10-F106NIA150SA-M136F

**flowNPC 1**

**600V/150A**

**Features**
- Neutral-point-Clamped inverter
- Compact flow1 housing
- Low Inductance Layout

**Target Applications**
- UPS
- Motor Drive
- Solar inverters

**Types**
- 10-F106NIA150SA-M136F

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**Maximum Ratings**

* TJ=25°C, unless otherwise specified *

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector-emitter break down voltage</td>
<td>VCE</td>
<td>TJ=150°C VCE=15V</td>
<td>600</td>
<td>V</td>
</tr>
<tr>
<td>DC collector current</td>
<td>IC</td>
<td>TJ= Tj,max</td>
<td>109</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TJ=80°C</td>
<td>144</td>
<td>A</td>
</tr>
<tr>
<td>Pulsed collector current</td>
<td>Icpulse</td>
<td>Ic limited by Tj,max</td>
<td>450</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per IGBT</td>
<td>Ptot</td>
<td>TJ= Tj,max</td>
<td>166</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TJ=80°C</td>
<td>251</td>
<td>A</td>
</tr>
<tr>
<td>Gate-emitter peak voltage</td>
<td>VGE</td>
<td>TJ= Tj,max</td>
<td>200</td>
<td>V</td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>tDC</td>
<td>TJ=150°C VCE=15V</td>
<td>6</td>
<td>μs</td>
</tr>
<tr>
<td></td>
<td>VCE</td>
<td></td>
<td>360</td>
<td>V</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>Tj,max</td>
<td>TJ= Tj,max</td>
<td>175</td>
<td>°C</td>
</tr>
<tr>
<td>Turn off safe operating area</td>
<td></td>
<td>TJ=150°C VCE=VCEES</td>
<td>300</td>
<td>A</td>
</tr>
</tbody>
</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>VRRM</td>
<td>TJ=25°C</td>
<td>600</td>
<td>V</td>
</tr>
<tr>
<td>DC forward current</td>
<td>IF</td>
<td>TJ= Tj,max</td>
<td>82</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TJ=80°C</td>
<td>82</td>
<td>A</td>
</tr>
<tr>
<td>Repetitive peak forward current</td>
<td>IRMS</td>
<td>Ic limited by Tj,max</td>
<td>450</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per Diode</td>
<td>Ptot</td>
<td>TJ= Tj,max</td>
<td>74</td>
<td>W</td>
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<tr>
<td></td>
<td></td>
<td>TJ=80°C</td>
<td>112</td>
<td>A</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>Tjmax</td>
<td>TJ= Tj,max</td>
<td>175</td>
<td>°C</td>
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Maximum Ratings

**Boost IGBT**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector-emitter break down voltage</td>
<td>$V_{CE}$</td>
<td>$T_j=T_{max}$</td>
<td>600</td>
<td>V</td>
</tr>
<tr>
<td>DC collector current</td>
<td>$I_C$</td>
<td>$T_j=80°C$</td>
<td>100</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_j=80°C$</td>
<td>134</td>
<td></td>
</tr>
<tr>
<td>Pulsed collector current</td>
<td>$I_{(pul)}$</td>
<td>$I_p$ limited by $T_{max}$</td>
<td>450</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per IGBT</td>
<td>$P_{int}$</td>
<td>$T_j=T_{max}$</td>
<td>151</td>
<td>W</td>
</tr>
<tr>
<td>Gate-emitter peak voltage</td>
<td>$V_{GE}$</td>
<td>$T_j=25°C$</td>
<td>228</td>
<td></td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>$t_{SC}$</td>
<td>$V_{CC}=15V$</td>
<td>6</td>
<td>µs</td>
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<tr>
<td></td>
<td></td>
<td>$V_{CC}=250°C$</td>
<td>360</td>
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<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{jmax}$</td>
<td>$T_j=150°C$</td>
<td>175</td>
<td>°C</td>
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<tr>
<td>Turn off safe operating area</td>
<td></td>
<td>$V_{CC}=V_{CES}$</td>
<td>300</td>
<td>A</td>
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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>
</tr>
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<tbody>
<tr>
<td>Peak Repetitive Reverse Voltage</td>
<td>$V_{RM}$</td>
<td>$T_j=25°C$</td>
<td>600</td>
<td>V</td>
</tr>
<tr>
<td>DC forward current</td>
<td>$I_F$</td>
<td>$T_j=T_{max}$</td>
<td>91</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_j=80°C$</td>
<td>121</td>
<td></td>
</tr>
<tr>
<td>Repetitive peak forward current</td>
<td>$I_{FRM}$</td>
<td>$I_p$ limited by $T_{max}$</td>
<td>300</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per Diode</td>
<td>$P_{tot}$</td>
<td>$T_j=T_{max}$</td>
<td>123</td>
<td>W</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{jmax}$</td>
<td>$T_j=80°C$</td>
<td>167</td>
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**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>$V_{RM}$</td>
<td>$T_j=25°C$</td>
<td>600</td>
<td>V</td>
</tr>
<tr>
<td>DC forward current</td>
<td>$I_F$</td>
<td>$T_j=T_{max}$</td>
<td>98</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_j=80°C$</td>
<td>129</td>
<td></td>
</tr>
<tr>
<td>Repetitive peak forward current</td>
<td>$I_{FRM}$</td>
<td>$I_p$ limited by $T_{max}$</td>
<td>300</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per Diode</td>
<td>$P_{tot}$</td>
<td>$T_j=T_{max}$</td>
<td>135</td>
<td>W</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{jmax}$</td>
<td>$T_j=80°C$</td>
<td>205</td>
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</table>

**Thermal Properties**

<table>
<thead>
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<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>Storage temperature</td>
<td>$T_{stg}$</td>
<td></td>
<td>-40…+125</td>
<td>°C</td>
</tr>
<tr>
<td>Operation temperature under switching condition</td>
<td>$T_{op}$</td>
<td></td>
<td>-40…+(T_{jmax} - 25)</td>
<td>°C</td>
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</table>

**Insulation Properties**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulation voltage</td>
<td>$V_{in}$</td>
<td>$I=2s$</td>
<td>4000</td>
<td>V</td>
</tr>
<tr>
<td>Creepage distance</td>
<td></td>
<td></td>
<td>min 12.7</td>
<td>mm</td>
</tr>
<tr>
<td>Clearance</td>
<td></td>
<td></td>
<td>min 12.7</td>
<td>mm</td>
</tr>
</tbody>
</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>Buck IGBT</td>
<td>V_{GE}(T)</td>
<td>VCE=VGE</td>
<td>0.0024</td>
<td></td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>V_{CEUH}</td>
<td>15</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Collector-emitter cut-off current incl. Diode</td>
<td>I_{CSS}</td>
<td>0</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>I_{GES}</td>
<td>20</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Integrated Gate resistor</td>
<td>R_{g}</td>
<td>none</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn-on delay time</td>
<td>t_{on}</td>
<td>±15</td>
<td>350</td>
<td>150</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}=4 \Omega</td>
<td>4.10</td>
<td>5.92</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>1.01</td>
<td>1.75</td>
</tr>
<tr>
<td>Turn-off energy loss per pulse</td>
<td>E_{off}</td>
<td></td>
<td>4.10</td>
<td>5.92</td>
</tr>
<tr>
<td>Input capacitance</td>
<td>C_{in}</td>
<td>f=1MHz</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>Output capacitance</td>
<td>C_{out}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reverse transfer capacitance</td>
<td>C_{ox}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gate charge</td>
<td>Q_{g}</td>
<td></td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>R_{thJH}</td>
<td>Thermal grease thickness=50um A,=0.81 W/mK</td>
<td>0.574</td>
<td>K/W</td>
</tr>
</tbody>
</table>

### Buck Diode

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diode forward voltage</td>
<td>V_{F}</td>
<td>±15</td>
<td>150</td>
<td>1.2</td>
</tr>
<tr>
<td>Peak reverse recovery current</td>
<td>I_{RSM}</td>
<td></td>
<td></td>
<td>1.69</td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>t_{r}</td>
<td>R_{goff}=4 \Omega</td>
<td>8.6</td>
<td>13.7</td>
</tr>
<tr>
<td>Reverse recovered charge</td>
<td>Q_{rec}</td>
<td></td>
<td>4.704</td>
<td>3013</td>
</tr>
<tr>
<td>Peak rate of fall of recovery current</td>
<td>di/dt</td>
<td></td>
<td>2.30</td>
<td>3.63</td>
</tr>
<tr>
<td>Reverse recovered energy</td>
<td>E_{rec}</td>
<td></td>
<td>1.288</td>
<td>K/W</td>
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</table>

Note: All characteristic values are related to gates of parallel IGBTs connected together.
### Characteristic Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>Boost IGBT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gate emitter threshold voltage</td>
<td>$V_{GE(th)}$</td>
<td>$V_{CE}=V_{CE}$</td>
<td>0.0024</td>
<td>$T=25^\circ C$, $T=150^\circ C$</td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>$V_{CE(sat)}$</td>
<td></td>
<td>15</td>
<td>$T=25^\circ C$, $T=150^\circ C$</td>
</tr>
<tr>
<td>Collector-emitter cut-off incl diode</td>
<td>$I_{CES}$</td>
<td></td>
<td>0</td>
<td>$T=25^\circ C$, $T=150^\circ C$</td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>$I_{GES}$</td>
<td></td>
<td>30</td>
<td>$T=25^\circ C$, $T=150^\circ C$</td>
</tr>
<tr>
<td>Integrated Gate resistor</td>
<td>$R_{Gate}$</td>
<td></td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>Turn-on delay time</td>
<td>$t_{d(on)}$</td>
<td></td>
<td>15</td>
<td>$T=25^\circ C$, $T=125^\circ C$, $T=150^\circ C$</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>$t_{d(off)}$</td>
<td>$R_{goff}=4$ Ω</td>
<td>±15</td>
<td>$T=25^\circ C$, $T=125^\circ C$, $T=150^\circ C$</td>
</tr>
<tr>
<td>Fall time</td>
<td>$t_{f}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn-on energy loss per pulse</td>
<td>$E_{on}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn-off energy loss per pulse</td>
<td>$E_{off}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input capacitance</td>
<td>$C_{in}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output capacitance</td>
<td>$C_{out}$</td>
<td>$f=1$MHz</td>
<td>0</td>
<td>$T=25^\circ C$</td>
</tr>
<tr>
<td>Reverse transfer capacitance</td>
<td>$C_{Ces}$</td>
<td></td>
<td>15</td>
<td>$T=25^\circ C$</td>
</tr>
<tr>
<td>Gate charge</td>
<td>$Q_{gnea}$</td>
<td></td>
<td>15</td>
<td>$T=25^\circ C$</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>$R_{JH}$</td>
<td>Thermal grease thickness55um $\lambda = 0.81$ W/mK</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Boost Inverse Diode

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diode forward voltage</td>
<td>$V_T$</td>
<td></td>
<td>150</td>
<td>$T=25^\circ C$, $T=125^\circ C$, $T=150^\circ C$</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>$R_{JH}$</td>
<td>Thermal grease thickness55um $\lambda = 0.81$ W/mK</td>
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</tbody>
</table>

### Boost Diode

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<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diode forward voltage</td>
<td>$V_T$</td>
<td></td>
<td>150</td>
<td>$T=25^\circ C$, $T=125^\circ C$, $T=150^\circ C$</td>
</tr>
<tr>
<td>Reverse leakage current</td>
<td>$I_{cm}$</td>
<td></td>
<td>600</td>
<td>$T=25^\circ C$, $T=150^\circ C$</td>
</tr>
<tr>
<td>Peak reverse recovery current</td>
<td>$I_{pmax}$</td>
<td>$R_{gon}=4$ Ω</td>
<td>±15</td>
<td>$T=25^\circ C$, $T=125^\circ C$, $T=150^\circ C$</td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>$t_{rr}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reverse recovered charge</td>
<td>$Q_{r}$</td>
<td></td>
<td>15</td>
<td>$T=25^\circ C$, $T=125^\circ C$, $T=150^\circ C$</td>
</tr>
<tr>
<td>Peak rate of fall of recovery current</td>
<td>$V_{di(max)}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reverse recovery energy</td>
<td>$E_{rec}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>$R_{JH}$</td>
<td>Thermal grease thickness55um $\lambda = 0.81$ W/mK</td>
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### Thermistor

<table>
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<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated resistance</td>
<td>$R$</td>
<td></td>
<td>$T=25^\circ C$</td>
<td>22000</td>
</tr>
<tr>
<td>Deviation of $R_{100}$</td>
<td>$\Delta R/R$</td>
<td>$R_{100}=1486$ Ω</td>
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<td>$T=100^\circ C$</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>$P$</td>
<td></td>
<td>$T=25^\circ C$</td>
<td>200</td>
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<tr>
<td>Power dissipation constant</td>
<td></td>
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<td>$T=25^\circ C$</td>
<td>2</td>
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<tr>
<td>B-value</td>
<td>$B(25/50)$</td>
<td>Tol. ±3%</td>
<td>$T=25^\circ C$</td>
<td>3950</td>
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<tr>
<td>B-value</td>
<td>$B(25/100)$</td>
<td>Tol. ±3%</td>
<td>$T=25^\circ C$</td>
<td>3996</td>
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<tr>
<td>Vincotech NTC Reference</td>
<td></td>
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</tbody>
</table>
Figure 1  
**IGBT**

**Typical output characteristics**

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

![Graph](image1)

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

Figure 2  
**IGBT**

**Typical output characteristics**

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

![Graph](image2)

**At**
- \( t_p = 250 \, \mu s \)
- \( T_j = 150 \, ^\circ C \)
- \( V_{CE} \) from 7 V to 17 V in steps of 1 V

Figure 3  
**IGBT**

**Typical transfer characteristics**

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

![Graph](image3)

**At**
- \( t_p = 250 \, \mu s \)
- \( V_{CE} = 10 \, V \)
- \( T_j = T_{jmax} - 25^\circ C \)
- \( T_j = 25^\circ C \)

Figure 4  
**FRED**

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

\[ I_V = f(V_f) \]

![Graph](image4)

**At**
- \( t_p = 250 \, \mu s \)
Buck

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

\[ E = f(I_C) \]

With an inductive load at:
- \( T_j = 25/150 \) °C
- \( V_{CE} = 175 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{on} = 4 \) Ω
- \( R_{off} = 4 \) Ω

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

\[ E = f(R_G) \]

With an inductive load at:
- \( T_j = 25/150 \) °C
- \( V_{CE} = 175 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_C = 150 \) A

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

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

With an inductive load at:
- \( T_j = 25/150 \) °C
- \( V_{CE} = 175 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{on} = 4 \) Ω

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

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

With an inductive load at:
- \( T_j = 25/150 \) °C
- \( V_{CE} = 175 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_C = 150 \) A
Typical switching times as a function of collector current
\[ t = f(I_C) \]

With an inductive load at

- \( T_j = 150 \) °C
- \( V_{CE} = 175 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 4 \) Ω
- \( R_{goff} = 4 \) Ω

Typical reverse recovery time as a function of collector current
\[ t_r = f(I_C) \]

At

- \( T_j = 25/150 \) °C
- \( V_{CE} = 175 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 4 \) Ω
Typical reverse recovery charge as a function of collector current

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

At
\[ T_j = 25/150 \degree C \]
\[ V_{CE} = 175 \text{ V} \]
\[ V_{GE} = \pm 15 \text{ V} \]
\[ R_{gon} = 4 \text{ } \Omega \]

Typical reverse recovery current as a function of collector current

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

At
\[ T_j = 25/150 \degree C \]
\[ V_{CE} = 175 \text{ V} \]
\[ V_{GE} = \pm 15 \text{ V} \]
\[ R_{gon} = 4 \text{ } \Omega \]
Typical rate of fall of forward and reverse recovery current as a function of collector current $\frac{\text{d}I}{\text{d}t}, \frac{\text{d}I_{\text{rec}}}{\text{d}t} = f(I_c)$

\[
\frac{\text{d}I_0}{\text{d}t}, \frac{\text{d}I_{\text{rec}}}{\text{d}t} = f(R_{\text{gon}})
\]

At $T_j = 25/150 \, ^\circ\text{C}$

$V_{CE} = 175 \, V$

$V_{GE} = \pm 15 \, V$

$I_F = 150 \, A$

$R_{\text{gon}} = 4 \, \Omega$

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

At $D = \frac{t_p}{T}$

$R_{thJH} = 0.574 \, \text{K/W}$

IGBT thermal model values

\[
\begin{array}{ll}
R \ (\text{C/W}) & \text{Tau (s)} \\
0.05 & 4.5E+00 \\
0.10 & 1.0E+00 \\
0.26 & 2.0E-01 \\
0.10 & 6.1E-02 \\
0.05 & 1.3E-02 \\
0.01 & 1.8E-03 \\
\end{array}
\]

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

At $D = \frac{t_p}{T}$

$R_{thJH} = 1.288 \, \text{K/W}$

FRED thermal model values

\[
\begin{array}{ll}
R \ (\text{C/W}) & \text{Tau (s)} \\
0.07 & 4.9E+00 \\
0.20 & 1.0E+00 \\
0.60 & 2.3E-01 \\
0.28 & 8.0E-02 \\
0.12 & 1.6E-02 \\
0.03 & 1.8E-03 \\
\end{array}
\]

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Buck

**Figure 21** IGBT

Power dissipation as a function of heatsink temperature

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

![Graph showing power dissipation vs. heatsink temperature for IGBT](image)

At

\[ T_j = 175 \degree C \]

**Figure 22** IGBT

Collector current as a function of heatsink temperature

\[ I_C = f(T_h) \]

![Graph showing collector current vs. heatsink temperature for IGBT](image)

At

\[ T_j = 175 \degree C \]

**Figure 23** FRED

Power dissipation as a function of heatsink temperature

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

![Graph showing power dissipation vs. heatsink temperature for FRED](image)

At

\[ T_j = 175 \degree C \]

**Figure 24** FRED

Forward current as a function of heatsink temperature

\[ I_F = f(T_h) \]

![Graph showing forward current vs. heatsink temperature for FRED](image)

At

\[ T_j = 175 \degree C \]
Figure 25  
Safe operating area as a function of collector-emitter voltage
\[ I_C = f(V_{CE}) \]

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

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

\( V_{CE}(V) \)
\( I_C(A) \)

\( Q_g(nC) \)

\( V_{GE}(V) \)

120V
480V

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

![Graph](image)

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

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

![Graph](image)

- $t_p = 250 \ \mu s$
- $T_j = 150 \ ^\circ C$
- $V_{CE}$ from 7 V to 17 V in steps of 1 V

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

![Graph](image)

- $I_C$ vs. $V_{GE}$
- $T_j = 25 \ ^\circ C$
- $T_j = T_{j_{max}} - 25 \ ^\circ C$

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

![Graph](image)

- $I_F$ vs. $V_F$
- $T_j = 25 \ ^\circ C$
- $T_j = T_{j_{max}} - 25 \ ^\circ C$

At  
- $t_p = 250 \ \mu s$
- $T_j = 25 \ ^\circ C$
- $V_{CE} = 10 \ \text{V}$
Figure 5  IGBT
Typical switching energy losses
as a function of collector current
\[ E = f(I_C) \]

With an inductive load at
- \( T_J = 25/150 \, ^\circ\text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( R_{GON} = 4 \, \Omega \)
- \( I_C = 149 \, \text{A} \)

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

With an inductive load at
- \( T_J = 25/150 \, ^\circ\text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( I_C = 149 \, \text{A} \)

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

With an inductive load at
- \( T_J = 25/150 \, ^\circ\text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( R_{GON} = 4 \, \Omega \)

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

With an inductive load at
- \( T_J = 25/150 \, ^\circ\text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( I_C = 149 \, \text{A} \)
With an inductive load at
$T_j = 150 \, ^\circ\text{C}$
$V_{CE} = 350 \, \text{V}$
$V_{GE} = \pm 15 \, \text{V}$
$R_{gon} = 4 \, \Omega$
$R_{goff} = 4 \, \Omega$

At
$T_j = 25/150 \, ^\circ\text{C}$
$V_{CE} = 350 \, \text{V}$
$V_{GE} = \pm 15 \, \text{V}$
$I_c = 149 \, \text{A}$

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

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

**At**

- \( T_J = 25/150 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 4 \) Ω

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

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

**At**

- \( T_J = 25/150 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_F = 149 \) A
- \( V_{GE} = \pm 15 \) V

---

*Boost*

- \( Q_{rr} \) = f(\( I_C \))
- \( I_{RRM} \) = f(\( R_{gon} \))

---

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Revision: 5
Typical rate of fall of forward and reverse recovery current as a function of collector current

\[
dI_0/dt, dI_{rec}/dt = f(Ic)
\]

At

- \( T_j = 25/150 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 4 \) Ω

Boost

IGBT transient thermal impedance as a function of pulse width

\( Z_{thJH} = f(t_p) \)

At

- \( D = \frac{t_p}{T} \)
- \( R_{hJH} = 0,630 \) K/W

IGBT thermal model values

<table>
<thead>
<tr>
<th>R (C/W)</th>
<th>Tau (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,06</td>
<td>4,3E+00</td>
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<tr>
<td>0,10</td>
<td>1,1E+00</td>
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<td>0,31</td>
<td>2,2E-01</td>
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<td>0,10</td>
<td>6,2E-02</td>
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<td>1,2E-02</td>
</tr>
<tr>
<td>0,02</td>
<td>1,3E-03</td>
</tr>
</tbody>
</table>

FRED transient thermal impedance as a function of pulse width

\( Z_{thJH} = f(t_p) \)

At

- \( D = \frac{t_p}{T} \)
- \( R_{hJH} = 0,701 \) K/W

FRED thermal model values

<table>
<thead>
<tr>
<th>R (C/W)</th>
<th>Tau (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,07</td>
<td>3,3E+00</td>
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<tr>
<td>0,17</td>
<td>4,3E-01</td>
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<td>0,34</td>
<td>9,8E-02</td>
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<tr>
<td>0,03</td>
<td>1,2E-03</td>
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</tbody>
</table>
Boost

**Figure 21**  
IGBT  
Power dissipation as a function of heatsink temperature  
\[ P_{\text{tot}} = f(T_h) \]

![Power dissipation graph](image)

At  
\[ T_j = 175 \degree \text{C} \]

**Figure 22**  
IGBT  
Collector current as a function of heatsink temperature  
\[ I_C = f(T_h) \]

![Collector current graph](image)

At  
\[ T_j = 175 \degree \text{C} \]

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

![Power dissipation graph](image)

At  
\[ T_j = 175 \degree \text{C} \]

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

![Forward current graph](image)

At  
\[ T_j = 175 \degree \text{C} \]
**Boost**

**Figure 25**

Typical diode forward current as a function of forward voltage

$I_F = f(V_F)$

![Graph showing diode forward current vs. voltage](image)

At $t_p = 250 \ \mu s$

**Figure 26**

Diode transient thermal impedance as a function of pulse width

$Z_{thJH} = f(t_p)$

![Graph showing thermal impedance vs. pulse width](image)

$D = \frac{t_p}{T}$

$R_{thJH} = 0.771 \ \text{K/W}$

**Figure 27**

Power dissipation as a function of heatsink temperature

$P_{tot} = f(T_h)$

![Graph showing power dissipation vs. heatsink temperature](image)

At $T_j = 175 \ ^\circ C$

**Figure 28**

Forward current as a function of heatsink temperature

$I_F = f(T_h)$

![Graph showing forward current vs. heatsink temperature](image)

At $T_j = 175 \ ^\circ C$
**Figure 1**

Typical NTC characteristic as a function of temperature

\[ R_T = f(T) \]

**Figure 2**

Typical NTC resistance values

\[ R(T) = R_{25} \cdot e^{\left(\frac{-R_{25}}{100} \left(\frac{1}{T_{25}} - \frac{1}{T}ight)\right)} \] [Ω]

<table>
<thead>
<tr>
<th>T (°C)</th>
<th>R (Ω)</th>
<th>T (°C)</th>
<th>R (Ω)</th>
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<tbody>
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<td>3006477</td>
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<tr>
<td>30</td>
<td>17830</td>
<td>125</td>
<td>756</td>
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</table>
Switching Definitions BUCK IGBT

General conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>$T_J$</td>
<td>150 °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 | Turn-off Switching Waveforms & definition of $t_{do}$, $t_{Eoff}$

$f_{do} = \text{integrating time for } E_{do}$

![Figure 1](image1)

$V_{GE}(0\%) = -15 \text{ V}$

$V_{GE}(100\%) = 15 \text{ V}$

$V_C(100\%) = 350 \text{ V}$

$I_C(100\%) = 150 \text{ A}$

$t_{do} = 0.25 \mu s$

$t_{Eoff} = 0.63 \mu s$

Figure 2 | Turn-on Switching Waveforms & definition of $t_{don}$, $t_{Eon}$

$f_{don} = \text{integrating time for } E_{don}$

![Figure 2](image2)

$V_{GE}(0\%) = -15 \text{ V}$

$V_{GE}(100\%) = 15 \text{ V}$

$V_C(100\%) = 350 \text{ V}$

$I_C(100\%) = 150 \text{ A}$

$t_{don} = 0.16 \mu s$

$t_{Eon} = 0.36 \mu s$

Figure 3 | Turn-off Switching Waveforms & definition of $t_{r}$

![Figure 3](image3)

$V_C(100\%) = 350 \text{ V}$

$I_C(100\%) = 150 \text{ A}$

$t_{r} = 0.11 \mu s$

Figure 4 | Turn-on Switching Waveforms & definition of $t_{f}$

![Figure 4](image4)

$V_C(100\%) = 350 \text{ V}$

$I_C(100\%) = 150 \text{ A}$

$t_{f} = 0.03 \mu s$
Switching Definitions BUCK IGBT

Figure 5  
Output inverter IGBT

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

![Graph showing turn-off switching waveforms]

- $P_{\text{off}}(100\%) = 52.44$ kW
- $E_{\text{off}}(100\%) = 5.92$ mJ
- $t_{\text{off}} = 0.63$ µs

Figure 6  
Output inverter IGBT

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

![Graph showing turn-on switching waveforms]

- $P_{\text{on}}(100\%) = 52.44$ kW
- $E_{\text{on}}(100\%) = 1.75$ mJ
- $t_{\text{on}} = 0.36$ µs

Figure 7  
Output inverter FRED

Gate voltage vs Gate charge (measured)

![Graph showing gate voltage vs gate charge]

- $V_{\text{GEoff}} = -15$ V
- $V_{\text{GEon}} = 15$ V
- $V_{\text{C}}(100\%) = 350$ V
- $I_{\text{d}}(100\%) = 150$ A
- $Q_{\text{g}} = 1585.43$ nC

Figure 8  
Output inverter IGBT

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

![Graph showing turn-off switching waveforms]

- $V_{\text{d}}(100\%) = 350$ V
- $I_{\text{d}}(100\%) = 150$ A
- $I_{\text{RRM}}(100\%) = -178$ A
- $t_{\text{r}} = 0.15$ µs
Switching Definitions BUCK IGBT

**Figure 9**
Output inverter FRED

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

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

\[
\begin{align*}
I_d(100\%) &= 150 \text{ A} \\
Q_{rr}(100\%) &= 13.73 \mu\text{C} \\
t_{Qrr} &= 0.30 \mu\text{s}
\end{align*}
\]

**Figure 10**
Output inverter FRED

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

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

\[
\begin{align*}
P_{rec}(100\%) &= 52.44 \text{ kW} \\
E_{rec}(100\%) &= 3.63 \text{ mJ} \\
t_{Erec} &= 0.30 \mu\text{s}
\end{align*}
\]

**Measurement circuit**

**Figure 11**
BUCK stage switching measurement circuit
Switching Definitions BOOST IGBT

General conditions

\[ T_j = 150 \, ^\circ \text{C} \]
\[ R_{\text{on}} = 4 \, \Omega \]
\[ R_{\text{off}} = 4 \, \Omega \]

Figure 1: 10-F106NIA150SA-M136F Output inverter IGBT
Turn-off Switching Waveforms & definition of \( t_{\text{doff}}, t_{\text{Eoff}} \)
(\( t_{\text{Eoff}} \) = integrating time for \( E_{\text{off}} \))

![Turn-off Switching Waveforms](chart)

- \( V_{\text{GE}}(0\%) = -15 \, \text{V} \)
- \( V_{\text{GE}}(100\%) = 15 \, \text{V} \)
- \( V_{\text{CE}}(100\%) = 350 \, \text{V} \)
- \( I_{\text{C}}(100\%) = 150 \, \text{A} \)
- \( t_{\text{doff}} = 0.25 \, \mu\text{s} \)
- \( t_{\text{Eoff}} = 0.49 \, \mu\text{s} \)

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

![Turn-on Switching Waveforms](chart)

- \( V_{\text{GE}}(0\%) = -15 \, \text{V} \)
- \( V_{\text{GE}}(100\%) = 15 \, \text{V} \)
- \( V_{\text{CE}}(100\%) = 350 \, \text{V} \)
- \( I_{\text{C}}(100\%) = 150 \, \text{A} \)
- \( t_{\text{don}} = 0.16 \, \mu\text{s} \)
- \( t_{\text{Eon}} = 0.34 \, \mu\text{s} \)

Figure 3: Output inverter IGBT
Turn-off Switching Waveforms & definition of \( t_{\text{f}} \)

![Turn-off Switching Waveforms](chart)

- \( V_{\text{CE}}(100\%) = 350 \, \text{V} \)
- \( I_{\text{C}}(100\%) = 150 \, \text{A} \)
- \( t_{\text{f}} = 0.10 \, \mu\text{s} \)

Figure 4: Output inverter IGBT
Turn-on Switching Waveforms & definition of \( t_{\text{r}} \)

![Turn-on Switching Waveforms](chart)

- \( V_{\text{CE}}(100\%) = 350 \, \text{V} \)
- \( I_{\text{C}}(100\%) = 150 \, \text{A} \)
- \( t_{\text{r}} = 0.03 \, \mu\text{s} \)

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Switching Definitions BOOST IGBT

**Figure 5** Output inverter IGBT

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

- $P_{\text{off}} (100\%) = 52.38$ kW
- $E_{\text{off}} (100\%) = 5.94$ mJ
- $t_{\text{Eoff}} = 0.49$ μs

**Figure 6** Output inverter IGBT

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

- $P_{\text{on}} (100\%) = 52.38$ kW
- $E_{\text{on}} (100\%) = 1.68$ mJ
- $t_{\text{Eon}} = 0.34$ μs

**Figure 7** Output inverter FRED

Gate voltage vs Gate charge (measured)

- $V_{\text{GEoff}} = -15$ V
- $V_{\text{GEon}} = 15$ V
- $V_{\text{C}} (100\%) = 350$ V
- $I_\text{C} (100\%) = 150$ A
- $Q_g = 1583.47$ nC

**Figure 8** Output inverter IGBT

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

- $V_{\text{d}} (100\%) = 350$ V
- $I_{\text{trr}} (100\%) = 150$ A
- $I_{\text{RR M}} (100\%) = -166$ A
- $t_{\text{trr}} = 0.15$ μs

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Switching Definitions BOOST IGBT

**Figure 9**
Output inverter FRED

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

<table>
<thead>
<tr>
<th>$I_d(100%)$</th>
<th>150 A</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Q_{rr}(100%)$</td>
<td>14.35 $\mu$C</td>
</tr>
<tr>
<td>$t_{Qrr}$</td>
<td>0.31 $\mu$s</td>
</tr>
</tbody>
</table>

**Figure 10**
Output inverter FRED

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

<table>
<thead>
<tr>
<th>$P_{rec}(100%)$</th>
<th>52.38 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{rec}(100%)$</td>
<td>4.14 mJ</td>
</tr>
<tr>
<td>$t_{Erec}$</td>
<td>0.31 $\mu$s</td>
</tr>
</tbody>
</table>

**Measurement circuit**

**Figure 11**

BOOST stage switching measurement circuit
Ordering Code and Marking - Outline - Pinout

Ordering Code & Marking

<table>
<thead>
<tr>
<th>Version</th>
<th>Ordering Code</th>
<th>in DataMatrix as</th>
<th>in packaging barcode as</th>
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</thead>
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<tr>
<td>without thermal paste 12mm housing</td>
<td>10-F106NIA150SA-M136F</td>
<td>M136F</td>
<td>M136F</td>
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</tbody>
</table>

Outline

<table>
<thead>
<tr>
<th>Pin Table</th>
<th>Pin Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>X  Y</td>
<td>X  Y</td>
</tr>
<tr>
<td>1  32.2  0.9</td>
<td>26  0  22.8</td>
</tr>
<tr>
<td>2  32.2  0</td>
<td>21  27  25.3</td>
</tr>
<tr>
<td>3  32.2  2.75</td>
<td>22  0  25.5</td>
</tr>
<tr>
<td>4  32.2  7.9</td>
<td>23  27  26.2</td>
</tr>
<tr>
<td>5  32.2  3.9</td>
<td>24  0  26.2</td>
</tr>
<tr>
<td>6  9.2  5.75</td>
<td>25  18.3  22.6</td>
</tr>
<tr>
<td>7  6.2  6.9</td>
<td>26  21.3  21.3</td>
</tr>
<tr>
<td>8  6.2  3.9</td>
<td>27  21.3  24.3</td>
</tr>
<tr>
<td>9  2.7  0</td>
<td>28  43  23.7</td>
</tr>
<tr>
<td>10 0   0</td>
<td>29  46  21</td>
</tr>
<tr>
<td>11 0   2.7</td>
<td>30  46  26</td>
</tr>
<tr>
<td>12 0   2.7</td>
<td>31  52.2  26.3</td>
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<tr>
<td>13 2.7  5.4</td>
<td>32  49.5  22.8</td>
</tr>
<tr>
<td>14 0   5.4</td>
<td>33  52.2  22.8</td>
</tr>
<tr>
<td>15 0   2.7</td>
<td>34  49.5  25.5</td>
</tr>
<tr>
<td>16 0   12.75</td>
<td>35  52.2  25.5</td>
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<tr>
<td>17 2.7  14.0</td>
<td>36  45.5  26.2</td>
</tr>
<tr>
<td>18 0   4.65</td>
<td>37  52.2  26.2</td>
</tr>
<tr>
<td>19 2.7  20.8</td>
<td></td>
</tr>
</tbody>
</table>

Pinout

[Diagram of the device's pinout, showing the connections and layout of the pins.]
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