degree C$
- $V_{CE} = 350 \, V$
- $V_{GE} = \pm 15 \, V$
- $I_C = 41 \, A$
Boost
neutral point IGBT and half bridge FRED

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

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

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

At
- \( T_j = 25/125 \) °C
- \( V_{GE} = \pm 15 \) V
- \( I_f = 41 \) A
- \( V_{GE} = \pm 15 \) V

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

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

At
- \( T_j = 25/125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_f = 41 \) A
- \( V_{GE} = \pm 15 \) V

**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 gate resistor](image)

At
- \( T_j = 25/125 \) °C
- \( V_{GE} = \pm 15 \) V
- \( I_f = 41 \) A
- \( V_{GE} = \pm 15 \) V
Boost
neutral point IGBT and half bridge FRED

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
\[ T_j = 25/125 \, ^\circ C \]
\[ V_{GE} = 350 \, V \]
\[ V_{FB} = \pm 15 \, V \]
\[ R_{son} = 8 \, \Omega \]

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
\[ T_j = 25/125 \, ^\circ C \]
\[ V_{GE} = 350 \, V \]
\[ I_f = 41 \, A \]
\[ V_{FB} = \pm 15 \, V \]

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

At
\[ D = \frac{t_p}{T} \]
\[ R_{son} = 1,30 \, KW \]

IGBT thermal model values

<table>
<thead>
<tr>
<th>R (C/W)</th>
<th>Tau (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,04</td>
<td>9,0E+00</td>
</tr>
<tr>
<td>0,17</td>
<td>1,1E+00</td>
</tr>
<tr>
<td>0,62</td>
<td>1,7E-01</td>
</tr>
<tr>
<td>0,31</td>
<td>3,9E-02</td>
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<tr>
<td>0,12</td>
<td>6,7E-03</td>
</tr>
<tr>
<td>0,06</td>
<td>4,1E-04</td>
</tr>
</tbody>
</table>

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

At
\[ D = \frac{t_p}{T} \]
\[ R_{son} = 1,55 \, KW \]

FRED thermal model values

<table>
<thead>
<tr>
<th>R (C/W)</th>
<th>Tau (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,06</td>
<td>3,9E+00</td>
</tr>
<tr>
<td>0,30</td>
<td>3,8E-01</td>
</tr>
<tr>
<td>0,77</td>
<td>7,8E-02</td>
</tr>
<tr>
<td>0,28</td>
<td>1,2E-02</td>
</tr>
<tr>
<td>0,14</td>
<td>1,2E-03</td>
</tr>
</tbody>
</table>
Figures 21 and 22: Power dissipation as a function of heatsink temperature.

**Figure 21**

IGBT

Power dissipation as a function of heatsink temperature

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

At

$$T_j = 175 \degree C$$

**Figure 22**

IGBT

Collector current as a function of heatsink temperature

$$I_C = f(T_h)$$

At

$$T_j = 175 \degree C$$

$$V_{GE} = 15 \text{ V}$$

Figures 23 and 24: Power dissipation as a function of heatsink temperature.

**Figure 23**

FRED

Power dissipation as a function of heatsink temperature

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

At

$$T_j = 150 \degree C$$

**Figure 24**

FRED

Forward current as a function of heatsink temperature

$$I_F = f(T_h)$$

At

$$T_j = 150 \degree C$$
Thermistor

Figure 1
Typical NTC characteristic
as a function of temperature

\[ R_T = f(T) \]

Figure 2
Typical NTC resistance values

\[ R(T) = R_{25} \cdot e^{\left( \frac{B_{25000}}{T - 25} - \frac{1}{R_{25}} \right)} \] [Ω]

<table>
<thead>
<tr>
<th>T (°C)</th>
<th>R (Ω)</th>
<th>T (°C)</th>
<th>R (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-55</td>
<td>5344.47</td>
<td>30</td>
<td>7839</td>
</tr>
<tr>
<td>-50</td>
<td>1952.73</td>
<td>40</td>
<td>11574</td>
</tr>
<tr>
<td>-45</td>
<td>13464.73</td>
<td>50</td>
<td>7796</td>
</tr>
<tr>
<td>-40</td>
<td>9200.76</td>
<td>60</td>
<td>6457</td>
</tr>
<tr>
<td>-35</td>
<td>6451.12</td>
<td>70</td>
<td>3791</td>
</tr>
<tr>
<td>-30</td>
<td>4567.84</td>
<td>80</td>
<td>2307</td>
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<tr>
<td>-25</td>
<td>3274.65</td>
<td>90</td>
<td>1491</td>
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<td>-20</td>
<td>2285.77</td>
<td>100</td>
<td>840</td>
</tr>
<tr>
<td>-15</td>
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<td>272</td>
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<td>-10</td>
<td>1390.14</td>
<td>125</td>
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<td>-5</td>
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<td>0</td>
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<td>570.68</td>
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<td>10</td>
<td>447.64</td>
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<td>1299</td>
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<td>15</td>
<td>390.31</td>
<td>110</td>
<td>1733</td>
</tr>
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<td>20</td>
<td>276.54</td>
<td>115</td>
<td>982</td>
</tr>
<tr>
<td>25</td>
<td>220.00</td>
<td>120</td>
<td>861</td>
</tr>
<tr>
<td>30</td>
<td>170.35</td>
<td>125</td>
<td>759</td>
</tr>
</tbody>
</table>
Switching Definitions BUCK IGBT

General conditions
\[ T_j = 125 \, ^\circ\text{C} \]
\[ R_{	ext{on}} = 8 \, \Omega \]
\[ R_{	ext{off}} = 8 \, \Omega \]

Figure 1 half bridge IGBT
Turn-off Switching Waveforms & definition of \( t_{\text{doff}} \), \( t_{\text{Eoff}} \)
\( t_{\text{doff}} = 0.28 \, \mu\text{s} \)
\( t_{\text{Eoff}} = 0.63 \, \mu\text{s} \)

\( V_{\text{GE}(0\%) } = -15 \, \text{V} \)
\( V_{\text{GE}(100\%) } = 15 \, \text{V} \)
\( V_{\text{CE}}(100\%) = 700 \, \text{V} \)
\( I_{\text{C}(100\%) } = 40 \, \text{A} \)

Figure 2 half bridge IGBT
Turn-on Switching Waveforms & definition of \( t_{\text{don}} \), \( t_{\text{Eon}} \)
\( t_{\text{don}} = 0.13 \, \mu\text{s} \)
\( t_{\text{Eon}} = 0.23 \, \mu\text{s} \)

\( V_{\text{CE}(1\%) } = 3 \, \text{V} \)
\( V_{\text{CE}(90\%) } = 0.15 \, \text{V} \)
\( V_{\text{CE}(90\%) } = 0.2 \, \text{V} \)
\( V_{\text{CE}(10\%) } = 0.25 \, \text{V} \)

Figure 3 half bridge IGBT
Turn-off Switching Waveforms & definition of \( t_f \)
\( V_{\text{CE}}(10\%) = 2,3 \, \text{V} \)
\( V_{\text{CE}}(60\%) = 2,4 \, \text{V} \)
\( V_{\text{CE}}(40\%) = 2,5 \, \text{V} \)
\( V_{\text{CE}}(10\%) = 2,6 \, \text{V} \)

Figure 4 half bridge IGBT
Turn-on Switching Waveforms & definition of \( t_r \)
\( V_{\text{CE}}(1\%) = 2,8 \, \text{V} \)
\( V_{\text{CE}}(10\%) = 2,9 \, \text{V} \)
Switching Definitions BUCK IGBT

**Figure 5**

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

- $P_{off} (100\%) = 28.05$ kW
- $E_{off} (100\%) = 1.65$ mJ
- $t_{Eoff} = 0.63 \mu s$

**Figure 6**

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

- $P_{on} (100\%) = 28.05$ kW
- $E_{on} (100\%) = 0.70$ mJ
- $t_{Eon} = 0.23 \mu s$

**Figure 7**

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

- $V_{GEoff} = -15$ V
- $V_{GEon} = 15$ V
- $V_{C}(100\%) = 700$ V
- $I_{C}(100\%) = 40$ A
- $Q_g = 1556.37$ nC

**Figure 8**

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

- $V_{d} (100\%) = 700$ V
- $I_{d} (100\%) = 40$ A
- $I_{RM} (100\%) = -43$ A
- $t_{rr} = 0.04 \mu s$
Switching Definitions BUCK IGBT

**Figure 9**
Neutral point FRED

Turn-on Switching Waveforms & definition of \( t_{Qrr} \)

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

\( I_d(100\%) = 40 \) A

\( Q_{rr}(100\%) = 0.95 \) \( \mu \)C

\( t_{Qrr} = 0.08 \) \( \mu \)s

**Figure 10**
Neutral point FRED

Turn-on Switching Waveforms & definition of \( t_{Erec} \)

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

\( P_{rec}(100\%) = 28.05 \) kW

\( E_{rec}(100\%) = 0.12 \) mJ

\( t_{Erec} = 0.08 \) \( \mu \)s

**Figure 11**
BUCK stage switching measurement circuit

Measurement circuit

\begin{align*}
I_d(100\%) & = 40 \text{ A} \\
Q_{rr}(100\%) & = 0.95 \text{ } \mu\text{C} \\
t_{Qrr} & = 0.08 \text{ } \mu\text{s} \\
P_{rec}(100\%) & = 28.05 \text{ kW} \\
E_{rec}(100\%) & = 0.12 \text{ mJ} \\
t_{Erec} & = 0.08 \text{ } \mu\text{s}
\end{align*}
Switching Definitions BOOST IGBT

General conditions

\[ T_j = 125 \, ^\circ C \]
\[ R_{on} = 8 \, \Omega \]
\[ R_{off} = 8 \, \Omega \]

**Figure 1**
Neutral point IGBT
Turn-off Switching Waveforms & definition of \( t_{off}, t_{Eoff} \)

- \( V_{GE}(0\%) = -15 \, V \)
- \( V_{GE}(100\%) = 15 \, V \)
- \( I_C(100\%) = 40 \, A \)
- \( t_{off} = 0.21 \, \mu s \)
- \( t_{Eoff} = 0.40 \, \mu s \)

**Figure 2**
Neutral point IGBT
Turn-on Switching Waveforms & definition of \( t_{on}, t_{Eon} \)

- \( V_{GE}(0\%) = -15 \, V \)
- \( V_{GE}(100\%) = 15 \, V \)
- \( I_C(100\%) = 40 \, A \)
- \( t_{on} = 0.10 \, \mu s \)
- \( t_{Eon} = 0.20 \, \mu s \)

**Figure 3**
Neutral point IGBT
Turn-off Switching Waveforms & definition of \( t_{f} \)

- \( V_C(100\%) = 350 \, V \)
- \( I_C(100\%) = 40 \, A \)
- \( t_f = 0.099 \, \mu s \)

**Figure 4**
Neutral point IGBT
Turn-on Switching Waveforms & definition of \( t_r \)

- \( V_C(100\%) = 350 \, V \)
- \( I_C(100\%) = 40 \, A \)
- \( t_r = 0.013 \, \mu s \)
Switching Definitions BOOST IGBT

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

- $P_{\text{off}}(100\%) = 13.96\ kW$
- $E_{\text{off}}(100\%) = 1.50\ mJ$
- $t_{\text{Eoff}} = 0.40\ \mu s$

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

- $P_{\text{on}}(100\%) = 13.9552\ kW$
- $E_{\text{on}}(100\%) = 0.72\ mJ$
- $t_{\text{Eon}} = 0.2025\ \mu s$

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

- $V_{\text{G(on)}} = -15\ V$
- $V_{\text{G(off)}} = 15\ V$
- $V_{\text{C(on)}}(100\%) = 350\ V$
- $V_{\text{C(off)}}(100\%) = 40\ A$
- $Q_g = 464.74\ nC$

**Figure 8**
Half Bridge FRED
Turn-off Switching Waveforms & definition of $t_{\text{tr}}$

- $V_d(100\%) = 350\ V$
- $i_d(100\%) = 40\ A$
- $i_{\text{rm}}(100\%) = -79\ A$
- $t_{\text{tr}} = 0.17\ \mu s$
Switching Definitions BOOST IGBT

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

- \( I_d \) (100%) = 40 A
- \( Q_{rr} \) (100%) = 6.14 μC
- \( t_{Q_{int}} \) = 1.00 μs

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

- \( P_{rec} \) (100%) = 13.96 kW
- \( E_{rec} \) (100%) = 1.78 mJ
- \( t_{E_{int}} \) = 1.00 μs

---

**Measurement circuit**

**Figure 11**
BOOST stage switching measurement circuit

---

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Ordering Code and Marking - Outline - Pinout

Ordering Code & Marking

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<th>in DataMatrix as</th>
<th>in packaging barcode as</th>
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Outline

Pin hole

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Pinout

GND 05,14

Line 08,09,10,11

-DC 03,04

+DC 15,16

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