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SiC JFET Brings Efficiency, Small Size And Robustness To Circuit Breakers

Qorvo's UJ4N075004L8S is described as the industry's first 4-mΩ silicon carbide (SiC) JFET in a TOLL package. It was designed for circuit protection applications including solid-state circuit breakers, where low resistance, superior thermal performance, small size and reliability are paramount. With an $R_{DS(ON)}$ of just 4 mΩ, the UJ4N075004L8S offers the industry's lowest on-resistance among the 650-V to 750-V class of power devices in standard discrete packages, according to the vendor.

This low $R_{DS(ON)}$ drives significant reductions in heat generation and, when coupled with a compact TOLL package, enables a solution size that is 40% smaller than competing devices in TO-263 packages, says Qorvo. This small solution size supports the space-limited dimensions of today's electromechanical circuit breakers and operates without the need for elaborate cooling systems, accelerating the transition from electromechanical circuit breakers to semiconductor-based solid-state circuit breakers (SSCBs).

"With the introduction of the UJ4N075004L8S, Qorvo continues to lead the way in SiC power innovation, catalyzing the emergence of applications such as circuit protection with ultra-low $R_{DS(ON)}$ FET offerings in very small footprints," says Ramanan Natarajan, director of product line marketing for Qorvo's SiC Power Products business. "The SSCB market is growing rapidly, and Qorvo's newest product marks a significant milestone in the evolution of the technology."

The move to solid-state circuit protection is motivated by faster interrupt speeds and the opportunities it brings to add new capabilities such as smart control, energy monitoring and load management. With regard to speed, a semiconductor-based circuit breaker can interrupt the current 100 times faster than a conventional electromechanical breaker, comments Andy Wilson head of Business Development—Power Device Solutions at Qorvo.

He adds that the industry has already begun to put the compliance framework into place for solid-state circuit breakers: UL 489I, which applies in the U.S., was passed in 2022 while IEC 60947-10, which will apply in Europe, is in the final stages of being passed.

However, as the industry looks to adopt solid-state circuit breakers, there are some obstacles that must be overcome, namely, heat, size and robustness. First, Qorvo points out that a semiconductor circuit breaker must operate in existing electrical panels that have no heat sinks or forced air cooling. Secondly, a semiconductor circuit breaker must fit within the same dimensions as an existing electromechanical circuit breaker. Additionally, it must tolerate and control high currents resulting from a short circuit event.

These challenges drive requirements for power devices with low conduction losses, hence low $R_{DS(ON)}$, both to reduce heating and to minimize the number of devices that may need to be paralleled to reduce the space required. Similarly, small packages are needed for these devices. Meanwhile the technology itself must be robust to tolerate the severe transient conditions experienced by circuit breakers.

While many SiC MOSFET suppliers are looking at those devices for circuit breaker applications, SiC JFETs offer some inherent advantages for these applications. In Fig. 1, Qorvo compares the capabilities of these two device structures.

Fig. 2. Illustrates how the advantages of the SiC JFET impact device requirements for a specific circuit breaker design when the UJ4N075004L8S is applied versus best-in-class silicon and SiC MOSFETs that are currently on the market. The key takeaway is that fewer devices and less board area are required to implement circuit breakers using SiC JFETs than if silicon or SiC MOSFETs are used.

Qorvo's JFETs are highly robust devices well suited to meet the challenges of circuit protection, providing the ability to turn off at very high inrush currents during circuit faults. Qorvo's newest JFET can also withstand high instantaneous junction temperatures without experiencing degradation or parametric drift. The normally on nature of the JFET lends itself to seamless integration into systems where the switch is in the on-state by default and in turn-off state under fault conditions.

The UJ4N075004L8S is now available for sampling and will enter full production in Q4 2024, accompanied by additional JFET options, including a 750-V device with 5-mΩ $R_{DS(ON)}$ and a 1200-V device with 8-mΩ $R_{DS(ON)}$—all in TO-247 packaging.

For more details about this technology and detailed product specifications, see the UJ4N075004L8S page or visit Qorvo's Power Solutions site.

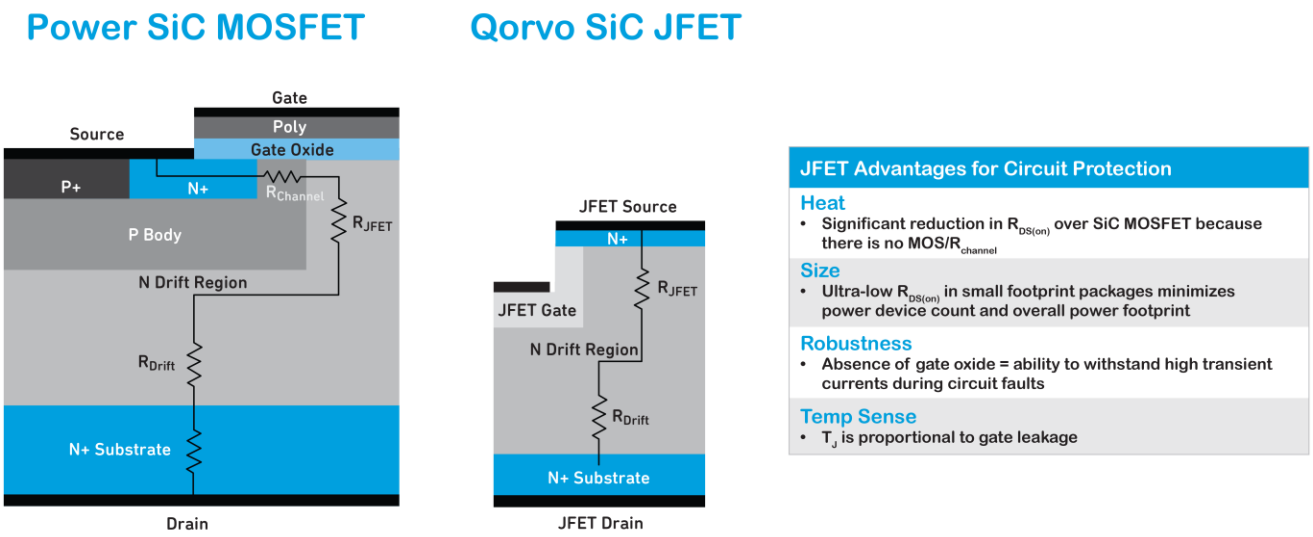
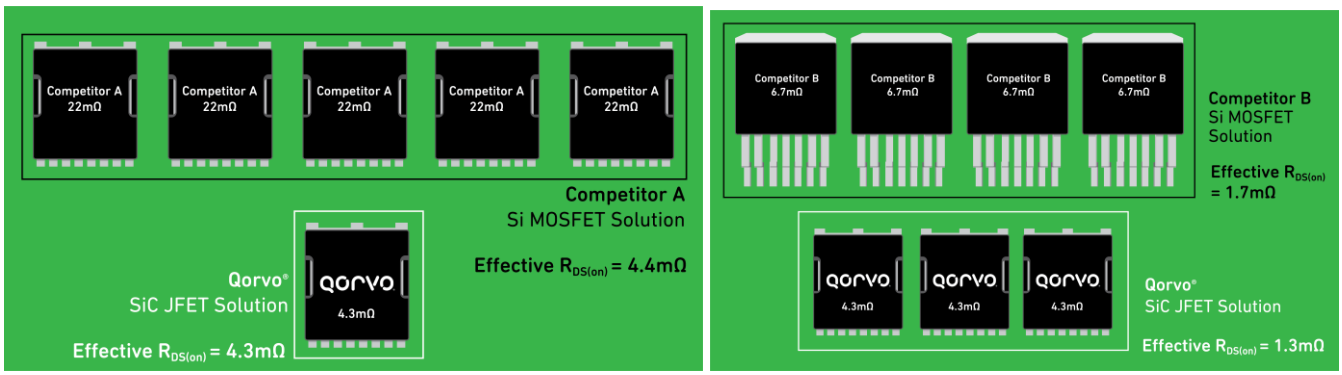


Fig. 1. The shorter conduction path of the SiC JFET results in lower $R_{DS(ON)}$ versus a similarly rated SiC MOSFET, while the absence of a gate oxide enables the JFET to withstand higher transient currents. The normally on characteristic of the JFET structure (versus the normally off MOSFET) is also advantageous in the circuit breaker application where the breaker is normally on.



(a) *(b)*

Fig. 2. According to Qorvo, a "best-in-class" silicon MOSFET (600-V superjunction, 22-mΩ $R_{DS(ON)}$ and TOLL package) will require five devices and 4X the board area to achieve the same on-resistance as one UJ4N075004L8S SiC JFET (a). Meanwhile, a "best-in-class" SiC MOSFET (650 V, 7-mΩ $R_{DS(ON)}$ and TO 263-7 package) will require four devices to achieve the same on-resistance as three UJ4N075004L8S SiC JFETs, which represents a 40% space savings for the JFETs (b).