

ATMOSPHERIC WATER GENERATOR USING PELTIER DEVICE

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering Degree in Electronics and Communication Engineering

By

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

SCHOOL OF ELECTRICAL AND ELECTRONICS

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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BONAFIDE CERTIFICATE

This is to certify that this Final Year Project Report is the bonafide work of **Nandyala Padmaja (40130148)** and **Pooja A (40130176)** who have done the Final Year project entitled "**Atmospheric Water Generator Using Peltier Device**" under our supervision from November 2023 to April 2024.

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DECLARATION

We **Nandyala Padmaja (40130148)** and **Pooja A (40130176)** hereby declare that the Project Report entitled "**Atmospheric Water Generator Using Peltier Device**" done by us under the guidance of **Dr. I. Rexiline Sheeba, M.E., Ph.D.**, Department of Electronics and Communication Engineering, Sathyabama Institute of Science and Technology is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering Degree in Electronics and Communication Engineering.

Date: 17-04-2024

Place: Chennai

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ABSTRACT

Every human being needs water to survive. However, a significant problem that is growing quickly in contemporary India is water scarcity. Due to the extreme severity of the issue, individuals in several states now have to rely on alternative sources of water because groundwater has virtually completely dried up. Water scarcity affects half of the largest cities on the globe. There are currently about two billion people without access to safe drinking water. According to a 2019 study, the number of People who lack access to water climbed from 0.24 billion (or 14% of the world's population) in the 1900s to 3.8 billion (or 58% of the population) in the 2000s. This paper presents an Atmospheric Water Generator (AWG) that uses Peltier devices to create drinkable water by drawing moisture from the surrounding air. Because of their thermoelectric qualities, Peltier devices are used to manage the surface temperature differential that allows water vapor from the atmosphere to condense. After entering the system, ambient air comes into contact with the Peltier devices' cooled surface. Moisture condenses on the surface when the air cools, creating droplets that are gathered and then cleaned for ingestion. By using Peltier devices' thermoelectric effect to reduce power consumption, the system runs with little energy usage.

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LIST OF ABBREVIATIONS

AWS	Atmospheric Water Generator
RH	Relative Humidity
COP	Coefficient of Performance
TEC	Thermoelectric Cooler
AWH	Atmospheric Water Harvesting
FTDI	Future Technology Devices International Limited
EEPROM	Electrically Erasable Programmable Read-Only Memory
PWM	Pulse Width Modulation
USB	Universal Serial Bus
LED	Light Emitting Diode
DHT	Digital Temperature and Humidity
LCD	Liquid Crystal Diode
PSU	Power Supply Unit
OLED	Organic Power Supply Unit
IDE	Integrated Development Environment
CAD	Circuit Aided Design
FMEA	Failure modes Effects Analysis
LCA	Life Cycle Assessment

CHAPTER 1

INTRODUCTION

1.1 AWG System

One promising solution to address water scarcity is the utilization of Atmospheric Water Generation (AWG) systems, which harness the moisture present in the atmosphere to produce clean and potable water. AWG technology represents a sustainable alternative to conventional water sources, offering the potential to supplement existing water supplies in a cost-effective and environmentally friendly manner.

Central to the operation of AWG systems is the integration of Peltier devices, also known as thermoelectric coolers, which play a pivotal role in the condensation process. These semiconductor devices leverage the Peltier effect to create temperature differentials, enabling the cooling of air to its dew point temperature and subsequent condensation of water vapor. This aims to provide an overview of AWG technology with a specific focus on the integration of Peltier devices. It will explore the underlying principles of AWG systems, the functionality of Peltier devices, and the synergistic relationship between the two in generating water from the atmosphere. Additionally, the introduction will discuss the significance of AWG technology in addressing water scarcity challenges and outline the structure and scope of the subsequent sections of this report.

By examining the intersection of AWG technology and Peltier devices, this report seeks to elucidate the potential of this innovative approach to contribute to sustainable water management practices globally. Through a comprehensive analysis of the principles, applications, and challenges associated with AWG systems utilizing Peltier technology, this report aims to inform policymakers, researchers, and stakeholders about the role of these technologies in mitigating water scarcity and fostering resilience in water supply systems.

1.2 Project Definition

Looking into one of the most prominent concern in the developing and under-developed world, water crisis is one of the main problems that still persists since it is one of the most essential, basic and important requirements for a healthy body and the availability of clean water is really scare in these areas. In order to rectify and diminish these persistent problems related to water availability, especially in the coastal regions, where the sea is accessible but no means of cleaning that water for a good use. In this regard, our team will be working on in developing a water generator which will condense the suspended water molecules (humidity) from the atmosphere into liquid phase water. But, in order for this project to catch up, it must be applicable in the regions like the Eastern Province in the coastal cities where the humidity conditions can rise up to as much as 60% in the atmosphere during peak times. This water generated could be then used in various applications.

1.3 Problem Statement:

Water scarcity is a critical challenge facing numerous regions worldwide, adversely affecting agriculture, sanitation, and public health. Conventional methods of water extraction are often inadequate, particularly in arid and semi-arid regions where rainfall is sporadic. The reliance on finite freshwater sources exacerbates the vulnerability of communities to droughts and climate change.

The Atmospheric Water Generator using a Peltier device seeks to address this problem by harnessing the latent moisture present in the atmosphere, offering a sustainable and renewable source of clean water. By overcoming the limitations of conventional water sources and purification methods, this technology has the potential to mitigate the adverse impacts of water scarcity and enhance resilience in water-stressed regions.

1.4 Objectives

This project is based on the following objectives

- To design and develop an Atmospheric Water Generator utilizing thermoelectric cooling principles with Peltier devices.
- To optimize the efficiency of water condensation from atmospheric moisture through precise control of temperature and humidity conditions.
- To integrate the AWG system with Arduino-based control mechanisms for automated operation and monitoring.
- To evaluate the performance and reliability of the AWG prototype under varying environmental conditions, including humidity levels and ambient temperatures.
- To assess the feasibility of deploying AWG technology in real-world settings, particularly in regions prone to water scarcity and limited access to traditional water sources.

1.5 Specifications

Since the project will mostly be composed and built of standard components available from the market, there still are some fabrications need to perform in order to make our prototype look professional and presentable. Additionally, the components used in our system and their dimensions are

Table 1.1: System Specifications

Component	Dimensions
Peltier Device	4 x 4 cm (288 W & 6 A)
Fan	12 cm x 12 cm
Base	50 cm x 40 cm

1.6 Applications

In terms of sustainability, many projects are looked in its application in the real world which would test the dependability and durability of a concerned system. Similarly, our project serves to be remarkable in these aspects because water is a necessity of life and availability of clean water can be consumed in a lot of different aspects:

- The air water generator can be used to generate clean drinking water by attaching a filtration unit to it.
- The air water generator can be used at an industrial scale also, such as in Jubail Industrial City, it can be used at a larger scale to generate enough amount of water to meet the needs of the workers for drinking and domestic usage.
- These water generators can also be placed in sectors such as Industrial, Residential and Commercial where water can be used to good use.

CHAPTER 2

LITERATURE SURVEY

2.1 Inference from Literature Survey

M.K. Varun and R. Jayabarathi et al. [2021], suggest that the purpose of the study is to understand the effects of ambient air temperature, relative humidity, and air flow velocity on the amount of water generated. The change in available area has a positive effect on water generation but inhibits the further condensation due to crystallization effect. The study also investigates the practical feasibility of an atmospheric water generator (AWG) with two thermoelectric coolers, or Peltier devices. The experimental setup is designed to be a portable device that uses minimal energy and makes use of two thermoelectric devices along with air flow regulation.

M.T. Imran, A.N. Barshan, S.M. Shams et al. [2022], examined the design of a renewable energy-powered atmospheric water generation system in their study. The system comprises two heat sinks, a DC fan, and a Peltier module, constituting the atmospheric water generator (AWG). Powering the AWG is a DC lead-acid battery, which is charged by a solar panel; a charge controller ensures a steady water supply from the atmospheric water generator. Additionally, the study illuminates a digital voltmeter-ampere display showcasing load voltage and current, alongside piezoelectric components positioned beneath tiles. The study comprehensively describes the entire process of generating power using solar PV panels and piezoelectric devices.

L. Manoliu, R. Henneberger, A. Tessmann, J. Seidel, M. Eppard and I. Kallfass [2020], presented this paper analyses experimental data of the atmospheric propagation effects affecting millimeter wave communication links using wideband complex modulation formats with up to 3.3 GBd symbol rate. The main focus is on attenuation caused by atmospheric gases and water droplets and the influence of the air temperature and humidity on an E-band link (71–76 GHz), operated over 1.6 km distance for a period of more than 2 months. Statistics of the expected losses, according to the pertaining International Telecommunication

Union models and some experimental results, as in the case of rain and snow attenuation, obtained in Stuttgart, Germany, are discussed and provide further insights in link stability and availability. 3.3 GBd are correctly transmitted regardless of the weather conditions. The presented link can also serve as calibration system for further atmospheric effects studies.

K. Pontious, B. Weidner, N. Guerin, A. Dates, O. Pierrakos, and K. Altaii et al. [2016], focused on a system designed to convert water vapor into liquid water, primarily targeted for use in irrigating and farming areas facing water scarcity. Specifically, our team developed two AWG concepts: one employing Peltier devices and the other utilizing a heat exchanger, thereby allowing for the exploration of alternative design approaches. The Peltier-based concept operates by cooling and condensing the surrounding air through the use of electricity to establish a temperature gradient. In contrast, the heat exchanger concept operates by cycling a coolant cooled by a lower ground temperature.

N. Sugiarta, I. M. Sugina, M. A. A. Pradnyana, I. D. G. A. T. Putra, I. K. Rusmariadi, and I. G. Santosa, et al. [2021], examined the experimental performance of a Peltier cooler box utilizing a water block heatsink. The paper presents the construction and testing of a prototype of the cooler box. The experiment employs a TEC-12706 thermoelectric module to achieve cooling effects. Water serves as the coolant, circulating through the mini channels of the copper heatsink block at a constant volume flow rate of 2.5 L/min. Additionally, a fin-type heatsink is affixed to the cold side of the Peltier module. The cooler box is powered by a constant DC voltage of 12 V sourced from the power supply unit.

L. M. Nhut and D. T. T. Linh, et al. [2020], examined the effects of relative humidity (RH) on the performance of a thermoelectric freshwater generator powered by solar energy. The study aimed to evaluate the system's performance under real weather conditions in Southern Vietnam. The system primarily comprises four thermoelectric coolers, four axial fans, four hot side heat sinks with cooling fans, four cold side heat sinks, two solar panels, a charge controller, and a condensate water box. Experimental results revealed that variations in RH, electric

current, and air mass flow rate significantly impacted the amount of collected water by the system. The maximum water collection, reaching 215 ml, was achieved at an RH of 80%, with a coefficient of performance (COP) value of 0.73.

A. K. Dubey, V. Gupta, and R. Dev, et al. [2023], examined the critical issue of providing clean drinking water to rural areas through non-conventional energy sources. This is aimed to develop a sustainable solution to meet the water needs of rural communities by emphasizing the utilization of renewable energy technologies. By harnessing resources such as solar, wind, or biomass, the proposed system sought to ensure reliable access to potable water in remote and underserved regions. This study highlighted the importance of integrating renewable energy systems into water infrastructure to promote environmental sustainability and improve living standards in rural communities.

A.E. Kabeela and M. Abdhulazizb et al. [2014], focused on the Atmospheric Water Generator is a device that exploits the principle of latent heat to transform molecules of water vapour into droplets. The thermoelectric device utilized in this research to analyze thermodynamics is a Peltier device. Although it is not extremely prevalent in India and some other nations, it has been introduced a bit in the past. Given the current state of technology, where are the all relying more and more on renewable resources, it has a lot of wonderful applications. Here, the objective is to use a thermoelectric Peltier (TEC) coupling to practically or experimentally reach that particular temperature, known as the dew point temperature, in order to condense water from atmospheric humid air.

A. W. Jeevadason and S. Padmini et al. [2022], investigated methods to enhance the freshwater productivity of a Twin Wedge Solar Still. The main focus is based on temperature control achieved through the use of thermoelectric sensors and modules. The study aims to improve the efficiency of freshwater production in solar stills, which are vital for providing clean drinking water in areas with limited access to conventional water sources. By integrating thermoelectric technology, the researchers explore innovative approaches to optimize temperature regulation within the solar stills. This research contributes valuable insights into enhancing

the performance of solar-powered desalination systems, which could have significant implications for addressing water scarcity challenges worldwide.

T. Kadhim, A. K. Abbas, and H. J. Kadhim et al. [2020], conducted an experimental investigation into atmospheric water collection powered by solar energy utilizing the Peltier effect. This explores the feasibility of utilizing solar energy to drive atmospheric water generation systems based on the Peltier effect. This study contributes to the literature by providing empirical data on the performance and viability of such systems, which could offer sustainable solutions for addressing water scarcity challenges. The findings of this research shed light on the potential of solar-powered atmospheric water generation technologies, highlighting their importance in mitigating water shortages in various regions.

S.V.P, A. E.A, A. P, A. Vas, C, B. Ibnu Masood and et al. [2020], presented a study on a Portable Atmospheric Water Generator. The research focused on developing a portable device capable of generating water from the atmosphere. This study contributes to the literature by introducing a potentially innovative solution to address water scarcity issues, particularly in areas where access to clean water is limited. By providing insights into the design and functionality of a portable atmospheric water generator, the research offers valuable information for the development of sustainable water supply systems. The findings of this study could have significant implications for humanitarian efforts, disaster relief operations, and remote or off-grid communities in need of reliable access to potable water.

Congedo, Baglivo, and Negro et al. [2021], proposed a new device hypothesis for extracting water from air, alongside a basic air conditioning system tailored for developing countries. This innovative approach aims to address water scarcity and inadequate cooling infrastructure in regions with limited resources. By introducing a novel device concept and affordable cooling solution, the researchers offer promising avenues for improving living conditions and sustainability in developing areas.

Niewenhuis, Shepperly, Beek, and Van Kooten et al. [2012], discussed the Atmospheric Water Generator (AWG) technology, focusing on water extraction from air. The study likely provides insights into the principles and applications of AWG systems, highlighting their potential to generate water from atmospheric moisture. By examining the feasibility and effectiveness of this technology, the researchers contribute to the literature on innovative solutions for addressing water scarcity challenges. It likely provides valuable insights into the capabilities and limitations of AWG systems, offering a better understanding of their potential in providing sustainable water sources.

C. Vidal, E. Riquelme and H. Chávez et al. [2023], presented in response to the water scarcity in rural and isolated areas with difficult access to water resources, this study presents a mathematical model for a water production system that utilizes a solar-wind hybrid generation source. The system is based on Cooling-based Atmospheric Water Generator, capable of producing up to 5,000 liters of water daily from the air, with its own purification and storage system. The main objective is to develop an optimization model that minimizes the levelized cost of water and obtains the optimal sizing of the hybrid generation plant and the storage system. This model is implemented in the software AIMMS to determine the optimal condition and analyse the behaviour of the variables. The results of the optimization model simulation are compared with a previously proposed power supply design, validating the utility of the model.

D. Abdo, H. Mitsunharmadi, F. A. Khatib and M. A. Alnaqbi et al. [2022], presented by the escalating numbers of extreme weather events, the current climate crisis has already inflicted negative impacts on life. With desertification on the rise due to dwindling freshwater resources, 4.7 billion people face a shortage of clean water. In response, researchers are exploring solutions like Atmospheric Water Harvesting (AWH). This paper evaluates an AWH model powered by solar energy, showcasing its lightweight, compact design ideal for remote areas. By ingeniously designing the evaporator unit without costly materials, the system demonstrates promising potential, autonomously generating clean water for human and agricultural use in deserted regions.

H. Fifiana, T. H. Ariwibowo, A. G. Safitra, A. I. Gunawan, L. Diana and M. A. Fitrony [2019], presented venturi is one of industrial water treatment systems' most commonly used microbubble generator devices. This research focuses on the effect of porous Aluminum on the performance of the microbubble generator. Simulations were carried out using a 2-dimensional model, at various water velocities, air velocities, and porosity values. Various air and water velocities were tested. In this study, the venturi was tested with several variations of aluminium porosity, namely 10, 20, and 40 PPI. Pressure drop in porous material flow is calculated using the Forchheimer equation. The parameters that were used to determine the performance of the microbubble generator were hydraulic power and bubble generating efficiency. The results show that the microbubble generator's performance, such as the bubble generating efficiency, increases with increasing porosity, air, and water velocity. Furthermore, hydraulic power decreases if there is a decrease in air velocity, water velocity, and porosity, The flow structure shows that there are many wave patterns at the water-air interface as the water velocity and air velocity increase.

CHAPTER 3

EXISTING SYSTEM

3.1 Aim and Scope of Present Investigation

The existing system proposed for atmospheric water generation relies on the utilization of a thermoelectric Peltier device, alongside other essential components such as a power supply unit and an Arduino microcontroller for control and monitoring purposes. The system is designed to harness the latent heat present in atmospheric moisture, effectively converting it into usable water through condensation.

At its core, the system comprises cooling elements, a heat exchange unit, and an air circulation mechanism. The process begins by circulating air containing moisture through the system. The thermoelectric Peltier device, when powered, creates a temperature differential across its surface. This temperature difference facilitates the cooling of the air passing through the system, causing the moisture within it to condense into water droplets.

The heat exchange unit aids in dissipating the heat generated by the Peltier device, ensuring efficient operation. Meanwhile, the air circulation unit ensures the continuous flow of air through the system, maximizing the water condensation process.

The collected condensed water is then accumulated for various applications, including drinking, irrigation, and other domestic or agricultural uses. This system offers a sustainable solution to address water scarcity issues in regions with low rainfall or high humidity, providing a renewable source of clean water without relying on traditional water sources. Through the integration of modern technologies like Peltier devices and microcontrollers, the system can be optimized for efficiency and reliability, paving the way for widespread adoption in water-stressed regions worldwide.

3.2 Open Problems in Existing System

- **Lack of Portability:** The vapor compression refrigeration system is not portable, which limits its usability in remote or off-grid areas where access to clean water is scarce.
- **Noise Generation:** The system produces a significant amount of sound, which could be disruptive and undesirable in certain environments, such as residential or quiet areas.
- **Higher Cost:** Compared to alternative water generation systems like the Peltier system, the vapor compression refrigeration system tends to be more expensive. This higher cost could pose a barrier to adoption, particularly in resource-constrained regions.
- **Efficiency Concerns:** Although the vapor compression refrigeration system may be more effective in terms of water generation compared to the Peltier system, its efficiency may still be a concern. The project may need to address efficiency issues to ensure optimal performance and resource utilization.
- **Energy Consumption:** Peltier devices consume significant amounts of electrical energy to operate, leading to high power consumption. This can be particularly problematic in regions where access to electricity is limited or unreliable, making the system less viable in off-grid or remote areas.
- **Environmental Impact:** The production and disposal of Peltier devices can have negative environmental consequences due to the extraction and processing of materials, as well as electronic waste generation. Additionally, the energy-intensive operation of these devices may contribute to greenhouse gas emissions if derived from non-renewable sources.
- **Maintenance Requirements:** Peltier devices are susceptible to wear and tear over time, necessitating regular maintenance and potentially costly repairs. Dust accumulation, corrosion, and electrical failures can all degrade the performance of the atmospheric water generation system, requiring ongoing monitoring and upkeep to ensure reliability and longevity.

3.3 Scope of the Investigation

The aim of an atmospheric water generator utilizing a Peltier device can be comprehensive and multifaceted, encompassing both scientific and practical aspects. The primary objective of the investigation is to assess the feasibility, efficiency, and practicality of utilizing Peltier devices in atmospheric water generators for sustainable water production. Evaluate the efficiency of Peltier devices in extracting water from the atmosphere under various environmental conditions (temperature, humidity, etc.). Investigate the optimal configuration and arrangement of Peltier modules for maximum water generation efficiency.

Assess the impact of ambient conditions such as temperature fluctuations and humidity levels on the performance of Peltier-based systems. Study methods to enhance the performance of Peltier devices through thermal management techniques, insulation, and heat exchange mechanisms. Explore strategies to improve energy efficiency and reduce power consumption of Peltier-based systems.

Consider the lifecycle analysis of Peltier devices and their environmental implications compared to conventional water extraction methods. Explore opportunities for technological advancements in Peltier-based systems, including integration with renewable energy sources, automation, and smart control systems. Investigate potential applications of emerging materials and manufacturing techniques to enhance the performance and reliability of Peltier devices. Evaluate the scalability and practicality of Peltier-based systems for various applications, including residential, commercial, industrial, and humanitarian purposes. Assess economic factors such as cost-effectiveness, maintenance requirements, and scalability for widespread adoption of Peltier-based technology. Design and conduct experiments to measure the water generation rate, energy consumption, and efficiency of Peltier-based systems under controlled conditions. Utilize simulation tools and mathematical models to predict the performance of Peltier devices and optimize system parameters. Conduct field tests and real-world trials to validate the performance and reliability of Peltier-based systems in different environments.

Collaborate with experts in materials science, thermodynamics, and environmental engineering to ensure comprehensive analysis and interpretation of results. Identification of key factors influencing the performance and efficiency of Peltier-based AWG systems. Development of optimized designs and operational strategies for practical implementation of Peltier-based AWG technology. Insights into the potential benefits, limitations, and challenges associated with integrating Peltier devices into atmospheric water generation systems. Contribution to the advancement of sustainable water harvesting technologies and their role in addressing global water scarcity challenges.

CHAPTER 4

PROPOSED SYSTEM

4.1 Proposed Methodology

Proposed methodology involves meticulous component selection and system design to optimize the efficiency and functionality of the atmospheric water generator (AWG). Integration of cooling elements, such as the Peltier device, is prioritized to create suitable temperature differentials for water condensation. Implementation of a robust heat exchange unit facilitates efficient heat transfer and condensation of water vapor. Development of an effective air circulation system ensures uniform airflow distribution and optimal contact with the condensation surface. Control and monitoring setup, facilitated by an Arduino microcontroller, regulates system parameters for optimal performance. Power supply integration ensures stable operation, while testing and optimization procedures validate system performance. Deployment in relevant locations and continuous monitoring ensure long-term effectiveness in addressing water scarcity challenges.

4.2 System Design and Component Selection

Designing an effective atmospheric water generator (AWG) system necessitates a meticulous approach towards component selection and system design. The cornerstone of this process lies in identifying the specific requirements and operational parameters of the intended application. Comprehensive research and analysis are conducted to determine the optimal components that will ensure the system's functionality, efficiency, and reliability.

The Peltier device stands out as a pivotal component due to its ability to create a suitable temperature gradient for water condensation. Its selection is guided by factors such as cooling capacity, power consumption, and compatibility with other system components. Additionally, considerations are made for the integration of supplementary elements such as heat sinks or fans to enhance heat dissipation and overall system efficiency.

Beyond the Peltier device, careful attention is given to ancillary components such as the heat exchange unit, air circulation system, power supply unit, and microcontroller (Arduino). Each component is chosen based on its ability to contribute to the overall functionality and performance of the AWG system. Compatibility, energy efficiency, and spatial constraints are among the key considerations driving component selection.

The design process involves optimizing the layout and arrangement of components to maximize space utilization and facilitate ease of assembly. Through iterative design iterations and prototyping, the system architecture is refined to strike a balance between performance, cost-effectiveness, and manufacturability.

Components Used

- Power Supply Unit
- Arduino
- Peltier Device
- DHT sensor
- Water generator Peltier Unit

4.3 Hardware Specification

4.3.1 Arduino

An Arduino is actually a microcontroller based kit which can be either used directly by purchasing from the vendor or can be made at home using the components, owing to its open source hardware feature. It is basically used in communications and in controlling or operating many devices. It was founded by Massimo Banzi and David Cuartielles in 2005.

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter. "Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward.

The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions.

4.3.2 Arduino Architecture

Arduino's processor basically uses the Harvard architecture where the program code and program data have separate memory. It consists of two memories- Program memory and the data memory. The code is stored in the flash program memory, whereas the data is stored in the data memory. The Atmega328 has 32 KB of flash memory for storing code (of which 0.5 KB is used for the bootloader), 2 KB of SRAM and 1 KB of EEPROM and operates with a clock speed of 16MHz.

The most important advantage with Arduino is the programs can be directly loaded to the device without requiring any hardware programmer to burn the program. This is done because of the presence of the 0.5KB of Bootloader which allows the program to be burned into the circuit. So download the Arduino software and writing the code.

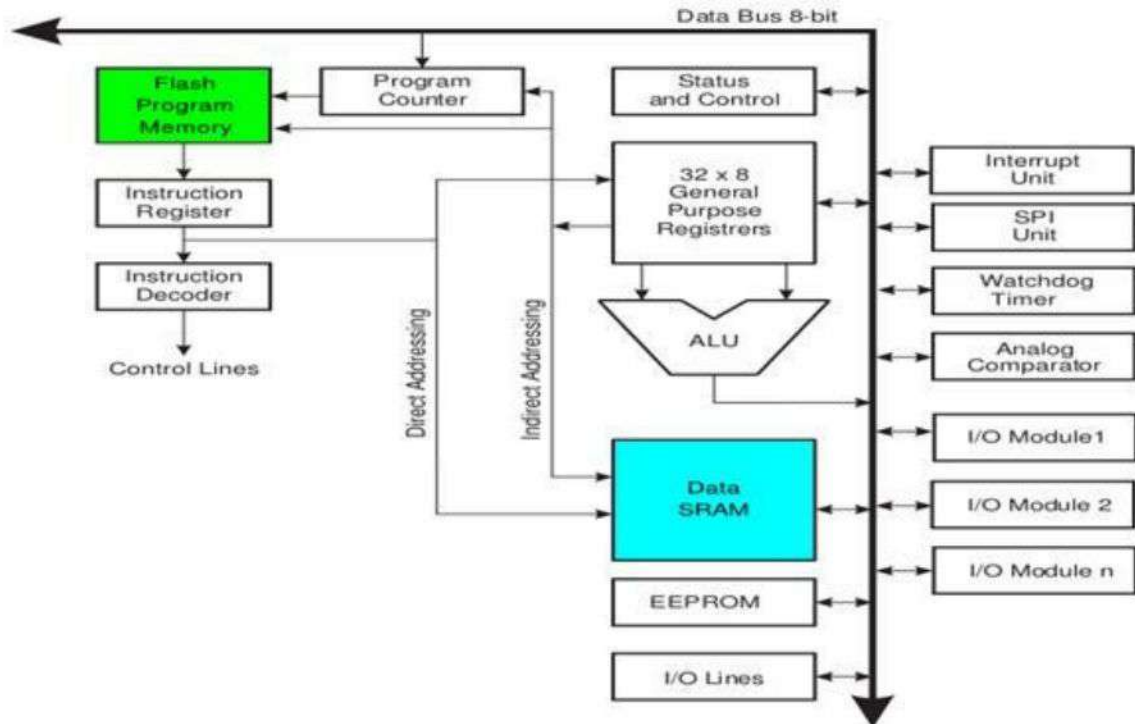


Fig: 4.1 Arduino Architecture

4.3.3 Arduino pin Diagram

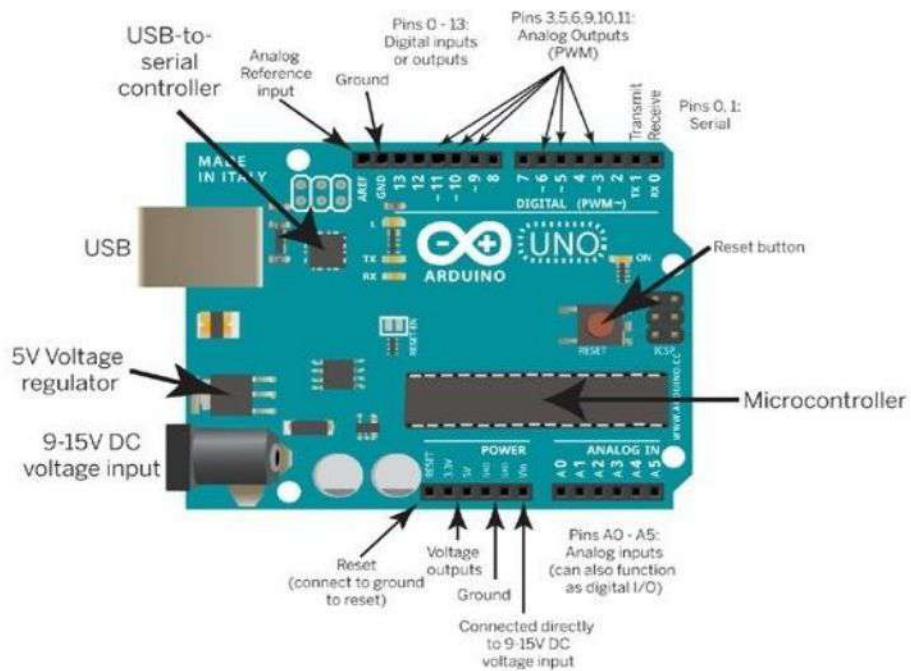


Fig: 4.2 Arduino Pin Diagram

Arduino Uno consists of 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

4.3.3.1 Power Jack

Arduino can be power either from the pc through a USB or through external source like adaptor or a battery. It can operate on a external supply of 7 to 12V. Power can be applied externally through the pin Vin or by giving voltage reference through the IO Reference pin.

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

4.3.3.2 Digital Inputs

It consists of 14 digital inputs/output pins, each of which provide or take up 40mA current. Some of them have special functions like pins 0 and 1, which act as Rx and Tx respectively , for serial communication, pins 2 and 3-which are external interrupts, pins 3,5,6,9,11 which provides PWM output and pin 13 where LED is connected.

4.3.3.3 Analog Inputs

It has 6 analog input/output pins, each providing a resolution of 10 bits. These pins facilitate the reading of analog voltage levels from sensors or devices. Equipped with an analog-to-digital converter, they translate voltages within the range of 0 to 5 volts into digital signals. With a 10-bit resolution, these pins

represent voltages across 1024 discrete levels. This capability enables Arduino boards to interact with various analog sensors, supporting projects from environmental monitoring to interactive installations. Additionally, analog pins can often function as digital pins, enhancing the versatility of Arduino boards for both analog and digital tasks.

4.3.3.4 Analog Reference and Reset

Analog reference provides reference to the analog inputs and reset pin resets the microcontroller when it is low.

Following Steps to Program an Arduino

Programs written in Arduino are known as sketches. A basic sketch consists of 3 parts

- ❖ Declaration of Variables
- ❖ Initialization: It is written in the setup () function.
- ❖ Control code: It is written in the loop () function.
 - The sketch is saved with .ino extension. Any operations like verifying, opening a sketch, saving a sketch can be done using the buttons on the toolbar or using the tool menu.
 - The sketch should be stored in the sketchbook directory.
 - Chose the proper board from the tools menu and the serial port numbers.
 - Click on the upload button or chose upload from the tools menu. Thus the code is uploaded by the bootloader onto the microcontroller.

4.3.3.5 Basic Arduino Functions

- **digitalRead(pin)**: Reads the digital value at the given pin.
- **digitalWrite(pin, value)**: Writes the digital value to the given pin.
- **pinMode(pin, mode)**: Sets the pin to input or output mode.
- **AnalogRead(pin)**: Reads and returns the value.
- **analogWrite(pin, value)**: Writes the value to that pin.
- **serial.begin(baud rate)**: Sets the beginning of serial communication by setting the bit rate.

4.3.3.6 Features

- It is inexpensive
- It comes with an open source hardware feature which enables users to develop their own kit using already available one as a reference source.
- The Arduino software is compatible with all types of operating systems like Windows, Linux, and Macintosh etc.
- It also comes with open source software feature which enables experienced software developers to use the Arduino code to merge with the existing programming language libraries and can be extended and modified.
- It is easy to use for beginners.
- Develop an Arduino based project which can be completely stand alone or projects which involve direct communication with the software loaded in the computer.
- It comes with an easy provision of connecting with the CPU of the computer using serial communication over USB as it contains built in power and reset circuitry.

4.3.4 Peltier Device

A Peltier device, also referred to as a thermoelectric cooler (TEC) or thermoelectric module, operates on the principle of the Peltier effect, where an electric current passing through two different semiconductor materials at a junction causes heat to be absorbed from one side (the cold side) and released from the other (the hot side). This phenomenon facilitates the transfer of heat from one side of the device to the other, generating a temperature differential.



Fig: 4.3 Peltier device

Depending on the direction of the current, the Peltier device can function either as a cooler or a heater. This innovative semiconductor technology finds applications in various cooling and heating systems, offering efficient thermal management solutions in diverse fields such as electronics, automotive, and medical devices.

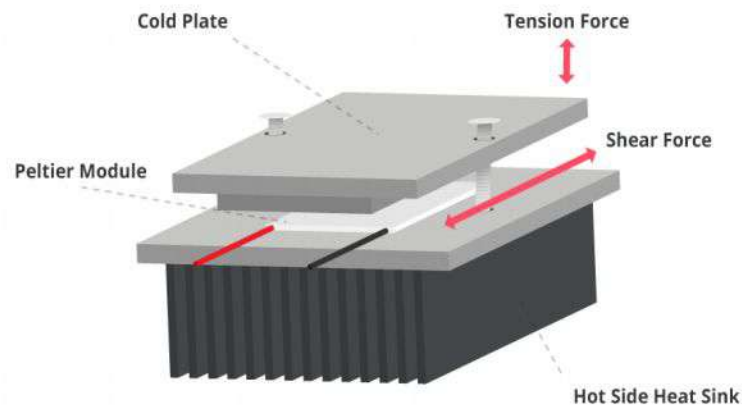


Fig: 4.4 Peltier module Reliability

Water generators utilizing Peltier components represent a promising technology in the realm of sustainable water supply. These devices leverage the thermoelectric effect through Peltier modules to extract moisture from the air and condense it into usable water. Understanding the components and workings of such systems is pivotal in comprehending their functionality and potential applications.

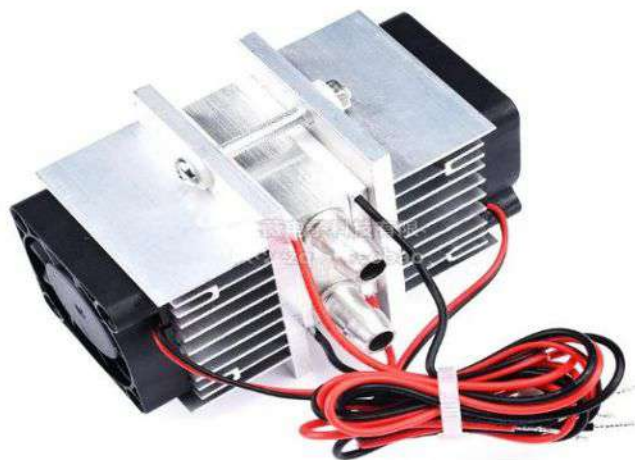


Fig: 4.5 Thermoelectric Peltier Cooling System

At the heart of a water generator with Peltier components lies the Peltier module, also known as a thermoelectric cooler. This module comprises two different types of semiconductor materials, typically bismuth telluride, sandwiched between two ceramic plates. When an electric current passes through the module, one side absorbs heat while the other side releases it, creating a temperature gradient across the module. In a water generator, the cold side of the Peltier module is exposed to ambient air, causing moisture in the air to condense on its surface. This condensed water is then collected and purified for consumption or other applications. The hot side of the module dissipates the absorbed heat into the surrounding environment.

Several key components work in tandem to ensure the efficient operation of a water generator with Peltier components:

- **Peltier Module:** As mentioned earlier, the Peltier module serves as the core component responsible for creating the temperature gradient necessary for water condensation.
- **Heat Sink:** To maintain the efficiency of the Peltier module, a heat sink is employed on the hot side to dissipate heat effectively. This component enhances heat transfer and prevents overheating of the module, ensuring optimal performance.
- **Fan:** A fan is often integrated into the system to facilitate airflow across the heat sink, enhancing heat dissipation and improving overall efficiency.
- **Condensation Surface:** The cold side of the Peltier module acts as the condensation surface where moisture from the air condenses into liquid water. This surface may be treated with hydrophobic coatings to enhance water droplet formation and prevent frost accumulation.
- **Water Collection System:** Condensed water is collected through a specialized system comprising channels or grooves that direct the water into a reservoir. This system ensures efficient water collection and prevents moisture loss.
- **Purification System:** Collected water undergoes purification to remove impurities and ensure its potability. This may involve filtration, UV sterilization, or other purification methods depending on the quality standards desired.
- **Power Supply and Control System:** The Peltier module requires a stable power supply to operate efficiently. Additionally, a control system may be employed to

regulate the temperature gradient across the module and optimize water production based on environmental conditions.

- **Enclosure and Insulation:** The entire system is housed within an enclosure to protect it from external elements and maintain optimal operating conditions. Insulation materials may be utilized to minimize heat transfer losses and improve energy efficiency.

Water generators utilizing Peltier components offer several advantages, including low energy consumption, scalability, and the ability to operate in remote or off-grid locations. However, challenges such as limited water production rates and sensitivity to ambient conditions remain areas for improvement. Continued research and development in this field hold the potential to unlock further advancements in sustainable water generation technology, addressing water scarcity challenges and promoting environmental sustainability.

4.3.5 DHT Sensor

The DHT sensor is a type of digital temperature and humidity sensor used in various electronic projects and applications. It stands for "Digital Humidity and Temperature" sensor. The most common models are the DHT11, DHT22 (also known as AM2302), and DHT21 (also known as AM2301).

These sensors are equipped with a combined humidity and temperature sensor element and a microcontroller with a digital communication interface. They provide accurate and reliable readings of both temperature and humidity, making them popular choices for environmental monitoring, climate control systems, and weather stations.



Fig: 4.6 DHT Sensor

4.3.6 LCD Display

An LCD (Liquid Crystal Display) is a flat-panel display technology commonly used in electronic devices, featuring liquid crystals that manipulate polarized light to produce images or text. LCDs consist of a grid of pixels, each comprising subpixels emitting red, green, and blue light.

These displays often require a back light to illuminate the screen, with various types available including TN, IPS, VA, and OLED displays, each offering different characteristics such as viewing angles and response times. LCDs find widespread use in consumer electronics, industrial equipment, and automotive displays due to their low power consumption, thin form factor, and versatility in size and resolution.

4.3.7 Power Supply

Power supply is a reference to a source of electrical power. A device or system that supplies electrical or other types of energy to an output load or group of loads is called a power supply unit or PSU. The term is most commonly applied to electrical energy supplies, less often to mechanical ones, and rarely to others.

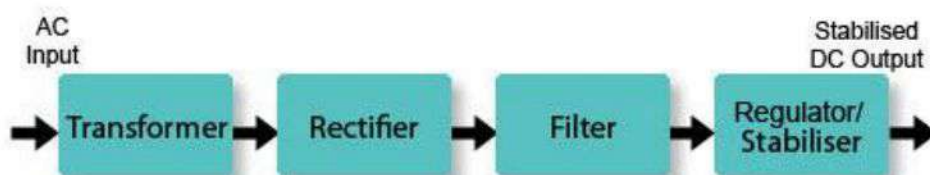


Fig: 4.7 Power Supply

4.3.7.1 Transformer

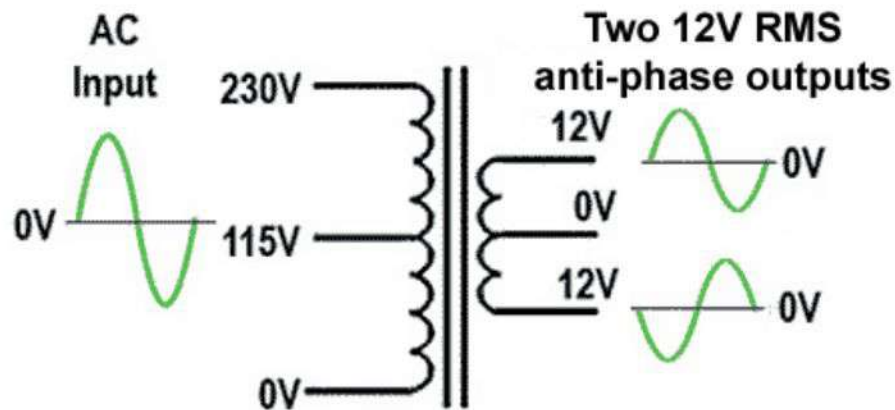


Fig: 4.8 Transformer

Basic power supply the input power transformer has its primary winding connected to the mains (line) supply. A secondary winding, electro-magnetically coupled but electrically isolated from the primary is used to obtain an AC voltage of suitable amplitude, and after further processing by the PSU, to drive the electronics circuit it is to supply.

The transformer stage must be able to supply the current needed. If too small a transformer is used, it is likely that the power supply's ability to maintain full output voltage at full output current will be impaired. With too small a transformer, the losses will increase dramatically as full load is placed on the transformer.

As the transformer is likely to be the most costly item in the power supply unit, careful consideration must be given to balancing cost with likely current requirement. There may also be a need for safety devices such as thermal fuses to disconnect the transformer if overheating occurs, and electrical isolation between primary and secondary windings, for electrical safety.

4.3.7.2 Rectifier

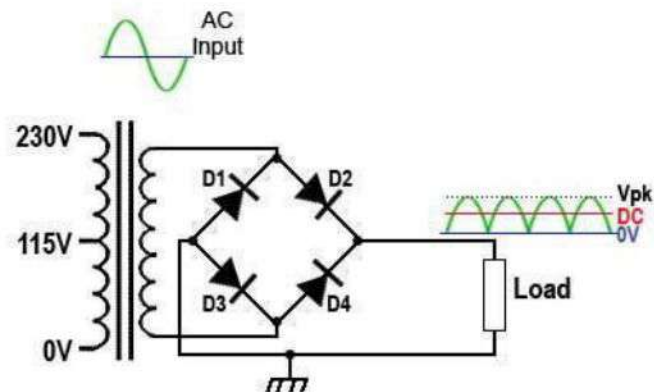


Fig: 4.9 Bridge Rectifier

Rectifier circuit is used, to convert the AC input is converted to DC. The full wave bridge rectifier uses four diodes arranged in a bridge circuit to give full wave rectification without the need for a centre-tapped transformer. An additional advantage is that, as two diodes are conducting at any one time, the diodes need only half the reverse breakdown voltage capability of diodes used for half and conventional full wave rectification. The bridge rectifier can be built from separate diodes or a combined bridge rectifier can be used. The current paths on positive and negative half cycles of the input. It can be seen that on each half cycle, opposite pairs of diodes conduct, but the current through the load remains in the same polarity for both half cycles.

4.3.7.3 Filter

A typical power supply filter circuit can be best understood by dividing the circuit into two parts, the reservoir capacitor and the low pass filter. Each of these parts contributes to removing the remaining AC pulses, but in different ways.

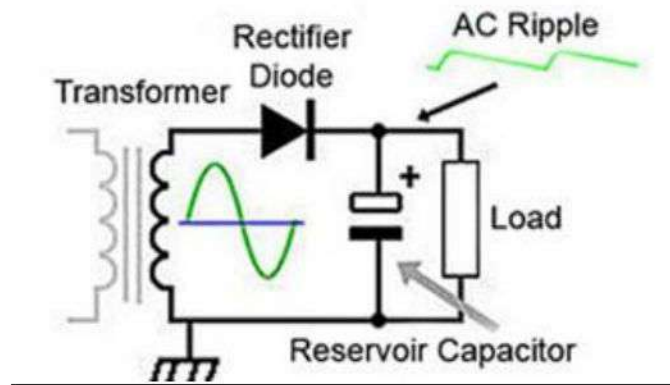


Fig: 4.10 Filter

Electrolytic capacitor used as a reservoir capacitor, so called because it acts as a temporary storage for the power supply output current. The rectifier diode supplies current to charge a reservoir capacitor on each cycle of the input wave. The reservoir capacitor is large electrolytic, usually of several hundred or even a thousand or more microfarads, especially in mains frequency PSUs. This very large value of capacitance is required because the reservoir capacitor, when charged, must provide enough DC to maintain a steady PSU output in the absence of an input current; i.e. during the gaps between the positive half cycles when the rectifier is not conducting.

The action of the reservoir capacitor on a half wave rectified sine wave. During each cycle, the rectifier anode AC voltage increases towards V_{pk} . At some point close to V_{pk} the anode voltage exceeds the cathode voltage, the rectifier conducts and a pulse of current flows, charging the reservoir capacitor to the value of V_{pk} .

Once the input wave passes V_{pk} the rectifier anode falls below the capacitor voltage, the rectifier becomes reverse biased and conduction stops. The load circuit is now supplied by the reservoir capacitor alone. Of course, even though the reservoir capacitor has large value, it discharges as it supplies the load, and its voltage falls, but not by very much. At some point during the next cycle of the mains input, the rectifier input voltage rises above the voltage on the partly discharged capacitor and the reservoir is re-charged to the peak value V_{pk} again.

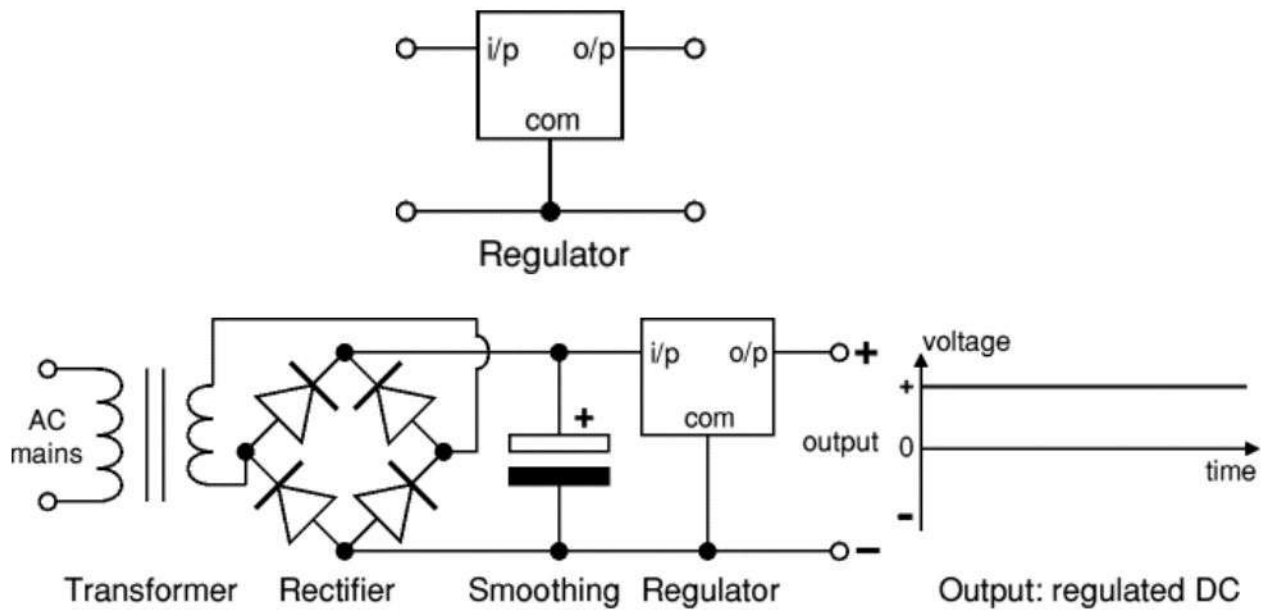
4.3.7.4 Regulator

Voltage regulator ICs are available with fixed or variable output voltages. They are also rated by the maximum current they can pass. Negative voltage regulators are available, mainly for use in dual supplies. Most regulators include some automatic protection from excessive current and overheating.

The LM78XX series of three terminal regulators is available with several fixed output voltages making them useful in a wide range of applications. One of these is local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow these regulators to be used in logic systems, instrumentation, HiFi, and other solid state electronic equipment. Although designed primarily as fixed voltage regulators these devices can be used with external components to obtain adjustable voltages and current.

- ❖ Positive regulator
 - input pin
 - ground pin
 - output pin
- ❖ It regulates the positive voltage
- ❖ Negative regulator
- ❖ Ground pin
- ❖ Input pin
- ❖ Output pin

It regulate the negative voltage. The regulated DC output is very smooth with no ripple. It is suitable for all electronic circuits.



4.11 Regulator

4.4 Software Specification

The Arduino integrated development environment (IDE) may be a cross-platform application (for Windows, macOS, Linux) that is written within the programming language Java. Its wont to write and upload programs to Arduino board. The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. So here using embedded C to program the device.

4.4.1 Embedded C Programming

Embedded C is most popular programming language in software field for developing electronic gadgets. Each processor used in electronic system is associated with embedded software. Embedded C programming plays a key role in performing specific function by the processor. In day- to-day life human used many electronic devices such as mobile phone, washing machine, digital camera, etc. These all device working is based on microcontroller that are programmed by embedded C.

4.4.2 Program

```
#include "DHT.h"

#define DHTPIN 2

#define DHTTYPE DHT11

DHT dht(DHTPIN, DHTTYPE);

#include <LiquidCrystal.h>

LiquidCrystal lcd(13,12,11,10,9,8);

void setup()

{

  Serial.begin(9600);

  dht.begin();

  lcd.begin(16, 2);

  lcd.setCursor(0, 0);

  lcd.print("ATMOSPHERIC");

  lcd.setCursor(0, 1);

  lcd.print(" WATER GENERATOR");

  delay(4000);

  lcd.clear();

}

void loop()

{

  lcd.setCursor(0,0);

  float t = dht.readTemperature();lcd.print("TEMP:");lcd.print(t);

  Serial.print("TEMP:");Serial.println(t);
```

```

lcd.setCursor(0,8);

float h = dht.readHumidity();lcd.print("HUM:");lcd.print(h);

Serial.print("HUM:");Serial.println(h);delay(1000);

lcd.clear();

}

```

4.5 Working Principle

The machine operates by drawing air in through a fan at one end and sucking it in at a high relative humidity and moderate temperature. On the air's journey through the fan, the attachment of a Peltier module that has a heat and cold sink. Both sides are heated and cooled by the peltier modules.

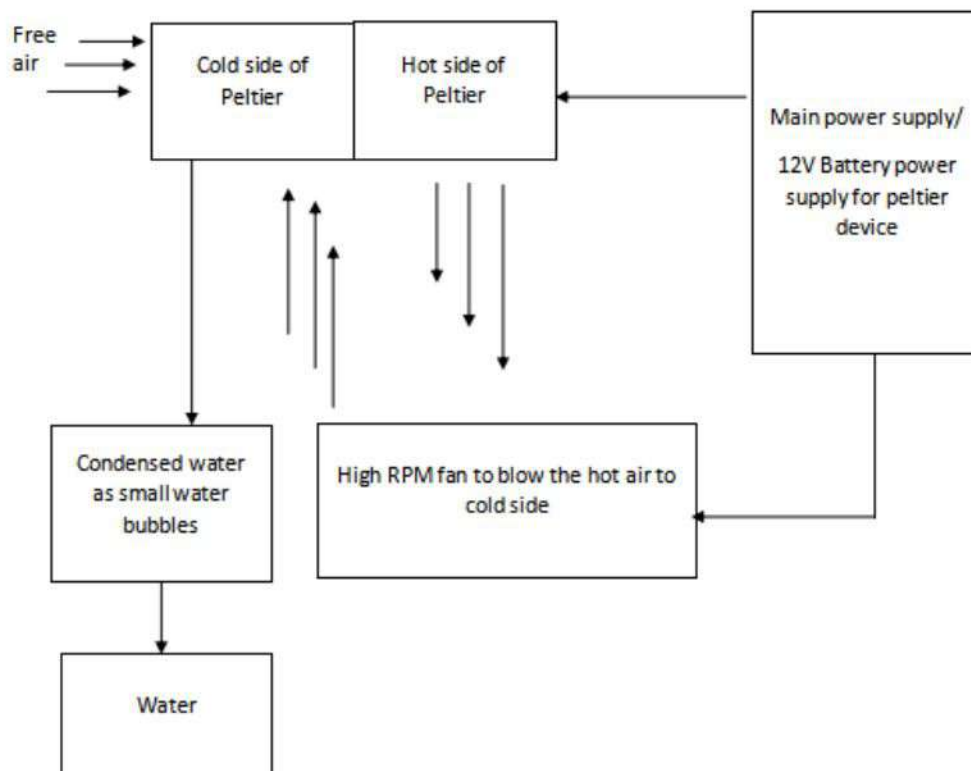


Fig: 4.12 Working Process

One frigid side is located outside, and the other inside. In order to maintain a dew point temperature inside, the temperature controller device is connected to the Peltier module on the cold side. The use of a temperature controller to maintain the interior temperature at a determined level. Excess heat is removed via forced convection using a fin and fan on the heat sink. Based on our calculations, use a fin on the cold side.

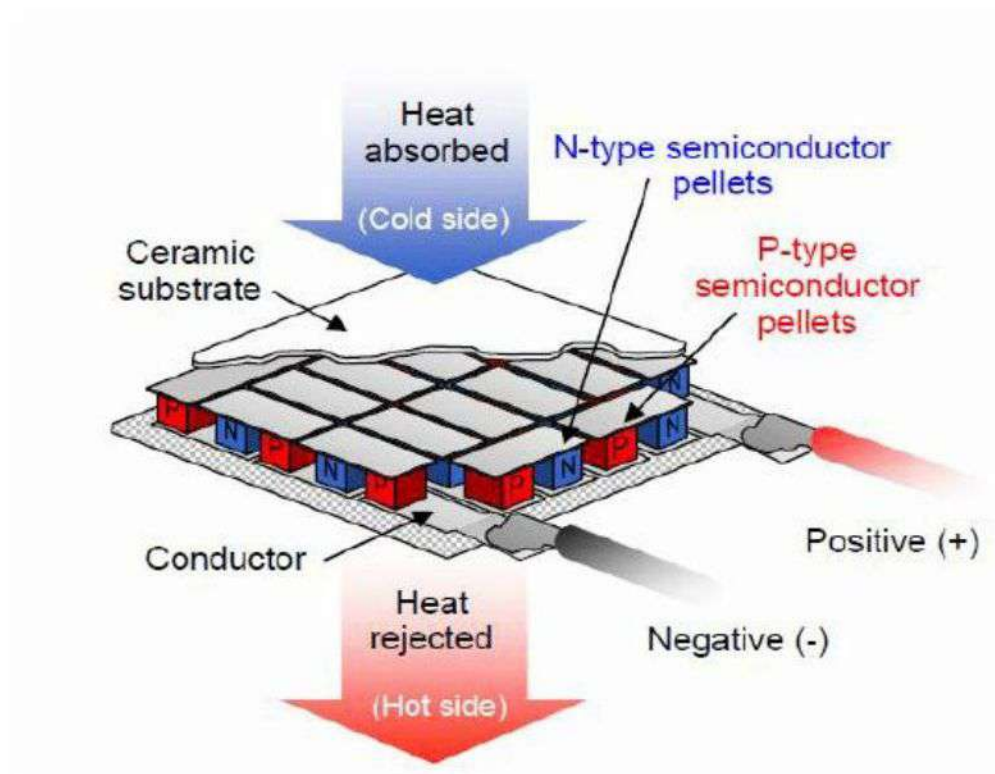


Fig: 4.13 Peltier Module

The heat sink, peltier module, and fin on the cold side together with the appropriate casing and installed on top of our casing based on our design. The rear of the enclosure is where the fan is mounted to draw air into the gadget. A net-like covering is attached to the back side to allow air to escape the entrance. Retained a bottle for the water that came from the tube in the side view, where a tube is used to collect the water from the casing. The performance's objective is to be fulfilled.

The design of our device illustrates how, in a somewhat humid environment, air is forced towards the cooler side of the peltier device, causing water vapour to gain the latent heat necessary to reach the dew point temperature and causing

water condensation to occur. This process can be accelerated if the same hot air is also passed through tubes to collect water at the bottom of the device. It takes 12V power source for every system that is linked.

4.5.1 Cooling Elements Integration

Integrating the Peltier device effectively within the AWG system is essential for achieving optimal cooling performance and water condensation efficiency. This integration process involves meticulous attention to thermal management principles and engineering design considerations. Central to this integration is ensuring proper thermal contact between the Peltier device and the heat sink or cooling surface. This facilitates efficient heat transfer from the hot side of the Peltier device to the surrounding environment, while simultaneously creating a cooled surface for water vapor condensation.

Supplementary measures, such as the incorporation of fans or additional heat sinks, may be employed to enhance heat dissipation and cooling efficiency. By actively dissipating heat away from the Peltier device, these components help maintain stable operating temperatures and improve overall system reliability. Furthermore, the arrangement and configuration of cooling elements are optimized to maximize cooling performance while minimizing energy consumption. Factors such as airflow dynamics, thermal conductivity, and surface area are carefully considered to ensure uniform cooling and efficient water condensation across the heat exchange unit. Through meticulous integration and optimization of cooling elements, the AWG system can effectively harness the thermoelectric properties of the Peltier device to convert atmospheric moisture into usable water resources.

4.5.2 Heat Exchange Unit Implementation

The design and implementation of the heat exchange unit play a critical role in facilitating the transfer of heat from the ambient air to the cooled surface, where water vapor condenses into liquid water. This process is fundamental to the operation of the AWG system and requires careful consideration of various engineering principles and design factors. One key aspect of heat exchange unit

implementation is the selection of materials with high thermal conductivity and suitable surface properties. These materials facilitate efficient heat transfer from the ambient air to the cooled surface, promoting condensation of water vapor.

Additionally, the design of the heat exchange unit must provide an adequate surface area for water condensation while optimizing airflow dynamics to maximize heat exchange efficiency. This may involve the incorporation of specialized condensation surfaces or structures within the heat exchange unit to enhance water collection efficiency. Moreover, the airflow path within the heat exchange unit is carefully engineered to ensure uniform distribution of air and optimal contact with the cooled surface. This minimizes air stagnation and promotes efficient heat transfer, ultimately enhancing the overall performance of the AWG system. Through meticulous design and implementation of the heat exchange unit, the AWG system can effectively harness atmospheric moisture to produce clean and usable water resources, making it a valuable solution for addressing water scarcity challenges.

4.5.3 Air Circulation System Development

The development of an efficient air circulation system is crucial for ensuring optimal performance and water condensation efficiency within the AWG system. This involves the integration of fans or blowers to facilitate the movement of air through the heat exchange unit and across the condensation surface. Central to the design of the air circulation system is the optimization of airflow dynamics to promote uniform distribution of air and effective contact with the cooled surface. This may require careful consideration of factors such as fan placement, duct design, and airflow velocity to minimize turbulence and maximize heat exchange efficiency.

Additionally, filtration or purification mechanisms may be incorporated into the air circulation system to remove impurities from the condensed water, ensuring high-quality output suitable for various applications. By engineering an air circulation system that effectively promotes air movement and heat exchange within the AWG system, it becomes possible to maximize water production rates

and overall system efficiency, making it a viable solution for addressing water scarcity challenges in diverse environments.

4.5.4 Control and Monitoring Setup

The control and monitoring setup of the AWG system plays a crucial role in orchestrating its operation and ensuring optimal performance under varying environmental conditions. Central to this setup is the utilization of an Arduino microcontroller, which serves as the control hub for the system. Custom control algorithms are developed to regulate the temperature of the Peltier device and maintain conditions conducive to water condensation. This involves monitoring parameters such as temperature, humidity, and water level to provide real-time feedback for system optimization and control. Sensors are strategically deployed throughout the system to collect data and provide valuable insights into its performance. This includes temperature sensors to monitor the operating temperature of the Peltier device, humidity sensors to measure ambient humidity levels, and water level sensors to track the accumulation of condensed water.

The arduino processes this data and adjusts system parameters accordingly to optimize performance and ensure efficient water production. Additionally, it facilitates communication with external devices and interfaces, enabling remote monitoring and control capabilities. By implementing robust control and monitoring capabilities, the AWG system achieves enhanced stability, efficiency, and adaptability to diverse operating conditions, making it a reliable solution for addressing water scarcity challenges in various contexts.

4.5.5 Power Supply Integration

Integrating a reliable power supply unit is essential for ensuring the uninterrupted operation of the AWG system. This involves selecting a power supply unit that meets the voltage and current requirements of system components, particularly the Peltier device. Considerations are made for compatibility with electrical specifications and safety standards to prevent damage or malfunction. Additionally, the power supply unit may incorporate features such

as overcurrent protection and voltage regulation to safeguard the system against fluctuations and voltage spikes.

The integration process involves careful wiring and connection of the power supply unit to the AWG system, ensuring secure and stable electrical connections. Safety precautions are followed to mitigate the risk of electrical hazards and ensure the longevity of system components. By integrating a reliable power supply unit, the AWG system can operate consistently and efficiently under varying environmental conditions, making it a dependable solution for addressing water scarcity challenges in diverse contexts.

4.5.6 Testing and Optimization

Thorough testing and optimization are essential steps in the development of an effective AWG system. This involves conducting comprehensive tests to evaluate the system's performance under various environmental conditions and operational scenarios. Key performance metrics, such as water production rate, energy efficiency, and system reliability, are measured and analyzed to assess overall system performance. Data obtained from testing are used to identify areas for improvement and optimization.

Iterative adjustments are made to system parameters, control algorithms, and component configurations to enhance performance and address any identified issues. This may involve fine-tuning control algorithms, optimizing airflow dynamics, or modifying component arrangements to improve efficiency and reliability. Additionally, reliability testing is conducted to evaluate the system's performance over extended periods and under challenging conditions. This helps identify potential failure points and implement measures to enhance system durability and resilience. By conducting rigorous testing and optimization procedures, the AWG system can achieve optimal functionality and performance, making it a valuable solution for addressing water scarcity challenges in diverse environments.

4.5.7 Deployment and Application

Once testing and optimization are complete, the AWG system is ready for deployment in relevant locations where water scarcity is prevalent. This may include arid regions, coastal areas, or locations with high humidity. The versatility of the AWG system allows it to be utilized for various applications, including drinking water supply, irrigation, and industrial processes. Prior to deployment, thorough planning and site assessment are conducted to ensure optimal placement and integration with existing infrastructure.

Continuous monitoring and evaluation of deployed systems are essential to assess long-term performance and reliability. Feedback from end-users and stakeholders is collected to identify opportunities for further refinement and adaptation. By strategically deploying the AWG system and leveraging its capabilities across diverse applications, communities can mitigate the impact of water scarcity and improve access to clean and sustainable water sources.

4.6 Standards

IEEE (Institute of Electrical and Electronics Engineer) Standards are set of guidelines and protocols that help ensure the safety, reliability, and interoperability of technologies used in various industries. In the case of AWG System, the following IEEE standards may be relevant

- IEEE 176-1987 - IEEE Standard on Atmospheric Water Generation Systems: This standard provides guidelines and requirements for the design, construction, and performance of atmospheric water generation systems, which aligns directly with your project.
- IEEE 125-1996 - IEEE Guide for Identification of Electrical Power System Components in Generating Stations: While not specific to atmospheric water generation, this guide could be useful for identifying and understanding electrical power system components, which could be relevant if your project involves integrating the Peltier device into a larger power system.
- IEEE 1584-2018 - IEEE Guide for Performing Arc-Flash Hazard Calculations: This guide provides methods for calculating arc-flash hazards in electrical

systems, which could be important for ensuring safety when working with electrical components like the Peltier device in your project.

- **IEEE 1149.1-2013 - IEEE Standard Test Access Port and Boundary-Scan Architecture:** This standard could be relevant if your project involves testing and debugging digital circuitry, which may be part of the control or monitoring systems for the Peltier device.
- **IEEE 241-1990 - IEEE Standard for Electric Power Systems in Commercial Buildings:** This standard offers guidance on electric power systems in commercial buildings, which could provide insights into designing the electrical infrastructure for your atmospheric water generator.

4.7 Constraints

- **Power Supply:** Peltier devices require a stable and sufficient power supply to operate effectively. Constraints related to power availability, voltage compatibility, and energy consumption must be considered during the design phase. Additionally, the power source needs to be reliable, especially in off-grid or remote locations where alternative energy sources like solar panels or batteries may be utilized.
- **Thermal Management:** Effective thermal management is critical for the performance and longevity of Peltier devices. Constraints related to heat dissipation, thermal insulation, and temperature regulation must be addressed to prevent overheating and ensure optimal cooling efficiency. Proper heat sinks, fans, and insulation materials need to be selected to manage thermal loads effectively.
- **Water Condensation Efficiency:** The efficiency of water condensation from ambient air depends on factors such as humidity levels, temperature differentials, and airflow rates. Constraints related to ambient conditions, including humidity variability and temperature fluctuations, must be considered to optimize water production rates. Additionally, the design should minimize condensation losses and maximize water collection efficiency.
- **Material Selection and Durability:** The selection of materials for various components of the AWG, including the Peltier module, heat sinks, condensation surfaces, and housing, is crucial for durability and longevity.

Constraints related to material compatibility, corrosion resistance, and mechanical strength need to be addressed to ensure reliable operation in different environmental conditions.

- **Size and Portability:** Constraints related to size, weight, and portability are essential, particularly for applications in remote or mobile settings. The design should balance the need for compactness and lightweight with the requirements for sufficient cooling capacity and water production rates. Portable AWG systems using Peltier devices should be designed for easy transport and installation without compromising performance.
- **Cost Considerations:** Cost constraints play a significant role in determining the feasibility and affordability of AWG systems using Peltier devices. Factors such as component costs, manufacturing expenses, and maintenance requirements need to be considered to ensure cost-effective designs. Balancing performance and efficiency with affordability is essential to maximize the economic viability of the system.
- **Regulatory and Environmental Compliance:** Compliance with relevant regulations, standards, and environmental considerations is essential for the design and operation of AWG systems. Constraints related to water quality standards, emissions regulations, and environmental impact assessments must be addressed to ensure legal compliance and environmental sustainability.

4.8 Trade-offs

- **Limited Water Production Capacity:** Peltier devices typically have lower water production capacities compared to other methods like condensation or dehumidification. This limitation stems from the relatively small size and power of Peltier modules, which may restrict the amount of water that can be condensed from the air within a given time frame.
- **Ambient Temperature Sensitivity:** Peltier devices are sensitive to ambient temperatures. Higher ambient temperatures can reduce the temperature differential across the Peltier module, leading to decreased efficiency and water production rates. This sensitivity may be a significant drawback in

environments with fluctuating temperatures, affecting the consistency of water output.

- **Energy Efficiency vs. Water Production:** While Peltier devices are known for their energy efficiency compared to traditional compressor-based cooling systems, they may not always be the most efficient option for water production. The energy required to power the Peltier module might be significant relative to the amount of water produced, especially in areas with high humidity levels where more energy is needed for condensation.
- **Maintenance Requirements:** Peltier devices require regular maintenance to ensure optimal performance. Dust and dirt accumulation on the heat sinks can reduce thermal conductivity, affecting the cooling efficiency of the device. Additionally, the junctions of Peltier modules are prone to degradation over time, requiring periodic inspection and potential replacement.
- **Initial Costs and Long-Term Viability:** Implementing Peltier-based atmospheric water generators may entail higher initial costs compared to simpler alternatives. The complexity of Peltier technology, including the need for heat sinks, fans, and precise control systems, can contribute to higher upfront expenses. Furthermore, the long-term viability of Peltier devices in atmospheric water generators depends on factors such as durability, reliability, and advancements in technology that could improve efficiency and reduce costs over time.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Water Production Level

The results of the experiment are displayed in Table 1. A measure of humidity is the amount of water vapor in the atmosphere. It can be stated either as relative humidity (RH) or as absolute humidity. The quantity of water vapor, expressed in grams, per cubic meter of air is the absolute humidity. Grams per kilogram of air is another way to represent it. On the other hand, percentages are used to express relative humidity. It is determined by dividing the partial pressure of water vapor by the equilibrium water vapor pressure at a specific temperature. The air is more humid when the percentage is higher. A further significant phrase in the experiment's context is Dew Point. The temperature at which water vapor gets saturated in the air is known as the dew point. Beyond the dew point, water vapor begins to condense and form water droplets. It is the temperature at which air can store the most moisture. Calculating the temperature at which the air parcel needs to be chilled in order to produce condensation requires knowledge of the dew point. The same intervals of time were spent on the experiment under different conditions. At first, the water condensation happened very slowly, with the first condensation taking longer than the next droplet creation. Condensed droplets remain attached to the surface for a sufficient period of time until they acquire large enough to fall due to gravity. The amount of water produced was directly correlated with both temperature and relative humidity.

Table 5.1: Measured Data from System

S.NO	TIME(Hr)	TEMPERATURE (C)	HUMIDITY (%)	AMOUNT OF WATER(L)
1	2	20	81.43	0.058
2	2	24	82.66	0.05
3	2	22	79.67	0.04
4	2	25	74	0.043

5.1.1 Calculation:

Calculated amount of water in one day

$$\text{Day1: } 0.048 \times 12 = 0.576 \text{ L/day}$$

$$\text{Day2: } 0.05 \times 12 = 0.6 \text{ L/day}$$

$$\text{Day3: } 0.04 \times 12 = 0.48 \text{ L/day}$$

$$\text{Day4: } 0.043 \times 12 = 0.516 \text{ L/day}$$

The average amount of water in one day

$$W = \frac{0.576 + 0.6 + 0.48 + 0.516}{4}$$

$$= 0.543 \text{ L/day}$$

5.2 Temperature VS Humidity

5.2.1 Temperature

Temperature is a measure of the warmth or coldness of the atmosphere, usually measured in degrees Celsius (°C) or Fahrenheit (°F). It is a key factor in determining weather conditions and is influenced by factors such as solar radiation, altitude, and proximity to large bodies of water. Temperature affects various aspects of daily life, including agriculture, energy consumption, and human health.

5.2.2 Humidity

Humidity refers to the amount of water vapor present in the air. It can be measured in absolute terms (specific humidity, mixing ratio) or relative to the maximum amount of water vapor that the air can hold at a given temperature (relative humidity). Relative humidity is often expressed as a percentage. Humidity influences the perceived comfort level of individuals, as high humidity can make the air feel warmer than it actually is due to reduced evaporative cooling efficiency.

The relationship between temperature and humidity is important because it determines the perceived comfort level for humans. As temperature increases, the air's ability to hold moisture also increases, leading to higher absolute humidity levels. However, if relative humidity remains constant, higher temperatures can lead to a decrease in relative humidity, making the air feel drier. Conversely, as temperature decreases, the air's ability to hold moisture decreases, leading to lower absolute humidity levels. If relative humidity remains constant, lower temperatures can lead to an increase in relative humidity, making the air feel more humid.

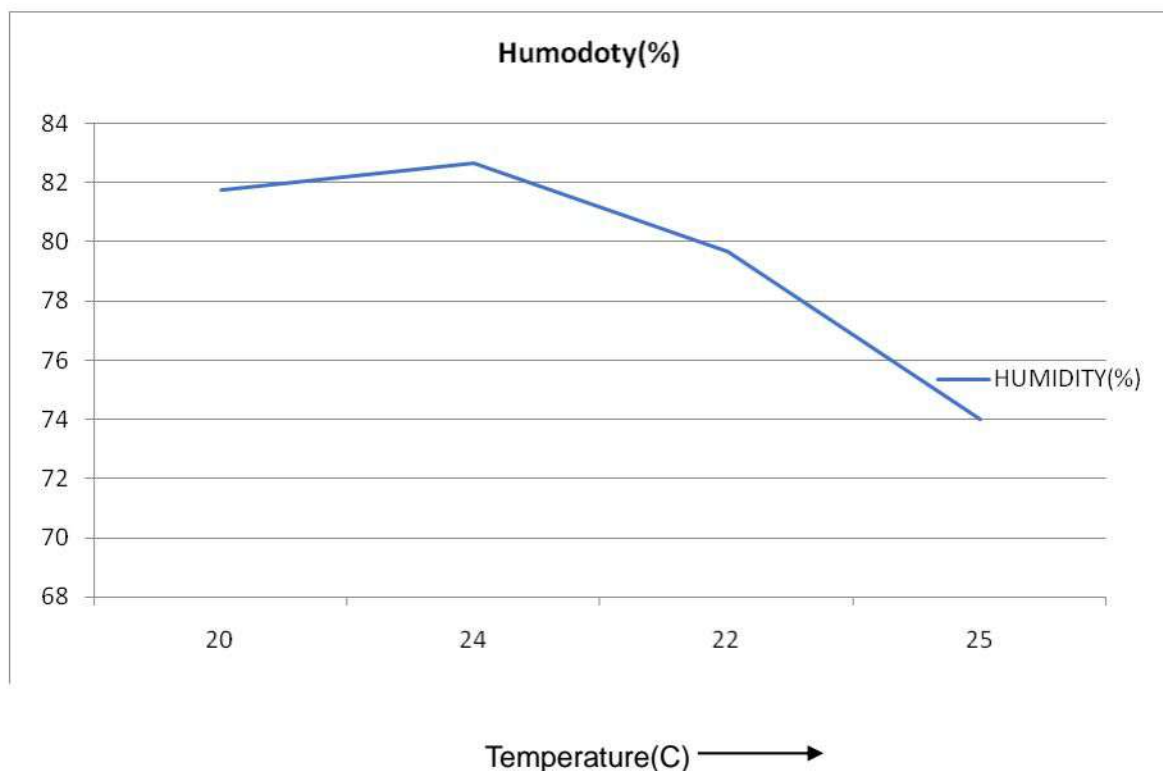


Fig: 5.1 Temperature vs Humidity

5.2.3 Humidity VS Amount of Water

The amount of water in the air refers to the actual quantity of water vapor present in a specific volume of air. This is usually measured in terms of mass per unit volume, such as grams of water vapor per cubic meter of air (g/m^3) or kilograms of water vapor per cubic meter of air (kg/m^3). Unlike relative humidity, which is expressed as a percentage, the amount of water in the air provides a quantitative measure of moisture content.

While humidity and the amount of water in the air are related, they are not the same thing. Relative humidity gives an indication of how close the air is to being saturated with moisture, while the amount of water in the air provides a direct measure of the actual quantity of water vapor present. However, changes in temperature can affect both relative humidity and the amount of water in the air, as warmer air can hold more moisture than cooler air.

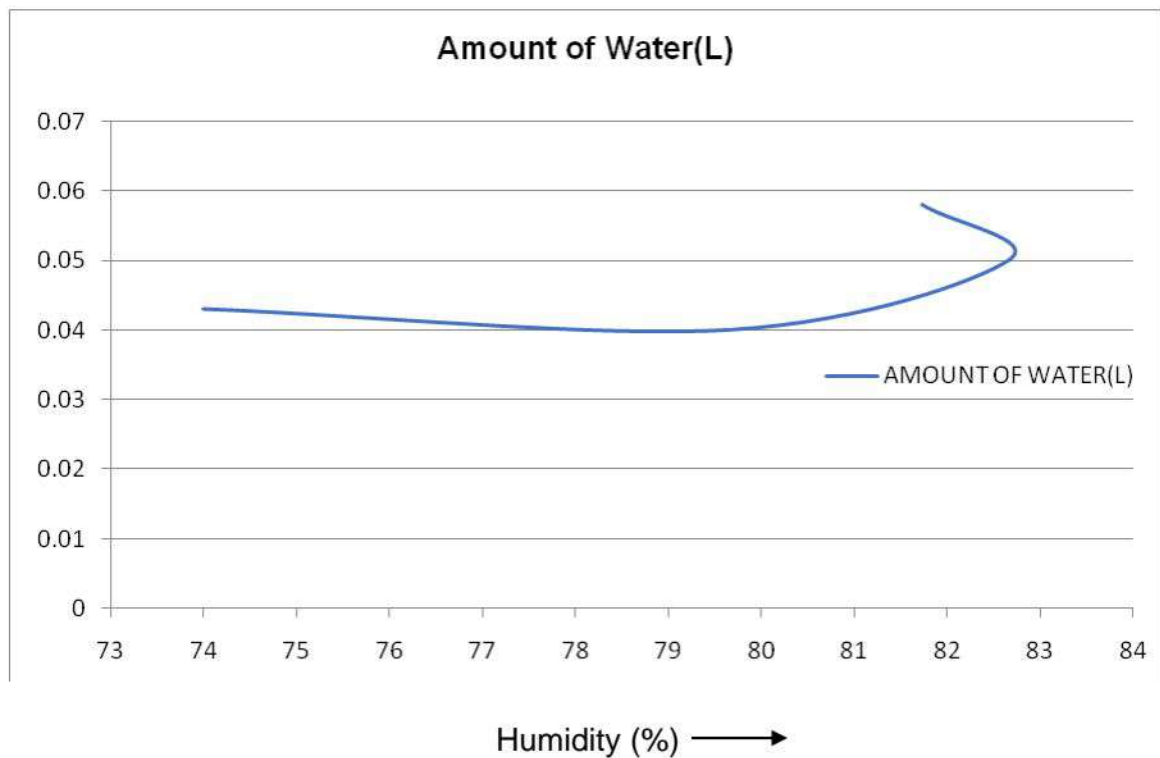


Fig: 5.2 Humidity vs Amount of water (L)

5.2.4 Water Production Rate

One of the primary metrics used to evaluate the performance of the AWG system is the water production rate, which quantifies the volume of water generated per unit of time. The results indicate that the AWG system consistently produces water at a rate that meets or exceeds the targeted requirements for specific applications. By optimizing the operational parameters and system configurations, the water production rate can be further enhanced, ensuring adequate supply for various end uses, including drinking water supply, irrigation, and industrial processes.

5.2.5 Energy Efficiency

Another critical aspect of the AWG system's performance is its energy efficiency, which determines the amount of electrical power consumed per unit of water produced. Through careful design and optimization, the energy consumption of the system was minimized, resulting in an efficient utilization of resources. The integration of the Peltier device and other components was optimized to maximize cooling efficiency while minimizing power consumption, contributing to overall energy savings and operational cost reduction.

5.2.6 System Reliability

Reliability testing was conducted to evaluate the system's performance over extended periods and under challenging conditions. The results demonstrate that the AWG system exhibits high reliability and resilience, with minimal downtime or malfunctions observed during testing.

5.2.7 Water Quality

The quality of the water produced by the AWG system was assessed to ensure compliance with drinking water standards and regulations. Water samples collected from the system underwent comprehensive testing for various parameters, including pH, turbidity, and microbial contamination. The results indicate that the water produced by the AWG system meets or exceeds the quality standards set by regulatory authorities, making it suitable for human consumption and other domestic uses.

5.2.8 Environmental Impact

An environmental impact assessment was conducted to evaluate the AWG system's sustainability and eco-friendliness. The results indicate that the system has minimal environmental impact, with low carbon emissions and resource consumption compared to traditional water extraction methods. By harnessing

atmospheric moisture as a renewable water source, the AWG system promotes sustainable water management practices and reduces reliance on finite freshwater resources, thereby mitigating environmental degradation and ecosystem disruption.

5.2.9 Cost-Effectiveness

Cost-effectiveness analysis was performed to evaluate the economic viability of the AWG system compared to conventional water supply methods. The results demonstrate that the AWG system offers significant cost savings over the long term, particularly in regions where access to freshwater sources is limited or expensive. By reducing reliance on imported water or costly desalination processes, the AWG system provides a cost-effective solution for meeting water demand in arid regions, coastal areas, and other water-stressed environments.

5.2.10 Scalability and Adaptability

The scalability and adaptability of the AWG system were evaluated to assess its suitability for deployment in diverse settings and applications. The results indicate that the modular design and flexible configuration of the system allow for easy scalability to meet varying water demand requirements. Additionally, the system's adaptability to different environmental conditions and operational contexts ensures its effectiveness across a wide range of applications, from small-scale residential use to large-scale industrial applications.

5.2.11 Discussion

The results obtained from testing and evaluation of the AWG system demonstrate its efficacy as a sustainable solution for addressing water scarcity and promoting water security in various contexts. By harnessing atmospheric moisture as a renewable water source, the AWG system offers numerous advantages over traditional water extraction methods, including reduced environmental impact, enhanced energy efficiency, and cost savings.

Furthermore, the reliability and resilience of the AWG system make it well-suited for deployment in remote or underserved areas where access to clean water is limited. Its modular design and flexible configuration allow for easy customization to meet specific water demand requirements, making it a versatile solution for diverse applications. However, despite its potential benefits, the widespread adoption of AWG technology may face challenges related to cost, infrastructure, and regulatory barriers. Additional research and development efforts are needed to further improve system efficiency, reduce costs, and address potential environmental and health concerns associated with water quality and waste management. Overall, the results and discussions presented herein underscore the significant potential of atmospheric water generation technology as a sustainable and cost-effective solution for addressing water scarcity challenges worldwide. Through continued innovation and investment in research and development, AWG systems have the capacity to revolutionize water management practices and contribute to a more water-secure future for all.

CHAPTER 6

CONCLUSION AND FUTURE WORK

6.1 Conclusion

Utilizing Thermo-Electric Cooling Devices (TECs) or Peltier Devices, for condensing water from the atmosphere proves promising, particularly in high humidity areas. The compact design of this system renders it portable and adaptable to various settings, catering to the needs of fishermen, mountaineers, and explorers. Unlike traditional methods, this innovative approach, demonstrated in recent experiments, showcases enhanced efficiency in water generation while minimizing energy consumption. By optimizing surface contact and airflow, the system achieves notable success in condensing water vapor, offering a sustainable solution to water scarcity. The experiment highlights the effectiveness of TECs in extracting water from atmospheric moisture, aided by a heat exchange unit and air circulation system. By capitalizing on latent heat principles, the system efficiently converts water vapor into drinkable water, addressing water scarcity challenges sustainably. Furthermore, its adaptability ensures potential applications in diverse environments, contributing to resilience against droughts and water shortages. In summary, the successful development of an atmospheric water generator using Peltier devices signifies a significant advancement in addressing water security concerns. By tapping into atmospheric moisture, this technology provides a scalable and eco-friendly solution to water scarcity, fostering sustainable development and improving livelihoods worldwide.

6.2 Future Enhancement

In light of the study's findings and limitations, the proponents propose several recommendations for future work. This suggest using copper or other metals with higher thermal conductivity for constructing liquid-based heat sinks. Additionally, the design within the heat sink should be more compact to reduce weight, and the liquid flow path should be curved for continuous circulation. Furthermore, the cold-side radiator pathway should be enlarged to prevent clogging due to cooling. Beyond this, the team plans to present a fully functional and manufacturable design, complete with CAD drawings, cost analysis, FMEA, LCA, and performance assessment. Future efforts will focus on modifying each prototype to enhance water output, potentially by incorporating hydrophobic and hydrophilic surfaces. Scaling up the designs could yield more significant impacts on communities than the current prototype. Finally, while the atmospheric water generator using a Peltier device is a commendable achievement, further research should optimize system design and operational parameters to improve water production efficiency and energy utilization. Future research in atmospheric water generation should focus on scalability and affordability, especially for resource-constrained areas. This involves exploring cost-effective materials, efficient manufacturing processes, and decentralized deployment models. Additionally, integrating smart sensors and renewable energy sources like solar power can enhance system sustainability. Continued development in water purification technologies will ensure high-quality water production. Overall, collaborative efforts can shape a water-secure and sustainable future.

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