AN-4178
New High-Voltage SMD Package, Power88 for High-Efficiency, and Low-Profile Power Systems

Summary
One of effort to overcome the planar MOSFET’s limit is super-junction technology in high voltage power MOSFET. This technology can dramatically reduce both on-resistance and gate charge, which is usually a trade-off. With smaller parasitic capacitances, the super-junction MOSFETs have extremely fast switching characteristics and therefore reduced switching losses. Naturally fast switching behavior of a super-junction MOSFET leads to device stress, including voltage and current spikes, and greater dv/dt and di/dt, by self-inflicted voltage transients during switching transition time due to combination with the stray parasites in devices and printed circuit board. Power Quad Flat No-lead package, which is widely used in low voltage applications, is a surface mount package to achieve power density and small form factor requirements of many applications. The Power88 package is a new leadless SMD package for high voltage super-junction MOSFET. This package provides excellent switching performance thanks to lower parasitic source inductance and Kelvin source configuration.

Power88 Package
To drive fast switching by using the super-junction MOSFETs in different applications, it is also necessary to understand the influence of parasitic components in MOSFET packages. This issue is well known and documented from the low voltage MOSFET area. Low R_Dson and low parasitic component are important factors to achieve reduced conduction losses and best switching performance for highest efficiency in low voltage packages. The super-junction MOSFETs are mainly used in the voltage range of 600-800 V. In these voltage ratings, the clearance and creepage distance requirements have to be considered. A Power Quad Flat No-lead package, which is widely used in low voltage applications, is a surface mount package to achieve power density and small form factor requirements of many applications. Power88 package is a new leadless package for high voltage super-junction MOSFET. As shown in Figure 1, this new package has a very low profile, with 1 mm ultra-slim thickness, 8 mm width, 8 mm length, and smaller foot print of 64 mm² compared to the D2PAK, which is the industry standard SMD package for high voltage MOSFET. This package separates power and driver source to minimize the commutation loop. As shown in Table 1, this package provides very lower parasitic inductance to achieve excellent switching performance. The approximately common source inductance value of the Power88 package is 3 nH, the D2PAK is 7 nH.

Figure 1. Comparisons of Package Dimension and Footprint area between D2PAK and Power88
The Power88 package can reduce both source and gate inductances compared to D2PAK. As shown in Figure 1, standard gate drive circuitry includes common source inductance, but power88 package separates the power and driver source to minimize common source inductance influence during switching transient.

**Table 1. Comparisons of Approximate Parasitic Inductances for Each Package**

<table>
<thead>
<tr>
<th>DUTs</th>
<th>Ls [nH]</th>
<th>LD [nH]</th>
<th>LG [nH]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power88 Package</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>D2PAK Package</td>
<td>7</td>
<td>1</td>
<td>7</td>
</tr>
</tbody>
</table>

**Figure 1. Gate Drive Schematic Comparison between D2PAK and Power88**

**Gate Oscillation Mechanism of Power MOSFET at Turn-off Transient**

To explain the oscillation mechanism, transient switching behavior is simulated using analytical PSPICE simulation, focusing on the impact of parasitic inductances, L_G and L_S, in a power MOSFET, and printed circuit board layout during turn-off transient. Figure 2 shows the PSPICE simulation waveforms of the gate-to-source voltage, V_GS; the internal gate-to-source voltage, V_GS,int; the drain-to-source voltage, V_DS; the current channel of MOSFET, I_channel; and the drain current, I_D, in clamped inductive load switching circuit. To explain the gate oscillation of the power MOSFET with the effect of parasitic inductances, the turn-off transient is divided into two intervals (t1–t2). Figure 4 shows the MOSFET equivalent circuit including parasitic inductances.

**During Time Interval t1**

The voltage V_GS decreases exponentially due to discharging of input capacitance, which the gate-to-source capacitance, C_GS, and the gate-to-drain capacitance, C_GD, via the gate resistance, R_g, as shown in Figure 4(a). When the gate voltage reaches the gate plateau voltage, the channel current in the MOSFET is reduced due to output characteristics in MOSFET, which is a characteristic curve between the gate voltage and drain current. At the same time, the output capacitance is charged up slowly.

**During Time Interval t2**

The Coss of the SJ MOSFET decreases very rapidly around 30–50 V drain-source voltage in the SJ MOSFET, shown in Figure 3.

**Figure 2. Simulation Waveforms at Turn-Off Transient**

**Figure 3. Non Linear Coss of SJ MOSFET**

These effects give an extremely fast dv/dt and di/dt, as shown in Figure 2. At the same time, the voltage drop across the common-source inductance L_S is caused by negative drain current slope (-di_D/dt). This voltage drop leads to negative gate voltage. Due to this effect, the discharged current flows in the opposite direction, as shown in Figure 4(b).
MOSFET

The measurements are at $V_{DD}=380\,\text{V}$, $I_D=8\,\text{A}$, $R_{on}=2\,\Omega$, $R_{off}=1\,\Omega$. Figure 5 (a) shows the waveforms comparisons of 600 V/199 mΩ SuperFET II MOSFET in both Power88 (white) and TO-220 (color). Figure 5(b) shows the waveforms comparisons of Power88 (white) and D2PAK (color). Also shown in Figure 5, Turn-on loss of SuperFET II MOSFET in Power88 is 53.7% and 67.3% (9.1 uJ) less than one of D2PAK (19.7 uJ) and TO-220 (27.9 uJ). The cross-over area of the drain-source voltage and drain current with SuperFET II MOSFET in Power88 is less than one of D2PAK and TO-220 at turn-on and turn-off transient. Furthermore, the gate oscillation (yellow) is highly reduced thanks to lower parasitic inductance and Kevin contact configuration of Power88 package.

Figure 5. Comparisons of Switching Performance 600 V/199 mΩ SuperFET II MOSFET in Power88, D2PAK and TO-220 under $V_{DD}=380\,\text{V}$, $V_{GS}=10\,\text{V}$, $R_{on}=2.0\,\Omega$, $R_{off}=1.0\,\Omega$, $V_{GS}=10\,\text{V}$. As shown in the switching loss analysis, total switching losses of 600 V 199 mΩ SuperFET II MOSFET in Power88 is greatly reduced compared to one of D2PAK and TO-220 package because voltage drop is minimized by common source inductance while minimizing voltage and current ringing.

Figure 6 shows the summary of switching losses under $V_{DD}=380\,\text{V}$, $I_D=8\,\text{A}$. $R_{on}=2.0\,\Omega$, $R_{off}=1.0\,\Omega$, $V_{GS}=10\,\text{V}$. As shown in the switching loss analysis, total switching losses of 600 V 199 mΩ SuperFET II MOSFET in Power88 is greatly reduced compared to one of D2PAK and TO-220 package because voltage drop is minimized by common source inductance while minimizing voltage and current ringing.
Application Evaluation Results

A 350 W, 67 kHz, CCM boost PFC is designed to compare the efficiency of 600 V/199 mΩ in Power88 and 600 V/199 mΩ in D2PAK as shown in Figure 7. 600 V / 6 A SiC Schottky diode was used as a boost diode. Measurements are made at entire load (60 W–350 W) and 230 VAC input voltage. As shown in Figure 8, efficiency of the Power88 package is improved about 0.05% compared to the D2PAK package. Shown in the switching loss analysis in Figure 6, the major reason for higher efficiency is the reduced switch-on loss because of Kelvin contact configuration of Power88 package. Efficiency improvement is more effective at higher current operation.

Key Features and Benefits

Fairchild Power88 is an ultra-slim surface-mount package (1 mm high) with a low profile, and small footprint (8x8 mm2). Power88 package offers excellent switching performance due to lower parasitic source inductance, separated power, and drive sources. Power88 offers Moisture Sensitivity Level 1 (MSL 1). Table 2 shows features and benefits of Power88 package.

Table 2. Features and Benefits of Power88 Package

<table>
<thead>
<tr>
<th>Key Package Features and Benefits</th>
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<tr>
<td>Key Features</td>
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<tr>
<td>• Small Footprint</td>
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<tr>
<td>• Low Profile Package</td>
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<td>• Kevin Contact Configuration</td>
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<td>• Low Package Inductance</td>
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<td>• Ribbon Bonding</td>
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<tr>
<td>• Moisture Sensitivity Level (MSL 1)</td>
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<tr>
<td>Application Benefits</td>
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<tr>
<td>• Highest Power Density Design</td>
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<tr>
<td>• Lower Switching Losses</td>
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<tr>
<td>• Lower Gate Oscillation</td>
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<tr>
<td>• Easy to Use</td>
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<tr>
<td>• Higher Current Capability</td>
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<td>• Lower Contact R and Parasitic L</td>
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<td>• The longer a device’s floor life, the less care to store the device.</td>
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Conclusion

As power conversion efficiency becomes more critical and technology of discrete devices advances every day, extremely fast switching of super-junction MOSFET is essential choice for higher efficiency. But it is not as easy to control compared to previous generation MOSFETs. The new HV SMD package, called Power88, not only maximizes switching performance but also achieves high efficiency and a low profile in power supply systems.
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