

Hot Air Rises and Heat Sinks

Everything You
Know About
Cooling Electronics
Is Wrong



by Tony Kordyban

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TOO MUCH OF A GOOD THING

*Pin fin heat sinks look like they have a lot more surface area in those magazine pictures. How come they don't work any better? **Lesson:** Convection works with surface area parallel to fluid flow.*

My wife and I were shopping at Hi-Tech Round-Up, the giant store near the tollway exit that sells music CDs and CD-ROM software with equal understanding. We were looking for a new modem for the home PC so we could send e-mail to all of the people we used to call from that phone in the airplane headrest and say, "Guess where we're calling from!" It didn't seem fun anymore since all those people got answering machines. In the computer doohickey aisle my wife pulled a blister pack off the rack.

"Isn't this the kind of thing you use at work? What is it you call it?" she asked.

I was a little shocked to see such a thing at a retail store. I suppose next they'll have lead-foil packs of plutonium.

I said, "You're right. It's a heat sink. But what I usually call that is a crime against nature."

Six or seven shoppers perked up their ears at that phrase. My wife rolled her eyes. "Is this going to be one of your speeches like Oliver Douglas on *Green Acres*? Why don't you write a book instead?"

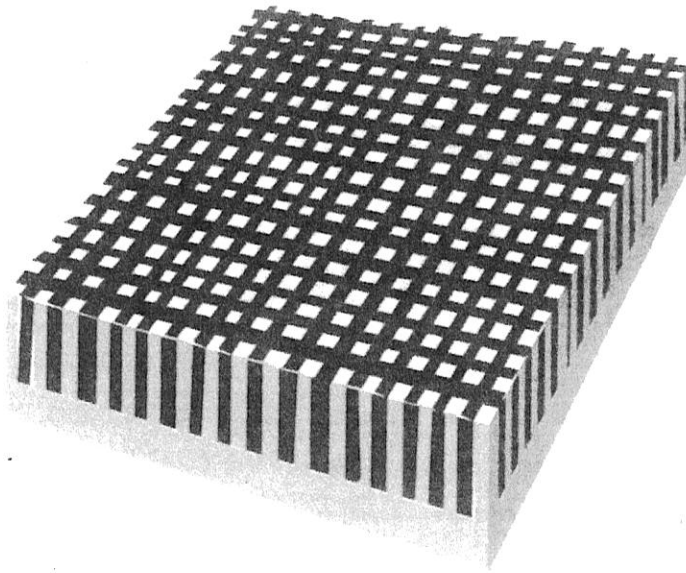


Figure 18-1 Pin fin heat sink: The choice of ignorance

So remember, it's *her* fault.

This is the crime against nature, the waster of aluminum — the ever-popular pin fin heat sink (Figure 18-1).

Hi-Tech Round-up sold them as “486 Coolers! Keep your PC’s CPU from overheating PDQ!” On the bottom was a piece of double-stick tape. You just peel off the liner and slap it on top of your 486 micro-processor, and then you don’t have to worry about premature failure of your computer due to heat.

I don’t know how good a job it’ll do inside a PC, but this is the pin fin Rule of Thumb I made up for TeleLeap:

Thumb Rule No. 1. DON’T USE PIN FIN HEAT SINKS.

I hate to give out Rules of Thumb. There’s a reason for their name. The thumb is the clumsiest finger on your hand. I want designers and engineers to be subtle and clever and elegant and efficient in their thermal designs. But in the case of pin fin sinks, a simple rule is justified.

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Based on a Good Idea

Heat sink vendors really push these things. They are featured in magazine ads and are on the front cover of the Sinkarama catalogs. The main reason pin fin heat sinks are so popular is that they look exotic. “Look at my board. It is very high tech. It has a *pin fin heat sink!*” Besides that, though, the pin fin sink is based on real science.

Remember this old equation?

$$Q = h A \Delta T \quad (18-1)$$

or

$$\text{Power} = h \times \text{Area} (\text{Temp}_{\text{high}} - \text{Temp}_{\text{low}}) \quad (18-2)$$

In street talk, the more surface area a heat sink has, the better it works. This is another one of those Rules of Thumb for heat sink design, but as you’ll see a little later, it doesn’t always hold water.

The concept of the pin fin heat sink is to try to pack as much surface area into a given volume as possible. It certainly *looks* like there is a lot of surface area sticking out all over the place on the heat sink shown in Figure 18-1.

The other concept of this design is that it works in more than one orientation. Air is supposed to be able to flow through the fins no matter in what direction it flows (except perpendicular to the solid base, of course).

Let’s compare the pin fin to the heat sink design it is intended to beat out — the extruded fin sink (Figure 18-2).

The extruded fin sink is made by squishing aluminum through a heat-sink-shaped hole and then chopping it to the right length, exactly the way the Play-Doh Fun Factory works. It can make fins in one direction only. The most common kind of pin fin sink is made by taking an extruded fin sink and crosscutting it with a saw or mill (Figure 18-3).

Now remember, the idea is to get more surface area than you had before. Take a look at the two sinks in Figure 18-3. Which one do you think has more surface area? It’s not that hard to figure out for yourself that every time the saw makes a cut, it creates some new surfaces, but it also takes some away. If the saw cut is wider than the pin thickness, then there will be less surface area than before. If the

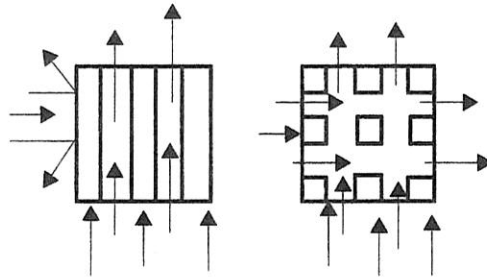


Figure 18-2 Extruded fins only work with airflow in one direction; pin fins work equally well in any direction

saw cut is narrower than the pin, then there will be a little more surface area. Commercial pin fin sinks seem always to have square pins, and the spaces are the same size as the pins themselves. With that kind of design, the amount of surface area is exactly the same as the original extruded sink.

Somebody should have said, “Hey, Vern, why are we spending money to crosscut this extrusion just so we get exactly the same amount of surface area?” But they didn’t, and the story still isn’t over. Because by itself, surface area isn’t very useful. It has to be in contact with the air flowing by or it doesn’t help at all.

The surfaces of the extruded fins are lined up with the direction of airflow (if you mount the heat sink correctly)(Figure 18-4). With the pin fin, only the vertical surfaces touch the flowing air. The horizontal surfaces touch only dead or recirculating air, and don’t get rid of much heat. So not only is there no extra area, but now half of the area is facing in the wrong direction.

The pin fin inventors have achieved one of their design goals. Air flows through the pin fins equally in any direction. For natural convection (which is the mode for 90% of TeleLeap products) that means air flows **EQUALLY POORLY** in any direction. Without going into a five-page explanation of boundary layer theory, I’ll describe the problem by saying that the pins on most of these pin fin sinks are just too darn close together. As air flows past a fin, it gets

Figure 18-

disturbed. touch each pins on the together (a minum. Th top of the problem. It

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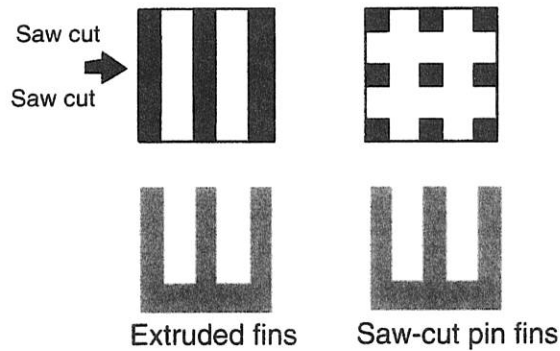


Figure 18-3 How to make an expensive, less effective heat sink out of a cheap one

disturbed. If two fins are too close together, these flow disturbances touch each other and plug up the flow channel with turbulence. The pins on the sink shown at the beginning of this chapter are so close together (about $\frac{1}{16}$ inch) you might as well use a solid block of aluminum. The air just flows around the outside of the sink and over the top of the pins. The extruded sink from which it is made has the same problem. Its fins are too close together for natural convection flow.

Textbook equations can give you the optimum fin spacing based on the power and the length of the fins. For typical heat sink sizes (an inch or two wide by an inch or two long) and power in the range of a few watts, the right spacing is about $\frac{1}{4}$ inch. Forget the equation. Remember $\frac{1}{4}$ inch. Or better yet, if you can't fit the tip of your

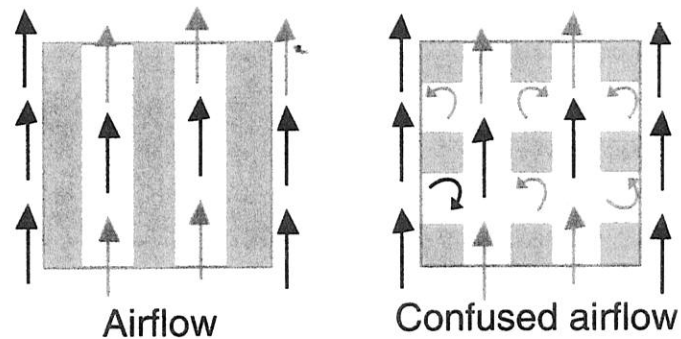


Figure 18-4 Pin fins put surface area where the flow is slow

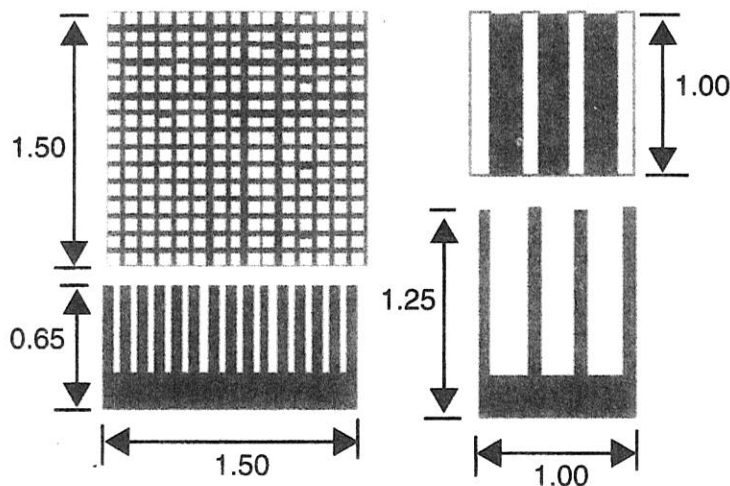


Figure 18-5 Which one looks high-tech, and which one works better?

pinky finger between the fins, don't use that heat sink in natural convection. Instead of a Rule of Thumb, call it the Pinky Rule.

A ¼-Inch Example

The Pinky Rule came in handy on the Optical Compensator Module (a sort of a set of reading glasses for a fiber optic receiver to help it detect signals that have come over quite a long distance and might be a little fuzzy). We needed a heat sink for a 3.5-watt integrated circuit in a package about 1 inch square. Figure 18-5 shows the two candidates.

Which one looks high-tech, and which looks like it would work better? Here are the actual case temperature measurements:

	Pin Fin	Extruded Fin
Surface area	30 in ²	9
$\Delta T_{\text{case-air}}$	51°C	44

The extruded fin sink has less than one-third the surface area, yet it cooled the device 7°C better than the larger, more expensive pin fin sink. It just goes to show you that you can have too much of a good thing.

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