THERMAL SOLUTIONS FOR POWER ELECTRONICS

ADVANCED COOLING TECHNOLOGIES

The Thermal Management Experts | www.1-ACT.com

Power Electronics are the most critical components in a large number of applications; including power generation and operational equipment. Power Electronics module manufacturers invest millions of dollars to make these devices as efficient as possible, aiming primarily to reduce waste heat. However, even with efficiency gains at the module level, overall waste heat is rising across the industry due to more system and user driven functional requirements. Increased system capability leads to higher power densities and more waste heat! Selecting off the shelf thermal solutions is no longer a viable option for applications that are pushing the envelope on power and operating efficiency.

Investing in an optimal thermal solution can be the design change with the largest payback potential in a high power system. If properly designed, the thermal management system should not only meet performance requirements, but do so while minimizing energy usage. This eBook provides a guide for designers looking to expand the operating limits of traditional air and liquid cooled thermal solutions.

DESIGN ANALYSIS & CONSIDERATIONS: AIR-COOLED POWER ELECTRONICS

ENCLOSURE COOLERS

LOW POWER

Some power electronic based control systems can have many small output devices packaged into a single cabinet. Instead of attempting to cool each component individually, it is often more beneficial to cool the air within the cabinet, and allow the components to be naturally cooled by the air surrounding them. In applications where the environment is harsh or dirty, it is not possible to blow the outside air through the cabinet. Therefore a method of exchanging heat with the surrounding environment without exchanging the air itself is beneficial. Sealed Enclosure Coolers provide this benefit!

BENEFITS TO THE CUSTOMER

- Simple integration
- Maintain a sealed enclosure and proper NEMA rating
- Low cost

SPECIFICATION/APPLICATION NOTES

- Suitable for low thermal dissipation applications with many heat generating components in one enclosure (<1000W)
- Best for applications in harsh environments and cabinets that need to maintain a specific NEMA rating while still dissipating heat

OPTIONS

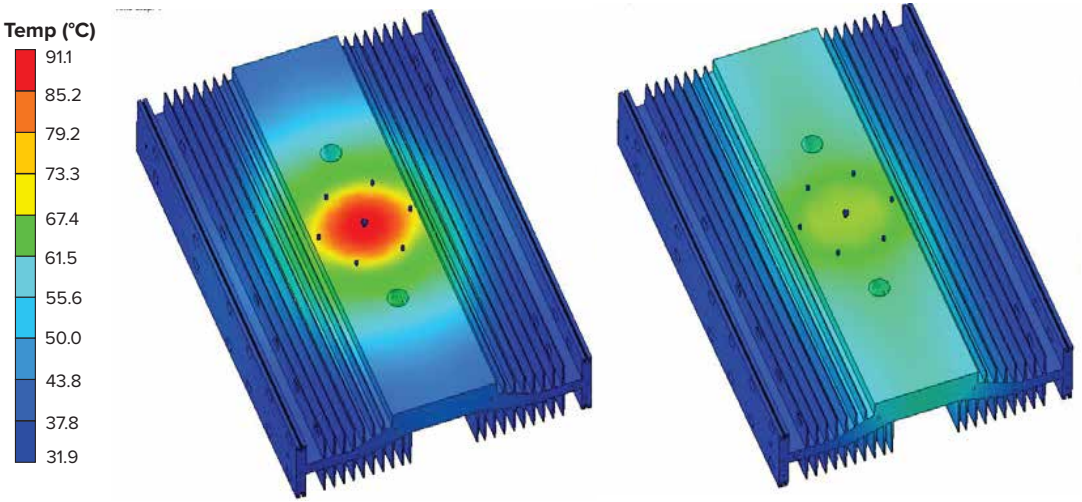
- ACT-HSC Heat Sink Cooler Series (low cost)
- ACT-HPC Heat Pipe Cooler Series (compact)
- ACT-LNC Low Noise Cooler Series
- ACT-TEC Thermoelectric Cooler Series (sub-ambient)

DESIGN ANALYSIS & CONSIDERATIONS: AIR-COOLED POWER ELECTRONICS

HIGH CONDUCTIVITY (HiK™) PLATES

LOW & MEDIUM POWER

Power electronics applications that currently utilize air-cooling and want to increase the power output without making substantial changes to the system or package can benefit from HiK™ technology. HiK™ plates or components are essentially heat pipe embedded systems that improve heat spreading and allow for better utilization of existing air-cooled heat sinks. If the system envelope is fully defined and the heat sink volume is fixed, it is often possible to increase the thermal performance of the heat sink.



Thermal image of Air Cooled IGBT Heat Sink. Left: no heat pipes. Right: with heat pipes (HiK™)

BENEFITS TO THE CUSTOMER

- Increased thermal performance with minimal impact to system packaging and volume
- Relatively low cost impact
- More isothermal module baseplate improves reliability

SPECIFICATION/APPLICATION NOTES

- Low-medium power applications (<5kW thermal)
- Most applicable for air-cooled systems
- Passive heat spreading (i.e. no moving parts)
- 15-20% thermal improvement

DESIGN ANALYSIS & CONSIDERATIONS: AIR-COOLED POWER ELECTRONICS

LOOP THERMOSYPHON

MEDIUM & HIGH POWER

A loop thermosyphon is a gravity-driven two phase cooling loop, and is a high performance solution for air-cooled power electronics cabinets with medium to high power dissipation. Power modules mount to the evaporator as they would on a traditional extruded heat sink or liquid cold plate. The heat is removed by a boiling dielectric fluid inside of the cold plate, and passively transported to a condenser mounted at the top of the cabinet. Loop thermosyphons are more effective than heat pipe systems, and offer the opportunity for remote condenser placement and electrical isolation between the evaporator and the condenser. Loop thermosyphons are best suited for applications requiring high performance at a reasonable cost and cabinets that allow for the required vertical mounting orientation.

BENEFITS TO THE CUSTOMER

- Passive, high performance cooling solution
- Dielectric fluid (no risk of electrical shorting)
- Potential for electrical isolation between evaporator and condenser if required
- Remote condenser location for improved system-level packaging
- Relatively low cost (~$0.15/W thermal)

SPECIFICATION/APPLICATION NOTES

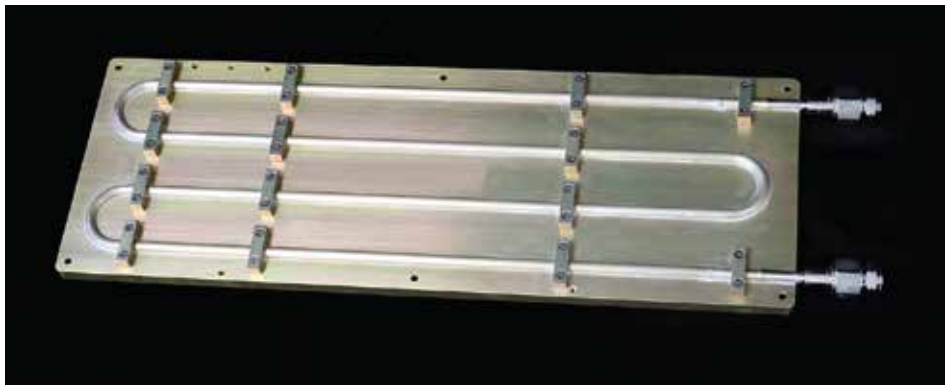
- Must be mounted vertically with respect to gravity
- Appropriate for medium to high power applications (<7kW)

DESIGN ANALYSIS & CONSIDERATIONS: LIQUID COOLED POWER ELECTRONICS

PUMPED SINGLE PHASE

MEDIUM & HIGH POWER

The next progression in thermal technologies is active, pumped single phase (liquid cooling). This offers higher power capability compared to air solutions. Liquid cooled systems typically use glycol/water cooling fluids for freeze and corrosion protection. The air-cooled heat exchanger can be remotely located outside of the cabinet, or even outside of the building to reduce heat load on the building HVAC system and surrounding systems. Selecting the proper pump, heat changer and cold plate design is important to achieving the desired results. All components must be specified to work together to provide the best results.



BENEFITS TO THE CUSTOMER

- High performance cooling
- Remote heat dissipation frees up space inside the electrical cabinet and reduces heat load to the surrounding environment

SPECIFICATION/APPLICATION NOTES

- Proper system-level design is critical
- Most applicable for the highest powered systems

DESIGN ANALYSIS & CONSIDERATIONS: LIQUID COOLED POWER ELECTRONICS

PUMPED TWO PHASE
HIGH POWER

Applicable for the highest powered systems, pumped two phase provides the highest level of heat dissipation with the least amount of energy consumption. Dielectric fluid is pumped to the cold plate where it boils as it absorbs the heat from the components. The two-phase fluid then flows to a remotely located condenser, where the vapor is condensed and pumped back around the loop. These systems are used in similar applications to single-phase cooling expect that electrical isolation around the cooling loop is possible because of the dielectric fluid. The pumping power required for two-phase cooling relative to single-phase cooling is reduced by about 85%, which improves system-level efficiency.

Example of ACT's custom designed and manufactured Pumped Two Phase system for a unique theater lighting application.

BENEFITS TO THE CUSTOMER

- Highest performance cooling
- Dielectric fluid for electrical isolation, if required
- Highly isothermal operating for improved reliability
- Lowest energy consumption for a liquid cooling system

SPECIFICATION/APPLICATION NOTES

- Highly engineered systems that require expertise to properly design and manufacture
- Uses refrigerants as working fluid
- Appropriate for applications trying to achieve the highest performance possible

	AIR COOLING	TWO PHASE AIR*	PUMPED LIQUID	PUMPED TWO PHASE
Heat Density	Low	Medium	High	High
Thermal Resistance	High	Medium	Medium	Low
Maintenance	Low	Low	High	Medium
Complexity	Low	Medium	Medium	Medium
Temperature Uniformity	Low	Medium	Low	High
Compactness	Low	Low	Low	High
Energy Efficiency	Medium/High	Medium/High	Low	Medium
Expandability	Low	Limited	Limited	High
Cost	Low	Low/Moderate	Moderate	Moderate

** HiK™, Loop Thermosyphons*

Applications using Power Electronics devices can range from 100s of watts to 100s of kilowatts of waste heat. Having a strong working knowledge of cooling options can lead to a design that meets your performance goals, and provides the end user with thermal system that minimizes operating cost and maintenance. Considering the following solutions may benefit you for future designs:

- **Enclosure Coolers:** Low Power, Sealed Electronics Cabinet Operation
- **HiK™ Plates:** Improved conduction, which increases ultimate heat sink performance
- **Loop Thermosyphon:** Higher power capabilities than heat pipes
- **Liquid Cooling (Single Phase):** Higher power and added complexity over air-cooled options
- **Liquid Cooling (Two Phase):** System level power and operating advantages over single phase

For any project for which are considering a custom design, call ACT for a free evaluation of your requirements!

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