# San'an 1200V 75mΩ SiC MOSFET in OBC

## *High-Efficiency, High-Power Density Design of Vehicle Power Systems*

**AN2025-D02 Application Note**

Author: Yang Wei, Huang Juntian, and Yao Chen, Senior Application Engineer

Translation: Deepak Srivatsa, Application Engineer, San'an Europe GmbH

The installed capacity of the high-voltage battery packs in electric vehicles is continuously increasing as the demand for and market share of Battery Electric Vehicles (BEVs) continue to increase. Electric Vehicles (EVs) with such large Battery capacities have the potential to act as Energy Storage systems to realize various scenarios of power supply from the vehicle to other electrical equipment, such as Vehicle-to-Home, Vehicle-to-Grid, and Vehicle-to-Vehicle charging scenarios. Hence, the architecture of On Board charges (OBCs) in EVs is changing from a Unidirectional to a Bidirectional topology. More EVs in the market today are equipped with a Bidirectional OBC. With increased battery capacities, more energy is required to charge the batteries, giving rise to many challenges. One approach is to increase the battery voltage, which increases the Power delivered by the OBC and benefits from the cost advantages of using less Copper. This can be seen from the increasing share of EVs with an 800V battery pack compared to the legacy 400V battery packs. It is expected that the Battery pack voltages in the future can go beyond 1000V, leading to further innovations and cost optimizations. The demand for higher battery capacity and faster charging time, the efficiency and power density requirements on the OBC are high, to fit in the limited space without increasing the volume and weight restrictions. Traditional Si MOSFETs have limited withstand voltages, and Si IGBTs switch slowly with high switching losses, making the design of OBCs with high efficiency and high power density challenging. SiC devices, which exploit the benefits offered by SiC, enable designers to meet the demanding requirements for OBCs. Due to its wide bandgap, high saturated electron mobility (means lower on-resistance), high thermal conductivity, low conduction loss, and higher switching frequency, it is predicted that SiC MOSFETs will gradually replace Si MOSFETs, super junction MOSFETs, and Si IGBTs, becoming the preferred switching device for automotive applications.

In response to the developing trend of OBC systems and market demand, San'an Semiconductor has introduced various SiC MOSFETs with low $R_{DS(ON)}$, in different packages. This application note focuses on the AMS1200075M, the 1200V, 75mΩ SiC MOSFET in a TO-247-4L package (Figure 1) used to design a 6.6kW bidirectional OBC. The AMS1200075M is a new third-generation semiconductor material SiC device from San'an, which adopts a kelvin-source design, which effectively reduces the interference of other circuits and parasitic parameters on the gate driver, reducing the risk of unwanted and unexpected damage to the switch. The AMS1200075M is an automotive-grade device with AEC-Q101 qualification, having a continuous DC rating of 41A and 1200V breakdown voltage, directly supporting 800V applications.

Figure 1: AMS1200075M (Left)   Pin Definitions (Right)

This performance of the AMS1200075M is evaluated in an independently designed 6.6kW OBC demonstration board. The Demo board adopts the mainstream topology of a commercially available OBC. The frontend, or the input stage on the Grid side, consists of a two-phase staggered bridgeless totem pole PFC followed by a CLLC resonant converter stage with synchronous rectification. Using SiC MOSFETs as synchronous rectifiers allows role reversal to facilitate the reverse flow of power from the output to the input.  The overall topology is shown in Figure 2. The gate driver for the SiC devices features DESAT short-circuit protection, MILLER clamp, low delay, high isolation voltage, low noise on gate drive, and high CMTI. The gate driver is also designed to provide adjustable drive strength and voltages to evaluate the performance at different drive configurations.

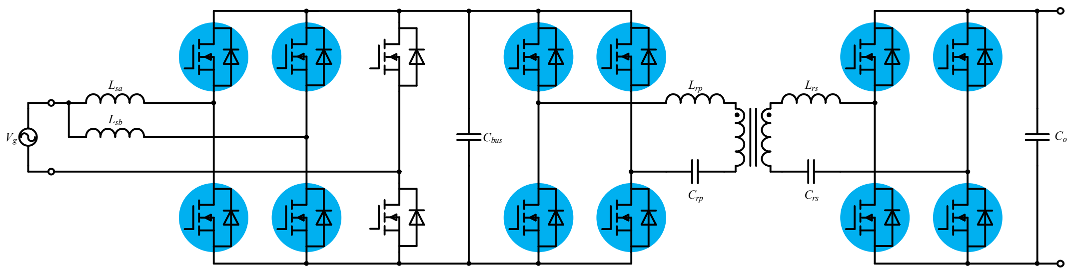

Figure 2: Circuit Topology

Unlike the traditional layout and appearance of standard OBCs, the Demo board uses a symmetrical structure with heatsinks on the top and bottom sides of the PCB to intuitively and conveniently evaluate the thermal and electrical performance of the SiC devices. This approach facilitates the assembly of the SiC devices either on the top or the bottom side of the PCB, depending on the test requirements. Windows have been provided in the enclosures to easily measure the operating temperature of the SiC devices through thermal camera. The SiC devices operate at a higher switching frequency, thereby reducing the size of the magnetic components like the PFC inductor, resonant inductors, and transformer, and increasing the power density of the system. The AMS1200075M has excellent on-resistance characteristics and smaller intrinsic capacitances, significantly reducing the switching and conduction losses compared to Si MOSFETs. Thus, simplifying Thermal management and improving the system reliability. The 3D model of the system is shown in Figure 3.

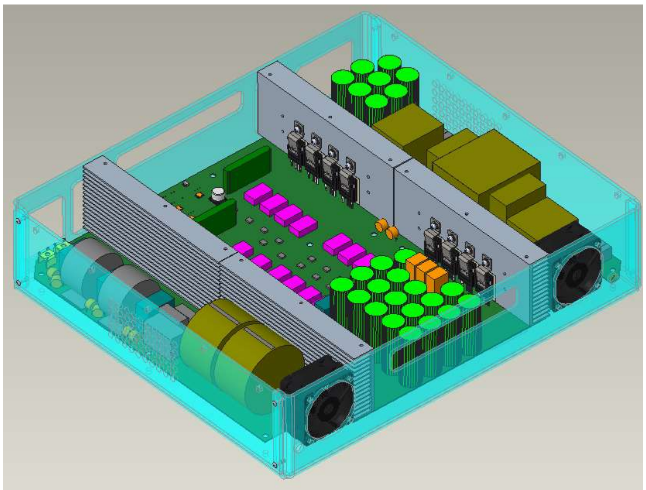

Figure 3: 3D View of the OBC

Due to the versatility of the circuit topology, various scenarios such as OBC, DC/DC, inverter power supply, etc., can be tested easily and comprehensively. Performance metrics, such as efficiency, temperature rise, voltage ripple, current ripple, power cycling, etc., can be easily measured, and the test data can be extracted automatically.

The OBC is designed for the following specifications:

- Input Voltage: 180 ~ 240$V_{AC}$.
- Output Voltage: 650 ~ 850 $V_{DC}$.
- Output Power: 6.6kW.
- Cooling: Forced Air Cooling.

Figure 5 shows the efficiency curves. The efficiency vs. load curve was plotted keeping the input voltage fixed at 230$V_{AC}$ for different loads at $V_{OUT}$ = 650$V_{DC}$, 750$V_{DC}$, and 850$V_{DC}$. The system operates at a maximum efficiency of 96.47%, 96.11%, and 95.9% at $V_{OUT}$ = 650$V_{DC}$, 750$V_{DC}$, and 850$V_{DC}$, respectively. The overall efficiency at full load of 6.6kW is also summarized for different output voltages. As the output voltage increases, the overall system efficiency varies slightly due to differences in the Synchronous Rectification Mode and SR turn-on triggers. Unlike Si power devices, OBC based on SiC devices, can leverage significant efficiency improvements by adopting a bridgeless totem pole PFC.

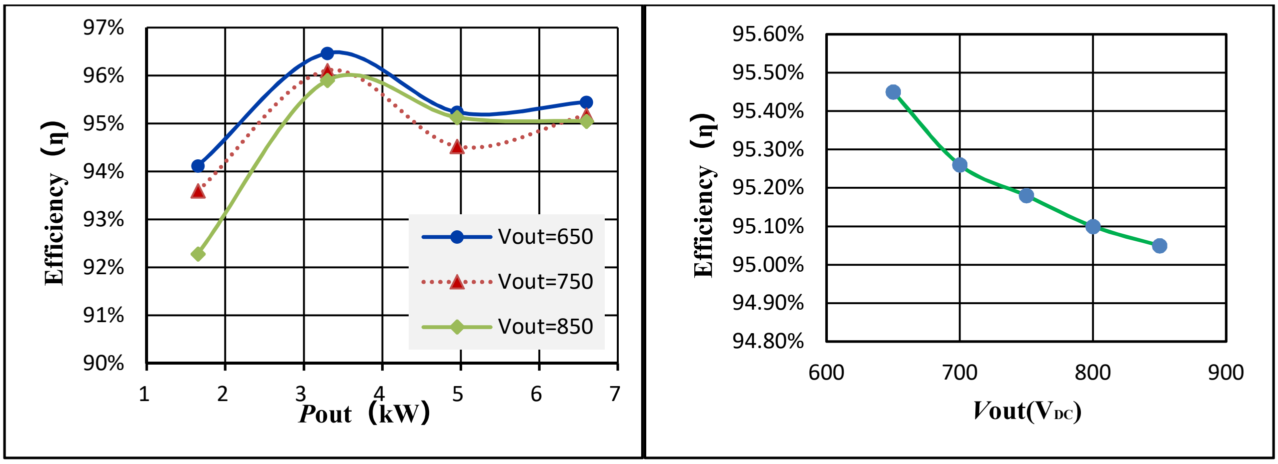


Figure 4: Efficiency VS Load at Different $V_{OUT}$ (left) and Efficiency VS $V_{OUT}$ at Full Load (right)

Real-time operating waveforms of various nodes of the OBC were captured for an input voltage of $230V_{AC}$, and a full load of 6.6kW, and $V_{OUT}$ = $650V_{DC}$ (Figure 5) and $750V_{DC}$ (Figure 6). The signal details are as follows:

- CH1 (Yellow): Output Voltage ($V_{OUT}$)
- CH2 (Cyan): SiC MOSFET Drain-to-source Voltage ($V_{DS}$)
- CH3 (Magenta): PFC Output Voltage ($V_{BUS}$)
- CH4 (Lemon Green): Current in the CLLC Resonant Tank
- CH5 (Orange): PFC Gate Drive Voltage ($V_{GS(PFC)}$)
- CH6 (Blue): CLLC stage Gate Drive Voltage ($V_{GS(CLLC)}$)
- CH8 (Bluish Green): PFC Inductor Current.

Oscillation or crosstalk interference in the gate voltage waveforms of the SiC MOSFET is not observed, and small oscillations without any obvious spikes are observed on the $V_{DS}$ waveforms of the SiC MOSFET. The waveforms demonstrate good switching behavior and low voltage stress on AMS1200075M at full load.

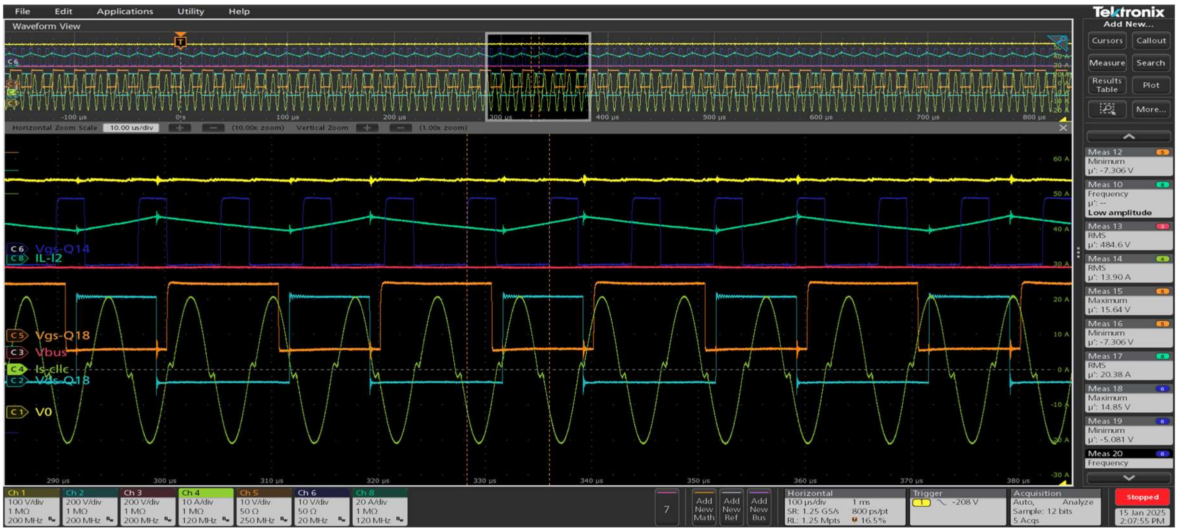


Figure 5: Waveforms at Full Load and $V_{OUT}$=650V DC.

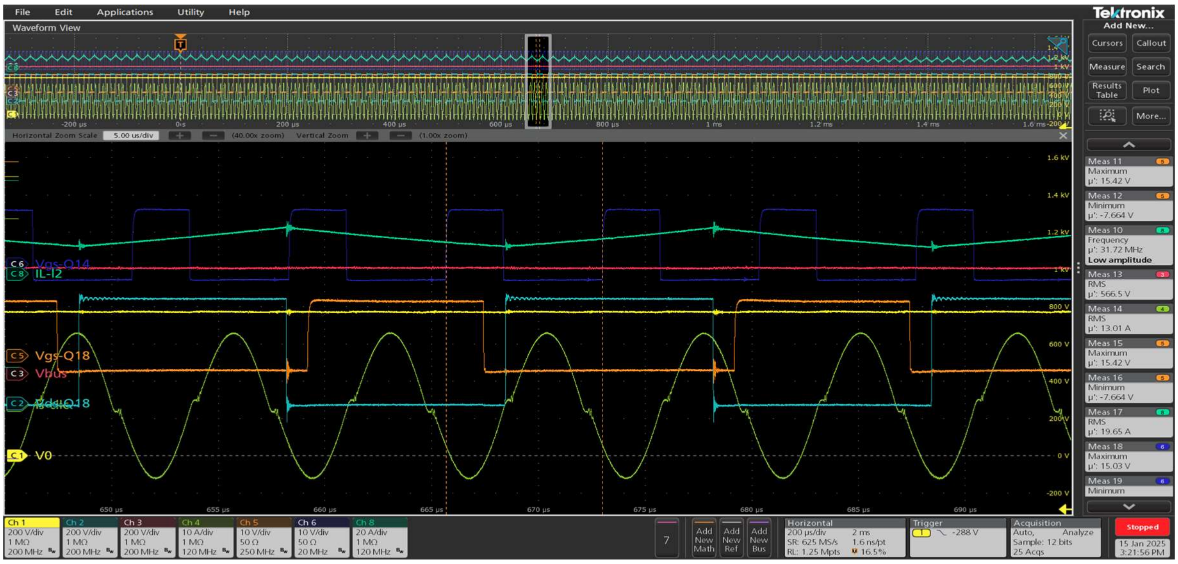


Figure 6: Waveforms at Full Load and $V_{OUT}$=750V DC.

The thermal behavior of the SiC MOSFETs was also evaluated at an input of 230$V_{AC}$, full load of 6.6kW at an output of 850$V_{DC}$, with an ambient temperature of 23°C. The thermal images of the SiC Devices were captured using an IR camera, and the case temperature was measured. Figure 6 shows the thermal images of the SiC MOSFETs in the PFC and CLLC stages, respectively. The thermal images show that the case temperature of the AMS1200075M reached a maximum of 63°C in the PFC stage and 46.5°C in the CLLC stage, demonstrating its excellent thermal performance, proving the reduced difficulty and design cost of thermal management.

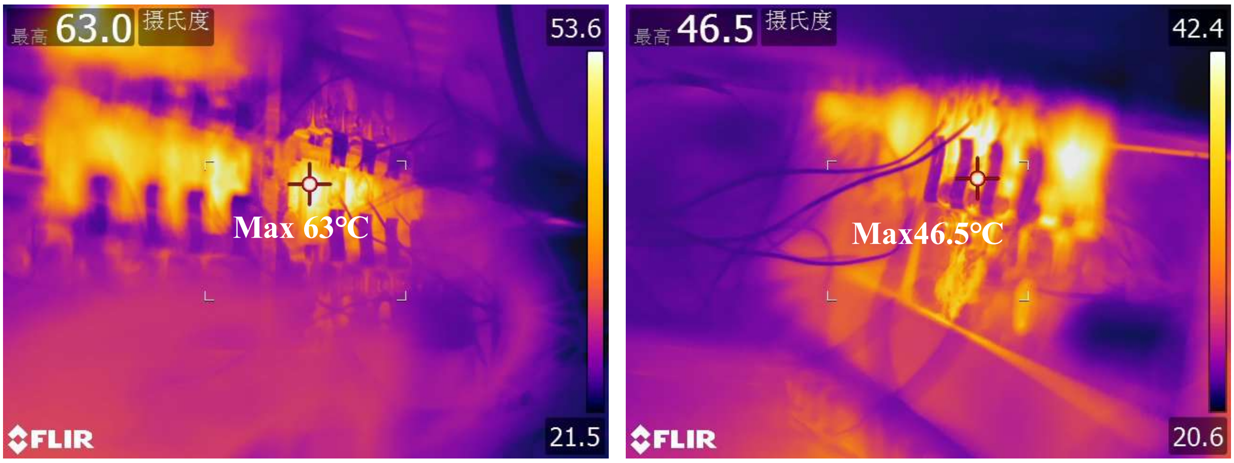


Figure 7: Device Temperature of the AMS1200075M in PFC stage (left) and CLLC Stage (right)

This application note demonstrates that the 1200V, 75mΩ SiC MOSFET from San'an Semiconductor, the AMS1200075M, has excellent performance and meets the performance requirements for OBC applications. San'an Semiconductor will continue to monitor the development of trends in the automotive space, especially in the OBC segment, keep up with market demand, and continue to innovate and bring new technologies to the market by leveraging the benefits of the fully vertically integrated Mega-Fab now equipped with an 8-inch line. San'an Semiconductor is continuously optimizing the design parameters, improving the production process, and taking initiatives to reduce cost, launching high-reliability and cost-effective SiC devices to the market, and providing momentum for miniaturization and breaking limits in power electronics, one SiC device at a time.