Vincotech

70-W212NMC400SH01-M709P datasheet

**flow MNPC 4w**

**1200 V / 400 A**

### Features
- Mixed voltage NPC
- Low inductive
- High power screw interface

### Target Applications
- Solar inverter
- UPS
- High speed motor drive

### Types
- 70-W212NMC400SH01-M709P

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### Maximum Ratings

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector-emitter break down voltage</td>
<td>$V_{ce}$</td>
<td>$T_j=T_{j\text{max}}$</td>
<td>1200</td>
<td>V</td>
</tr>
<tr>
<td>DC collector current</td>
<td>$I_c$</td>
<td>$T_j=T_{j\text{max}}$</td>
<td>405</td>
<td>A</td>
</tr>
<tr>
<td>Repetitive peak collector current</td>
<td>$I_{CEM}$</td>
<td>$t_\alpha$ limited by $T_{j\text{max}}$</td>
<td>1200</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>$P_{tot}$</td>
<td>$T_j=T_{j\text{max}}$</td>
<td>1105</td>
<td>W</td>
</tr>
<tr>
<td>Gate-emitter peak voltage</td>
<td>$V_{GE}$</td>
<td>$T_j=T_{j\text{max}}$</td>
<td>±20</td>
<td>V</td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>$\tau_{SC}$</td>
<td>$T_j\leq 150^\circ C$</td>
<td>10</td>
<td>$\mu$s</td>
</tr>
<tr>
<td></td>
<td>$V_{CC}$</td>
<td>$T_j\leq 150^\circ C$</td>
<td>800</td>
<td>V</td>
</tr>
<tr>
<td>Turn off safe operating area (RBSOA)</td>
<td>$I_{FMAX}$</td>
<td>$V_{CE}$ max = 1200V $T_{j\text{max}}$</td>
<td>1200</td>
<td>A</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{j\text{max}}$</td>
<td>$T_j=25^\circ C$</td>
<td>175</td>
<td>$^\circ$C</td>
</tr>
</tbody>
</table>

### neutral point FWD ( D2 , D3 )

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Repetitive Reverse Voltage</td>
<td>$V_{ASUM}$</td>
<td>$T_j=25^\circ C$</td>
<td>600</td>
<td>V</td>
</tr>
<tr>
<td>DC forward current</td>
<td>$I_F$</td>
<td>$T_j=T_{j\text{max}}$</td>
<td>282</td>
<td>A</td>
</tr>
<tr>
<td>Repetitive peak forward current</td>
<td>$I_{FDM}$</td>
<td>$t_p=1$ ms $T_{vI}&lt; 150^\circ C$</td>
<td>800</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation per FWD</td>
<td>$P_{F}$</td>
<td>$T_j=T_{j\text{max}}$</td>
<td>389</td>
<td>W</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{F\text{max}}$</td>
<td>$T_j=25^\circ C$</td>
<td>175</td>
<td>$^\circ$C</td>
</tr>
</tbody>
</table>
Maximum Ratings

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector-emitter break down voltage</td>
<td>$V_{CE}$</td>
<td>$T_j=T_{j\max}$</td>
<td>600</td>
<td>V</td>
</tr>
<tr>
<td>DC collector current</td>
<td>$i_c$</td>
<td>$T_j=T_{j\max}$</td>
<td>355</td>
<td>A</td>
</tr>
<tr>
<td>Repetitive peak collector current</td>
<td>$I_{Comm}$</td>
<td>$t_o$, limited by $T_{j\max}$</td>
<td>1200</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>$P_{tot}$</td>
<td>$T_j=T_{j\max}$</td>
<td>645</td>
<td>W</td>
</tr>
<tr>
<td>Gate-emitter peak voltage</td>
<td>$V_{GE}$</td>
<td>$\pm 20$</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Short circuit ratings</td>
<td>$t_{SC}$</td>
<td>$V_{CC}=15V$</td>
<td>6</td>
<td>$\mu s$</td>
</tr>
<tr>
<td>Turn off safe operating area (RBSOA)</td>
<td>$I_{cs}$</td>
<td>$t_{SC} = 150^\circ C$</td>
<td>360</td>
<td>V</td>
</tr>
<tr>
<td>Peak Repetitive Reverse Voltage</td>
<td>$V_{RMS}$</td>
<td>$T_j=25^\circ C$</td>
<td>1200</td>
<td>V</td>
</tr>
<tr>
<td>DC forward current</td>
<td>$i_f$</td>
<td>$T_j=T_{j\max}$</td>
<td>234</td>
<td>A</td>
</tr>
<tr>
<td>Surge forward current</td>
<td>$I_{tst}$</td>
<td>$t_{s}=10\mathrm{ms} \cdot \sin 180^\circ$</td>
<td>1800</td>
<td>A</td>
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<tr>
<td>$t^2$-value</td>
<td>$t^2$</td>
<td>$T_j=150^\circ C$</td>
<td>8100</td>
<td>$\mathrm{A^2s}$</td>
</tr>
<tr>
<td>Power dissipation per FWD</td>
<td>$P_{tot}$</td>
<td>$T_j=T_{j\max}$</td>
<td>468</td>
<td>W</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{j\max}$</td>
<td></td>
<td>175</td>
<td>°C</td>
</tr>
</tbody>
</table>

half bridge FWD (D1, D4)

<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>$T_j=25^\circ C$</td>
<td>1200</td>
<td>V</td>
</tr>
<tr>
<td>DC collector current</td>
<td>$i_c$</td>
<td>$T_j=T_{j\max}$</td>
<td>234</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>$P_{tot}$</td>
<td>$T_j=T_{j\max}$</td>
<td>468</td>
<td>W</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_{j\max}$</td>
<td></td>
<td>175</td>
<td>°C</td>
</tr>
</tbody>
</table>

General Module Properties

- Material of module baseplate: Cu
- Material of internal isolation: Al2O3

Thermal Properties

- Storage temperature: $T_{stg}$
- Operation temperature under switching condition: $T_{op}$

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>$V_u$</td>
<td>$t=2s$</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>
<tr>
<td>Comparative tracking index</td>
<td>CTI</td>
<td></td>
<td>&gt;200</td>
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## Characteristic Values

### half bridge IGBT (T1, T4)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate emitter threshold voltage</td>
<td>V_{GE(th)} = V_{GE}</td>
<td>Tj=25°C, Tj=125°C</td>
<td>5.3</td>
<td>5.8</td>
<td>6.3</td>
<td>V</td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>V_{CEO}</td>
<td>400 V</td>
<td>Tj=25°C, Tj=125°C</td>
<td>1.78</td>
<td>2.10</td>
<td>2.42</td>
</tr>
<tr>
<td>Collector-emitter cut-off current incl. FWD</td>
<td>I_{CS}</td>
<td>0, 1200</td>
<td>Tj=25°C, Tj=125°C</td>
<td>0.8</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>I_{PK}</td>
<td>20, 0</td>
<td>Tj=25°C, Tj=125°C</td>
<td>960</td>
<td>nA</td>
<td></td>
</tr>
<tr>
<td>Integrated Gate resistor</td>
<td>R_{PK}</td>
<td></td>
<td></td>
<td>0.5</td>
<td>Ω</td>
<td></td>
</tr>
<tr>
<td>Turn-on delay time</td>
<td>t_{on}</td>
<td></td>
<td></td>
<td>202</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>Rise time</td>
<td>t_{r}</td>
<td>Rgoff=1 Ω Rgon=1 Ω</td>
<td>15</td>
<td>350</td>
<td>406</td>
<td></td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>t_{rec}</td>
<td></td>
<td></td>
<td>0.0136</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Reverse recovered charge</td>
<td>Q_{rr}</td>
<td></td>
<td></td>
<td>341</td>
<td>341</td>
<td></td>
</tr>
<tr>
<td>Peak rate of fall of recovery current</td>
<td>(d/dt)</td>
<td></td>
<td></td>
<td>342</td>
<td>342</td>
<td></td>
</tr>
<tr>
<td>Reverse recovered energy</td>
<td>E_{on}</td>
<td>Tj=25°C</td>
<td>8524</td>
<td>4659</td>
<td></td>
<td>μJ</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink</td>
<td>R_{th(j-s)}</td>
<td>Phase-Change Material</td>
<td>K = 3.4 W/mK</td>
<td>0.09</td>
<td>K/W</td>
<td></td>
</tr>
</tbody>
</table>

### neutral point FWD (D2, D3)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>FWD forward voltage</td>
<td>V_{F}</td>
<td>600 V</td>
<td>Tj=25°C, Tj=125°C</td>
<td>1.2</td>
<td>1.75</td>
<td>1.9</td>
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<tr>
<td>Peak reverse recovery current</td>
<td>I_{RMS}</td>
<td></td>
<td></td>
<td>1.64</td>
<td></td>
<td></td>
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<tr>
<td>Reverse recovery time</td>
<td>t_{r}</td>
<td></td>
<td></td>
<td>294</td>
<td>341</td>
<td></td>
</tr>
<tr>
<td>Reverse recovered charge</td>
<td>Q_{RR}</td>
<td></td>
<td></td>
<td>242</td>
<td>242</td>
<td></td>
</tr>
<tr>
<td>Peak rate of fall of recovery current</td>
<td>(d/dt)</td>
<td></td>
<td></td>
<td>14</td>
<td>14</td>
<td></td>
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<tr>
<td>Reverse recovered energy</td>
<td>E_{on}</td>
<td>Tj=25°C</td>
<td>8524</td>
<td>4659</td>
<td></td>
<td>μJ</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink</td>
<td>R_{th(j-s)}</td>
<td>Phase-Change Material</td>
<td>K = 3.4 W/mK</td>
<td>0.24</td>
<td>K/W</td>
<td></td>
</tr>
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### neutral point IGBT (T2, T3)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate emitter threshold voltage</td>
<td>V_{GE(th)} = V_{GE}</td>
<td>Tj=25°C, Tj=125°C</td>
<td>5.3</td>
<td>5.8</td>
<td>6.3</td>
<td>V</td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>V_{CEO}</td>
<td>400 V</td>
<td>Tj=25°C, Tj=125°C</td>
<td>1.78</td>
<td>2.10</td>
<td>2.42</td>
</tr>
<tr>
<td>Collector-emitter cut-off incl. FWD</td>
<td>I_{CS}</td>
<td>0, 600</td>
<td>Tj=25°C, Tj=125°C</td>
<td>0.02</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>Gate-emitter leakage current</td>
<td>I_{PK}</td>
<td>20, 0</td>
<td>Tj=25°C, Tj=125°C</td>
<td>2400</td>
<td>nA</td>
<td></td>
</tr>
<tr>
<td>Integrated Gate resistor</td>
<td>R_{PK}</td>
<td></td>
<td></td>
<td>0.5</td>
<td>Ω</td>
<td></td>
</tr>
<tr>
<td>Turn-on delay time</td>
<td>t_{on}</td>
<td></td>
<td></td>
<td>198</td>
<td>199</td>
<td></td>
</tr>
<tr>
<td>Rise time</td>
<td>t_{r}</td>
<td>Rgoff=1 Ω Rgon=1 Ω</td>
<td>15</td>
<td>350</td>
<td>407</td>
<td></td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>t_{rec}</td>
<td></td>
<td></td>
<td>287</td>
<td>288</td>
<td></td>
</tr>
<tr>
<td>Fall time</td>
<td>t_{f}</td>
<td></td>
<td></td>
<td>28</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Reverse recovered energy</td>
<td>E_{on}</td>
<td>Tj=25°C</td>
<td>11.22</td>
<td>15.22</td>
<td></td>
<td>μJ</td>
</tr>
<tr>
<td>Input capacitance</td>
<td>C_{int}</td>
<td></td>
<td></td>
<td>26640</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output capacitance</td>
<td>C_{out}</td>
<td></td>
<td></td>
<td>1536</td>
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<tr>
<td>Reverse transfer capacitance</td>
<td>C_{int}</td>
<td></td>
<td></td>
<td>732</td>
<td></td>
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</tr>
<tr>
<td>Gate charge</td>
<td>Q_{0}</td>
<td></td>
<td></td>
<td>2480</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink</td>
<td>R_{th(j-s)}</td>
<td>Phase-Change Material</td>
<td>K = 3.4 W/mK</td>
<td>0.15</td>
<td>K/W</td>
<td></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>V_{GE} [V] or V_{GS} [V]</td>
<td></td>
<td>T_{j}=25°C or 125°C</td>
<td>2.18 2.46</td>
<td>V</td>
</tr>
<tr>
<td>V_{r} [V] or V_{CE} [V] or V_{DS} [V]</td>
<td></td>
<td>T_{j}=25°C or 125°C</td>
<td>2.18 380 15</td>
<td>V, µA</td>
</tr>
<tr>
<td>I_{C} [A] or I_{F} [A] or I_{D} [A]</td>
<td></td>
<td>T_{j}=25°C</td>
<td>360 511 75</td>
<td>A, ns</td>
</tr>
<tr>
<td>T_{j}</td>
<td></td>
<td>T_{j}=25°C or 125°C</td>
<td>436 75 15</td>
<td>A, µs</td>
</tr>
<tr>
<td>FWD forward voltage</td>
<td>V_{F}</td>
<td>T_{j}=25°C or 125°C</td>
<td>200 22850 22850</td>
<td>mW</td>
</tr>
<tr>
<td>Reverse leakage current</td>
<td>I_{r}</td>
<td>T_{j}=25°C or 125°C</td>
<td>15 15</td>
<td>µC</td>
</tr>
<tr>
<td>Peak reverse recovery current</td>
<td>If_{rr}</td>
<td>T_{j}=25°C or 125°C</td>
<td>15 15</td>
<td>µA</td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>t_{rr}</td>
<td>T_{j}=25°C or 125°C</td>
<td>15 15</td>
<td>µs</td>
</tr>
<tr>
<td>Reverse recovered charge</td>
<td>Q_{rr}</td>
<td>T_{j}=25°C or 125°C</td>
<td>15 15</td>
<td>µC</td>
</tr>
<tr>
<td>Peak rate of fall of recovery current</td>
<td>(dI_{rr}/dt)</td>
<td>T_{j}=25°C or 125°C</td>
<td>15 15</td>
<td>A/µs</td>
</tr>
<tr>
<td>Reverse recovery energy</td>
<td>E_{rec}</td>
<td>T_{j}=25°C or 125°C</td>
<td>15 15</td>
<td>mJ/m²s</td>
</tr>
<tr>
<td>Thermal resistance chip to heatsink</td>
<td>R_{th(j-s)}</td>
<td>T_{j}=25°C</td>
<td>0.20</td>
<td>K/W</td>
</tr>
</tbody>
</table>

### Thermistor

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated resistance</td>
<td>R</td>
<td>T_{j}=25°C</td>
<td>22000</td>
<td>Ω</td>
</tr>
<tr>
<td>Deviation of R_{th}</td>
<td>A_{25}</td>
<td>T_{j}=10°C</td>
<td>±2</td>
<td>%</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>P</td>
<td>T_{j}=25°C</td>
<td>200</td>
<td>mW</td>
</tr>
<tr>
<td>Power dissipation constant</td>
<td></td>
<td>T_{j}=25°C</td>
<td>2</td>
<td>mW/K</td>
</tr>
<tr>
<td>B-value</td>
<td>B_{125°C}</td>
<td>T_{j}=25°C</td>
<td>3950</td>
<td>Ω</td>
</tr>
<tr>
<td></td>
<td>B_{100°C}</td>
<td>T_{j}=25°C</td>
<td>3996</td>
<td>Ω</td>
</tr>
<tr>
<td>Vincotech NTC Reference</td>
<td></td>
<td>T_{j}=25°C</td>
<td>B</td>
<td></td>
</tr>
</tbody>
</table>

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Buck operation
half bridge IGBT (T1,T4) and neutral point FWD (D2,D3)

Figure 1
 Typical output characteristics $V_{ge}=15V$

$I_C = f(V_{ce})$

![Graph showing typical output characteristics for IGBT with $V_{ge}=15V$.]

At
$\tau_p = 350 \ \mu s$
$T_j = 25/125/150 \ ^\circ C$
$V_{ce}= 10 \ \text{V}$

Figure 2
 Typical output characteristics

$I_C = f(V_{ce})$

![Graph showing typical output characteristics for IGBT.]

At
$\tau_p = 350 \ \mu s$
$T_j = 150 \ ^\circ C$
$V_{ce}$ from 7 V to 17 V in steps of 1 V

Figure 3
 Typical transfer characteristics

$I_C = f(V_{ce})$

![Graph showing typical transfer characteristics for IGBT.]

At
$\tau_p = 350 \ \mu s$
$V_{ce} = 10 \ \text{V}$
$T_j = 25/125/150 \ ^\circ C$

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

$I_F = f(V_F)$

![Graph showing typical FWD forward current as a function of forward voltage.]

At
$\tau_p = 350 \ \mu s$
$T_j = 25/125/150 \ ^\circ C$
Buck operation
half bridge IGBT (T1,T4) and neutral point FWD (D2,D3)

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

With an inductive load at
\[ T_j = 25/125/150 \degree C \]
\[ V_{CE} = 350 \text{ V} \]
\[ V_{GD} = \pm 15 \text{ V} \]
\[ R_{gon} = 1.0 \text{ } \Omega \]
\[ I_C = 406 \text{ A} \]

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

With an inductive load at
\[ T_j = 25/125/150 \degree C \]
\[ V_{CE} = 350 \text{ V} \]
\[ V_{GD} = \pm 15 \text{ V} \]
\[ I_C = 406 \text{ A} \]

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

With an inductive load at
\[ T_j = 25/125/150 \degree C \]
\[ V_{CE} = 350 \text{ V} \]
\[ V_{GD} = \pm 15 \text{ V} \]
\[ R_{gon} = 1.0 \text{ } \Omega \]

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

With an inductive load at
\[ T_j = 25/125/150 \degree C \]
\[ V_{CE} = 350 \text{ V} \]
\[ V_{GD} = \pm 15 \text{ V} \]
\[ I_C = 406 \text{ A} \]
**Buck operation**

half bridge IGBT (T1,T4) and neutral point FWD (D2,D3)

---

**Figure 9**

Typical switching times as a function of collector current

\[ t = f(I_C) \]

With an inductive load at

- \( T_j = 124 \, ^\circ\text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( R_{gon} = 1.0 \, \Omega \)
- \( R_{goff} = 1.0 \, \Omega \)

---

**Figure 10**

Typical switching times as a function of gate resistor

\[ t = f(R_g) \]

With an inductive load at

- \( T_j = 124 \, ^\circ\text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( I_C = 406 \, \text{A} \)

---

**Figure 11**

Typical reverse recovery time as a function of collector current

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

At

- \( T_j = 25/125/150 \, ^\circ\text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
- \( R_{gon} = 1.0 \, \Omega \)

---

**Figure 12**

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

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

At

- \( T_j = 25/125/150 \, ^\circ\text{C} \)
- \( V_{CE} = 350 \, \text{V} \)
- \( I_F = 406 \, \text{A} \)
- \( V_{GE} = \pm 15 \, \text{V} \)
Buck operation
half bridge IGBT (T1,T4) and neutral point FWD (D2,D3)

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

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

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

At
- \( T_j = 25/125/150 \, ^\circ C \)
- \( V_{CE} = 350 \, V \)
- \( V_{GE} = \pm 15 \, V \)
- \( R_{gon} = 1,0 \, \Omega \)

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

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

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

At
- \( T_j = 25/125/150 \, ^\circ C \)
- \( V_R = 350 \, V \)
- \( I_F = 406 \, A \)
- \( V_{GE} = \pm 15 \, V \)

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

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

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

At
- \( T_j = 25/125/150 \, ^\circ C \)
- \( V_{CE} = 350 \, V \)
- \( V_{GE} = \pm 15 \, V \)
- \( I_F = 406 \, A \)
- \( R_{gon} = 1,0 \, \Omega \)

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

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

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

At
- \( T_j = 25/125/150 \, ^\circ C \)
- \( V_R = 350 \, V \)
- \( I_F = 406 \, A \)
- \( V_{GE} = \pm 15 \, V \)
Typical rate of fall of forward and reverse recovery current as a function of collector current:

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

At

\[
T_j = 25/125 \, ^\circ C
\]

\[
V_{CE} = 350 \, V
\]

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

\[
R_{gon} = 1.0 \, \Omega
\]

IGBT transient thermal impedance as a function of pulse width:

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

At

\[
D = 0.5
\]

\[
R_{\infty} = 0.9 \, \text{K/W}
\]

IGBT thermal model values:

<table>
<thead>
<tr>
<th>R (K/W)</th>
<th>Tau (s)</th>
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<tr>
<td>0.005</td>
<td>0.0003</td>
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</table>

FWD transient thermal impedance as a function of pulse width:

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

At

\[
D = 0.5
\]

\[
R_{\infty} = 0.24 \, \text{K/W}
\]

FWD thermal model values:

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<th>Tau (s)</th>
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<td>0.043</td>
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</table>
Buck operation
half bridge IGBT (T1,T4) and neutral point FWD (D2,D3)

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

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

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

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

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

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

half bridge IGBT (T1,T4) and neutral point FWD (D2,D3)

Figure 25  
Reverse bias safe operating area

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

At:
- \( T_j = 150 \) °C
- \( U_{\text{continua}} = U_{\text{peak}} = U_{cc}/2 \)
- \( V_{CE} = \pm 15 \) V
- \( R_{\text{on}} = 1.0 \) Ω
- Switching mode: 3 level

Figure 26  
Gate voltage vs Gate charge

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

At:
- \( I_C = 400 \) A

Vcc=240V  Vcc=960V
**Boost operation**
neutral point IGBT (T2,T3) and half bridge FWD (D1,D2)

**Figure 1**
Typical output characteristics $V_{GE}=15V$
$I_C = f(V_{CE})$

At $t_p = 350 \ \mu s$
$T_j = 25/125/150 \ ^\circ C$
$V_{CE}$ = 15 V

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

At $t_p = 350 \ \mu s$
$T_j = 150 \ ^\circ C$
$V_{CE}$ from 7 V to 17 V in steps of 1 V

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

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

At $t_p = 350 \ \mu s$
$T_j = 25/125/150 \ ^\circ C$
$V_{CE}$ = 10 V
**Boost operation**
neutral point IGBT (T2,T3) and half bridge FWD (D1,D2)

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

\[ E = f(I_c) \]

With an inductive load at
- \( T_j = 25/125/150 \) °C
- \( V_{ce} = 350 \) V
- \( V_{gg} = \pm 15 \) V
- \( R_{gon} = 1 \) Ω
- \( R_{goff} = 1 \) Ω

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

\[ E = f(R_g) \]

With an inductive load at
- \( T_j = 25/125/150 \) °C
- \( V_{ce} = 350 \) V
- \( V_{gg} = \pm 15 \) V
- \( I_c = 407 \) A

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

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

With an inductive load at
- \( T_j = 25/125/150 \) °C
- \( V_{ce} = 350 \) V
- \( V_{gg} = \pm 15 \) V
- \( R_{gon} = 1 \) Ω

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

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

With an inductive load at
- \( T_j = 25/125/150 \) °C
- \( V_{ce} = 350 \) V
- \( V_{gg} = \pm 15 \) V
- \( I_c = 407 \) A
Boost operation
neutral point IGBT (T2,T3) and half bridge FWD (D1,D2)

Figure 9
Typical switching times as a function of collector current
\[ t = f(I_C) \]

With an inductive load at
\[ T_j = 125 \ degree\ C \]
\[ V_{CE} = 350 \ V \]
\[ V_{GE} = \pm 15 \ V \]
\[ R_{g_{on}} = 1 \ \Omega \]
\[ I_C = 407 \ A \]

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

With an inductive load at
\[ T_j = 125 \ degree\ C \]
\[ V_{CE} = 350 \ V \]
\[ V_{GE} = \pm 15 \ V \]
\[ I_C = 407 \ A \]

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

At
\[ T_j = 25/125/150 \ degree\ C \]
\[ V_{CE} = 350 \ V \]
\[ V_{GE} = \pm 15 \ V \]
\[ R_{g_{on}} = 1 \ \Omega \]

Figure 12
Typical reverse recovery time as a function of IGBT turn on gate resistor
\[ t_{rr} = f(R_{g_{on}}) \]

At
\[ T_j = 25/125/150 \ degree\ C \]
\[ V_{CE} = 350 \ V \]
\[ I_T = 407 \ A \]
\[ V_{GE} = \pm 15 \ V \]
Boost operation
neutral point IGBT (T2, T3) and half bridge FWD (D1, D2)

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

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

At
\[ T_j = 25/125/150 \, ^\circ C \]
\[ V_{CE} = 350 \, V \]
\[ V_{GE} = \pm 15 \, V \]
\[ R_{gon} = 1 \, \Omega \]

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

At
\[ T_j = 25/125/150 \, ^\circ C \]
\[ V_{CE} = 350 \, V \]
\[ I_F = 407 \, A \]
\[ V_{GE} = \pm 15 \, V \]

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

At
\[ T_j = 25/125/150 \, ^\circ C \]
\[ V_{CE} = 350 \, V \]
\[ V_{GE} = \pm 15 \, V \]
\[ R_{gon} = 1 \, \Omega \]

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

At
\[ T_j = 25/125/150 \, ^\circ C \]
\[ V_{CE} = 350 \, V \]
\[ I_F = 407 \, A \]
\[ V_{GE} = \pm 15 \, V \]
Boost operation
neutral point IGBT (T2,T3) and half bridge FWD (D1,D2)

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

\[ \frac{dI}{dt}, \frac{dI_{\text{rec}}}{dt} = f(I_C) \]

At:
- \( T_j = 25/125/150 \) °C
- \( V_{GE} = 350 \) V
- \( V_{ds} = \pm 15 \) V
- \( R_{gon} = 1 \) Ω

Figure 18: Typical rate of fall of forward and reverse recovery current as a function of IGBT turn on gate resistor.

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

At:
- \( T_j = 25/125/150 \) °C
- \( V_{GE} = 350 \) V
- \( I_F = 407 \) A
- \( V_{ds} = \pm 15 \) V

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

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

At:
- \( D = \frac{t_p}{T} \)
- \( R_{thJH} = 0.15 \) K/W

IGBT thermal model values

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<thead>
<tr>
<th>( R ) (K/W)</th>
<th>Tau (s)</th>
</tr>
</thead>
<tbody>
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<td>0.74</td>
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<tr>
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<td>0.18</td>
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<td>0.03</td>
<td>0.04</td>
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<tr>
<td>0.01</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:
- \( D = \frac{t_p}{T} \)
- \( R_{thJH} = 0.20 \) K/W

FWD thermal model values

<table>
<thead>
<tr>
<th>( R ) (K/W)</th>
<th>Tau (s)</th>
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<td>0.03</td>
<td>0.02</td>
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Boost operation
neutral point IGBT (T2,T3) and half bridge FWD (D1,D2)

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

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

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

At
\[ T_j = 175 \, ^\circ C \]
\[ V_{GS} = 15 \, V \]

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

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

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

At
\[ T_j = 175 \, ^\circ C \]
Boost operation
neutral point IGBT (T2,T3) and half bridge FWD (D1,D2)

**Figure 25**
Reverse bias safe operating area

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

**Figure 26**
Gate voltage vs Gate charge

\[ V_G = f(Q_g) \]

At
\[ T_J = 25,150 \] °C
\[ U_{commia}=U_{voltage},U_{C}/2 \]
\[ V_{GE} = \pm 15 \] V
\[ R_{gon} = 1 \] Ω

---

Boost operation
neutral point IGBT (T2,T3) and half bridge FWD (D1,D2)

**Figure 25**
Reverse bias safe operating area

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

**Figure 26**
Gate voltage vs Gate charge

\[ V_G = f(Q_g) \]

At
\[ I_C = 400 \] A
Thermistor

Figure 1

Typical NTC characteristic as a function of temperature

\[ R_T = f(T) \]
**Switching Definitions Half Bridge**

**General conditions**

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

**Figure 1**

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

- $V_{CE} (0\%) = -15 \, \text{V}$
- $V_{CE} (100\%) = 15 \, \text{V}$
- $V_c (100\%) = 700 \, \text{V}$
- $I_c (100\%) = 407 \, \text{A}$
- $t_{doff} = 0,305 \, \mu\text{s}$
- $t_{Eoff} = 0,715 \, \mu\text{s}$

**Figure 2**

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

- $V_{CE} (0\%) = -15 \, \text{V}$
- $V_{CE} (100\%) = 15 \, \text{V}$
- $V_c (100\%) = 700 \, \text{V}$
- $I_c (100\%) = 407 \, \text{A}$
- $t_{don} = 0,210 \, \mu\text{s}$
- $t_{Eon} = 0,488 \, \mu\text{s}$

**Figure 3**

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

- $V_c (100\%) = 700 \, \text{V}$
- $I_c (100\%) = 407 \, \text{A}$
- $t_f = 0,053 \, \mu\text{s}$

**Figure 4**

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

- $V_c (100\%) = 700 \, \text{V}$
- $I_c (100\%) = 407 \, \text{A}$
- $t_r = 0,033 \, \mu\text{s}$

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Switching Definitions Half Bridge

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

- $P_{off} (100\%) = 284,95$ kW
- $E_{off} (100\%) = 15,78$ mJ
- $t_{Eoff} = 0,715$ µs

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

- $P_{on} (100\%) = 284,95$ kW
- $E_{on} (100\%) = 9,85$ mJ
- $t_{Eon} = 0,488$ µs

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

- $V_s (100\%) = 700$ V
- $I_s (100\%) = 407$ A
- $I_{d080} (100\%) = -341$ A
- $t_{rr} = 0,242$ µs
Switching Definitions Half Bridge

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

$I_d (100\%) = 407$ A  
$Q_{rr} (100\%) = 31,93$ $\mu$C  
$t_{Qrr} = 0,51$ $\mu$s

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

$P_{rec} (100\%) = 284,95$ kW  
$E_{rec} (100\%) = 8,01$ mJ  
$t_{Erec} = 0,51$ $\mu$s
Half Bridge switching measurement circuit

Figure 10

![Half Bridge switching measurement circuit diagram]
Switching Definitions Neutral Point

General conditions

\[ T_i = 125 \, ^\circ C \]
\[ R_{gon} = 1 \, \Omega \]
\[ R_{goff} = 1 \, \Omega \]

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

\[
\begin{align*}
V_{CE} (0\%) &= -15 \, V \\
V_{CE} (100\%) &= 15 \, V \\
V_c (100\%) &= 350 \, V \\
l_c (100\%) &= 403 \, A \\
t_{doff} &= 0.23 \, \mu s \\
t_{Eoff} &= 0.58 \, \mu s \\
\end{align*}
\]

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

\[
\begin{align*}
V_{CE} (0\%) &= -15 \, V \\
V_{CE} (100\%) &= 15 \, V \\
V_c (100\%) &= 350 \, V \\
l_c (100\%) &= 403 \, A \\
t_{don} &= 0.199 \, \mu s \\
t_{Eon} &= 0.38 \, \mu s \\
\end{align*}
\]

Figure 3: Neutral Point IGBT
Turn-off Switching Waveforms & definition of \( t_f \)

\[
\begin{align*}
V_c (100\%) &= 350 \, V \\
l_c (100\%) &= 403 \, A \\
t_f &= 0.06 \, \mu s \\
\end{align*}
\]

Figure 4: Neutral Point IGBT
Turn-on Switching Waveforms & definition of \( t_r \)

\[
\begin{align*}
V_c (100\%) &= 350 \, V \\
l_c (100\%) &= 403 \, A \\
t_r &= 0.030 \, \mu s \\
\end{align*}
\]

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Switching Definitions Neutral Point

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

- $P_{Eoff}$ (100%) = 140.97 kW
- $E_{Eoff}$ (100%) = 15.22 mJ
- $t_{Eoff}$ = 0.58 $\mu$s

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

- $P_{Eon}$ (100%) = 140.9653 kW
- $E_{Eon}$ (100%) = 13.39 mJ
- $t_{Eon}$ = 0.38 $\mu$s

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

- $V_d$ (100%) = 350 V
- $I_d$ (100%) = 403 A
- $I_{dRM}$ (100%) = -511 A
- $t_{rr}$ = 0.08 $\mu$s
Switching Definitions Neutral Point

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

- $I_d (100\%) = 403$ A  
- $Q_{rr} (100\%) = 31.37$ $\mu$C  
- $t_{Qint} = 0.33$ $\mu$s

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

- $P_{rec} (100\%) = 140.97$ kW  
- $E_{rec} (100\%) = 8.74$ mJ  
- $t_{Erec} = 0.33$ $\mu$s
Neutral Point switching measurement circuit

Figure 10
Ordering Code and Marking - Outline - Pinout

Outline

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<thead>
<tr>
<th>Driver pins</th>
<th>Low current connections</th>
<th>Power connections</th>
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<td>Group</td>
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Driver pins

Low current connections

Power connections

Ordering Code & Marking

Ordering Code

In DataMatrix as

In packaging barcode as

M709P

M709P

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### Ordering Code and Marking - Outline - Pinout

#### Pinout

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<th>DC+</th>
<th>Neutral</th>
<th>DC-</th>
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#### Identification

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<th>Voltage</th>
<th>Current</th>
<th>Function</th>
<th>Comment</th>
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<td>T1, T4</td>
<td>IGBT</td>
<td>1200V</td>
<td>400A</td>
<td>Half Bridge Switch</td>
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<td>IGBT</td>
<td>600V</td>
<td>400A</td>
<td>Neutral Point Switch</td>
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<td>D1, D4</td>
<td>FWD</td>
<td>1200V</td>
<td>300A</td>
<td>Half Bridge Diode</td>
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