Why Engineers Should Move to Integrated Power Switches

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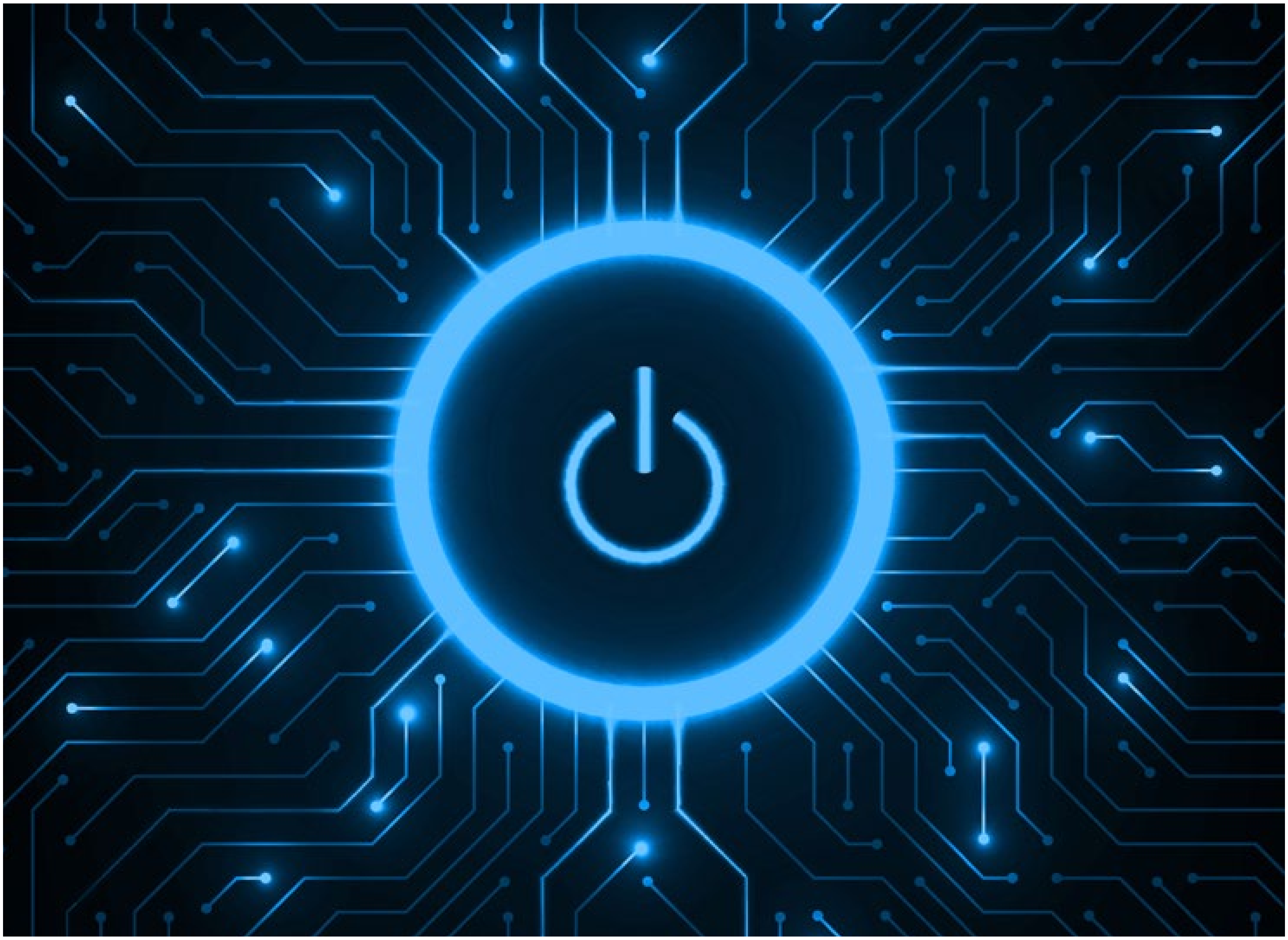

Introduction

The power electronics market will grow more than 25 percent to $44.2 billion (USD) by 2025. As consumers across vertical power electronics markets continue to push for higher efficiency, and smaller, more economical solutions, a significant market trend in power electronics is shifting toward higher degrees of integration.

It makes sense. Natural benefits come with integrating power management solutions. Combining functions in one package reduces routing and connection points. This approach improves ease of use, converging toward a desirable plug-and-play outcome for the end-user. Integration also leads to smaller package sizes and simplifies assembly of the application. Finally, having fewer connections reduces voltage drop and line losses throughout the circuit, raising efficiency.

But with the benefits of integration comes the challenge of implementation. Transitioning to a higher degree of integration means dedicating engineering and design resources to evaluate and test the new technology. Higher pressure on speed-to-market to support new applications induces risk in the product development process. Traditionally, the sticker price of integrated components would be higher than a comparable discrete based solution, but advancements in today's process and packaging technology are making these high-performance solutions more affordable.

With such apparent challenges in front of enormous potential, which way should designers go? Should they develop simple, singular-function components, or create more integrated, robust power-management solutions? The clear choice is integration, as evidenced by the market data. This paper explains why integrated solutions are the preferred direction over discrete components through the lenses of improved long-term ease of use, reduced packaging footprint, and increased efficiency. The following products from Texas Instruments (TI) illustrate the impact of integrated power switches on the system.

Load switches

Load switches are semi-integrated power solutions that provide a simple, cost-effective way to turn on and off power rails. These switches improve speed-to-market with a reduced bill of material component count. TI offers load switches down to 5V/2A, in a 0.78mm x 0.78mm footprint. This size allows design engineers to reduce the printed circuit board (PCB) area up to 75 percent to 90 percent over an existing (discrete) MOSFET-based solution. Load switches also offer low-voltage operation to manage any power requirement, reducing system engineering burden by managing power requirements internally. And its ability to interface directly with low-voltage control signals makes it easy to control the switch ON state, keeping the system off until sequencing is complete and reducing power loss.

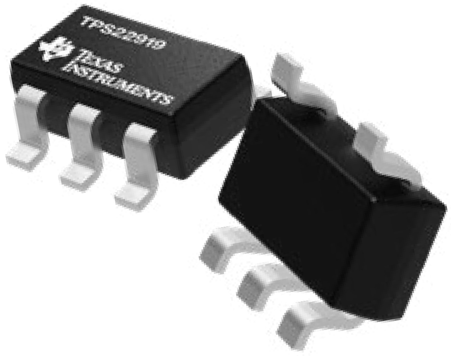

Figure 1 - Texas Instruments TPS22919 load switches offer protection against fault cases with output short circuit protection. (Image Source: Mouser Electronics)

The TI TPS22919 **(Figure 1)** is a compact single-channel load switch used in personal electronics, personal home computing, and docking stations. It offers protection against fault cases with output short circuit protection. At a nominal body size of 2.1mm x 2.0mm, an integrated constant slew rate control minimizes inrush current, according to the boundaries defined by Coulomb's Law. This feature is an example of an integrated passive control that improves ease of use and efficiency.

A load switch is the final opportunity in the power path to reduce power consumption. Using them to disconnect not-in-use product features during the power cycle of a smartwatch can extend battery life by nearly two percent per load switch. This control increases efficiency by applying a higher percentage of the current to the desired application while extending battery life.

Load switches are designed to meet the demands of space-constrained automotive applications, and TI now has an AEC-Q100 qualified version of the TPS22919. The self-protected TPS22919-Q1 includes thermal shutdown to withstand overheating during turn-on, making it a good option for infotainment and ADAS.

eFuses

eFuses, incorporate more protection features within the component but are also not fully-integrated PMICs. They act like electrical fuses in that the chip can trip the "fuse" if an operation is consuming too much power. This action enables dynamic performance tuning of circuits on a chip. The Texas Instruments TPS1663x series is a best-in-class example of a suite of eFuses that offer compact, easy-to-use, efficient power switching.

Used in a variety of industrial applications such as factory automation/control, CNC motor drives, and industrial printers, this solution for power management offers precise current limiting with fast protection, limiting current to within 7 percent accuracy over temperature. The eFuse can also protect a short circuit event within 4.5us.

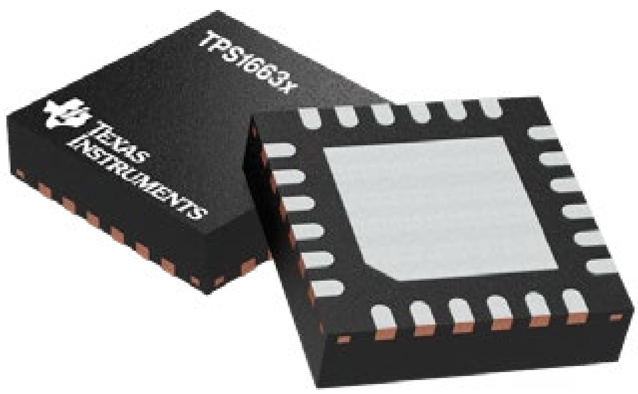

Figure 2 - Texas Instruments TPS1663x 60V, 6A power-limiting eFuses integrate features that improve ease of use. (Image Source: Mouser Electronics)

The TI TPS1663x series eFuses **(Figure 2)** integrate additional features to improve ease of use. Among them are an integrated field-effect transistor (FET), protection against overvoltage, and adjustable power limiting to promote compliance with UL and IEC standards. These regulatory bodies have already certified some eFuses, such as the TI TPS2596. This precertification at the component level qualifies the eFuse as a low-power circuit (LPC) and does not require retesting when certifying the full system, saving time and cost. The TI product also includes real-time system performance monitoring and downstream load control. Finally, like load switches, eFuses incorporate in-rush current management through output slew rate control. All the features listed above point to the benefits of integration; passive control features used to optimize and streamline the component's use.

Simplified packaging is another benefit of the integrated eFuse. The packaging envelope for the TPS1663x series is 4mm x 4mm. In addition to the output power-limiting (PLIM), the switch integrates adjustable overcurrent protection, and internal FET engagement/disabling control. The TI TPS1663x series offers superior performance with the features listed above. Integrating these reduces bill-of-materials count and decreases assembly costs for system manufacturers. For example, the integration of overvoltage and overcurrent protections dramatically reduces the size of input power protection while increasing its reliability.

The integrated eFuse also offers efficiency gains due to combining features and functionality in a single component. Low-current shutdown mode reduces unnecessary power draw during standby operation. This feature combined with a low ON resistance reduces overall power consumption, improving system efficiency.

The TI TPS1663x series eFuse has also demonstrated the benefit of integrating features in the IC vs. connecting multiple discrete components to achieve similar functions.

Ideal diodes

Ideal diodes integrate single-input/single-output (SISO) into the component. Ideal diodes, such as the LM66100, appear in smart meters, global-position system (GPS) and location tracking, primary and secondary batteries, and building automation. Principal benefits of ideal diodes are blocking of reverse-current conditions and other undesired electrical transients. The most beneficial ease-of-use conditions for ideal diodes are in protecting against the reversing of battery polarity. These components contain an internal voltage comparator that compares input and output voltages to enable the system to block the reverse current flow.

The high degree of integration enables ideal diodes to provide up to 75 percent reduction in package envelope over discrete solutions. Typically, the degree of integration is inversely proportional to the package size, meaning the more features that engineers combine into a component, the smaller that component can be.

The main benefit of ideal diodes is efficiency gain. These components provide smart control of internal or external MOSFETs to have them react like diodes. This control allows ideal diodes to replace a high-power silicon or a Schottky diode, reducing power dissipation up to 75 percent to 98 percent, assuming a 0.7V silicon diode and a 10mV ideal diode controller. Another enhancement to system efficiency is in voltage drop reduction in forward bias operation, aiding in applications with tight power constraints. Reducing voltage drop leaves a higher fraction of the voltage for the primary application. For example, the LM66100 can replace a diode in a 3x AAA alkaline battery-powered usage that specified >2.5-V operating voltage. This substitution increases battery capacity utilization, raising efficiency.

Ideal diodes offer another efficiency gain that is related to one of their ease-of-use benefits. Protecting against reverse polarity reduces power loss by a factor of 10. This protection enables lower thermal dissipation, reducing waste heat that is managed by the electronics cooling medium. Thermal management is a significant component of facility cost and overall system efficiency, so operating more than 50 percent cooler substantially improves efficiency.

More rugged applications such as factory automation might benefit from a wide-input voltage range ideal diode. The TI LM74700-Q1 ideal diode controller utilizes an external N-channel MOSFET and operates across a 3.2V to 65V input voltage range, which makes it suitable for cold-crank scenarios in automotive designs. Because of its robust protection features, it is commonly utilized in Functional Safety systems, and comes ready with FIT Rate and Failure Mode Distribution documentation, making the transition to integration and time–to-market easier.

Conclusion

Integrating product features comes with several challenges, including product development time, cost, and complexity. But the ability to incorporate passive control features to improve ease-of-use scenarios, reduce package volume, and improve system efficiency far outweigh the flexibility of using simpler discrete components. A 10x order of magnitude improvement in performance, such as reverse polarity power loss with ideal diodes, refutes any flexibility afforded by a discrete solution.

Commercial availability of discrete components can be more counterbalanced by a 75 percent reduction in packaging envelope. This advantage leads to less space taken up and lower overhead cost-per-W managed and provides more room for efficient wire routing and efficiency intra-component connection geometry.

With quantifiable benefits, it is no surprise that the market is moving toward increased integration. Armed with that knowledge, engineers should quickly recommend increased integration in their components and system designs to reap the rapidly evolving technology landscape benefits.