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Design Odyssey Social Innovation Project

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ABSTRACT

This report delves into the topic of SIP (Social Innovation Project) where a problem for a particular group of people needs to be solved. With the help provided from the Design Odyssey team from SUTD (Singapore University of Technology and Design), we were able to streamline our idea after going through the Design Thinking Workshop that was organised by the team which lasted for three days. Once we reached a point where we were satisfied with our target audience and their needs, we started to brainstorm on ways to remedy this problem. The target audience that was chosen was people who live in dormitories which includes but not subjected to, university students who live on campus as well as foreign workers who live in hostels. The problem that we wanted to tackle was cooling since these places often do not include adequate cooling systems in place. Furthermore, a poll done in 2013 by the Ministry of the Environment and Water Resources states that the percentage of people who use fans majority of the time are 51.4% with the rest using air-conditioners. Using this information, we started on making a product that could provide an experience that is cooler than a fan but at a price that is lower than an air-conditioner. This report explains how and why the product turned out the way it did as well as the limitations that had to be accommodated for, when designing and piecing the product together to make it appealing to the intended target audience both aesthetically and practically.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledgements</td>
<td>ii</td>
</tr>
<tr>
<td>Abstract</td>
<td>iii</td>
</tr>
<tr>
<td>Table of Contents</td>
<td>iv</td>
</tr>
<tr>
<td>List of Figures</td>
<td>v</td>
</tr>
<tr>
<td>List of Tables</td>
<td>vi</td>
</tr>
</tbody>
</table>

1. **Chapter 1**
   1. Background                                               | 1    |
   2. Objectives                                               | 1    |
   3. Project Scope                                            | 1    |
   4. Design Odyssey Program (SUTD-SP)                         | 1    |
       1. Discover Process                                      | 2    |
       2. Problem Finding                                       | 3    |
   5. Market Survey                                            | 5    |

2. **Chapter 2**
   1. Define Process                                           | 7    |
       1. Cooling Methods                                       | 7    |
       2. Types of Fans Considered                              | 10   |
       3. Concept Design                                        | 11   |
       4. Comparison of Prototypes                              | 14   |
       5. Limitations                                           | 14   |
   2. Develop Process                                          | 15   |
       1. Variables to Consider                                 | 15   |
       2. Types of Metal for Heat Sink Fin(s)                   | 16   |
       3. Apparatus Dew Point (ADP)                             | 17   |
       4. Power consumption                                     | 22   |
       5. Airflow Rate                                           | 22   |
       6. Material for Case                                      | 24   |
       6. Aesthetics                                             | 25   |
3. Deliver Process .........................................................25
   1. The Product(s) .......................................................29
   2. Final Prototype .....................................................29
   3. How it Works .........................................................31

4. User Review...............................................................31
   1. User Testing ..........................................................31
   2. Feedback .............................................................33

3. Chapter 3
   1. Recommendations ...................................................33
   2. Conclusion ............................................................35

References .................................................................37
Appendix .................................................................41
LIST OF TABLES/FIGURES

Fig. 1 Design Thinking Process .........................................................2
Fig. 2 Dyson Fan .................................................................4
Fig. 3 Traditional Fan .............................................................4
Fig. 4 How Evaporative Cooling Works .................................7
Fig. 5 Evaporative Cooler System ..............................8
Fig. 6 Homemade Air-Conditioner ...........................................8
Fig. 7 Peltier Device ............................................................9
Fig. 8 12V Computer Fan .....................................................10
Fig. 9 Centrifugal Blower ......................................................11
Fig. 10 Heatsink .................................................................12
Fig. 11 First Design ............................................................12
Fig. 12 First Design Sketch ..................................................12
Fig. 13 Alternative Design .................................................13
Fig. 14 Second Design .........................................................13
Fig. 15 Climate Values in Singapore .................................16
Fig. 16 Dewpoint and Relative Humidity Chart ..................17
Fig. 17 Comparison of Price of Electricity in Singapore ..........17
Fig. 18 Solar Panel .............................................................18
Fig. 19 Battery Holder ........................................................18
Fig. 20 Embedded Switch Mode Power Supply ..............21
Fig. 21 3mm Thick Acrylic ...............................................23
Fig. 22 85mm Tall Heatsink .............................................24
Fig. 23 Drawing of the Centrifugal Fan ..........................25
Fig. 24 Centrifugal Model .................................................26
Fig. 25 Drawing of Centrifugal Fan ..............................26
Fig. 26 Axial Model ..........................................................27
Fig. 27 Drawing of Axial Fan ............................................27
Fig. 28 Fan types being used ...........................................30
Fig. 29 Heatsinks are Sticking Out ..............................33
Fig. 30 H-Bridge Circuit Board .......................................34
LIST OF TABLES

Table 1 User Suggestions ..............................................5
Table 2 Comparison of Types of Cooling............................9
Table 3 Comparison Chart of Metals ..............................15
Table 4 Potential Materials for Case ..............................23
Table 5 Comparison of the Products with Other Fans .............28
Chapter 1

1.1 Background

The SUTD Design Odyssey Program is one that focuses on the topic of SIP. SIP is a topic that emphasises on the needs of a particular group usually one that encounters a very niche problem and the goal is to come up with a solution that appeals to the members of this community.

1.2 Objectives

The objective of this project is to provide an affordable cooling experience for people who live in dormitories.

1.3 Project Scope

The scope of the project is to use affordable materials that cost around $9 - $15 per sheet while having a mass of around 800g which would make in line with most affordable fans in the market. The goal is to be able to provide a cooling experience that about 2 °C - 3 °C difference to the surrounding temperature.

1.4 Design Odyssey Program (SUTD - SP)

Similarly to what was taught in the SIP module in Singapore Polytechnic (SP), the Design Odyssey workshop that lasted for two and a half days at SUTD was mandatory to guide us with our thinking processes. An example of the Design Thinking Process was Discover, Define, Develop and Deliver.

Firstly, Discover is meant to uncover existing problems that a typical Singaporean faces. Secondly, Define is where the scouting of the core problem is carried out. Followed by Develop where brainstorming began to solve the issue at hand. Lastly, Deliver is the point where refinement of the ideas are concocted into a solution that caters to the specified target audience.
1.4.1 Discover Process

During this phase, ideation occurred where concepts were generated to fulfil the SIP criteria. The theme for the concepts had to be something that was learnt in school in past modules that could be incorporated into the Social Innovation umbrella. Below are some of the ideas that were generated during the discover process:

**Idea (1): Solar Light Lamp**
This first idea was a version of a solar light that can be charged during the day and used in the night while also being portable. The intended target audience was primarily people who lived in dim lighting conditions in third world countries. Unfortunately, this idea was already being done by other companies like D.Light.

**Idea (2): Lighted Footwear**
The next idea was an alternative to the first idea which was to incorporate the lighting mechanic into a shoe. This idea similarly is targeted at people who lived in dim lighting conditions in third world countries which suffers from the fact that SIP requires user interviews and feedback which is not possible.
Idea (3): Turbine Rain Generator
Sticking with the idea of energy, the thought of using the rain as a form of power was considered since it rains on average in Singapore for 179.0 days in a year. Hence, the Turbine Rain Generator idea came up which uses water from the rain as a means to generate electricity. However, this idea did not really address any needs of a group but rather an alternative to the other forms of energy already available.

Final Pick
In the end, after going through various concepts, a fan that can blow cold wind was the clear winner. This idea was the most realistic out of all of the ones that were brainstormed and addressed the needs of many users around Singapore. At this stage prototyping of this concept commenced and was nicknamed ‘Fan o’Matic’.

1.3.2 Problem Finding

According to National Fire and Civil Emergency Preparedness Council(NFEC), a subsidiary of Singapore Civil Defence Force(SCDF), 76.1% of Singaporeans use air-conditioners in 2013.[2] An air-conditioner may negate the heat outside which can reach up to 32°C, making it comfortable for the users. This not only justifies the claim that an air-conditioning unit is almost mandatory. However, an air-conditioning unit uses up a lot of electricity, skyrocketing the electricity bills of the owner. According to National Environment Agency(NEA), an air-conditioning unit consumes 10 times the electricity compared to that of a fan.[11] In addition, the installation cost of an air-conditioning unit ranges between S$1000-S$4000.[10]

The envisioned product was inspired by one of the many needs of the target audience, an affordable cooling system. Research suggests that the closest thing that provides more cooling than the fan is the Dyson Fan, often coined ‘Bladeless Fan’, which is able to deliver cool wind that is more streamlined than a traditional fan but still not as cool as an air-conditioner. In addition to not having any blades, it makes cleaning easier as well as being child friendly. Although this invention is innovative, it is still incredibly new and retails for anywhere between S$300 - S$800 which is out of reach for most of these individuals especially for those who are not able to afford air-conditioning.
Though the Dyson Fan may seem promising, many people cannot afford such a luxurious fan and thus invest in the traditional fan which is much more affordable. Ideally the product would consume less power than a Dyson Fan but also provide a higher cooling capacity. While competing directly with the Dyson Fan would prove to be a challenge, a more realistic approach would be to innovate a product that is cheaper than air-conditioning but is able to provide a higher cooling capacity than the traditional fan.

The Dyson Fan provides a better cooling experience of up to 15 times, according to Dyson themselves, than the traditional fan but at 10 times the price. It is this exact reason why the
Dyson Fan is seen as a ‘Rich person’s fan’ with only a handful of people being able to afford one. In conclusion, the goal of this project is to hit a sweet medium where the idealised product would be cheaper than the Dyson Fan but also provides a higher cooling capacity than a traditional fan.

1.4 Market Survey

In the beginning, we assumed the consumer wanted a cooling system to produce minimal noise, be similar to a typical desk fan, be made of lightweight materials and feature a simplistic design. During the concept design, the mentor from SUTD suggested that we should not assume the consumer’s needs but instead interview several individuals to find out what their needs are. At this point questions were generated to ask potential users for the interview. Below is an extract of the first set of questions that were asked (not in order):

- If the size of the product were to be around the same as a typical 12” inch would you buy it?
- Is $100 - $150 too much for the product?
- Do you mind paying about $3 per month for a cooler experience?
- Is the ease of maintenance a concern?
- Is 800 g - 1 kg too heavy for a fan?

Below are some of the key information that was tabulated from the questions asked above (up to 6 people were interviewed at this point):

<table>
<thead>
<tr>
<th>User:</th>
<th><strong>Steven</strong></th>
<th><strong>Bob</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Size:</td>
<td>15”</td>
<td>No preference</td>
</tr>
<tr>
<td>Electrical Bill:</td>
<td>$2</td>
<td>$3.50</td>
</tr>
<tr>
<td>Weight:</td>
<td>800g</td>
<td>800g</td>
</tr>
<tr>
<td>Price willing to pay:</td>
<td>$300</td>
<td>$200</td>
</tr>
<tr>
<td>Maintenance:</td>
<td>No concern</td>
<td>Easy to maintain</td>
</tr>
</tbody>
</table>
With the information gathered, a few things can be concluded. First, the interviewees do not have a problem with the product’s portability as they do not see themselves bringing it outdoors. Secondly, the interviews gave more things to consider in the product. A key takeaway from the interviews is that all of them would gladly use a product that can blow cold wind over a traditional fan in spite of the increase in price and electricity bills, however since the product was not made yet at this point the users’ opinion might differ later on.
Chapter 2

2.1 Define Process

2.1.1 Cooling Methods

The very first idea was similar to how an air-conditioner works. It would have all the components of an air-conditioner which include a compressor, expansion valve and a pump. While this idea seemed feasible, it is not practical for the target audience that was selected as it would be too expensive. Hence, alternative ways to cool air was considered that would meet the criteria that have been set. It came down to three ideas that were in line with the goals set, below are those examples:

First Idea: Evaporative Cooling

1) First was evaporative cooling which uses evaporation to cool the air around it while using a fan to draw out this cooled air. A pump is used in an evaporative cooler to circulate water from the reservoir onto a cooling pad, which in turn becomes very wet. A fan draws air from outside the unit through the moistened pad. As it passes through the pad the air is cooled by evaporation. In order to make the cooler effective, the cooling pads are to be completely saturated at all times during operations and that the systems fan & motor are to be sized and designed to deliver the proper airflow for the house.[5] However the cooler is not effective in humid climates especially for ones with Relative Humidity(RH) of 50% and above. Thus, using this form of cooling is not recommended in Singapore.

How EVAPORATIVE COOLING works

Fig. 4 How evaporative cooling works[13]
Second Idea: Homemade Air Conditioner

2) Second were two ideas that was inspired by a couple of YouTube videos, one involved cool water flowing through a metal pipe which was then coiled around a fan and the other involved ice cubes that were placed into a cooler box with a fan attached to it. These simple contraptions were able to get temperatures as low as 12°C. Replicating one of these concepts would prove to be ineffective as the user would need to constantly refill either the pipe with cool water or ice cubes in the cooler in order for the blown air to be cool. Once again, this idea was scrapped due to its inconvenience.
**Final Pick: Peltier Device**

3) The final cooling method that was considered was the Peltier Device, or thermoelectric cooler, which uses the Peltier effect to cool a fluid. Peltier effect is the phenomenon that a potential difference applied across a thermocouple causes a temperature difference between the junctions of the different materials in the thermocouple[^32]. This leads to Peltier Devices having a junction that is cool while the other junction being hot. After much comparisons and research, it was decided that the Peltier Device was seen as the best choice for the main cooling unit. Available from anywhere between $2 - $5, the thermoelectric cooler does not have any movable parts which renders it silent as well as being environmentally friendly making it the premier choice for cooling among the ones suggested.[^11]

![Fig. 7 Peltier Device][8]

Reasons for picking the Peltier Device over the other cooling methods is mostly down to cost and effectiveness. Below is a table that compares all the types of cooling:

<table>
<thead>
<tr>
<th>Variables</th>
<th>Evaporative Cooling</th>
<th>Fan with Ice</th>
<th>Peltier Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature achieved [°C]</td>
<td>26.8</td>
<td>3</td>
<td>-22</td>
</tr>
<tr>
<td>Cost [$]</td>
<td>&lt;100</td>
<td>-</td>
<td>2</td>
</tr>
</tbody>
</table>
2.1.2 Types of Fans Considered

There are different types of fans that are available in the market, from Dyson Fans to ceiling fans. However due to the size of our product, the fan(s) that need to be selected are the ones that are small in size but provide sufficient blowing capacity of anywhere around 5 m³/min - 10 m³/min. Below are a list of the type of fans that were considered:

a) 12 & 24V MINI EXTRACTOR FANS: These are small 120mm fans similar to cooling fans on desktop computer cabinets. They use around 6W and are effective within about 1m. They are rated to move 2 to 3 cubic metres of air per minute. These are the smallest fans available in the market. The main drawback is that it is relatively noisy, when compared to a 30W 230V fan.

b) SMALL TABLE FAN - 230V: This is a 23cm table fan with a 30W rating. Running on the SE22 Selectronic Inverter with no other loads, it draws 38 and 41 Watts on slow and fast speeds respectively. When run on the same inverter with the television on, it drew 13W to 15W. This type of fan provides optimal cooling when placed 2-3m away. It is very quiet and ideal as a bedside fan.

c) CENTRIFUGAL BLOWER - 12V: This is a fan size of 30.5cm with a 7.2W rating centrifugal fan. These fans increase the speed and volume of air stream with the rotating impellers. It is available in wide variety of sizes typically comes in 12V, 24V or even 48V.
The reason these types of fans were considered over the rest is that mainly due to their size. Making the product as small as possible not only reduces the cost but also the noise that it is likely to produce. The intention is to make it no bigger than a desk fan which is about 17” in diameter.

2.1.3 Concept Design

While working on the placement of the thermoelectric cooler, a heat sink which typically consists of many small fins, would be needed to increase the surface area of the hot section of the peltier device so as to dissipate heat quickly. A thermal conductor is used to carry away heat from the object to the heat sink and it is normally placed in between the object and the heat sink. However, the heat sink requires airflow to dissipate heat away, therefore it requires an exhaust fan to increase the rate of heat loss. If the surface area is large enough, more air would be in contact with the fins which enables the heat to be dissipated quickly. This would allow the peltier device to continue cooling without periodically overheating.

Heat sinks can also be used on the cool side of the Peltier device. However, when using heat sinks for the cool side of the device, there are certain factors to consider. Factors include the surface area of the heat sink, number of fins, as well as the size of the fins.

- If the surface area is too big, it would be ineffective for the heatsink to absorb all the heat that causes the cooling phenomenon. However, if it is too small, there would not be enough contact with the air.

- If the number of fins used is too little, the blown air would not be cold enough as there are too little fins in contact with the air. If there are too many fins, the blown air
would face resistance flowing through the fins, thus making it cool in exchange for the strength of the blown air.

- As for the size of the fins, being too small, again there will be little contact with the blown air. However, if it is too large, the heat sink might lose its effectiveness as certain parts of the fin might not be cold, therefore mitigating the effect altogether.

![Fig. 10 Heatsink Fin][17]

Designing the case with Styrofoam was needed to point out the flaws that has yet to be encountered. The first design featured very small vents in order to increase the airflow of the fan which was placed at the front, while having the thermoelectric cooler at the rear of the case. The idea was that the fan would create a vacuum when it rotates and would blow out the cool air from within the casing. This concept did not work as intended as the fan needed more airflow than the small vents that were provided and thus less cool air was blown. Furthermore, only the air in the immediate vicinity of the Peltier Device was cool while the rest of the casing was still warm in comparison.

![Fig. 11 & 12 First Design & Sketch (Respectively)]
The main problems for the first prototype were mostly airflow and temperature drop. Another variable that was not considered was the direction of airflow in the case. To combat this, the improved design was made in such a way that the cold side of the heatsink is placed in front of the centrifugal fan. This decision led to the air temperature being significantly lower than the first design.

With the alternative design being the one that makes the most of the cool side of the Peltier Device, it was decided that this be the design that the product will be based on. The idea is to place the thermoelectric coolers on either side of the case with the cold heat sink fins facing one another within the case. A fan would be placed at the rear of the case with the exhaust side facing the heat sink fins as this would minimise the need to account for airflow. This leaves the outlet as the last thing to consider. One way is to imitate the grills which are commonly used in automobiles and the other is to use the same outlet control as the one seen in buses with the adjustable twin-blades. However, the design would feature many protruding parts and thus, potential users would be turned off by this design.
The follow up to this idea involved placing the fan parallel to the cool fins so that the air being blown will be cool. The best way to do this was by placing the fins along the same plane as the fan and parallel to the case. This design allows for a higher airflow and does not require vents for the case as the intake section of the fan has the outside air to work with. In theory, this concept would be blowing more cool air to the user than the previous design. However, once again this design does suffer aesthetically which needs to be thought of during the design process.

All of the above designs were meant to be non-portable. The size of the fan, which was 8”, made the mounting methods obsolete. After much brainstorming, the new design was to use a centrifugal fan but an axial model would be made as well which would enable users to make comparisons between the two and gauge their advantages.

### 2.1.4 Comparison of Prototypes

From all the designs and concepts that were considered, the version that utilises the most of the cooling effect was the second design. The reason for this is that having the air blown from the rear end of the case would maximise the cooling effect that can be felt by the user. If the alternative design were to be used instead, the airflow would be much less in comparison as most of the wind from the fan would be facing the ground instead of the front which is where the user would be likely to expect. Furthermore, if the alternative design was implemented, the material chosen would have to be able to withstand the mass of the fan acting towards the case which might increase the cost of the product.

### 2.1.5 Limitations

With the idea of Social Innovation in mind, fabricating the absolute best product is not feasible as these groups would not be able to afford it or have space to accommodate such a device. Since our target audience is people who live in dormitories, the need to make a product that is compact and effective at a reasonable price point would prove to be a challenge. This is the reason why interviews and surveying is conducted in order to find out the needs of the user as much as possible.

One of the takeaways from this programme is that the needs of the user should never be assumed and questions should be asked when faced with an engineering difficulty to find a compromise that rectifies the needs of the user while providing the best possible experience. For example, the product might work at full capacity with two 100mm x 40mm x 90mm heat sinks paired with an 8” fan but the user might not be able to afford such a product as just those items alone are worth over S$50. This example illustrates the compromises that need to
be taken when creating a product for a niche group of individuals and thus needs to be researched extensively to find a healthy medium.

### 2.2 Develop Process

#### 2.2.1 Types of Metal for Heat Sink Fin(s)

There are several types of materials being used in the fabrication of heat sinks such as brass, steel and bronze but the two most common types of metals used commercially are aluminium and copper. With this in mind, a table was made to showcase why exactly these two metals are favoured over the rest:

<table>
<thead>
<tr>
<th>Variables</th>
<th>Aluminium</th>
<th>Copper</th>
<th>Brass (70%Cu - 30%Zn)</th>
<th>Stainless Steel</th>
<th>Bronze</th>
<th>Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Conductivity (W/mK)</td>
<td>235</td>
<td>400</td>
<td>115</td>
<td>45</td>
<td>110</td>
<td>0.02624</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>2700</td>
<td>8960</td>
<td>8730</td>
<td>7700</td>
<td>8359</td>
<td>1.177</td>
</tr>
<tr>
<td>Cost ($/metric ton)</td>
<td>2192</td>
<td>6826</td>
<td>3006</td>
<td>2796.5</td>
<td>19500</td>
<td>-</td>
</tr>
</tbody>
</table>

The three variables that are considered in the table above are the most important when purchasing or fabricating heatsinks. As seen in the above table, the thermal conductivity of air is very low therefore the need for a heatsink is essential to ensure that as much of the heat absorbed by the cold junction is maximised. One of the factors to consider is price as it will dictate final cost of the product. However, thermal conductivity is equally important as it determines the amount of heat gain or loss the metal can undergo. Mass is a concern when it comes to this product as a lighter metal will result in an overall lighter product. Even though the interviewees did state that portability is of no concern, making a product that requires a few people to carry would not be ideal for a spot cooler. Hence, finding the right metal that satisfies these criteria will determine the outcome of the price and performance of the final product.
After considering these factors, the conclusion was to use aluminium as the material for our heat sink as it is not only lightweight but also affordable with respectable thermal conductivity when compared to other metals in the table. Furthermore, aluminium heatsinks are widely available and can be bought for as low as $6 - $8 including shipping. This made it ideal for the usage of our product.

### 2.2.2 Apparatus Dew Point (ADP)

One thing that needs to be accounted for when dealing with cool objects is the condensation that is bound to occur. Since the thermoelectric cooler can achieve temperatures as low as -2°C, this means that the Apparatus Dew Point (ADP) has to be considered. ADP is defined as the temperature which the relative humidity is equal to 100% and is often expressed in temperature (°C) [15]. This value can be calculated by using an instrument called a Sling Psychrometer which has a wet bulb and a dry bulb. The dry bulb, in this instance, is used to measure the ambient temperature while the wet bulb is used to obtain temperature achieved via evaporative cooling. How much water is wicked away is dependent on the dryness of the air. The difference between the two temperatures of the bulbs will provide the ADP. With the ADP, the Relative Humidity (RH), which is the amount of moisture in the air compared to what the air can ‘hold’ at that temperature, can be found [15].

The RH in Singapore is 80% which results in the annual dew point being 24°C. For context, the ideal humidity at 32°C is anywhere between 31%-37% and anything above 65% can be deadly to asthma related illnesses. With this information, the thermoelectric cooler will produce water droplets at temperatures below that of 24°C and dehumidify the air to a lower relative humidity level.

<table>
<thead>
<tr>
<th>All Year Climate &amp; Weather Averages in Singapore</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Temp: 33 °C</td>
</tr>
<tr>
<td>Low Temp: 24 °C</td>
</tr>
<tr>
<td>Mean Temp: 28 °C</td>
</tr>
<tr>
<td>Precipitation: 75.1 mm</td>
</tr>
<tr>
<td>Humidity: 80%</td>
</tr>
<tr>
<td>Dew Point: 24 °C</td>
</tr>
<tr>
<td>Wind: 8 km/h</td>
</tr>
<tr>
<td>Pressure: 1010 mbar</td>
</tr>
<tr>
<td>Visibility: 10 km</td>
</tr>
</tbody>
</table>

**Fig. 15 Climate Values in Singapore** [42]
The reason for this consideration is that if water droplets were to form in the system, the electronics may be affected since every component is in the case. From the data obtained, it is evident that the Peltier Device is likely to form water droplets when it is running at full capacity since the Peltier Device can reach temperatures of up to -2°C.

### 2.2.3 Power Consumption

Power consumption in Singapore, as of Q2 2017, is $0.2135/kWh. However, power consumption, as of Q1 2018, is $0.2156/kWh. Due to this increase in the electricity bills in Singapore, many people have struggled to battle with this heat with a ceiling fan, table/desktop fan or a tower fan only. The reason behind them using the fan only is because the air conditioning unit consumes a lot of power, about 10 times more than the fan. Therefore, people may consider the product as it consumes a little more than the fan while giving off a cooling sensation to the user.
Acquiring power was something that cannot be overlooked. Alternate ways to acquire power were laid bare: the sun through solar energy, battery operated, and just a simple power supply:

![Fig. 18 Solar Panel](image)

- Solar power is an environmentally friendly power source. The solar energy, which is gathered using solar panels, can be used to charge the product in the day and then be used in the night, or be used during the day itself. Solar power, although environmentally friendly, is not feasible to use. It is expensive to obtain, and has an efficiency of 22%[^45], which would not be efficient. Furthermore, there are days where it will rain, or that it will be cloudy, thus hindering the solar panels from obtaining the electricity needed to power the product.

![Fig. 19 Battery holder](image)

[^45]: Efficiency of solar panels.
The most ideal way to get power would be battery operated as it would be able to make the product portable. The idea of having a portable cooling device could help a lot of users with their battle against the heat in Singapore. Unfortunately, after calculating the power needed to get the device to work for at least an hour would be 72000 mWh.

\[ \text{Input Power needed for Product (P)} = \text{Input Voltage (V)} \times \text{Input Current (I)} \]

\[ P = 12V \times 6000\text{mAh} \]

\[ \therefore \text{Power} = 72000 \text{ mWh} \approx 72\text{Wh} \]

Therefore it seems that 72W would be needed to power the product for an hour. This amount of power does not seem like it was a bad idea at first. However, after seeing how much power a single AA battery provides, the idea instantly became unfeasible. The reason is that we needed 8 batteries just to power the product, for only 30 minutes. We have also thought of different types of AA battery to use:

- Lithium-ion Battery\(^{[21]}\)
  - This is one of the most commonly used batteries. It cost about US$10 and has a standard voltage of about 3.7V or 4.2V\(^{[22]}\). The batteries are able to store high energy, meaning it can power up devices requiring high power input. In addition to that, the batteries have a longer shelf life due to their low self-discharge. This makes it ideal for our product to use.
  - Unfortunately, these batteries are sensitive to high temperatures as the heat will make the batteries degrade faster. As our product would normally be used by users during hot days, this might not be a good idea for usage. Moreover, they are expensive, further supporting the fact of not using the batteries.

- Alkaline Battery\(^{[24]}\)\(^{[20]}\):
  - This is another most commonly used batteries. It usually cost about US$1 and has a standard voltage of 1.5V. The lifespan of the non-rechargeable battery is longer than the rechargeable battery. For rechargeable batteries, “they can be used hundreds of time if the recharging is done after the battery has been used to 25 percent of its capacity or less,”\(^{[20]}\)
  - Furthermore, “the cost of an alkaline battery is much lower than the other more sophisticated ones containing nickel and cadmium, and
alkaline batteries can be disposed of as normal waste rather than requiring special disposal techniques.\(^{20}\)

- Though it is cheaper and its lifespan is better than most battery, an alkaline battery cannot last long for appliances requiring high current startup or high power usage. Alkaline batteries give low performance, although rechargeable battery gives a lower performance than standard alkaline battery. However, rechargeable batteries are able to close that gap in the present, due to the current technology as well as purer products that are used to manufacture the batteries.

- The alkaline batteries cannot be kept in the device for long periods of time as it will completely ruin the device. The reason why is that the batteries will leak out materials that are corrosive in nature.

- **Nickel Cadmium (NiCd) Battery**\(^{22}\)\(^{23}\)\(^{25}\)\(^{26}\)

  - NiCd Battery is only rechargeable. It cost about US$1 and has a standard voltage of 1.2V. This battery is simple and it is fast to charge. Under optimal condition, it is able to last longer than most batteries. Since it is rechargeable as well, many users need not inconvenient themselves by purchasing more batteries.

  - Additionally, the batteries are inexpensive. This mean that a single purchase of the batteries could potentially effectively provide a long lifespan for the product.

  - Although NiCd Battery is rechargeable as well as inexpensive, it has a low energy density, relative to the other batteries. It is able to handle storage, however, it may be required to charge it before use.

  - Moreover, the batteries are not environmentally friendly as it contains toxic metal. Therefore, if the batteries do leak, it might be hazardous to the users. Furthermore, certain countries have started limiting the use of these types of batteries due to the toxic metal issue, making it hard for users living in those countries to purchase the batteries.

- **Nickel Metal Hydride(Ni-MH) Battery**\(^{27}\)\(^{28}\)\(^{29}\)

  - Ni-MH Battery are more popular than most rechargeable battery, and their good at replacing alkaline battery in many cases. They cost up to
about US$2 and a standard voltage of 1.2V. It has 30-40% higher capacity than the NiCd Battery. It is also environmental friendly as it contains mild toxins.

However, it requires high maintenance so as to prevent crystalline structure in the battery. This crystalline would affect performance of the battery. The batteries are also more expensive than normal battery, as it is used for appliances that draws high currents.

- Lithium Polymer (LiPo) Battery[^30]:

  - LiPo Battery, on the other hand, has about four times the energy of density of NiCd or Ni-MH battery. They are lightweight too and costs about US$1.20/Wh. They are more resistant, in terms of physical durability, than most batteries.

  - As good as it sounds, LiPo batteries has its flaws. Overcharging and overheating the battery would result in fire. Specific instructions on charging and storage should be followed closely. Also, if the battery is bulging or is out of shape, it should not be charged again.

This is one of the reasons why battery operated was not chosen to be a way to power the product. User convenience is another factor to consider as they would have to keep buying new batteries if the batteries are dead, or constantly recharge the batteries if they are rechargeable and to do so for every hour seemed ludicrous.

![Fig. 20 Embedded Switch Mode Power Supply][51]
The final decision was just to use a power supply, specifically, an embedded power supply. Wall sockets are typically Alternate Current (AC) voltage. However, the product uses Direct Current (DC) voltage. Therefore, the power supply draws AC voltage which would be then converted to DC voltage. It requires an input voltage of 115VAC 3.2A or 230VAC 1.6A, and is able to have an output voltage of +12V 12.5A. This amount was sufficient for all the components of the product to consume.

2.2.4 Airflow Rate

Airflow rate is defined as the velocity of air flowing through a particular area. Airflow rate may be the most important feature of the system as it is what dictates the amount of cool air the user will be able to experience. Since the inlet of a centrifugal blower has a flow rate of 0.48m³/min, the flow rate at the outlet would be the same if losses were to not be present in the product. While measuring the actual flow rate, the value achieved was 0.29376m³/min. This means that there is about a 39% loss, which is due to the two heatsinks in the product as well as the small openings and rectangular corners.

While centrifugal fans typically have a higher airflow rate than axial fans of the same size, the same goes for its noise and price. As for table desk fans, the airflow rates range from anywhere between 2.52m³/min - 3.18 m³/min. In an ideal scenario, a table desk fan would be used to direct the wind pass the cool heat sinks, however the airflow rate is too high for the cold wind to be felt which leads to the same effect as if the Peltier Device was not there. This reason is why smaller axial fans and centrifugal fans are considered instead as the airflow rates provided by these fans leads to a result where the range for the cool air is not high but can be felt. This further emphasises that the product can only be used for spot cooling (for one user) as opposed to an entire room.

2.2.5 Material for Case

Various materials were considered when fabricating the case, however picking one that is inexpensive and lightweight were paramount among all factors. Other factors, such as thermal conductivity and difficulty of machining would have to be considered as well when selecting a suitable material.

For example, heat intrusion through the casing was a problem faced. In order to achieve the ultimate cooling effect, the air should have sufficient thermal contact with fins before being blown out, and maintain the fins at lower temperature. Therefore, the casing material must have lower thermal conductivity to prevent air from gaining heat. A handful of materials were selected: stainless steel, acrylic, styrofoam, as well as aluminium.
### Table 4: Potential Materials for Case[34]

<table>
<thead>
<tr>
<th>Materials</th>
<th>Aluminium</th>
<th>Stainless Steel</th>
<th>Acrylic</th>
<th>Polystyrene (Styrofoam)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Conductivity (W/mK)</td>
<td>235</td>
<td>45</td>
<td>0.19</td>
<td>0.033</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>2700</td>
<td>7700</td>
<td>1180</td>
<td>50</td>
</tr>
<tr>
<td>Tensile Yield Strength (MPa)</td>
<td>276</td>
<td>215</td>
<td>69</td>
<td>178.7</td>
</tr>
</tbody>
</table>

Aluminium, as seen in the table above, was something the workshops had an abundance of. Unfortunately, aluminium is not a suitable material for the case as its thermal conductivity is relatively high as discussed earlier. Similarly, stainless steel was out of the question, though its thermal conductivity pales in comparison to that of aluminium.

Styrofoam seemed like a promising choice instead of acrylic due to its low thermal conductivity as it is usually used in ice boxes and chillers. On top of that, it is easy to cut and incredibly lightweight. However, this choice material was quickly shot down due to its durability.

Thus, the final choice was acrylic. Although acrylic has a slightly higher thermal conductivity compared to that of styrofoam, it has more to offer in other aspects. As an example, its thermal conductivity is relatively low while having high durability. Furthermore, it is considerably lightweight and easy to fabricate which makes it ideal for the material of the case.
2.2.6 Aesthetics

Users would generally be concerned about the way a product is presented as no one would purchase a product that is hideous even if it were to work optimally. To quote Steve Jobs: “Design is not just what it looks like and feels like. Design is how it works.” This further emphasises the importance of the aesthetics of a product.

When designing the first prototype, the heatsink that was used while favourable, suffered from being too big and heavy to fit in the case without having any protrusions. At 85mm in height and weighing more than a third of a kilogram, this made incorporating the heatsink into the case a huge challenge as the casing was made of 3mm thick plastic. However, the problems only piled on from there with the ideal fan size being anywhere between 8” to 10” in diameter, which meant that the case would have to be between 9” to 11” tall just to fit the fan. Since peltier devices are relatively small at 40mm x 40mm x 3mm, the heatsinks were also limited in size if the desired cooling effect were to be achieved. With this in mind, this version of the prototype was quickly scrapped in favour of a smaller unit.

![Fig. 22 85mm Tall Heatsink](image)

The second prototype involved the use of a centrifugal fan. As an example, the current centrifugal fan of Ø120mm has an airflow rate of 0.78m³/min when compared to the axial fan of 90mm x 90mm and has an airflow rate of 0.3m³/min. With this in mind the product can be made smaller with the downside being that it would be longer due to not having an exhaust fan to direct the airflow at the end of the flow.
The alternative prototype uses two axial fans, one as an inlet fan and the other as an exhaust fan. This concept would allow the air to fully flow through the heatsink(s) while directing the air to the user more accurately. Another added benefit to the axial version is that the design is almost 1.5 times smaller than the centrifugal version as well as being cheaper. However, axial fans do have lower airflow rates in comparison to a centrifugal fan which does lead to a lower airflow rate.

As for the placement of the wires, it was ideal if it were to be placed at the rear end of the product as it would not be an exposed mess that the user would encounter when opening the back panel. On top of that, enclosing the heatsinks entirely would lead to the heat generated by the Peltier Device to be inadequately dissipated, hence the heatsinks will be exposed to the surroundings in order to improve the cooling rate of the Peltier Device. The downside to this is that the fan blades will be exposed to the user which is a hazard in itself. Furthermore, the product will look unpleasant with the two fans sticking out at the sides, but it is a small price to pay to provide cool blowing air.

2.3 Deliver Process

2.3.1 The Product(s)

After going through all the design thinking methods, the various ideation processes and the constant prototyping, the products that were idealised since the start of the program finally came to fruition. The two products utilises different types of fans. The first model consist of a 120mm Centrifugal Fan with a dimension of 516mm x 129mm x 129mm and the second model uses a pair of 90mm x 90mm axial fans which results in a much smaller frame of 251mm x 105mm x 138mm.
Fig. 24 Centrifugal Model

Fig. 25 Drawing of Centrifugal Fan
Both products have their pros and cons, one of them being size. As seen from the pictures above, the axial model is much smaller in comparison to the centrifugal model but suffers performance wise. Ideally, the product would be the same size as the axial model with the blowing capacity of the centrifugal model. The centrifugal model offers almost three times the airflow of its axial counterpart. Due to this complication, both models were made to illustrate the differences that each model represents while also showcasing their advantages.
As far as comparisons are concerned, the main competitor to this product is the traditional fan and Dyson Fan. This product is not made to replace the air-conditioner but rather provide an alternative to users who would prefer a cooler experience that the fan is incapable of providing.

Table 5: Comparison of the Product(s) with Other Fans[^35][^36]

<table>
<thead>
<tr>
<th>Variables</th>
<th>Dyson Fan</th>
<th>Traditional Desk Fan</th>
<th>Axial Model (Prototype)</th>
<th>Centrifugal Model (Final)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Consumption (W)</td>
<td>32</td>
<td>41</td>
<td>126.48</td>
<td>131.52</td>
</tr>
<tr>
<td>Size (cm)</td>
<td>55.2(H)</td>
<td>14.5(L) 30(B)</td>
<td>30</td>
<td>13.85(H) 24.5(L) 10.5(B) 12.9(H) 51.6(L) 12.9(B)</td>
</tr>
<tr>
<td>Airflow Rate (m³/min)</td>
<td>22.2</td>
<td>17.2</td>
<td>0.17</td>
<td>0.3</td>
</tr>
<tr>
<td>Price ($)</td>
<td>300-400</td>
<td>30-40</td>
<td>112.5</td>
<td>125.8</td>
</tr>
<tr>
<td>Temperature Drop [°C]</td>
<td>1</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

As seen from the table above, the key difference between the two fans that were made and what is already out there is the low airflow rate. However, the temperature drop achieved is the highest for the Centrifugal Model despite its lack of airflow. Another thing to consider is the size of the product, the Centrifugal Model is about three times smaller in volume when compared to the Dyson Fan while costing about four times more than a traditional fan. It is clear that the Centrifugal Model provides the best temperature drop when compared to what is already available in the market. However, it is not the clear winner when other factors like airflow and power consumption are considered as these variables are vastly inferior to the competition.
2.3.2 Final Prototype

After some testing, the final product that was chosen was the Centrifugal Model. The reason for this was that of the two models, the airflow for the Centrifugal Model was three times higher than the Axial Model. Another reason why it was favoured was that the temperature drop that was achieved is almost one-and-a-half times higher. However, the one thing the Axial Model has over its counterpart is that it has a smaller frame while also weighing much less. In the end, the Axial Model does not have enough benefits that outweigh its disadvantages to make it superior to the Centrifugal Model.

2.3.3 How it works

The whole basis of blowing cold wind is thanks to the Peltier Device or Thermoelectric Modules. However, just having this device is insufficient when cool wind is concerned, which is why other items like Heatsink Fans, Heatsink Fins, and the Fan are integral to providing cool air to a user. Below will be an explanation of the 4 main components and the part they play in the experience.

Heatsink Fan(s)
In order to maximise the cooling capacity of the Peltier Modules, a heatsink fan is used in conjunction in order to dissipate heat quickly. The reason for this is that the temperature difference between the cool and hot junctions are constant. Hence, lowering the temperature of the hot junction would result in the cool side being colder.

\[ T_C = T_H - \Delta T \]

Typically, the temperature drop between two junctions of a Peltier module is between 40°C. When paired with a heatsink, the Peltier Module is able to reach temperatures as low as 2°C while the hot junction was giving off heat of up to 40°C. Since the difference in temperature denoted by \( \Delta T \) is constant, the temperature achieved on the cold junction could be reduced even further if more dissipation were to occur on the hot junction.

Heatsink Fins
As discussed earlier in the report, the heatsink fins are what enables the cooling effect to be controlled without it going to waste to the surroundings. Ideally, the heatsinks would be large enough that the cooling from the Peltier Device can be achieved without a drop in temperature, which means that a fan with high flow rate can be used. However, due to Peltier Devices being no more than 40mm x 40mm x 3mm in size, using a large heatsink without compromising the temperature drops is impossible. Thus, the product is made for spot-cooling instead which lead to its small frame.
**Fan**
Since both types of fans, centrifugal and axial, have their pros and cons, both models were made. Primarily the difference between the two is size with the centrifugal model being 516mm x 129mm x 129mm while the axial model only being 251mm x 105mm x 138mm. However, the centrifugal model does have an airflow value of 0.78 m³/min compared to the axial model which has a relatively low airflow of 0.3 m³/min. Furthermore, the centrifugal model does come at a higher cost of S$125.80 while the axial model is valued at S$112.50. It is evident that the centrifugal model is the superior of the two but it does come at a slight bump in cost when compared to the axial model.

![Fig. 28 Fan Types being Used][52]

All of these components combined with the Peltier Device is what enables the cooling effect to be experienced. Heatsink fans are the second most important component in the system with it being able to dictate the temperatures that the cold side is able to achieve. Furthermore, if the Peltier Devices were to be left with no heatsink on the cold side, the air around the Peltier Device would take too long to cool, which in turn minimises the cooling effect. In conclusion, while the Peltier Device is integral to the whole cooling process, the heatsinks ensure that none of the cooling would go to waste whilst rejecting the hot junction.
2.4 User Review

2.4.1 User Testing

The final prototype was ready for testing. After testing the product’s capability for ourselves, we decided to test it out on our users. The test was to let the users sit in front the product, turn on the product and let the user test it for a while. After the test, a series of questions were asked, below are a few examples of the questions (not in order):

1. What are your thoughts after seeing the design of the product?
2. The product’s electricity cost is about S$4 more than the normal fan. After hearing this, would you still use the product?
3. Can you see yourself using such a product in the near future?

The reason for asking these questions is to figure out the flaws in the product that were not considered during the design phase and enables the user to test out the product while seeing it in the flesh. This gives a rough idea of what the product looks like and also shows its capabilities, so as to better understand the product in order to give constructive feedback.

2.4.2 Feedback

Since the focus of the programme is SIP (Social Innovation Project), going back to the target audience to let them try out the product is essential after completion. After conducting a few rounds of interviewing and user testing, their critiques are recorded below:

Comments made by Mr Tan

- Waste of space
- Not very portable
- Very obstructing
- Feels like an eyesore
- Noise level higher than fan.
- Make it more compact so that it will be more portable and easier to carry.
- Wants to control speed of fan.
- Will use traditional fan as it is cheaper to buy and to use than the product.

Comments made by Mr Seah

- Too big
- Rather have a fan
- More expensive in the energy consumption
- Colder air than traditional fan
- Less exposure to air
- Do not mind design
- Serves no purpose compared to traditional fan

**Comments made by Mr Cheong**

- Not easy to produce compared to fan
- Take up a lot of space
- As good as normal fan
- Design can be better
- Rather use our product if it is just a little more expensive than the fan
- Does not mind being fixed at a certain speed
- Expensive in electricity bill

**Comments made by Mr Ow**

- Would like oscillation
- Wants to control fan speed
- Wants a safety feature for product
- Wants a better design. Product is too long and has redundant parts.
- Rather have switch in front for convenient.
- Would use the product compared to fan if at same price
- Noise level lower than fan
- Low maintenance
- Small outlet surface area.
- Would still use Fan O’matic even though it cost more per month.
- Product needs to be lighter
Chapter 3

3.1 Recommendations

The product designed was made with limitations and constraints which led to its current iteration(s) being far from perfect. Finding the right balance of size, mass, and airflow proved to be a challenge. The improvements that could be made to the current models are listed below:

Placement of Heatsinks
Currently the heatsink fans requires a mounting tab to stick on either sides of the case, which results in it sticking out like a sore thumb. The improvements that could have been made was to use a heatsink that has mounting capabilities already built into it. For example, a heatsink with a clamp or one with threaded holes would allow the product to look much sleeker as well improving its safety aspects. This change alone would make the product much more attractive aesthetically which could draw in potential users to use the product.

Fig. 29 Heatsinks are Sticking Out
**Size of Heatsinks**
The heatsinks alone are not able to dissipate heat which is why exhaust fans are typically used in tandem to provide sufficient heat rejection. However, if the heatsink and exhaust fans were to be small, the heat would take a longer time to dissipate. For context, the current exhaust fans, which are Ø90mm, is not enough to make heat dissipate at a fast rate. However, with a bigger exhaust fan, the same amount of heat dissipation can be achieved but at a higher rate, which would result in a lower temperature of the cold side.

**Temperature of Peltier Devices**
Currently, the device draws a fixed amount of 3.15A from the power supply. The current drawn is what dictates the temperature of the Peltier Device. However, by being able to use a device like a variable resistor, it would give users a sense of control over the product’s capability to blow out cool air at a specific temperature.

**Usage of H-Bridge**
Installation of a H-bridge would mean that the current supplied could be inverted hence changing the polarity of the cold and hot junctions. This means that the product would be able to blow out hot air, similar to that of a hair dryer. The thought of being able to cool down an individual, whilst being able to make use of the hot side, whether it is to dry something or warm up the individual on days where it would prove to be cold, could potentially make the product a cut above the rest.

![Fig. 30 H-Bridge Circuit Board](image)
Addition of Vanes
Another user friendly feature, which was not considered, was an adjustable stand or vane. Similar to what is being used in buses and commercial airplanes, a vane would allow the user to direct the flow of the cool wind without having to physically move the entire product just to get the wind blowing in a specific angle. These improvements could have helped the product, one way or another making it more marketable. Unfortunately, under many limitations and constraints, these improvements could not be consolidated into a new an improved version without flaws from each model resurfacing once more. Hence, two models were made to showcase these differences to allow users to experience both models to have a better idea of what exactly they are looking for in the product.

3.2 Conclusion

While the product that came from the programme did not fully cater to do needs of the people who live in dormitories, the product did provide something that does address the needs of these people at a minimum capacity. While the cost of this product may be too high for these individuals, Peltier Devices are currently being developed to be more efficient and cost friendly to cater to the cooling industry. Furthermore, the addition of components like a H-Bridge and Circuit Boards would result in the product bringing more value to potential users which would lead to the high cost being less intimidating. The final product is one that uses a completely different method to blow cool air, which has never been done before. This project is still in its infancy and could be the spark to a new age of household cooling.
REFERENCES


https://image.slidesharecdn.com/74ea41ac-91e8-4549-869b-54aa135a1fffd-150815191322-lva1-app6891/95/design-thinking-process-5-638.jpg?cb=1439666060 [3]


https://www.youtube.com/watch?v=ITtlxjvLQis [7]


https://i.pinimg.com/originals/db/40/aa/db40aa27e08fd784efccac196409ff9f.jpg [13]


https://i5.walmartimages.com/asr/60d4ccfc-a35c-4707-b1c7-43b82fb8ce7a_1.61ca929a976c6a525cea27e905da636d.jpeg [15]

https://www.youtube.com/watch?v=OZh9ksAy9kc [16]


https://www.boston.com/weather/weather/2014/07/10/understanding_dew_point_and_re [18]

https://www.researchgate.net/profile/Tosawat_Seetawan/publication/251716178_Analyzing_of_Thermoelectric_Refrigerator_Performance/links/55b382dd08aec0e5f4347160/Analyzing-of-Thermoelectric-Refrigerator-Performance.pdf [40]

http://www.pathways.cu.edu.eg/ec/text-pdf/part%20c-17.pdf [41]

https://www.timeanddate.com/weather/singapore/singapore/climate [42]

https://www.spgroup.com.sg/wcm/connect/spgrp/55619e11-884a-4f18-b28b-8b3f2d697a0e/%5B20170331%5D+Media+Release+-+Electricity+Tariff+Revision+For+The+Period+1+April+To+30+June+2017.pdf?MOD=AJP_FRES&CVID= [43]

http://www.qrg.northwestern.edu/projects/vss/docs/power/2-how-efficient-are-solar-panels.html [44]

https://image.slidesharecdn.com/74ea41ac-91e8-4549-869b-54aa135a1ffed-150815191322-lva1-app6891/95/design-thinking-process-5-638.jpg?cb=1439666060 [45]


https://cdn-shop.adafruit.com/1200x900/200-07.jpg [49]

https://a.pololu-files.com/picture/0J1057.1200.jpg?58edf1bd55b8cbb613f964f22f61d56e [50]


https://www.youtube.com/watch?v=w1cTmX-EyBA [53]

https://www.youtube.com/watch?v=Ev8Xu8fnAL4 [54]
Appendix

A. Project Cost

1) Professional Cooling System Kit Thermoelectric Peltier Refrigeration Cooler Fan
   Qty: 1
   Seller: lagobuy
   Price: $13.49 includes shipping

2) Thermal Grease
   Qty: 1
   Seller: Retail Store
   Price: $4.00

3) Portable Fan
   Qty: 1
   Seller: Retail Store
   Price: $8.00

4) Aluminium Foil
   Qty: 1
   Seller: Fairprice
   Price: $1.90

5) Poly Foam
   Qty: 2
   Seller: Artfriend
   Price: $3.20

6) Deep Cool Gammmaxx 200T Heat Sink with Fan
   Qty: 2
   Seller: Retail Store
   Price: $48.00
7) 12V 12.5amp150W DC Switching Mode Power Supply  
   Qty: 2  
   Seller: Wenzhou Zhiwen Electric Co. Ltd.  
   Price: $91.63 includes shipping

8) Sona SCF 6031 8” Circulator Metal Fan  
    Qty: 1  
    Seller: Silla Electronics  
    Price: $39.00

9) Cutter PC-S (P-450) OLFA  
    Qty: 1  
    Seller: Artfriend  
    Price: $10.27

10) Acrylic Sheet 2mm 18”x 24” White Diamond  
    Qty: 2  
    Seller: Artfriend  
    Price: $17.98

11) 6.9cm x 6.9cm x 3.6cm Aluminium Heatsink Radiation Cooling Fin Silver  
    Qty: 4  
    Seller: dsltd  
    Price: $30.40 includes shipping

12) Metal Brackets  
    Qty: 2  
    Seller: Retail Store  
    Price: $16.00

13) 70mm Centrifugal Blower 12VDC 4.32W  
    Qty: 1  
    Seller: Element14  
    Price: $22.14 includes shipping
14) Intel CPU Fan  
   Qty: 4  
   Seller: Make Fine Computer Pte Ltd  
   Price: $40.00

15) Acrylic Sheet 3mm 18”x 24” Clear Diamond  
   Qty: 4  
   Seller: Artfriend  
   Price: $39.80

16) Go X Go CPU Fan  
   Qty: 1  
   Seller: Costronic.SG Pte Ltd  
   Price: $12.00

17) Araldite High Performance Epoxy Adhesive  
   Qty: 4  
   Seller: Sun Hee Hardware  
   Price: $24.00

18) Bondite Epoxy Putty  
   Qty: 3  
   Seller: Sun Hee Hardware  
   Price: $14.70

19) Super Strength Mounting Tabs  
   Qty: 1  
   Seller: Samroc Paints & Hardware & Gas Supply Pte Ltd  
   Price: $3.90

20) 120mm Centrifugal Blower 12VDC 7.2W  
   Qty: 1  
   Seller: Element14  
   Price: $39.92
21) 8mm Heat Shrink Tubes  
Qty: 2  
Seller: Sun Hee Hardware  
Price: $3.00

22) 10mm Clear Spiral Wrapping  
Qty: 1  
Seller: Sun Hee Hardware  
Price: $5.00

23) 20mm Mounting Tabs  
Qty: 20  
Seller: Sun Hee Hardware  
Price: $3.00

24) Zip Ties  
Qty: 15  
Seller: Sun Hee Hardware  
Price: $1.00
B. Cost of Prototypes

**Model A (Axial Fan)**

1) Case: S$10.00  
2) Fan(s): S$24.00  
3) Heatsink(s): S$20.00  
4) Heatsink Fin(s): S$14.50  
5) Power Supply: S$32.00  
6) Epoxy Adhesives: S$5.00  
7) Switch: S$2.50  
8) Wall Adapter: S$2.00  
9) Misc: S$2.50

**Total: S$112.50**  
**Dimension: 251mm x 105mm x 138mm**

**Model B (Centrifugal Fan)**

1) Case: S$10.00  
2) Fan(s): S$37.30  
3) Heatsink(s): S$20.00  
4) Heatsink Fin(s): S$14.50  
5) Power Supply: S$32.00  
6) Epoxy Adhesives: S$5.00  
7) Switch: S$2.50  
8) Wall Adapter: S$2.00  
9) Misc: S$2.50

**Total: S$125.80**  
**Dimension: 516mm x 129mm x 129mm**

**NOTE:**  
The prices listed are based on retail pricing, if parts were to be bought directly from suppliers the price would be cheaper. Furthermore most of these parts were bought individually, if parts were to be bought in bulk, prices would be 5% lower.
C. Gantt Chart
D. Drawings/Sketches
D1. Drawings of Centrifugal Type Cooling Unit
Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>QTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Centrifugal Fan Case</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Heatsink</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Intel fan</td>
<td>2</td>
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<tr>
<td>4</td>
<td>Peltier</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Power Supply</td>
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</tr>
<tr>
<td>6</td>
<td>Switch</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>120mm Fan</td>
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</table>
D2. Drawings of Axial Type Cooling Unit
### Parts List

<table>
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<th>ITEM</th>
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<th>QTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Axial Fan Casing</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Axial Fan</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Heatsink</td>
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<tr>
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<td>Intel fan</td>
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<tr>
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<tr>
<td>6</td>
<td>Power Supply</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Switch</td>
<td>1</td>
</tr>
</tbody>
</table>
D3. Sketches