Benefits of Modular Approach in Medium Power Automotive Applications

Inside automotive applications, especially for on board converters, dimension and weight are two fundamental parameters. Lighter, smaller and efficient applications as well as semiconductors and packages are crucial. For this reason, STMicroelectronics developed the ACEPACK SMIT, a top side cooling SMT package that houses the latest and efficient SiC, Super Junction and Si IGBT technologies. The aim of this article is to show the benefits deriving from the adoption of modular approach based on ACEPACK SMIT respect to the traditional trough-hole discrete one.

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ACEPACK SMIT allows designer to increase the power density, increase the power efficiency, reducing the power loop, reducing the switching energies and working with a cold temperature.

ACEPACK SMIT Overview

ACEPACK SMIT is one of the latest top side cooling SMT packages with automotive grade qualification, AEC-Q101, from STMicroelectronics. It is available for several technologies: diodes, thyristors, SiC MOSFETs (650V and 1200V), Si Super Junction MOSFET and IGBT.

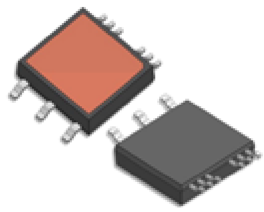

Figure 1: ACEPACK SMIT

Regarding active devices, ACEPACK SMIT enables very fast switching thanks to the kelvin pin that provides a low noise returning path for the gate signals.

Different topologies and configuration can be obtained with ACEPACK SMIT: Full bridge diodes, half bridge thyristors, boost PFC, half bridge and source to source.

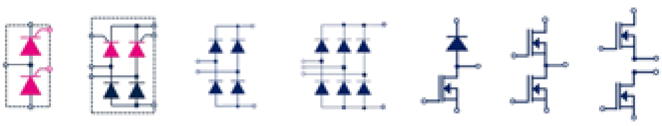

Figure 2: Possible configurations inside ACEPACK SMIT

Thanks to the DBC, direct bonded copper substrate and extended creepage it achieves a 4kV isolation. The total footprint area is 33.20x25.20 mm^2 that enables a compact design and cost-effective solution.

Test vehicle overview

For our analysis ACEPACK SMIT with two MOSFETS in half bridge configuration is chosen and we use it inside an 1500W resonant LLC half bridge. The same silicon MOSFET is used for both ACEPACK SMIT, SH68N65DM6AG, and TO-247, STWA68N65DM6AG, solutions and it is a 650V 39mΩ MOSFET. Figures 3 and 4 show the power loop respectively for ACEPACK SMIT and for TO-247.

The ACEPACK SMIT solution allows to reduce the length of power loop about 25% respect traditional TO-247 layout, indeed the total power loop Length is:

77.91mm for ACEPACK SMIT
103.63mm for TO-247

Reducing the power loop length also the stray inductance will be reduced, therefore, the overvoltage and the ringing during the turn-off are both mitigated.

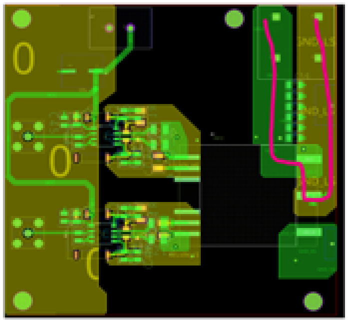

Figure 3: Layout and power loop (purple) for ACEPACK SMIT solution

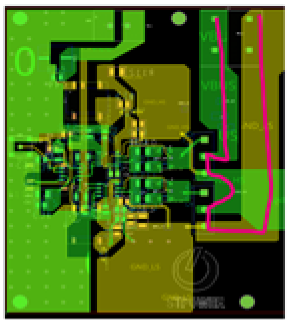

Figure 4: Layout and power loop (purple) for TO-247 solution

The test vehicle used in these tests, is a 1500W, 400V – 48V, half bridge LLC, with a resonance frequency of 125 kHz on the secondary side a center tap transformer with STPS61170C-Y, AG qualified diodes, are used.

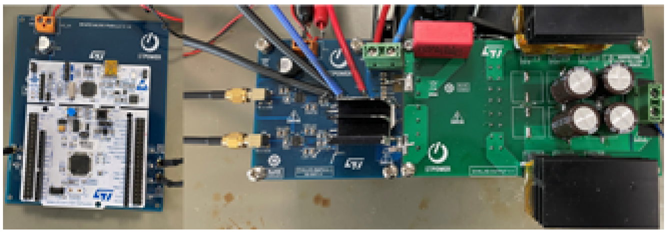

Figure 5: Test vehicle

Figure 6 shows the mounting of the ACEPACK SMIT and heatsink on the PCB. From thermal characterization also the $R_{THj\text{-}amb}$, for this solution, was measured and the value is 12 °C/W.

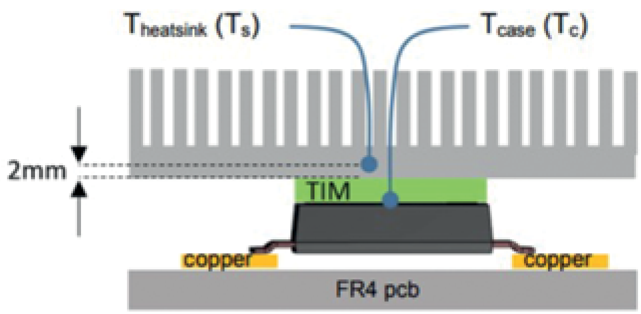

Figure 6: ACEPACK SMIT and heatsink mounting details

For both module and discrete in this analysis the same external gate resistance are used, 22 Ω for the turn-on and 10Ω for the turn-off.

Applicative results

The first analysis regards switching energies during turn-off and the overvoltage.

In resonant applications, the E_{OFF} includes the energy stored in the C_{OSS} (E_{OSS} not thermally dissipated) and energy lost[1]. To account this, Equation 1 is modified to include the contribution of E_{OSS} and therefore derive the equation 2. Thus, the E*off represent the thermally dissipated energy that contribute to the switching losses [1].

$$P_{off} = f_{SW} \cdot E_{off} \quad \text{Eq. 1}$$

$$P^{*}_{off} = f_{SW} \cdot (E_{off} - E_{OSS}) = f_{SW} \cdot E^{*}_{off} \quad \text{Eq. 2}$$

The ACEPACK SMIT has in the entire range lower E*off, a lower value of both stray capacitance and stray inductance, respect troughhole, allows to achieve a faster commutation, thus, reducing the switching losses.

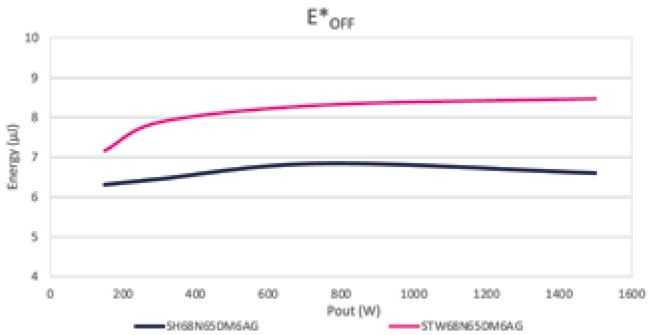

*Figure 7: E*off*

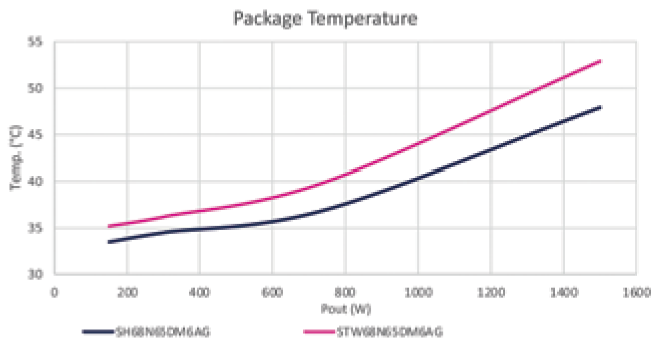

Figure 8: Case temperature

In resonant converters, that typically works with higher switching frequencies respect to hard switching converters, even a small reduction of the switching energy allows to reduce the working temperature of device and increase power efficiency. Moreover, also the smaller turn-off overvoltage contributes to reduce the switching losses. Table 1 reports the overvoltage during turn-off at different level of power. The ACEPACK SMIT helps to reduce about 8% the overvoltage.

V_{DS} turn-off peak		
Pout (W)	SH68N65DM6 (V)	STW68N65DM6 (V)
150	420	455
300	421.1	456.8
750	422.4	459.2
1500	419.2	456.5

Table 1: Turn-off overvoltage during turn-off

Figures 9 and 10, show the main waveforms at maximum load, 1500W, respectively for ACEPACK SMIT and TO-247 solution.

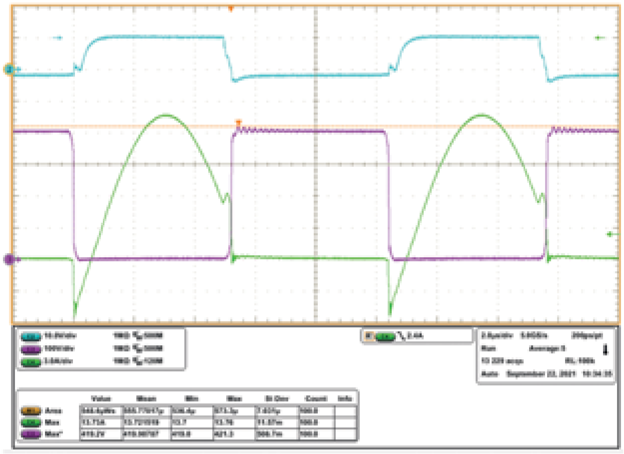

Figure 9: ACEPACK SMIT waveforms at 1500W. Light blue V_{GS}, Purple V_{DS}, Green I_{DS}

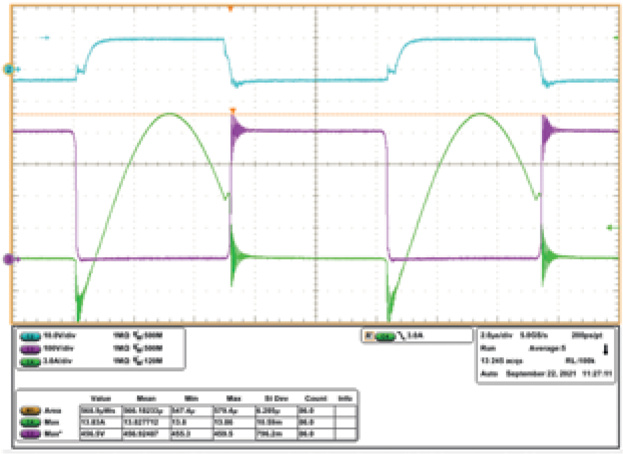

Figure 10: TO-247 waveforms at 1500W. Light blue V_{GS}, Purple V_{DS}, Green I_{DS}

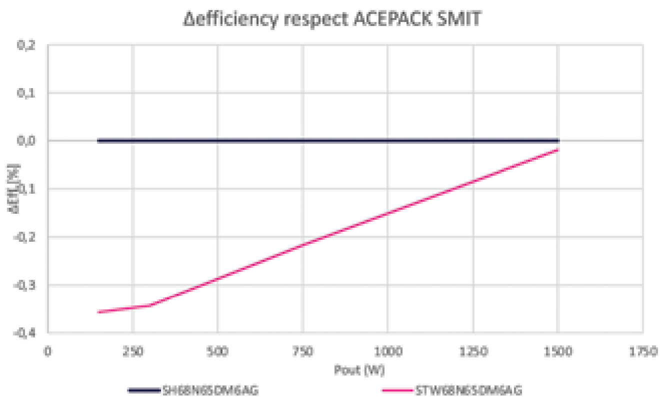

Figure 11: Delta efficiency between ACEPACK SMIT and TO-247 solutions

The lower device losses of ACEPACK SMIT, considering two devices, HB configuration, help to increase the power efficiency, but also to lower the working temperatures. At maximum load, the modular solution is five degrees coolest respect to discrete approach, as showed in figure 13.

Conclusion

In this article were compared SH68N65DM6AG and STW68N65DM6AG, same silicon but housed in two different packages respectively ACEPACK SMIT and TO-247.

Using as test vehicle a 1.5kW HB LLC. Both devices were measured at the same electrical steady-state conditions: switching frequency, dead-time, power out.

In terms of power efficiency using ACEPACK SMIT solution helps to improve it, especially at light load, indeed, SH68N65DM6AG has 0.3% better efficiency respect to the discrete solution.

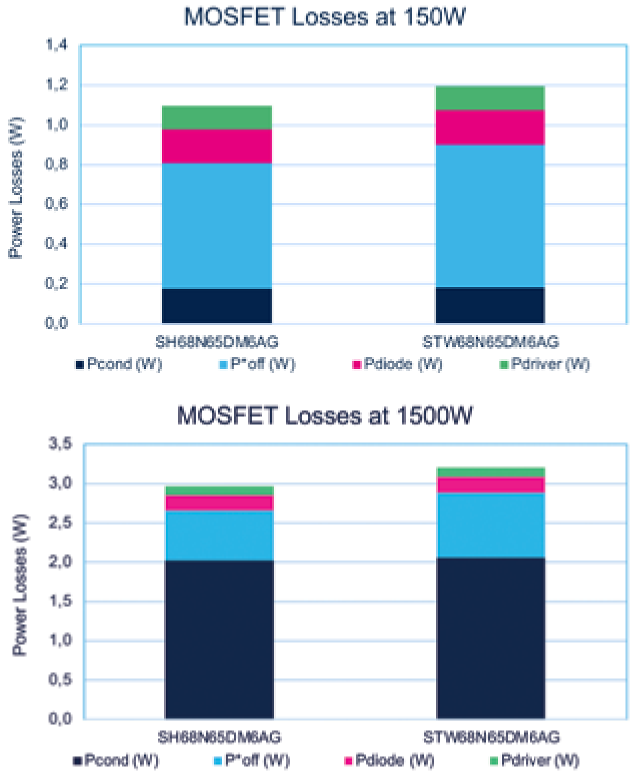

Figure 12: Device power losses

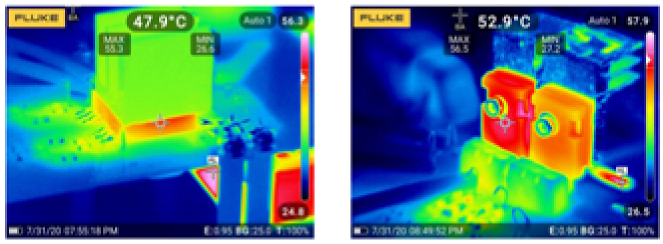

Figure 13: On the left ACEPACK SMIT case temperature at 1500W. On the right TO-247 case temperature at 1500W

Thermal analysis confirms the electrical one, thus SH68N65DM6AG has lower temperature in the entire range respect to TO-247 approach. Of course, the performance of ACEPACK SMIT can be further increased, reducing the value of the RGoff, it is possible to speed up the switching transition and reducing the power losses. Indeed, the smaller overvoltage and less ringing, compared to TO-247, give to the designer some margin for reducing gate resistances.

References

[1] AN5384 - ACEPACK SMIT module package guidelines for mounting and thermal management, STMicroelectronics
[2] AN1703 - Guidelines for using ST's MOSFET smd Packages, STMicroelectronics
[3] F. Scrimizzi, A. Scuto, S. Buonomo and D. Nardo, "ST's MDmesh??? M6 technology improves efficiency in LLC resonant half-bridge converters," PCIM Europe 2019; International Exhibition and Conference for Power Electronics, Intelligent Motion, Renewable Energy and Energy Management, 2019, pp. 1-7.

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