Managing the Heat in the Next Generation of ATCA Chassis

ATCA / PICMG chassis designs dominate the industry as the platform for designing new systems. This choice is driven by economics in that the cost of any product, whether in electronics or another market, plays a pivotal role in its success. Standardizing around a particular chassis design offers economies of scale in both product availability and deployment in the field. However, as the physical design of a chassis becomes standardized, the power dissipation occurring inside is far from standardized. An ATCA enclosure designed for 1kW and managed by air is now being considered for electronics that can dissipate in excess of 2-4 kW!

Obviously, if a chassis' physical design is not changing and it is suitable for the initial power dissipation – the dissipation from both the current and forecasted cards can strain the enclosure's cooling capacity. The lingering questions are: What cooling technology is suitable for higher power dissipations? Will standards need to change in order to address the cooling requirements of future systems?

Previously, we explored the possibility of refrigeration as the means for managing higher power systems, [1]. We clearly showed that, by using refrigeration, many thermal issues can be successfully mitigated. However, the practical deployment of refrigeration in a data center or a central office is always a point of concern and poses significant cost for the center's manager. We also looked at the potential use of other technologies that may become attractive in thermally managing higher power ATCAs.

Figure 1 compares several cooling technologies for ATCA chassis, while considering the junction-to-ambient temperature rise of a 100 W device. The technologies considered are:

1. Conventional Air Cooling – standard fans on either or both sides of the system.
2. Cold Plate
3. Fan Assisted Air-Jet
4. Fan Assisted Air-Jet with High Performance Heat Sink
5. Liquid Spray Cooling
6. Water Jet

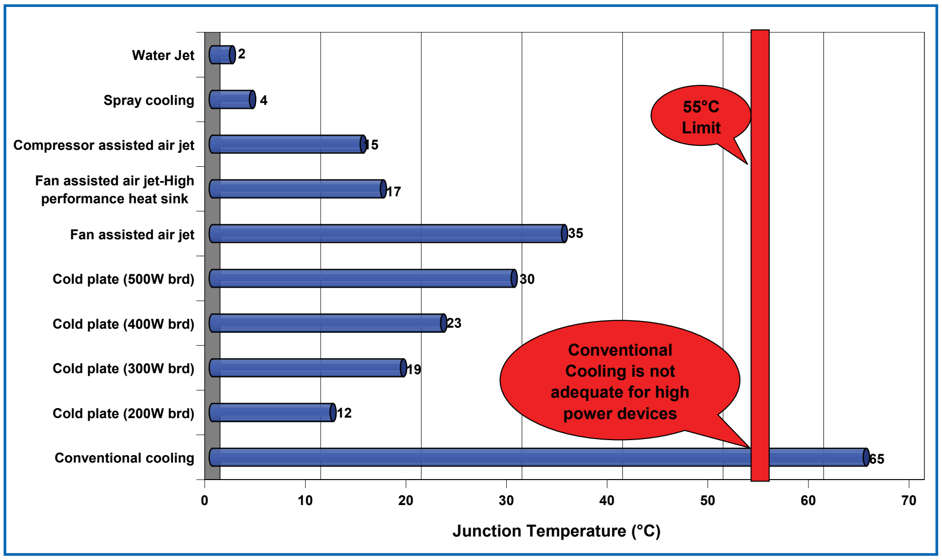

Figure 1. Device Junction Temperature Rise for Different Cooling Schemes as Applied to a 5-Slot ATCA Chassis [2].

Option 1 uses high performance fans on one or both sides of the system along with a high performance heat sink for device cooling. Option 2 uses a standard cold-plate whose blades are attached – thus, requiring a liquid coolant to transport the heat from the PCBs to a liquid-to-air heat exchanger. Options 3 and 4 feature a patent pending technology by Advanced Thermal Solutions, Inc., in the same configuration as Option 1, where system fans are used along with plenum ducting. Figure 2 is the schematic of this design. It shows the system parallel flow diverted to jet impingement, which can be directed to the entire PCB or the critical components on the PCBs.

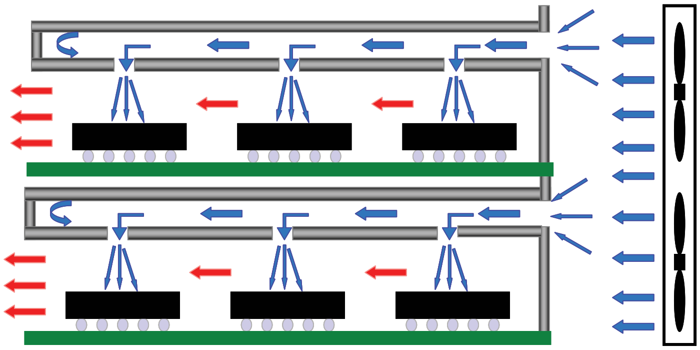

Figure 2. Fan Assisted Air Jet (FAAJ) for High Capacity Cooling of PCBs in an ATCA or PICMG Chassis.

Option 5 considers a liquid spray (Fluorinert) pointed at the high power devices or the entire PCB. The spray acts as the thermal transport vehicle between the hot sources and the liquid-to-air heat exchanger. There is no other layer of resistance between the heat source and the heat sink, which is the liquid-to-air heat exchanger. This option requires the PCBs to be sealed, a practice common in military avionics. Option 6 uses water as the coolant. The hot devices/PCBs are physically isolated from the liquid, and water transports the heat from the hot sources to the liquid-to-air heat exchanger.

Other methods, not shown here, take advantage of the conduction cooling of the PCBs and use the chassis as the heat sink. Such methods require changing the physical architecture of the ATCA chassis, thus creating custom solutions. Options 1-6 are drop-ins to an already existing system. One may argue that options 5 and 6 also require changes, but these are not external to the system and can be done at the PCB level as a drop-in solution. But the conduction cooled ATCA does require significant architectural changes in order to make it a successful cooling system.

Examining the temperature rises in Figure 1 clearly shows that conventional air cooling will not meet the requirements of the high-power PCBs (400-600 W) or of devices that dissipate 80 W or higher. With highly protocol-integrated communication chips and CPUs, power dissipation exceeding 80 W is the norm rather than the exception. Hence, the cooling system needs to accommodate such devices. In [1] we looked at several fan scenarios where three out of four fans were currently available on the market and the fourth fan was a hypothetical one – or in other words, in the thermal engineer's dream.

The mechanical performance of these fans is presented in Table 1, [2].

Table 1. Three Available Air Movers (fans) and a Hypothetical One - Fan No. 3.

Let's assume that we have applied these fans to a standard five slot ATCA chassis in a push-pull situation. Considering that power dissipation is on the rise, let us consider four PCB level power dissipations as shown in Table 2:

Table 2. PCB and System Power Dissipations for the Four Configurations Considered.

No.	PCB Power (W)	System Power (W)
1	200	1,000
2	300	1,500
3	400	2,000
4	500	2,500

To examine the effectiveness of air cooling and compare it to other cooling options, we must establish some thermal design rules. Some in the industry falsely use the fluid temperature rise in the PCB channel as a measure of performance. For the sake of clarity only, we adhere to this rule. Otherwise, such a gauge is perhaps the most ambiguous criterion for determining if a cooling solution is acceptable. The falsehood of this gauge "fluid temperature rise in a PCB channel" resides in the huge temperature and velocity gradients that exist in the PCB channel and change of flow distribution on the PCB as the inlet boundary condition changes, i.e., fluid velocity. The best test is the device junction temperature; whether calculated or measured. Thus, let us follow the industry practice and set 10,15 and 20°C as the three temperature rises that we want our cooling solution to deliver for a given PCB-level power dissipation, as shown in Table 2.

What this gauge states is that if the fluid temperature rise is within the set limit (10, 15 and 20°C) the given cooling solution is acceptable and the system will meet the required thermal criterion. In the three conditions, 10°C represents the most stringent and 20°C the most relaxed criteria. Figure 3 shows the PCB fluid temperature rise plotted against volumetric flow rate through each PCB channel for the four PCB power dissipations considered in Table 2.

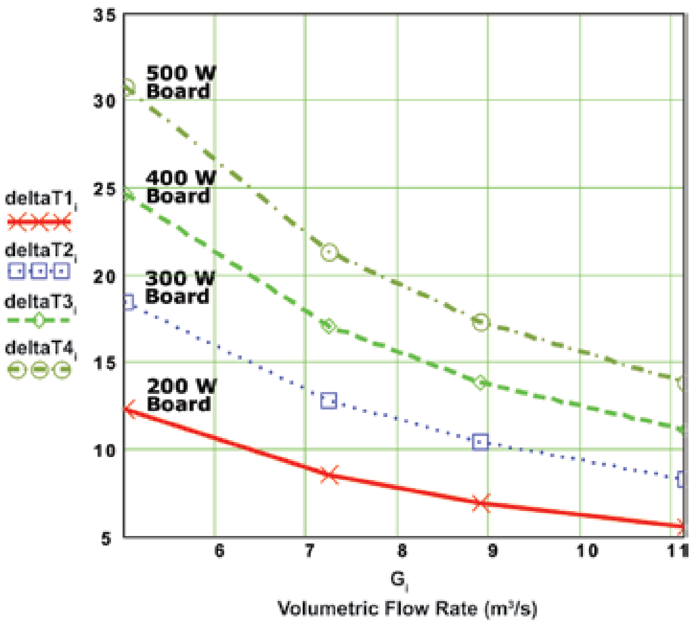

Figure 3. Temperature Rise Between the Inlet and Outlet of the ATCA Chassis for the Four Operating Points and at Four Different PCB Power Levels [2].

The plot clearly shows that if the PCB power dissipation is 200 or 300 W, the 10°C fluid temperature rise criterion can be met provided that the air flow inside the chassis is at least 6.8 m³/min (240 CFM) and 9.9 m³/min (350 CFM), respectively. The 10°C criterion can not be met even by the hypothetical super fan for higher powered PCBs. If we loosen our gauge and consider 15 or 20°C criteria, we see that higher PCB power dissipation is acceptable (400 W per PCB) provided that the volumetric flow rate is 8.5 m³/min (~300 CFM) and at 500 W the flow rate is 10.6 m³/min (375 CFM). Creating such a flow in a small chassis like an ATCA is a rather daunting task with many reliability and compliance issues, including acoustic noise and fan failure. Therefore, for cooling higher power PCBs, conventional air cooling is a difficult, if not an impossible task to accomplish, even if super fans were available on the market and the compliance requirements were relaxed.

However, deployment of the fan assisted air jets (FAAJ), without the high performance heat sink, has shown a significant improvement over the conventional air cooling. Figure 4 shows the schematic of FAAJ deployment into a conventional ATCA chassis.

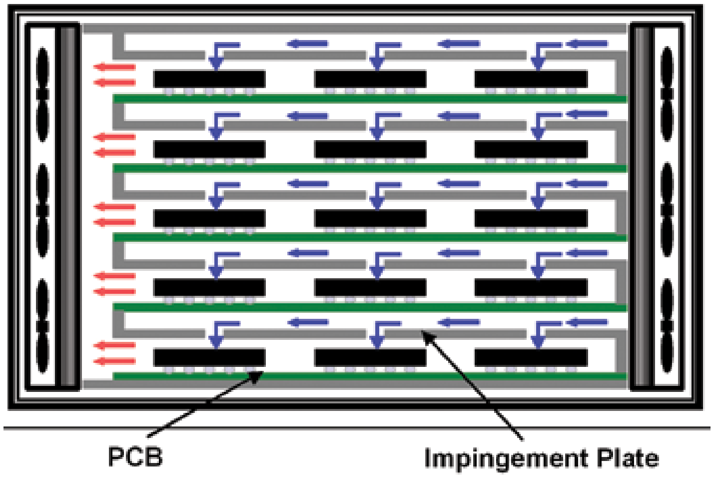

Figure 4. Deployment of Fan Assisted Air Jets (FAAJ) in a Standard ATCA Chassis.

Figure 5 shows the measured data for randomly placed components, comparing the thermal response (case-to-ambient temperature rise) of 15 components cooled by conventional air (CA) and FAAJ methods.

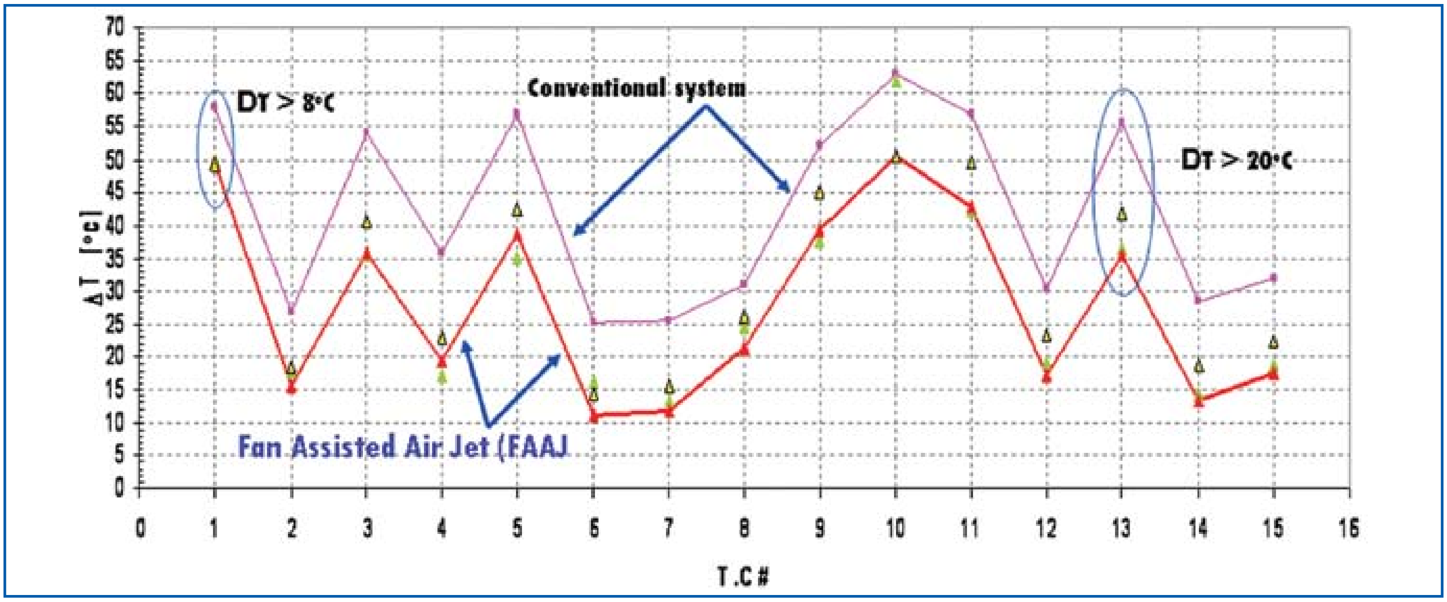

Figure 5: Component Case Temperature Rise for a Standard PCB Placed in an ATCA Chassis Cooled by Conventional Air (CA) and Fan Assisted Air Jets (FAAJ). The Magenta Line is the Conventional Air Cooled, The Red Line is FAAJ and Shows Cooling Improvement in Excess of 20°C Over CA.

A number of technologies are well established for cooling future ATCAs. Conventional air cooling will not be adequate for thermally managing such systems using the fan technology that currently exists. Even if a super fan is developed, compliance and reliability requirements necessary for deploying ATCA chassis in data centers or central offices will become a gating factor. We must depart from conventional cooling and explore technologies that retain the intended use of the ATCA chassis. In this article we have shown several techniques that can be used for such systems. All but liquid cooling do not require major architectural changes. Liquid cooling in the mode of direct or indirect contact with the components or PCBs will certainly handle the power dissipation of the future systems. However, the issue of liquid in a data center or central office, though receiving more acceptance, continues to be tenacious. The technique that requires least modification to the chassis and can be deployed at the PCB level is FAAJ - Fan Assisted Air Jets. These redirect the air from parallel flow to jet impingement resulting in the highest heat transfer coefficient. The data show that, with no heat sink, temperature reduction in excess of 20°C can be gained by taking advantage of jet impingement and the existing fans in the system. Further optimization of the impingement plate and the use of high performance heat sinks has shown gains in excess of 40°C on some components on the PCB as compared to conventional air cooling.

References:

1. Cooling ATCA and PICMG Chassis with Refrigeration, Qpedia eMagazine, Advanced Thermal Solutions, Inc.
2. Azar, K., Limits of Air Cooling for ATCA and the Role of Liquid Cooling in Growing Thermal Demands,. ATCA Summit, San Jose, CA, 2008.

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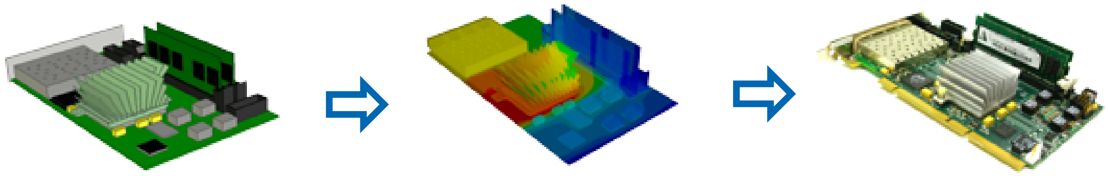

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