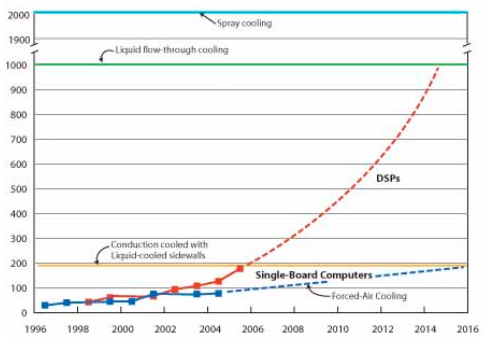
Liquid Coolers Chill Out

Jon Titus, Senior Technical Editor

Liquid cooling provides a convenient way to remove heat from electronic components, boards, and systems. Its efficiency exceeds that of moving air, and liquid-cooling equipment does not require air channels throughout an enclosure.

Some engineers may think of liquid cooling and picture leaking pipes and damaged electronics. Fortunately, liquid cooling has moved from the prove-it-to-me stage to routine use in high-end computers and military-and-aerospace equipment. So, just think of liquid cooling as a reliable and efficient way to move heat from one place to another. The removed heat can travel some distance to a radiator that dissipates the heat into outdoor air, municipal water, seawater or even another cooling system.



Liquid-cooling techniques fall into two categories; those that transfer heat to a liquid and those that use heat to vaporize a liquid. Figure 1 shows the cooling capabilities of four types of cooling. To investigate how vendors can help customers apply liquid cooling, ECN talked with people at four companies that produce liquid-cooling products.

Cooligy

From the start, Cooligy has focused on liquid cooling and developed a closed-loop cooling system that requires no service. "Engineers can buy components and assemble a liquid-cooling system," said Fred Rebarber, director of sales and marketing at Cooligy, a division of Emerson Network Power. "But they must ensure everything works together, assure customers of long-term reliability and guarantee service-free equipment. That can be a heavy added burden." Rebarber noted Cooligy has shipped 50,000 liquid-cooling systems for use in high-end PC workstations and so far, no system has required service.

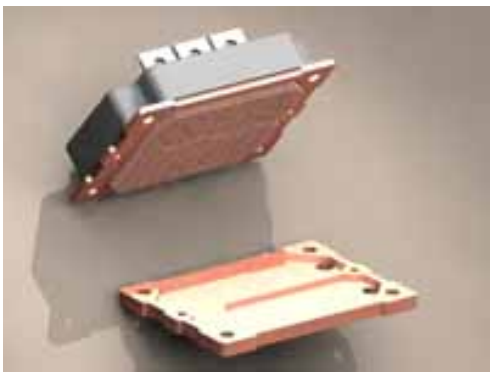
Typically, Cooligy's engineers work with a customer to model liquid cooling techniques and include them in a design from the start. Engineers may fear a liquid leak in their equipment, so Cooligy's liquid-cooling products offer double redundancy. "We have designed our own connector barbs and tubing, and we use a proprietary sealant," explained Rebarber. "Clamps and epoxy also ensure a no-leak cooling system, and the permeability of our flexible tubing approaches that of metal."

Everyone has a different layout of the components they need to cool, and they have space and performance requirements. "Our micro heat-exchangers efficiently transfer heat from a chip to the liquid," said Rebarber. "We can make heat exchangers to cool a spot or zone on a chip or to uniformly cool an entire chip package. Heat exchangers can form a series loop to extract heat from many parts in equipment." Cooligy uses the same building blocks in many designs, so it does not have to design everything from scratch for new customers.

Engineers may wonder about the performance of cooling liquids at low temperatures. "PCs may have a temperature range between -40°C and up to 85°C, explained Douglas Werner, Cooligy's senior director of research and development." But this temperature range is usually a shipping spec, not operating temperatures. We have standard fluids that perform like an antifreeze solution, but we also offer a glycol-free, water-based solution. Water has a high heat capacity, and it will not hurt the environment. If you add a glycol-based antifreeze, you decrease the liquid's heat capacity and increase its viscosity. So, you get less efficient heat removal."

Amulaire

Some liquid-cooling equipment suppliers serve specialized markets. Amulaire Thermal Technology, for example, offers liquid-cooled cold plates and liquid-cooling systems that mate with drive electronics in hybrid and electric vehicles and in high-energy electrical devices such as quad-core CPUs, MRI machines and lasers.



"Engineers must realize that liquid cooling does not simply replace air cooling," emphasized David Bono, director of sales and marketing at Amulaire. "Instead, it lets the engineers increase the performance or efficiency of a product. They can get more power from IGBT modules or overclock a CPU, for example."

Unfortunately, many engineers do not want to "mix" water other fluids with electronics. But, vehicle manufacturers have used liquid cooling for many years and computer manufacturers now offer liquid-cooling systems in off-the-shelf PCs. But to engineers familiar with only air-cooled products, liquid-cooling still can look a bit scary. Now, they must think about a pump, a radiator, a fan, hoses and clamps, a cold plate and a fluid in addition to their electronics.

"Automotive engineers already have radiators and pumps in cars, so for them, liquid cooling does not present a big barrier," said Bono. “Using the existing coolant 'loop' to cool power electronics in hybrid vehicles saves cost, weight and space. Because the loop delivers coolant to equipment at an 'inlet' temperature of 85°C, you need an efficient cold plate. Say an electronic module has a maximum operating temperature of 120°C. That gives you a delta-T of 35°C to work with." According to Bono, a typical IGBT produces approximately a two-percent loss of energy as heat. "Our cooling technology gives engineers about a 20°C delta-T for a 2,000 Watt module, so even high-power modules can use a vehicle's existing cooling loop.”

"To efficiently move heat away from hot spots, engineers want as much surface area as possible in a liquid-cooled cold plate, and, they want a high flow rate to dissipate that heat." said Bono. Amulaire molds copper cold plates that include round 'nanopins' that provide a large surface area that water can easily flow around. You can buy cold plates with smaller channels, but you need a lot of pressure to get liquid through them.

If a liquid-cooling system involved dissimilar metals, Bono cautions engineers to prepare for galvanic corrosion. "When you mix copper and aluminum in a loop, you can have problems. So, if engineers specify a copper cold plate, they must ask if any aluminum exists within the coolant loop." The coolant can transport ions, and electrons can flow through electrical paths that may not appear obvious. Even without a direct electrical path, you can have problems. Corrosion inhibitors in the water capture ions, but you must replenish the inhibitors periodically.

"When we sell a copper cold plate to a company that supplies its own pump,

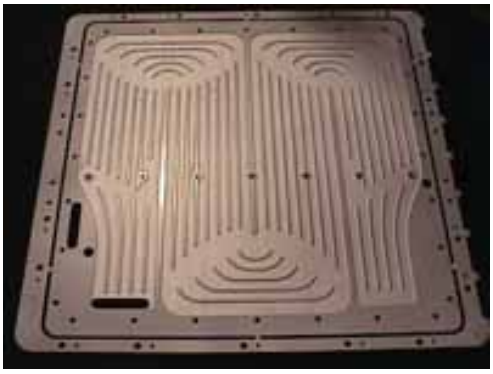
radiator and fluid, they know how to solve the corrosion problem, or they do not mix metals," said Bono. "If necessary, we can nickel plate the copper cold plate to prevent galvanic corrosion."

Parker-Hannifin

Parker-Hannifin concentrates its liquid-cooling technologies on commercial off-the-shelf (COTS) computer boards used in commercial, military and aerospace applications. The company's electronics enclosures with liquid-cooled side walls provide heat removal for conduction-cooled board modules that use a thermally conductive frame. Heat

flows from hot components through the frame to the edges of the circuit board. Liquid coolant circulates through the enclosure's side walls that mechanically hold board modules in place and remove heat from individual boards. "For a typical 6 × 9" board, liquid side-wall cooling lets us remove just under 200 Watts,, which approaches the practical limit for this cooling approach" said Andy Odar, a systems engineer at Parker. "Liquid flow-through modules, on the other hand, raise the heat-removal capacity to 1,000 Watts per board. Because these modules remove heat directly from its source and eliminate the heat-conducting frame, engineers prefer them in new applications that have high heat-load requirements."

Figure 2 shows a liquid-cooled demonstration enclosure that accepts electronic boards and a pump module that circulates fluid through a cooling manifold. "The pump and boards plug directly into the backplane and manifold,"



explained Odar. "The drip-less liquid couplings keep the electronics and the chassis dry." If engineers prefer an external pump, they can use one. According to Odar, the

internal pump can cool several enclosures, depending on the total heat load.

"One of our customers has an air-cooled electronics enclosure that measures approximately 8 × 5 × 3 feet. The enclosure contains a large number of sub-system drawers, each of which contains many boards that produce over 3,000 Watts of waste heat." said Odar. "The customer needed to move a lot of cool air through the equipment. We can remove the same amount of heat from a standard enclosure that measures roughly 8 × 10 × 20 inches." Parker's liquid-cooled demonstration enclosure complies with the Air Transport Rack (ATR) ARINC-404 standard and accepts board modules built to the emerging VME VITA 46/48 standards. The demo enclosure accepts as many as 11 modules and an optional pump module, and it can dissipate up to 4,000W with coolants such as water or water/glycol solutions. Dielectric cooling fluids reduce the cooling capacity to approximately 2,000W.

Parker's flow-through modules use macrolaminate structures that force fluid to flow over specific hot components or areas. "We can fabricate complex flow-channel patterns in thin sheets of aluminum or stainless steel," explained Odar. "Then we bond these layers and machine the assembly to its final shape. Customers get a compact thin coldplate module they can use in a chassis side wall, in a board module, or on a component."

"Liquid cooling lets engineers think about their electronic designs from a different perspective," said Rex Harvey, principal engineer at Parker. "Often, engineers continue to accept the limits of air cooling, which has approached its peak. Instead, they should think, 'What can our electronics do now that liquid cooling removes most thermal limits?' It does not make much sense to add liquid cooling to an existing design or to

a new design that raises performance only slightly. But, when engineers include liquid cooling as an integral part a system, they can achieve much better performance and reduce the size of their product."

SprayCool

SprayCool offers two types of phase-change cooling systems; those that spray non-conductive coolant on a heat-exchange plate and those that spray the coolant directly on a board or assembly. Tahir Cader, technical director at SprayCool noted the company currently has a liquid-cooled product for the military that has operated

for over 55,000 hours. And, SprayCool has delivered indirect cooling systems for IBM computers used at a national lab.

"Sometimes, engineers show us an air-cooled device and say 'We want to liquid cool this,'" said Cader. They have designed for air cooling, so we must add cooling components to the existing product, which can dramatically

increase cost. When they design for liquid cooling from the start, they lower the cost, decrease product size, and increase performance.

"In a direct-spray application, customers can use their existing cPCI, VME, and other cards that comply with 6U standards," explained Andrew Finch, lead systems engineer and product marketing manager at SprayCool. "They do not change their electronics. They take a COTS boards, remove the heat sinks and put the boards directly into our Multi-Platform Enclosures that can accommodate from four to 20 six-U cards." The enclosures include atomizers that spray coolant between the cards. "We can direct the spray at hot chips, or we can spray an entire card rather than focus on specific components," said Finch.

Sealed, or indirect-spray, modules attach directly to processors and absorb heat through a plate that separates the spray from the processor. "We can select modules, so if you have a quad-core package or a Pentium chip, they each get the right amount of cooling." The sealed cooling modules take the place of heat sinks and use the same mounting hardware.

"In the military and aerospace industries, people have an aversion to maintaining liquid-cooled equipment, noted Finch. So, we provide a basic fluid-handling tool that lets technicians fill or drain cooling systems. Then they service the equipment just as they would air-cooled or conduction-cooled electronics."

SIDEBAR: Embed Thermoelectric Coolers **[1]**

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