An Advanced Isolated Discrete Package to Keep SiC MOSFET Chip up to 60°C Cooler

Isolation of conventional discrete SiC MOSFETs from heatsinks relies on an external, thermally conductive, electrically isolating material. This not only increases thermal resistance junction-to-heatsink, but also complicates thermal management and creates obstacles in both automated and manual assembly processes. Furthermore, poor thermal conductivity reduces power and current handling capabilities, significantly limiting optimal SiC chip utilization. The ISO247 package from Littelfuse, featuring high performance silicon nitride (Si_3N_4) ceramic, addresses these challenges, improving SiC chip utilization and enhancing SiC MOSFET based applications.

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ISO247 – High Performance Ceramic based Discrete Isolated Package

The ISO247 belongs to the ISOPLUS™ family of internally isolated discrete power semiconductor device packages. The ISOPLUS™ family features direct copper bonding (DCB) substrates with aluminum oxide (Al_2O_3) ceramic, which was first pioneered by IXYS Semiconductor (now a part of Littelfuse) in 2003. The ISO247 adheres to the JEDEC TO-247AD outline, ensuring pin compatibility with the standard TO-247 package. The ISO247 spans a variety of semiconductor technologies including Si/SiC MOSFETs, IGBTs and Diodes with voltage classes ranging from 70 V to 1600 V. The ISO247 package, with advanced high performance silicon nitride ceramic, as detailed in reference [1], is specifically tailored to meet the demanding requirements of SiC MOSFET-based applications and offers the following key advantages compared to standard TO-247:

- High performance ceramic-based active metal brazing (AMB) substrate offers inherent isolation, higher thermal conductivity and reduced thermal resistance junction-to-heatsink [1].
- Isolation voltage rating of 2.5 kV AC, 1 minute or 3 kV AC, 1 second.
- Higher temperature and power cycling in seconds (PCsec) withstand capability ascribed to the matched co-efficient of thermal expansion (CTE) for SiC chip and AMB substrate [1].
- Increased power density and simplified thermal management.
- Reduced EMI attributed to the small chip-to-heatsink stray capacitance.

Although ISO247 and TO247 packages share identical outer dimensions and pinout configurations, their internal structures and mounting approach exhibit notable distinctions as depicted in Figure 1. While the TO-247 device necessitates external isolation during its attachment to the heatsink, the ISO247 device employs only thermal interface material for its mounting to the heatsink [2]. Note: The thermal interface material provides no electrical isolation, its function is only to improve thermal conductivity.

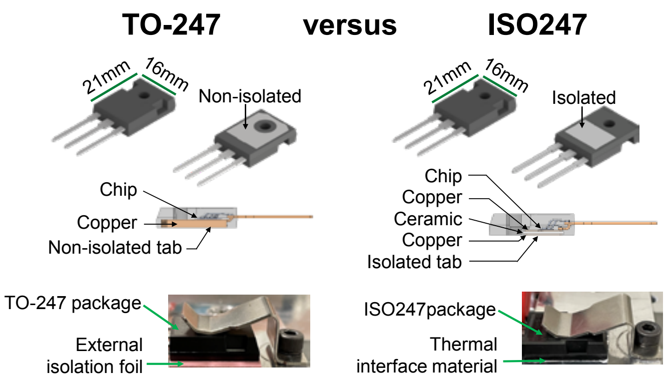

Figure 1: Internal construction and mounting difference between TO-247 vs ISO247 packages.

Thermal Performance Comparison between ISO247 and TO-247 based SiC MOSFETs

The standard TO-247 package has an electrically conductive mounting tab, which is typically at the drain potential. It is generally desirable to electrically isolate the device mounting tab from the heat sink due to safety concerns and the desire to mount multiple discrete devices on the same heat sink frame. The utilization of an external, thermally conductive, electrically isolating foil between the semiconductor package and the heatsink has become a widely adopted approach in the industry for this purpose. Nonetheless, employing external isolation entails significant drawbacks. Increased thermal resistance, diminished power and current handling capacity, complex thermal management, and substantial assembly efforts are each either direct or indirect consequences of external isolation tactics. The mentioned penalties, particularly the issue of reduced power handling capabilities, become unacceptable, especially in cases where wide-bandgap (WBG) semiconductors like SiC MOSFETs are utilized.

To evaluate the performance advantages of the advanced ISO247 package, thermal measurements were conducted using a 1200 V, 25 mΩ SiC MOSFET chip in various packaging and thermal interface configurations summarized in Table 1. Thermal measurements were executed using the cooling curve method in accordance with IEC 60747-8 [3], with measurement set-up detailed in reference [4, 5].

Device	Device 1	Device 2	Device 3
Chip	1200 V, 25 mΩ SiC MOSFET		
Package	TO-247	TO-247	ISO247
Device-to-Heatsink Isolation	External isolation foil with thermal conductivity 1.8 W/mK	External isolation foil with thermal conductivity 6.5 W/mK	Internal isolation with high performance Si_3N_4 ceramic*

*DOWSIL 340 thermal grease was used.

Table 1: ISO247 and TO-247 devices for thermal performance comparison featuring SiC MOSFETs.

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Thermal measurement results for a heating current I_H=40 A are illustrated in Figure 2. As evident from Figure 2a, the ISO247 with high performance ceramic improves the steady state thermal resistance R_{thJH}, by up to 64% when compared to the TO-247 devices. Likewise, as depicted in Figure 2b, the SiC chip in the advanced ISO247 package stays up to 60°C cooler when compared to the TO-247 devices with external isolation. This results in a lower temperature swing between the junction and heatsink, ΔT_{JH}, at the given heating current. The advanced ISO247 has nearly a 53% reduction in temperature swing ΔT_{JH} compared to the standard discrete, significantly improving the device's lifetime and in turn the reliability of the system.

Enhancing Application Power Output and Reducing System-Level Costs by using ISO247

To demonstrate the improvement in application power output using the ISO247, thermal measurements with a heating current I_H resulting in a chip temperature T_{vj} of 130°C were applied to different packages, all containing the same 25 mΩ, SiC MOSFET chip. A junction temperature, T_{vj} of 130°C was selected, as most real-world applications are designed to operate with chip temperatures T_{vj}≤130°C. The results from the thermal measurements have been summarized in Figure 3a. It is apparent that the ISO247 package demonstrates a remarkable 170% improvement in power handling capacity and 30% improvement in current handling capacity compared to the TO-247 packages at a junction temperature of 130°C.

The exceptional thermal performance exhibited by the advanced ISO247 package unleashes the potential for enhancing power density and output power in the end application. Upgrading an active front end converter with a DC-link voltage of 800 V originally designed for 20 kW from 1200 V, 25 mΩ, SiC MOSFETs in TO-247 package with external isolation foil to the same SiC MOSFETs in advanced ISO247 packaging solution could potentially increase the DC power output of this system to ~30 kW. This represents a substantial increase in DC power output—up to 48% —as depicted in Figure 3b.

The ISO247 solution additionally offers a considerable opportunity for cost savings. An example scenario is shown in Table 2.

- Direct cost savings attributed to the enhancement in current and power handling capability, improved power density, savings in PCB area, and SiC chip cost.
- Indirect cost savings due to reduction in potential warranty claims by eliminating isolation foil.

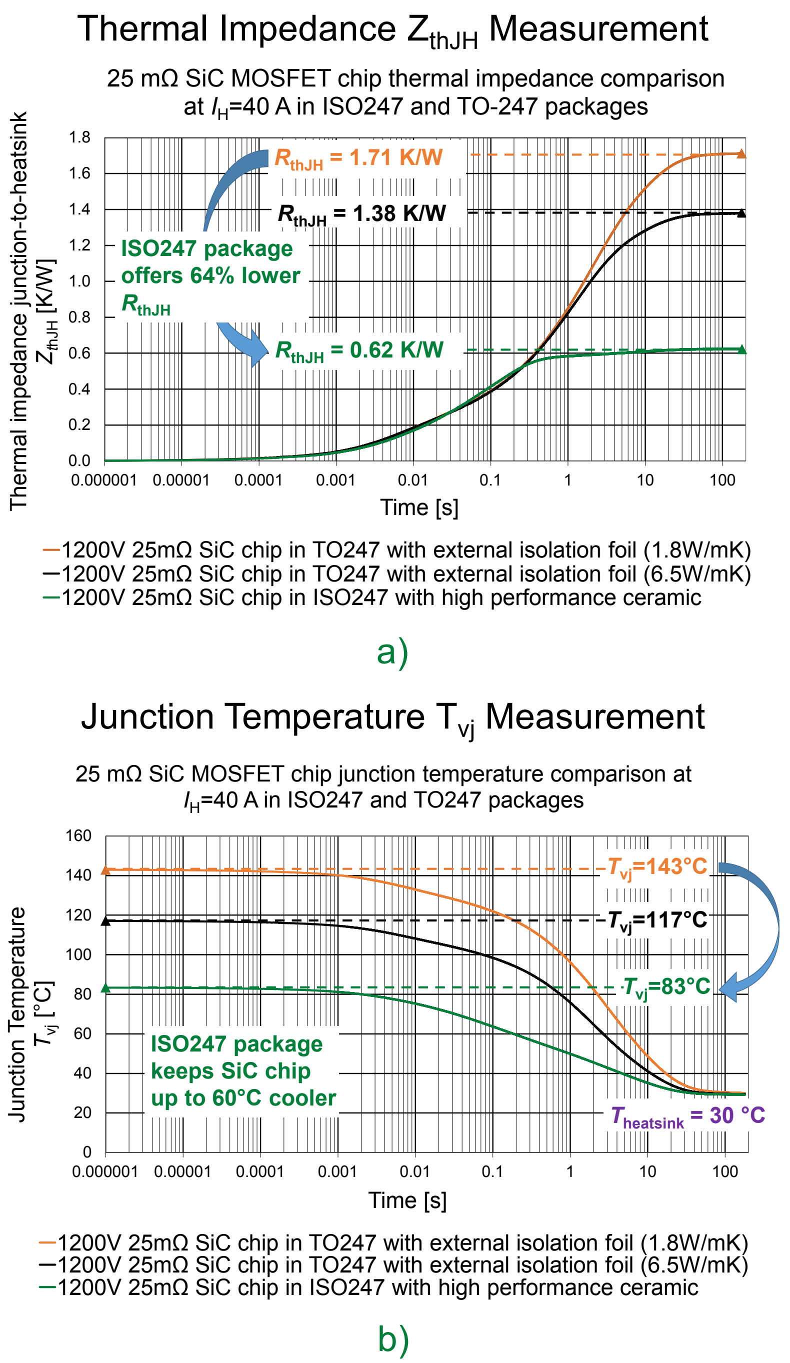

Figure 2: Comparison of a) thermal impedance and b) junction temperature measurement between ISO247 and TO-247 based SiC MOSFETs.

Device and isolation type	T_{vj} [°C]	I_H [A]	R_{thJH} [K/W]	P_{DJH} [W]
TO-247 with 1.8 W/mK isolation foil	130	38.8	1.71	59
TO-247 with 6.5 W/mK isolation foil	130	42.2	1.38	73
ISO247 with High performance ceramic	130	50.8	0.62	160

30% and 170% increase in current and power handling resp.

a)

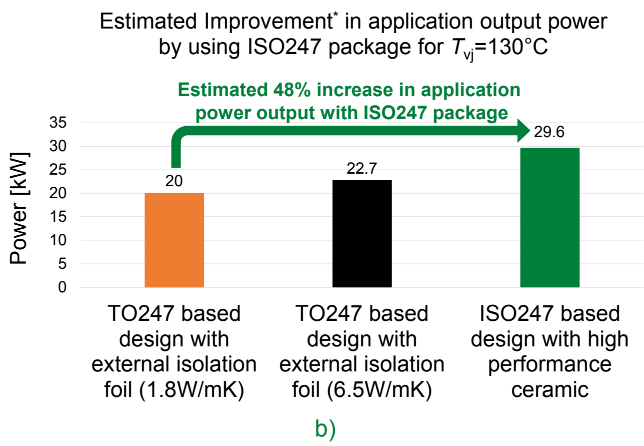

Figure 3: a) Thermal measurement results at T_{vj}=130°C and b) estimated increase in application power output by using ISO247.

Parameter	*ISO247 solution	TO-247 solution
No. of devices	6	12
No. of isolation pads	Not Required	12
Ease of assembly	Simple	Complex
PCB area	Up to 50% less area for ISO247 solution	
SiC chip cost	Up to 50% savings for ISO247 solution due to the elimination of SiC device paralleling	
Dollar per Ampere ($/A)	Up to 50% savings with ISO247 solution	

*Indicates potential for savings

Table 2: System-level cost savings opportunity using the ISO247.

References

[1] S. Shridhar Paradkar, F. Perraud, A. Bhatt, 'ISO247: High Performance Ceramic based Advanced Isolated Discrete Package to Fully Exploit the Advantages of SiC MOSFET'; PCIM-2024, Nuremberg, Germany

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[4] A. Bhatt, U. Kulsoom, F. Perraud, M. Schulz, L. Gant, 'ISOPLUS - SMPD: An Advanced Isolated Packaging to Fully Exploit the Advantages of SiC MOSFETs'; PCIM-2023, Nuremberg, Germany

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Summary

The growing prevalence of WBG devices demands innovative advancements in packaging technology to fully harness the advantages offered by WBG semiconductors. The ISO247 from Littelfuse is a unique isolated package specifically designed to address the rigorous requirements of SiC-based applications while remaining compatible with the standard TO-247 footprint. From the thermal measurement comparison, between the ISO247 and TO-247 packages, it has been established that the Littelfuse ISO247 with high performance Si_3N_4 ceramic offers a remarkable 64% reduction in thermal resistance, R_{thJH} and 53% reduction in temperature swing, ΔT_{JH}. Consequently, the SiC MOSFET chip in the ISO247 package remains up to 60°C cooler at the same DC current. This significantly improves overall device lifetime and application reliability. In simpler terms, due to the improved thermal resistance, R_{thJH} and power dissipation, P_{DJH} of the ISO247 package with high performance ceramic, engineers can choose higher $R_{DS(on)}$ chips for a given application power rating. This presents a significant cost-saving opportunity at the system level. Additionally, employing the ISO247 in power-electronic applications reduces mounting efforts, enables space-saving, decreases overall thermal resistance, and increases power density, all while simplifying thermal design.