**Features**

- 1500 V NPC-topology
- 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

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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>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Buck Switch</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collector-emitter break down voltage</td>
<td>$V_{CE}$</td>
<td>$T_j = T_{j\text{max}}$, $T_s = 80 , ^\circ\text{C}$</td>
<td>1200</td>
<td>V</td>
</tr>
<tr>
<td>DC collector current</td>
<td>$I_C$</td>
<td>$T_j = T_{j\text{max}}$, $T_s = 80 , ^\circ\text{C}$</td>
<td>326</td>
<td>A</td>
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<tr>
<td>Pulsed collector current</td>
<td>$I_{CM}$</td>
<td>$T_s$ limited by $T_{j\text{max}}$</td>
<td>1200</td>
<td>A</td>
</tr>
<tr>
<td>Turn off safe operating area</td>
<td>$V_{CE}$</td>
<td>$V_{CE} \leq 1200 , V$, $T_j \leq T_{j\text{op max}}$</td>
<td>800</td>
<td>A</td>
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<tr>
<td>Power dissipation</td>
<td>$P_{tot}$</td>
<td>$T_j = T_{j\text{max}}$, $T_s = 80 , ^\circ\text{C}$</td>
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<td>W</td>
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<tr>
<td>Gate-emitter peak voltage</td>
<td>$V_{CE}$</td>
<td>$T_j = T_{j\text{max}}$</td>
<td>±20</td>
<td>V</td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>$V_{CC}$, $V_{CE}$</td>
<td>$T_j \leq 150 , ^\circ\text{C}$, $V_{CE} = 15 , V$</td>
<td>10</td>
<td>µs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>800</td>
<td>V</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{j\text{max}}$</td>
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<td>175</td>
<td>°C</td>
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| **Buck Diode** | | | | |
| Peak Repetitive Reverse Voltage | $V_{RRM}$ | | 1200 | V |
| DC forward current | $I_F$ | $T_j = T_{j\text{max}}$, $T_s = 80 \, ^\circ\text{C}$ | 270 | A |
| Repetitive peak forward current | $I_{F\text{max}}$ | $T_s = 10 \, \text{ms}$, sin $180^\circ$ | 800 | A |
| Power dissipation | $P_{tot}$ | $T_j = T_{j\text{max}}$, $T_s = 80 \, ^\circ\text{C}$ | 565 | W |
| Maximum Junction Temperature | $T_{j\text{max}}$ | | 175 | °C |
### Maximum Ratings

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

<table>
<thead>
<tr>
<th>Parameter</th>
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<tr>
<td><strong>Boost Switch</strong></td>
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<tr>
<td>Collector-emitter break down voltage</td>
<td>$V_{CE}$</td>
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<td>1200</td>
<td>V</td>
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<td>DC collector current</td>
<td>$I_C$</td>
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<td></td>
<td>$V_{CC}$</td>
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<td>°C</td>
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<td><strong>Boost Inverse Diode</strong></td>
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<tr>
<td>Peak Repetitive Reverse Voltage</td>
<td>$V_{RRM}$</td>
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<td>V</td>
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<tr>
<td>DC forward current</td>
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<tr>
<td>DC forward current</td>
<td>$I_F$</td>
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Maximum Ratings

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

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<tr>
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<td>Repetitive peak reverse voltage</td>
<td>( V_{\text{RRM}} )</td>
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<td>V</td>
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<tr>
<td>Forward average current</td>
<td>( I_{\text{FAS}} )</td>
<td>( T_j = T_{\text{max}} ), ( T_s = 80 , ^\circ\text{C} )</td>
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<tr>
<td>Surge forward current</td>
<td>( I_{\text{sm}} )</td>
<td>( t_s = 10 , \text{ms, sin } 180^\circ ), ( T_j = 150 , ^\circ\text{C} )</td>
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<td>A</td>
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<tr>
<td>( i^2t )-value</td>
<td>( I_{\text{t}} )</td>
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<td>W</td>
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<td>Maximum Junction Temperature</td>
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<td>°C</td>
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<tr>
<td>Thermal Properties</td>
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<tr>
<td>Storage temperature</td>
<td>( T_{\text{stg}} )</td>
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<td>-40...+125</td>
<td>°C</td>
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<tr>
<td>Operation temperature under switching condition</td>
<td>( T_{\text{op}} )</td>
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<td>-40...+(( T_{\text{jmax}} - 25 ))</td>
<td>°C</td>
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<tr>
<td>Insulation Properties</td>
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<tr>
<td>Insulation voltage</td>
<td>( V_{\text{ins}} )</td>
<td>DC Test Voltage</td>
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<td>V</td>
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<tr>
<td></td>
<td></td>
<td>AC Voltage</td>
<td>2500</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>
</tr>
<tr>
<td>Comparative Tracking Index</td>
<td>CTI</td>
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<td>&gt;200</td>
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*100 % tested in production
### Characteristic Values

<table>
<thead>
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<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>$V_{CE} = V_{CE}$</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>5,2</td>
</tr>
<tr>
<td>Collector-emitter cut-off incl. Diode</td>
<td>$I_{CES}$</td>
<td>0</td>
<td>1200</td>
<td>25</td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>$I_{IAS}$</td>
<td>20</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>Integrated Gate resistor</td>
<td>$R_{gas}$</td>
<td></td>
<td>0,5</td>
<td>Ω</td>
</tr>
<tr>
<td>Turn-on delay time</td>
<td>$t_{ON}$</td>
<td>±15</td>
<td>600</td>
<td>398</td>
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<tr>
<td>Rise time</td>
<td>$t_r$</td>
<td>25</td>
<td>125</td>
<td>171</td>
</tr>
<tr>
<td>Turn-off delay time</td>
<td>$t_{OFF}$</td>
<td>$R_{gas} = 1 \Omega$</td>
<td>25</td>
<td>125</td>
</tr>
<tr>
<td>Fall time</td>
<td>$t_f$</td>
<td>25</td>
<td>125</td>
<td>238</td>
</tr>
<tr>
<td>Turn-on energy loss per pulse</td>
<td>$E_{on}$</td>
<td></td>
<td>25</td>
<td>125</td>
</tr>
<tr>
<td>Turn-off energy loss per pulse</td>
<td>$E_{off}$</td>
<td></td>
<td>25</td>
<td>125</td>
</tr>
<tr>
<td>Input capacitance</td>
<td>$C_{IN}$</td>
<td>$f = 1 \text{ MHz}$</td>
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<td>25</td>
</tr>
<tr>
<td>Output capacitance</td>
<td>$C_{OUT}$</td>
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<td>μF</td>
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<td>Reverse transfer capacitance</td>
<td>$C_{RSS}$</td>
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<td>3040</td>
<td>nC</td>
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<tr>
<td>Gate charge</td>
<td>$Q_r$</td>
<td>15</td>
<td>960</td>
<td>400</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink</td>
<td>$E_{on}$</td>
<td>phase-change material</td>
<td>0,105</td>
<td>K/W</td>
</tr>
</tbody>
</table>

| **Buck Diode**                                  |        |            |       |        |
| Diode forward voltage                           | $V_J$ | 400 | 25 | 2,34 | 2,38 | V |
| Reverse leakage current                         | $I_{RMS}$ | 1200 | 25 | 480 | μA |
| Peak reverse recovery current                   | $I_{RMS}$ |                | 25 | 125 | 506 | A |
| Reverse recovery time                           | $t_r$ | 25 | 125 | 86 | 624 | ns |
| Reverse recovered charge                        | $Q_{rr}$ | $R_{gas} = 1 \Omega$ | 25 | 125 | 34,86 | 117 | μC |
| Peak rate of fall of recovery current           | $E_{off}$ | $V_{CEsat}$ | 25 | 125 | 14614 | 15212 | A/μs |
| Reverse recovered energy                        | $E_{rr}$ | $R_{gas} = 1 \Omega$ | 25 | 125 | 15,14 | 26,14 | mWs |
| Thermal resistance chip to heatsink             | $R_{th(j-s)}$ | phase-change material | 0,163 | K/W |

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## Characteristic Values

<table>
<thead>
<tr>
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<th>Unit</th>
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<tr>
<td>Boost Switch</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gate emitter threshold voltage</td>
<td>$V_{GE}$</td>
<td>$V_{CE}$ = $V_{CE}$</td>
<td>0,0152</td>
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<tr>
<td>Collector-emitter saturation voltage</td>
<td>$V_{CEsat}$</td>
<td>15</td>
<td>25</td>
<td>1,91</td>
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<tr>
<td>Collector-emitter cut-off incl diode</td>
<td>$I_{CES}$</td>
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<td>25</td>
<td>125</td>
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<tr>
<td>Gate-emitter leakage current</td>
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<td>Integrated Gate resistor</td>
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<td>Turn-on delay time</td>
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<tr>
<td>Rise time</td>
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<td>Turn-off delay time</td>
<td>$t_{off}$</td>
<td>$R_{gas} = 1 \ \Omega$</td>
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<tr>
<td>Fall time</td>
<td>$t_f$</td>
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<td>25</td>
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<td>Turn-on energy loss per pulse</td>
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<td>Turn-off energy loss per pulse</td>
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<td>Input capacitance</td>
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<td>Output capacitance</td>
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<td>Reverse transfer capacitance</td>
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<td>Gate charge</td>
<td>$Q_g$</td>
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<tr>
<td>Thermal resistance chip to heatsink</td>
<td>$R_{th(j-s)}$</td>
<td>phase-change material $\lambda = 3,4 \ \text{W/mK}$</td>
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<tr>
<td>Boost Inverse Diode</td>
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<tr>
<td>Diode forward voltage</td>
<td>$V_D$</td>
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<td>Reverse leakage current</td>
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<td>phase-change material $\lambda = 3,4 \ \text{W/mK}$</td>
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<td>Reverse leakage current</td>
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<td>Peak reverse recovery current</td>
<td>$I_{RRM}$</td>
<td>$R_{gas} = 1 \ \Omega$</td>
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<td>Reverse recovery time</td>
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<td>Reverse recovered charge</td>
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<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
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#### Thermistor

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<td>25</td>
<td>22</td>
<td>kΩ</td>
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<tr>
<td>Deviation of $R_{100}$</td>
<td>$\Delta R$</td>
<td>100</td>
<td>-5</td>
<td>%</td>
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<tr>
<td>Power dissipation</td>
<td>$P_{10}$</td>
<td>25</td>
<td>5</td>
<td>mW</td>
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<tr>
<td>Power dissipation constant</td>
<td>$P_{100}$</td>
<td>25</td>
<td>1,5</td>
<td>mW/K</td>
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<tr>
<td>B-value</td>
<td>$B_{10}$</td>
<td>25</td>
<td>1,5</td>
<td>mΩ</td>
</tr>
<tr>
<td>B-value</td>
<td>$B_{100}$</td>
<td>25</td>
<td>1,5</td>
<td>mΩ</td>
</tr>
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### Module Properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
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<tr>
<td>Module inductance (from chips to PCB)</td>
<td>$L_{sCE PCB-PCB}$</td>
<td>Buck</td>
<td>15</td>
<td>nH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Boost</td>
<td>28</td>
<td>nH</td>
</tr>
<tr>
<td>Module inductance (from PCB to PCB using Intercon board)</td>
<td>$L_{sCE PCB-PCB}$</td>
<td>5</td>
<td>nH</td>
<td></td>
</tr>
<tr>
<td>Resistance of Intercon boards (from PCB to PCB using Intercon board)</td>
<td>$R_{sCE}$</td>
<td>1,5</td>
<td>mΩ</td>
<td></td>
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<tr>
<td>Weight</td>
<td>$G$</td>
<td></td>
<td>580</td>
<td>g</td>
</tr>
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</table>
Buck
Buck IGBT and Buck FWD

**figure 1.** IGBT
Typical output characteristics

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

At
\[ t_p = 350 \, \mu s \]
\[ T_j = 25 \, ^\circ C \]

\[ V_{CE} \text{ from } 7 \text{ V to 17 V in steps of 1 V} \]

**figure 2.** IGBT
Typical output characteristics

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

At
\[ t_p = 350 \, \mu s \]
\[ T_j = 125 \, ^\circ C \]

\[ V_{CE} \text{ from } 7 \text{ V to 17 V in steps of 1 V} \]

**figure 3.** IGBT
Typical transfer characteristics

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

At
\[ t_p = 350 \, \mu s \]
\[ V_{CE} = 10 \, \text{V} \]

**figure 4.** FWD
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
\[ E = f(I_C) \]

With an inductive load at
\[ T_j = 25/125 \, ^\circ\text{C} \]
\[ V_{CE} = 600 \, \text{V} \]
\[ V_{GE} = \pm 15 \, \text{V} \]
\[ R_{gon} = 1 \, \text{J} \]
\[ I_C = 398 \, \text{A} \]

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

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

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

With an inductive load at
\[ T_j = 25/125 \, ^\circ\text{C} \]
\[ V_{CE} = 600 \, \text{V} \]
\[ V_{GE} = \pm 15 \, \text{V} \]
\[ R_{gon} = 1 \, \text{J} \]

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

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

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

\[ t = f(I_C) \]

With an inductive load at

\[ T_J = 125 \, ^\circ\text{C} \]
\[ V_C = 600 \, \text{V} \]
\[ V_{CE} = \pm 15 \, \text{V} \]
\[ R_{gon} = 1 \, \Omega \]
\[ R_{goff} = 1 \, \Omega \]

**Figure 10.**
Typical switching times as a function of gate resistor

\[ t = f(R_G) \]

With an inductive load at

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

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

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

At

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

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

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

At

\[ T_J = 25/125 \, ^\circ\text{C} \]
\[ V_{ES} = 600 \, \text{V} \]
\[ I_F = 398 \, \text{A} \]
\[ V_{CE} = \pm 15 \, \text{V} \]
**Buck**

Buck IGBT and Buck FWD

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

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

At

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

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

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

At

- \( T_j = 25/125 \, ^\circ C \)
- \( V_k = 600 \, V \)
- \( I_F = 398 \, A \)
- \( V_{JE} = \pm 15 \, V \)

**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

- \( T_j = 25/125 \, ^\circ C \)
- \( V_k = 600 \, V \)
- \( I_F = 398 \, A \)
- \( V_{JE} = \pm 15 \, V \)
**Buck**

Buck IGBT and Buck FWD

**Figure 17.** Typical rate of fall of forward and reverse recovery current as a function of collector current

\[
\frac{dI}{dt}, \frac{dI_{rec}}{dt} = f(I_{c})
\]

**Figure 18.** Typical rate of fall of forward and reverse recovery current as a function of gate resistor

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

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

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

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

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

\[
\begin{align*}
D &= \frac{t_{p}}{T} \\
R_{th(j-s)} &= 0.105 \text{ K/W} \\
R_{th(j-s)} &= 0.163 \text{ K/W}
\end{align*}
\]

**IGBT thermal model values**

<table>
<thead>
<tr>
<th>With phase change material</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R ) (K/W)</td>
</tr>
<tr>
<td>1.04E-02</td>
</tr>
<tr>
<td>3.34E-02</td>
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<tr>
<td>2.40E-02</td>
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<td>2.73E-02</td>
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<tr>
<td>6.18E-03</td>
</tr>
<tr>
<td>3.33E-03</td>
</tr>
</tbody>
</table>

**FWD thermal model values**

<table>
<thead>
<tr>
<th>With phase change material</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R ) (K/W)</td>
</tr>
<tr>
<td>1.77E-02</td>
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<td>3.03E-02</td>
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<td>3.09E-02</td>
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<td>4.17E-02</td>
</tr>
<tr>
<td>3.22E-02</td>
</tr>
<tr>
<td>1.01E-02</td>
</tr>
</tbody>
</table>
**Buck**

Buck IGBT and Buck FWD

**Power dissipation as a function of heatsink temperature**

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

---

**Collector current as a function of heatsink temperature**

\[ i_c = f(T_s) \]

---

**Forward current as a function of heatsink temperature**

\[ i_f = f(T_s) \]

---

**At**

\[ T_j = 175 ^\circ C \]

---

**At**

\[ T_j = 175 ^\circ C \]

---

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

---

\[ V_{JE} = 15 \text{ V} \]
**Buck**
Buck IGBT and Buck FWD

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

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

At

- Single pulse
- \( T_s = 80 \) °C
- \( V_{CE} = \pm 15 \) V
- \( T_j = T_{j_{max}} \)

**figure 26.**
Gate voltage vs Gate charge

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

At

- \( I_C = 400 \) A

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

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

At

- \( V_{ce_{bias}} = V_{ce_{max}} \)

Switching mode: 3 level switching
Boost
Boost IGBT and Boost FWD

**Figure 1.** IGBT
Typical output characteristics
\[ I_C = f(V_{CE}) \]

At
\[ t_p = 350 \ \mu s \]
\[ T_j = 25 \ \degree C \]
\[ V_{CE} \text{ from } 7 \text{ V to } 17 \text{ V in steps of } 1 \text{ V} \]

**Figure 2.** IGBT
Typical output characteristics
\[ I_C = f(V_{CE}) \]

At
\[ t_p = 350 \ \mu s \]
\[ T_j = 125 \ \degree C \]
\[ V_{CE} \text{ from } 7 \text{ V to } 17 \text{ V in steps of } 1 \text{ V} \]

**Figure 3.** IGBT
Typical transfer characteristics
\[ I_C = f(V_{GE}) \]

At
\[ t_p = 350 \ \mu s \]
\[ V_{CE} = 10 \ \text{ V} \]

**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
- \( T_J = 25/125 \) °C
- \( V_{CE} = 600 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 1,0 \) Ω
- \( I_C = 398 \) A

**figure 6. IGBT**

Typical switching energy losses as a function of gate resistor

\[ E = f(R_G) \]

With an inductive load at
- \( T_J = 25/125 \) °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

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

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

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

With an inductive load at
- \( T_J = 25/125 \) °C
- \( V_{CE} = 600 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_C = 398 \) A
### Boost

**Boost IGBT and Boost FWD**

**figure 9.**

**IGBT**

*Typical switching times as a function of collector current*

\[ t = f(I_C) \]

With an inductive load at

- \( T_J = 125 \, ^\circ C \)
- \( V_{CE} = 600 \, V \)
- \( V_{GE} = \pm 15 \, V \)
- \( R_{gon} = 1,0 \, \Omega \)
- \( R_{goff} = 1,0 \, \Omega \)

**figure 10.**

**IGBT**

*Typical switching times as a function of gate resistor*

\[ t = f(R_g) \]

With an inductive load at

- \( T_J = 125 \, ^\circ C \)
- \( V_{CE} = 600 \, V \)
- \( V_{GE} = \pm 15 \, V \)
- \( I_C = 398 \, A \)

**figure 11.**

**FWD**

*Typical reverse recovery time as a function of collector current*

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

At

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

**figure 12.**

**FWD**

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

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

At

- \( T_J = 25/125 \, ^\circ C \)
- \( V_{CE} = 600 \, V \)
- \( V_{GE} = \pm 15 \, V \)
- \( I_C = 398 \, A \)
**Boost**

**Boost IGBT and Boost FWD**

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

$q_{rr} = f(I_C)$

![Graph 1](image1)

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 2](image2)

At

- $T_J = 25/125 \, ^\circ C$
- $V_K = 600 \, V$
- $I_F = 398 \, A$
- $V_{GE} = \pm 15 \, V$

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

$I_{RRM} = f(I_C)$

![Graph 3](image3)

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 4](image4)

At

- $T_J = 25/125 \, ^\circ C$
- $V_K = 600 \, V$
- $I_F = 398 \, A$
- $V_{GE} = \pm 15 \, V$
Boost

Boost IGBT and Boost FWD

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

**At**
- \( T_j = 25/125 \) °C
- \( V_{CE} = 600 \) V
- \( I_F = 398 \) A

**Figure 18.** FWD
Typical rate of fall of forward and reverse recovery current as a function of gate resistor
\[ \frac{dI_f}{dt} \text{ and } \frac{dI_{rec}}{dt} = f(R_{gon}) \]

**At**
- \( T_j = 25/125 \) °C
- \( V_E = \pm15 \) V
- \( R_{gon} = 1,0 \) Ω

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

**At**
- \( D = \frac{t_p}{T} \)
- \( R_{al(j)} = 0,112 \) K/W

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

**At**
- \( D = \frac{t_p}{T} \)
- \( R_{al(j)} = 0,204 \) K/W

**IGBT thermal model values**

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<thead>
<tr>
<th>( R ) (K/W)</th>
<th>Tau (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,16E-02</td>
<td>6,35E+00</td>
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<td>4,61E-02</td>
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<td>2,00E-02</td>
<td>3,94E-01</td>
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<td>1,28E-02</td>
<td>8,72E-02</td>
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<td>1,94E-02</td>
<td>1,94E-02</td>
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<tr>
<td>1,72E-03</td>
<td>2,24E-03</td>
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</table>

**FWD thermal model values**

<table>
<thead>
<tr>
<th>( R ) (K/W)</th>
<th>Tau (s)</th>
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<tbody>
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<td>3,03E-02</td>
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<td>1,20E-02</td>
<td>7,56E-03</td>
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<tr>
<td>6,49E-03</td>
<td>7,59E-04</td>
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</table>
Boost

Boost IGBT and Boost FWD

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

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

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

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

\[ I_C = f(T_s) \]

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

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

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

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

**Figure 24.**
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

\[ V_{\text{continuous}} = U_{\text{supply}} \]

\[ L_s = 12 \text{ nH} \]

Switching mode: 3 level switching
Boost Inverse Diode

**figure 25. Boost Inverse Diode**

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

\[ I_{F} = f(V_{F}) \]

![Graph showing typical forward current as a function of forward voltage.](image)

At
\[ t_{p} = 250 \ \mu s \]

**figure 26. Boost Inverse Diode**

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

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

![Graph showing FWD transient thermal impedance as a function of pulse width.](image)

At
\[ D = \frac{t_{p}}{T} \]

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

**figure 27. Boost Inverse Diode**

**Power dissipation as a function of heatsink temperature**

\[ P_{tot} = f(T_{s}) \]

![Graph showing power dissipation as a function of heatsink temperature.](image)

At
\[ T_{j} = 175 \ ^\circ C \]

**figure 28. Boost Inverse Diode**

**Forward current as a function of heatsink temperature**

\[ I_{F} = f(T_{s}) \]

![Graph showing forward current as a function of heatsink temperature.](image)

At
\[ T_{j} = 175 \ ^\circ C \]
Snubber Diode

**Figure 1.** Snubber Diode

Typical diode forward current as a function of forward voltage

\[ I_F = f(V_F) \]

**Figure 2.** Snubber Diode

Diode transient thermal impedance as a function of pulse width

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

At

\[ t_p = 250 \ \mu s \]

**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

\[ T_J = 125 \, ^{\circ}C \]
\[ R_{ON} = 1 \, \Omega \]
\[ R_{OFF} = 1 \, \Omega \]

Test setup inductance: 9 nH

---

**figure 1. IGBT**

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

\( t_{doff} = \) integrating time for \( E_{off} \)

\[ V_{CE} (0\%) = -15 \, V \]
\[ V_{CE} (100\%) = 15 \, V \]
\[ V_C (100\%) = 600 \, V \]
\[ I_C (100\%) = 402 \, A \]
\[ t_{doff} = 0,29 \, \mu s \]
\[ t_{Eoff} = 0,45 \, \mu s \]

---

**figure 2. IGBT**

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

\( t_{don} = \) integrating time for \( E_{on} \)

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

---

**figure 3. IGBT**

Turn-off Switching Waveforms & definition of \( t_f \)

\[ V_C (100\%) = 600 \, V \]
\[ I_C (100\%) = 402 \, A \]
\[ t_f = 0,04 \, \mu s \]

---

**figure 4. IGBT**

Turn-on Switching Waveforms & definition of \( t_r \)

\[ V_C (100\%) = 600 \, V \]
\[ I_C (100\%) = 402 \, A \]
\[ t_r = 0,03 \, \mu s \]
Switching Definitions Buck

**figure 5. IGBT**

Turn-off Switching Waveforms & definition of $t_{E\text{off}}$

$P_{\text{off}}$ (100%) = 241,06 kW
$E_{\text{off}}$ (100%) = 21,33 mJ
$t_{E\text{off}} = 0,45 \ \mu$s

**figure 6. IGBT**

Turn-on Switching Waveforms & definition of $t_{E\text{on}}$

$P_{\text{on}}$ (100%) = 241,06 kW
$E_{\text{on}}$ (100%) = 14,33 mJ
$t_{E\text{on}} = 0,30 \ \mu$s

**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
$t_{rr} = 0,12 \ \mu$s

---

copyright Vincotech
Switching Definitions Buck

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

$I_d$ ($100\%) = 402$ A
$Q_{rr}$ ($100\%) = 57,89$ µC
$t_{Qrr} = 1,00$ µs

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

$P_{rec}$ ($100\%) = 241,06$ kW
$E_{rec}$ ($100\%) = 26,14$ mJ
$t_{Erec} = 1,00$ µs
Switching Definitions Boost

**General conditions**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
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<tr>
<td>$R_{on}$</td>
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<tr>
<td>$R_{off}$</td>
<td>1 Ω</td>
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Test setup inductance: 9 nH

**figure 1. Boost IGBT**

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

$t_{Eoff}$ = integrating time for $E_{off}$

- $V_{CE} (0\%) = -15 \ V$
- $V_{CE} (100\%) = 15 \ V$
- $I_C (100\%) = 398 \ A$
- $t_{don} = 0,40 \ \mu s$
- $t_{Eoff} = 0,76 \ \mu s$

**figure 2. Boost IGBT**

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

$t_{Eon}$ = integrating time for $E_{on}$

- $V_{CE} (0\%) = -15 \ V$
- $V_{CE} (100\%) = 15 \ V$
- $V_C (100\%) = 600 \ V$
- $I_C (100\%) = 398 \ A$
- $t_{on} = 0,24 \ \mu s$
- $t_{Eon} = 0,48 \ \mu s$

**figure 3. Boost IGBT**

Turn-off Switching Waveforms & definition of $t_f$

- $V_C (100\%) = 600 \ V$
- $I_C (100\%) = 398 \ A$
- $t_f = 0,099 \ \mu s$

**figure 4. Boost IGBT**

Turn-on Switching Waveforms & definition of $t_r$

- $V_C (100\%) = 600 \ V$
- $I_C (100\%) = 398 \ A$
- $t_r = 0,049 \ \mu s$
Switching Definitions Boost

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

- $P_{off}$ (100%) = 238,67 kW
- $E_{off}$ (100%) = 37,62 mJ
- $t_{E_{off}} = 0,76 \mu s$

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

- $P_{on}$ (100%) = 238,672 kW
- $E_{on}$ (100%) = 13,39 mJ
- $t_{E_{on}} = 0,48 \mu s$

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

- $V_d (100\%) = 600$ V
- $i_d (100\%) = 398$ A
- $i_{RRM (100\%)} = -403$ A
- $t_{rr} = 0,34 \mu s$
Switching Definitions Boost

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

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

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

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

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**Outline**

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**Low current connections**

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**Power connections**

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Pinout

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

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