RUGGED THERMAL MANAGEMENT SOLUTIONS FOR HIGH-POWER EMBEDDED ELECTRONICS

ADVANCED COOLING TECHNOLOGIES

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

Military electronics have some of the most stringent requirements when you combine the total power of the devices and the environment they will experience over the course of missions. Unlike most other high-power computing applications, military electronics need to withstand shock, vibration, humidity, salt, fog, dust debris and extremely high temperature environments. Coupling these thermal and mechanical (must-have) requirements with the ongoing SWaP goals of military systems makes it extremely challenging for design engineers to properly develop a thermal solution, predict performance and sustain cost effective manufacturing.

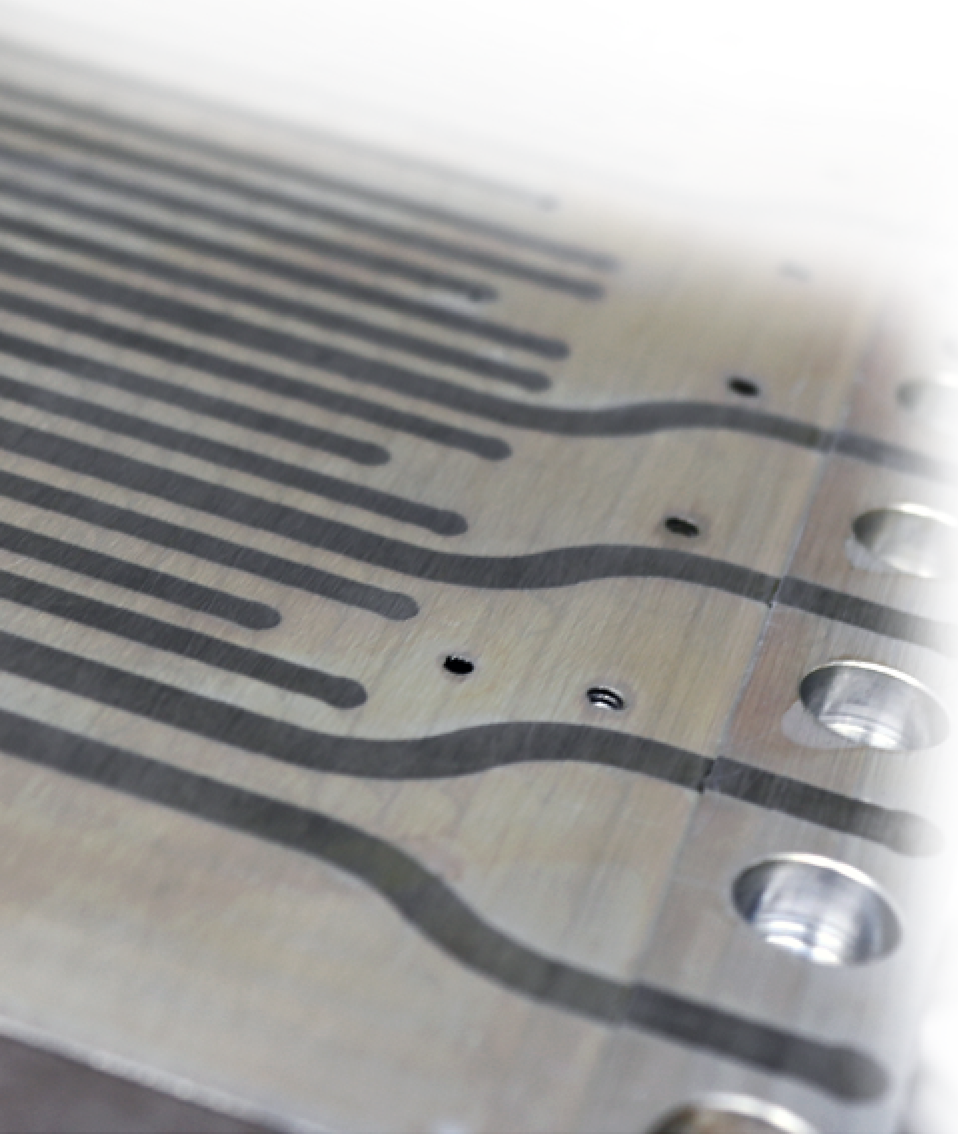
Investing in an advanced custom thermal solution is often the design change with the largest payback potential in a high-power system. If properly designed, the thermal management system should not only meet performance requirements, but do so while minimizing energy usage. This eBook provides a guide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

TABLE OF CONTENTS

PRODUCT GLOSSARY

ICON KEY

ACT's custom thermal solutions offer a variety of enhancements depending on the design parameters. In each section an icon(s) will be highlighted to show a given technology has this advantage over traditional solutions.



HIGH POWER DISSIPATION

Solutions that dissipate high heat loads created from extreme amounts of power.

SIZE/WEIGHT ADVANTAGES

The solution is compact, meeting form and fit requirements of the system.

LOW MAINTENANCE RELIABILITY

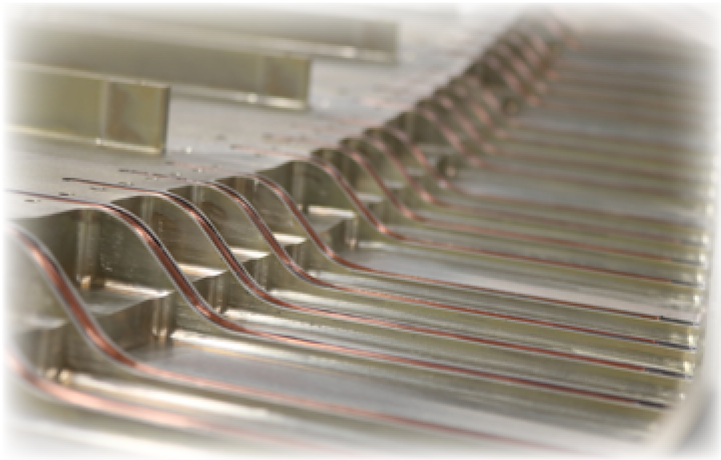
Solutions that provide little maintenance and are highly sought after for reliability.

LOW POWER CONSUMPTION

Solutions should be energy efficient, requiring as little power as possible to operate.

COOLING METHODS

Due to the environments the ultimate system will be exposed to, high cost electronics are typically stored in ruggedized enclosures or chassis to maintain safety and long-term operation. Managing heat from these boxes can be categorized under three primary methods.

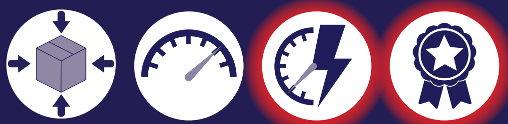


The method chosen generally corresponds to how the heat is transferred from the component or board to the ultimate heat sink.

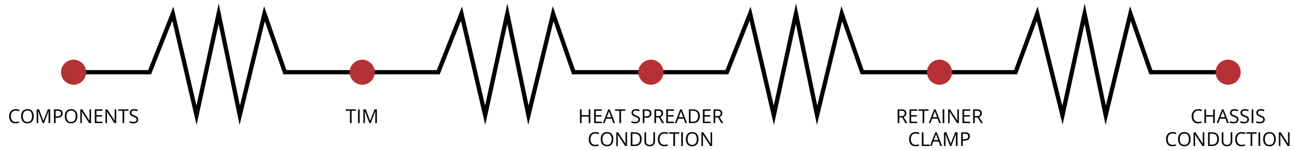
PRIMARY COOLING	CARD LEVEL COOLING	RELIABILITY	POWER CAPABILITY
CONDUCTION COOLED	This method keeps the box fully sealed; conducting heat to the exterior skin and having the ultimate heat sink located externally.	HIGH	LOW
AIR COOLED	In these systems, components transfer waste heat to localized heat sinks and rejects to forced air moving through the enclosure.	MEDIUM	MEDIUM
LIQUID COOLED	This method uses localized liquid cold plates to directly cool components. The high h-value allows for high power, but the system adds cost, complexity and any leak could cause catastrophic damage.	LOW	HIGH

1 CONVENTIONAL CONDUCTION COOLED

Conduction Cooled Embedded Computing systems use standard factors such as 3U, 6U and 9U VME or VPX cards; these are governed by VITA standards. For thermal and mechanical considerations VITA 48.2 is the critical standard to understand.



In military conduction cooled systems, the primary goal is keeping the internal electronics safe from moisture, dust, and other harmful contaminants. This cooling method provides the highest reliability and lowest power draw since it relies solely on passive methods to get the heat out of the sealed environment, while concentrating heat from many components and boards to a few surfaces. These systems are typically comprised of several high heat generating components, such as FPGA's, power amplifiers, or a series of embedded computing boards that slide into a chassis.



In multi-board embedded applications, some important modeling considerations:

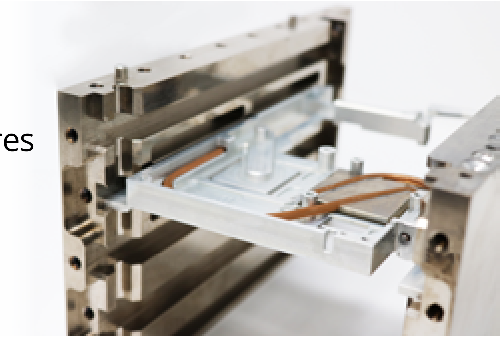
- ***Components:*** heat flux (if not uniform) and junction to case resistance
- ***TIM:*** Thickness for tolerance stack up and thermal performance
- ***Heat Spreader:*** Material properties and enhancement options
- ***Retainer Clamp:*** Outward force/pressure and thermal paths
- ***Chassis Conduction:*** Temperature and h-value on the sidewall

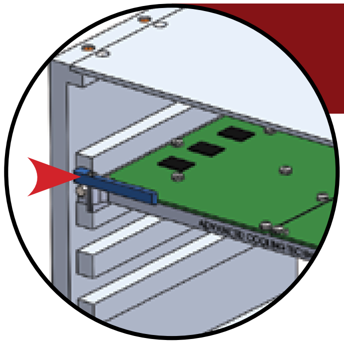
HEAT SPREADERS

Heat spreaders are required to move the heat from the component to the sidewall, where they are mechanically clamped (via wedge lock) to the chassis.

Typical Heat Spreaders are Aluminum because:

- Cost effective and easy to machine intricate features
- Lightweight
- K = 167 W/m-k





RETAINER CLAMPS

This component is critical for military embedded computing, because the systems often have requirements that allow for boards or components to be swapped out. A retainer clamp allows for a quick and easy removal, and for in-field servicing of the electronics boards. The most common retainers are standard (COTS) wedge locks which provide:

Good mechanical connection | Easy installations/servicing | Poor thermal performance

ENHANCING THE CONDUCTION PATHS

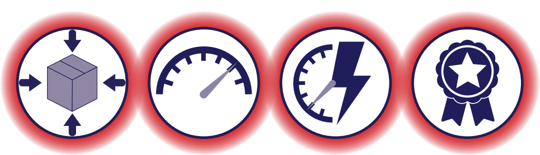
Many defense electronics integrators have been searching for ways to improve the two key areas mentioned on the previous page. ACT offers many solutions but in terms of the best SWaP for embedded computing applications, we turn to the following technologies.

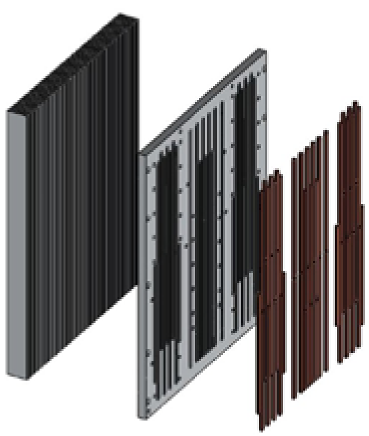
HiK™ HEAT SPREADERS

HiK™ (high conductivity) plates use embedded heat pipes to improve thermal performance. This method allows for a low-profile design with similar machining features as typical metallic VME/VPX heat spreaders. By incorporating heat pipes, the thermal conductivity increases 3-5x that of aluminum, without adding any significant weight.

Product Specifications

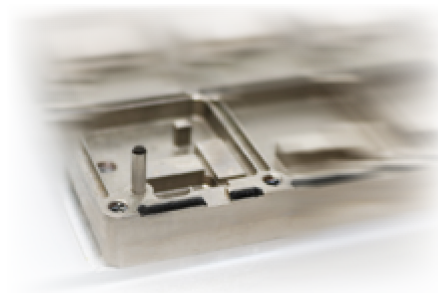
- Thermal Conductivity (k) = 500-1,200 W/m-K
    - 600-800 W/m-K is typical for 6U cards
- Thin profile: Designed to 0.072"
- HiK™ plates have been designed for and fielded in numerous shock, vibration, acceleration and salt/fog environments.

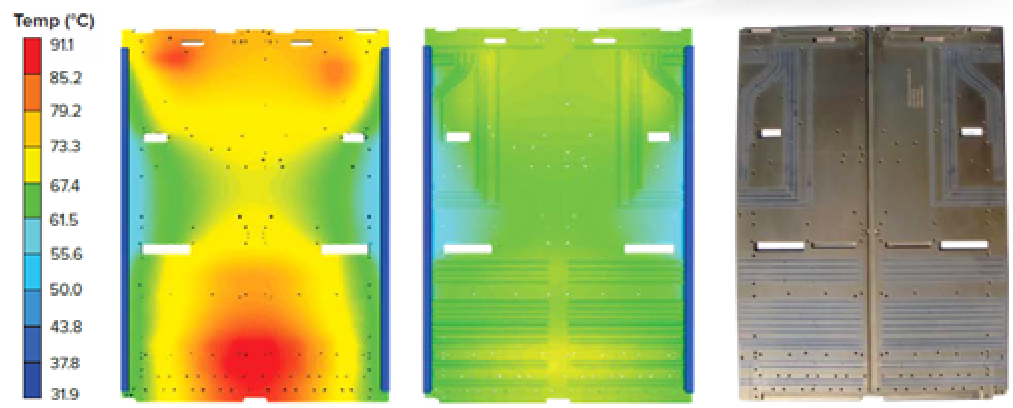




MANUFACTURING OPTIONS

- Coatings: Chem Film, Electroless Nickel, Matte Tin
- Pin, Helicoil, Hardware installation
- Ejector Clips
- TIM
- EMI Shielding
- Part Marketing / Engraving
- Laser Etching



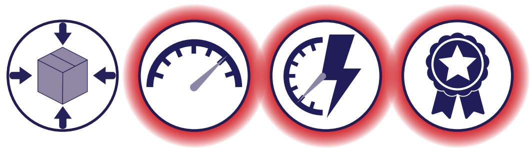


Heat Spreader for Shipboard Rack with liquid cooled rails. Images: Aluminum (Left), HiK™ (Middle), Manufactured HiK™ (Right)

READ MORE >

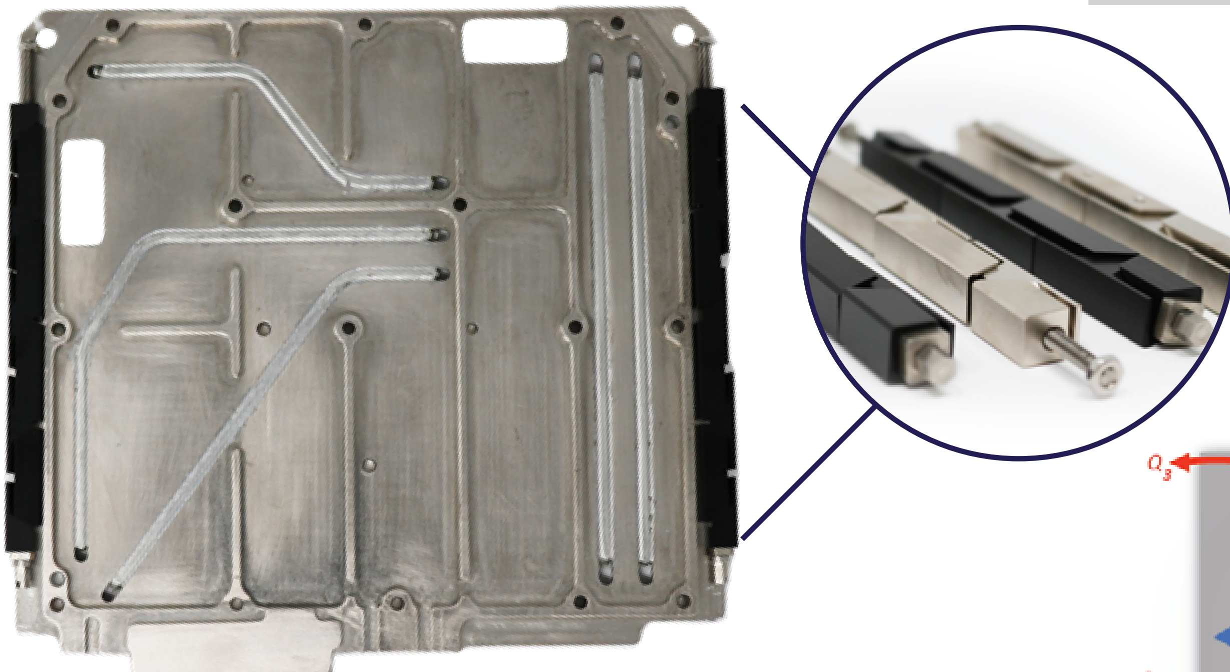
ICE-LOK®

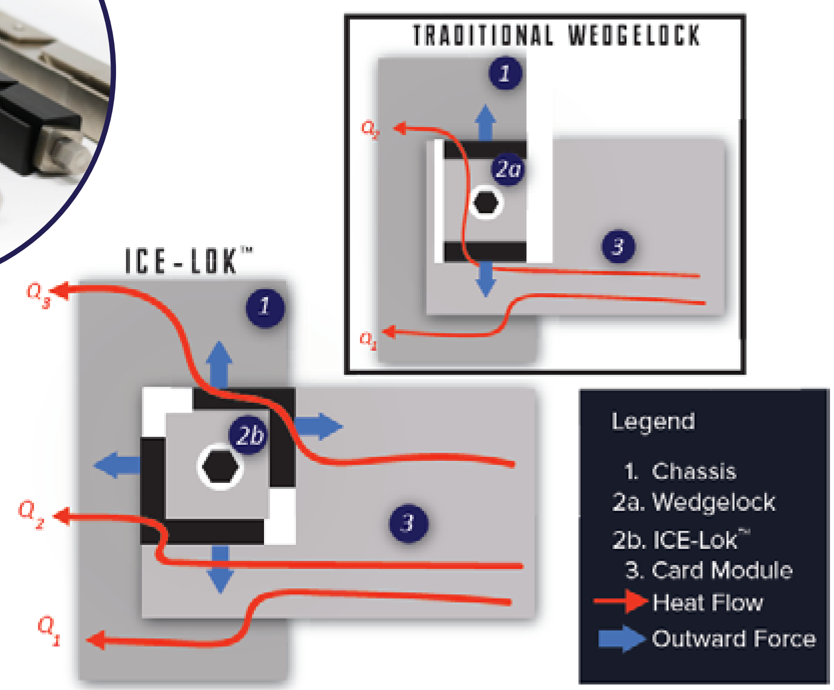
Many custom wedge locks exist but often require modifications to the board or chassis to fit and still comply with VITA specifications. The patented ICE-Lok® is the first of these custom wedge locks to incorporate additional contact surfaces. It expands in all directions allowing for two contact points on the board and two contact points on the chassis. Not only does this create additional thermal paths, but it eliminates the path through multiple wedges (*See bottom right image)*.



ICE-LOK® SPECIFICATIONS

Dimensions	VITA compliant for 3/8" and 1/4" cross sections, custom sizes available
Base Material	Aluminum
Finish	Nickle Plated, Anodized, Chem Film, other available upon request
Thermal Resistance	0.13 to 0.15°C/W
Required Torque	Similar to conventional wedgelocks





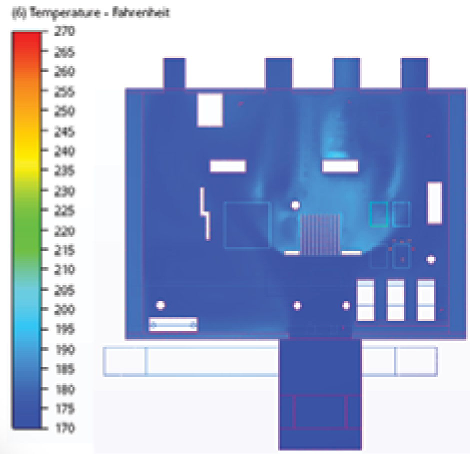
COMPARATIVE TEST DATA >

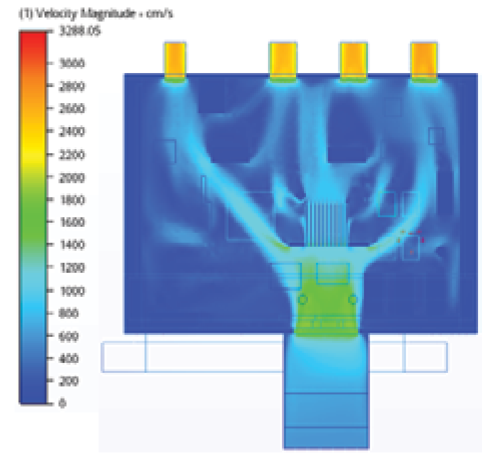
2 AIR COOLED

Air Flow Through uses internal fans/blowers to force outside air across high heat generating components and exhaust the air to the external ambient. In forced convection scenarios, the overall effectiveness is a combination of airflow (velocity, pressured drop), fin pitch and spacing, and conduction along the base of the fins.

AIR FLOW THROUGH DESIGNS

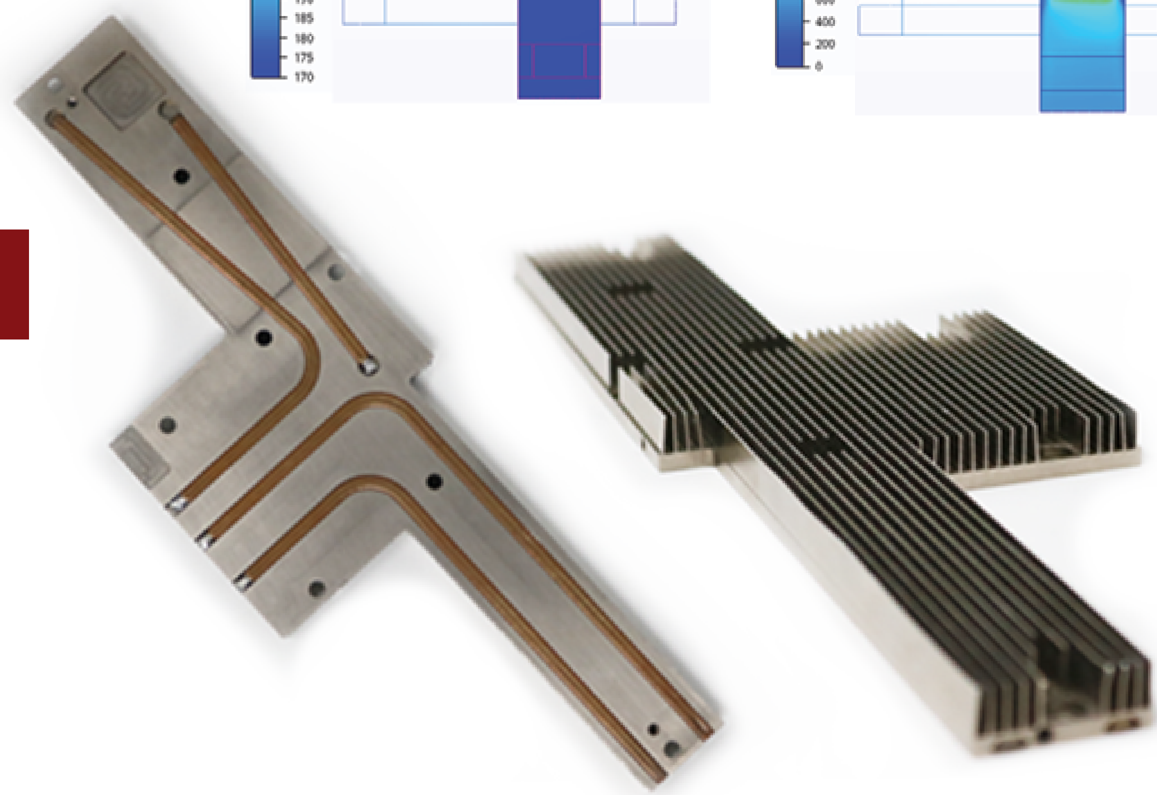
- Component/Board level heat sinks with direct airflow
- Lowers the emphasis on conduction resistances
- Various Mil-Std fan options exist
- Requires inlet and exhaust airflow
- Exposes internals to debris from the environment
- Filters, can be used but require maintenance





PRODUCT FEATURE

HiK™ Finned Heat Sinks can provide increased fin efficiency and lower overall case temperatures with enhanced spreading and isothermalization across a larger fin area. This can maintain a low profile design even with an enhanced fin stack, allowing designers to still stack numerous boards in a single chassis.



Tekgard® Environmental Control Units

Environmental control units or ECUs are responsible for taking in the ambient air, cooling (or heating) it, and returning the conditioned air to the relevant space, which may include military or medical shelters, base camp facilities, ground support, or command centers and emergency response shelters. This keeps the inside of the shelter or container at the required temperature necessary for operation.

Unlike commercial air conditioners, Tekgard® Environmental Control Units (ECUs) are designed to be rugged. They must survive the rough terrain that the military encounters daily and remain operational at the extreme temperatures and conditions to which they will be exposed. Environmental Control Units (ECUs) are mobile, capable, durable solutions for environmental control needs.

ECU CONFIGURATIONS

CONFIGURATION	CHASSIS	COOLING CAPACITY
UNITARY	U24, U42	24,000/42,000 BTU/hr
HORIZONTAL	H48, H60, H96, H144	48,000/60,000/96,000/144,000 BTU/hr
VERTICAL	V12, V40, V72, V96	12,000/40,000/68,000/96,000 BTU/hr

COMMON POWER SUPPLY

Single-Phase - 110, 230, 240 V | 50, 60 Hz

Three-Phase - 208, 220, 380, 440 V | 50, 60 Hz

DC Power - 24, 48, 270 V

**Additional configurations available upon request.*

AIR COOLED, SEALED DESIGNS

Conduction cooled designs mentioned on pages 4-6, often utilizing natural or forced convection cooling on external surfaces; however, there are other scenarios and form factors to accomplish sealed, clean air within the chassis. One scenario is directly mounting your high-power components to a sidewall and utilize a larger external surface area to dissipate the heat to the environment, outlined in Case Study 1. Another is using a sealed enclosure cooler to circulate internal air while maintaining a seal, outlined in Case Study 2.

CASE STUDY 1

Two (2) high power IGBTs and several other components are mounted along the cutouts shown in Figure 1.

PROBLEM

The power distribution was uneven, putting a larger portion of the work on a small number of fins. Although the fin stack was designed and optimized for natural convection (oriented vertically, large fin spacing, thicker fins), it wasn't able to maintain safe case temperature operation because of limited fin volume and heat spreading.

REQUIREMENTS

Power: 250+ Watts, 75% of heat concentrated to 2 components
Sink: Natural Convection, conditioned air
Rise above Ambient: < 35 C

SOLUTION

Thermosyphons (gravity aided heat pipes) were implemented into the design and the high-power components were located along the lower half of the heat sink to assure gravity assist. The final design met all thermal requirements, it maintained the required seal and was powder coated for environmental protection. This design was fielded in a mission critical naval application.

CASE STUDY 2

PROBLEM

In many cases, the overheating of an enclosure may not be occurring because of one high power device, but many low to medium power devices. In this case, the cost to implement advanced heat spreading or heat transport to get all the heat to the outside may not be feasible.

SOLUTION

To create a clean internal environment in this scenario, enclosure coolers are often utilized. Sealed Enclosure Coolers are compact heat exchangers that use a fan and heat sink design inside to circulate and collect heat from the various components and concentrate it to the internal heat sink. The heat is transferred out of the cabinet via conduction and a similar fan, heat sink combination is used on the outside. NEMA 4X ratings can be used for harsh environment applications. Low-cost Heat Sink Coolers (HSC), compact Heat Pipe Coolers (HPC) and sub-ambient Thermoelectric Coolers (TEC) are ACT's standard offerings. Customizations are often done for specific mil requirements.

PRODUCT FEATURE

TEC-90 ENCLOSURE COOLER

- Compact, sub-ambient cooler
- 90 W dissipation with 0 C rise
- Reliable with no maintenance

Applications:

- Mobile communications equipment
- Control electronics cabinets
- Transit electronics cabinets

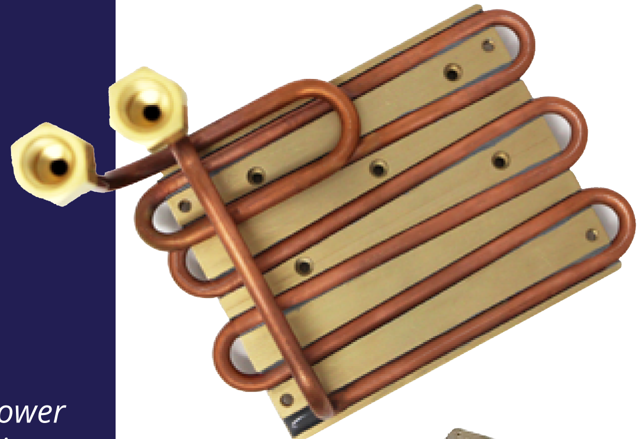
ONLINE TOOLS

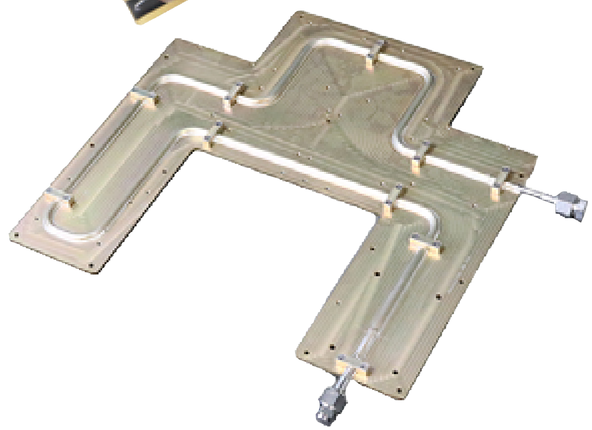
SELECTION TOOL >

ORDER ONLINE >

3 LIQUID COOLED

For avionics boxes and other high power embedded computing applications, system level liquid cooling may be required due to the total power and available rise above ambient parameters. Military vehicles may also have a readily available liquid loop that can be leveraged.





While liquid flow through offers the best thermal performance (by implementing the liquid loop closest to the electronics case), it creates significant integration and reliability concerns. Any leak realized during operation would damage the expensive electronics. A more reliable approach is to implement the liquid cold plates external to a fully sealed box; either attached to the sidewalls or along the base of the electronics box and use enhanced conduction products for the interior:

- HiK™ card frames
- ICE-Lok®
- HiK™ sidewalls

PRODUCT FEATURE

Pumped Two-Phase (P2P) uses very similar components as a single-phase liquid loop, however the P2P cold plates or evaporators take advantage of a fluids' latent heat of vaporization, which can provide the aforementioned thermal benefits. By adjusting the fluids' quality as it progresses through the P2P cold plate, very precise temperature control can be achieved. These systems also leverage dielectric working fluids for additional reliability from traditional water/glycol loops.

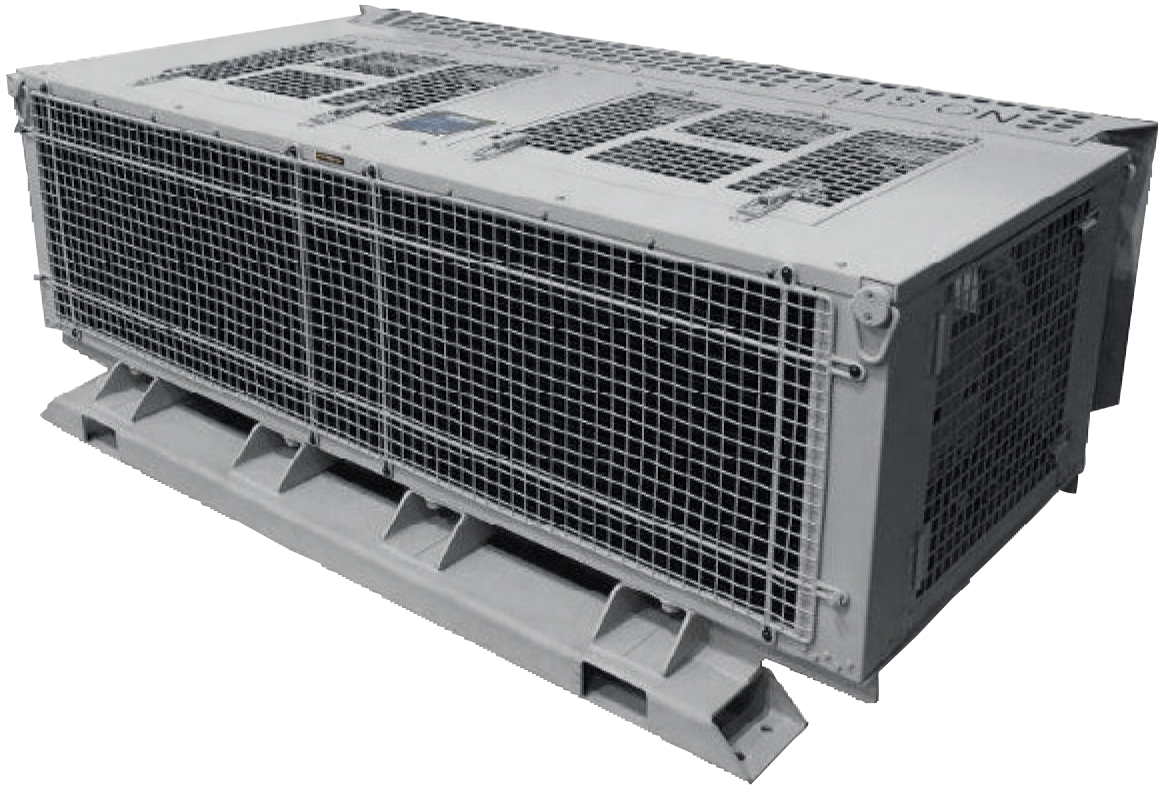
For very high power and high heat flux applications, managing the heat away from the components may not be an option. In extreme cases, even direct contact liquid flow may not provide enough temperature uniformity across the contact surface to provide long life and precise operation. Systems like Directed Energy Weapons and Battery Thermal Management require isothermal surfaces and high power dissipation. Pumped Two-Phase (P2P) offers an ideal solution for these applications.

2020 Military & Aerospace Electronics INNOVATORS AWARDS

GOLD HONOREE

ACT's Pumped Two-Phase Technology wins Gold in Military and Aerospace Electronics Innovators Award

Tekgard® Chillers



We offer a line of rugged fluid cooling solutions under the Tekgard® brand with capacities from 8-24kW (28,000 – 82,000 BTU/hr). When it comes to keeping mission-critical equipment at optimum operating temperatures, Tekgard® liquid chillers and heat exchangers are proven, with fielded systems in dozens of deployed operations.

These units deliver superior results for high-intensity workloads. Projects such as radar and missile defenses rely on our chillers to keep their systems cool and their personnel safe. Thanks to their rugged design and build quality, Tekgard® systems can support operations anywhere in the world.

CHILLER SPECIFICATIONS

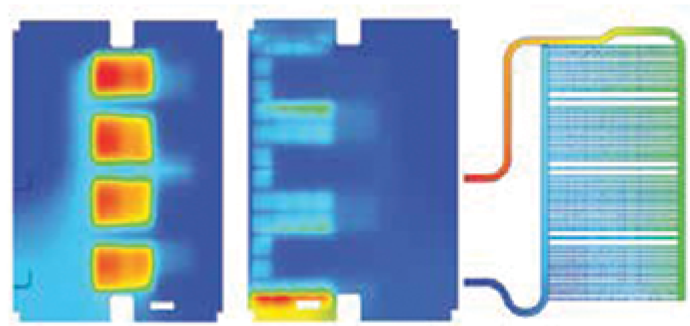
INPUT POWER	Single or three-phase, 120-480 V, 50/60/400 Hz or DC
CONTROL CONNECTIONS	Hard-wired or preferred MIL-STD connector

4 DESIGN & ANALYSIS

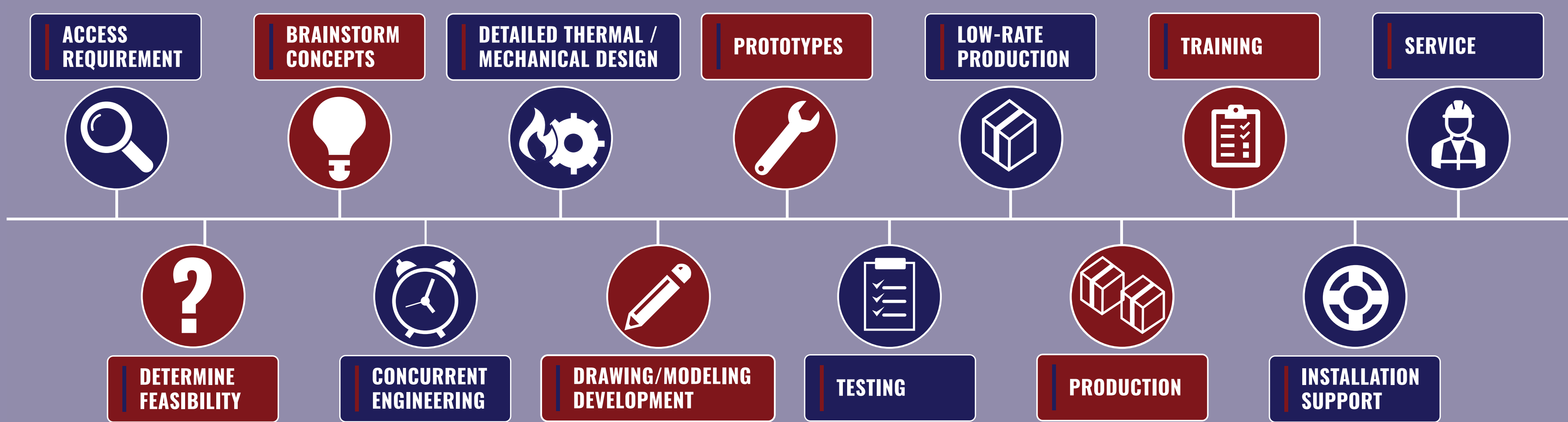
ACT values the genuine customer care and partnerships that are created through this process. Our engineers have many years of experience working with engineering teams outside of our doors and look forward to learning more about yours!

There are many options and trades to consider when designing high power systems; and solving critical component thermal issues. Whether you are working through the board level, box level or system level, it is extremely important to understand the trade-offs between performance, reliability, energy consumption and cost.

Thermal analysis early on in the design cycle is often a worthwhile investment to properly down-select the appropriate system. The electronics involved in these systems are extremely expensive, therefor extending the system life with proper thermal management is worth the investment.



COLLABORATION & PARTNERSHIP



> **Great supplier with excellent management and engineering team. ACT has an excellent and highly capable team that provides outstanding service.**

- Defense Prime Customer

ADVANCED COOLING TECHNOLOGIES

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