# Measurements of air temperature distribution and optimum cooling condition inside the computer system [†]

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## Abstract

Measurements of the temperature distributions of the cooling air flow inside a computer system have been made. An investigation of the optimum cooling condition for the computer system has also been made. Seventy-one K-type (Chromega-Alumega) thermocouples were used to measure distributions of the air flow temperature inside the computer system. They were calibrated against the standard platinum resistance thermometer (PRT) in a constant water circulating bath within an accuracy of ± 0.15 ºC. It was found that the number and position of cooling fans as well as their operating condition, whether air intake or air discharge, can greatly influence the cooling effectiveness in the computer system. The results show that the flow rate of intake air should not be higher than that of the discharge air for the most effective cooling. It follows that the optimum cooling has been achieved inside the computer when the three fans are positioned in the inlet front, outlet back, and outlet top in the computer, respectively. Under these conditions, not only is the average temperature inside the computer system maintained at an appropriate level, but the most effective cooling around the central processor (CPU) and graphic card which are responsible for the largest amount of heat dissipation can be accomplished.

*Keywords*: Computer system; Air flow; Temperature distribution; Cooling fan; Optimum cooling condition

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## 1. Introduction

Every component in a computer consumes electric power. In general, the faster a component performs its function, the more electric power it needs. But computer components consume the electric power very inefficiently, and the majority of the power input is wasted as heat with only a small portion being used for data generation [1]. The speed of the central processor (CPU), 3D-graphic card, and hard disk drive (HDD) has continually increased in the last few years. And, HDD has reached a speed of 15,000 RPM, and every component of the computer has to deal with heat

dissipation to some extent [2]. The heat generation in all computer chip-sets occurs due to switching between 0 and 1, which requires power consumption. On the other hand, heat is generated by the rotational motion in HDD and CD-ROM devices [3]. If any of these devices exceeds a suitable operation temperature, computer malfunction or even damage may occur. This is the reason computer laboratories in the research institutes or companies install a constant temperature air circulation system in order to maintain a room temperature of 18°C.

Various methods of computer cooling have been suggested: cooling of individual components by the fan and heat sink attached to each component, cooling by making an appropriate cable arrangement inside the computer for a smooth flow of the air, control of CPU speed by the software, ice cooling by a peltier device,

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and cooling the entire computer system by fans installed at the computer case [4]. Pastukhov and Maydanik [5] studied a low-noise cooling system for computer on the base of loop heat pipes. Coolers are located inside the computer body where the air temperature may be considerably higher than the ambient temperature. This causes the use of coolers that have quite a low thermal resistance, which makes it possible to sustain an acceptable operating temperature on the thermal interface of the object to be cooled.

The present research aims at finding the optimum cooling condition by measuring the temperatures of the cooling air corresponding to changes in the number and position of cooling fans installed on the computer case.

## 2. Test apparatus and procedure

Fig. 1 shows a schematic diagram of the experimental set-up for the present research. Seventy-one K-type thermocouples (only 13 of them are shown in Fig.1 for simplicity) are used to measure distributions of the air flow temperature inside the computer system. The thermocouples are connected to a digital data acquisition system (Data Shuttle A/D conversion board & Pentium Ⅲ PC). All thermocouples were calibrated by using a platinum resistance thermometer (PRT) in a constant water circulating bath (NESLAB/ RTE-221D) within an accuracy of ± 0.2 °C.

An outer cover of the computer having a size of 425(L)x440(H)x200(W) mm was replaced by a transparent acrylic plate in order to better observe and change the number of the fans and their positions according to the test conditions. When the power was
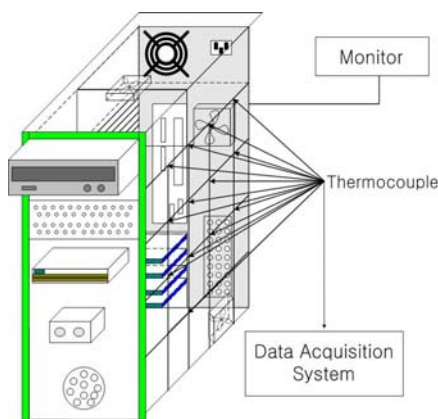


Fig. 1. Schematic diagram of experimental set-up in the computer (128MB RAM, Celeron 500 MHz).

on the computer, the Turbo-C program for the CPU operation and moving picture file for the graphic card operation were running. It usually took about one hour for the temperature inside the computer to reach a steady-state condition after the power was on. Once the system reached the steady-state condition, the temperatures were measured with the thermocouples and the digital data acquisition system and plotted by using the TECPLOT program. The two-dimensional temperature distributions were drawn about the depth axis. Table 1 is a summary of the experimental cases that show details of the test conditions.

## 3. Discussion of results

Figs. 2 and 3 show the temperature distributions inside the computer (128MB RAM, Celeron 500 MHz). Fig. 2 shows case1 when the power supply fan only is on. It can be seen that temperatures near the CPU and graphics card are quite high because the Turbo-C
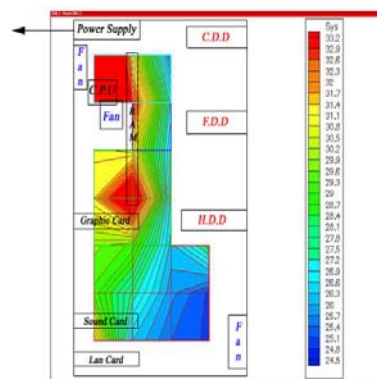


Fig. 2. Temperature distribution inside the computer with power supply fan only operating.
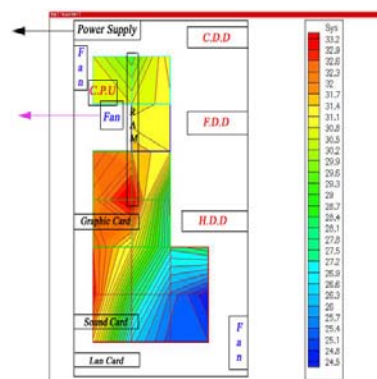


Fig. 3. Temperature distribution inside the computer with power supply and CPU fans operating.
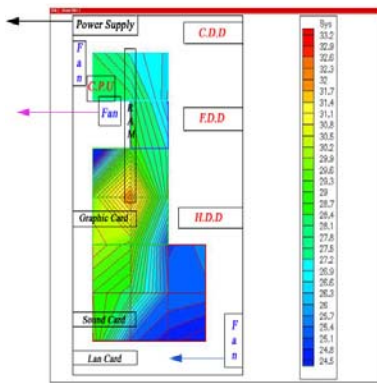
Fig. 4. Temperature distribution inside the computer with inlet fan (front) operating.
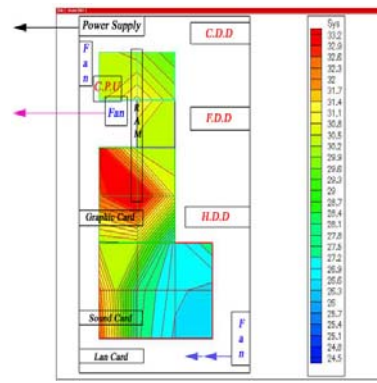


Fig. 6. Temperature distribution inside the computer with double inlet fans (front) operating.
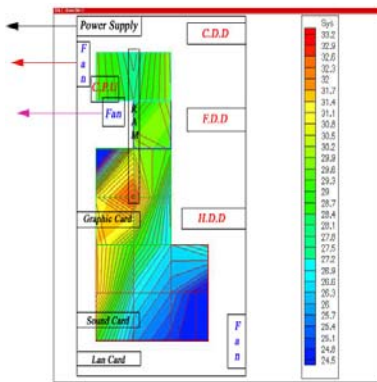


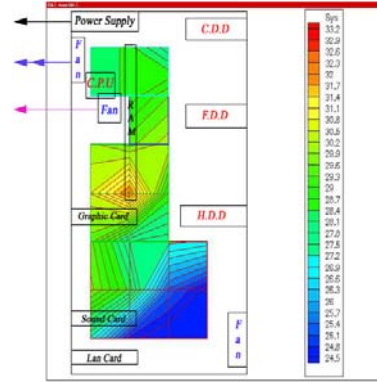Fig. 5. Temperature distribution inside the computer with outlet fan (back) operating.



Fig. 7. Temperature distribution inside the computer with double outlet fans (back) operating.

program and movie file are running, reaching temperatures of 41.3°C and 35°C, respectively. Fig. 3 shows the temperature distributions when both the power supply fan (80x80x15 mm) and CPU fan (50x50x10 mm) are operated. The temperature near the CPU significantly dropped to 30.5°C. However, the temperatures near the graphics card and sound card were slightly increased. It follows that although the CPU alone was cooled effectively by the cooling fan, the spent air (heated air by the CPU) was circulated inside the computer and caused a rise in the temperature of components like the graphics and sound cards.

Figs. 4 and 5 show the temperature distributions with the cooling fans (60x60x10 mm) installed in the inlet or outlet of the computer case to investigate the cooling fan's position effect. In Fig. 4, the inlet fan is positioned at the bottom front of the computer and operated at a constant speed of around 3,000 rpm.

Thus, the cooling air was drawn into the computer and moved horizontally from the front to the back, becoming the most effective cooling at the bottom. It is also observed from Fig. 4 that the temperatures are higher near the top part of the cards due to a recirculation of the spent air which flows upward after being bumped to the back of the computer.

Fig. 5 shows the case where the outlet fan is positioned at the back of the computer. It shows that the cooling is not as effective as the case with the inlet fan operated in a wide area of the lower-center region due to a lack of the cooling air intake.

Figs. 6 and 7 show the temperature distributions of the case with double cooling fans installed both in the inlet and in the outlet of the computer case, respectively. It is expected that the cooling effect in Fig. 6, where the double inlet fans are used, is better than the case with a single inlet fan (Fig. 4) due to the larger amount of the air flow. However, the result was an
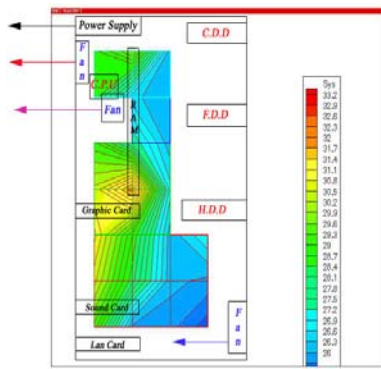
Fig. 8. Temperature distribution inside computer with inlet (front) & outlet (back) fans operating.
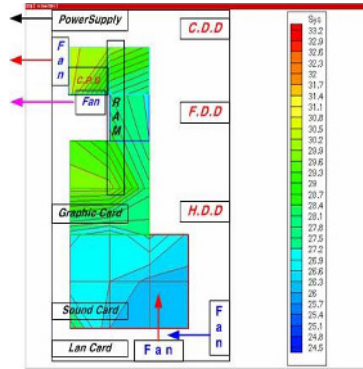


Fig. 10. Temperature distribution inside the computer with inlet (front) & outlet (back) & inlet (bottom) fans operating.
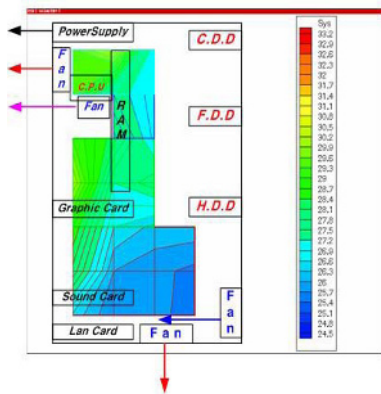


Fig. 9. Temperature distribution inside the computer with inlet (front) & outlet (back) & outlet (bottom) fans operating.

opposite of that. The temperature near the graphics card rose to 34.1°C. It may be due to the fact that the air intake flow rate is greater than the discharge rate; subsequently the spent air was not being discharged through the exit, but creating a stagnation zone around the graphics and sound cards.

It is observed from Fig. 7 that, in general, the cooling effectiveness is superior to that of the case in Fig. 5. In particular, the heated air at the lower-center region is effectively discharged due to the increased ventilation power. Fig. 8 shows the temperature distributions with single inlet and outlet fans installed both in the inlet and in the outlet of the computer. It can be seen that this arrangement is an improvement of cases in Figs. 4 and 5 in that the inlet cooling air flows through the components inside the computer, removes heat from them, and exits to the atmosphere. Up to this point, the most effective cooling method was found when both the inlet and outlet fans were

simultaneously operated with each fan position at the front bottom-side and back top-side of the computer case.

On the basis of the above findings, an extra cooling fan was installed on top and bottom of the computer to investigate the cooling effectiveness and to see how it may affect the electric power consumption and noise level. The results are shown in Figs. 9 and 10.

The cooling effectiveness of these two cases is much better than that of any other case. The case in Fig. 9 with the outlet fan at the bottom of the computer shows better cooling results near the electronic components than the case of Fig. 10 with the inlet fan at the bottom in spite of the significant amount of the inlet air being discharged to the ambient. It is due to the fact that too much of the intake air disrupts the fluid flow, causing an adverse effect on the cooling as previously seen in Fig. 6.

In Figs. 11 and 12, the fans were installed on top of the computer and their cooling effectiveness was compared to the case with the fan installed at the bottom. In Fig. 11, while excellent cooling effectiveness can be observed near each drive, the temperature near the graphics and sound cards rose to 31.6 °C. This temperature rise may have been caused by the stagnant air that came from the top inlet fan and circulated inside the computer. On the other hand, case 11(Fig. 12) with the top outlet fan shows better cooling than case 10(Fig. 11) with the top inlet fan, resulting in a lower average temperature. It is also observed in Figs. 11 and 12 that the fans at the top show lower temperatures both near the CPU and graphic card than the cases (Figs. 9 and 10) with the fans at the bottom.

Figs. 13 and 14 show the temperatures near the CPU and graphics card for all cases. When the double
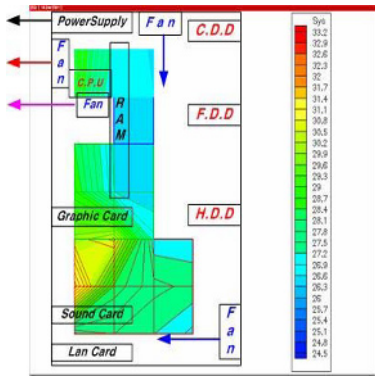
Fig. 11. Temperature distribution inside the computer with inlet (front) & outlet (back) & inlet (top) fans operating.
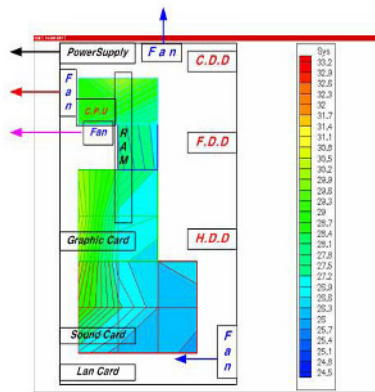


Fig. 12. Temperature distribution inside the computer with inlet (front) & outlet (back) & outlet (top) fans operating.

Table 1. Summary of the experimental cases.

| Case1(Fig. 2) | Power supply fan only |
|---|---|
| Case2(Fig. 3) | Power supply & CPU fan |
| Case3(Fig. 4) | Inlet fan(front) |
| Case4(Fig. 5) | Outlet fan(back) |
| Case5(Fig. 6) | Double inlet fans(front) |
| Case6(Fig. 7) | Double outlet fans(back) |
| Case7(Fig. 8) | Inlet(front) & outlet(back) fans |
| Case8(Fig. 9) | Inlet(front), outlet(back) & outlet(bottom) fans |
| Case9(Fig. 10) | Inlet(front), outlet(back) & inlet(bottom) fans |
| Case10(Fig. 11) | Inlet(front), outlet(back) & inlet(top) fans |
| Case11(Fig. 12) | Inlet(front), outlet(back) & outlet(top) fans |



Fig. 14. Temperature on graphic card for each case.



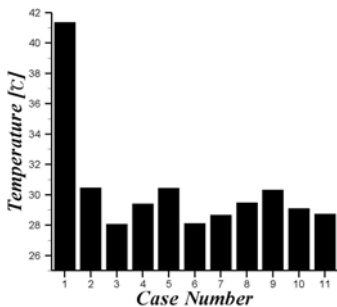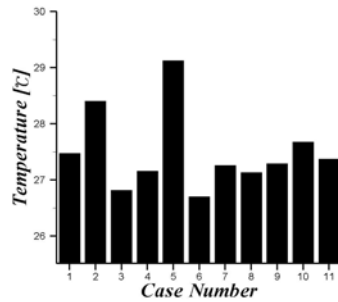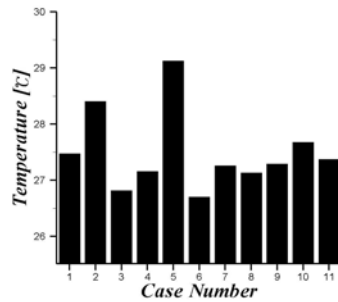Fig. 15. Average temperature inside the computer for each ease.



Fig. 13. Temperature on CPU for each case.

outlet fans are installed at the back side (case 6), the temperature near the CPU is lowest at 28.1°C, but near the graphics card it is highest at 32.1°C. This result leads to the conclusion that creating a smooth air flow passage inside the computer and achieving a uniform temperature distribution is a more effective cooling method than simply increasing the cooling air flow rate at specific points within the system.

Fig. 15 shows the average temperatures inside the computer for each case. Through a thorough and comprehensive analysis of Figs. 13, 14, and 15, we concluded that case 11(Fig. 12) with a single front inlet fan, a single back outlet fan, and a single top outlet fan is the best arrangement in maintaining the inner air temperature to an appropriate level and effectively cooling the CPU and graphics cards. While

all cases using the outlet fan (cases 4, 6, 8, and 11) resulted in an effective internal cooling, case 5 with double inlet fans resulted in a higher average temperature than case1 without a cooling fan at all. As mentioned above, an oversupply of the intake air exceeding the discharge air capacity causes poor cooling effectiveness due to an obstruction to the flow of cooling fluid as well as the stagnation zone created inside the computer.

## 4. Conclusions

Experiments were performed to determine the effect of fan numbers and location on the cooling of a computer system. The results show that increasing the number of cooling fans increases the cooling effect, but too many fans can create an unstable air flow, resulting in a reduction in the cooling effectiveness.

For the effective cooling inside the computer, the amount of intake air should not exceed the amount of discharged air. It follows from the present experiment that the optimum cooling inside the computer was achieved when three fans were positioned in the inlet front, outlet back, and outlet top of the computer. Under this arrangement, not only was the average temperature maintained at an appropriate level, but also the CPU and graphics cards were cooled most effectively.

## Acknowledgment

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