Keeping cool

*Pin fin heat sinks point the way to more efficient cooling. By **Barry Dagan**.*

In recent years, increases in processing power mean advanced semiconductor devices now dissipate astounding levels of power. For many applications, cooling these devices has become a major challenge. Older style heat sinks are often inadequate for cooling newer, hotter running components.

For several years, thermal management suppliers have been developing an array of new heat sink technologies, including the pin fin heat sink.

To explain how pin fin heat sinks achieve more efficient cooling, it's helpful to briefly discuss the elements that determine the cooling capability of any heat sink: surface area; metallurgy; and the impact of heat sink structure on incoming airstreams.

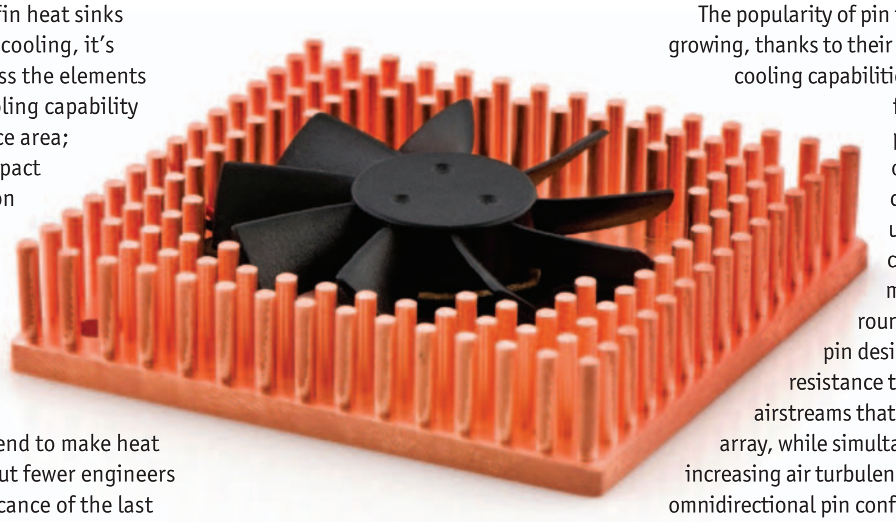
Many designers recognise the importance of the first two elements – greater surface area and more thermally conductive materials tend to make heat sinks more efficient. But fewer engineers understand the significance of the last element – how the heat sink structure uses surrounding air streams. And it's this aspect of heat sink design that has the greatest effect on performance.

Any heat sink removes heat by 'breaking' the boundary layers of still air that are wrapped around its surface because still air is a very good thermal insulator.

The boundary layers are broken by accelerating the flow of air into the heat sink – either using fans and forced airflow or via the chimney effect. In either case, the faster the airstream, the more likely the boundary layers are to break and the more effective the heat sink will be. The heat sink's structure is important because it affects the speed with which air flows into the heat sink.

Heat sink evolution

While early devices consisted mainly of sheet metal components and simple bidirectional aluminium extrusions, heat sinks have evolved into omnidirectional, often exotic, constructions. But, in terms of performance, the most important advances relate to structural changes that enable heat sinks to make the best use of surrounding airflows. These changes can be seen in designs such as pin fin, skived and blade fin heat sinks, which provide substantially greater cooling power than their predecessors.



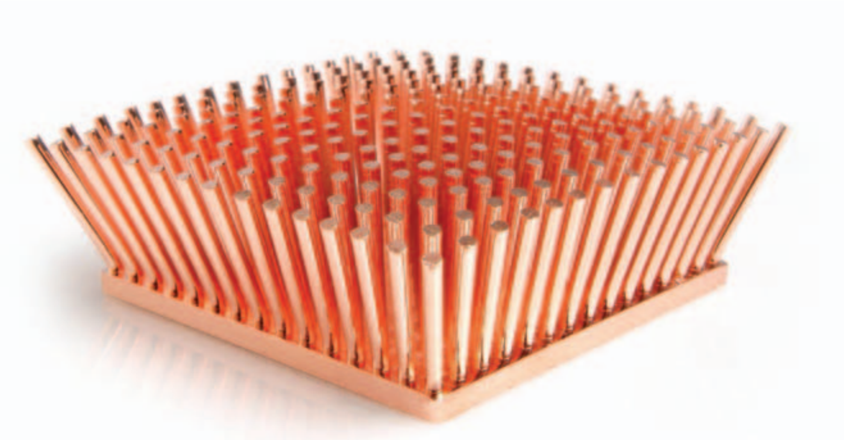
Pin fin fansinks have a low profile, but offer high levels of efficiency.

Pin fin heat sinks

Pin fin technology represents an emerging class of high performance heat sinks that can address cooling challenges in many cutting edge applications. Although there are different styles of pin fin heat sinks, all styles share one distinct physical characteristic: instead of square or rectangular fins, pin fin heat sinks make use of round, pin shaped fins.

The popularity of pin fin heat sinks is growing, thanks to their exceptional cooling capabilities, which stem from their round pin geometry, omnidirectional configuration and use of highly conductive materials. The round, aerodynamic pin design reduces resistance to surrounding airstreams that enter the pin array, while simultaneously increasing air turbulence. The omnidirectional pin configuration, which allows air to enter and exit the heat sink in any direction, exposes the heat sink to the fastest possible air speed. That fast airflow in and out of the heat sink in combination with the large surface area of the pin fin heat sink, results in very efficient heat removal.

Pin fin heat sinks are generally manufactured via a forging process that allows the use of highly conductive aluminium and copper alloys, which



Above: *Splayed pin aluminium heat sinks are suited to use in dense pcbs with a large number of 'hot' devices.* ***Below:*** *Round pin fin heat sinks reduce resistance to air flow.*

further improves heat sink performance.

The devices are offered in footprints ranging from the miniature 0.27 x 0.27in to 10 x 10in and in aluminium, copper and aluminium/copper hybrid variations, each of which has its advantages in terms of performance, weight, and cost. Pin fin heat sinks are also offered in a variety of pin densities, which allows them to be optimised for different airspeed environments. The general rule is that dense pin arrays are best suited to high airspeed environments, while sparsely populated pin arrays are optimum for low airspeed environments.

Copper or aluminium?

As heat loads continue to escalate, copper pin fin heat sinks are seeing increased use in state of the art applications. For these applications, the high thermal conductivity of copper (approximately twice that of aluminium) often becomes a necessity. Higher thermal conductivity results in two cooling advantages for copper heat sinks. They have lower thermal resistance and superior heat spreading capabilities when compared with aluminium heat sinks. As a result, copper heat sinks are generally suitable for two types of design scenarios.

The first would be any design with extreme cooling requirements such that aluminium heat sinks cannot achieve sufficiently low thermal resistance. The other scenario is any application in which the heat sink is significantly larger than the device being cooled. In that case, the ability of copper to spread heat rapidly through the base of the heat sink becomes a necessity to ensure the effectiveness of the pins located far away from the heat generating device.

However, the benefits of copper do not come free and engineers must remember that copper cost more and weighs more than aluminium.

Splayed pin fin heat sinks

These are relatively new derivatives of the standard pin fin heat sink. Unlike standard pin fin heat sinks, which contain an array of vertically oriented pins, splayed pin fins features pins that gradually bend outward. Curving the pins in this way increases the spacing between the pins and allows surrounding airstreams to enter and exit the pin array more efficiently without sacrificing surface area.

In low airspeed environments and in natural convection, the increased spacing between the pins reduces the heat sink's thermal resistance by up to thirty percent versus a standard pin fin heat sink. An additional advantage of the splayed structure is that it exhibits a lower pressure drop than a standard pin fin heat sink of comparable pin density. Lower pressure drop means less air is consumed by the heat sink and is available for cooling other devices on the pcb. Therefore splayed pin fins are well suited to dense pcbs with a large number of 'hot' devices.

Pin fin fansinks

Fansinks, which combine a heat sink and fan in the same assembly, are active cooling devices and are used when a heat sink by itself does not provide sufficient cooling power.

The parts are suitable for the heat sink portion of the fan sink because of the increased turbulence generated by their round pins and because of their highly efficient nature. The resulting fansink is highly effective, yet low profile.

Looking forward

As designers of cutting edge systems continue to pack more and more semiconductors into their applications the use of exotic heat sink designs, such as the splayed pin fin design, and fansinks is expected to increase, due to the simple fact that traditional vertically constructed heat sinks will not be able to provide the required cooling power tomorrow's systems will require.

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