Features

- 2400 V NPC-topology (2x 1200 V)
- High power screw interface
- Low inductive interface for external DC-capacitors and paralleling on component level
- Snubber diode for optional asymmetrical inductance
- High speed buck IGBT’s
- Temperature sensor

Target Applications

- UPS
- Solar Inverters

Types

- 70-W224NIA400SH-M400P

Maximum Ratings

$T_j = 25 \, ^\circ C$, 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>$T_j = T_{j\max}$</td>
<td>1200</td>
<td>V</td>
</tr>
<tr>
<td>DC collector current</td>
<td>$I_C$</td>
<td>$T_s = 80 , ^\circ C$</td>
<td>326</td>
<td>A</td>
</tr>
<tr>
<td>Pulsed collector current</td>
<td>$I_{CM}$</td>
<td>$T_s$ limited by $T_{j\max}$</td>
<td>1200</td>
<td>A</td>
</tr>
<tr>
<td>Turn off safe operating area</td>
<td>$V_{CE} \leq 1200 , V$, $T_j \leq T_{j\max}$</td>
<td></td>
<td>800</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>$P_{tot}$</td>
<td>$T_j = T_{j\max}$</td>
<td>881</td>
<td>W</td>
</tr>
<tr>
<td>Gate-emitter peak voltage</td>
<td>$V_{GE}$</td>
<td>$T_j = T_{j\max}$</td>
<td>$\pm 20$</td>
<td>V</td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>$I_{SC}$</td>
<td>$T_j \leq 150 , ^\circ C$</td>
<td>10</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>$V_{CC}$</td>
<td>$V_{CC} = 15 , V$</td>
<td>800</td>
<td>A</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{j\max}$</td>
<td></td>
<td>175</td>
<td>°C</td>
</tr>
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</table>

Buck Diode

<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>$V_{RRM}$</td>
<td>$T_j = T_{j\max}$</td>
<td>1200</td>
<td>V</td>
</tr>
<tr>
<td>DC forward current</td>
<td>$I_F$</td>
<td>$T_s = 80 , ^\circ C$</td>
<td>270</td>
<td>A</td>
</tr>
<tr>
<td>Repetitive peak forward current</td>
<td>$I_{F\max}$</td>
<td>$t_s = 10 , ms$, sin 180°</td>
<td>800</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>$P_{tot}$</td>
<td>$T_j = T_{j\max}$</td>
<td>565</td>
<td>W</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{j\max}$</td>
<td></td>
<td>175</td>
<td>°C</td>
</tr>
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</table>
Maximum Ratings

$T_j = 25 \, ^\circ C$, 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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</thead>
<tbody>
<tr>
<td>Booster Switch</td>
<td>$V_C E$</td>
<td>$T_j = T_{\text{min}}$</td>
<td>1200</td>
<td>V</td>
</tr>
<tr>
<td>Collector-emitter break down voltage</td>
<td>$I_C$</td>
<td>$T_j = T_{\text{max}}$, $T_s = 80 , ^\circ C$</td>
<td>348</td>
<td>A</td>
</tr>
<tr>
<td>DC collector current</td>
<td>$I_{CSS}$</td>
<td>$T_j = T_{\text{min}}$, $T_s = 80 , ^\circ C$</td>
<td>1200</td>
<td>A</td>
</tr>
<tr>
<td>Pulsed collector current</td>
<td>$V_{CE}$</td>
<td>$T_j = T_{\text{min}}$, $T_s = 80 , ^\circ C$</td>
<td>800</td>
<td>A</td>
</tr>
<tr>
<td>Turn off safe operating area</td>
<td>$P_{tot}$</td>
<td>$T_j = T_{\text{min}}$, $T_s = 80 , ^\circ C$</td>
<td>826</td>
<td>W</td>
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<tr>
<td>Power dissipation</td>
<td>$V_{GE}$</td>
<td>$T_j = T_{\text{min}}$</td>
<td>±20</td>
<td>V</td>
</tr>
<tr>
<td>Gate-emitter peak voltage</td>
<td>$t_{SC}$</td>
<td>$T_j = 150 , ^\circ C$, $V_{GE} = 15 , V$</td>
<td>10</td>
<td>µs</td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>$V_{CC}$</td>
<td>$T_j = 150 , ^\circ C$, $V_{GE} = 15 , V$</td>
<td>800</td>
<td>V</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{\text{max}}$</td>
<td></td>
<td>175</td>
<td>°C</td>
</tr>
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Boost Inverse Diode

<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>Peak Repetitive Reverse Voltage</td>
<td>$V_{IRM}$</td>
<td>$T_j = T_{\text{min}}$, $T_s = 80 , ^\circ C$</td>
<td>1200</td>
<td>V</td>
</tr>
<tr>
<td>DC forward current</td>
<td>$I_F$</td>
<td>$T_j = T_{\text{min}}$</td>
<td>242</td>
<td>A</td>
</tr>
<tr>
<td>Repetitive peak forward current</td>
<td>$I_{FMAX}$</td>
<td>$T_j = T_{\text{min}}$</td>
<td>600</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>$P_{tot}$</td>
<td>$T_j = T_{\text{min}}$, $T_s = 80 , ^\circ C$</td>
<td>423</td>
<td>W</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{\text{max}}$</td>
<td></td>
<td>175</td>
<td>°C</td>
</tr>
</tbody>
</table>

Boost Diode

<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>Peak Repetitive Reverse Voltage</td>
<td>$V_{IRM}$</td>
<td>$T_j = T_{\text{min}}$, $T_s = 80 , ^\circ C$</td>
<td>1200</td>
<td>V</td>
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<tr>
<td>DC forward current</td>
<td>$I_F$</td>
<td>$T_j = T_{\text{min}}$</td>
<td>257</td>
<td>A</td>
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<tr>
<td>Repetitive peak forward current</td>
<td>$I_{FMAX}$</td>
<td>$T_j = T_{\text{min}}$</td>
<td>600</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>$P_{tot}$</td>
<td>$T_j = T_{\text{min}}$, $T_s = 80 , ^\circ C$</td>
<td>452</td>
<td>W</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{\text{max}}$</td>
<td></td>
<td>175</td>
<td>°C</td>
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### Maximum Ratings

$T_J = 25^\circ C$, unless otherwise specified

<table>
<thead>
<tr>
<th>Parameter</th>
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<th>Condition</th>
<th>Value</th>
<th>Unit</th>
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<tbody>
<tr>
<td><strong>Snubber Diode</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Repetitive peak reverse voltage</td>
<td>$V_{RRM}$</td>
<td>$I_{FSM} = I_{FSMx}$, $T_J = 80^\circ C$</td>
<td>1200</td>
<td>V</td>
</tr>
<tr>
<td>Forward average current</td>
<td>$I_{FSM}$</td>
<td>$I_{FSMx} = 80^\circ C$</td>
<td>90</td>
<td>A</td>
</tr>
<tr>
<td>Surge forward current</td>
<td>$I_{FSM}$</td>
<td>$I_{FSMx} = 10 ms, sin 180^\circ$</td>
<td>540</td>
<td>A</td>
</tr>
<tr>
<td>$i^2$t-value</td>
<td>$i^2$t</td>
<td>$I_{FSMx} = 150^\circ C$</td>
<td>730</td>
<td>A$^2$s</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>$P_{tot}$</td>
<td>$T_J = 80^\circ C$</td>
<td>162</td>
<td>W</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{jmax}$</td>
<td>$T_J = 80^\circ C$</td>
<td>175</td>
<td>$^\circ C$</td>
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#### Thermal Properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Storage temperature</td>
<td>$-40...+125$</td>
<td>$^\circ C$</td>
</tr>
<tr>
<td>Operation temperature under switching condition</td>
<td>$-40...+(T_{jmax} - 25)$</td>
<td>$^\circ C$</td>
</tr>
</tbody>
</table>

#### Insulation Properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>Insulation voltage</td>
<td>$4000$</td>
<td>V</td>
</tr>
<tr>
<td>AC Voltage</td>
<td>$2500$</td>
<td>V</td>
</tr>
<tr>
<td>Creepage distance</td>
<td>$min 12,7$</td>
<td>mm</td>
</tr>
<tr>
<td>Clearance</td>
<td>$min 12,7$</td>
<td>mm</td>
</tr>
<tr>
<td>Comparative Tracking Index</td>
<td>$&gt;200$</td>
<td></td>
</tr>
</tbody>
</table>

*100 % tested in production
### Characteristic Values

<table>
<thead>
<tr>
<th>Parameter</th>
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</thead>
<tbody>
<tr>
<td><strong>Buck Switch</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gate emitter threshold voltage</td>
<td>$V_{GE(th)}$</td>
<td>$V_{ce} = V_{he}$</td>
<td>0,0136</td>
<td>V</td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>$V_{CEsat}$</td>
<td>15</td>
<td>25</td>
<td>0,048</td>
</tr>
<tr>
<td>Collector-emitter cut-off incl. Diode</td>
<td>$I_{CES}$</td>
<td>0</td>
<td>1200</td>
<td>5,8</td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>$I_{gas}$</td>
<td>20</td>
<td>0</td>
<td>960</td>
</tr>
<tr>
<td>Integrated Gate resistor</td>
<td>$R_{gas}$</td>
<td></td>
<td></td>
<td>0,5</td>
</tr>
<tr>
<td>Turn-on delay time</td>
<td>$t_{(on)}$</td>
<td></td>
<td></td>
<td>171</td>
</tr>
<tr>
<td>Turn-off delay time</td>
<td>$t_{(off)}$</td>
<td>$R_{gas} = 1 \Omega$</td>
<td>15</td>
<td>600</td>
</tr>
<tr>
<td>Fall time</td>
<td>$t_{f}$</td>
<td>$R_{gas} = 1 \Omega$</td>
<td>25</td>
<td>125</td>
</tr>
<tr>
<td>Turn-on energy loss per pulse</td>
<td>$E_{on}$</td>
<td></td>
<td></td>
<td>9,03</td>
</tr>
<tr>
<td>Turn-off energy loss per pulse</td>
<td>$E_{off}$</td>
<td></td>
<td></td>
<td>13,20</td>
</tr>
<tr>
<td>Input capacitance</td>
<td>$C_{iss}$</td>
<td>$f = 1 \text{ MHz}$</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>Output capacitance</td>
<td>$C_{oes}$</td>
<td></td>
<td></td>
<td>22160</td>
</tr>
<tr>
<td>Reverse transfer capacitance</td>
<td>$C_{res}$</td>
<td></td>
<td></td>
<td>1280</td>
</tr>
<tr>
<td>Gate charge</td>
<td>$Q_{g}$</td>
<td>phase-change material $\lambda = 3,4 \text{ W/mK}$</td>
<td>15</td>
<td>960</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink</td>
<td>$R_{th(j-s)}$</td>
<td>phase-change material θ = 3,4 W/mK</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Buck Diode</strong></td>
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<tr>
<td>Diode forward voltage</td>
<td>$V_{f}$</td>
<td></td>
<td>400</td>
<td>25</td>
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<tr>
<td>Reverse leakage current</td>
<td>$I_{r}$</td>
<td></td>
<td>1200</td>
<td>25</td>
</tr>
<tr>
<td>Peak reverse recovery current</td>
<td>$I_{RRM}$</td>
<td>$R_{gas} = 1 \Omega$</td>
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<tr>
<td>Reverse recovery time</td>
<td>$t_{r}$</td>
<td></td>
<td></td>
<td>86</td>
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<tr>
<td>Reverse recovered charge</td>
<td>$Q_{rr}$</td>
<td>$R_{gas} = 1 \Omega$</td>
<td></td>
<td>34,86</td>
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<tr>
<td>Peak rate of fall of recovery current</td>
<td>$dV_{CES}/dt_{off}$</td>
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<td>14614</td>
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<tr>
<td>Reverse recovered energy</td>
<td>$E_{rr}$</td>
<td></td>
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<td>15,14</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink</td>
<td>$R_{th(j-s)}$</td>
<td>phase-change material θ = 3,4 W/mK</td>
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</tbody>
</table>

copyright Vincotech
## Characteristic Values

<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Boost Switch</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gate emitter threshold voltage</td>
<td>$V_{GE(th)}$</td>
<td>$V_{CE} = V_{CE}$</td>
<td>0,0152</td>
<td>V</td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>$V_{CEsat}$</td>
<td></td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>Collector-emitter cut-off incl diode</td>
<td>$I_{rss}$</td>
<td></td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>$I_{Ges}$</td>
<td></td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Integrated Gate resistor</td>
<td>$R_{gon}$</td>
<td></td>
<td></td>
<td>nA</td>
</tr>
<tr>
<td>Turn-on delay time</td>
<td>$t_{on}$</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>Rise time</td>
<td>$t_r$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn-off delay time</td>
<td>$t_{off}$</td>
<td>$R_{goff} = 1 \Omega$</td>
<td>±15</td>
<td>600</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>25</td>
<td>398</td>
</tr>
<tr>
<td>Turn-off energy loss per pulse</td>
<td>$E_{off}$</td>
<td></td>
<td>25</td>
<td>398</td>
</tr>
<tr>
<td>Input capacitance</td>
<td>$C_{iss}$</td>
<td></td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>Output capacitance</td>
<td>$C_{oss}$</td>
<td></td>
<td></td>
<td>pF</td>
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<tr>
<td>Reverse transfer capacitance</td>
<td>$C_{riss}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gate charge</td>
<td>$Q_{G}$</td>
<td>phase-change material $\lambda = 3,4 W/mK$</td>
<td>±15</td>
<td>600</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink</td>
<td>$R_{th(j-s)}$</td>
<td></td>
<td></td>
<td>K/W</td>
</tr>
</tbody>
</table>

| **Boost Inverse Diode** | | | | |
| Diode forward voltage | $V_s$ | | 300 | 25 | 1.35 | 1.90 | V |
| Reverse leakage current | $I_r$ | | 1200 | 25 | | 56 | µA |
| Thermal resistance chip to heatsink | $R_{th(j-s)}$ | phase-change material $\lambda = 3,4 W/mK$ | | | | 0,204 | K/W |

| **Boost Diode** | | | | |
| Diode forward voltage | $V_s$ | | 300 | 25 | 1.35 | 1.90 | V |
| Reverse leakage current | $I_r$ | | 1200 | 25 | | 56 | µA |
| Peak reverse recovery current | $I_{RRM}$ | $R_{goff} = 1 \Omega$ | ±15 | 600 |
| Reverse recovery time | $t_{rr}$ | | 25 | 398 |
| Reverse recovered charge | $Q_{rec}$ | $R_{goff} = 1 \Omega$ | ±15 | 600 |
| Peak rate of fall of recovery current | $E_{df}$ | | 25 | 398 |
| Reverse recovery energy | $E_{rec}$ | | 25 | 398 |
| Thermal resistance chip to heatsink | $R_{th(j-s)}$ | phase-change material $\lambda = 3,4 W/mK$ | | | | 0,204 | K/W |
### Characteristic Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
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<tbody>
<tr>
<td><strong>Snubber Diode</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward voltage</td>
<td>$V_{F}$</td>
<td>100</td>
<td>25</td>
<td>1.91</td>
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<tr>
<td>Reverse current</td>
<td>$I_{F}$</td>
<td>1200</td>
<td>25</td>
<td>0.12</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink</td>
<td>$R_{R+2}$</td>
<td>phase-change material $\lambda = 3.4 \text{ W/mK}$</td>
<td></td>
<td>0.588</td>
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<tr>
<td><strong>Thermistor</strong></td>
<td></td>
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<tr>
<td>Rated resistance</td>
<td>$R$</td>
<td>25</td>
<td>22</td>
<td>20</td>
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<tr>
<td>Deviation of $R_{180}$</td>
<td>$\Delta_{R/180}$</td>
<td>$R_{180} = 1484 \Omega$</td>
<td>100</td>
<td>-5</td>
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<tr>
<td>Power dissipation</td>
<td>$P$</td>
<td>25</td>
<td>5</td>
<td>1.5</td>
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<tr>
<td>Power dissipation constant</td>
<td></td>
<td></td>
<td>25</td>
<td>1.5</td>
</tr>
<tr>
<td>B-value</td>
<td>$R_{(25/100)}$</td>
<td>Tol. ±1%</td>
<td>25</td>
<td>3962</td>
</tr>
<tr>
<td>B-value</td>
<td>$B_{(25/100)}$</td>
<td>Tol. ±1%</td>
<td>25</td>
<td>4000</td>
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<td>Vincotech NTC Reference</td>
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<tr>
<td><strong>Module Properties</strong></td>
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<tr>
<td>Module inductance (from chips to PCB)</td>
<td>$L_{IICV-C}$</td>
<td>Buck</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Module inductance (from PCB to PCB using Intercon board)</td>
<td>$L_{IIC-CPB}$</td>
<td></td>
<td></td>
<td>28</td>
</tr>
<tr>
<td>Resistance of Intercon boards (from PCB to PCB using Intercon board)</td>
<td>$R_{C1-C2}$</td>
<td></td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>Weight</td>
<td>$G$</td>
<td></td>
<td>580</td>
<td>g</td>
</tr>
</tbody>
</table>

---

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**Buck**

*Buck IGBT and Buck FWD*

---

**Figure 1.** Typical output characteristics

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

At

- \( t_p = 350 \ \mu s \)
- \( T_j = 25 ^\circ C \)
- \( V_{CE} \) from 7 V to 17 V in steps of 1 V

---

**Figure 2.** Typical output characteristics

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

At

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

---

**Figure 3.** Typical transfer characteristics

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

At

- \( t_p = 350 \ \mu s \)
- \( V_{CE} = 10 \ \text{V} \)

---

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

\[ I_F = f(V_F) \]

At

- \( t_F = 350 \ \mu s \)

---
Buck

Buck IGBT and Buck FWD

**Figure 5.** IGBT

Typical switching energy losses as a function of collector current

\[ E = f(I_C) \]

![Graph showing typical switching energy losses as a function of collector current.](image)

With an inductive load at

- \( T_j = 25/125 \) °C
- \( V_{CE} = 600 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 1 \) Ω
- \( I_C = 398 \) A

**Figure 6.** IGBT

Typical switching energy losses as a function of gate resistor

\[ E = f(R_G) \]

![Graph showing typical switching energy losses as a function of gate resistor.](image)

With an inductive load at

- \( T_j = 25/125 \) °C
- \( V_{CE} = 600 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_C = 398 \) A

**Figure 7.** FWD

Typical reverse recovery energy loss as a function of collector current

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

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

With an inductive load at

- \( T_j = 25/125 \) °C
- \( V_{CE} = 600 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 1,0 \) Ω

**Figure 8.** FWD

Typical reverse recovery energy loss as a function of gate resistor

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

![Graph showing typical reverse recovery energy loss as a function of gate resistor.](image)

With an inductive load at

- \( T_j = 25/125 \) °C
- \( V_{CE} = 600 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_C = 398 \) A
Typical switching times as a function of collector current
\[ t = f(I_C) \]

With an inductive load at
- \( T_j = 125 \, ^\circ\text{C} \)
- \( V_{CE} = 600 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( R_{gon} = 1 \, \Omega \)
- \( R_{goff} = 1 \, \Omega \)

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

At
- \( T_j = 25/125 \, ^\circ\text{C} \)
- \( V_{CE} = 600 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( R_{gon} = 1.0 \, \Omega \)
- \( I_F = 398 \, \text{A} \)
- \( V_{LE} = \pm 15 \, \text{V} \)
Buck

Buck IGBT and Buck FWD

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

- $T_j = 25/125 \ ^\circ C$
- $V_{CE} = 600 \ \text{V}$
- $V_{GE} = \pm 15 \ \text{V}$
- $I_F = 398 \ \text{A}$
- $R_{gon} = 1,0 \ \text{Ω}$

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

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

- $T_j = 25/125 \ ^\circ C$
- $V_{CE} = 600 \ \text{V}$
- $V_{GE} = \pm 15 \ \text{V}$

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

- $T_j = 25/125 \ ^\circ C$
- $V_{CE} = 600 \ \text{V}$
- $V_{GE} = \pm 15 \ \text{V}$
- $I_F = 398 \ \text{A}$
- $R_{gon} = 1,0 \ \text{Ω}$

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

- $T_j = 25/125 \ ^\circ C$
- $V_{CE} = 600 \ \text{V}$
- $V_{GE} = \pm 15 \ \text{V}$
Typical rate of fall of forward and reverse recovery current as a function of collector current
\[
\frac{dI}{dt}, \frac{dI_{rec}}{dt} = f(I_c)
\]

At
\[
T_J = 25/125 °C
\]
\[
V_{CE} = 600 \text{ V}
\]
\[
V_{GE} = ±15 \text{ V}
\]
\[
I_F = 398 \text{ A}
\]
\[
R_{gon} = 1.0 \text{ Ω}
\]

IGBT transient thermal impedance as a function of pulse width
\[
Z_{th(j-s)} = f(t_p)
\]

At
\[
D = 0.5
\]
\[
R_{eq(j)} = 0.105 \text{ K/W}
\]

With phase change material
\[
R (\text{K/W}) \quad \text{Tau (s)}
\]
\[
1.04E-02 \quad 5.24E+00
\]
\[
3.34E-02 \quad 1.19E+00
\]
\[
2.40E-02 \quad 2.95E-01
\]
\[
2.73E-02 \quad 1.03E-02
\]
\[
6.18E-03 \quad 7.56E-03
\]
\[
3.33E-03 \quad 7.59E-04
\]

FWD transient thermal impedance as a function of pulse width
\[
Z_{th(j-s)} = f(t_p)
\]

At
\[
D = 0.5
\]
\[
R_{eq(j)} = 0.163 \text{ K/W}
\]

With phase change material
\[
R (\text{K/W}) \quad \text{Tau (s)}
\]
\[
1.77E-02 \quad 7.43E+00
\]
\[
3.03E-02 \quad 1.59E+00
\]
\[
3.09E-02 \quad 2.90E-01
\]
\[
4.17E-02 \quad 6.32E-02
\]
\[
3.22E-02 \quad 2.05E-02
\]
\[
1.01E-02 \quad 1.83E-03
\]
Buck
Buck IGBT and Buck FWD

**Figure 21.** IGBT
Power dissipation as a function of heatsink temperature

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

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

**Figure 22.** IGBT
Collector current as a function of heatsink temperature

\[ I_C = f(T_s) \]

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

**Figure 23.** FWD
Power dissipation as a function of heatsink temperature

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

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

**Figure 24.** FWD
Forward current as a function of heatsink temperature

\[ I_F = f(T_s) \]

At
\[ T_j = 175 \ ^\circ\text{C} \]
**Buck**

Buck IGBT and Buck 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
- \( T_s = 80 \) °C
- \( V_{CE} = \pm15 \) V
- \( T_j = T_{j\text{max}} \)

**figure 27.**
Reverse bias safe operating area

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

At

- \( U_{\text{cm}} = U_{\text{cgb}} \)

Switching mode:

- 3 level switching
Boost
Boost IGBT and Boost FWD

**figure 1.** IGBT
**Typical output characteristics**
$I_C = f(V_{CE})$

At
$t_p = 350 \ \mu s$
$T_J = 25 \ {}^\circ C$
$V_{CE}$ from 7 V to 17 V in steps of 1 V

**figure 2.** IGBT
**Typical output characteristics**
$I_C = f(V_{CE})$

At
$t_p = 350 \ \mu s$
$T_J = 125 \ {}^\circ C$
$V_{CE}$ from 7 V to 17 V in steps of 1 V

**figure 3.** IGBT
**Typical transfer characteristics**
$I_C = f(V_{GE})$

At
$t_p = 350 \ \mu s$
$V_{CE} = 10 \ \text{V}$
$T_J = 25^\circ C \text{ and } 125^\circ C$

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

At
$t_p = 350 \ \mu s$
Boost
Boost IGBT and Boost FWD

**figure 5.** IGBT
Typical switching energy losses as a function of collector current

\[ E = f(I_C) \]

With an inductive load at
\[ T_j = 25/125 \quad ^\circ C \]
\[ V_{CE} = 600 \quad V \]
\[ V_{GE} = \pm 15 \quad V \]
\[ R_{g(on)} = 1.0 \quad \Omega \]
\[ I_C = 398 \quad A \]

**figure 6.** IGBT
Typical switching energy losses as a function of gate resistor

\[ E = f(R_G) \]

With an inductive load at
\[ T_j = 25/125 \quad ^\circ C \]
\[ V_{CE} = 600 \quad V \]
\[ V_{GE} = \pm 15 \quad V \]
\[ I_C = 398 \quad A \]

**figure 7.** FWD
Typical reverse recovery energy loss as a function of collector current

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

With an inductive load at
\[ T_j = 25/125 \quad ^\circ C \]
\[ V_{CE} = 600 \quad V \]
\[ V_{GE} = \pm 15 \quad V \]
\[ R_{g(on)} = 1.0 \quad \Omega \]

**figure 8.** FWD
Typical reverse recovery energy loss as a function of gate resistor

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

With an inductive load at
\[ T_j = 25/125 \quad ^\circ C \]
\[ V_{CE} = 600 \quad V \]
\[ V_{GE} = \pm 15 \quad V \]
\[ I_C = 398 \quad A \]
Boost IGBT and Boost FWD

**figure 9.** Typical switching times as a function of collector current

\[ t = f(I_C) \]

With an inductive load at

\[ T_j = 125 \] °C
\[ V_{CE} = 600 \] V
\[ V_{GE} = \pm 15 \] V
\[ R_{gon} = 1,0 \] Ω
\[ R_{goff} = 1,0 \] 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
\[ V_{CE} = 600 \] V
\[ V_{GE} = \pm 15 \] V
\[ I_C = 398 \] A

**figure 11.** Typical reverse recovery time as a function of collector current

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

At

\[ T_j = 25/125 \] °C
\[ V_{CE} = 600 \] V
\[ V_{GE} = \pm 15 \] V
\[ R_{gon} = 1,0 \] Ω

**figure 12.** Typical reverse recovery time as a function of IGBT turn on gate resistor

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

At

\[ T_j = 25/125 \] °C
\[ V_{GE} = \pm 15 \] V
\[ I_F = 398 \] A
Boost

Boost IGBT and Boost FWD

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

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

![Graph](image)

**At**

\[ T_J = 25/125 \, ^\circ C \]
\[ V_{CE} = 600 \, V \]
\[ V_{GE} = \pm 15 \, V \]
\[ R_{gon} = 1,0 \, \Omega \]

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

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

![Graph](image)

**At**

\[ T_J = 25/125 \, ^\circ C \]
\[ V_C = 600 \, V \]
\[ I_F = 398 \, A \]
\[ V_{GE} = \pm 15 \, V \]

**figure 15.** Typical reverse recovery current as a function of collector current

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

![Graph](image)

**At**

\[ T_J = 25/125 \, ^\circ C \]
\[ V_{CE} = 600 \, V \]
\[ V_{GE} = \pm 15 \, V \]
\[ R_{gon} = 1,0 \, \Omega \]

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

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

![Graph](image)

**At**

\[ T_J = 25/125 \, ^\circ C \]
\[ V_C = 600 \, V \]
\[ I_F = 398 \, A \]
\[ V_{GE} = \pm 15 \, V \]
**Boost**

Boost IGBT and Boost FWD

![Figure 17](image1.png)

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

\[
\frac{dI_0}{dt}, \frac{dI_{rec}}{dt} = f(I_{C})
\]

At

- \(T_j = 25\,\degree C\)
- \(V_{CE} = 600\, V\)
- \(V_{GE} = \pm 15\, V\)
- \(R_{gon} = 1,0\, \Omega\)

![Figure 18](image2.png)

**Typical rate of fall of forward and reverse recovery current as a function of gate resistor**

\[
\frac{dI_0}{dt}, \frac{dI_{rec}}{dt} = f(R_{gon})
\]

At

- \(T_j = 25\,\degree C\)
- \(V_k = 600\, V\)
- \(I_F = 398\, A\)
- \(V_{GE} = \pm 15\, V\)

![Figure 19](image3.png)

**IGBT transient thermal impedance as a function of pulse width**

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

At

- \(D = 0.5\)
- \(R_{DG(j-o)} = 0,112\, \text{K/W}\)

<table>
<thead>
<tr>
<th>(R_{DG(j-o)} (\text{K/W}))</th>
<th>(\tau_p / T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,16E-02</td>
<td>6,35E+00</td>
</tr>
<tr>
<td>4,61E-02</td>
<td>1,77E+00</td>
</tr>
<tr>
<td>2,00E-02</td>
<td>3,94E-01</td>
</tr>
<tr>
<td>1,28E-02</td>
<td>8,72E-02</td>
</tr>
<tr>
<td>1,94E-02</td>
<td>1,94E-02</td>
</tr>
<tr>
<td>1,72E-03</td>
<td>2,24E-03</td>
</tr>
</tbody>
</table>

IGBT thermal model values

With phase change material

<table>
<thead>
<tr>
<th>(R) (K/W)</th>
<th>(\text{Tau}) (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,16E-02</td>
<td>6,35E+00</td>
</tr>
<tr>
<td>4,61E-02</td>
<td>1,77E+00</td>
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<td>2,00E-02</td>
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<td>1,94E-02</td>
</tr>
<tr>
<td>1,72E-03</td>
<td>2,24E-03</td>
</tr>
</tbody>
</table>

FWD thermal model values

With phase change material

<table>
<thead>
<tr>
<th>(R) (K/W)</th>
<th>(\text{Tau}) (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,03E-02</td>
<td>5,24E+00</td>
</tr>
<tr>
<td>6,52E-02</td>
<td>1,19E+00</td>
</tr>
<tr>
<td>4,67E-02</td>
<td>2,95E-01</td>
</tr>
<tr>
<td>5,32E-02</td>
<td>3,03E-02</td>
</tr>
<tr>
<td>1,20E-02</td>
<td>7,56E-03</td>
</tr>
<tr>
<td>6,49E-03</td>
<td>7,59E-04</td>
</tr>
</tbody>
</table>

![Figure 20](image4.png)

**FWD transient thermal impedance as a function of pulse width**

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

At

- \(D = 0.5\)
- \(R_{W(j-o)} = 0,204\, \text{K/W}\)

<table>
<thead>
<tr>
<th>(R_{W(j-o)} (\text{K/W}))</th>
<th>(\tau_p / T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,03E-02</td>
<td>5,24E+00</td>
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<tr>
<td>6,52E-02</td>
<td>1,19E+00</td>
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<tr>
<td>6,49E-03</td>
<td>7,59E-04</td>
</tr>
</tbody>
</table>
Boost
Boost IGBT and Boost FWD

Figure 21. IGBT
Power dissipation as a function of heatsink temperature

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

At

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

Figure 22. IGBT
Collector current as a function of heatsink temperature

\[ I_C = f(T_s) \]

At

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

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

Figure 23. FWD
Power dissipation as a function of heatsink temperature

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

At

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

Figure 24. FWD
Forward current as a function of heatsink temperature

\[ I_F = f(T_s) \]

At

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

**Reverse bias safe operating area**

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

At

- \( U_{\text{continue}} = U_{\text{cutoff}} \)
- \( L_s = 12 \text{ nH} \)

Switching mode: 3 level switching

---

**Boost**

**Boost IGBT**

**Figure 25.**

\[ V_{ce} \text{ (V)} \]

\[ I_C \text{ (A)} \]

\[ V_{ce \text{ max}} \]

\[ V_{ce \text{ max}} \]

\[ V_{ce \text{ max}} \]
**Boost Inverse Diode**

**figure 25.** Boost Inverse Diode

Typical FWD forward current as a function of forward voltage

\[ I_F = f(V_F) \]

**figure 26.** Boost Inverse Diode

FWD transient thermal impedance as a function of pulse width

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

At

\[ t_p = 250 \ \mu s \]

\[ D = 0.5 \]

\[ R_{th(j-o)} = 0.204 \ \text{K/W} \]

**figure 27.** Boost Inverse Diode

Power dissipation as a function of heatsink temperature

\[ P_{tot} = f(T_s) \]

At

\[ T_j = 175 \ ^\circ C \]

**figure 28.** Boost Inverse Diode

Forward current as a function of heatsink temperature

\[ I_F = f(T_s) \]

At

\[ T_j = 175 \ ^\circ C \]
Snubber Diode

**Figure 1.** Snubber Diode

Typical diode forward current as a function of forward voltage

\[ I_F = f(V_F) \]

At

\[ t_p = 250 \ \mu s \]

**Figure 2.** Snubber Diode

Diode transient thermal impedance as a function of pulse width

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

At

\[ D = \frac{t_p}{T} \]

\[ R_{th(j-s)} = 0.588 \ \text{K/W} \]

**Figure 3.** Snubber Diode

Power dissipation as a function of heatsink temperature

\[ P_{tot} = f(T_s) \]

At

\[ T_j = 175 \ ^\circ C \]

**Figure 4.** Snubber Diode

Forward current as a function of heatsink temperature

\[ I_F = f(T_s) \]

At

\[ T_j = 175 \ ^\circ C \]
Thermistor

Figure 1. Thermistor

Typical NTC characteristic as a function of temperature

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

General conditions

\[ T_j = 125 \, ^\circ\text{C} \]
\[ R_{on} = 1 \, \Omega \]
\[ R_{off} = 1 \, \Omega \]

Test setup inductance: 9 nH

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

- \( V_{\text{CE}} (0\%) = -15 \, \text{V} \)
- \( V_{\text{CE}} (100\%) = 15 \, \text{V} \)
- \( I_C (100\%) = 402 \, \text{A} \)
- \( t_{\text{doff}} = 0,29 \, \mu\text{s} \)
- \( t_{\text{Eoff}} = 0,45 \, \mu\text{s} \)

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

- \( V_{\text{CE}} (0\%) = -15 \, \text{V} \)
- \( V_{\text{CE}} (100\%) = 15 \, \text{V} \)
- \( I_C (100\%) = 600 \, \text{V} \)
- \( I_C (100\%) = 402 \, \text{A} \)
- \( t_{\text{don}} = 0,17 \, \mu\text{s} \)
- \( t_{\text{Eon}} = 0,30 \, \mu\text{s} \)

**Figure 3.**
Turn-off Switching Waveforms & definition of \( t_f \)

- \( V_C (100\%) = 600 \, \text{V} \)
- \( I_C (100\%) = 402 \, \text{A} \)
- \( t_f = 0,04 \, \mu\text{s} \)

**Figure 4.**
Turn-on Switching Waveforms & definition of \( t_r \)

- \( V_C (100\%) = 600 \, \text{V} \)
- \( I_C (100\%) = 402 \, \text{A} \)
- \( t_r = 0,03 \, \mu\text{s} \)
Switching Definitions Buck

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

- $P_{off} (100\%) = 241.06$ kW
- $E_{off} (100\%) = 21.33$ mJ
- $t_{Eoff} = 0.45$ µs

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

- $P_{on} (100\%) = 241.06$ kW
- $E_{on} (100\%) = 14.33$ mJ
- $t_{Eon} = 0.30$ µs

**Figure 7.** FWD Turn-off Switching Waveforms & definition of $t_{rr}$

- $V_d (100\%) = 600$ V
- $i_d (100\%) = 402$ A
- $i_{RRM} (100\%) = -624$ A
- $t_{rr} = 0.12$ µs
Switching Definitions Buck

Figure 8. FWD
Turn-on Switching Waveforms & definition of $t_{Qrr}$
($t_{Qrr} = \text{integrating time for } Q_{rr}$)

- $I_d (100\%) = 402 \text{ A}$
- $Q_{rr} (100\%) = 57.89 \text{ µC}$
- $t_{Qrr} = 1.00 \text{ µs}$

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

- $P_{rec} (100\%) = 241.06 \text{ kW}$
- $E_{rec} (100\%) = 26.14 \text{ mJ}$
- $t_{Erec} = 1.00 \text{ µs}$
Switching Definitions Boost

General conditions

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_J$</td>
<td>125 °C</td>
</tr>
<tr>
<td>$R_{on}$</td>
<td>1 Ω</td>
</tr>
<tr>
<td>$R_{off}$</td>
<td>1 Ω</td>
</tr>
</tbody>
</table>

Test setup inductance: 9 nH

---

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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{CE}$ (0%)</td>
<td>-15 V</td>
</tr>
<tr>
<td>$V_{CE}$ (100%)</td>
<td>15 V</td>
</tr>
<tr>
<td>$I_C$ (100%)</td>
<td>398 A</td>
</tr>
<tr>
<td>$t_{doff}$</td>
<td>0,40 µs</td>
</tr>
<tr>
<td>$t_{Eoff}$</td>
<td>0,76 µs</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{CE}$ (0%)</td>
<td>-15 V</td>
</tr>
<tr>
<td>$V_{CE}$ (100%)</td>
<td>15 V</td>
</tr>
<tr>
<td>$I_C$ (100%)</td>
<td>398 A</td>
</tr>
<tr>
<td>$t_{don}$</td>
<td>0,24 µs</td>
</tr>
<tr>
<td>$t_{Eon}$</td>
<td>0,48 µs</td>
</tr>
</tbody>
</table>

---

**Turn-off Switching Waveforms & definition of $t_f$**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{CE}$</td>
<td>600 V</td>
</tr>
<tr>
<td>$I_C$</td>
<td>398 A</td>
</tr>
<tr>
<td>$t_f$</td>
<td>0,099 µs</td>
</tr>
</tbody>
</table>

**Turn-on Switching Waveforms & definition of $t_r$**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{CE}$</td>
<td>600 V</td>
</tr>
<tr>
<td>$I_C$</td>
<td>398 A</td>
</tr>
<tr>
<td>$t_r$</td>
<td>0,049 µs</td>
</tr>
</tbody>
</table>
Switching Definitions Boost

**Figure 5. Boost IGBT**

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

\[
\begin{align*}
P_{off} (100\%) &= 238,67 \text{ kW} \\
E_{off} (100\%) &= 37,62 \text{ mJ} \\
t_{Eoff} &= 0,76 \mu\text{s}
\end{align*}
\]

**Figure 6. Boost IGBT**

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

\[
\begin{align*}
P_{on} (100\%) &= 238,672 \text{ kW} \\
E_{on} (100\%) &= 13,39 \text{ mJ} \\
t_{Eon} &= 0,48 \mu\text{s}
\end{align*}
\]

**Figure 7. Boost FWD**

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

\[
\begin{align*}
V_d (100\%) &= 600 \text{ V} \\
i_d (100\%) &= 398 \text{ A} \\
i_{RRM} (100\%) &= -403 \text{ A} \\
t_{rr} &= 0,34 \mu\text{s}
\end{align*}
\]
Switching Definitions Boost

**Figure 8. Boost FWD**
Turn-on Switching Waveforms & definition of $t_{Qrr}$
($t_{Qrr}$ = integrating time for $Q_{rr}$)

- $I_d (100\%) = 398$ A
- $Q_{rr}(100\%) = 58,83$ µC
- $t_{Qrr} = 0,69$ µs

**Figure 9. Boost FWD**
Turn-on Switching Waveforms & definition of $t_{Erec}$
($t_{Erec}$ = integrating time for $E_{rec}$)

- $P_{rec} (100\%) = 238,67$ kW
- $E_{rec} (100\%) = 24,53$ mJ
- $t_{Erec} = 0,69$ µs
**Ordering Code & Marking**

<table>
<thead>
<tr>
<th>Version</th>
<th>Ordering Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>without thermal paste</td>
<td>70-W224NIA400SH-M400P</td>
</tr>
<tr>
<td>with thermal paste</td>
<td>70-W224NIA400SH-M400P* / 3</td>
</tr>
</tbody>
</table>

**Pin table (mm)**

<table>
<thead>
<tr>
<th>Pin</th>
<th>X</th>
<th>Y</th>
<th>Function</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>-2.15</td>
<td>84.85</td>
<td>G1-1</td>
<td>T1</td>
</tr>
<tr>
<td>1.2</td>
<td>-2.15</td>
<td>81.95</td>
<td>E1-1</td>
<td>T1</td>
</tr>
<tr>
<td>1.3</td>
<td>46.15</td>
<td>84.85</td>
<td>G1-2</td>
<td>T1</td>
</tr>
<tr>
<td>1.4</td>
<td>46.15</td>
<td>81.95</td>
<td>E1-2</td>
<td>T1</td>
</tr>
<tr>
<td>1.5</td>
<td>19.45</td>
<td>93.05</td>
<td>DC+ desat</td>
<td>T1</td>
</tr>
<tr>
<td>1.6</td>
<td>24.55</td>
<td>93.05</td>
<td>DC+ desat</td>
<td>T1</td>
</tr>
<tr>
<td>1.7</td>
<td>-7.65</td>
<td>70.05</td>
<td>G2-1</td>
<td>T2</td>
</tr>
<tr>
<td>1.8</td>
<td>-7.65</td>
<td>67.15</td>
<td>E2-1</td>
<td>T2</td>
</tr>
<tr>
<td>1.9</td>
<td>51.65</td>
<td>70.05</td>
<td>G2-2</td>
<td>T2</td>
</tr>
<tr>
<td>1.10</td>
<td>51.65</td>
<td>67.15</td>
<td>E2-2</td>
<td>T2</td>
</tr>
<tr>
<td>1.11</td>
<td>16.75</td>
<td>75.35</td>
<td>GND desat</td>
<td>D5</td>
</tr>
<tr>
<td>1.12</td>
<td>27.25</td>
<td>75.35</td>
<td>GND desat</td>
<td>D5</td>
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<td>1.13</td>
<td>-2.55</td>
<td>28</td>
<td>G3-1</td>
<td>T3</td>
</tr>
<tr>
<td>1.14</td>
<td>-5.45</td>
<td>28</td>
<td>E3-1</td>
<td>T3</td>
</tr>
<tr>
<td>1.15</td>
<td>46.55</td>
<td>28</td>
<td>G3-2</td>
<td>T3</td>
</tr>
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<td>28</td>
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<td>T3</td>
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<td>50.85</td>
<td>G4-2</td>
<td>T4</td>
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<td>45.6</td>
<td>49.05</td>
<td>E4-2</td>
<td>T4</td>
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<tr>
<td>1.21</td>
<td>67.65</td>
<td>89.8</td>
<td>NTC1</td>
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</tr>
<tr>
<td>1.22</td>
<td>67.65</td>
<td>86.7</td>
<td>NTC2</td>
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</table>

**Low current connections**

<table>
<thead>
<tr>
<th>M6 screw</th>
<th>X3</th>
<th>Y3</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>-39.1</td>
<td>89.8</td>
<td>TR+</td>
</tr>
<tr>
<td>3.2</td>
<td>-39.1</td>
<td>89.8</td>
<td>GND</td>
</tr>
<tr>
<td>3.3</td>
<td>-39.1</td>
<td>89.8</td>
<td>DC+</td>
</tr>
<tr>
<td>3.4</td>
<td>83.1</td>
<td>89.8</td>
<td>TR+</td>
</tr>
<tr>
<td>3.5</td>
<td>83.1</td>
<td>89.8</td>
<td>GND</td>
</tr>
<tr>
<td>3.6</td>
<td>83.1</td>
<td>89.8</td>
<td>DC+</td>
</tr>
<tr>
<td>3.7</td>
<td>-39.1</td>
<td>65.2</td>
<td>T2C</td>
</tr>
<tr>
<td>3.8</td>
<td>-39.1</td>
<td>65.2</td>
<td>GND</td>
</tr>
<tr>
<td>3.9</td>
<td>-39.1</td>
<td>65.2</td>
<td>Phase</td>
</tr>
<tr>
<td>3.10</td>
<td>83.1</td>
<td>65.2</td>
<td>T2C</td>
</tr>
<tr>
<td>3.11</td>
<td>83.1</td>
<td>65.2</td>
<td>GND</td>
</tr>
<tr>
<td>3.12</td>
<td>83.1</td>
<td>65.2</td>
<td>Phase</td>
</tr>
<tr>
<td>3.13</td>
<td>-39.1</td>
<td>45.2</td>
<td>Phase</td>
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</table>

**Power connections**

<table>
<thead>
<tr>
<th>M6 screw</th>
<th>X2</th>
<th>Y2</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.14</td>
<td>-39.1</td>
<td>45.2</td>
<td>GND</td>
</tr>
<tr>
<td>3.15</td>
<td>-39.1</td>
<td>45.2</td>
<td>DK</td>
</tr>
<tr>
<td>3.16</td>
<td>83.1</td>
<td>45.2</td>
<td>Phase</td>
</tr>
<tr>
<td>3.17</td>
<td>83.1</td>
<td>45.2</td>
<td>GND</td>
</tr>
<tr>
<td>3.18</td>
<td>83.1</td>
<td>45.2</td>
<td>DK</td>
</tr>
<tr>
<td>3.19</td>
<td>-39.1</td>
<td>20.6</td>
<td>DC-</td>
</tr>
<tr>
<td>3.20</td>
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<td>20.6</td>
<td>GND</td>
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<tr>
<td>3.21</td>
<td>-39.1</td>
<td>20.6</td>
<td>TR-</td>
</tr>
<tr>
<td>3.22</td>
<td>83.1</td>
<td>20.6</td>
<td>DC-</td>
</tr>
<tr>
<td>3.23</td>
<td>83.1</td>
<td>20.6</td>
<td>GND</td>
</tr>
<tr>
<td>3.24</td>
<td>83.1</td>
<td>20.6</td>
<td>TR-</td>
</tr>
</tbody>
</table>

**Outline**

- **Pin** refers to the physical pin location on the component.
- **Date code** refers to the date the component was manufactured.
- **Lot & Serial** refer to the lot number and serial number, respectively.

**Ordering Code & Marking**

- **Ordering Code** includes the name of the component, version, and date code.
- **UL & Vinco** identifies the component's compliance with UL and Vinco standards.

**Outline Diagram**: A detailed diagram of the component's outline, showing the location of each pin and connection point.
Pinout

**NOTE:** Driver pins for parallel devices are not connected inside the module!

### Identification

<table>
<thead>
<tr>
<th>ID</th>
<th>Component</th>
<th>Voltage</th>
<th>Current</th>
<th>Function</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>T11, T12</td>
<td>IGBT</td>
<td>1200 V</td>
<td>400 A</td>
<td>Buck Switch</td>
<td></td>
</tr>
<tr>
<td>D11, D12</td>
<td>FWD</td>
<td>1200 V</td>
<td>400 A</td>
<td>Buck Diode</td>
<td></td>
</tr>
<tr>
<td>T13, T14</td>
<td>IGBT</td>
<td>1200 V</td>
<td>400 A</td>
<td>Boost Switch</td>
<td></td>
</tr>
<tr>
<td>D13, D16</td>
<td>FWD</td>
<td>1200 V</td>
<td>300 A</td>
<td>Boost Inverse Diode</td>
<td></td>
</tr>
<tr>
<td>D13, D14</td>
<td>FWD</td>
<td>1200 V</td>
<td>300 A</td>
<td>Boost Diode</td>
<td></td>
</tr>
<tr>
<td>D61, D62</td>
<td>FWD</td>
<td>1200 V</td>
<td>50 A</td>
<td>Snubber Diode</td>
<td></td>
</tr>
<tr>
<td>Rt</td>
<td>NTC</td>
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<td>Thermistor</td>
</tr>
</tbody>
</table>
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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.