AdvancedMCs:

Thermal Problems and Cooling Limitations

The Advanced Mezzanine Card, or AdvancedMC, standard applies to a modular PCB card that attaches to a carrier board to upgrade functionality, as mechanically and electrically defined by the PCI Industrial Computer Manufacturers Group (PICMG). The primary function of an AdvancedMC varies, but the card is commonly devoted to one of the following functions [1]:

- Telecommunications Connectivity
- Computation Processing
- Network Communication Processing
- Mass Storage

The modular nature of the system allows customization of carrier boards with swappable capability. A typical use for the AdvancedMC system is seen with AdvancedTCA blades, where the modular primary carrier board has integral hot-swappable AdvancedMCs interfacing to the faceplate, as shown in Figure 1.

As these modular systems grow in power due to faster computing and network switching rates, the thermal challenges involving these advanced mezzanine cards are becoming more difficult. The enclosed and small form factors of these systems, coupled with the high power consumption of many designs, call for increased attention to their cooling methods.

While the PMC (PCI Mezzanine Card) is rated for only 7.5W of power, and the PrPMC (Processor PCI Mezzanine Card) is rated to 12W, a single-slot wide AMC card is specified to a 30W thermal envelope. The connector itself is standardized to 60W per modular unit, in anticipation of lower resistance thermal techniques in the future [2]. The possibility for high power within a small form factor is apparent for AMC modular systems.

Functionality and power levels aside, the form factor of the AdvancedMC system varies significantly, ranging from single to half height, and single to double width. The depth of all units is kept fixed. Figure 2 highlights a typical AMC card and the different configurations which are possible.

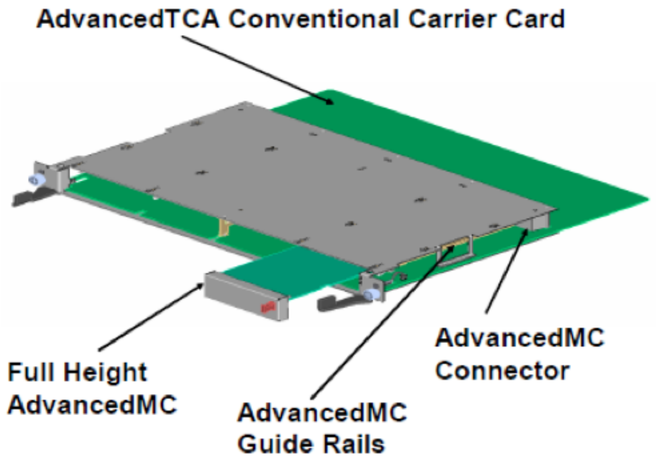


Figure 1. AdvancedTCA Conventional Blade with Integral AdvancedMC Assembly[1].

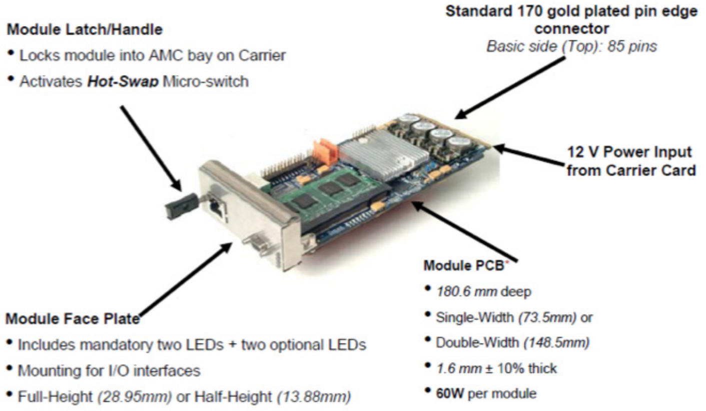


Figure 2. Example of an AdvancedMC Unit [3].

Because the boards are stacked in series relative to the direction of flow, the last card in the series will often run hottest because of upstream preheating of the airflow. For AdvancedTCA applications, this can mean significantly high operating temperatures at lower flow rates. Consider the following scenario: a stack of four single height and single width 30W AMC cards are assembled onto an AdvancedTCA carrier blade. We can predict that an ambient airflow initially at 50°C flows at one meter per second across the representational channel of 180 mm by 20 mm (the board and components discount from the available channel height). Because of its careful design, the airflow does not diverge from the channel. Air temperature rise is governed by the following thermodynamic equation:

$$\dot{V} = 1.83 \frac{Q}{\Delta T}$$

Where:
$\dot{V}$ = the volumetric flow rate in cubic feet per minute,
Q = the heat applied to the system in Watts, and
ΔT = the air temperature rise past the heat source(s) in degrees Celsius.

Because the air flows over the preceding three cards before reaching the fourth, the heat applied to the air is equal to about 90W. Based on the situation, we can calculate the air temperature rising 21°C before reaching the fourth AMC module, so that the air temperature entering the last module is around 71°C. If the hypothetical device which generates the 30W will fail at a junction temperature of 110°C and we need to keep the case temperature of the device lower than 90°C, the device will require a solution with a thermal resistance of 0.63°C/W, as opposed to 1.33 for the first AdvancedMC module. Reaching this thermal target will certainly be a challenge given the low cross sectional available area for a heatsink and low airflow.

Given these thermal challenges, one of the issues from using a stack of high powered AdvancedMC modules is the preheating of air before the final module. Compromises often must be made as to the allowable power levels of upstream modules. Because of the stack of modules, each with individual heat sinks and mechanical structures, there can be a high pressure drop associated with the air flow through the channels. This requires greater fan power or a reduction in heat sink size. Figure 3 shows a thermal solution for a mass storage device used on an AMC card. A heat sink was designed to use the airflow which normally diverts around the case of the hard drive. The end result is a heat sink which will increase the pressure drop across the entire card, therefore lowering the cumulative airflow, while conversely performing its function and keeping the mass storage device operating at a safe core temperature.

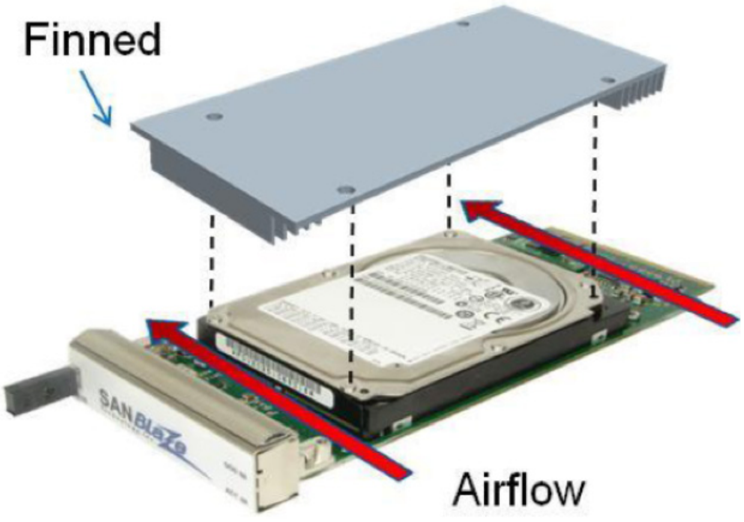
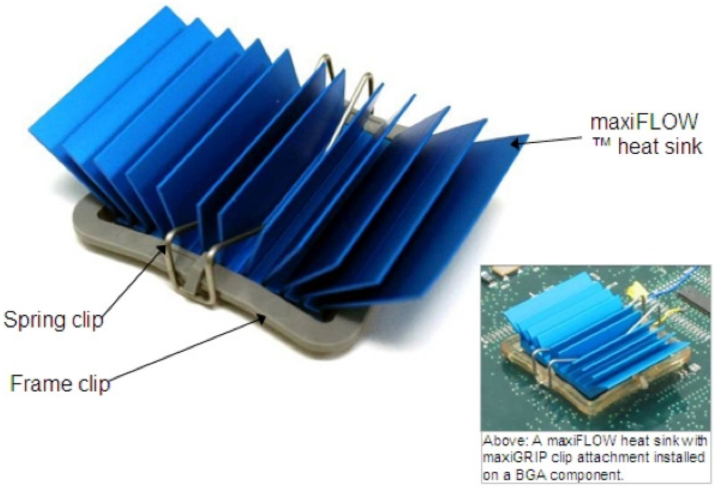


Figure 3. Proposed Heatsink for an AMC Mass Storage Module [4].

When the power levels of the modules are high and there is significant impedance to the airflow, it is difficult to obtain the necessary heat transfer ability to keep devices running at safe levels. Active solutions are generally not possible for many AdvancedMC applications, given the reduced height [3]. Because of the difficulty in designing for an active solution without making major sacrifices, a passive solution may be needed for most applications. It is important for designers to understand that a large, restrictive heat sink as shown in Figure 3 will cause lower airflow as previously mentioned. Advanced Thermal Solutions, Inc. (ATS) has developed a line of low profile maxiFLOW® heatsinks with maxiGRIP™ clip-on attachment technology, which are ideal for high power AdvancedMC applications where high performance and low air restriction are fundamental, as shown in Figure 4.



Above: A maxiFLOW heat sink with maxiGRIP clip attachment installed on a BGA component.

Figure 4. ATS's maxiGRIP™ / maxiFLOW™ BGA Heatsink with Clip Attachment

Because a common use of AdvancedMC modules is in AdvancedTCA applications, these boards must conform with the applicable standards. The maximum power consumption of an AdvancedTCA board including AMC modules is 200W. If each of the modules is rated at maximum 30W, then the available heat load for the rest of the board is about 80W. Power budgeting within the thermal envelope may be required if high power electronics are needed on the carrier and the mezzanine modules. Also, the AMC card should not allow violate the uniform airflow requirements at the entrance of the AdvancedTCA board, as shown in Figure 5. It is important to note that if air deviates from the AMC channel, the fourth card will suffer even lower flow rate. It is important to mount fan trays, ducts, or high density heat sinks in such a way that airflow can reach places where it is needed while at the same time the arrangement can fulfill the airflow uniformity requirements as mandated by PICMG.

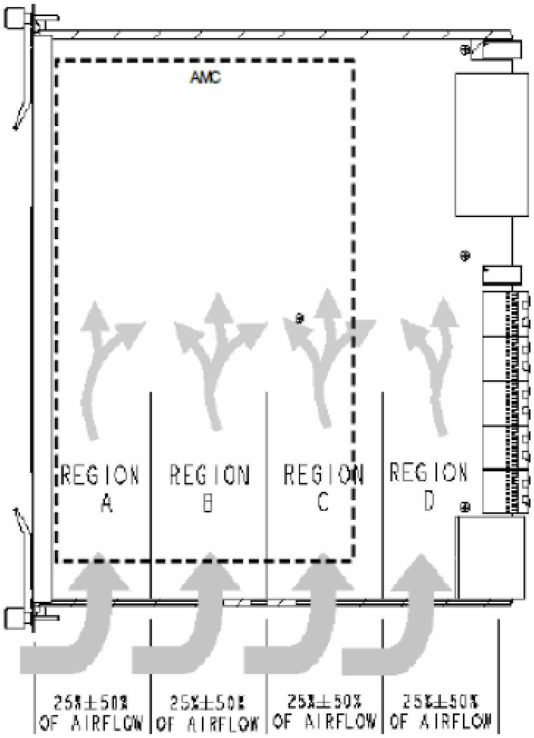


Figure 5. Airflow Uniformity Requirement Across Each AdvancedTCA Slot [1].

In conclusion, despite the low flow, high power, and highly restrictive environment of the AdvancedMC, multiple steps can be taken to increase the cooling of these modules.

- It is important to prevent the use of structures with high flow impedance, when considerable heat transfer needs to be taken downstream. This may include the use of heat sinks where they may not be necessary, e.g. on devices that can be relocated to cooler parts of the board where conduction through the board can provide enough cooling without a heat sink.
- The use of low profile heat sink clips, such as the ATS proprietary maxiGRIP™ system, will prevent airflow from bypassing much of the surface area of a heat sink. Some clips on the market can block a significant amount of airflow from cooling much of the surface area on low profile heat sinks. A clip such as maxiGRIP™ allows for the use of lower resistance thermal interface materials, including phase change materials. The use of these clips will allow more flow rate due to lesser pressure drop.

- Preventing preheated air to reach sensitive components or high power devices because a cooler local ambient temperature allows these devices to run significantly cooler, consequently allowing less intrusive heat sinks.

- Baffling or ducting airflow to high power electronics can reduce the dependency on powerful fan trays and can help lessen the concerns of an uneven airflow profile across the AdvancedTCA board.
- Board layout is critical to isolate heat sources. By taking the appropriate measures, designers can ensure that cooler air is available to the heat generating components. This also ensures that a maximum amount of heat can be transferred through the PCB since the local PCB temperature under an isolated device will be cooler.

References:

1. Leija, W., Thermal Design Consideration for the Advanced Mezzanine Card Form Factor, 21st IEEE SEMI-THERM Symposium, 2005.

2. Beaton, S., Usage Models for Advanced Mezzanine Card (AdvancedMC), Compact PCI Systems Magazine, Novermber 2003.

3. Watt, R., The Design Challenges of an AMC Card, White Paper: Freescale Semiconductor, Inc., 2006.

4. Thermal Solutions for AMC Disks, White Paper: SANBlaze Technology Inc., 2008.