TO-247PLUS in reflow-solderable package

Product description, simulations and enclosure recommendations

About this document

Scope and purpose

This application note is intended to describe Infineon's TO-247PLUS package suitable for reflow soldering in accordance with the J-STD-020 standard. It is fitted with the 750 V EDT2 technology having a high current class up to 200 A. This document will focus on the product features and system enclosure recommendations for applications that operates in extreme environments.

Intended audience

This application note is intended for design engineers of main inverters used especially in commercial vehicles.

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1 Product Description

TO-247PLUS SMD package uses the existing TO-247PLUS [1] package with its backside suitable for reflow soldering at 245°C. Designed for main inverter systems, particularly commercial, construction and agricultural vehicle (CAV) applications, a 750 V/ 200 A EDT2 IGBT co-packed with a 200 A EC3 diode in this package was used. EDT2 IGBT technology is already successfully used in several automotive inverter modules. It has a nominal blocking voltage of 750 V, enabling DC bus systems to operate up to 470 V and providing a higher margin for voltage overshoots. It has an automotive cell design with a micro-pattern trench field stop, which significantly reduces conduction and turn-off switching losses [2]. The trade-off is optimized for switching frequencies up to 10 kHz. In the next sections, the key features are listed, simulations and recommended enclosures ingress protection (IP) requirements are discussed.

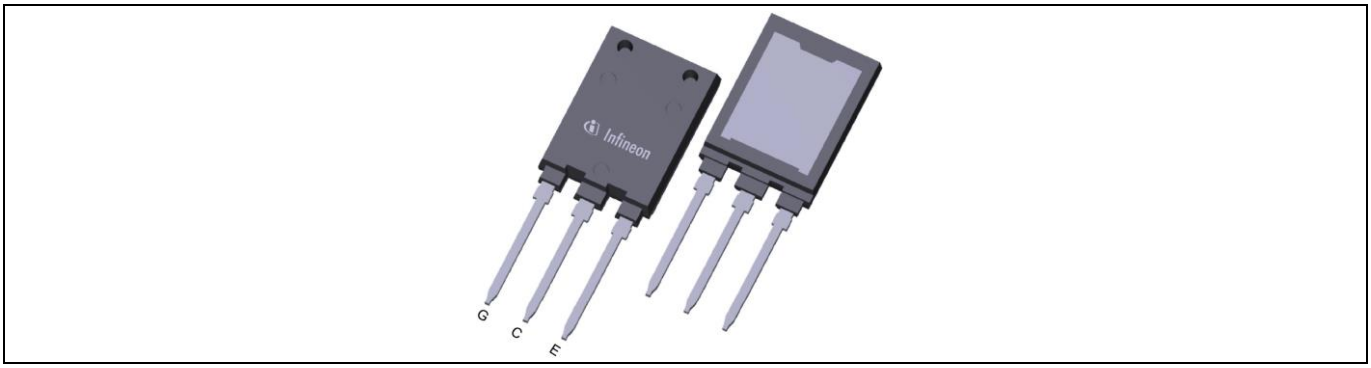

Figure 1 Top side and bottom side of the IGBT in TO-247PLUS SMD package

1.1 PG-TO247-3-PLUS-NN8.5 package

- TO-247PLUS package with high creepage distance
- Package backside suitable for reflow soldering at 245°C, 3 times
  - Moisture-sensitivity level (MSL) 1 according to JEDEC J-STA-020
- Plating of pins further enable electrical resistance welding

1.2 IGBT and co-pack diode

- 750 V collector-emitter blocking voltage capability
- Three current classes: 120 A, 160 A and 200 A
- Low saturation voltage V_{CEsat} = 1.4 V at I_{Cnom} and 25°C
- Short circuit ruggedness with a withstand time of 3 µs at $V_{CC} \leq 450$ V and V_{GE} = 15 V
- Co-packed with full current, soft and fast recovery diode
- Optimized for hard switching topologies up to 10 kHz

2 Simulation of system thermal impedance

Several simulations were done during the course of the development of the TO-247PLUS SMD package. The device considered in these simulations uses the largest chip size that can fit into a TO-247 package. To see the advantages of using a reflow-solderable TO-247, the thermal resistance of the total system must first be validated.

2.1 Effects of different DCB materials on system thermal impedance

Before proceeding with reliability tests on the device assembled on a DCB, thermal simulations using the finite element method (FEM) software, Ansys, were performed. They give a first indication of the thermal performance of the system for different types of DCB materials. To simplify the DUT model, the wiring was omitted, since the simulation was focused on the junction to-ambient thermal flow. The DCB used two copper layers with an Al_2O_3 ceramic material between the layers. The material thickness of the three layers used for this model were 0.3 mm Cu, 0.38 mm Al_2O_3 and 0.3 mm Cu, respectively. The DUT was soldered to the top Cu DCB layer with an 80 µm SAC alloy, while the bottom copper of the DCB was soldered to a copper baseplate as illustrated in Figure 2. The simulation results were then compared to real values.

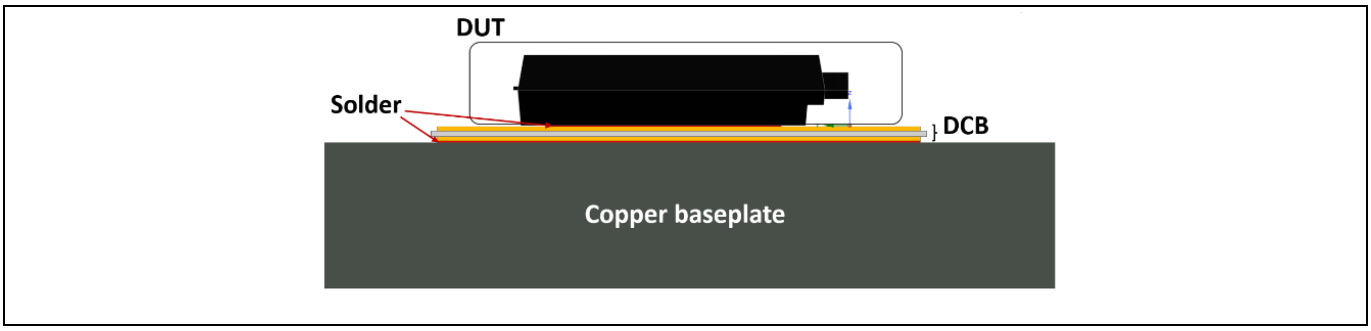

Figure 2 Simulated system. The TO-247PLUS SMD package (DUT) is soldered on the top of the DCB and the bottom of the DCB is soldered to a copper baseplate.

The thermal impedance was then determined based on the cooling curve, after the chip had been heated up to 150°C for 20 seconds to reach a static heat distribution between the chip, DCB and baseplate. Further tests were conducted using different size and thickness of the DCB copper. Solder quality was also considered to understand its' influence on the overall thermal resistance of the system.

2.1.1 Simulated thermal resistance for the total system

Initial measurements of the IGBT that were used in the subsequent simulations had a typical thermal resistance from junction to case ($R_{th(j-c)}$) of 0.120 K/W. Based on these value, Figure 3 shows the simulated thermal resistance for the total system from junction to ambient ($R_{th(j-a)}$) at 0.292 K/W.

Focusing on the impact of material choice while not considering any clearance and creepage requirements, initial simulations were performed with a minimum size DCB set slightly larger than the back side of the device. The DCB measured 20 mm by 23 mm, while the back side of the DUT was typically 15.8 mm by 20.36 mm.

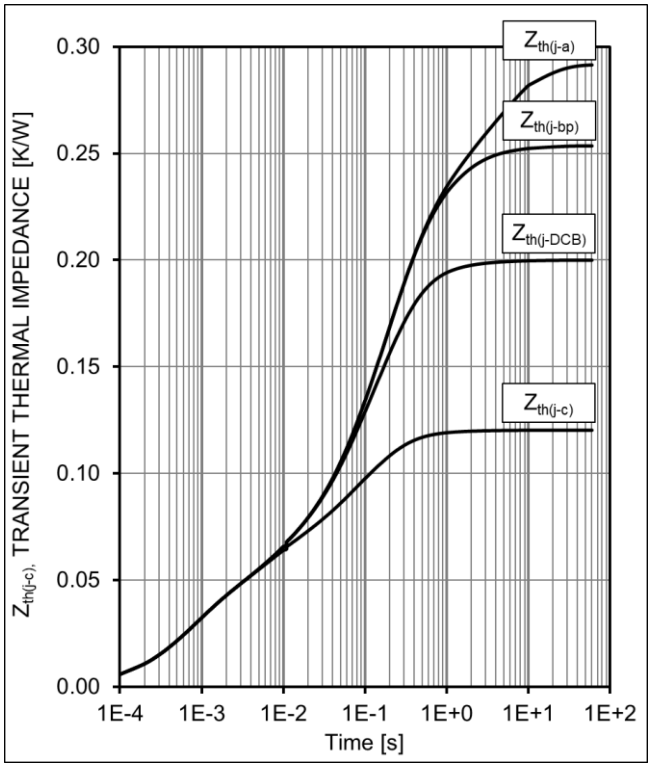

Figure 3 Simulated transient thermal impedance with a DCB size of 20 mm by 23 mm.

2.1.2 Effect of bigger DCB

Some DCB suppliers only offer substrates larger than 20 mm by 23 mm. Bearing this in mind, a $R_{th(j\,a)}$ simulation was done using a DCB that was twice the size of the previous one. The simulated $R_{th(j\,a)}$ with a substrate of 28 mm by 32 mm now measured 0.288 K/W, which was an improvement of 1.4%. This slight improvement in the simulated $R_{th(j-a)}$ gives an indication of how the DCB size affects the overall thermal resistance.

2.1.3 Effect of reducing thickness of DCB copper

The next simulation was carried out to test the effect of a reduced thickness on the DCB thermal resistance for the top and bottom side copper of the DCB. From an initial thickness of 0.3 mm, it was reduced to 0.2 mm. Simulated $R_{th(j-a)}$ resulted in 0.294 K/W, an increase of 0.7% compared to a thicker DCB copper. Reducing the thickness of the copper with a higher thermal conductivity at 398 W/mK at 25°C, compared to the Al_2O_3 ceramic material with 26 W/mK at 25°C, increases the overall thermal resistance of the DCB. One reason for this is that the heat could not spread evenly over the entire area with a reduced copper thickness. Thus the DCB thermal resistance increased [3].

2.1.4 Effect of solder quality of DCB copper with DUT and baseplate

When a semiconductor device is soldered to a DCB and a heatsink, solder voids are unavoidable. It is widely known that solder voids decrease the thermal performance of the system, and can even affect long-term system reliability. There are several ways to minimize these solder voids [4]. We have run simulations to account for these possibilities in the customer assembly process. Considering the worst case condition [5], the single solder void had a circular shape underneath the center of the DUT chip, placed between the DUT and the top copper of the DCB, and the bottom copper of the DCB and baseplate. Initially, the $R_{th(j-a)}$ of 0.292 K/W was without a solder void. When the solder void increased by 10%, thermal resistance increased by 10.3%. The maximum simulated void of 25% resulted in a thermal resistance of 0.39 K/W or 34.2% more than a 0% void. Figure 4 shows the simulated $R_{th(j-a)}$ at an increasing percentage of solder voids.

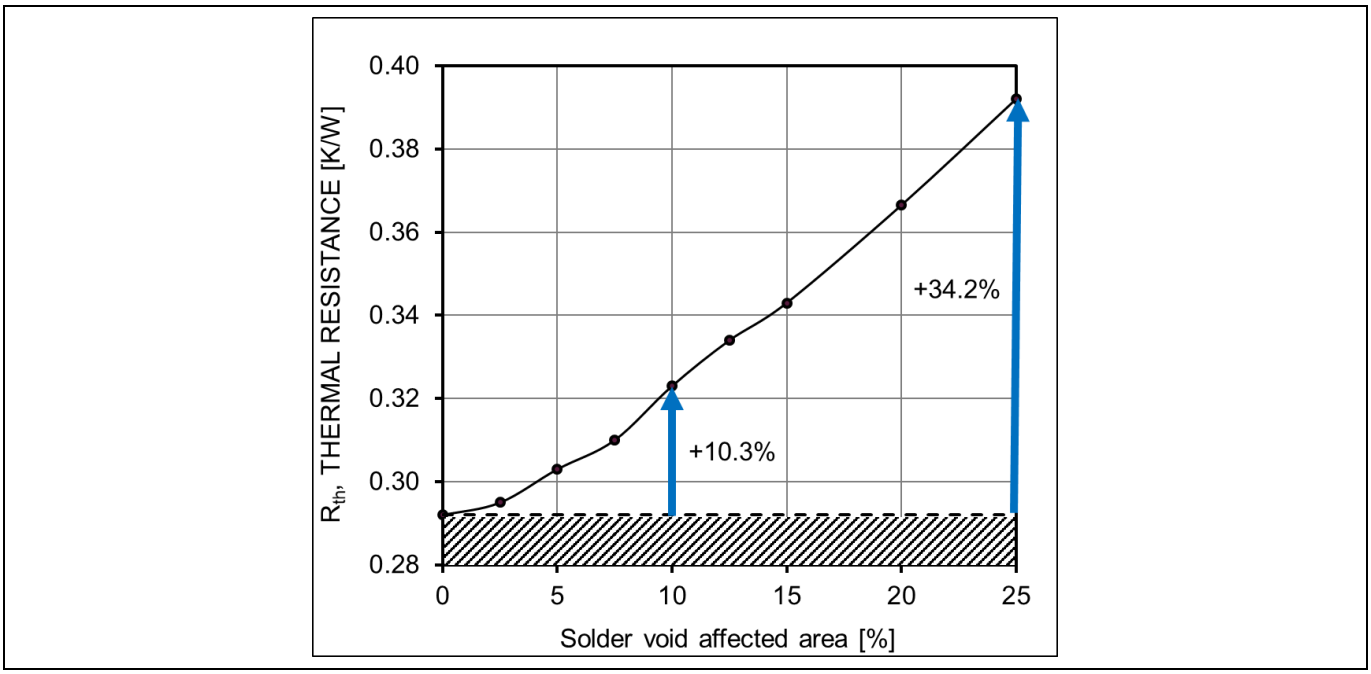

Figure 4 Simulated thermal resistance for a given percentage of solder voids. A 10.3% increase in R_{th} at a solder void of 10%.

2.1.5 Silver sintering compared to soldering

Silver sintering is a process in which a cohesive material is formed into compressed power using heat. It is an alternative to soldering, and is characterized by the strength and quality of the connection. A model with 25 µm sintered DUT on the DCB and baseplate was investigated. This high-quality solution built with silver sinter connections had a $R_{th(j-a)}$ of 0.280 K/W. This represents a 4.1% improvement compared to the soldering process.

Table 1 summarizes the simulated $R_{th(j-a)}$ for different DCB materials. Increasing the DCB size can reduce the system thermal impedance while reducing the thickness of the copper of the DCB increased the $R_{th(j-a)}$. A critical parameter is the single solder void, at which a considerable increase in $R_{th(j-a)}$ was seen. To improve the strength and quality of the connections between DUT, DCB and baseplate, and overall thermal performance, one should consider using silver sintering as opposed to the soldering process.

Table 1 Summary of simulated $R_{th(j-a)}$ of varying DCB materials, and assembly process

Parameter	$R_{th(j-a)}$, [K/W]	Difference, [%]
DCB size: 20 x 23 mm DCB Cu thickness: 0.3 mm Solder void: 0% Solder: 80 µm SAC alloy	0.292	reference
DCB size: 28 x 32 mm	0.288	-1.4
DCB Cu thickness: 0.2 mm	0.294	0.7
Single solder void: 10%	0.323	10.3
Silver sintering: 25 µm thick	0.280	-4.1

3 Enclosure recommendations

Applications like commercial vehicles could operate in a harsh and extreme environment. It is exposed to humidity and dust that could cause malfunction to a system that comprises environment sensitive components. It is important that these parts are well protected at a system level. A properly sealed enclosure is needed for such extreme applications. Commonly used housing is a die-cast aluminum which protects the system to water and dust. The level of protection of these enclosures can be classified by its ingress protection ratings or IP ratings developed by IEC. IEC 60529 [6] details the levels of protection against water and dust for an enclosure. For applications that operate in extreme environments like CAV, an IP67 enclosure supported by an appropriate thermal management is generally recommended.

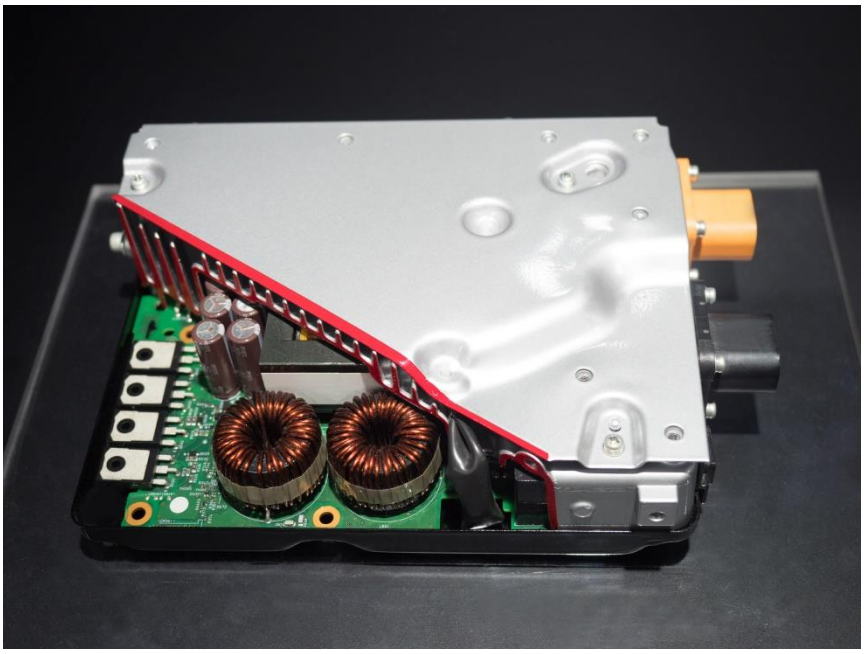

Figure 5 Sample inverter for electric vehicles

Referring to IEC 60529, an enclosure with an IP rating of IP67 can protect the system from ingress of dust (6) and temporary immersion in water under certain conditions (7).

4 Conclusion

A TO-247PLUS SMD is the ideal discrete package for demanding applications, such as CAV. The package is capable of reflow soldering at 245°C to a DCB. It has a moisture-sensitivity level 1 according to JEDEC J-STA-020. Thermal simulations show that single soldering voids have a huge impact on the overall system thermal performance, while silver sintering can greatly improve system thermal conductivity. Enclosures for applications that operate in a harsh and extreme environment should provide IP67 ingress protection to the sensitive components.

5 References

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