

**SOLAR ENERGY HARVESTING SYSTEM**

**BY**

**HO JIAN QIN, STANLEY**

**A REPORT**

**SUBMITTED TO**

**Universiti Tunku Abdul Rahman**

**in partial fulfillment of the requirements**

**for the degree of**

**BACHELOR OF INFORMATION TECHNOLOGY (HONS)**

**COMPUTER ENGINEERING**

**Faculty of Information and Communication Technology**

**(Perak Campus)**

**JAN 2016**

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## DECLARATION OF ORIGINALITY

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## ABSTRACT

This project is to study and build a solar energy harvesting system for academic, research and development purpose. This project focuses on how to harvest solar energy more efficiently and effectively. In this project energy of light from the sun will be harvested using solar panels and the thermal energy from the sun using thermoelectric generators (TEC). That way both photovoltaic effect and Seebeck effect will be used to produce electricity. The solar panels and TECs will be attached to a 5V DC-to-DC converter to regulate the output to 5V. One side of the TEC would have to be exposed to cooler temperatures in order to obtain better results hence the whole system would be placed in water such as ponds, pools, etc. Water propellers will be integrated into the system so that the system will be able to be manoeuvred on water. This system will consist of five major components, which are the solar panels, the TECs, microcontroller, water propellers, and a floatation device. Two Arduino Uno microcontrollers are used in this project. One will be attached to the system and the other will be connected to the remote control. Both microcontrollers will have 2.4GHz NRF24L01 (wireless transceiver/receiver modules) attached to them to enable wireless communication. The microcontroller will be used to perform data logging during the early stages of this project. The expected outcome of the project is to be able to use the constructed system to charge batteries and being able to be manoeuvred on water and perform data logging via wireless communications.

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## LIST OF SYMBOLS

V	Voltage
GHz	Giga Hertz
\$	United State Dollars
%	Percentage
~	To
W	Watts
Lbs	Pounds
mAh	milli ampere per hour
mA	milli ampere
uF	micro farad
I	Current
A	Ampere
R	Resistance
$\Omega$	Ohm

## LIST OF ABBREVIATIONS

CPU	Central processing unit
USB	Universal Serial Bus
TEC	Thermoelectric cooler
PV	Photovoltaics
TEG	Thermoelectric generator
U.S.	United States
TFSC	Thin Film Solar Cells
LCD	Liquid Crystal Display
2D	Two-Dimension
DC-to-DC	Direct current to direct current



## **CHAPTER 1: INTRODUCTION**

### **1.1 Problem Statement**

Many countries around the world are still using fossil fuels to generate electricity. Not only they are depleting resources, they also cause a lot of pollution to the environment. Although it is still cheap to use fossil fuels to generate electricity now, it will eventually cost a fortune when the world's fossil fuel starts to deplete. Hence why more studies and researches should be done on renewable energy such as solar energy, wind energy, and more as they will be the best source of energy when fossil fuel are depleted.

Not only renewable energy is unlimited, it is also pollution free. The only downside is that some renewable energy system is not very efficient. Another problem is that solar panels are usually installed to a fixed location and sometimes it will be sheltered by objects. Hence in this project I would like to develop a solar energy harvesting system that floats and able to manoeuvre around water. It will utilize both TEC and Solar panels to generate even more electricity compared to the conventional solar harvesting energy system which only utilizes solar panels.

Generally, most of the clean energy harvesting system are stationary and requires constant maintenance / monitoring. This project might be the answer to self-sustainability clean energy that it both portable and easy to manoeuvre.

### **1.2 Background information and motivation**

Solar panels are composed of a number of solar cells that converts energy obtained from light into electricity also known as Photovoltaics (PV). As long as there is direct sunlight towards the solar panels, it will produce electricity. Solar cells were invented back in 1839 and were inefficient and expensive to produce at the time. As of now, solar panels are cheaper to produce and are more efficient compared to the past.

TECs are small devices that can converts temperature differences directly into electricity, also known as the Seebeck effect. The device basically consists of two sides, one would be exposed to heat and the other side will be exposed to cooler temperatures. These devices were discovered in the 19<sup>th</sup> century and only in recent years have been put to good

use. TECs are used in gas pipelines, automobiles, etc. TECs only generate a small amount of electricity under normal circumstances.

The amount of electricity produced from the solar panels themselves are fairly small, hence almost every solar harvesting system consist more than 1 solar panel in their system.

The Arduino Uno is a programmable microcontroller that needs an input of 5V in order to function. It can be used in many ways by attaching more components to the microcontroller.

With the current market on fossil fuels being unstable, one can only predict that it might come to a day that fossil fuels are either too expensive to be used or too hard to be obtained. With solar panels and TEC being easily accessible and cheap to obtain in this era, it is a great time to be researching on clean self-sustainability solar energy harvesting projects that is both efficient and portable.

### 1.3 Objectives

The main objective of this project is to improve the effectiveness and efficiency of solar energy harvesting. Below are the sub-objectives that are aimed to be achieved in this project.

- Produce better results than the conventional solar energy harvesting system.
- Optimizing the TECs to produce better results.
- To integrate TECs and solar panels together into one system.
- To install floatation device onto the system.
- Able to perform data logging wirelessly.
- Install necessary components to allow the system to be manoeuvred via wireless remote.
- To be able get harvest more electricity than electricity consumption.

We are only going to use natural heat and cold to power up the TECs as using artificial heat and cold will destroy the purpose of renewable energy harvesting.

#### 1.4 What have been achieve

Below are the highlights of what have been achieved in this project so far.

- Data collection of how much energy the TECs and Solar panels collect.
- Building a TEC system consisting of 7 TECs and heat sinks attached to both sides with charging output capability. (Attached to a 5V DC-to-DC converter)
- Merging of the two solar energy harvesting systems onto a floatation platform.
- Able to charge and discharge electricity at the same time.
- Being able to communicate with the system via wireless communication using Arduino Uno R3.
- Able to perform data logging via wireless communication
- Programming of the two Arduino devices to control underwater motors of the solar energy harvesting system.
- Able to harvest more energy than discharging rate
- The entire system is able to float on water

## CHAPTER 2: LITERATURE REVIEW

### 2.1 Literature Review

#### 2.1.1 Solar Panels (Solar cells)

There are a few systems that have been created to harvest solar energy and convert them into electricity to power up household appliances or industrial level appliances. One of the most commonly known systems is solar panels. The practical solar cells that are used to create solar panels were invented in the 1950's by a few companies. Back then solar cells were too expensive to be bought in large amounts. But as time passes, the cost to buy solar cells becomes cheaper and cheaper. And the year 2011, China has managed to push manufacturing costs down to \$1.25 per watt for silicon photovoltaic modules which then caused the installations of the solar cells to be double worldwide in that year itself. In figure 2.1 below is a picture of a typical solar panel that is being used to power up appliances used in a house.



Figure 2.1

A solar panel consist of a set of solar photovoltaic (PV) modules that are electrically connected and mounted on a frame or a structure. Most of the photovoltaic cells are made of semiconductors such as silicon, which is the most frequently used material to build a photovoltaic cell. Below in Figure 2.2 is how the solar cells and other materials are assembled to form a solar panel.

UDBS CAFE 524

## Photovoltaic Cells technology

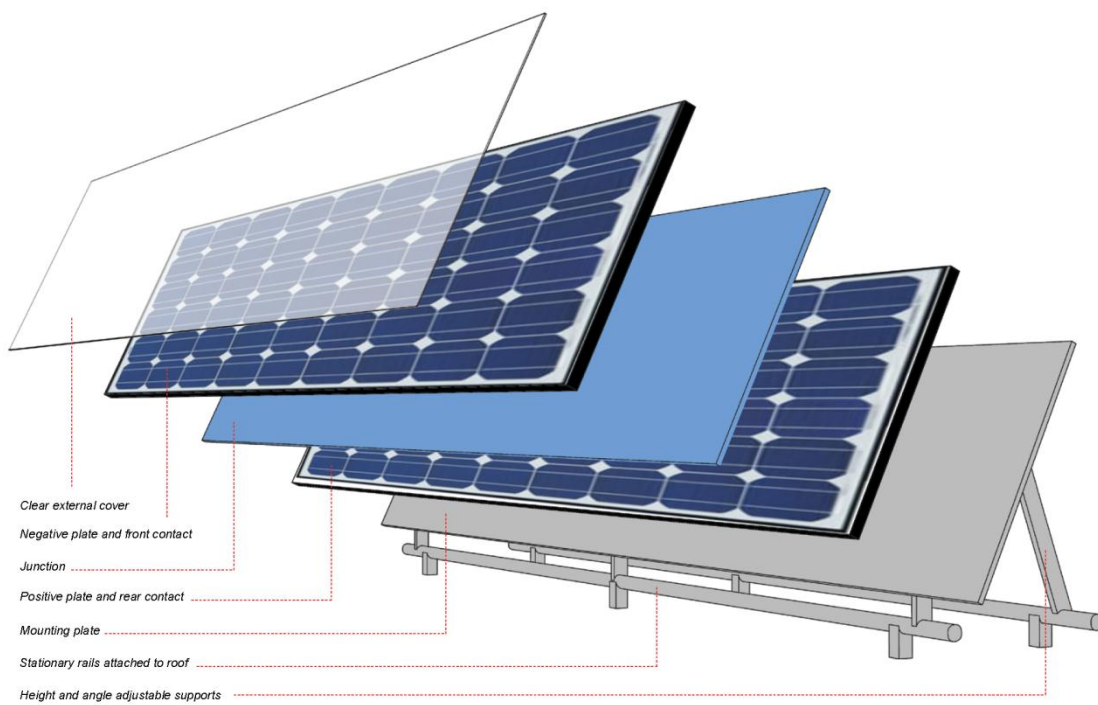


Figure 2.2

When sunlight shines into these cells, the electrons will be freed due to the photon absorption. This will then cause the free electrons from the negative plate to pass through a wire (which is connected from the negative plate to the positive plate) and be recombined with a hole in the positive plate. The freed electrons in the positive plate will then be transferred to the negative plate through the junction. Figure 2.3 will illustrate how a PV cell works in detail.

# How PV Cells Work

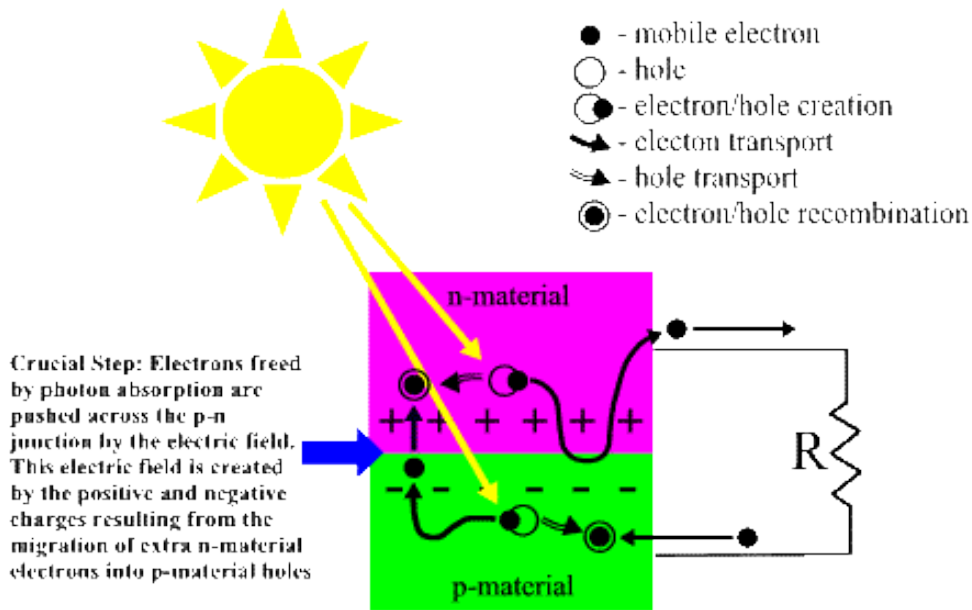


Figure 2.3

The n-material is usually silicon doped with phosphorous. This is because the silicon which is doped with phosphorous will only require a lot less energy to free the electrons. This will cause the n-material to be negatively charged. The p-material on the other hand is silicon doped with boron. Instead of having free electrons like the n-material, the p-material has free openings to hold electrons and therefore is positively charged. The electrons that flow through the wire will then provide current and the cell's electric field causes a voltage. With this two, current and voltage, I now have power. Since silicon itself happens to be very shiny which can then cause the photons to bounce, an antireflective coating is applied onto it.

These solar panels can be connected to a set of batteries to be charged and used during the night since there won't be any sunlight in the night to provide power the solar panels. Solar panels are relatively cheap now so they can be used in large quantities to harness large amount of current during the day. These solar panels don't need constant maintenance and in a long run, it will be cheaper than other source of power. Also solar panels are environment friendly as they don't produce any pollution.

The downside of this technology is that up until now, the most efficient solar panel only has 40.7% solar efficiency which was invented and produced by the U.S. Department of Energy. The more energy a person wants to harvest using solar panels, the more surface area of direct sunlight is needed outdoors ( Solar panels won't work indoors as they are not exposed to sunlight ). To always maximize energy production, the panels must never be shaded by objects and it must always be inclined properly towards the sun.

These weaknesses and limitations can be reduced by installing a motor to the frame and allowing the panels to face towards the sun wherever the sun is positioned at to maximize energy production. And also in the future with the help of further research, the solar efficiency can be further increased.

### 2.1.2\_Monocrystalline and Polycrystalline solar panels

A conventional monocrystalline solar cell is dark black in colour and the corners of the cells are usually missing due to the production process and the physical nature of monocrystalline silicon. A conventional Polycrystalline are light or dark blue in colour. These two different types of solar panels have not much of a difference in efficiency when compared side by side although monocrystalline solar panels have higher efficiency rates. This is due to them being made out of the highest-grade silicon. Figure 2.4 is picture of a monocrystalline solar panel and figure 2.5 displays a common polycrystalline solar panel.

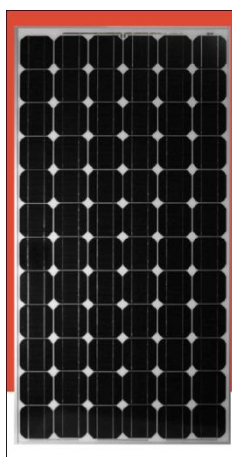


Figure 2.4



Figure 2.5

Monocrystalline solar panels are more space-efficient. They also last longer in terms of lifespan and most manufacturers give a 25-year warranty for their monocrystalline solar

panels. They also perform better at low-light conditions when compared to polycrystalline solar panels. However, despite the advantages, monocrystalline solar panels are the most expensive type of solar panels one can find. And due to the manufacturing process required to manufacture these solar panels, a lot of original silicon ends up as waste. Monocrystalline solar panels tend to perform better in warm weather.

Polycrystalline solar panels however are simpler to be manufactured and cost less. They also tend to have slightly lower heat tolerance than monocrystalline solar panels. However due to their lower silicon purity, they have lesser efficiency compared to monocrystalline solar panels. And they are not very space efficient.

### 2.1.3 Thin-Film Solar Cells (TFSC)

Thin-Film solar cells are second generation solar cell that is made by depositing one or more thin films of PV (photovoltaic) materials on a substrate such as plastic, metal or glass. Figure 2.6 shows a picture of Thin-Film solar panels in an open field.



Figure 2.6

One of the advantages of this type of solar panel is that mass-production of it is simple and thus making them potentially cheaper to be manufactured. They also look better and they are also flexible. Shading and high temperatures have less impact on the performance efficiency.



Although they are cheap and easy to be mass-produced, they are generally not very useful in residential areas as they require a lot of space. Low space efficiency means that installing them will require more cost for the PV-equipment such as the support structures, cables, frames and more. They also do not last as long as the crystalline solar panels.

#### 2.1.4 Thermoelectric generator (TEG)

A thermoelectric generator (TEG) is basically a device that generates electricity when there is a temperature difference between the two surfaces using the Seebeck Effect. The Seebeck Effect is the conversion of temperature difference into usable electricity. This effect is named after Thomas Johann Seebeck. He discovered the Seebeck Effect in 1821. Figure 2.7 shows what a common TEG looks like.

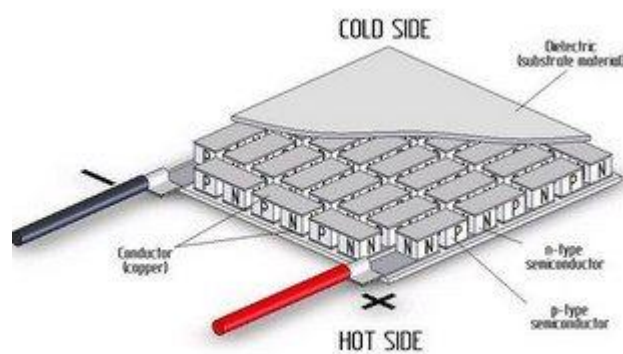


Figure 2.7

A TEG consist of four main parts: A high temperature side heat exchanger, a low temperature side heat exchanger, thermoelectric materials and a compression assembly system. The thermoelectric materials that sandwiched in between the hot side and the cold side are made up of p-type and n-type semiconductors. The heat exchangers plates are made up of metals with high thermal conductivity. When heat is applied to the hot-side heat exchanger, the charge carriers of the semiconductors will then diffuse from the hot-side to the cold-side, therefore producing current and voltage. The compression assembly system is aimed to decrease the thermal contact resistance between the heat exchanger surfaces and the thermoelectric module. These TEGs are primarily used to reduce fuel consumption.

TEG allows cars to generate electricity from the engine's thermal energy which it uses mechanical energy to power it. Using this technology onto a vehicle will help decrease

fuel consumption and also therefore decrease pollution. These TEGs can also use the heat generated from the sun to produce electricity (in very small amount).

The downside of these TEGs is that they are only about 5% efficient. It is also very heavy as there are primarily made of metal. It is hard to find a situation where one can supply heat on one-side and cold on the other side.

TECs on the other hand, are thermoelectric cooler that looks exactly like a TEG. It converts electric into heat or cold (depending on the flow of current). They can also be used as a TEG by supply heat on one side and cold to the other side and channelling the electricity out to an electricity storage device.

To use this TEG to harvest renewable energy, one can provide the sun's heat to the hot-side of the TEG and use water to cool the cold-side of the TEG to produce electricity. Also, since this TEG has very low efficiency, one can attach another kind of renewable harvesting energy system as a backup.

#### 2.1.5 Thermoelectric Fan Powered by a Candle

This is one of the very popular mini projects that utilize a single TEC to generate electricity. The components used in this project are two heat sinks that are generally used in CPUs (Central Processing Unit), a candle, a TEC, thermal paste, USB-fan, a piece of wood, two pull springs, a few bolts and a DC motor of 1,5-3V. Figure 2.8 of how the fully constructed mini project looks like.

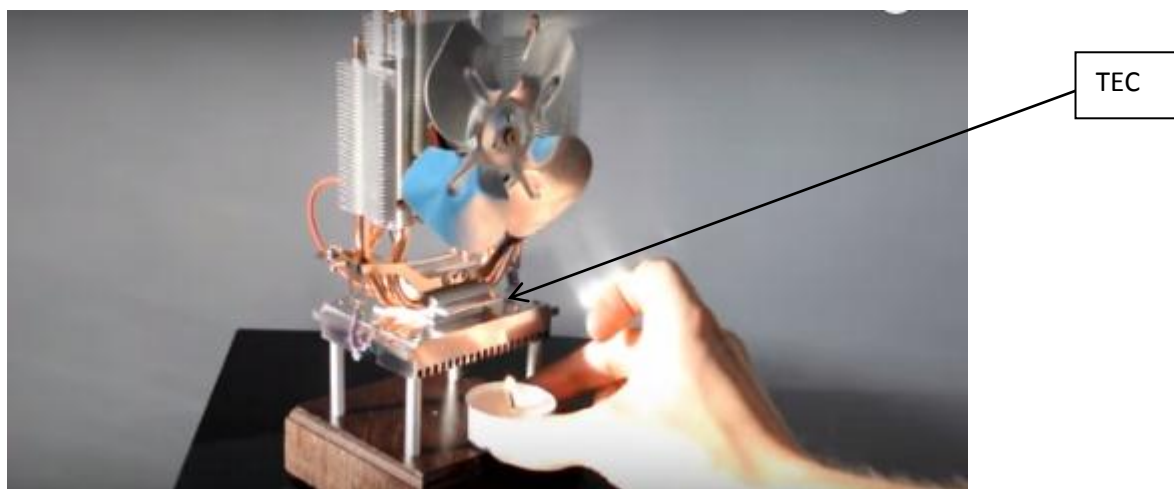


Figure 2.8

As noted in the above figure 2.8, the TEC is sandwiched between the two heat sinks. Where the bottom piece of heat sink is exposed to the heat of the candle and the other heat sink at the top dissipates the heat through exposed large surface area. When one side is provided with heat and the other side is cooler, it will create a Seebeck effect and hence generates electricity. So basically the higher the temperature difference, the more the output power of the mini project.

When the hot side gets up to 100-150 Celsius, it can yield up to 0.4V to 0.67V from 1 TEC alone. The two resulted in 0.1W and 0.36W respectively.

#### 2.1.6 NOMAD 7 solar panel

The NOMAD 7 solar panel is a portable solar panel unit that is sold internationally, mainly in the U.S. It is produced and sold by GOALZERO, a company which focuses on solar energy. The NOMAD 7 solar panel is made of monocrystalline solar cells and it has a solar capacity of 7W. It only weights 0.8lbs and it has a 12V and USB output. It has an open circuit voltage of 8-9V. It is capable of charging through two ports simultaneously and capable of charging a 2200mAh battery in 4 to 8 hours. Figure 2.9 is a picture of the NOMAD 7 solar panel.



Figure 2.9

## 2.2 Critical Remarks of previous works

Conventional solar panels that are used in homes are usually placed on top of the roof facing in one direction. Although they do produce a good amount of electricity but they are stationary and might be shaded by objects from time to time. With the system produced in this project, one can move the system wirelessly if it were ever to be shaded by an unwanted object.

TECs are generally used in places where there is a big difference in heat and cold temperatures. Examples would be automobiles, gas pipelines, etc. The only downside to these are that the TECs still depends on the primary object that is it attached to and the primary object requires non-renewable energy to operate. Hence, in this project I am only going to obtain thermal energy from the sun and cooler temperature from a water source to obtain an output from the TECs.

## CHAPTER 3: SYSTEM DESIGN

There are three main parts to be designed and implemented. The first part is to design the TEC system and perform data collection of it. Second part would be the design and combination of the solar panels and to perform data collection of it. And lastly is to assemble the two built system onto a floatation device and connect them to the four water motor with wireless communication.

### 3.1 Design and implementation of the TEC system

The design flow of the TEC system is as follow (Diagram 3.1).

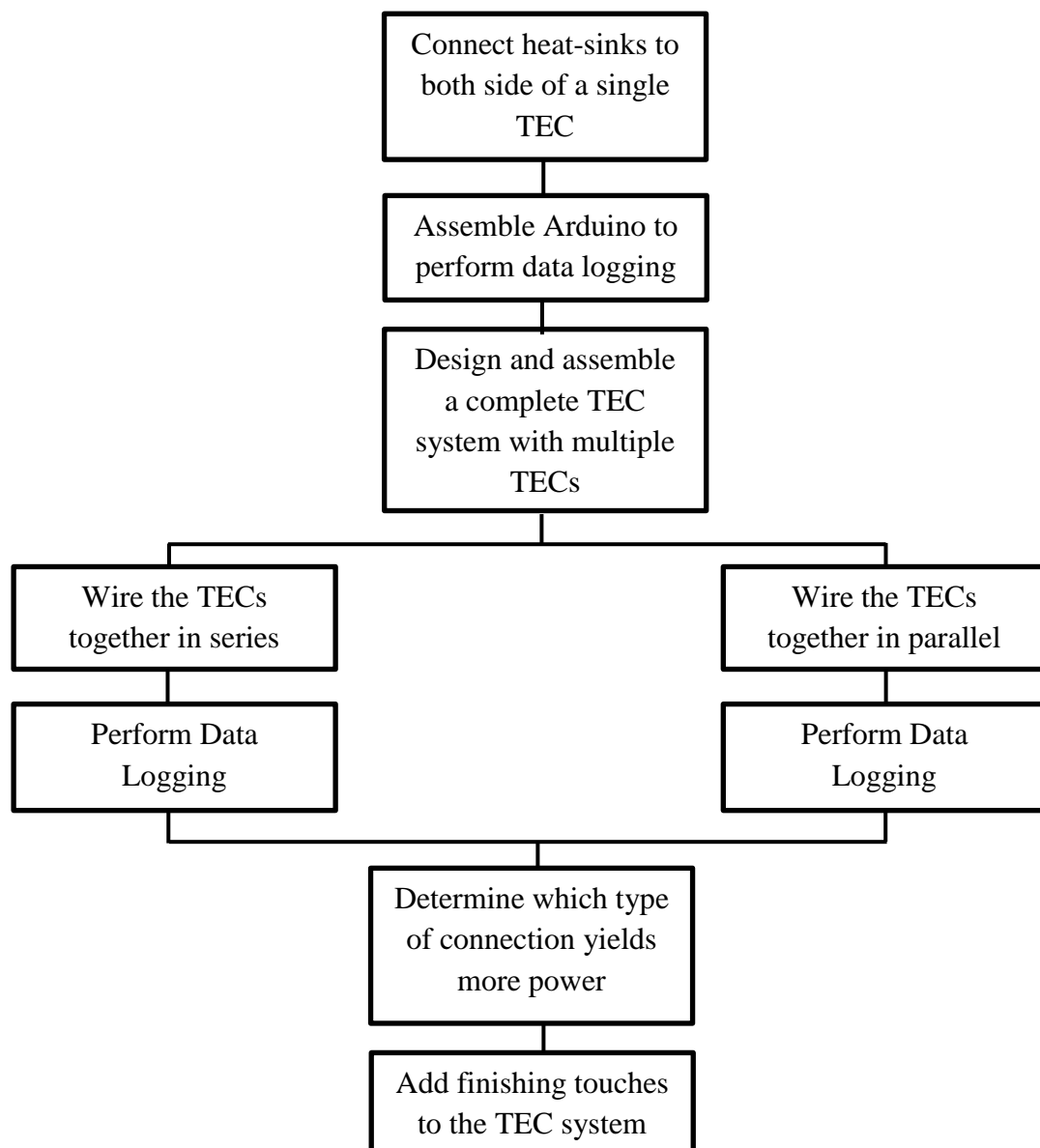


Diagram 3.1

### 3.1.1 Connecting the TEC module to heat-sinks

The very first step is to connect two heat-sinks to the TEC. This step is a research step in order to help determine what the final design of the TEC would be. This will help determine how many units of TEC should be used, placement of the heat-sinks and so on.

One heat-sink will be connected to the hot-side of the TEC and the other will be connected to the cold-side of the TEC. The main purpose of this step is to increase the thermal conductivity on both sides. With better thermal conductivity on both sides, the TEC, ideally, would be able to produce better results over a period of time (Figure 3.1).



Figure 3.1

### 3.1.2 Assemble Arduino to perform data logging

After this step is completed, a simple data logging system is built using a Arduino Uno R3, a LCD, and jumper wires. The connection of the Arduino and the LCD are as follow (Table 3.1).

LCD Pin	Connect to
1 (VSS)	GND Arduino pin*
2 (VDD)	+ 5v Arduino pin
3 (contrast)	Resistor or potentiometer to GND Arduino pin*
4 RS	Arduino pin 12
5 R/W	Arduino pin 11
6 Enable	Arduino pin 10
7 No connection	
8 No connection	
9 No connection	
10 No connection	
11 (Data 4)	Arduino pin 5
12 (Data 5)	Arduino pin 4
13 (Data 6)	Arduino pin 3

14 (Data 7)	Arduino pin 2
15 Backlight +	Resistor to Arduino pin 13**
16 Backlight GND	GND Arduino pin*

Table 3.1

After having the connections between the Arduino and the LCD done, a simple program is written and uploaded into the Arduino Uno R3 using a computer and the Arduino software. A library of LiquidCrystal.h must be downloaded online first and then placed in the Arduino's library. The program is written as follow:

```
#include <SPI.h>
#include <LiquidCrystal.h>

#define CE_PIN 9
#define CSN_PIN 10

LiquidCrystal lcd(8, 7, 6, 5, 4, 3, 2);

int backLight = 1; // pin 1 will control the backlight
int analogPin = 3;

int val=0;

float voltage=0.00;

void setup()
{

// test[0] = 1;
Serial.begin(9600);

pinMode(backLight, OUTPUT);
digitalWrite(backLight, LOW);
lcd.begin(20,4);
lcd.clear();
lcd.setCursor(0,0);
lcd.print("Stanley's Project"); //print to LCD
lcd.setCursor(0,1);
lcd.print("Phase 1"); //print to LCD
lcd.setCursor(0,2);
lcd.print("ADC and LCD"); //print to LCD
}
```

```

void loop()
{
  val = analogRead(analogPin);
  voltage = val * 5.0 / 1024; // Formula to convert ADC value to real voltage value

  lcd.setCursor(0,3); // set cursor to column 0, row 3
  lcd.print("Voltage: "); //print to LCD
  lcd.setCursor(9,3);
  lcd.print(voltage);

  delay(1000);
}

```

After uploading the program into the Arduino, we can now add a jumper wire to A3 and another jumper wire to GND of Arduino and use the two wires to measure Voltage using the ADC of the Arduino. In order to verify that it is working, a simple verification test is done to test on whether the arduino is functioning as expected. This is done by attaching Arduino's A3 to the positive side of the AAA battery and the Arduino's GND to the negative side of the AAA battery. Pictures shown below are the result of the small verification test (Figure 3.2 & 3.3).

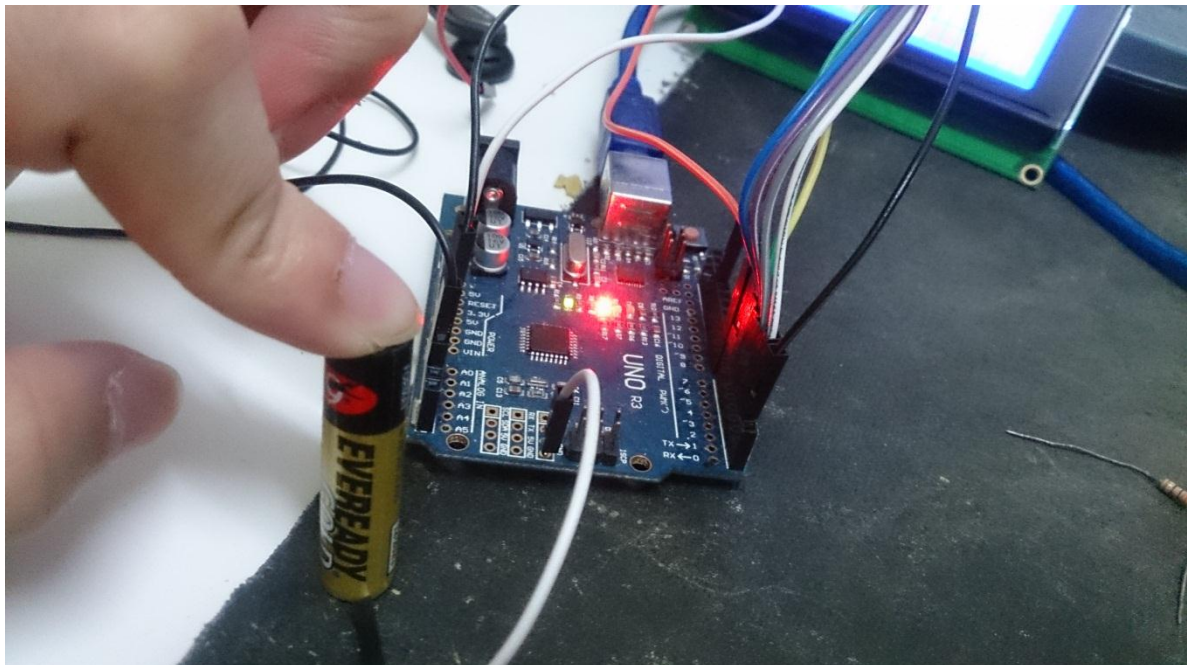


Figure 3.2



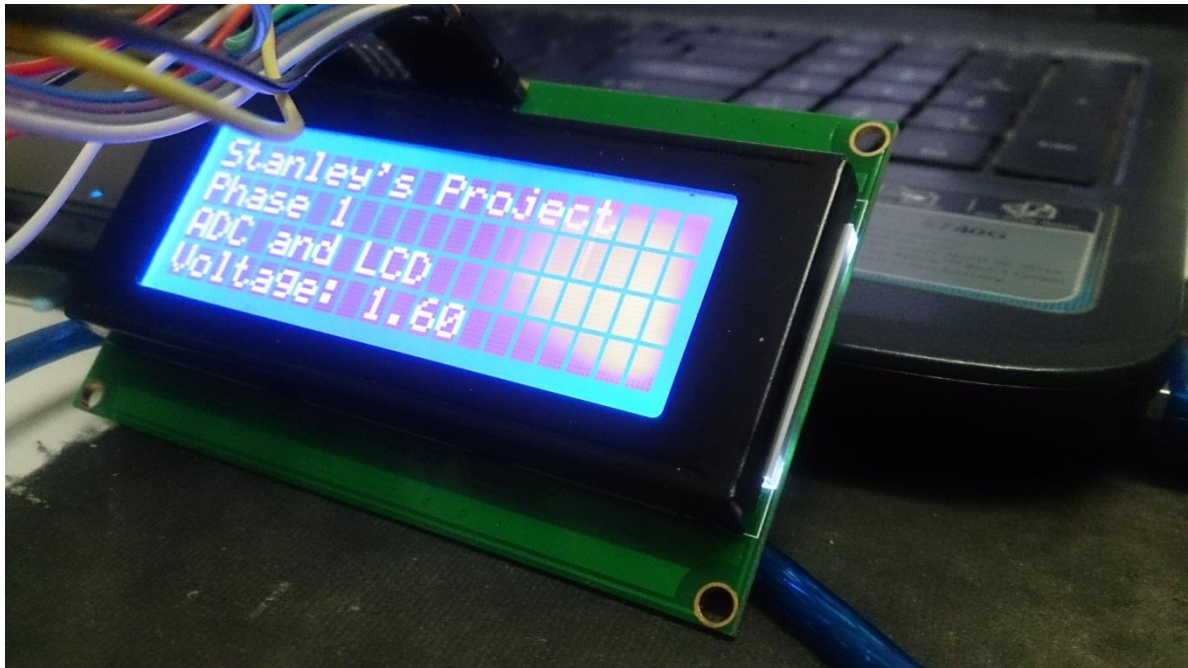


Figure 3.3

Knowing that the Arduino is functioning properly, it can now be used to perform data logging with the TEC. This is done by connecting the positive wire of the TEC to the Arduino's A3 and the negative side of the TEC to the GND of the Arduino. The results will then be displayed on the LCD.

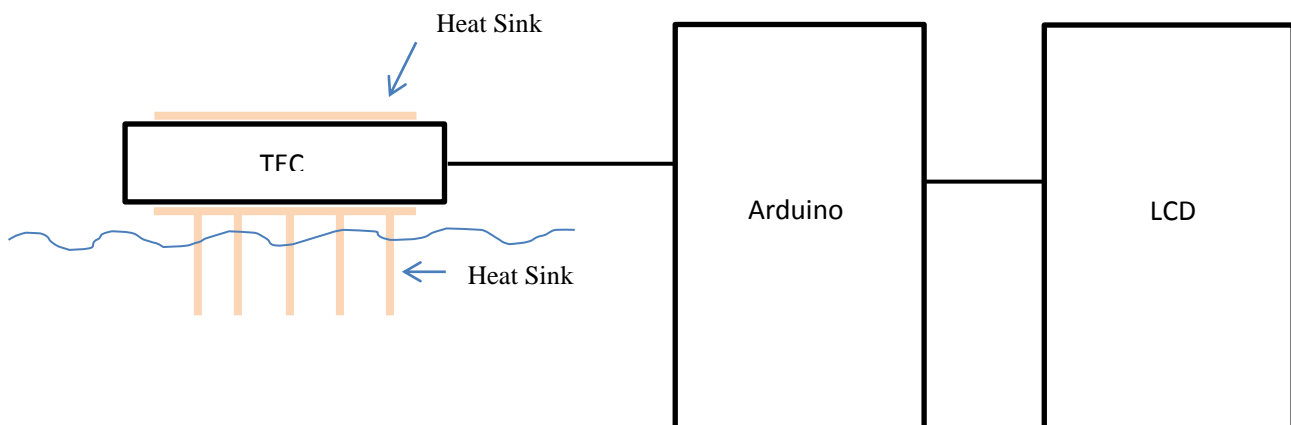


Figure 3.4

To perform the data logging, the cold side of the TEC will be partially submerged in the water to simulate a pond or lake, and the hot side of the TEC to be exposed to the sun (Figure 3.4). The voltage produced from a single TEC itself can generate 0.03V to 0.11V. From the experiments done, it is deduced that more than one TEC should be used in order

to get a bigger voltages. Therefore it is decided that 7 TECs should be used to design the TEC system.

### 3.1.3 Design and assemble a complete TEC system with multiple TECs

The assembly of the TEC system is almost the same as the assembly of the single TEC used to perform the first data logging. All 7 TECs cold side was paste onto a big sized heat-sink with the help of a thermal sticker. The thermal sticker helps stick the TECs to the heat-sink firmly and at the same time conduct good thermal conductivity. If conventional two-sided tape were used, the heat conductivity between the heat-sink and the TEC will be greatly reduced as conventional two-sided tape has lower thermal conductivity. After that, the hot side of all 7 TEC are then connected to another heat-sink with the help of thermal stickers.

With the TEC system now fully designed and implemented, the TEC system will now be connected in two modes, series and parallel. This step is to compare which of this two modes will the TEC generate most power. To be able to get a better understanding of the power generated from this TEC, two simple temperature readers are connected to the TEC system. One of the temperature readers will be connected to the hot-side and the other will be connected to the cold side.

### 3.1.4 Wire the TECs together in parallel and perform data logging

To connect them in parallel, all the positive wire of the TECs are wired together and all the negative wire of the TECs are wired together. The TEC system that is connected in parallel is then connected to a multimeter to obtain voltage and ampere readings (Figure 3.5). The reason why in this data logging phrase it wasn't connected to the Arduino to be performed automated data logging is because the temperature readings had to be done manually.

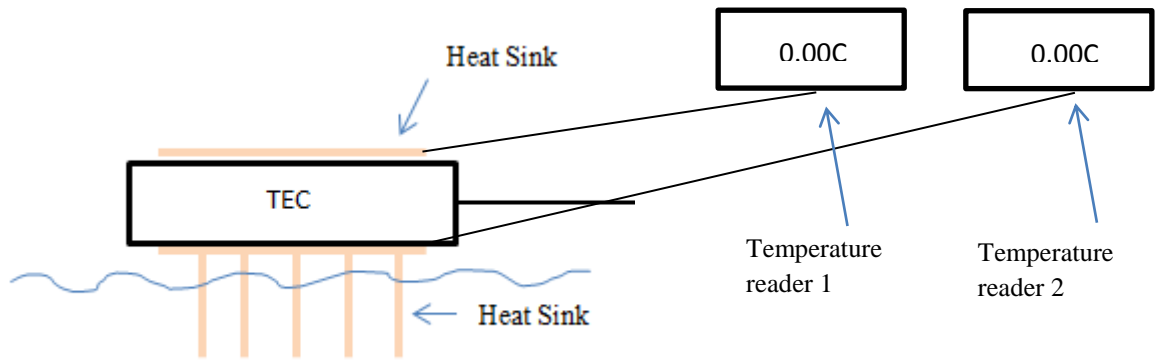


Figure 3.5

Below is the result obtained from the data logging performed after submerging the cold side of TEC system in water and having the hot side of the TEC system exposed to sunlight (Table 3.2 & Figure 3.6).

Temperature difference(C)	Voltage (V)	Amp (A)	Power (W)
0.4	0.01	0.03	0.0003
0.8	0.02	0.04	0.0008
1	0.025	0.05	0.00125
1.6	0.04	0.06	0.0024
1.8	0.045	0.065	0.002925
2	0.05	0.07	0.0035

Table 3.2

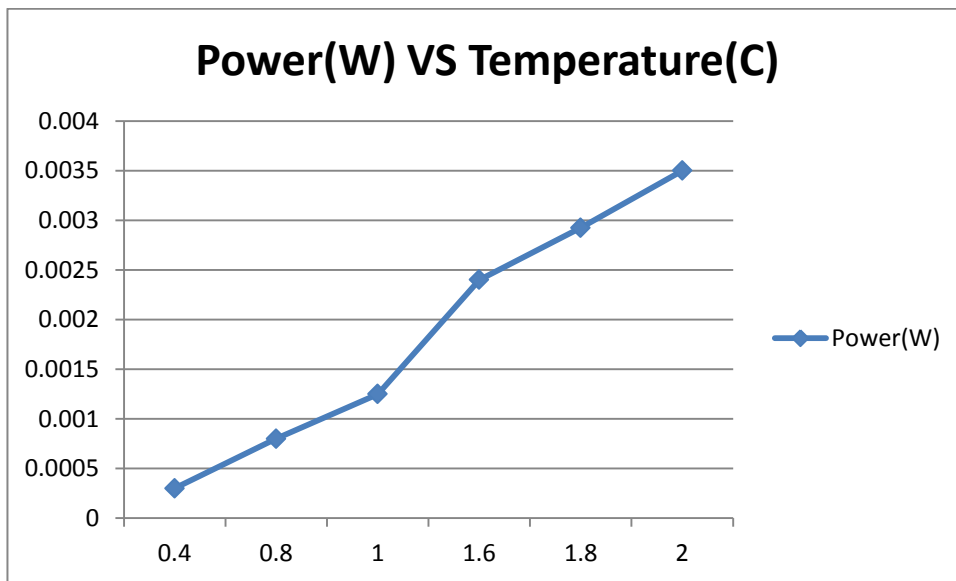


Figure 3.6

Using this method there could only be a temperature difference of up to 2°C due to the small amount of water being heated up quickly under the blazing sun, causing the cold side of the TEC to not be as ideal as the temperature expected from the open lake as this project is meant to be placed in the lake for cooler temperature. At 2°C, only a 0.0035W is obtained. To further obtain the desire results, a pot of boiling water is placed directly on top of the TEC system while having the bottom part submerged in water (Figure 3.7).



Figure 3.7

With this method, a better temperature difference was obtained. Below is the graph and reading obtained from putting a pot of boiling water on top of the hot side of the TEC system and having the cold side of the TEC system submerged in water (Table 3.3 & Figure 3.8).

Difference in Temperature ( C )	Voltage ( V )	Current ( A )	Power ( W )
1	0.02	0.04	0.0008
2	0.04	0.08	0.0032
3	0.05	0.11	0.0055
4	0.08	0.14	0.0112
5	0.11	0.2	0.022
6	0.15	0.27	0.0405

Table 3.3

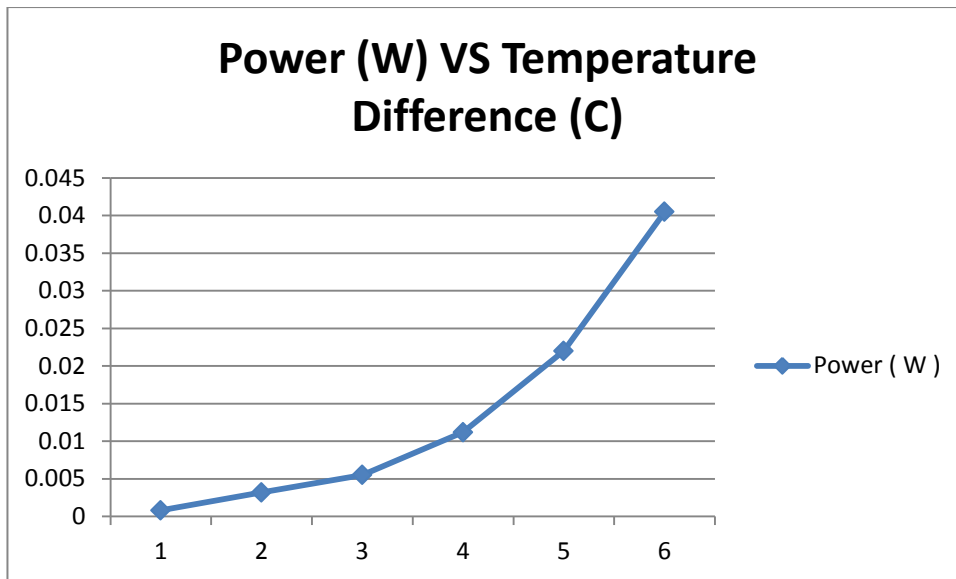


Figure 3.8

As observed from the graphs above, as the temperature difference increases, the power produced from the TEC system drastically increases.

Once the data logging is done for the parallel circuit of TEC. The next step is to disassemble the wiring of the parallel circuit of TEC and wire them in series.

### 3.1.5 Wire the TECs together in series and perform data logging

To connect all the TECs together in series, the first TEC's negative end will be connected to the second TEC's positive end, and the negative end of the second TEC is connected to the third TEC's positive end. This is continued until all TECs are connected leaving the first TEC's positive end not connected to anything and the last TEC's negative end not connected to anything. The diagram shown below is how the TEC is a diagram of how the TEC is set-up (Diagram 3.2).

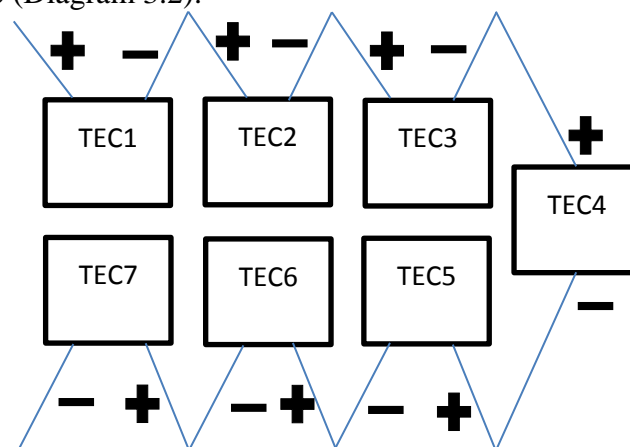


Diagram 3.2

By having the heat-sink of the cold side of the TEC system submerged in water, and having the heat-sink of the hot side of the TEC system exposed to the sun, there will be a voltage reading and ampere when measured across positive end of the first TEC and the negative end of the 7<sup>th</sup> TEC. Below is the table and graphical representation of the result obtained from doing data logging through this method (Table 3.4 & Figure 3.9).

Temperature difference(C)	Voltage (V)	Amp (A)	Power (W)
1.4	0.23	0.01	0.0023
1.6	0.25	0.02	0.005
1.7	0.26	0.02	0.0052
1.9	0.27	0.02	0.0054
2.1	0.28	0.02	0.0056
2.2	0.29	0.02	0.0058
2.4	0.33	0.03	0.0099

Table 3.4

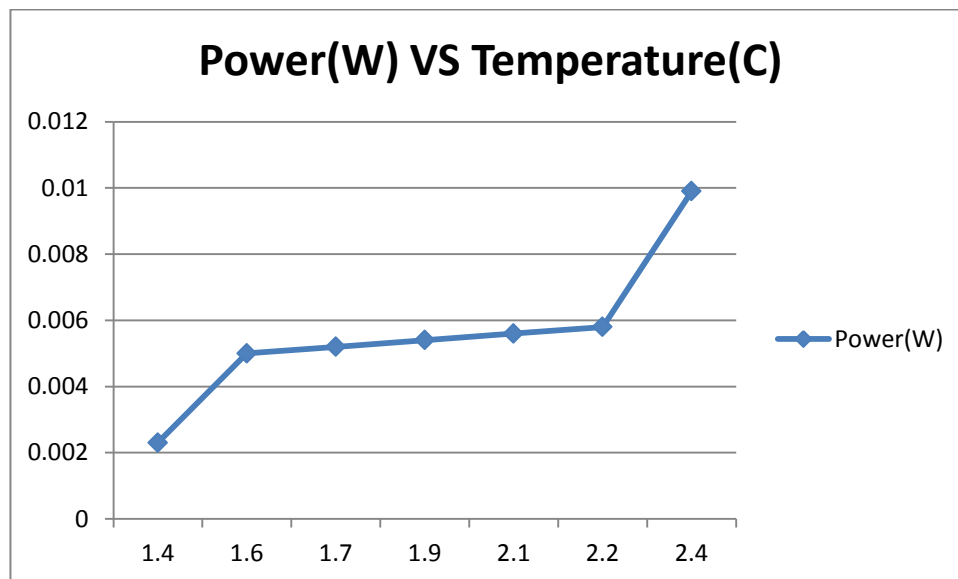


Figure 3.9

Using this method can only produce up to 2.4°C temperature difference due to the small sample of water being used to submerge the cold side of the TEC system, it is very hard to be able to obtain the data for a bigger temperature difference reading. To do be able to get a bigger temperature difference, a pot of boiling water is placed on the heat-sink of the hot side of the TEC while having the heat-sink of the cold side submerged in water.

The results obtained are shown below (Table 3.5 & Figure 3.10).

Difference in Temperature ( C )	Voltage ( V )	Current ( A )	Power ( W )
1	0.26	0.02	0.0052
2	0.5	0.03	0.015
3	0.71	0.04	0.0284
4	0.88	0.05	0.044
5	1.1	0.06	0.066
6	1.31	0.07	0.0917

Table 3.5

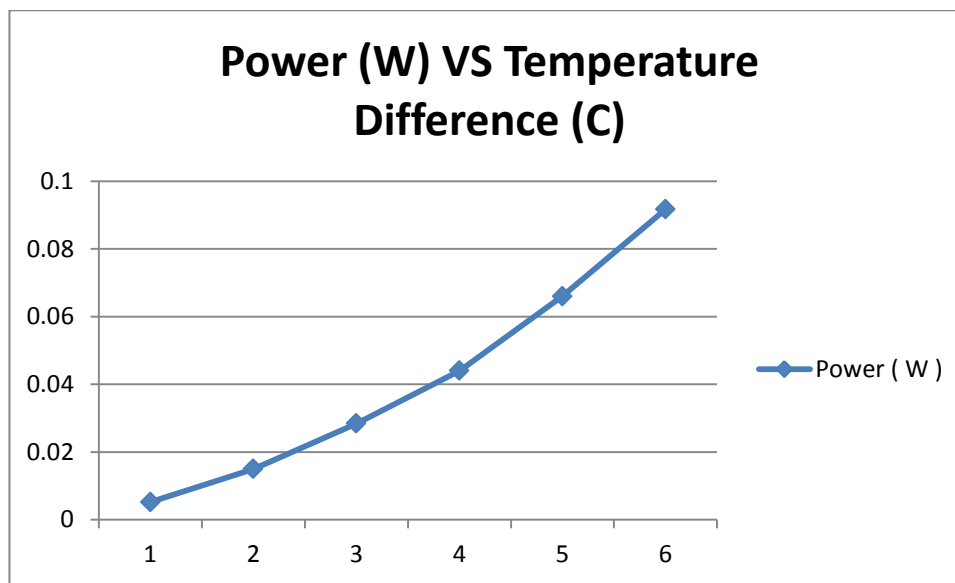


Figure 3.10

As we can observe from the readings and the graphs, the larger the temperature difference, the larger the power produced from the TEC system.

### 3.1.6 Comparing both connection methods

Comparing both graphs, it is noted that the TEC system connected in series do produce more power compared to the TEC system connected in parallel. Even at 1°C temperature difference, the difference in power of the series connection to the parallel connection is nearly two folds. Since the series connection can produce higher Voltages and better power, the TEC system wired in series is chosen as the final choice.

### 3.1.7 Adding finishing touches to the TEC system

Heat shrink tubes are added to seal the connections at the end of the TECs to prevent water entering and also to strengthen the bond of the connection. Below is a picture of the completed TEC system (Figure 3.11).

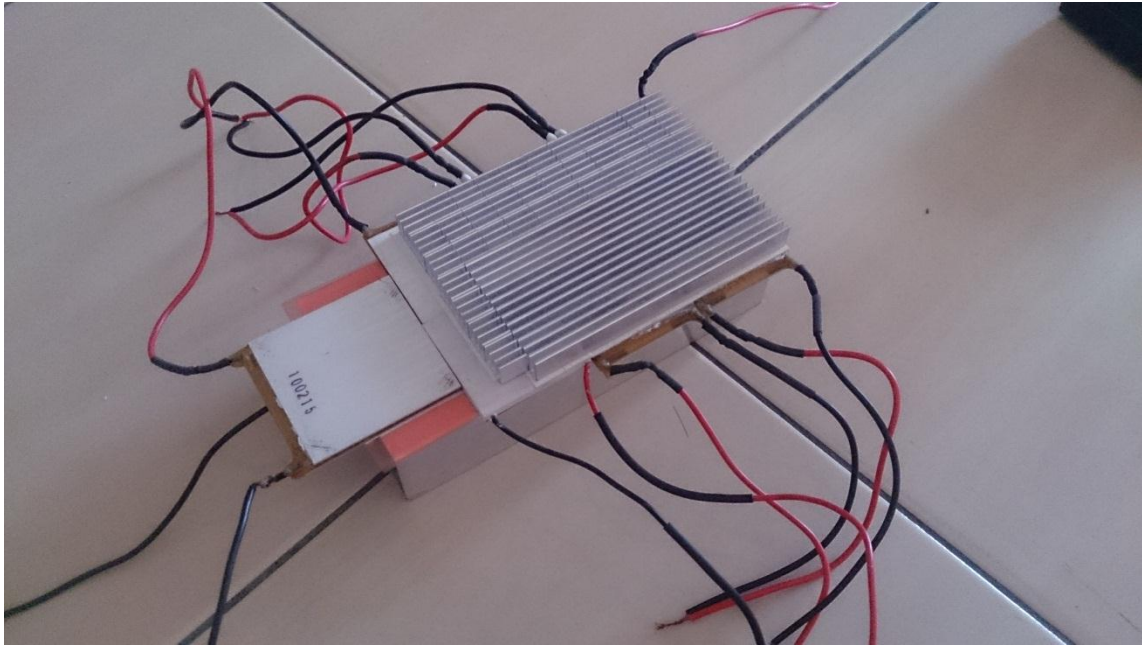


Figure 3.11

### 3.2 Design and Implementation of the solar cell system

Below is the design flow of the solar cell system (Diagram 3.3).

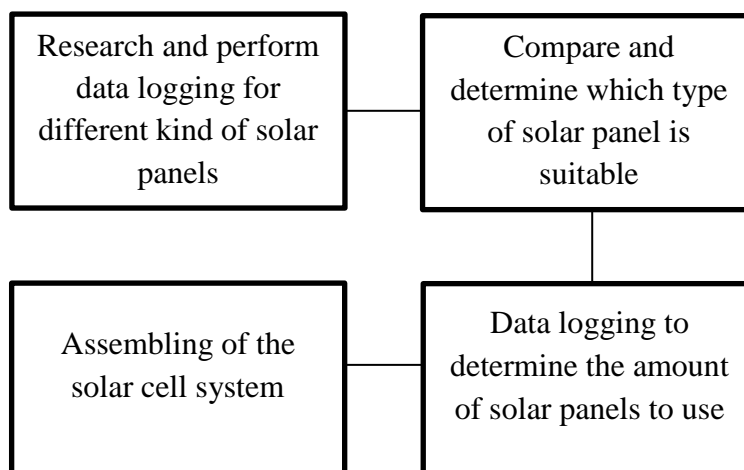


Diagram 3.3



### 3.2.1 Research and perform data logging for different kind of solar panels

Three different kinds of solar panels were researched and performed data logging on to determine which solar panels are suitable to be used to build the solar panel system.

The first type of solar panel used to perform data logging was the 5V polycrystalline solar panel. A simple circuit and Arduino were used to perform data logging for this solar panel. The connection between the circuit, Arduino and the 5V polycrystalline are as follow (Diagram 3.4).

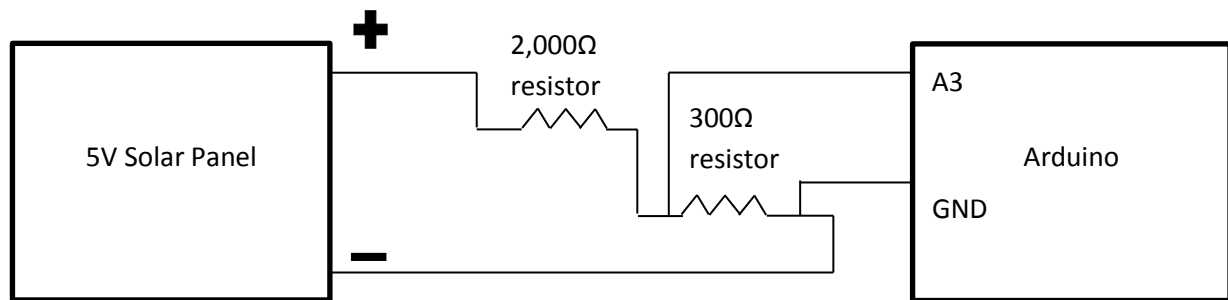


Diagram 3.4

The reason why a voltage divider circuit was used to perform this data logging is because the Arduino is only able to read up to 5V maximum. And after having the 5V solar panel's voltage read across a multimeter, it is noted that the 5V solar panel can have readings up to 5.74V. Hence we use a voltage divider circuit and have the Arduino read the voltage across the 300Ω resistor, and later multiply it by 8 times. The reason why it is multiplied 8 times is because there is a total of 2,300Ω of resistance in the circuit. Using the voltage divider rule, the 300Ω resistor will give  $300/2300 * \text{voltage}$ , giving only roughly  $1/8^{\text{th}}$  of the total voltage in the circuit. Hence, the voltage reading across the 300Ω resistor was multiplied by 8 when data logging was performed.

Having the Arduino read voltage across the 300Ω resistor, we can have the Arduino perform data logging automatically without having the user record the readings manually. Data logging using only one Arduino requires a serial to computer or having it connected to

a SD card to log data automatically. This is both not ideal as the serial to computer requires cable constantly connected between the computer and the Arduino and if having the Arduino store data in a SD card, the user can't monitor the data directly. Hence to overcome these problem and to allow the user to have perform data log with ease, two Arduino was used.

Each of the Arduino will be connected to a NRF24L01+, so they can communicate wirelessly. Refer to Chapter 4 of this report to see how the wireless communication was set-up and programmed, and tested.

Below are the results obtained after performing data logging on the 5V solar panel (Table 3.6).

Time	Voltage (V)	Power (W)
10am	5.16	2.322
11 am	5.47	2.418
12pm	5.74	2.634
1pm	5.75	2.679
2pm	5.74	2.634
3pm	5.74	2.634
4pm	5.74	2.634
5pm	5.47	2.418

Table 3.6

As noted, the power range obtained from the 5V solar panel is around 2.322W to 2.634W. After wiring the solar panel through a 5V DC-to-DC converter, the power dropped slightly and it was giving out readings ranging from 2W to 2.5W.

Next step is to perform data logging on the 20V polycrystalline solar panel. The same method was used to perform data logging on the 20V solar panel as it was used to previous log the reading of the 5V model. The voltage reading that was recorded from 20V solar panel was ranging from 19V to 20V from 10am to 5pm. And it was producing a 2W to 2.5W after passing the 5V DC-to-DC converter. Almost the same result as obtained from the 5V solar panel.

The last type of solar panel which was research on was a thin film solar panel. This solar panel, after performing data logging on it, can only produce a maximum of 1W-1.5W.

### 3.2.2 Compare and determine which type of solar panel is suitable

Due to budget constraint, the thin film solar panel was ruled out, as it was very expensive and it only gives out very little power compared to the other two polycrystalline solar panels. Even though the thin film solar panel was significantly lighter, but it would require more than 4 units to produce an amount of power big enough to charge a 5V portable battery bank.

Since there were already one unit of the 5V solar panel readily available from the University, only 3 more 20V solar panels was obtained. The reason why the 5V solar panel was also chosen is because it was planned to be combined together with the TEC system in series and to wire them into another 5V DC-to-DC converter. It was expected that 3 20V solar panels will be more than enough to supply a steady constant 1A after passing through the DC-to-DC converter.

### 3.2.3 Data logging to determine the amount of solar panels to use

To perform this phase, 3 20V solar panels were wired in parallel and then through a 5V DC-to-DC converter which was limited at 5W. 3 20V solar panels were used because it is expected that the 3 solar panels will be able to supply a constant 5W power to the portable battery bank. Below is a simple diagram to show how the solar panels were wired (Diagram 3.5).

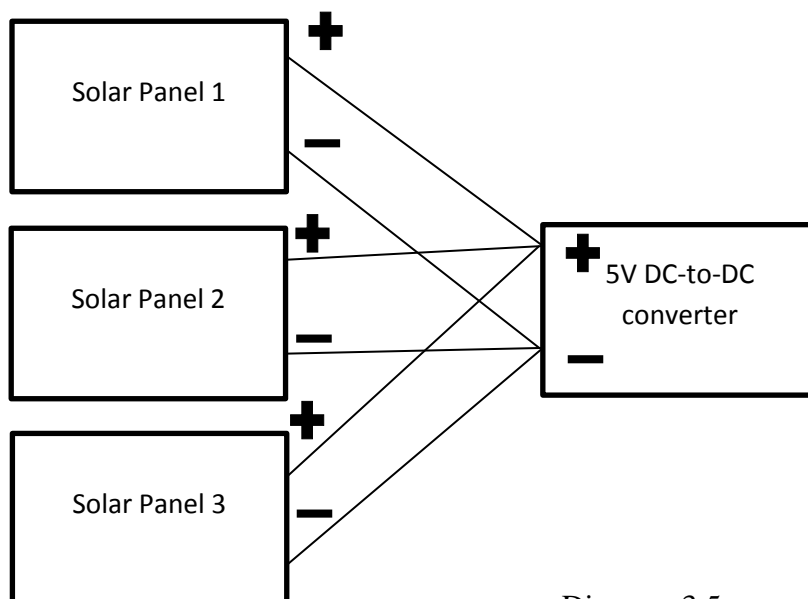


Diagram 3.5

Connection in parallel for the 3 20V solar panel was chosen because if series connection were chosen, the resulting total voltage at the end will go up to 60V and it was determined that the resulting voltage might be too much for the 5V DC-to-DC converter to be handled. After the connecting the 3 20V solar panels together, a simple data logging was performed to see how much power it could supply to the portable battery bank after going through the 5V DC-to-DC converter. Below are the results obtained from the data logging phase (Table 3.7).

Time	Voltage (V)	Ampere (A)
10am	4.89	0.98
11am	4.89	0.98
12pm	4.89	0.98
1pm	4.89	0.98
2pm	4.89	0.98
3pm	4.89	0.98
4pm	4.89	0.98
5pm	4.89	0.98

Table 3.7

As observed, the 3 20V solar panels wired in parallel can produce a constant 4.7922W of power throughout the day as long as there is sunlight.

### 3.2.4 Assembling of the solar cell system

A total of four solar panels were used. 3 of the 20V solar panels were connected in parallel and through 5V DC-to-DC converter. The other 5V solar panel which is expected to be wired in series with the TEC system was also wired to a 5V DC-to-DC converter.

### 3.3 Integration of the two the system onto a floatation device

The first step was to combine the 5V solar panel with the TEC system and perform a little data logging to determine whether there is an increase in power or a decrease. A diode was also connected to ensure current flow only in one direction. This is because the TEC can work in both ways, it can discharge when there is a temperature difference between the hot side and the cold side. It can be also charged to cause the cold side to have a

temperature drop and the hot side to have a temperature increment. Hence a diode is added to prevent this from happen, where the solar panel is charging the TEC system. A 1n4001 diode was used in this connection. Below is the connection of how the diode was added and how the TEC system with the 5V solar panel is connected (Diagram 3.6).

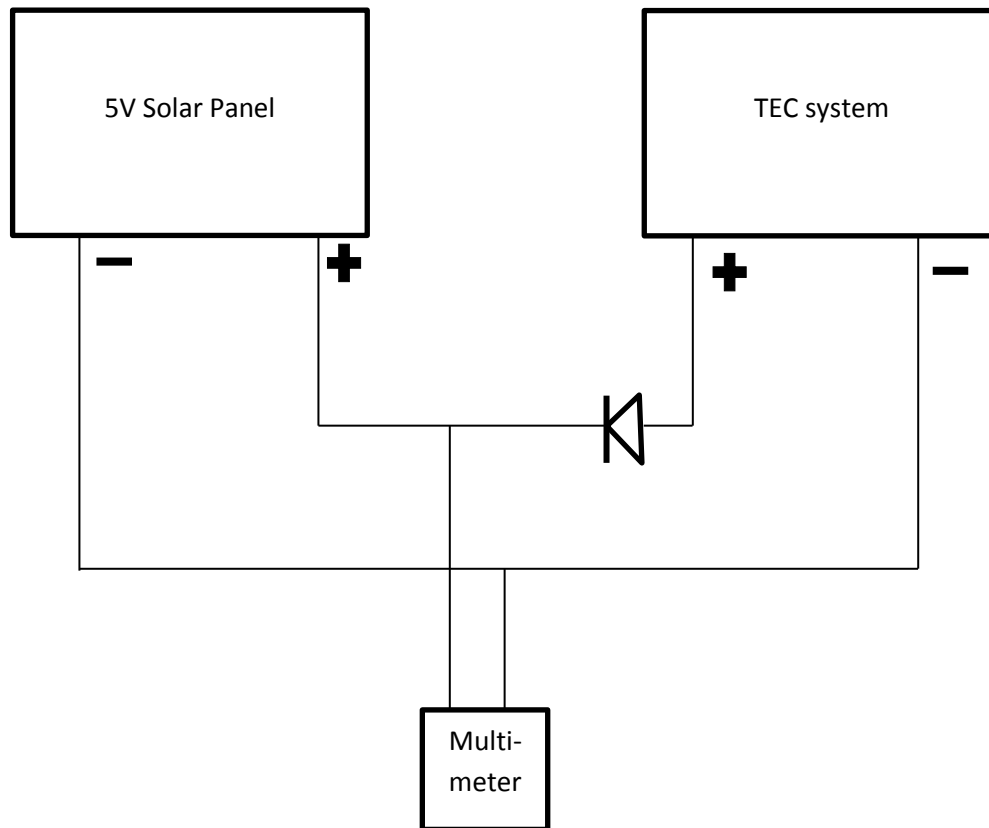


Diagram 3.6

There is a notable power drop when compared to the reading of the 5V solar panel by itself. This might be the power dissipation from the diode and connection between the TEC system and the solar panel itself. Hence it was determine that the 5V solar panel and the TEC system won't be connected into one single system to produce current. Due to the voltage that TEC system produces is very small, a special DC-to-DC converter ordered, which was the TPS61202EVM from Texas Instruments. This converter can convert low voltages into a 3.3V output.

After having the TEC system now connected to the TPS61202EVM low voltage to 3.3V DC-to-DC converter, a little data logging is then perform is see its output. This is done by connecting the output end of the DC-to-DC converter to a multimeter so that the readings of both voltage and ampere can be read. And because a bigger temperature difference is needed for better data logging, the method involving placing a pot of boiling

water on top of the hot side of the TEC system was used again. Below are the readings obtained from the output of the DC-to-DC converter (Table 3.8).

Temperature difference (°C)	Voltage (V)	Ampere (A)
1	0.00	0.00
2	0.28	0.01
3	0.40	0.01
4	0.54	0.01
5	3.31	0.02
6	3.31	0.03

Table 3.8

The TPS61202EVM only manage to convert input 1.18V onwards to 3.3V output. In ideal weather conditions, temperature difference of more than 5°C can be easily achieved.

To build the floatation device, a big cut-out piece of plastic cardboard was obtained. This plastic cardboard has holes in between. This type of cardboard was chosen because it can help increase buoyancy after having the ends of the holes sealed up. A shape of the heat sink of the cold side of the TEC system was traced in the centre of the cardboard piece and cut out. Below is the picture of the cardboard piece after cutting out the centre shape (Figure 3.12).



Figure 3.12

After having done so, the 4 solar panels and the TEC system was placed on top of the cardboard piece to determine how much space was needed exactly and the rest was cut off using a blade. The next step was to use a hot-glue gun to seal all the holes that were found around the plastic cardboard piece. One thick layer of Styrofoam was hot-glued to the

bottom side of the plastic cardboard piece to increase buoyancy. Below is a picture of the cardboard piece after being hot-glued to seal the holes and to add the Styrofoam board (Figure 3.13).



Figure 3.13

After having those steps done, it is then time to add all the other components in. The 4 solar panels are added around the centre and laid down flat. Although this will make the surface area of the whole system bigger and might have a bigger resistance drag when it is needed to be manoeuvred around water, but this is a safer choice. If the solar panels were to be laid upwards, it might drift away when there is wind in the area. The TEC system is then placed in the centre, with the DC-to-DC converter placed on the side with the Arduino device and the portable battery bank. Everything is secured with a two-sided tape. Two-sided tape was used because if there is ever a need to modify the parts/system, it would be easier for future users to perform the modification. The following picture and diagram is the product after assembling the solar panels, TEC system, DC-to-DC converters, Arduino device and the portable battery bank (Figure 3.14 & Diagram 3.7).



Figure 3.14

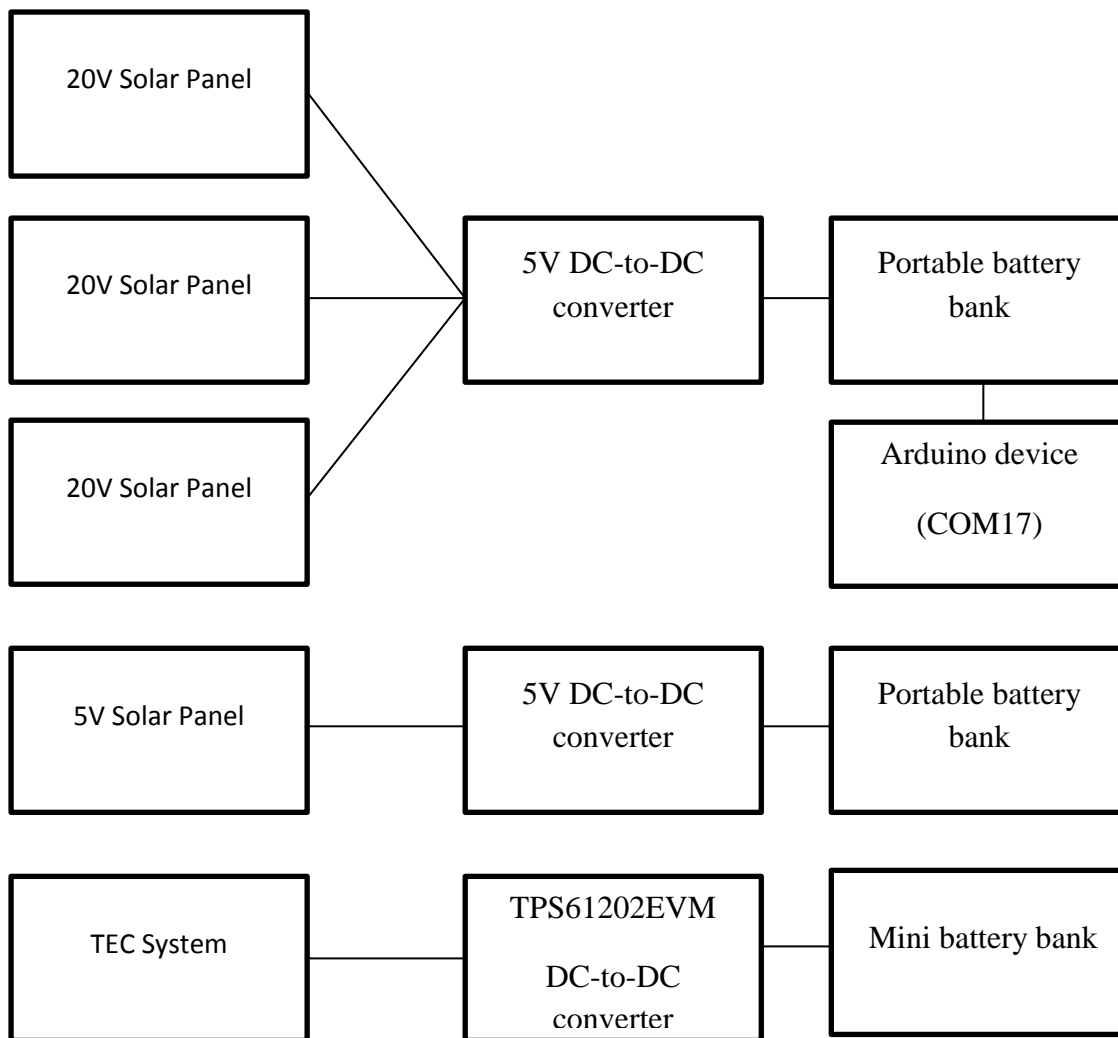


Diagram 3.7

After having everything built and set-up, the next step is to add in two  $1\Omega$  resistors to the output of the DC-to-DC converter for the TEC system and also for the output of the DC-to-DC converter for the single solar panel system. The reason why the two resistors are added is to allow voltage measurement across those resistors and with that, data logging of the two systems can be done. Since this project is still in the research phase, hence why data logging is important even after having the system bring completely build. Below are diagrams of how the resistors are being added and how to wire them together with the Arduino so that the Arduino will be able to perform the data logging (Diagram 3.8 & 3.9).



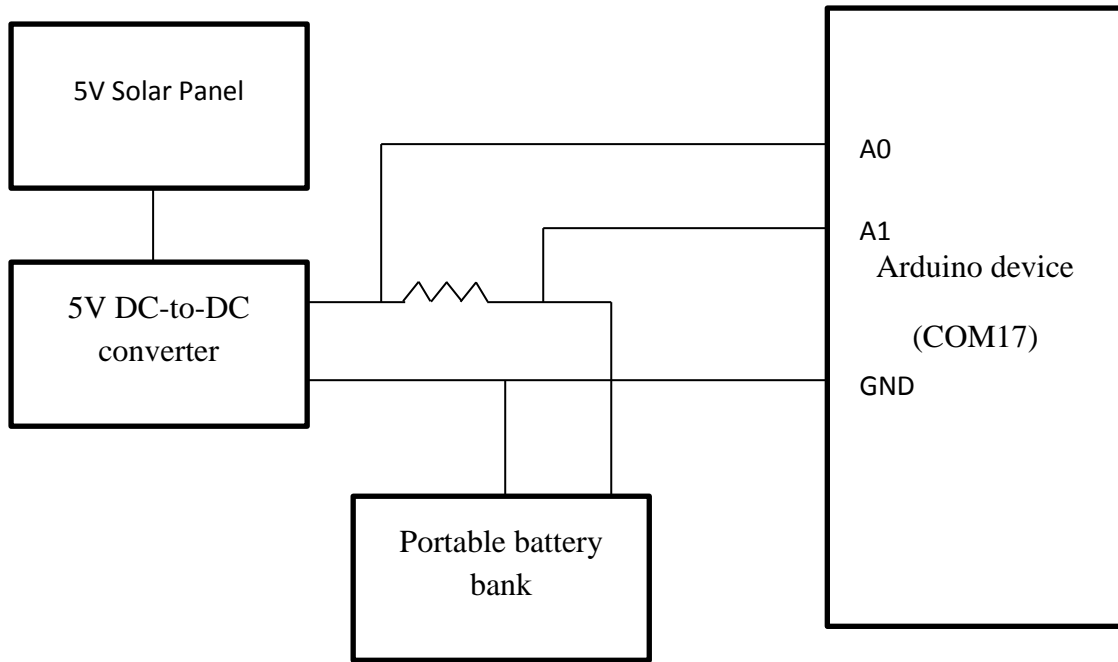


Diagram 3.8

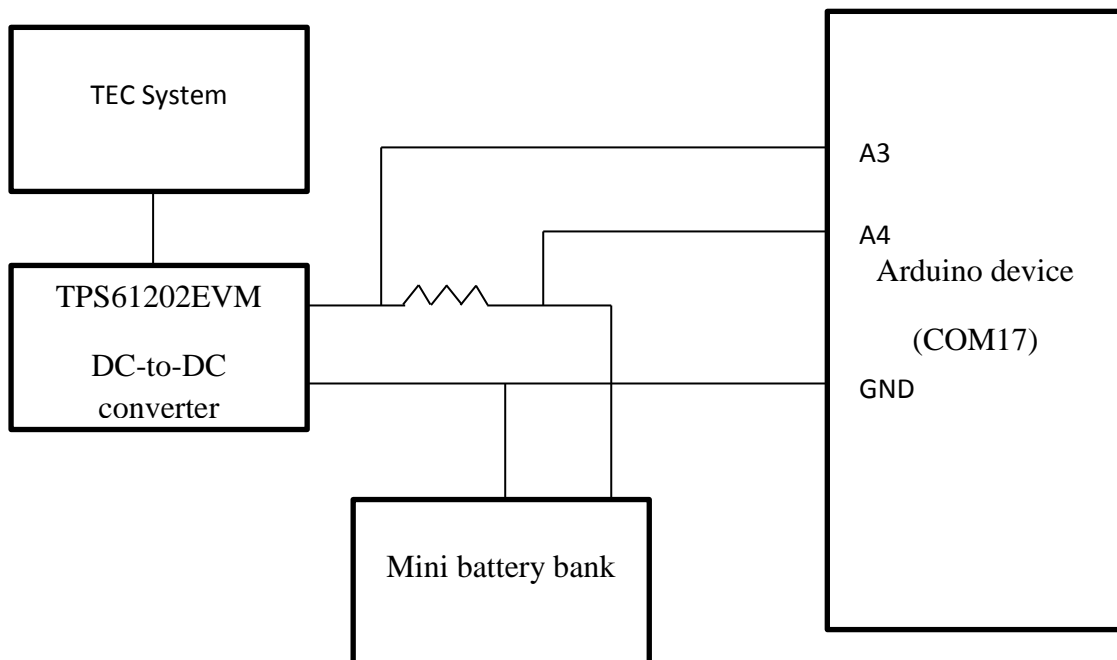


Diagram 3.9

To measure the Ampere output of the two systems, the voltage before the resistor and after the resistor are both taken and calculations are done based on the output. For example, to calculate the Solar Panel's Ampere output, we take the value read by Arduino (COM17)'s A1 and minus the value read by Arduino (COM17)'s A0. Using Ohm's law,  $V=IR$ , we can then deduce the Ampere from I by deriving the equation to  $I=V/R$ . Below is a picture of the Solar Energy Harvesting System after having the connections with resistors set up (Figure 3.15).

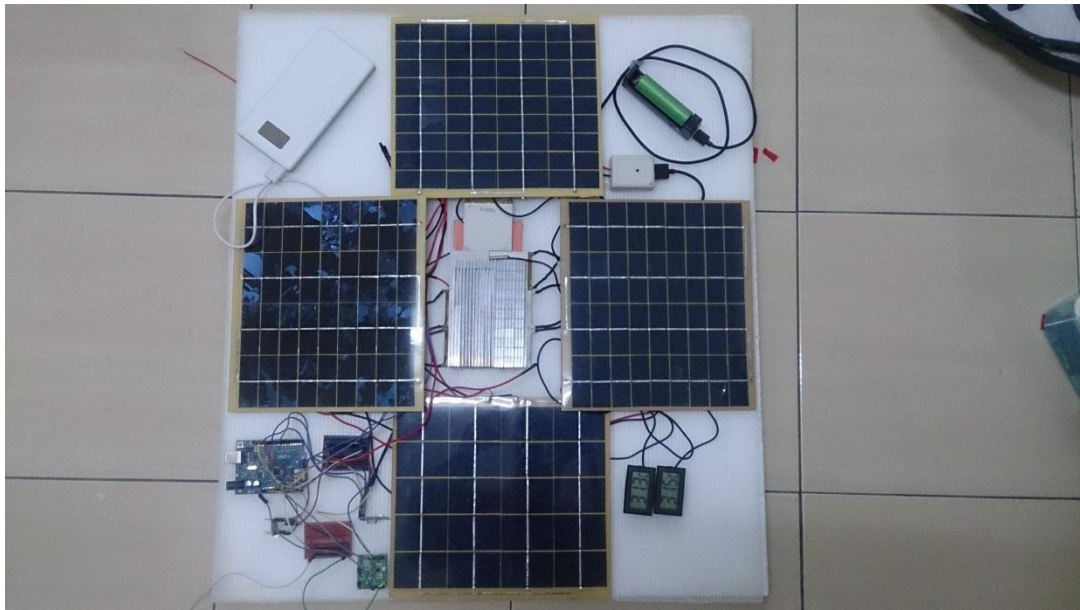


Figure 3.15

After having both of these connections done and the system is all assembled, the last thing remaining is to set up the underwater motors and reprogram the Arduino so that it will be able to power the motors and to also perform data logging for both the TEC system and Solar panel. Unfortunately due to the time and budget constraint, the ESC, which is the electronic speed controller, needed to supply current and drive the motors, were not able to be obtained. In this scenario, it is still possible to set up the Arduino program and show diagrams of how the ESC and motors should be connected. To perform motor controls using Arduino, we have to add a remote control to the Arduino (COM18). Below is a picture and diagram of how the Funduino(remote control) looks like when connected to the Arduino (COM18). (Figure 3.16 & Diagram 3.10)

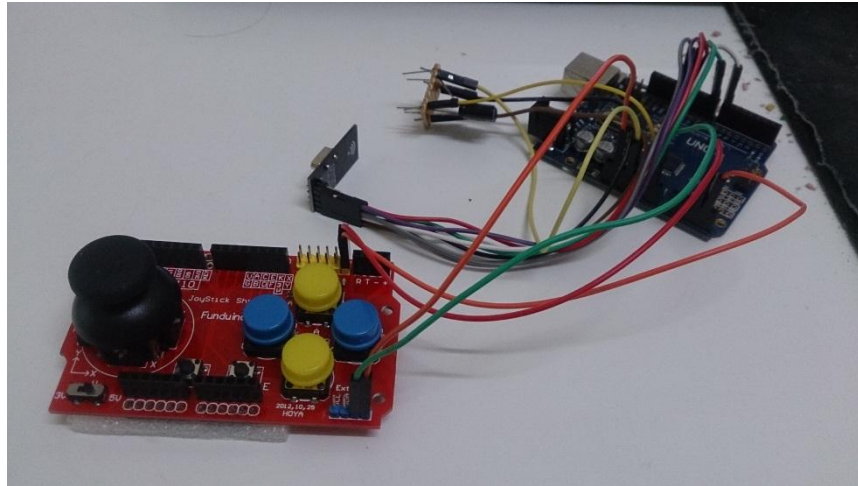


Figure 3.16

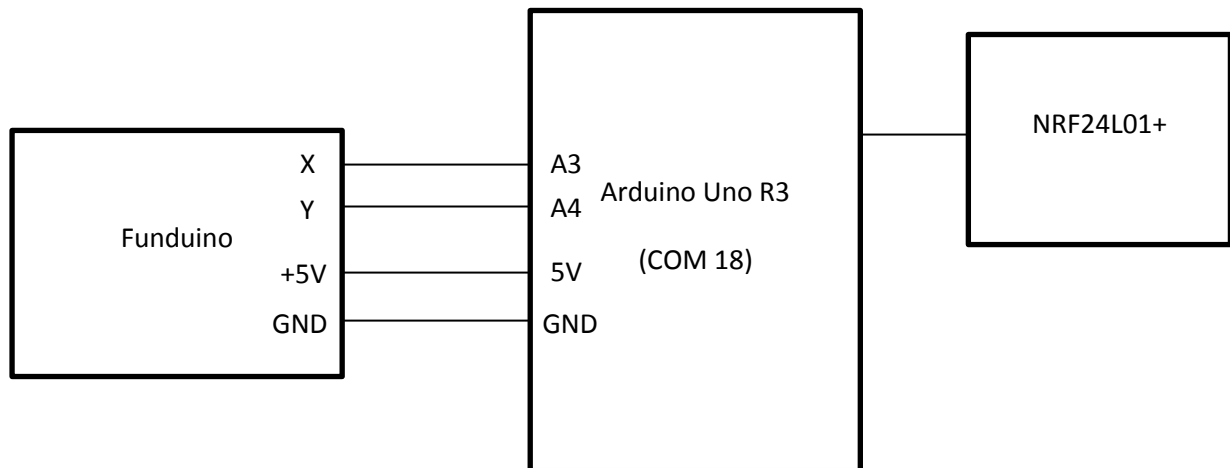


Diagram 3.10

After having Funduino set up, the program for Arduino (COM18) was reprogrammed and uploaded into the Arduino using a computer. Below are the new codes for the Arduino (COM18). With these codes, the user will be able to perform data logging while having access to control the motors.

```

#include <SPI.h>
#include "RF24.h"

bool radioNumber = 1;

RF24 radio(7,8);

byte addresses[][6] = {"1Node", "2Node"};
  
```

```

bool role = 0;
bool readTEC = true;

int i=0;
float x=0.0;
float y=0.0;

int xaxis = 3;
int yaxis = 4;
int moving_position=0;    //to indicate moving position

void setup() {
  Serial.begin(115200);
  Serial.println(F("Waiting for sender to send"));

  radio.begin();

  radio.setPALevel(RF24_PA_LOW);

  if(radioNumber){
    radio.openWritingPipe(addresses[1]);
    radio.openReadingPipe(1,addresses[0]);
  }else{
    radio.openWritingPipe(addresses[0]);
    radio.openReadingPipe(1,addresses[1]);
  }

  radio.startListening();
}

void loop() {

  if ( role == 0 )
  {
    float TECvoltage=0.00;
    float Solarvoltage=0.00;

    if( radio.available() && readTEC==true){

      while (radio.available()) {
        radio.read( &TECvoltage, sizeof(float) );
      }

      Serial.print("Time: ");
      Serial.print(i);
      i++;
      Serial.print("Min    ");
      Serial.print(F("TEC Voltage Reading: "));
      Serial.print(TECvoltage);
      Serial.print("V    ");

```

```

    readTEC= false;
}
else if(radio.available() && readTEC==false){
    while (radio.available()) {
        radio.read( &Solarvoltage, sizeof(float) );
    }

    Serial.print(F("Solar Voltage Reading: "));
    Serial.print(Solarvoltage);
    Serial.println("V");
    readTEC= true;
}
}

x = analogRead(xaxis);
y = analogRead(yaxis);

if(y==0){
    //when Funduino analog button is pushed down

    Serial.println("Down");
    moving_position = 1;
    radio.stopListening();
    radio.write( &moving_position, sizeof(int) );
    radio.startListening();
}

else if(y>1000){
    //when Funduino analog button is pushed up

    Serial.println("Up");
    moving_position = 2;
    radio.stopListening();
    radio.write( &moving_position, sizeof(int) );
    radio.startListening();
}

else if(x==0){
    //when Funduino analog button is pushed left

    Serial.println("Left");
    moving_position = 3;
    radio.stopListening();
    radio.write( &moving_position, sizeof(int) );
    radio.startListening();
}

else if(x>1000){
    //when Funduino analog button is pushed right

    Serial.println("Right");

```

```

moving_position = 4;
radio.stopListening();
radio.write( &moving_position, sizeof(int) );
radio.startListening();
}

moving_position = 0;
} // Loop

```

How the Funduino analogue button functions is that when the analogue button is being pushed up, it will return a value of nearly 5V to the connected A3 of Arduino COM18. Then value is then converted to digital value which will be >1000. Hence, in the program written, if A3 (which is variable y in the program) is more than 1000, it will send a value of 2 to Arduino (COM17) which will then translate to move up.

Below are the new codes that are uploaded to Arduino (COM17) so that it is able to read the commands sent from Arduino (COM18).

```

#include <SPI.h>
#include "RF24.h"

bool radioNumber = 0;
int TECanalogPin1 = 0; //A0
int TECanalogPin2 = 1; //A1
int SolaranalogPin1 = 3; //A3
int SolaranalogPin2 = 4; //A4
int timer=0;
RF24 radio(7,8);

byte addresses[][6] = {"1Node","2Node"};

bool role = 1;
float voltage=0.00;

float TECraw1=0.00;
float TECraw2=0.00;
float Solarraw1=0.00;
float Solarraw2=0.00;

float TECvoltage1=0.00;
float TECvoltage2=0.00;
float Solarvoltage1=0.00;
float Solarvoltage2=0.00;

float TotalTec=0.00;
float TotalSolar=0.00;

```

```

int i=0;
float amp=0.00;
int move_up = 5;
int move_down = 4;
int move_left = 3;
int move_right = 2;

void setup() {
  Serial.begin(115200);
  Serial.println(F("Sending Voltage"));
  pinMode(move_up, OUTPUT);
  pinMode(move_down, OUTPUT);
  pinMode(move_left, OUTPUT);
  pinMode(move_right, OUTPUT);
  radio.begin();

  radio.setPALevel(RF24_PA_LOW);

  if(radioNumber){
    radio.openWritingPipe(addresses[1]);
    radio.openReadingPipe(1,addresses[0]);
  }else{
    radio.openWritingPipe(addresses[0]);
    radio.openReadingPipe(1,addresses[1]);
  }

  radio.startListening();
}

void loop() {

  if (role == 1) {

    if( timer%600 == 0 || timer == 0 ){
      radio.stopListening();

      Serial.print(i);
      Serial.print("Min");
      i++;

      TECraw1 = analogRead(TECanalogPin1);
      TECvoltage1 = TECraw1 * 5.0 / 1024;

      TECraw2 = analogRead(TECanalogPin2);
      TECvoltage2 = TECraw2 * 5.0 / 1024;

      TotalTec = TECvoltage1 - TECvoltage2; //Voltage drop across the resistor

      Solarraw1 = analogRead(SolaranalogPin1);
      Solarvoltage1 = Solarraw1 * 5.0 / 1024;

```

```

Solarraw2 = analogRead(SolaranalogPin2);
Solarvoltage2 = Solarraw1 * 5.0 / 1024;

TotalSolar = Solarvoltage1 - Solarvoltage2; //Voltage drop across the resistor

delay(500);

if (!radio.write( &TotalTec, sizeof(float) )){
  Serial.println(F("failed"));
}

delay(500);

if (!radio.write( &TotalSolar, sizeof(float) )){
  Serial.println(F("failed"));
}

boolean timeout = false;

if ( timeout ){
  Serial.println(F("Failed, response timed out."));
}else{
  Serial.print(F("  Sent "));
  Serial.print(TotalTec);
  Serial.print("V");
  Serial.print("    ");
  Serial.print(TotalSolar);
  Serial.print("V");
}
}
int moving_position=0;

radio.startListening();

radio.read( &moving_position, sizeof(int) );

if(moving_position==1){
  Serial.println("Move Down");
  digitalWrite(move_down, HIGH);
}
else if(moving_position==2){
  Serial.println("Move Up");
  digitalWrite(move_up, HIGH);
}
else if(moving_position==3){
  Serial.println("Move Left");
  digitalWrite(move_left, HIGH);
}
else if(moving_position==4){
  Serial.println("Move Right");
}

```



```

    digitalWrite(move_right, HIGH);
  }
  else {
    digitalWrite(move_up, LOW);
    digitalWrite(move_down, LOW);
    digitalWrite(move_left, LOW);
    digitalWrite(move_right, LOW);
  }
  timer++;
  delay(100);
}
} // Loop

```

How this program works is that when a user push the analogue button of the Funduino attached to the Arduino COM18 to the left, it will send an integer value of 3 to Arduino COM17. Arduino COM17 will then read the integer value of 3 and set digital pin 3 to high. When this happens, the digital pin 3 will then send a 5Volts output. After having this two Arduino reprogrammed and set up, the motors with ESC will then be connected. Below is a diagram of how the Arduino and power supply should be connected to the ESC and motors (Diagram 3.11).

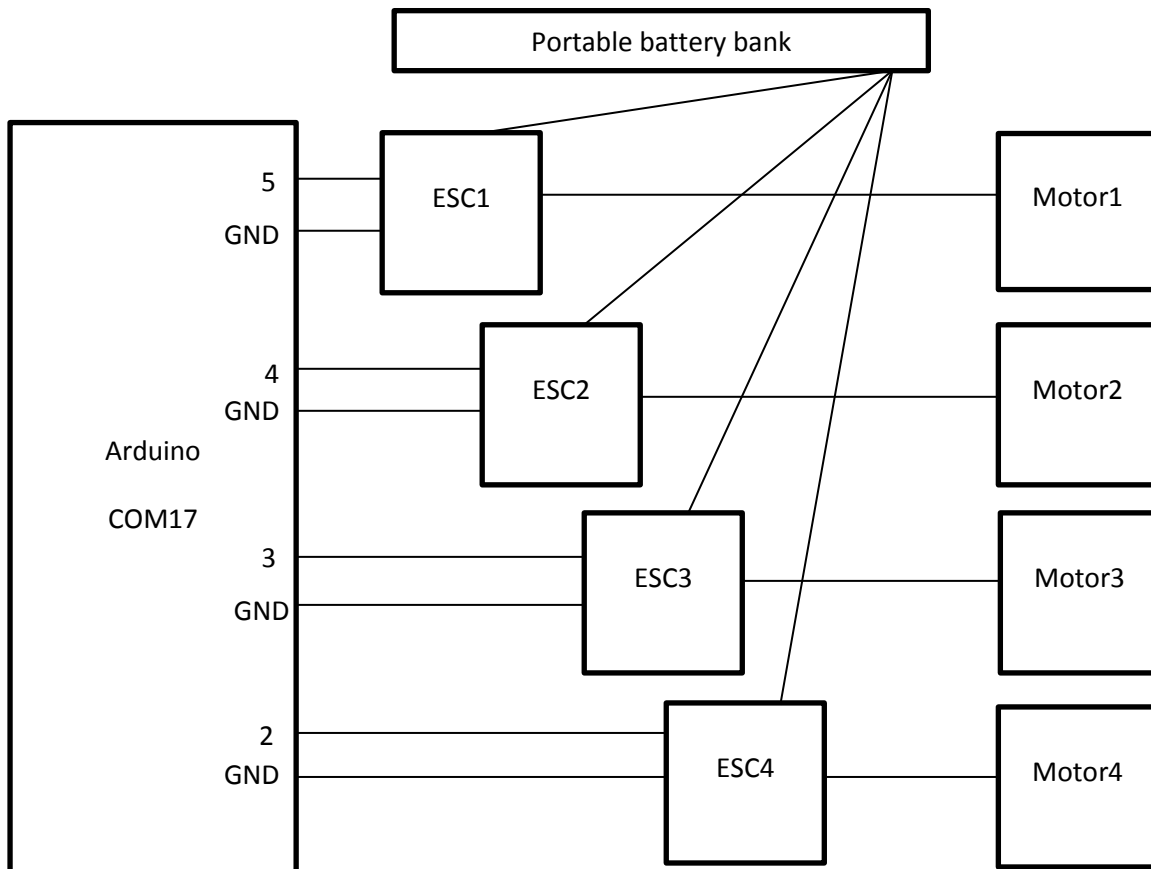


Diagram 3.11

The ESC power will be supplied by the portable battery bank and one digital pin from the Arduino will be connected to the ESC to control the motor. The ESCs will then be individually attached to each motor. How the ESC works is that, for example, when pin no.5 of the Arduino sends out a 5V to the ESC1, ESC1 will draw power from the portable battery pack and forwards them to the motor1 to power motor1. Below is a simple verification test done to check whether the program is functional or not. This is done by pushing the analogue button up, down, left and right and check Arduino COM17 serial's output.

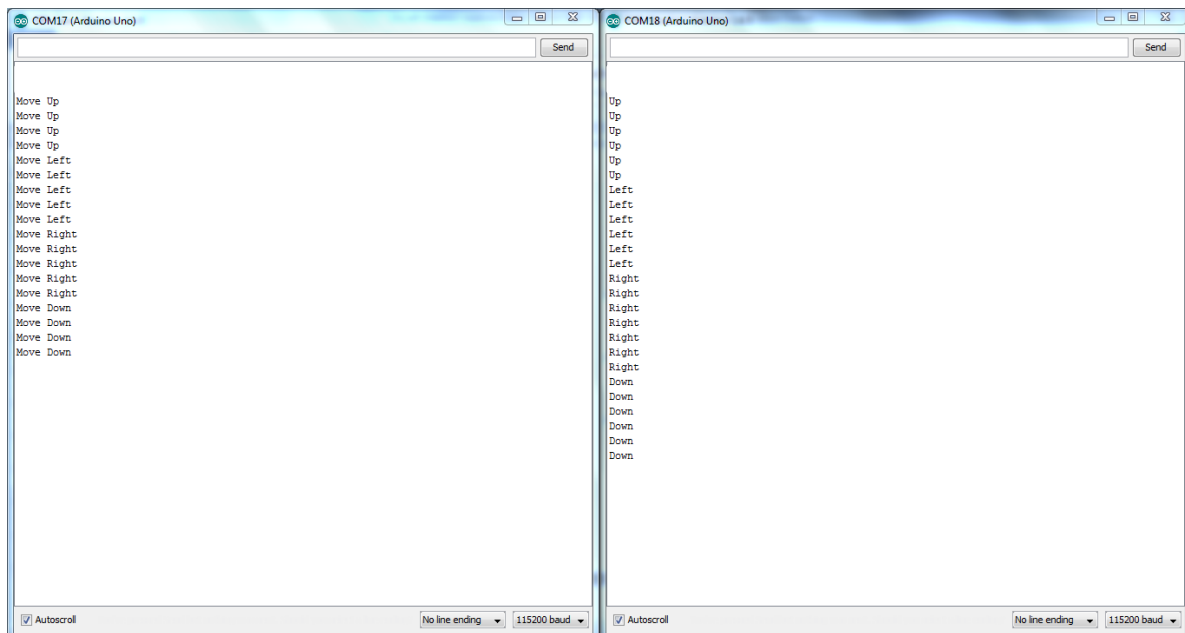


Figure 3.17

As observed in Figure 3.17, when the analogue button of the Funduino is pushed up, Arduino COM17 receives the command and prints move up and setting the digital pin no.5 to HIGH.

Due to unpredictable weather, a simple measurement of the power consumption of the Arduino (COM17) was done. The Arduino (COM17) draws current of 60mA and the NRF24L01+, which is the wireless communicator, draws current of about 20mA. In total, the Arduino together with the NRF24L01+ attached together with it will draw 80mA of current per hour. Since the portable battery bank attached to the system has a capacity of 10,000mAh. By assuming the portable battery bank is fully charged, we can take 10,000mAh and divide by 80 to get a rough estimation of how long can the system stay powered if there were no sunlight.

After performing the calculations, it is estimated that this system can stay powered for at least 125 hours, which is amounts up to roughly 5 days. Since the solar panels can charge the portable battery bank at 1000mAh, it would only take 10 hours of high intensity sunlight to charge the portable battery bank from empty to full.

### 3.4 Testing of floatation device of the completed system

To test the floatation device of the system, the entire system is placed on water. Below is a picture to show that the entire system can float on water effortlessly (Figure 3.18).

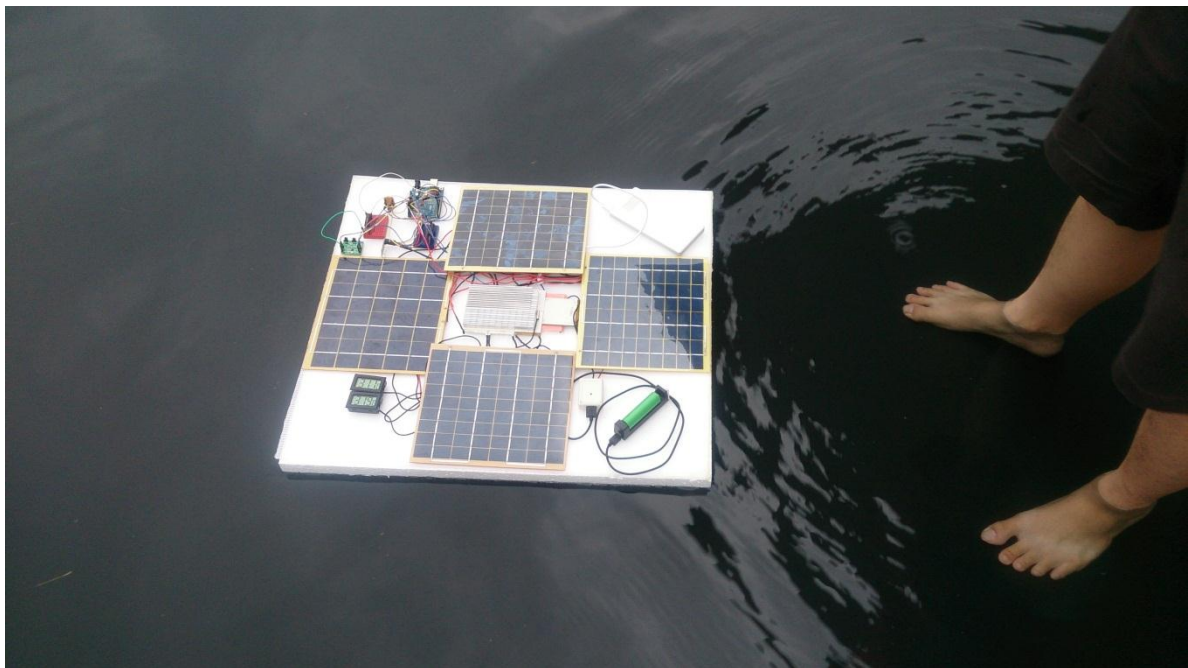


Figure 3.18

Still, more research and modification are bound to be done to ensure that the entire system can withstand all weather conditions and rough water conditions.

## CHAPTER 4: WIRELESS COMMUNICATION USING ARDUINO

This wireless communication was set up using 2 units Arduino Uno R3, 2 units NRF24L01+, 2 units of 10uF capacitor, 2 units of 0.1uF capacitor, and a computer to upload the program into the Arduino units. The purpose of building this wireless communication is to provide an ease of data logging (in chapter 3.2.1) as well as being able to control the motors attached to the solar harvesting system. Below is the schematic diagram of how they are all connected (Diagram 4.1).

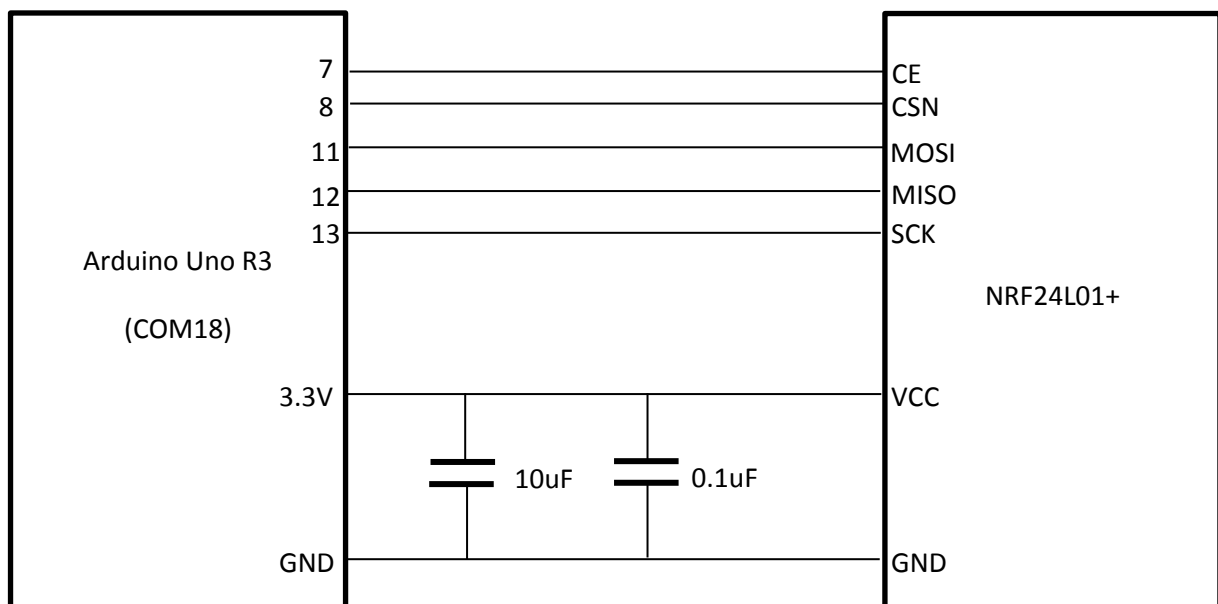


Diagram 4.1

A 10uF and 0.1uF was connected in parallel from the 3.3V to GND was to act as a filter. This is because the 3.3V power from the Arduino most of the time has power supply regulation issues. Without adding the capacitors to act as a filter, most of the time the signal is cut off and the other end could not receive any data. To prevent data loss through transmission, the capacitors must be added. To secure all the connections together, the capacitors were soldered into a board. Below is a picture of one of the Arduino after adding the capacitors and NRF24L01+ (Figure 4.1).

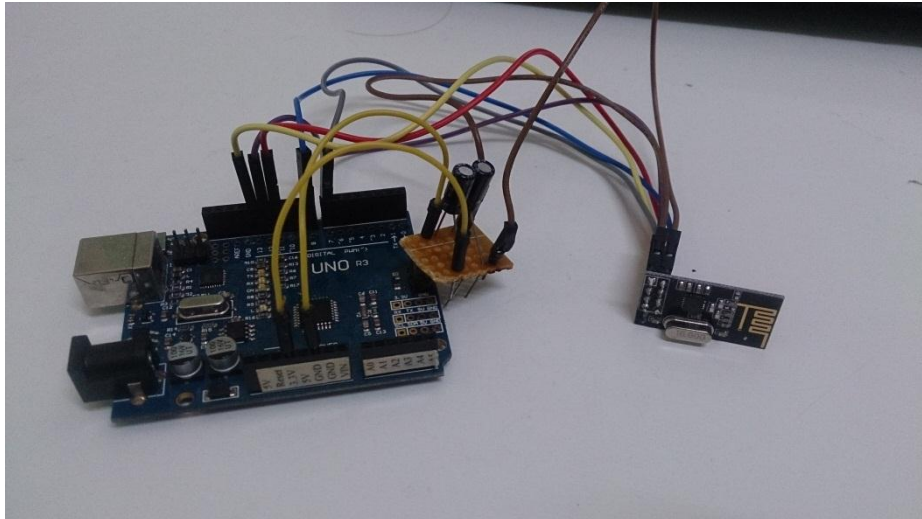


Figure 4.1

After assembling two of the Arduino with their respective NRF24L01+, the next step is to program the Arduinos. The following codes are uploaded to the First Arduino(COM 17) device using a computer and the Arduino software. A library of RF24.h must be downloaded online first and then placed in the Arduino's library. This Arduino device will then be attached to the TEC system to read voltage reading and perform data logging. It will then send back the data to the receiving end.

```
#include <SPI.h>
#include "RF24.h"

bool radioNumber = 0;
int analogPin = 3;
int timer=0;
RF24 radio(7,8);

byte addresses[][6] = {"1Node", "2Node"};

bool role = 1;           //set to 0 to kill function
float voltage=0.00;     //this variable will be sent over to the other arduino
float val=0.00;         //this variable is to read the analog value of A3
int i=0;

void setup() {
  Serial.begin(115200);
  Serial.println(F("Sending Voltage"));
  pinMode(ledPin, OUTPUT);
  digitalWrite(ledPin, HIGH);
  radio.begin();
```

```

radio.setPALevel(RF24_PA_LOW);           //set to low power to save power

if(radioNumber){
  radio.openWritingPipe(addresses[1]);
  radio.openReadingPipe(1,addresses[0]);
}else{
  radio.openWritingPipe(addresses[0]);
  radio.openReadingPipe(1,addresses[1]);
}

radio.startListening();                 //start listening for data
}

void loop() {

if (role == 1) {

  if( timer%600 == 0 || timer == 0 ){           //send readings at 60sec interval
    radio.stopListening();                     //stop listening for data

    Serial.print(i);                          //variable i represents minutes
    Serial.print("Min");
    i++;

    val = analogRead(analogPin);              //read analog value of A3
    voltage = val * 5.0 / 1024;               //converting value to real life analog voltage

    if (!radio.write( &voltage, sizeof(float) )){ //send to other Arduino
      Serial.println(F("failed"));
    }

    boolean timeout = false;

    if ( timeout ){
      Serial.println(F("Failed, response timed out.));
    }else{

      Serial.print(F("  Sent "));
      Serial.print(voltage*8);
      Serial.println("V");
    }
  }
  timer++;
  delay(100);
}
}

```

The reason why we use the timer variable is to send data to the Second Arduino(COM 18) is because we want the First Arduino to be active still, instead of just setting the delay(100) to delay(60000). If the delay is set to 60000, which is 60seconds, the First Arduino will then not be able to receive any data from the Second Arduino which will be a problem later on when instructions are needed to be sent to the First Arduino via the Second Arduino (Motor Controls).

Below are the codes uploaded to the Second Arduino through serial port, using Arduino software and a computer.

```
#include <SPI.h>
#include "RF24.h"

bool radioNumber = 1;

RF24 radio(7,8);

byte addresses[][6] = {"1Node", "2Node"};

bool role = 0;           //set to 1 if want function to stop
int i=0;

void setup() {
  Serial.begin(115200);
  Serial.println(F("Waiting for sender to send"));

  radio.begin();

  radio.setPALevel(RF24_PA_LOW);           //set to low power to save power

  if(radioNumber){
    radio.openWritingPipe(addresses[1]);
    radio.openReadingPipe(1,addressses[0]);
  }else{
    radio.openWritingPipe(addressses[0]);
    radio.openReadingPipe(1,addressses[1]);
  }

  radio.startListening();           //start listening for data
}

void loop() {

  if ( role == 0 )
  {
    float voltage=0.00;
    if( radio.available()){
```

```

while (radio.available()) {                                //if radio is available
  radio.read( &voltage, sizeof(float) );                 //read voltage
}

Serial.print("Time: ");                                  //print to serial
Serial.print(i);
Serial.print("Min   ");
Serial.print(F("Voltage Reading: "));
Serial.print(voltage*8);
Serial.println("V");
}
}
}

```

With this two Arduino set up, the first Arduino as COM17 and the second Arduino as COM18 in the Computer, to do a simple test to determine whether this two wireless communication system is functioning properly, we have to open two separate Arduino softwares in the computer.

With the first Arduino software port set to COM17, and the second port set to COM18. Below is a picture of two Arduino software with their respective port being set (Figure 4.2).

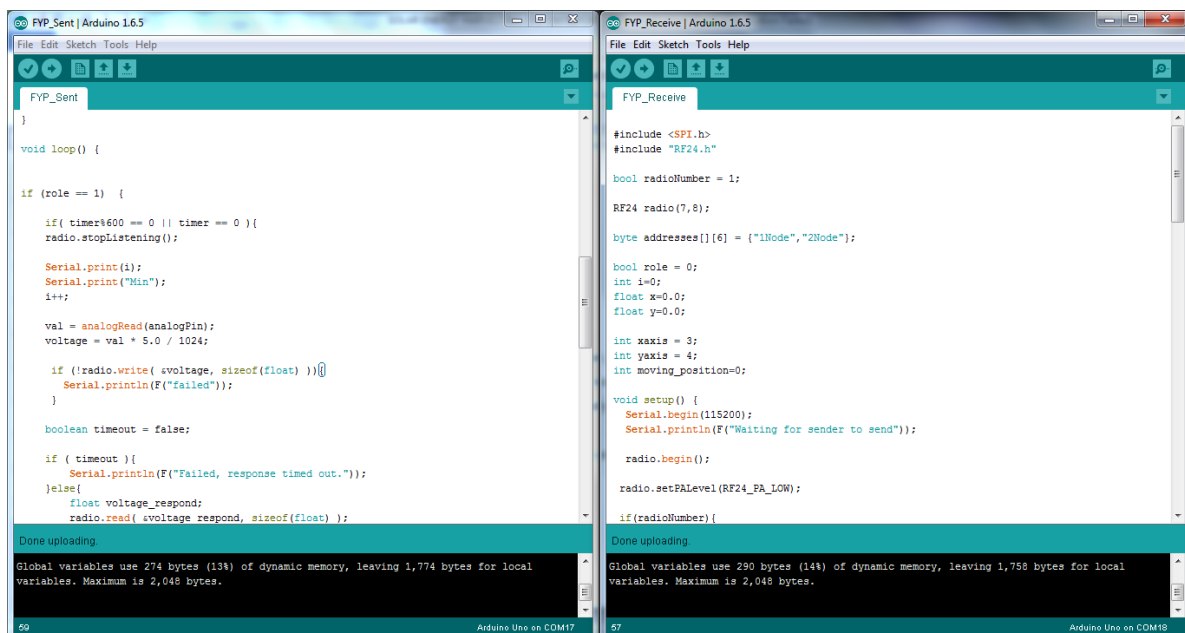


Figure 4.2

By pressing the magnify glass icon placed on the top right of each Arduino software, it will launch a serial screen. By setting the baud rate to 115200 at the bottom right of the



serial screen, it is then ready to be tested on. Below is a picture to show that both the wireless communication is working (Figure 4.3).

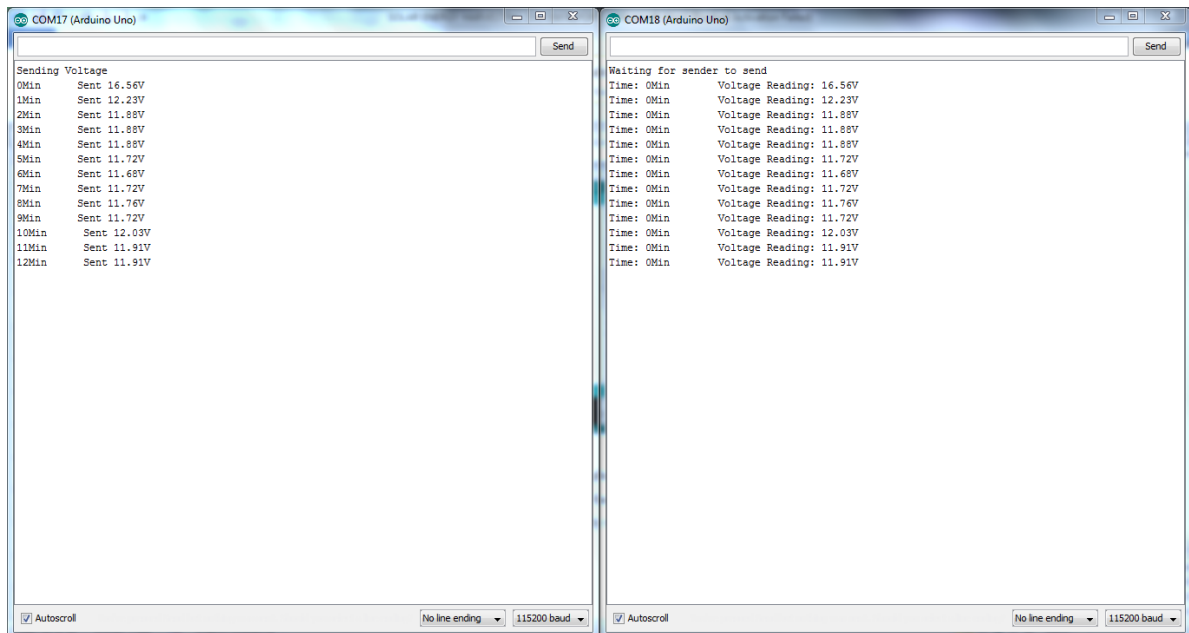


Figure 4.3

With this wireless communication done, users are now able to perform data logging via wirelessly. This program will also be modified in later parts to be able to perform motor controls.

## CHAPTER 5: CONCLUSION

### 5.1 Project Review, Discussions and Conclusions

In this project, an energy harvesting system that uses TECs to harvest power from the sun's thermal heat and surrounding temperature was successfully built. Often times the power generated was always very little, hence special DC-to-DC converters and heat-sinks were used to optimize the TEC system to produce better results.

It was expected for the TEC to be able to combine with the solar panels to produce more power. But due to the small power the TEC system generates, it does not have produce more power when connected to the solar panels together, instead it has a power drop when they are both connected together in series or parallel. Hence, it is then separated to two systems.

The system is now able to float on water and it can perform data logging wirelessly. More research and testing is still needed to test the durability of the whole system as it was still not tested under different weather conditions such as rain and thunderstorms.

The system is able to charge and discharge electricity at the same time. And it harvests more electricity than its consumption rate. A problem that this project is currently facing that it might be using more electricity than it harvest once the motors with the ESC are installed.

Although the most of the components were already set-up for the system to be manoeuvred wirelessly, it is still unable to move underwater. This is because due to time and budget constraint, the 4 ESC weren't able to be obtained and installed. However instructions, codes and diagrams of how it should be connected are already included in this report (Chapter 3) for future use if this project is to be continued by an individual.

This project has contributed a new unique way of harvesting solar energy by using the sun's thermal energy to produce electricity. Very few to zero projects and research have been made to harvest the sun's thermal energy using TEC. Although it might be as effective

now, with sufficient research and future upgrades, it might be a very effective method to harvest the sun's thermal energy.

This project has also made a solar energy harvesting system that can be manoeuvred away from the shaded areas if ever the solar panels were shaded or blocked. This is help increase the maximum possible solar energy that it can harvest.

Having spent time in researching and development for this project, the world should put in more research for other methods to harvest clean energy and in portable energy harvesting systems.

## 5.2 Future work

Installation of the ESC and motors will be needed to manoeuvre the system on water. One thing to bear in mind is to perform research and the amount of power dissipated and used to power up the motors. If the motor consumes more power than what it can harvest, then more research should be done to reduce the consumption rate of the motors.

This TEC system in this project can be further improved by doing more research and upgrades to the current built TEC system. With better efficiency it can produce more power and can later be used to charge or power up more components.

This project could be made to be self-sustaining and other functions can be added. Function such as weather monitoring can be added. Since the project already has a wireless data logging system, it can harvest solar energy to power up the weather monitor and send the data across wireless for data logging purpose.

Besides that, the system can be programmed to automatically move away from shaded area and obstacles by adding infrared sensors and Photoresistors. With that being installed, the system will then be self-sustaining and not much maintenance or monitoring will then be needed.

There are still many functions and improvements that can be added/made to the current project to create a solar energy harvesting system with more utility and function.

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