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Real-world power tests model FPGA's thermal characteristics

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Given ever-increasing clock frequencies and higher gate counts, many systems that include high-performance FPGAs (field-programmable gate arrays) routinely require a thoroughly analyzed thermal model. While working on a project that contained an FPGA, I realized that I had insufficient data to determine the FPGA's exact power dissipation, which my mechanical-engineering colleague required to construct a system model for thermal analysis using Flomerics' (www.flomerics.com) Flotherm software.

Although we had created fully functional hardware, we hadn't included a method of measuring the FPGA's exact power consumption, a problem further complicated by the presence of multiple power-supply voltages that fed additional circuits on the board. Although the manufacturer's FPGA-power-calculation spreadsheet allowed us to approximate the circuit's total wattage, the calculated values related only to its internal power consumption and didn't account for power not dissipated in the chip—that is, power delivered to I/O lines that drive other devices. To further confuse the issue, we lacked information about the FPGA package's thermal properties.

My mechanical-engineering colleague and I decided to create a controlled experiment by placing a functioning PCB (printed-circuit board) inside an improvised temperature chamber—a cardboard box. We would apply a precise amount of power only to the FPGA, measure its package's external temperature, and measure its internal die temperature using the FPGA's on-chip temperature-sensing diode. We would then model the experiment in Flotherm and adjust the package's thermal properties until the simulation's results matched the measurements.

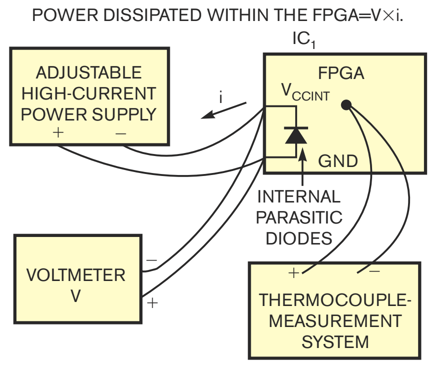

Figure 1 To measure an FPGA's thermal parameters, apply controlled forward bias to its internal parasitic diodes, thereby dissipating a known amount of power within its die.

Next, we would measure the FPGA's temperature while it executed an actual VHDL application within the temperature-controlled environment and work backward to determine the true power dissipation. Finally, we would create an accurate Flotherm model that would allow completion of a properly rated heat-sink design for the FPGA.

The only nonobvious part of this process involved how to dissipate a controlled amount of power within the FPGA. Acting on a flash of inspiration, I connected a nonfunctional PCB to a power supply and reversed the polarity of the FPGA's core voltage. By doing so, I applied forward bias to the FPGA's internal parasitic diodes that connect between power and ground and the device's I/O-voltage rails and protection diodes (**Figure 1**). Under normal circumstances, these diodes remain reverse-biased and dissipate no power. Reversing the power-supply polarity forward-biased the diodes, dissipating power and heating the FPGA's die.

To obtain an exact voltage measurement, I added Kelvin-connected sense leads to the FPGA's power pins. I configured the power supply to operate in constant-current mode and adjusted its output to deliver exactly 2W of power as determined by multiplying the supply current and the voltage at the FPGA's power pins. My colleague configured the test probes' placement and performed the temperature measurements. Upon completion of our experiments, the temperatures that the Flotherm model predicted agreed with those we measured in our system's final configuration, including its heat sink, within a margin of 3 to 4°C.EDN