Improve Server Efficiency with Advanced Control Electronics

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Power-management methods and three-phase BLDCs for cooling reduce data-center energy use. This note discusses emerging energy-conservation strategies and examines some of the Allegro™ products that support these technologies.

Introduction

The worldwide growth in computer server farms and Internet traffic has resulted in this infrastructure consuming global energy production at an accelerating rate. It is now estimated that the world's 500,000 data centers and 32 million individual servers consume 1.5% of global electricity—about 300 TWh of electricity per year (reference 1).

With significant efficiency improvements already attained, attention is now turning to power and heat management at the server-component level, specifically the on-board cooling fans themselves, which consume 10% to 15% of the total power used by the server (reference 2).

Recent advances in integrated control electronics provide local closed-loop control of both supply to the server and demand within components. These advances also make it practical to migrate from traditional single-phase BLDC (brushless DC) motors to highly efficient three-phase BLDC motors for the fans, typically realizing up to 25% improvement in efficiency.

The electronic devices allow inexpensive management of server components with minimal contributions to thermal signature, power draw, or physical size. Some, such as the Allegro MicroSystems A4942 three-phase sensorless BLDC fan- motor driver chip, are small enough to fit onto the hub PCB of mini ducted fans. The hub PCB is a small ring-shaped board with as little as 5-mm effective width, to accommodate the rotor shaft (figure 1). Monitor ICs, such as the ACS761, provide current and power monitoring and control, enabling hot-swap management at the individual server blade level.

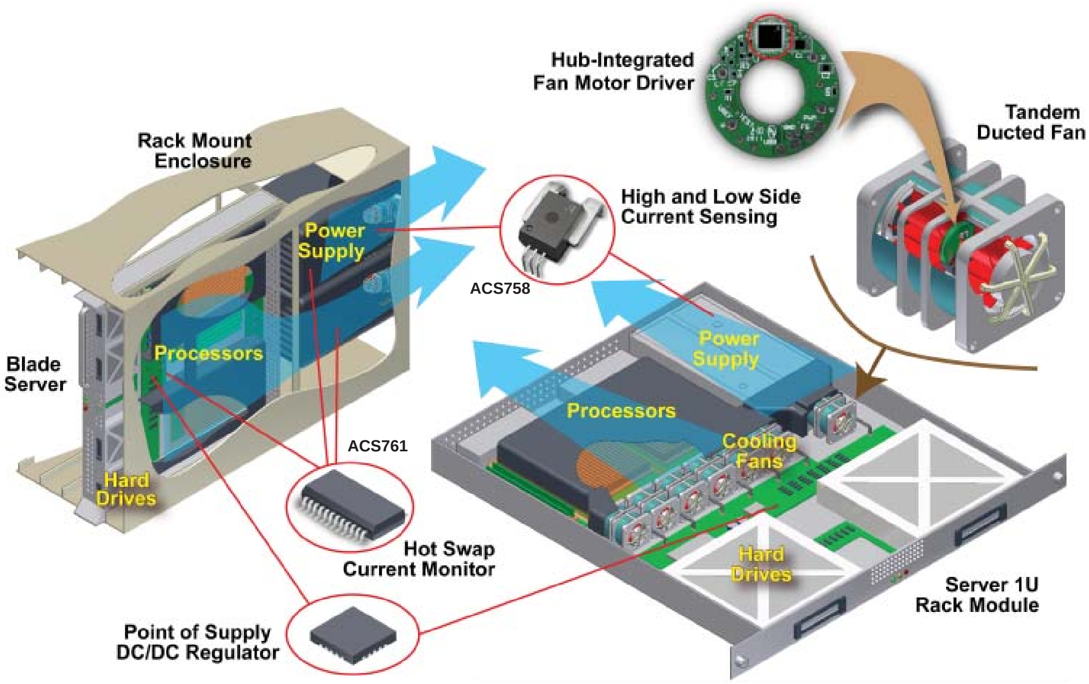

Figure 1 Fan-management, current-sensing, hot-swap-management, and PoS-regulation applications in standard rack-mount and blade servers.

Energy reduction strategies

The latest generations of servers provide several new approaches to energy management, which allow rapid recovery of conversion costs—often within a year. For example, microprocessors have been designed for higher throughput in smaller packages, requiring less power and generating less heat.

Studies of the individual thermal sources, principally power supplies and microprocessors and their enclosures, have led to optimized heatsink geometries and component layouts, with channeled shrouds to direct laminar airflow across these key areas. This complements the more recent high-efficiency ducted miniature (less than 40-mm) tandem fan-motor assemblies, arranged in series or parallel arrays within these flow paths.

To increase airflow efficiency and minimize footprint, the integrated fans assemble in tandem pairs that share the same ducting. The two fans are, however, completely independent in terms of mounting shaft and drive electronics. While this could gain an advantage from modular control, in fact it can introduce problems effecting reliable sensorless motor startup: left to themselves, one of the motors will start first, causing airflow over the other fan and dragging the motor and interfering with the open-loop startup sequence.

A similar problem can occur when one fan has not yet stopped turning when the motors restart. In the past, this phenomenon made it necessary to allow both fans to come to a complete stop before restarting. The new motor-driver ICs contain an adaptive startup algorithm that can interpret when the motor is being driven by airflow over the fan blades from the tandem fan or when the motor and fan are already in motion from a previous power cycle. The advanced IC can modify the power-on sequence to adjust for this and allow both fans to operate synchronously at maximum efficiency throughout the power cycles.

Optimization of airflow is fixed, however, and improvements in PID control systems are required to optimize fan usage in terms of speed and idle time. Many servers are utilized only a small percentage of the time. Energy during the low demand periods can be saved by low-power modes or even power-down modes with automatic startup.

This can be accomplished by monitoring current consumption as the components operate, using current sensing ICs that can mount on the PCBs in the servers for lower-current onboard applications, or on supply lines for high-side current sensing. These compact ICs measure current magnetically, using the Hall effect, eliminating the need for sense resistors, which dissipate heat. For example, an integrated conductor, such as in the Allegro ACS758, presents only 100 μΩ resistance, which is an order of magnitude lower than typical sense resistors, and results in significant power savings.

This technology also provides isolated current sensing in a compact package, providing a low voltage output signal for closed-loop feedback. Applied with advanced PWM motor drivers, these devices can control supply current surges and ensure direct closed loop fan speed control to hold the airflow rate consistent and in proportion to the actual cooling requirement.

This also results in material savings because motors do not have to be overdesigned to compensate for large motor-to-motor torque and speed variations. Individual motors often have electrical characteristics that vary more than 10% between units. In addition, the local environments in which the motors mount vary substantially and inconsistently in terms of electrical supply and load, as well as thermal loading from coolant flow and adjacent heat sources.

Advanced PWM motor drivers and hot-swapping current monitoring ICs can suppress current surges as the motors turn on. New device types apply soft-start PWM current-ramping techniques that allow the designer to optimize tradeoffs between surge current and power cycle times (figure 2).

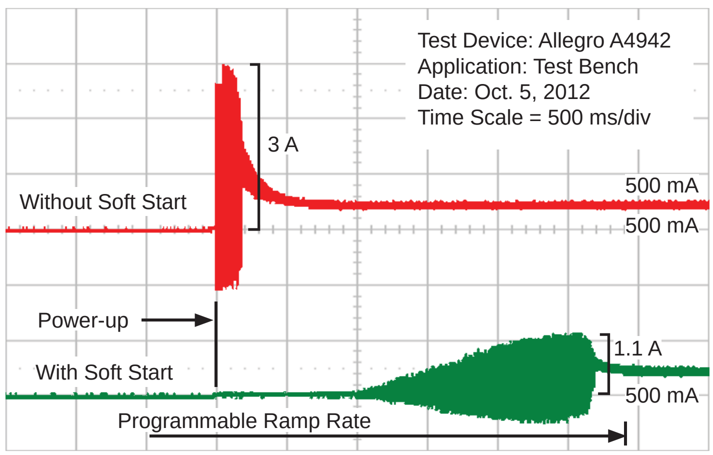

Figure 2. Effect of soft start in reducing surge current

Additional efficiency is gained by the test device—in this case, the A4942—which has advanced features that start to energize the motor phase windings in advance of the timing defined by the rotor position.

This phase advance technique ensures that the phase windings have reached the required current level at the point where the resulting forward torque on the rotor will be most effective, thereby improving motor efficiency. Note that the start and stop conditions are the same but with soft start, the maximum current is greatly reduced. The longer power-up may not be significant in start-stop fan applications, and can be programmed to tradeoff with power surge.

Integrating Hot-Swap Management

Existing server-blade technology seeks to minimize these variances by the modular approach, placing power supplies and cooling fans off-board from the memory storage and processor elements. However, this incurs significant risks in hot swapping. Current sensor ICs with integrated hot swapping controls manage power surges that occur due to the makes and breaks of electromechanical connections. The soft start of an external FET controls the hot-swap power surge and provides current limiting (figure 3). By controlling the FET turn-on time when power is connected, the hot-swap current-sensor IC, in this example the ACS761, reduces the inrush current from 32 A to 12 A.

Hot-swap management affects the design of the other components in the server. This reduces the requirement for components to be rated for high inrush current levels. Additionally, by integrating current and power limiting, the hot-swap IC not only minimizes the board area that must be isolated from the operator for compliance with UL 60950, but also provides short-circuit protection.

Three-phase motor advantages

Although single-phase BLDC motors cost less than three phase motors, increasing energy costs have made the higher efficiency of the three-phase motor an economic offset. Typical efficiency improvements from single-phase BLDC motors to three-phase BLDCs are approximately 25%.

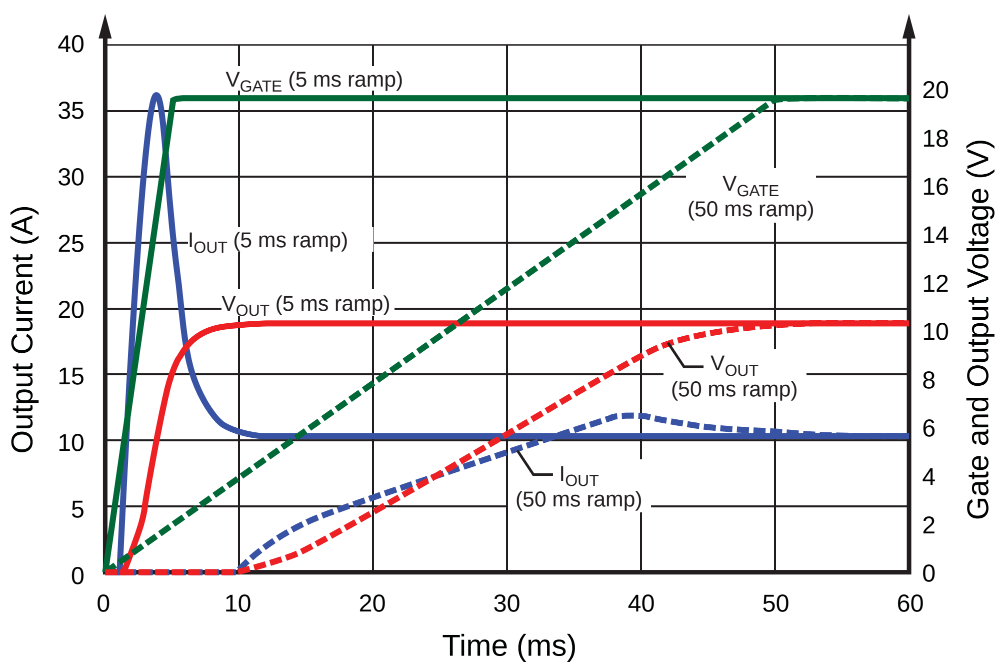

Figure 3. Hot-swapping current-surge suppression simulation

Designs achieve further cost reductions using techniques such as motor soft start to reduce the current surges from the power supply at startup. This reduction in surge current also allows smaller FETs and reduces costs for power supplies.

Along with optimized motor drivers, power-regulation techniques can optimize the operation of various components and systems within the server. QFN-sized DC-to-DC regulators provide point-of-supply management integrated with advanced features, such as synchronous rectification for high efficiency, short minimum controllable on-times, and optimized high- and low-side FET $R_{DS(on)}$ ratios for V_{IN}/V_{OUT} ratios commonly found in servers. These provide robust fault-tolerant power management to withstand variable operating conditions, and detect and report a wide variety of fault conditions.

Three-phase BLDC motors used with advanced integrated circuit control and monitoring are providing significant efficiency gains now, and provide a path to future improvements. Because these technologies can apply at the subsystem level, they can scale to both DG (distributed generation) and CHP (combined heat and power) systems. With the improved electronic evaluation techniques, these devices enhance server-system microgrid integration with Smart Grid systems.

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