TECHNICAL CASE STUDY

Thermal Management · Design Optimization

Thermal Optimization of a Passive Aluminum Enclosure

At a Glance

Advanced Thermal Solutions, Inc. (ATS) evaluated and optimized a sealed passive aluminum enclosure dissipating 75.8 W under 25°C ambient conditions. Through baseline CFD and targeted parametric analysis, ATS identified the primary thermal constraints and developed a focused passive-cooling optimization strategy.

CUSTOMER OVERVIEW

The customer develops sealed aluminum enclosures for avionics and embedded defense electronics, integrating high-power components such as CPUs, FPGAs, and power devices in a compact, airflow-restricted architecture (Figure 1).

- Passive cooling only
- Thermal performance directly tied to reliability
- Design changes needed to preserve the sealed architecture

CHALLENGE

The enclosure exceeded its thermal target, with housing temperatures near 55°C and CPU temperatures near 85°C. The customer needed to reduce housing temperature below 49°C and lower the approximately 30°C CPU-to-case differential without introducing active cooling.

Baseline performance:

- Housing temperature: ~55°C
- CPU temperature: ~85°C
- CPU-to-case differential: ~30°C

The challenge was to identify which thermal resistances were limiting performance and determine which passive changes would have the greatest effect.

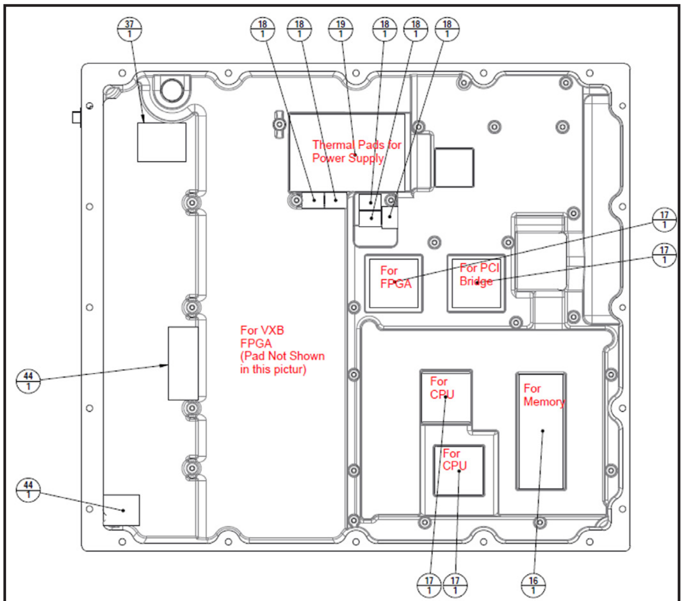

Figure 1. Baseline Thermal Distribution from Enclosure Components.

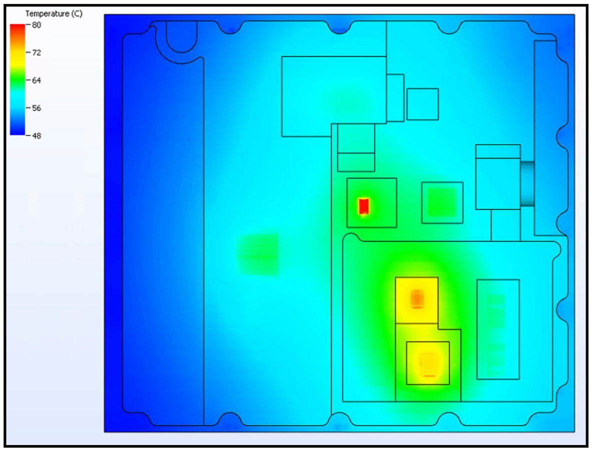

Figure 2. Baseline Thermal Distribution CFD.

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METHODOLOGY

ATS applied 3D CFD simulation with conjugate heat transfer to model conduction paths and natural convection within the sealed enclosure (Figures 2, 3, 4). Baseline and parametric studies were used to isolate the impact of specific design changes.

Boundary Conditions

- Ambient temperature: 25°C
- Total heat load: 75.8 W
- Enclosure material: Aluminum 383
- Cooling mode: Passive only

Key Investigation Areas

- CPU-to-enclosure conduction paths
- External natural convection efficiency
- Thermal interface resistance
- Surface area and fin optimization
- Internal airflow restrictions

SOLUTION

ATS found that enclosure performance was limited by a combination of internal conduction resistance and external convection constraints rather than a single bottleneck. The recommended passive optimization strategy addressed both.

- Upgrade the thermal interface material to reduce CPU resistance
- Improve heat spreading into the enclosure structure
- Optimize fin geometry and effective surface area
- Reduce airflow obstruction near mounting features
- Add cross-cut vent gaps to improve natural convection pathways (Figure 5)

Together, these changes improved thermal distribution while maintaining the fully passive enclosure concept.

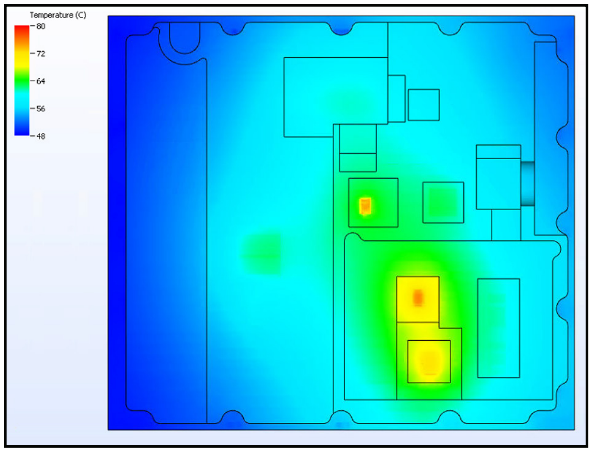

Figure 3. Optimized Configuration CFD – With Higher Performance Thermal Gap Filler Pad.

Figure 4. Optimized Configuration CFD – With Added Heat Sink Fin Pattern, Fin Height, and Surface Area Optimization.

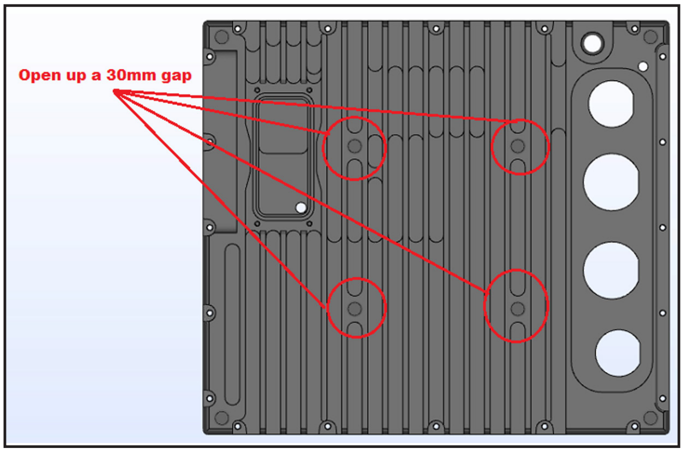

Figure 5. Enclosure Optimization – With Cross Cut Venting Gaps Optimization.

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RESULTS & DATA

Key Findings:

- Baseline housing temperature: ~55°C
- Baseline CPU temperature: ~85°C
- CPU-to-case differential: ~30°C
- TIM upgrade reduced CPU temperature by ~2°C (Figures 6 & 7)
- Cross-cut venting reduced housing temperature by ~5°C

The study showed that meeting the final housing target required coordinated improvements in both conduction and convection, not isolated changes.

Qualitative Wins

- Dominant thermal resistances were identified
- The effect of each major design variable was quantified
- The passive architecture was preserved
- The customer received a clearer redesign path for validation

SPECIFICATIONS

TYPICAL PROPERTIES	VALUE	TEST METHOD
Construction & Composition	Ceramic filled silicone sheet	N/A
Color	Grey	Visual
Thickness Range	0.020″ (500 µm) - 0.20″ (5000 µm)	N/A
Thermal Conductivity (W/mK)	7.5	Hot Disk
Density (g/cc)	3.5	Helium Pycnometer
Hardness (Shore 00)	500 and 750 µm: 45 1000 µm and up: 32	ASTM D2240
Outgassing TML (weight %)	0.17	ASTM E595
Outgassing CVCM (weight %)	0.01	ASTM E595
Temperature Range	-65°C to 125°C	Laird Test Method
Rth at 40 mils, 10 psi, 50° C	0.198°C–in2/W	ASTM D5470
Dielectric Constant at 1 MHz	8.14	ASTM D150
UL Flammability Rating	V-0	UL 94
Volume Resistivity	8.73×10^{13} ohm-cm	ASTM D257

Figure 6. Typical Properties of (top) Original Thermal Gap Filler Pad

TYPICAL PROPERTIES

PROPERTIES	TYPICAL VALUE	TEST METHOD
Construction & Composition	Aligned Graphite	N/A
Color	Grey	Visual
Thickness Range	1mm - 5mm	N/A
Thickness Tolerance	+/- 10%	N/A
Bulk Thermal Conductivity	34 W/mk	ASTM D5470
Density	2.3 g/cc	Helium Pycnometer
Thermal Resistance (1.5mm) @ 30% deflection, 50 ⁰C	0.589 °C*cm2/W (0.096 °C*in2/W)	ASTM D5470
Temperature Range	-40⁰ C to 125⁰ C	Laird Test Method
Hardness Shore 00 (3 second)	50	ASTM D2240
Hardness Shore 00 (30 second)	20	ASTM D2240
Volume Resistivity (Ω cm)	10 Ω-cm	ASTM D991
UL Flammability Rating	V-0	UL 94

Figure 7. Typical Properties of (top) Replacement Higher-Performing Thermal Gap Filler, HP34

ANALYSIS & CONCLUSION

Passive cooling performance in sealed electronic enclosures is governed by the interaction of internal conduction and external convection. In this design, the key limits were interface resistance, restricted airflow paths, and diminishing returns from geometry-only changes.

- Balanced conduction and convection is critical
- Targeted passive changes can deliver meaningful gains
- System-level optimization is more effective than a single isolated fix

ATS provided a data-driven path to reduce thermal risk while preserving the simplicity and reliability of a passive cooling solution.

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.