

AN EDN SPECIAL SECTION

# POWER TECHNOLOGY

# TOPS IN POWER

**Editor's  
Letter**

**Tops in power:**  
articles, news,  
and blogs

**Selecting  
heat sinks**  
for heavily  
populated  
boards

**EDN**







# Tops in power: BLOGS

AS WITH *EDN*'s news articles and features, energy efficiency, especially discussion about the practicality of compact fluorescent lights, proved popular with readers. Other popular topics were *EDN*'s series on the power subsystem for the Phoenix Mars lander and an interview with a young engineer who's started a successful electronic-kit business. All of these articles were from the Power-Source blog, but two other posts were power-related topics in Paul Rako's Anablog.

"This was not the right application for a compact fluorescent light,"

[www.edn.com/blog/1470000147/post/1420034342.html](http://www.edn.com/blog/1470000147/post/1420034342.html)

"Not so easy to run an LED 'bulb' off of a dimmer switch—but here's how,"

[www.edn.com/blog/1470000147/post/380022638.html](http://www.edn.com/blog/1470000147/post/380022638.html)

"Why diesel is so expensive,"

[www.edn.com/blog/1470000147/post/560027656.html](http://www.edn.com/blog/1470000147/post/560027656.html)

"Lithium-ion capacitor: best of both worlds?"

[www.edn.com/blog/1470000147/post/1110030711.html](http://www.edn.com/blog/1470000147/post/1110030711.html)

"Electricity cost versus gasoline and the 135-mpg myth,"

[www.edn.com/blog/1700000170/post/1490036349.html](http://www.edn.com/blog/1700000170/post/1490036349.html)

"Feds call halt to new solar-plant permits, may give boost to municipal installations,"

[www.edn.com/blog/1470000147/post/1290029129.html](http://www.edn.com/blog/1470000147/post/1290029129.html)

"Wind power is great; government subsidies are not,"

[www.edn.com/blog/1700000170/post/630032463.html](http://www.edn.com/blog/1700000170/post/630032463.html)

"Massive solar project garners protests from solar-energy industry,"

[www.edn.com/blog/1470000147/post/960031696.html](http://www.edn.com/blog/1470000147/post/960031696.html)

"Power on Mars, Part 1: Dust devils clean up solar arrays,"

[www.edn.com/blog/1470000147/post/1070028307.html](http://www.edn.com/blog/1470000147/post/1070028307.html)

"15 steps to starting your own electronic-kit business,"

[www.edn.com/blog/1470000147/post/1630025963.html](http://www.edn.com/blog/1470000147/post/1630025963.html)





Heat sinks are important in complex systems in which the sink's impact on airflow matters as much as its thermal resistance.

# Selecting heat sinks for heavily populated boards

BY BARRY DAGAN AND PHILIP RAYNHAM, COOL INNOVATIONS INC

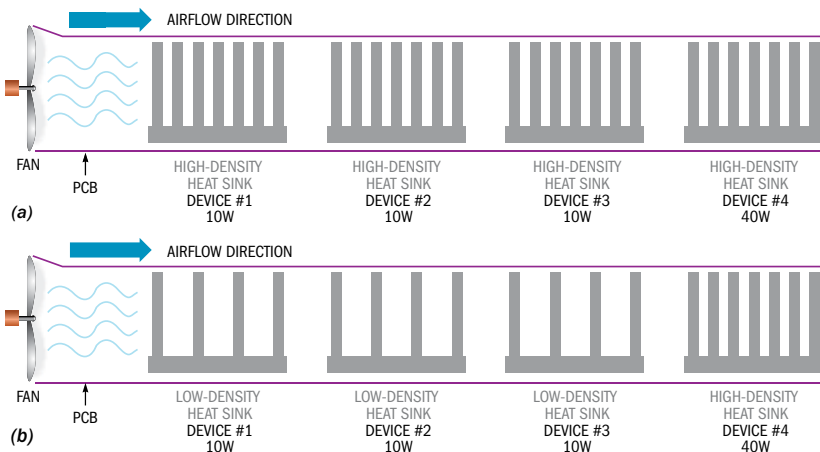
When facing the task of cooling heavily populated PCBs (printed-circuit boards), designers must understand that careful management of airflow along the boards is the key to effective cooling. In these dense-PCB applications, pressure drop is

as important as thermal resistance when it comes to selecting heat sinks. Designers regularly use the parameters of thermal resistance and pressure drop to quantify the performance of heat sinks. Thermal resistance, the temperature increase in degrees Celsius per watt, measures how effectively a heat sink transfers heat from

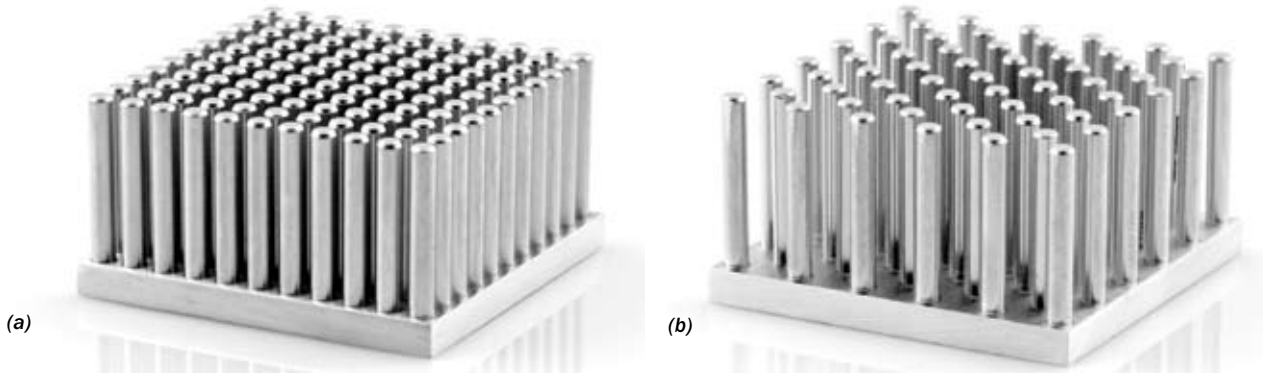
the heat-generating device to the ambient environment. The lower the thermal resistance, the more effective the heat sink because heat sinks with low thermal resistance can cool heavier heat loads before the heat-generating device reaches its maximum allowed temperature. Thermal-resistance values for heat sinks are a function of the airflow through the heat sink. In other words, faster airflow results in lower thermal-resistance values.

The other parameter, pressure drop, is the resistance to the air moving through the heat-sink fins—that is, the difference between the airflow speed as it enters the heat sink's fin array and the airflow speed as it exits the array. The lower the pressure drop, the less airflow the heat sink "consumes" and the more airflow that's available to cool other devices on the board. With heavily populated boards, engineers need to balance the requirements for low thermal resistance and low pressure drop. Doing so requires an understanding of the relationships among heat-sink performance, heat-sink-fin density, airflow, and pressure drop.

The speed of the air stream as it ap-



**FIGURE 1** In two experiments, engineers lined up two sets of heat-generating devices and their heat sinks on a PCB in front of identical fans. The heat sinks differed only in their pin density—117 pins (a) and 61 pins (b). The densely configured heat sink contained substantially more surface area—167 versus 87 in.<sup>2</sup>—and, thus, showed a higher pressure drop.



**FIGURE 2** At low air speeds, a densely populated heat sink with greater surface area (a) may perform worse than a sparsely populated device (b).

proaches a heat sink has a critical effect on heat-sink performance because, to remove heat, you must break the boundaries of still air encircling the surface of the heat sink. The faster the air stream, the more likely the boundary layers are to break and the more effective the heat sink is in removing heat. Conversely, in low-air-speed environments, the boundary layers of still air are less likely to break, resulting in a less effective heat sink. A densely populated—that is, high-pin-count—heat sink with greater surface area will likely perform worse at low air speeds than a sparsely populated heat sink with less surface area because the incoming air stream cannot penetrate the densely populated heat sink. That situation runs counter to the conventional thinking that more surface area always enhances cooling. Air speed has a tremendous impact: Some heat sinks are as much as 100 times more effective in thermal resistance in high-air-speed environments than in those with natural-convection cooling—

that is, environments without airflow. For boards containing one device, heat-sink selection is simple: The only relevant engineering parameter is the heat sink's thermal resistance. However, for boards that contain a large number of devices, you must take into account the allocation of available airflow along the board. You accomplish this task by considering the heat sink's pressure drop and thermal resistance. Two simple experiments using pin-fin heat sinks illustrate the importance of airflow management on heavily populated boards. In these experiments, engineers lined up two sets of heat-generating devices and their heat sinks on a PCB in front of identical fans (Figure 1). To analyze the effect of pressure drop on the thermal performance of a system, the engineers chose heat sinks of the same construction but with different pin densities. The heat sinks had identical footprints, heights, and pin diameters, each measuring 2×2×1.1 in. with 0.125-in.-diameter pins. The heat sinks differed only in pin

count. The densely populated heat sink (Figure 2a) had 117 pins, and the sparsely configured version had 61 pins (Figure 2b). The densely populated heat sink contained a 167 in.<sup>2</sup> surface area—and, thus, higher pressure drop—than the sparsely populated heat sink, with 87 in.<sup>2</sup> of surface area. In both experiments, the board contained four heat-generating devices directly in front of a fan blowing air at 1000 lfm (linear feet per minute) in free air. The first three devices dissipated moderate heat loads of 10W, whereas the fourth device dissipated 40W. The experimenters intended that this “hot” device would mimic the main CPU on a PCB. The goal of this experiment was to optimize for thermal performance on the hottest device.

In the first experiment, the engineers placed four sparsely populated heat sinks on the four devices. In the second experiment, they placed three sparsely populated heat sinks on the first three devices—those with moderate heat loads—and another densely populated heat sink on the fourth device, with the heavy heat load. In the first experiment, the first three devices provided an outstanding level of cooling. However, the last device, which is the critical one due to the high power it dissipates, was too hot: The temperature rose 44°C, significantly higher than the maximum 35°C increase that many typical applications can tolerate. The large temperature increase stemmed from the fact that

TABLE 1 PERFORMANCE OF FOUR HIGH-DENSITY HEAT SINKS					
	Device 1	Device 2	Device 3	Device 4	
Heat sink	3-202011R	3-202011R	3-202011R	3-202011R	Cumulative pressure drop
Pressure drop (mm water)	2.1	2.1	2.1	2.1	8.4
Thermal resistance (°C/W)	1.1	1.1	1.1	1.1	
Power dissipation (W)	10	10	10	40	
Temperature rise (°C) at case	11	11	11	44	
Notes: Airflow approaching Device 4 is 210 lfm. The 3-202011R is a densely populated heat sink.					

the cumulative pressure drop was too high to drive enough air through the heat sink. In this case, only 210 lfm of air reached the fourth device (Table 1).

In the second experiment, the first three devices were warmer than those in the first experiment, but the cooling power was sufficient because they dissipated only moderate loads of heat, and, in both experiments, the temperature increase was substantially lower than the allowed maximum of 35°C. However, due to the superior pressure drop of the three sparsely populated heat sinks in the second experiment, the air speed approaching the fourth device—320 lfm—was higher. As a result, the temperature increase of the fourth device was only 32°C versus 44°C, even though the fourth heat sink was identical in both experiments (Table 2).

The two experiments illustrate the importance of airflow management in boards that contain multiple devices. In the first experiment, the experimenters did not manage airflows at all. However, in the second experiment, through the use of sparsely populated heat sinks that obstruct less air, more air was available for the fourth device, which needed greater cooling. Along with the performance results, it's worth noting that the airflow management in the second experiment would result in a more cost-effective design. To achieve sufficient cooling of the critical device in the first experiment



**FIGURE 3** Splayed-pin-fin heat sinks extend cooling performance with their unique shape, which provides lower thermal resistance and lower pressure drop than do most traditional heat sinks.

would have required an expensive heat pipe or fan sink to reduce the device temperature because the speed of the approaching air stream was too low. What's more, the heat sinks in the second experiment were less expensive than those in the first because sparsely configured heat sinks use less metal and are therefore cheaper than dense heat sinks.

#### MINIMUM-COOLING-POWER APPROACH

As the experiments illustrate, every heat sink on a heavily populated board affects not only the device it resides on, but also the other devices on the board. So, to properly select a heat sink, you must take into account both thermal resistance and pressure drop. One way to make this selection is with the minimum-cooling approach—selecting a heat sink that achieves the lowest pressure drop and provides the least amount of required cooling. Because pressure drops along the board add up, following this method for every heat sink significantly improves the

overall cooling of the board.

You can achieve the minimum-cooling-power approach by identifying a heat-sink technology that offers low pressure drop for a given level of cooling. Once you have identified an appropriate heat-sink technology, the next step is to select a heat sink with the lowest possible fin density. Employing the minimum-cooling approach, an efficient heat-sink technology provides low pressure drops and low thermal resistance. In obtaining low pressure drop, no simple formula is available to guide designers in heat-sink selection. Nevertheless, a few heat-sink characteristics are worth examining. For example, the heat sink should have an omnidirectional structure that enables air to enter and exit the fin array from all directions and therefore eliminate directional constraints.

The second property is fin shape: The more aerodynamic the fin structure, the less resistance it presents to surrounding air streams as they enter or exit the fin array. For example, round pins provide lower resistance than do square fins due to the round pins' smooth, aerodynamic nature. The use of highly conductive materials is also beneficial because these materials provide better cooling—that is, lower thermal resistance—than do non-conductive materials without affecting pressure drop. Some cases warrant the use of copper or copper-and-aluminum combinations rather than a lower-cost, all-aluminum design. With materials selection, as with other aspects of heat-sink specification, keep in mind that better heat-sink performance leads to greater PCB-layout flexibility. This fact, in turn, may help you to avoid significant pressure drops that affect the cooling of hot devices.

#### FIN-DENSITY SELECTION

An important distinction exists between heat-sink technology and fin density. Although heat-sink technology refers to the shape of the fins, fin density refers to the number of fins

**TABLE 2** PERFORMANCE OF THREE LOW-DENSITY HEAT SINKS AND ONE HIGH-DENSITY HEAT SINK

	Device 1	Device 2	Device 3	Device 4	
Heat sink	3-202011M	3-202011M	3-202011M	3-202011R	Cumulative pressure drop
Pressure drop (mm water)	1.2	1.2	1.2	2.7	6.3
Thermal resistance (°C/W)	1.5	1.5	1.5	0.8	
Power dissipation (W)	10	10	10	40	
Temperature rise (°C) at case	15	15	15	32	

Notes: Airflow approaching Device 4 is 320 lfm.  
The 3-202011M is a sparsely populated heat sink.  
The 3-202011R is a densely populated heat sink.



per given footprint. And, whereas comparing the pressure drop of heat sinks of technologies can be complicated, comparing the pressure drop of heat sinks from the same technology is a simple task. The lower the fin or pin count, the lower the pressure drop is. Consequently, following the minimum-cooling approach

with a given heat-sink technology is fairly straightforward. Start by identifying the semiconductor devices in your system that need cooling. Then, determine the maximum case-to-ambient temperature ratios that will keep these devices within their safe operating ranges. Using those maximum temperatures and the devices'

expected levels of power dissipation, you can determine the thermal resistance required for each heat sink.

Then, select the most sparsely finned heat sinks that provide the necessary values of thermal resistance, given the expected airflow and mechanical constraints of your design. When selecting heat sinks, remember the experiments and start off assuming that there will be less airflow for devices downstream than for those devices closest to the fan.

Looking for superior heat-sink technologies that provide lower pressure drop for a given level of cooling is becoming an increasingly important task as boards become denser and heat loads become heavier. Adopting such technologies can give designers a competitive edge, allowing them to build ever-more-complex equipment. One example of a new advanced technology is the splayed-pin-fin heat sink (**Figure 3**). Splayed-pin-fin heat sinks extend cooling performance with their shape, which provides lower thermal resistance and lower pressure drop than do most traditional heat sinks. Splaying, or bending, the pins outward increases the spacing between the pins, which lowers pressure drop without changing surface area or heat-sink footprint.

#### **AUTHORS' BIOGRAPHIES**

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