Exclusive Technology Feature

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How2 Get From AC To Below 1 V With eGaN FETs

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A common challenge in power management for the computing industry is how to most efficiently convert ac line voltage to the approximately 1.2 V dc consumed by high-performance digital processors and peripherals.

Today, the most common approach is to first convert the ac line voltage directly to a 12-V dc power distribution bus in one isolated power supply, and subsequently convert 12 V dc down to about 1.2 V dc in a second, nonisolated stage. It is possible to achieve 92% conversion efficiency (or even 94% in next-generation systems) from ac to 12 V. From 12 V to 1.2 V, conversions can be 90% efficient utilizing buck-topology point-of-load (POL) converters running at a modest 300 kHz.

At times overlooked is the fact that the 12-V distribution bus can dissipate an additional 2% of the total power in resistive losses when used in high-performance computers and servers. Multiply these two conversion efficiencies together with the additional distribution losses, and the total system, from ac line to the 1.2-V output of the POL achieves a conversion efficiency of approximately 81%.

What options do we have to improve this system, and what happens when the operating voltage of the highest-performance digital ICs drops below 1 V? In this article, we explore various options and add a new tool to the designer's tool box—the latest generation of enhancement-mode gallium nitride (eGaN) FETs.[1,2]

Changing The Voltage Of The Distribution Bus

Changing the distribution bus from 12 V to 48 V yields an immediate reduction in conversion and distribution losses. Today, high-performance ac-dc power supplies can deliver isolated 48 V with 96% conversion efficiency. By coupling that with the reduced power losses in the 48-V power bus, which are 16 times lower than those produced by a 12-V bus, you are starting out with a six percentage point advantage over the baseline system.

The challenge now is to convert from 48 V down to 1.2 V as efficiently as possible.

Fig. 1 shows the efficiency achieved using 100-V EPC2001 eGaN FETs switching at 500 kHz in the buck converter circuit in reference 3 compared against state-of-the-art silicon MOSFETs switching at 300 kHz and 500 kHz. Note that the silicon MOSFETs have the same on-resistance but a lower breakdown voltage (60 V). This mismatch in voltages reflects the fact that there are no optimized 60-V eGaN FETs available yet, so 100-V devices are used instead. (Were 60-V eGaN FETs available, the efficiency of the buck converter would be even better than those shown for the 100-V FETs.)

The 48-V to 1.2-V converter, having a peak efficiency of 80%, yields an ac to 1.2-V system with an overall efficiency of 77%. That's four percentage points worse than the baseline system with a 12-V distribution bus. To help find a more-efficient alternative, the graph in Fig. 2 will be the starting point.

The next step may be to compromise by using a 24-V distribution bus. This bus would have one-quarter the resistive losses compared to a 12-V bus, and ac to 24-V isolated power supplies can be found with 94% conversion efficiency. Using the graph in Fig. 2, a conversion efficiency of 87.5% at 500 kHz can be achieved. This computes to a total system efficiency of 82%; slightly better than the benchmark system. An additional benefit of the higher switching frequency is a reduction of board area and an increased control bandwidth.

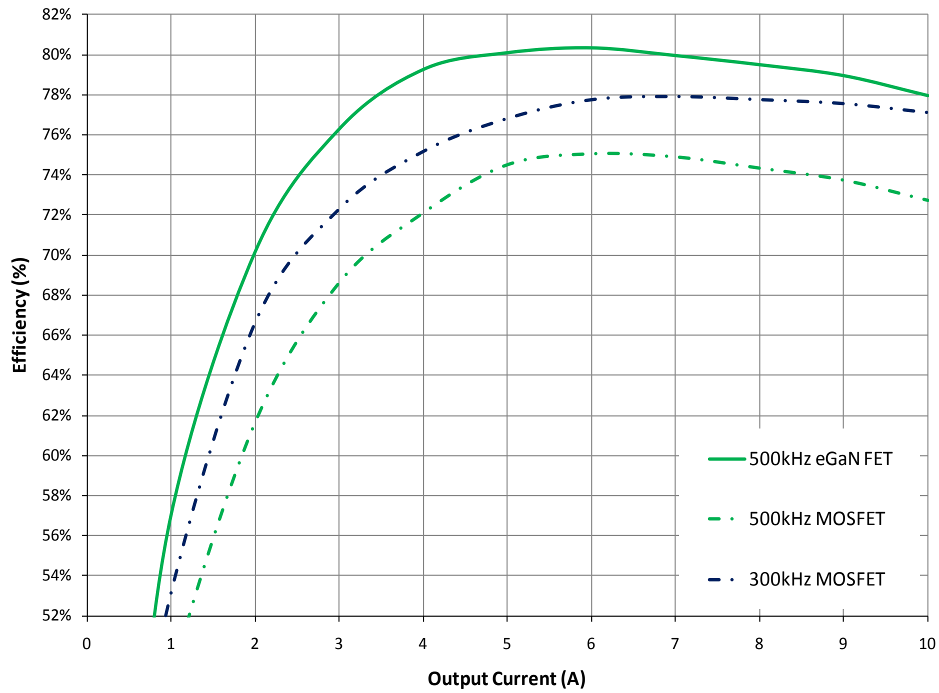

Fig. 1. 48-V to 1.2-V conversion efficiency achieved using 100-V EPC2001 eGaN FETs compared against state-of-the-art 60-V silicon MOSFETs.

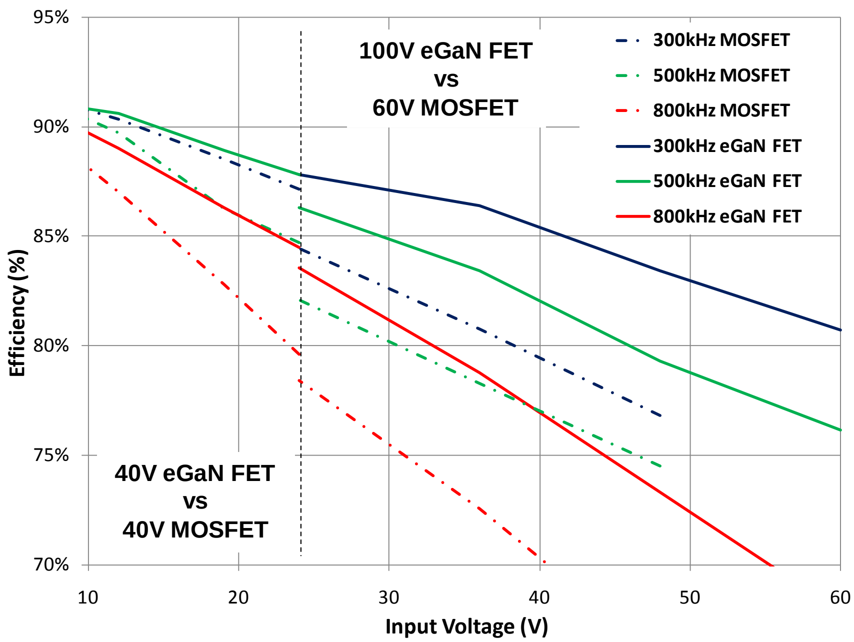

Fig. 2. POL efficiency of eGaN FETs compared with silicon power MOSFETs vs input voltage at various PWM frequencies.

Fig. 3 shows a buck converter designed and built for 24-V to 1.2-V conversion.[4] This converter was experimentally evaluated using both MOSFETs and eGaN FETs to facilitate direct comparisons. Note that the area occupied by the eGaN POL (121 mm^2) is two-thirds the area occupied by the MOSFET POL (181 mm^2). The converter losses of the eGaN POL operating at 800 kHz switching frequency were measured to be 30% lower than the MOSFET POL.

Opening up the possibility of going from 48 V to 1.2 V in two stages provides more options for improving efficiency, albeit at a slightly higher cost for the two-stage eGaN POLs. In this scenario, a 48-V to 5-V conversion followed by a 5-V to 1.2-V conversion yields an overall system efficiency of 83% even when the final 5-V to 1.2-V stage is operated at a 1-MHz switching frequency. The designer can now also take advantage of the higher transient response afforded by the higher PWM frequency while enjoying 10% lower system power losses compared with our baseline “all silicon” solution (Fig. 4).

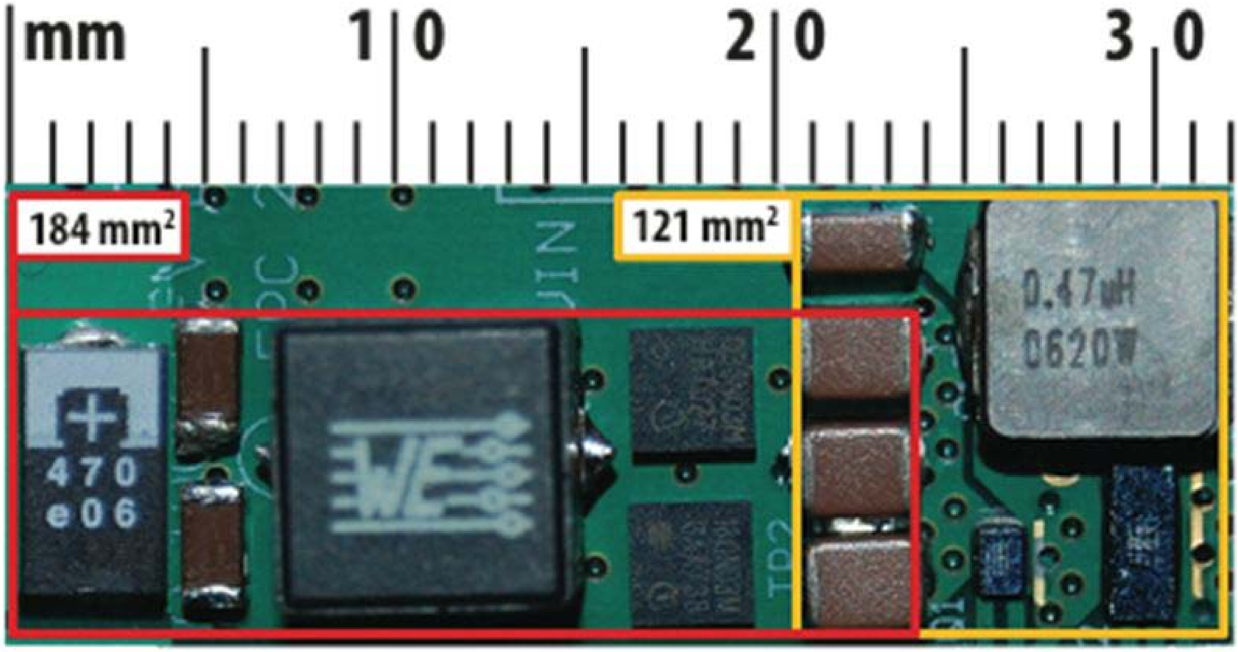

Fig. 3. A 24-V to 1.2-V buck converter was built and tested in two configurations—one using eGaN FETs and another with state-of-the-art silicon power MOSFETs.

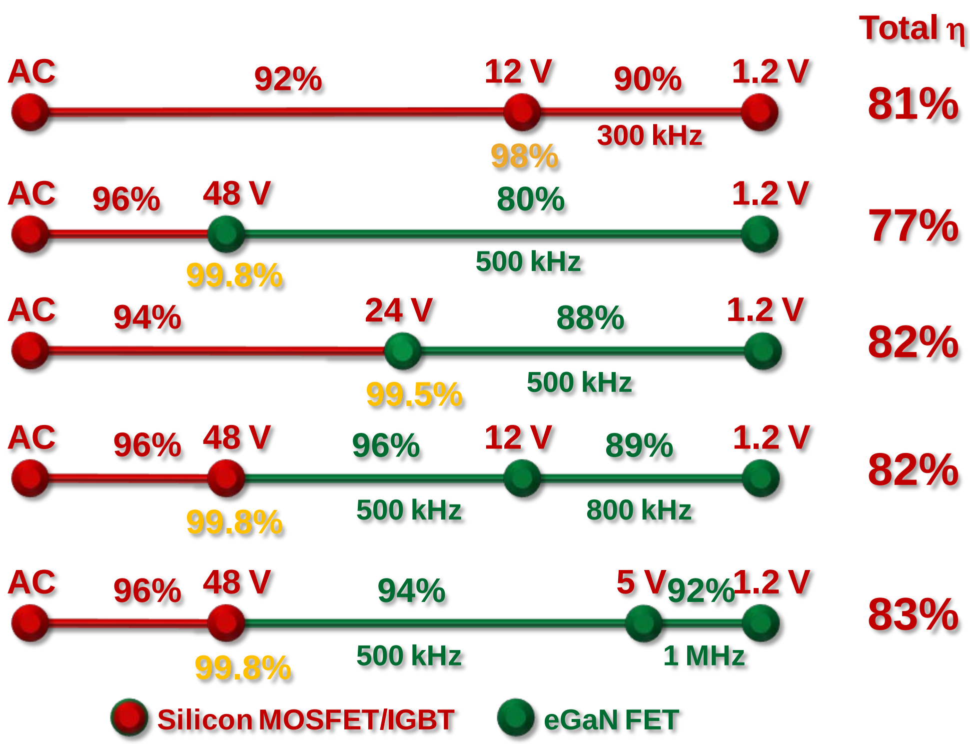

Fig. 4. The various scenarios examined in this article for converting ac line voltage to 1.2 V dc. Also shown are overall efficiencies and PWM frequencies.

Getting Below 1 V

What happens when the designer is faced with the challenge of supplying power at 0.6 V? In this case, our baseline "all-silicon" solution with a 12-V bus becomes even less efficient. Instead of 90% efficiency from 12 V to 1.2 V, only 84% can be achieved going all the way to 0.6 V. The overall system efficiency has now dropped to 76%.

Going through the same analysis as we did above, and using the data from Fig. 5, eGaN FETs can help the designer get back to the 81% efficiency of the original 1.2-V baseline by using a 48-V primary bus and two 500-kHz buck converter stages.[4] This two-stage solution with the higher-frequency converter also allows the physically smaller final POL to be located very close to the load. This further reduces the significant resistive losses that occur between the POL and the load that, although very real, are typically not considered in these types of calculations. Fig. 6 gives an overview of the various scenarios that are examined for converting from ac to 0.6 V.

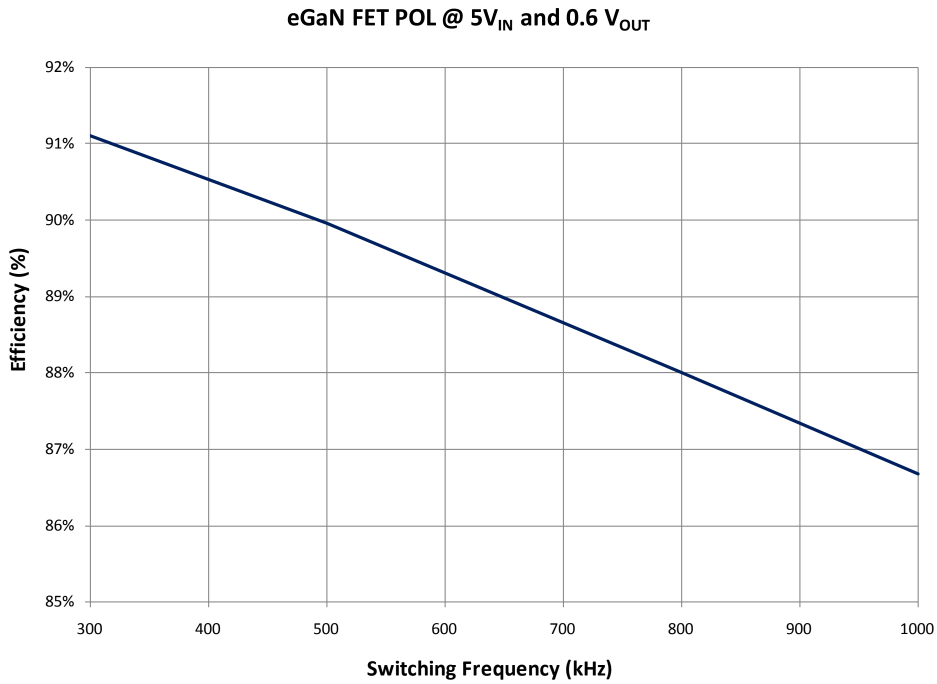

Fig. 5. eGaN-based buck converter efficiency vs frequency with V_{IN} = 5 V and V_{OUT} = 0.6 V.

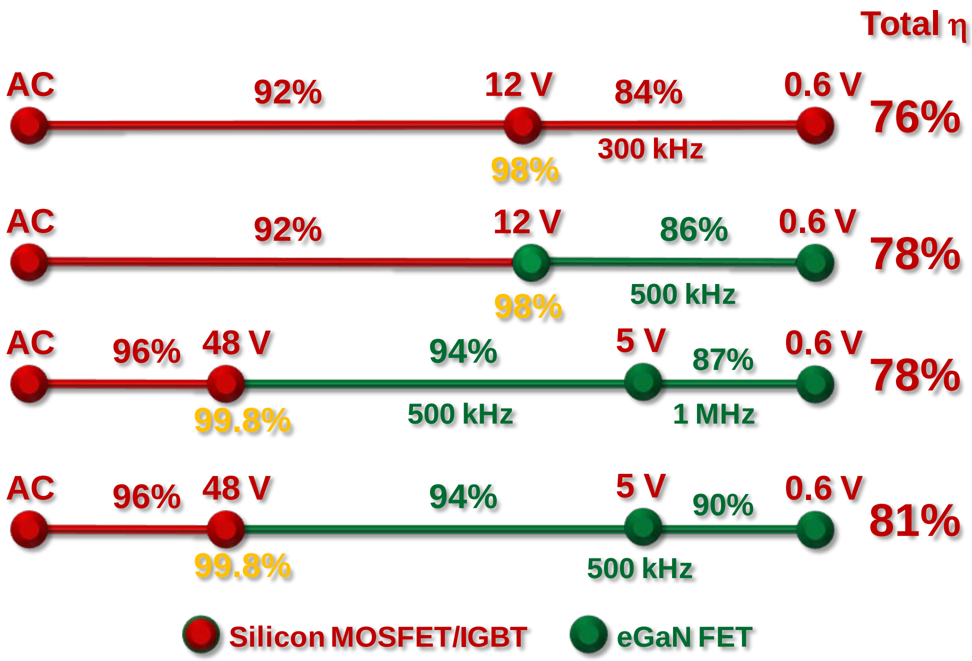

Fig. 6. The various scenarios examined in this article for converting from ac to 0.6 V. Also shown are overall efficiencies and PWM frequencies.

Summary

Enhancement-mode gallium nitride (eGaN) technology opens up a new set of options for improving overall system efficiency in high-performance computing applications. When going from ac to 1.2 V, a combination of higher-voltage distribution and eGaN FETs reduces overall power losses by 10%, which represents a 2% improvement in overall efficiency. As digital voltages decline even further, the advantages of eGaN FETs compared with silicon power MOSFETs will continue to increase.

References

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About The Author

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For more on the design of power converters using GaN power transistors, see the How2Power Design Guide, search by Design Guide Category, and select “Silicon Carbide and Gallium Nitride” in the Popular Topics category.