

Achieving high power density in a 48V buck converter with integrated GaN FETs and dual-side cooling

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Introduction

The continued adoption of 48V power distribution architectures in automotive, industrial, and data center systems has increased the demand for compact, high-efficiency DC/DC converters capable of supporting high output currents while minimizing solution size. Integrated gallium nitride (GaN) power converters address these requirements by reducing switching losses and package parasitics, which enables increased power density compared to conventional silicon-based solutions.

As converter power density increases, thermal management becomes a critical design consideration. This article examines a 48V-to-12V, four-phase synchronous buck converter using integrated GaN power integrated circuits (ICs) and demonstrates how designers can leverage dual-side cooling alongside printed circuit board (PCB) thermal spreading to manage power dissipation at high load operation.

Integrated GaN for high power density conversion

Silicon metal-oxide semiconductor field-effect transistor (MOSFET) technology has served as the foundation of power converter design due to its availability and proven performance. However, as converter power levels and power density requirements continue to increase, conventional silicon-based implementations face growing challenges associated with switching losses and package parasitics. Integrated GaN power ICs address these limitations by combining high-speed GaN power FETs, gate drivers, and control circuitry within a single package, reducing parasitic inductance while simplifying converter implementation. The higher switching capability of GaN also enables operation at increased switching frequencies, which can reduce the required size of magnetic and capacitive components while enabling faster control-loop response.

Reducing the parasitic inductance between the GaN power FETs and integrated gate driver also improves control of the switching transitions, reducing unwanted ringing and associated switching losses. This improved switching behavior can help reduce electromagnetic interference (EMI), an important consideration for high-density power converters operating at high slew rates [1].

The four-phase converter design presented in this article uses the TI [LMG708B0](#) integrated GaN power multi-chip module (MCM) IC to support the efficiency and power-density requirements of 48V-to-12V step-down conversion.

Thermal challenges and dual-side cooling

Integrated GaN power ICs can improve converter efficiency and reduce solution size, but concentrating power dissipation within a small package increases thermal density and heat flux. As a result, achieving the full performance potential of integrated GaN depends not only on minimizing electrical losses but also on providing effective pathways for transferring heat from the device to the surrounding ambient environment. In a conventional PCB-cooled implementation, heat generated by the device must conduct through the package into the PCB, where copper planes and thermal vias spread the heat toward the surrounding surfaces and to the local ambient environment. As a general rule of thumb, approximately 1 in^2 of cooling area per watt of dissipated power may be required for natural-convection cooling. Maximizing the thermal spreading capability of the PCB is therefore a critical part of managing the device temperature in a high-power-density converter.

The addition of a dual-side cooling structure provides a parallel thermal path from the LMG708B0 package directly to the external cooling interface. This additional path allows heat to be transferred through both the PCB and the dual-side cooling structure, reducing the overall junction-to-ambient thermal resistance. The top-side cooling approach therefore builds upon the PCB thermal path rather than fully replacing it, providing additional heat-removal capability while maintaining the compact footprint of the integrated GaN power ICs. **Figure 1** is a simplified representation of the package heat-flow path.

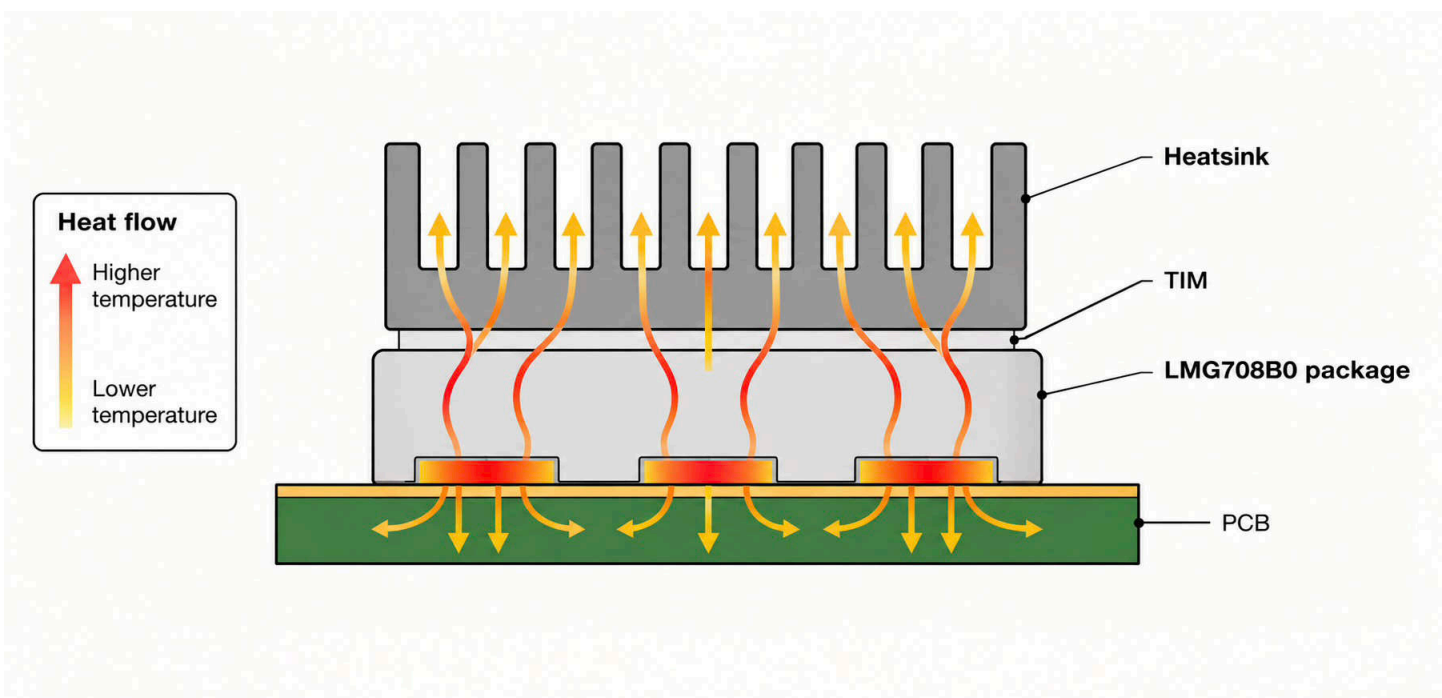


Figure 1. Simplified heat-flow paths through the LMG708B0 integrated GaN power multichip module package

GaN converter IC design and implementation

The **48V_{IN}, 960W Four-Phase Buck Converter with Integrated GaN Reference Design** was used to evaluate the thermal-focused design considerations. Distributing the load across four interleaved integrated GaN phases reduces the current and power dissipation in each phase while simultaneously supporting high output-current capability and compact solution size that 48V power conversion requires. **Table 1** lists the overall design specifications.

Design parameters	Value
Input voltage	48V (36V to 60V)
Output voltage	12V
Output current	80A (electrical design and thermal design current)
Topology	Four-phase synchronous buck
Switching frequency	400kHz (each phase)
Power stage	Four LMG708B0 devices
Reference design number	PMP23595

Table 1. Buck converter design specifications

To evaluate the resulting temperature distribution and heat flow through the package, cooling structure, and PCB a thermal simulation was conducted. The thermal simulation was created using Ansys Icepak® thermal modeling software tool. **Figure 2** shows the steady-state thermal simulation of the four-phase buck converter at the full 960W output at an ambient temperature of 25°C with no airflow, and 6.29W of power dissipation assigned to each of the four LMG708B0 devices. The power dissipation was calculated by obtaining the total power losses of the reference design at the full 960W output under the 25°C ambient temperature condition and subtracting the losses generated from the surrounding passives, leaving only the losses generated by the LMG708B0 devices. The device power dissipation corresponded to 25.16W of total power dissipation across the four phases. The simulated package temperatures are approximately 108°C across the four phases, still well below the recommended case temperature of the LMG708B0 device, which is 135°C.

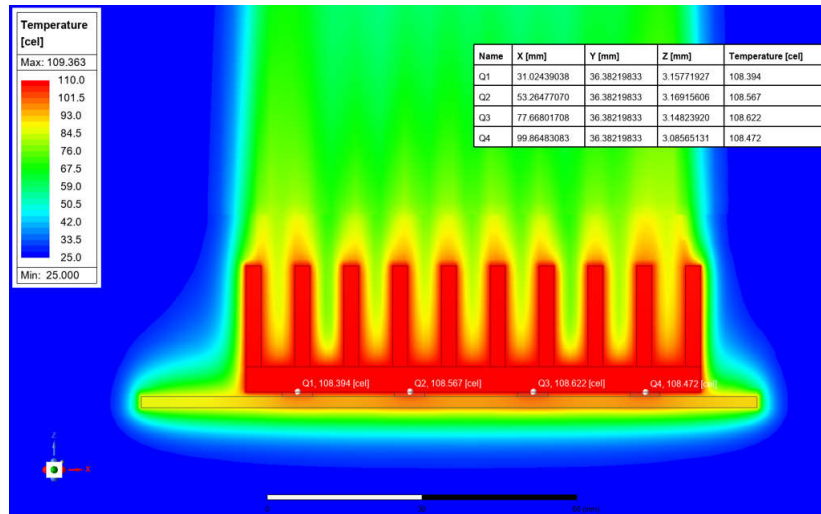


Figure 2. Thermal simulation of the four integrated GaN power stages with the dual-side cooling structure

The simulation also illustrates the thermal paths from the integrated GaN devices through both the dual-side cooling structure and the PCB. However, the simulation represents an approximation of the final hardware implementation. The modeled heat-sink geometry differs slightly from the final heat sink and does not account for the thermal interface material (TIM) used between the LMG708B0 packages and the heat sink. The TIM introduces additional case-to-sink thermal impedance that can affect the overall thermal performance of the dual-side cooling path. Therefore, the simulated temperatures provide a thermal reference for comparison with the measured converter performance discussed later in the article.

Experimental evaluation

The operating load range for evaluating converter performance was at a 48V input and 12V output. **Figure 3** shows the measured efficiency and corresponding power losses as a function of output current. Presenting both quantities provides a more complete view of converter performance. Efficiency indicates the effectiveness of power conversion, whereas the power-loss curve represents the thermal load that the converter must dissipate. To maximize the effect of the dual-side cooling package, a heat sink was attached during data capture with no additional airflow used. Details about the heat sink and the test setup are discussed later in the article.

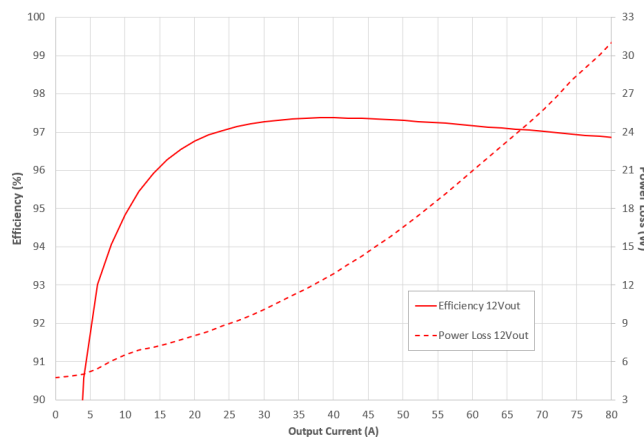


Figure 3. Measured efficiency and power loss vs output current

At lighter loads, relatively fixed losses associated with inductor core loss, gate drivers, and other control-related losses represent a larger percentage of the processed power. As the output current increases, these fixed losses become less significant relative to the output power and efficiency improves, reaching a maximum near 40A. Beyond this point, current-dependent losses become increasingly dominant because resistive conduction losses increase approximately with the square of the current (I^2R). Conduction losses within the power ICs, inductors, and high current PCB copper paths therefore increase rapidly with load current, resulting in a gradual reduction in efficiency as the converter approaches full load.

Although the efficiency decreases by only 0.5% between the peak efficiency and the maximum load, the corresponding power losses increase by 18.2W. This increase in absolute power losses represents a significant thermal load within the compact converter footprint and reinforces the importance of providing effective heat-removal paths for the power stages and surrounding components.

The measured power-loss data also provides context for the thermal simulation in **Figure 2**. The simulation assigned 6.29W of dissipation to each LMG708B0 IC, corresponding to 25.16W across the four phases at the 80A full-load operating point. At the measured 80A operating point, the total converter power losses are 31.2W. The difference between these values represents losses distributed among other converter components, mainly inductors and current sense shunt resistors, and PCB current paths, while also reflecting the assumptions used in the thermal model. Nevertheless, the comparison indicates that a substantial portion of the total thermal load is associated with the four integrated GaN power ICs, supporting the use of dedicated dual-side cooling to supplement heat spreading through the PCB.

Thermal performance

To characterize both the package-level temperature distribution and the effectiveness of the dual-side cooling approach, thermal performance was evaluated under two steady-state operating conditions. The first measurement, shown in **Figure 4**, is a 50A output current with the heat sink removed, enabling the thermal camera to directly observe the four LMG708B0 packages and surrounding PCB. At this operating point, the four-phase implementation delivers 600W of output power while dissipating approximately 16.6W of total measured power losses. The maximum observed temperature was approximately 97°C, with the highest temperatures concentrated around the power-stage region.

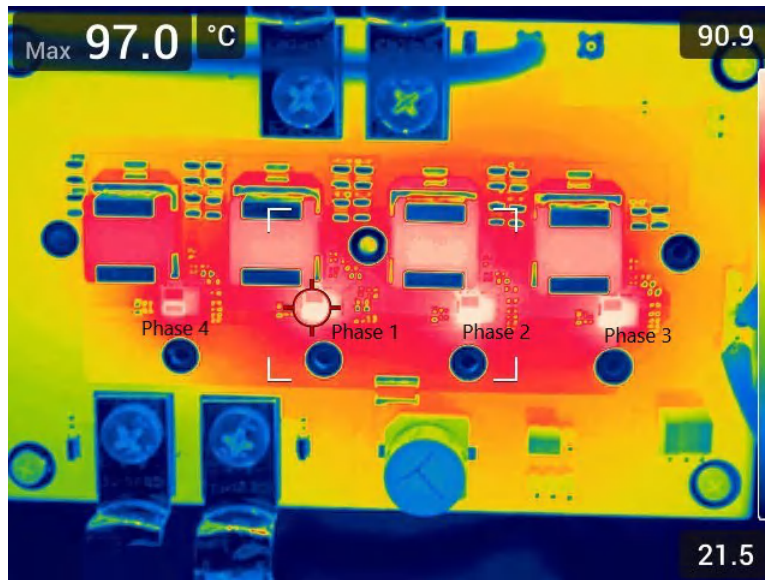


Figure 4. Infrared thermal image at 50A load without heat sink

Subsequently, the converter was evaluated at the full 80A load condition with a heat sink installed to maximize the effect of the dual-side cooling structure. The heat sink is made from aluminum, with a base size of 10.72 centimeters (4.22 inches) by 2.70 centimeters (1.06 inches) with a height of 1.61 centimeters (0.63 inches). Additionally, the heat sink has seven 2.54 centimeters (1.00 inch) high fins that extend from the base. The heat sink is designed to have a simple yet effective way of extracting heat away from the IC through the dual-side cooling package. Most applications, notably in the automotive sector, will have either a larger heat sink, such as the housing of the electronic control unit (ECU), or a more optimized cooling structure that will enable better performance. The TIM used between the heat sink and the LMG708B0 devices was the T-WORK9000, which is 1mm thick and has a thermal conductivity of 20W/m-K. At this operating point, the converter delivers 960W, corresponding to approximately 31.2W of total converter power losses. With the heat sink covering the integrated GaN packages, the thermal image shown in **Figure 5** primarily illustrates the temperature distribution across the external cooling structure and surrounding converter. The thermal image was taken after letting the converter maintain steady-state operation at 960W for approximately 20 minutes to reach thermal equilibrium.

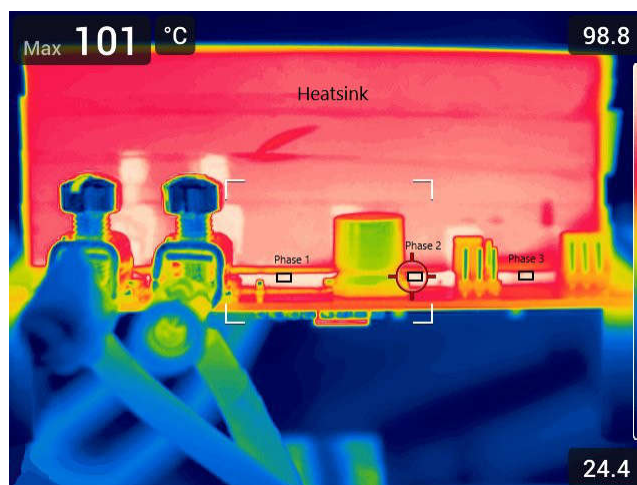


Figure 5. Infrared thermal image at 80A load with heat sink installed

Together, the two measurements demonstrate the complementary thermal paths incorporated into the converter design. The 50A measurement in [Figure 4](#) provides a direct observation of the power-stage and PCB temperature distribution, while the 80A measurement in [Figure 5](#) evaluates the complete cooling implementation under the maximum operating condition and illustrates the effectiveness of the dual-side cooling structure. These results complement the thermal simulation presented in [Figure 2](#), which modeled the 80A full-load condition. [Figure 5](#) presents a glimpse of the power stage region showing each IC to have an approximate temperature of 101°C. A more accurate case temperature was taken using thermal coupling with the wire leads placed on top of the primary LMG708B0 device but underneath the TIM and heat sink. The case temperature of the primary LMG708B0 device was 105.4°C. [Figure 6](#) shows the setup used for measuring the case temperature of the primary IC.

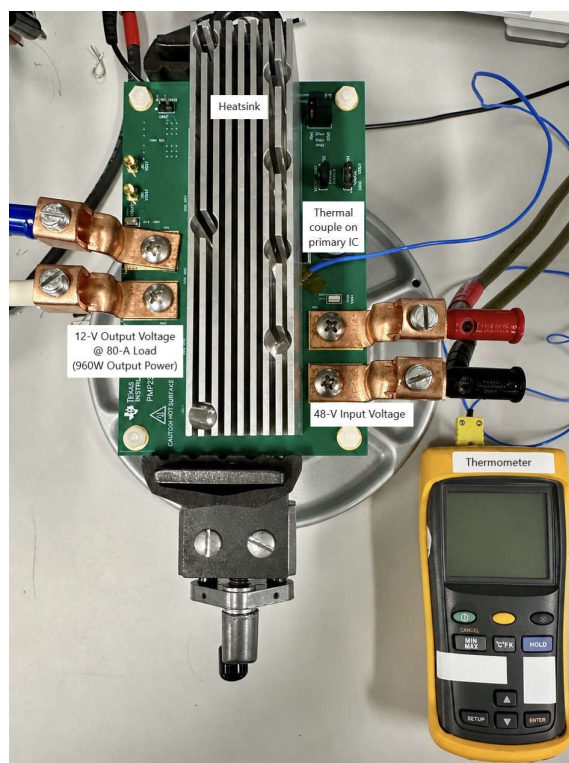


Figure 6. Test setup for thermal evaluation

These results coincide with the thermal simulation results to show the significance of the dual-side cooling structure. Moreover, the use of a larger or more reliable cooling system or adding a fan to provide airflow would achieve lower temperatures and thus enable even better system performance.

Conclusion

High-power-density converters require consideration of both electrical and thermal performance throughout the development process. While integrated GaN power ICs enable improvements in efficiency and power density, realizing these benefits depends on careful converter architecture, PCB layout, and thermal management.

The 48V_{IN}-to-12V_{OUT} four-phase synchronous buck converter design presented in this article demonstrates how integrating dual-side cooling within the overall converter design supports high efficiency while providing an effective path for managing power dissipation at high load. Considering electrical performance, power losses, and thermal behavior together enables compact and reliable integrated GaN power converters for high-current 48V power-conversion applications.

About the author

Matthew Bowers is a systems engineer in TI's Power Design Services team, focused on developing power solutions for automotive applications. He received his bachelor's degree in electrical engineering from Texas Tech University in 2023.

References

1. Texas Instruments. March 2016. "[Optimizing GaN performance with an integrated driver](#)." Texas Instruments white paper No. SLYY085. Accessed September 22, 2026.

Additional resources

- For more insight into the optimization of 48V multiphase applications, read the article "[Power Tips #151: Improving Efficiency in 48V-Input Multiphase Buck Converters with GaN](#)."

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