Development of an External Laptop Cooler with Thermoelectric Device

by

Wan Mohd Safwan Bin Wan Mazlan

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Mechanical Engineering)

JULY 2008

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Development of an External Laptop Cooler with Thermoelectric Device

by

Wan Mohd Safwan Bin Wan Mazlan

A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

(Ir. Dr. Shaharin Anwar Sulaiman)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2006

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

WAN MOHD SAFWAN BIN WAN MAZLAN

ABSTRACT

One of the major problems among laptops is overheating. Overheating laptop can give numerous effects in term of performance and stability: performing poorly which lead to lagging and freezing experience to the user or even crashing the system and caused hardware fatality. Laptops are basically equipped with internal cooling system in order to keep the temperature as low as possible. However, the internal cooling is simply not enough especially when the laptop undertakes simultaneous tasks or processes. Although various external laptop coolers are available in the market, they are yet to be a promising solution to the overheating problem. The objective of this research project is to develop an alternative design for external laptop cooling to overcome the overheating problem. The proposed cooling system contains of two main parts. The first part, which is the cool air feeder, thermoelectric device is used to control the temperature of intake air into the laptop internal cooling system. The second part, which is the external exhaust blower, is located at the exit point of laptop ventilation system to assist and increase the air flow rate. The effect of laptop overheating is studied through experiment of induced overheating and performance of the laptop. To install the thermoelectric device on the proposed cooling system, the characteristic and handling of the device is analyzed. The prototype casing of the cooling system is designed so that compatibility with various models of laptop is not an issue. The prototype has been tested and comparison with existing cooling solution has been made. Recommendations for future development have been discussed.

ACKNOWLEDGEMENT

First and foremost, I would like to thank the lord for constantly giving the strength and courage in completion of this project. Even in good and bad times of the semester where many obstacles were faced and overcome.

Secondly, a handful of appreciation is dedicated to my project supervisor, Ir. Dr. Shaharin Anwar Sulaiman who was responsible for supervising me throughout the period of this project. He have given the guidance and advice needed in the process of completing the final year project. The time spent and endless support that he has given to me is highly appreciated.

A special thanks goes to all of my colleagues for continuously supporting me in solving some problems occurred in this project. I appreciated the time spent and all positive comments given which are critical to improve my project.

Also not forgetting the support, encouragement and love from my family and friends that has kept me going throughout the process. Last but not least, I would like to express my sincere gratitude towards the FYP coordinator, Dr. Puteri Sri Melor Bt Megat Yusoff and members for providing the assistance and guidelines for the project.

Finally I thank UTP, for providing me the necessary facilities in completing this project. I thank God again for the blessings he has given me in completing this final year project and the strength during the endless time spent and constant hardship I endured during the whole period of this project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Laptop technology, especially in hardware development such as in processors, graphic cards and storage media is aggressively developed nowadays. Various powerful laptops have been built in order to fulfill consumer demands. For instance, Intel launched its dual-core processor-based platform for laptop in February 2006, and in January 2007, Intel's quad-core processor-based platform has been used by Sager for their NP9262 laptop series (Intel Corp., 2008). However, a fast and multi-functionality laptop tends to consume more electrical power. As the result, it will generate more heat while in operation (Incropera et al., 2007).

Almost all laptop users will experience laptop overheating during the usage, especially if operated in rooms or areas with high ambient temperatures. This will lead to uncomfortable situation to the users, and even worse, it will cause data and system failure. Hard Knocks (2007a) explained that typical problems that usually occurred are reduction in performance such as lagging and not responding, sudden shutdown, unexplained memory or operation errors, and inexplicable BSOD - blue screens of death. Thus, the phenomenon of laptop overheating seems to be common and this is not a good sign for the user. It is identified that there are three main contributors of the heat source in a laptop system – central processing unit (CPU), graphic processing unit (GPU) and hard disk drive (HDD). However, it is not only limited to this main component.

There are few factors that lead to laptop overheating. Poor ventilation system and flow circulation could be one of them. It is either poorly designed, or the ventilation system is clogged with undesired solid such as dust, thus reduce the rate of heat transfers (Hard Knocks, 2007b). Laptop overheating also can be caused by high ambient temperature, where the intake air temperature is significantly higher than desired temperature. The convective heat transfer equation is given as:

$$q = \bar{h}A_s(T_s - T_\infty) \tag{1.1}$$

where $\bar{h}$ is the average convection coefficient, and A_s is the surface area, the heat transfer rate, q, is directly proportional to the difference of surface temperature, T_s, and ambient temperature, T_∞. As the intake air temperature (which is also T_∞) is increased, the heat transfer rate of internal laptop cooling system is decreased, and thus the laptop becomes overheated.

The third factor that leads to laptop overheating is overloading in the processing within the laptop itself (Hard Knocks, 2007c). When a laptop is intensively used, especially during operation such as gaming software, antivirus scanning, program compiling, video editing, and others memory consuming processes, the processing hardware tends to operate at higher capacity and produces more heat. If this excessive heat is uncontrollable, laptop overheating might happened.

Laptop overheating not only causes interference to the user but could also involve high cost in replacing the major hardware. Common related problems are laptop lagging and operation-freezing while performing specified tasks. As a further consequence, the laptop overheating might shut down automatically due to crash in the operating system. If the overheating condition becomes worse, of which the working temperature exceeds the design temperature for the laptop component, hardware failure may occur and this may lead to permanent dysfunction.

Although laptops are equipped with internal cooling system by default, the system just cannot hold the operating temperature to the desired one. There are several types of external laptop cooler devices, or known as cooler pad, available commercially, ranging from passive cooling to active cooling, to support heat dissipation process. However, even those are not capable to achieve the target. Furthermore, particular cooler pad will only work best within a specified range of laptop model while others do not. This depends on the design of the cooler pad and the laptop itself, in which the resemblance of the cooler pad blowers and the laptop ventilation inlet is critical.

1.2 OBJECTIVE

The main objective of this project was to develop an effective external cooling system for laptop incorporating thermoelectric device and exhaust blower in order to achieve suitable laptop operating temperature. The system was expected to be able to dissipate heat from the laptop body at a satisfactory rate, in order to give significant temperature decrease as compared to traditional cooling method.

1.3 SCOPE OF WORK

The main tasks in this project were to design and fabricate the prototype of the cooling system. The design of the system relied mostly on theoretical study instead of lab experiment due to cost constraint of apparatus setup. However, specific lab experiment for component and performance testing was conducted if considered as critical towards the project development. The cooling system will be designed to achieve specified target and the prototype of the external cooler was fabricated in order to produce a real scale functioning system. A module of prototype performance test was carried out at the end of the project to assess the performance of the system.

CHAPTER 2

LITERATURE REVIEW

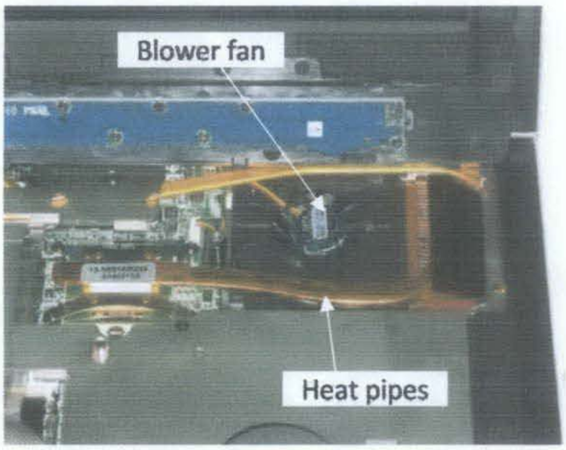
2.1 INTRODUCTION

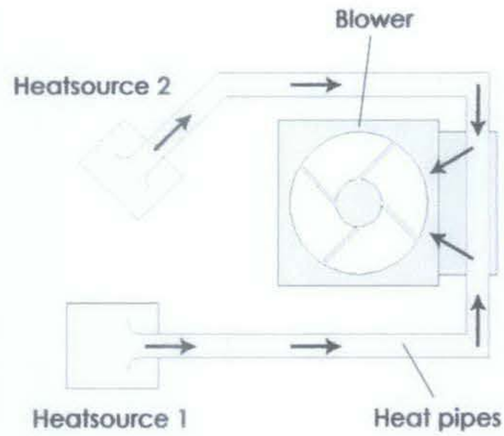
Laptop is defined as a portable microcomputer having its main components (as processor, keyboard, and display screen) integrated into a single unit capable of battery-powered operation (Mish, 2003). Having those high performance microchips and microprocessors, laptop tends to generate thermal energy during operation. Handby (2008) stated that modern laptop processors mostly operated at around 50°C at normal condition but can rise up to 90°C during peak usage.

Internal laptop cooling system usually comes in combination of heat pipes, heat sinks, and fan as shown in Figure 2.1. However, the cooling system cannot afford the amount of heat produced during the operation and obviously require external solution to deal with the heat. External laptop cooling can generally be divided into two main types which are active cooling and passive cooling. Active cooling is a cooling system with the presence of fan or blower, and passive cooling is the one that relies on natural heat transfer of either conduction or convection.

A typical laptop active cooling may consist of up to four fans, depending on the computer specification. The fans are installed to provide better air flow for the laptop to enhance heat dissipation process. If fans with same capacity are considered, the more fans are mounted, the better is the airflow. Good airflow provides a better heat dissipation process. However, the used of more fans will lead to extra power consumption. As the laptop coolers are generally powered by the laptop itself through

(USB) cable, this will consume a lot of the battery power and thus will shorten the laptop's operating duration.





(a) (b)

Figure 2.1: Typical internal laptop cooling system (a) picture of cooling system (Kirsch, 2004), (b) schematic.

Figure 2.2: Elevation angle technique in passive cooling (Hilal, 2007).

As for passive cooling, the laptop is elevated at certain angle, θ, of typically between 10° and 30°, to provide ample space for natural air flow to be supplied to the laptop internal cooling system as shown in Figure 2.2. This system will produce a silent solution but with limited capability. This can be explained by the cooling system for an Otto-cycle engine. Single-cylinder system with lower heat rate will only require forced air to cool the system down during operation while four-cylinder system with higher heat rate will need both forced air and water cooling. Furthermore, improper elevated height and angle will create discomfort among users.

2.2 ESSENTIALS COMPONENT

2.2.1 Thermoelectric Device

The thermoelectric device is the core component used in this project. Until the time when this report is written, there has been no commercial development of laptop cooling system incorporating thermoelectric device yet. The nearest application of thermoelectric device in computers cooling solution is the cooling system of personal computer's processors modified by individuals who overclocked (push up the process more than the factory setup) the system. In this case, the processor generates more heat and need to be cooled down rapidly by using thermoelectric device.

Thermoelectric device is a solid state device which can convert the electric current to temperature gradient. It basically applies Peltier effect which is one side of a junction of two different electrical conductors will get cold and another will get hot when the current is passing through. The basic working principle of the thermoelectric device is, the heat from the hot side has to be removed and the better the heat removal, the cooler the other side will be (Lewis, 2006). Thermoelectric device utilizes bismuth telluride, a quaternary alloy of bismuth, tellurium, selenium and antimony, sandwiched by two metalized ceramic substrates as depicted in Figure 2.3. The pellets have been doped in order to make one type of charge carrier carries the majority of current. Also, they are arrayed in positive-negative configuration to allow them to be electrically connected in series but thermally in parallel (Redfish Photonics, 2008).

At the cold side, energy (heat) is absorbed by electrons as they pass from a low energy level in the p-type semiconductor element, to a higher energy level in the n-type semiconductor element. The power supply provides the energy to move the electrons through the system. At the hot side, the energy is transferred to a heat sink as electrons move from a high energy level element (n-type) to a lower energy level element (p-type). The thermoelectric device performance basically relies on few variables such as ambient temperature, heat load, efficiency of heat sink or cold plate and wattage of the power supply.

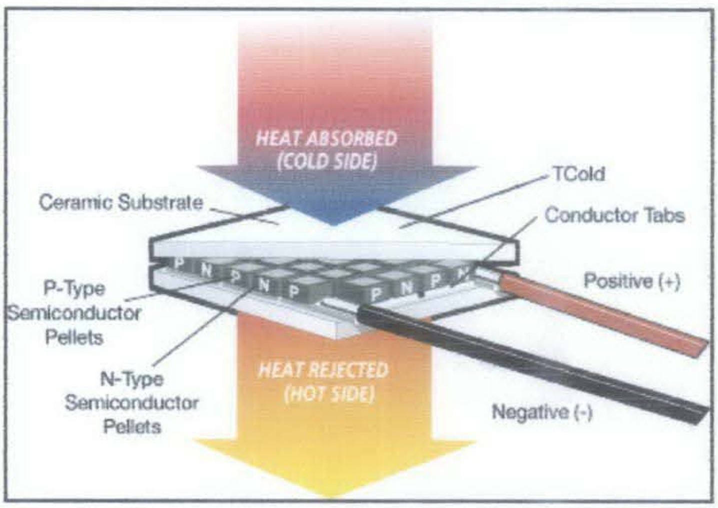
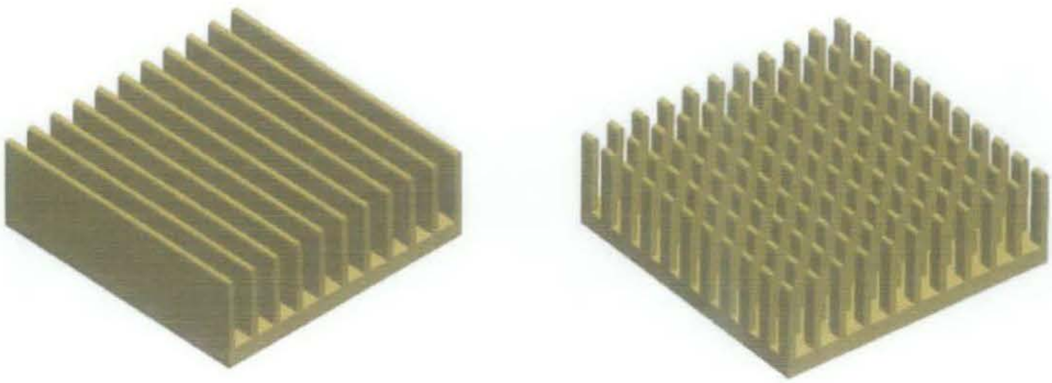


Figure 2.3: Thermoelectric device structure (Tellurex Corporation, 2008).

2.2.2 Heat sink

Heat sink is a metal component, usually with high specific heat capacity, used to absorb and dissipate heat from heat source by thermal contact. There are two main categories of heat sink – passive heat sink and active heat sink. Passive heat sink operates without a fan and use natural convection to dissipate heat while active heat sink operates with fan for forced convection. As heat transfer rate increased by increasing the surface area where the convection occurs, fins that extend from the wall into the surrounding fluid are employed. There are several types of fin configuration for heat sink. Some of the common ones are straight fin and pin fin as shown in Figure 2.4.



(a) (b)

Figure 2.4: Heat sink (a) Straight fin, (b) Pin fin (Advance Thermal Solution, 2008).

The common materials used to fabricate the heat sink are copper or aluminum or the combination of both. In most cases, where material cost and fabrication cost are taken into consideration, aluminum will be used as it is inexpensive and relatively easy to fabricate due to its softness (Steinbrecher, 2008). On the other hand, when the level of thermal management is critical, copper might be chose as its thermal conductivity is twice as aluminum, thus makes it an excellent material for heat sinks.

The efficiency of heat sinks performance is depending on various parameters such as types of heat sinks, nature of application (passive or active) and so on. The volumetric heat transfer efficiency is used to quantify the effectiveness of different types of heat sinks, and can be defined as,

$$\eta = \frac{Q}{\dot{m}c\Delta T_{SA}} \tag{2.1}$$

where Q is the total heat dissipated, $\dot{m}$ is the mass flow rate through the heat sink, c is the heat capacity of the fluid, and ΔT_{SA} is the average temperature difference between the heat sink and the ambient fluid (Lee, 1995). Table 2.1 showed the range of heat transfer efficiencies based on heat sinks types.

Table 2.1: Range of heat transfer efficiencies.

Heat Sink Type	**Efficiency, η (%)**
Stampings & Flat Plates	10 – 18
Finned Extrusions	15 – 22
Impingement Flow Fan Heat Sinks	25 – 32
Fully Ducted Extrusions	45 – 58
Ducted Pin Fins, Bonded & Folded Fins	78 - 90

Heat sink design plays a big role in cooling application. A poorly designed heat sink might end up with heating up the devices instead of cooling it. The important factors in designing heat sink are the material, dimension of the heat sink, and overall surface heat transfer coefficient. The heat sinks used in electronic peripherals are designed based on specific thermal design power (TDP), which indicates the maximum heat power that need to be dissipated by the cooling system of the particular device (Chin, 2004). Figure 2.5 shows typical heat sink used in laptops.

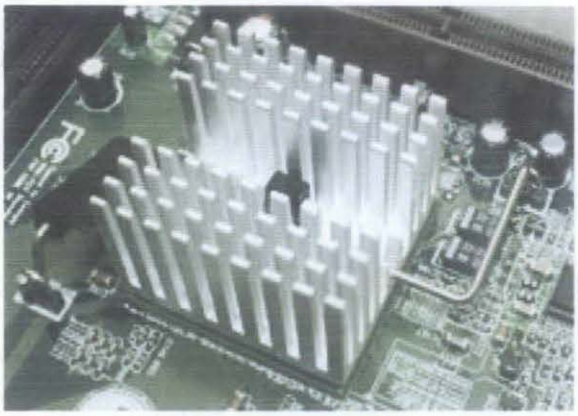


Figure 2.5: Typical heat sink used in laptops (Rutter, 2007).

CHAPTER 3

METHODOLOGY

A series of fundamental activities were planned throughout the project as shown in the Gantt chart in Appendix I. The flow of the project work is shown in Figure 3.1 and is elaborated in Sections 3.1 to 3.4. A detailed flow chart is shown in Appendix II. The project was generally divided into four main categories which were the preliminary data gathering, design of prototype, fabrication of prototype, and prototype performance testing. The first two parts were covered in the January 2008 semester and two remaining parts were covered in the July 2008 semester.

3.1 PRELIMINARY DATA GATHERING

The elements used in this project were determined by detailed research. This included study on thermoelectric operation principle and behavior, heat sink profile and attribute, exhaust blower system, material handling and proper assembling process. To come out with the new design, the desired operation temperature and the heat dissipated by the laptop were determined. Two experiments were carried out in order to study the effect of laptop overheating on the performance of the existing products.

3.1.1 Effect of Overheating to Processing Performance

The purpose of the first experiment was to determine the effect of overheating to the processing performance of the laptop. In this experiment, a java script program originally written by Nicholson (1996) as shown in Figure 3.2 was used with Internet

Explorer 6 web browser to observe the time taken by the laptop to count prime numbers from 0 to 5000 under normal and overheated conditions. The time taken for each attempt indicated the processing performance of the processor, in which a longer time taken implies a lower performance.

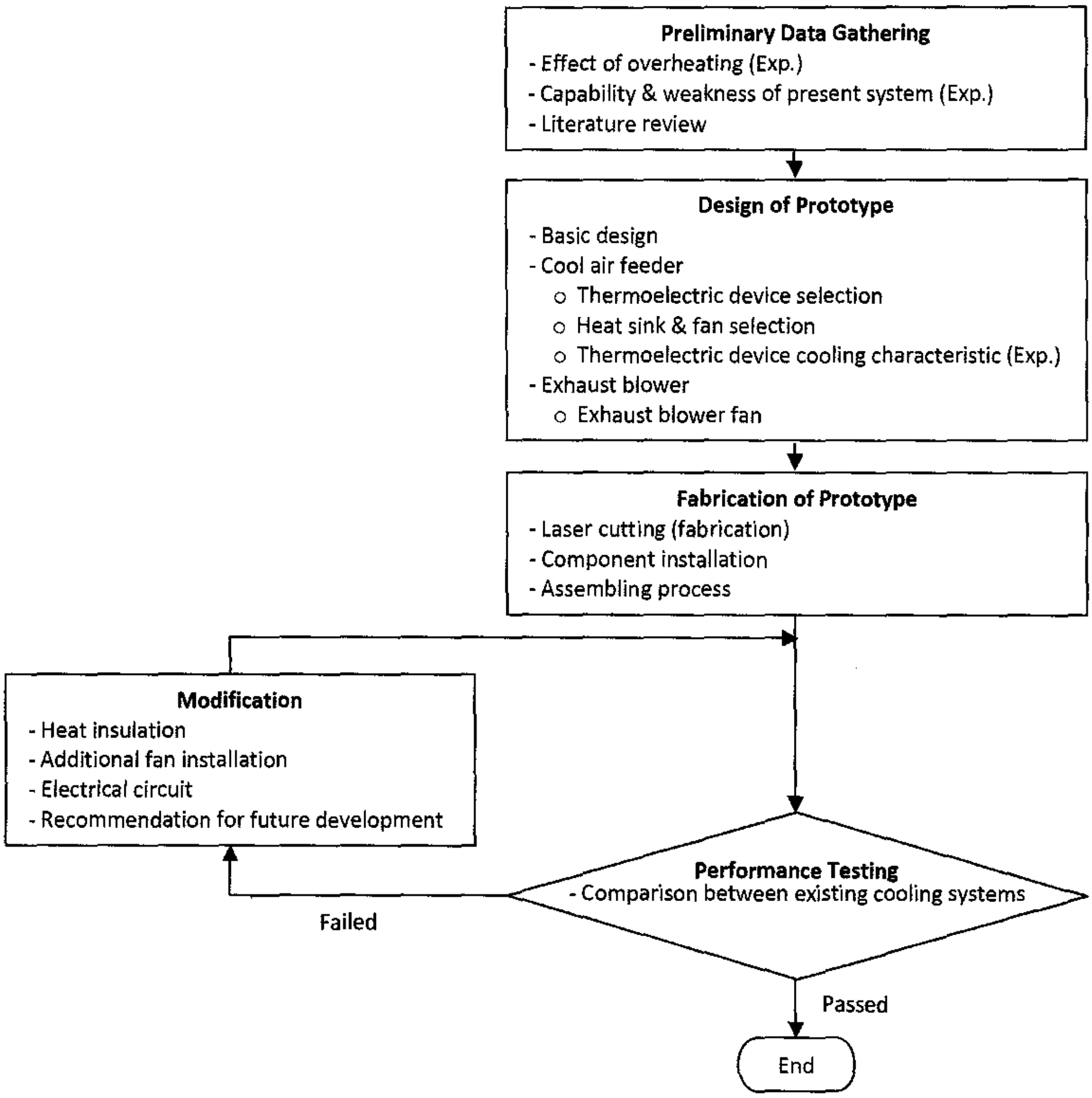
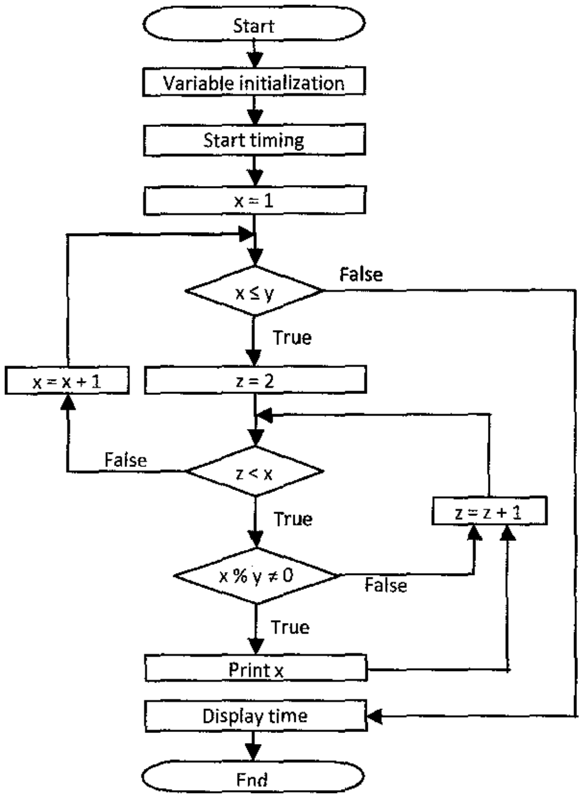


Figure 3.1: Flow chart of the project work.

Five measurements were taken for each condition. The first condition was the idling operating temperature where the laptop was left for 30 minutes without any load. The second condition was the peak operating temperature where the laptop was fully loaded with high resources consuming software and applications for 30 minutes to "heat up" the laptop. All of the applications then were turned off before the tests were performed to avoid lack of resources affect the processing time.



Prime Number Counter – Java script

```
<script>
var x=1;
var y=5000;
var z;
var w=new Date(), starttime=(w.getTime());
for(x=1; x<=y; x++)
{
        prime=1;
        for(z=2; z<x; z++)
        if(x%z==0) prime=0;
        if(prime) document.write(x+" ");
}
var t=new Date();
var endtime=Number(t.getTime());
alert(Time taken = (endtime-starttime)/1000);
</script>
```

Figure 3.2: Pseudo-code and JavaScript code used in processing time experiment; reproduced from Nicholson (1996).

Based on the result in Table 3.1, there are significant differences between the time taken between idle condition and overheated condition where the latter took longer time (36.6% longer) to perform same task. This result indicates that, in real processing activity the laptop will take longer time to perform a process when it is overheated thus will lead to lag and freeze the laptop.

Table 3.1: Result of processing time experiment in seconds.

Condition	Measurement (s)					Avg.	σ
	1	2	3	4	5		
Idle	8.453	8.781	8.578	8.641	8.672	8.625	0.108
Overheated	11.762	11.811	11.803	11.779	11.765	11.784	0.020

3.1.2 Strength and Weaknesses of Existing Cooling Solution

The purpose of the second experiment was to study the capability and weakness of the conventional laptop cooler by measuring the temperature difference at specific location of the laptop component, 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, SpeedFan 4.33, to access the digital built-in temperature sensors of each component (Comparetti, 2008). The built-in sensors were the silicon-bandgap-type temperature sensors, which utilized the silicon voltage bandgap (1.12V at room temperature) for the temperature measurements (Smith, 1999).

In this experiment, the temperature from different critical area was measured under different room conditions. Table 3.2 shows the results of the experiment. The temperature measurements of each column are the average value out of five readings. Condition A was a controlled condition where there was no air movement and heat source in the room. Condition B was a normal room condition with air movement. Condition C is air-conditioned room. For each reading, the laptop was left for 30 minutes under either idle or loaded condition. This is to let the temperature of the laptop to stabilize first so more accurate value can be obtained.

The result for the GPU is shown in the bar chart in Figure 3.3. The data obtained from this experiment is plotted as a bar chart according to the component for cooling system comparison as shown in Appendix V.

Table 3.2: Result of temperature measurement experiment in °C.

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

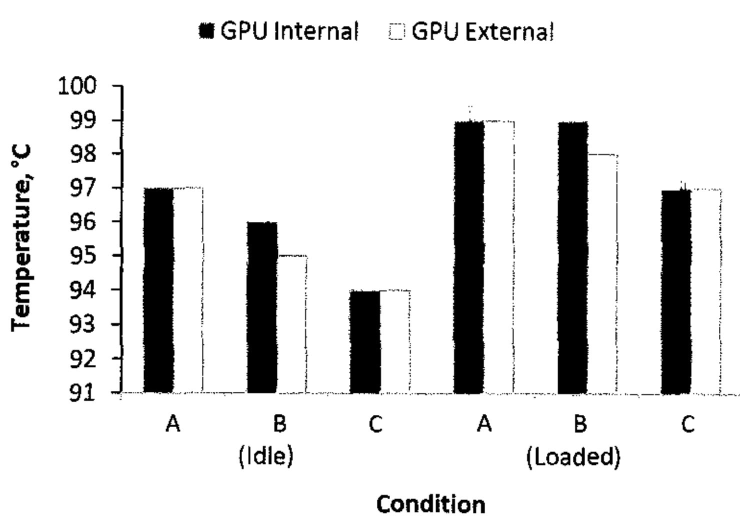


Figure 3.3: Temperature reading for GPU.

Based on the result, it is observed that the temperatures of motherboard and processor are independent from the room condition. This might be caused by the location of the sensors itself since they are built beneath the laptop housing so room condition cannot give significant effect to the temperature reading. As for the GPU, the room condition seems to give some differences but still not satisfying. The temperature measurement recorded the same regardless the cooling system used for the test. This might be caused by unparallel alignment between the laptop cooler blower and laptop ventilation inlet.

3.2 DESIGN OF PROTOTYPE

3.2.1 Basic Design

In the second phase of the project, the prototype was designed based on the information from previous research. For this purpose, a Compaq Presario V3415AU laptop was chosen as the experimentation device. The newly designed cooling system was generally divided into two parts – the cool air feeder and the exhaust blower. Figure 3.4 shows the basic operation flow of the proposed cooling system.

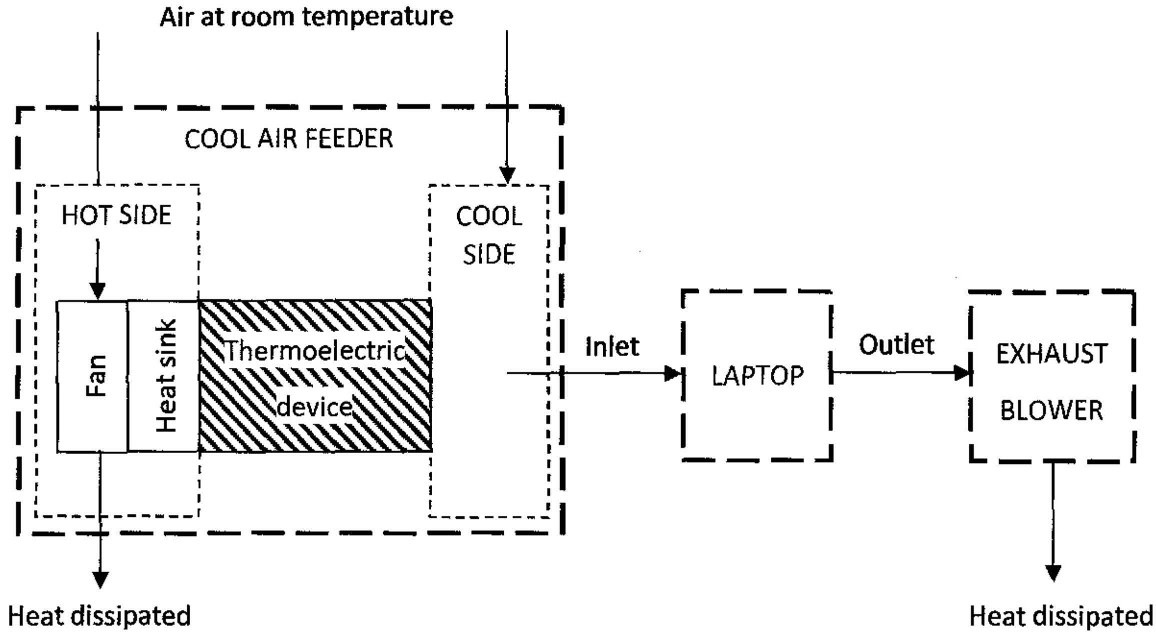


Figure 3.4: Basic operation flow of the cooling system.

3.2.2 Cool Air Feeder

The cool air feeder is functioning to supply the cool air to the laptop ventilation system. It has the cooled air intake for better cooling purpose which was built by using thermoelectric device. The design concept of the cool air feeder is as illustrated in Figure 3.5 where the thermoelectric device was located at the middle of two different thermal zones – hot and cold. The hot side of the thermoelectric device was attached to the heat sink and the cold side was exposed to the air in insulated housing to avoid it from being warmed up by external heat. Note that there was no fan installed at the cold side since the cooled air will be transferred into laptop ventilation system by the laptop fan itself.

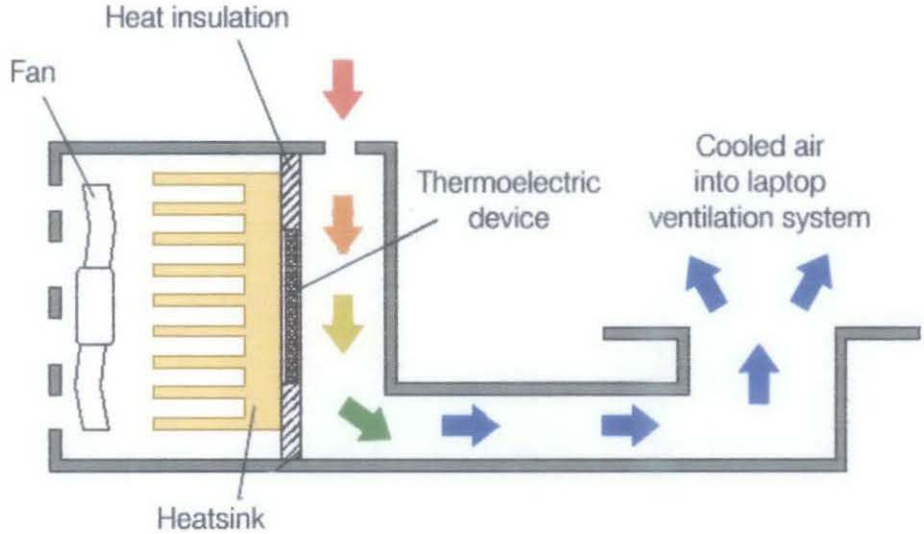


Figure 3.5: Design concept of the cool air feeder.

3.2.3 Exhaust Fan

The exhaust blower was functioning to forcedly extract the heat from the underside of the laptop. A blower fan was mounted to the end of the casing as shown in Figure 3.6. The casing was equipped with a clipping mechanism for attachment to the laptop ventilation outlet.

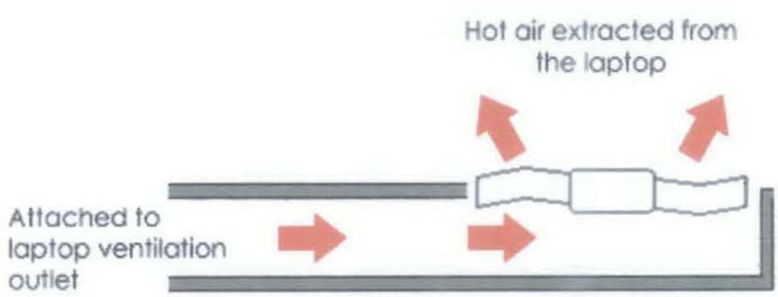


Figure 3.6: Design concept of the exhaust blower.

3.2.4 Thermoelectric Device Selection

To determine the specification of the thermoelectric device, the amount of heat generated by the laptop was determined first based on the components thermal design power (TDP), as explained in Section 2.2.2. Table 3.3 shows the TDP for each component as indicated on the component labels.

Table 3.3: Thermal design power (TDP) for each component in Watts.

Component	Model	TDP (W)
CPU	AMD Turion™ 64 X2 TL-56	33.0
GPU	NVIDIA GeForce 6150 Go	7.5
HDD	Samsung HM080GC	2.1
RAM	Kingston KVR667D2S5/2G	2.0
	TOTAL	44.6

For simplification, the overall TDP of 44.6 Watts was assumed as the heat load of the system. In real application, the amount of heat might be less since some of it can be dissipated through the keyboard area. The desired maximum temperature, T_{max}, for the device was set to 50°C as suggested by Handby (2008) in Section 2.1. Based on these assumptions, the thermoelectric device with cooling load of 45.6W is selected. The thermoelectric device is shown in Figure 3.7 and the specification of the device is shown in Table 3.4.

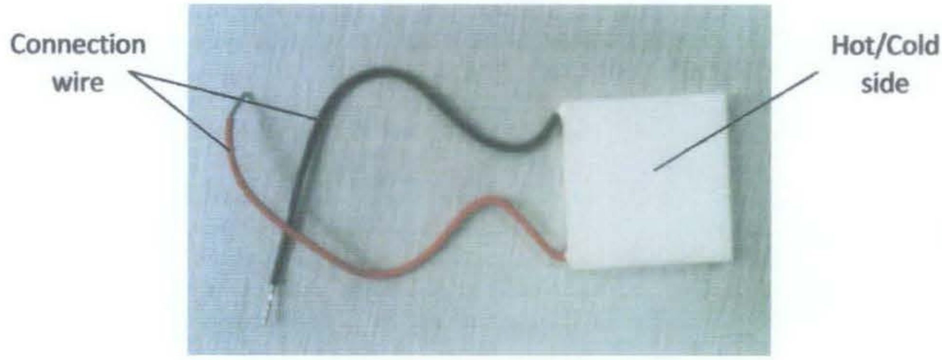


Figure 3.7: Thermoelectric device.

Table 3.4: Specification of selected thermoelectric device.

Specification	Value
Cooling Power	45.6W
V_{max}	12V
I_{max}	3.8A
ΔT_{max}	69°C
Dimension	40 x 40 x 5 mm

3.2.5 Heat Sink & Fan Selection

The heat sink mounted on the hot side of the thermoelectric device was selected based on the heat sink design specification. It was an active type heat sink and was generally used with Intel Processor 478-socket for personal computers to dissipate 50W of heat. Figure 3.8 shows the heat sink fins heat dissipation and fin efficiency of the selected heat sink as obtained from Frigus Primore Online Heatsink Tools.

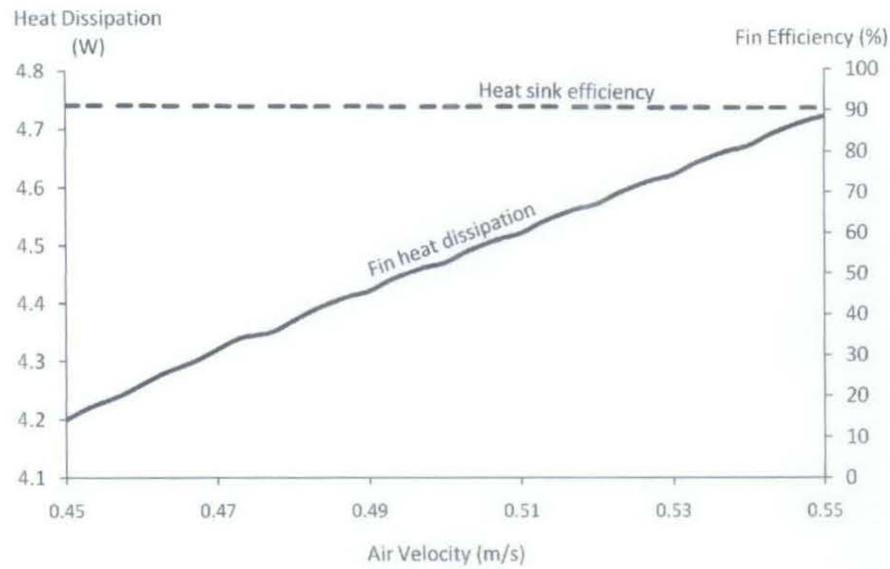


Figure 3.8: Variations of heat sink fin heat dissipation and fin efficiency with air velocity for aluminum heat sink, based on Frigus Primore Online Heatsink Tools.

In order to determine the fan flow rate for the heat sink, an additional 25% allowance have been considered as safety factor to the total heat generated by the thermoelectric device, Q_{tot} which is, $Q_{tot} = 1.25 \times 45.6W = 57W$. Thus, the heat should be dissipated by a single fin is $Q_{sf} = 57W / 13$ fins $= 4.38W$. From the graph, the fan air velocity is equal to 0.485 m/s. By using 80mm x 80mm fan, the flow rate of the fan is determined at 9.75×10^{-3} m^3/s or 20.67 cfm. Based on the specification, a fan with 29.07 cfm ± 10% was selected. The details of the fan are shown in Table 3.5.

Table 3.5: Specification of selected fan.

Specification	Value
Model	Cooler Master SAF-B83 Silence Fan
Dimension (W x H x D)	80 x 80 x 25 mm
Speed	2500 RPM ± 10%
Air Flow	29.07 cfm ± 10%
Air Pressure	2.8 mm H2O± 10%
Noise	26 dBA
Input Power	1.08 W

3.2.6 Exhaust Blower Fan Selection

The air flow for exhaust blower fan was determined using the simplified steady flow thermal energy equation and Newton's law of cooling, as represented by:

$$Q = \dot{m} \times c_p \times (T_e - T_{max}) \tag{3.1}$$

$$Q = \bar{h} \times A_s \times (T_s - T_m) \tag{3.2}$$

where Q is the thermal design power, $\dot{m}$ and c_p are the mass flow rate and the heat capacity of the air, T_e is the air temperature entering the laptop, $\bar{h}$ is the average convection heat transfer coefficient, A_s is the internal laptop surface area, T_s is the surface temperature, and T_m is the mean temperature. Figure 3.9 shows various temperature values with respect to the blower flow obtained from calculation using equations above. From the chart, it is theoretically concluded that, to achieve T_{max} = 50°C, the blower fan flow rate must be higher than 0.017 m^3/s and the thermoelectric device cold side must be able to cool down until 10°C.

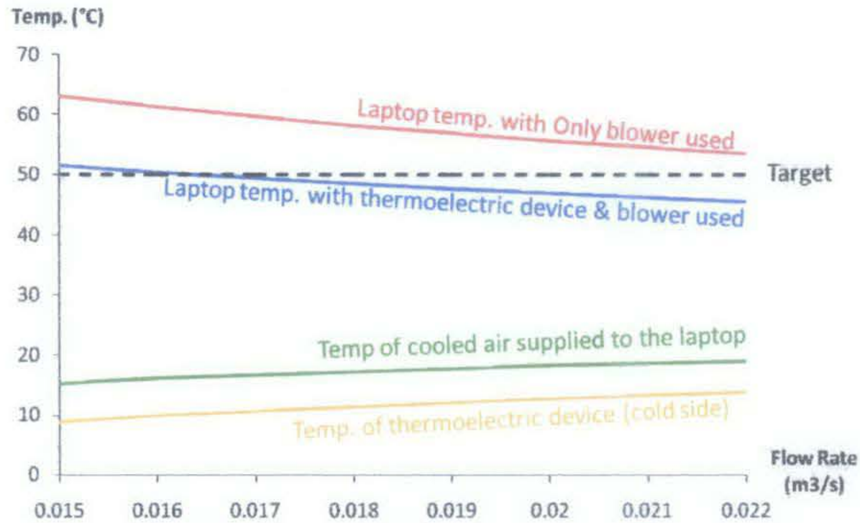


Figure 3.9: Theoretical temperatures with respect to the blower flow rate as calculated using Equation 3.1 and 3.2.

3.2.7 Thermoelectric Device Experiment

An experiment was conducted to test the cooling characteristics of the thermoelectric device as shown in Figure 3.10. The experiment was done by measuring the temperature of both sides (hot and cold) of the thermoelectric device when the electrical current flowed through it. The experiment also determined whether the thermoelectric device was able to achieve the desired temperature of 10°C at the cold side as rated by

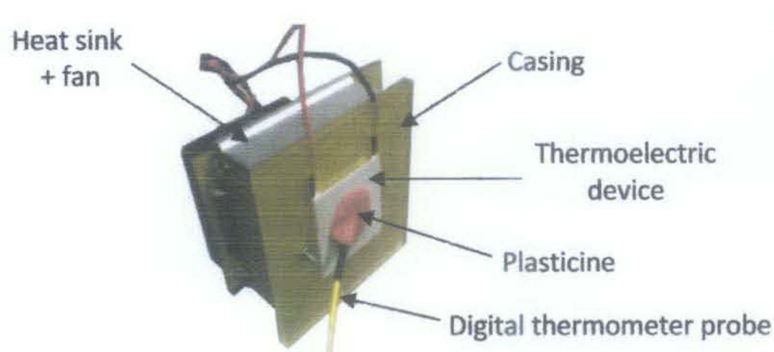


Figure 3.10: Thermoelectric device cooling characteristic test.

manufacturer. Figure 3.11 shows the schematic diagram of the experiment apparatus setup. The thermoelectric device was connected to 12V DC 3.8A power source.

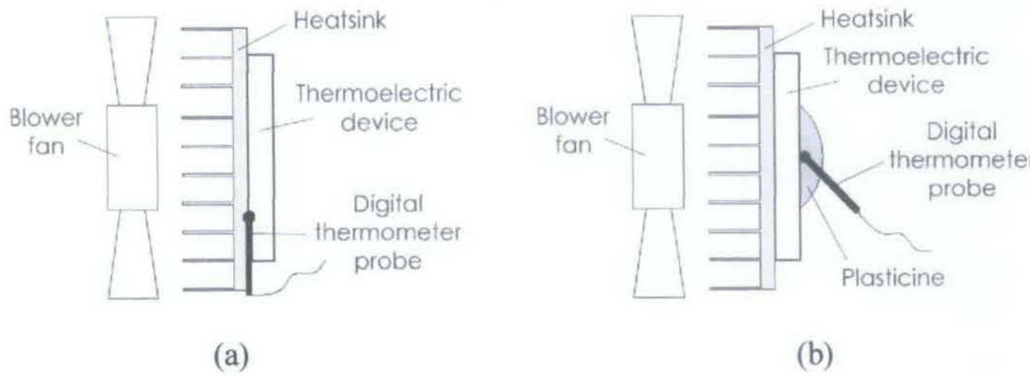


Figure 3.11: Thermoelectric experiment apparatus setup (a) Hot side temperature measurement (b) Cold side temperature measurement.

From the experiment, the thermoelectric device temperature characteristic graph is plotted as shown in Figure 3.12. From the chart, it is observed that the minimum temperature at the cold side is 0°C and the maximum temperature at the hot side is 45°C. The difference between the hot and cold side was about 65% from the manufacturer's data which is 69°C for ideal working condition. From Section 3.2.6 it is known that the design requirement for the temperature of thermoelectric device is 10°C. Thus this thermoelectric device satisfies the design requirement of the prototype.

However, there might be some error in hot side temperature measurement as the thickness of the thermometer probe disrupts the contact area between the heat sink and the hot side of the thermoelectric device as shown in Figure 3.13. To overcome this problem, it is recommended to use film type probe in this experiment to improve the effective contact area.

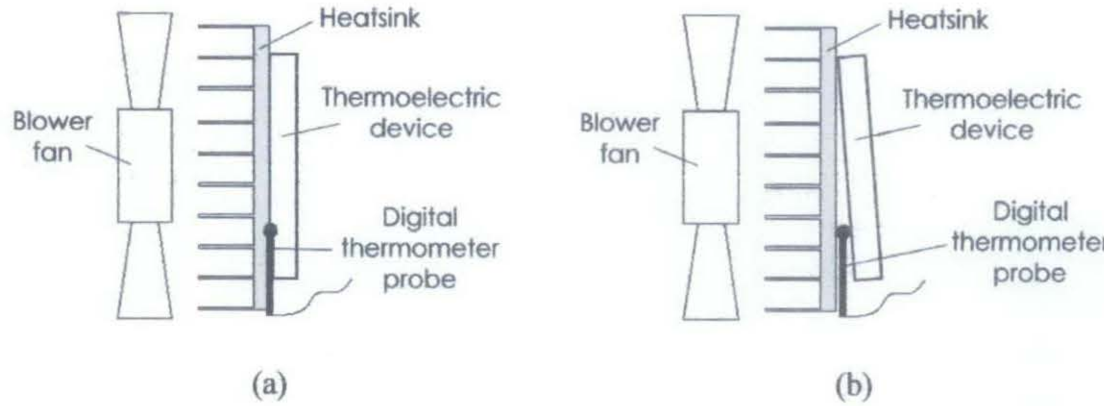


Figure 3.13: Apparatus setup for hot side temperature measurement (a) ideal setup (b) actual setup.

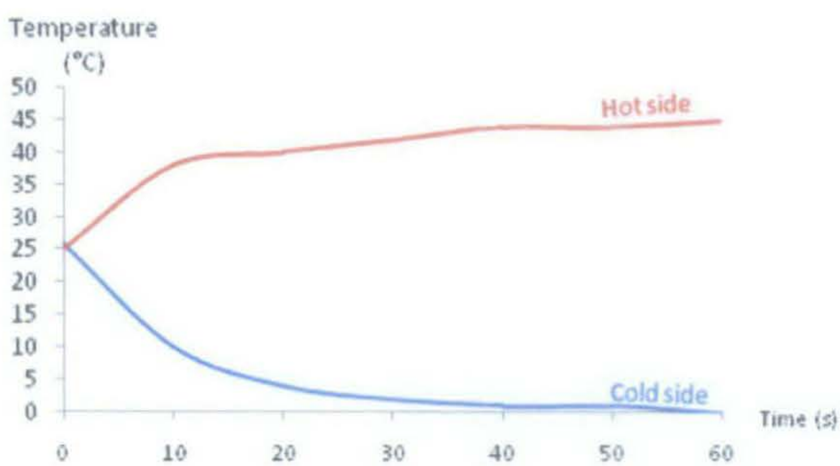


Figure 3.12: Temporal variation of temperatures measured on the surfaces of the thermoelectric device.

3.3 FABRICATION OF PROTOTYPE

As explained in Section 3.2.1, the proposed cooling system contained of two main parts which were the cool air feeder and exhaust blower. The designs for both casing prototype were drawn by using AutoCAD 2006. Precise laser cutting process was selected to ensure the smooth edge of the casing part. The same material, of 3 mm thick clear acrylic sheet was used to fabricate both casings.

3.3.1 Material Selection

Of the various fabrication materials available, acrylic (polymethyl methacrylate) was chosen to be used as the materials to fabricate the prototype casings. The reason behind this selection was that acrylic had desired properties and preferable to be used generally in prototyping. Some of the acrylic properties are that it has good impact strength and easy to be processed especially by using laser cutting process thus made acrylic a handy material (Blachford, 2008).

3.3.2 Cutting Technique

The prototype was formed from the assembly of various pieces of processed acrylic. As the precision in this stage was critical to ensure that the acrylic pieces can be joined perfectly, precision laser cutting method was used to fabricate the acrylic pieces. Precision laser cutting is a process of melts, burns, vaporizes away the specific material by using high power pulsed laser beam to produce preferred product with cutting tolerance of 0.1 mm (Steen, 1998). For this project, the cutting was done by an external party which was Laser Cutting Engineering Sdn. Bhd.

3.3.3 Assembly Process

Besides the properties of acrylic described in Section 3.3.1, acrylic also can be diffused by using special chemical bonding agent. This technique was used to assemble the acrylic pieces to form the casing. Chloroform was used in order to melt the acrylic pieces and the pieces diffused to form permanent joint. The process was done by the author in the mechanical laboratory during the project period. The parts were joined one by one with the sum of 48 joint for overall process. Each joint will be left dried about 3 minutes before continued with another joint.

3.3.4 Technical Drawing

The cool air feeder, as shown if Figure 3.14 is the main part, of which the size was 22.7 cm in length, 10.9 cm in width and 9.1 cm in height. The technical drawing is shown in Appendix III. This part contains of the thermoelectric device, fan and heat sink. The section of the air feeder is tabulated in Table 3.6.

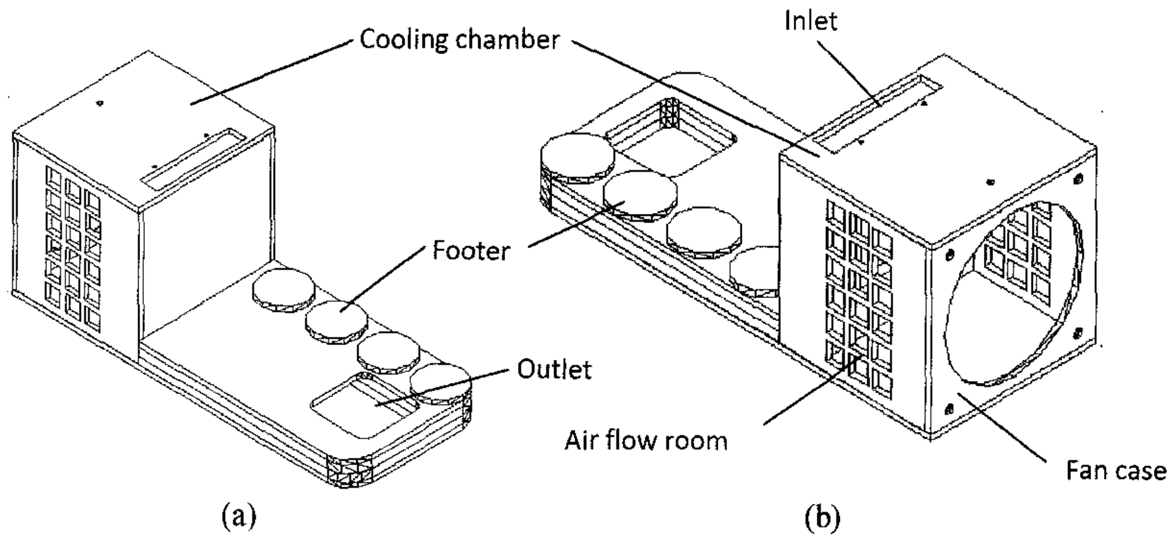
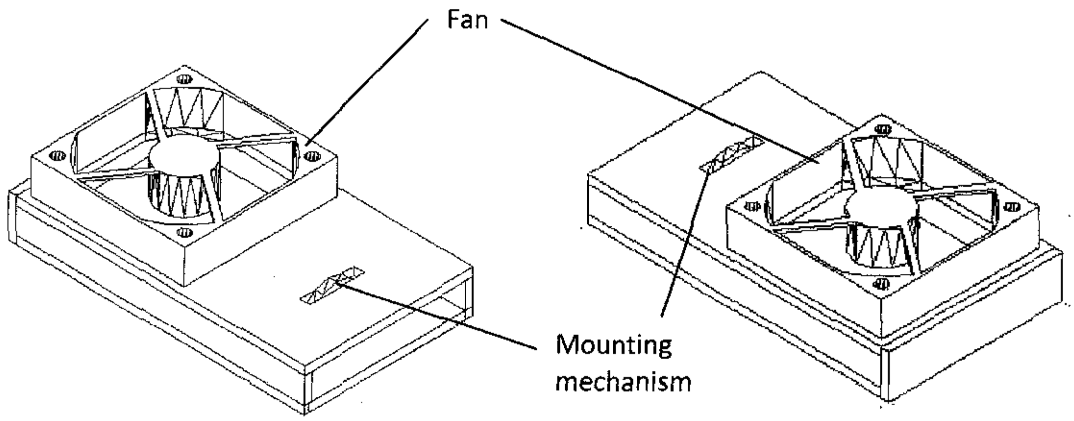


Figure 3.14: The cool air feeder (a) SE Isometric (b) NW Isometric.

Table 3.6: The sections of cool air feeder.

No.	Component	Function	Qty.
1	Cooling chamber	Contains thermoelectric device to cool down the air before supplied to the laptop.	1
2	Inlet	The way where the air entered the cooling chamber.	1
3	Outlet	The way where the air entered the laptop ventilation system.	1
4	Fan case	The section to install fan for heat sink cooling purpose.	1
5	Air flow room	The room for better air flow for heat sink cooling purpose.	2
6	Footer	To be used as laptop foot together with the cooler	4

The exhaust blower, as shown in Figure 3.15 size is about 11.6cm in length, 6.6cm in width, and 2.9cm in height. The technical drawing is shown in Appendix IV. This part contains of a blower fan and attaching mechanism. Figure 3.16 shows how the laptop is mounted with the cooling system.



(a) (b)

Figure 3.15: The exhaust blower (a) SE Isometric (b) NW Isometric.

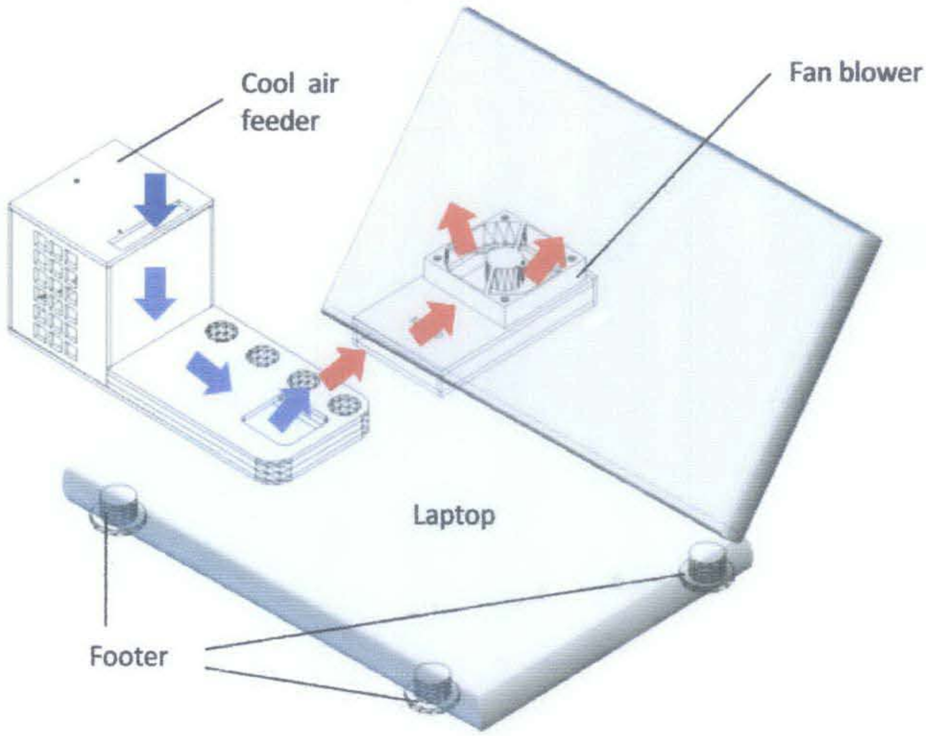


Figure 3.16: Laptop is mounted with the cooling system.

3.4 PERFORMANCE TESTING

An experiment was carried out to assess the performance of the prototype as comparison with the traditional cooling devices. In this experiment, four sets of tests were conducted using different cooling methods which are:

a) Reference system

   This set is to indicate how exactly the maximum temperature will be reached by the laptop for reference value. The laptop will be cooled by stock ventilation system.

b) Passive Cooling System

   This set is to test how much the temperature can be reduced by using passive cooling by elevating the laptop to certain degrees (15°-30°) from the horizontal surface.

c) Active Cooling System

   This set will use normal cooler pad and it will be the main comparison reference to the designed system.

d) Cooled Air Cooling System with Exhaust Blower

   This set is to test how much the temperature will drop and to be compared with other sets.

The experiment was done in normal room condition with air movement. The temperature recorded was 32°C. To test the cooling performance of each system, the laptop was loaded with high resource consuming softwares which are antivirus scanner, disk defragmenter, and 3D software renderer. By using this method, the laptop was put at the high operating stage and generates heat rapidly. The time allocated for each test was 30 minutes for each set, and repeated for three times.

For data acquisition process, the same software stated in Section 3.12 was used to measure the temperature of five main components which are CPU, GPU, HDD, Motherboard and RAM. The result of this experiment and discussion is elaborated in Chapter 4.

CHAPTER 4

RESULT AND DISCUSSION

4.1 PROTOTYPE PERFORMANCE TESTING

In order to test the prototype cooling performance, an experiment was done as explained in Section 3.4. The purpose of this experiment was to evaluate the feasibility of the prototype as well as to observe any weaknesses that could be modified later. The result of the experiment for graphic processor unit (GPU) was depicted in Figure 4.1 and the result for other components is shown in Appendix VI. From the chart shown, it was observed that the temperature decrement for the prototype was insignificant. The temperature recorded only showed 3°C decrement compared to active cooling. The result obtained was out of expectation and details observation was done to investigate the contributing factors towards the problem which will be discussed in Section 4.2.

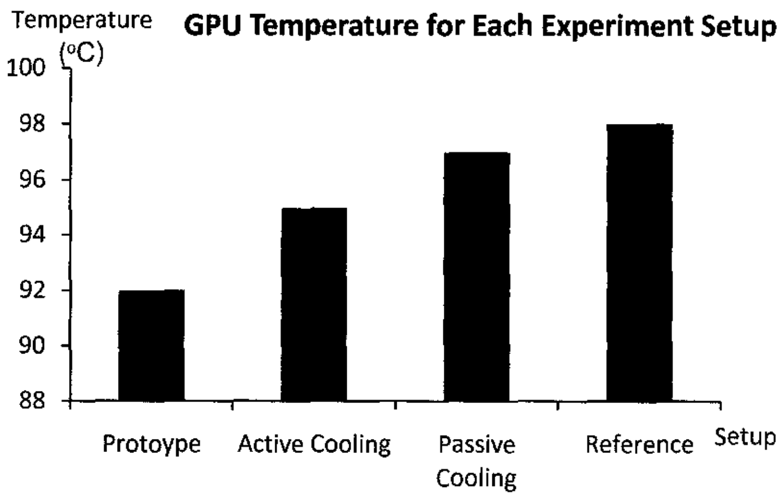


Figure 4.1: Experiment result for GPU.

4.2 DISCUSSION AND MODIFICATION

There are few factors that might contribute to the failure of the prototype. All of these factors will be further discussed in this section for modification and future recommendation.

4.2.1 Heat transfer from hot side to the cold side

There are possibility of heat generated by the thermoelectric device at the hot side was transferred to the cold side. This was happened since the heat sink has direct contact to the casing as shown in Figure 4.2. When the heat was transferred, the cool air temperature will be increased and will fail the prototype if it exceeds the designed temperature. To reduce the effect, the surface which is directly contacted the heat sink was insulated.

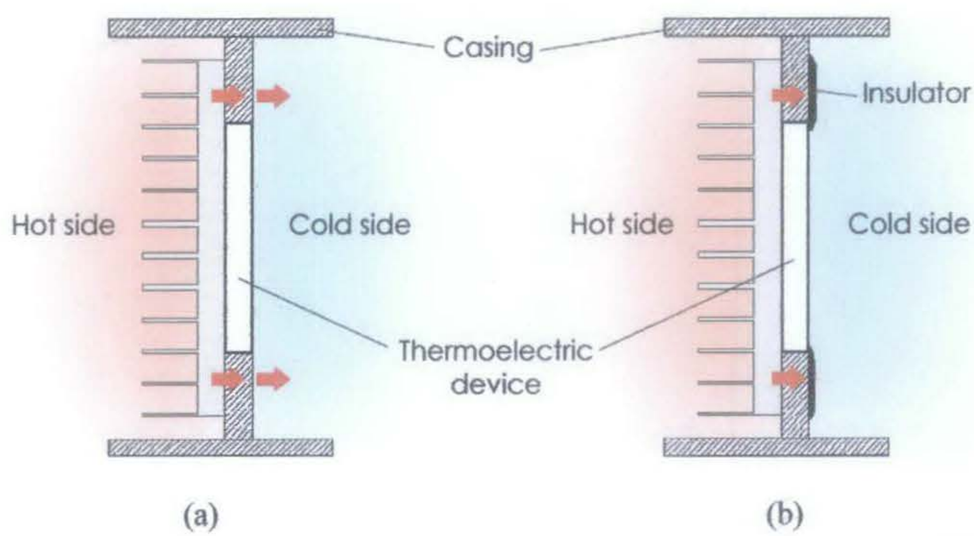


Figure 4.2: Insulation at area in contact with heat sink (a) before insulation (b) after insulation.

4.2.2 Insufficient fan flow rate

Since the cooled air was transferred through enclosed ducting to the laptop, there might be pressure loss to the flow thus resulting in poor air. Furthermore, the cool air feed was depending on the laptop fan to absorb the air from the duct. As a countermeasure, a 40mm x 40mm fan was installed at the duct outlet, just before the laptop ventilation inlet as shown in Figure 4.3. The fan will be powered by using USB cable.

Figure 4.3: Additional fan installed at the prototype duct outlet.

However, after the air flow is tested, the modification created new problem where it did induced the air to inversely flow back to the cooling chamber as shown in Figure 4.4. This is possibly caused by the limited location to install the fan itself. Since the fan installed is at the same level with the flow, it might accidentally blow the cooled air away instead of absorb it to be supplied to the laptop ventilation.

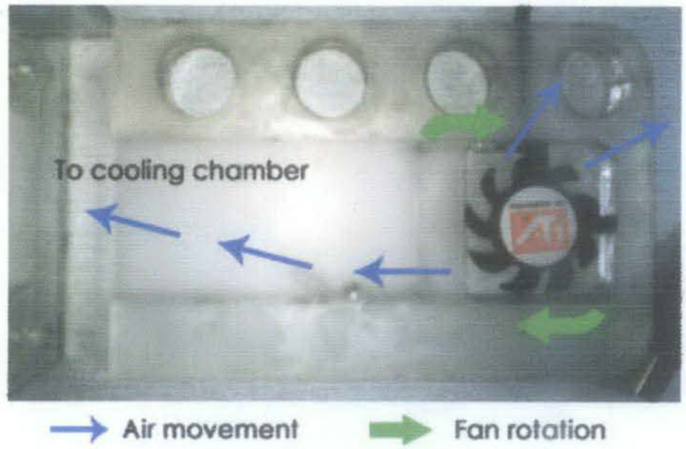


Figure 4.4: Air flow after fan installation.

4.2.3 Connection not fully enclosed

For the exhaust blower, there might be problem with the connection to the laptop ventilation outlet. The prototype is not perfectly attached to the laptop thus resulting suction pressure loss as shown in Figure 4.5.

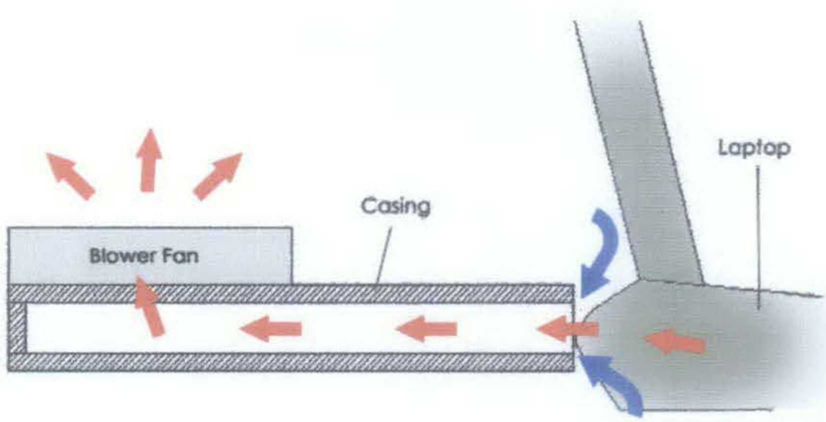


Figure 4.5: Imperfect exhaust blower attachment to the laptop.

4.2.4 Electrical circuit

The electrical circuit for the prototype is an additional modification done towards the development of the system. The schematic diagram of the circuit is shown in Figure 4.6. For this system, 12V DC 4A power adapter need to be used in order to provide proper voltage and current.

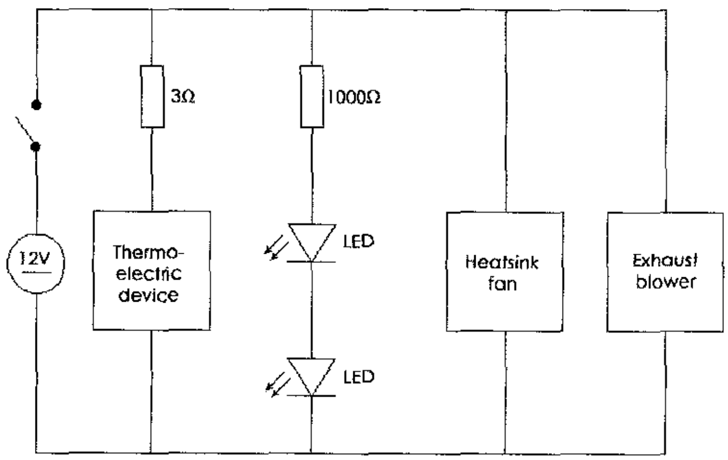


Figure 4.6: Electrical circuit for the prototype.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 CONCLUSION

As the computing technology is aggressively widening, consumers are still suffering to this traditional overheating problem and it is even worse. A new technology need to be developed to cope this problem or at least to slowly reducing. At the moment, there is still no universal complete solution for laptop overheating problem although several of new ideas have been invented to improve the cooling performance.

A study has been done on the laptop overheating problem and the effect of overheating towards laptop processing performance has been proven through experiment as well as the effect of high ambient temperature in contributing to laptop overheating. The proposed cooling system was intended to provide cooling air with lower temperature in order to assist the laptop heat dissipation process.

The essentials component used in this project was studied including the operation principle and attribute of thermoelectric device, heat sink profile and attribute, exhaust blower system, material handling and proper assembling process. The design specification for the cool air feeder and the exhaust blower to assist heat transfer rate of laptop was obtained. Using these specifications, the cooling system composed of thermoelectric device, heat sinks, fans and insulated casing was constructed by using precise laser cutting technology.

At the end of this project, the prototype of the cooling system was tested with a series of experiment to assess whether the cooling system is capable enough to solve the laptop overheating problem. 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.

5.2 RECOMMENDATION

For future development of the prototype, a few recommendations have been made especially on the problem stated in previous section. Although the recommendation might not ensure the workability of the prototype, it may be considered important towards the development of the system.

5.2.1 Heat sink design revision

The design of the heat sink should be revised in order to solve the heat transfer problem in cooling chamber. The contact between heat sink and the casing should be minimized to reduce the heat transferred to the cold side. Alternatively, a details study on insulation could be done to replace the critical part with thermal non-conductive material.

5.2.2 Air flow study

A details study on air flow also should be done in order to determine the air flow profile in the duct. Pressure loss caused by the casing design and any other factors should be considered too. In order to make the flow smoother, the design as shown in Figure 5.1 might be considered.

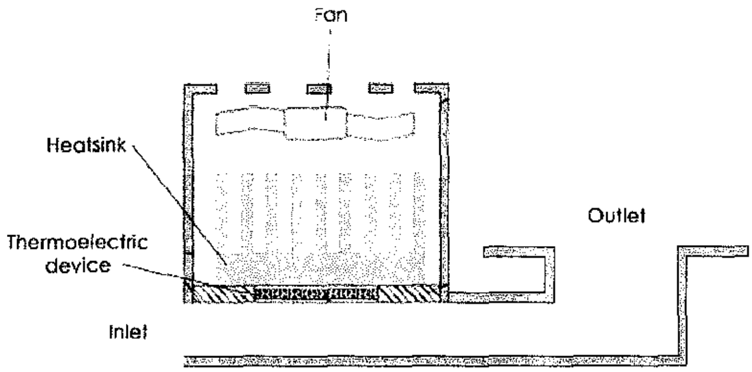


Figure 5.1: Recommendation design for smoother air flow.

5.2.3 Exhaust blower attachment mechanism

The attachment mechanism for the exhaust blower also needs to be improved. The current mechanism is only able to clip the exhaust blower to the laptop but not in perfectly attached. Thus, the improved system should ensure the attachment is perfectly enclosed the space to avoid pressure loss.

REFERENCES

Advance Thermal Solution. (2008, April 24). *Advance Thermal Solution.* <http://www.qats.com/productlit.asp>

Blachford., E. S. (2008). *Acrylic Plastic.* <http://www.enotes.com/how-products-encyclopedia/>

Chin, M. (2004, June 15). *Athlon 64 for Quiet Power* . <http://www.silentpcreview.com/article169-page3.html>

Comparetti, A. M. (2008, February 27). *What is SpeedFan.* <http://www.almico.com/speedfan.php>

Handby, S. (2008, February 26). *Mobile Computer - How hot laptops can damage your health.* <http://www.mobilecomputermag.co.uk/20080226317/how-hot-laptops-can-damage-your-health.html>

Hard Knocks. (2007a, January 10). *Laptop Overheating Overview.* <http://www.laptop-overheating.com/node>

Hard Knocks. (2007b, January 10). *Laptop Overheating Overview.* <http://www.laptop-overheating.com/>

Hard Knocks. (2007c, January 10). *Laptop Overheating Overview.* <http://www.laptop-overheating.com>

Hilal, N. A. (2007, June 29). *Laptop Stand "Note Pal S" Cooling Your Laptop Silently.* <http://www.laptopgram.com/2007/06/29/laptop-stand-note-pal-s-cooling-your-laptop-silently/>

Intel Corp. (2008, February 14). *Intel Microprocessor Quick Reference Guide.* <http://www.intel.com/pressroom/kits/quickreffam.htm>

Kirsch, N. (2004, July 15). *Building a Whitebox Notebook.* <http://www.legitreviews.com/article/55/1/>

Lee, S. (1995). Optimum Design and Selection of Heat Sinks. *Eleventh IEEE SEMI-THERM Symposium* , 49-50.

Lewis, K. (2006). *Thermoelectric Handbook.* New Jersey: Acrobat Distiller.

Mish, F. C. (2003). *Merriam-Webster's Collegiate Dictionary.* Springfield: Merriam-Webster.

Nicholson, R. (1996, May 16). *Javascript Bench.* <http://www.rahul.net/rhn/bench.js.html>

Redfish Photonics. (2008, March 23). *What's in a Name: Thermoelectric Coolers, Solid-state Heat Pumps, Peltier Cooler, Microcoolers.* <http://www.redfishphotonics.com/thermoelectric_coolers.htm>

Rutter, D. (2007, November 13). *Abit BW7 and Asus P4B i845 chipset Pentium 4 motherboards.* <http://www.dansdata.com/i845s.htm>

Smith, M. (1999). A new approach using silicon sensors and off-chip processing. *Measuring temperatures on computer chips with speed and accuracy* , 1-5.

Steen, W. M. (1998). Laser Material Processing. Great Britain: Springer-Verlag.

Steinbrecher, T. (2008, August 3). *Information About Heatsinks.* <http://www.heatsink-guide.com/content.php?content=heatsinkinfo.shtml>

Tellurex Corporation. (2008, March 15). *An Introduction to Thermoelectrics.* <http://www.tellurex.com/cthermo.html>

APPENDICES

NO	ACTIVITY	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic	⇢ →	⇢ →						MID-SEMESTER BREAK							
2	Preliminary Research Work - Details Study & Research - TEC - Heat sink - Exhaust blower		⇢ →	⇢ →	⇢ →											
3	Submission of Preliminary Report							△ ▲								
4	Seminar 1							⇢ →								
5	Project Work - Cont. Details Study & Research - Experiment					⇢ →	⇢ →	⇢ →								
6	Submission of Progress Report									△						
7	Seminar 2									⇢ →						
8	Project Work Continues - Design of Prototype									⇢ →	⇢ →	⇢ →	⇢ →	⇢ →		
9	Submission of Interim Report Final Draft														△	▲
10	Oral Presentation															△ ▲

Legend: ⇢ Tentative Activity → Actual Activity △ Tentative Submission ▲ Actual Submission

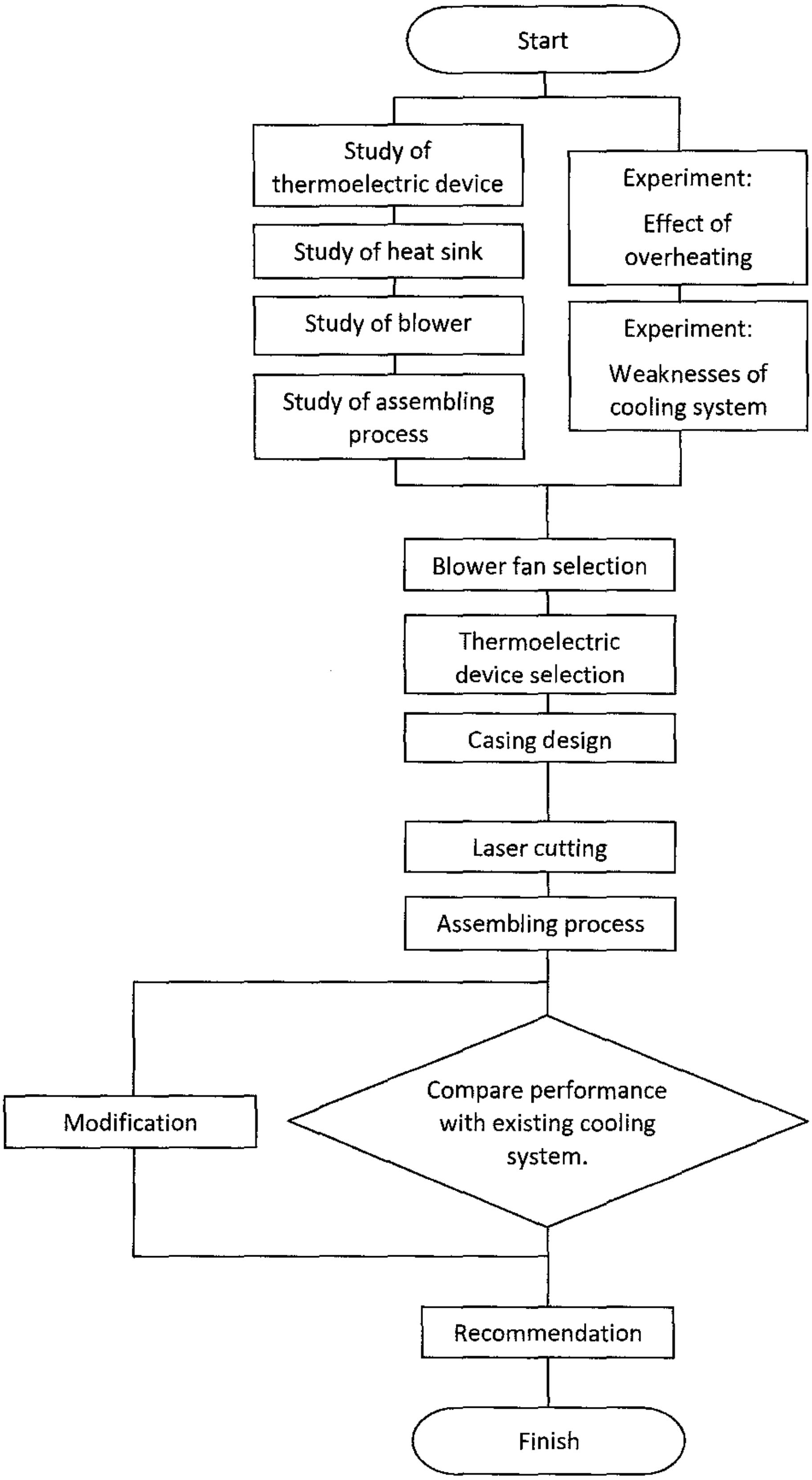
(a)

NO	ACTIVITY	1	2	3	4	5	6	7	8	9	10	MID SEMESTER BREAK	11	12	13	14
1	Preparing Casing Technical Drawing															
2	Design revision															
3	Material Preparation & Purchasing															
4	Prototype Fabrication															
5	Progress Report I Submission				△ ▲											
6	Prototype Performance Testing															
7	Prototype Modification (if any)															
8	Progress Report II Submission								△ ▲							
9	Seminar									△ ▲						
10	Final Report Preparation															
11	Poster Exposition													△ ▲		
12	Dissertation Draft														△ ▲	
13	Final Report Submission & Oral Presentation															△ ▲

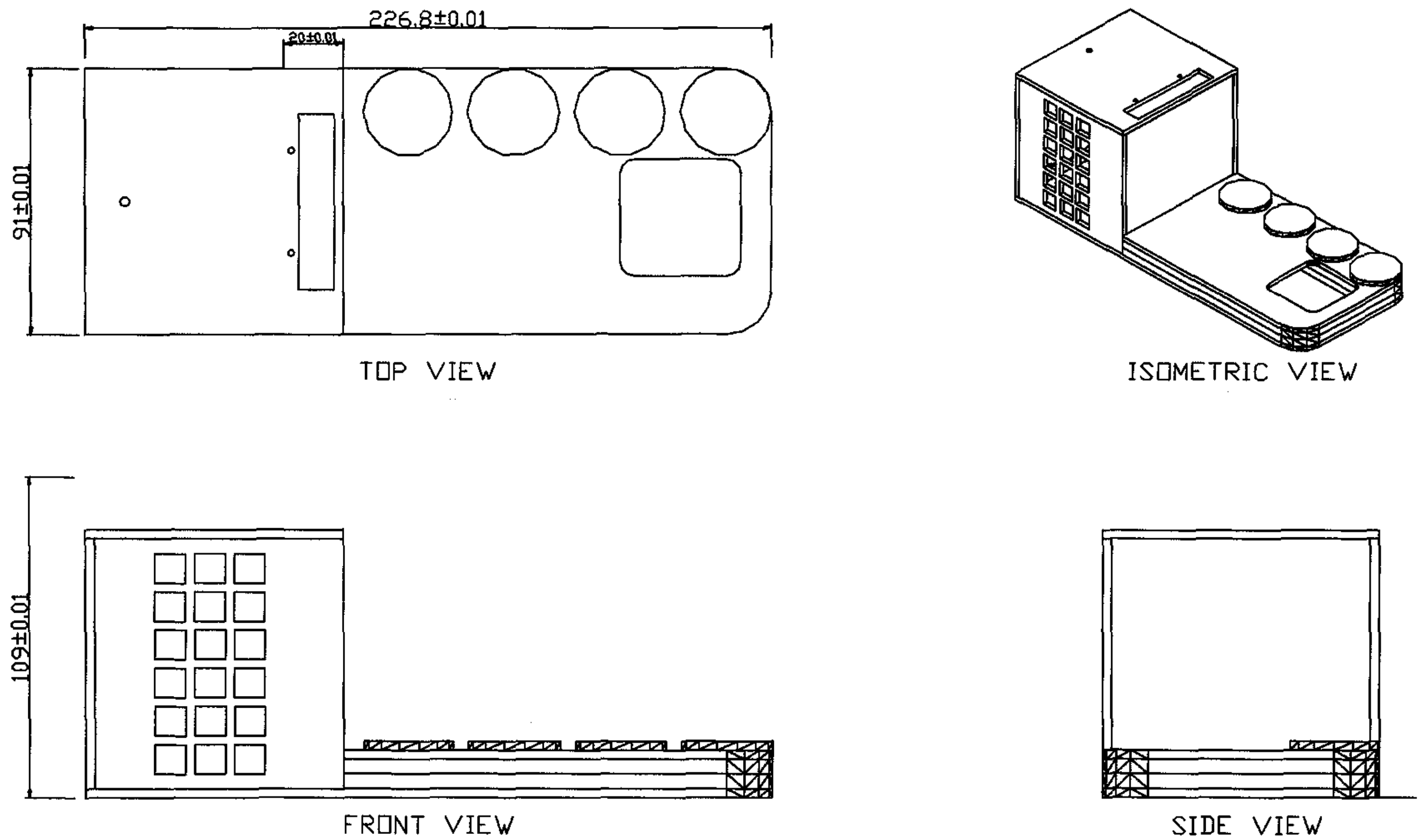
Legend: Tentative Activity; Actual Activity; △ Tentative Submission; ▲ Actual Submission

(b)

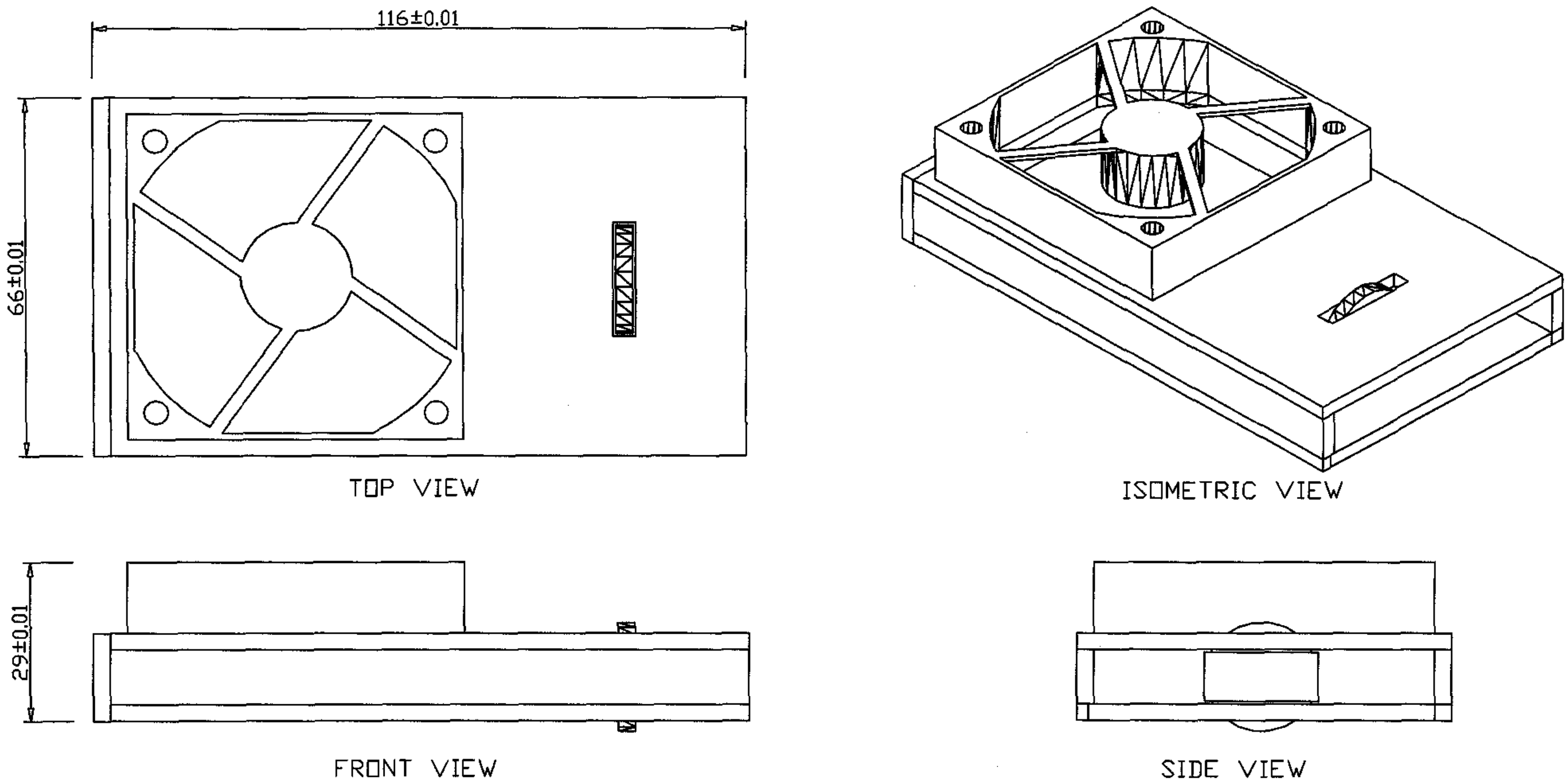
APPENDIX I: Project Gantt chart (a) First semester of Final Year Project, (b) Second semester of Final Year Project.



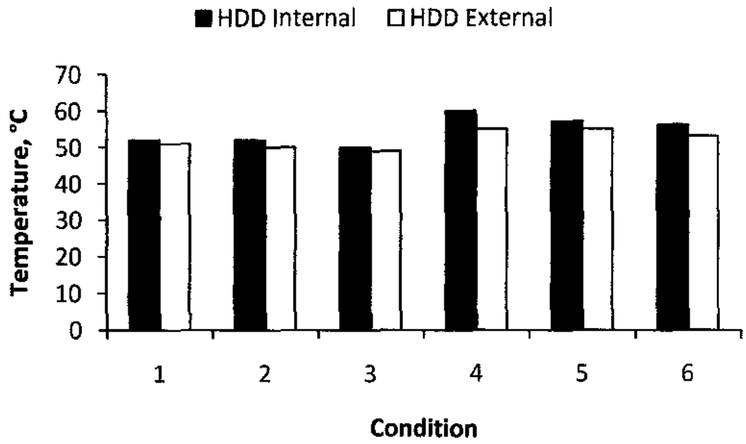
APPENDIX II: Project overall flow chart.

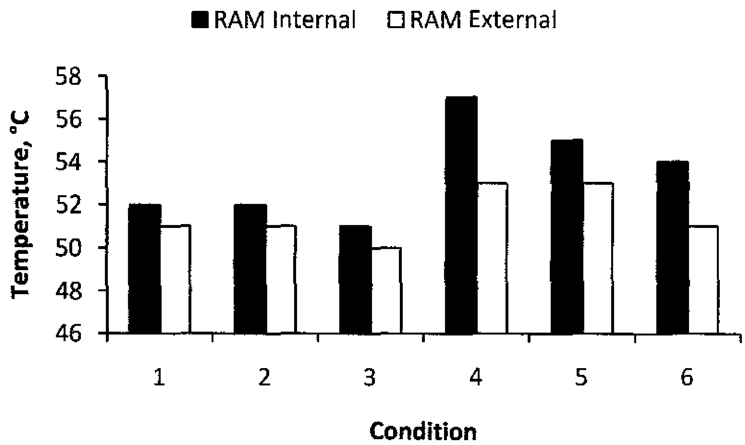


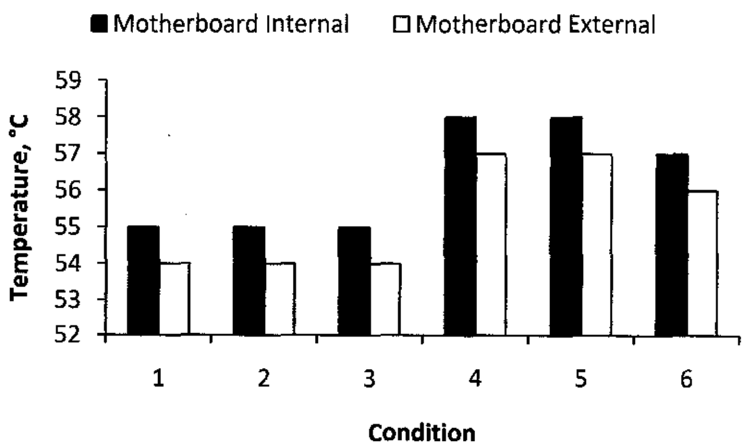
APPENDIX III: Technical drawing of cool air feeder.

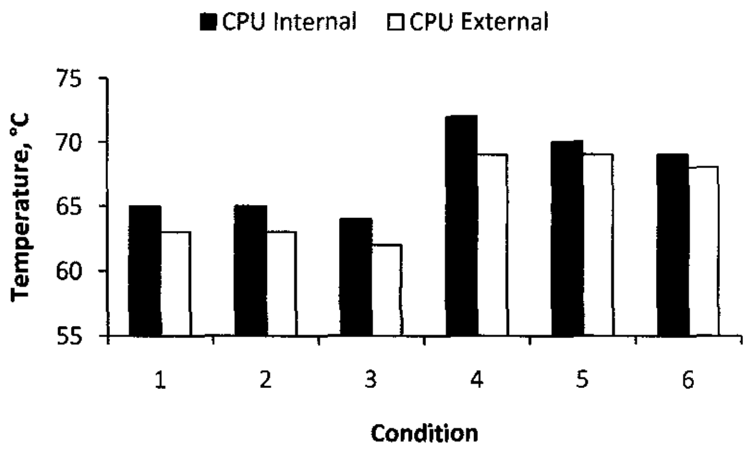


APPENDIX IV: Technical drawing of exhaust blower.

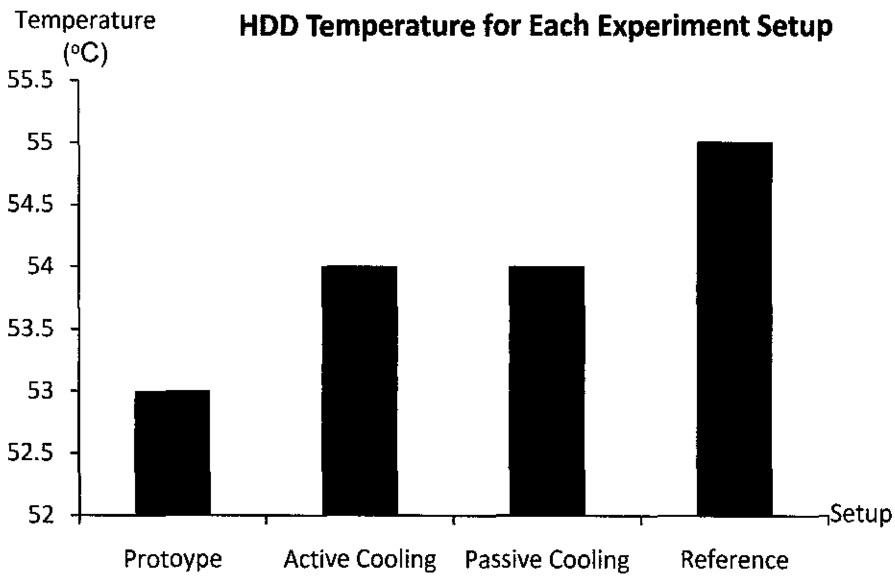

HDD Internal
HDD External
Temperature, °C
70
60
50
40
30
20
10
0
1
2
3
4
5
6
Condition

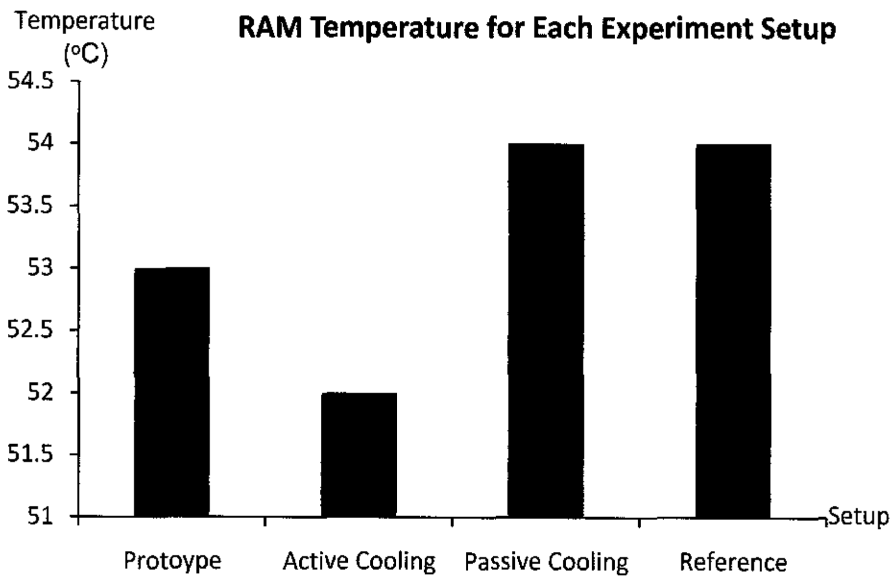

RAM Internal
RAM External
Temperature, °C
58
56
54
52
50
48
46
1
2
3
4
5
6
Condition

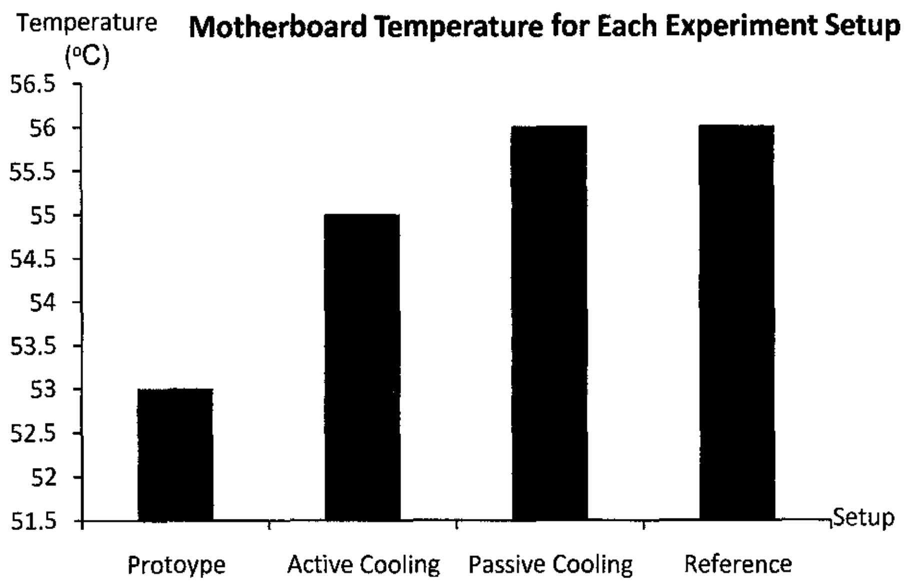

Motherboard Internal
Motherboard External
Temperature, °C
59
58
57
56
55
54
53
52
1
2
3
4
5
6
Condition

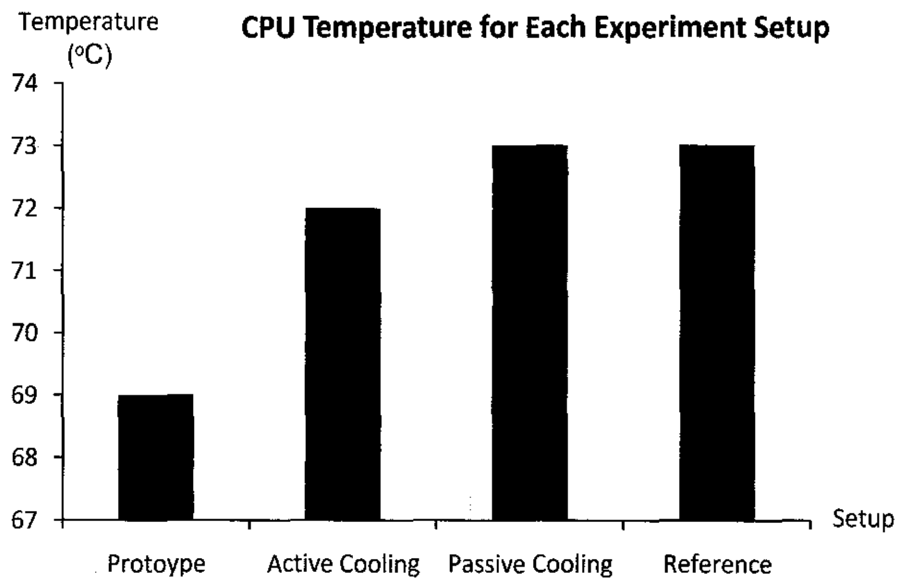


APPENDIX V: Result of experiment plotted in bar chart according to component.


Temperature (°C)
HDD Temperature for Each Experiment Setup
55.5
55
54.5
54
53.5
53
52.5
52
Setup
Protoype
Active Cooling
Passive Cooling
Reference


Temperature (°C)
RAM Temperature for Each Experiment Setup
54.5
54
53.5
53
52.5
52
51.5
51
Setup
Protoype
Active Cooling
Passive Cooling
Reference





APPENDIX VI: Result of prototype testing plotted in bar chart according to experiment setup.