Three-Phase CoolSiC Inverter Evaluation Kit with Double Sided Cooling: Architecture, Thermal Design, and Test Methodology

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***Abstract*— This paper provides an overview of a flexible evaluation platform for three-phase inverters that use silicon carbide power semiconductors in double-sided cooling (DSC) modules. The paper focuses on the fundamental design principles, as well as the thermal and electrical aspects of system integration and typical commissioning, measurement, and analysis procedures. The goal is to facilitate early, application-oriented research and establish a solid foundation for evaluating various application scenarios. This article is intended for engineers seeking a foundation for systematic testing and application-oriented evaluations.**

I. INTRODUCTION TO THE DSC EVALUATION KIT

The DSC-SiC Inverter Evaluation Kit (see Fig. 1) is designed to analyze the technical properties and performance characteristics of the HybridPACK DSC CoolSiC G2 Module. It supports power outputs of up to 150 kW. Rather than requiring a fully custombuilt setup, the kit provides a functional three-phase inverter that can be quickly commissioned to provide early insights into the behavior of the SiC module under realistic operating conditions.

The focus areas are switching behavior, dynamic effects within the SiC power stage, loss performance at defined operating points, and the effectiveness of double-sided cooling. The goal is to provide a comprehensive assessment of the module's capabilities and potential applications to serve as a basis for product development and implementation.

This kit is an evaluation platform, not a production ready product. Protection and operating limits can be adjusted via software to enable boundary tests and targeted scenarios. Therefore, it is the user's responsibility to ensure a safe, controlled test environment with appropriate high-voltage safety measures and a reliable cooling system.

The inverter is implemented as a three-phase B6 topology. The core power module is the Hybrid-PACK DSC-S (FF06MR12A04MA2) featuring 1200 V SiC MOSFETs and an integrated NTC temperature sensor. The gate driver boards use a high-voltage gate driver optimized for SiC (EiceDriver). A logic board based on the AURIX platform handles operation, status management, and communication.

A DC-link capacitor (TDK, 135 µF, 850 V) is integrated on the supply side. For laboratory testing, a high-voltage source, a load (e.g., an inductive load or an electric machine), and a cooling system with volume and temperature control is also required.

The kit is compatible with all DSC-S-SiC variants because the modules share a common footprint, which enhances their versatility and adaptability across applications. With dimensions of 370 mm × 135 mm × 190 mm, the kit has a compact form factor suitable for various test environments.



Fig. 1. Inverter Evaluation Kit for HybridPACK™ DSC CoolSiC™

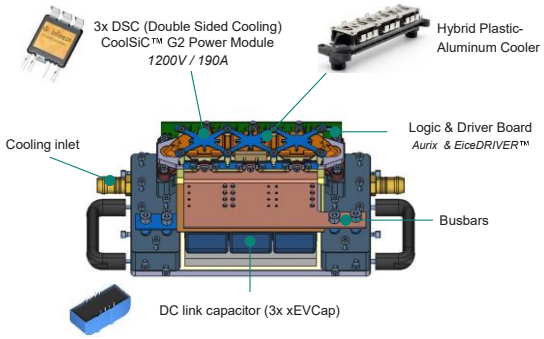


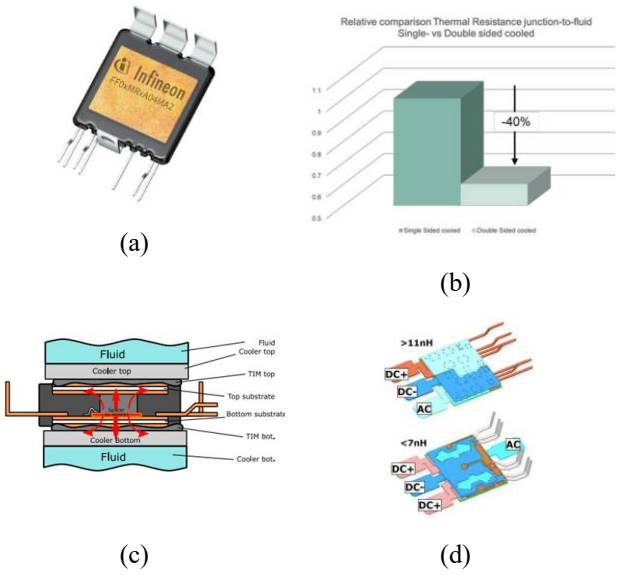
Fig. 2. Main components of the Evaluation Kit

II. OPTIMIZED THERMAL AND ELECTRICAL DESIGN OF THE DOUBLE-SIDED-COOLED SIC MODULE

The DSC package (see Fig. 3a) is designed for double-sided heat dissipation. Compared to single-sided cooled modules, its architecture provides an additional thermal path, which leads to a significant reduction in junction-to-fluid thermal resistance Rth,jf. Estimates indicate a reduction of up to 40% relative to single-sided concepts (see Fig. 3b). In a typical DSC heat stack, heat dissipation is asymmetrical, with a greater proportion of heat dissipated through the bottom than the top.

Since cooling is indirect, there is a thermal interface layer between the module and the cooler (see Fig. 3c). Therefore, Rth,jf is determined by the module itself, the quality of the contact interface, the clamping mechanics, and the thermal interface material (TIM). Thus, measured thermal performance should be interpreted as a system-level characteristic considering the entire assembly, including the module, TIM, clamping mechanism, cooler, and operating conditions.

DSC-S-SiC modules are scalable and suitable for applications ranging from 750 V to 1200 V. This allows them to adapt to specific requirements and diverse operating scenarios. For SiC MOSFETs, parasitic inductance in the commutation path is critical because it can cause overshooting and additional switching stress. It also impacts electromagnetic compatibility (EMC) and component reliability. The DSC package mitigates these issues with a highly symmetrical design that distributes parasitic inductances and resistances evenly and optimizes the commutation loop. The target stray inductance is specified to be less than 7 nH (see Fig. 3d). This low inductance enables controlled switching under realistic conditions and simplifies tuning of gatedriver parameters to achieve the desired dv/dt limits [1,2].



(a) (b) (c) (d)

Fig. 3. a) Double-sided cooled module (DSC); b) Thermal resistance junction-to-fluid (Rthjf) comparison: SSC vs DSC Thermal stack of DSC; c) Thermal stack; d) Electrical layout [3]

III. HIGH-PERFORMANCE HYBRID COOLER: ARCHITECTURE AND RELIABLE THERMO-MECHANICAL INTEGRATION

The kit features a hybrid cooling system from Erwin Quarder Systemtechnik GmbH (see Fig. 3) that combines an aluminum heat transfer surface with plastic components that distribute fluid and facilitate mechanical integration. This design uses MPDB® technology to creates a helium-tight and mechanically robust joint between the aluminum and plastic components without the use of adhesives or additional sealing materials. During manufacturing, the aluminum surface is pre-structured so that the plastic can penetrate its nano-microstructures during the joing process and form a sealed connection as it cools and solidifies.

Three DSC half-bridge modules are positioned within a support frame and clamped between the top and bottom cooler sections with approximately 800 N of force per module. Fluid distribution on the top side is configured as serial flow, while the bottom side is arranged in parallel. The total volume flow splits at a ratio of about 20% to the top and 80% to the bottom, aligning with the typical heat dissipation characteristics of the DSC package.

To compensate for temperature gradients in the top-side flow, which is cooled serially, the flow rate in the bottom-side parallel path increases slightly from the first to the last module position. This ensures a more uniform temperature distribution across all three modules.

In the indirectly cooled DSC setup, the quality of contact between the module and the cooler is paramount. The cooling system addresses this issue by ensuring the contact surfaces have low surface roughness and high planarity. It also incorporates flexible elements in the top cooler and metallic springs above to compensate for tolerances and thermo-mechanical effects. Additionally, a thin thermal interface material closes micro air gaps and reduces contact thermal resistance [3,4].

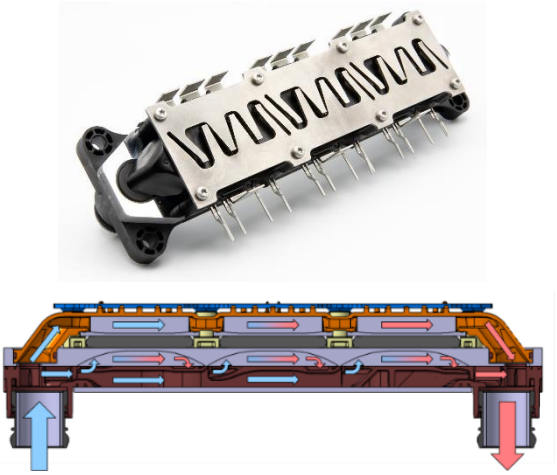


Fig. 4. Quarder DSC MPDB® HybridCooler & Cooling Path

IV. EVALUATION KIT TESTING CAPABILITIES ND APPLICATION-ORIENTED MEASUREMENT METHODOLOGY

The evaluation kit provides a range of interaction and analysis options. Communication can be established via a USB serial interface or a CAN bus. For testing under high voltage and load conditions, the CAN bus is strongly recommended due to its stability and robustness (e.g. via a PEAK PCAN-USB interface).

The OneEye software from Infineon manages operation and analysis, offering user-friendly configuration of operating modes and parameters. It provides comprehensive visualisation and recording capabilities for measured data and includes a pre-configured CAN message catalogue, facilitating the reading of status and measurement data, or the injection of setpoints via external CAN tools.

A typical workflow begins in configuration mode, where parameters such as pulse width modulation (PWM) frequency, dead time, shutdown limits and sensor scaling can be customised and saved as non-volatile data. Once configured, the system transitions to run mode, where open-loop setpoints such as amplitude, speed or output frequency can be defined. Measurements are continuously monitored via status pages. Advanced analysis is supported by a data logger and a software-based scope function that captures signals synchronised to the PWM pattern.

A laboratory setup with an inductive load is recommended for structured electrical characterisation. In this configuration, the three-phase pulse width modulation (PWM) inverter generates defined currents, which are measured by integrated sensors. An oscilloscope can capture switching transitions, enabling the analysis of switching performance and energy losses based on parameters such as the gate-driver settings, the DC-link voltage, the switching frequency and the package inductance.

To take a more application-oriented approach, the evaluation kit can be integrated into an electric motor test bench. Unlike with passive loads, the inverter powers an electric machine in this configuration, enabling dynamic states such as acceleration, steady-state operation and regenerative braking to be simulated. These tests provide valuable data on system efficiency, the interaction between the inverter and motor, and thermal performance under dynamic load conditions.

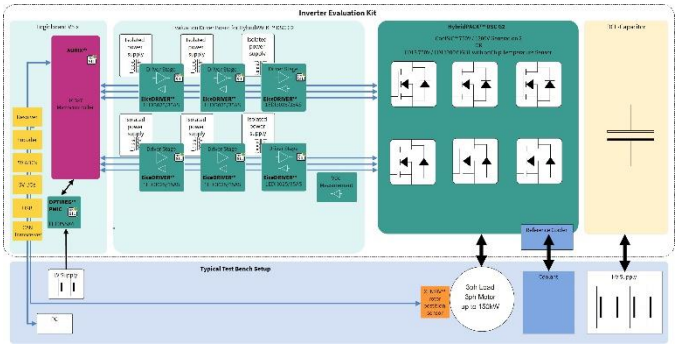


Fig. 5. Structure of the DSC HybridKIT™

V. CONCLUSION

In summary, the new DSC Evaluation Kit provides a robust foundation for application-oriented characterization of three-phase SiC inverters with double-sided cooling. The kit's combination of a symmetrical, low-inductance power stage; an optimized, double-sided thermal path; and a customizable measurement and control environment enables the reproducible investigation of switching behavior, losses, and thermal performance under realistic conditions.

From the users's perspective, the platform is available as a fully integrated, ready-to-use system. This includes a high-performance hybrid plastic-aluminium cooler from Quarder for double-sided cooling. Commissioning only requires standard laboratory equipment: a programmable high-voltage DC source, an inductive load or motor test bench, and a conventional cooling loop with volume and temperature control. Thanks to the integrated protection, parameterisation and data acquisition (CAN/USB, OneEye), there is no need for custom mechanics, PCBs or firmware to begin carrying out safe, controlled boundary and application-oriented tests. This lowers the entry barrier, shortens time-to-first-data, and mitigates the risks associated with early design decisions.

These integration and testing principles can be transferred to other module families and power classes. The common DSC-S footprint supports variants across 750–1200 V, enabling the early evaluation of efficiency, power density, and reliability across diverse operating points.

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