Design Report
Laptop Cooling Solution

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16 September, 2004
Project Description

► Provide a new cooling solution for two 60W Sun Sparc Processors in a laptop assy. The new solution needs to cool an increase in the thermal load due to the addition of the 2\textsuperscript{nd} processor.

► The current laptop design uses an active, ducted cooling solution to cool one processor. The heated air is removed via an integral fan/duct solution.
Main Design Considerations

- Both processors will be collocated next to each other on the motherboard.
- Both processors will be located in a “pocket” created by a daughter card on top, 2 sets of DIMM’s on either side and a riser card at the rear (Figure 1)
- PCB mounting holes for the heatsinks will be limited due to routing density constraints. The number of holes provided for the heatsink mounting will limited to a total of 4 holes in the pcb. This limitation will necessitate that a sub-frame be implemented to provide proper heatsink retention and heatsink-to-cpu pressure.
- The maximum allowed cpu case temperature is 90C.
Main Design Considerations – Cont

Figure 1
Cooling Strategy

- Two individual fan/heatsinks using internal air will cool the cpu’s and route the hot exhaust air through one common duct out of the enclosure (Figures 2 and 3).
- Both heatsinks will see impingement cooling. Air removal from the two heatsinks will be as shown in Figure 2 (from each side for heatsink #1 and from one end for heatsink #2. Orientation of each heatsink will be at right angles to each other.
- Both heatsinks will be spring loaded, via shoulder screws and springs, to a sub-frame which is directly mounted to the pcb. The spring load will maintain the proper heatsink pressure and retention.
- The duct assy will be mounted to the top of the heatsinks, sandwiched between the fans and the heatsink, with additional board mounting for proper retention.
Cooling Strategy – Cont.

Figure 2

Direction of airflow out of each heatsink, through the duct and exiting the duct.

Heatsink/Fan #1

Duct Assy

Heatsink/Fan #2
Cooling Strategy – Cont.

Figure 3
The cooling solution consists of 2 fan-heatsink assemblies, a heatsink mounting frame and a duct assembly to remove the heated air from the chassis.

See Figures 4, 5, 6, 7 and 8 for the major mechanical parts and overall assembly.

The heatsinks are oriented in such a manner that the airflow from heatsink #1 is exhausted through the sides and into the duct while airflow from heatsink #2 is exhausted out of the end and straight into the main duct exhaust (Figure 2).

Both heatsinks are fabricated using the skived copper process for maximum thermal performance. If actual system level testing shows that there is sufficient thermal margin, it may be possible to re-specify the heatsinks to be fabricated from a lower cost process such as aluminum extrusion.

The heatsink fans are 60mm X 60mm X 15mm thick, type HH (Cofan P/N F-615HH12 rated @ 5400 rpm, 0.41 A, 4.92 W) fans capable of 31.31 cfm no-load and 0.223 inch H₂O maximum pressure. However, these are 12 VDC fans. If usage is limited to 5 VDC fans, the fans will be type H (Cofan P/N F-615H05 rated @ 4600 rpm, 0.79 A, 3.95 W), capable of 26.68 cfm no-load and 0.162 in H₂O maximum pressure. The airflow rates may be reduced due to the lower fan capacity.
Mechanical Components

Heatsinks

Figure 4 – Heatsink #1

Figure 5 – Heatsink #2
Mechanical Components – Cont.

► Duct Assy

Figure 6 – Duct Assembly
Mechanical Components – Cont.

► Heatsink Mounting Bracket

Figure 7 – Heatsink Mounting Bracket
Mechanical Components – Cont.

► Complete Thermal Solution Assy.

Figure 8 – Complete Heatsink, Fan and Duct Assy
Thermal Model

- The thermal model will closely follow the mechanical model (Figures 9 and 10).
- CFD (Icepak) will be used to model the thermal layout.
- $T_{ambient}$ is equal to $T_{heatsink-inlet}$ and is 40°C maximum.
- Due to the close proximity of the daughter card and the possible thermal effect it could have on the air intake to the heatsink-fans, 20W was applied to the daughter card and allowed to dissipate heat into the area of the heatsinks.
- Two separate CFD models were run.
  - Case 1 included just the fans, heatsinks and duct.
  - Case 2 included Case 1 plus a laptop enclosure to determine overall system airflow and to balance the airflow.
- The Case 2 chassis fans used for the thermal analysis were of the tube axial variety, 40mm X 40mm X 28mm, 5 VDC fans with a no-load flow rate of 11.3 cfm and maximum pressure of 0.414 in H$_2$O running at 8700 rpm, 0.68 A, 3.4 W.
Correlation Between Mechanical and Thermal Models

Figure 9

Mechanical Model

Thermal Model
Correlation Between Mechanical and Thermal Models – Cont.

Figure 10. Top Down View of Mechanical and CFD Models
Airflow Results (Case 1)

- CFD analysis indicates that the fan operating points are as follows:
  - Heatsink Fan #1 Operating Point: 6.2 cfm at 0.131 inch H₂O
  - Heatsink Fan #2 Operating Point: 5.7 cfm at 0.138 inch H₂O

- This results in a total airflow through the heatsinks of 11.9 cfm. Since 11.9 cfm is needed from the internal air volume, there will need to be 11.9 cfm air “replacement” from outside the laptop. This could be achieved via adequate vent holes in the casing to allow sufficient airflow. However, there will be extra “work” for the heatsink fans due to the extra pressure drop needed to move air through the venting, through the laptop, into the heatsink and through the ducting.

- The Case 2 scenario will help to alleviate some of the “work” by the heatsink fans with augmentation by the chassis fans.

- See Figures 11, 12 and 13 for a view of the airflow.
Airflow Results (Case 1) – Cont.

Figure 11. Air Flow Through Fans, Heatsinks and Duct
Airflow Results (Case 1) – Cont.

Figure 12. Side View of Fan, Heatsinks and Duct Airflow
Airflow Results (Case 1) – Cont.

Figure 13. Top View of Fan, Heatsinks and Duct Airflow
Airflow Results (Case 2)

► CFD analysis indicates that the fan operating points are as follows:
  - Heatsink Fan #1 Operating Point: 6.2 cfm at 0.131 inch H₂O
  - Heatsink Fan #2 Operating Point: 5.6 cfm at 0.140 inch H₂O
  - System Fans #1, #2 and #3 Operating Points: 9.8 cfm each at .045 inch H₂O

► This results in a total airflow through the heatsinks of 11.9 cfm. Since 11.9 cfm is needed from the internal air volume, there will need to be 11.9 cfm air “replacement” from outside the laptop. This indicates that 1 fan would come close to achieving the air replenishment and 2 fans would provide extra margin.

► See Figures 14 and 15 for a view of the airflow.
Airflow Results (Case 2) – Cont.

Figure 14. Air Flow Through Fans, Heatsinks, Duct and Laptop
Airflow Results (Case 2) – Cont.

Figure 15. Top View of Fan, Heatsinks, Duct and Laptop Airflow
Temperature Results - Case 1

- **Heatsink #1** Location: maximum case temperature = 85.5°C (Figure 16)
- **Heatsink #2** Location: maximum case temperature = 89.3°C (Figure 17)
- Maximum allowed case temperature is 90°C
Figure 16. Heatsink #1 Case Temperature
Temperature Results – Case 1 - Cont.

Figure 17. Heatsink #2 Case Temperature
Temperature Results – Case 2

- Heatsink #1 Location: maximum case temperature = 82.0°C (Figure 18)
- Heatsink #2 Location: maximum case temperature = 87.7°C (Figure 18)
- Maximum allowed case temperature is 90°C
Temperature Results – Case 2 - Cont.

Figure 18. Heatsinks #1 and #2 Case Temperature
The proposed design solution will maintain the maximum case temperature of the two Sun Sparc processors to below their rated maximums in an ambient environment of 40°C.

Both heatsinks are copper skived. During system level testing with the actual prototype (Figure 19), if the actual temperatures show additional margin, then it may be possible to use aluminum heatsinks for cost reduction.

The current duct design is sheetmetal. Plastic ducting could also be developed with tooling to reduce cost.
Prototype of Heatinks, Fans and Duct

Figure 19. Actual Prototype