SOLAR POWERED AUTOMATED ATMOSPHERIC WATER GENERATOR USING PELTIER DEVICE

A Thesis Submitted to the Department of Electrical and Electronic Engineering of BRAC University

By

Raihan Islam ID-13110037
Abu Saleh Musajjee ID-16221019
S M Habib Ullah ID-13110037
Iffatul bushra siddique ID- 13121172

Supervised by

Dr. Md. Belal Hossain Bhuian
Assistant Professor
Department of Electrical and Electronic Engineering BRAC University, Dhaka.

In partial fulfilment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering
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DECLARATION

We do thus proclaim that the proposal titled "Solar powered automated atmospheric water Generator Using Peltier device” is submitted to the Department of Electrical and Electronics Engineering of BRAC University in partial fulfilment of the Bachelors of Science in Electrical and Electronics Engineering. This is our unique work and the work has not been exhibited somewhere else for evaluation. The materials gathered from different sources have been recognized here.

Signature of Supervisor

....
Dr. Md. Belal Hossain Bhuian

Signature of Authors

....
Raihan Islam

....
Abu Saleh Musajje

....
S M Habib Ullah

....
Iffatul Bushra Siddiqui

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ABSTRACT

There is a saying, “water has only two aspects; when mixed with anything it’s NEED, and when not it’s LIFE”. Sometimes the terrible water scarcity in tropical countries like Bangladesh reminds us this quote immensely. Despite the fact that water covers more than two third (around 70%) of the Earth's surface yet at the same time fresh water which can be utilized for drinking and doing regular errands stays rare (just around 2.5%). Drinking water accessibility is a noteworthy issue in some country region in Bangladesh during the summer because of absence of precipitation. For that reason, people need to go a couple of kilometers far from home to get the water. This project aims to solve this problem. In the coastal areas of Bangladesh the percentage of relative humidity is quite high (around 70-80%). Along these regions, the humid air can be utilized to meet the water needs of individuals by utilizing a dehumidifier unit. Further the sun oriented insolation is very high in these zones round the year. The Atmospheric Water Generator (AWG) is one of the option answer for new water recuperation from environment which is straightforwardly consolidated the dampness substance of water vapor from the air. This paper introduces the strategy to build up a model of an AWG in light of Thermo-electric cooler (TEC) that utilized 12 Volt DC, consequently its appropriateness for utilizing sustainable power source asset

Keywords: Atmospheric Water Generator, Desalination, Relative humidity, Dehumidifier unit

TABLE OF CONTENTS

Chapter 1: Introduction

Chapter 2: Overview of the Solar Powered AWG

Chapter 3: Thermoelectric or Peltier Cooling

Chapter 4: Calculation, Field Test Data and Results

Chapter 5: Software Simulation

Chapter 6: Energy and Feasibility Analysis

Chapter 7: Conclusion and Future Scope

LIST OF FIGURES

LIST OF TABLES

Acronyms

PV	Photovoltaic
MPP	Maximum Power Pointer
PWM	Pulse Width Modulation
BLDC	Brushless DC
AC	Alternative Current
DC	Direct Current
COP	Coefficient of Performance
AWG	Atmospheric Water Generator
TEC	Thermoelectric Cooler
WHO	World Health Organization
DPDT	Double Pole Double Throw
CPU	Graphics Processing Unit
GPU	Central Processing unit
MTBF	Mean Time between Failures
DBT	Dry Bulb Temperature
RH	Relative Humidity
BTU	British thermal unit
EVM	Evaluation Module
UV	Ultraviolet
RO	Reverse Osmoses
NOAA	National Oceanic and Atmospheric Administration

Chapter 1

Introduction

1.1 Background

There is a saying, "water has only two aspects; when mixed with anything it's NEED, and when not it's LIFE". Sometimes the terrible water scarcity in tropical countries like Bangladesh reminds us this quote immensely. The thermoelectric term manages the change of thermal energy into electrical energy and the other way around. When working in a cooling or warming mode the thermoelectric gadget is named a thermoelectric cooler (TEC).The point of the project is to make a versatile gadget using TEC that can be utilized to meet the drinking water prerequisites. The gadget will first consolidate water available in the air and after that purification unit can be introduced to this gadget for fresh drinking water reason. While planning the atmospheric water generator it was distinguished that three prerequisites were necessary to guarantee that the last venture would successfully satisfy its expected reason.

They are-

- Portability (H20) - Water created by the gadget must adjust to the World Health Organization (WHO) drinking water quality guidelines.
- Simplicity- Design must be operable by people who has minimum amount of knowledge of electrical appliance.
- Safety - Design must not represent a risk to clients anytime amid its typical operation.

We built up a few objectives that the outline ought to have the capacity to meet. They are-

- Flexibility in Power Source - The plan ought to have the capacity to use an assortment of energy sources, including (however not restricted to) sun based, wind, and the customary power framework.
- Maximize Efficiency - The plan ought to augment the water delivered per unit vitality.
- Minimize Cost - The plan ought to limit the cost per unit water creation for both capital cost and generation cost.

1.2 Objectives

Indeed there are numerous items that are accessible in the market which utilize this innovation. Yet, on earlier research and experiencing the item improvement page of different organizations we found that the gadgets which utilize this innovation are extremely cumbersome and substantial. They are not compact and since they utilize a compressor they have overwhelming power request and are not eco-accommodating. Additionally these gadgets create a considerable measure of commotion and require occasional support. Since we needed to make a convenient gadget consequently we considered utilizing some other strategy to accomplish our objective. In their outline report "Water generator water from air using liquid desiccant method" Niewenhuis [1] and others have attempted to use fluid desiccant strategy for dehumidification. After they made a model and place it into testing they found that water yield from the gadget was extremely less. Consequently we chose not to utilize this strategy for dehumidification for our model. After experiencing all the accessible choices we at last inferred that we would utilize a Peltier gadget to make the Atmospheric Water Generator. We propelled the review by making a model first and afterward subjecting the model to comsol multi physics software. At that point we computed for various ecological and relative humidity conditions, the dew point temperatures and after that counted it with the outcomes acquired from examination. Subsequent to getting the outcomes we gathered the metrological information for various costal and mountain areas of Bangladesh and investigated whether our proposed model would work or not. Additionally for purification of dense water we chose to utilize a monetarily accessible filtration unit. This guaranteed the water which is acquired from the gadget is consumable and free from any microbes and germs.

1.3 Literature Review

Vapor pressure refrigeration framework, can be used to produce fresh drinking water by extricating water from humid encompassing air by utilizing Cooling Condensation process. In a cooling buildup based air water generator, a compressor flows refrigerant through a condenser and an evaporator loop which cools the air encompassing it, bringing down the air's temperature to that of dew indicate and creating water gather. A controlled-speed fan pushes sifted air over the loop. The subsequent water is then passed into a holding tank with sanitization and filtration framework to keep the water unadulterated. Atmospheric water producing innovation offers 99.9% immaculate drinking water 365 days a year. The atmospheric water generator is a naturally safe wellspring of reasonable water. The water generator, produced using cooling and dehumidifier parts, can create enough of water to meet the drinking water prerequisites of a consistent family unit. It likewise addresses the requirement for safe savoring water to remote zones and reacts to the looming shortage of consumable water in specific territories because of the impacts of an unnatural weather change and catastrophic events. It can substitute accessible water gadgets in the market to spread the more remote regions. A senior outline venture was gone for planning and making a model of an environmental water generator [1]. They have attempted to join Liquid Desiccant technique to concentrate dampness from air and change over it into drinking water. Wet drying up is a procedure where a saline solution arrangement is presented to damp air to assimilate water vapor from that air. The arrangement is then sent into a regenerator where the water vapor is removed from the arrangement. This strategy has developed in notoriety due to its productivity and the straightforwardness with which it can be adjusted to sustainable power source, especially sun power based. In their paper (Niewenhuis et.al. 2012) and others have additionally portrayed a novel and one of a kind strategy to collect water from air. They have said that it is conceivable to compress damp air so much that it will begin gathering at the surrounding temperature itself. As pressure increases at the same time dew point rises; therefore, enough pressure will drive the dew point over the surrounding temperature bringing about unconstrained condensation. But, compacting air to concentrate water could possibly require weights up to five times the surrounding weight. This will require an exceptionally durable tank that can deal with high measures of stress in its dividers. This strategy has extraordinary potential for low vitality requests, particularly on the off chance that one could recover a portion of the vitality in the packed air utilizing a turbine or cylinder. The vitality effectiveness of this outline alternative has incredible guarantee however it is intensely subject to compressor and decompress or productivity and mugginess. The essential preferred standpoint of weight dehumidification is the low vitality prerequisite; the main unavoidable misfortune is the weight connected to the water vapor. Be that as it may, any wastefulness in the pressure/decompression cycle is enhanced by the substantial volume of air handled per unit water delivered. Also, the rate of generation when driven by regular convection cooling to the air is too moderate for critical creation; some component to accelerate this warmth exchange should be actualized, expanding the vitality cost. A research paper named "Solar-based atmospheric water generator utilization of a fresh water recovery: A numerical study " [2] has done thermodynamic examination for a Peltier gadget which is utilized to build up a gadget that uses the rule of inert warmth to change over particles of water vapor into water beads called the

Atmospheric Water Generator. It has been presented a bit some time recently, however it is not extremely normal in Bangladesh and some different nations. It has an extraordinary application remaining on such period of innovation where we as a whole are running behind sustainable sources. Here, the objective is to acquire that particular temperature, called the dew point temperature, essentially or tentatively to consolidate water from climatic muggy air with the assistance of thermoelectric Peltier (TEC) couple.

1.4 Basic perceptions from distributed papers

we surmise that despite the fact that dehumidifying unit utilizing vapor pressure refrigeration framework is more powerful than the Peltier framework yet it needs as in it is not versatile and it produces a great deal of sound. And furthermore this framework is more costly. We watched that despite the fact that dehumidification by fluid desiccant technique is new and have a considerable measure of potential hypothetically yet when the scientists made a model and tried it the outcomes were not attractive. The gadget could deliver just 72.1 mL of water for every kW-hr. [1] .We acknowledge the way that dehumidification unit utilizing Peltier gadget is exceptionally convenient and condition amicable after reading the paper [2]. It has straightforward plan and has high continuance capacity. Along these lines, this kind of Atmospheric Water Generator is the gadget which can be executed in extraordinary circumstances like amid surges or in abandon and rustic zones. It has incredible points of interest as it does not require high power source. Applying this framework in an exceedingly moist locale just about 1 Liter of consolidated water can be created every hour amid the sunlight, which is an exceptionally encouraging outcome.

1.4 Motivation

In thought and correlation of the considerable number of projects described in the literature review section, a system has been designed and developed which is a totally power efficiency solution. This system has been designed in such a route in this way, to the point that its proficiency is superior to the next existing frameworks. As compressor refrigeration system is more costly and create sound, we utilized Peltier cooling. Powering the device with PV boards and batteries is the most sensible choice to run the AWG device. The majority of the sun based cooling system incorporate AC compressor and inverter which alters the DC current taken from the PV boards to AC. However, this procedure is wasteful and energy is squandered while DC current is changed over into AC by the inverter. Though, Peltier cooling is more productive as far as power effectiveness and power utilization. Additionally, its voltage is effectively controllable. Henceforth, running the AWG with the Peltier plate and PV boards is a superior alternative than whatever other existing system utilized as a part of solar based cooling unit. The schematic diagram of the proposed solar based AWG system is shown in Figure 1.1.

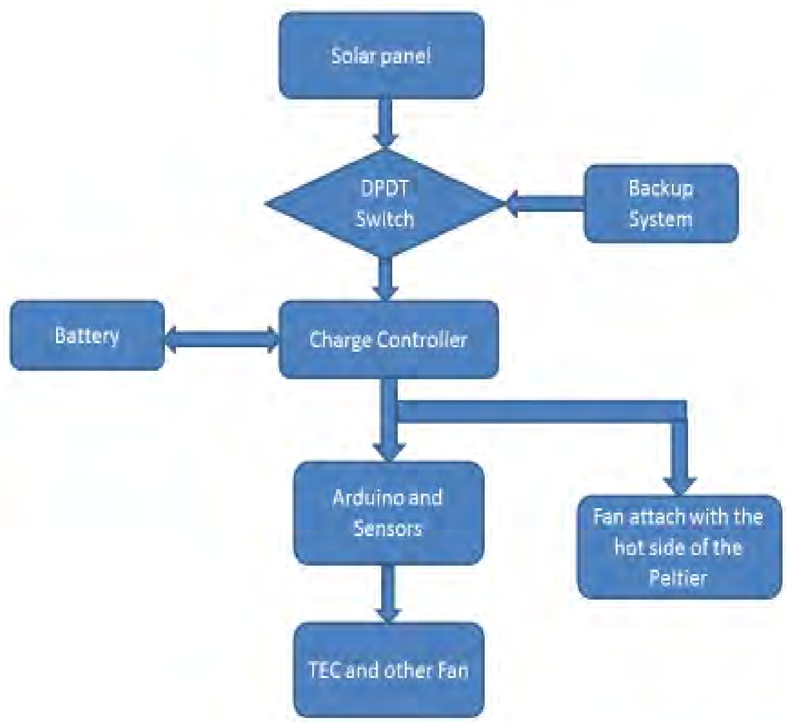


Figure 1. 1: Block Diagram of the whole system

Figure 1.1 shows the system takes energy from PV Panel and passes it to the charge controller. The charge controller dissipates the energy to the whole system and also charges the battery instantaneously. At night the batteries give backup and when there is no power supply from the PV panel or batteries, the powered source is kept for the ultimate backup.

1.5 Justification

Lack of fresh drinking water and energy is a combination that fails to fulfill the demand of drinking water of the people of Bangladesh who stays at the coastal and mountain side. This leads to the idea of fulfilling their demand of water in a cost effective way. Also the lack of electricity supply is the main concern. Water purification system or compressor based AWG is expensive and unaffordable for the poor people. Moreover, many rural areas of Bangladesh do not have electricity supply. Keeping these in consideration, a system needed to be developed that will be cost effective as well as easy to operate. Solar being an excellent source of renewable energy, it has been used in this project making it a total off grid system using batteries as backup. By virtue of that the coastal and mountain side people will be relieved from the pressure of fresh drinking water without paying for electricity. In Bangladesh, solar powered Peltier cooling system has not been introduced yet. This project is the first attempt incorporating solar power into cooling system. Successful implementation of this project can meet the demand of water of the sea side people and also improve the economy of the country. Moreover, it will consume less power, it is cost effective and can run the AWG system efficiently.

1.6 Overview of the Content

The following chapters portray the work that has been accomplished, the field tests, energy calculation, payback calculation and suggested future plans. The first chapter gives the overall introduction of the system and literature review on AWG. The second chapter gives an overview of the whole system and the components. The third chapter shows the basic mechanism of thermoelectric cooling. The fourth chapter is about calculation, field test data and results. In the chapter five, we have incorporate software simulations that was required for our project. The sixth chapter focuses the energy efficiency of the system and the feasibility analysis. The seventh chapter gives an overview of the limitations, solutions , conclusions and also the future work that is yet to be done

Chapter 2

Overview of the Solar Powered AWG

2.1. Introduction

The solar powered atmospheric water generator is aimed to incorporate an off grid cooling system to give water supply in the coastal and hilly areas for fresh drinking water purpose. The proposed solar powered AWG consists of one solar panels, one rechargeable batteries, one pulse width modulation (PWM) charge controller, two thermoelectric cooler, two dc fan and two heat sink. There will also be a backup system which will be controlled by the Double Pole Double Throw (DPDT) switch. The schematic diagram of the proposed solar powered refrigeration system is shown in Fig 2.1.

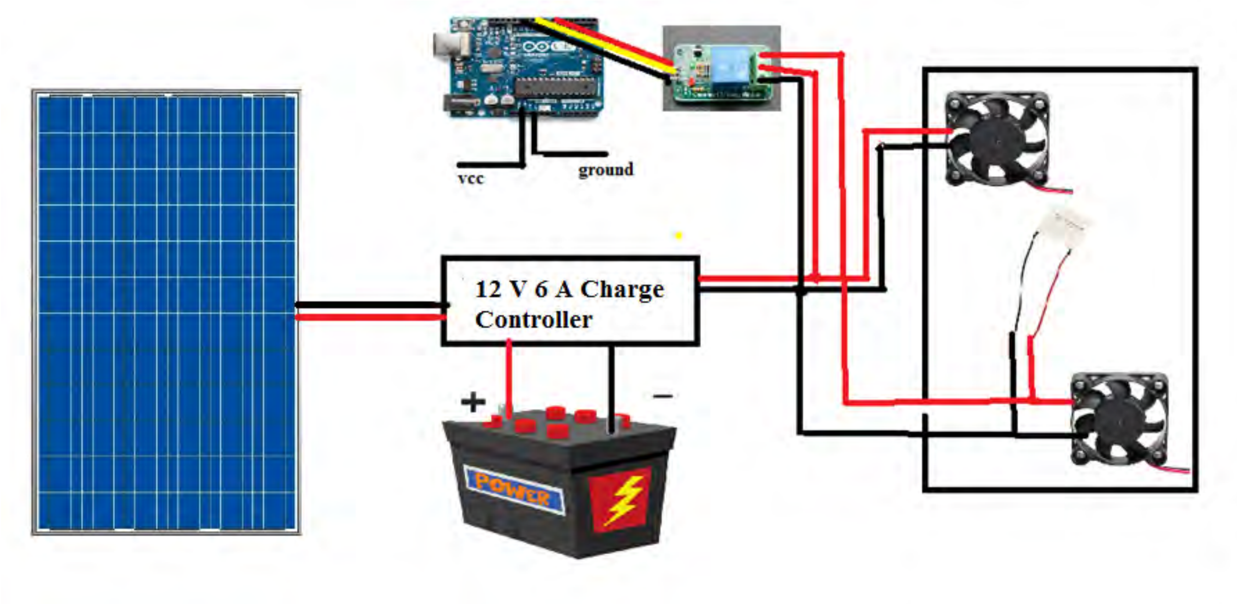


Figure 2.1: Schematic diagram of the whole AWG system.

2.2 Description of Individual Components

2.2.1 Solar Photovoltaic Panels

In the period of industrialization, practicing environmental safety with sun based is the best arrangement. Sunlight based boards have been utilized worldwide and it is easy to store and generally safe to use in business purposes. Sunlight based photovoltaic boards are being utilized worldwide for creating power. The innovation of retaining sun's beam to energy has included numerous parts of utilizing the sun based as sustainable power source. Its every module is evaluated as DC output and normally delivers 100-365 Watts, which is a gigantic source of energy. In our system we have used one 65 watt 18V Poly crystalline solar panels which was purchased from Raisa Engineering Bangladesh. Its rated short circuit current is 6.2A and Maximum Power Pointer (MPP) current 5.7A. The panel is tilted in 10 degree angle facing south. A single unit of solar panel is presented in Figure 2.4.

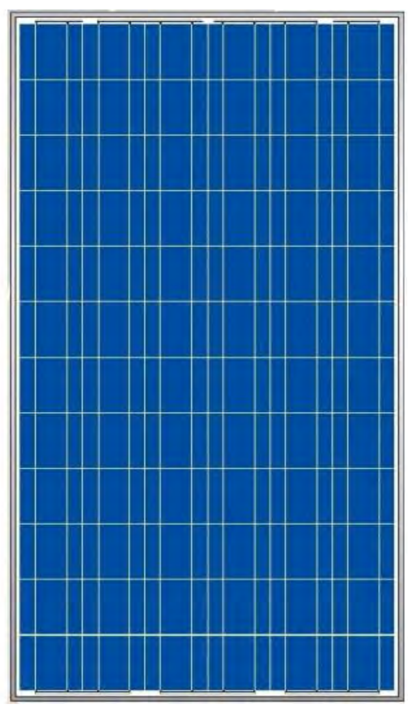


Figure 2.2: A single unit of Poly crystalline Photovoltaic Panel.

2.2.2 Charge Controller

Solar Charge Controllers provide a low-cost and excellent solution to regulating the harvested solar energy from the solar panels into the batteries and into the range required for the system. The charge controller having Pulse Width Modulation (PWM) strategy of 12V and 6A rated has been utilized as a part of our framework from Electro sun powered organization to run the 12V DC AWG. PWM charge controllers pull the sun based voltage to the essential voltage required for the load. Ideal execution is accomplished when sunlight based board output voltage is around 20% above battery full charge voltage. The charge controller is appeared in Fig. 2.3.

Figure 2.3: 12 V-6A Charge Controller

2.2.3 Battery

Sunlight is not always same in our country due to cloud, rain and night time. For that reason, in the system, we have used batteries as back up when there is not enough sunlight. The rating of battery is 12 V and 20Ah. One 12V battery has been connected with the solar panel and AWG system.

The dimension of the battery is 16.5 X 17.5 X 12.6 cm. The battery used for the proposed system is shown in Figure 2.4.

Figure 2.4: 12V-20Ah battery

2.2.4 Heat Sink

Basically heat sink is a hardware component that is attached above microprocessor or raspberry pie to keep it cool. It consist a dc fan and aluminum component to reduce heat from microprocessor or raspberry. For our project heat sink is a major part. We have attached one large heat sink at the hot side of Peltier device. Using a heat sink at the hot side of Peltier plate is must because it reduce the heat and the heat is extracted by a dc fan. If a heat sink is not attached at the hot side of a Peltier device, the device will burn within 5 seconds after powering up. We have also attached a small aluminum heat sink at the cold side of Peltier device. That's how it helps the humid air to condense. The dimension of the large heat sink is 12.5*5.5*2 cm and the small one is 7.5*3.8*2 cm. The heat sink used for the proposed system is shown in Figure 2.5.

Figure 2.5: Heat Sink (Attached at the hot & cold side of Peltier)

2.2.5 Thermal Paste

Heat sink compound or thermal paste is a very high heat conductive paste that is used between two objects (usually a heat sink and a CPU/GPU) to get better heat conduction. We need physical contact to move heat from the hot side of the Peltier to the heat sink. The job of thermal glue is to "fill in the crevices" and take into consideration better exchange of heat from the hot side of the Peltier to the heat sink. For that reason, we have used thermal paste in between hot side of Peltier plate and heat sink. The thermal paste used for the proposed system is shown in Figure 2.6.

Figure 2.6: Thermal paste

2.2.6 Brushless Dc Fan

Two 12v 0.16 A dc fan has been used in our project. We have attached one fan along with heat sink to extract heat. Another fan is used to pass external humid air to the system. The best thing is this fans consume very low current. The dc fan used for the proposed system is shown in Figure 2.7.

Figure 2.7: Brushless DC Fan

2.2.7 Digital circuitry components

A digital system has been designed which consist of a DPDT relay switch, a sonar sensor and an Arduino Uno. This system has been designed such a way that when AWG filled with water, then the system shuts down automatically. A sonar sensor measures the distance of water and send signal to the Arduino. The digital system used for the proposed system is shown in Figure 2.8.

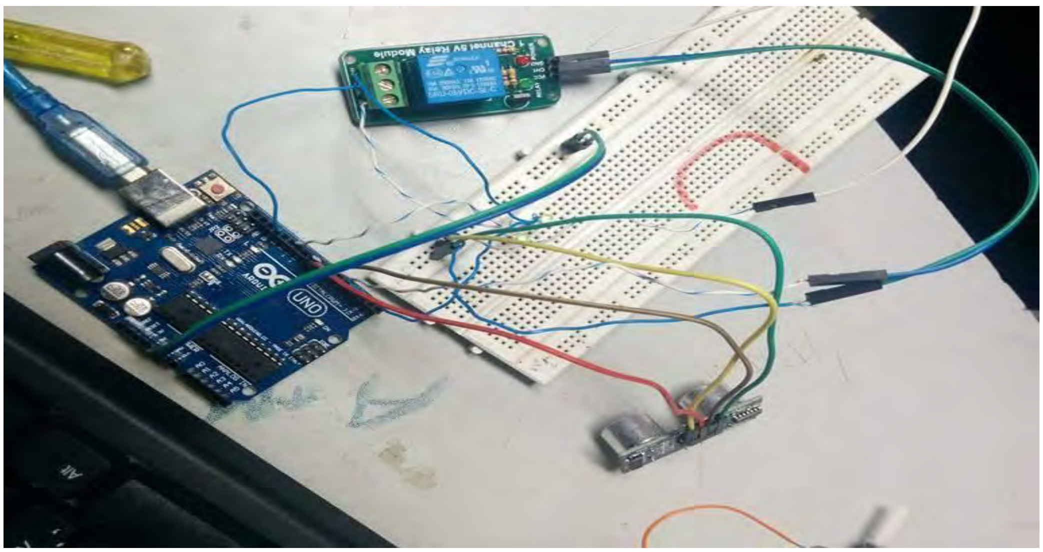


Figure 2.8: Digital circuit setup

2.2.8 Peltier

30x30 mm thermoelectric cooler (TEC-12704) has been used in your project. This device is also known as peltier plate. These coolers create a temperature differential on each side. One side gets hot and the other side gets cool. The Specification of TEC-12704 is given below-

Dimensions (mm):30*30*3.2
Color: White
Maximum Power consumption: 60W
Maximum Voltage: 15V
Maximum Current Rating: 4A
Maximum allowable temperature: 66°C
The peltier used for the proposed system is shown in Figure 2.9.

Figure 2.9: Peltier (TEC-12704)

2.3 Total Infrastructure of AWG

We have tested the whole system at roof top and the total system is shown in figure 2.10-

Figure 2.10: Peltier (TEC-12704)

Chapter 3

Thermoelectric or Peltier Cooling

3.1 Introduction

This technique is precisely same as that of Vapor Compression Refrigeration strategy however here we utilize a Peltier gadget to accomplish the required dew point temperature. Pettier gadget is reduced, has less moving parts, is vitality proficient and has a long life expectancy which requires less support. Despite the fact that there is a variety of the utilization of thermoelectric devices, but all of them depend on a similar standard. When outlining a thermoelectric application, it is important that the majority of the significant electrical and thermal parameters be joined into the plan procedure. Once these elements are considered, a reasonable thermoelectric gadget can be chosen based on the guidelines. Utilizing this straightforward way to deal with "heat pumping", thermoelectric innovation is connected to some broadly fluctuated applications– little laser diode coolers, compact fridges, fluid coolers etc. The image of basic peltier cooling system is shown in Figure 3.1.

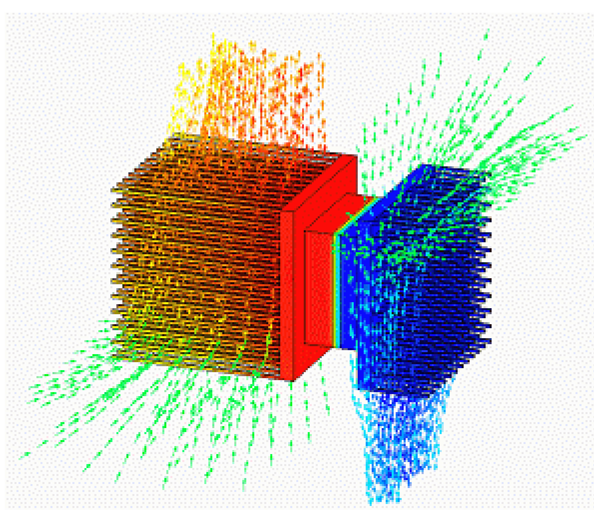


Figure 3.1: Peltier device

3.2 Principle of Peltier Device

Thermoelectric cooling utilizes the Peltier impact to make a heat flux between the intersections of two unique sorts of materials. A Peltier cooler, is a strong solid state dynamic heat pump which exchanges heat from one side of the gadget to the next, with utilization of electrical vitality, contingent upon the heading of the current. Such an instrument is likewise called a Peltier gadget, or thermoelectric cooler (TEC) [3]. At the point when DC voltage is connected to the module, the positive and negative charge bearers in the pellet cluster assimilate heat from one substrate surface and discharge it to the substrate at the inverse side. The surface where heat is assimilated ends up noticeably icy; the inverse surface where heat is discharged, winds up noticeably hot. The internal structure of a peltier is shown in Figure 3.2.

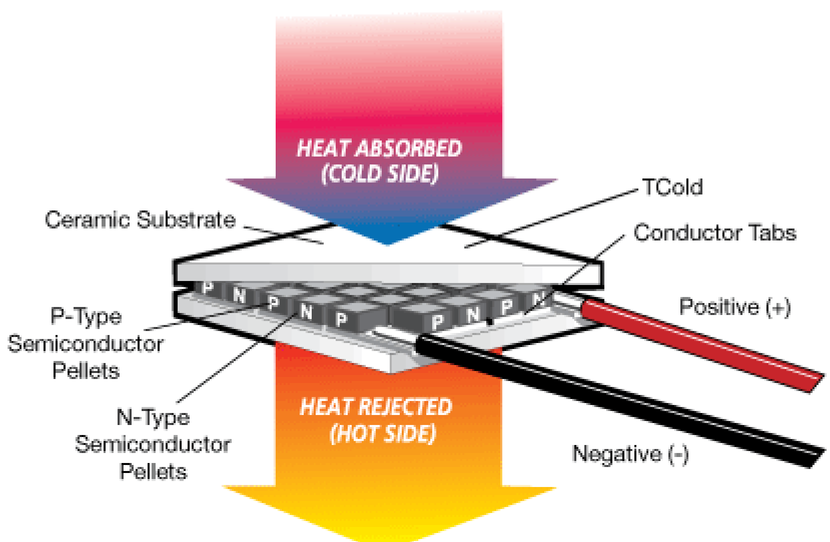


Figure 3.2: Internal Structure of Peltier device

Every individual thermoelectric framework configuration has a remarkable limit with respect to pumping heat (in Watts or BTU/hour) and this are affected by many variables. The most critical factors are ambient temperature, physical and electrical attributes of the thermoelectric modules utilized, and productivity of the heat dispersal framework (i.e., sink). Ordinary thermoelectric applications generally pump heat loads ranging from a few milli watts to several watts.

3.3 Working Features

For all intents and purposes TE couples are joined in a module, associated electrically in series and thermally in parallel to get a promising output. Be that as it may, it will be badly arranged to utilize such a gadget, to the point that has less beneficial work done to power proportion. There are modules accessible in the market as indicated by assortment of sizes, shapes, working voltages-currents and feature of heat pumping. The present pattern, be that as it may, is towards a bigger number of couples working at lower streams; before picking a proficient gadget, a few parameters must be resolved.

These are:
TC: Temperature at Cold Surface.
TH: Temperature at Hot Surface.

Hot side temperature is associated with two noteworthy parameters:

1. The effectiveness of the gadget i.e. between the hot surface of the TEC and the ambient environment.
2. The temperature of surrounding condition into which the heat is being rejected.

QC: The heat to be assimilated at the Cold Surface.
The object to be cooled is attached with the frosty surface of TEC, accordingly the temperature of that object begins falling until it is as same as the temperature of the icy surface of the TEC.
Presently, ΔT can be characterized as:
$\Delta T = TH - TC$
This contention ought to be precisely decided whether the plan is to work as wanted.
For example, we are considering few values [4] to make it more understanding through graph
Q = 20 watt
TA = 35°C most extreme ambient air temperature
TC = 20°C required temperature of electronic part
Before utilizing the graph to figure out which thermoelectric module is fitting for our application, we should first recognize the hot side temperature (TH) and the resultant temperature differential over the module (ΔT).

TH = TA + warm sink transcend surrounding = 25°C + 15°C = 50°C

The temperature differential over the module can now be ascertained as follows:

ΔT = TH - TC= 50°C – 20°C = 30°C

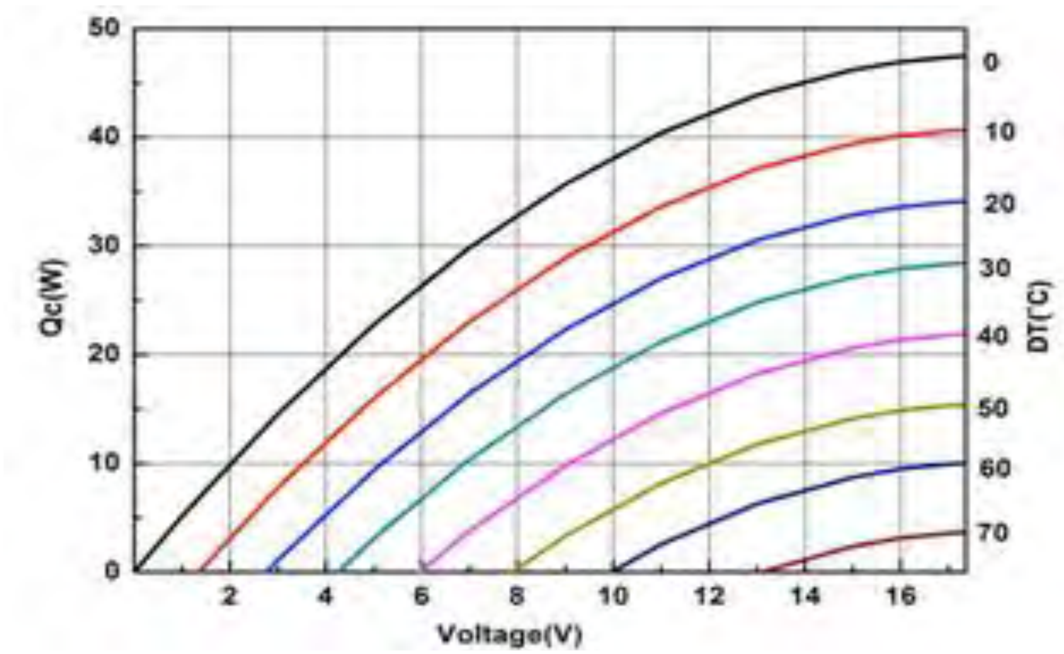


Figure 3.3: Voltage under various DT

3.4 Heat sink selection:

The heat pumping ability of the thermoelectric module is essentially impacted by the productivity of the heat sink. The hot side of the module must interface with a productive warmth expulsion framework to accomplish valuable temperature differential over the thermoelectric module. Normal convection, constrained convection, and fluid cooled are three of the most widely recognized sorts of heat sinks. Thermal resistance shifts among the distinctive sorts and sizes of sinks with normal convection being the slightest proficient and fluid cooled the most effective. The greater part of thermoelectric cooling applications utilize constrained convection heat sinks with heat resistance values (RQ) running from 0.05°/W to 0.9°/W. The hot side temperature will be equivalent to the surrounding temperature (TA) in addition to the ascent in temperature over the warmth sink from disseminating the heat load (Q) and the heat coming resulting thermoelectric module electrical power which is (V x I).

TH = TA + (V x I + Q) RQ

Where RQ = thermal resistance of heat sink in C° temperature rise per Watt dispersed.

RQ = (TH — TA)/ (V x I +Q)

So, at last heat sink should be chosen depending on the value of RQ.

3.5 Advantage of pettier over traditional gadget:

1. No moving part: It has any moving part. So support is required less much of the time.
2. Flexible shape: The general thermoelectric cooling framework is considerably smaller and lighter than a practically identical mechanical framework. Furthermore, an assortment of standard and uncommon sizes and arrangements are accessible to meet strict application prerequisites. It is perfect for present day innovation patterns.
3. Environment friendly: Traditional refrigeration system can't be manufactured without utilizing chlorofluorocarbons or different chemicals that might be destructive to our environment. Thermoelectric gadgets don't utilize or create gasses of any sort.
4. Precise temperature control: - With a suitable temperature control circuit, thermoelectric module can control temperatures to superior to +/ - 0.1˚C.
5. Capacity to cool underneath ambient: - Unlike a general heat sink whose temperature fundamentally should increase in respect with surrounding; a thermoelectric framework appended to that same heat sink can lessen the temperature beneath the ambient temperature.
6. Using in Extreme condition: It can be utilized as a part of situations that are littler or more extreme than ordinary refrigeration.
7. Long life span & reliability: Thermoelectric modules show high dependability because of their solid state development. Has a long life, MTBF surpassing just about 100,000 hours.
8. Control: Controllable by means of changing the input voltage/current effectively.
9. Low power consumption: Draw similarly low current than a compressor based refrigeration framework. Thermoelectric coolers can operate directly from a DC power source.
10. Soundless Operation: - Unlike like a general mechanical refrigeration framework, thermoelectric modules produce purposes no electric commotion and can be utilized as a part of conjunction with touchy electronic sensors. They are additionally acoustically quiet.

11. Operation in any Condition: - Thermoelectric modules can be utilized as a part of any introduction and in zero gravity conditions. Consequently they are prevalent in numerous aviation applications.
12. Individual Cooling: - With a thermoelectric module it is easy to cool one particular segment or territory just.
13. Ability to Generate Electric Power: - When utilized in reverse by applying a temperature differential over the characteristics of a thermoelectric refrigeration framework, it is mindful to create a little measure of DC power.

Another advantage to thermoelectric gadgets is that they change thermal vitality straight forwardly into power, or the other way around. Coordinate transformation disposes of misfortunes related with various vitality change forms. Coordinate transformation likewise implies there is no requirement for extra gear or materials, making for a simple gadget. Thermoelectric energy transformation is done in the solid state. All things considered, the gadgets have no moving parts that can destroy.

Chapter 4
Calculation, Field Test Data and Results

4.1 Time vs. temperature Test Keeping a Constant Voltage

After analyzing a lot of journal our first laboratory test was to find out the phenomena of peltier device across different voltage. We wanted to find out the temperature vs voltage graph and from that we wanted to find out some important information for our project. We have started applying voltage from 5v till 12v having an interval of .5v. Keeping voltage in constant position, after each five second we measure the temperature of the hot and the cold side of the peltier device. We plotted those value on the graph to understand the phenomena of peltier device when a constant DC voltage is applied, the change in temperature with time (second). For our purpose we applied 16 different constant voltage starting from 5v to 12 v.

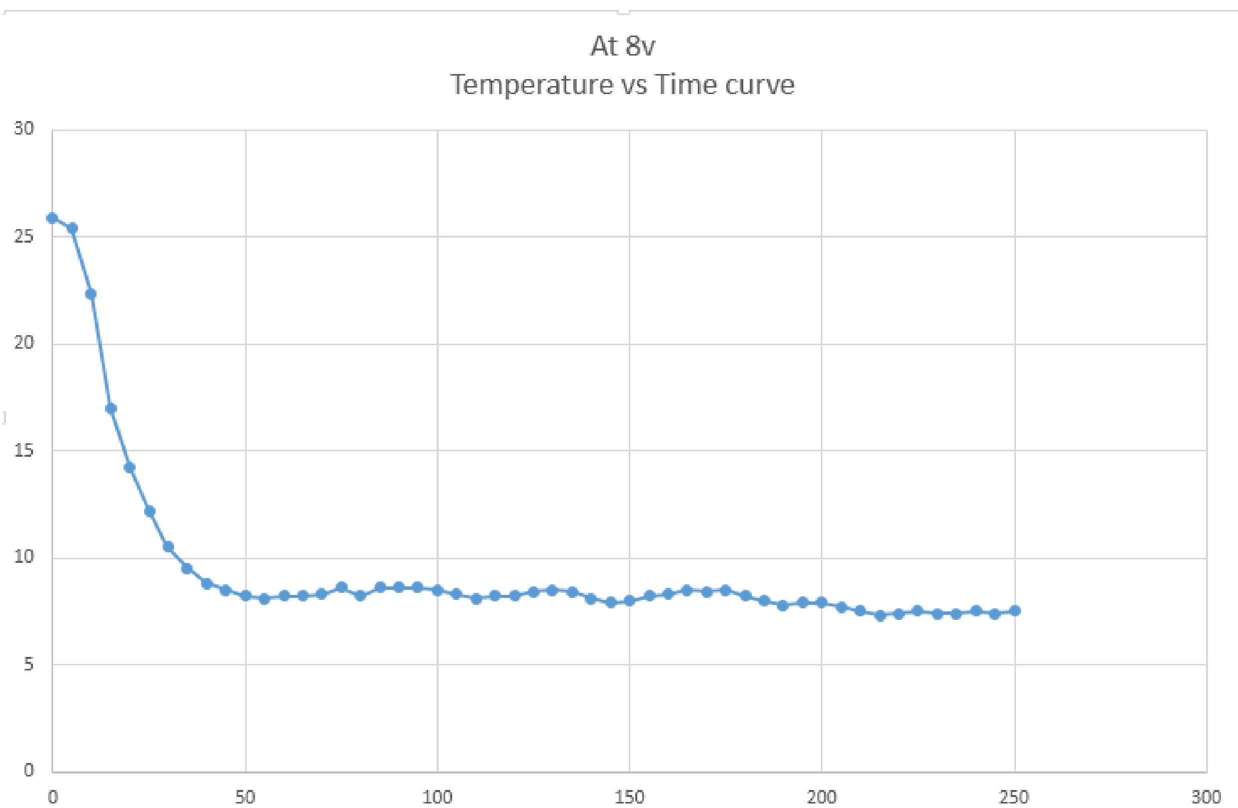


Fig 4.1: Temperature vs Time Curve at 8V for cold side of the peltier.

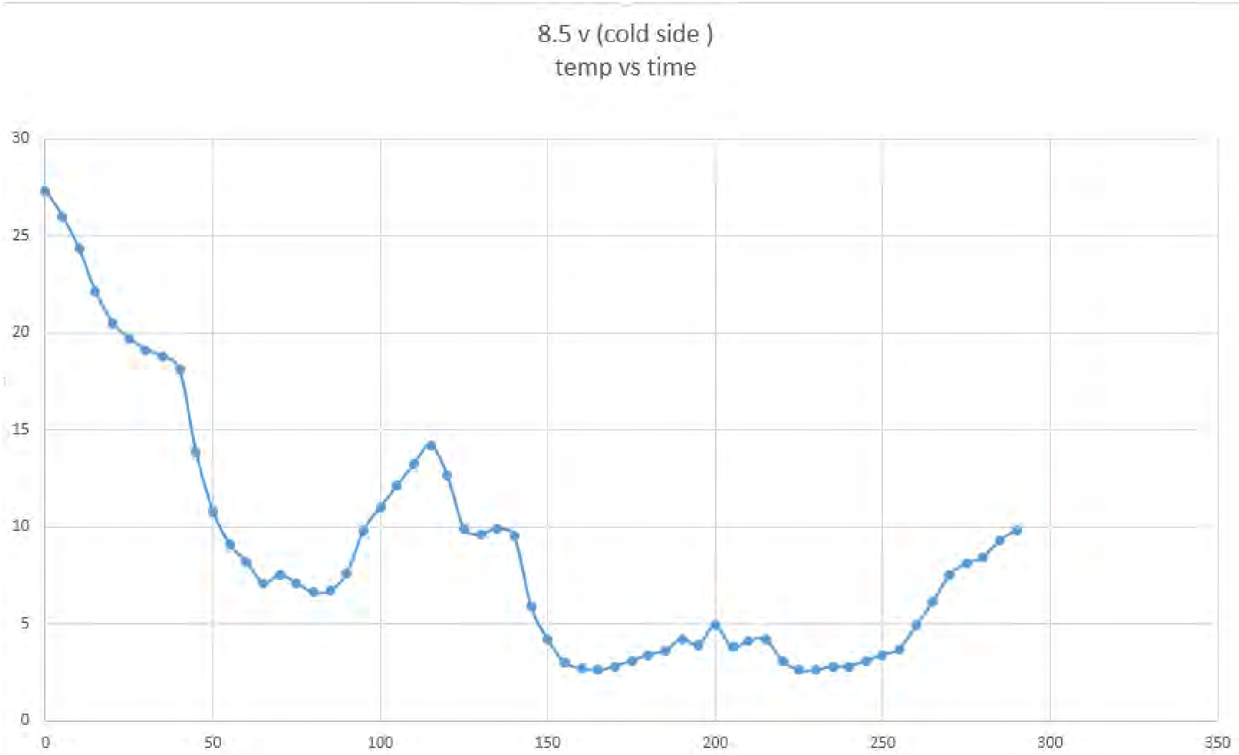


Fig 4.2: Temperature vs Time Curve at 8.5V for cold side of the peltier.

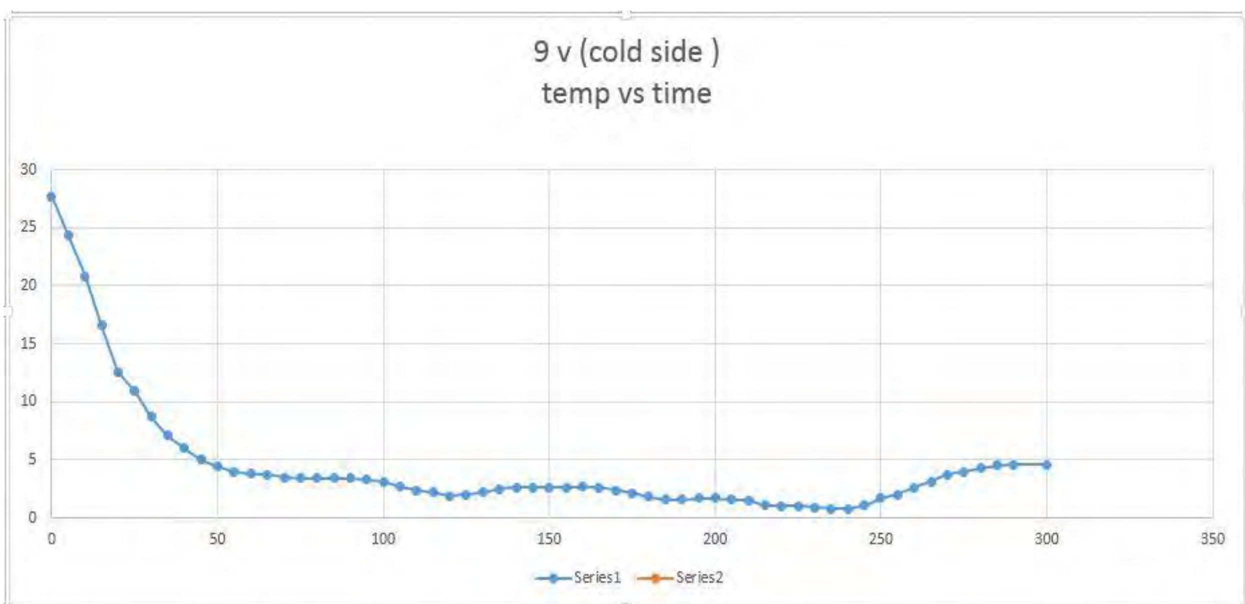


Fig 4.3: Temperature vs Time Curve at 9V for cold side of the peltier.

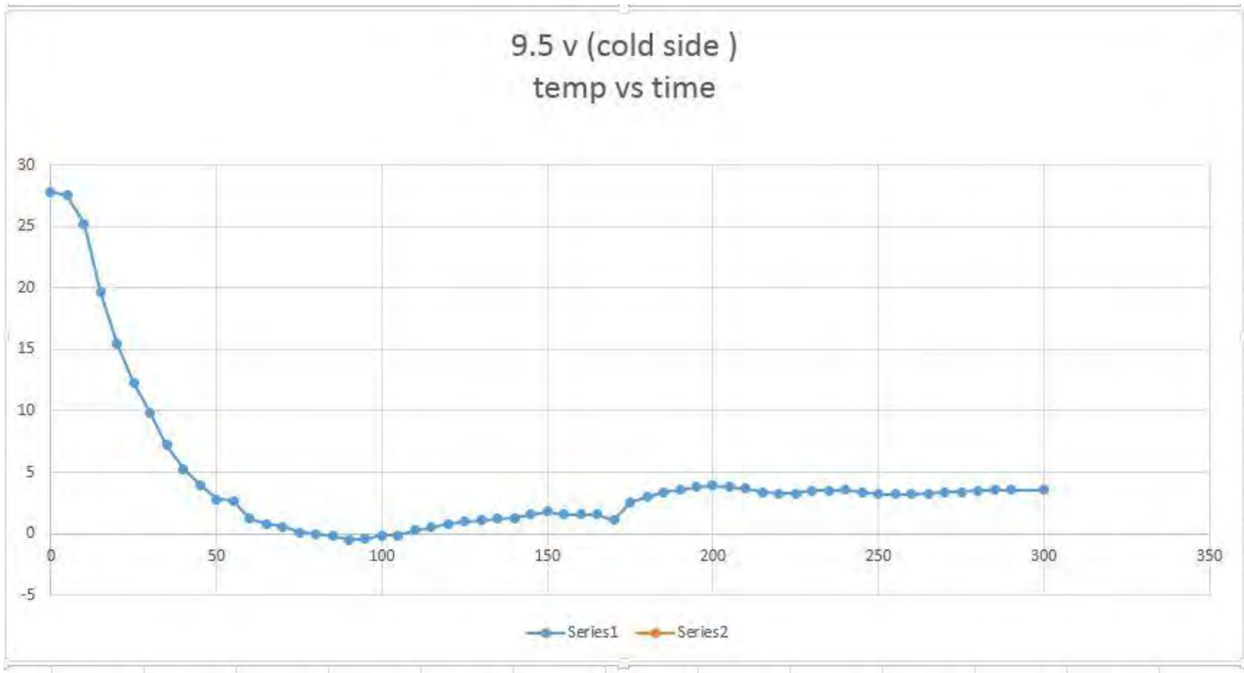


Fig 4.4: Temperature vs Time Curve at 9.5V for cold side of the peltier.

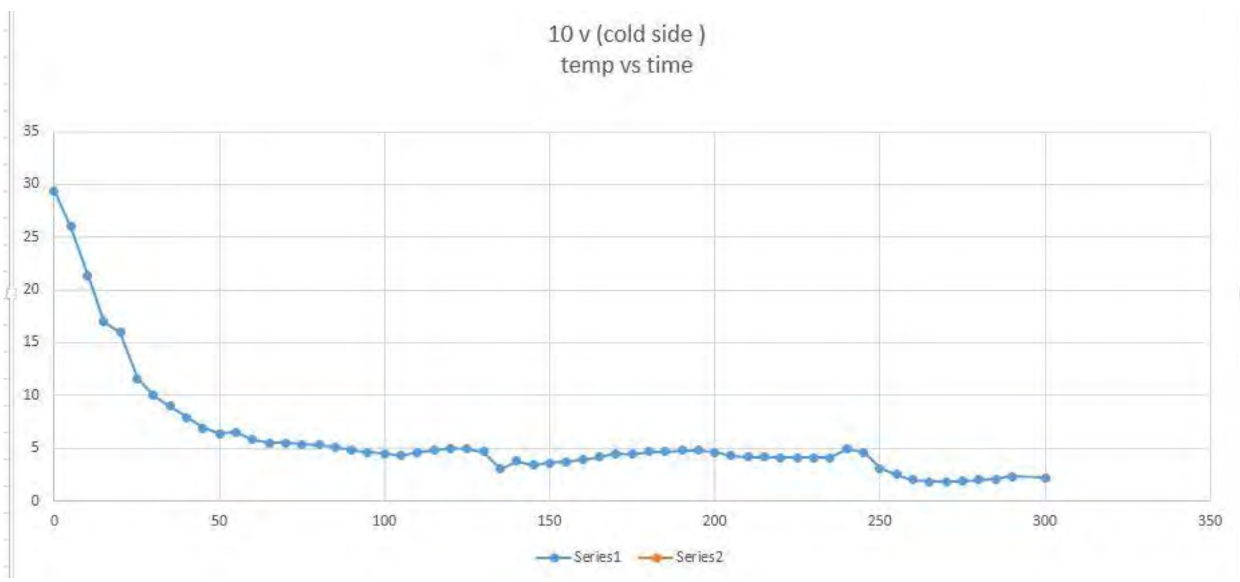


Fig 4.5: Temperature vs Time Curve at 10V for cold side of the peltier.

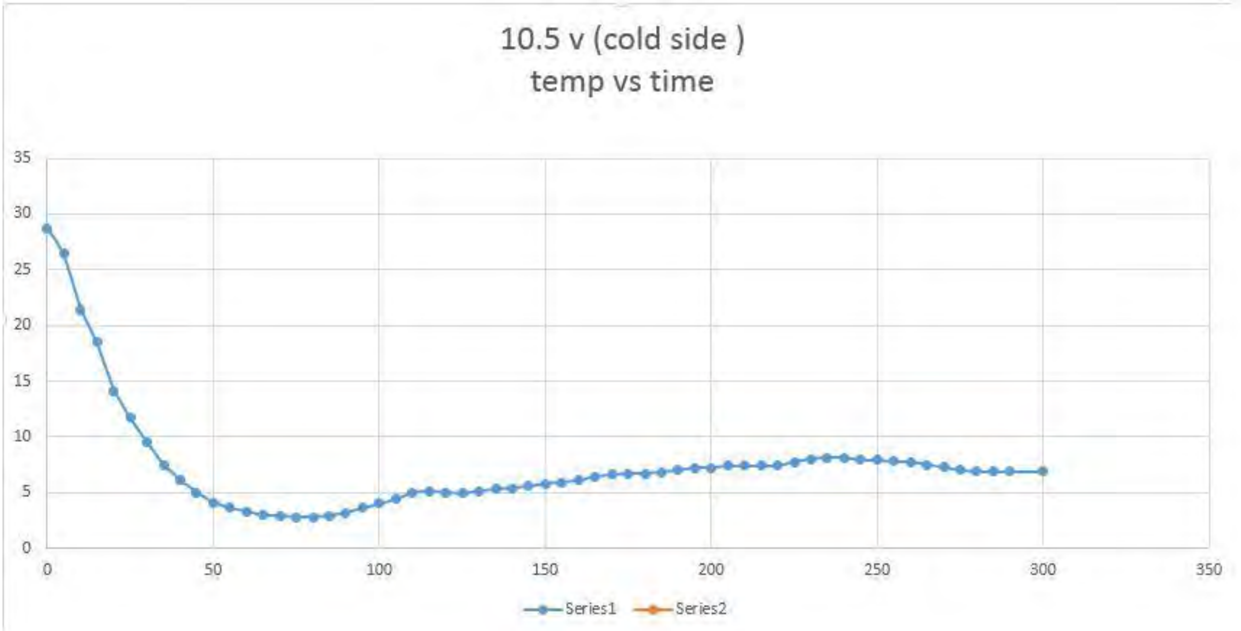


Fig 4.6: Temperature vs Time Curve at 10.5V for cold side of the peltier.

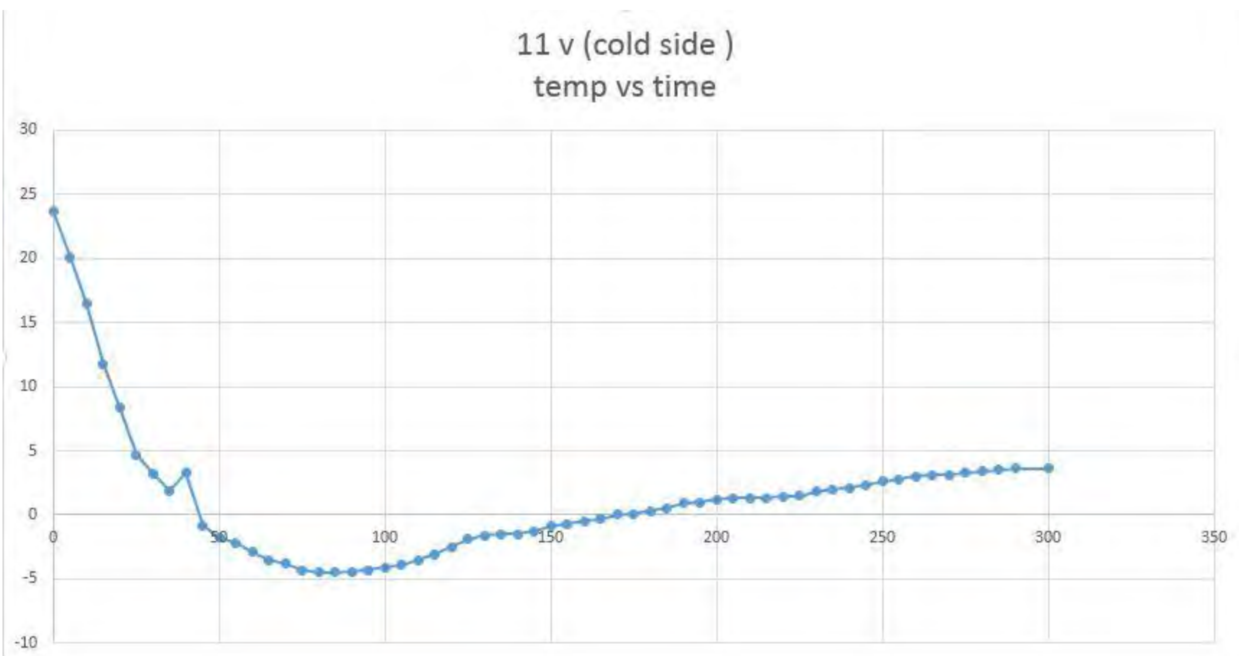


Fig 4.7: Temperature vs Time Curve at 8V for cold side of the peltier.

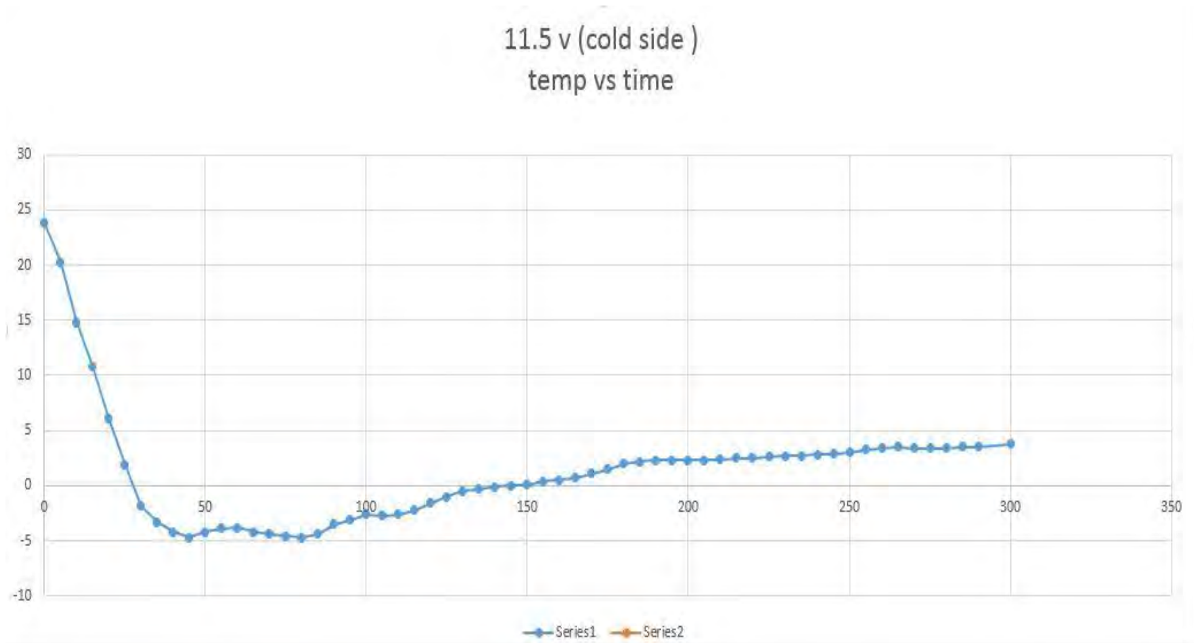


Fig 4.8: Temperature vs Time Curve at 11.5V for cold side of the peltier.

Fig 4.9: Temperature vs Time Curve at 12V for cold side of the peltier.

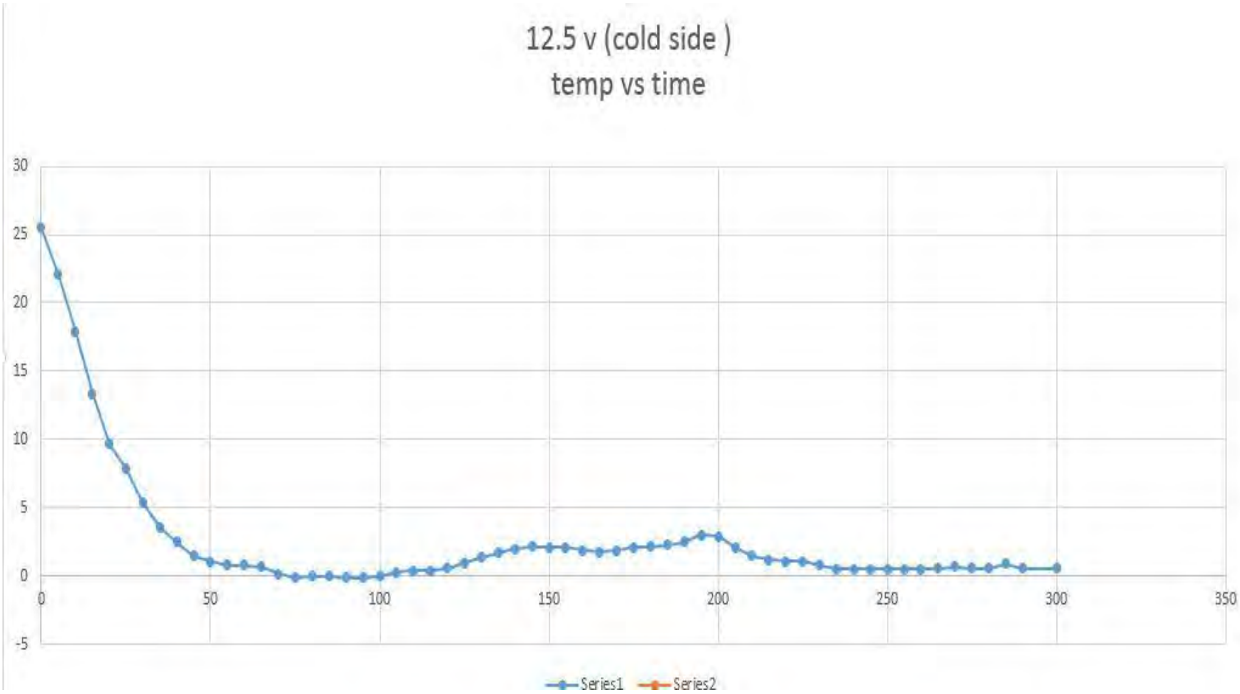


Fig 4.10: Temperature vs Time Curve at 12.5V for cold side of the peltier.

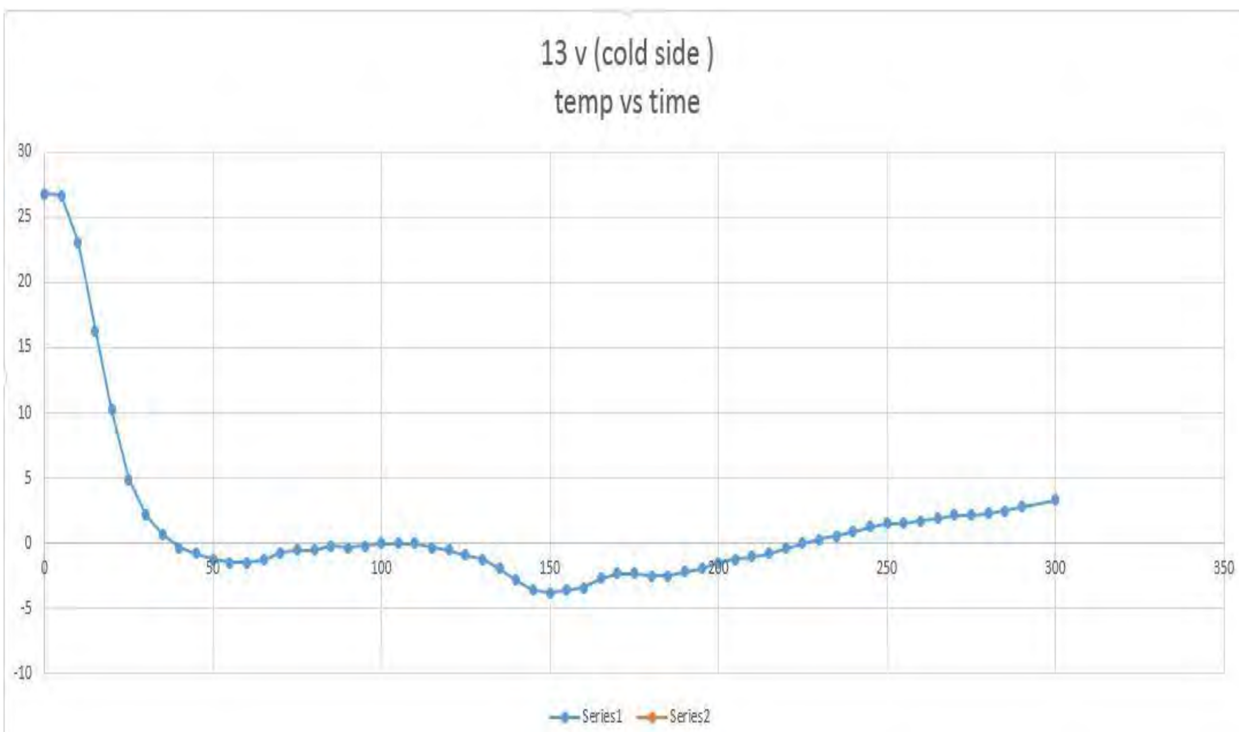


Fig 4.11: Temperature vs Time Curve at 13V for cold side of the peltier.

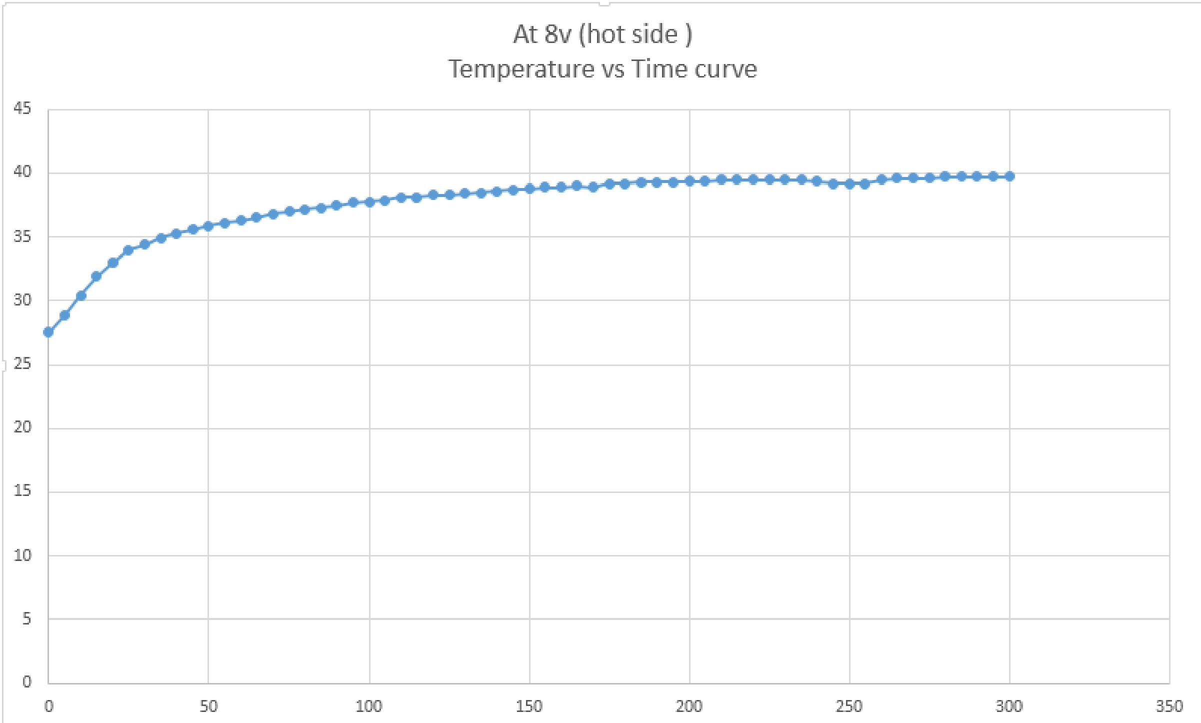


Fig 4.12: Temperature vs Time Curve at 8V for hot side of the peltier.

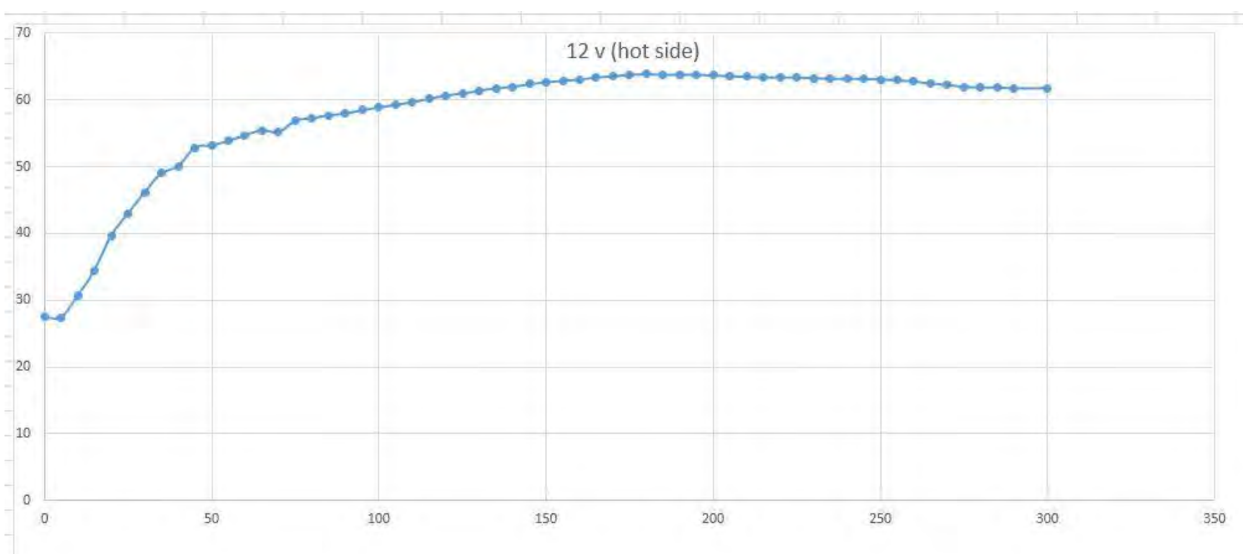


Fig 4.13: Temperature vs Time Curve at 12V for hot side of the peltier.

If we look at the graphs we can find that the hot side phenomena of peltier device keeping voltage constant is almost similar to the rated condition. Starting from the ambient temperature, for certain voltage the hot side of a peltier gives up to 60 to 70 degree Celsius with respect to the time. On the other hand we have observed sudden rise and fall in case of cold side phenomena. For each constant voltage the temperature was started to fall down. When the temperature reached the theoretical dew point, the humid air came in contact with the Peltier's cold side and started to condense into water. After a few seconds, the condensed water on the surface of the peltier will start to absolve temperature from the atmosphere. So that the temperature of the cold side will be slightly increased and again within a few seconds, the dew gathered on the Peltier's surface have turned into ice. This process continues again and again and gives us a graph which has too many ups and down point.

4.2 Theoretical Calculation

If we can calculate dry-bulb temperature and use relative humidity in the Magnus formula, then for each dry-bulb temperature and corresponding relative humidity we can calculate required dew point.

The temperature at which humidity in the air starts condensing at the same rate at which it is evaporating at a given constant barometric process is called dew point temperature (T_{dp}) and the temperature that is usually thought of as atmospheric temperature which is truly thermodynamic temperature is called dry-bulb temperature (DBT). The ratio of the partial pressure of water vapor to the equilibrium vapor pressure of water at the same temperature is called relative humidity (RH). The famous Magnus equation for calculating dew point temperature is given below.

$$\gamma(T, RH) = \ln\left(\frac{RH}{100}\right) + \frac{bT}{c+T}$$

$$T_{dp} = \frac{C\gamma(T, RH)}{b - \gamma(T, RH)}$$

Where b and c are constants. The ones used in NOAA's presentation are taken from a 1980 paper by Devid Bolton in the monthly weather review are

a= 6.112 mili bar

b= 17.67

c= 243.5°C

Using these equations we have calculated required dew point temperature. We have varied temperature from 25° to 35° C and also for each degree centigrade temperature we have varied relative humidity from 78% to 89%. As we have made this theoretical calculation in summer that is why we have found relative humidity in that range. In winter we have found the relative humidity in the range of 35% to 55%.

Table 4.1: Dew point temperature calculations at 25 degree Celsius and different relative humidity conditions Temperature

Temperature (in C)	Relative Humidity (%)	Required Dew Point Temperature (in C)	$\gamma\ (T,RH)$
25	78	20.90050917	1.396790037
25	79	21.10764985	1.409529063
25	80	21.31250362	1.422107845
25	81	21.5151241	1.434530365
25	82	21.71556299	1.446800458
25	83	21.91387018	1.458921818
25	84	22.11009385	1.47089801
25	85	22.30428051	1.482732467
25	86	22.49647511	1.494428507
25	87	22.68672108	1.505989329
25	88	22.87506045	1.517418025
25	89	23.06153385	1.52871758

Table 4.2: Dew point temperature calculations at 27 degree Celsius and different relative humidity conditions Temperature

Temperature (in C)	Relative Humidity (%)	Required Dew Point Temperature (in C)	$\gamma\ (T,RH)$
27	78	22.83968237	1.515272467
27	79	23.04987383	1.528011493
27	80	23.25774708	1.540590275
27	81	23.46335644	1.553012795
27	82	23.66675431	1.565282888
27	83	23.86799124	1.577404248
27	84	24.06711604	1.589380439
27	85	24.26417584	1.601214897
27	86	24.45921621	1.612910937
27	87	24.65228114	1.624471759
27	88	24.84341323	1.635900455
27	89	25.03265364	1.64720001

Table 4.3: Dew point temperature calculations at 30 degree Celsius and different relative humidity conditions Temperature

Temperature (in C)	Relative Humidity (%)	Required Dew Point Temperature (in C)	$\gamma\ (T,RH)$
30	78	25.74761539	1.68974705
30	79	25.96242355	1.702486076
30	80	26.17486623	1.715064858
30	81	26.38499881	1.727487378
30	82	26.59287474	1.739757471
30	83	26.79854556	1.751878831
30	84	27.00206106	1.763855022
30	85	27.20346931	1.77568948
30	86	27.40281675	1.78738552
30	87	27.60014828	1.798946342
30	88	27.79550732	1.810375038
30	89	27.98893587	1.821674593

Table 4.4: Dew point temperature calculations at 33 degree Celsius and different relative humidity conditions Temperature

Temperature (in C)	Relative Humidity (%)	Required Dew Point Temperature (in C)	$\gamma\ (T,RH)$
33	78	28.6545567	1.860435567
33	79	28.87403016	1.873174592
33	80	29.09109048	1.885753375
33	81	29.30579413	1.898175895
33	82	29.5181956	1.910445987
33	83	29.72834744	1.922567348
33	84	29.93630041	1.934543539
33	85	30.14210352	1.946377996
33	86	30.34580413	1.958074036
33	87	30.54744802	1.969634859
33	88	30.74707946	1.981063554
33	89	30.94474126	1.99236311

Table 4.5: Dew point temperature calculations at 35 degree Celsius and different relative humidity conditions Temperature

Temperature (in C)	Relative Humidity (%)	Required Dew Point Temperature (in C)	$\gamma\ (T,RH)$
35	78	30.59196688	1.97218496
35	79	30.81457751	1.984923986
35	80	31.03474302	1.997502768
35	81	31.25252061	2.009925288
35	82	31.46796546	2.022195381
35	83	31.6811308	2.034316741
35	84	31.89206805	2.046292932
35	85	32.10082685	2.05812739
35	86	32.30745517	2.06982343
35	87	32.51199937	2.081384252
35	88	32.7145043	2.092812948
35	89	32.91501334	2.104112503

Now with the help of the value of relative humidity, humidity ratio we can calculate the amount of water present in $1m^3$of air. The equation needed foe this calculation are given below:

$$RH = \frac{P_W}{P_s} \times 100$$

$$P_W = \frac{RH}{100} \times P_s$$

$$\text{Humidity Ratio} = 0.622 \times \frac{P_W}{P_a - P_W}$$

Table 4.6: The amount of water present in $1m^3$in different temperature and different RH

Serial no.	Temperature, (in ◦C/ K)	Saturation pressure, Ps (in Pascal)	Relative humidity, RH (in Percentage)	Partial pressure of water, Pw (in Pascal)	Humidity ratio	Amount of water (in Littre)
1	25/298	0.03167	78	0.0247026	1.554×10^{-2}	15.54
2	27/300	0.03565	78	0.027807	1.755×10^{-2}	17.55
3	30/303	0.04005	78	0.031239	1.979×10^{-2}	19.79
4	33/306	0.05031	78	0.0392418	2.506×10^{-2}	25.06
5	35/308	0.05624	78	0.0438672	2.815×10^{-2}	28.15
6	25/298	0.03167	79	0.0250193	1.575×10^{-2}	15.75
7	27/300	0.03565	79	0.0281635	1.778×10^{-2}	17.78
8	30/303	0.04005	79	0.0316395	2.005×10^{-2}	20.05
9	33/306	0.05031	79	0.0397449	2.539×10^{-2}	25.39
10	35/308	0.05624	79	0.0444296	2.852×10^{-2}	28.52
11	25/298	0.03167	80	0.025336	1.595×10^{-2}	15.95
12	27/300	0.03565	80	0.02852	1.801×10^{-2}	18.01

13	30/303	0.04005	80	0.03204	2.031×10^{-2}	20.31
14	33/306	0.05031	80	0.040248	2.573×10^{-2}	25.73
15	35/308	0.05624	80	0.044992	2.857×10^{-2}	28.57
16	25/298	0.03167	81	0.0256527	1.616×10^{-2}	16.16
17	27/300	0.03565	81	0.0288765	1.825×10^{-2}	18.25
18	30/303	0.04005	81	0.0324405	2.057×10^{-2}	20.57
19	33/306	0.05031	81	0.0407511	2.606×10^{-2}	26.06
20	35/308	0.05624	81	0.0455544	2.928×10^{-2}	29.28
21	25/298	0.03167	82	0.0259694	1.636×10^{-2}	16.36
22	27/300	0.03565	82	0.029233	1.848×10^{-2}	18.48
23	30/303	0.04005	82	0.032841	2.084×10^{-2}	20.84
24	33/306	0.05031	82	0.0412542	2.640×10^{-2}	26.40
25	35/308	0.05624	82	0.0461168	2.966×10^{-2}	29.66
26	25/298	0.03167	83	0.0262861	1.657×10^{-2}	16.57
27	27/300	0.03565	83	0.0295895	1.871×10^{-2}	18.71
28	30/303	0.04005	83	0.0332415	2.110×10^{-2}	21.10
29	33/306	0.05031	83	0.0417573	2.674×10^{-2}	26.74
30	35/308	0.05624	83	0.0466792	3.004×10^{-2}	30.04
31	25/298	0.03167	84	0.0266028	1.667×10^{-2}	16.67
32	27/300	0.03565	84	0.029946	1.894×10^{-2}	18.94
33	30/303	0.04005	84	0.033642	2.136×10^{-2}	21.36
34	33/306	0.05031	84	0.0422604	2.707×10^{-2}	27.07
35	35/308	0.05624	84	0.0472416	3.042×10^{-2}	30.42

So, this are the theoretical calculation by which we can calculate the amount of water can be produce from the environment by peltier model at different condition and different kind of atmospheric configuration.

4.3 Practical Calculation

In our field work we have tested our system in different conditions. The presence of humidity in the air was not same every time and the condition was not even similar. That is why the amount of water produced was not alike. All the test were done with just two peltier. The result of field test in respect to RH is shown below:

Table 4.7: Practically produced water in different percentage of humidity and in different time period.

Day	Humidity Rate (%)	Hours	Amount of water produced (ml)
22 February 2017	77	4	63
23 February 2017	58	3.5	55
24 February 2017	48	4	63
25 February 2017	44	4.5	71
26 February 2017	53	3.5	55
27 February 2017	67	4	63
28 February 2017	57	6	94
26 March 2017	73	5	78
27 March 2017	91	4	63
28 March 2017	71	2	31
29 March 2017	79	5	78
30 March 2017	74	4.5	71
31 March 2017	77	3.5	55
1 April 2017	72	6	94
2 April 2017	75	7	110
3 April 2017	71	7	110
4 April 2017	74	7.5	118
5 April 2017	79	8	126
6 April 2017	83	9.5	150

Here the amount of water produced which is shown in figure - 4.14

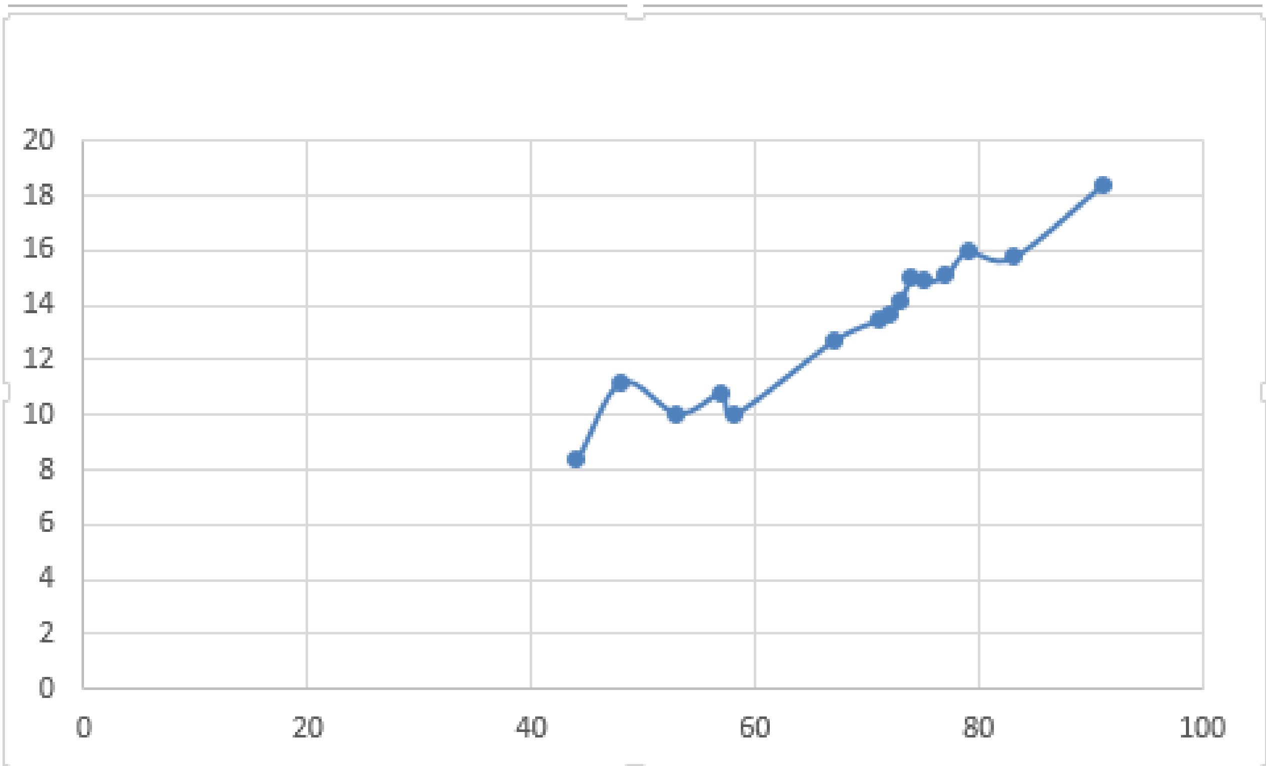


Fig 4.14: Amount of water in ml vs percentage of humidity graph

In x axis we have kept the percentage of humidity and in y axis we have kept the amount of water produced in ml at 1 hour.

So in a 300 mm^2surface we can use up to 100 piece of 30 mm×30 mm peltier. If 2 peltier can produce 150 ml of water in 9.5 hours then. Then from a 600mm^2surface having 400 piece of peltier can produce, = (100×150)

=15,000 ml

=15 liter.

Which is very much similar to our theoretical calculation.

Chapter 5
Software Simulation

5.1 Simulation in Nano Hub

As we wanted to do different software simulations to understand and explain our topic deeply, we have done an online simulation using nanoHub.org, which can be kept running on any web interface without the necessity to install the commercial software. Moreover, this simulator is efficient in such a way that can be utilized to teach the principles of thermoelectric energy transformation, and break down the nitty gritty execution of Peltier devices. By means of 1D thermal network model the simulation tool resolves the heat equilibrium equations at the top and bottom sides of the thermoelectric device and also with the help of the electric circuit model it scrutinizes the steady-state temperature and the thermoelectric energy conversion efficiency of the device. Furthermore, users are able to optimize the capabilities of a thermoelectric device with various different design parameters such as the device dimensions and material properties, by utilizing this simulator**.** Besides, this simulation is also helpful to show how material properties improve “Carnot limit” can be achieved at negligible output power, while efficiency at maximum output power converges to Curzon-Ahlborn limit.

5.1.1 Carnot's rule

Carnot's theorem established in 1824 by Nicolas Léonard Sadi Carnot, also known as Carnot's rule, is a theorem that defines limits on the maximum efficiency any heat engine can achieve. The efficiency of a Carnot engine depends only on the difference between the hot and cold temperature relevance.

Carnot's rule states:

- ❖ All heat engines between two heat reservoirs are less efficient than a Carnot heat engine operating between the same reservoirs.
- ❖ Every Carnot heat engine between a pair of heat reservoirs is equally efficient, regardless of the working substance employed or the operation details. [5]

The formula for this maximum efficiency is

$$\eta_{max} = \eta_{\text{Carnot}} = 1 - \frac{T_C}{T_H}$$

Curzon and Ahlborn showed that provided all the parts of an engine are ideal but heat transfer is irreversible, [6] the engine efficiency at maximum output power, also known as Chambadal-Novikov efficiency, is

$$\eta = 1 - \sqrt{\frac{T_2}{T_1}}$$

Where T_2 is the temperature of the heat sink, and T_1 is the temperature of the heat source.

5.1.2 PRINCIPLES AND MODELING OF THERMOELECTRIC DEVICES

Peltier effect is the fundamental physics of thermoelectric cooling. During the current flow throughout an interface between two different materials, thermal energy is engrossed or wasted depending on the direction of current flow. The thermal energy *Q* transferred by a current *I* in a material having a Seebeck coefficient *S* at absolute temperature *T* is given by *Q*=*STI*. Therefore, the engrossed or wasted heat at the interface connecting material 1 and material 2 by the Peltier effect becomes the difference of the transferred thermal energies or Q_1-Q_2= (S_1-S_2)TI. Moreover, there are some more thermal transport effects: Joule heating and thermal conduction. For a material with electrical resistance R, Joule heating is I^2R and it is evenly divided and generated to the two ends of the material. If a temperature gradient is made for a substance, we will see heat conduction Q_{cond} occurs from the hot side to cold side proportional to the temperature difference ΔT, so that $Q_{cond} = \Delta T/\psi$, where ψ is a constant which is considered the thermal resistance of the substance.

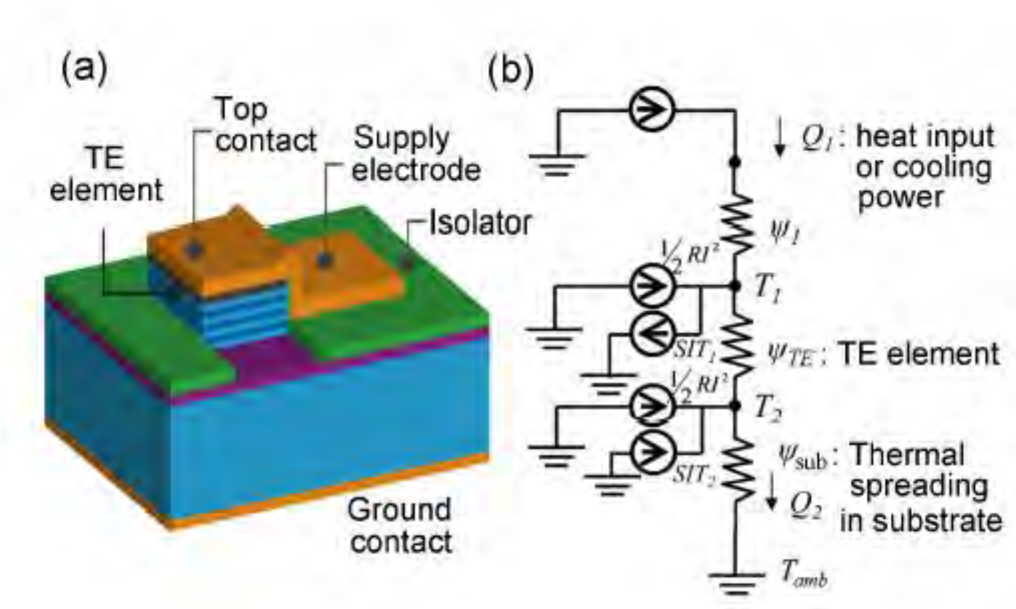


Figure 5.1: Schematic of a thin film TE device on a substrate & b) the corresponding id thermal network model

Fig. 5.1 shows a usual configuration of a thin layer TE device fabricated on a conducting surface. The thin film of TE element has a metal contact as 'top contact' on the upper surface and a ground contact is deposited at the underneath of the surface, so that both current and heat flow in a upright direction through the entire structure. In our simulator, we solve the heat equilibrium equations gained at the upper surface of the TE element and also at the interface between the TE element and the substrate from the 1D thermal network model shown in Fig. 1(b).

The heat equilibrium equation shows that the Peltier heating/cooling, the Joule heating, and the heat conduction are all in balance. As the substrate is much larger than the TE device on it, it is necessary to include the heat and current 3D spreading effect in the substrate. A closed-form thermal spreading resistance in a substrate is adopted from Lee et al [7]. With a presumption of an infinitely large substrate and a perfect heat sink below it. The electrical spreading resistance is obtained from Vashaee et al [8], which is based on ANSYS finite element simulation.

5.1.3 SIMULATION METHOD AND BOUNDARY CONDITION:

A thermoelectric device can be a power generator as well as a cooler. In the cooling mode, a current is injected into the TE device. Two boundary conditions can be considered: one is that the cooling power Q1 is known, from which T1 and T2 are calculated by solving the coupled heat balance equations. The other boundary condition is that the upper surface temperature T1 is known, from which T2 and the cooling power Q1 are calculated. Then the coefficient of performance (COP) is obtained by

$$COP = \frac{Q_1}{W}$$

Where W is the work done by the electrical current to achieve the cooling performance given by

$$W = IV_{OC} + I^2 R_i$$

Where V_{OC} is the open-circuit voltage induced internally in the device because of the Seebeck effect, $V_{OC} = S_{TE}(T_1 - T_2) + S_{sub}(T_2 - T_{amb})$, and R_i is the total internal resistance of the device, $R_i = R_c + R_{TE} + R_{sub}$.

5.1.4 IMPLEMENATION ON nanoHUB.org

From our point of view, doing simulation on nanoHUB.org was really a great experience and it was quite hassle free because of many reasons. Firstly, nanoHUB provides an uncomplicated and simple Java-based graphical user interface. Secondly, accessing and operating the program can be done just by visiting the website. Thirdly, during the beginning of the program, an introduction page is shown up to give users a brief outline and directions on how to use the simulator. Additionally, users can choose from a simulation option in either cooling or power generation mode for single element simulation or multi-element module simulation. In the second page of the simulator, users are asked to choose an independent variable, for which all the outputs are calculated and plotted as its function, and the range of the independent variable to simulate, and enter material properties and dimensions of the TE elements. Then simulation is performed when the simulate button is pressed by user, and the resulting output data are plotted as a function of the independent variable.

The simulator is very resourceful and it allows students to study the limit of thermoelectric power generation as the material properties are improved. Carnot limit ($1- T_{cold}/T_{hot}$) can be achieved at negligible output power, while efficiency at maximum output power converges to Curzon-Ahlborn limit ($1-\sqrt{T_{cold}}/\sqrt{T_{hot}}$). [9]

5.1.5 Simulation of Different Modes

Mode 1

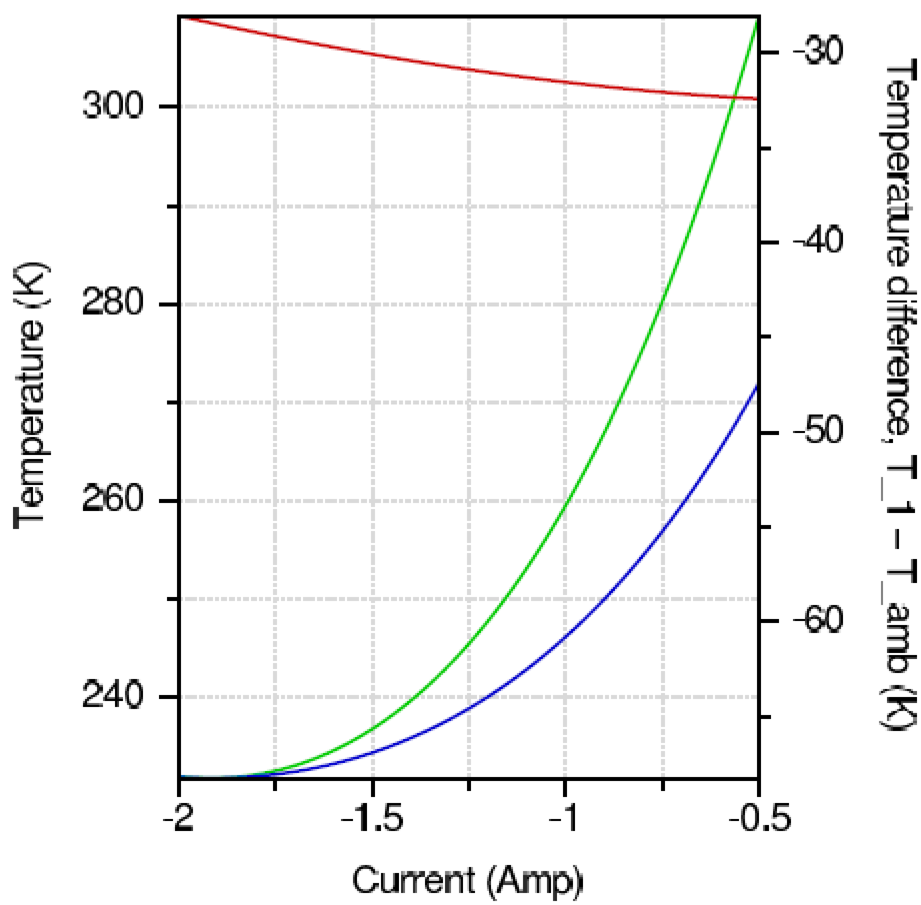
Thermoelectric thin fin cooler: cooling power is known.

Boundary condition,

Cooling power density = 100 w/cm^2

Ambient temperature = 300K

Independent variable= current (Amp)



Mode 2:

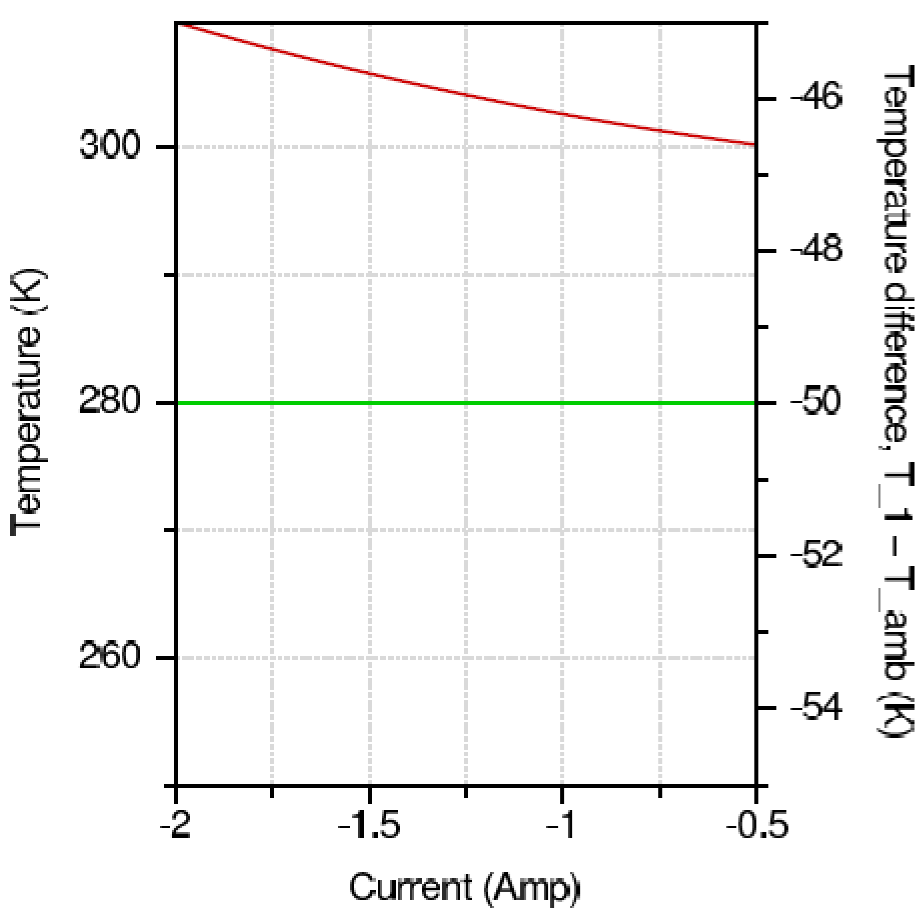
Thermoelectric thin fin cooler: Top temperature is known

Boundary condition,

Temperature T1=250 k

Ambient temperature =300K

Independent variable= current (Amp)



Mode 5

Thermoelectric module for cooling: Top temperature is known

Boundary condition,

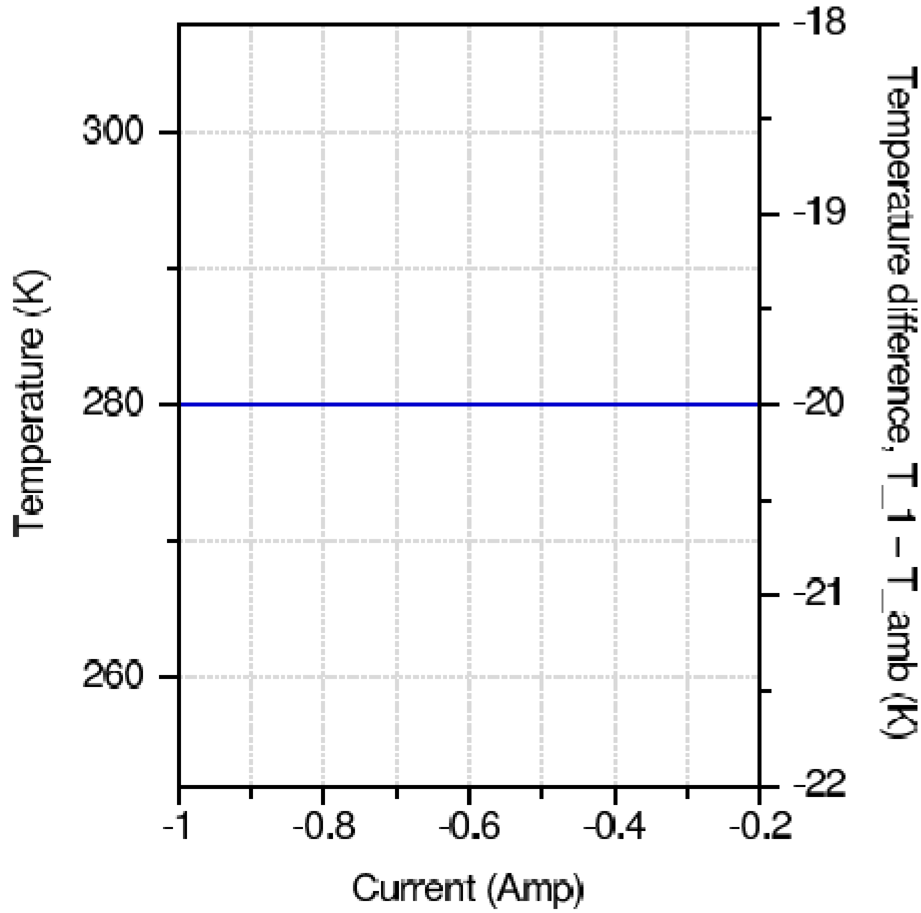
Temperature T1=280 k

Ambient temperature =300K

Number of N-type element= 10

Number of P-type element =10

Independent variable= current (Amp)



5.2 Aztec Simulation

Ambient temperature, Ta = 27◦C

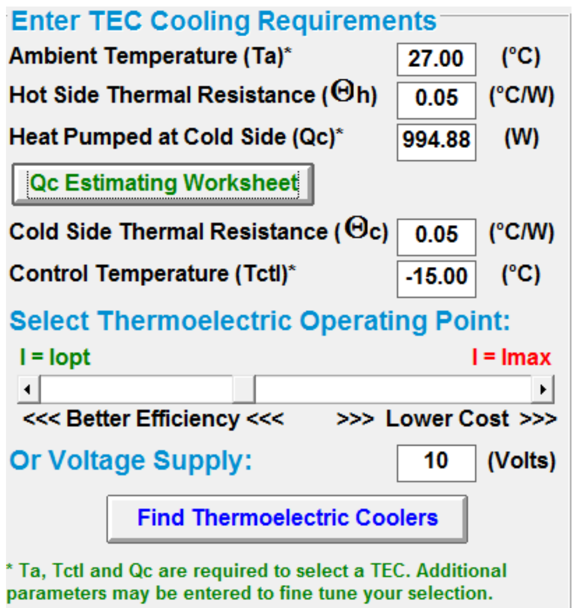
Hot side thermal resistance, Ѳh =0.05◦C/W

Heat pumped at cold side, Qc = 994.88W

Cold side thermal resistance, Ѳc =0.05◦C/W

Control Temperature, T_{ctl} =-15◦C

Voltage Supply, V = 10 Volts



5.2.1 Dimensions of box shape Container

Length, L = 155mm

Width, W = 155mm

Height, H = 400 mm

Surface area = 2720.3 sq cm

Device Volume = 9610.0 cu cm

Active load = 20W

Time to cool from Ta to Td = 515 s.

To build the prototype, we used different software simulations. For Aztec simulations we cared about some matters like load type, ambient and control temperature, thermal resistance etc.

5.2.2 Ambient Temperature

The temperature of the room when a component or system is tested on the bench, on an evaluation module (EVM) or a real system board (with or without an enclosure). So we chose 27◦C for Ta .

5.2.3 Control Temperature

Temperature of the cold side of thermoelectric cooler (measured one at 12 Volt).Generally we use 12 Volt as the supply voltage but through the software simulation we saw it's better to use 10 Volt.

To choose the load type we thought about the power dissipation as load is related with the power dissipation during cooling the device. Our load is active load and the general equation for active heat load power dissipation is:

- $Q_{active} = V^2/R = VI = I^2R.$

Where:

- Q_{active} = active heat load (watts)
- V = voltage applied to the device being cooled (volts)
- R = device resistance (ohms)
- I = current through the device (amps)

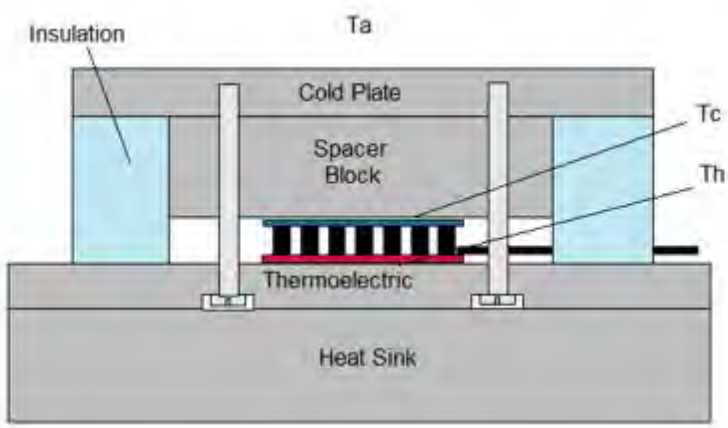


Figure 5.2: assembly drawing of the system in the software after putting the values.

5.2.4 Convection

When a fluid (in this case, air) flows over an object while the temperatures of the fluid and the object are different, heat transfer takes place. The amount of heat transfer may vary depending on the rate at which the fluid is flowing across the object. Convective heat loads on TECs are generally a result of natural (or free) convection. The convective loading on a system is a function of the exposed area, and the difference in temperature between this area and the surrounding air. Convective loading is usually most significant in systems operating in a gaseous environment with small active loads, or large temperature differences.

The fundamental equation which describes convective loading is:

$$Q_{conv} = h\,A\,(T_{air} - T_c)$$

Where

- Q_{conv} = convective heat load (watts)
- h = convective heat transfer coefficient (w/m^2C)
- (typical value 21.7 for a flat, horizontal plate in air at 1 atm)

- A = exposed surface area (m^2)
- T_{air} = temperature of surrounding air(C)
- T_c = temperature of cold surface (C)

For our system, $Q_{conv} = 21.7 * 0.27203 * (27+15)$ Watts

$= 247.928$ Watts

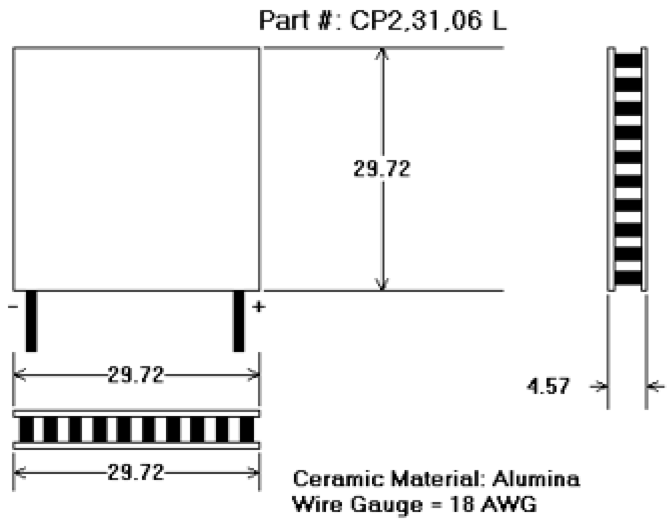


Figure 5.3: Dimensional drawing of the system in the software after putting the values.

5.2.5 Conduction

Another noteworthy thing is Conduction. Conductive heat transfer occurs when energy exchange takes place by direct impact of molecules from a high temperature region to a low temperature region.

Conductive heat loading on a system may occur through lead wires, mounting screws, etc., which form a thermal path from the device being cooled to the heat sink or ambient environment.

The fundamental equation which describes conductive loading is:

$Q_{cond} = \underline{k\ A/L}\ \Delta T$

Where

- Q_{cond} = conductive heat load (watts)
- k = thermal conductivity of the material (w/m C)
- A = cross-sectional area of the material (m^2)
- L = length of the heat path (m)
- ΔT = temperature difference across the heat path(C)

- k = 386 w/mC, from Table I
- $\Delta T = [27 - (-15)] = 42C$
- $[A = pi\ d^2 / 4 = 3.14159\ (25\ m^{-6})^2 / 4\ ]$

For us, $Q_{cond} = \frac{150*0.27203}{*40}$

After simulation we've got some graphs [10] according to our values.

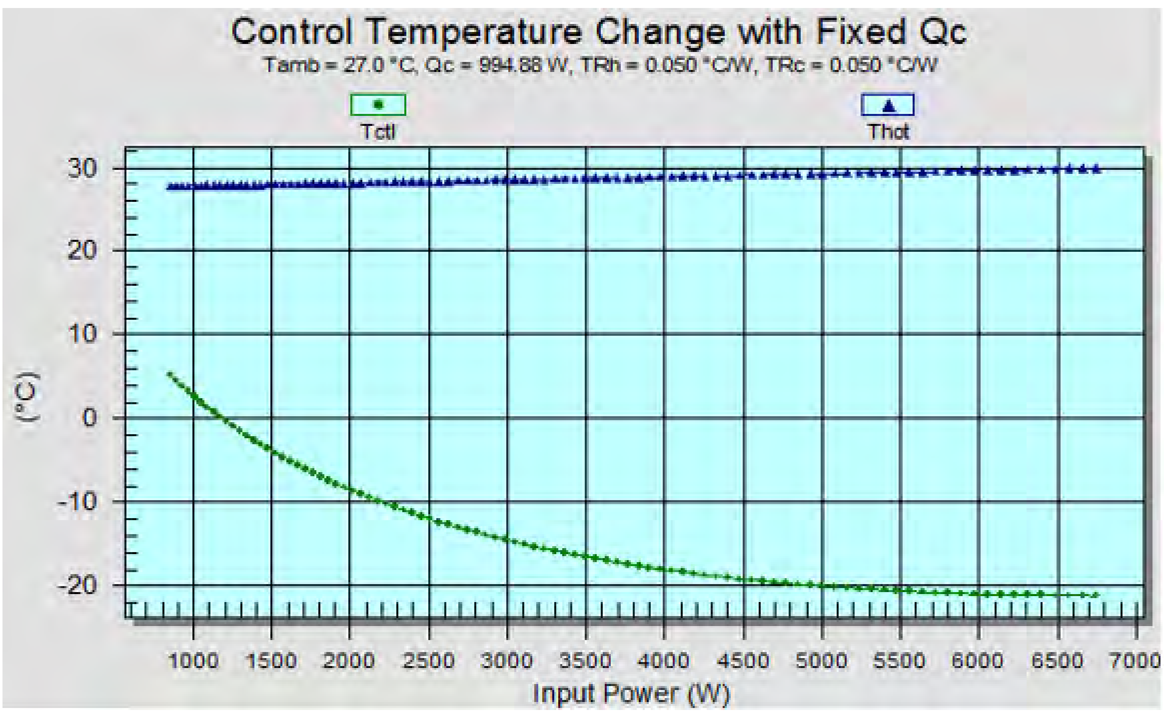


Figure 5.4: Control Power Vs Input Power

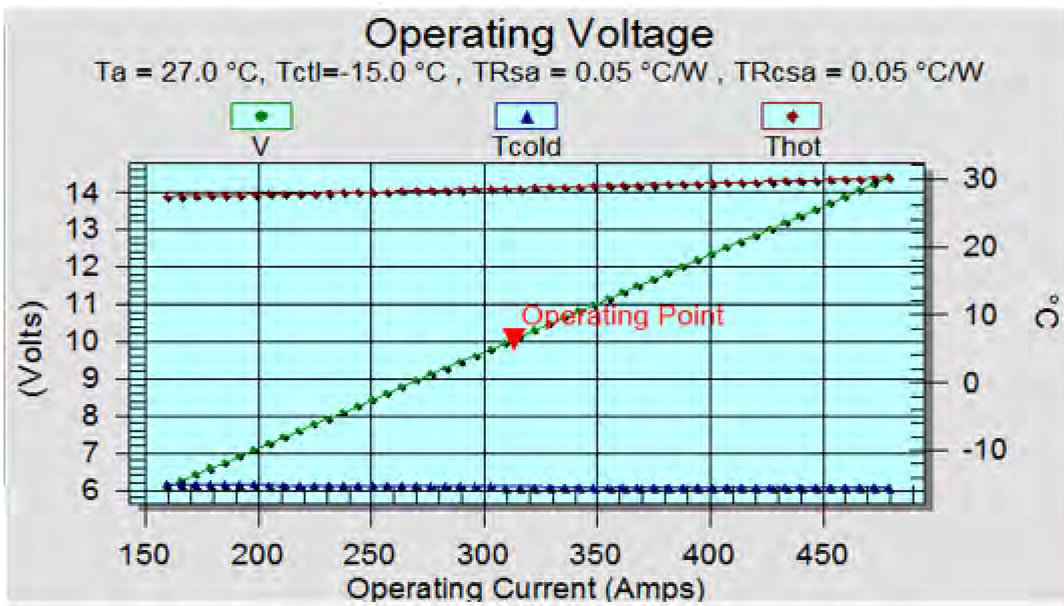


Figure 5.5: Operating Voltage Vs Operating Current

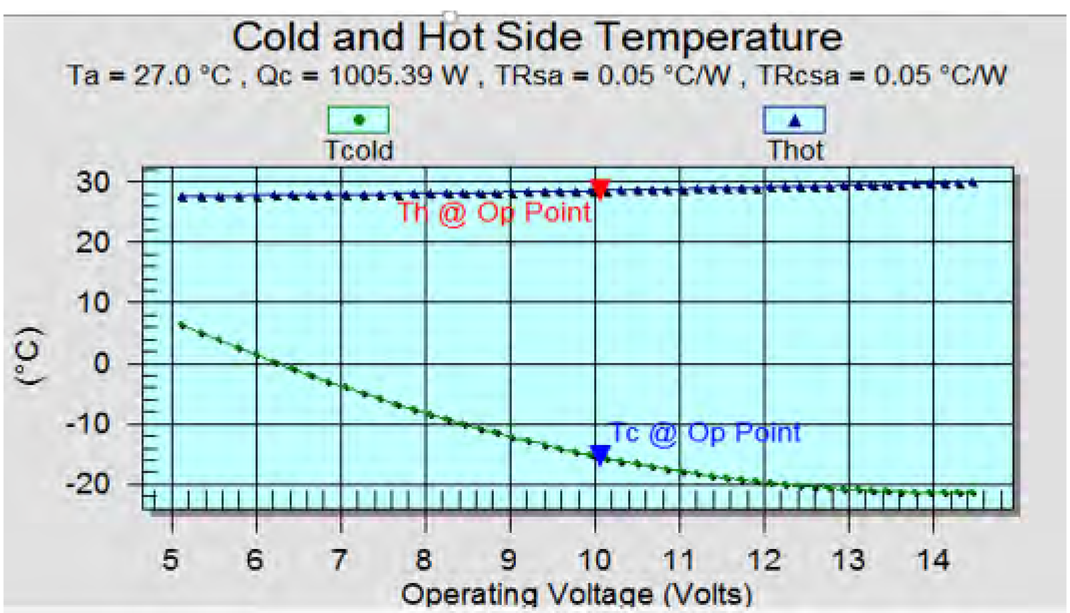


Figure 5.6: Control Temperature Vs Operating Voltage

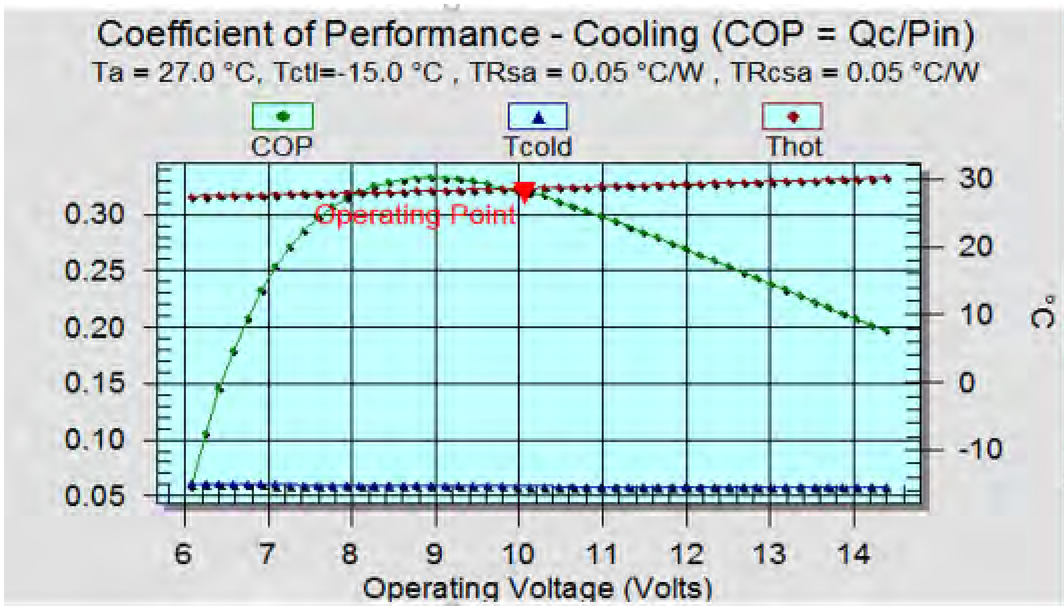


Figure 5.7: COP Vs Operating Voltage

5.3 Comsol Simulation

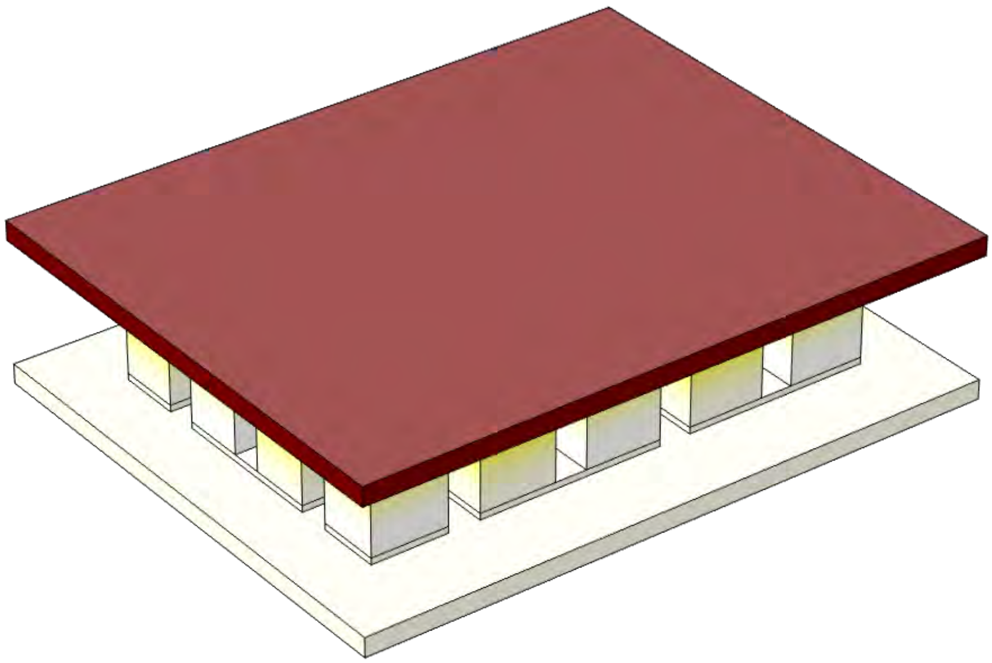


Figure 5.8: P & N Thermal Legs with Substrate

Author

COMSOL

Report date

Apr 17, 2017 12:02:24 AM

Summary

Thermoelectric coolers are widely used for electronics cooling in various application areas, ranging from consumer products to spacecraft design. Exploiting the Peltier effect, they consist of several thermoelectric legs sandwiched between two thermally conductive plates, one cold and one hot. Due the variety of applications, there can be many different thermoelectric cooler configurations. The Thermoelectric Cooler app covers the basic design of a single-stage thermoelectric cooler of different sizes with different thermocouple sizes and distributions. You

can use the app to help find the best thermoelectric cooler for a specific application. Manufacturers can also use it to optimize designs and provide application-related performance values. Additionally, the app serves as a starting point for more detailed calculations with additional input options and can be extended to multistage thermoelectric coolers.

This is done by varying the geometric parameters of the different components of the thermoelectric cooler, the material that makes up the thermoelectric legs, and some operating conditions.

5.3.1Software Information

Author	COMSOL
Date	Dec 15, 2015 7:39:18 PM

Global settings

COMSOL version	COMSOL 5.2 (Build: 184)

Study 1

Computes the optimal operating conditions for maximum cooling, that is, when the temperature difference between the ceramics plates reaches its maximum value. This study uses an optimization solver to find the applied current that gives the maximum temperature difference. The corresponding voltage and electrical resistance are also returned.

Study 2

In this study, the optimal electric current is the operating current in the thermoelectric cooler. Under such a condition, the study computes the limiting dissipative power at which the temperature difference between the ceramics plates is zero.

Study 3

Computes the temperature difference between the ceramics plates for different prescribed applied currents. The parametric sweep over the applied current goes from 0.1 IMAX to 1.1 IMAX. The results are used to produce the performance chart of temperature difference vs electric current.

Study 4

Computes the dissipative heat rate and electrical power for different prescribed applied currents at a temperature difference of 20 K, 40 K, and 60 K. This is performed by a double parametric sweep. The results are used to produce curves of coefficient of performance, ratio of dissipative heat rate and electrical power, at different values of temperature difference.

5.3.2 Input Data

Table 5.1: Parameters

Name	**Expression**	**Value**	**Description**
length	8[mm]	0.008 m	Total length
width	10[mm]	0.01 m	Total width
height	2.5[mm]	0.0025 m	Total height
d_conductor	100[um]	1E−4 m	Conductor thickness
d_ceramics	0.3[mm]	3E−4 m	Ceramics thickness
leg_length	1[mm]	0.001 m	Leg cross section in length
leg_width	1.2[mm]	0.0012 m	Leg cross section in width
leg_height	height - 2*(d_conductor + d_ceramics)	0.0017 m	Leg height
pitch	0.5[mm]	5E−4 m	Pitch
n_length	floor((length - 2*pitch - leg_length)/(leg_length + pitch)) + 1 - mod(floor((length - 2*pitch - leg_length)/(leg_length + pitch)) + 1, 2)	4	Number of legs in length
n_width	floor((width - 2*pitch - leg_width)/(leg_width + pitch)) + 1	5	Number of legs in width
network_length	(leg_length + pitch)*n_length - pitch	0.0055 m	Length of legs network
network_width	(leg_width + pitch)*n_width - pitch	0.008 m	Width of legs network
N	(floor((length - 2*pitch - leg_length)/(leg_length + pitch)) + 1 - mod(floor((length - 2*pitch	10	Number of thermocouples

Name	Expression	Value	Description
	- leg_length)/(leg_length + pitch)) + 1, 2))*((floor((width - 2*pitch - leg_width)/(leg_width + pitch)) + 1))/2		

Name	Expression	Value	Description
Tref	323.15[K]	323.15 K	Hot side temperature
dT0	50[K]	50 K	Prescribed temperature difference
I0	1	1	Prescribed relative electrical current

5.3.3 Materials

For p-type semiconductor materials, a Seebeck coefficient with negative sign is used. For n-type semiconductors, the Seebeck coefficient should be positive.

5.3.4 Link settings

Material	Bismuth Telluride - Bi2Te3, P-Type (mat1)

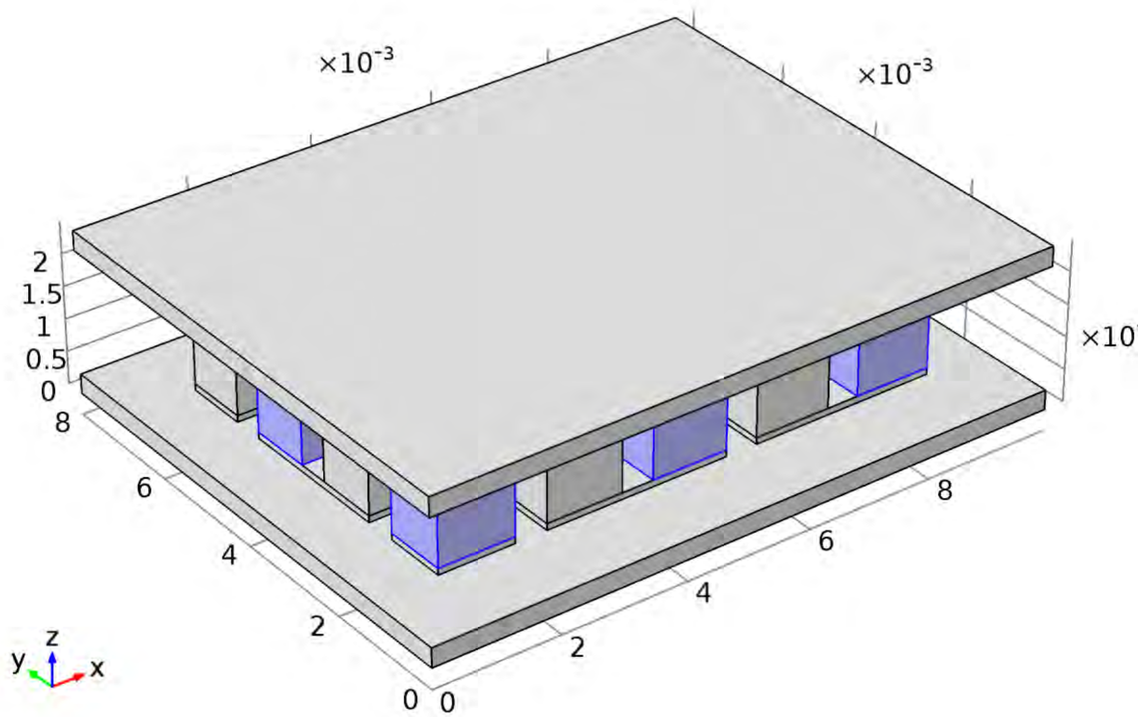


Fig 5.9: *P-Type Legs*

Link settings

Material	Bismuth Telluride - Bi2Te3, N-Type (mat3)

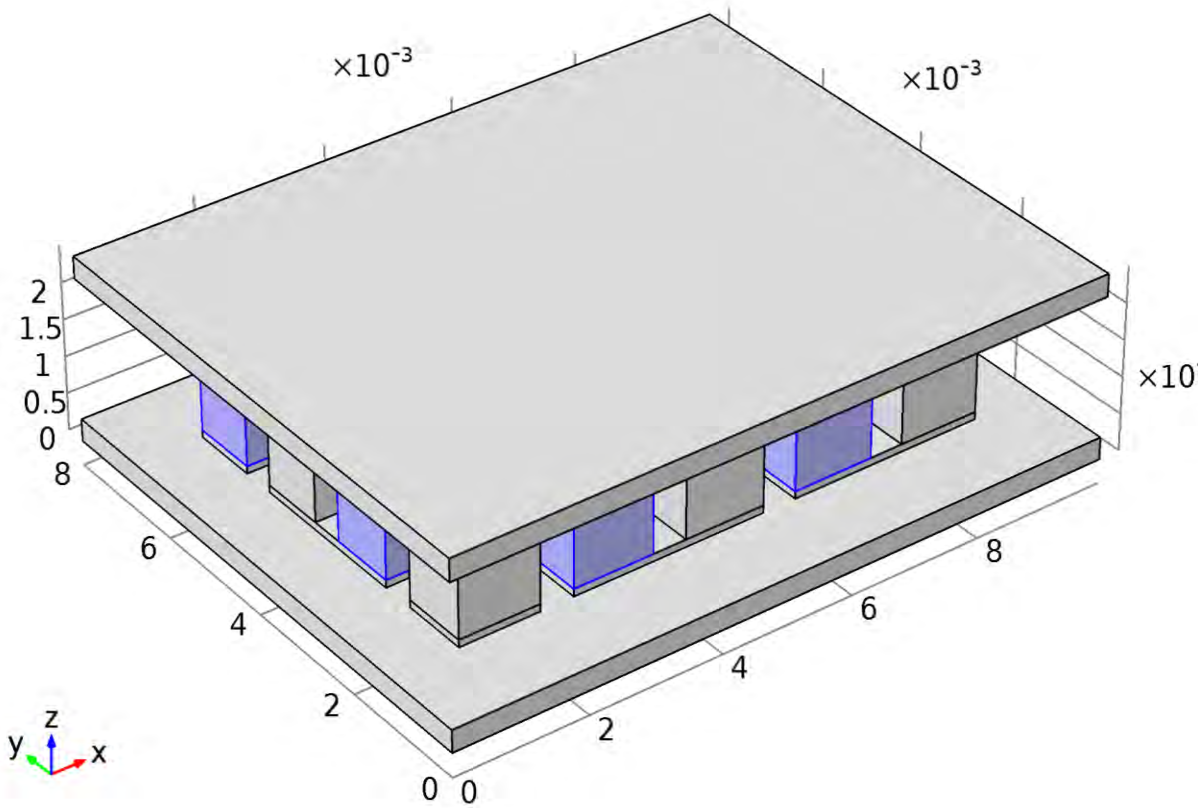


Fig 5.10: N-Type Legs

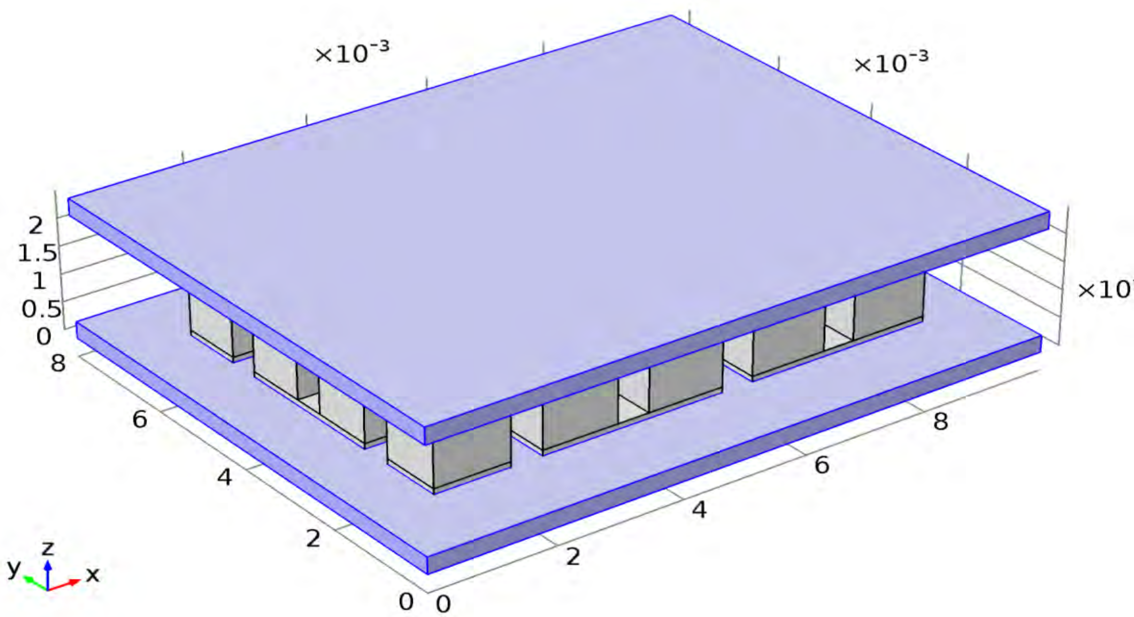


Fig 5.11: Tungsten

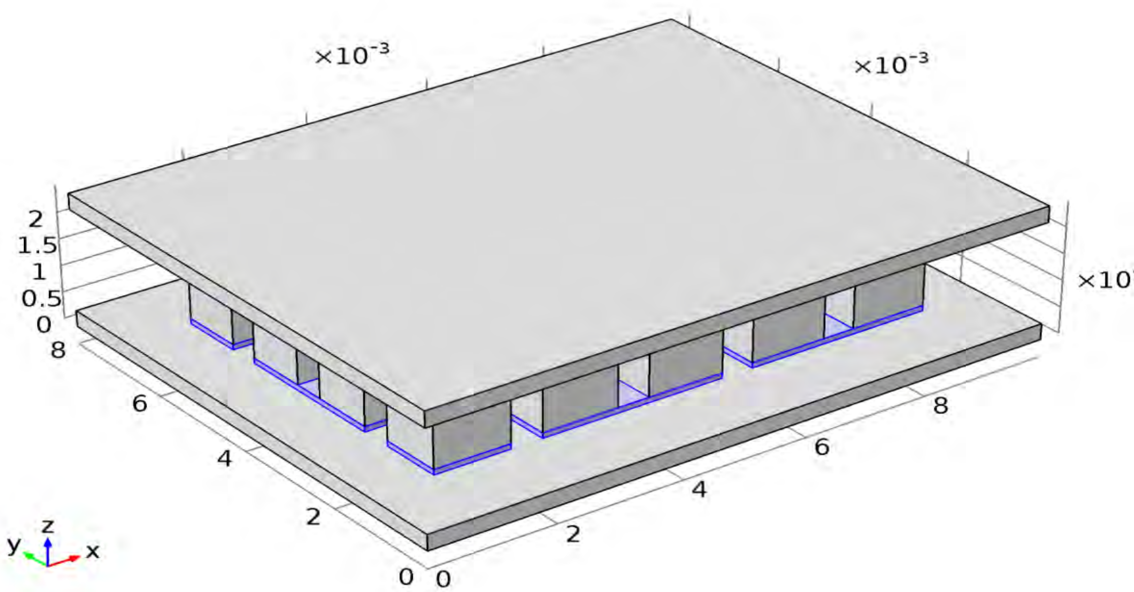


Fig 5.12: N & *P-Type Legs Copper Contact*

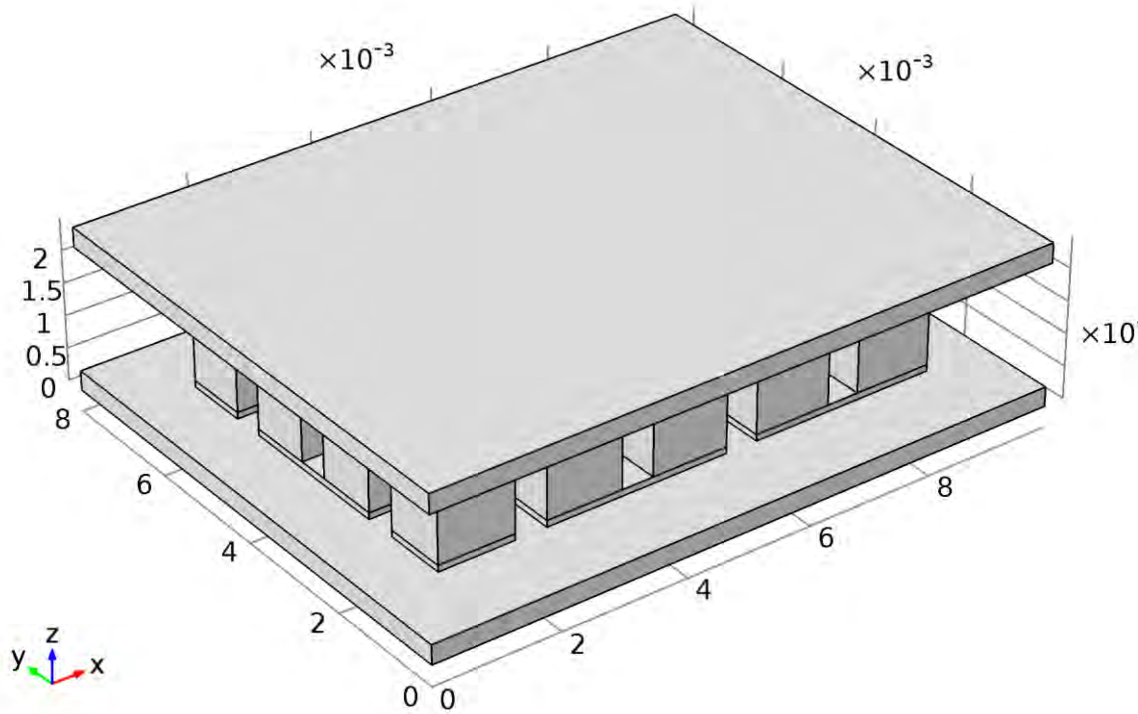


Fig 5.13: *Geometry 1*

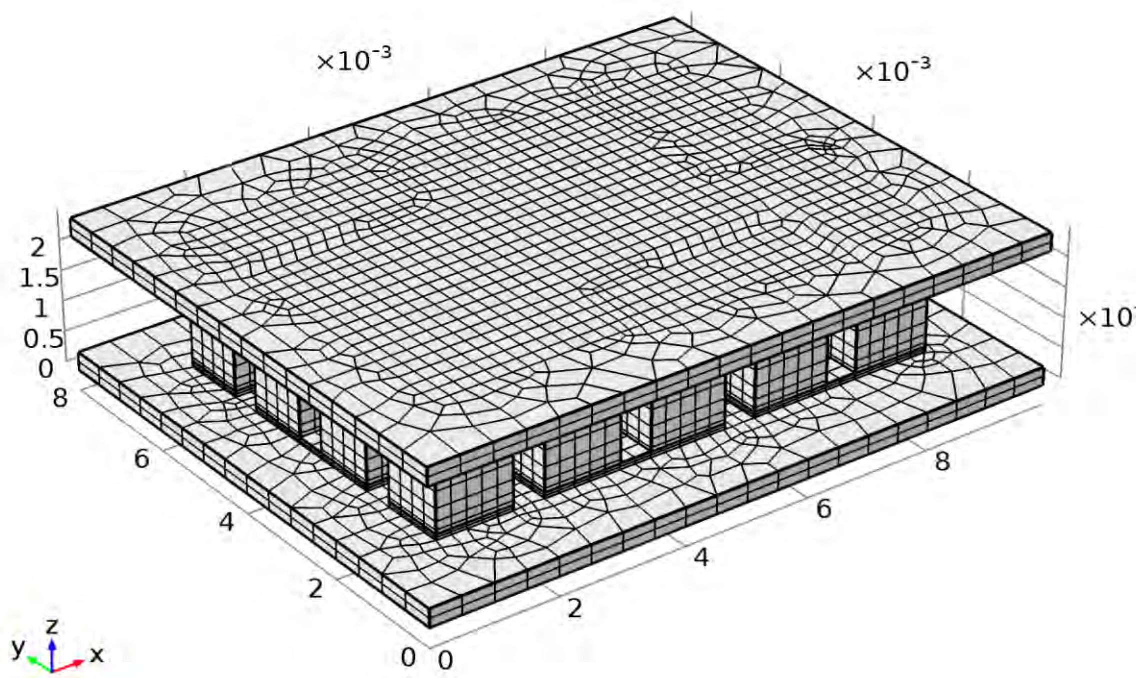


Fig 5.14: *Mesh 1*

5.3.4 Results

Table 5.2 -Parameters

Name	Expression	Value	Description
d_conductor	100[um]	1E−4 m	Conductor thickness
d_ceramics	0.3[mm]	3E−4 m	Ceramics thickness
leg_length	1[mm]	0.001 m	Leg cross section in length
leg_width	1.2[mm]	0.0012 m	Leg cross section in width
leg_height	height - 2*(d_conductor + d_ceramics)	0.0017 m	Leg height
pitch	0.5[mm]	5E−4 m	Pitch
n_length	floor((length - 2*pitch - leg_length)/(leg_length + pitch)) + 1 - mod(floor((length - 2*pitch - leg_length)/(leg_length + pitch)) + 1, 2)	4	Number of legs in length
n_width	floor((width - 2*pitch - leg_width)/(leg_width + pitch)) + 1	5	Number of legs in width
network_length	(leg_length + pitch)*n_length - pitch	0.0055 m	Length of legs network
network_width	(leg_width + pitch)*n_width - pitch	0.008 m	Width of legs network
N	(floor((length - 2*pitch - leg_length)/(leg_length + pitch)) + 1 - mod(floor((length - 2*pitch - leg_length)/(leg_length + pitch)) + 1, 2))*((floor((width - 2*pitch - leg_width)/(leg_width + pitch)) + 1))/2	10	Number of thermocouples

Table 1

Maximum temperature difference (K)
73.823

Table 2

Required current for maximum temperature difference (A)
3.1737

Table 3

Required voltage for maximum temperature difference (V)
1.4006

Table 4

Overall electrical resistance (Ω)
0.44131

Table 5

Maximum heat dissipation (W)
2.5982

Table 6

I0 (1)	dT0=20, Coefficient of performance (1)	dT0=40, Coefficient of performance (1)	dT0=60, Coefficient of performance (1)
0.10000	-0.73128	-5.8687	-8.8394
0.15000	1.1332	-2.2082	-4.3390
0.20000	1.5795	-0.77418	-2.3854
0.25000	1.6374	-0.11296	-1.3770
0.30000	1.5707	0.21666	-0.80292
0.30000	1.5707	0.21666	-0.80292
0.50000	1.1340	0.51425	-0.0031660
0.70000	0.80002	0.44528	0.13244
0.90000	0.56935	0.34020	0.13113

Table 7

dT0 (K)	Maximum: Maximum coefficient of performance (1)
20.000	1.6374
40.000	0.51425
60.000	0.13244

Table 8

Figure of merit (1/K)
0.0023767

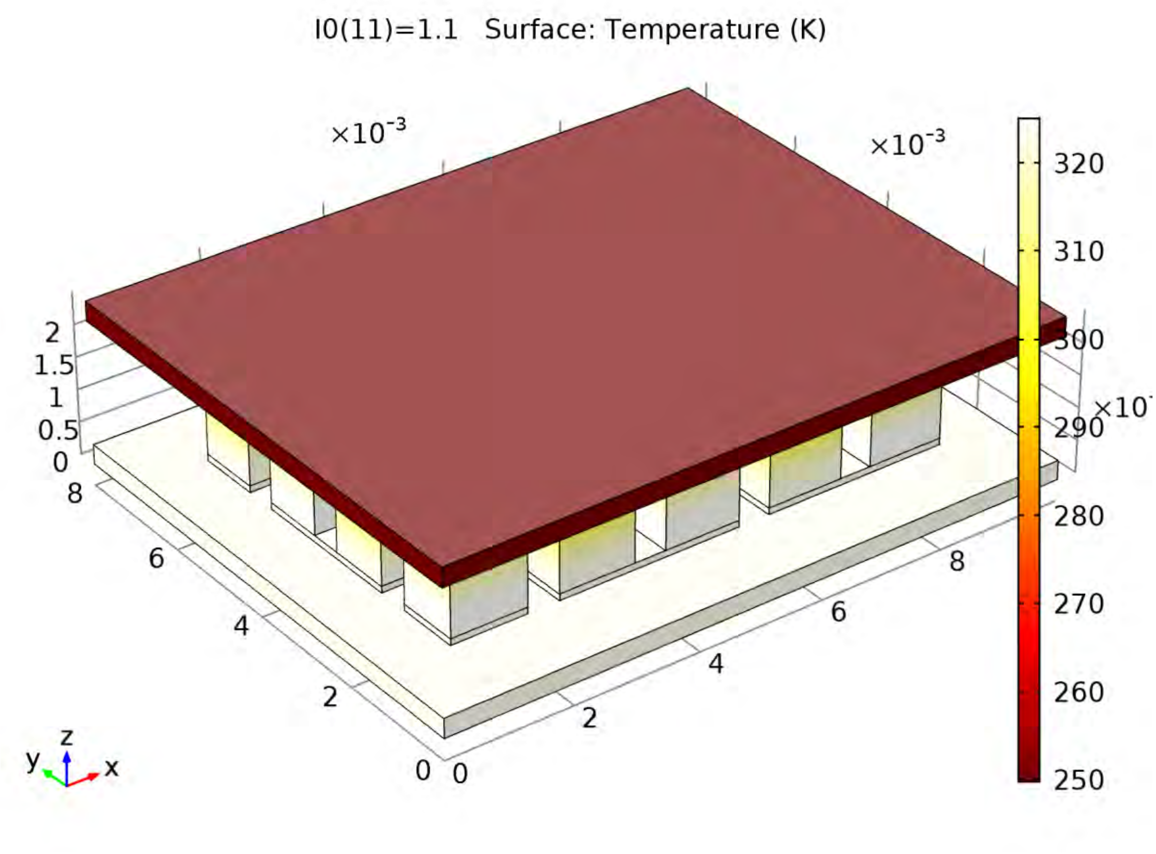


Fig 5.15: Surface: Temperature (K)

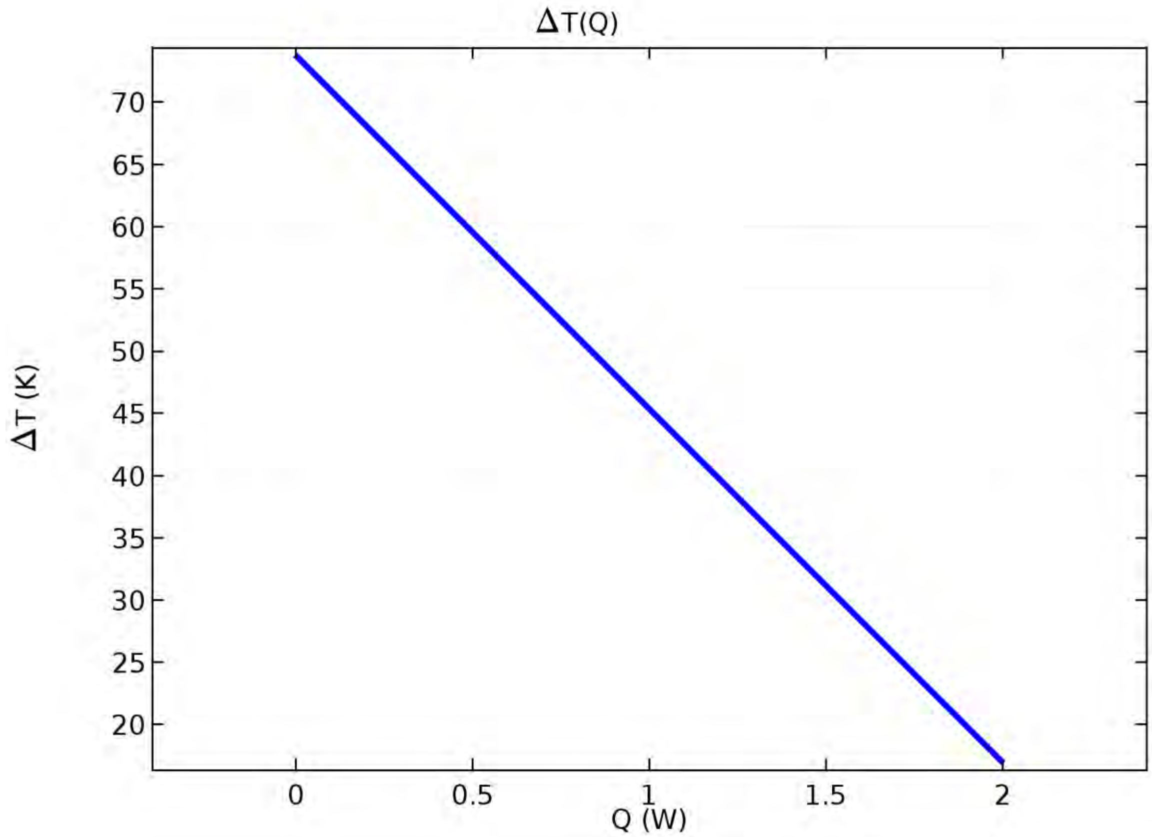


Fig 5.16: Δ T (K) Vs Q (W)

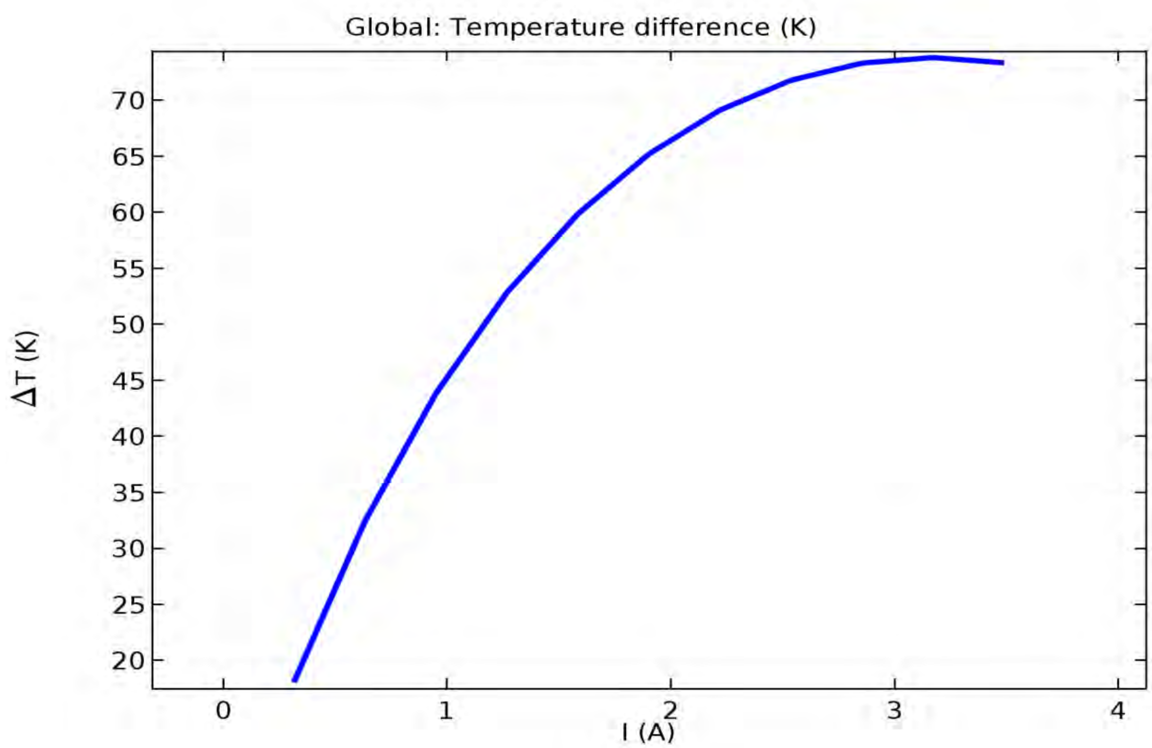


Fig 5.17: Δ T (K) Vs I (A)

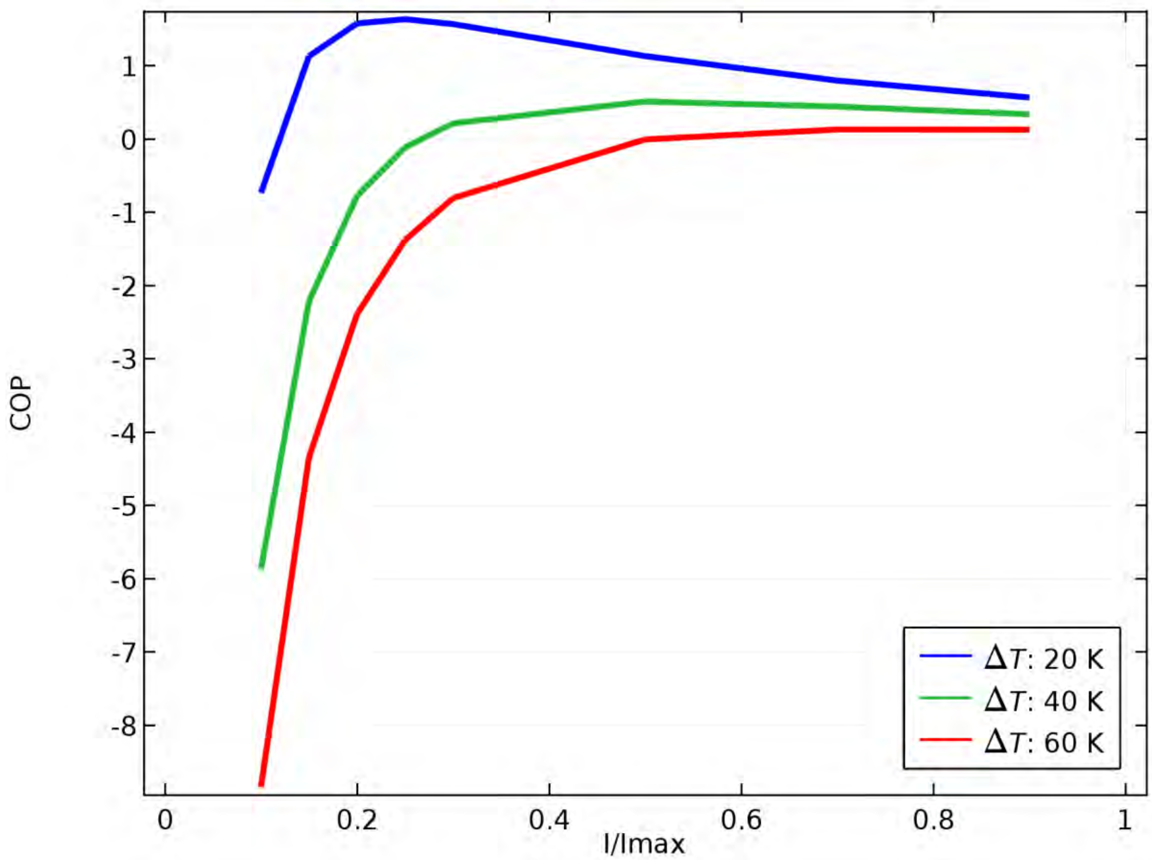


Fig 5.18: COP Vs I (A) / I max

Chapter 6

Energy and Feasibility Analysis

6.1 Energy Analysis

With the comparative increase of safe drinking water demand, now it has become a very big challenge for us to fulfill the demand. Specially the coastal are and the high hilly area where the amount of safe drinking water is very low and have to spend a lot of energy for collecting water, it very important to apply efficient way to solve the problem. Here total cost of physical energy is very high. We are trying to implement a system where cost of energy will be less compare to present scenario. As we know that the amount of energy used in the household area is increasing. So it will not be a very big problem for the community to use it. Due to the availability of high amount of humidity throughout the year, this type of system will be able to supply safe drinking water all the year round in a very cheap way.

6.2 Feasibility analysis

For feasibility analysis we have to consider some important factors.

1. First of all, we have to focus on the total weight of the system and the portability. As the device is so much light (less than 1 kilogram) and easy to carry or move it is too much comfortable for the people to use. It proves the feasibility of the device.
2. Another thing is that, we have to find how much humidity available on that particular area we want to use the device throughout the year. If the humidity of that particular area is below 35%, we can't be able to collect as much water as we want. Here is the graphs of humidity [11] throughout the year of some particular area of Bangladesh.

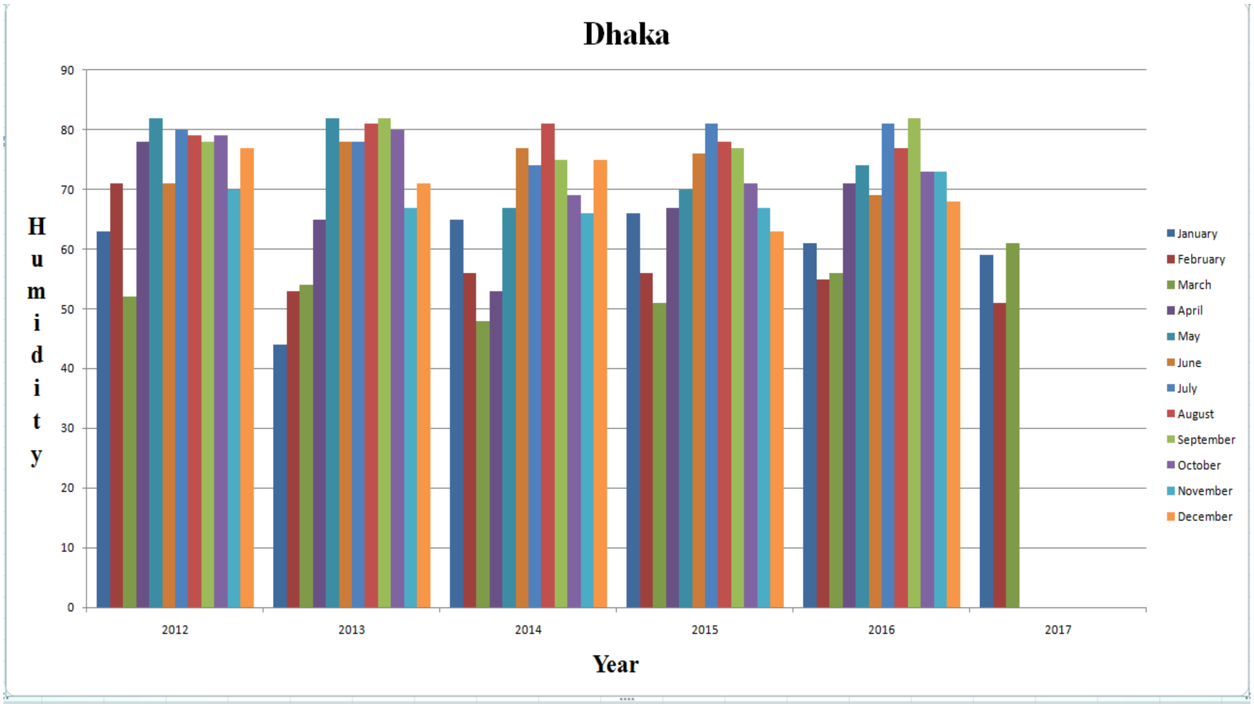


Fig 6.1: Humidity present in Dhaka city in the last 6 years

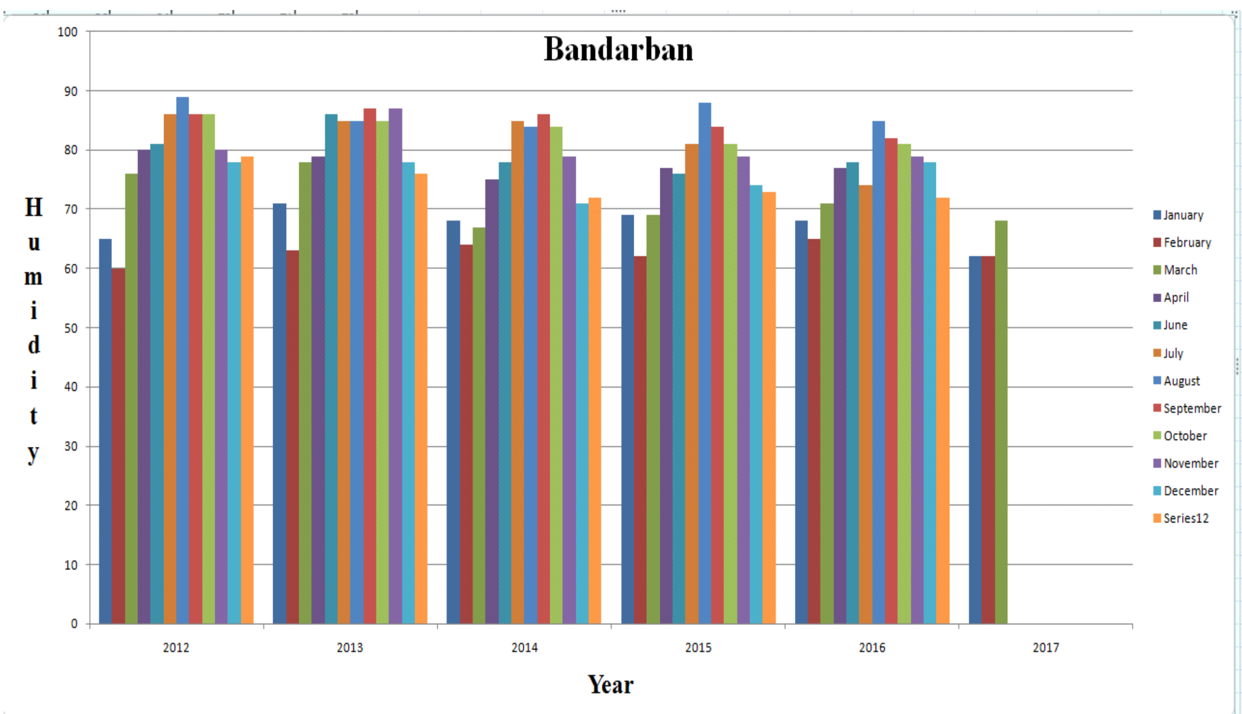


Fig 6.2: Humidity present in Bandarban in the last 6 years

Fig 6.3: Humidity present in Sylhet in the last 6 years

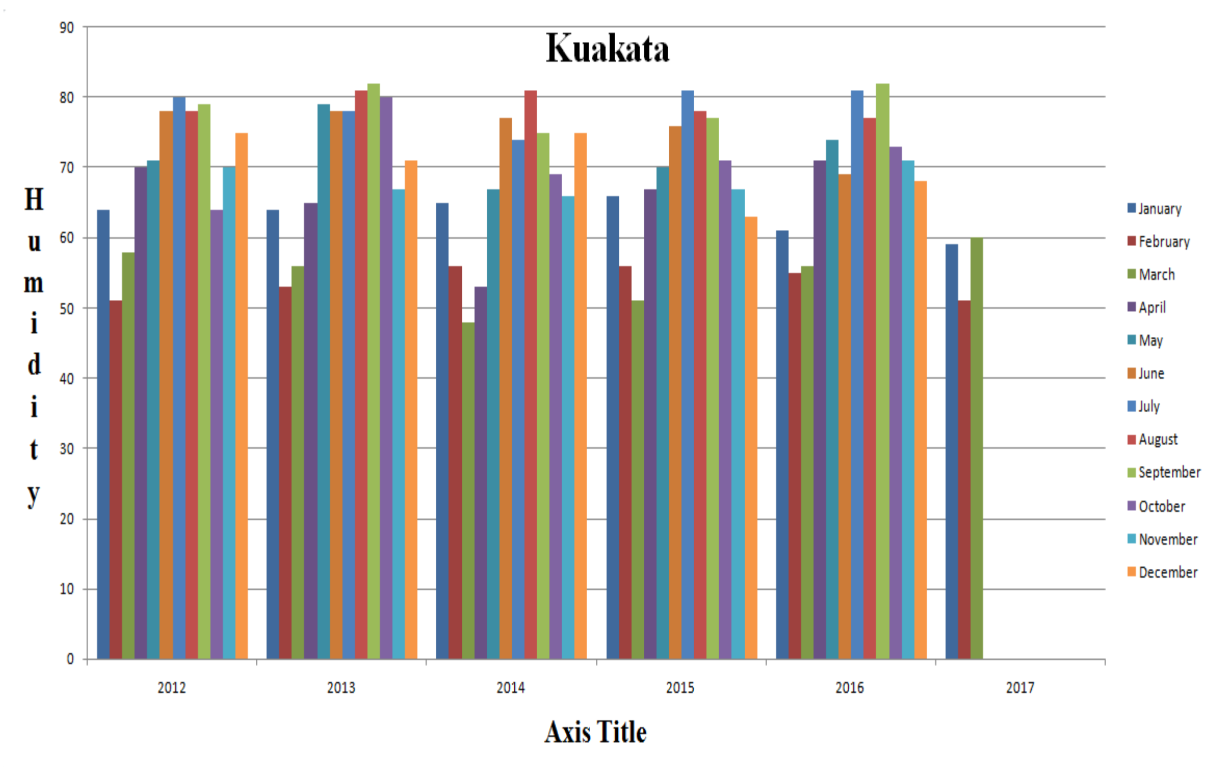


Fig 6.4: Humidity present in Kuakata in the last 6 years

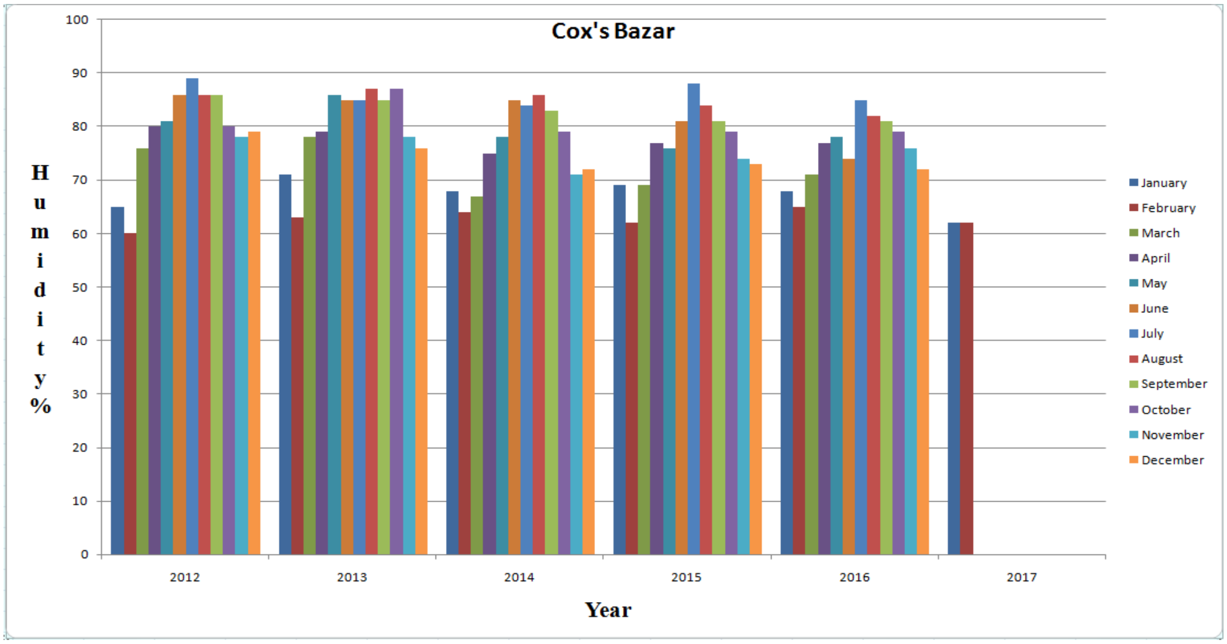


Fig 6.5: Humidity present in Cox's Bazar in the last 6 years.

These graphs show that there is plenty of humidity on the coastal and hilly area of Bangladesh through the year. So that we won't have to face any problem about humidity in availability and we can easily get output water through the year. That is why we can say that in terms of availability of the humidity the system is much more feasible.

3. One more thing is that how much energy is needed to establish the system. As we have said that the system is not that much complex. So one person can easily set up the whole system within 2.5 hours work. So it needs too little physical energy to implement which is feasible for the rural area.

4. Another thing is the cost of the device. If the whole system works too nice and the price becomes too high, the people can't afford to buy it. But as a matter of pleasure that we have built the whole system in a cost efficient way so that even our lowest income family can easily afford to buy it. So in the scenario of Bangladesh, we can easily say that it is much more feasible than any other water supplying system. There is a comparison between our system and other commercial devices in the following the table-

Table 6.1: Total cost analysis of the system

Equipment	Cost
Peltier (30 piece)	6,000/=
Solar panel	20,000/=
DC Fan (16 piece)	800/=
Digital System Equipment	1,000/=
Heatsink	5,000/=
Others	1,000/=
Total cost	41,000/=

Table 6.2: Comparison among existing devices.

Device	Manufacturer	Production (L/day)	Power (W)	Water Filtration Stages	Unit Cost
Ecoloblue 26[15]	Ecoloblue	26	1050	11	$1,199
Dolphin1[16]	Air2Water	22.8	500	5	$1,799
Atmos 28[17]	Atmos H2O	28	500	5	$1,545
Our Device	N/A	8	720	N/A	$512

We can see that the device we are expecting to build up costs much less than any other available devices in the world. Though there is a little higher power consumption rate and a little less output, the efficiency is much better.

6.3 Life cycle:

In the beginning of developing the system we had considered the life time of the system very carefully. The peltier which is available in our Bangladeshi market has an estimated life expectancy is about 200,000 hours. If we can use the best quality of product available in the market place, the total system will run at least 10 years without any trouble.

Chapter 7

Conclusion & Future Scope

7.1 Conclusion

A solar powered AWG system is built using a TE cooler, solar panels, heat exchange unit and a digital control unit. The system is self powered and can be used in coastal and hilly areas to produce water from the surrounding humid air. Applying the system in Dhaka we got 150 mL in nine hours. Our initial motivation was to make a device which can produce fresh drinking water form air. Before started practical analysis, we have calculated mathematically about the expected output which we can get from air. At that time the result was very much satisfactory. The model was subjected to tests at Dhaka and it was found that the water that we get from the gadget was not satisfactory. This system would be a long-term cost effective system since the energy source is free and the solar system generally requires less support. The improvement and generation of such gear is a future business plausibility.

7.2 Limitations and the Solutions

After tireless review and research we found that the following reasons might be in charge of the low water output of the gadget and the possible solutions are also mentioned-

7.2.1 Lack of Humidity Percentage

The tests were done in Dhaka which is a district with average humidity. Also, based on our calculation we have learned that when the humidity is above 50 % then the AWG performs better. So we expect that the water output from AWG may increment if the gadget is tried in coastal and hilly region where the amount of relative humidly is very high throughout the year.

7.2.2 Deficiency of Perfect Heat Sink

Heat sink is one of the main limitations in our device. The heat sinks which are available in our local market is not perfect for our system. We didn't find any perfect size in the market. For that reason we have used raw Thai aluminum channel in our system which was collected from chunghua aluminum industries. It doesn’t work properly. We need a heat sink which has spikes. Another thing is in this type of heat sinks sometimes pump heat to the cold side which decrease the output production of water. The spikes in the heat sinks sometimes stores some water in its internal space which absorbs heat and cause a negative effect on the production. . Since, the cold surface region of the Peltier gadget is (30mm*30mm). So we have utilized a little heat sink (7.5 *3.8*2 cm) in contact with the cooling surface of the Peltier gadget as a result of its high conductivity expecting that the cold surface zone will increment along these lines expanding the buildup region. At last in the final prototype model when we utilized the aluminum heat sink appropriate contact between the cold Peltier surface and the aluminum heat sink couldn't be accomplished. This perhaps the conceivable explanation behind low productivity.

7.2.3 Water collection System

In terms of water collection there are some limitations. We couldn't find any way to collect water without any loss. We wanted to use Fin Pin heat sink which can be attached at the cold side of peltier to collect water. But this material is not available in our in our local market. If we can use this Fin Pin heat sink then the water can be collected without any loss because the Fin Pin gives a way to gather the drops of water perfectly without any delay in the designated tank.

7.2.4 Lack of Wiping Mechanism

On running the gadget, at first the condensation began and water drops were formed on the icy surface of the Peltier gadget. But due to the gatherings of these water droplets the thermal conductivity of the area decreased as water is not a decent thermal conductor. Henceforth the condensation procedure backed off accordingly. In order to increase the output in the future, a wiping mechanism may be incorporated in the device so as to increase the condensation rate.

7.2.5 Inadequacy of Filtration System

In the first place, for an expanded implementation our system must have the skill of purifying water that’s been come from nature. UV water filter and Colloidal Silver Layer would help to disinfect the water; because of using these technologies no bacteria, viruses, parasites can exist in the water. Additionally, the mentioned procedures are very much usable in many developed and developing countries and so condensed water would surely meet to WHO standards. For huge scale usage, RO and UV water filtration system can be utilized for creating such water that meets the standard of WHO and BIS effortlessly.

7.2.6 Poor Quality of Peltier

One of the most important limitations is the peltier device itself. The peltier we have found in Bangladeshi market is not that much effective in producing water. While experimenting with the local available peltier device we have observed that these devises lose their ability frequently and doesn't work perfectly. Peltier gadget has many sorts of models which are much effective than TEC (12704). Those can be utilized for better performance and outputs in upcoming days. The surface materials used in this local peltier is ceramic. If we can change the surface materials, inner materials (usually used in making semiconductor legs), contact materials, we will be able to boost up the output supply. It will perfectly balance the ratio of hot side and cold side temperature and won't affect one another. High quality of peltier device is the main requirement of this type of system. So we need a best quality of device which can be found in foreign countries. For the better ourput we have design a peltier which has beed added in the simulation chapter.

7.2.7 Air circulation

We have faced some unexpected problem as well. We have noticed that the flow of air takes away some water with it and if we cannot be able to keep the output water away from the air circulation path it will reduce the output. So the total output becomes less. In a closed surface we have found this is severe but the open circumstance takes less water than closed system.

7.3 Future Scope

1) As the venture goes for delivering water from environment and keeping this gadget convenient, extensive measured scrubbers are not utilized for better air filtration. Scrubbers can expel oxides from the air. For substantial usage it can be taken care of.
2) The idea of this venture can likewise be utilized as a superior option in refrigeration science against traditional frameworks.

3) For now, we have used only two Peltier devices in the prototype. In the future the prototype may incorporate multiple number of Peltier to increase the water output.

Furthermore, we can use the heat produced in solar panels in a fruitful and utilizable way. From a typical solar panel operating in its maximum power point, only 10-15% incident sunlight is converted into electricity with much of the remainder being converted into heat [11].Thermal resistance and configuration of the materials used in solar cells specify heat transfer competence of the PV panels. We can apply this solar thermal energy in various ways. For example, the heat can be used in cooking which would reduce a little bit pressure on gas simultaneously operating the main apparatus (here I have just mentioned an application of the unused heat of the solar panel for not wasting an energy). As a consequence, we can make use of solar thermal energy along with running our machine.

In short, the final observation is the utilization of such low power semiconductor gadgets are indicating towards more noticeable advancement of cooling system that will adjust the entire situation and myths about the power utilization of refrigeration science. In near future we will have the capacity to utilize such gadgets that are currently constrained inside the project works. To sum up, I want to say like the proverb "There is light at the end of the tunnel"; so we will try to use our project for larger implementation and will not give up if we face ups and downs.

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