

High-Density GaN and SiC Power Module Cooling with Ducted Airflow and CFD Validation

At a Glance

Advanced Thermal Solutions, Inc. (ATS) performed analytical and CFD-based thermal design for a power supply company whose high-density GaN and SiC power stage operated at 40°C ambient. The objective was to keep multiple GaN and SiC devices below their temperature limits using a ducted air-cooling architecture compatible with an IP-rated enclosure.

CUSTOMER OVERVIEW

The customer was developing a high-density GaN and SiC power stage for a power supply application operating at 40°C ambient. The thermal design had to cool multiple high-power devices in a compact package while integrating with an environmental module's IP-rated enclosure layer.

- Mixed GaN and SiC device architecture in a compact power stage (Figure 1)
- High device power density with tight junction temperature limits
- Cooling solution required compatibility with IP-rated enclosure integration

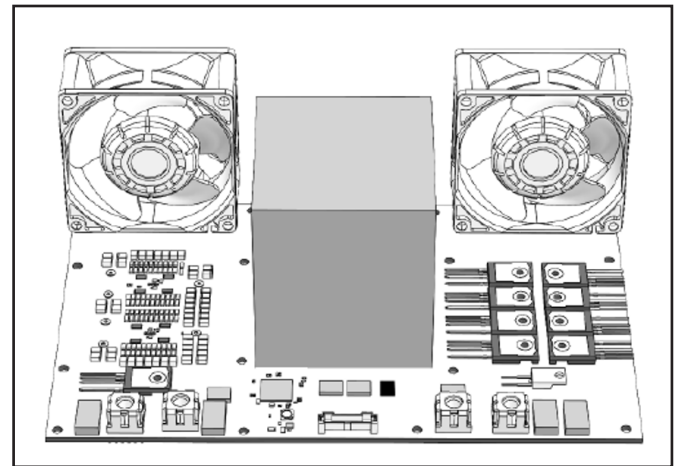


Figure 1. Board Layout of GaN and SiC Power Module Without Heat Sinks

CHALLENGE

The system needed to maintain junction temperatures below device limits for both the GaN and SiC stages under 40°C ambient conditions. The design challenge was to deliver effective fin-field airflow, validate fan performance at the correct operating point, and ensure the same heat sink architecture could support both load cases without bypass or recirculation.

Thermal load characterization:

- **GaN stage:** 8 × EPC2305 GaN FETs at ~16 W each, 127 W total
- GaN junction-to-case thermal resistance: approximately 0.2 K/W
- GaN junction-to-case rise: approximately 3.2 K
- GaN maximum junction temperature: 150°C
- **SiC stage:** 8 × SiC FETs at 26.7 W each, 213.5 W total
- SiC junction-to-case thermal resistance: 0.66 K/W
- SiC maximum junction temperature: 175°C
- SiC maximum case temperature: 125°C

The design also had to account for thermal interface material (TIM) compression sensitivity and maintain reliable contact performance within expected assembly tolerances.

High-Density GaN and SiC Power Module Cooling with Ducted Airflow and CFD Validation



METHODOLOGY

ATS used analytical thermal resistance calculations and CFD modeling to validate the heat sink, duct, and fan architecture for both GaN and SiC stages. The work focused on flow path quality, fin-field utilization, fan operating point stability, and case temperature compliance (Figure 2).

Heat Sink and Airflow Architecture

- Heat sink: ATS-EXL312-300-R0, 90 × 50 × 30 mm
- Fan: Delta FFB0448EN-00EEY, 31.86 CFM, 982.9 Pa
- Ducted airflow through the IP enclosure layer
- TIM: Bergquist SIL PAD TSP A3000 at 50 PSI

Key Investigation Areas

- Board-level layout without and with integrated heat sinks
- Duct geometry and airflow routing through the fin field (Figures 3 & 4)
- Fan operating point relative to the stable region of the performance curve
- Top and bottom temperature contours for GaN and SiC heat sinks
- TIM compression sensitivity within expected assembly tolerances

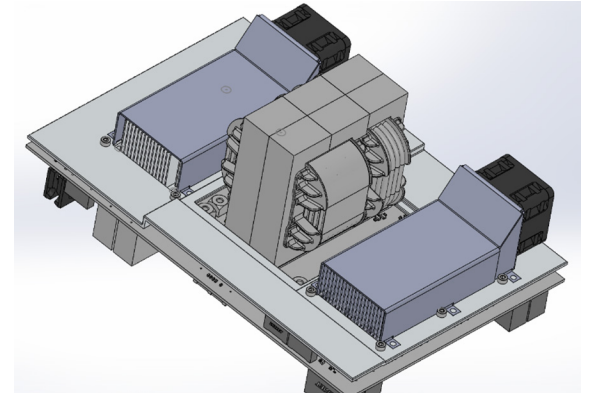


Figure 2. Modeled Image of GaN and SiC Power Module With Ducts, Fans, and Heat Sinks

CFD confirmed that the duct geometry created a well-defined flow path across the fin field with minimal bypass and recirculation.

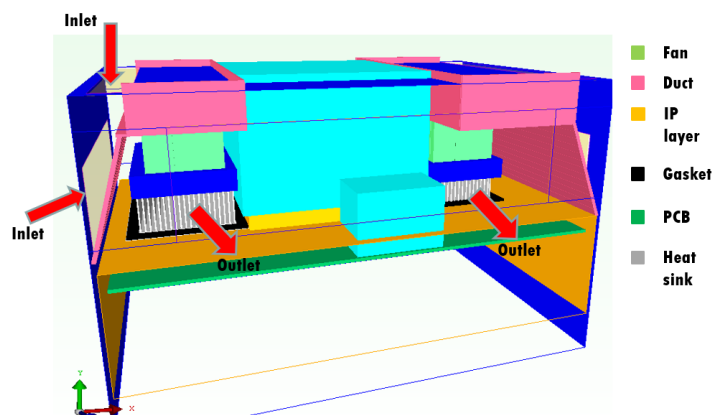


Figure 3. Flotherm Model Shows Airflow Routing

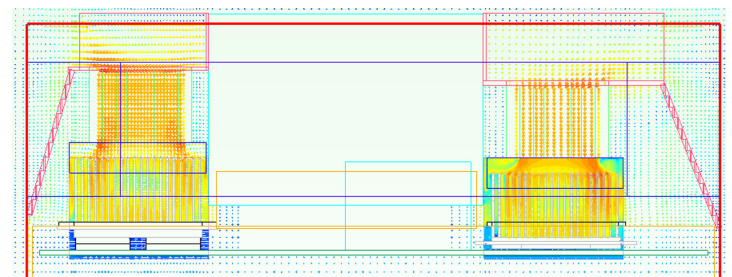


Figure 4. Flow Path Visualization of Ducting Directing Airflow onto the Heat Sinks

High-Density GaN and SiC Power Module Cooling with Ducted Airflow and CFD Validation

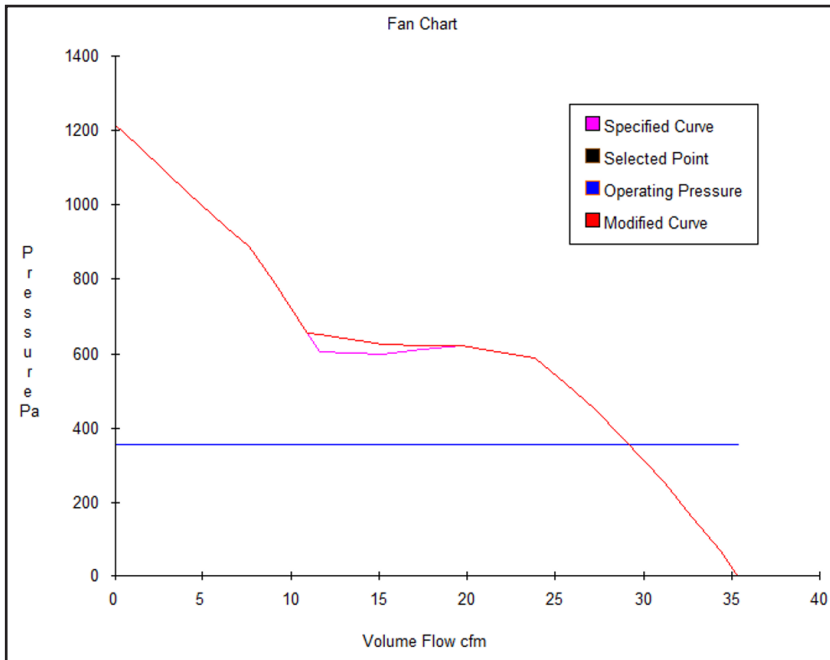


Figure 5. The Operating Point of the Fan is in the Desirable Section of the Curve

SOLUTION

ATS developed a ducted forced-air cooling architecture using the ATS-EXL312-300-R0 heat sink, Delta axial fan, and controlled airflow through the IP-layer interface. The same heat sink platform was validated for both the 127 W GaN stage and the 213.5 W SiC stage while maintaining acceptable case temperature performance.

- Applied a common heat sink architecture to both GaN and SiC modules (Figures 6 & 7)
- Used ducted airflow to force flow directly across the fin field
- Validated fan selection at an effective operating point of approximately 29.17 CFM at 1.528 inH₂O (Figure 5)
- Confirmed stable fan operation outside the knee region
- Validated TIM performance across expected compression tolerances
- Preserved cooling effectiveness while integrating with the IP-rated enclosure layer

This produced a practical cooling solution that combined flow-path control, heat sink reuse, and enclosure compatibility.

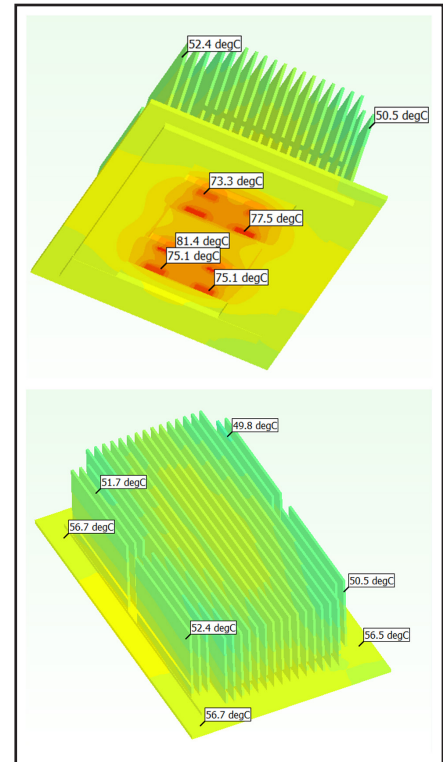


Figure 6. Top and Bottom of the GaN Heat Sink

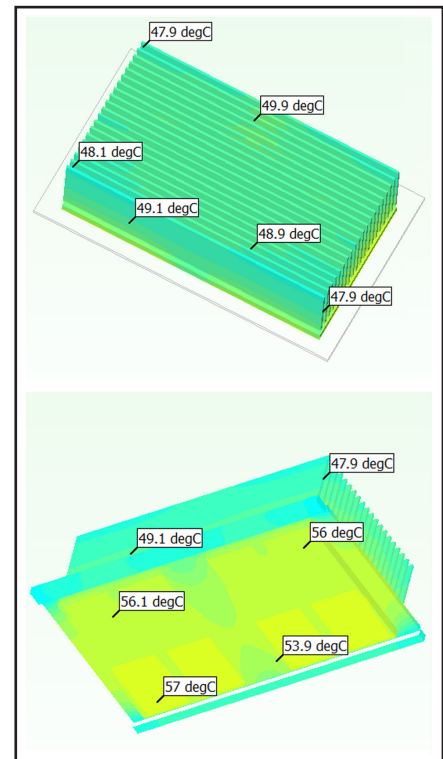


Figure 7. Top and Bottom of the SiC Heat Sink

High-Density GaN and SiC Power Module Cooling with Ducted Airflow and CFD Validation



RESULTS & DATA

CFD temperature contours confirmed that case temperatures remained below allowable limits for both GaN and SiC modules under worst-case ambient conditions.

Validated performance:

- Junction-to-case thermal resistance validated analytically
- Ducted airflow confirmed as critical for effective fin utilization
- Fan selection validated at the correct operating point
- Same heat sink found adequate for both 127 W GaN and 213.5 W SiC loads
- IP-layer integration did not compromise cooling performance

The analysis also showed that TIM compression sensitivity remained acceptable within expected assembly tolerances, preserving junction-to-case thermal performance while maintaining reliable contact.

Thermal engineering outcomes:

- Well-defined ducted flow path minimized bypass and recirculation
- Approximately 29 CFM effective airflow delivered by each fan
- Case temperatures remained below allowable limits for both module types
- Common heat sink architecture simplified implementation across mixed device loads

ANALYSIS & CONCLUSION

This study shows that cooling high-density GaN and SiC power modules depends on more than heat sink selection alone. Performance was driven by the combination of ducted airflow control, stable fan operation, reliable TIM contact, and effective fin utilization within the enclosure.

- Duct geometry was essential to directing airflow where it was needed
- Fan operating point validation ensured usable flow under real system resistance
- The same heat sink architecture supported both GaN and SiC stages
- IP-layer integration was achieved without sacrificing thermal margin

ATS delivered a CFD-validated, enclosure-compatible cooling architecture for dense GaN and SiC power electronics using ducted airflow and shared heat sink design.

Take control of your thermal performance with expert analysis and design services, contact ATS to speak with our engineers and start optimizing your system today.

