IRFR3707Z
IRFU3707Z
HEXFET® Power MOSFET

Applications
- High Frequency Synchronous Buck Converters for Computer Processor Power
- High Frequency Isolated DC-DC Converters with Synchronous Rectification for Telecom and Industrial Use

Benefits
- Very Low $R_{DS(on)}$ at 4.5V $V_{GS}$
- Ultra-Low Gate Impedance
- Fully Characterized Avalanche Voltage and Current

<table>
<thead>
<tr>
<th>$V_{DSS}$</th>
<th>$R_{DS(on)}$ max</th>
<th>$Q_g$</th>
</tr>
</thead>
<tbody>
<tr>
<td>30V</td>
<td>9.5mΩ</td>
<td>9.6nC</td>
</tr>
</tbody>
</table>

Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{DS}$</td>
<td>Drain-to-Source Voltage</td>
<td>30</td>
</tr>
<tr>
<td>$V_{GS}$</td>
<td>Gate-to-Source Voltage</td>
<td>± 20</td>
</tr>
<tr>
<td>$I_D @ T_C = 25^\circ C$</td>
<td>Continuous Drain Current, $V_{GS} @ 10V$</td>
<td>56®</td>
</tr>
<tr>
<td>$I_D @ T_C = 100^\circ C$</td>
<td>Continuous Drain Current, $V_{GS} @ 10V$</td>
<td>39®</td>
</tr>
<tr>
<td>$I_{DM}$</td>
<td>Pulsed Drain Current ⊗</td>
<td>220</td>
</tr>
<tr>
<td>$P_D @ T_C = 25^\circ C$</td>
<td>Maximum Power Dissipation</td>
<td>50</td>
</tr>
<tr>
<td>$P_D @ T_C = 100^\circ C$</td>
<td>Maximum Power Dissipation</td>
<td>25</td>
</tr>
<tr>
<td>$T_J$</td>
<td>Operating Junction and Storage Temperature Range</td>
<td>-55 to + 175</td>
</tr>
<tr>
<td>$T_{STG}$</td>
<td>Soldering Temperature, for 10 seconds</td>
<td>300 (1.6mm from case)</td>
</tr>
</tbody>
</table>

Thermal Resistance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{jC}$</td>
<td>Junction-to-Case</td>
<td>3.0</td>
<td>°C/W</td>
</tr>
<tr>
<td>$R_{jA}$</td>
<td>Junction-to-Ambient (PCB Mount) ⊗</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>$R_{jA}$</td>
<td>Junction-to-Ambient</td>
<td>110</td>
<td></td>
</tr>
</tbody>
</table>

Notes ⊗ through ⊗ are on page 11

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### IRFR/U3707Z

**Static @ T<sub>J</sub> = 25°C (unless otherwise specified)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>BV&lt;sub&gt;DSS&lt;/sub&gt;</td>
<td>30</td>
<td>——</td>
<td>——</td>
<td>V</td>
<td>V&lt;sub&gt;GS&lt;/sub&gt; = 0V, I&lt;sub&gt;D&lt;/sub&gt; = 250µA</td>
</tr>
<tr>
<td>ΔBV&lt;sub&gt;DSS&lt;/sub&gt;/ΔT&lt;sub&gt;J&lt;/sub&gt;</td>
<td>——</td>
<td>0.023</td>
<td>——</td>
<td>V/°C</td>
<td>Reference to 25°C, I&lt;sub&gt;D&lt;/sub&gt; = 1mA</td>
</tr>
<tr>
<td>R&lt;sub&gt;DS(on)&lt;/sub&gt;</td>
<td>7.5</td>
<td>9.5</td>
<td>——</td>
<td>mΩ</td>
<td>V&lt;sub&gt;GS&lt;/sub&gt; = 10V, I&lt;sub&gt;D&lt;/sub&gt; = 15A ⊕</td>
</tr>
<tr>
<td>V&lt;sub&gt;GS(th)&lt;/sub&gt;</td>
<td>1.35</td>
<td>1.80</td>
<td>2.25</td>
<td>V</td>
<td>V&lt;sub&gt;DS&lt;/sub&gt; = V&lt;sub&gt;GS&lt;/sub&gt;, I&lt;sub&gt;D&lt;/sub&gt; = 250µA</td>
</tr>
<tr>
<td>ΔV&lt;sub&gt;GS(th)&lt;/sub&gt;/ΔT&lt;sub&gt;J&lt;/sub&gt;</td>
<td>——</td>
<td>——</td>
<td>0.023</td>
<td>V/°C</td>
<td></td>
</tr>
<tr>
<td>I&lt;sub&gt;DS&lt;/sub&gt;</td>
<td>——</td>
<td>——</td>
<td>1.0</td>
<td>µA</td>
<td>V&lt;sub&gt;DS&lt;/sub&gt; = 24V, V&lt;sub&gt;GS&lt;/sub&gt; = 0V</td>
</tr>
<tr>
<td>I&lt;sub&gt;SS&lt;/sub&gt;</td>
<td>——</td>
<td>——</td>
<td>150</td>
<td>nA</td>
<td>V&lt;sub&gt;DS&lt;/sub&gt; = 24V, V&lt;sub&gt;GS&lt;/sub&gt; = 0V, T&lt;sub&gt;J&lt;/sub&gt; = 125°C</td>
</tr>
<tr>
<td>R&lt;sub&gt;DS&lt;/sub&gt;</td>
<td>71</td>
<td>——</td>
<td>——</td>
<td>S</td>
<td>V&lt;sub&gt;DS&lt;/sub&gt; = 15V, I&lt;sub&gt;D&lt;/sub&gt; = 12A</td>
</tr>
<tr>
<td>Q&lt;sub&gt;gs&lt;/sub&gt;</td>
<td>——</td>
<td>9.6</td>
<td>14</td>
<td>nC</td>
<td>V&lt;sub&gt;DS&lt;/sub&gt; = 15V, V&lt;sub&gt;GS&lt;/sub&gt; = 0V</td>
</tr>
<tr>
<td>Q&lt;sub&gt;gs1&lt;/sub&gt;</td>
<td>——</td>
<td>2.6</td>
<td>——</td>
<td>nC</td>
<td>V&lt;sub&gt;DS&lt;/sub&gt; = 15V</td>
</tr>
<tr>
<td>Q&lt;sub&gt;gs2&lt;/sub&gt;</td>
<td>——</td>
<td>0.90</td>
<td>——</td>
<td>nC</td>
<td>V&lt;sub&gt;DS&lt;/sub&gt; = 15V, V&lt;sub&gt;GS&lt;/sub&gt; = 4.5V</td>
</tr>
<tr>
<td>Q&lt;sub&gt;gd&lt;/sub&gt;</td>
<td>——</td>
<td>3.5</td>
<td>——</td>
<td>nC</td>
<td>I&lt;sub&gt;D&lt;/sub&gt; = 12A</td>
</tr>
<tr>
<td>Q&lt;sub&gt;gdr&lt;/sub&gt;</td>
<td>——</td>
<td>2.6</td>
<td>——</td>
<td>nC</td>
<td>See Fig. 16</td>
</tr>
<tr>
<td>Q&lt;sub&gt;sw&lt;/sub&gt;</td>
<td>——</td>
<td>4.4</td>
<td>——</td>
<td>nC</td>
<td>V&lt;sub&gt;DS&lt;/sub&gt; = 15V</td>
</tr>
<tr>
<td>Q&lt;sub&gt;oss&lt;/sub&gt;</td>
<td>——</td>
<td>5.8</td>
<td>——</td>
<td>nC</td>
<td>V&lt;sub&gt;DS&lt;/sub&gt; = 15V, V&lt;sub&gt;GS&lt;/sub&gt; = 0V</td>
</tr>
<tr>
<td>t&lt;sub&gt;on&lt;/sub&gt;</td>
<td>——</td>
<td>8.0</td>
<td>——</td>
<td>ns</td>
<td>V&lt;sub&gt;DS&lt;/sub&gt; = 16V, V&lt;sub&gt;GS&lt;/sub&gt; = 4.5V ⊕</td>
</tr>
<tr>
<td>t&lt;sub&gt;r&lt;/sub&gt;</td>
<td>——</td>
<td>11</td>
<td>——</td>
<td>ns</td>
<td>I&lt;sub&gt;D&lt;/sub&gt; = 12A</td>
</tr>
<tr>
<td>t&lt;sub&gt;off&lt;/sub&gt;</td>
<td>——</td>
<td>12</td>
<td>——</td>
<td>ns</td>
<td>Clamped Inductive Load</td>
</tr>
<tr>
<td>t&lt;sub&gt;f&lt;/sub&gt;</td>
<td>——</td>
<td>3.3</td>
<td>——</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>C&lt;sub&gt;iss&lt;/sub&gt;</td>
<td>——</td>
<td>1150</td>
<td>——</td>
<td>pF</td>
<td>V&lt;sub&gt;DS&lt;/sub&gt; = 0V</td>
</tr>
<tr>
<td>C&lt;sub&gt;oss&lt;/sub&gt;</td>
<td>——</td>
<td>260</td>
<td>——</td>
<td>pF</td>
<td>V&lt;sub&gt;DS&lt;/sub&gt; = 15V</td>
</tr>
<tr>
<td>C&lt;sub&gt;rss&lt;/sub&gt;</td>
<td>——</td>
<td>120</td>
<td>——</td>
<td>pF</td>
<td>f = 1.0MHz</td>
</tr>
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</table>

**Avalanche Characteristics**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>E&lt;sub&gt;AS&lt;/sub&gt;</td>
<td>——</td>
<td>42</td>
<td>mJ</td>
<td></td>
</tr>
<tr>
<td>I&lt;sub&gt;AR&lt;/sub&gt;</td>
<td>——</td>
<td>12</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>E&lt;sub&gt;AR&lt;/sub&gt;</td>
<td>——</td>
<td>5.0</td>
<td>mJ</td>
<td></td>
</tr>
</tbody>
</table>

**Diode Characteristics**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>I&lt;sub&gt;S&lt;/sub&gt;</td>
<td>——</td>
<td>56</td>
<td>——</td>
<td>A</td>
<td>MOSFET symbol showing the p-n junction diode.</td>
</tr>
<tr>
<td>I&lt;sub&gt;SM&lt;/sub&gt;</td>
<td>——</td>
<td>220</td>
<td>——</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>V&lt;sub&gt;SD&lt;/sub&gt;</td>
<td>——</td>
<td>1.0</td>
<td>——</td>
<td>V</td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = 25°C, I&lt;sub&gt;S&lt;/sub&gt; = 12A, V&lt;sub&gt;GS&lt;/sub&gt; = 0V ⊕</td>
</tr>
<tr>
<td>t&lt;sub&gt;r&lt;/sub&gt;</td>
<td>——</td>
<td>25</td>
<td>38</td>
<td>ns</td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = 25°C, I&lt;sub&gt;r&lt;/sub&gt; = 12A, V&lt;sub&gt;D&lt;/sub&gt; = 15V</td>
</tr>
<tr>
<td>Q&lt;sub&gt;r&lt;/sub&gt;</td>
<td>——</td>
<td>17</td>
<td>26</td>
<td>nC</td>
<td>di/dt = 100A/µs ⊕</td>
</tr>
<tr>
<td>t&lt;sub&gt;on&lt;/sub&gt;</td>
<td>Intrinsic turn-on time is negligible (turn-on is dominated by LS+LD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fig 1. Typical Output Characteristics

Fig 2. Typical Output Characteristics

Fig 3. Typical Transfer Characteristics

Fig 4. Normalized On-Resistance vs. Temperature

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**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

**Fig 8.** Maximum Safe Operating Area
Fig 9. Maximum Drain Current vs. Case Temperature

Fig 10. Threshold Voltage vs. Temperature

Fig 11. Maximum Effective Transient Thermal Impedance, Junction-to-Case

Notes:
1. Duty Factor D = t1/t2
2. Peak Tj = P dm x Zthjc + Tc
Fig 12a. Unclamped Inductive Test Circuit

Fig 12b. Unclamped Inductive Waveforms

Fig 13. Gate Charge Test Circuit

Fig 12c. Maximum Avalanche Energy vs. Drain Current

Fig 14a. Switching Time Test Circuit

Fig 14b. Switching Time Waveforms
Fig 15. Peak Diode Recovery dv/dt Test Circuit for N-Channel HEXFET® Power MOSFETs

Fig 16. Gate Charge Waveform
**Power MOSFET Selection for Non-Isolated DC/DC Converters**

**Control FET**

Special attention has been given to the power losses in the switching elements of the circuit - Q1 and Q2. Power losses in the high side switch Q1, also called the Control FET, are impacted by the $R_{ds(on)}$ of the MOSFET, but these conduction losses are only about one half of the total losses.

Power losses in the control switch Q1 are given by:

$$P_{loss} = P_{conduction} + P_{switching} + P_{drive} + P_{output}$$

This can be expanded and approximated by;

$$P_{loss} = \left( I_{rms} \times R_{ds(on)} \right)$$

$$+ \left( I \times \frac{Q_{gs}}{i_g} \times V_{in} \times f \right)$$

$$+ \left( \frac{Q_{gs}}{2} \times V_{in} \times f \right)$$

$$+ \left( \frac{Q_{max}}{2} \times V_{in} \times f \right)$$

This simplified loss equation includes the terms $Q_{gs}$ and $Q_{max}$ which are new to Power MOSFET data sheets. $Q_{gs}$ is a sub element of traditional gate-source charge that is included in all MOSFET data sheets. The importance of splitting this gate-source charge into two sub elements, $Q_{gs1}$ and $Q_{gs2}$, can be seen from Fig 16.

$Q_{gs1}$ indicates the charge that must be supplied by the gate driver between the time that the threshold voltage has been reached and the time the drain current rises to $I_{drain}$, at which time the drain voltage begins to change. Minimizing $Q_{gs1}$ is a critical factor in reducing switching losses in Q1.

$Q_{gs2}$ is the charge that must be supplied to the output capacitance of the MOSFET during every switching cycle. Figure A shows how $Q_{gs}$ is formed by the parallel combination of the voltage dependant (non-linear) capacitance’s $C_{gs}$ and $C_{oss}$ when multiplied by the power supply input buss voltage.

**Synchronous FET**

The power loss equation for Q2 is approximated by;

$$P_{loss} = P_{conduction} + P_{drive} + P_{output}$$

$$P_{loss} = \left( I_{rms} \times R_{ds(on)} \right)$$

$$+ \left( Q_{gs} \times V_{in} \times f \right)$$

$$+ \left( \frac{Q_{max}}{2} \times V_{in} \times f \right)$$

$$+ \left( Q_{rr} \times V_{in} \times f \right)$$

$dissipated primarily in Q1$.

For the synchronous MOSFET Q2, $R_{ds(on)}$ is an important characteristic; however, once again the importance of gate charge must not be overlooked since it impacts three critical areas. Under light load the MOSFET must still be turned on and off by the control IC so the gate drive losses become much more significant. Secondly, the output charge $Q_{oss}$ and reverse recovery charge $Q_r$ both generate losses that are transferred to Q1 and increase the dissipation in that device. Thirdly, gate charge will impact the MOSFETs’ susceptibility to Cdv/dt turn on.

The drain of Q2 is connected to the switching node of the converter and therefore sees transitions between ground and $V_{in}$. As Q1 turns on and off there is a rate of change of drain voltage dV/dt which is capacitively coupled to the gate of Q2 and can induce a voltage spike on the gate that is sufficient to turn the MOSFET on, resulting in shoot-through current. The ratio of $Q_{gs}/Q_{gs1}$ must be minimized to reduce the potential for Cdv/dt turn on.

![Figure A: Q_{gs} Characteristic](www.irf.com)
D-Pak (TO-252AA) Package Outline

Dimensions are shown in millimeters (inches)

![Package Diagram]

**LEAD ASSIGNMENTS**
1 - GATE
2 - DRAIN
3 - SOURCE
4 - DRAIN

**NOTES:**
1 DIMENSIONING & TOLERANCING PER ANSI Y14.5M, 1982.
2 CONTROLLING DIMENSION : INCH.
3 CONFORMS TO JEDEC OUTLINE TO-252AA.
4 DIMENSIONS SHOWN ARE BEFORE SOLDER DIP, SOLDER DIP MAX. +0.16 (.006).

**D-Pak (TO-252AA) Part Marking Information**

**Notes:** This part marking information applies to devices produced before 02/26/2001

**EXAMPLE:** THIS IS AN IRFR120 WITH ASSEMBLY LOT CODE 9U1P

![Part Marking Diagram 1]

**NOTES:** This part marking information applies to devices produced after 02/26/2001

**EXAMPLE:** THIS IS AN IRFR120 WITH ASSEMBLY LOT CODE 1234 ASSEMBLED ON WW 16, 1999 IN THE ASSEMBLY LINE "A"

![Part Marking Diagram 2]
**IRFR/U3707Z**

**I-Pak (TO-251AA) Package Outline**

Dimensions are shown in millimeters (inches)

---

**I-Pak (TO-251AA) Part Marking Information**

**Notes:** This part marking information applies to devices produced before 02/26/2001

**EXAMPLE:**

THIS IS AN IRFR120
WITH ASSEMBLY LOT CODE 9U1P

---

**INTERNATIONAL RECTIFIER LOGO**

**ASSEMBLY LOT CODE**

**DATE CODE**

YEAR = 0
WEEK = 16

---

**Notes:** This part marking information applies to devices produced after 02/26/2001

**EXAMPLE:**

THIS IS AN IRFR120
WITH ASSEMBLY LOT CODE 5678
ASSEMBLED ON WW 19, 1999
IN THE ASSEMBLY LINE "A"

---

**INTERNATIONAL RECTIFIER LOGO**

**ASSEMBLY LOT CODE**

**PART NUMBER**

**DATE CODE**

YEAR 9 = 1999
WEEK 19
LINE A

---

**www.irf.com**
**D-Pak (TO-252AA) Tape & Reel Information**

Dimensions are shown in millimeters (inches)

Notes:

1. Repetitive rating; pulse width limited by max. junction temperature.
2. Starting $T_J = 25^\circ C$, $L = 0.58mH$, $R_G = 25\ \Omega$, $I_{AS} = 12A$.
3. Pulse width $\leq 400\mu s$; duty cycle $\leq 2\%$.
4. Calculated continuous current based on maximum allowable junction temperature. Package limitation current is 30A.
5. When mounted on 1" square PCB (FR-4 or G-10 Material).
   For recommended footprint and soldering techniques refer to application note #AN-994.

Data and specifications subject to change without notice.
This product has been designed and qualified for the Industrial market.
Qualification Standards can be found on IR’s Web site.

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Note: For the most current drawings please refer to the IR website at:
http://www.irf.com/package/