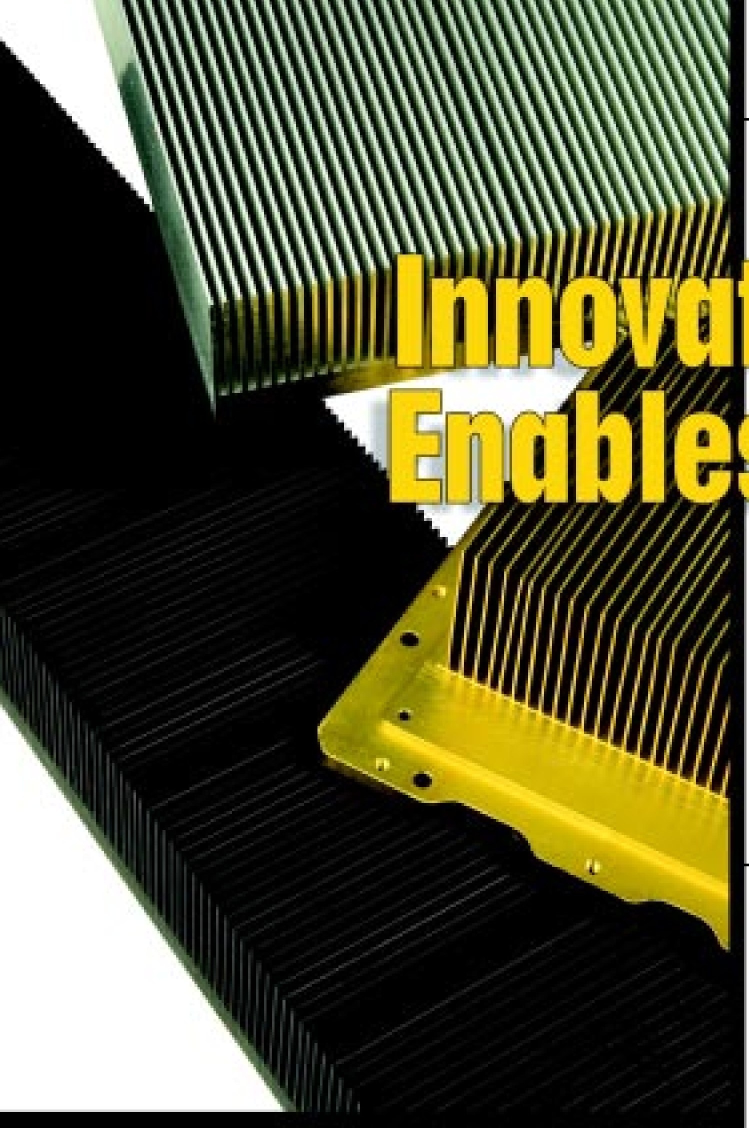
Innovative Heatsink Enables Hot Uplinks



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Hybrid-extruded heatsinks with high aspect ratios accommodate higher power densities than similarly sized bonded-fin heatsinks, as demonstrated in an HDTV transmitter application.

New consumer technologies such as 3G, WIFI, HDTV and their associated networks are driven by a consumer expectation that their "always on" device must be ready to reliably deliver and/or transmit information on demand. Power demand on the access side has grown over the past few years from 0.5 W per subscriber to, on average, more than 10 W per subscriber.

To meet this demand, network operators must be aware of new deployment cooling requirements or risk unexpected network failures. Although next-generation network equipment is more efficient, it generally dissipates more watts per square foot of deployed area. As power density increases, it is imperative that the equipment efficiently remove heat from both the electronic enclosure and the room that houses the equipment.

Remote signal repeater locations are even more challenging to cool than the equipment in full utility-serviced buildings. First, they are subject to greater fluctuations in ambient air temperature. This means the cooling system must be able to reject heat at significant temperature extremes while trying to maintain the smallest available volume. Second, because of their locale, they often lack low-cost facility infrastructure (such as plumbing) necessary to deploy efficient liquid-cooling solutions. Third, if the cooling solution is not easily replaced during a system upgrade, costs escalate rapidly.

Management of these distributed locations is evolving to allow more remote management and quicker upgrade cycles. Yet, this approach demands that more intelligence be added into the channel circuitry, which translates into more silicon and consequently more heat energy to be dissipated. The more system upgrades a cooling system is able to accommodate, the more cost savings will be realized by the network operator.

Thermal Management Options

Heatsink-based cooling solutions implemented in the applications above vary, depending on the total thermal power dissipation requirement. For lower power systems, extruded aluminum heatsinks are effective solutions. As power requirements increase, the use of aluminum extrusions decreases because of fin-density limitations. The relationship between the height and spacing of the fins is called the aspect ratio.

Over the last decade, the generally accepted limit of fin extrudability improved from less than 4-to-1 to about 8-to-1, with some manufacturers able to hit 10-to-1. Over the same period, the fin thickness produced by extrusion processes remained confined to the 0.040-in. to 0.050-in. range. As a result, the usefulness of extruded aluminum heatsinks for cooling high-power electronics cooling applications was extended into the next generation of electronic upgrades.

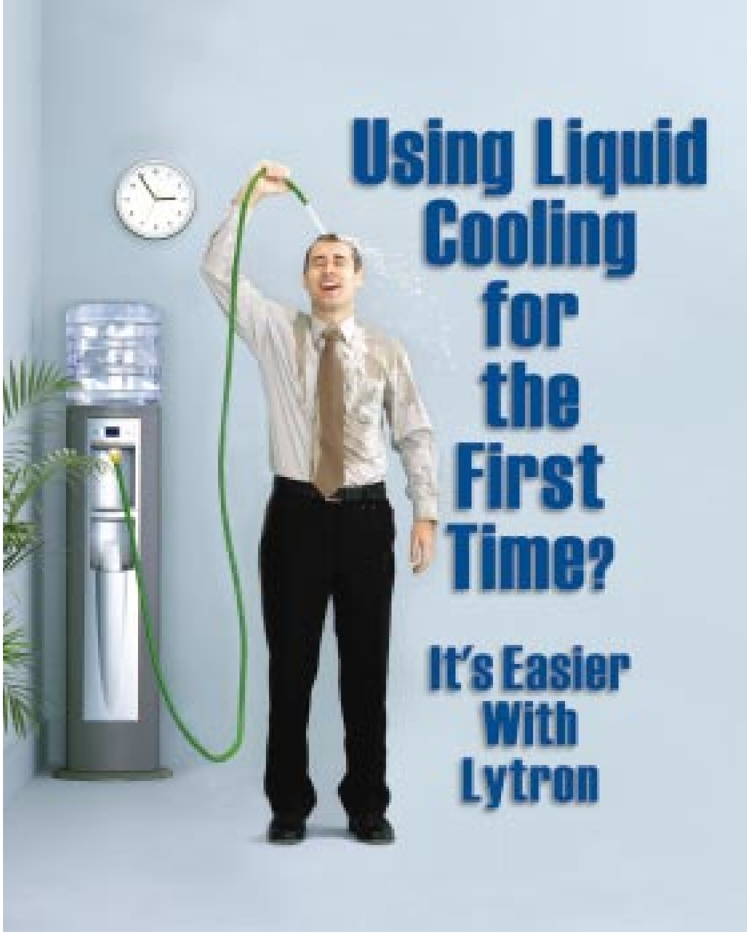
As extruded aluminum heatsinks became less able to meet system-performance requirements, bonded-fin heatsinks were the next mechanical cooling solution. This technology usually involves bonding either an aluminum or copper fin to a pre-grooved aluminum or copper baseplate. The process achieves a greater aspect ratio, ranging from 20-to-1 to 40-to-1, which effectively increases the volumetric impedance.

However, the thermal performances of bonded-fin solutions ultimately are constrained by the epoxy interface between the cooling fins and the baseplate. The epoxy interface creates a thermal barrier between the baseplate (heat source) and the cooling fins. This barrier can be significant, depending on the number of fins, total power dissipation and the thickness of the fins.

In addition, the epoxy joint interface is subject to plastic degradation over time. When the joint between the fins and baseplate fails, the result is less effective heat transfer from the base to the cooling fins and degradation of thermal performance over time. Bonded-fin heatsinks also are manually assembled and for this reason are best suited for low-volume production applications.

Liquid cooling is an essential part of many systems, especially systems whose total power dissipation requirements are in the mid-kilowatt range. Liquid cooling effectively removes large heat loads from devices with high heat fluxes. Generally, a liquid-cooled solution is used in conjunction with a folded-fin heat exchanger under forced convection control.

Folded fins may best be described as a continuous strip of a convoluted stamping of a specified height manufactured from either aluminum or copper coil stock. The folding process allows for high aspect ratios (hence, increased surface area resulting in lower thermal resistance) and thin fins (as low as 0.005-in. thick) to be produced. The fin stock is independently affixed to either an aluminum or copper baseplate using either an epoxy or a brazing technique. This technology is able to produce a high-performance, light-



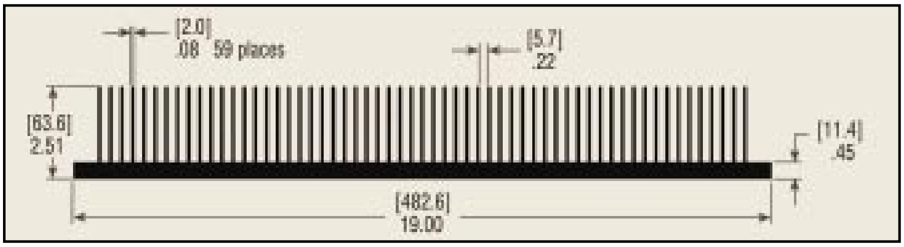


Fig. 1. *Existing bonded-fin profile.*

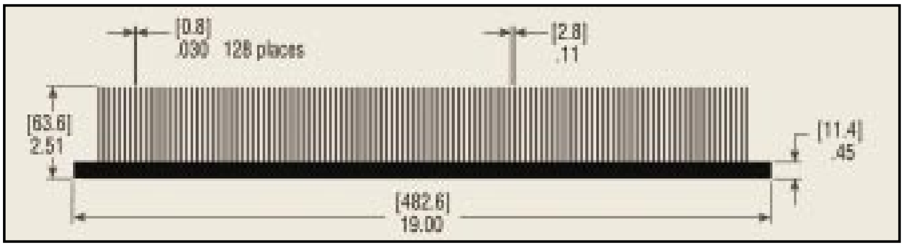


Fig. 2. *Proposed hybrid extruded-fin extrusion.*

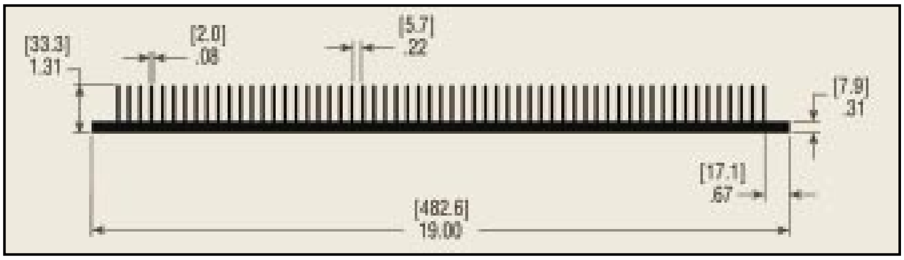


Fig. 3. *ThermaFlo E3120 extrusion profile.*

weight heatsink. Epoxy-folded fins are subject to the same failure modes and degradation models as bonded fin.

Hybrid-Extrusion Technology

The latest development in producing cooling solutions for high power density electronics is a unique hybrid-aluminum-extrusion process. In this technique, an aluminum-extrusion profile is extruded to an aspect ratio of up to 20-to-1 with fins as thin as 0.020 in. to 0.030 in. and widths up to 48 in.

Unlike bonded-fin heatsinks, the hybrid-extrusion heatsink is neither composed of nor constructed from multiple components, and is not subject to any long-term thermal performance degradation due to either failure or weakening of the epoxy interface between the baseplate and fins. Another advantage of the hybrid-aluminum extrusion is that the cooling fins are not subject to falling out or becoming weakened over time from the effects of exposure to continuous vibration or plasticized (age hardened) of the epoxy due to thermal overexposure.

The end product is a high-volume producible heatsink that has eliminated the highly resistive thermal impedance between the fins and baseplate. With the thermal barrier paths eliminated, the performance of the hybrid-extrusion heatsink may attain the maximum performance within the given volume.

Because the hybrid-extrusion material is a monolithic piece of aluminum, it can be cut, plated and machined using standard secondary processes to add mounting holes or to prepare the base to achieve the flatness required to mount large IGBT modules. Machine feeds and speeds are nearly identical to what is required for machining standard aluminum extrusions.

Cooling HDTV Transmitters with Hybrid Extrusion

As the government mandate requiring TV station networks to broadcast HDTV signals simultaneously along side of existing UHF and VHF frequencies ramps up, companies that design and manufacture broadcast antenna equipment are moving to meet compliance requirements.

Recently, one company undertook a new approach to upgrade its existing chassis design with new electronics. The company's primary goal was not to change the existing chassis form factor, because its customers wanted a field-replaceable unit identical to units already installed in the field. The driving factor for this requirement was that the field units already deployed had considerable on-site facilities modifications to optimize the existing cooling scheme of the old unit.

The amount of total dissipated power for these new units was going to increase by approximately 27% over the current design. The initial approach by the customer was to replace the aluminum bonded-fin design with either a copper bonded-fin or a folded-fin design. However, the copper bonded-fin solution would significantly increase the cost, while the folded-fin design would require significant post assembly machining through the delicate 0.010-in. thin fins, also causing a noticeable increase in hardware cost. Because of these drawbacks, the customer needed to develop a new cooling hardware that would not greatly expand beyond the current solution.

The size of the existing cooling hardware was a 19-in. × 19-in. bonded fin with 2-in.-tall fins (profiles shown in Fig. 1 [For a further description of the system, see the boundary conditions in the analysis section below]).

Initial analysis (see Analysis No. 2 in test results section) indicated that the existing bonded-fin heatsink could be replaced with a direct surface area equivalent, hybrid extruded heatsink resulting with a 23% initial gain in performance. This would be 4% less than the minimum performance gain required of 27% and certainly not allow for future product development.

Thus, the next step was to maximize the surface area using the hybrid-

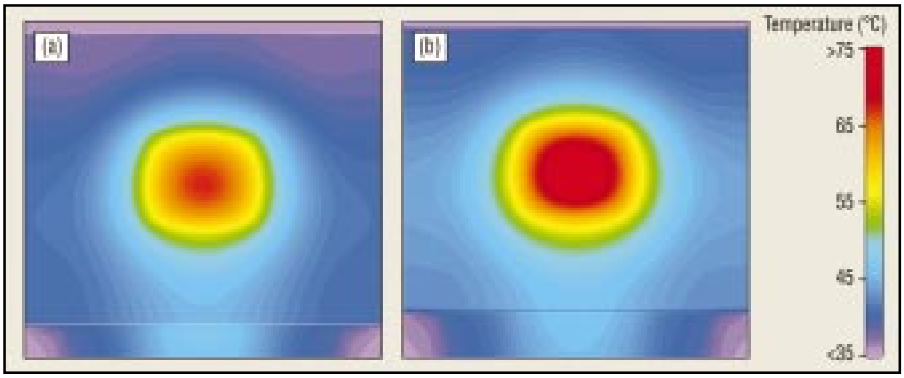


Fig. 4. *Baseplate-surface temperature of hybrid-extruded heatsink (first design) (a), and existing bonded-fin heatsink (b).*

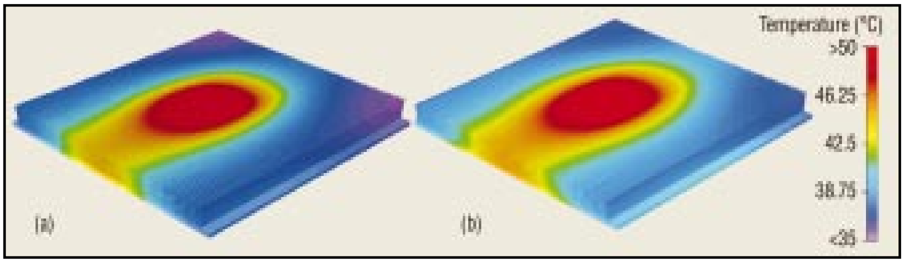


Fig. 5. *Fin-surface temperatures of hybrid-extruded heatsink (first design) (a), and of existing bonded-fin heatsink (b).*

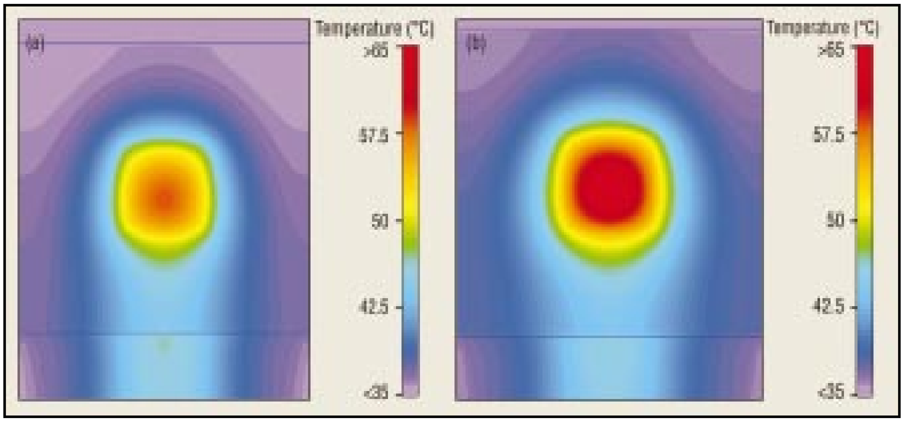


Fig. 6. *Baseplate-surface temperatures of hybrid-extruded heatsink (second design with doubled surface area) (a), and of the equivalent-surface-area bonded-fin heatsink (b).*

extrusion technology. Fig. 2 shows the new cooling hardware that would double the surface area from the current design while reducing the product weight by approximately 3 lbs versus the original bonded-fin heatsink.

The new hybrid-extruded heatsink provided a 46% gain in total performance over the existing hardware (see Analysis No. 3). This allowed for sufficient cooling of existing systems and at least one next-generation upgrade in the future. More importantly, the new heatsink achieved the goal of not changing the chassis footprint.

Evaluating Extrusion Equivalent Technology

Marlboro Test Labs, an independent engineering test and services company located in Marlboro, Mass., evaluated the customer's current and proposed heatsinks using computational fluid dynamics (CFD) techniques.

The various heatsinks were each evaluated using the following boundary conditions:

Dimensions:
19 in. × 19 in. (length × width)
Height: 2 in.
Baseplate: thickness 0.450 in.
Power Source Size:
6 in. × 6 in. (length × width)
Power Level: 750 W
Air Flow: Fully ducted, 1000 LFM
Fins Structure: Dependent variable.

Analysis No. 1—Extrusion baseline analysis. As a baseline comparison to the bonded-fin and hybrid-extrusion technologies, consider a standard aluminum extrusion developed for near-maximum performance, but still capable of volume production. Such an extrusion would measure 19-in. wide, 1.31-in. tall, with a base thickness of 0.31 in. and with a total of 59 fins for a total surface area of 2954 in.^{2} (Fig. 3).

In this analysis, using the boundary conditions shown above, the baseline heatsink has a thermal performance of 0.081°C/W performance at 1000 LFM.

Analysis No. 2—Existing bonded-fin evaluation. As shown in Fig. 2, the bonded-fin heatsink implemented by the customer had slightly less than twice the surface area, or 5344 in^2, over the extruded baseline heatsink. The analysis on the existing bonded-fin solution and the direct surface-area-equivalent hybrid-extruded heatsink (first design) resulted in the baseplate temperature levels shown in Fig. 4.

Of key note is the maximum baseplate temperature observed on the bonded-fin heatsink. The distribution of heat was wider and hotter compared to the hybrid-extruded product, which means that less heat was being transferred to the cooling fins.

Fig. 5 shows the fin-surface temperatures of the hybrid-extruded heatsink (first design) versus that of the existing bonded-fin heatsink. Results reveal higher fin temperatures for the hybrid-extruded heatsink, which indicates higher fin efficiency.

Analysis No. 3—Hybrid extrusion with maximum surface area density. The proposed hybrid-extrusion heatsink (Fig. 2) eventually tested by the customer had approximately twice the surface area (or 10,537 in^2) over the existing bonded-fin design and about a 3.5 times increase in surface area over the standard extruded baseline product. The analysis on the hybrid-extruded heatsink with doubled surface area versus a bonded-fin heatsink of equivalent surface area yielded the performance levels shown in Fig. 6. Again, the hybrid-extruded heatsink showed cooler baseplate temperatures and results consistent with the fin temperatures in Analysis No. 2.

In the final analysis, the new hybrid-extruded heatsink had a 46.8% improvement over the current bonded-fin design in the same volume. Analyses of the performance of the hybrid-extrusion technology test results demonstrate that it is an excellent successor to bonded-fin designs. While beyond the scope of this article, other design issues were considered and addressed accordingly when implementing the hybrid-extrusion heatsink. Most of these issues centered on optimizing the pressure drop through the heatsink and minimizing the airflow by-pass.

The hybrid-extrusion technology is a robust solution that can be used in many types of applications—especially those products that incorporate thermoelectric coolers as a part of their design. These diverse thermoelectric applications include laser diodes, medical diagnostic equipment, electro-optic components, global positioning satellites, high-resolution infrared systems and spectrophotometers, microprocessors, inertial guidance systems, medical diagnostic equipment, as well as a variety of industrial and consumer products.

While thermoelectric coolers provide fast and reliable spot cooling to a particular component, the opposite side of the thermoelectric module requires that the heat be discharged from the system efficiently. Minimizing the heat load allows the cooler to achieve colder temperatures or reduces the power required to reach the defined cooling level. With more efficient heatsinks, as demonstrated with the new hybrid extrusion, heat removal for low delta-T thermoelectric modules becomes more manageable.

The process of choosing heatsinks for high-power-density electronics used to be a simple process—open a catalog and choose a part that would come close to meeting the requirements. Now, cooling solutions have to be prepared with more thought given to pre-planning the airflow, the impact of cables and other components, as well as where the equipment will be placed or used. **PETech**

Acknowledgment

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