How Thermal Efficiency Is Helping Data Centers Run More Sustainably

Innovative semiconductor design and packaging technologies are improving efficiencies in data centers as server power demands increase

Every time we stream the latest movie, talk to AI-driven voice assistance or attend a business meeting from home using a laptop computer, we're pushing large amounts of digital information through data centers and using resources that consume vast amounts of electricity. And that usage is only increasing.

By Les Stark, Director of QFN and SOT Package Development, and Robert Taylor, Applications Engineer, Texas Instruments

In 2022, the world created and consumed nearly 100 zettabytes – 100,000 billion gigabytes – of data. That incomprehensibly vast ocean of bits is projected to almost double by 2025.1 And increasingly, that data is running through hyperscale data centers, each filled with thousands of servers.

Estimates by the U.S. government place the energy demands of data centers at 70 terawatt-hours per year.2 Increases in blockchain mining alone have more than doubled that figure since then. Current data center consumption is likely accounting for at least 2% of total U.S. electric power consumption, according to the Center of Expertise for Energy Efficiency in Data Centers.3 That's enough to have a significant impact on the environment, which adds urgency to the goal of enabling data centers to run more sustainably.

As servers in these centers evolve to handle and process the exploding flow of data, the electric power consumed by each server is growing as well — from an average 1,500 watts per server in previous years to 3,000 watts in newer servers, said Robert Taylor, a systems manager with our company who specializes in industrial power management.

Achieving higher power densities and thus improved efficiency in server power supply units (PSUs) is one way to achieve more efficient data center operations.

There's an additional urgency to upgrade server PSUs, Robert said. The growing power demands of data centers are bumping up against a bottleneck: Most hyperscale data centers can't bring in more than 50 megawatts of electric power.

"Because the total amount of power is limited in these data centers, they need to waste as little power as possible on cooling and on losses due to inefficiencies in the electronics," Robert said.

At the same time, he said, the server industry is demanding smaller printed circuit board footprints to fit more computing power in each rack. That means the power components in servers have to become smaller and more efficient without producing excessive heat.

Our company has taken the lead in producing innovative semiconductor power products that meet the daunting performance, efficiency and thermal management demands of the current and future generations of leading-edge data centers. The resulting power supplies are helping keep even the largest data centers running smoothly with more sustainable footprints.

Handling higher power and temperatures

The key to high-performance, energy-efficient semiconductor power supplies is to achieve ever-higher levels of power density — that is, to pack more power-handling capacity into smaller volumes. But higher power densities also pack more heat into that reduced volume, and that requires advanced thermal management techniques to sustain performance and protect components.

The need for higher power density isn't unique to data centers. Electric systems from grid and communications equipment to electric vehicles and personal electronics also need the performance and efficiencies offered by denser, thermally efficient power chips.

Produce less heat with efficient packages

Our company is stepping up to the challenge of providing higher power density in server power supply chips. Small outline transistor (SOT) packages with integrated switches are expanding the boundaries of power densities and performance while lowering cost.

Advances such as these wouldn't be possible without innovative approaches to thermal management. There are three key areas we focus on to optimize thermal performance and break through power density barriers at the chip level: process technology, circuit design techniques and thermally optimized packaging.

Much of the heat produced in servers has come from power losses due to the conversion of incoming AC power at 400V down to DC power at 6V or less. Products such as the TLVM13630 power module use our Enhanced Hotrod™ Quad-flat No Lead (QFN) package technology with integrated field-effect transistors (FET) that deliver fast switching speeds and lower resistance to sharply cut those power losses, boosting chip efficiency and thus trimming heat.

"Any resistance in the silicon is inefficiency, and that's wasted power and extra heat," said Les Stark, director of QFN and SOT package development at our company.

To further cut losses that produce extra heat, our company is taking advantage of industry-leading capabilities such as integrating more components into power chips, including FETs and capacitors. That integration provides faster, more efficient switching with less noise, as with the TPS25985 eFuse with ultra-low on-resistance, delivering better thermal performance while achieving as much as 80A of current. In some cases, our company achieves higher integration through 3-dimensional stacking of components on the chip.

Remove heat effectively with thermally enhanced packages

Our company also has taken the lead in getting heat off of chips with innovative device packaging. For example, our company pioneered HotRod and Enhanced HotRod QFN packages that use a flip-chip style package to directly bond the surface of the chip and its connectors to the circuit board, instead of relying on bond wires to get signals in and out of the chip. That more direct connection is highly efficient at moving heat off the chip onto the board.

"This package design provides large ground pads that weren't previously possible, allowing good thermal paths from the devices into the printed circuit board," Les said.

Our company's other advanced approaches to removing heat include more effective heat-sink placement to achieve improved top-side cooling. Our gallium nitride (GaN) FETs employ top-side cooled packages, which will become increasingly important in data center systems as the drive to pack more computing power into each server leads to new, denser component arrangements that require more ways to get heat off of the chips.

"As GaN enables us to achieve ever-higher power densities, this sort of flexible approach to cooling will become all the more important," Robert said.

Any one of these efficiency-increasing and heat-removing approaches in a tiny chip can make a big contribution to thermal management and efficiency. By optimizing packages for both size and efficiency, we are helping solve data-center customers' heat problems and reducing environmental footprints.

Ressources:

1 Source: https://www.statista.com/statistics/871513/worldwide-data-created/

2 Source: Center of Expertise for Energy Efficiency in Data Centers - https://datacenters.lbl.gov/resources/united-states-data-center-energy-usage

3 Source: Center of Expertise for Energy Efficiency in Data Centers – https://datacenters.lbl.gov/who-we-are

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