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Case Study: ATR Design Tackles Thermal Hurdles

Tasked to improve upon the power dissipation capabilities of a standard ATR chassis, a design team puts thermal modeling to good use.

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In publication since 1974, the ATR ARINC 404A specification spells out a tried and true airborne chassis design. So when the engineers at Carlo Gavazzi Mupac set out to craft a system to meet this specification they didn't want to re-invent the wheel. Their challenge was to implement an ATR ARINC 404A system with improved resistance to environmental conditions, while still adhering to the strict guidelines of the spec.

With that in mind, the engineers embarked on a conduction-cooled 3/4 ATR (Air Transport Rack) short chassis design that could dissipate enough power at the harsh ambient temperatures of up to 70°C. The other design goals included flexibility for customization of input and I/O connections, switches and monitoring. The 3/4 chassis would also need to suit the needs of not only industry standard VME, but also VME 64X and CompactPCI structures. It was established that the chassis needed to be versatile and adaptable to as many configurations as possible.

Get the Heat Out

The thermal side of the team's design goal was straightforward: gets as much heat out of the chassis as possible in order to raise the maximum power dissipation at an elevated ambient temperature. The first step was to design a conduction-cooled, high-power, efficient power supply that would have an operational maximum base plate temperature of 85°C. That called for using highly efficient power modules for +5V, +12V, -12V and 3.3V. The supply was designed and built to deliver 500W of total power in the 6U x 0.80 configurations. De-rating the supply to more than half its available power increases its reliability and efficiency. Moreover, the supply was designed to sink all heat losses to the base plate of the case.

Before the chassis design and thermal models were created, the team established a goal of dissipating 135W at 50°C ambient. The design temperature of -55°C to 70°C would cause de-rating above ambient of 50°C. Figure 1 graphs the maximum power supply temps for various power ratings and temperatures. The total surface area of the

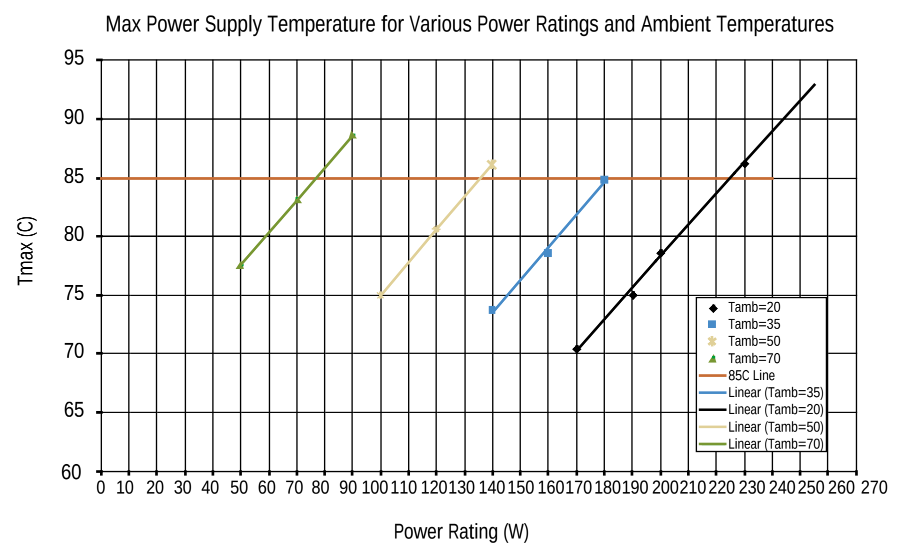

Figure 1

This graph tracks the maximum power supply temps for various power ratings and temperatures.

3/4 ATR short chassis of 1300 square inches plays a critical role in a cooler design.

Thermal modeling of the chassis played a key role in the design process. Using Fluent's IcePak software, the design team began to look for ways to increase chassis surface to ambient air interface. IcePak is an object-based thermal management software tool that handles systems, components, heat sinks and packages. With IcePak software the engineers were able to increase and modify the calculations, until they came up with an optimized fin size and pattern that would cool the chassis. The surface area was increased by the use of multi-fin heat dispersion sidewalls and rear panel.

That approach boosted the chassis' surface area by 15 percent. The thermal models also showed the engineers some interesting results they'd not expected. The mechanical layout in Figure 2 shows eight standard conduction-cooled slots in a front to rear configuration. That configuration meant that the distribution of heat had to pass through the two card retainer plates.

By modeling the rear card plate to combine with the rear fin plate of the brazed chassis, the designers found a direct air-cooling effect. Further study of the thermal results showed that the heat generated by the cards in slots one and eight was creating intense hot spots in the sidewalls of the ATR in the areas where the card retainers were brazed to the sidewalls.

Heat Transfer Tricks

Taking advantage of cooler areas that were non-heat saturated already proved to be a challenge. The power supply the team had designed was modified by creating a heat-spreading wedge-lock base that takes the heat from the power supply and, instead of directing it to the card edge, transfers it directly to the sidewall (Figure 3). The heat from the power supply transfers to the centrally located non-heat saturated area of the sidewall. The unique reverse direction wedge-lock card guide forces the power supply in the opposite direction from the other cards, engaging its base plate to the sidewall of the ATR chassis.

After adding the heat spreading wedge-lock base, new thermal models

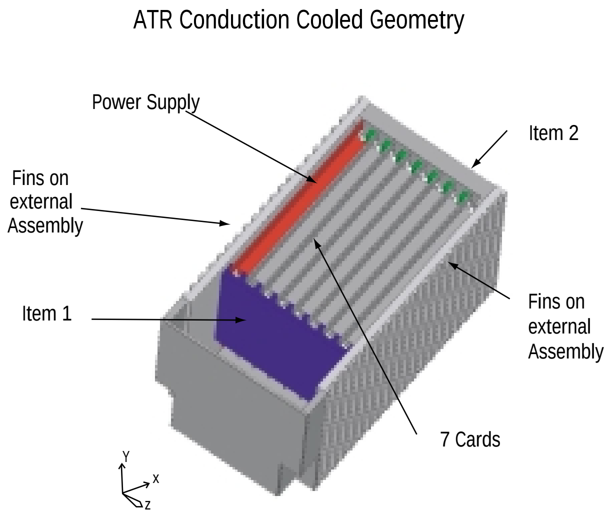

Figure 2

This mechanical layout shows eight standard conduction-cooled slots in a front to rear configuration. Thermal results showed that the heat generated by the cards in slots one and eight was creating intense hot spots in the sidewalls of the ATR in the areas where the card retainers were brazed to the sidewalls.

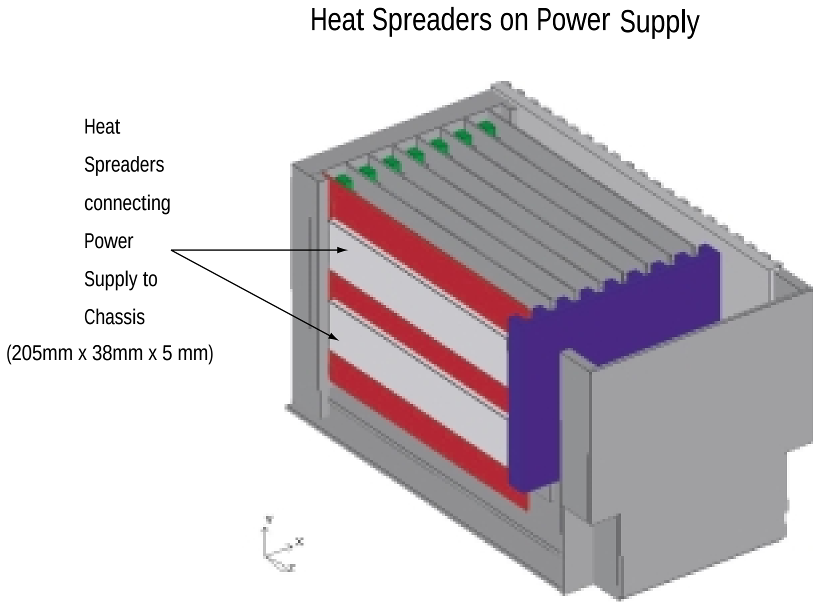

Figure 3

By connecting heat-spreading wedge locks, the chassis designers were able to force heat away from the power supply and, instead of directing it to the card edge, transferring it directly to the sidewall.

showed an increase in heat dispersion along the sidewall and showed a marked decrease in temperature at the all important junctions of the cards to the card guides. The base plate temperature also showed a marked drop, therefore allowing more power dissipation at higher temps.

Table 1 lists "per card" power rating boundary conditions that became the guidelines for the design. As the table shows, the goal ambient temperature of 50ºC and a rated power of 140W corresponds to 20.0 Watts per slot and a heat loss of 35W at the supply board. Again, Figure 1 shows the maximum power supply base plate temperature as the cutoff for maximum power rating for various ambient temperatures. To simplify the process, the lowest ambient tested was 20ºC. Lower temperatures of operation result in much higher power dissipation ratings. That's based on the ability for cooler ambient air to assist cooling of the fins on the chassis. Reviewing Figure 1 shows that at 20ºC ambient the power supply base temperature will remain below the cutoff of 85°C all the way to 225W.

With the guideline boundary conditions in mind, the power supply can deliver up to 500W. At the extreme limit of 70°C ambient temperature the supply will deliver near 80W. That's a reasonable cutoff anyway, given that most conduction-cooled boards have maximum junction temperatures of 70-75°C. Figure 4 graphs the decrease in available power consumption based on ambient operating temperatures. The values in the graph are maximums based on power supply operating temperatures of 85°C.

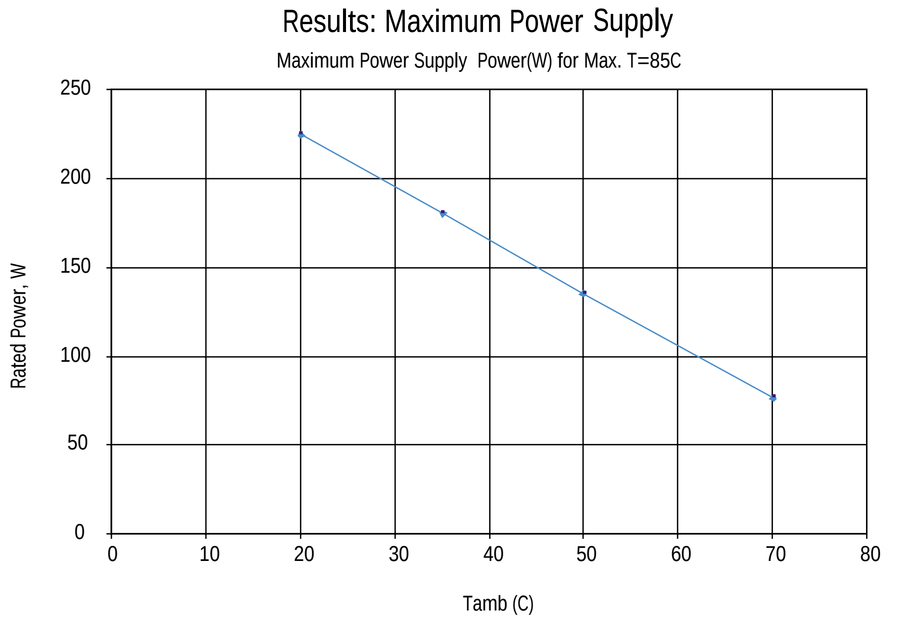

Figure 4

This graph shows the decrease in available power consumption based on ambient operating temperatures. The values in the graph are maximums based on power supply operating temperatures of 85ºC.

Input Boundary Conditions

	Rated Power, W	Heat @ Power Supply, W	Card Power, W
Tamb=20 °C	170	42.5	24.3
	190	47.5	27.1
	200	50	28.6
	230	57.5	32.9
Tamb=35 °C	140	35	20
	160	40	22.9
	180	45	25.7
Tamb=50 °C	100	25	14.3
	120	30	17.1
	140	35	20.0
Tamb=70 °C	50	12.5	7.1
	70	17.5	10.0
	90	22.5	12.9

Table 1

Listed here are the "per card" power rating boundary conditions that became the guidelines for the design. For instance, the goal ambient temperature of 50ºC and a rated power of 140W corresponds to 20.0 Watts per slot and a heat loss of 35W at the supply board.

Heat Sink on SBC Too

While developing the chassis, the CG Mupac design team saw a chance to apply the same principle to the single board computer that would reside in the opposite side of the chassis. With that in mind, they set out to design a heat sink for the heat generating components on the ruggedized simple board computer and wedge lock that to the sidewall. This removes more of the heat away from the card retainer plates and ensures better cooling for slots two through seven. The heat sink on the SBC takes the heat directly to the non-heat saturated center portion of the right sidewall.

It was important for the chassis design to incorporate as much flexibility as possible to make it a “one design meets all options” solution. With that in mind, the card cage configuration accepts up to seven slots including the system slot, and can accept VME 64, VME 64X as well as CompactPCI conduction-cooled boards per IEEE std 1101.2. Each backplane, regardless of the type, is designed to permit easily accessible top side I/O connectors. The I/O can then be routed to a fully removable factory customizable front I/O panel.

Because the front of the chassis is a removable panel, it can be changed to accommodate any custom design including AC/DC input connection, I/O connectors, reset, LEDs and monitoring. Monitoring can include voltage monitoring at the supply and temperature monitoring of various surfaces throughout the chassis. The chassis is designed to operate under the temperatures described previously, but the optional cooling methods that have been added to the ATR specification can be simply added to the chassis. The flange mounts and cold plate base can easily be used in the design.

Because the chassis does not require access to the bottom, a cold plate can be added, distributing heat from the sides, rear and card retainer plates to the base plate and transferring to the cold plate. There is an optional version of the ATR chassis that uses internal fin sidewalls with rear fan assistance. There is a front to rear air flow path that takes air in through the front sides; the rear fan pulls air through the specially designed heat sink fin sidewalls and exhausts out the rear bottom. That option is only available in long versions.

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