# Vincotech 10-FZ06NRA041FS02-P965F68

## Features
- Neutral point clamped inverter
- Reactive power capability
- Low inductance layout

## Target Applications
- Solar inverter
- UPS

## Types
- 10-FZ06NRA041FS02-P965F68
- 10-PZ06NRA041FS02-P965F68Y

## Schematic

### Maximum Ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boost Inv. Diode</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repetitive peak reverse voltage</td>
<td>$V_{	ext{RRM}}$</td>
<td></td>
<td>600</td>
<td>V</td>
</tr>
<tr>
<td>Forward current per diode</td>
<td>$I_{	ext{FAV}}$</td>
<td>DC current $T_c=80^\circ\text{C}$</td>
<td>17</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_j=80^\circ\text{C}$</td>
<td>17</td>
<td>A</td>
</tr>
<tr>
<td>Maximum repetitive forward current</td>
<td>$I_{	ext{F RM}}$</td>
<td>$T_j=\text{max}$</td>
<td>20</td>
<td>A</td>
</tr>
<tr>
<td>I2t-value</td>
<td>$t_{	ext{I2}}$</td>
<td>$I_{	ext{F}}=10\text{ms}$</td>
<td>9.5</td>
<td>A$^2$</td>
</tr>
<tr>
<td>Power dissipation per Diode</td>
<td>$P_{	ext{D}}$</td>
<td>$T_j=T_{j\text{max}}$</td>
<td>44</td>
<td>W</td>
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<tr>
<td></td>
<td></td>
<td>$T_c=80^\circ\text{C}$</td>
<td>61</td>
<td>W</td>
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<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{j\text{max}}$</td>
<td></td>
<td>175</td>
<td>°C</td>
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</table>

### Buck Diode

<table>
<thead>
<tr>
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<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>Peak Repetitive Reverse Voltage</td>
<td>$V_{	ext{RRM}}$</td>
<td></td>
<td>600</td>
<td>V</td>
</tr>
<tr>
<td>DC forward current</td>
<td>$I_{p}$</td>
<td>$T_j=T_{j\text{max}}$</td>
<td>19</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_c=80^\circ\text{C}$</td>
<td>24</td>
<td>A</td>
</tr>
<tr>
<td>Repetitive peak forward current</td>
<td>$I_{	ext{FRM}}$</td>
<td>$I_{p}$ limited by $T_{j\text{max}}$</td>
<td>66</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per Diode</td>
<td>$P_{	ext{D}}$</td>
<td>$T_j=T_{j\text{max}}$</td>
<td>32</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_c=80^\circ\text{C}$</td>
<td>49</td>
<td>W</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{j\text{max}}$</td>
<td></td>
<td>150</td>
<td>°C</td>
</tr>
</tbody>
</table>
## Maximum Ratings

**Parameter** | **Symbol** | **Condition** | **Value** | **Unit**
--- | --- | --- | --- | ---

### Buck MOSFET

<table>
<thead>
<tr>
<th>Drain to source breakdown voltage</th>
<th>$V_{DS}$</th>
<th></th>
<th>600</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC drain current</td>
<td>$I_D$</td>
<td>$T_J = T_{max}$, $T_C = 25°C$</td>
<td>29</td>
<td>A</td>
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<tr>
<td>Pulsed drain current</td>
<td>$I_D_{pul}$</td>
<td>$I_D$ limited by $T_{max}$, $T_C = 25°C$</td>
<td>272</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>$P_{tot}$</td>
<td>$T_J = T_{max}$, $T_C = 25°C$</td>
<td>78</td>
<td>W</td>
</tr>
<tr>
<td>Gate-source peak voltage</td>
<td>$V_{GS}$</td>
<td></td>
<td>≤20</td>
<td>V</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{Jmax}$</td>
<td></td>
<td>150</td>
<td>°C</td>
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</table>

### Boost IGBT

<table>
<thead>
<tr>
<th>Collector-emitter break down voltage</th>
<th>$V_{CE}$</th>
<th></th>
<th>600</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC collector current</td>
<td>$I_C$</td>
<td>$T_J = T_{max}$, $T_C = 25°C$</td>
<td>58</td>
<td>A</td>
</tr>
<tr>
<td>Pulsed collector current</td>
<td>$I_{Cpul}$</td>
<td>$I_C$ limited by $T_{max}$, $T_C = 25°C$</td>
<td>225</td>
<td>A</td>
</tr>
<tr>
<td>Turn off safe operating area</td>
<td></td>
<td>$T_J ≤ 150°C$, $V_{CE} ≤ V_{CES}$</td>
<td>225</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per IGBT</td>
<td>$P_{tot}$</td>
<td>$T_J = T_{max}$, $T_C = 25°C$</td>
<td>93</td>
<td>W</td>
</tr>
<tr>
<td>Gate-emitter peak voltage</td>
<td>$V_{GE}$</td>
<td></td>
<td>≤20</td>
<td>V</td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>$I_{SC}$</td>
<td>$T_J ≤ 150°C$, $V_{GE} = 15V$</td>
<td>6</td>
<td>μs</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{Jmax}$</td>
<td></td>
<td>175</td>
<td>°C</td>
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### Boost Diode

<table>
<thead>
<tr>
<th>Peak Repetitive Reverse Voltage</th>
<th>$V_{DRM}$</th>
<th></th>
<th>1200</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC forward current</td>
<td>$I_F$</td>
<td>$T_J = T_{max}$, $T_C = 25°C$</td>
<td>17</td>
<td>A</td>
</tr>
<tr>
<td>Repetitive peak surge current</td>
<td>$I_{FSM}$</td>
<td>20kHz Square Wave</td>
<td>36</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per Diode</td>
<td>$P_{tot}$</td>
<td>$T_J = T_{max}$, $T_C = 25°C$</td>
<td>33</td>
<td>W</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{Jmax}$</td>
<td></td>
<td>150</td>
<td>°C</td>
</tr>
</tbody>
</table>

### Thermal Properties

| Storage temperature | $T_{stg}$ |  | -40...+125 | °C |
| Operation temperature under switching condition | $T_{op}$ |  | -40...+(Tmax - 25) | °C |

### Insulation Properties

| Insulation voltage | $V_{in}$ | $I=2s$ | DC voltage | 4000 | V |
| Creepage distance |  |  |  | min 12.7 | mm |
| Clearance |  |  |  | min 12.7 | mm |
### 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><strong>Boost Inv. Diode</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward voltage</td>
<td>( V_f )</td>
<td>10, 25°C, 125°C</td>
<td>1.25, 1.88, 1.95</td>
<td>V</td>
</tr>
<tr>
<td>Threshold voltage (for power loss calc. only)</td>
<td>( V_{th} )</td>
<td>10, 25°C, 125°C</td>
<td>1.37, 0.70</td>
<td>V</td>
</tr>
<tr>
<td>Slope resistance (for power loss calc. only)</td>
<td>( t_r )</td>
<td>10, 25°C, 125°C</td>
<td>0.04, 0.04</td>
<td>Ω</td>
</tr>
<tr>
<td>Reverse current</td>
<td>( I_r )</td>
<td>600, 125°C</td>
<td>0.027</td>
<td>mA</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>( R_{thJH} )</td>
<td>Thermal grease thickness 50um ( λ = 1 \text{ W/mK} )</td>
<td>2.17</td>
<td>kW</td>
</tr>
<tr>
<td><strong>Buck Diode</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diode forward voltage</td>
<td>( V_f )</td>
<td>10</td>
<td>1.61, 1.88</td>
<td>1.7</td>
</tr>
<tr>
<td>Reverse leakage current</td>
<td>( I_l )</td>
<td>600, 125°C</td>
<td>320</td>
<td>µA</td>
</tr>
<tr>
<td>Peak reverse recovery current</td>
<td>( I_{rmax} )</td>
<td>10</td>
<td>2</td>
<td>A</td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>( t_{rr} )</td>
<td>10, 125°C</td>
<td>10</td>
<td>ns</td>
</tr>
<tr>
<td>Reverse recovered charge</td>
<td>( Q_{rr} )</td>
<td>10</td>
<td>10</td>
<td>µC</td>
</tr>
<tr>
<td>Peak rate of fall of recovery current</td>
<td>( V_{dr} )</td>
<td>2333</td>
<td>100</td>
<td>A/µs</td>
</tr>
<tr>
<td>Reverse recovered energy</td>
<td>( E_{rec} )</td>
<td>1808</td>
<td>0.02</td>
<td>mWs</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>( R_{thJH} )</td>
<td>Thermal grease thickness 50um ( λ = 1 \text{ W/mK} )</td>
<td>2.16</td>
<td>kW</td>
</tr>
<tr>
<td><strong>Buck MOSFET</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static drain to source ON resistance</td>
<td>( R_{ds(on)} )</td>
<td>10</td>
<td>41</td>
<td>mΩ</td>
</tr>
<tr>
<td>Gate threshold voltage</td>
<td>( V_{GDON} )</td>
<td>20</td>
<td>9</td>
<td>100</td>
</tr>
<tr>
<td>Gate to Source Leakage Current</td>
<td>( I_{gs} )</td>
<td>0</td>
<td>600</td>
<td>5</td>
</tr>
<tr>
<td>Zero Gate Voltage Drain Current</td>
<td>( I_{bs} )</td>
<td>0</td>
<td>600</td>
<td>34</td>
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</table>
### Boost IGBT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate emission threshold voltage</td>
<td>$V_{GES}$</td>
<td>$V_{CES}$</td>
<td>0.0012</td>
<td>$T_j$=25°C</td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>$V_{GE}$</td>
<td>$V_{CE}$</td>
<td>16</td>
<td>$T_j$=25°C</td>
</tr>
<tr>
<td>Collector-emitter cut-off incl diode</td>
<td>$I_{CES}$</td>
<td></td>
<td>30</td>
<td>$T_j$=25°C</td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>$I_{GES}$</td>
<td></td>
<td>20</td>
<td>$T_j$=25°C</td>
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<tr>
<td>Integrated Gate resistor</td>
<td>$R_{G}$</td>
<td></td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>Turn-on delay time</td>
<td>$t_{(on)}$</td>
<td></td>
<td></td>
<td>$T_j$=25°C</td>
</tr>
<tr>
<td>Rise time</td>
<td>$t_r$</td>
<td></td>
<td></td>
<td>$T_j$=25°C</td>
</tr>
<tr>
<td>Turn-off delay time</td>
<td>$t_{(off)}$</td>
<td>$R_{g(0f)=4\ \Omega}$</td>
<td>±15</td>
<td>350</td>
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<tr>
<td>Fall time</td>
<td>$t_f$</td>
<td></td>
<td></td>
<td>$T_j$=25°C</td>
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<tr>
<td>Turn-off energy loss per pulse</td>
<td>$E_{off}$</td>
<td></td>
<td></td>
<td>$T_j$=25°C</td>
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<tr>
<td>Input capacitance</td>
<td>$C_{iss}$</td>
<td>$f=1\ \text{MHz}$</td>
<td>0</td>
<td>25</td>
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<tr>
<td>Output capacitance</td>
<td>$C_{oss}$</td>
<td>$f=1\ \text{MHz}$</td>
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<td>25</td>
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<tr>
<td>Reverse transfer capacitance</td>
<td>$C_{riss}$</td>
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<tr>
<td>Gate charge</td>
<td>$Q_{Gmax}$</td>
<td></td>
<td>15</td>
<td>480</td>
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<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>$R_{thJH}$</td>
<td>Thermal grease thickness 50µm $\lambda = 1\ \text{W/mK}$</td>
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</table>

### Boost 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></td>
<td>18</td>
<td>$T_j$=25°C</td>
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<tr>
<td>Reverse leakage current</td>
<td>$I_r$</td>
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<tr>
<td>Peak reverse recovery current</td>
<td>$I_{rr}$</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>$t_{(rr)}$</td>
<td>$R_{g(on)=4\ \Omega}$</td>
<td>±15</td>
<td>350</td>
</tr>
<tr>
<td>Reverse recovered charge</td>
<td>$Q_{rr}$</td>
<td>$R_{g(on)=4\ \Omega}$</td>
<td></td>
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</tr>
<tr>
<td>Peak rate of fall of recovery current</td>
<td>$dI_{(max)}$</td>
<td>$\text{di}(rec)_{max}$</td>
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<tr>
<td>Reverse recovery energy</td>
<td>$E_{rec}$</td>
<td></td>
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<td>$T_j$=25°C</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink per chip</td>
<td>$R_{thJH}$</td>
<td>Thermal grease thickness 50µm $\lambda = 1\ \text{W/mK}$</td>
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### Thermistor

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Rated resistance</td>
<td>$R$</td>
<td></td>
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<td>$T_j$=25°C</td>
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<td>Deviation of $R_{25}$</td>
<td>$\Delta R/R$</td>
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<td>$T_j$=25°C</td>
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<tr>
<td>Power dissipation</td>
<td>$P$</td>
<td></td>
<td></td>
<td>$T_j$=25°C</td>
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<tr>
<td>Power dissipation constant</td>
<td></td>
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<td>$T_j$=25°C</td>
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<tr>
<td>$B$-value</td>
<td>$B_{25}$</td>
<td></td>
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<td>$T_j$=25°C</td>
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<tr>
<td>$B$-value</td>
<td>$B_{25}$</td>
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<td>$T_j$=25°C</td>
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<td>Vincotech NTC Reference</td>
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</tbody>
</table>

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Buck

**Figure 1** MOSFET

**Typical output characteristics**

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

- At
  - \( t_p = 250 \ \mu s \)
  - \( T_J = 25 \ ^\circ C \)
  - \( V_{CE} \) from 0 V to 20 V in steps of 2 V

**Figure 2** MOSFET

**Typical output characteristics**

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

- At
  - \( t_p = 250 \ \mu s \)
  - \( T_J = 125 \ ^\circ C \)
  - \( V_{CE} \) from 0 V to 20 V in steps of 2 V

**Figure 3** MOSFET

**Typical transfer characteristics**

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

- At
  - \( t_p = 250 \ \mu s \)
  - \( V_{CE} = 10 \ \text{V} \)

**Figure 4** FWD

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

\[ I_F = f(V_F) \]

- At
  - \( t_p = 250 \ \mu s \)
  - \( T_J = 25 \ ^\circ C \)
  - \( T_J = T_{J_{\text{max}}}-25 \ ^\circ C \)

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Figure 5  
MOSFET  
Typical switching energy losses as a function of collector current  
\[ E = f(I_C) \]

With an inductive load at  
\[ T_j = 25/125 \; ^\circ C \]
\[ V_{CE} = 350 \; V \]
\[ V_{GE} = 10 \; V \]
\[ R_{g,on} = 8 \; \Omega \]
\[ R_{g,off} = 8 \; \Omega \]

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

With an inductive load at  
\[ T_j = 25/125 \; ^\circ C \]
\[ V_{CE} = 350 \; V \]
\[ V_{GE} = 10 \; V \]
\[ I_C = 20 \; A \]

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

With an inductive load at  
\[ T_j = 25/125 \; ^\circ C \]
\[ V_{CE} = 350 \; V \]
\[ V_{GE} = 10 \; V \]
\[ R_{g,off} = 8 \; \Omega \]

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

With an inductive load at  
\[ T_j = 25/125 \; ^\circ C \]
\[ V_{CE} = 350 \; V \]
\[ V_{GE} = 10 \; V \]
\[ I_C = 20 \; A \]
Typical switching times as a function of collector current

\[ t = f(I_C) \]

With an inductive load at

\[ T_j = 125 \, ^\circ C \]
\[ V_{CE} = 350 \, V \]
\[ V_{GE} = 10 \, V \]
\[ R_{gon} = 8 \, \Omega \]
\[ R_{goff} = 8 \, \Omega \]

Typical reverse recovery time as a function of collector current

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

At

\[ T_j = 25/125 \, ^\circ C \]
\[ V_{CE} = 350 \, V \]
\[ V_{GE} = 10 \, V \]
\[ R_{gon} = 8 \, \Omega \]
Figure 13  FWD
Typical reverse recovery charge as a function of collector current

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

![Figure 13](image1)

At
\[ T_j = 25/125 \, ^\circ C \]
\[ V_{CE} = 350 \, V \]
\[ V_{GE} = 10 \, V \]
\[ R_{g on} = 8 \, \Omega \]

Figure 14  FWD
Typical reverse recovery charge as a function of MOSFET turn on gate resistor

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

![Figure 14](image2)

At
\[ T_j = 25/125 \, ^\circ C \]
\[ V_{OE} = 350 \, V \]
\[ I_F = 20 \, A \]
\[ V_{GE} = 10 \, V \]

Figure 15  FWD
Typical reverse recovery current as a function of collector current

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

![Figure 15](image3)

At
\[ T_j = 25/125 \, ^\circ C \]
\[ V_{CE} = 350 \, V \]
\[ V_{GE} = 10 \, V \]
\[ R_{g on} = 8 \, \Omega \]

Figure 16  FWD
Typical reverse recovery current as a function of MOSFET turn on gate resistor

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

![Figure 16](image4)

At
\[ T_j = 25/125 \, ^\circ C \]
\[ V_{OE} = 350 \, V \]
\[ I_F = 20 \, A \]
\[ V_{GE} = 10 \, V \]
Figure 17
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
- \( T_j = 25/125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = 10 \) V
- \( R_{gon} = 8 \) Ω

Figure 18
Typical rate of fall of forward and reverse recovery current as a function of MOSFET turn on gate resistor
\( \frac{dI_0}{dt}, \frac{dI_{rec}}{dt} = f(R_{gon}) \)

At
- \( T_j = 25/125 \) °C
- \( V_{HI} = 350 \) V
- \( I_f = 20 \) A
- \( V_{GE} = 10 \) V

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

At
- \( D = t_p / \tau \)
- \( R_{thJH} = 0,90 \) K/W

MOSFET thermal model values

<table>
<thead>
<tr>
<th>R (C/W)</th>
<th>Tau (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,13</td>
<td>4,5E+00</td>
</tr>
<tr>
<td>0,26</td>
<td>1,1E+00</td>
</tr>
<tr>
<td>0,25</td>
<td>2,4E-01</td>
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<tr>
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</tr>
<tr>
<td>0,03</td>
<td>1,1E-03</td>
</tr>
</tbody>
</table>

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

At
- \( D = t_p / \tau \)
- \( R_{thJH} = 2,16 \) K/W

FWD thermal model values

<table>
<thead>
<tr>
<th>R (C/W)</th>
<th>Tau (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,08</td>
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<td>8,2E-01</td>
</tr>
<tr>
<td>0,62</td>
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<td>1,9E-03</td>
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<tr>
<td>0,09</td>
<td>5,1E-04</td>
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Buck

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

\[ I_C = f(T_h) \]

At
\[ T_j = 150 \degree C \]

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

At
\[ T_j = 150 \degree C \]
\[ V_{GE} = 15 \text{ V} \]

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

At
\[ T_j = 150 \degree C \]

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

At
\[ T_j = 150 \degree C \]
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
- $V_{GE} =$ 15 V
- $T_j =$ $T_{jmax}$ °C

For Buck

- $I_{GREF} =$ 1 mA, $R_L =$ 15 Ω
**Boost**

**Figure 1**
Typical output characteristics

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

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

**Figure 2**
Typical output characteristics

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

At
- \( t_p = 250 \mu s \)
- \( T_j = 125 \degree C \)
- \( V_{CE} \) from 7 V to 17 V in steps of 1 V

**Figure 3**
Typical transfer characteristics

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

At
- \( t_p = 250 \mu s \)
- \( T_j = 25\degree C \)
- \( V_{CE} = 10\, V \)

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

\[ I_F = f(V_F) \]

At
- \( t_p = 250 \mu s \)
- \( T_j = T_{j\text{max}} - 25\degree C \)
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
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{g_{on}} = 4 \) Ω
- \( R_{g_{off}} = 4 \) Ω

Figure 6  
**IGBT**

**Typical switching energy losses**

as a function of gate resistor

\[ E = f(R_G) \]

With an inductive load at

- \( T_J = 25/125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_C = 30 \) 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

- \( T_J = 25/125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{g_{on}} = 4 \) Ω

Figure 8  
**IGBT**

**Typical reverse recovery energy loss**

as a function of gate resistor

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

With an inductive load at

- \( T_J = 25/125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( I_C = 30 \) A

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Revision: 1
Figure 9  
Typical switching times as a function of collector current  
\( t = f(I_C) \)

With an inductive load at  
\( T_j = 25/125 \) °C  
\( V_{CE} = 350 \) V  
\( V_{CE} = \pm 15 \) V  
\( R_{gon} = 4 \) Ω  
\( R_{goff} = 4 \) Ω

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

With an inductive load at  
\( T_j = 25/125 \) °C  
\( V_{CE} = 350 \) V  
\( V_{CE} = \pm 15 \) V  
\( I_C = 30 \) A

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

At  
\( T_j = 25/125 \) °C  
\( V_{CE} = 350 \) V  
\( V_{CE} = \pm 15 \) V  
\( R_{gon} = 4 \) 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  
\( V_{BE} = 350 \) V  
\( I_C = 30 \) A  
\( V_{GE} = \pm 15 \) V
**Boost**

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

![Graph showing Qrr vs Ic]

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

At
- \( T_j = 25/125 \) °C
- \( V_C = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 4 \) Ω

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

![Graph showing IRRM vs IC]

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

At
- \( T_j = 25/125 \) °C
- \( V_C = 350 \) V
- \( I_F = 30 \) A
- \( V_{GE} = \pm 15 \) V
Figure 17  
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
- \( T_j = 25/125 \) °C
- \( V_{CE} = 350 \) V
- \( V_{GE} = \pm 15 \) V
- \( R_{gon} = 4 \) Ω

Figure 18  
Typical rate of fall of forward and reverse recovery current as a function of reverse recovery current 
\[ \frac{di_0}{dt}, \frac{di_{rec}}{dt} = f(R_{gon}) \]

At
- \( T_j = 25/125 \) °C
- \( V_{CE} = 350 \) V
- \( I_f = 30 \) A
- \( V_{GE} = \pm 15 \) V

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

At
- \( D = t_p / T \)
- \( R_{thJH} = 1,02 \) K/W

IGBT thermal model values
<table>
<thead>
<tr>
<th>( R ) (C/W)</th>
<th>( \tau ) (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,08</td>
<td>4,30</td>
</tr>
<tr>
<td>0,12</td>
<td>1,00</td>
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<tr>
<td>0,47</td>
<td>0,15</td>
</tr>
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<td>0,26</td>
<td>0,05</td>
</tr>
<tr>
<td>0,08</td>
<td>0,01</td>
</tr>
</tbody>
</table>

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

At
- \( D = t_p / T \)
- \( R_{thJH} = 2,11 \) K/W

FWD thermal model values
<table>
<thead>
<tr>
<th>( R ) (C/W)</th>
<th>( \tau ) (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,04</td>
<td>6,53</td>
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<tr>
<td>0,11</td>
<td>1,19</td>
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<td>0,96</td>
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<tr>
<td>0,30</td>
<td>0,01</td>
</tr>
<tr>
<td>0,17</td>
<td>0,00</td>
</tr>
</tbody>
</table>
Power dissipation as a function of heatsink temperature

Figure 21  
$P_{\text{tot}} = f(T_h)$  

At  
$T_j = 175 \, ^{\circ}C$

Power dissipation as a function of heatsink temperature

Figure 23  
$P_{\text{tot}} = f(T_h)$  

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

Collector current as a function of heatsink temperature

Figure 22  
$I_C = f(T_h)$  

At  
$T_j = 175 \, ^{\circ}C$

Forward current as a function of heatsink temperature

Figure 24  
$I_F = f(T_h)$  

At  
$T_j = 150 \, ^{\circ}C$
Boost Inverse Diode

**Figure 25**
IGBT Inverse Diode
Typical diode forward current as a function of forward voltage
\[ I_F = f(V_F) \]

![Diagram showing diode forward current as a function of forward voltage.]

At
\[ t_p = 250 \mu s \]

**Figure 26**
IGBT Inverse Diode
Diode transient thermal impedance as a function of pulse width
\[ Z_{thJH} = f(t_p) \]

![Diagram showing diode transient thermal impedance as a function of pulse width.]

At
\[ D = \frac{t_p}{T} \]
\[ R_{thJH} = 2.17 \text{ K/W} \]

**Figure 27**
IGBT Inverse Diode
Power dissipation as a function of heatsink temperature
\[ P_{tot} = f(T_j) \]

![Diagram showing power dissipation as a function of heatsink temperature.]

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

**Figure 28**
IGBT Inverse Diode
Forward current as a function of heatsink temperature
\[ I_F = f(T_j) \]

![Diagram showing forward current as a function of heatsink temperature.]

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

Typical NTC characteristic as a function of temperature

\[ R_T = f(T) \]

![Graph: NTC-typical temperature characteristic](image)

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

<table>
<thead>
<tr>
<th>T (°C)</th>
<th>R_min [Ω]</th>
<th>R_max [Ω]</th>
<th>ΔR/R [%]</th>
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</thead>
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<td>28.7</td>
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<td>30</td>
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<td>50</td>
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<td>9.1</td>
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<tr>
<td>70</td>
<td>3848.8</td>
<td>4151.1</td>
<td>7.9</td>
</tr>
<tr>
<td>90</td>
<td>2757.7</td>
<td>2947.1</td>
<td>6.9</td>
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<tr>
<td>100</td>
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<td>2128.2</td>
<td>5.9</td>
</tr>
<tr>
<td>150</td>
<td>400.2</td>
<td>435.7</td>
<td>8.6</td>
</tr>
</tbody>
</table>
Switching Definitions BUCK

General conditions

- $T_j = 125 \, ^\circ C$
- $R_{ Thom \, IGBT } = 8 \, \Omega$
- $R_{ Eoff \, IGBT } = 8 \, \Omega$

**Figure 1**
BUCK MOSFET

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

- $V_{GE}(0\%) = 0 \, V$
- $V_{GE}(100\%) = 10 \, V$
- $V_{CE}(100\%) = 700 \, V$
- $I_{C}(100\%) = 20 \, A$
- $t_{Eoff} = 0.29 \, \mu s$
- $t_{Eon} = 0.33 \, \mu s$

**Figure 2**
BUCK MOSFET

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

- $V_{GE}(0\%) = 0 \, V$
- $V_{GE}(100\%) = 10 \, V$
- $V_{CE}(100\%) = 700 \, V$
- $I_{C}(100\%) = 20 \, A$
- $t_{Eon} = 0.03 \, \mu s$
- $t_{Eoff} = 0.07 \, \mu s$

**Figure 3**
BUCK MOSFET

Turn-off Switching Waveforms & definition of $t_T$

- $V_{CE}(100\%) = 700 \, V$
- $I_{C}(100\%) = 20 \, A$
- $t_T = 2.756 \, \mu s$

**Figure 4**
BUCK MOSFET

Turn-on Switching Waveforms & definition of $t_T$

- $V_{CE}(100\%) = 700 \, V$
- $I_{C}(100\%) = 20 \, A$
- $t_T = 0.01 \, \mu s$

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Switching Definitions BUCK

**Figure 5** BUCK MOSFET
Turn-off Switching Waveforms & definition of \( t_{\text{Eoff}} \)

\[
\begin{align*}
P_{\text{off}} \,(100\%) & = 13.98 \, \text{kW} \\
E_{\text{off}} \,(100\%) & = 0.07 \, \text{mJ} \\
t_{\text{Eoff}} & = 0.33 \, \mu\text{s}
\end{align*}
\]

**Figure 6** BUCK MOSFET
Turn-on Switching Waveforms & definition of \( t_{\text{Eon}} \)

\[
\begin{align*}
P_{\text{on}} \,(100\%) & = 13.98 \, \text{kW} \\
E_{\text{on}} \,(100\%) & = 0.15 \, \text{mJ} \\
t_{\text{Eon}} & = 0.07 \, \mu\text{s}
\end{align*}
\]

**Figure 7** BUCK MOSFET
Turn-off Switching Waveforms & definition of \( t_{\text{Qrr}} \)

\[
\begin{align*}
V_{\text{d}} \,(100\%) & = 700 \, \text{V} \\
i_{\text{d}} \,(100\%) & = 20 \, \text{A} \\
i_{\text{RRM}} \,(100\%) & = -10 \, \text{A} \\
t_{\text{Qrr}} & = 0.02 \, \mu\text{s}
\end{align*}
\]

**Figure 8** BUCK FWD
Turn-on Switching Waveforms & definition of \( t_{\text{Qrr}} \)

\[
\begin{align*}
i_{\text{d}} \,(100\%) & = 20 \, \text{A} \\
Q_{\text{r}} \,(100\%) & = 0.12 \, \mu\text{C} \\
t_{\text{Qrr}} & = 0.08 \, \mu\text{s}
\end{align*}
\]
Switching Definitions BUCK

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

![Graph showing turn-on switching waveforms and definition of $t_{E_{rec}}$.]

$P_{rec}(100\%) = 13.98$ kW
$E_{rec}(100\%) = 0.02$ mJ
$t_{E_{rec}} = 0.08$ $\mu$s

Figure 11
BUCK stage switching measurement circuit

Figure 12
BOOST stage switching measurement circuit

Measurement circuits

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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>$R_{th,IGBT}$</td>
<td>4 Ω</td>
</tr>
<tr>
<td>$R_{th,IGBT}$</td>
<td>4 Ω</td>
</tr>
</tbody>
</table>

Figure 1

Output inverter IGBT

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

$t_{off}$ = Integrating time for $E_{off}$

$t_{Eoff}$ = Integrating time for $E_{on}$

- $V_{GE}(0\%) = -15$ V
- $V_{GE}(100\%) = 15$ V
- $I_C(100\%) = 30$ A
- $t_{off} = 0.24 \mu$s
- $t_{Eoff} = 0.52 \mu$s

Figure 2

Output inverter IGBT

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

$t_{on}$ = Integrating time for $E_{on}$

$t_{Eon}$ = Integrating time for $E_{off}$

- $V_{CE}(100\%) = 350$ V
- $I_C(100\%) = 30$ A
- $t_{on} = 0.08 \mu$s
- $t_{Eon} = 0.10 \mu$s

Figure 3

Output inverter IGBT

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

- $V_{CE}(0\%) = -50$ V
- $V_{CE}(10\%) = 50$ V
- $V_{CE}(90\%) = 150$ V
- $I_C(10%) = 3,05$ A
- $I_C(90%) = 3,15$ A
- $t_{r} = 0,20 \mu$s

Figure 4

Output inverter IGBT

Turn-on Switching Waveforms & definition of $t_f$

- $V_{CE}(0\%) = -25$ V
- $V_{CE}(10\%) = 25$ V
- $V_{CE}(50\%) = 75$ V
- $I_C(10%) = 3,06$ A
- $I_C(90%) = 3,12$ A
- $t_f = 0,09 \mu$s

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Switching Definitions BOOST

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

- $P_{off}$ (100%) = 10.46 kW
- $E_{off}$ (100%) = 1.36 mJ
- $t_{E_{off}}$ = 0.52 µs

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

- $P_{on}$ (100%) = 10.46 kW
- $E_{on}$ (100%) = 0.39 mJ
- $t_{E_{on}}$ = 0.10 µs

**Figure 7**
Output inverter IGBT
Turn-off Switching Waveforms & definition of $t_{Q_{rr}}$

- $V_{d}$ (100%) = 350 V
- $i_{d}$ (100%) = 30 A
- $i_{d_{90}}$ (100%) = -67 A
- $t_{Q_{rr}}$ = 0.10 µs

**Figure 8**
Output inverter FWD
Turn-on Switching Waveforms & definition of $t_{Q_{rr}}$

- $i_{d}$ (100%) = 30 A
- $Q_{rr}$ (100%) = 4.72 µC
- $t_{Q_{rr}}$ = 1.00 µs

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Switching Definitions BOOST

Figure 9
Output inverter FWD

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

($t_{E_{rec}}$ = integrating time for $E_{rec}$)

$P_{rec}(100\%) = 10.46$ kW

$E_{rec}(100\%) = 1.45$ mJ

$t_{E_{rec}} = 1.00$ $\mu$s

Measurement circuits

Figure 11
BUCK stage switching measurement circuit

Figure 12
BOOST stage switching measurement circuit
Ordering Code and 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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<td>10-FZ06NRA041FS02-P965F68</td>
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<td>w/o thermal paste 12mm housing Press-fit pin</td>
<td>10-FZ06NRA041FS02-P965F68Y</td>
<td>P965F68Y</td>
<td>P965F68Y</td>
</tr>
</tbody>
</table>

Outline

Pinout

Pin 19: G3
Pin 18: S3
Pin 17: G2
Pin 16: S2
Pin 15: G1
Pin 14: S1
Pin 13: G0
Pin 12: S0
Pin 11: Line 9, 10, 11
Pin 10: NTC1
Pin 9: NTC2
Pin 8: G4
Pin 7: S4
Pin 6: G3, 17 are NOT CONNECTED
Pin 5: Line 4, 5
Pin 4: DC-
Pin 3: DC+
Pin 2: G4
Pin 1: S4

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