

Efficiency and Thermal Performance Comparison of SiC-MOSFET and Si-IGBT IPMs in the SPM31

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Motivation

- Electrification is increasing the demand for high efficiency power semiconductor solutions.
- SiC-MOSFETs provide lower conduction and switching losses than conventional Si-IGBTs.
- Higher power density of SiC devices enables more compact inverter and cooling system designs.
- Thermal performance and heatsink size were compared to evaluate the benefits of SiC-based IPMs.

Thermal Simulation

- The SiC MOSFET reached the same junction temperature at lower power dissipation due to its higher junction-to-case thermal resistance.
- The power dissipation required to reach the same junction temperature was compared between Si-IGBT and SiC-MOSFET IPMs using two different heat sinks.

Unit[mm]	Heatsink A	Heatsink B
Dimension (W x L x H)	27.7 x 64.75 x 65	173 x 130 x 65
Fin Height	50	
Fin Thickness	1.85	
Fin to Fin Distance	7.15	
Material	Aluminum	

- SiC-MOSFET reached the same junction temperature with lower power dissipation than the IGBT.
- The SiC-MOSFET exhibited higher junction-to-case thermal resistance due to its smaller chip size (R_{thjc} IGBT: 0.7 °C/W, SiC-MOSFET: 1.1 °C/W)

Simulation Condition

- Same SPM31 package for both Si-IGBT and SiC-MOSFET (Same DBC, Package structure, solder)
- Still air condition and TIM : 30um, 1W/mK
- FRD and body diode losses excluded for intuitive thermal comparison

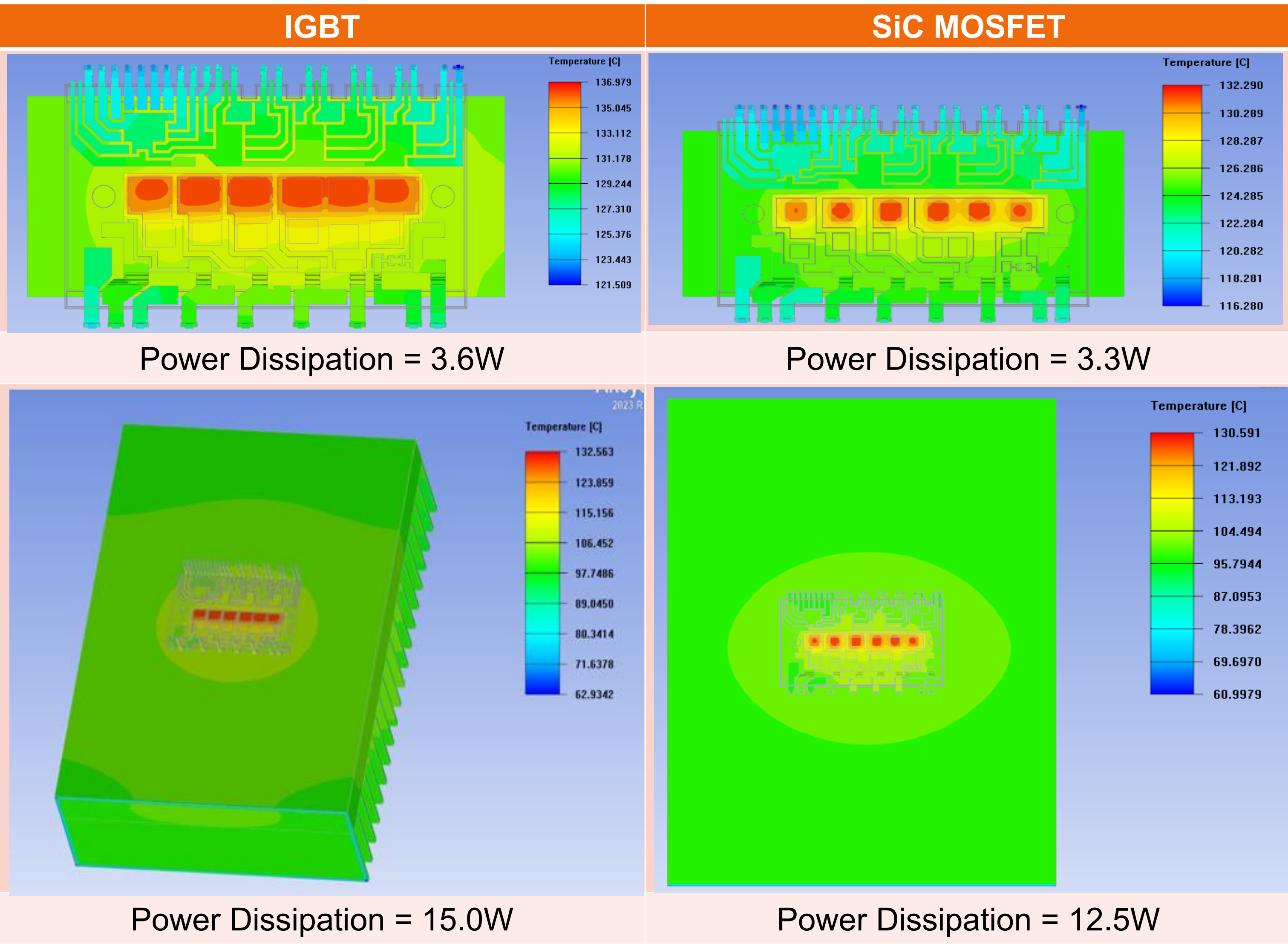


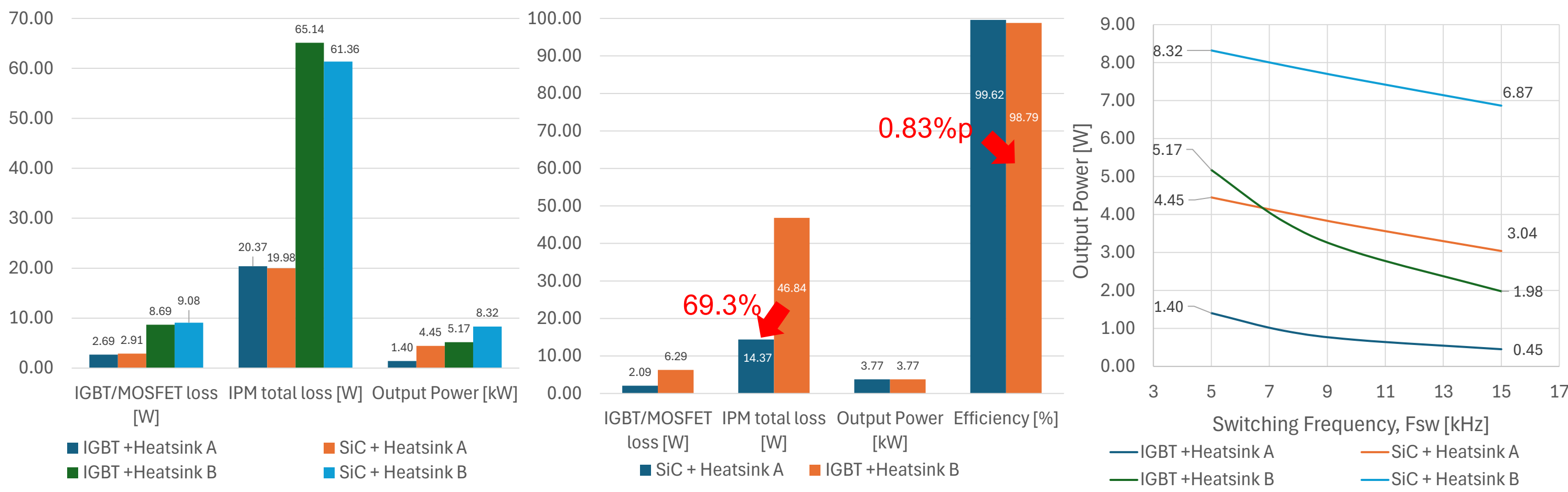
Fig. 1. Thermal Simulation Result with Heatsink A and B at T_j =130 °C

Loss and power Comparison

- Lower loss of the SiC-MOSFET enables higher output power and a more compact cooling system.
- SiC MOSFET achieved approximately 3 kW higher output power under the same cooling conditions.
- Lower loss characteristics of the SiC-MOSFET enable a more compact cooling system design for the same output power (reduced 87% Heatsink size).
- SiC-MOSFET maintains higher output power as switching frequency increases.

Simulation Condition

- VDC=600V, M.I.=0.95, P.F.=0.9, T_a=30°C, f_{sw}=1-15kHz, 3 phase modulation



Experimental Validation

- Experimental validation confirmed that the SiC-MOSFET based IPM maintained the same T_j while significantly reducing heatsink size.
- Both IPMs achieved approximately the same junction temperature (~120°C).
- The SiC-MOSFET based IPM required up to 87% smaller heatsink area than the IGBT based IPM.
- The difference between simulation and measurement is mainly attributed to: Natural convection instead of still-air conditions, Thermal coupling effects, TIM thickness variation

Experimental setup

- 4kW motor drive test bench, VDC=600V, f_{sw}= 5kHz, I_o=8Arms, still air condition

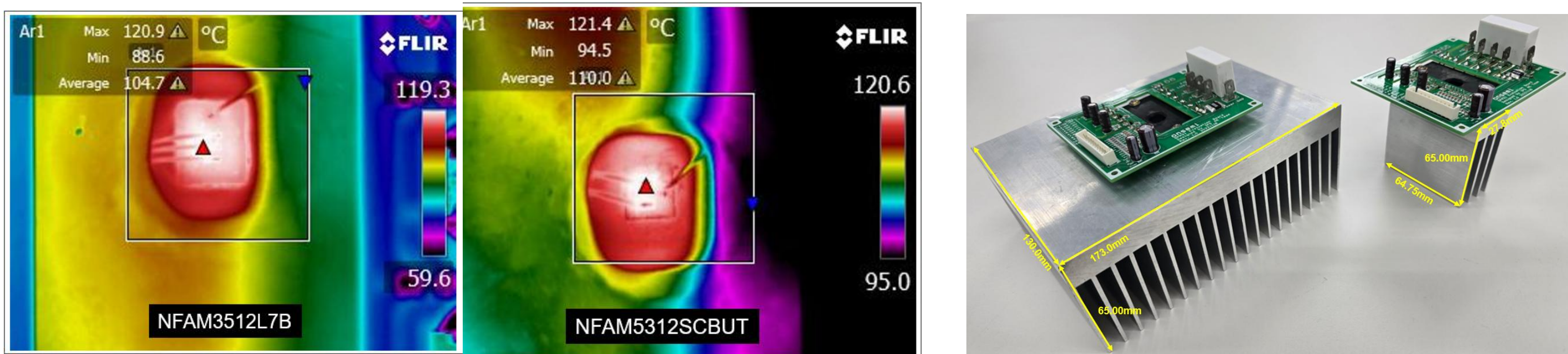


Fig. 3. Junction temperature measurement result and heatsink comparison

Conclusion

- SiC-MOSFET based IPMs provide lower losses, higher efficiency, and improved thermal performance, enabling more compact inverter designs.
- As the thermal simulation result, SiC-MOSFET reached the same junction temperature at lower power dissipation than the IGBT.
- Under the same cooling conditions, the SiC-MOSFET based IPM achieved up to 3 kW higher output power than the Si-IGBT-based IPM.
- At the same junction temperature and output power, the SiC MOSFET-based IPM showed about 69.3% lower total loss and achieved similar thermal performance with up to 87% smaller heatsink area compared to the IGBT.
- Experimental validation using a 5 kHz motor-drive test bench confirmed the thermal advantages of the SiC MOSFET-based IPM.