

Inside the Silicon Carbide JFET: Specs, Stability, and the new Performance Frontier

JFETs have advantages over MOSFETs for specialized applications such as high-voltage SSCBs

Global electricity consumption continues to rise sharply across regions, sectors, and end-use systems. Electrification of transport, heating and cooling, industrial equipment, and data center expansion are among the strongest contributors to this trend (IEA, 2025) [1]. As demand grows, so does the pressure on distribution infrastructure to operate faster, safer, and more efficiently.

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Traditional electromechanical switching, designed for a different era, cannot meet the microsecond-scale response times and long-life reliability now expected. The shift toward solid-state architectures reflects this need for speed, precision, and durability.

As power systems evolve, so does the semiconductor technology enabling them. Widebandgap (WBG) materials, especially silicon carbide (SiC), have become foundational for high-voltage, high-current switching thanks to their thermal performance, low losses, and voltage-handling capability. SiC MOSFETs are well-established, but recent advancements highlight another device class whose time has come again: the silicon carbide junction field-effect transistor (JFET). Fabrication maturity, improved packaging, and the emergence of high-voltage solid-state power distribution (HV SSPD) make the SiC JFET newly relevant and powerfully differentiated.

From market pressures to material choice

Today, the world faces not only increasing power consumption but more volatile demand profiles, driven by fast-charging systems, industrial automation, distributed generation, and high-power digital loads. High-speed fault isolation is critical in these applications but electromechanical circuit breakers typically take more than 10 ms to interrupt a fault, whereas solid-state approaches can achieve response times under 5 μ s. This dramatically reduces current overshoot and stress on downstream equipment.

These system-level requirements have elevated the role of SiC, now the primary WBG material enabling (HV SSPD). In this context, SiC JFETs stand out for their ability to pair extremely low conduction losses with high robustness, making them a compelling fit for fault-tolerant, high-current distribution architectures.

Change in electricity demand by region, 2021-2027

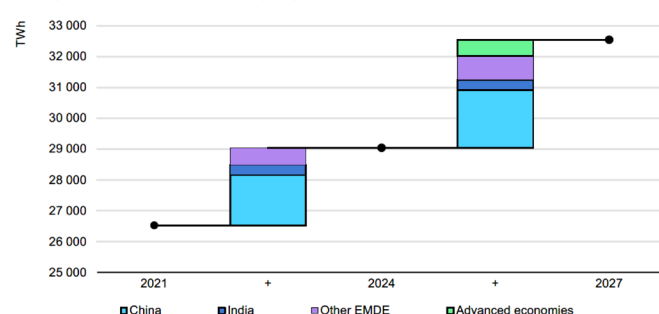


Figure 1: Change in electricity demand by region, 2021-2027. Note: EMDE = Emerging Markets and Developing Economies [1]

Why the SiC JFET is reemerging

Several industry trends have converged to lift the SiC JFET back into prominence.

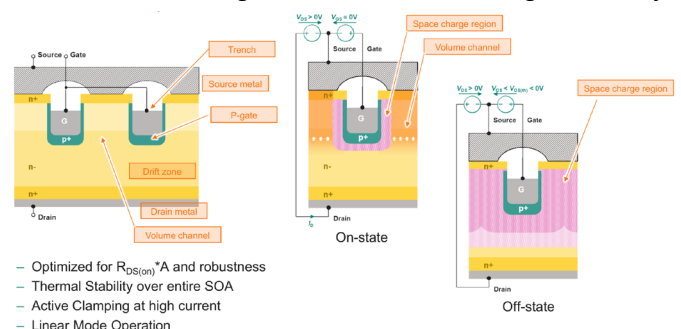
1. SiC manufacturing has improved significantly, reducing variability and enabling larger die with consistent performance
2. Modern packaging - especially thermally optimized, topside-cooled designs - supports higher current densities
3. The rise of HV SSPD has created demand for devices with ultralow $R_{DS(on)}$, stable linear-mode behavior, and high avalanche robustness

These characteristics are the JFET's natural strengths. Devices now achieve best-in-class typical $R_{DS(on)}$ values such as 1.6 m Ω at 750 V and 2.3 m Ω at 1200 V. This makes them ideal for current-intensive applications where conduction loss dominates total system loss.

Device construction and operating principles

Modern SiC JFETs typically use a trench-based structure with a p-type gate region sculpted into the n-type drift zone. This creates a vertical channel whose conductivity is modulated by gate voltage. The structure is optimized to minimize the $R_{DS(on)} \times A$ figure-of-merit (FOM) while maintaining thermal stability and robust avalanche behavior.

During on-state conduction, current flows through the volume channel, while in the off-state the space-charge region expands to pinch off conduction. Because the device is normally on, it provides extremely low resistance when conducting but requires careful control to ensure a safe turnoff. These characteristics can be managed either through gate-drive schemes or through cascode configurations where a low-voltage MOSFET controls the JFET gate indirectly.



- Optimized for $R_{DS(on)} \times A$ and robustness
- Thermal Stability over entire SOA
- Active Clamping at high current
- Linear Mode Operation

Figure 2: Cross-section of trench-based SiC JFET showing P-gate, drift region, and channel

Ultralow $R_{DS(on)}$: Scaling efficiency and density

In highcurrent distribution and protection systems, designing components to manage conduction loss becomes a dominant contributor to footprint, thermal design effort, and cost. SiC JFETs currently deliver some of the lowest devicelevel $R_{DS(on)}$ values available in their voltage classes, with typical ratings such as:

- 1.6 m Ω (750 V)
- 2.3 m Ω (1200 V)

This performance supports system designs operating at 32 A to 63 A and above, within compact footprints—levels that would require significantly larger silicon or MOSFET-based stages.

Lower conduction loss also reduces heatsink mass and cooling requirements, improving system compactness and lowering overall cost.

Improved linearmode stability for safe inrush handling

A defining strength of the SiC JFET is its improvement in stability in linear mode, compared to a SiC MOSFET. When a system powers a capacitive load, the device can safely operate in a highresistance regime, naturally limiting inrush current without additional circuitry.

This simplifies the implementation of “connect” functions such as precharging, hotswap operations, and soft starts. It also reduces stress on both the device and the surrounding system during high-current transients.

Avalanche robustness for inductive disconnect

Disconnecting inductive loads can generate large overvoltage spikes. SiC JFETs are rated for; and productiontested in; highcurrent avalanche conditions, allowing them to clamp these events safely.

This high avalanche energy handling:

- Reduces the need for external clamping networks
- Improves current sharing during paralleling
- Enhances reliability during repeated inductive switching cycles

Some JFETbased implementations still need metal oxide varistors (MOVs) or transient voltage suppression (TVS), but they reduce the MOV + RC snubber combinations required by MOSFET architectures, reducing BOM complexity and potential failure points.

Packaging and system integration: The role of QDPAK

Packaging is crucial for realizing device potential. The QDPAK form factor used in CoolSiC™ JFETs incorporates:

- Large drain and source interface areas for low electrical resistance
- A large, topsidecooled heatslug for low R_{th}
- Internal diffusion soldering for high current capability
- Extendable thermal capacitance to adapt overload behavior

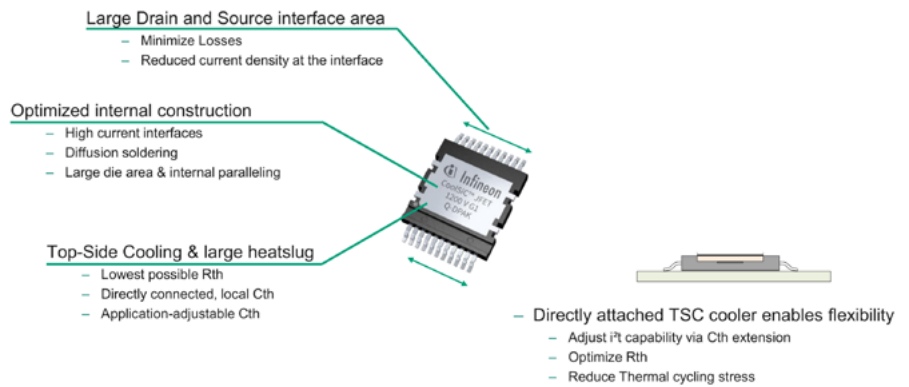


Figure 4: Q-DPAK package layout illustrating drain/source pads and heatslug

This approach directly supports highcurrent SSPD designs by minimizing temperature rise and reducing interface bottlenecks.

Driving concepts: Normally on and cascode options

Although the JFET is inherently normally on, several practical driving strategies exist:

- Direct drive with negative gate bias
- Classic cascode using a lowvoltage MOSFET for normallyoff behavior
- Adapted cascode with additional gatenetwork tuning

These options improve compatibility with existing MOSFEToriented architectures, giving system designers flexibility to integrate JFETs without major architectural redesign.

JFET vs. MOSFET: A comprehensive comparison

Dimension	SiC MOSFET	SiC JFET
Conduction mechanism	Channel conduction	Bulk conduction
Gate structure	Fully isolated	Non-isolated p-gate
Normal state	Normally off	Normally on
$R_{DS(on)}$	Higher for same voltage class	Lowest per device
Temperature coefficient	Lower	Higher but stable SOA
Linear-mode capability	Limited	Improved, inrush-limiting
Avalanche behavior	Good, but requires clamping	Highly rugged, simplifies clamping
Control complexity	Simple	Requires drive strategy or cascode
System implications	Best for legacy -friendly designs	Best for maximum power density and protection

Table 1: JFET vs. MOSFET comparison across critical dimensions

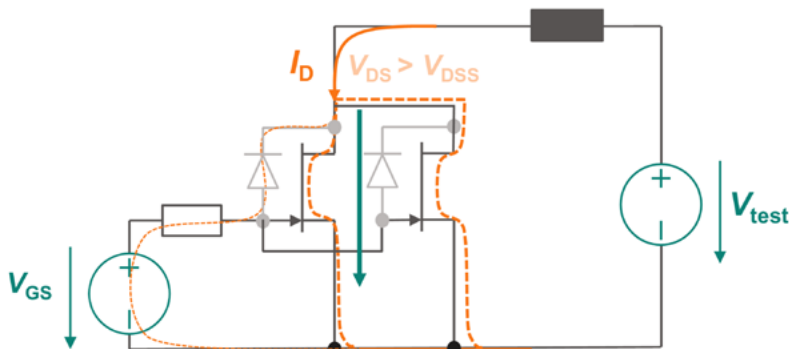
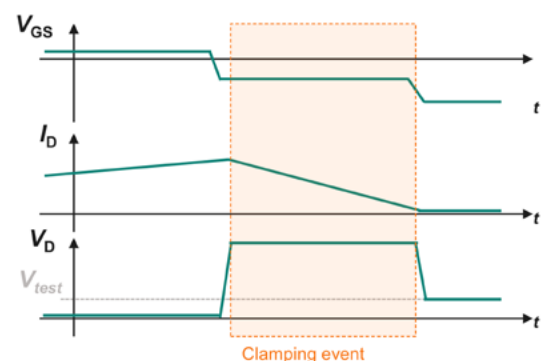


Figure 3: Overvoltage clamping waveform demonstrating stable avalanche behavior



April 2026

Business implications

While technical differentiation matters, evaluating SiC device choices focus on system-level outcomes. Several implications stand out:

- Lower TCO from miniaturization and reduced cooling requirements
- Simplified architecture from reduced clamping components and fewer failure modes
- Higher reliability through stable linear-mode operation and robust avalanche capability
- Scalability in improved thermal performance using advanced packaging like Q-DPAK

These advantages translate directly into operational efficiency, long-life performance, and reduced downtime for critical infrastructure.

Conclusion

The SiC JFET has returned to prominence not because it replaces MOSFETs, but because it excels in domains where ultralow conduction loss, linear-mode stability, and avalanche resilience are essential. Today's power-distribution landscape demands precisely these characteristics, particularly as systems evolve toward solid-state protection, compact power stages, and long-lifetime operation.

With manufacturing improvements, advanced packaging, and flexible control strategies, modern SiC JFETs present a compelling option for high-current, high-reliability designs. For businesses rethinking their next generation of power architectures, exploring what CoolSiC™ JFETs can offer is a strategic step toward meeting the demands of an increasingly electrified world.



To learn more about the CoolSiC™ JFET family, visit:
<https://www.infineon.com/product-information/power/silicon-carbide-jfets>

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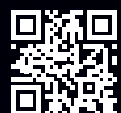
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