### Maximum Ratings

\( T = 25 \, ^\circ C \), 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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<tbody>
<tr>
<td><strong>Buck Switch</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collector-emitter voltage</td>
<td>( V_{CE} )</td>
<td>( T_j = T_{j_{max}} ), ( T_s = 80 , ^\circ C )</td>
<td>650</td>
<td>V</td>
</tr>
<tr>
<td>Collector current</td>
<td>( I_c )</td>
<td>( T_j = T_{j_{max}} ), ( T_s = 80 , ^\circ C )</td>
<td>118</td>
<td>A</td>
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<tr>
<td>Repetitive peak collector current</td>
<td>( I_{PK} )</td>
<td>( T_j = T_{j_{max}} )</td>
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</tr>
<tr>
<td>Total power dissipation</td>
<td>( P_{DD} )</td>
<td>( T_j = T_{j_{max}} ), ( T_s = 80 , ^\circ C )</td>
<td>171</td>
<td>W</td>
</tr>
<tr>
<td>Gate-emitter voltage</td>
<td>( V_{GE} )</td>
<td>( T_j = T_{j_{max}} )</td>
<td>±30</td>
<td>V</td>
</tr>
<tr>
<td>Maximum junction temperature</td>
<td>( T_{j_{max}} )</td>
<td>( T_j = T_{j_{max}} )</td>
<td>175</td>
<td>^\circ C</td>
</tr>
<tr>
<td><strong>Buck Diode</strong></td>
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<td></td>
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<tr>
<td>Peak repetitive reverse voltage</td>
<td>( V_{RRM} )</td>
<td>( T_j = T_{j_{max}} )</td>
<td>650</td>
<td>V</td>
</tr>
<tr>
<td>Continuous (direct) forward current</td>
<td>( I_F )</td>
<td>( T_j = T_{j_{max}} ), ( T_s = 80 , ^\circ C )</td>
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<td>W</td>
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<tr>
<td>Maximum junction temperature</td>
<td>( T_{j_{max}} )</td>
<td>( T_j = T_{j_{max}} )</td>
<td>175</td>
<td>^\circ C</td>
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### Maximum Ratings

$T_j = 25 \, ^\circ\text{C}$, unless otherwise specified

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
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<tr>
<td><strong>Out. Boost Switch</strong></td>
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<tr>
<td>Collector-emitter voltage</td>
<td>$V_{CES}$</td>
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<td>V</td>
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<tr>
<td>Collector current</td>
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<td>$I_{\text{PEAK}}$</td>
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<td>159</td>
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<td>Gate-emitter voltage</td>
<td>$V_{GES}$</td>
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<td>±30</td>
<td>V</td>
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<td>Short circuit ratings</td>
<td>$t_{SC}$</td>
<td>$V_{ds} = 15 , \text{V}$, $V_{cc} = 360 , \text{V}$</td>
<td>2</td>
<td>$\mu\text{s}$</td>
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<td>$^\circ\text{C}$</td>
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<td><strong>Out. Boost Diode</strong></td>
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<td></td>
</tr>
<tr>
<td>Peak repetitive reverse voltage</td>
<td>$V_{RRM}$</td>
<td></td>
<td>650</td>
<td>V</td>
</tr>
<tr>
<td>Continuous (direct) forward current</td>
<td>$I_F$</td>
<td>$T_j = T_{j_{\text{max}}}$</td>
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<td>Repetitive peak forward current</td>
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<tr>
<td>Total power dissipation</td>
<td>$P_{\text{tot}}$</td>
<td>$T_j = T_{j_{\text{max}}}$</td>
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<td>W</td>
</tr>
<tr>
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<td>$T_{j_{\text{max}}}$</td>
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<td>175</td>
<td>$^\circ\text{C}$</td>
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<td><strong>Out. Boost Inverse Diode</strong></td>
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<tr>
<td>Peak repetitive reverse voltage</td>
<td>$V_{RRM}$</td>
<td></td>
<td>650</td>
<td>V</td>
</tr>
<tr>
<td>Continuous (direct) forward current</td>
<td>$I_F$</td>
<td>$T_j = T_{j_{\text{max}}}$</td>
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<td>A</td>
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<td>Repetitive peak forward current</td>
<td>$I_{\text{FRM}}$</td>
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<td>400</td>
<td>A</td>
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<tr>
<td>Total power dissipation</td>
<td>$P_{\text{tot}}$</td>
<td>$T_j = T_{j_{\text{max}}}$</td>
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<td>W</td>
</tr>
<tr>
<td>Maximum junction temperature</td>
<td>$T_{j_{\text{max}}}$</td>
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<td>$^\circ\text{C}$</td>
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<td><strong>Module Properties</strong></td>
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<td><strong>Thermal Properties</strong></td>
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<tr>
<td>Storage temperature</td>
<td>$T_{stg}$</td>
<td></td>
<td>-40...+125</td>
<td>$^\circ\text{C}$</td>
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<td>Operation temperature under switching condition</td>
<td>$T_{j_{op}}$</td>
<td>$T_j = T_{j_{\text{max}}}$</td>
<td>-40...($T_{j_{\text{max}}}$ - 25)</td>
<td>$^\circ\text{C}$</td>
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<td><strong>Isolation Properties</strong></td>
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<tr>
<td>Isolation voltage</td>
<td>$V_{\text{isol}}$</td>
<td>$t_p = 2 , \text{s}$</td>
<td>6000</td>
<td>V</td>
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<tr>
<td>AC Voltage</td>
<td>$c_i = 1 , \text{min}$</td>
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<td>2500</td>
<td>V</td>
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<tr>
<td>Creepage distance</td>
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<td>min. 12,7</td>
<td></td>
<td>mm</td>
</tr>
<tr>
<td>Clearance</td>
<td></td>
<td>solder pin \ press-fit pin</td>
<td>8,07 \ 7,86</td>
<td>mm</td>
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<tr>
<td>Comparative Tracking Index</td>
<td>CTI</td>
<td>$&gt; 200$</td>
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*100 % tested in production
### 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>Min</td>
<td>Typ</td>
<td>Max</td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>$V_{CEsat}$</td>
<td>15</td>
<td>200</td>
<td>25</td>
</tr>
<tr>
<td>Collector-emitter cut-off current</td>
<td>$I_{CEO}$</td>
<td>0</td>
<td>650</td>
<td>25</td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>$I_{GES}$</td>
<td>30</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>Gate charge</td>
<td>$Q_{g}$</td>
<td>15</td>
<td>400</td>
<td>200</td>
</tr>
<tr>
<td>Thermal resistance junction to sink</td>
<td>$R_{th(j-s)}$</td>
<td>$λ_{paste} = 3,4 , \text{W/mK}$</td>
<td>(PSX)</td>
<td>0,56</td>
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<tr>
<td>Turn-on delay time</td>
<td>$t_{(on)}$</td>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
</tr>
<tr>
<td>Rise time</td>
<td>$t_{r}$</td>
<td>$R_{gs} = 4 , \Omega$</td>
<td>$R_{ds} = 4 , \Omega$</td>
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</tr>
<tr>
<td>Turn-off delay time</td>
<td>$t_{(off)}$</td>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
</tr>
<tr>
<td>Fall time</td>
<td>$t_{f}$</td>
<td></td>
<td>25</td>
<td>125</td>
</tr>
<tr>
<td>Turn-on energy (per pulse)</td>
<td>$E_{on}$</td>
<td>$\Theta_{PEAK} = 6,5 , \mu C$</td>
<td>$\Theta_{PEAK} = 9,7 , \mu C$</td>
<td>$\Theta_{PEAK} = 11 , \mu C$</td>
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<tr>
<td>Turn-off energy (per pulse)</td>
<td>$E_{off}$</td>
<td>25</td>
<td>125</td>
<td>150</td>
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</table>
## Characteristic Values

<table>
<thead>
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<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
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<tbody>
<tr>
<td>Forward voltage</td>
<td>$V_F$</td>
<td>160</td>
<td>25</td>
<td>125</td>
</tr>
<tr>
<td>Reverse leakage current</td>
<td>$I_L$</td>
<td>650</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Thermal</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Thermal resistance junction to sink</td>
<td>$\theta_{th(j-s)}$</td>
<td>λ paste = 3.4 W/mK (PSX)</td>
<td>0,77</td>
<td>K/W</td>
</tr>
<tr>
<td>Dynamic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak recovery current</td>
<td>$I_{RRM}$</td>
<td>-5 / 15</td>
<td>25</td>
<td>125</td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>$\tau_r$</td>
<td>350</td>
<td>25</td>
<td>125</td>
</tr>
<tr>
<td>Recovered charge</td>
<td>$Q_r$</td>
<td>-5 / 15</td>
<td>25</td>
<td>125</td>
</tr>
<tr>
<td>Reverse recovered energy</td>
<td>$E_{rec}$</td>
<td>25</td>
<td></td>
<td>125</td>
</tr>
<tr>
<td>Peak rate of fall of recovery current</td>
<td>$(di/dt)_{max}$</td>
<td>25</td>
<td></td>
<td>125</td>
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</table>
## Characteristic Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>VGE</td>
<td>[V]</td>
<td>5</td>
<td>0,1142</td>
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</tr>
<tr>
<td>VGS</td>
<td>[V]</td>
<td>15</td>
<td>160</td>
<td>125</td>
</tr>
<tr>
<td>VCE</td>
<td>[V]</td>
<td>15</td>
<td>25</td>
<td>650</td>
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<tr>
<td>VDS</td>
<td>[V]</td>
<td>30</td>
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<td>400</td>
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<tr>
<td>IF</td>
<td>[A]</td>
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<td>400</td>
<td>160</td>
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<tr>
<td>Tj</td>
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<td>25</td>
<td>1,75</td>
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<tr>
<td></td>
<td></td>
<td>30</td>
<td>125</td>
<td>1,962</td>
</tr>
</tbody>
</table>

### Out. Boost Switch

#### Static
- **Gate-emitter threshold voltage**: $V_{GE(th)} = 5 \leq 0,1142 \leq 7$ V
- **Collector-emitter saturation voltage**: $V_{CEsat} = 15 \leq 1,65 \leq 1,9$ V
- **Collector-emitter cut-off current**: $I_{CEO} = 650 \leq 20 \mu A$
- **Gate-emitter leakage current**: $I_{GE} = 30 \leq 400 \mu A$
- **Internal gate resistance**: $r_g = \text{none}$ Ω
- **Input capacitance**: $C_{GS, f = 1 \text{ MHz}} = 368$ pF
- **Output capacitance**: $C_{CO} = 158$ nF
- **Gate charge**: $Q_{g} = 15 \leq 400 \leq 160 \leq 25 \leq 342$ nC
- **Reverse transfer capacitance**: $C_{res} = 158$ nF

#### Dynamic
- **Turn-on delay time**: $t_{on} = 25 \leq 85$ ns
- **Rise time**: $t_{r} = 25 \leq 165$ ns
- **Turn-off delay time**: $t_{off} = 25 \leq 85$ ns
- **Fall time**: $t_{f} = 25 \leq 49$ ns
- **Turn-on energy (per pulse)**: $E_{on} = 25 \leq 1,293 \text{ mWs}$
- **Turn-off energy (per pulse)**: $E_{off} = 25 \leq 1,962 \text{ mWs}$
### Characteristic Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
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<th>Value</th>
<th>Unit</th>
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#### Out. Boost Diode

**Static**

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<tr>
<td>Forward voltage</td>
<td>$V_F$</td>
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<tr>
<td>Reverse leakage current</td>
<td>$I_R$</td>
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<td>20</td>
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**Thermal**

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<th>Symbol</th>
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<th>Value</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Thermal resistance junction to sink</td>
<td>$R_{th(j-s)}$</td>
<td></td>
<td>0.88</td>
<td>K/W</td>
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**Dynamic**

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<th>Symbol</th>
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<tbody>
<tr>
<td>Peak recovery current</td>
<td>$I_{RPM}$</td>
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<td>Reverse recovery time</td>
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<td>Recovered charge</td>
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<td>Reverse recovered energy</td>
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<td>$(di/dt)_{max}$</td>
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#### Out. Boost Inverse Diode

**Static**

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<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Forward voltage</td>
<td>$V_F$</td>
<td></td>
<td>100</td>
<td>1.51</td>
</tr>
<tr>
<td>Reverse leakage current</td>
<td>$I_R$</td>
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<td>650</td>
<td>20</td>
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</table>

**Thermal**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
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<td>Thermal resistance junction to sink</td>
<td>$R_{th(j-s)}$</td>
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<td>0.88</td>
<td>K/W</td>
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## Characteristic Values

<table>
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<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$V_{GE}$ [V]</td>
<td>$V_{GS}$ [V]</td>
<td>$I_a$ [A]</td>
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<tr>
<td>$V_{CE}$ [V]</td>
<td>$I_d$ [A]</td>
<td>$I_f$ [A]</td>
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<td>$R$</td>
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<td>22</td>
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<td></td>
<td>$\Delta R_{100}$</td>
<td>$R_{25}$ = 1484 Ω</td>
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<td>5</td>
<td>mW</td>
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<td>Power dissipation constant</td>
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<td>1,5</td>
<td>mW/K</td>
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<tr>
<td>B-value</td>
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<td>Tol. ±1 %</td>
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<td>Vincotech NTC Reference</td>
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Buck Switch Characteristics

**Figure 1.** 
Typical output characteristics

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

- \( I_p = 250 \mu s \)
- \( V_{CES} = 15 \) V
- \( T_j: 25 \) °C
- \( V_{CES} = 150 \) °C

**Figure 2.** 
Typical output characteristics

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

- \( I_p = 250 \mu s \)
- \( V_{GE} \) from 7 V to 17 V in steps of 1 V
- \( T_j: 150 \) °C
- \( V_{GE} = 15 \) V

**Figure 3.** 
Typical transfer characteristics

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

- \( I_p = 100 \mu s \)
- \( V_{CES} = 10 \) V
- \( T_j: 25 \) °C
- \( V_{CES} = 150 \) °C

**Figure 4.** 
Transient thermal impedance as function of pulse duration

\[ Z_{th(j-s)} = f(t_p) \]

- \( D = \frac{I_p}{T} \)
- \( R_{th(j-s)} = 0,56 \) K/W
- \( T \) (s)
  - 6,25E-02: 4,60E+00
  - 9,27E-02: 1,18E+00
  - 1,98E-01: 1,90E-01
  - 1,40E-01: 5,31E-02
  - 4,05E-02: 8,08E-03
  - 2,15E-02: 5,71E-04

\( T_j: \)
- 0
- 50
- 100
- 150
- 200

\( V_{GE}: \)
- 7 V
- 8 V
- 9 V
- 10 V
- 11 V
- 12 V
- 13 V
- 14 V
- 15 V
- 16 V
- 17 V

\( I_C (A): \)
- 0
- 100
- 200
- 300
- 400
- 500
- 600

\( V_{CE} (V): \)
- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9

\( Z_{th (K/W)} (s): \)
- 10^{-3}
- 10^{-2}
- 10^{-1}
- 10^{0}
- 10^{1}
- 10^{2}
- 10^{3}
- 10^{4}
- 10^{5}
- 10^{6}
- 10^{7}

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Buck Switch Characteristics

Figure 5. IGBT Safe operating area

\( I_c = f(V_{CE}) \)

- \( D = \) single pulse
- \( T_s = 80 \) °C
- \( V_{GE} = 0 \) V
- \( T_j = T_{\text{max}} \)
Buck Diode Characteristics

Figure 1: Typical forward characteristics

\[ I_F = f(V_F) \]

Figure 2: Transient thermal impedance as a function of pulse width

\[ Z_{th(j-s)} = f(t_p) \]

 transient thermal impedance as a function of pulse width

\[ t_p = 250 \mu s \]

\[ T \]

R \(_{th(j-s)}\) = 0.77 K/W

FWD thermal model values:

<table>
<thead>
<tr>
<th>I (K/W)</th>
<th>T (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.15E-02</td>
<td>5.35E+00</td>
</tr>
<tr>
<td>1.37E-01</td>
<td>1.13E+00</td>
</tr>
<tr>
<td>1.90E-01</td>
<td>1.82E-01</td>
</tr>
<tr>
<td>2.57E-01</td>
<td>5.47E-02</td>
</tr>
<tr>
<td>8.27E-02</td>
<td>9.48E-03</td>
</tr>
<tr>
<td>2.02E-02</td>
<td>1.43E-03</td>
</tr>
<tr>
<td>2.82E-02</td>
<td>2.96E-04</td>
</tr>
</tbody>
</table>

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Out. Boost Switch Characteristics

**Figure 1.** IGBT Typical output characteristics

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

- \( t_p = 250 \, \mu s \)
- \( V_{CE} = 15 \, V \)
- \( T_j = 25 \, ^\circ C \)
- \( V_{GE} = 15 \, V \)
- \( T_j = 150 \, ^\circ C \)

**Figure 2.** IGBT Typical output characteristics

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

- \( t_p = 250 \, \mu s \)
- \( V_{GE} \) from 7 V to 17 V in steps of 1 V
- \( R_{th(j-s)} = 0.60 \, K/W \)

**Figure 3.** IGBT Typical transfer characteristics

\[ Z_{th(j-s)} = f(t_p) \]

- \( t_p = 100 \, \mu s \)
- \( V_{CE} = 10 \, V \)
- \( T_j = 25 \, ^\circ C \)
- \( V_{GE} = 7 \, V \)

**Figure 4.** IGBT Transient thermal impedance as function of pulse duration

\[ Z_{th(j-s)} = f(t_p) \]

- \( t_p = 10^{-5} \) to \( 10^{-1} \) s
- \( R_{th(j-s)} = 0.60 \, K/W \)

IGBT thermal model values

- \( R_{th(j-s)}(K/W) \)
- \( \tau(s) \)

<table>
<thead>
<tr>
<th>( \tau ) (s)</th>
<th>( R_{th(j-s)} ) (K/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
<td>0.60</td>
</tr>
<tr>
<td>0.1</td>
<td>0.57</td>
</tr>
<tr>
<td>1.0</td>
<td>0.50</td>
</tr>
<tr>
<td>10</td>
<td>0.35</td>
</tr>
<tr>
<td>100</td>
<td>0.25</td>
</tr>
<tr>
<td>1000</td>
<td>0.15</td>
</tr>
<tr>
<td>10000</td>
<td>0.09</td>
</tr>
<tr>
<td>100000</td>
<td>0.05</td>
</tr>
</tbody>
</table>

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Out. Boost Switch Characteristics

Figure 5. IGBT Gate voltage vs gate charge $V_{GE} = f(Q_G)$

$V_{CE} = 400$ V

$I_{C} = 160$ A

$D = $ single pulse

$T_s = 80^\circ C$

$V_{CE} = \pm 15$ V

$T_j = T_{j\max}$

Figure 6. IGBT Safe operating area $I_{C} = f(V_{CE})$

$I_{C}$

$V_{CE}$

$1000$

$100$

$10$

$1$

$0,01$

$1000$

$100$

$10$

$1$
Out. Boost Diode Characteristics

**Figure 1.** Typical forward characteristics

\[ I_F = f(V_F) \]

<table>
<thead>
<tr>
<th>( V_F ) (V)</th>
<th>0</th>
<th>0.5</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I_F ) (A)</td>
<td>0</td>
<td>50</td>
<td>100</td>
<td>150</td>
<td>200</td>
<td>250</td>
<td>300</td>
</tr>
</tbody>
</table>

\( t_p = 250 \mu s \)

\( T_J \): 25 °C

\[ R_{th(j-s)} = 0.88 \text{ K/W} \]

**Figure 2.** Transient thermal impedance as a function of pulse width

\[ Z_{th(j-s)} = f(t_p) \]

<table>
<thead>
<tr>
<th>( t_p ) (s)</th>
<th>0.1</th>
<th>0.2</th>
<th>0.5</th>
<th>1.0</th>
<th>2.0</th>
<th>3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_{th(j-s)} ) (K/W)</td>
<td>0.88</td>
<td>2.35E-01</td>
<td>3.35E-01</td>
<td>5.35E-01</td>
<td>7.35E-01</td>
<td>9.35E-01</td>
</tr>
</tbody>
</table>

Out. Boost Inverse Diode Characteristics

**Figure 1.** Typical forward characteristics

\[ I_F = f(V_F) \]

<table>
<thead>
<tr>
<th>( V_F ) (V)</th>
<th>0</th>
<th>0.5</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I_F ) (A)</td>
<td>0</td>
<td>50</td>
<td>100</td>
<td>150</td>
<td>200</td>
<td>250</td>
<td>300</td>
</tr>
</tbody>
</table>

\( t_p = 250 \mu s \)

\( T_J \): 25 °C

\[ R_{th(j-s)} = 0.88 \text{ K/W} \]

**Figure 2.** Transient thermal impedance as a function of pulse width

\[ Z_{th(j-s)} = f(t_p) \]

<table>
<thead>
<tr>
<th>( t_p ) (s)</th>
<th>0.1</th>
<th>0.2</th>
<th>0.5</th>
<th>1.0</th>
<th>2.0</th>
<th>3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_{th(j-s)} ) (K/W)</td>
<td>0.88</td>
<td>2.35E-01</td>
<td>3.35E-01</td>
<td>5.35E-01</td>
<td>7.35E-01</td>
<td>9.35E-01</td>
</tr>
</tbody>
</table>

\( D = t_p / T \)

\( T_J \): 125 °C

\[ R_{th(j-s)} = 0.88 \text{ K/W} \]

FWD thermal model values

\( h \) (K/W) \( \tau \) (s)

9,17E-02 3,12E+00
2,61E-01 2,35E-01
3,62E-01 4,36E-02
1,21E-01 5,86E-03
4,11E-02 8,97E-04

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Thermistor Characteristics

Figure 1. Typical NTC characteristic as a function of temperature

\[ R = f(T) \]
Buck Switching Characteristics

Figure 1.  IGBT
Typical switching energy losses as a function of collector current

\[ E = f(I_C) \]

With an inductive load at 25 °C

| \( V_{in} \) | 350 V | \( T_J \) | 125 °C |
| \( V_{on} \) | -5 / 15 V |
| \( R_{on} \) | 4 Ω |

| \( V_{in} \) | 350 V | \( T_J \) | 150 °C |
| \( V_{on} \) | -5 / 15 V |
| \( R_{on} \) | 4 Ω |

Figure 2.  IGBT
Typical switching energy losses as a function of gate resistor

\[ E = f(R_g) \]

With an inductive load at 25 °C

| \( V_{in} \) | 350 V | \( T_J \) | 125 °C |
| \( V_{on} \) | -5 / 15 V |
| \( I_C \) | 200 A |

| \( V_{in} \) | 350 V | \( T_J \) | 150 °C |
| \( V_{on} \) | -5 / 15 V |
| \( I_C \) | 200 A |

Figure 3.  FWD
Typical reverse recovered energy losses as a function of collector current

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

With an inductive load at 25 °C

| \( V_{in} \) | 350 V | \( T_J \) | 125 °C |
| \( V_{on} \) | -5 / 15 V |
| \( R_{on} \) | 4 Ω |

| \( V_{in} \) | 350 V | \( T_J \) | 150 °C |
| \( V_{on} \) | -5 / 15 V |
| \( R_{on} \) | 4 Ω |

Figure 4.  FWD
Typical reverse recovered energy losses as a function of gate resistor

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

With an inductive load at 25 °C

| \( V_{in} \) | 350 V | \( T_J \) | 125 °C |
| \( V_{on} \) | -5 / 15 V |
| \( I_C \) | 200 A |

| \( V_{in} \) | 350 V | \( T_J \) | 150 °C |
| \( V_{on} \) | -5 / 15 V |
| \( I_C \) | 200 A |
Buck Switching Characteristics

Figure 5. IGBT
Typical switching times as a function of collector current

$t_{\text{on}} = f(I_C)$

With an inductive load at
- $T_J = 150 \, ^\circ\text{C}$
- $V_{CE} = 350 \, \text{V}$
- $V_{GE} = -5 / 15 \, \text{V}$
- $R_{gon} = 4 \, \Omega$
- $I_C = 200 \, \text{A}$

Figure 6. IGBT
Typical switching times as a function of gate resistor

$t_{\text{on}} = f(R_g)$

With an inductive load at
- $T_J = 150 \, ^\circ\text{C}$
- $V_{CE} = 350 \, \text{V}$
- $V_{GE} = -5 / 15 \, \text{V}$
- $I_C = 200 \, \text{A}$

Figure 7. FWD
Typical reverse recovery time as a function of collector current

$t_{rr} = f(I_C)$

With an inductive load at
- $T_J = 25 \, ^\circ\text{C}$
- $V_{CE} = 350 \, \text{V}$
- $T_J = 125 \, ^\circ\text{C}$
- $V_{CE} = 350 \, \text{V}$
- $V_{GE} = -5 / 15 \, \text{V}$
- $R_{gon} = 4 \, \Omega$
- $N_C = 200 \, \text{A}$

Figure 8. FWD
Typical reverse recovery time as a function of IGBT turn-on gate resistor

$t_{rr} = f(R_{gon})$

With an inductive load at
- $T_J = 25 \, ^\circ\text{C}$
- $V_{CE} = 350 \, \text{V}$
- $T_J = 125 \, ^\circ\text{C}$
- $V_{CE} = 350 \, \text{V}$
- $V_{GE} = -5 / 15 \, \text{V}$
- $I_C = 200 \, \text{A}$
Buck Switching Characteristics

Figure 9. FWD
Typical recovered charge as a function of collector current

\[ Q_r = f(I_C) \]

With an inductive load at 25 °C
- \( V_{in} = 350 \) V
- \( T_j = 125 \) °C
- \( R_{on} = 4 \) Ω

Figure 10. FWD
Typical recovered charge as a function of IGBT turn on gate resistor

\[ Q_r = f(R_{on}) \]

With an inductive load at 25 °C
- \( V_{in} = 350 \) V
- \( T_j = 125 \) °C

Figure 11. FWD
Typical peak reverse recovery current as a function of collector current

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

With an inductive load at 25 °C
- \( V_{in} = 350 \) V
- \( T_j = 125 \) °C
- \( R_{on} = 4 \) Ω

Figure 12. FWD
Typical peak reverse recovery current as a function of IGBT turn on gate resistor

\[ I_{RM} = f(R_{on}) \]

With an inductive load at 25 °C
- \( V_{in} = 350 \) V
- \( T_j = 125 \) °C
- \( I_C = 200 \) A
Buck Switching Characteristics

**Figure 13.** FWD
Typical rate of fall of forward and reverse recovery current as a function of collector current
\[ \frac{di_F}{dt}, \frac{di_{rr}}{dt} = f(I_C) \]

With an inductive load at 25 °C
- V_{CE} = 350 V
- T_j = 125 °C
- V_{in} = -5 / 15 V
- R_{goff} = 4 Ω

**Figure 14.** FWD
Typical rate of fall of forward and reverse recovery current as a function of IGBT turn on gate resistor
\[ \frac{di_F}{dt}, \frac{di_{rr}}{dt} = f(R_{gon}) \]

With an inductive load at 25 °C
- V_{CE} = 350 V
- T_j = 125 °C
- V_{in} = -5 / 15 V
- I_C = 200 A

**Figure 15.** IGBT
Reverse bias safe operating area
\[ I_{C} = 4(V_{CE}) \]

At
- T_j = 125 °C
- R_{goff} = 4 Ω
- R_{goff} = 4 Ω

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Buck Switching Definitions

General conditions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_j$</td>
<td>125 °C</td>
</tr>
<tr>
<td>$R_{on}$</td>
<td>4 Ω</td>
</tr>
<tr>
<td>$R_{off}$</td>
<td>4 Ω</td>
</tr>
</tbody>
</table>

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

- $V_{GE}(0\%) = -5$ V
- $V_{GE}(100\%) = 15$ V
- $I_{C}(100\%) = 200$ A
- $t_{on} = 206$ ns

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

- $V_{GE}(0\%) = -5$ V
- $V_{GE}(100\%) = 15$ V
- $I_{C}(100\%) = 200$ A
- $t_{on} = 80$ ns

Figure 3. IGBT Turn-off Switching Waveforms & definition of $I_{C}$

- $V_{CE}(10\%) = 350$ V
- $I_{C}(10\%) = 200$ A
- $t_{on} = 39$ ns

Figure 4. IGBT Turn-on Switching Waveforms & definition of $I_{C}$

- $V_{CE}(10\%) = 350$ V
- $I_{C}(10\%) = 200$ A
- $t_{on} = 22$ ns
Buck Switching Characteristics

**Figure 5.** Turn-off Switching Waveforms & definition of \( t_{tr} \)

- \( V_F(100\%) = 350 \, \text{V} \)
- \( I_F(100\%) = 200 \, \text{A} \)
- \( I_{RRM}(10\%) = 224 \, \text{A} \)
- \( t_{tr} = 104 \, \text{ns} \)

**Figure 6.** Turn-on Switching Waveforms & definition of \( t_{Qr} \) \( (t_{Qr} = \text{integrating time for } Q_r) \)

- \( V_F(100\%) = 350 \, \text{V} \)
- \( I_F(100\%) = 200 \, \text{A} \)
- \( I_{RRM}(10\%) = 224 \, \text{A} \)
- \( Q_r(100\%) = 0 \, \mu\text{C} \)
Boost Switching Characteristics

**Figure 1.** IGBT
Typical switching energy losses as a function of collector current

\[ E = f(I_C) \]

With an inductive load at 25 °C
- \( V_{in} = 350 \) V
- \( T_j = 125 \) °C
- \( R_{on} = 4 \) Ω
- \( R_{off} = 4 \) Ω

**Figure 2.** IGBT
Typical switching energy losses as a function of gate resistor

\[ E = f(R_g) \]

With an inductive load at 25 °C
- \( V_{in} = 350 \) V
- \( T_j = 125 \) °C
- \( I_c = 160 \) A

**Figure 3.** FWD
Typical reverse recovered energy loss as a function of collector current

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

With an inductive load at 25 °C
- \( V_{in} = 350 \) V
- \( T_j = 125 \) °C
- \( R_{on} = 4 \) Ω
- \( R_{off} = 4 \) Ω

**Figure 4.** FWD
Typical reverse recovered energy loss as a function of gate resistor

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

With an inductive load at 25 °C
- \( V_{in} = 350 \) V
- \( T_j = 125 \) °C
- \( I_c = 160 \) A
Boost Switching Characteristics

**Figure 5.** IGBT
Typical switching times as a function of collector current

\[ t_{d(on)} = f(I_C) \]

With an inductive load at
- \( T_j = 150 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 4 \) Ω
- \( I_C = 160 \) A

**Figure 6.** IGBT
Typical switching times as a function of gate resistor

\[ t_{d(off)} = f(R_g) \]

With an inductive load at
- \( T_j = 25 \) °C
- \( V_{CE} = 125 \) °C
- \( V_{GE} = \pm 15 \) V
- \( I_C = 160 \) A

**Figure 7.** FWD
Typical reverse recovery time as a function of collector current

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

With an inductive load at
- \( T_j = 25 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 4 \) Ω

**Figure 8.** FWD
Typical reverse recovery time as a function of IGBT turn-on gate resistor

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

With an inductive load at
- \( T_j = 150 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_C = 160 \) A

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Boost Switching Characteristics

**Figure 9.**
Typical recovered charge as a function of collector current

$Q_r = f(I_C)$

- With an inductive load at $25^\circ C$
  - $V_{in} = 350 \, V$
  - $T_j = 125 \, ^\circ C$
  - $R_{gon} = 4 \, \Omega$

- With an inductive load at $150 \, ^\circ C$
  - $V_{in} = \pm 15 \, V$
  - $I_C = 160 \, A$

**Figure 11.**
Typical peak reverse recovery current as a function of collector current

$I_{RM} = f(I_C)$

- With an inductive load at $25^\circ C$
  - $V_{in} = 350 \, V$
  - $T_j = 125 \, ^\circ C$
  - $R_{gon} = 4 \, \Omega$

- With an inductive load at $150 \, ^\circ C$
  - $V_{in} = \pm 15 \, V$
  - $I_C = 160 \, A$
Boost Switching Characteristics

**Figure 13.** FWD

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

\[
\frac{di_F}{dt}, \frac{di_{rr}}{dt} = f(I_C)
\]

With an inductive load at

- \( V_C = 350 \text{ V} \)
- \( T_j = 125 ^\circ \text{C} \)
- \( R_{gon} = 4 \text{ Ω} \)
- \( V_{CE} = 350 \text{ V} \)
- \( I_C = 160 \text{ A} \)

**Figure 14.** FWD

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

\[
\frac{di_F}{dt}, \frac{di_{rr}}{dt} = f(R_{gon})
\]

With an inductive load at

- \( V_C = 350 \text{ V} \)
- \( T_j = 125 ^\circ \text{C} \)
- \( R_{gon} = 4 \text{ Ω} \)
- \( V_{CE} = 350 \text{ V} \)
- \( I_C = 160 \text{ A} \)

**Figure 15.** IGBT

Reverse bias safe operating area

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

At

- \( V_{CE} = 350 \text{ V} \)
- \( T_j = 125 ^\circ \text{C} \)
- \( R_{com} = 4 \text{ Ω} \)
- \( R_{pin} = 4 \text{ Ω} \)
Boost Switching Definitions

General conditions

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_J$</td>
<td>$125 , ^\circ C$</td>
</tr>
<tr>
<td>$R_{DS,ON}$</td>
<td>$4 , \Omega$</td>
</tr>
<tr>
<td>$R_{DS,OFF}$</td>
<td>$4 , \Omega$</td>
</tr>
</tbody>
</table>

**Figure 1.** IGBT

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

- $V_{GE}(0\%) = -15 \, V$
- $V_{GE}(100\%) = -15 \, V$
- $V_{CE}(0\%) = 350 \, V$
- $V_{CE}(100\%) = 350 \, V$
- $I_{C}(0\%) = 93 \, A$
- $I_{C}(100\%) = 160 \, A$
- $I_{doff} = 93 \, ns$
- $I_{Eoff} = 100 \, ns$

**Figure 2.** IGBT

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

- $V_{GE}(0\%) = -15 \, V$
- $V_{GE}(100\%) = -15 \, V$
- $V_{CE}(0\%) = 350 \, V$
- $V_{CE}(100\%) = 350 \, V$
- $I_{C}(0\%) = 93 \, A$
- $I_{C}(100\%) = 160 \, A$
- $I_{don} = 86 \, ns$

**Figure 3.** IGBT

Turn-off Switching Waveforms & definition of $t_f$

- $V_{CE}(0\%) = 350 \, V$
- $V_{CE}(100\%) = 350 \, V$
- $I_{C}(0\%) = 93 \, A$
- $I_{C}(100\%) = 160 \, A$
- $t_{f} = 48 \, ns$

**Figure 4.** IGBT

Turn-on Switching Waveforms & definition of $t_r$

- $V_{CE}(0\%) = 350 \, V$
- $V_{CE}(100\%) = 350 \, V$
- $I_{C}(0\%) = 93 \, A$
- $I_{C}(100\%) = 160 \, A$
- $t_{r} = 15 \, ns$
Boost Switching Characteristics

**Figure 5.** FWD

<table>
<thead>
<tr>
<th>%</th>
<th>$t_o$</th>
<th>$t_{rr}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>fitted</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$V_F(100\%) = 350$ V  
$I_F(100\%) = 160$ A  
$I_{RRM}(100\%) = 183$ A  
$t_{rr}(100\%) = 108$ ns

**Figure 6.** FWD

<table>
<thead>
<tr>
<th>%</th>
<th>$t_o$</th>
<th>$Q_r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>fitted</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$I_{RRM}(10\%) = 160$ A  
$I_{RRM}(90\%) = 160$ A  
$I_{RRM}(100\%) = 0$ μC  
$q_r(100\%) = 0$ μC
<table>
<thead>
<tr>
<th>ID</th>
<th>Component</th>
<th>Voltage</th>
<th>Current</th>
<th>Function</th>
<th>Comment</th>
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</thead>
<tbody>
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<td>T11, T12, T15, T16</td>
<td>IGBT</td>
<td>650V</td>
<td>100A</td>
<td>Buck Switch</td>
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<td>D11, D12</td>
<td>FWD</td>
<td>650V</td>
<td>200A</td>
<td>Buck Diode</td>
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<tr>
<td>T13, T14, T17, T18</td>
<td>IGBT</td>
<td>650V</td>
<td>100A</td>
<td>Out. Boost Switch</td>
<td></td>
</tr>
<tr>
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<td>FWD</td>
<td>650V</td>
<td>100A</td>
<td>Out. Boost Diode</td>
<td></td>
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<td>FWD</td>
<td>650V</td>
<td>100A</td>
<td>Out. Boost Inverse Diode</td>
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<tr>
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<td>NTC</td>
<td>-</td>
<td>-</td>
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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.