Comparing Naturally Cooled Horizontal Backplane Heat Sinks With Vertical Backplane Heat Sinks

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

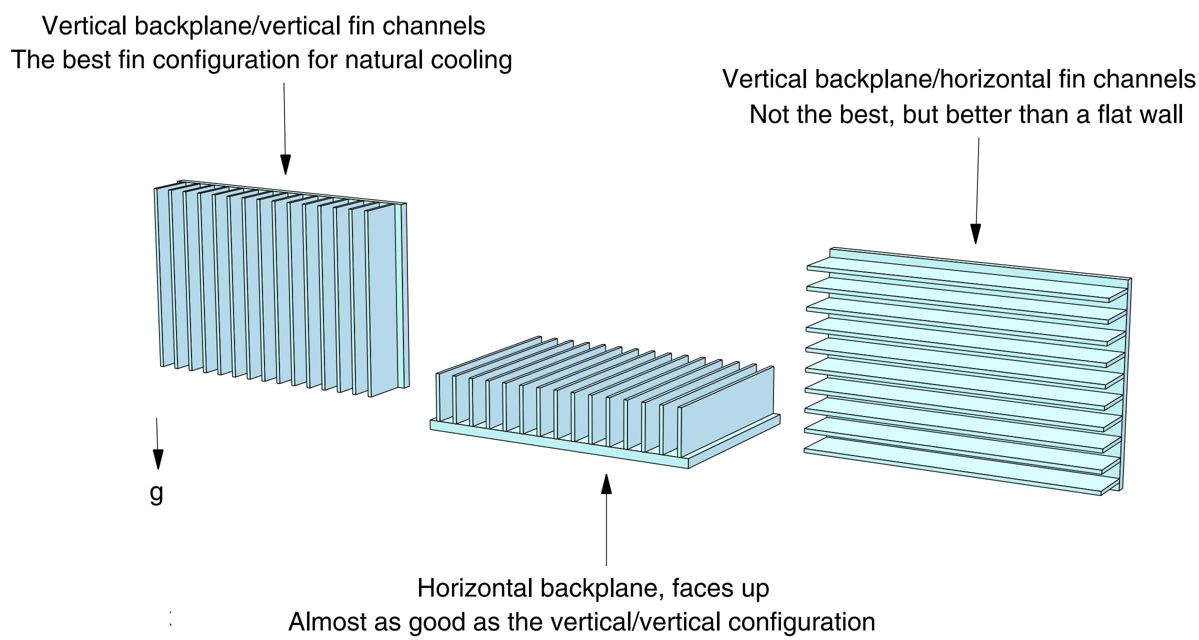

Figure 1: Fin configurations for natural cooling

The vertical/vertical configuration

The "vertical backplane / 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]. Sauna 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 nears 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.

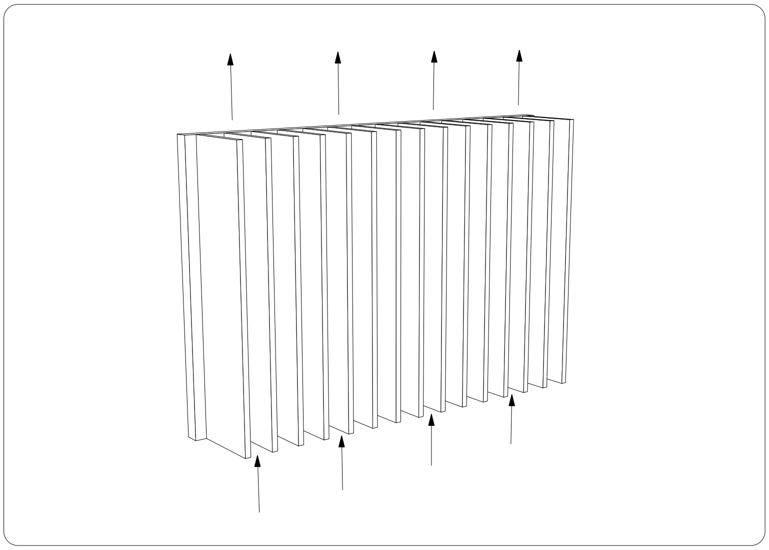

Figure 2: Primary air flow pattern for the vertical/vertical configuration

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. (Note that the graph shows the air gap distance between fins, not the centerline

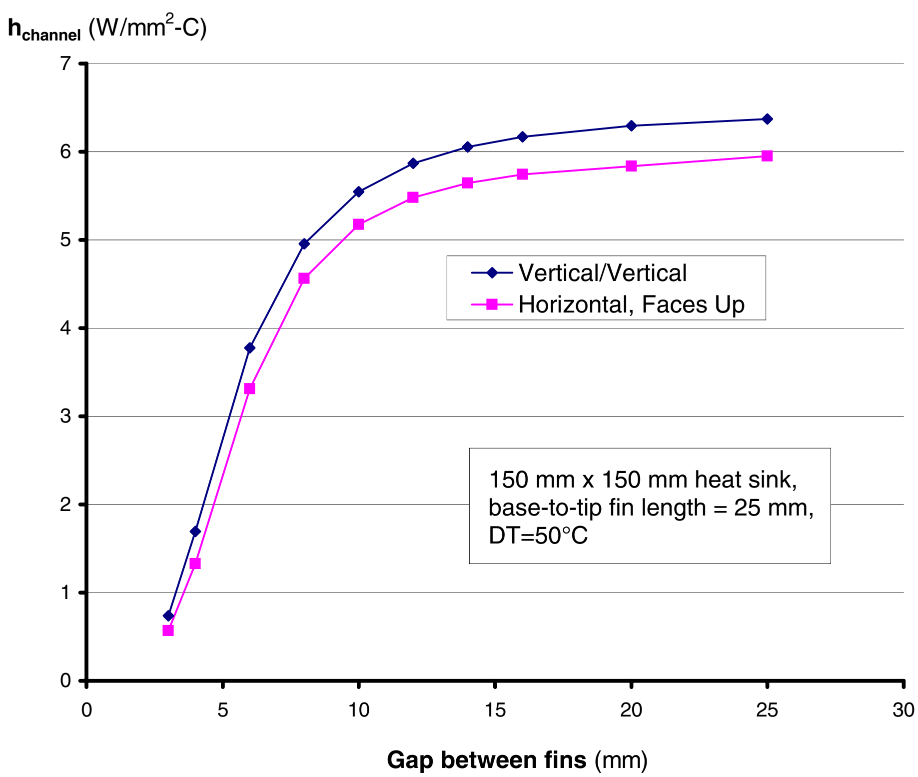

Figure 3: $h_{channel}$ for vertical and horizontal 150 mm x 150 mm heat sinks

fin spacing.) However, if the fins are closely spaced, there is also more dissipating surface 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.

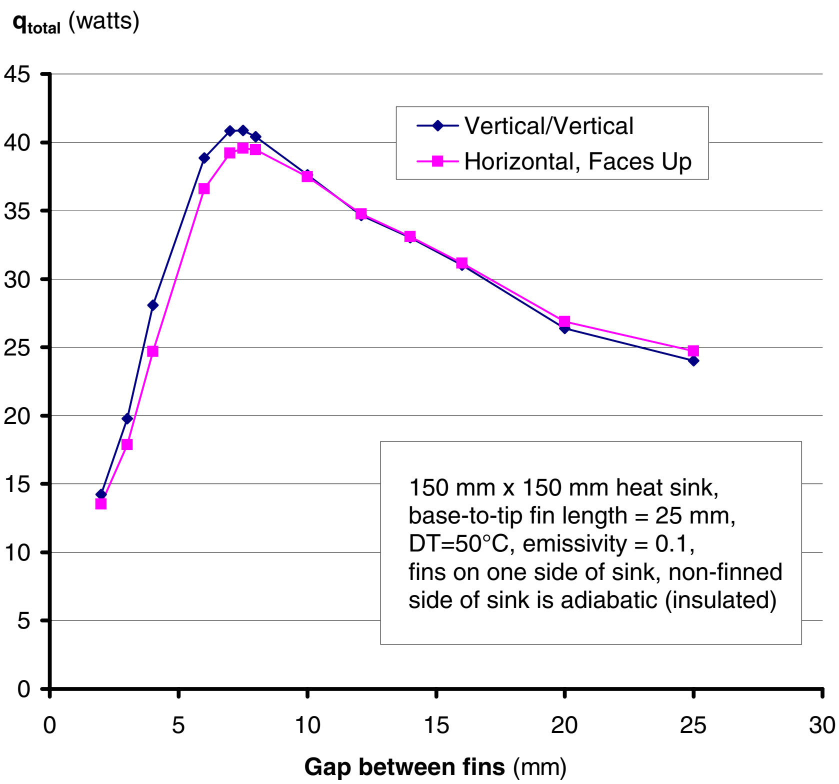

Figure 4: q_{total} for vertical and horizontal 150 mm x 150 mm heat sinks

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 Sauna, 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.

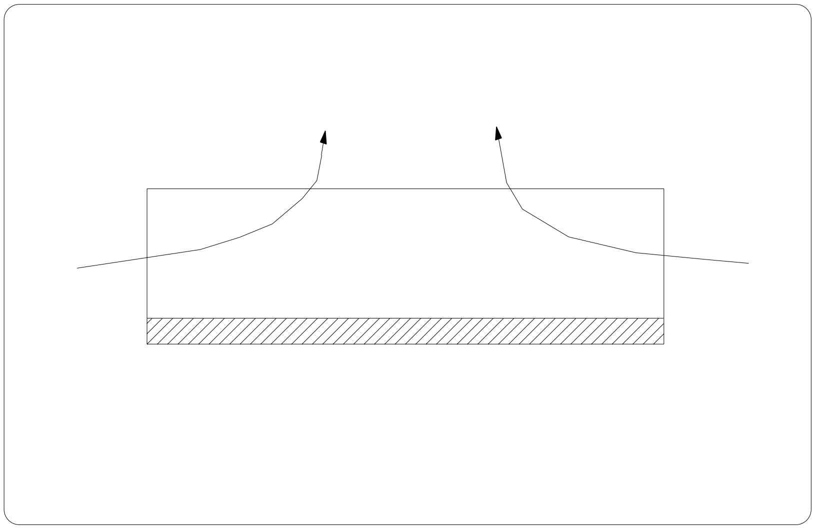

Figure 5: Inflow from ends of horizontal backplane heat sink

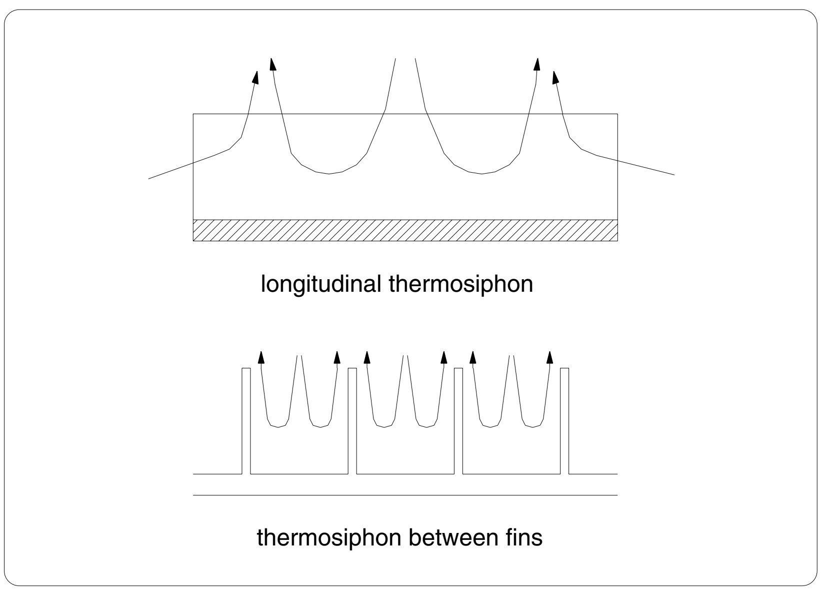

Figure 6: Thermosiphoning with horizontal backplane heat sinks

Examination of Figure 3, presented earlier, shows that $h_{convection}$ for horizontal backplane fin channels is lower than $h_{convection}$ 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 backplane 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 backplane which is 100 mm X 50 mm, the example shown in Figure 7, the proper channel orientation will provide 15% better performance.

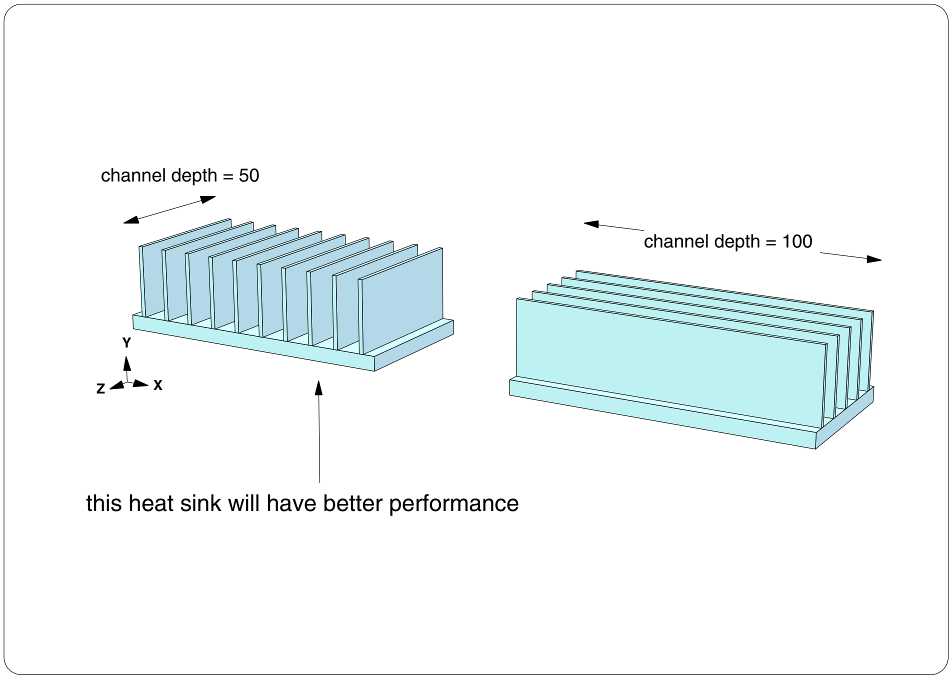

Figure 7: Proper fin channel orientation for horizontal heat sinks

Horizontal backplane heat sinks on the top of boxes

Unlike vertical/vertical heat sinks, horizontal backplane heat sinks are frequently mounted on the top of boxes. The hot air rising from the side walls can have a negative impact on the performance of the heat sink.

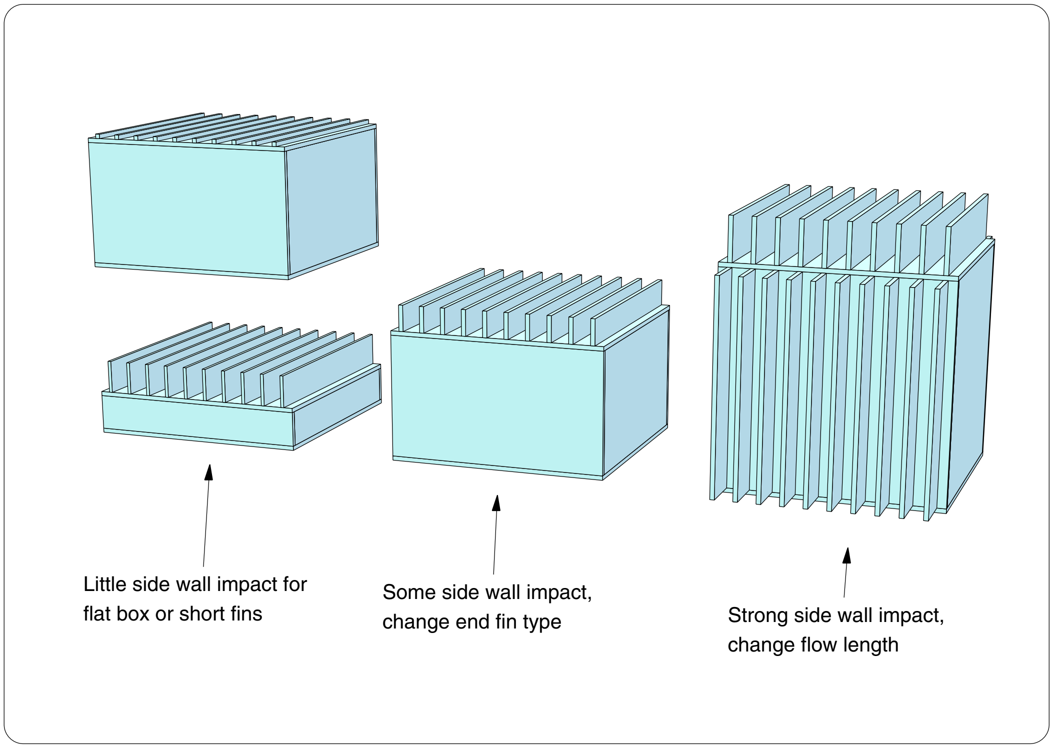

Figure 8: Heat sinks on top of boxes

If the box is short and flat, as shown on the lower-left of Figure 8, there is not likely to be a major impact from the side walls. In this situation, the volume of air rising from the side walls will be substantially less than the air flow generated by the heat sink (the surface area ratio is strongly in favor of the heat sink). Also, if the heat sink fins are short (less than 6 mm), as shown in the upper-left, the heat sink will start to resemble a horizontal plate, with only a minor impact from the side walls.

For a medium height box, as shown in the middle of Figure 8, there will be some impact from the side walls. The impact is a little difficult to judge because of the thermosiphoning which may occur, lessening the side wall effect. In any case, the impact should be minor if the heat sink dissipating area is at least two times greater than the side wall area. In the picture, the middle heat sink surface area is 2.5 times the surface area of the front and back wall, so the side wall impact should be limited. However, the end fins will be affected by the left/right side walls. To compensate, you should use the "Same As Mid" option for the end fins of the heat sink (**Edit ➔ Plate/Board ➔ Fin Props ➔ End Fins ➔ Same As Mid...**).

The most negative impact will occur for the box style shown on the right of Figure 8. In this case there are heat sinks on the side walls and each of these heat sinks has as much surface area as the top heat sink. To compensate, you will need to change the flow length for the float resistors connected to the top heat sink (**Edit ➔ Resistor ➔ Float ➔ Isoltd->Fix ➔ Flow Length...**). The new flow length should be: flow length = 2 x box height + channel depth, assuming the fin lengths and spacing are comparable. The heat sink should also be edited to use the "Same As Mid" option for the end fins (**Edit ➔ Plate/Board ➔ Fin Props ➔ End Fins ➔ Same As Mid...**).

The vertical/horizontal configuration

The final heat sink configuration to be discussed is the "vertical backplane / horizontal fin channel" shown at the right of Figure 1. The only data available for this configuration is provided by Bilitzky [2,3]. A equation was derived to match the Bilitzky data and incorporated into Sauna.

Most persons do not expect good thermal performance from this geometry and this proves to be the case. Figure 9 shows a comparison between a vertical / vertical heat sink and a vertical / horizontal heat sink:

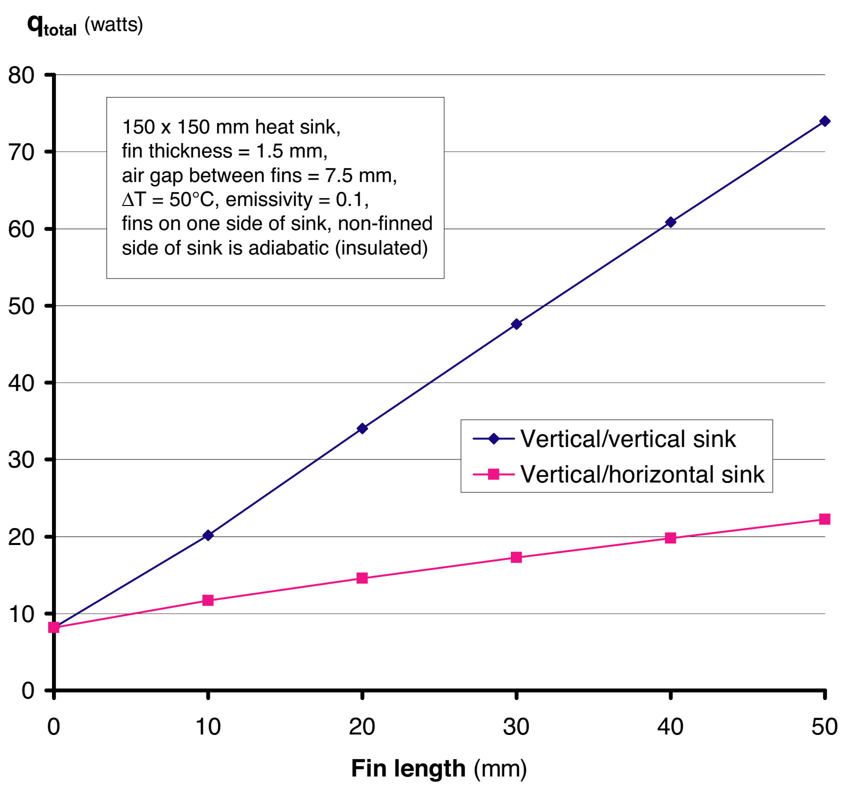

Figure 9: Comparing vertical/vertical and vertical/horizontal heat sinks

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.
If there are questions, feel free to contact Technical Support (support@thermalsoftware.com).

References

1. Van de Pol, D.W., and Tierney, J.K., "Free Convection Heat Transfer from Vertical Fin Arrays", *IEEE Trans. Part, Hybrids, and Packaging*, Vol. PHP-10, no. 4, Dec. 1974, pp 267-271.

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4. Jones, C.D., and Smith, L.F., “Optimum Arrangement Of Rectangular Fins On Horizontal Surfaces For Free Convection Heat Transfer”, *ASME Journal Of Heat Transfer*, Vol. 92, pp. 6-10, 1970.

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