Environmental Thermal Management of a Ruggedized Router Module

At a Glance

Advanced Thermal Solutions, Inc. (ATS) engineered an environmental thermal solution for a ruggedized router module required to operate from -30°C to 55°C ambient. The design integrated both cooling and controlled heating to maintain reliable internal operating conditions across extreme environments.

CUSTOMER OVERVIEW

The customer required a ruggedized router module capable of reliable operation across extreme ambient conditions. The system needed to reject 250–300 W under hot conditions while maintaining minimum internal air temperature during cold-weather startup and operation.

- Environmental operating range from -30°C to 55°C ambient
- Cooling requirement of 250–300 W at high ambient
- Heating requirement to maintain internal ambient above -10°C in cold conditions

CHALLENGE

The router module required two integrated thermal functions: high-capacity cooling at elevated ambient temperatures and controlled internal heating at subzero conditions. ATS had to meet thermal, acoustic, mechanical, and weight constraints within one coordinated architecture.

Thermal design targets:

- Internal discharge temperature less than 5°C above ambient
- T_{CI} less than 60°C at 55°C ambient
- Audio noise limit of 65 dBA or less
- Heat dissipation of 250–300 W
- Internal air temperature maintained between -10°C and 60°C

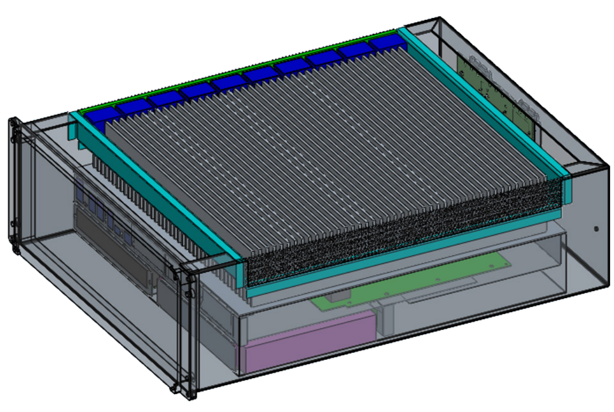

Figure 1. Orthometric (Right Angled Axes) Heat Sink Design to Cool a Ruggedized Router

The core challenge was creating a single system that combined fan architecture, airflow control, heat sink design, and heater integration across the full environmental range.constrained package (Figure 1).

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METHODOLOGY

ATS approached the project in two parts: cooling engineering and heating engineering. Analytical modeling and CFD were used to optimize heat sink structure, airflow paths, fan operating points, and internal heating behavior under the required extremes (Figure 2).

Part I – Cooling Engineering

- Developed dual orthometric fin heat sinks in 26 lb and 30 lb configurations (Figures 3 & 4)
- Optimized internal air channels, baffles, and perforated plate porosity
- Matched fan operating points to system resistance
- Validated cooling performance with analytical and CFD correlation

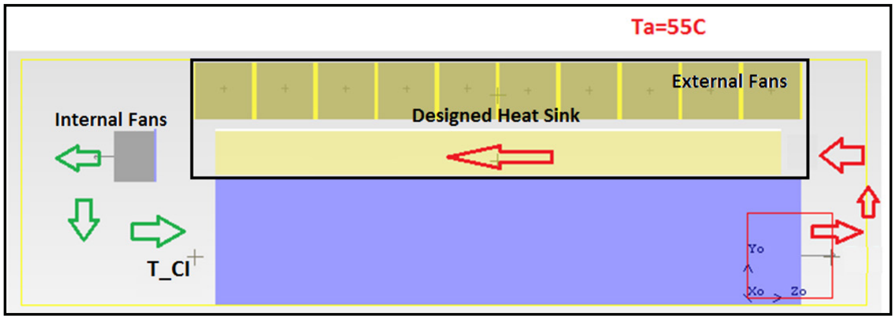

Figure 2.
The System Heating Part of the Thermal Design Involved both Internal and External Fans and Continue Airflow Through the Heat Sink Fin Field

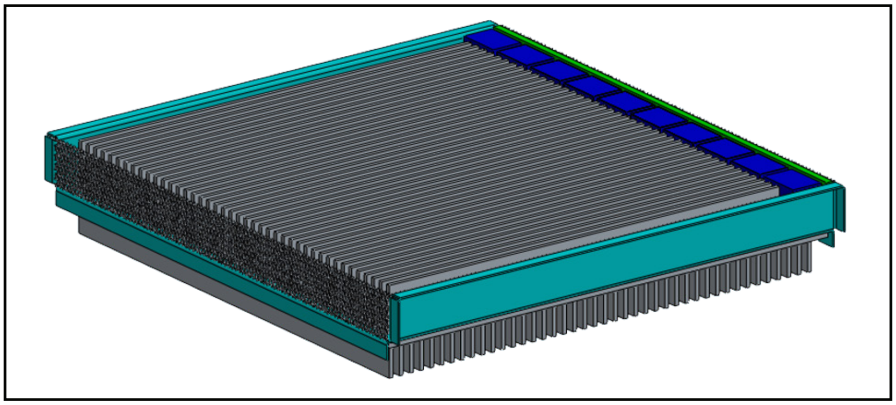

Figure 3.
The Heat Sink Design Featured Top and Bottom Side Orthometric Fins. One Side is an External Heat Sink, the Other Side is an Internal Heat Sink

R_IHS (C/W)	R_EHS (C/W)	R_HS (C/W)	Power (W)	dT (°C)	T_av (°C) (T_a=55C)	T_CI (°C)	Temperature Rise (°C)	Weight (lb.)
0.0216	0.0142	0.036	250	9	64	59.5	4.5	30
0.0230	0.0152	0.038	250	9.5	64.5	60.0	5.0	26
0.0230	0.0152	0.038	300	11.4	66.4	61.9	6.9	26

Figure 4.
Comparative Performance of 30 lb and 26 lb Heat Sinks at 250W. The 26 lb Sink was Also Modeled at 300W Where It Showed the Worst Performance

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METHODOLOGY

Part II – Heating Engineering

- Performed heater energy balance analysis using $Q_{heater} = Q_{HS} + Q_{air}$
- Maintained airflow below 0.2 m/s with PWM fan control to reduce convective loss
- Recommended polyimide film heaters based on power density and integration constraints (Figure 5)
- Added a pair of ATS standard heat sinks to distribute internal heat (Figure 6)

This method allowed ATS to optimize the system as a complete environmental thermal architecture rather than as separate heating and cooling problems.

Air velocity (m/s)	CFM / fan	Duty cycle %	Q_heater (W)	Q_HS (W)	Q_air (W)	Air mass (kg)	Time for 20˚C rise (s)
0.1	0.62	4	70	25	45	0.0184	<20s
0.2	1.23	8	70	50	20	0.0184	<40s

Figure 5.
Internal Heating was Provided from a Polyimide Film Heater, a Pair of Heat Sinks, and the Heated Local Air

Model No.	Size	R / heater	Power @ 12V / heater	Current / heater	No.	Heat Sink
KHLVA-202/(10)-P	2”X2”	19.4Ω	7.34W	0.62A	9	ATS maxiFLOW Heat Sink w/ thermal tape
KHLVA-303/(10)-P	3”X3”	8.71Ω	16.53W	1.38A	4	ATS pushPIN Heat Sink

Figure 6.
Standard ATS Heat Sinks Help Maintain the Needed Internal Heat

SOLUTION

ATS engineered an environmental thermal architecture combining weight-optimized dual orthometric heat sinks, fan and airflow optimization, and an integrated low-temperature heating strategy. The design addressed 250–300 W dissipation at high ambient while maintaining internal air temperature during subzero operation.

- Developed 26 lb and 30 lb orthometric fin heat sink configurations
- Optimized internal channels, baffles, and perforated plate porosity for heat removal
- Selected and matched 10 external fans and 6 internal fans to the system curve
- Recommended polyimide film heaters for compact, high-density integration
- Used PWM fan control to minimize convective heat loss during heating mode
- Added ATS standard heat sinks to distribute and radiate heater energy internally

The final design balanced cooling capacity, acoustic limits, structural constraints, and low-temperature survivability in one coordinated system.

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RESULTS & DATA

The validated design achieved full environmental compliance, with close analytical and CFD agreement and a production-ready architecture optimized for both thermal performance and weight.

Key results:

- Full environmental compliance from -30°C to 55°C
- Cooling capacity of 250–300 W
- Analytical and CFD agreement within 2.5%
- Worst-case 300 W, 55°C ambient rise predicted at only 4.7–8°C above ambient
- Acoustic performance of 61 dBA
- Production-ready weight-optimized heat sink architecture

The validated design achieved full environmental compliance, with close analytical and CFD agreement and a production-ready architecture optimized for both thermal performance and weight.

System-level outcomes:

- Integrated cooling and heating environmental control strategy validated
- Fan architecture optimized with 10 external fans and 6 internal fans
- Predictive confidence strengthened by close CFD and analytical correlation
- Heating and cooling were successfully engineered as one coordinated system

ANALYSIS & CONCLUSION

This study shows that ruggedized electronics for extreme environments require a broader strategy than cooling alone. ATS delivered a complete environmental thermal solution integrating forced-air cooling, structural heat sink optimization, heating control, and airflow management into one manufacturable system.

- Cooling performance depended on coordinated heat sink, fan, and airflow path optimization
- Heating performance required controlled low-velocity airflow and efficient internal heat distribution
- Analytical and CFD correlation supported strong predictive confidence in the design
- The final solution balanced thermal, acoustic, mechanical, and environmental requirements

ATS delivered a practical environmental thermal architecture for a ruggedized router, combining integrated cooling and heating within a validated, manufacturable design.