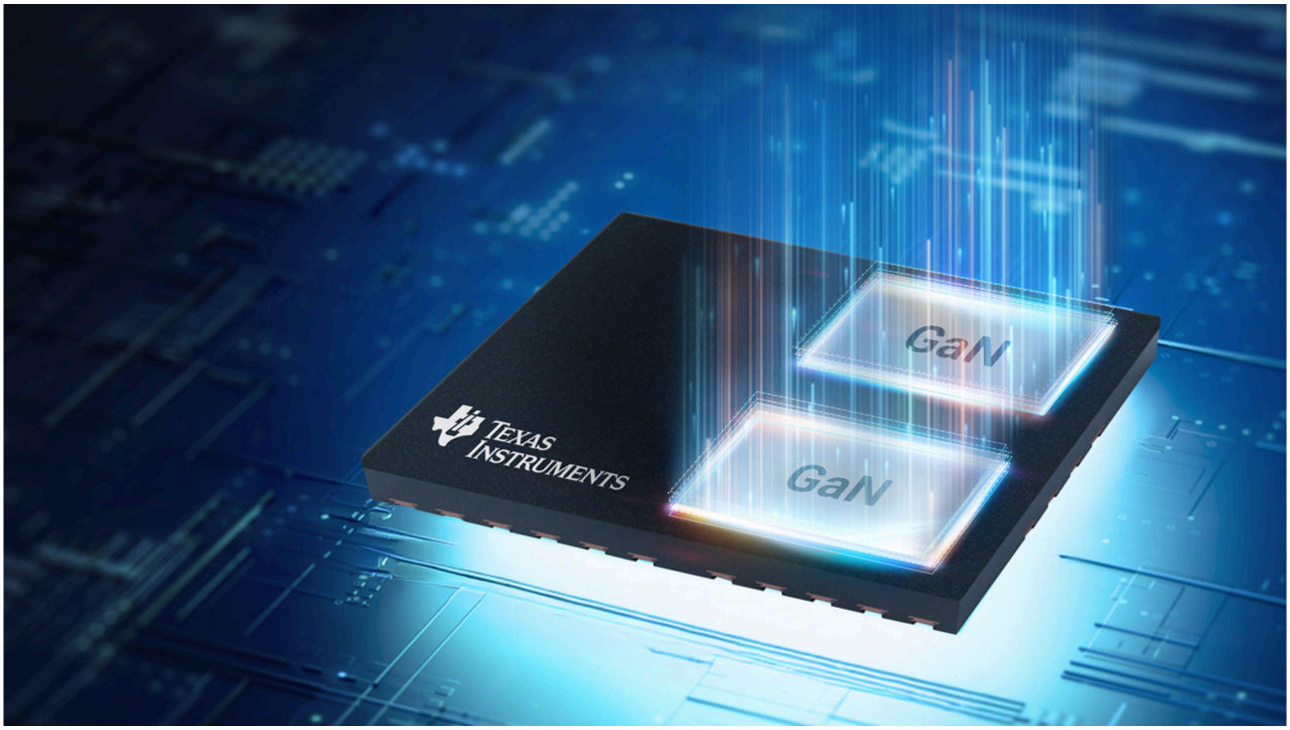
Technical Article

Four ways integrated GaN converters are redefining high-current power-supply design

- GaN integration drives reduced switch losses, innovative circuit techniques, component integration and improved thermal performance.
- Medium-voltage **GaN integrated buck and boost converters** achieve up to 50% smaller footprints than silicon alternatives without sacrificing efficiency.



The push for higher power density continues to shape every major design decision for high-current power supplies. Data centers and compute infrastructure are growing at a pace that is straining traditional power architectures. From robotics to test and measurement equipment, engineers are facing the same fundamental challenge: deliver more power, in less space, without sacrificing efficiency.

For years, silicon-based switching converters and discrete power-FET designs stretched what has been possible in medium-voltage, high-current applications. But as switching frequencies increase and footprints shrink, silicon FETs' fundamental limitations – higher on-state resistance, reverse-recovery losses and greater parasitic charges – become significant barriers to design goals. The power electronics industry has spent more than 15 years investing in, developing, and validating gallium nitride (GaN) technology as the proven alternative for high-current power-supply designs.

GaN power FETs deliver fundamentally better electrical characteristics than their silicon counterparts, along with deep integration. Combining power FETs, gate drivers, controllers and passive components into a single, compact package maximizes efficiency and power density in ways that silicon approaches cannot match. Among TI's medium-voltage GaN multichip module (MCM) integrated circuits (ICs), the LMG708B0 80V buck converter and LMG5126 42V boost converter achieve footprints as much as 50% smaller than silicon solutions without sacrificing efficiency, meeting the design requirements of high-current applications – typically ≥ 20A.

Meeting the demands of high-current DC/DC converter design requires understanding the trade-offs and technologies that make four key GaN advances possible:

1. Reducing switch power losses
2. Adopting innovative circuit techniques
3. Embracing component integration
4. Improving package thermal performance

Let's briefly examine each of these advances enabled by GaN.

1. Reducing switch power losses unlocks higher frequency and smaller passives

The wide bandgap (WBG) characteristics and lateral structure of enhancement-mode GaN power FETs provide lower drain-to-source on-resistance $R_{DS(on)}$ and lower parasitic charges (gate charge [Q_G], gate-drain charge [Q_{GD}] and output charge [Q_{OSS}]) compared to silicon power devices. As a result, the $R_{DS(on)} \times Q_G$ and $R_{DS(on)} \times Q_{OSS}$ figures of merit improve significantly as well.

GaN FETs also eliminate the body diode and associated reverse-recovery charge [Q_{RR}], removing frequency-proportional reverse-recovery losses while reducing switch-node voltage ringing and related electromagnetic interference (EMI). Predictively timed GaN-specific gate drivers yield approximately 4ns of deadtime, further minimizing power dissipation during switch commutations.

In addition to lower conduction losses, the increased switching capability and reduced parasitics of GaN-based converters equate to lower total power dissipation, enabling you to increase the switching frequency, shrink magnetic and capacitive passive components, and reduce or eliminate heatsinking. This results in an overall smaller system footprint without sacrificing efficiency. Figure 1 confirms the efficiency performance for high-current DC/DC buck and boost converter designs.

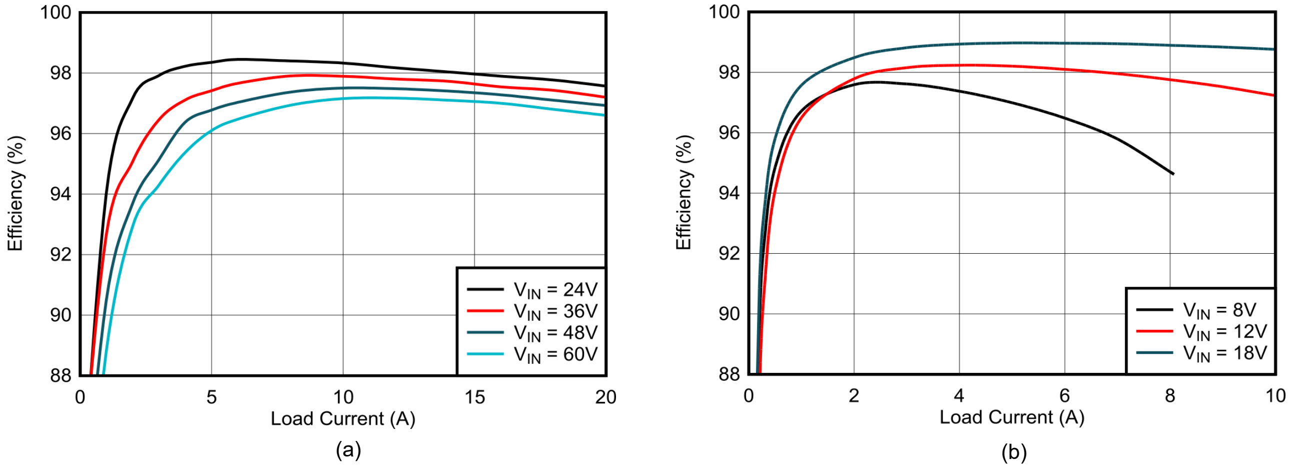
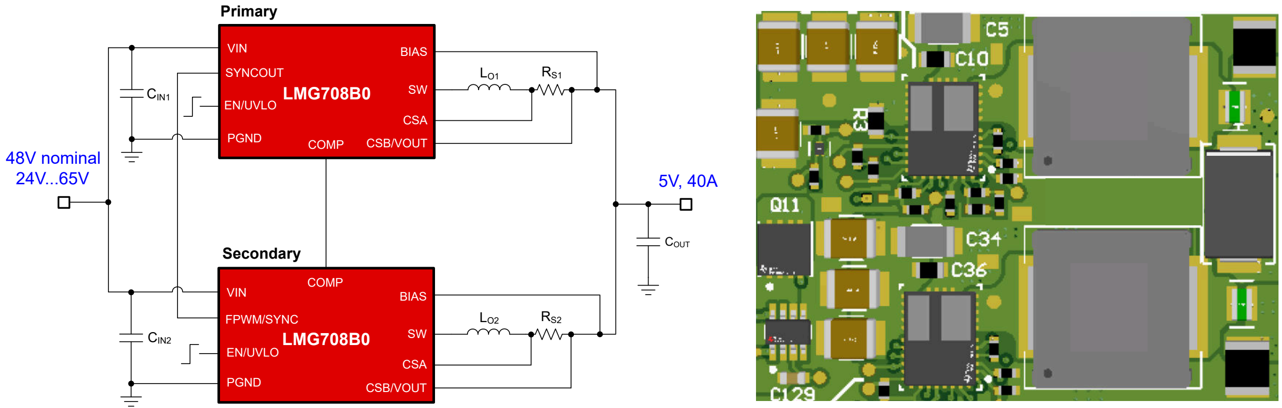


Figure 1. GaN buck converter efficiency, V_{OUT} = 12V (a); GaN boost converter efficiency, V_{OUT} = 24V (b)

2. Adopting innovative circuit techniques to enable scalability and improve light-load efficiency

A multiphase stackable topology provides the ability to scale the current multiples higher and enables phase shedding for higher light-load efficiency, increasing design flexibility for high-current applications. To this end, the LMG708B0 GaN buck converter features an intelligent multiphase clock SYNC that communicates both frequency and phase information using a daisy-chain connection between phases. The resultant interleaving reduces input ripple current and EMI filter size.

Figure 2 shows a $48V_{IN}$ to $5V_{OUT}$, 40A, 500kHz two-phase design on a 30mm-by-25mm single-sided layout, cutting the implementation size in half compared to a legacy silicon-based design.



(a) (b)

Figure 2. Simplified two-phase buck converter schematic (a), high-density layout (b)

3. Embracing integration of both active and passive components

Traditional medium-voltage (12V to 80V) high-current (> 20A) buck and boost regulators typically require four or more discrete power components, including the high- and low-side FETs, gate drivers, bootstrap circuit and controller. As shown in Figure 3, TI's MCM integration approach consolidates the design into a 4.5mm-by-6mm-by-0.8mm, 22-pin package using a flip-chip routable leadframe (FCRLF) packaging technique that incorporates four dies (two GaN FETs, a controller and a boot trench capacitor). The FCRLF packaging structure minimizes parasitic inductance between the FET power terminals and underlying PCB solder pads, directly improving switching performance.

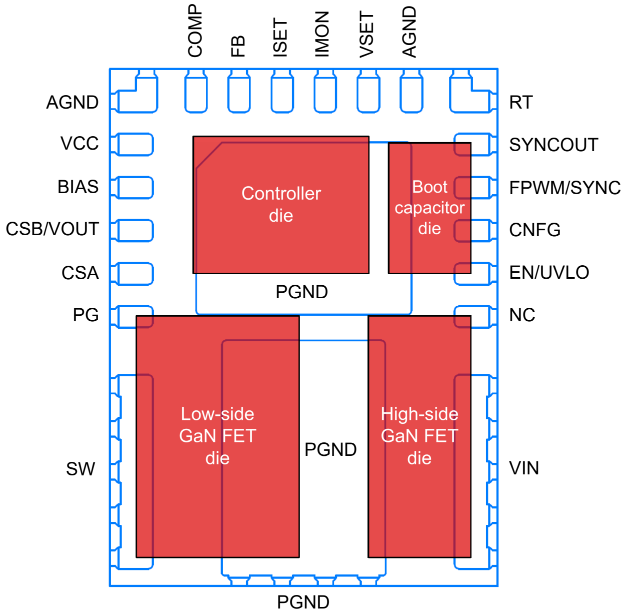


Figure 3. Component integration increases power density

Integration also tightens power- and gate-loop switching areas, producing a lower EMI signature. The resulting reduction in inductive parasitics delivers cleaner switching waveforms with no ringing – critical for the high slew-rate voltage and current integral to GaN switching performance. Together, these integration benefits enable you to optimize your designs for performance metrics correlated to efficiency and size.

4. Improving package thermal performance

FCRLF packaging technology for LMG708B0 and LMG5126 GaN converters supports a thermally enhanced package with dual heat-flow paths. The backside of both GaN FET dies are exposed on the top of the package, creating top- and bottom-side thermal landing pads that support optional dual-sided cooling through a heatsink mounted above the device (see Figure 4).

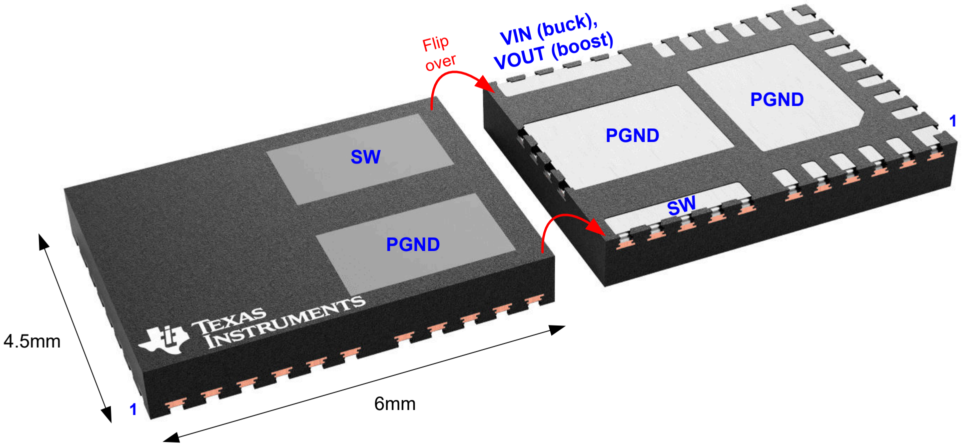


Figure 4. Thermally enhanced packaging top and bottom views

Without a heatsink, most of the heat flows through the bottom-side thermal pads (PGND) and fused thermal bars (VIN or VOUT, SW) into the multilayer board and the ambient environment. With a heatsink configuration, heat transfers from the IC toward the board while simultaneously flowing in the opposite direction toward the package case through exposed top-side thermal pads (SW, PGND) and to the attached heatsink for top-side cooling.

As shown in Figure 5, this creates parallel junction-to-ambient thermal resistance paths that lower effective thermal resistance, enabling either a lower operating temperature for a given IC power dissipation or higher current capability for a defined case temperature setpoint.

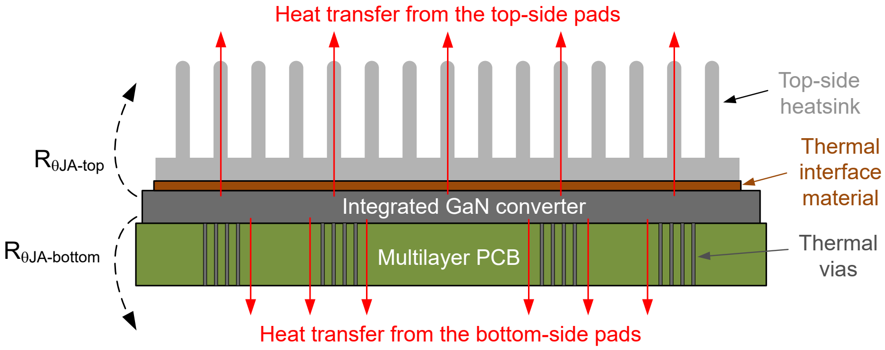


Figure 5. Illustration of dual heat-flow paths for lower thermal impedance

Conclusion

By reducing switch losses, embracing innovative circuit techniques, advancing component integration and improving package thermal performance, integrated GaN converters can help you overcome power density barriers that silicon-based designs can no longer address. Operating across a 12V to 80V DC/DC conversion space at higher frequencies and greater power densities, integrated GaN converters deliver superior efficiency in footprints up to 50% smaller than silicon-based alternatives.

Additional resources

- Evaluate GaN performance with LMG708B0 buck converter evaluation modules (EVMs) in 20A single-phase and 40A two-phase configurations and the LMG5126 15A boost converter EVM.
- Explore the $48V_{IN}$, 960W, Four-Phase Buck Converter with Integrated GaN reference design and the 3V to 42V Synchronous GaN Boost Converter reference design.
- Download quick-start calculator tools for the LMG708B0 and LMG5126 converters.

About the author

Timothy Hegarty is Senior Member Technical Staff in the Switching Regulators business unit at Texas Instruments. With more than 25 years of power-management engineering experience, he has written numerous conference papers, articles, seminars, white papers and application notes. His current focus is on enabling technologies for high-density, low-EMI switching regulators with a wide input-voltage range for automotive, industrial and data-center applications.

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