Application Brief

Layout Design Guide with DRV7308 for Improved Thermal Performance

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Thermal performance is one of the most important considerations when designing a motor driver system's PCB layout. Poor thermal design can lead to significantly reduced device performance, system performance, and even result in damage to the IC. The DRV7308 is a high-voltage integrated GaN-FET BLDC motor driver which requires additional design considerations to maximize the thermal performance and efficiency of the driver for 250W-450V systems. The goal of the documentation is to highlight the key aspects of designing a thermally effiicient 250W capable PCB layout using the 250W Motor Inverter Reference Design with GaN IPM DRV7308.

PCB Layer Choice Consideration for Thermal Efficiency

The first important consideration for designing a PCB for high-power applications is deciding the amount of substrate layers the board can have. Selecting an appropriate amount of layers can have a significant impact on the board's overall thermal performance of the motor driver design that relates to the dissipation of heat through the boards materials.

For high-voltage motor driver applications like those using the DRV7308, four-layer PCBs can offer a much better balance between thermal dissipation, electrical performance, and safety considerations compared to two-layer or 6+ layer boards. With the DRV7308 operating at 250W the supporting circuitry requires excellent heat management due to the high power levels involved, and four-layer boards, with dedicated copper power and ground planes, allow for this effective heat spreading. These additional layers help dissipate heat from the on-board hotspots in the power stage of the design by distributing heat throughout the inner layers and preventing those hotspots from compromising reliability and safety of the driver. These extra internal layers can also allow for increased copper thickness of 2oz to more efficiently dissipate heat.

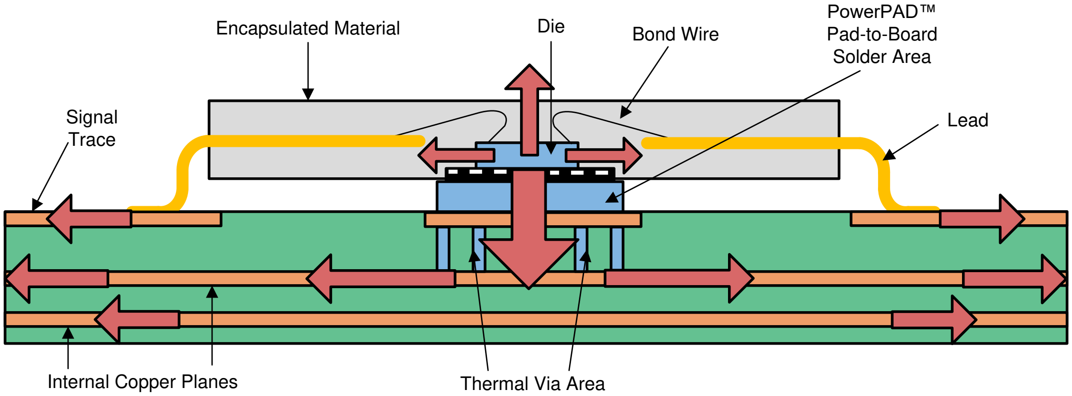


Figure 1. Cross Section of Thermal Pad™ Package Mounted to PCB and Resulting Heat Transfer

The DRV7308 VQFN package comes equipped with a thermal pad that more easily allows heat to transfer from the device directly into the channels of the PCB.

Compared to four-layer boards, the extra thickness of 6 or 8 layer boards can act as thermal insulation trapping heat within the structure, especially if the design does not adequately route thermal vias to dissipate heat toward the surfaces or away from critical components. For high-voltage designs, simplicity is also important for safety; utilizing four layers reduces unnecessary design complexity, allowing for better trace widths, trace routing, necessary isolation standards while still enabling effective heat dissipation. Overall, four-layer PCBs provide an exceptional balance of thermal performance and design flexibility.

Benefit of Copper Pours for Thermal Dissipation

Using larger copper pours where possible in a motor driver PCB instead of wider traces to deliver current is a highly effective technique for improving thermal dissipation, which is crucial in 250W applications where integrated power components like the DRV7308 generate substantial heat. Some benefits of using copper pours:

- **Reduces the complexity of trace-routing by connecting NETs through a surface area**
- **Increases maximum surface thermal dissipation capability**
- **Increases the effectiveness of thermal stitching vias**
- **Reduces the chance of bottle-necking current flow through constricted traces**

Copper is an excellent conductor of heat, so increasing the copper surface area allows for more efficient spreading of heat away from hotspot components like bulk capacitors, rectifiers, and the motor driver. Larger copper pours on the power and ground planes create a low-resistance path for both electrical current and heat, minimizing localized heating and distributing thermal energy throughout the board. Additionally, larger copper areas reduce thermal impedance, making sure that heat flows more efficiently from heat-generating components to the rest of the board, where the heat can dissipate into the environment.

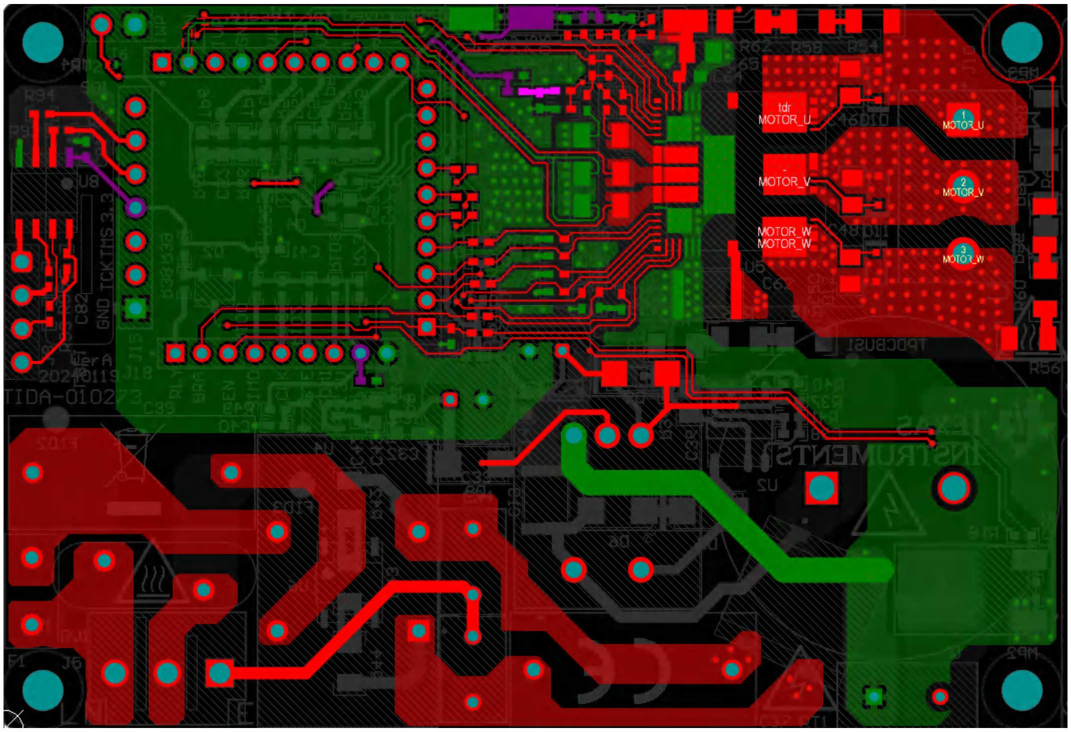
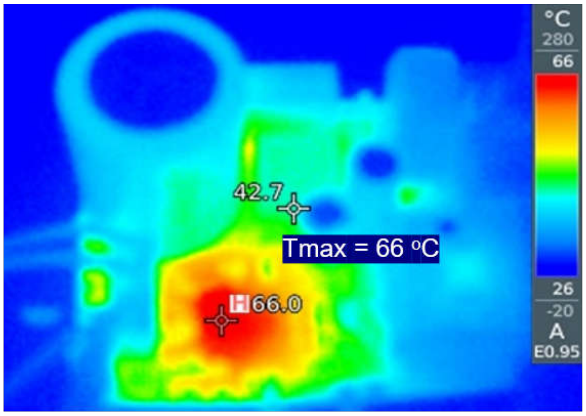


Figure 2. TIDA-010273 DRV7308 PCB Trace and Copper Pour Routing

The DRV7308 utilizes integrated GaN-FETs that, despite having a low 205mOhm $R_{DS(ON)}$, still produces additional heat due to motor output current dissipating directly inside the IC package. This approach of using large copper pours for routing the output motor current enhances the reliability and longevity of the motor driver by reducing the thermal stress localized on the board, preventing thermal cycling, and avoiding heat build-up around each GaN-FET that can lead to premature component failure. The copper pouring in the TIDA-010273 for non-motor output channels is approximately 118mills^2 at minimum and provides wide paths for current to flow and heat to dissipate through the board.



*Tested at 300VDC, 250W, 0.85ARMS, TA = 25 °C,
Slew rate = 5V/ns*

Figure 3. TIDA-010273 Hotspot Thermal Efficiency Test

With proper utilization of copper pouring a high thermal performance can be achieved more easily. With the routing designed in Figure 3, the TIDA-010273 DRV7308 PCB can achieve a peak operating temperature of 66°C at 250W.

Larger copper pours provide a practical, cost-effective way to achieve better thermal performance without adding extra layers or complex thermal management features. In high-voltage applications, these pours can also act as robust ground planes, stabilizing the board electrically and making sure there is adequate spacing around high-voltage traces to prevent arcing or dielectric breakdown.

Thermal Via Placement and Density

Thermal stitching vias are another crucial design implementation necessary for maximizing thermal performance for higher-power applications like the TIDA-010273 250W design. Thermal vias are small copper-plated holes strategically placed under or around heat-generating components, such as capacitors, rectifiers, and the motor driver IC, to conduct heat from the surface layers down into the inner layers or ground planes of the PCB. This vertical heat path effectively spreads heat away from sensitive components and distributes heat across a broader area of the board, reducing the risk of localized hotspots. In high-voltage DRV7308 motor driver designs where safety and thermal management are essential, well-placed thermal vias help make sure of temperature stability, prevent overheating, and enhance overall board reliability and efficiency.

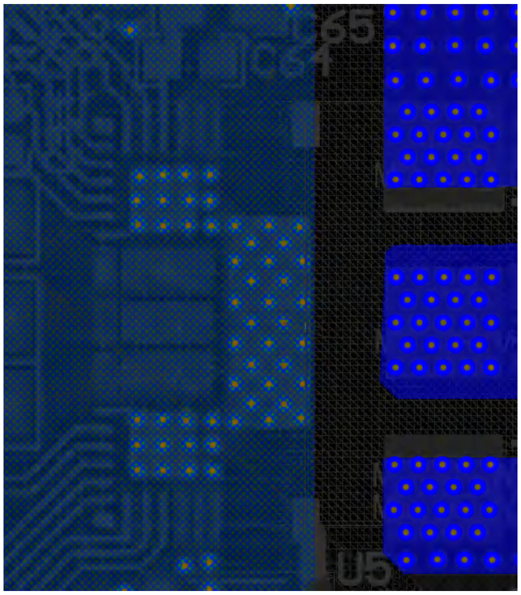


Figure 4. TIDA-010273 Thermal Vias Under DRV7308 Pad

The required size and placement of vias depend on the specific thermal requirements and current load of the application. For a 250W application, vias with a diameter of 0.3-0.5mm are very effective. This size provides sufficient cross-sectional area to allow heat transfer without taking up excessive space on the board or affecting electrical isolation requirements. Using multiple vias in parallel is also ideal for spreading heat evenly near device hotspots. For the TIDA-010273 reference design, a via density of approximately 12 stitching vias per 110mills^2 allows for effective heat transfer under the driver's thermal pad and phase output terminals while maintaining structural integrity and avoiding electrical faults. It is essential to fill or plug the vias if the component requires a flat mounting surface, like the DRV7308's VQFN package, as this can help avoid solder wicking during assembly, ensuring solid component-to-board contact for efficient thermal transfer. For higher-current designs, the copper plating thickness of thermal vias also matters significantly. Thicker copper plating improves conductivity, lowering thermal resistance through the via. PCBs with a higher copper weight, such as 2 oz copper, can benefit more from these vias, as PDBs connect heat-generating components directly to substantial ground or power planes allowing for a better distribution of built-up heat. Using thermal vias, combined with large copper pours and appropriate trace widths, helps keep the PCB cool, enhancing both the thermal and electrical performance of the DRV7308.

Operating Voltage, Current, and Power Output

While the DRV7308 is rated for 250W without a heatsink, using the 5A peak current output to achieve this power can lead to an increase in internal heat generated by the IC. Following the relationship between voltage, current, and power, **P = I x V**, this is more efficient to use higher voltages with lower current to achieve the desired power level. For example, a 250W design can be achieved with a supply voltage of 300V and RMS current of 0.85A, or with a 450V supply drawing 0.55A RMS. As mentioned previously in this document, the DRV7308 features low 205mΩ $R_{DS(ON)}$ which is factored into the equation for heat generated proportional to the square of the current: **Heat =** $\mathbf{I^2R_{DS(ON)}}$. At 0.85A and 0.55A current draw, the heat generated at 300V compared to 450V is produced in a ratio of [2.4 : 1], which is a significant decrease in heat losses. This information showcases why it is best recommended to operate closer to the maximum rated voltage, if possible, and to make sure the layout design and system is equipped with components rated for the maximum operating voltage of 450V at minimum.

Conclusion

There are many important decisions that contribute to a thermally efficient system, and designing a PCB for high-power, high-voltage motor drivers requires careful consideration of thermal management techniques to make sure maximized reliability and efficiency. A four-layer board is often ideal for such applications, providing a balance between cost, thermal dissipation, and electrical stability. Larger copper pours effectively spread generated heat across the board, reducing localized hotspots and allowing excess heat to dissipate through the surface and inner layers. Thermal vias further enhance heat transfer by creating vertical pathways from surface-mounted components into internal ground or power planes, helping to manage the high thermal load of the DRV7308. Using a thermal via diameter (0.3-0.5mm) and density (12 / 110mills^2) allows heat to spread evenly while maintaining the board's structural integrity and high-voltage isolation. Component placement and supply considerations allow for additional options to reduce the amount of heat generated and where concentrated. Together, these design elements combine to create a robust, thermally efficient PCB capable of handling the demands of 250W GaN.

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