

# Comparing naturally cooled horizontal baseplate heat sinks with vertical baseplate heat sinks

**Keywords:** heat sink heatsink fin array natural convection natural cooling free convection horizontal baseplate vs. vertical baseplate fin optimization horizontal backplane thermal dissipation management performance

This article compares horizontal baseplate heat sinks with vertical baseplate heat sinks for natural cooling applications. (Some papers refer to the baseplate as the "backplane" of the heat sink.) As shown in Figure 1, three different configurations are discussed: (1) vertical baseplate/vertical fin channels, (2) horizontal baseplate with fins facing up, and (3) vertical baseplate/horizontal fin channels. Note that Figure 1 gives some quick guidelines on the merits of the different configurations.

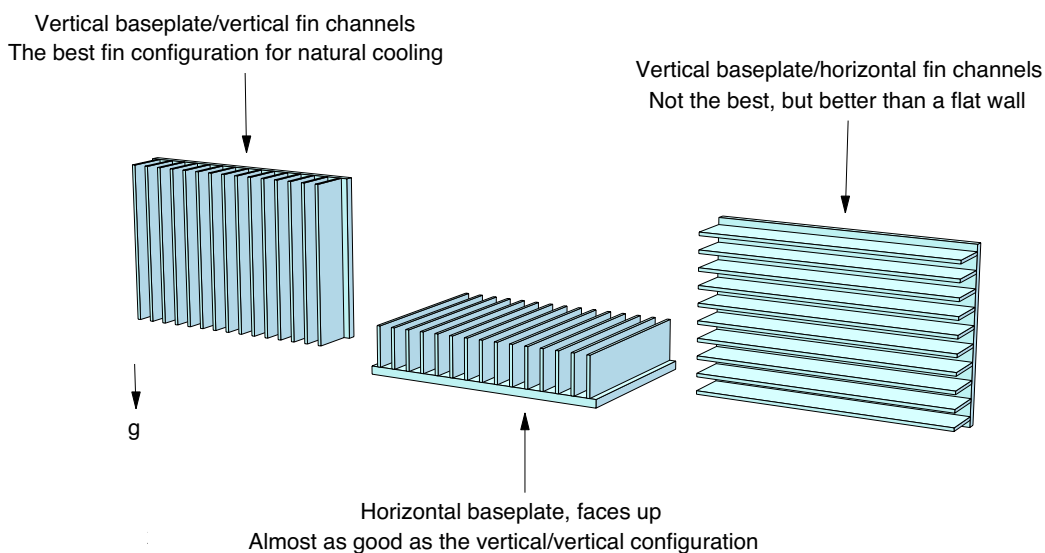


Figure 1: Fin configurations for natural cooling

## The vertical/vertical configuration

The “vertical baseplate/vertical fin channel” configuration is the most common geometry for a naturally cooled heat sink. The configuration has been studied by a number of researchers. The most commonly used predictive equation for convection was derived by Van De Pol and Tierney [1]. The Sauna program uses the Van de Pol and Tierney equation.

The primary air flow pattern for the vertical/vertical configuration is shown in Figure 2. As most persons imagine, air enters near the bottom of the fin channels. There will also be some air inflow from the fin tips. Air is heated within the fin channels and exits at the top. With this simple air flow path, the vertical/vertical configuration delivers the best performance for natural cooling.

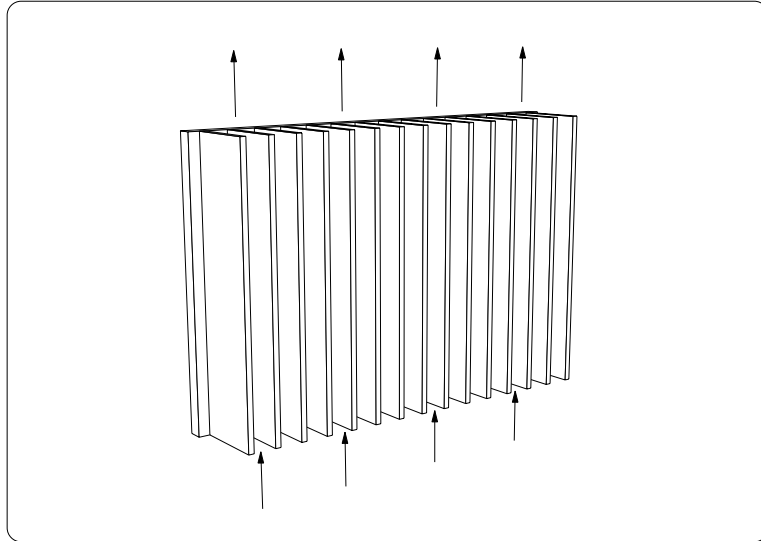


Figure 2: Primary air flow pattern for the vertical/vertical configuration

For a given heat sink volume, there exists an optimal fin spacing. The optimum value occurs when two trends are balanced. If the fins are closely spaced, the heat transfer coefficient ( $h$ ) is lower because mixing of the boundary layer occurs (the fin channel fills up with warm air). The graph in Figure 3 clearly shows that the heat transfer coefficient decreases as the gap between fins decreases. However, if the fins are closely spaced, there is also more dissipating surface

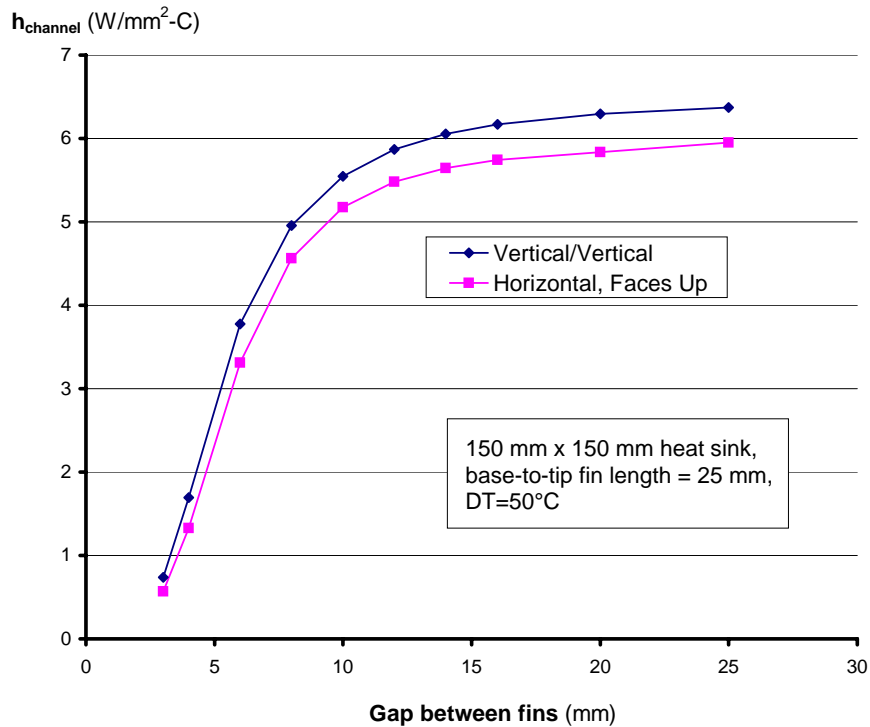


Figure 3:  $h_{channel}$  for vertical and horizontal 150 mm x 150 mm heat sinks

area (more fins for a given volume). The additional surface area can counteract the reduced heat transfer coefficient. This can be seen by examining the graph of total wattage dissipated in Figure 4. For the 150 mm X 150 mm vertical/vertical heat sink shown in the graph, the spacing of 7.5 mm provides the optimal combination of heat transfer coefficient and dissipating surface area.

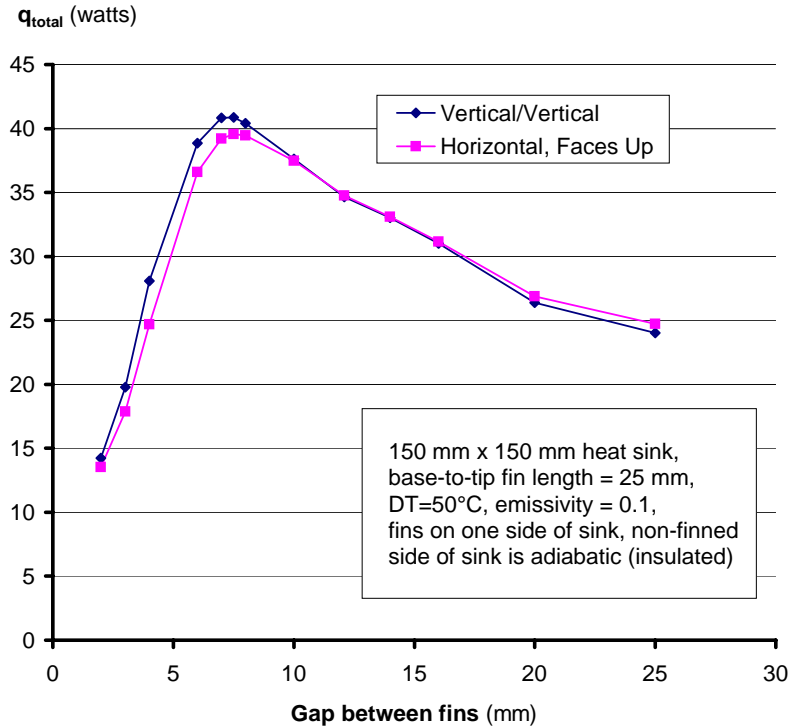


Figure 4:  $q_{total}$  for vertical and horizontal 150 mm x 150 mm heat sinks

### The horizontal, faces up configuration

Unlike the well-studied vertical/vertical configuration, very few research papers have been written on the horizontal/up configuration. The most comprehensive experimental investigation was performed by Bilitzky [2, 3], a graduate student working under the supervision of noted heat transfer researcher Avram Bar-Cohen. Bilitzky, however, did not derive an accurate equation which matched the full range of his experimental data. A new equation was derived which matches the Bilitzky data to within +14%/-18%. This new equation, which was incorporated into the Sauna program, also accurately describes the data of Jones and Smith [4].

The basic flow configuration for the horizontal, faces up configuration is shown in Figure 5 on the next page [2, 5]. As the figure shows, and as most persons would imagine, there is an inflow from the ends of the heat sink. However, as pointed out by Harahap and McManus [5], as well as Bilitzky [2], other flow patterns can coexist with the inflow from the ends. In particular, as shown in Figure 6, thermosiphoning can occur both longitudinally and between fins. In thermosiphoning, cool air is drawn down into the fins and then rises in a cellular pattern. This flow pattern is similar to the flow pattern which occurs over larger horizontal plates. As pointed out by Harahap and McManus, thermosiphoning is a minor effect for some

heat sinks, but can be significant for other configurations. In particular, thermosiphoning is likely to be a more significant contributor when there are large gaps between fins or when fins are short (the heat sink starts to behave like a horizontal plate). It's important to note that the thermosiphoning effect does not occur in any significant manner for the vertical/vertical configuration.

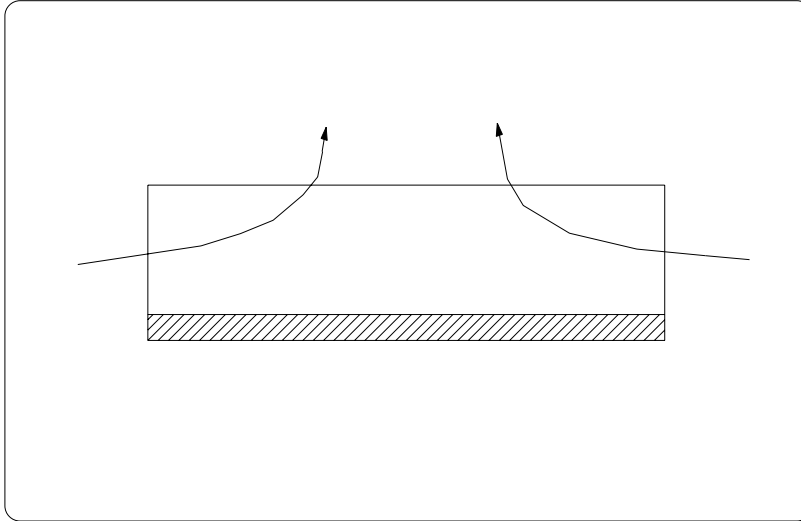


Figure 5: Inflow from ends of horizontal baseplate heat sink

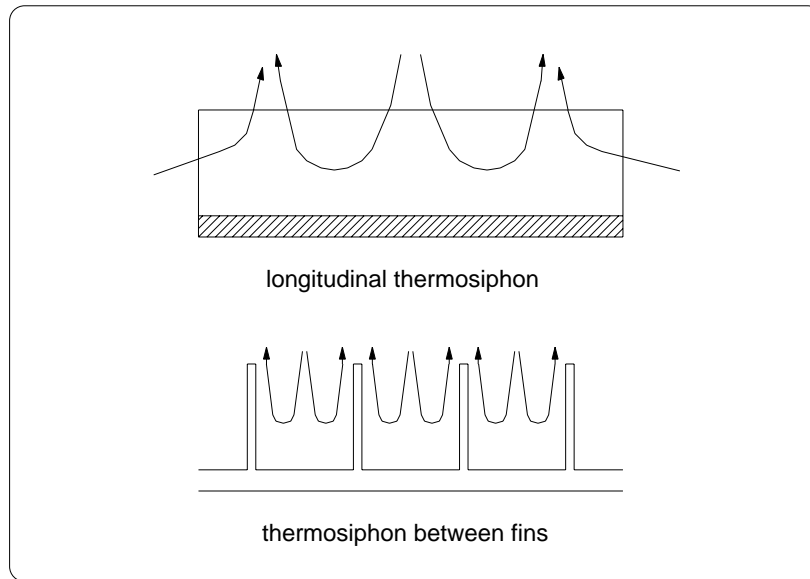


Figure 6: Thermosiphoning with horizontal baseplate heat sinks

Examination of Figure 3, presented earlier, shows that  $h_{\text{convection}}$  for horizontal backplane fin channels is lower than  $h_{\text{convection}}$  for vertical/vertical fin channels. However,  $h$  for the horizontal/up configuration is only moderately lower, typically around 10%. Additionally, this does not mean that a vertical/vertical heat sink will be 10% better overall. Thermal radiation

must also be considered, as well as heat dissipation from the non-channel surfaces of the heat sink. The outer surfaces on the ends of a horizontal heat sink are relatively short vertical surfaces, as compared to the taller vertical surfaces found on the ends of a vertical/vertical heat sink. Since short vertical surfaces have higher heat transfer coefficients than tall vertical surfaces, the end fins will be a more significant contributor for a horizontal backplane heat sink, which narrows the performance gap with a vertical/vertical sink.

Figure 4, presented above, shows the wattage dissipated for an entire 150 mm x 150 mm heat sink, including end fins and radiation (emissivity = 0.1, typical of a bare extruded surface). In this case, the vertical/vertical configuration is only around 3% better than the horizontal, faces up geometry. In fact, for large fin spacings, the horizontal heat sink actually performs slightly better! Although it is surprising to some people, horizontal backplane heat sinks provide good thermal performance.

Figure 4 also shows that the optimal fin spacing is similar for the vertical and horizontal cases. It is recommended that a somewhat larger fin spacing than the optimum be used if the horizontal heat sink is mounted on top of a tall box. The greater fin spacing will promote thermosiphoning, which will in turn lessen the impact of hot air rising from the side walls.

### Shorten the channel depth for best performance

When a horizontal baseplate heat sink is not square, there will be two possible orientations for the fin channels. As shown in Figure 7, the fins should be oriented to provide the shortest channel depth. For a baseplate which is 100 mm X 50 mm, the example shown in Figure 7, the proper channel orientation will provide 15% better performance.

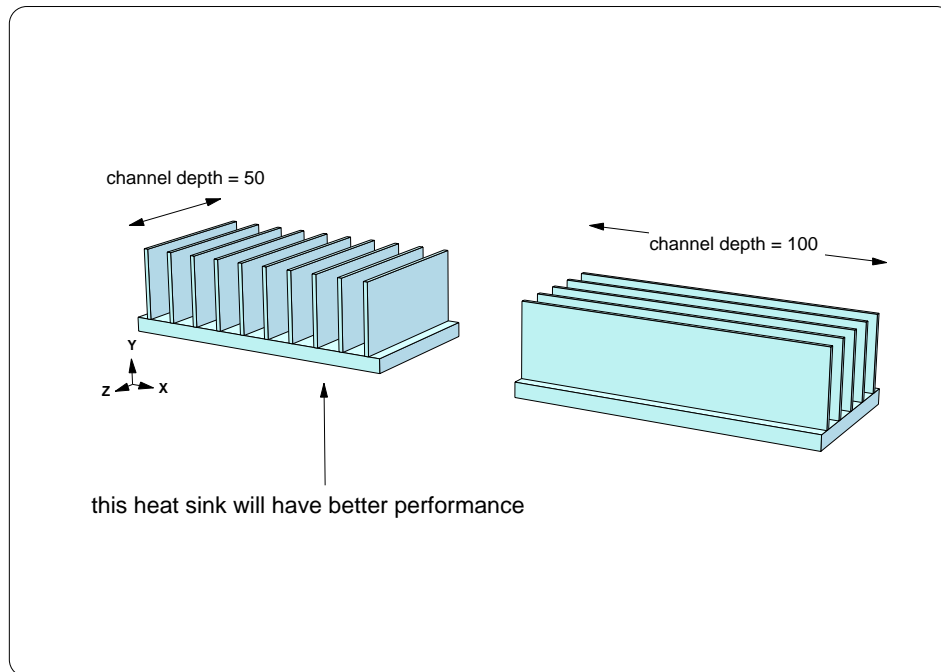


Figure 7: Proper fin channel orientation for horizontal heat sinks

## The vertical/horizontal configuration

The final heat sink configuration to be discussed is the "vertical baseplate/horizontal fin channel" geometry shown below in Figure 8. The only data available for this configuration is provided by Bilitzky [2]. A equation was derived to match the Bilitzky data and incorporated into Sauna.

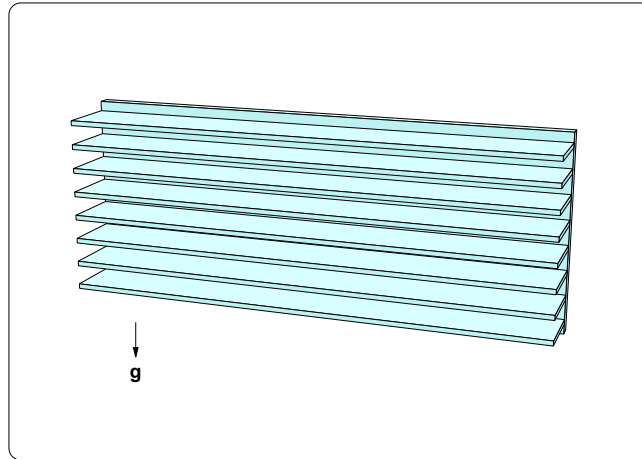


Figure 8: Vertical baseplate/horizontal fin configuration

Most persons do not expect good thermal performance from this geometry and this proves to be the case. Figure 5-15 shows a comparison between a vertical/vertical heat sink and a vertical/horizontal heat sink:

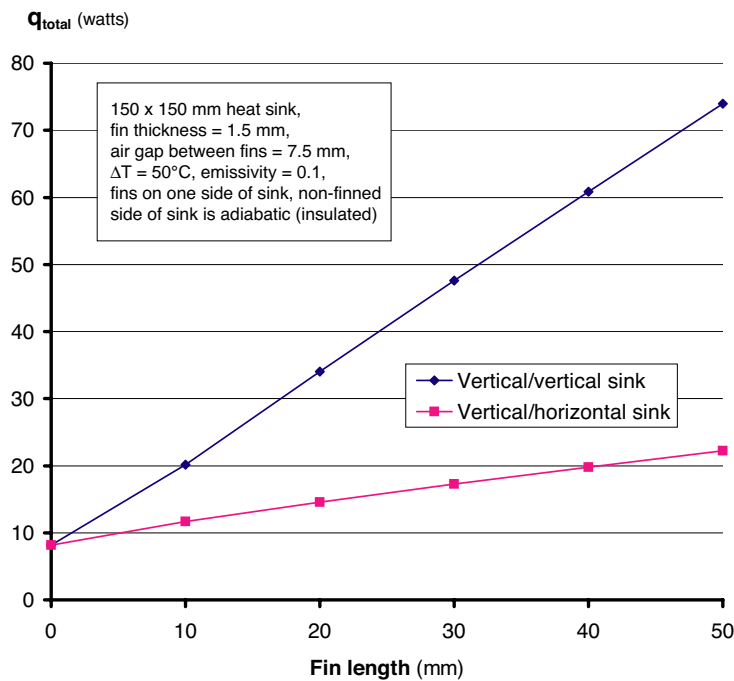


Figure 5-15: Comparing vertical/vertical and vertical/horizontal heat sinks

As the figure illustrates, vertical fin channels are better. However it should be mentioned that the vertical/horizontal sink is certainly better than a flat wall, which is represented by the limit “fin length = 0” in the graph. With a fin length of 25 mm, or about 1”, the vertical/horizontal heat sink provides roughly twice the wattage dissipated, an appreciable improvement. Also, the fins allow for an additional conduction path, which reduces the spreading thermal resistance of the heat sink. So there are situations where it is logical to use vertical/horizontal heat sinks.

This concludes the comparison of vertical backplane and horizontal backplane heat sinks. ♦

Written by Thermal Solutions Technical Support, 24 March 2004.

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