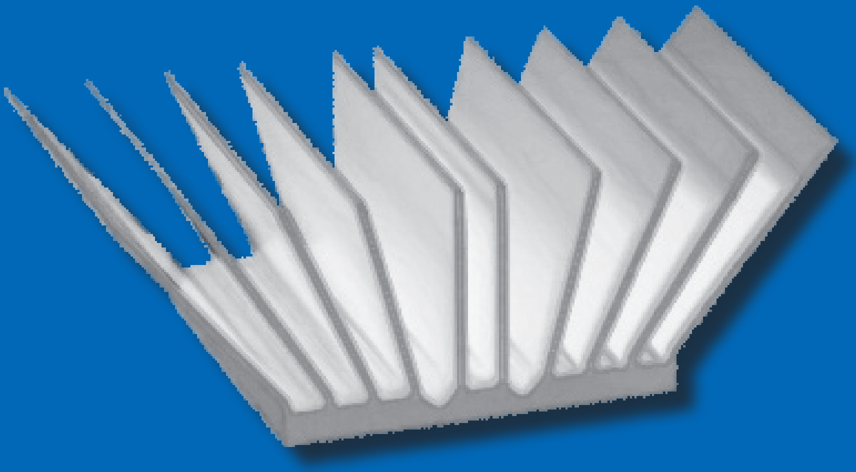

ATS WHITE PAPER

fanSINK Deployment in a System

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How System Flow Affects Fan Sink Performance

Cooling fans consist of an aggregate of airfoils, i.e. blades, positioned around a hub that is driven by an electric motor. Due to their airfoil nature, a pressure differential is required across the blades to create the required flow. Therefore, if this pressure differential is disturbed, fan will suffer performance degradation.

Because air cooling is the most desired method for the thermal management of electronics equipment, fans are used extensively. Applications range from a simple projector to a sophisticated computer. The use of fans in such fluid dynamically complex geometries must be well understood. Equally important is the interaction of the fan with its environment, which will determine its effectiveness as an air mover.

There is much that impacts fan performance. The list includes entrance and exit geometries, size and location of the plenum, its placement in the system, effects of swirl in the air flow, altitude, etc. One area that is not accurately studied, and is continually faced in electronics systems, is the effect of parallel flow over the fan hub.

As mentioned, fans are formed from a series of airfoils. A flow going over the fan hub may impact the pressure differential across the blade that is necessary for the fan to operate properly. This article reports the results of an experimental investigation for a fan sink that is commonly used in electronics such as PCs and servers.

Fan sinks are commonly used in electronics systems to deliver direct air to devices that need additional cooling. Fans are pressure driven devices, and peripheral flow around them, specifically over the fan blades, may impact their performance. To determine the effect of such system by-pass flow over a fan hub, we considered the fan sink shown in Figure 1. This fan sink is used for cooling a microprocessor and its integral power supply. Our objectives were to determine the air flow of the fan sink, with and without the power supply (blockage), and to evaluate the effect of main stream flow on the fan sink's performance.

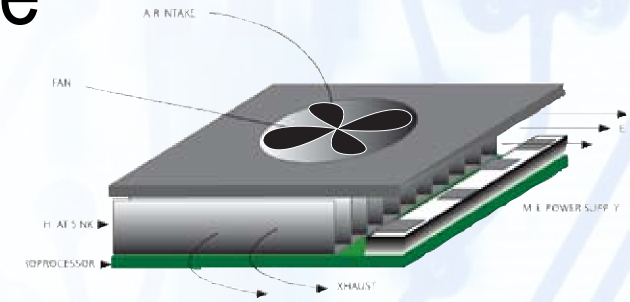

Figure 1. Fan Sink Assembly.

Experimental Procedure

The fan sink was set up in a research-standard wind tunnel allowing the main stream air flow to course over the hub of the fan. This is similar to a typical 1U chassis, where system fans move the air from the rear to the front and the CPU is directly cooled by a dedicated fan sink. A high performance hot wire anemometer (HWA)was used for mapping the flow field in the exhaust of the heat sink. This was done with and without the presence of the CPU's integral power supply. The locations of the velocity probe are shown in Figures 2, 3, and 4.

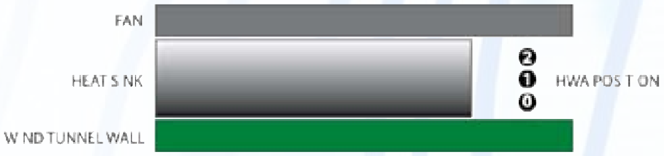

Figure 2. Side View of the Test Rig, Showing the Vertical Position of the Velocity Probe (HWA).

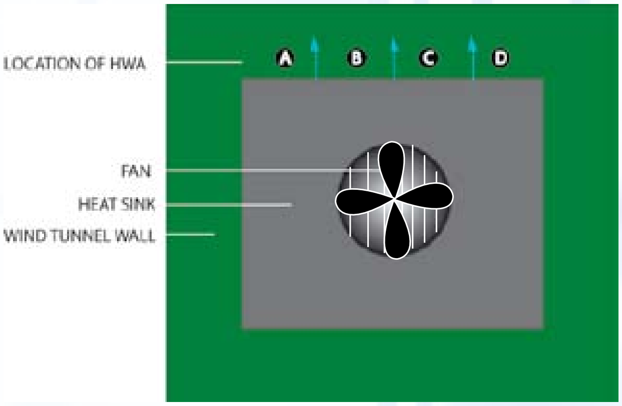

Figure 3. Top View of the Test Rig, Showing the Horizontal Position of the Velocity Probe.

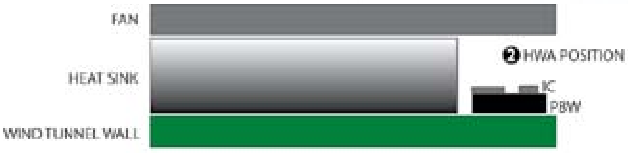

Figure 4. Side View of the Test Rig With ME Power Supply in Place, Showing the Vertical Position of the Velocity Probe (HWA).

Positions 0, 1, and 2 (Figure 2) are normal to the planar area of the fan sink, and A, B, C, and D (Figure 3) are along the exhaust area of the unit. Positions A and D were set at the first and last opening of the heat sink, and B and C were 1/3 and 2/3 the distance from the edge, respectively. For all tests, the velocity probe was placed at the halfway point between the heat sink exhaust and the edges of the heat sink, as shown in Figures 2 and 4. This corresponds to positions 0, 1, and 2 in Figure 2 and position 2 in Figure 4. This configuration enabled us to map out the velocity profile in the exhaust of the fan sink at 12 different locations, four positions from left to right (A—D) and three positions top-to-bottom (0—2).

The fan was powered at the nominal 5 volts, consistent with the actual application. The parallel flow was set at four conditions. The first was no flow (V = 0), which established the reference point for this study. Then, the wind tunnel was set at V= 0.5, 1.5, and 3 m/s (100, 300, and 600 ft/min), while measuring at 15 cm upstream of the fan sink assembly. The fan sink was positioned where 0.5 to 3 m/s of flow would pass by its hub while it operated at its nominal condition. Because a fan is a pressure-driven device, it was expected that the flow bypass would adversely impact its performance. At every point of observation, the velocity was measured for two minutes at the rate of two samples per second, resulting in an uncertainty level of + 0.9%.

Results

Table 1 shows the averaged data for velocity and mass flow rate, with and without the power supply in place. The effect of the bypass flow on the fan sink's performance was quantified by comparing the mass flow rates at different velocities. Depending on the magnitude of the system velocity, (i.e. parallel flow) the data shows that the mass flow rate required for cooling the device can be reduced by more than 60.4%.

Table 1. Average Air Velocity and Mass Flow Rate for Fan Sink at Different Bypass Air Velocities.

V, System Velocity (m/sec)	Fan Sink Output Velocity Without PS	Mass Flow Rate Without PS (kg/sec) X10^3	Fan sink Output Velocity With PS (m/sec)	Mass Flow Rate With PS (kg/sec) X10^3	Percentage Reduction in Mass Flow Rate
0	0.79	0.604	1.63	0.239	0
0.5	0.83	0.54	1.46	0.214	60.4
1.5	0.91	0.53	1.30	0.189	64.2
3.0	0.81	0.46	0.98	0.151	67.5

Figure 5 shows the raw velocity data for all positions measured. Figure 6 shows the velocity data at vertical position 2 and the 4 horizontal positions for the blocked and unblocked cases. It is noteworthy that in both cases the exhaust flow is highly non-uniform. The mass flow rate was calculated based on the open cross-sectional area of the fan sink assembly. The area for the unit with and without the power supply was 0.32x10^{-3} m^2 and 0.13x10^{-3} m^2, respectively.

Observations

The following observations were made as the result of this experimental investigation:

- The fan sink exhibits uneven flow across its exhaust where the power supply resides, as seen in Figures 5 and 6. This may adversely impact the thermal performance of the power supply, depending on its power distribution.

- The uneven flow distribution was observed for both cases (with or without the power supply). Hence, it is attributed to the design of the fan sink rather than the system flow condition alone. For this reason, it is prudent to characterize any fan sink before its implementation in the system.

- Because of the uneven flow distribution, the layout of the component power supply must be carefully considered. The available mass flow rate for cooling is approximately 0.25x10^{-3} kg/sec.

- The increase in velocity (approximately 20% to 100%) when the power supply is placed in the exhaust of the

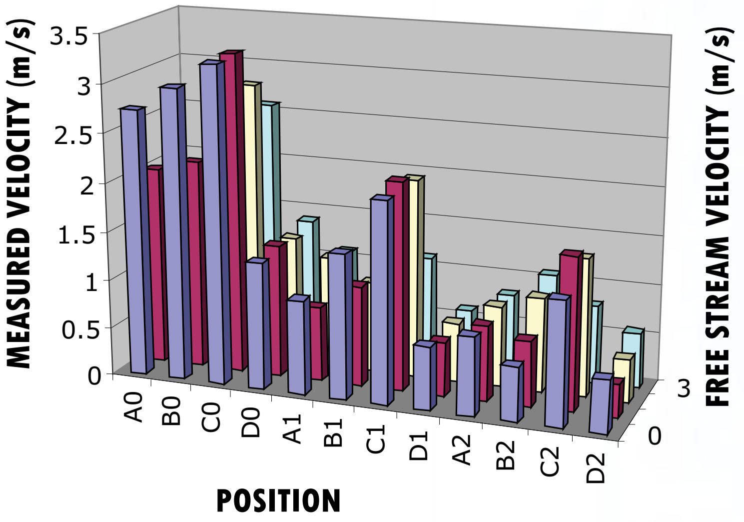

Figure 5. Measured Velocity as a Function of Position and Free Stream Velocity for Unblocked Cases.

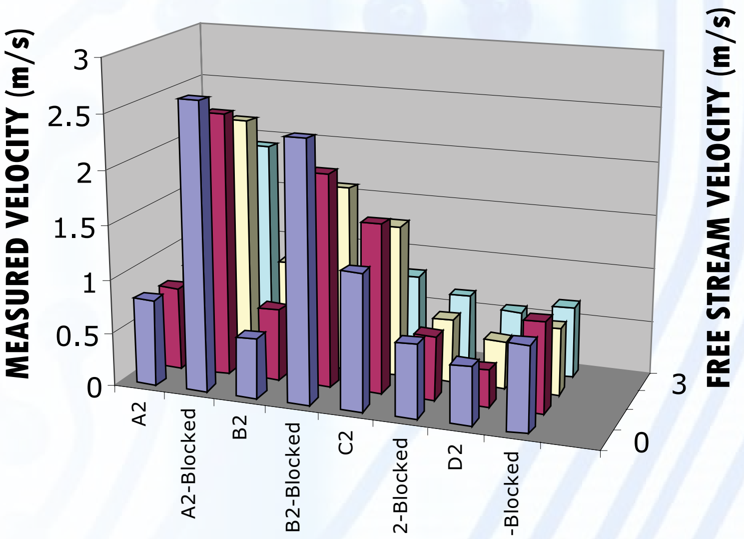

Figure 6. Measured Velocity as a Function of Horizontal Position and Free Stream Velocity at Vertical Position for 2 Blocked and Unblocked Cases.

fan sink is attributed to area reduction. The mass flow rate is the true measure of available coolant for the power supply, not the air velocity alone. Any obstruction in the intake or exhaust of the fan, e.g. neighboring components in the board layout, must be carefully considered as their presence will impact the performance of the fan sink.

- The flow bypass adversely impacts the performance of the fan sink. The data show ≥60% reduction in air velocity when the bypass flow is 3 m/sec (with the power supply in place). Additional clogging of the fan sink from dust and other debris will further diminish its performance.

The adverse effect of system flow bypass on the fan sink suggests that system implementation of the fan sink should be carefully considered at the board and system levels. At the very least, the selection (for size) and position of the adjacent components should be carefully considered because the measurement shows that any near vicinity obstacle has a direct impact on the fan's performance. As we design fan trays with sufficient plenum for the fan to freely exhaust, board level implementation of the fan sink requires similar consideration.

Although detailed flow measurements were taken to characterize the fan sink, the result may not explicitly determine the thermal performance of the power supply and microprocessor. The non-uniformity of the exhaust air from the fan sink suggests that, depending on the heat sink material and the device's power concentration, the heat sink base temperature may be highly non-isothermal. Because fan sinks are used for direct cooling of certain devices, this non-uniformity may adversely impact the thermal management of the device. The combination of spreading resistance between the fan sink and the device, and the non-uniformity of the exhaust air and the system bypass flow on the fan's performance, may render the fan sink inadequate for a given cooling application.

The data suggests that although fan sinks are attractive cooling options, their implementation in a system environment may be more complicated and requires additional investigation. Simply placing a fan sink on top of a hot device may not provide the desired cooling that the engineer envisioned. Therefore, it is strongly recommended not only to carefully quantify system flow bypass on the fan sink, but to also make the proximity of components neighboring the fan sink a point of consideration in the design cycle. ▪