Eighth Brick DC-DC Converter

Using Efficient GaN Transistors

In this article, we show that using GaN Transistors such as Efficient Power Conversion's eGaN® FETs [1] can improve the efficiency of isolated eighth brick DC-DC converters. This type of power converters is used extensively in mainframes, servers and telecommunication systems, and is available in a variety of sizes, output power capability, and input and output voltage ranges. It's modularity, power density, reliability and versatility have simplified the isolated power supply market.

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Even so, there are a number of factors such as transient response, efficiency, environmental conditions, or mechanical packaging that can influence the final choice of converter [2]. In this article, we will look at a particular subset of isolated DC-DC converter, the "brick" converter, which is perhaps, the most widely adopted format in the computer and telecommunications industries.

Brick Converters:

As these types of converters are of a defined size, designers are motivated to come up with innovative ideas to increase their output power and power density. For example, within the spectrum of eighth brick converters there are numerous input and output voltage configurations, topologies and output range tolerances (regulated, semi-regulated or unregulated), and they all have a very similar maximum power loss between 12-14 W at full power. Eighth Brick converters have a standard 58 x 23 mm (2.3 x 0.9 inch) footprint which sets the physical limit based not only on the fixed volume of the converter, but also on the common method of heat extraction. Thus, for an eighth brick converter that is 90% efficient (η = 0.9) at full load, the maximum output power (assuming 14 W loss) will be:

$P_{outmax} = P_{max\ loss} \times \eta/(1-\eta) =$
$14\ W \times 0.90/(1-0.90) = 126\ W.$

If the efficiency can be improved by 3%, the output power is increased to 186 W. That's 48% more output power!

It is possible to reduce the power loss in the magnetic components by increasing the operating frequency. However, this is not normally done because the increase in the silicon MOSFET switching losses outweighs the potential improvement. For that reason, the operating frequency is typically reduced to the point where the magnetic structure's size is maximized within the overall brick's size constraints. This lower frequency limit can be a significant constraint when fast transient response is needed to react to rapid changes in the load.

A common topology that we can use to explore the capabilities of eGaN FETs in isolated DC-DC converters is a full-bridge primary side and a synchronous rectifier secondary side. The test vehicle chosen was a fully regulated eighth brick with a nominal input voltage of 48 V_{IN}, and an output of 12 V_{OUT}. It is shown that eGaN FETs enable the user to significantly improve efficiency, and therefore power output and cost, while maintaining the required size constraint of an eighth brick.

The eGaN FET-based eighth brick converter developed for this article is not necessarily an optimal solution. The design goal was to deliberately push the operating frequency higher than current commercial systems to show that eGaN devices could enable someone skilled in power supply design to take advantage of the superior switching characteristics in developing next-generation products that are smaller and have a faster transient response.

Description

The phase-shifted full-bridge (PSFB) converter with a full-bridge synchronous rectifier (FBSR) topology is shown in Figure 1. The objective was to show that, due to their relatively small device size, a significant number of eGaN FETs could be used within the restrictive eighth brick size limitations.

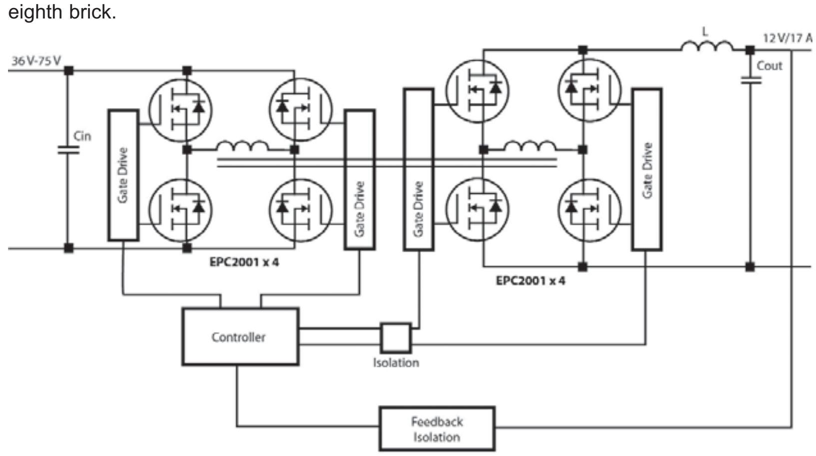


Figure 1: Eighth brick fully regulated, phase shifted full bridge (PSFB) topology, with full bridge synchronous rectification (FBSR) using eGaN FETs

The choice of transformer turns ratio (5:2) means that, at 60 V_{IN}, the secondary side winding voltage is only 24 V but the overshoot can be as high as 60 V without a clamp. For this reason 100 V devices were used on both the primary and the secondary sides.

The final circuit is a 12 V output, 375 kHz phase-shifted full bridge (PSFB) eighth brick converter with a maximum output current of 17 A and a 36 V to 60 V input voltage range. The demonstration board (EPC9102) features the EPC2001 enhancement mode (eGaN®) field effect transistors (FETs) [3], as well as the first eGaN FET specific integrated circuit driver – the LM5113 from Texas Instruments [4]. A complete block diagram of the circuit is given in Figure 2 and the actual eighth brick is shown in Figure 3 [5].

Note that the significant amount of 'green' space (unfilled PCB area) could certainly be further exploited to improve efficiency.

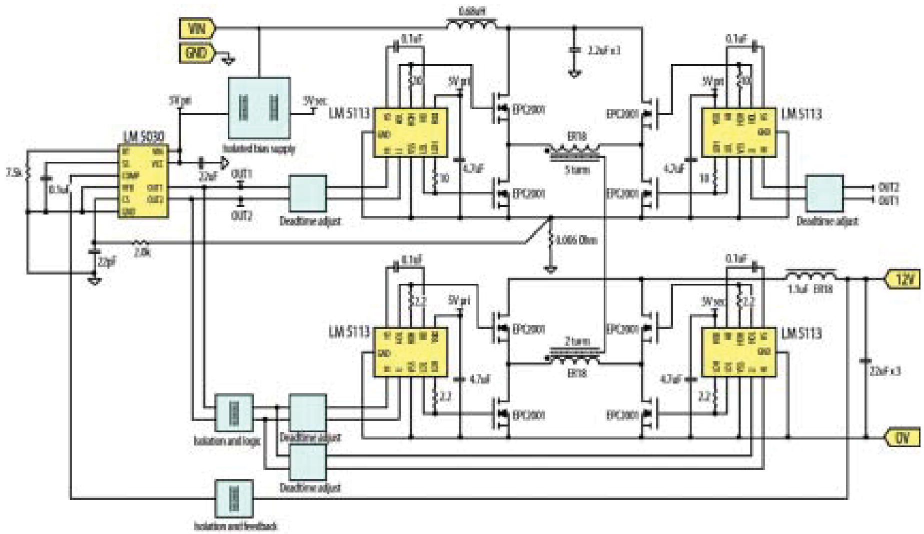
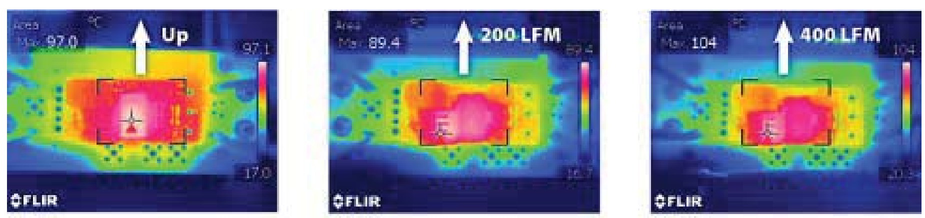


Figure 2: Block Diagram of EPC9102 Demonstration Board



(a) 48 V_{IN}, 8 A_{OUT}, 96 W, convection cooled

(b) 48 V_{IN}, 15 A_{OUT}, 160 W, 200 LFM airflow

(c) 48 V_{IN}, 17 A_{OUT}, 200 W 400 LFM airflow

Figure 6: Thermal images of EPC9102 under different cooling conditions: (a) convection cooled, (b) 200 LFM, and (c) 400 LFM.

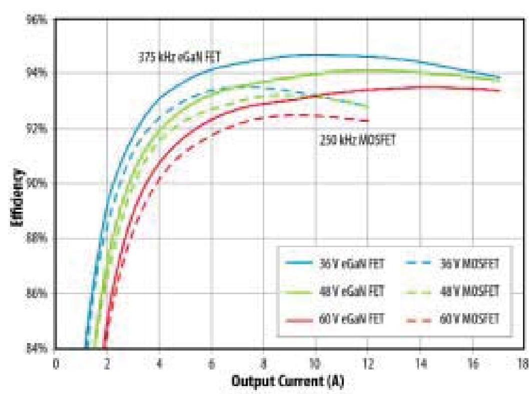


Figure 4: Efficiency comparison between eighth brick converters

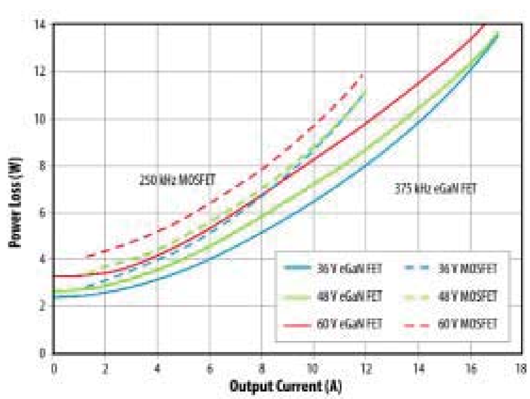


Figure 5: Power loss comparison between eighth brick converters

Eighth Brick Performance

Efficiency and power loss results are shown in figure 4 and figure 5 respectively and are compared against a comparable, commercially available silicon-based eighth brick [6]. Despite the eGaN FET converter operating at 50% higher frequency, it is able to produce 33% more output power for the same power loss.

Thermal considerations

The eighth brick PCB thermal images for steady state full load operation are shown in Figure 6 (a), (b), and (c). Operation without forced-air cooling is possible for limited power operation and quickly becomes thermally limited. Addition of airflow improved the power handling significantly, and with an airflow 400 linear feet per minute (LFM), and 200 W output power delivered to the load, the maximum temperature of the FETs on the board is approximately 104°C, safely below the 125°C maximum for the device.

(a) 48 V_{IN}, 8 A_{OUT}, 96W, convection cooled
(b) 48 V_{IN}, 15 A_{OUT}, 160 W, 200LFM airflow
(c) 48 V_{IN}, 17 A_{OUT}, 200 W 400LFM airflow

Summary

An eGaN FET-based fully regulated eighth brick converter is significantly more efficient than its MOSFET-based counterpart that enables 33% more output power at a 50% higher switching frequency.
More improvement is possible. For example, the full-bridge synchronous rectifier, using 100 V eGaN devices, could be changed to a center-tap with two devices in parallel (similar to the MOSFET-based design). Instead of the output inductor current flowing through two

devices in series, it would then flow through two devices in parallel. This would reduce the secondary-side device conduction losses by 75% (1.3 W, or roughly 10% of total power losses) at 14 A output current [7].

The choice of topology and component optimization is as important in brick converter design as the selection of the best power devices. Someone skilled in these arts should be able to further improve the eGaN FET converters presented here.
eGaN is a registered trademark of Efficient Power Conversion Corporation.

[1] http://epc-co.com/epc/Products/eGaNFETs.aspx
[2] Paul, Knauber, "Select the Best Isolated Brick DC-DC Converter For Your Application," ECN, February 5, 2010, http://www.ecnmag.com/articles/2010/02/select-best-isolated-brick-dc-dc-converter-your-application
[3] http://epc-co.com/epc/Products/eGaNFETs/EPC2001.aspx
[4] http://epc-co.com/epc/Products/eGaNDrivers/LM5113Bridge-GateDriverOptimizedforeGaNFET.aspx
[5] http://epc-co.com/epc/Products/DemoBoards.aspx#democircuits
[6] Ericsson BMR454 series 48 V to 12 V eighth brick converter, Ericsson website, http://www.ericsson.com/ourportfolio//products/bmr454-series-eighth-brick-intermediate-bus-converter
[7] Lidow, Strydom, deRooij, and Ma, "GaN Transistors for Efficient Power Conversion" Power Conversion Publications, 2012, pages 90-92.

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