



50% more power from SiC chips in high performance ceramic-isolated discrete packages

F. Perraud, Product Marketing Manager, Littelfuse

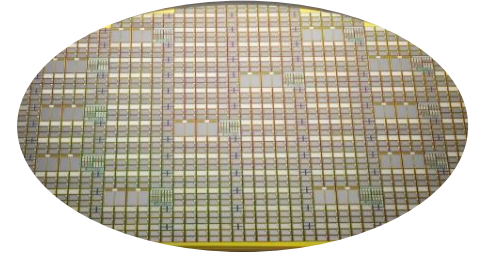
**Bodo's
Wide Bandgap
Event 2024**

Making WBG Designs Happen

SiC

Design challenges

- Increase power density, bring down system \$/A
- Simplify mechanical, thermal design
- Simplify assembly, improve yield and quality



Can we get
more power out
of our SiC
devices

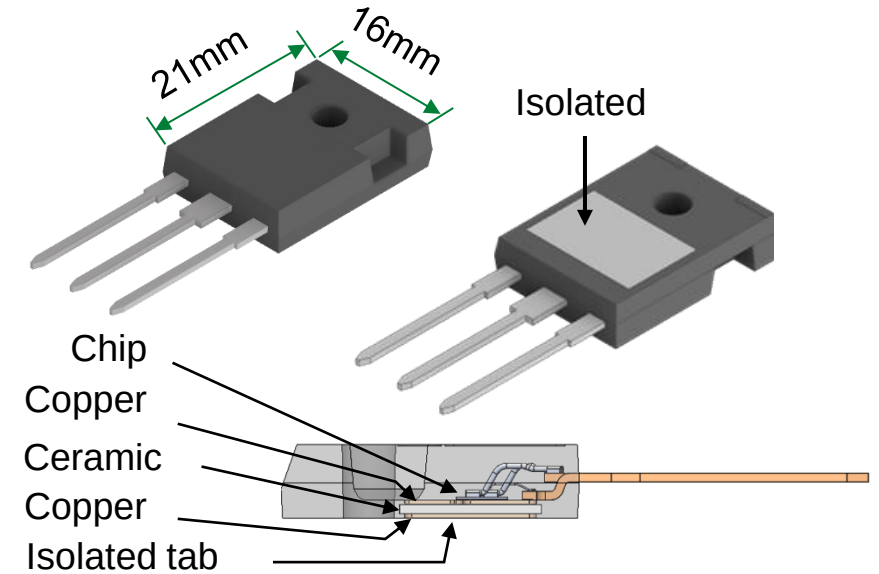
We need to parallel too
many devices in our
current design

Our yield suffers
from complicated
assembly



ISO247 package with AMB substrate isolation

- AMB* substrate using high performance ceramic
 - 2.5kVrms (AC) 1min isolation**
 - Follows JEDEC TO247-AD
 - Ceramic's CTE matching SiC's
- Reduced Rth J-H
- Reduced chip to heatsink parasitic C
- Power cycling robustness



* Active metal brazing

** UL pending

Test Setup (I) - Thermal Performance Comparison

- SiC MOSFET, 1200V, 25mΩ
- Comparing thermal performance in 3 different setups

	TO-247	TO-247	ISO247
Isolation	External foil 1.8W.mK^{-1}	External foil 6.5W.mK^{-1}	Internal, AMB Thermal paste
Package R_{thJC} [K/W]	0.27	0.27	0.45

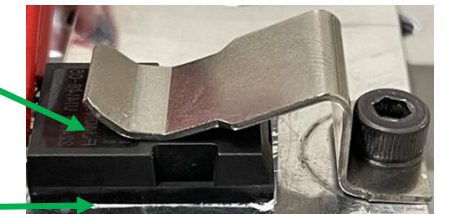
TO247
package

External
isolation foil



ISO247
package

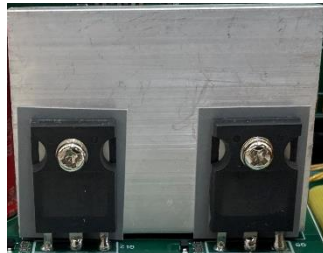
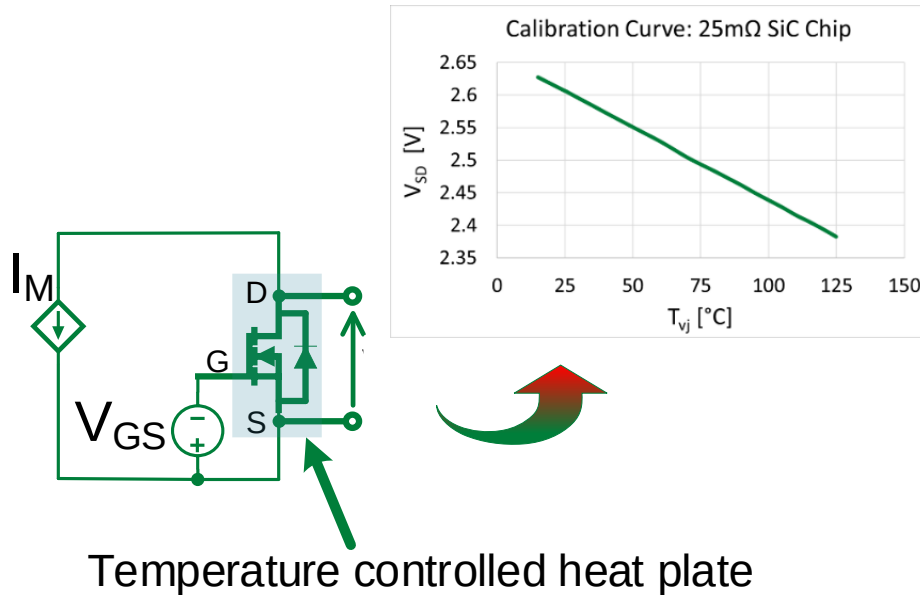
Thermal
interface
material



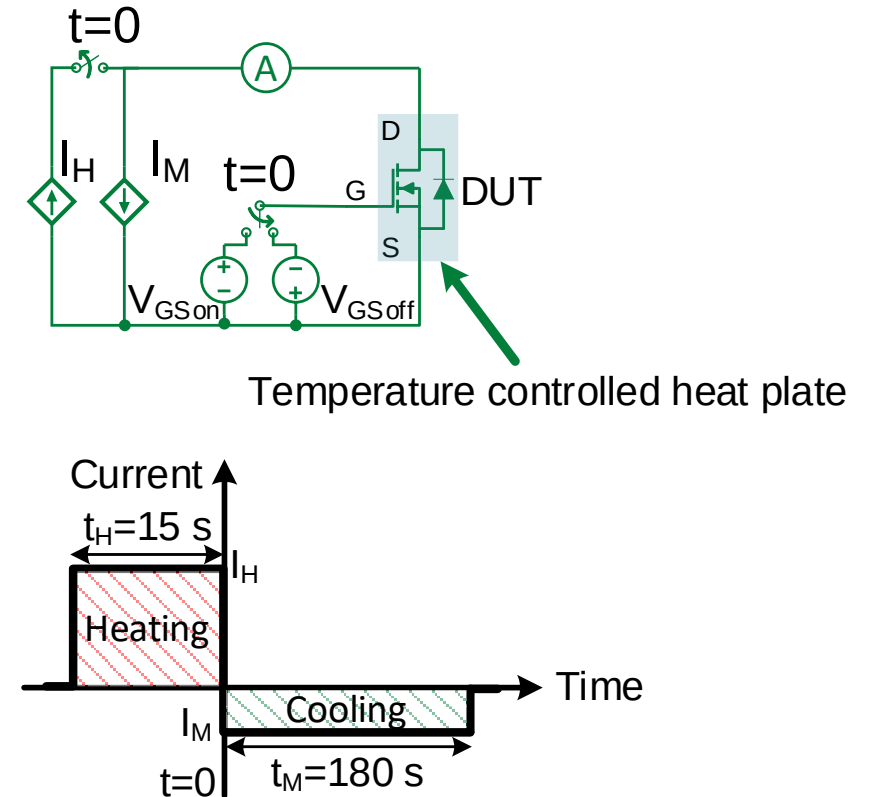
Test Setup (II) - Thermal measurement

■ Z_{th} -measurement according to IEC 60747-8

1. Calibration Curve extraction

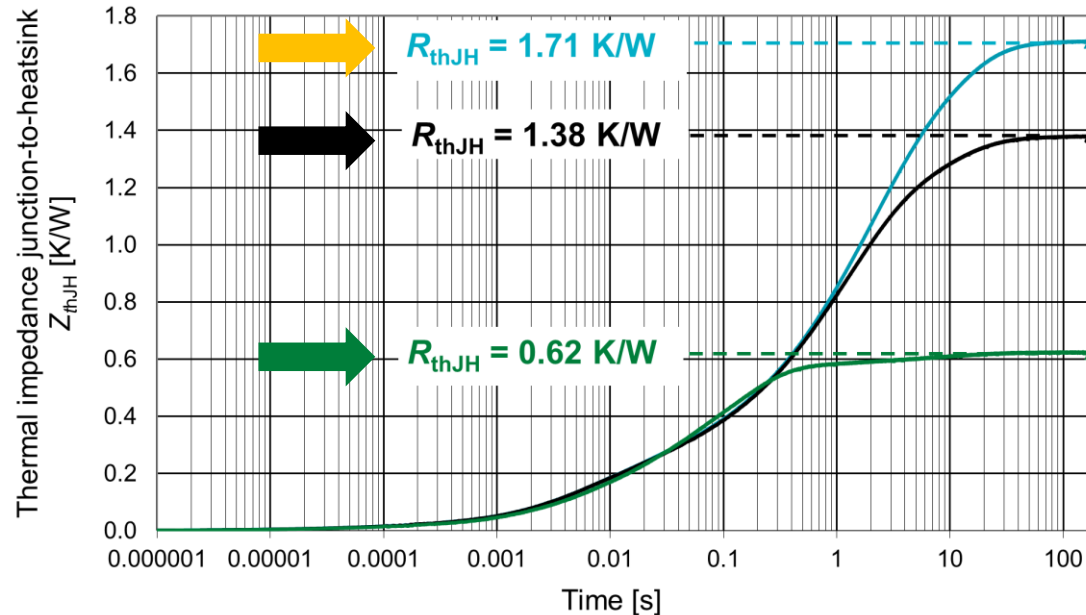


2. Thermal Impedance Measurement



Thermal Performance Advantages – Rth J-H

- Comparing Rth J-H at identical heating current $I_H = 40A$
- 64% lower Rth J-H with the ISO247 package

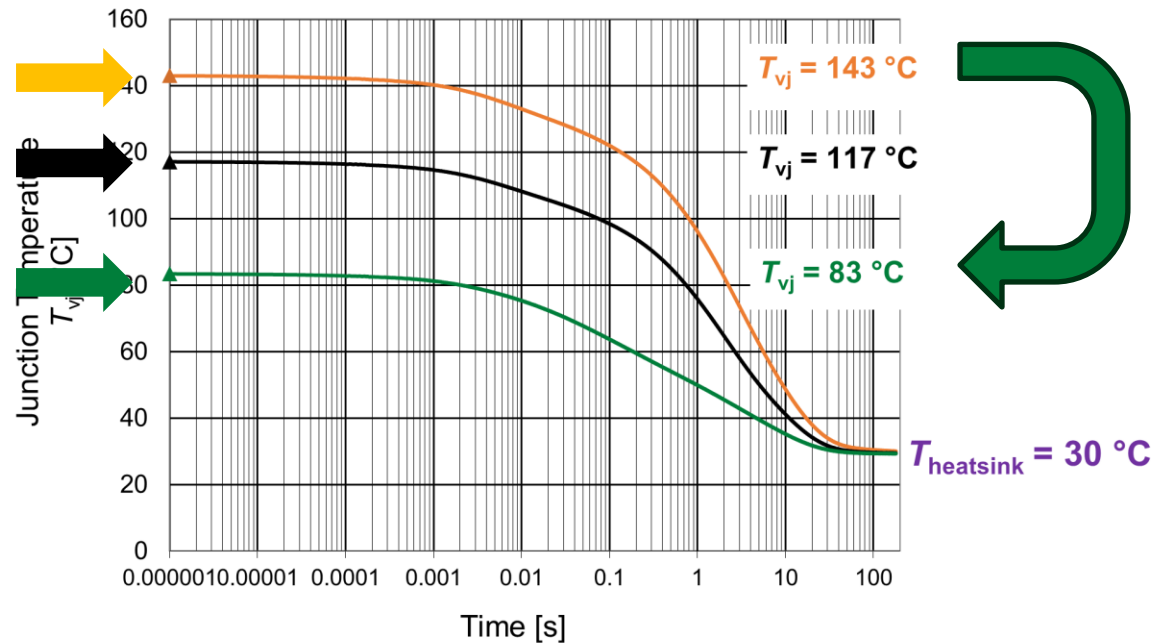


64% lower Rth J-H
with the ISO247
package

—1200V 25mΩ SiC chip in TO247 with external isolation foil (1.8W/mK)
—1200V 25mΩ SiC chip in TO247 with external isolation foil (6.5W/mK)
—1200V 25mΩ SiC chip in ISO247 with high performance ceramic

Thermal Performance Advantages - Tvj

- Comparing Tvj at identical heating current $I_H = 40A$
- Up to 60°C reduction in T_{vj}



The ISO247 package keeps the SiC chip 60 °C cooler

— 1200V 25mΩ SiC chip in TO247 with external isolation foil (1.8W/mK)
— 1200V 25mΩ SiC chip in TO247 with external isolation foil (6.5W/mK)
— 1200V 25mΩ SiC chip in ISO247 with high performance ceramic

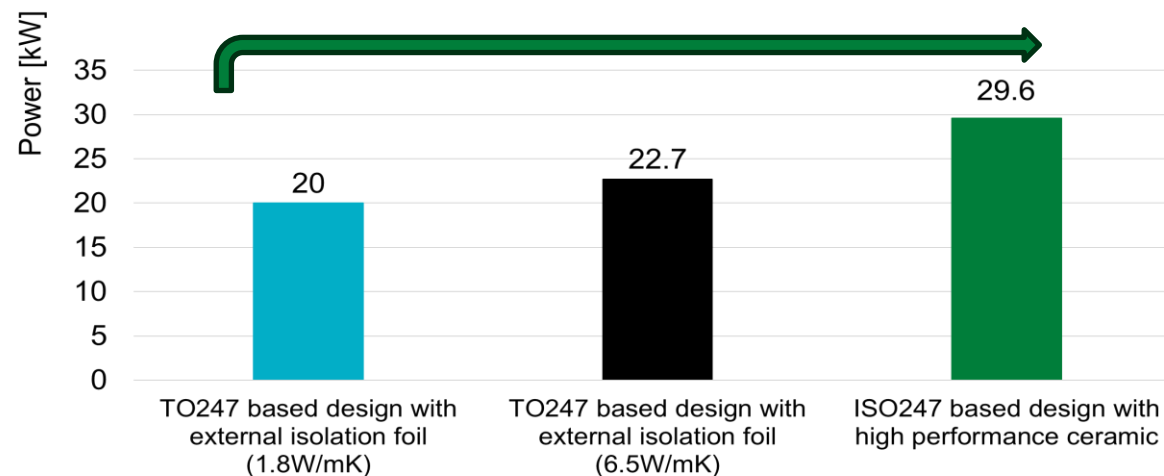
Application – increase the power output at same T_{vj}

- In reverse - implied I_H to reach $T_{vj}=130^{\circ}\text{C}$
- Theoretical 20kW (800V DC) power converter operating at $T_{vj} = 130^{\circ}\text{C}$

30% higher drain current
170% higher power handling

48% increase potential in power output *

	I_H [A]	R_{thJH} [K/W]	P_{DJH} [W]
TO-247 with 1.8 W/mK isolation foil	38.8	1.17	59
TO-247 with 6.5 W/mK isolation foil	42.2	1.38	73
ISO247 with high performance ceramic	50.8	0.62	160

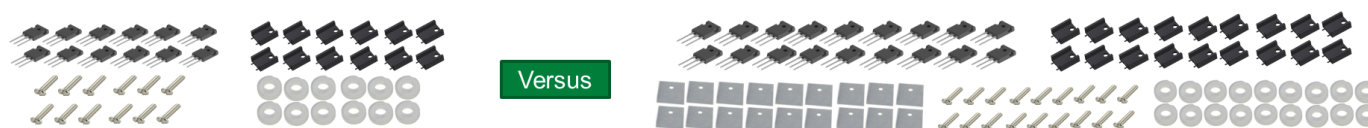
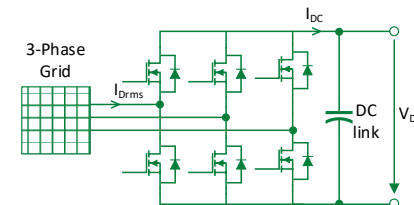


*Calculated based on the thermal measurement results @ $T_{vj}=130^{\circ}\text{C}$ for theoretical 20 kW application with 800 V DC-link

System simplification / cost saving opportunities

■ Illustrative example 50kW active front end converter

- Paralleled 1200V/30mΩ SiC MOSFETs



	ISO247 with AMB substrate	TO247
Total number of devices	12 (2 per switch position)	18 (3 per switch position)
No. of isolation pad	0	12
Mounting & assembly	No isolation pad	Place and assemble 18 isolation pads
Production yield improvement	+10 p.p. vs base case*	Base case

* Based on feedback from lead customer

Littelfuse new SiC lineup

- ~50 new SiC diodes and MOSFET planned for release until Q2'2025
- Commodity line: state of the art standard discrete devices
- Performance line: isolated, multichip devices

										Released	R&D
Commodity line						Performance line					
MOSFETs			Diodes			MOSFET		Diodes			
Single			Single	Common cathode		Single	Half bridge	1PH rectifier	Parallel		
<u>TO247</u>	<u>TO263</u>	<u>TOLL</u>	<u>TO220, TO247, TO263</u>	<u>TO247</u>		<u>ISO247-3L and ISO247-4L</u>	<u>SOT227</u>	<u>SMPD</u>	<u>SMPD, i4</u>	<u>SOT227</u>	
650V											
1200V											
1700V											

1200V SiC MOSFETs - ISO247 new lineup

Non released devices' schedule and characteristics subject to change without notice

- State of the art SiC trench MOSFET
- TO247-AD compatible isolated package, high performace AMB substrate

			Q4 24	Q1 25
V_{DSS} (V)	$R_{DS(on)}$ (m Ω)	I_D @ 25°C (A)	ISO247-3L (2500V~ isolation) 	ISO247-4L (2500V~ isolation w/ Kelvin source) 
1200	18	80	IXSJ80N120R1	IXSJ80N120R1K
	36	43	IXSJ43N120R1	IXSJ43N120R1K
	62	25	IXSJ25N120R1	IXSJ25N120R1K

Takeways – ISO247 with AMB substrate isolation

- **Increased power output, up to 30% more current**
- **Decreased Rth J-C, chip up to 60° C cooler**
- **System level cost saving opportunities**
- **Simplified mounting and production yield improvement**
- **Littelfuse new SiC portfolio**



Thank You

Related Materials

<https://www.bodospower.com/>

<https://pcim.digital.mesago.com/>

Bodo's Article Oct 2022

SMPD™ : An Advanced Isolated Packaging to Fully Exploit the Advantages of SiC MOSFETs

In the standard discrete packages of power semiconductor, application specific topology needs are not taken into consideration. On the other hand, power modules typically incorporating a full topology but feature complex package handling requirement. The advanced isolated packages from Littelfuse such as SMPD fill the gap between modules and discrete, offering the performance of power module with the flexibility of discrete devices.

By Ajayk Bhatt, Francois Perreault, José Padilla and Martin Schulz, Littelfuse

ISOPLUS™ SMPD and its Advantages
SMPD stands for Surface Mount Power Device. The advanced top side cooled isolated package was first powered by IGBTs in 2010. In 2021, the SMPD is displayed in Figure 1, offers several key advantages:

- The integrated isolation provides excellent reliability under power and temperature cycling environments.
- Lower junction-heatsink thermal resistance and higher power handling capability compared to discrete devices using an external heatsink.
- The advanced top side cooled package and standard reflow soldering for the ease of manufacturing.

The SMPD is a revolutionary package which simplifies the way designers address their power semiconductor system requirements and concerns. They are available in standard configurations, but are available in a variety of technologies such as SiC MOSFET, IGBT, Diode, Thyristor. They are connected configurations with all four voltage classes from 600V to 3300V.

Figure 1: SMPD internal construction
The SMPD is a revolutionary package which simplifies the way designers address their power semiconductor system requirements and concerns. They are available in standard configurations, but are available in a variety of technologies such as SiC MOSFET, IGBT, Diode, Thyristor. They are connected configurations with all four voltage classes from 600V to 3300V.

Bodo's Article July 2023

SMPD: An Advanced Isolated Package to Keep the SiC MOSFET Chip up to 75°C Cooler

The advanced isolated packaging from Littelfuse, the SMPD, fills the gap between modules and discrete, by offering the performance of a power module with the flexibility of a discrete.

By Ajayk Bhatt, Umme Kulsoom, Francois Perreault, Martin Schulz, Levi Gant, Littelfuse

With the major benefits of increased junction-heatsink thermal resistance, R_{jsh} , reduced power and current handling capability and complex thermal management with significant efficiency, offering IGBTs, the SMPD is displayed in Figure 1, offers several key advantages:

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• The advanced top side cooled package and standard reflow soldering for the ease of manufacturing.

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Conference Paper PCIM 2023

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Abstract

Power semiconductor typically are presented in two types of packages: discrete and module. Though both seem to be innovative solutions of delivering semiconductor capability, each one is limited by its own structural and functional capacities. Discrete tend to be highly standardized often incorporating single switch configuration, whereas power modules feature complex package handling requirements often incorporating complex topology. Therefore, in an effort to bridge the gap between the two, Littelfuse offers an advanced isolated package, the SMPD, anchored with the performance of a power module and designed with the flexibility of a discrete. The SMPD is available in standard power electronics building blocks to realize full topology by distributed arrangement of functional groups. This work compares the dynamic performance of the SMPD versus standard discrete packaging to highlight the advantages of the SMPD in Silicon Carbide (SiC) MOSFET based applications. Additionally, thermal measurements comparing the SMPD with different scenarios to standard TO-247 package show the SMPD proves to be the ideal choice when aiming to minimize chip junction temperatures and junction-heatsink thermal resistance. The latter thermal performance of the SMPD leads to potential increase in application power output without affecting to greater system-level cost savings.

1 The ISOPLUS™ SMPD and its Advantages

The design space for Surface Mount Power Device, with the advanced top side cooling, this isolated package was first powered by IGBTs in 2010. In 2021, the SMPD is displayed in Fig. 1, offers several key advantages:

- Integrated Direct Copper Bonded (DCB) isolation provides inherent thermal resistance and higher power handling capability compared to discrete devices using an external heatsink.
- The advanced top side cooled package and standard reflow soldering for the ease of manufacturing.
- Reduced EMI attributed to the small chip-to-heatsink stray capacitance.

The primary motivation to use the SiC MOSFET in application is high power density, improved efficiency and high frequency operation capability reducing compact design. However, to offset the

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ISO247: High Performance Ceramic based Advanced Isolated Discrete Package to Fully Exploit the Advantages of SiC MOSFET

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Abstract

In power electronic applications, achieving electrical isolation between a discrete semiconductor package and the heatsink often results in an increase in the thermal resistance junction-to-heatsink R_{jsh} , limiting the current carrying capacity of the packaged device. Littelfuse's innovative isolated discrete ISO247 package directly addresses this issue. The ISO247 with high performance ceramic enhances power and current density while providing inherent isolation and remaining isolated compatible with standard TO-247 package. This paper compares ISO247 and TO-247 devices carrying the same 1200 V SiC MOSFET. Thermal resistance, junction temperature and power handling capability are analyzed to demonstrate the superiority of the ISO247 package for SiC power devices. Thermal measurements indicate that selecting the ISO247 is optimal for minimizing chip junction temperature and thermal resistance junction-to-heatsink, potentially leading to increased application power output and cost savings at the system-level.

1 ISOPLUS™ – The Revolution in Discrete Isolation Technique

ISOPLUS™ is the family of internally isolated discrete power semiconductor devices, first pioneered by IGBTs in 2010. In 2023, the ISO247 belongs to the ISOPLUS™ product family and adheres to the JEDEC TO-247AD outline, ensuring pin compatibility with the standard TO-247 package. The ISO247 displayed in Fig. 1, offers several key advantages:

- Isolation voltage rating of 2.5 kV AC, 1 minute or 3 kV AC, 1 second.
- Higher temperature and fast power cycling with standard capability compared to standard TO-247 ascribed to the matched coefficient of thermal expansion (CTE) for SiC chip and AMB substrate [2].
- Increased power density and simplified thermal management.
- Reduced EMI attributed to the small chip-to-heatsink stray capacitance.

The primary motivation to use SiC MOSFETs in an application is to achieve improved efficiency, high power density and high frequency operation, enabling a compact design. Maximizing chip performance becomes imperative to offset the high cost associated with SiC. Conventional TO-247 packages often suffer from junction-heatsink thermal resistance from thermal management, resulting in a sub-optimal utilization of the SiC chip. The ISO247 package addresses this drawback and presents a revolutionary solution by enabling the use of SiC MOSFETs in a wide range of applications, from power electronics to industrial automation and assembly lines. The ISO247 is available in a variety of technologies such as SiC MOSFETs, IGBTs and Diodes with different voltage classes ranging from 70 V to 1600 V.

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