

Powering modern AI data centers with industry's first integrated 48V integrated hot swap (eFuse)



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As high-performance computing and artificial intelligence continue to grow, data centers demand power-dense, efficient solutions to support the latest central processing units, graphics processing units (GPUs) and hardware accelerators. The need for increased power density and a shift to 48V power architectures to accommodate processing demands introduces new challenges, however, particularly in managing power levels >6kW while maintaining reliability, efficiency and scalability.

Increasing power requirements often lead to larger solution sizes, complex designs, and inefficiencies in fault detection and protection. Additionally, managing high currents while ensuring safe operation and minimal power losses becomes an important concern. Traditional hot-swap controllers combined with discrete field-effect transistors (FETs) face significant limitations in high-power applications.

To address these challenges, TI's 48V hot-swap eFuse device with power-path protection is designed to be a reliable and compact solution for data center applications. Unlike approaches that require external sense resistors and current-sense amplifiers for current monitoring, the TPS1689 and [TPS1685](#) simplifies designs by integrating these functionalities, reducing solution size upto 50% while enabling seamless scalability to support high power levels.

One of the differentiating features of the TPS1689 is the blanking timer, which prevents false tripping by enabling the system to distinguish between peak load currents and actual fault conditions. This feature enhances system reliability and avoids unnecessary shutdowns. The device also supports stacking capabilities for increased current handling, allowing multiple devices to work together in high-power applications.

An integrated black box for fault logging, a guaranteed FET safe operating area, active current sharing and health monitoring further enhance system resiliency. Available in an industry-standard common footprint, the TPS1689 provides a power-management solution that ensures reliable operation.

Enhancing server protection and performance

The blanking timer offers advantages in enterprise server systems by striking a balance between system protection and performance optimization. As shown in [Figure 1](#), this feature enables short transient overloads to pass through without triggering a circuit breaker, ensuring that temporary, high-amplitude load pulses common in AI, GPU and processor-intensive applications do not disrupt the system. However, the eFuse promptly shuts down the circuit during sustained overcurrent events.

Other advantages include:

- Cost optimization. The blanking timer minimizes the need for oversized power-supply units (PSUs) and reduces the number of eFuses required in parallel configurations. This significantly lowers bill-of-materials costs while maintaining reliable operation.
- Improved power density. By reducing the number and size of high-current-carrying components, the system can achieve a more compact design, freeing up valuable printed circuit board (PCB) space and improving thermal management.
- Flexibility and customization. Programmable fault intervals enable designers to fine-tune the system response to match specific transient profiles, optimizing performance for unique workloads.

Part doesn't shut off for short load transient (~1ms)

Part shuts off for persistent fault (>2.2ms)

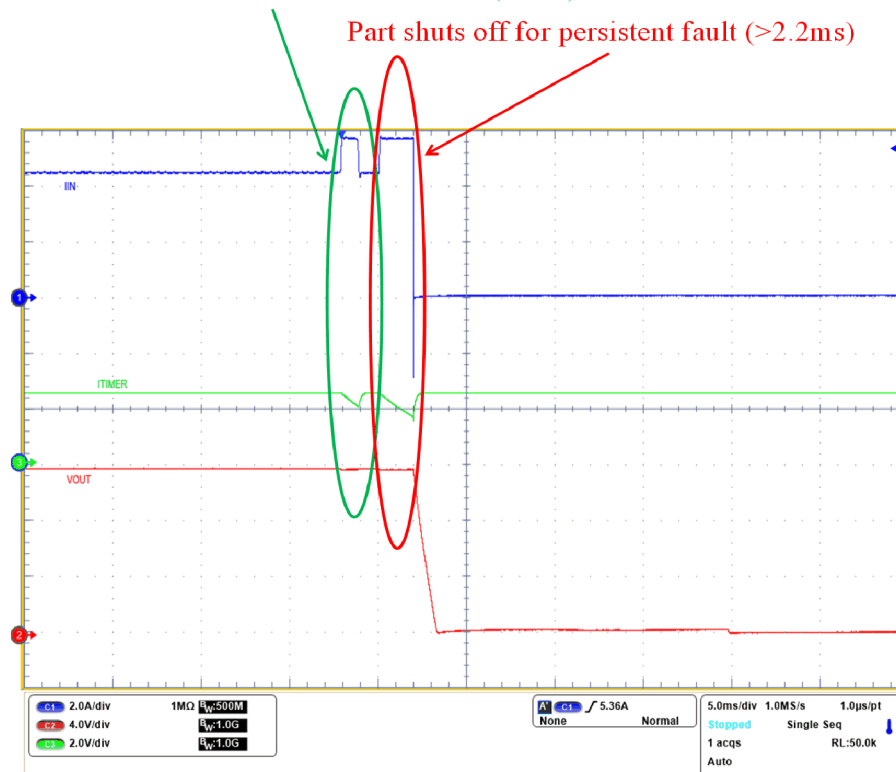


Figure 1. Overcurrent response (circuit breaker) after a user-defined blanking

You can set the overcurrent protection threshold to 1.1 times the thermal design current instead of accounting for maximum transient loads (typically 1.7 times). This approach reduces the size and cost of PSUs compared to conventional designs, which require the PSU to support the peak transient current. These benefits make the blanking timer a pivotal feature for high-performance server systems.

Advanced stacking and current-sharing solutions

The growing power demands of AI-driven processors and servers have made efficient power distribution systems a requirement, with smart eFuses playing an important role. Traditional parallel operation of eFuses, as shown in Figure 2, presents significant challenges given mismatches in the drain-to-source on-resistance ($R_{DS(on)}$), PCB trace resistances, and comparator thresholds. These mismatches result in uneven current sharing among eFuses (where some eFuses carry more current than others) and often cause premature tripping of individual eFuses, even when the overall system current is below the trip threshold. Such false tripping can lead to unnecessary system downtimes, reduced reliability, and increased operational inefficiencies.

To address these challenges, TI has introduced a total system current-limit approach in its eFuses that leverages interconnected IMON pins. This approach designates one eFuse as the primary controller to monitor the total system current. By relying on the total current rather than individual eFuse currents, the system avoids inaccuracies caused by mismatched path resistances and ensures that the system trips only when necessary, enhancing operational stability.

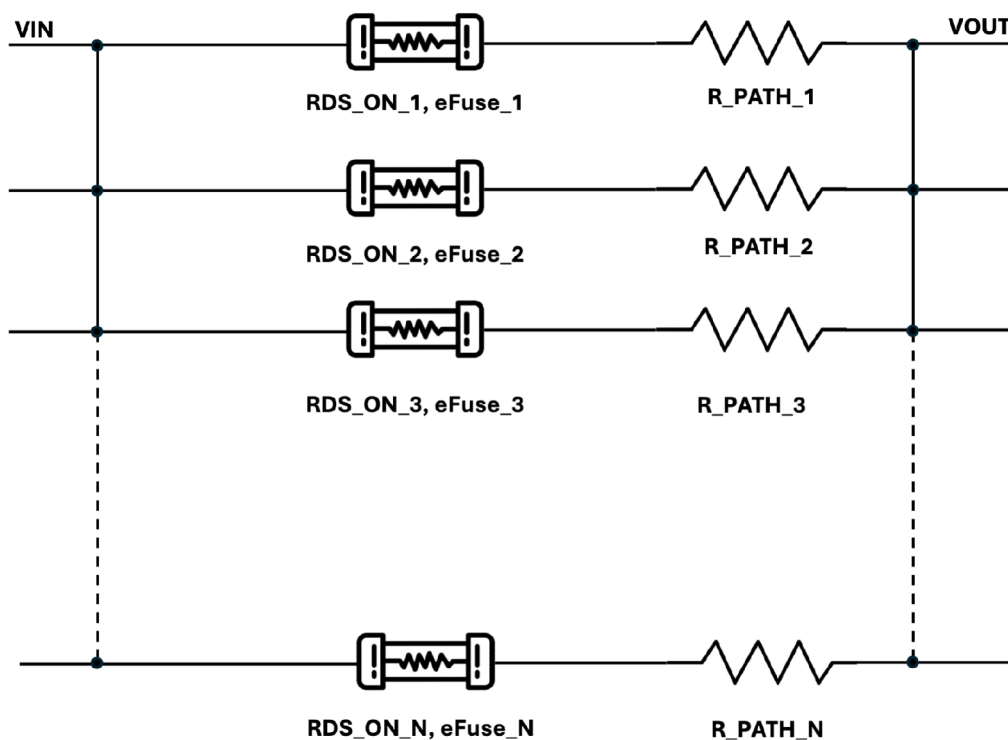


Figure 2. Parallel stacking of eFuses, enabling support for higher current loads

Active current-sharing technology aids in efficient power distribution by dynamically adjusting the $R_{DS(on)}$ of the FETs to achieve balanced current sharing among eFuses. When one eFuse carries a disproportionately higher current, increasing its $R_{DS(on)}$ slightly redistributes the current more evenly across all devices. This dynamic regulation minimizes thermal stress on individual eFuses, improving system reliability over extended periods.

Having active current sharing occur near the overcurrent protection threshold ensures that it only operates when necessary to avoid unnecessary power losses at lower currents. By activating active current sharing at the optimal threshold, the system achieves uniform thermal stress distribution during high-current operations, improving long-term reliability.

Conclusion

With increased power density, a simplified design, enhanced protection and cost optimization, hot-swap eFuse devices enable more efficient and reliable power management for high-performance computing applications. The integration of features such as the blanking timer and stacking capabilities further strengthens these devices' suitability for supporting the growing power needs of modern AI data centers.

Additional resources

- Download the [TPS1685x 9V–80V, 3.65mΩ, 20A Stackable Integrated Hotswap \(eFuse\) With Accurate and Fast Current Monitor Data Sheet](#).
- Check out the “[TPS1685 Evaluation Module for eFuse EVM User's Guide](#)”.

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