Global Journal of Computer Science and Technology: H
Information & Technology
Volume 15 Issue 5 Version 1.0 Year 2015
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 0975-4172 & Print ISSN: 0975-4350

Enhanced Cooling of Laptop Computer for Improvement of Processing Performance

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Abstract- A major problems in the operation of laptop computers is overheating since it can affect the performance and stability, sometimes leading to system crash and hardware fatality. The objective of this work was to study the thermal behavior inside a laptop computer and to test the effectiveness of apropposed cooling method to overcome overheating problem. The proposed cooling system contained a thermoelectric device that reduced the intake air temperature into the laptop internal cooling system. An external exhaust blower, located at the exhaust air outlet of the laptop, was mounted to ensure sufficient air flow rate delivered by the cooling system. To assess the effectiveness of the system, temperatures of critical components in the computer were measured. It was found from the study that, under extreme utilization situation, the temperature of the graphic processing unit could increase to 99°C. The proposed cooling system could bring down the temperature by up to 6°C.

Keywords: computer; power electronics; laptop; overheating; cooking; heat dissipation; thermoelectric.

GJCST-H Classification: B.5.2 B.7.1

ENHANCEDCOOLINGOFLAPTOPCOMPTERFORIMPROVEMENTOFPROCESSINGPERFORMANCE

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Enhanced Cooling of Laptop Computer for Improvement of Processing Performance

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Abstract- A major problems in the operation of laptop computers is overheating since it can affect the performance and stability, sometimes leading to system crash and hardware fatality. The objective of this work was to study the thermal behavior inside a laptop computer and to test the effectiveness of aproposed cooling method to overcome overheating problem. The proposed cooling system contained a thermoelectric device that reduced the intake air temperature into the laptop internal cooling system. An external exhaust blower, located at the exhaust air outlet of the laptop, was mounted to ensure sufficient air flow rate delivered by the cooling system. To assess the effectiveness of the system, temperatures of critical components in the computer were measured. It was found from the study that, under extreme utilization situation, the temperature of the graphic processing unit could increase to 99°C. The proposed cooling system could bring down the temperature by up to 6°C.

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I. Introduction

Laptop computer technology, especially in hardware development such as in processors, graphic cards and storage media are developing fast. Various powerful laptops have been built in order to fulfill consumer demands. For instance, Intel launched the 5th Generation Intel® Core ™ i7 Processors. It was the latest Intel® microarchitecture to deliver significant performance advancement which included vastly improved graphics, battery life and security for a zero compromise computing experience [1]. However, fast and multi-functional laptop computers tend to consume high electrical power, and at the same time generate more heat while in operation.

There are three main contributors of heat source in a laptop computer system; they are central processing unit (CPU), graphic processing unit (GPU) and hard disk drive (HDD) [2]. There are few factors that lead to laptop overheating. Poor ventilation system and flow circulation could be one of them; this could be due to poor design or clogging as a result of accumulation of undesired solid, such as dust, on heat sink or other components, which cause reduction on the heat dissipation rate [3]. Overheating can also be caused by high ambient temperature, for which the intake air temperature would be significantly higher than the recommended level. Another factor that can lead to overheating is overloading of the processordue to operations of many large programs con-currently [4].

Overheating of laptop computers is common especially if operated in rooms or areas with high ambient temperatures. This can lead to disruptions and, even worse, it can cause data and system failure. In addition, such a problem may lead to costly repairs or replacements of major hardware components. Common related symptoms of over heatingare lagging and freezing in operation while performing computing tasks[5]. Although, by default, a laptop computer is equipped with an internal cooling mechanism, the system is often not capable in maintaining appropriate operating temperature.

This objective of this work was to understand study the thermal behavior inside laptop computers in relation to healthy operations. In addition, the potential of an alternative cooling system based on Peltier effect was studied preliminarily in order to overcome overheating problem.

II. Methodology

Two experiments were carried out in order to study the effect of laptop overheating on the performance of the existing products. The first one involved measurement of processing time under different operating conditions. The other test was done by measuring the temperature difference at specific locations of the laptop component under different conditions.

The purpose of the first experiment was to study the effect of laptop computer overheating to its processing performance by comparing the times taken to complete an identified task under idle and busy operating conditions. The assigned task was for the computer to count and display prime numbers in between 0 and 5000 by using a java script program, which was originally written by Nicholson [6]. The tests were conducted under two conditions: (1) the computer was left idle for 30 minutes prior to test, and (2) the computer was loaded with high resources consuming software and applications for 30 minutes to cause overheating. For the second condition, all the applications then were turned off just before the tests were performed in order to avoid lack of resources

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which would consequently affect the processing time. For each condition, the test was repeated five times.

The purpose of the second experiment was to study the capability and weakness of the conventional laptop cooler by measuring temperatures at specific locations around the laptop components, with and without the presence of an external laptop cooler in three different room conditions. The temperature was measured by using third-party temperature measurement software, Speed Fan 4.33, to access the digital built-in temperature sensors of each component [7]. The built-in sensors were the silicon band-gap-type temperature sensors [8], which utilized the silicon voltage band gap (1.12 V at room temperature).

The proposed alternative cooling system based on Peltier effect [9] was designed with the setting shown in Figure 2. The cool air feeder was intended to function as supplier of cool air for the laptop ventilation system. It has a cooler which was built by using a thermoelectric device.

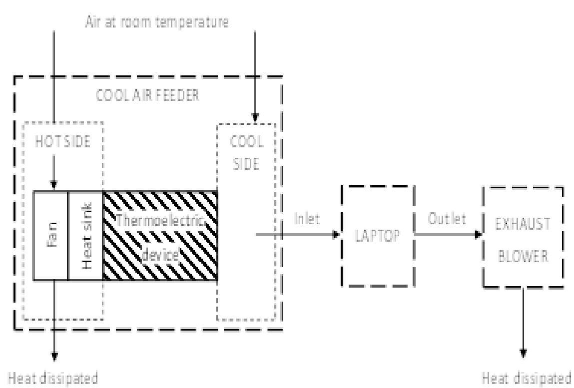

Figure 2 : Basic operation flow of the cooling system

The design concept of the cool air feeder is as illustrated in Figure 3, in which the thermoelectric device is shown located at the middle of the two different thermal zones (hot and cold zones).The exhaust blower was intended to extract the heat from the underside of the laptop. A blower fan was mounted to the end of the casing to discharge hot air from the laptop computer.

The cooling capacity of the thermoelectric device was determined based on the total heat generated by the main heat sources from the system components. The calculated total electric power was 44.6W based on four major components; i.e. computer processing unit (CPU, 33W), graphic processing unit (GPU, 7.5 W), hard disk drive (HDD, 2.1W) and random access memory (RAM, 2.0W). For simplicity, a thermoelectric device with cooling capacity of 45.6 W was chosen. It must be noted that the heat generated was expected to be lower than 44.6W. Furthermore, some of the heat may be dissipated through the keyboard area. The desired maximum temperature was set to 50°C, as recommended by Hand by [10].

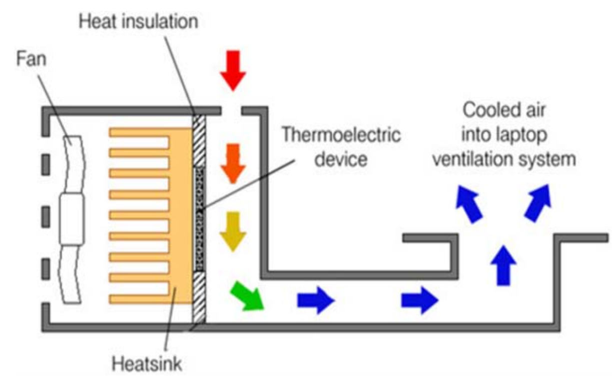

Figure 3 : Design concept of the cool air feeder

The heat sink mounted on the hot side of the thermoelectric device was an active-type heat sink, which was also used with Intel Processor 478-socket for personal computers. The unit was capable to dissipate 50 W of heat. The air flow for exhaust blower fan was determined using the simplified steady flow thermal energy equation and Newton's law of cooling. For the desired maximum temperature, the fan's flow rate must be larger than 700 liter per minute, with the consideration that the thermoelectric device temperature on the cold side was 10°C.

The proposed system was tested by measuring the temperature on both sides (hot and cold) of the thermoelectric device when the electrical current flowed through it. The test was carried out to assess the performance of the proposed prototype in comparison to traditional cooling devices. In this work, four sets of tests were conducted using different cooling methods.

The first set of test was a reference, which was intended to determine the maximum temperature that can be reached by the GPU under the manufacturer's design setting. The second set was for temperature measurement under passive cooling system, in which the laptop was tilted by 30° from the horizontal surface. The third set was different than the first one only by using a normal cooler pad. The last set was conducted by using the Peltier-effect cooling system proposed in this work.

III. Result and Discussion

Shown in Table 1 are the time taken for the laptop computer to perform the counting and displaying tasks under idle and busy operating conditions. The average and standard deviation for each condition as a result of five repeated measurements are also shown in Table 1.It is shown that the time taken for the task under overheated condition is significantly longer (by 36.6%) than that under idle condition. The small standard deviation indicates good repeatability of the measurements. This result clearly implies that in real processing conditions the laptop will take longer time to perform a process when it is overheated and thus this can lead to reduction in performance and dissatisfaction among users.

Table 1: Processing time under different conditions

Condition	Measurement (s)					Avg.	σ
	1	2	3	4	5		
Idle	8.45	8.78	8.58	8.64	8.67	8.63	0.10
Overheated	11.76	11.81	11.80	11.77	11.77	11.78	0.02

Table 2 shows the results of the temperature measurements at identified locations with in the laptop computer. Each of the temperatures displayed is an average value determined from five readings. Ventilation condition A was a condition, in which there was nearly no air movement and no mean of heat dissipation in the room (windows and doors were shut). Ventilation condition B had air movement in the room through operation of a ceiling fan and openings of windows and doors. Ventilation condition C was when the room was air-conditioned. For each reading, the laptop was left for 30 minutes under either idle or loaded condition. The highest temperature rise, as a result of loading, is shown for the HDD (at 8°C) under ventilation condition A.

It is clearly shown in Table 2 that at idling condition, the temperature differences due the different ventilating conditions are small with typical difference of 2°C; the highest difference of 3°C only occurred for the GPU. As anticipated, the temperature differences due to the different ventilating condition sare slightly higher when loaded (as compared to idling), with a maximum temperature of 4°C.

Table 2 : Measured temperatures of different components of laptop computer under different room ventilation conditions and different computer cooling systems

Cooling System	Sensor Location	Average Measurement (°C)					
		Idle Condition			Loaded Condition		
		A	B	C	A	B	C
Internal	HDD	52	52	50	60	57	56
	RAM	52	52	51	57	55	54
	Motherboard	55	55	55	58	58	57
	Processor	65	65	64	72	70	69
	GPU	97	96	94	99	99	97
Internal + External	HDD	51	50	49	55	55	53
	RAM	51	51	50	53	53	51
	Motherboard	54	54	54	57	57	56
	Processor	63	63	62	69	69	68
	GPU	97	95	94	99	98	97

The GPU is shown to experience the highest temperature (94°C to 99°C), while the HDD and RAM had the relatively lowest temperatures (49°C to 60°C). The measured temperatures for the GPU are shown in Figure 4. The black bars represent GPU temperatures when using internal cooling system for all room conditions; the white ones represent those using external cooling system. Overall histogram indicates that external cooling results in very small change in the GPU temperature. In short, the results in Table 2 and Figure 4 show that the room ventilation system within this study did not have significant effect in bringing down the temperature of laptop components, and thus introduction of a new cooling system would be justified.

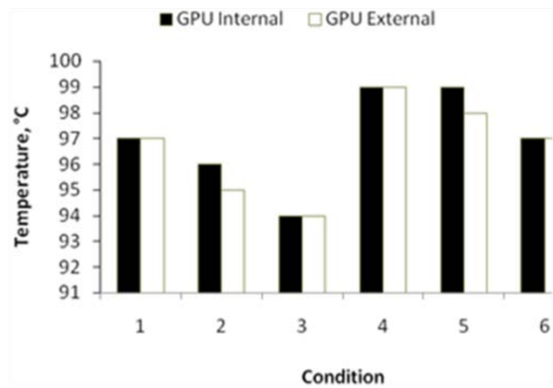

Figure 4 : Measured temperatures of the GPU

The proposed cooling system was tested out to assess its performance in comparison to or inary cooling devices. Measurements were made on the temperatures on both sides of the thermoelectric device during operation. Shown in Figure 5 is the variation of temperature with time from start of experiment. The red line represents temperature on the hot side, while the blue line represents that on the cold side.

The test was conducted for 60 seconds, during which the rate of change in temperature was approximately zero. It is shown that the minimum temperature on the cold side is 0°C and the maximum temperature at the hot side is 45°C. It was claimed by the manufacturer that the difference between the hot and cold sides could reach 69°C under ideal working condition. However, in this study, the difference was only about 65% of that claimed by the manufacturer.

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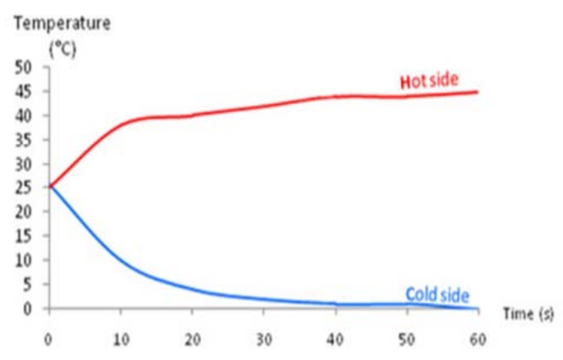

Figure 5 : Temporal variation of temperatures measured on surfaces of the thermoelectric device

The proposed prototype was tested for its feasibility. The result of the experiment for graphic processor unit (GPU) is shown in Figure 6, which displays histogram of the GPU temperatures under different cooling mechanisms. Obviously, the figure shows that reduction in GPU temperature as a result of installing the prototype was insignificant, that is only 4°C lower than the reference setup and 3°C lower than that with active cooling. Since the cool air was transferred through enclosed ducting into the laptop, it was suspected that there could be large pressure loss and thus resulting in poor air flow and heat convection. Further study would be made in order to improve the cooling.

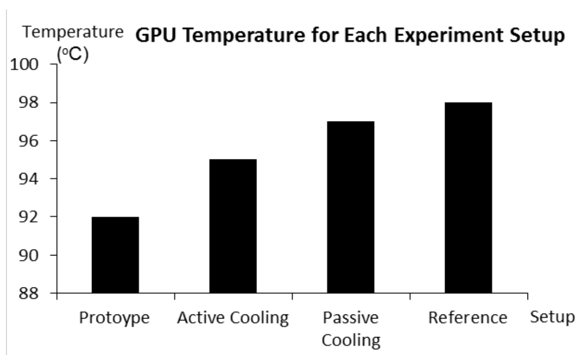

Figure 6 : Temperatures of GPU for different cooling mechanisms

IV. Conclusions

From the results, the prototype was failed to provide cooling solution at satisfactory rate. Although the experiment result was out of expectation, a series of future modification and recommendation have been suggested for the continuous development of the system.

In this work, the thermal behavior inside laptop computers was investigated. In addition, the potential of anewcooling system based on Peltier-effect was also tested. From the study, the following conclusions could be made:

1. The time taken for computation test under overheated condition was found to be significantly longer (by over 35%) than that under idle condition.
2. The commercial external computer ventilation system was demonstrated to be not significantly effective in reducing the components' temperatures especially when performing heavy loads.
3. The room ventilation system was found to not have significant effect in bringing down the temperature of laptop components.
4. The proposed Peltier-effect cooling system was found to be able to reduce the GPU's temperature by only 1°C relative to the commercial external ventilation system. It was suggested that this was due to poor air flow within the compartment of the prototype.

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