

Air-Cooled Heat Sink Design for High Power Applications

At a Glance

Advanced Thermal Solutions, Inc. (ATS) designed and validated a high-power air-cooled heat sink for an IT OEM. The project combined analytical modeling and CFD validation to create an air-cooled solution capable of dissipating 900 W while meeting an aggressive thermal resistance target.

CUSTOMER OVERVIEW

The customer was an IT OEM seeking a manufacturable air-cooled heat sink for a high-heat-flux electronics application. The solution needed to dissipate 900 W while clarifying the material, spreading, and airflow tradeoffs that would govern real-world performance.

- High-power electronic application requiring 900 W heat dissipation
- Air-cooled architecture preferred over more complex approaches
- Design decisions supported by both analytical and CFD validation



CHALLENGE

The design objective was to create an air-cooled heat sink capable of dissipating 900 W while achieving a thermal resistance of 0.038 °C/W or lower. The key challenge was balancing fin geometry, base thickness, spreading resistance, material selection, and airflow delivery at a very high power level.

Scope of work:

- Define thermal and airflow boundary conditions
- Perform analytical heat sink optimization
- Quantify spreading resistance effects
- Validate design concepts using CFD
- Evaluate heat sink material and airflow sensitivity

Success depended not just on creating surface area, but on ensuring that available airflow and base heat spreading could support a low overall thermal resistance.

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METHODOLOGY

ATS began with first-order analytical calculations to estimate the heat sink surface area required to meet the target thermal resistance across a range of conservative convective heat transfer coefficients. The design was then refined through parametric studies and validated with CFD.

Analytical Optimization Approach

- Estimated required heat sink area across multiple assumed HTC values (Figures 1 & 2)
- Performed parametric studies on fin count, fin height, fin thickness, and base thickness (Figures 3, 4, 5)
- Included spreading resistance in evaluating base thickness and material choices
- Identified diminishing returns beyond 60 mm fin height
- Found minimal benefit for base thickness greater than 10 mm once spreading resistance was included

HTC (W/m ² K)	Required HS Surface Area (cm ²)
25	10526
50	5260
75	3509
100	2631

Figure 1. Calculations to Find the Required Heat Sink Surface Area to Achieve the Required Thermal Resistance at Different Values of the Convective Heat Transfer Coefficient

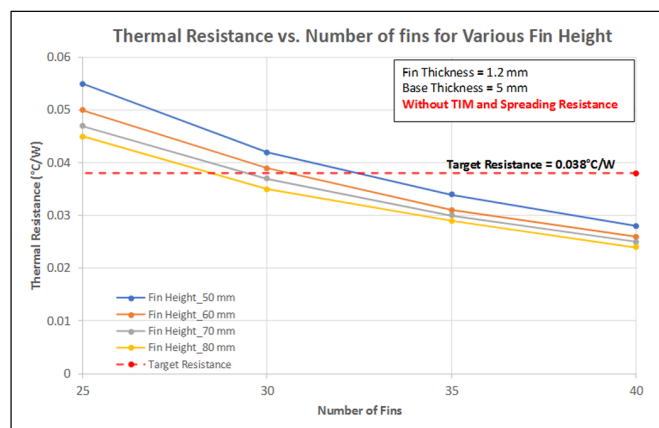


Figure 3. Variation in Thermal Resistance with the Number of Fins for Different Fin Heights

Heat Sink Dimensions		
Length (mm)	Width (mm)	Height (mm)
150	80	125

Figure 2. Initial Heat Sink Dimensions per Customer Specifications

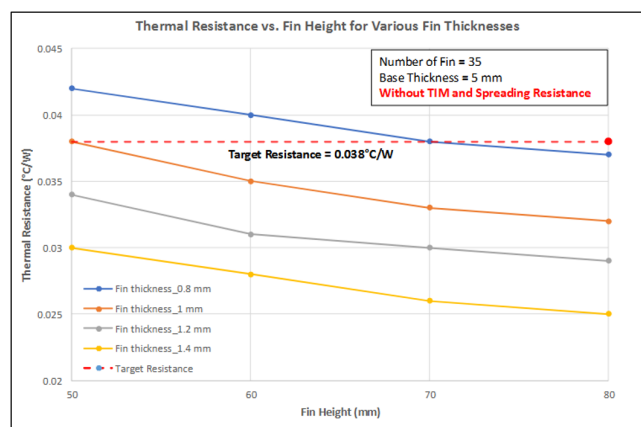


Figure 4. Variation in Thermal Resistance with Fin Height for Different Fin Thicknesses

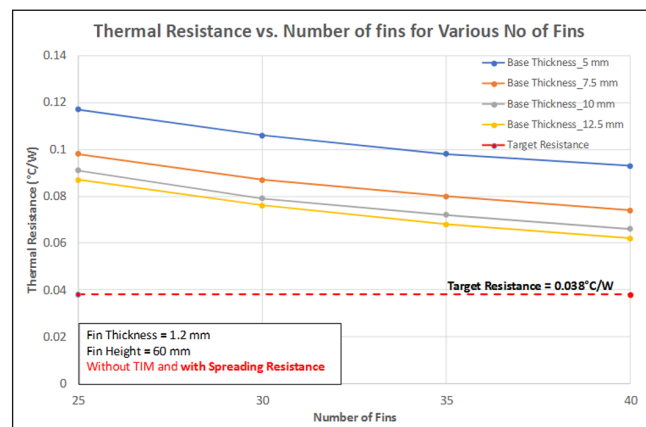


Figure 5. Variation in Thermal Resistance with Different Numbers of Fins

CFD Validation Basis

- Total heat load: 900 W
- Inlet air velocity: 12 m/s
- Inlet air temperature: 30°C
- Thermally optimized geometry carried into CFD for validation (Figure 6)

This workflow moved from first-principles sizing to validated performance while also assessing the effect of advanced spreaders and airflow enhancement.

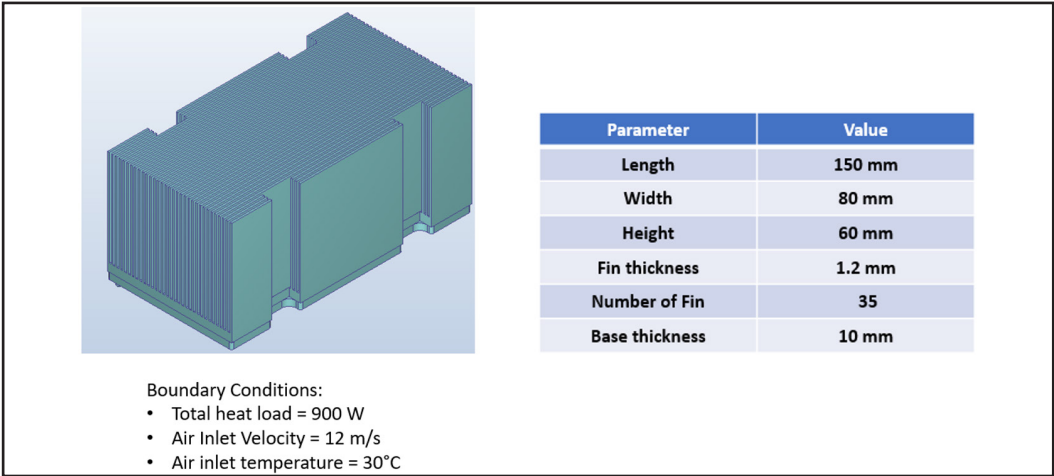


Figure 6. The Same Optimized Heat Sink Parameters were Applied to the CFD Model for Validation Purposes

SOLUTION

ATS developed an analytically optimized heat sink geometry and improved performance further through advanced heat spreading and airflow management. The final design combined optimized fin geometry, controlled base thickness, integrated heat spreaders, and convergent ducted airflow to reduce both spreading resistance and convection limitations.

- Optimized fin count, fin height, fin thickness, and base thickness analytically
- Validated the optimized aluminum design using CFD
- Evaluated integrated copper heat spreaders to reduce base temperature gradients (Figure 7)
- Examined ultra-high-conductivity spreader concepts for further improvement (Figure 8)
- Used convergent inlet ducting to increase local air velocity and mixing (Figure 9)
- Assessed pressure drop and airflow availability as part of the final design tradeoff

This created a realistic high-power air-cooling solution by addressing both conduction-side and airflow-side constraints together.

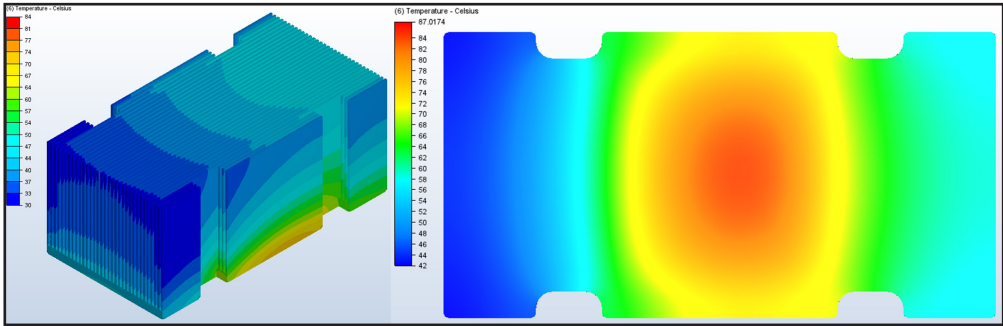


Figure 7. With a 5 mm Integrated Copper Heat Spreader and a 5 mm Heat Sink Base, the Temperature Difference (ΔT) at the Spreader is Reduced from 55°C to 45°C

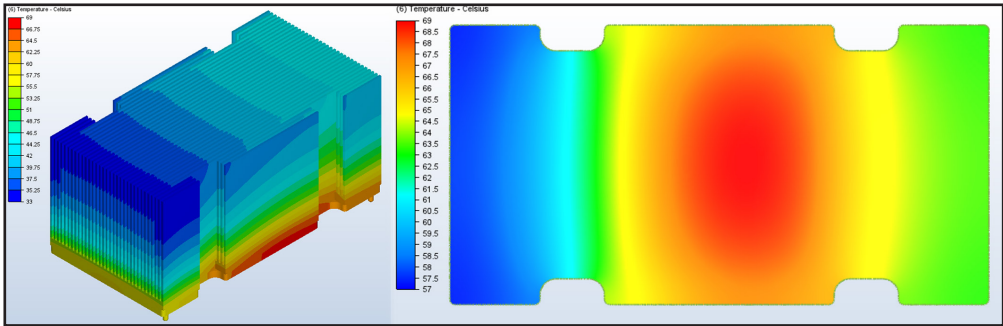


Figure 8. Replacing Copper with a Diamond Heat Spreader Reduced the Temperature Difference (ΔT) Significantly, from 45°C

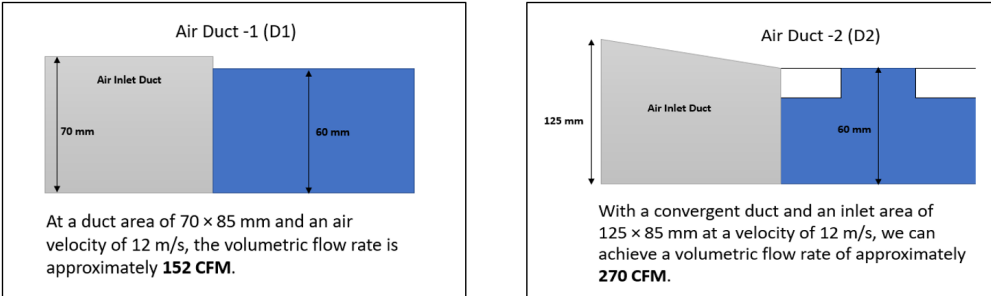


Figure 9. A Convergent Duct Greatly Increases the Exit Air Velocity, Significantly Enhancing the Local Heat Transfer Coefficient

Scenario	Max Base Temperature (°C)	Thermal Resistance (°C/W)
10 mm Aluminum Base	95.5	0.072
5 mm AL base With Copper IHS	87	0.063
4 mm Diamond base	69	0.043
4 mm Diamond base With Convergent Duct	62.5	0.036

Figure 10. With a Heat Spreader Based on Diamond Technology, the Thermal Resistance is Reduced by 37% Compared to a Copper Heat Spreader

RESULTS & DATA

The study showed that optimized air-cooled performance depended strongly on the combination of heat spreading and airflow delivery. When advanced spreading was paired with optimized ducted airflow, the design exceeded the original thermal resistance target.

Key findings:

- Target thermal resistance was ≤ 0.038 °C/W
- Optimized system achieved thermal resistance as low as 0.036 °C/W (Figure 10)
- Copper spreader reduced base temperature rise by approximately 10°C
- Diamond-based spreader concepts further reduced base temperature non-uniformity
- Diamond spreader concept reduced thermal resistance by 37% compared with copper heat spreading

CFD also showed that airflow delivery was a major determinant of performance. Convergent ducting increased local air velocity at the heat sink face, producing stronger mixing and improved convective heat transfer.

Thermal engineering outcomes:

- Diminishing returns occurred beyond approximately 60 mm fin height
- Base thickness beyond 10 mm delivered minimal additional benefit once spreading resistance was included
- Fan-limited airflow cases highlighted pressure drop as a critical design constraint
- Coupled airflow and material optimization enabled the final performance gain

ANALYSIS & CONCLUSION

This study shows that high-power air cooling is achievable when analytical modeling, CFD validation, heat spreading strategy, and airflow engineering are treated as one integrated problem.

- Analytical modeling established the feasible design space before CFD refinement
- Spreading resistance was a major limiting factor in the aluminum-only baseline
- Advanced spreaders materially improved base temperature uniformity
- Ducted airflow optimization was essential to achieving the final thermal resistance target

ATS delivered a practical optimization path that combined analytical modeling, CFD validation, material selection, and airflow design to achieve high-power air-cooled performance under real packaging and airflow constraints.

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.

