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

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

By Aalok Bhatt; Umme Kulsoom; Francois Perraud; Martin Schulz; Levi Gant, Littelfuse

ISOPLUS - SMPD and its Advantages

The SMPD stands for Surface Mount Power Device. This top side cooled isolated package was first pioneered by IXYS (Littelfuse) in 2012. The SMPD as displayed in Figure 1, offers several key advantages:

- The integrated isolation provides excellent reliability under power and temperature cycling environment.
- Isolation voltage rating of minimum 2.5 kV AC, 1 minute.
- Lower junction-heatsink thermal resistance and higher power handling capability compared to discrete device using an external isolation foil.
- Allows fully automated pick & place and standard reflow soldering for the ease of manufacturing.

The SMPD is a revolutionary package which simplifies the way engineers address the system integration, thermal and assembly challenges of their power semiconductor designs. The SMPDs are already available with standard topologies such as rectifier, buck, boost, phase-leg in a variety of technologies such as Si/SiC MOSFET, IGBT, Diode, Thyristor, Triac, or other tailored solutions with voltage classes ranging from 40 V to 3000 V.

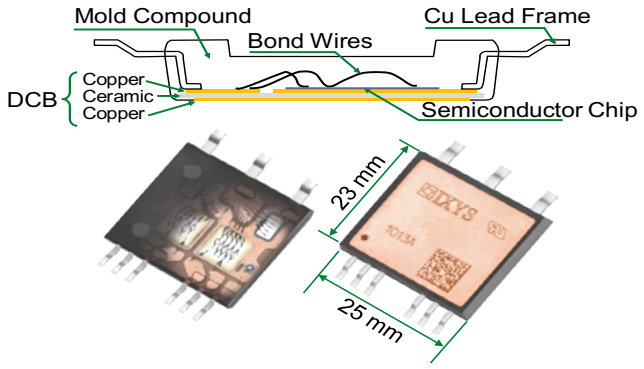


Figure 1: SMPD internal construction and size

Performance advantages of SiC based SMPD compared to standard discrete

The electrical performance advantages of SiC MOSFET based SMPD compared to standard discretes were highlighted in Bodo's power magazine article, October-2022 [1]. The article also emphasized on the applicational advantages including the power loop optimization when using the SMPD.

Thermal performance comparison between SiC based SMPD and standard discrete

Most of the standard discrete power semiconductor packages have an electrically conductive mounting tab. It is typically desired to electrically isolate the device mounting tab from the heat sink due to safety concerns and due to the need to mount multiple discrete devices with different tab potentials on the same heat sink frame. External thermally conductive electrical isolation foil between the package tab and heatsink has become a widely used approach in the industry for such a purpose. However, this approach comes with the major penalties of increased junction-heatsink thermal resistance, R_{thJH}, reduced power and current handling capability and complex thermal management with significant assembly efforts [2]. In contrast, the DCB-isolated SMPD doesn't require an external isolation foil, thus improving its thermal performance significantly when compared to conventionally isolated discretes. Thermal measurements were carried out to demonstrate the improved thermal performance and power handling capability of the isolated SMPD compared to externally isolated standard discretes. Littelfuse has developed the SMPD with a high-performance ceramic which further reduces the junction-case thermal resistance, R_{thJC}, and junction-heatsink thermal resistance, R_{thJH}, consequently improving power handling capability even further [3]. Thermal measurements incorporating 1200 V SiC MOSFET chips were conducted in three different packages as shown in Figure 2: the standard TO-247, the SMPD with alumina ceramic, and the SMPD with high performance ceramic.

	TO-247	SMPD	SMPD
Isolation	External, Thermally conductive foils with thermal conductivity 4.5W/mK and 6.5W/mK	Internal, Alumina ceramic	Internal, High performance ceramic
SiC die	Same in all three packages		
$V_{(BR)DSS}$ [V]	1200	1200	1200
$R_{DS(on)}$ [mΩ]	25	25	25
I_{D25} [A]	90	55	77
R_{thJC} [K/W]	0.27	0.7	0.45

Figure 2: Devices for thermal performance comparison featuring SiC MOSFETs

Thermal measurement results for the 1200 V, 25 mΩ SiC MOSFET chip in different packages at heating current, I_H=40 A are illustrated in Figure 3.

As evident from Figure 3, the SMPD with high performance ceramic can improve the thermal resistance, R_{thJH}, by up to 56% when compared to the TO-247 with the same chip. This directly translates into increased power handling potential and lower chip temperature at the given current. It was observed that the SiC chips in the SMPD package with improved ceramic stays up to 75°C cooler when compared to the TO-247 device with external isolation at I_H=40 A. The SMPD with high performance ceramic enables therefore nearly a 58% reduction in temperature swing ΔT_{JH} compared to the standard discrete. However, it is worth mentioning that the practical zone for T_{vj} within an application is usually only up to 130°C to ensure safe operation. By comparing the SMPD's performance to the TO-247 with 6.5 W/mK foil at this junction temperature, the SMPD with high performance ceramic improves thermal resistance, R_{thJH}, by 48% and offers 45% lower temperature swing, ΔT_{JH}. Compared to conventional alumina ceramic based SMPD, the high-perfor-

mance ceramic based SMPD offers 30% lower R_{thJH} and 40% lower temperature swing, ΔT_{JH} with the same SiC chip. The SMPD package thus can contribute to significantly improving the device's lifetime and in turn the reliability of the application under realistic application conditions.

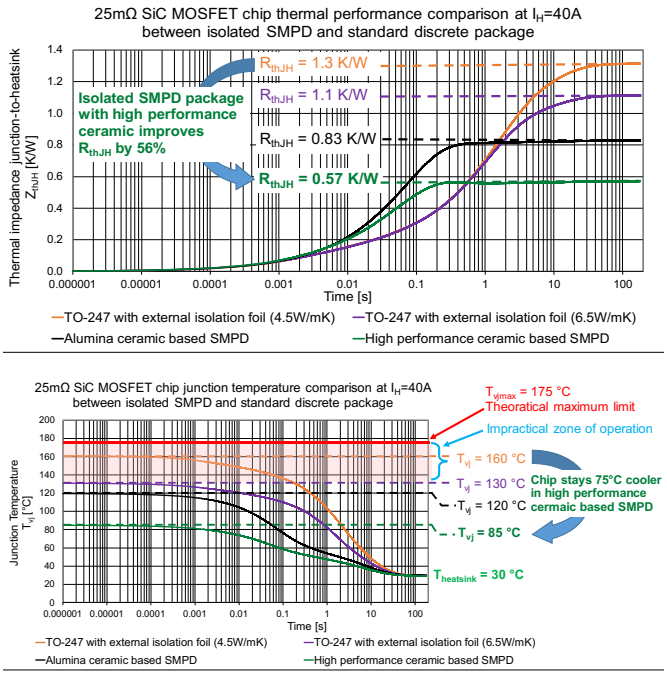
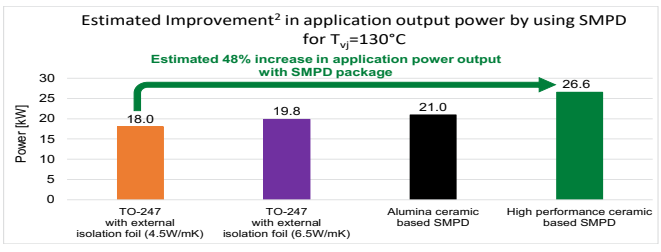


Figure 3: Thermal measurement comparison results on devices featuring SiC MOSFETs

Application power output increase by 48% using SMPD

The reduction in overall thermal resistance and chip junction temperature by using the SMPD package may lead to significant increase potential in application power output. To demonstrate this fact, thermal measurements were performed such that the SiC MOSFET chip will reach the junction temperature of 130°C for the different packages listed in Figure 4. The SMPD with the high performance ceramic could handle 28% higher heating current and 130% higher power dissipation as compared to conventionally isolated discrete solution. The thermal measurement results can be interpreted in terms of percentage power output increase potential of an application by using the SMPD. Let's consider an 18 kW power converter operating at 800 V DC-link voltage, designed with TO-247 discrete and external isolation foil. Replacing the standard discretes with the SMPD will not only reduce the number of necessary power components but also, for the given junction temperature limit of 130°C, the SMPD can push the theoratical DC power output of an 18 kW application by 48% to 26.6 kW.

Thermal Measurement Results at T_{vj}= 130°C	I_H [A]	R_{thJH} [K/W]	P_{DJH} [W]
TO-247 with 4.5 W/mK isolation foil	37.7	1.31	77
TO-247 with 6.5 W/mK isolation foil	40	1.11	91
SMPD with Alumina ceramic	41.4	0.83	122
SMPD with High performance ceramic	48.4	0.57	177

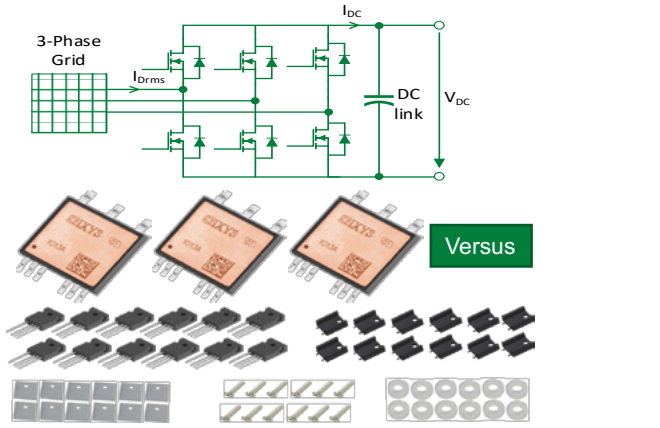


²Calculated based on the thermal measurement results @T_{vj}=130°C for theoratical 18 kW application with 800 V DC-link voltage.

Figure 4: Potential increase in application power output using SMPD

System level cost saving by using the SMPD

The SMPD offers significant indirect cost saving opportunity at system level in the application thanks to its pick & place compatibility, reduction in potential warranty claims by eliminating isolation foil, and reduced space and size on the PCB. Figure 5 illustrates the system level direct cost saving opportunity in the application using the SMPD versus standard discrete using the example of a 22 kW active front end converter for DC charger.



	SMPD	TO-247
Total number of device	3	12
No. of isolation pad	No need	12
Mounting efforts	Simplified [2]	12 screw, washer, heat-sink, man power, tooling
Minimum required PCB area	2400 mm²	5000 mm²

Figure 5: System level cost saving opportunity by using the SMPD in application

Summary

By comparing the thermal performance of the Littelfuse SMPD with standard TO-247 discrete having the same SiC MOSFET chip, it was observed that the SMPD package offered thermal resistance R_{thJH} reduction by up to 56% and temperature swing ΔT_{JH} reduction by up to 58%. The SiC MOSFET chip in the SMPD package could stay up to 75°C cooler at given DC power. The usage of SMPD in application reduces mounting efforts, enables space saving, provides integrated isolation, increases power density and efficiency along with simplified thermal design compared to the standard discrete packages. The Littelfuse SMPD product portfolio can be checked and inquired at Littelfuse web page [4].

References

[1] A.Bhatt, F.Perraud, J.Padilla, M.Schulz, 'SMPD™: An Advanced Isolated Packaging to Fully Exploit the Advantages of SiC MOSFETs'; Bodo's power article, Oct-2022, https://www.bodospower.com/

[2] Application Note: 'Mounting and Cooling Solutions for SMPD Packages'; www.littelfuse.com.

[3] 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

[4] Littelfuse SMPD product offering; https://www.littelfuse.com/products/power-semiconductors.aspx

www.littelfuse.com