

High Efficiency Power Supply Design for FPGA-Based Systems

Part 2 of 2 Thermal Performance and Layout

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60W by Paralleling Four DC/DC μ Module Regulators

In part one of this article, we discussed the circuit and electrical performance of a compact and low profile 48A, 1.5V DC/DC regulator solution for a four-FPGA design. The new approach uses four DC/DC μ Module™ regulators in parallel (Figure 1) to increase output current while sharing the current equally among each device. This solution relies on the accurate current sharing of these μ Module regulators to prevent hot-spots by dissipating the heat evenly over a compact surface area. Each DC/DC μ Module is a complete power supply with on-board inductor, DC/DC controller, MOSFETs, compensation circuitry and input/output bypass capacitors. It occupies only 15mm \times 15mm of board area and has a low profile (height) of only 2.8mm. This low profile allows air to flow smoothly over the entire circuit. Moreover, this solution casts no thermal shadow on its surrounding components, further assisting in optimizing thermal performance of the entire system.

Thermal Performance

Figure 2 is a thermal image of the board shown in Figure 1 with readings of the temperatures at specific locations. Cursors 1 to 4 show an estimation of the surface temperature on each module. Cursors 5 to 7 indicate the surface temperature of the PCB. Notice the difference in temperature between the inner two regulators, cursors 1 and 2, and the outside, cursors 3 and 4. The LTM4601 μ Module regulators placed on the outside have large planes to the left and right promoting heat sinking to cool the part down a few degrees. The inner two only have small top and bottom planes to draw heat away, thus becoming slightly warmer than the outside two.

Airflow also has a substantial effect on the thermal balance of the system. Note the difference in temperature between Figures 2 and 3. In Figure 3, a 200LFM airflow travels evenly from the bottom to the top of the demo board, causing a 20°C drop across the board compared to the no airflow case in Figure 2.

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Figure 1. Four DC/DC μ Module Regulator Systems Current Share to Regulate 1.5V at 48A With Only 2.8mm Profile and 15mm \times 15mm of Board Area for Each Device. Each μ Module Regulator Weighs Only 1.7g and Has an IC Form-Factor that Can Easily be Used With Any Pick-and-Place Machine During Board Assembly

Application Note 119B

The direction of airflow is also important. In Figure 4 the system is placed inside a 50°C ambient chamber with airflow traveling from right to left, pushing the heat from one μ Module regulator to the next, creating a stacking effect. The μ Module device on the right, the closest to the airflow source, is the coolest. The leftmost μ Module regulator has a slightly higher temperature because of spillover heat from the other μ Module regulators.

Heat transfer to the PCB also changes with airflow. In Figure 2, heat transfers evenly to both left and right sides of the PCB. In Figure 4, most of the heat moves to the left side. Figure 5 shows an extreme case of heat stacking from one μ Module device to the next. Each of the four μ Module regulators is fitted with a BGA heat sink and the entire board is operated in a chamber with an ambient temperature of 75°C.

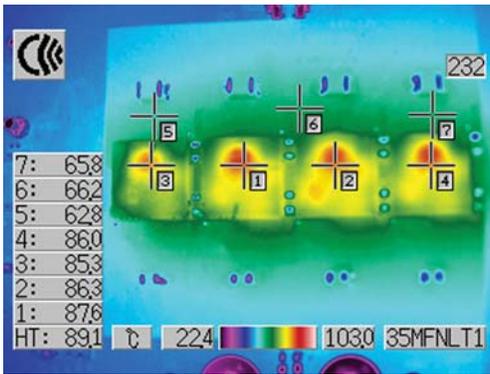


Figure 2. Thermograph of 48A, 1.5V Circuit of Figure 1 Shows Balanced Current Sharing Among Each DC/DC μ Module Regulator and Low Temperature Rise Even Without Airflow ($V_{IN} = 20V$ to $1.5V_{OUT}$ at 40A)

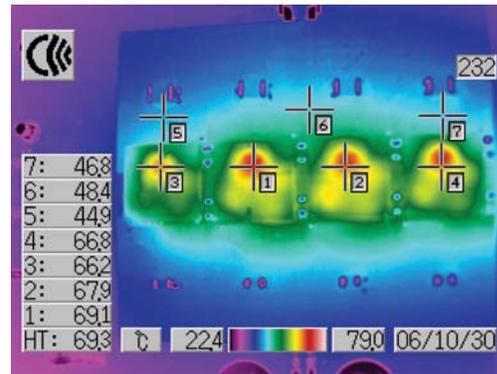


Figure 3. Thermograph of Four Parallel LTM4601 with 200LFM Bottom-to-Top Airflow ($20V_{IN}$ to $1.5V_{OUT}$ at 40A)

↑↑↑
AIRFLOW
DIRECTION

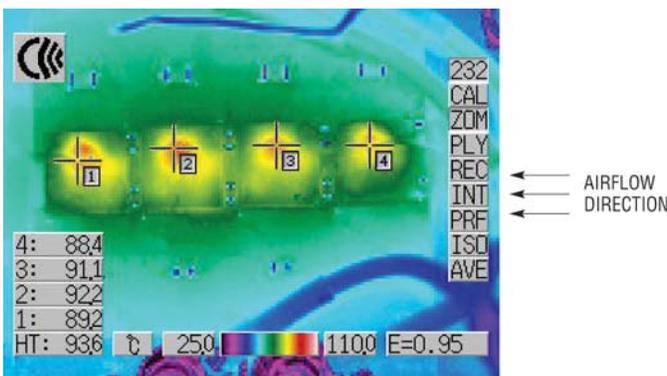


Figure 4. Thermograph of Four Parallel LTM4601 with 400LFM Right-to-Left Airflow in 50°C Ambient Chamber ($12V_{IN}$ to $1V_{OUT}$ at 40A)

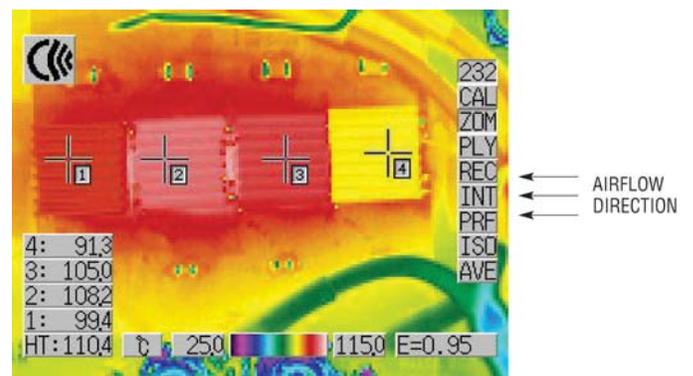


Figure 5. Thermograph of Four Parallel LTM4601 With BGA Heatsinks and 400LFM Right-to-Left Airflow in a 75°C Ambient Chamber ($12V_{IN}$ to $1V_{OUT}$ at 40A)

Simple Copy and Paste Layout

Layout of the parallel μ Module regulators is relatively simple, in that there are few electrical design considerations. Nevertheless, if the intent of a design is to minimize the required PCB area, thermal considerations become paramount, so the important parameters are spacing, vias, airflow and planes.

The LTM4601 μ Module regulator has a unique LGA package footprint, which allows solid attachment to the PCB while enhancing thermal heat sinking. The footprint itself simplifies layout of the power and ground planes, as shown in Figure 6. Laying out four parallel μ Module regulators is just as easy, as shown in Figures 7 and 8.

If laid out properly, the LGA packaging and the power planes alone can provide enough heat sinking to keep the LTM4601 cool.

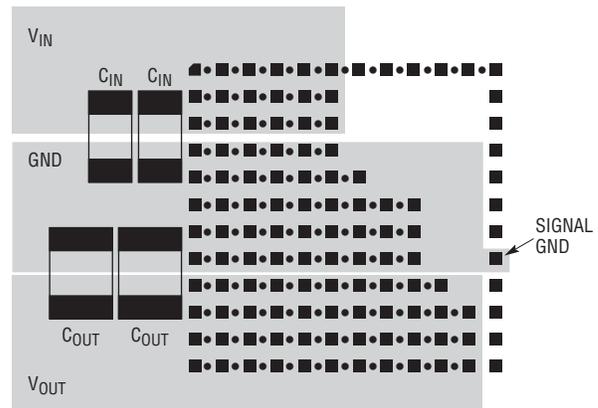


Figure 6. The LTM4601's Pin Layout Provides Simple Power Plane Placement and Easy Paralleling Capability (Copy and Paste Approach)

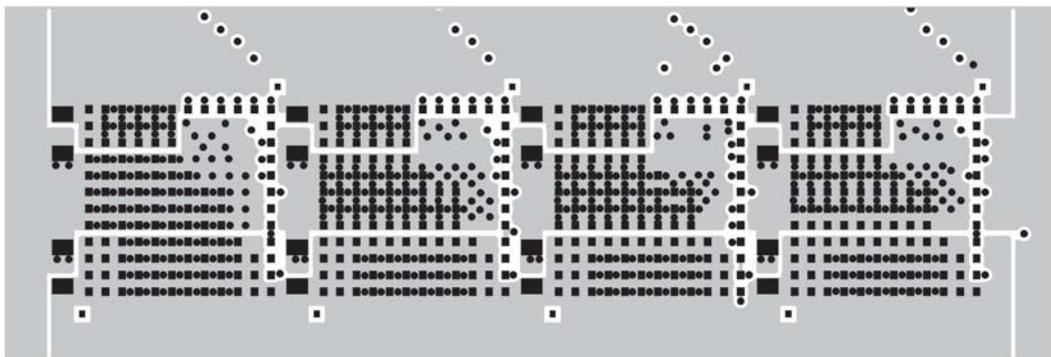


Figure 7. Top Layer Planes for Figure 1 Circuit

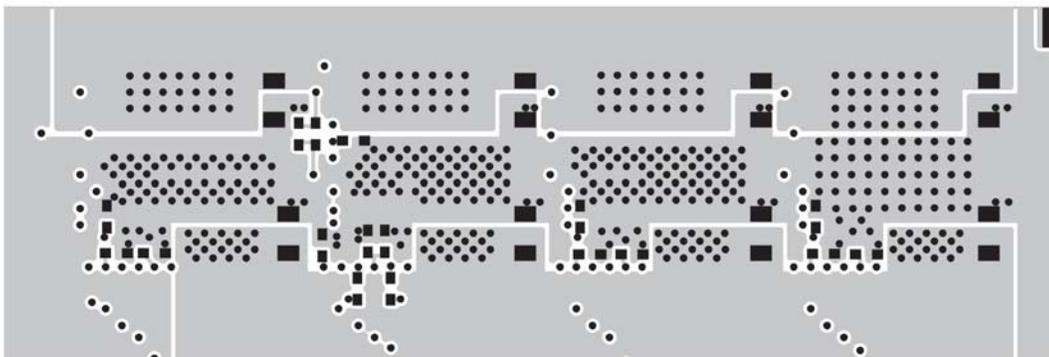


Figure 8. Bottom Layer Planes for Figure 1 Circuit

Application Note 119B

Conclusion

Delivering 60W of power in a compact space without efficient means to remove the heat from the power supply exacerbates the already difficult task of system heat management and cooling. The DC/DC μ Module family is designed with careful attention to the layout of its internal components, package type, and electrical operation, which ease thermal management of a very dense power supply

circuit. The LGA package and simple layout allow 100% surface mountable and low profile design for maximum efficiency in air flow. This new approach in power supply design takes advantage of paralleling multiple DC/DC μ Module regulators and following a copy and paste approach in layout design, to provide a 60W power supply with minimum components while operating efficiently in a compact and low profile space.