D Series Power MOSFET

**PRODUCT SUMMARY**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Limit</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain-Source Voltage</td>
<td>VDS</td>
<td>450</td>
<td>V</td>
</tr>
<tr>
<td>On-Resistance at 25 °C (Ω)</td>
<td>RDS(on) max.</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Gate-Source Capacitance (nF)</td>
<td>Cgs</td>
<td>3</td>
<td>nF</td>
</tr>
<tr>
<td>Source-Drain Capacitance (nF)</td>
<td>Cgd</td>
<td>4</td>
<td>nF</td>
</tr>
<tr>
<td>Configuration</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FEATURES**

- Optimal Design
  - Low Area Specific On-Resistance
  - Low Input Capacitance (Ciss)
  - Reduced Capacitive Switching Losses
  - High Body Diode Ruggedness
  - Avalanche Energy Rated (UIS)

- Optimal Efficiency and Operation
  - Low Cost
  - Simple Gate Drive Circuitry
  - Low Figure-of-Merit (FOM): Ron x Qg
  - Fast Switching

- Material categorization:
  - For definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)

**APPLICATIONS**

- Consumer Electronics
  - Displays (LCD or Plasma TV)
- Server and Telecom Power Supplies
  - SMPS
- Industrial
  - Welding
  - Induction Heating
  - Motor Drives
- Battery Chargers

**ORDERING INFORMATION**

<table>
<thead>
<tr>
<th>Package</th>
<th>Lead (Pb)-free</th>
<th>Lead (Pb)-free and Halogen-free</th>
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</thead>
<tbody>
<tr>
<td>TO-220AB</td>
<td>SiHP6N40D-E3</td>
<td>SiHP6N40D-GE3</td>
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</tbody>
</table>

**ABSOLUTE MAXIMUM RATINGS**

- **Drain-Source Voltage**
  - VDSV = 400 V
- **Gate-Source Voltage**
  - VGS = ±30 V
- **Continuous Drain Current (TJ = 150 °C)**
  - ID = 6 A
- **Pulsed Drain Current**
  - IDM = 13 A
- **Linear Derating Factor**
  - 0.8 W/°C
- **Single Pulse Avalanche Energy**
  - EA = 104 mJ
- **Maximum Power Dissipation**
  - PD = 104 W
- **Operating Junction and Storage Temperature Range**
  - TJ, Tstg = -55 to +150 °C
- **Drain-Source Voltage Slope**
  - Tj = 125 °C
  - dV/dt = 24 V/ns
- **Reverse Diode dv/dt**
  - 0.48 V/ns
- **Soldering Recommendations (Peak Temperature)**
  - for 10 s
  - 300 °C

**Notes**

- a. Repetitive rating; pulse width limited by maximum junction temperature.
- b. VDD = 50 V, starting TJ = 25 °C, L = 2.3 mH, Rg = 25 Ω, IS = 9.5 A.
- c. 1.6 mm from case.
- d. ISD = Ip, starting TJ = 25 °C.

For technical questions, contact: hvm@vishay.com

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### THERMAL RESISTANCE RATINGS

<table>
<thead>
<tr>
<th>PARAMETER</th>
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<th>TYP.</th>
<th>MAX.</th>
<th>UNIT</th>
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</thead>
<tbody>
<tr>
<td>Maximum Junction-to-Ambient</td>
<td>R_{thJA}</td>
<td>-</td>
<td>62</td>
<td>°C/W</td>
</tr>
<tr>
<td>Maximum Junction-to-Case (Drain)</td>
<td>R_{thJC}</td>
<td>-</td>
<td>1.2</td>
<td></td>
</tr>
</tbody>
</table>

### SPECIFICATIONS (T_J = 25 °C, unless otherwise noted)

#### Static

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>TEST CONDITIONS</th>
<th>MIN.</th>
<th>TYP.</th>
<th>MAX.</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain-Source Breakdown Voltage</td>
<td>V_{DS}</td>
<td>V_GS = 0 V, I_D = 250 μA</td>
<td>400</td>
<td>-</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td>VDS Temperature Coefficient</td>
<td>ΔV_{DS}/T_J</td>
<td>Reference to 25 °C, I_D = 250 μA</td>
<td>-</td>
<td>0.53</td>
<td>-</td>
<td>V/°C</td>
</tr>
<tr>
<td>Gate-Source Threshold Voltage (N)</td>
<td>V_{GS(th)}</td>
<td>V_{DS} = V_{GS}, I_D = 250 μA</td>
<td>3</td>
<td>-</td>
<td>5</td>
<td>V</td>
</tr>
<tr>
<td>Gate-Source Leakage</td>
<td>I_{DSS}</td>
<td>V_{DS} = ± 30 V</td>
<td>-</td>
<td>-</td>
<td>± 100</td>
<td>nA</td>
</tr>
<tr>
<td>Zero Gate Voltage Drain Current</td>
<td>I_{DSS}</td>
<td>V_{DS} = 400 V, V_{GS} = 0 V</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>μA</td>
</tr>
<tr>
<td>Drain-Source On-State Resistance</td>
<td>R_{D(on)}</td>
<td>V_{GS} = 10 V, I_D = 3 A</td>
<td>-</td>
<td>0.85</td>
<td>1</td>
<td>Ω</td>
</tr>
<tr>
<td>Forward Transconductance</td>
<td>g_{fs}</td>
<td>V_{DS} = 50 V, I_D = 3 A</td>
<td>-</td>
<td>1.7</td>
<td>-</td>
<td>S</td>
</tr>
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#### Dynamic

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>TEST CONDITIONS</th>
<th>MIN.</th>
<th>TYP.</th>
<th>MAX.</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Capacitance</td>
<td>C_{iss}</td>
<td>V_GS = 0 V,</td>
<td>-</td>
<td>311</td>
<td>-</td>
<td>pF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V_{DS} = 100 V, f = 1 MHz</td>
<td>-</td>
<td>38</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Reverse Transfer Capacitance</td>
<td>C_{rss}</td>
<td>V_{GS} = 0 V,</td>
<td>-</td>
<td>7</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>V_{DS} = 0 V to 320 V</td>
<td>-</td>
<td>44</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Effective output capacitance, energy related</td>
<td>C_{o(er)}</td>
<td>V_{GS} = 0 V,</td>
<td>-</td>
<td>54</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>V_{DS} = 0 V to 320 V</td>
<td>-</td>
<td>44</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Total Gate Charge</td>
<td>Q_{g}</td>
<td>V_{GS} = 10 V, I_D = 3 A, V_{DS} = 320 V</td>
<td>-</td>
<td>9</td>
<td>18</td>
<td>nC</td>
</tr>
<tr>
<td>Gate-Source Charge</td>
<td>Q_{gs}</td>
<td></td>
<td>-</td>
<td>3</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Gate-Drain Charge</td>
<td>Q_{gd}</td>
<td></td>
<td>-</td>
<td>4</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Turn-On Delay Time</td>
<td>t_{d(on)}</td>
<td>V_{DD} = 400 V, I_D = 3 A, V_{GS} = 10 V, R_G = 9.1 Ω</td>
<td>-</td>
<td>12</td>
<td>24</td>
<td>ns</td>
</tr>
<tr>
<td>Rise Time</td>
<td>t_{r}</td>
<td></td>
<td>-</td>
<td>11</td>
<td>22</td>
<td>ns</td>
</tr>
<tr>
<td>Turn-Off Delay Time</td>
<td>t_{d(off)}</td>
<td>V_{GS} = 0 V,</td>
<td>-</td>
<td>14</td>
<td>28</td>
<td>ns</td>
</tr>
<tr>
<td>Fall Time</td>
<td>t_{f}</td>
<td></td>
<td>-</td>
<td>8</td>
<td>16</td>
<td>ns</td>
</tr>
<tr>
<td>Gate Input Resistance</td>
<td>R_{g}</td>
<td>f = 1 MHz, open drain</td>
<td>-</td>
<td>1.9</td>
<td>-</td>
<td>Ω</td>
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</tbody>
</table>

### Drain-Source Body Diode Characteristics

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>TEST CONDITIONS</th>
<th>MIN.</th>
<th>TYP.</th>
<th>MAX.</th>
<th>UNIT</th>
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</thead>
<tbody>
<tr>
<td>Continuous Source-Drain Diode Current</td>
<td>I_{S}</td>
<td>MOSFET symbol showing the integral reverse p-n junction diode</td>
<td>-</td>
<td>-</td>
<td>6</td>
<td>A</td>
</tr>
<tr>
<td>Pulsed Diode Forward Current</td>
<td>I_{SM}</td>
<td></td>
<td>-</td>
<td>-</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Diode Forward Voltage</td>
<td>V_{BD}</td>
<td>T_J = 25 °C, I_S = 3 A, V_{GS} = 0 V</td>
<td>-</td>
<td>-</td>
<td>1.2</td>
<td>V</td>
</tr>
<tr>
<td>Reverse Recovery Time</td>
<td>t_{rr}</td>
<td>T_J = 25 °C, I_F = I_S = 3 A, dl/dt = 100 A/μs, V_R = 20 V</td>
<td>-</td>
<td>236</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Reverse Recovery Charge</td>
<td>Q_{rr}</td>
<td></td>
<td>-</td>
<td>1.1</td>
<td>-</td>
<td>μC</td>
</tr>
<tr>
<td>Reverse Recovery Current</td>
<td>I_{RRM}</td>
<td></td>
<td>-</td>
<td>9</td>
<td>-</td>
<td>A</td>
</tr>
</tbody>
</table>

**Notes**

a. C_{iss} is a fixed capacitance that gives the same energy as C_{oss} while V_{DS} is rising from 0 % to 80 % V_{DS}.
b. C_{o(er)} is a fixed capacitance that gives the same charging time as C_{oss} while V_{DS} is rising from 0 % to 80 % V_{DS}.
**TYPICAL CHARACTERISTICS** (25 °C, unless otherwise noted)

**Fig. 1 - Typical Output Characteristics**

**Fig. 2 - Typical Output Characteristics**

**Fig. 3 - Typical Transfer Characteristics**

**Fig. 4 - Normalized On-Resistance vs. Temperature**

**Fig. 5 - Typical Capacitance vs. Drain-to-Source Voltage**

**Fig. 6 - Typical Gate Charge vs. Gate-to-Source Voltage**
Fig. 7 - Typical Source-Drain Diode Forward Voltage

![Graph showing typical source-drain diode forward voltage.](image)

- $I_{SD}$, Reverse Drain Current (A)
- $V_{SD}$, Source-Drain Voltage (V)
- $T_J = 150 \, ^\circ C$
- $T_J = 25 \, ^\circ C$
- $V_{GS} = 0 \, V$

Fig. 8 - Maximum Safe Operating Area

![Graph showing maximum safe operating area.](image)

- $I_D$, Drain Current (A)
- $V_{DS}$, Drain-to-Source Voltage (V)
- $T_J = 150 \, ^\circ C$ for limited operation
- $T_J = 25 \, ^\circ C$ for limited operation
- $V_{GS}$ limited by $R_{DS(on)}$
- Operation in this area limited by $R_{DS(on)}$
- Single Pulse
- Single Pulse limited by $R_{DS(on)}$

* $V_{GS} > \text{minimum } V_{GS} \text{ at which } R_{DS(on)} \text{ is specified}

Fig. 9 - Maximum Drain Current vs. Case Temperature

![Graph showing maximum drain current vs. case temperature.](image)

- $I_D$, Drain Current (A)
- $T_J$, Case Temperature (°C)
- $V_{GS} = 0 \, V$

Fig. 10 - Temperature vs. Drain-to-Source Voltage

![Graph showing temperature vs. drain-to-source voltage.](image)

- $V_{DS}$, Drain-to-Source Voltage (V)
- $T_J$, Junction Temperature (°C)
- $T_J = 150 \, ^\circ C$
- $T_J = 25 \, ^\circ C$
- $V_{DS}$ limited by $R_{DS(on)}$
- Single Pulse

Fig. 11 - Normalized Thermal Transient Impedance, Junction-to-Case

![Graph showing normalized thermal transient impedance.](image)

- Normalized Effective Transient Thermal Impedance
- Pulse Time (s)

For technical questions, contact: hvmsales@vishay.com

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Fig. 12 - Switching Time Test Circuit

Fig. 13 - Switching Time Waveforms

Fig. 14 - Unclamped Inductive Test Circuit

Fig. 15 - Unclamped Inductive Waveforms

Fig. 16 - Basic Gate Charge Waveform

Fig. 17 - Gate Charge Test Circuit
Peak Diode Recovery dV/dt Test Circuit

Circuit layout considerations:
- Low stray inductance
- Ground plane
- Low leakage inductance current transformer

Note:
- dV/dt controlled by $R_g$
- Driver same type as D.U.T.
- $I_{SD}$ controlled by duty factor “D”
- D.U.T. - device under test

Driver gate drive

$D = \frac{P.W.}{Period}$

Reverse recovery current

$\frac{dI}{dt}$ controlled by $R_g$

Body diode forward current

$\frac{dV}{dt}$ controlled by duty factor “D”

D.U.T. waveform

Re-applied voltage

Inductor current

Note:
- $V_{GS} = 5$ V for logic level devices

Fig. 18 - For N-Channel
TO-220-1

Note

- \( M' = 0.052 \text{ inches to 0.064 inches} \) (dimension including protrusion), heatsink hole for HVM

<table>
<thead>
<tr>
<th>DIM.</th>
<th>MILLIMETERS</th>
<th>INCHES</th>
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<tbody>
<tr>
<td>A</td>
<td>4.24</td>
<td>1.67</td>
</tr>
<tr>
<td>b</td>
<td>0.69</td>
<td>0.027</td>
</tr>
<tr>
<td>c</td>
<td>0.36</td>
<td>0.014</td>
</tr>
<tr>
<td>D</td>
<td>14.33</td>
<td>0.564</td>
</tr>
<tr>
<td>E</td>
<td>9.96</td>
<td>0.392</td>
</tr>
<tr>
<td>e</td>
<td>2.41</td>
<td>0.095</td>
</tr>
<tr>
<td>e(1)</td>
<td>4.88</td>
<td>0.192</td>
</tr>
<tr>
<td>F</td>
<td>1.14</td>
<td>0.045</td>
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<tr>
<td>H(1)</td>
<td>6.10</td>
<td>0.240</td>
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<tr>
<td>J(1)</td>
<td>2.41</td>
<td>0.095</td>
</tr>
<tr>
<td>L</td>
<td>13.36</td>
<td>0.526</td>
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<tr>
<td>L(1)</td>
<td>3.33</td>
<td>0.131</td>
</tr>
<tr>
<td>Ø P</td>
<td>3.53</td>
<td>0.139</td>
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<tr>
<td>Q</td>
<td>2.54</td>
<td>0.100</td>
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</table>

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DWG: 6031

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