New Power MOSFETs Enable 3% Efficiency Gain in DC-DC Converters

International Rectifier's latest technology sets a new benchmark for MOSFETs with the lowest $R_{DS(on)}$ and lowest R x Q_{switch} product, thereby significantly enhancing the efficiency of DC-DC converters

By Ken Dierberger, Applications Engineering Manager and Naresh Thapar, Senior Design Engineer

Introduction

Faster microprocessor speeds, wider bandwidths and the explosive growth of the Internet continue to push power management efficiency, density and reliability requirements to higher levels. New GHz class processors require higher current and lower voltages than the previous generation. Today's high-end notebook computers consume 20A, requiring MOSFET paralleling. Servers and high-end desktop computers presently require 60 to 90A and often use a multiphase topology. The latest CPU voltage regulators used to power the next generation Intel and AMD processors are rated at 120A, which is approximately a 9-fold increase when compared to the CPU requirements of two years ago.

In telecom and networking industries, which use isolated converters, the output voltage of the converter may go down to as low as 1.5V to power the next generation of broadband equipment, where the ASIC is expected to operate at this low voltage. Under these conditions, synchronous rectification is necessary to reduce power dissipation and maintain the required efficiency level.

These high current requirements in both industries need to be achieved with no additional real estate being available on the PCB. Rather, as digital circuits are replaced by higher density integrated circuits, system size is decreasing and has driven the need to reduce the form factor of the DC-DC converter.

This paper introduces International Rectifier's newest generation of stripe trench MOSFETs which effectively decouples on-resistance and gate-drain charge, enabling a low $R_{DS(on)}$ X gate charge product, an industry accepted figure of merit for MOSFETs used in DC-DC converter topologies. The result is an optimized chipset for high performance DC-DC converters enabling benchmark efficiency levels in a range of circuit topologies.

IR's New MOSFET Specifications

The typical parameters of the optimized chipset for the DC-DC converters now offered by International Rectifier are shown the table below. IRF7822 has been optimized for the synchronous FET socket while IRF7811W has been optimized for the control FET socket. The IRF7811W can also be used as a sync FET in lower power applications, depending on the target efficiency and power density required by the application. The in-circuit performance of this ultra-efficient chipset is also discussed below.

Parameter	**IRF7811W** (typical)	**IRF7822** (typical)
$R_{DS(on)}$ @Vgs=4.5 V	9.0 mΩ	5.0 mΩ
Q_G	18 nC	44 nC
Q_{SW}	5.5 nC	11.5 nC
Q_{OSS}	12 nC	27 nC

In-circuit Performance

International Rectifier tested the in-circuit performance of power MOSFETs in a range of DC-DC converters using various circuit topologies under different operating conditions.

Topology 1. Single Phase Sync Buck DC-DC Converter

Figure 1 illustrates an efficiency comparison between the new optimized wire bonded IRF7811W/IRF7822 chipset and the industry's previous best *CopperStrap*™ IRF7811/IRF7809 chipset tested in a two-device, buck regulator with synchronous rectification (sync buck) operating at 300kHz, output voltage/current of 1.3V/15A and input voltage of 14V. The circuit was configured with a single control FET and a single sync FET. In one case the IRF7811 and the IRF7809 chipset was used and in the second case the IRF7811W and the

IRF7822 chipset was used. At 15A output load conditions the results show the new chipset has a distinct efficiency advantage of 2% over the *CopperStrap*™ MOSFETs. At peak efficiency, the IRF7811W/IRF7822 chipset maintained its 2% advantage over the IRF7811/IRF7809 chipset.

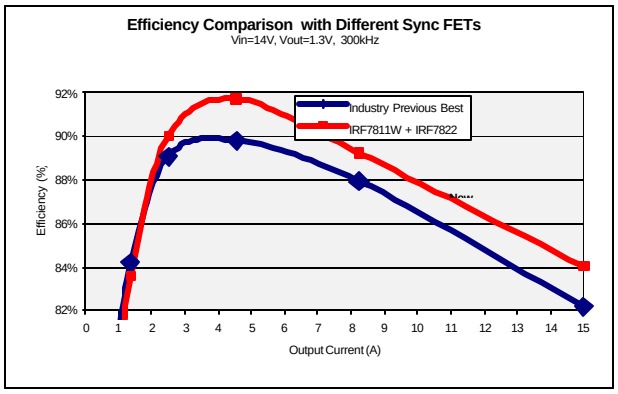

Figure 1. Efficiency comparison between the wire bonded IRF7811W/IRF7822 chipset and the *CopperStrap*™ IRF7811/IRF7809 chipset illustrates the better performance of the IRF7811W/IRF7822 chipset.

Topology 2. Multiphase Sync Buck DC-DC Converter

In a multiphase sync buck converter, configured with two control FETs and four sync FETs in each phase, the efficiency of six IRF7811Ws at full load was at 78.7%, 3.7% better than six IRF7811s at 75.0%. This circuit was operating at **700kHz per phase**, 12V input voltage and output voltage/current of 1.4V/**35A per phase**. Replacing the four IRF7811W sync FETs with two IRF7822 sync FETs, the efficiency remained a very respectable 78.4% (see Fig 2).

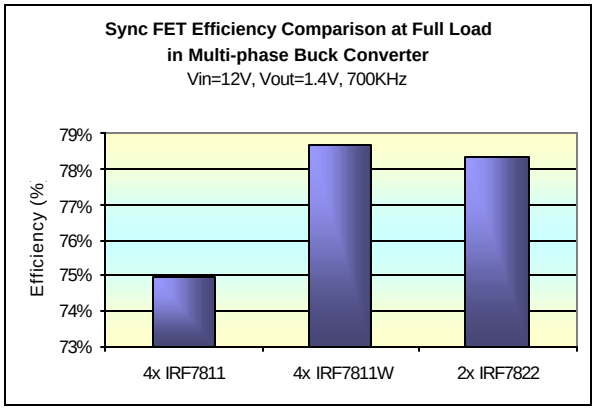

Figure 2. Efficiency Comparison in a multiphase buck converter, operating at full load, between four IRF7811s, four IRF7811Ws or two IRF7822s.

The operating case temperature of the *CopperStrap*™ IRF7811 was 90.4°C, nearly 6°C hotter than the wire bonded IRF7811W (see Figure 3).

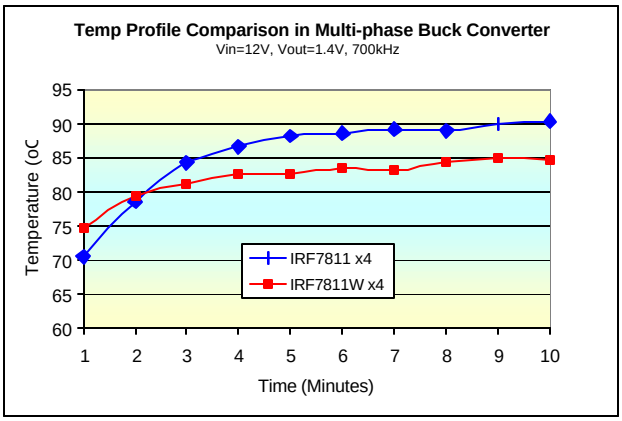

Figure 3. Temperature Profile Comparison

Topology 3. Isolated DC-DC Converter with Synchronous Rectification

Six IRF7822 MOSFETs were paralleled and used as synchronous rectifiers in an isolated single-ended DC/DC converter. The efficiency was measured at between 86% to 88% (see Figure 4), with output current between 20A and 40A, an output voltage of 1.5V and an operating frequency of **200kHz**.

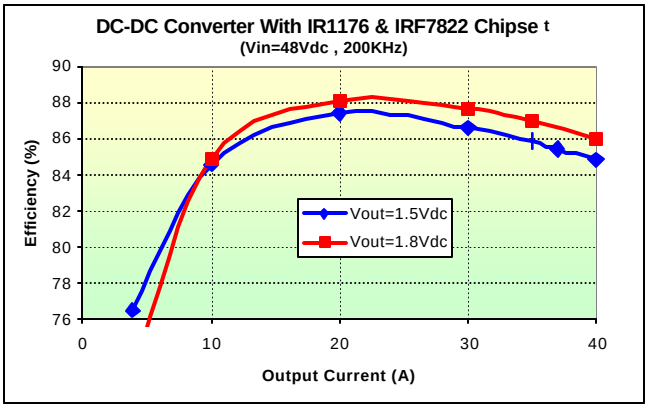

Figure 4. Efficiency curves for an isolated DC/DC converter, where six IRF7822 MOSFETs per leg are used as synchronous rectifiers.

New MOSFET Technology

International Rectifier continues to push the envelope for planar and trench structure to optimize MOSFETs for DC-DC converters with stripe and cellular designs.

In the past two years, International Rectifier introduced technologies targeted specifically for control and sync FET sockets that set the standard for DC-DC converters. The planar stripe DMOS technology (used in IRF7811) optimized for the control FET socket has the industry's lowest R x Q_{switch} product of 50mΩ-nC, while the trench FET technology optimized for the sync FET socket (used in IRF7809) has the industry lowest R x A product of 39 mΩ-mm2. To reduce the power losses in the control FET, a technology with a R x Q_{switch} product lower than that of IRF7811 (50mΩ-nC) is needed and to reduce the power losses in the sync FET, a technology with a R x A product lower than that of IRF7809 (39 mΩ-mm2) is needed while maintaining a low total gate charge.

IR engineers realized that just taking the popular market approach of having more cells per unit area to maximize the channel density was not enough to reduce the power losses occurring in the sync FET. This is because, in addition to the conduction losses, the sync FET also has the associated gate drive losses that are directly proportional to gate charge of the sync FET. The channel density of the sync FET could also possibly be constrained by the limited drive currents of the IC drivers thereby imposing an upper limit on the maximum gate charge of sync FET. For MOSFETs, the total gate charge increases linearly with the number of cells per unit area while the $R_{DS(on)}$ reduces sub-linearly with the number of cells per unit area. This is because of the total $R_{DS(on)}$, the channel component (which is inversely proportional to the number of cells per unit area), is only about 20%-40% depending on the channel length. Hence, more cells per unit area always increase the R x Qg product, which is not desirable. With this in mind, the focus of research at International Rectifier shifted to improving both $R_{DS(on)}$ and gate charge per unit cell.

The latest trench technology being introduced by International Rectifier was developed to achieve all these ends. Significant changes in the trench FET unit cell structure were successfully incorporated in this technology to break the traditional $R_{DS(on)}$ versus Q_{switch} trade-off inherent in all the commercially available FET technologies. As a result, lower channel resistance and reduced gate-drain charge have been *simultaneously* achieved for the same cell density as the previous trench technology. An R x A product of 26 mΩ-mm2 is possible with this advanced technology which is about 33% lower than the R x A product offered by the previous trench technology. In addition, this technology also has a 36% lower Qg and 41% lower Q_{switch} than the previous trench technology. Furthermore, the R x Q_{switch} product possible with this technology is 28mΩ-nC which is about 44% lower than the R x Q_{switch} of products previously introduced. It is worth pointing out that this improvement over the R x Q_{switch} product also comes with a 57 % lower R x A product. This implies that more efficient control FETs can be manufactured using International Rectifier's latest trench technology. This increase in efficiency along with die size reduction, when compared to the prior generation planar technology, leads to a smaller footprint thus saving the valuable onboard real estate.

Conclusions

The new IRF7811W/IRF7822 chipset has been shown to perform better than the best *CopperStrap*Ô IRF7811/IRF7809 chipset in several power supply applications. These devices have been shown to operate with higher efficiency and lower case temperature.