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How eFuses Strengthen Power-Path Protection For Cooling Fans In AI Servers

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As use cases for high-performance computing and artificial intelligence (AI) continue to expand, data centers demand power-dense, efficient solutions to support the latest central processing units, graphics processing units (GPUs) and hardware accelerators. Significant heat generation makes effective cooling solutions—particularly cooling fans—an indispensable component of AI server racks.

GPUs and specialized accelerators in AI servers consume substantial power, often exceeding 300 W per unit. When housed in densely packed server racks, these components generate heat faster than what natural dissipation can manage, causing temperatures to rise rapidly. Without proper cooling, overheating triggers "thermal throttling," a safety measure that forces hardware to reduce its processing speed, significantly lowering performance.

The escalating power densities in modern server racks necessitate advanced cooling solutions. To address this challenge, cooling fans continually circulate air within the rack, dissipating excess heat and maintaining a stable thermal environment to increase efficiency in AI processors. Over the past decade, power levels per rack server have surged from 10 kW or 15 kW to as high as 100 kW, increasing demand for more effective power dissipation. Consequently, fans are transitioning to higher voltage rails (48 V) to accommodate increased power requirements.

Historically, eFuses such as the TPS25981 (12 V, 10 A) were used for power-path protection for the 120-W power range. However, the rising power demands of contemporary fans necessitate higher-rated eFuses, such as the TPS1685 (48 V, 20 A), which supports approximately 960 W. This enhancement is crucial for maximizing thermal performance in servers.

This article will discuss the application requirements for fan-based cooling in AI server racks and the role of eFuses in protecting the fans against both overcurrent, overvoltage and overtemperature events. Among the eFuse features which are particularly beneficial in enterprise server cooling is a user defined blanking timer, which will be explained.

Enhancing System Reliability And Preventing Failures

Excessive heat causes electronic component failures. Inadequately cooled server racks increase the risk of unexpected shutdowns, crashes, and data loss, disrupting operations. Cooling fans prevent sudden failures by keeping AI hardware within safe temperature limits and minimizing downtime in data centers, where system outages can lead to costly business consequences.

In AI accelerators, processors and other semiconductor components, prolonged high temperatures accelerate electromigration, a process that degrades semiconductor materials and reduces hardware longevity. Implementing efficient cooling solutions enables organizations to reduce thermal stress on components and sustain AI infrastructure operations by lowering maintenance and replacement costs and maximizing return on investment by prolonging the life span of costly AI hardware.

How eFuses Protect Fans

As shown in Fig. 1, AI server cooling fans operate continuously under high-power conditions, and any fault (such as overcurrent, voltage spikes or short circuits) can damage the fans or disrupt server operations. eFuses play a crucial role in protecting the power path of these cooling fans.

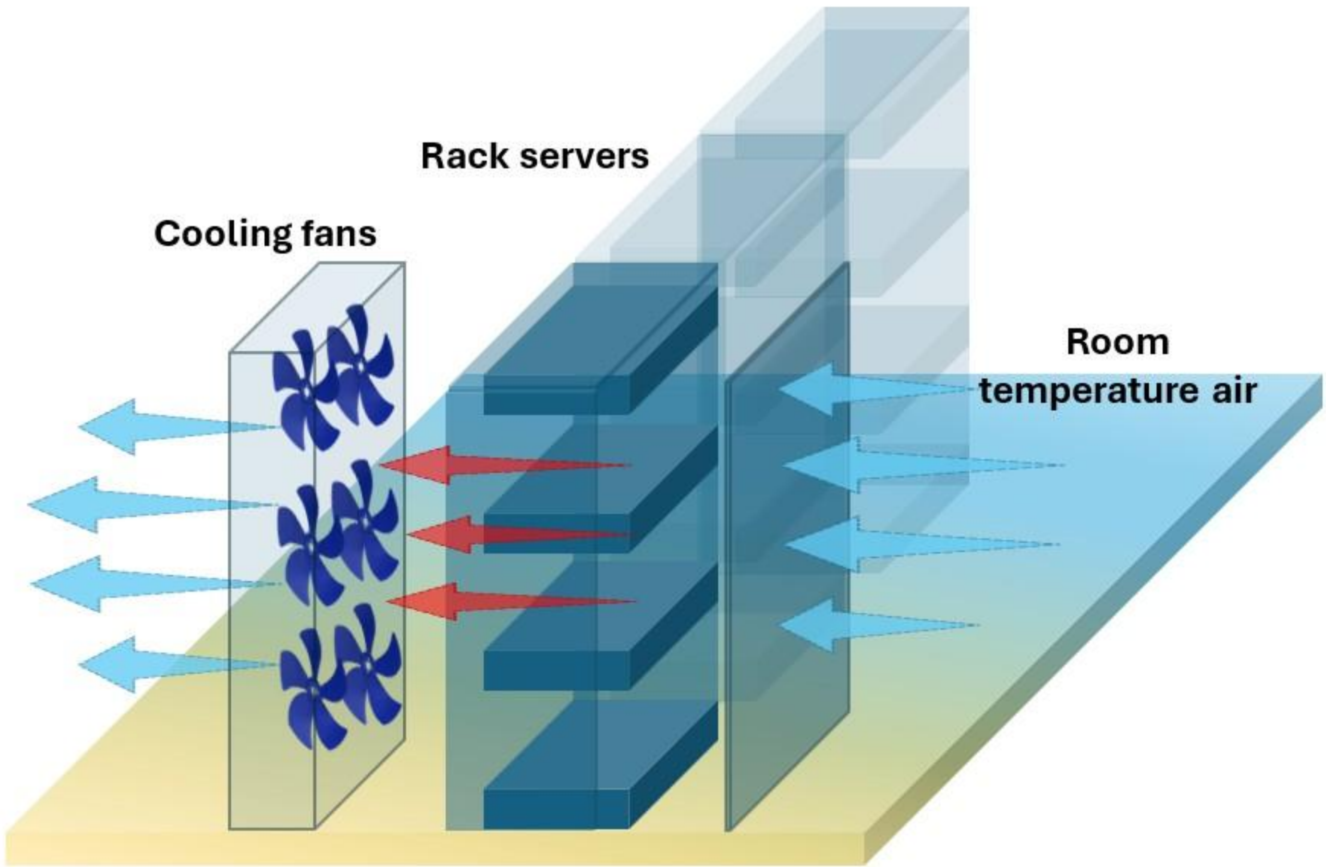

Fig. 1. Fan-based cooling in a server room to cool down rack servers and prevent overheating.

eFuses can help enhance the reliability and safety of AI data centers by providing intelligent power protection. Unlike traditional fuses that require manual replacement, eFuses instantly detect excessive current; cut off power to prevent fire hazards; and either autorecover or remain latched off until the issue is resolved, minimizing downtime.

AI server cooling fans often experience high inrush currents at startup, which can stress power rails and cause voltage sags. eFuses gradually ramp up current, ensuring smooth startup without tripping breakers or disrupting power stability. They also protect against voltage fluctuations on 48-V or 12-V power rails, clamping excessive voltage and isolating loads from harmful levels while preventing erratic fan behavior from undervoltage conditions.

Overheating can lead to component failure or fire hazards. eFuses monitor temperature in real time, shutting down power upon the detection of excessive heat to prevent thermal runaway. Their built-in I^2C and SPI interfaces enable real-time power monitoring, predictive maintenance and fault logging, allowing AI data centers to optimize energy use and reduce downtime. By integrating eFuses, data centers ensure safer, more efficient and uninterrupted operation.

Smart Power Management For Enterprise Server Cooling Systems

Fig. 2 illustrates a generic power delivery network for a server motherboard with multiple fans running on 12-V and 48-V power rails. Each fan rail includes an independent eFuse to protect the power path. This architecture isolates faults such as overcurrent, short circuits or overvoltage within a specific fan rail, preventing them from affecting other fan rails or disrupting their operation. As a result, the respective eFuse isolates the faulty rail, allowing the remaining fans to continue operating without interruption. This design enhances system reliability by minimizing downtime and ensuring continuous cooling.

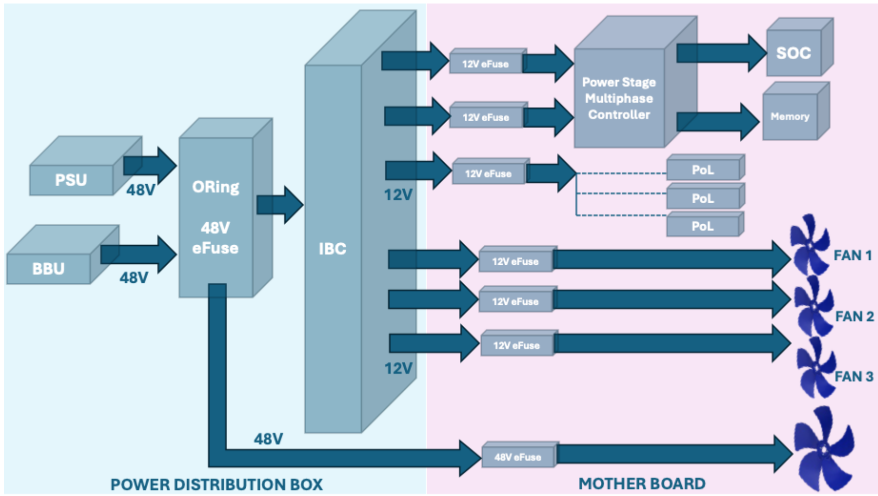

Fig. 2. Power-delivery network for a server motherboard application.

The blanking timer feature in the TPS1685 eFuse offers advantages in enterprise server fan-cooling systems by balancing system protection with performance optimization. This feature allows short transient overloads to pass through without triggering a circuit breaker, as shown in Fig. 3, ensuring that temporary high-amplitude load pulses commonly observed during fan startup do not disrupt system operation. During sustained overcurrent events, the eFuse promptly disconnects the circuit, safeguarding system components.

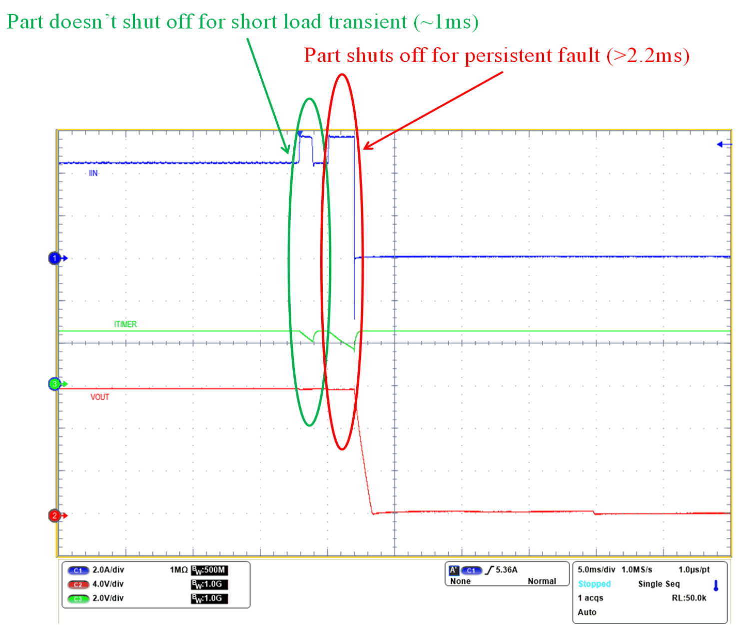

Fig. 3. Overcurrent response (circuit breaker) after a user-defined blanking.

The blanking timer feature allows you to set the overcurrent protection threshold slightly above the thermal design current instead of accounting for maximum transient loads, which are typically 1.7 times higher. This approach reduces the required power-supply unit (PSU) capacity, leading to smaller, more cost-effective PSU designs compared to conventional systems that must accommodate peak transient currents.

The TPS1685x responds to output overcurrent conditions during steady-state by performing a circuit-breaker action after a user-adjustable transient fault blanking interval. A capacitor from this TIMER pin to GND sets the overcurrent blanking interval during which the output current can temporarily exceed the overcurrent threshold.

Upon detection of an overcurrent condition, wherein the load current surpasses the user-adjustable overcurrent limit threshold (I_{OCP}) yet remains below the short-circuit threshold (I_{SFT}), the device initiates discharge of the I_{TIMER} pin capacitor via an internal pulldown current. If the load current subsequently drops below the current limit threshold prior to the I_{TIMER} capacitor discharging by ΔV_{ITIMER}, the I_{TIMER} is reset by being pulled up to default voltage internally, thereby preventing circuit-breaker activation. This mechanism enables the device to tolerate brief overload transient pulses without triggering the circuit.

Conversely, if the overcurrent condition persists, the I_{TIMER} capacitor continues to discharge, and upon reaching a ΔV_{ITIMER} reduction, the circuit-breaker action promptly turns off the FET. Concurrently, the I_{TIMER} capacitor is recharged to V_{INT}, resetting it to its default state in preparation for the next overcurrent event. This ensures that the full blanking timer interval is consistently provided for every overcurrent occurrence.

The duration for which transients are allowed can be adjusted using an appropriate capacitor value from TIMER pin to ground. The transient overcurrent blanking interval can be calculated using the following equation:

$$t_{ITIMER}(ms) = \frac{C_{ITIMER}(nF) \times \Delta V_{ITIMER}(V)}{I_{ITIMER}(\mu A)}$$

where t_{ITIMER} is the transient overcurrent blanking timer and C_{ITIMER} is the capacitor connected between the TIMER pin of the device and GND. I_{ITIMER} = 2 μA (typical) and ΔV_{ITIMER} = 1.3 V (typical). So, a 4.7-nF capacitor with a 10% tolerance and dc voltage rating of 25 V when used as the C_{ITIMER} in this design, will result in a t_{ITIMER} of 3 ms.

Conclusion

eFuses are an essential component in high-performance AI server cooling systems, enhancing reliability, efficiency and overall system cost-effectiveness. They enhance fan power-path protection by preventing overcurrent damage, limiting inrush currents, safeguarding against voltage fluctuations, and enabling thermal shutdown. With real-time fault monitoring, eFuses improve uptime and system efficiency, making them essential for reliable AI data center operations.

References

1. TPS1685x Stackable Integrated Hotswap (eFuse) With Accurate and Fast Current Monitor, datasheet.
2. "Enhancing Server Power Design Using Advanced Features of TI's Smart eFuses".

About The Author

Kshitiz Khatri is a product marketing engineer at Texas Instruments, specializing in the enterprise and communication markets. He has a strong passion for artificial intelligence and machine learning. Khatri began his career at Texas Instruments in 2020 in design roles and spent 3.5 years in product development before transitioning to a business-oriented role. He holds a degree in electrical and electronics engineering from the National Institute of Technology Karnataka, Surathkal.

For further reading on circuit protection techniques and devices, see the How2Power Design Guide, locate the Design Area category and select "Power Protection." Also see the Component category and select "Circuit Protection Devices".

