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CoolSiC™ 2000 V SiC Trench MOSFET defines an enhanced benchmark for increased power density in new energy applications

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Abstract

This paper presents the new CoolSiC™ trench MOSFET 2000 V series. In the new TO-247PLUS-4-HCC package with .XT technology, these devices increase power density. In the 62mm package, they can be used as half-bridge modules and in an EasyPACK™ 3B package as boost modules for string inverters. The enhanced performance of these devices leads to higher power density, excellent reliability, higher efficiency, and ease of design.

1 Introduction

The new requirements in solar, energy storage, and high-power chargers (1500 V_{DC}) require higher voltage margins for safer system operation. The CoolSiC™ MOSFET 2000 V has been designed to offer increased power density without compromising the system's reliability under demanding conditions, such as high voltage and high switching frequencies. A new TO-247PLUS-4-HCC package with high creepage, high clearance, and .XT interconnection technology has been introduced for the 2000 V SiC MOSFET discrete devices. The evaluation board for these 2000 V discrete devices helps in easily evaluating the performance. The 62mm CoolSiC™ MOSFET 2000 V half-bridge module revolutionizes the 1500 V_{DC} solar and energy storage systems with a 2-level or NPC2 topology.

In this paper, the topology, chip size, waveforms, and efficiency of the EasyPACK™ 3B CoolSiC™ MOSFET module with 2000 V, 60 A boost is compared with a traditional 3-level topology Si solution. All these devices aim at providing higher power density, higher efficiency, and ease of design.

2 CoolSiC™ trench MOSFET 2000 V in a TO-247PLUS-4-HCC package

The CoolSiC™ MOSFET 2000 V in a TO-247PLUS-4-HCC package has been designed to offer higher power density without compromising the system's reliability even under demanding high voltage and switching frequency conditions. As shown in Fig. 1, the new package has a 5.5 mm clearance and 14 mm creepage. This can prevent corona high frequency discharge for high peak voltages (see in Fig. 2). The TO-247PLUS-4-HCC package has the same height and width as other TO-247 packages. It is pin-to-pin compatible with the standard TO-247-4 pin and the Kelvin emitter 4-pin package to enable ultra-low switching loss due to a low inductance gate-emitter control loop.

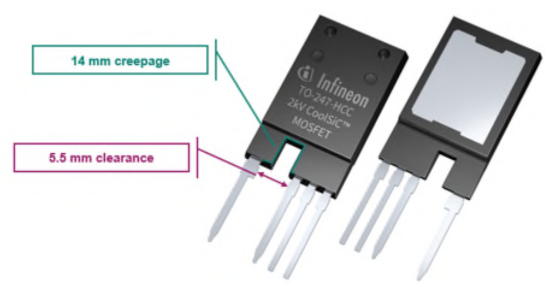

Fig. 1. High creepage and clearance distance of the TO-247PLUS-4-HCC package

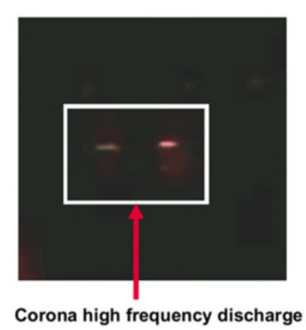

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Fig. 2. Corona high frequency discharge under 1.6 kV voltage spike, 80 kHz switching frequency, with the TO-247-3 package

The .XT interconnection technology in the TO-247PLUS-4-HCC package:

- significantly improves thermal capabilities
- reduces the junction-to-case thermal resistance and impedance
- prevents die tilt and solder bleed-out for better assembly control
- increases active and passive thermal cycling capacity due to lower operating temperature for better performance under thermo-mechanical stress

Compared to standard soldering, the .XT interconnection can have up to 25% lower junction-to-case thermal resistance (R_{thjc}), as shown in Fig. 3. The CoolSiC™ trench MOSFET 2000 V family has a range between 12 to 100 mΩ along with the matching diode portfolio ranging from 10 to 80 A.

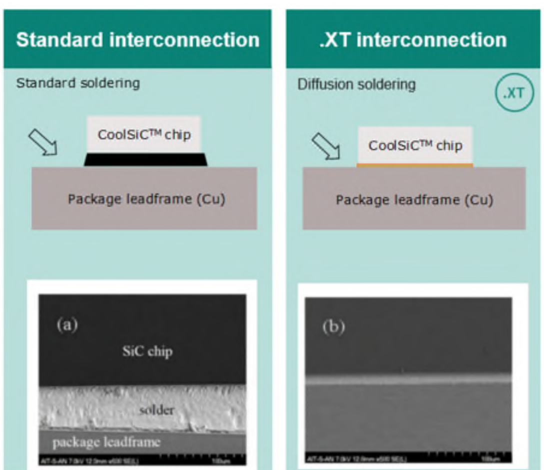

Fig. 3. Diffusion soldering to reach low R_{thjc}

The EVAL-COOLSIC-2kVHCC evaluation board has been developed to display the unique features of the CoolSiC™ 2000 V 24 mΩ in the TO-247PLUS-4-HCC package. It can be used as an accurate universal test platform to evaluate any CoolSiC™ MOSFET 2000 V discrete device and the EiceDRIVER™ Compact single-channel isolated gate driver family (1ED31xx) through a double-pulse or continuous pulse-width modulation (PWM) operation. The board's flexible design allows for a variety of measurements at different testing conditions focusing on half-bridge topology applications, such as solutions for solar and energy storage systems. [1]

Figure 5 shows an almost perfect test gate waveform without overshoot or undershoot. The oscillation seen is caused by the stray capacitor of the layout and not by the device itself. The test conditions were: DC link voltage = 1200 V, gate voltage = 18 V/-2.5 V, at normal temperature.

Fig. 4. The EVAL-COOLSIC-2kVHCC evaluation board

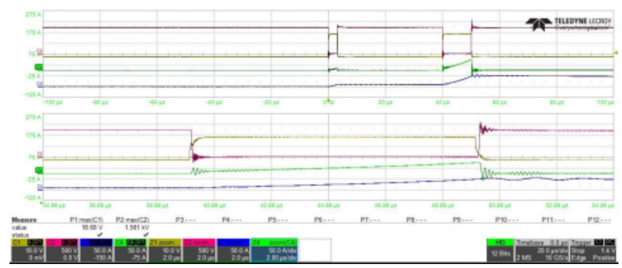

Fig. 5. The test waveform 1200 V/50 A using the EVAL-COOLSIC-2kVHCC evaluation board

3 The 62mm CoolSiC™ MOSFET 2000 V half-bridge module

The 62mm CoolSiC™ MOSFET 2000 V half-bridge module comes in the well-known 62mm housing with M1H chip technology. Besides the half-bridge topology, a common source topology with the same 62mm housing devices will be coming soon. This will enable not only a 2-level but also a 3-level NPC2 topology.

Currently, the NPC1 and ANPC topology are widely used in 1500 V_{DC} solar and energy storage systems. With the new 2000 V devices, 2-level and 3-level NPC2 topology can be realized. [2] [3]

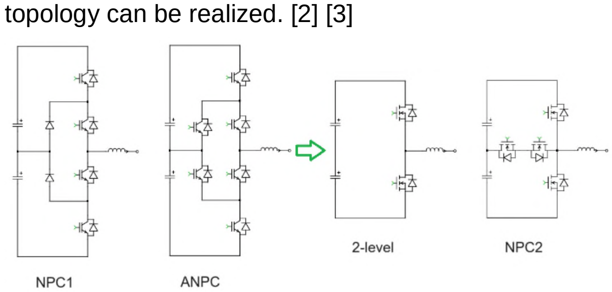

Fig. 6. Topology change from NPC1/ANPC to 2-level/NPC2 in 2000 V devices

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4 EasyPACK™ 3B CoolSiC™ MOSFET module with 2000 V, 60 A boost

Traditional boost solutions for high-power string solar inverters usually use the fly cap or dual boost topologies. The 2000 V SiC MOSFET in an Easy 3B package enables a simpler solution with a 2-level topology, as shown in Fig. 7. This lowers the number of components while increasing power density and reducing total system cost for 1500 V_{DC} applications. DF4-19MR20W3M1HF_B11 has a 4-leg boost configuration in an Easy 3B package with a 2000 V SiC MOSFET and diode in a symmetrical and low inductive design (see Fig. 8). It offers the lowest $R_{DS(on)}$ and FIT rate, higher switching frequency, and higher power density. The module can also be used in a 2-leg boost configuration with two parallel legs. The current can rise up to 120 A.

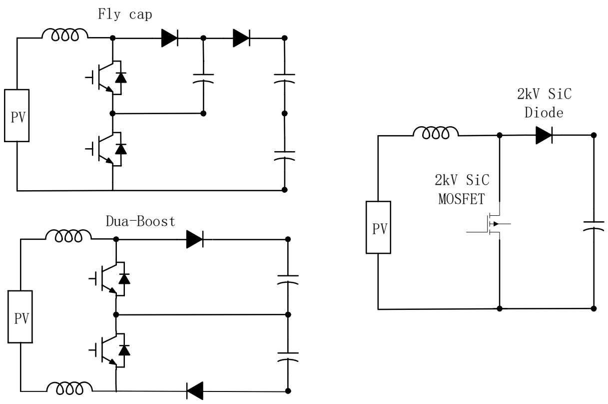

Fig. 7. Fly cap, dual boost, and 2-level topologies with 2000 V SiC devices

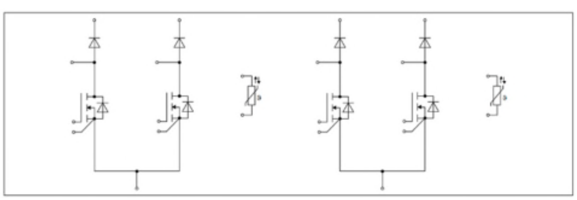

Fig. 8. A circuit diagram with a 2-level topology for boost solutions

Figure 9 shows a comparison between the chip sizes of a dual boost module and a 2-level full SiC module. It shows that a 2-level full SiC solution has 70% smaller chip size. The power density of a 2-level full SiC module is also higher. The test waveforms in figures 10 and 11 show different turn-off between 1200 V IGBT/diode and 2000 V SiC MOSFET/SiC diode. The only difference seen is in the turn-off voltage platform as the 2000 V devices have a higher voltage platform. This can simplify the whole system and increase its power density. Figure 12 shows the boost efficiency curve under different load percentage conditions. At light loads, the 2-level full SiC solution has a 1% increase in efficiency, and an average of about 0.5% increase under all working conditions.

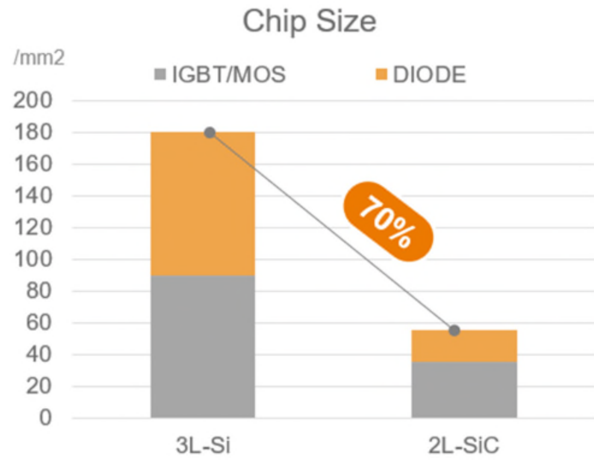

Fig. 9. Chip size comparison between dual boost module and 2-level full SiC module

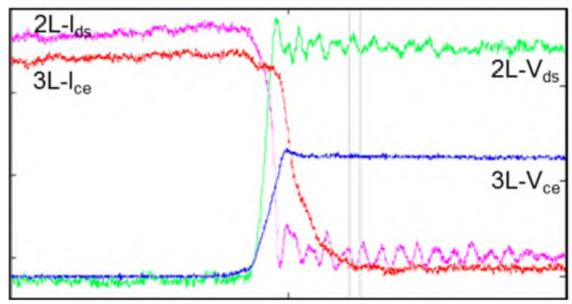

Fig. 10. IGBT/2000 V SiC MOSFET turn-off comparison

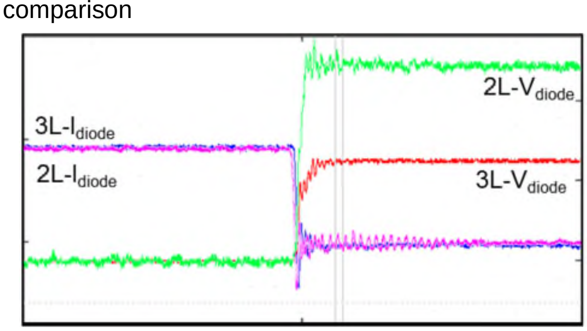

Fig. 11. 1200 V SiC diode/2000 V SiC diode turn-off comparison

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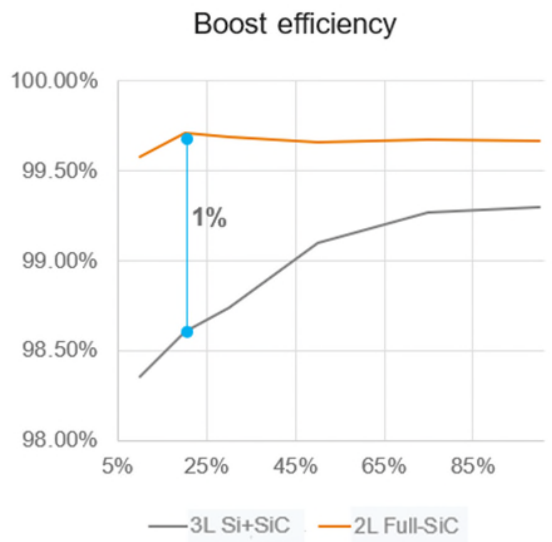

Fig. 12. Comparison of boost efficiency between a dual boost module and a 2-level full SiC module

5 Conclusion

This paper presents the new CoolSiC™ trench MOSFET 2000 V devices with high creepage, high clearance, and .XT interconnection technology in a TO-247PLUS-4-HCC package; a half-bridge and common source topology in a 62mm package; and a 4-leg boost topology in an EasyPACK™ 3B package. All these devices with a 2000 V SiC chip in 1500 V_{DC} system offer higher power density, higher efficiency, and ease of design. The evaluation board is a test platform for designers to tryout and understand this revolutionary 2000 V device.

6 References

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