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Ministry of Higher Education and Scientific Research
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Engineering and Information Technology Faculty
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Environment Generator for Indoor Aeroponic Agriculture

مولد البيئة للزراعة المائية الداخلية

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Abstract

Aeroponics is a type of hydroponics, which is the development of traditional agriculture and the application of modern technology to produce healthier, more abundant and productive crops in a smaller area and at competitive costs compared to traditional agriculture, as well as providing seasonal crops throughout the year by providing a suitable environment at all times. This project focuses on automating the provision of suitable environments at the lowest costs so that farmers can benefit from them in general. It aims to solve many of the problems that they may face in traditional agriculture, including solving the problem of the availability of fertile soil and the harmful weeds that may be present in it, in addition to providing water, which is considered a dilemma for most farmers, as well as pesticides. Insecticides, fertilizers, and the provision of organic products, by providing a suitable environment for plant growth in closed cultivation using hydroponic (vertical) farming technology, not using soil and replacing it with inert alternatives, using a closed irrigation system in proportion to the needs of the system, and employing engineering techniques to manage all of this without any interference from the human side and providing A suitable environment throughout the year, which achieves the sustainability factor. In conclusion, the hydroponic (vertical) farming system was implemented and tested after engineering techniques were employed, and this system demonstrated its effective effect.

الزراعة المائية هي تطوير الزراعة التقليدية وتطبيق التقنية الحديثة لإنتاج محاصيل أكثر صحية واكثر وفرة وانتاجية في اقل مساحة وبتكاليف منافسه مقارنه بالزراعة التقليدية وكذلك توفير المحاصيل الموسمية على مدار العام من خلال توفير بيئة ملائمة طوال الوقت. يركز هذا المشروع على أتمتة توفير البيئات الملائمة بأقل التكاليف لكي يستفيد منها المزارعين بشكل عام ويهدف لحل كثير من المشاكل التي قد تواجههم في الزراعات التقليدية منها حل مشكلة توافر التربة الخصبة والحشائش الضارة التي قد تتواجد فيها إضافة الى توفير الماء الذي يعتبر معضلة لأكثر المزارعين وكذلك المبيدات الحشرية والأسمدة وتوفير منتجات عضوية وذلك من خلال توفير بيئة ملائمة لنمو النبات في زراعة مغلقة بتقنية الزراعة المائية (العمودية) وعدم استخدام التربة واستبدالها ببدائل خاملة واستخدام نظام ري مغلق بما يتناسب مع احتياج النظام وتوظيف التقنيات الهندسية لإدارة كل ذلك بدون اي تدخل من الجانب البشري وتوفير بيئة ملائمة على مدار العام ما يحقق عامل الاستدامة .وفي الختام نُفذ و ُجرب نظام الزراعة المائية (العمودية) بعد ان تم توظيف التقنيات الهندسية وقد أبدى هذا النظام تأثيره الفعال.

Authorization

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Student Name	Student	Date

Dedication

We dedicate this research to our beloved homeland, Yemen For every simple farmer who does not benefit from engineering techniques. To those who illuminated the way for us, waited for our success and gave us unlimited support with all the love and friendliness of our families.

Acknowledgement

The beginning of thanks and appreciation to Allah the Almighty who has succeeded us, guided us, helped us, strengthened our determination and endowed us with patience, strength, challenge and love to complete this research and made it a science to benefit from, God willing. We offer the most beautiful words of thanks and gratitude from hearts overflowing with love, respect and appreciation, our most beautiful and most honorable greetings to our esteemed doctor, our moral father, and the father of all our batch, Dr. Radwan Al-Budhaiji. He has all our thanks and gratitude for all the advice, guidance and assistance he provided in our steps in this project. We also extend our sincere thanks, and gratitude to those who provided a helping hand, whether in terms of expertise, knowledge or advice. We also extend our thanks to our distinguished doctors in our educational journey, Dr. Farouk Al Fuhaidi, and everyone who studied us and shared his scientific and practical experiences with us, for everything they provided to us throughout the period of our studies.

Supervisor Certification

We certify that the preparation of this project entitled

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Prepared by

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Was made under my supervision at Mechatronics Engineering department in partial fulfillment to the requirements of /Bachelor Degree in MECHATRONICS ENGINEERING

Supervisor Name

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Department Head

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Chapter 1

Introduction

1.1.General Introduction:

As it is known, traditional agriculture depends mainly on climatic conditions such humidity and temperature

It also depends on the duration of solar lighting directed at the plant, it is known that sunlight is short in winter and vice versa in summer. All of these factors, in addition to the availability of fertile soil in some areas and its lack in other areas, affect the sustainability of agricultural production. As well as the dependence of many areas on rain and other areas on pumping groundwater and the weakness of qualified agricultural staff as a result of the varying and erroneous use of agricultural products such as improved seeds fertilizers and pesticides with pesticides with pesticides. The passage of time has led to problems with soiling, and the high production costs resulting from the high costs of labor, supplies, agricultural machinery and oil derivatives needed to operate them have led to the deterioration of agriculture and agricultural production over the years. With the continuous urban sprawl and the shrinking of agricultural areas and the emergence of soil problems and the volatility of climatic conditions led to the reluctance of traditional agriculture and the search for modern farming mechanisms to keep pace with all these variables and as a result of continuous scientific research and the pursuit of food security with the increase of the population, the researchers reached the mechanism of contemporary agriculture that we see today, namely hydroponics and there are three main types as follows:

1.1.1. Aquaponic:

Aquaponic is a combination of aquaculture, which is growing fish and other aquatic animals, and hydroponics which is growing plants without soil. Aquaponic uses these two in a symbiotic combination in which plants are fed the aquatic animals discharge or waste. In return, the vegetables clean the water that goes back to the fish. Along with the fish and their waste, microbes play an important role to the nutrition of the plants [1].

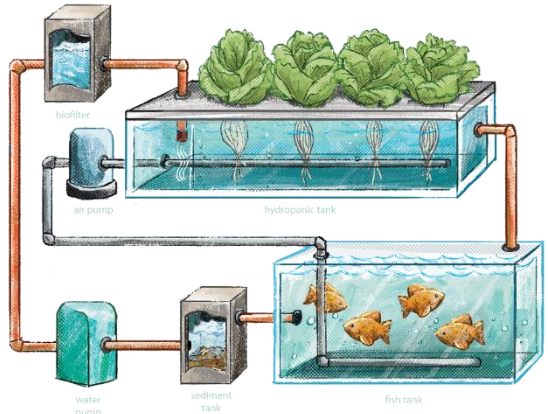


Figure 1.1: Aquaponic System.

1.1.2. Hydroponic:

Agriculture without soil is intended to grow plants in agricultural settings where the soil is not a component, and is fed using special nutritious solutions containing nutrients for plant growth, and is intended to develop plants in the middle of (inert) such as perlite, volcanic apples and rock wool that are suitable for their growth, whether in homes, offices, lounges, entrances, etc., or outside in balconies, roof gardens and exposed spaces. It is a sophisticated method of agriculture that helps to eliminate problems related to low soil fertility, inadequate plant growth, harsh climatic conditions, lack of water resources and other problems facing regular agriculture. The results of experiments and studies have shown that this method exceeds this method in many respects, giving abundant production and helping to provide a large amount of irrigation water up to 70-80% of the water consumed in regular agriculture, in addition to eliminating the various processes required by regular agriculture, such as soil preparation, the addition of organic fertilizers and the agricultural cycle, as well as helping to exploit non-arable land and save the cost in the labour force in addition to producing crops in the off-season. Since plants differ in their needs for these elements and for different environmental factors, it is necessary to find different species and many solutions each with its own characteristics that suit certain types of crops and under certain environmental conditions [1].

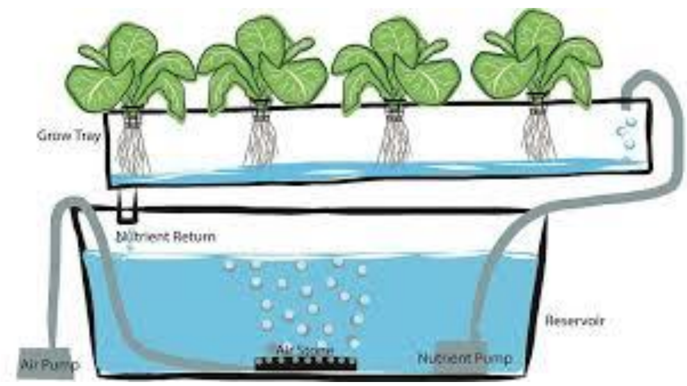


Figure 1.2: Hydroponic System.

1.1.3. Aeroponic:

As for the aeroponic it depends on the same idea, but instead of irrigation with water, the irrigation is with water spray, so that the nutritional solution reaches the plant faster [1].

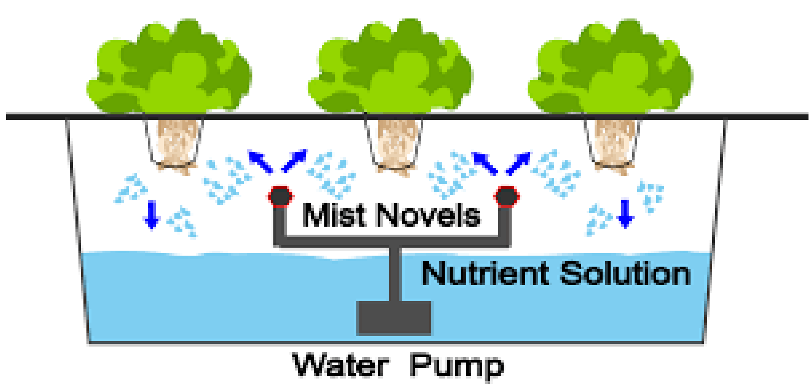


Figure 1.3: Aeroponic System.

1.1.4. Vertical Aeroponic System:

It is a type of aeroponic agriculture, but vertically **(This type what we will use in this project)**.

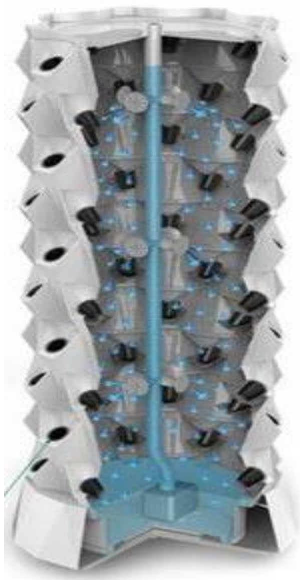


Figure 1.4: Vertical Aeroponic System.

With all the types of modern agriculture mentioned previously, the problem of climate instability and annual seasons remains, which makes the environment unsuitable at certain times of the year here modern science has developed the technique of indoor cultivation.

Figure 1.5: Indoor Agriculture System.

1.2.Problem Statement:

As we mentioned previously about modern agriculture and its role in solving several problems in traditional agriculture, such as irrigation problems, water consumption, and reducing the use of insect control, and through our research and field visits, we found that there are still other problems facing modern hydroponic agriculture, which are:

1- **Change in weather and temperatures.**
2- **Change in air humidity.**
3- **Change in the duration of sunlight according to the seasons of the year.**
4- **Randomness in providing spaces (this depends on the type of plant grown).**
5- **Non-automated control systems (such as mixing agricultural solutions and fertilizers).**

All of these problems lead to weak agricultural sustainability.

Figures 1.6: Picture from the field visits.

1.3.Possible Solution:

Through describing the problems and research, we arrived at a solution to some problems:

1- Using vertical farming technology to save agricultural space.

2- Injection system (a system for checking and mixing agricultural solutions and fertilizers).

3- The environmental system (the system that provides climatic conditions - such as temperature and humidity - suitable for agriculture).

4- Providing alternatives to sunlight (LED lights with a color and rays suitable for indoor agriculture).

5- Use an irrigation system to save water.

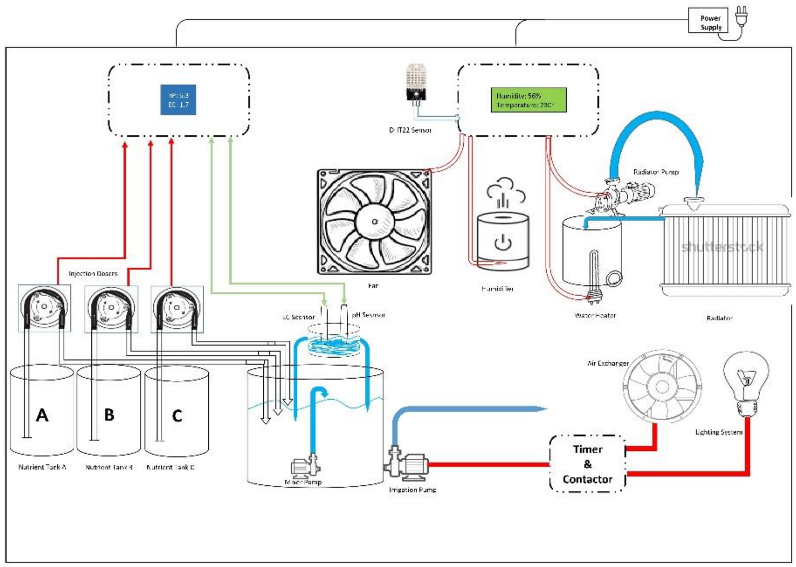
Through the mentioned solutions, we can achieve agricultural sustainability

1.4.Motivation and Contributions:

1. Achieving agricultural sustainability, which ensures greater productivity, a better economy, and greater returns.
2. Saving huge areas and using them to cultivate 75 percent larger quantities, which achieves greater productivity throughout the year.
3. Reducing consumption of large quantities of water and saving water by 80 percent.
4. Providing healthy and safe products to the consumer by reducing the use of harmful pesticides and fertilizers, and of high quality through appropriate nutrition and environmental conditions.
5. Allowing agriculture in any land and under any environmental conditions.

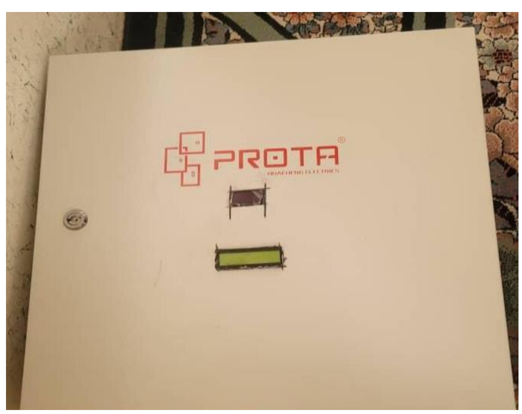
1.5. Aims and Objectives:

1. Automation of the agricultural system.



Figures 1.7: Architecture of an automated agricultural system.

2. Ability to cultivate throughout the year.
3. Providing the smart and professional agricultural system.
4. Achieving flexibility in the system (in terms of environmental parameters, fertilizer parameters, and ease of system maintenance, disassembly, and installation).



Figures 1.8: Flexibility of system.

Chapter 2

Literature Review

2.1.Literature Review:

REF	A Name of the article	description	Protocols	Controller	Sensor
[2]	Design and Implementation of a Hydroponic Strawberry.	In this paper, we design and implement an integrated system that monitors strawberry hydroponic environmental data and determines when to harvest with the concept of IoT-Edge-AI-Cloud.	the IoT-Edge module.	Arduino Mega 2560.	Light intensity sensor. pH sensor. Dissolved oxygen sensor. Ultraviolet sensor. TDS Sensor. Temperature/Humidity/Pressure/ Altitude. Water temperature sensor. CO2 sensor.
[3]	Smart Hydroponic Greenhouse.	Sensing, monitoring and control the micro-climate measurements and environmental conditions of greenhouse prototype to create a smart hydroponic greenhouse for maximizing the food production as well as minimizing the ecological footprint under the climate change impacts, Coved 19 crisis, and natural resources shortages.	NODE MCU Esp 8266.	Arduino Mega 2560.	DHT 22 sensor. luminsoity sensor. TDS sensor. PH sensor. Waterproof temperature Sensor. Float switch sensor.
[4]	Low-Cost Monitoring System for Hydroponic Urban Vertical Farms.	in this paper is a step toward filling this knowledge and technological gap, as it enables collection of sensor data related to water and air temperature, water level, humidity, pressure, light intensity, pH and electric conductivity without requiring any human intervention.	MySQL database.	Raspberry Pi 3 model B.	EC sensor. pH sensor. water temperature. water level sensor. light sensor.

[5]	Applied Internet of Thing for Smart Hydroponic Farming Ecosystem (HFE).	This paper will propose a Hydroponic Farming Ecosystem (HFE) that uses IoT devices to monitor humidity, nutrient solution temperature, air temperature, PH and Electrical Conductivity (EC).	Wi-Fi Shield was used the MQTT Broker.	Arduino UNO.	DHT 22 sensor. PH sensor. EC sensor. water temperature. water Flow sensor. Solenoid Valve.
[6]	CPS/IoT Ecosystem: Indoor Vertical Farming System.	In this paper we explore infrastructural requirements necessary to build modular indoor vertical farming system.	GATT protocol.	Raspberry Pi Model 3 B.	PH sensor. EC sensor. humidity sensor. water level sensor. humidity sensor.
[7]	IoT based hydroponics system using Deep Neural Networks.	This work proposes to develop an intelligent IoT based hydroponic system by employing Deep Neural Networks which is first of its kind.	using UART.	Raspberry Pi Model 3.	DHT11 sensor. Water Level Sensor. Photo resistor or LDR. The LED Bulb. light intensity sensor. PH sensor. water level sensor.
[8]	Architecture design of monitoring and controlling of IoT-based aquaponics system powered by solar energy.	The remainder of this paper is structured as follows. Some related works are summarized in section 2. Our proposed architecture and implementation of the prototype are presented in section 3. And finally the last section consists to present the conclusion and perspectives of our work.	ESP8266 use MQTT protocol to connect to the Cloud.	NodeMCU microcontroller.	Solar Panel. PH Sensor. Sunlight Sensor. Water-level Sensor. Water Temperature Sensor. EC Sensor. Soil Moisture Sensor. TDS Sensor. CO2, Temperature and Humidity Sensor. Ion Sensor for Ammonia, Nitrate and Nitrite.

[9]	Design, Construction and Testing of IoT Based Automated Indoor Vertical Hydroponics Farming Test-Bed in Qatar.	In this paper all the reading of the sensors such as: pH, EC, water level, humidity, and temperatures sensors along with the power consumptions of the system were sent to web server, through a Wi-Fi-module, ESP8266.	ESP 8266Wi-Fi module.	Arduino Mega 2560.	EC and pH Sensor. Water Flow Sensors. Water level Sensor. Dosing Pump. Water flow sensor. Humidity and temperature sensor. RTC Circuit.

2.2.Aeroponic System Considerations:

2.2.1. Closed room and Internal Structure of The System:

A closed room is an indoor space designed for plant growth to protect it from external environmental and climatic conditions and provide suitable conditions for cultivation. Therefore, since the main focus of a vertical farm is to provide nutritional growth, closed rooms become essential for this type of project. There are many aspects to consider when designing a closed room space [2] [3].

2.2.1.1. Materials:

Greenhouses have existed since the 17th century, when they were built out of brick and timber and did not have much window space. However, through the centuries, as materials became less expensive, the availability of different types of heating evolved and the advances in science and technology, its original design evolved. Today, one of the most important elements of a greenhouse space is its glazing system. Glazing allows day light to enter the spaces, as well as permits solar heat into the structure however, in this project, the glass system will not be used to enter daylight. Rather, we will use a closed opaque system to prevent sunlight from penetrating the closed room. An insulating material must be used to prevent external environmental conditions from affecting internal conditions. This material not only achieves good opacity and insulation function, but is also very durable; It is non-flammable and provides very low expansion or contraction with changing temperatures. Also with technological advances, new types of insulators have been developed with additional layers or layers that improve insulation and reduce heat loss. However, there are other types of insulation materials currently available. One of them is polyurethane, a rigid foam insulation material. This material usually used in central cooling roomsThe walls of cooling rooms and doors contain this material. Polyurethane foam (including foam rubber) is sometimes made using small amounts of blowing agents to give less dense foam, better cushioning/energy absorption or thermal insulation. In addition to darkening the room with this thermal insulator, lighting must be taken into consideration to achieve the conditions for plant growth. Therefore, it is important to choose the appropriate lighting that will replace sunlight and ensure plant growth. In summary, the wall of the closed room will be made of polyurethane insulating material, and the lighting will be detailed in the following item.

2.2.1.2. Lighting:

Light is an essential element in agriculture (in general) and indoor farming (in particular). Most plants need light for photosynthesis to occur, allowing them to grow. Therefore, when the closed room space is designed, it is very important to take into account lighting time that plants need and any appropriate lights needed to ensure sufficient growth of the plants in the closed room area [4].

2.2.1.2.1. Types of Lighting for Indoor Farming:

2.2.1.2.1.1. Day Lighting:

Day lighting involves using naturally available sunlight to compensate for artificial lighting and energy consumption. In the case of a greenhouse, it not only helps to reduce the energy usage, but is also needed by the plants in order to grow. Therefore, to guarantee the maximum available sunlight in this space there are several aspects that need to be taken into account. The first one is the location of the greenhouse. This space should not only be located toward the exterior of the building, but its orientation will also influence the presence of day light in the space. The sunlight is easiest to control on the north and south facades. During the summer, most of the solar gain will be provided by the east and west, meanwhile in the winter, when the solar gain is needed at its most, its majority falls on the south end (Nicolow, 2004). Therefore, in the northern hemisphere, the best orientation is south, even though southeast and southwest are also acceptable (Biehle, 2006). Another important aspect needed to harvest as much sunlight as possible is to understand its path. Each site has a precise location of the sun at a given time, which helps understand the areas where more light can be gained (Nicolow, 2004). This analysis can also assist in determining the areas where too much sun or glare might cause a problem. Trying to gain as much daylight as possible can increase the cooling load and affect the growth of sensitive plants, leading to the need of shading in some cases. Some of the options used are aluminum slats or mesh, ultraviolet resistant fabric or typical window shades. Also, there are motorized shades that function with daylight sensors to determine the light present in the room and the need for shades (Biehle, 2006)[5].

2.2.1.2.1.2. Fluorescent lighting:

is a low-pressure mercury-vapor gas-discharge lamp that uses fluorescence to produce visible light.

Figures 2.1: Fluorescent lighting Overview.

2.2.1.2.1.3. Full Spectrum Lighting:

Blue Lighting:

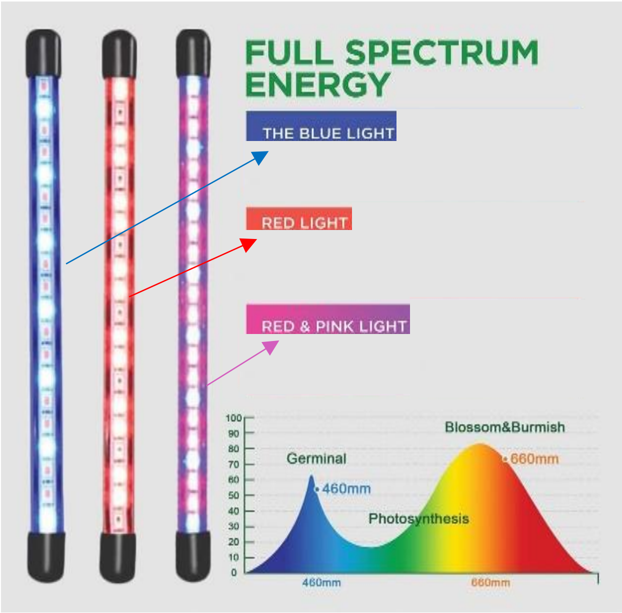
Ensure plans take in more energy through the synthesis of chlorophyll to help in germination.

Red lighting:

Contributes to effective germination, flowering and enhances photosynthesis for better results.

Red & Pink Lighting:

Supplement the lack of natural sunlight for indoor plants improve the health of plants.



Figures 2.2: Full spectrum lighting Overview

2.2.1.3. Structure:

2.2.1.3.1. Building:

Since indoor cultivation takes place in closed rooms, we designed a special room to carry out the experiment. The room was designed in the form of a 3^3 meter cube.

H = 3 m D = 3 m W = 3 m

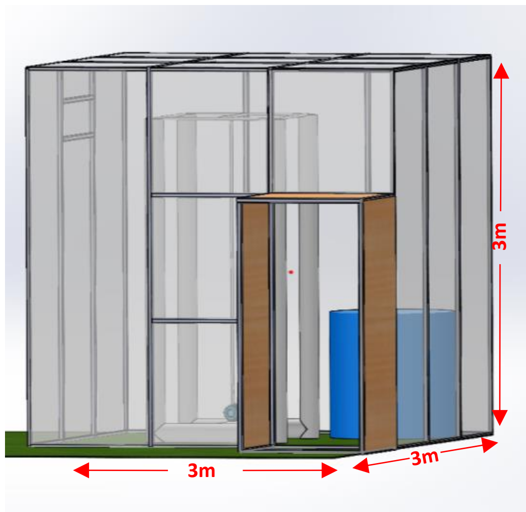


Figure 2.3: 3^3 m cubic room.

2.2.1.3.2. Towers:

There is a variety of vertical shapes for indoor farming construction, the most famous of them is the one shown below that called towers(as we mentioned by vertical aeroponic system) because it is characterized by the exploitation of a small area and can accommodate a large number of plants, which is the type used in this research [6].
We will use PVC pipes to implement that.

Figure 2.4: PVC Pipes.

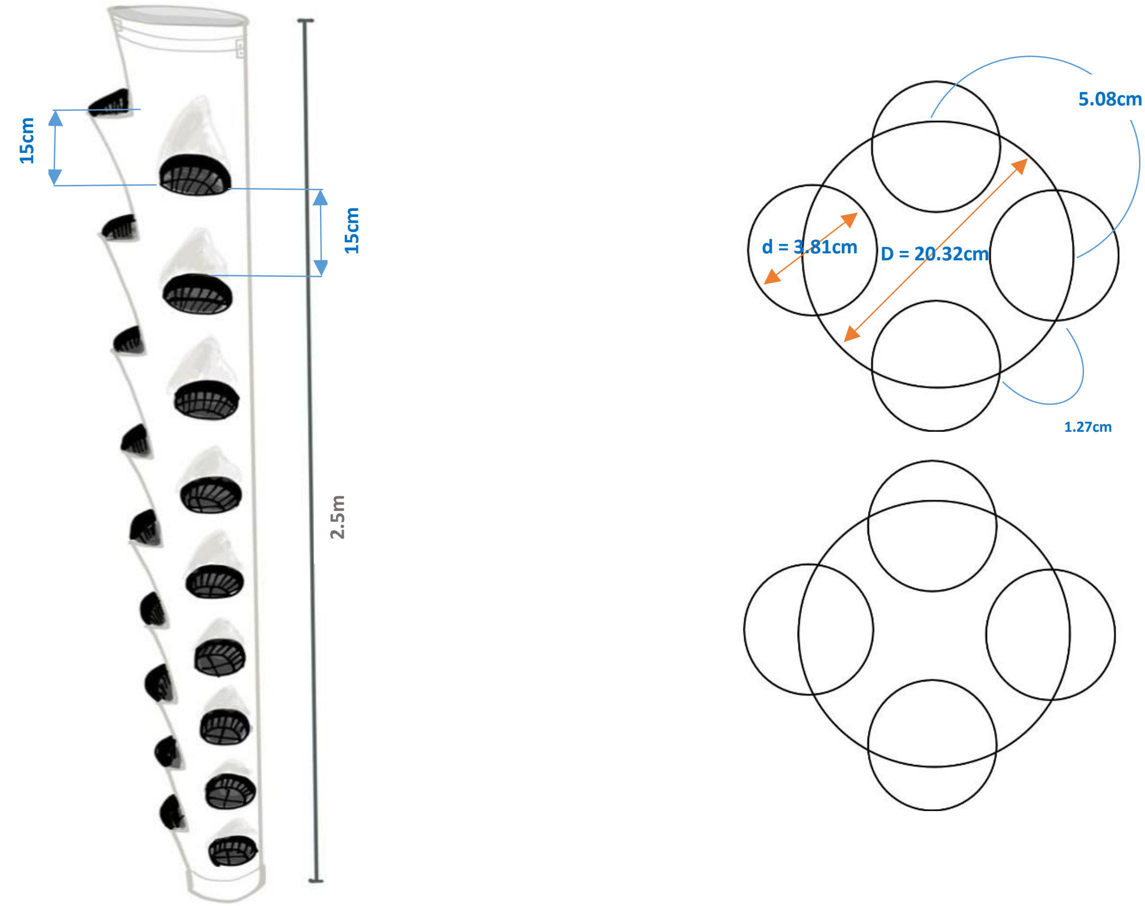


Figure 2.5: Towers Design.

Figure 2.6: Views of multiple aspects of tower design.

2.2.2. Common Nutrients and Plant Types:

When considering the nutrients required to grow different types of plants, it is important to realize that each plant variety is unique. As such, each may require a different combination of nutrients, different concentrations of nutrients, or supplied in different stages in the plant's life cycle. However, there are some nutrients that are fundamental to plant growth, meaning that they are found in the requirements of most plants across many varieties. In our research we found that of these nutrients, there are three different categories: macronutrients, secondary macronutrients, and micronutrients. A summary of the different nutrients and an estimation of the range of their presence in a plant is available in Table 2.1. Macronutrients owe their name to the fact that they are the most fundamental nutrients for plant growth and that they also are absorbed at a higher rate than other nutrients that a specific plant need. While the exact concentration of each macronutrient necessary for a specific plant may differ from other varieties, or even change during that plant's life cycle, the three macronutrients remain the same. Nitrogen is the first of these nutrients and is arguably the most important of them all. Nitrogen is used to create amino acids, which are necessary for the development of proteins. In addition to amino acids, nitrogen is also used in the creation of enzymes as well as an important component of chlorophyll. When plants are nitrogen deficient, they often suffer poor growth and may even gain a purple color on the stems and on the underside of the leaves [7]. The next macronutrient is phosphorus, which is almost as important as nitrogen. Phosphorus is often found in the composition of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). While these more than demonstrate the importance of phosphorus in plant growth, phosphorus is also incredibly important for the transfer of energy within a cell. Phosphorus deficiency in a plant can diagnosed by the appearance of an intense either green or red coloration of the leaves. It may also result in plant leaves appearing very denatured, or a purple coloring similar to nitrogen deficiency. However, phosphorus deficiency is often much more difficult to diagnose than nitrogen deficiency, with symptoms appearing only in extreme cases [8]. The final macronutrient is potassium. Potassium is slightly less important than nitrogen and phosphorus, however, it still plays an instrumental role in healthy leaves and plant growth. Potassium is involved in the creation of carbohydrates and proteins, it also helps to control the moisture within a plant, helping the plant survive drought. Potassium also makes fruits more colorful and improves their shape. Potassium deficiency may lead to wilting, increased damage from drought, and lesser resistance to cold and hot environments. Secondary macronutrients are the next group of nutrients considered necessary for plant growth. They are required in moderate amounts, less than macronutrients but still more than micronutrients. This category is comprised of just three different nutrients. The first of these three is sulfur, which is primarily used in the creation of chloroplasts. As such, sulfur is also necessary for photosynthesis. Sulfur deficiency is often noticed in newer plant tissues first with its symptoms being stunted growth and the yellowing of a plant's leaves. The next secondary macronutrient is calcium. Calcium is primarily used to help regulate the transportation of the other nutrients to the plant, help form the cell walls for the plant, and like many of the previous nutrients, is utilized in photosynthesis. Also, similar to some of the other nutrients already discussed, calcium deficiency will result in yellowing of leaves and stunted growth. However, unlike the previous nutrients, the stunted plant growth primarily affects the roots underneath the ground. The last of this category of secondary macronutrients is magnesium. Magnesium is primarily used in the creation of chlorophyll and in the activations of different enzyme reactions. Magnesium deficiency is evidenced by yellowing and begins in older tissues before translating to newer tissues. Micronutrients are the final category of the most common plant nutrients. While micronutrients are still necessary for a healthy plant to grow, they are needed in smaller quantities than macronutrients. This category is comprised of eight different nutrients, the first nutrient to be discussed is boron. In combination with calcium, boron helps to create the cell walls within a plant. In addition, boron is utilized in pollen germination and salt absorption. Boron deficiency is one of the most common among the micronutrients and symptoms involve the same traits common to many of the nutrients already discussed such as stunted growth and physical changes[9].

The next micronutrient we will be discussing is copper which is primarily used I the activation of different enzymes, and is also necessary for photosynthesis. Symptoms of deficiency are similar to many of the symptoms already discussed but are much more difficult to detect. Like the macronutrient nitrogen, iron is necessary for the formation of chlorophyll, though not structurally, as well as the activation of enzymes. Deficiency will lead to interveinal necrosis, and it also should be noted that iron deficiency can be caused by copper deficiency [9][10]. Some final micronutrients and their importance to plant growth include: • Molybdenum: Creation of amino acids and activation of enzymes. • Manganese: Creation of chloroplasts. • Zinc: Utilized in many enzymes and in the transcription of DNA. • Chlorine: Needed for plant osmosis. • Sodium: Creation of amino acids.

Table 2.1: Common Nutrients for Plant Growth.

Element	Ionic forms absorbed by plants	common range (ppm = mg/l)
Nitrogen	Nitrate (NO3-), Ammonium (NH4+)	100-250
Phosphorus	H2PO4-, PO43-, HPO42-	30-50
Potassium	Potassium (K+)	100-300
Calcium	Calcium (Ca2+)	80-140
Magnesium	Magnesium (Mg2+)	30-70
Sulfur	Sulfate (SO42-)	50-120
Iron	Fe2+, Fe3+	1.0-3.0
Copper	Copper (Cu2+)	0.08-0.2
Manganese	Manganese (Mn2+)	0.5-1.0
Zinc	Zinc (Zn2+)	0.3-0.6
Molybdenum	Molybdate (MoO42-)	0.04-0.08
Boron	BO32-, B4O72-	0.2-0.5
Chloride	Chloride (Cl-)	<75
Sodium		<50

2.2.3. Water Pump and Irrigation System Configurations:

The various types of hydroponic systems require varying water pump configurations. In general, all hydroponic systems incorporate a submersible pump of some size and strength depending on the particular water flow needs. The pump is utilized to deliver the water-nutrient solution from the main reservoir and up to the growing chamber(s) and root zones. Submersible pumps are abundantly available on the market in a wide range of strengths at low cost. It is this low-cost factor that has made DIY hydroponic gardening so popular in the recent years. The submersible pumps are simply constructed from mainly an impeller and an electromagnet to spin it and create suction. In any hydroponic system, the pumps and filters need to regularly cleaned to ensure healthy plant growing conditions. Selecting the strength of the submersible pump for a hydroponic system is based on each individual structure's needs. Things such as head height, system volume, flow rate, and maintained depth are just a few important factors that must be taken into consideration when the strength of a pump is determined. Generally, though, the main factors to determine the strength needed are the head height, system volume, and flow rate. The strength of a pump is determined in gallons per hour (GPH). A pump's GPH and its cost are directly correlated. Depending on the type of system, the minimum pump strength is determined by dividing the system reservoir volume by the amount of time needed to circulate the entire system's volume of water (in hours). This system volume circulation time varies per type of hydroponic system A good rule of thumb is to choose a pump that has at least twice the minimum GPH that a system needs. The flow can then be adjusted by installing restrictive valves off of the main pump outlet to reduce the flow down to the desired level. The main argument for this is that a pump can always be weakened, but never strengthened, so designers should always resort to redundancy. Head height is the last important factor to consider when determining the minimum pump strength. Head height is defined as the vertical distance between the water line in the reservoir and the system's delivery outlet. Most pump manufacturers include a head height flow-chart that describes what the GPH rates are for the pump at several different head heights. This piece of information is crucial for establishing the correct flow rate throughout the hydroponic system. The different system configuration all require different strength pumps to achieve their respective nutrient solution flow rates. For this project, each design configuration is considered to observe the importance of water flow in hydroponic systems. In a flood and drain system, the total volume of all of the growth containers needs to be obtained. The head height for the system and the flooding time needs to be determined as well. These three factors typically result in the need for a stronger pump because the flooding time needs to be rather short in this type of system. Drip systems are rather simple in concept but the forms to construct them vary in numerous ways. The same two factors are involved, water volume and head height. The GPH is not as important though, as the system simply soaks the root system enough to last for a period of time, and the control timer can be easily adjusted for accommodations. NFT systems take into consideration the same factors as mentioned before as well as the angle of each tube to determine the flow rate. The pump just needs to be able to keep up with how fast the water is flowing down the angle of the growth channels. Typically, NFT pumps are weaker (and cheaper) because the head height and GPH are kept lower than other systems. Lastly, Aeroponic systems require stronger pumps in direct correlation with the number of sprinkler heads installed. The more sprinkler heads involved, the higher a GPH pump is needed to maintain high psi to achieve an ideal mist of the nutrient solution. The water flow design (Irrigation System) for a hydroponic system varies greatly depending on the overall structural design of the system. The different designs require significantly different water flows. For example, an aeroponic system requires a water flow through the use of fine misting sprinkler heads placed near the seedling. In contrast, a nutrient film technique (NFT) system requires an ever-constant flow of water flowing at a shallow depth inside the system plumbing. The water flow is essential to the type of hydroponic system that is implemented.The water flow technique chosen helps to determine several significant factors that go into configuring the water flow rate and water level.

Being that a hydroponic system's growth success is largely related to the absorption of nutrients through the water flow, the importance of water flow is even more apparent because the plant growth and nutrient absorption are correlated with the water flow efficiency.

In a NFT system, the water and nutrients are constantly flowing throughout the system. The water is pumped to growth tubes, flows down, and exits the tubes at another end. The water is recycled in a main water reservoir where nutrients and oxygen are added again. The rate at which water flows through a NFT system is generally recommended to be about one liter (one quarter gallon) per minute per growth channel. The main feature of NFT is the shallow “film” of water maintained throughout the growth tubes. Generally, the water film for most NFT systems tends to be about 0.1 inches deep. This allows the plant root systems to be constantly absorbing oxygen and nutrient rich water from the film while also having plentiful access to moist air inside the growth tube. Since the quantity of water in the system is rather shallow, the overall volume of the system is able to be lower in comparison to other systems. A lower water level is recommended because it also prevents the water from damming inside the main growth pipes where the root systems can become rather large. The flow of water and nutrients is generated not only from a main water pump, but also from a gradual slope in the implementation of the piping. Many sources highly recommend this strategy over relying on the water pump alone to control the flow. This sloping of the main growth pipes allows for a finite control of the water flow. It is also beneficial to incorporate a structural design that allows for the ability to adjust the slope of the growth channels. The thinness of the water film is very important and as the root systems grow larger, the channel’s slope will require adjustments to maintain the correct water flow rate. Plant roots also require access to abundant oxygen in addition to the water and nutrient solution. This oxygen is also critical to promote healthy and growing plants. In order to provide this in a hydroponic system, there must be some form of dissolved oxygen (DO) reaching the plant roots. Most NFT systems tend to require very saturated DO levels in order to yield abundant plant growth. The ideal DO level for an NFT system is around 40 ppm. In comparison, the DO levels of tap water tend to be about 5-7 ppm. This super saturation is necessary in a NFT system because the amount of water in contact with roots is kept quite low. An air stone is the most viable option for substantially increasing the DO level of water in a hydroponic system. An air stone can be easily used to produce bubbles of oxygen in the main water reservoir. Oxygen then diffuses into the water as the bubbles rise up through the water in the reservoir, and therefore saturate the water with oxygen. The size of bubbles that the air stone produces is also an important factor that can lead to an even higher yield of DO. An air stone producing smaller bubbles will yield more bubble surface area against the water than larger bubbles with the same total amount of air. The increase in surface area of air against the water will increase the capacity to raise the DO levels of the water [10][11][12][13].

2.2.4. Temperature and Humidity:

An important factor for hydroponics that we are taking into consideration for our design is the temperature of both the air conditions and water-nutrient solution. This variable is very critical to our design decisions, as maintaining the proper temperature conditions can help to promote the best plant growth conditions. Maintaining the ideal temperatures can help to repel bugs, algae growth, plant disease, and fungus growth. All of these symptoms can be fatal conditions to the life of a typical plant. Our project will stress the significance of temperature conditions to the user of the system. It can also be pointed out that temperature and humidity are important for the growth and life of the plant if the external environmental conditions are not suitable for the growth of the plant, which may lead to the end of the plant's life. Our sensor measurements will help to provide accurate monitoring of the temperature conditions for the user. In general, the proper temperature for most plants is about 18-26 degrees Celsius. This range is a broad range and covers most plants. Plant types can be classified into two different classes, warm season crops and cool season crops.

It is possible to grow these types of plants together, but in general it is recommended to grow the same type to yield the best results. Warm season plant temperature conditions consist of a daytime temperature range of 21-26 degrees Celsius and a night-time temperature range of 15-21 degrees Celsius. The absolute max for warm season plants is 90 degrees Celsius. Cool season plants have a daytime temperature range of 15-21 degrees Celsius, a night-time temperature range of 10-15 degrees Celsius, and an absolute minimum of 4.44 degrees Celsius. If the air temperature for a plant is kept to high, then it will go into photorespiration which leads to the destruction of glucose supplies and slows the growth rate. If the air temperature is kept too low, the photosynthesis and respiration process will be suppressed and hinder plant growth and other processes. The general “magic temperature” is 25 degrees Celsius during the daytime for most plants.

Another important factor to mention is the requirement for variations in temperature indoors just as with regular outdoor conditions. This cycle of temperature during a 24-hour period is crucial to a plant’s metabolic process. If a light/heat source for the plants is left running constantly 24/7, it will affect the overall health of the plant and the growth yield will be hindered. Plants require a cool down phase to promote a healthy metabolic process. Temperature conditions should change by about 10 degrees for about 12 hours during a cool down process. In addition to the air temperature, the water-nutrient temperature must also be closely monitored and maintained to promote healthy growth conditions. The temperature of the water does have an effect on the nutrient levels of the solution delivered to the root systems. In fact, as the temperature of the solution increases, the solution’s ability to retain dissolved oxygen decreases. As mentioned in other sections of this paper, dissolved oxygen is a crucial component to the nutrient solution delivered to the root systems. Also, as the air temperature increases, the plant’s respiration rate increases which in turn increases the root system’s need for dissolved oxygen. Therefore, as the air temperature increases, the dissolved oxygen levels must be kept high to properly oxygenate the plant. Fully oxygenated water at a temperature of 20 degrees Celsius has been shown to hold about 9 ppm (parts per million) of dissolved oxygen (DO), while water at 30 degrees Celsius will hold about 7.5 ppm of DO. This level of 9 ppm of DO is the ideal level to promote vigorous plant growth[19]. As about the humidity is the amount of water vapor in the air relative to the maximum amount of water vapor that the air can hold at a certain temperature. If the relative humidity level is 75 percent at 80° F, this means that every kilogram of the air in the respective space contains 75 percent of the maximum amount of water that it can hold for the given temperature. Relative humidity levels affect when and how plants open the stomata on the undersides of their leaves. Plants use stomata to transpire, or “breathe.” When the weather is warm, a plant may close its stomata to reduce water losses. The stomata also act as a cooling mechanism. When ambient conditions are too warm for a plant and it closes its stomata for too long to conserve water, it has no way to move carbon dioxide and oxygen molecules, slowly causing the plant to suffocate on water vapor and its own transpired gases. As plants transpire, the humidity around saturates leaves with water vapor. When relative humidity levels are too high or there is a lack of air circulation, a plant cannot make water evaporate (part of the transpiration process) or draw nutrients from the soil. When this occurs for a prolonged period, a plant eventually rots. When surrounded by warm temperatures in low relative humidity levels, transpiration rates in a plant increase, reducing the need for a grower to fertilize it. And here the following percentages [20]: • 80% - 90%: This is tropical weather that were not likely to encounter in temperate regions. Plants growing in a greenhouse or glasshouse can reach above 80%. For some species it's the best place for them to grow. • 60% - 80%: This is the ideal level which is difficult to maintain indoors, especially for tropical plants. If a plant is sensitive to lower levels than 70%, increasing the humidity will be required. • 40% -60%: You'll find most homes are about this level during the summer which the majority of plants thrive in. Certain plants will need some assistance, which may only be misting. • 10% - 40%: Below 40% is becoming very dry and is likely to be the levels indoors when central and artificial heating is being used. Your cacti and succulents will be fine but the majority of plants are going to have leaf and flower problems.

2.2.5. pH Level:

Plants are very sensitive to the environment they are grown in and it is vital for them to have a standard pH. Maintaining the pH of plants in a hydroponic system is crucial because if the pH levels deviate too high or too low from the recommended range for a specific plant, it can affect the plant's ability to absorb nutrients causing stunted growth or in the worst-case scenario, dying plants. The recommended pH range for plants depends on the following key factors: the type of plant that is present and the nutrients that are to be absorbed. Plants come in many varieties due to their different genotypes and can differ from the size of their leaves to the taste of their fruits. Owing to these differences, all plants will not thrive under the same conditions and so a range is often selected to accommodate these plants. One example of this is the difference in the recommended pH of pumpkin which is 5.0 compared to broccoli which is around 6. The recommended range of pH is normally between 5.5-6.5. Since most plants thrive under neutral conditions the pH usually stays closer to 7. Table 2.2 shows the most suitable plants for a hydroponic system and their corresponding optimal pH levels.

Table 2.2: Common Hydroponic Plant pH Levels.

Type	Plants	Optimal pH
Vegetables	Lettuce	6.0-7.0
	Tomatoes	5.5-7.5
	Radishes	6.0-7.0
	Celery	6.0-7.0
	Cucumbers	5.0-6.0
Fruits	Watermelon	6.0-6.8
	Cantaloupe	6.0-7.5
	Strawberries	5.5-6.5
	Blueberries	4.5-5.5
	Grapes	5.5-7.0
Herbs	Chives	5.0-6.0
	Oregano	6.0-8.0
	Basil	5.5-6.5
	Sage	6.0-6.5
	Rosemary	5.5-6.5

In order to maintain the pH of the water system it is necessary to first be aware of the pH level for the hydroponic system. To do so, the system can be tested using the following methods:

- Liquid kits - Uses a pH sensitive dye, which changes in color when you add to a small sample of the nutrient solution and compare to a color chart.
- Disposable strips - Function similarly to the liquid kits; however, it is the least accurate of the three.
- A digital meter is the most expensive option but is more effective and efficient long term once taken care of properly. It is also the simplest and quickest method, which is helpful

when you test pH once a day or more. The pH meter can be dipped straight into the nutrient solution and will give the exact pH reading shortly after.

The next phase in maintaining pH is to determine whether you need a pH “level up” or a pH “level down”. If the pH is too low (closer to the acidic scale of the pH meter) a pH level up is required to bring it closer to the recommended level. A popular choice for this would be an alkaline substance such as potassium hydroxide. Similarly, if the pH is too high (closer to the alkaline side of the pH scale) a pH level down would be needed to bring it back down to the recommended pH range. A suitable choice for this would be phosphoric acid. Nitric acid is also a popular choice however it is not heavily recommended since it is known to give off toxic fumes when in use. It is important to note that when maintaining pH levels of the nutrient solution, measurements must be a part of the process as this could risk burning out the crops if too much is used or have little to no effect if too little is used.

To ensure proper maintenance of pH level, the following method would be utilized: 1) Measure the required fertilizers then add it to the proposed nutrient solution. This is not an everyday task but when nutrients are being added, ensure that this is the first step since they can severely alter the nutrient solution’s pH. 2) Ensure that the air stone is turned on and the water is properly aerated. 3) Test the solution’s pH using your chosen method. If using a digital meter, make sure to hold it in the water for at least 3 seconds to get a proper reading. 4) Add chemicals to alter the solution’s pH, if necessary. Do not add too much – go slowly. 5) Re-test pH levels. 6) Repeat step 4 if necessary [13][14][15].

2.2.6. Electrical Conductivity:

Electrical conductivity (EC) is the ability of a material or solution to conduct electricity. The EC of a hydroponic system is useful because the nutrient ion in the water carries an electrical charge. This electrical charge can be measured using an electrical conductivity meter. The meter uses an electrical current and two electrodes spaced 1 centimeter apart. The meter then shows the amount of electrical current passing between the two electrodes in terms of electrical conductivity. This electric charge can be used to calculate and estimate the amount of nutrients in the water. This is true because as the concentration of the nutrient salts in the solution increases so too does the electrical conductivity. This is a very important aspect to consider in hydroponics when trying to control the nutrient level of the solution. This information is vital as plants thrive under different pH levels and therefore knowing the pH level of the system allows the system to make necessary adjustments to obtain the desired pH level. However, some limitations stem from the chemical nature of the property being measured. Considering EC is proportional to the amount of salt dissolved in the solution, one would expect that measuring the EC would allow accurate calculation of the amount of nutrient in the solution. This is not true. Even though salts increase the conductivity, each different salt ion has a different specific conductivity and contributes differently to the overall EC. This may result in inaccurate calculations if the solution contains small amounts of an ion that conducts a great deal. The important ions are the ions, which have very large conductivity that helps to determine the pH. Considering these limitations, the EC should always be measured at a specific pH. EC is measured at different pH levels; for example, 4 would be completely different to an EC measured at 7 due to the fact that the ions that determine the pH has a very significant effect on the EC value. More importantly, the conductometer should be calibrated at a known conductivity. Failing to meet this requirement would result in meaningless measurements. With the necessary precautions taken into consideration, the EC will provide information as to whether your solutions have lost nutrients from the growth of the plants or if there has been significant water evaporation, but only if measured at the exact pH levels.

It is good practice the measure the EC when it is prepared and at least three other times throughout the day. If the EC rises too high, water should be added to lower it however if the EC drops below 70 percent of the original value, then a new solution should be prepared[13][14][15].

Table 2.3: Common Hydroponic Plant EC Levels.

Optimal pH & EC

HYDROPONIC VEGETABLES

VEGETABLE	pH	EC	VEGETABLE	pH	EC
ARTICHOKE	6.5-7.5	0.8-1.8	MARROW	6.0	1.8-2.4
ASPARAGUS	6.0-6.8	1.4-1.8	OKRA	6.5	2.0-2.4
BASIL	5.5-6.5	1.0-1.6	ONIONS	6.0-6.7	1.4-1.8
BEAN (COMMON)	6.0	2.0-4.0	PAK CHOI	7.0	1.5-2.0
BEETROOT	6.0-6.5	0.8-5.0	PARSNIP	6.0	1.4-1.8
BOK CHOI	6.0-7.0	1.5-2.5	PEA	6.0-7.0	0.8-1.8
BROAD BEAN	6.0-6.5	1.8-2.2	PEA (SUGAR)	6.0-7.0	0.8-1.8
BROCCOLI	6.0-6.5	2.8-3.5	PEPINO	6.0-6.5	2.0-5.0
BRUSSELL SPROUT	6.5-7.5	2.5-3.0	PEPPERS	5.8-6.3	2.0-3.0
CABBAGE	6.5-7.0	2.5-3.0	PEPPERS (BELL)	6.0-6.5	2.0-3.0
CAPISCUM	6.0-6.5	1.8-2.2	PEPPERS (HOT)	5.0-6.5	3.0-3.5
CARROTS	6.3	1.6-2.0	POTATO	5.0-6.0	2.0-2.5
CAULIFLOWER	6.0-7.0	0.5-2.0	PUMPKIN	5.5-7.5	1.8-2.4
CELERY	6.5	1.8-2.4	RADISH	6.0-7.0	1.6-2.2
CUCUMBER	5.8-6.0	1.7-2.5	SPINACH	6.0-7.0	1.8-2.3
EGGPLANT	5.5-6.5	2.5-3.5	SILVERBEET	6.0-7.0	1.8-2.3
ENDIVE	5.5	2.0-2.4	SWEET CORN	6.0	1.6-2.4
FODDER	6.0	1.8-2.0	SWEET POTATO	5.5-6.0	2.0-2.5
GARLIC	6.0	1.4-1.8	TARO	5.0-5.5	2.5-3.0
KALE	5.5-6.5	1.25-1.5	TOMATO	5.5-6.0	2.0-5.0
LEEK	6.5-7.0	1.4-1.8	TURNIP	6.0-6.5	1.8-2.4
LETTUCE	5.5-6.5	0.8-1.2	ZUCCHINI	6.0	1.8-2.4

These values are general guidelines for hydroponic gardening, and may be slightly different based on your climate and growing conditions.

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Chapter 3

Methodology

This chapter will focus on the construction of the automated system and assembling the sensors and actuators. The closed room with internal structure has been explained.

3.1.Hardware:

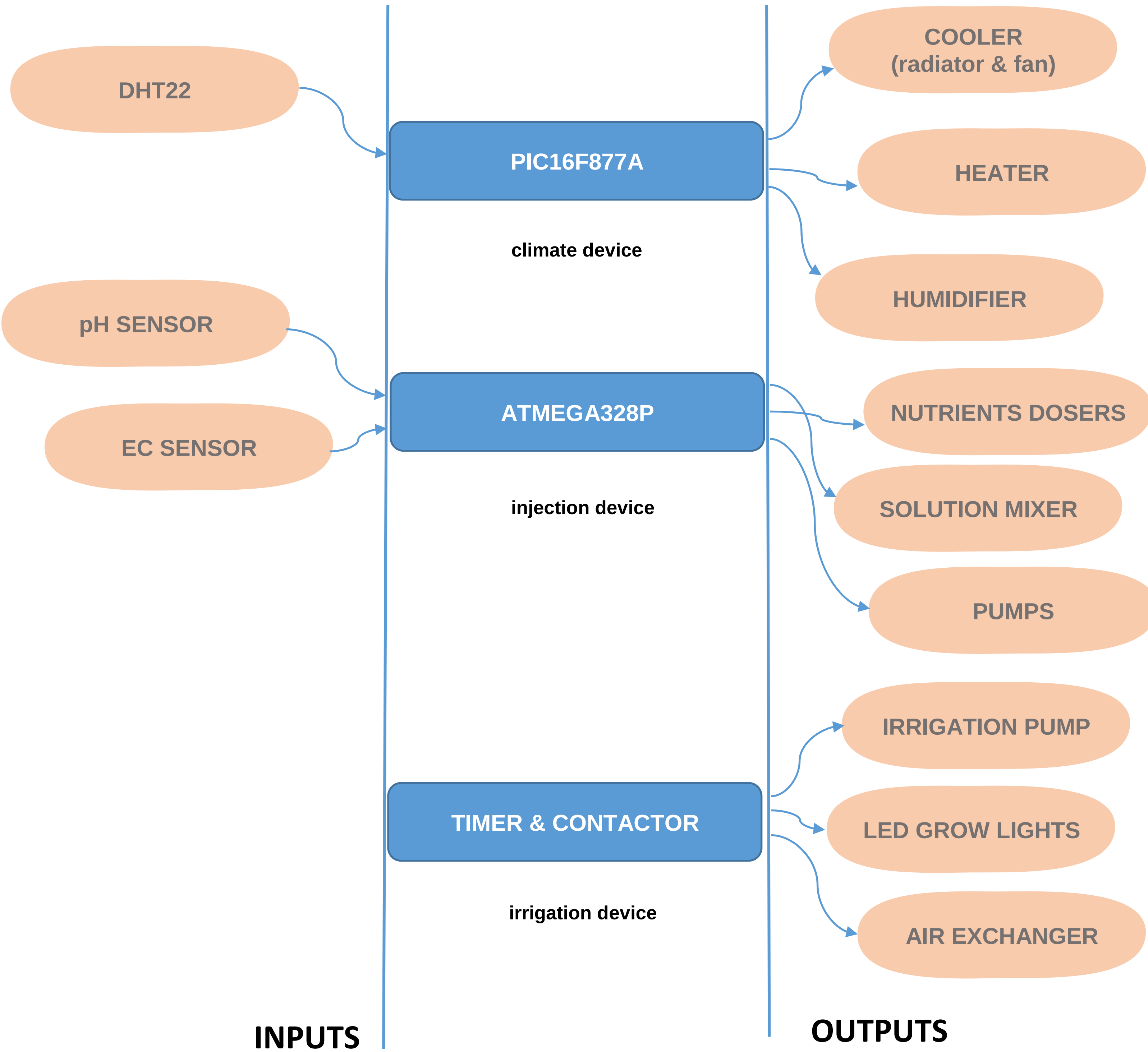

Figure 3.1: Schematic of (CONTROL SYSTEM).

The closed room relies on a number of sensors to give accurate measurements of, for example, water level, pH and EC. With different operators such as pH, nutrient doses, and a water pump, all of this is in the **(injection device)** as we talked about previously, and we have another device **(Climate device)** as we talked previously about temperature and humidity sensors. In addition to the **(irrigation device)** through which irrigation is done. The plant is automated according to a specific schedule. The sensors and actuators used in this project are shown in Figures 12,13 and explained below.

3.1.1. Sensors:

3.1.1.1. pH Sensors:

Figure 14 shows the pH sensor used with model name of pH Sensor Module E-201-C This sensor has an operating voltage of 5V and response time of less than 5 sec. The accuracy is ± 0.1 pH at 25 ºC which makes it ideal for this project as the pH of water is critical and any change will affect the water quality. The measuring temperature ranges from 0 to 80 ºC. Its laboratory-grade probe is made up of a pH glass electrode and a silver chloride silver reference electrode that can be used to measure the pH value of aqueous solution from 0 to 14. When the probe is immersed into water, hydrogen ions in the water exchange for other positively charged ions on the glass bulb and thus an electrochemical potential is created across the bulb. The electronic amplifier in the breakout board detects the difference in electrical potential between the two electrodes generated and amplify the output analog signal, so the pin needs to be connected to the analog pin of microcontroller for analog to digital conversion. A formula is applied to convert the digital millivolt to pH units [16].

Figure 3.2: pH sensor.

3.1.1.2. EC Sensor:

Analog electrical conductivity meter V2 is specially used to measure the electrical conductivity of an aqueous solution, and then to evaluate the water quality, which is often used in water culture, aquaculture, environmental water detection, and other fields. This EC meter product, as an upgraded version of the electrical conductivity meter V1, greatly improves the user experience and data precision. It supports 3 -5V wide voltage input, and is compatible with 5V and 3.3V main control board; the output signal filtered by hardware has low jitters; the excitation source adopts AC signal, witch effectively reduces the polarization effect, improves the precision, and prolongs the life of the probe; the software library uses two-point calibration method, and can automatically identify standard buffer solution, so simple and convenient. And here are other general characteristics; Measurement Accuracy: ±5% F.S, Temperature Range: 0~40°C, Support Detection Range: 0~20ms/cm, Recommended Detection Range: 1~15ms/cm, Output Voltage: 0~3.4V [17]

Figure 3.3: Analog Electrical Conductivity Sensor /Meter V2(K=1).

But due to the lack of sensors in our local market, we had to find an alternative to this sensor. Since the EC sensor can measure liquid ions and salinity (dissolved solids), then we can reverse the process on the TDS sensor (total dissolved solids), and this is by understanding the relationship between the measurement units of the TDS sensor and the measurement units of the EC sensor.

THE RELATIONSHIP:

$$\because \qquad \boldsymbol{TDS = Cf \times \; EC \; => EC = \frac{TDS}{Cf}}$$

Cf: conversion ratio = 700.

And TDS value given from TDS sensor that mean EC value will be output. It is clear from the above that the replacement sensor will be a TDS sensor.

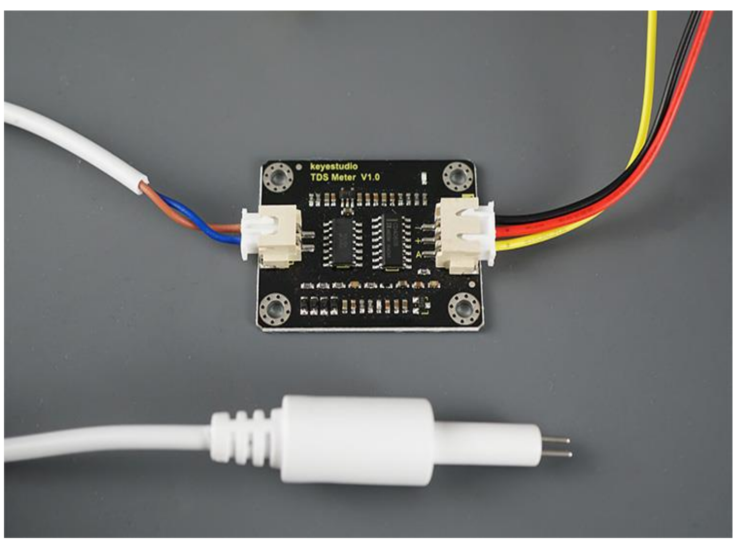

Figure 3.4: TDS (total dissolved solids).

3.1.1.3. DHT22 Sensor:

DHT22 output calibrated digital signal. It utilizes exclusive digital-signal-collecting-technique and humidity sensing technology, assuring its reliability and stability. Its sensing elements is connected with 8-bit single-chip computer. Every sensor of this model is temperature compensated and calibrated in accurate calibration chamber and the calibration-coefficient is saved in type of programme in OTP memory, when the sensor is detecting, it will cite coefficient from memory. Small size & low consumption & long transmission distance(20m) enables DHT22 to be suited in all kinds of harsh application occasions. Single-row packaged with four pins, making the connection very convenient [18].

Table 3.1: General Characteristics of a DHT22.

Model	**DHT22**
Power supply	3.3-6V DC
Output signal	digital signal via single-bus
Sensing element	Polymer capacitor
Operating range	humidity 0-100% RH temperature -40~80Celsius
Accuracy humidity	+-2%RH (Max +-5% RH) temperature <+-0.5Celsius
Resolution or sensitivity	humidity 0.1%RH temperature 0.1Celsius
Repeatability humidity	+-1%RH temperature +-0.2Celsius
Humidity hysteresis	+-0.3%RH
Long-term Stability	+-0.5%RH/year
Sensing period	Average 2s
Interchangeability	fully interchangeable
Dimensions	small size 14*18*5.5mm big size 22*28*5mm

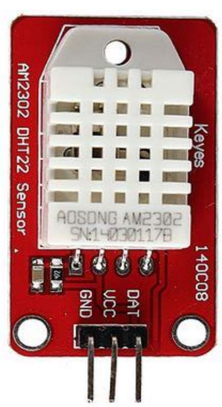

Figure 3.5: DHT22 Sensor.

3.1.2. Actuator:

3.1.2.1. Water Pump:

The water pump used in this project is of the model HYUNDAI HPm100, as shown in figure (3.8). It has the capacity to pump up to 60 liters per minute to a maximum height of 70 meters and power 1hp. The pump runs on 220 V AC and is thereby controlled by timer and a relay. The pump is placed above the water tank that is below the level of draining water returning from the farming towers and pumps to a height of 2.3 meters to farming towers network and it is pumped through a 1/2 inch [19].

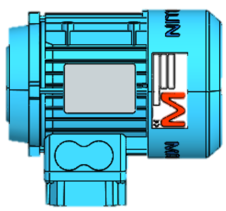

Figure 3.6: Water Pump Design.

Figure 3.7: Water Pump Design.

3.1.2.2. pH And Nutrient Dosers:

We used five of these dosers shown in figure 3.8. One is to add water in case of excess salt in the tank, and the second is to empty the measuring box from water into the tank. Its run on 12v DC, its pump 1.5-2 liter per minute, max lift 3m & max section 2m, and used in water below 80 ºC [20].

The solution doser is used to add nutrients to the mixing tank (water tank), and we have the other 3 dosers for three solutions A, B, C, solution A, B and they are the basis for plant food and they control the reading of the EC sensor, and solution C contains concentrated acid from PH. The first and second pumps pumping two solutions, A, B, separately, into the mixing tank, and they are mixed with water. After that, the measurement is done by the EC sensor to send the reading to the controller, which compares the reading after reading it and converts it from volts to ms/cm and compares it to the allowed range between two values according to the type The plant being cultivated, if the reading is within the lawful range, the solution C is pumped by the third pump to complete the pumping of the solutions, If the reading is not within the permissible range, the first and second pumps are operated again to pump a quantity of solutions A, B into the tank, and so the process is repeated until the required values are reached. The third pump performs the same mechanism as the first and second pumps, except that this pump works to pump C solution, which is a concentrated solution of PH, to the tank that is measured by a PH sensor and transmits the reading to the controller and so on with the same previous mechanism of action.

Figure 3.8: Dosers.

3.1.2.3. Solution Mixer and Raiser:

We used two of these submersible pumps shown in figure 3.9. One is to raise the water to the small solution metering tank and the other is to stir the water in the tank after adding the solutions in it (mixing process). The engine has the characteristics run on a 220-240V AC & 50/60 Hz, the consumes 65W of electricity, and pumps 3500L/H with H.MAX:3m [21].

Figure 3.9: Water pump (mixer and raising).

3.1.2.4. Temperature System:

3.1.2.4.1. Fan:

As for the ventilation fans, we used fans that have a greenhouse fan mechanism, for strong performance and because they have a self-shut-off mechanism to preserve the indoor climate. As for the characteristics, the consumes 360 W of electricity and run on a 12-V DC system and 33A DC[22].

Figure 3.10: Fan.

3.1.2.4.2. Radiator:

We used the same radiator mechanism as greenhouses. Through the radiator, it is controlled whether the incoming air is for cooling or heating, which are called cooling and heating cells.

Figure 3.11: Cooling & Heating Cells.

3.1.2.4.3. Water Heater:

To heat the air in order to warm the closed room (as will be explained in the temperature mechanism section), we relied on an immersion industrial water heater as shown in figure below 3.12, operating at a voltage of 220 AC and with a capacity of 2000 watts.

Figure 3.12: Industrial Immersion Water Heater.

3.1.2.4.4. Temperature Liquide Pump:

This pump is responsible for raising the temperature fluid from the main tank to the radiator, the consumes 20 W of electricity and run on a 9-V DC system, 2.2A DC with 80 psi of pressure (5.5bar) and
3 LPM (liter/minute).

Figure 3.13: Temperature Liquide Pump.

3.1.2.5. Temperature Mechanism:

It is natural for temperatures to change from time to time (day to night) and from season to season, and since the temperature sensor gives values to the microcontroller, the controller must give the command based on the value of the received temperature. If the temperature is higher than what the closed room needs, in this case it must Cooling the room, and vice versa, if the temperature is lower than what is required here, the room must be heated. Here we had to invent a mechanism for heating and cooling in one device to reduce costs (because the temperature mechanism in general requires two devices, one for cooling and the other for heating). Therefore, reliance is placed here on the air entering from the radiator. In this case, for cooling, cold water is pumped into the radiator so that the fan draws in the air, which passes through the radiator and enters the cold air. As for heating, here comes the role of the water heater, as it works for a period of time until the water is completely heated to a temperature Then the pump pumps the hot water into the radiator, and the fan pulls the air to pass through the radiator and the hot air enters.

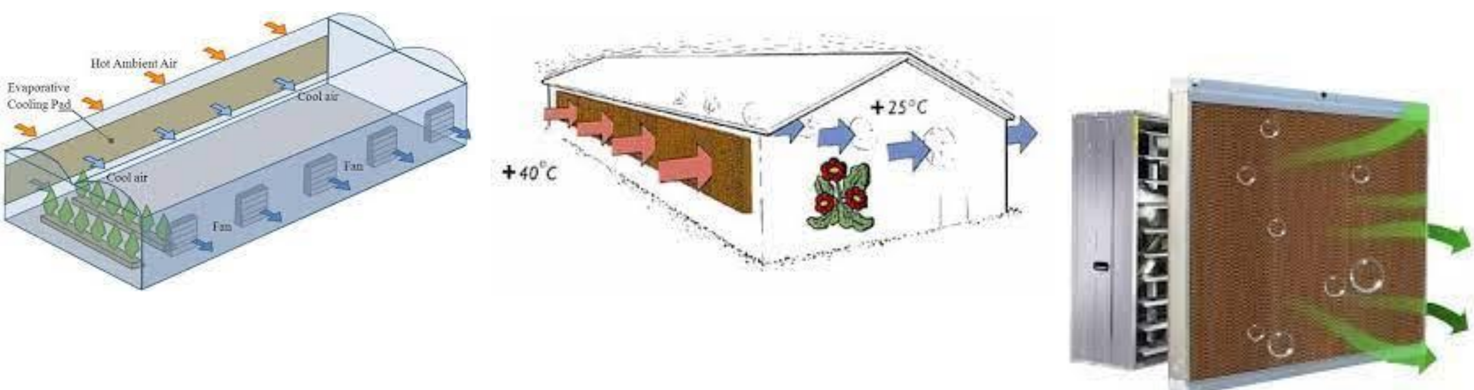

Figure 3.14: Temperature Mechanism.

3.1.2.6. Air Exchanger:

Since the room is closed and almost devoid of air outlets, and the plant needs fresh air for better growth, the indoor air in the room must be purified from time to time, so we designed air exchanger based on international designs and standards for air exchanger.

The mechanism of the air exchanger's work is to draw outside air through a fan, purify it through filters in the middle of the exchanger box, and bring it in, and another fan pulls in the old indoor air.

In addition to the operation of the inner box, the exchanger box has a specific mechanism, which is when the external and internal air collide in the middle box. Here, the heat exchange process occurs, and the effect of the external air temperature on the internal temperature is reduced by approximately 60%.

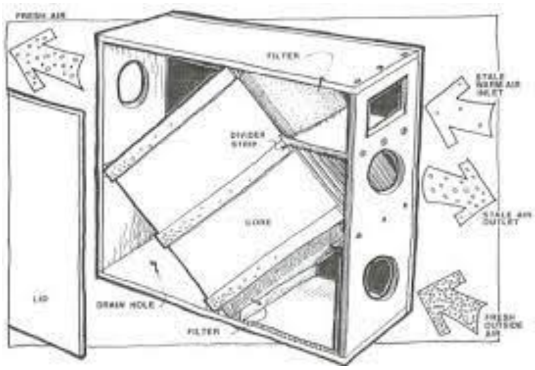

Figure 3.15: Mechanism of Air Exchanger.

Figure 3.16: Internal Design of Air Exchanger.

Figure 3.17: Explain The Function Of The Inner Box.

3.1.2.7. Humidifier:

When temperatures change, there is an effect on the percentage of humidity, and plants have appropriate levels of humidity to help them grow. In the event of a decrease in humidity, the plant may enter a state of frost, which may lead to the death of the plant, or in the event of an increase in humidity, the plant may enter a state of wilting and dampening of the plant, which may It causes the plant to suffer from diseases and rots. Since the humidity in closed places is usually low, we used an air humidifier to humidify the closed room when needed.

The mechanism of the humidifier: is to immerse it in water. The humidifier contains several heads of ultrasonic transducers, emitting very high mechanical frequencies of up to 2 MHz. This frequency produces waves and disturbances in the water, which causes it to break up and turn into fog. Vibration up to 2 MHz is capable of breaking up water into parts with a size of less than 5 microns. Then a small fan is used to blow the mist resulting from the humidifier into the surrounding air.

Figure 3.18: Ultrasonic Heads Humidifier.

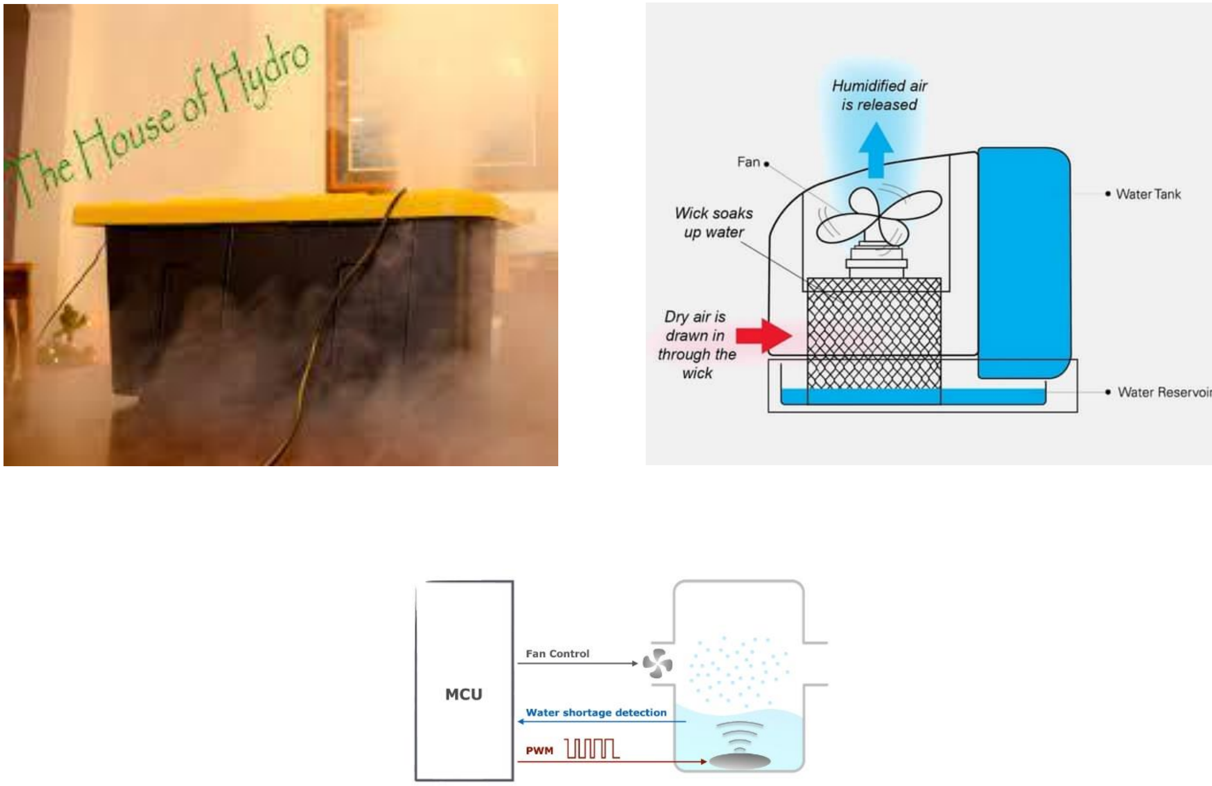

Figure 3.19: Ultrasonic Humidifier Mechanism.

3.1.3. Microcontroller:

3.1.3.1. PIC16F877A Microcontroller:

It was used in this project as a controller for a **(climate device)**. Because they are reliable. Moreover, performance of the PIC is very fast because of using RISC architecture (Reduced instruction set computer). Power consumption is also very less when compared to other micro controllers. When we see in the programmatic point of view interfacing is very easy, also we can connect analog devices directly without any extra circuitry and use them. Programming is also very easy when compared to other microcontrollers [23].

Figure 3.20: PIC16F877A Microcontroller.

3.1.3.2. ATMEGA328P Microcontroller:

It was used in this project as a controller for a **(injection device)**. Because the ATmega328 preprogrammed with a bootloader that allows the user to upload new code to the MCU without the use of an external hardware programmer. And has 8-bit, 28-Pin AVR Microcontroller, manufactured by Microchip, follows RISC Architecture and has a flash-type program memory of 32KB. Power consumption is also very less when compared to other micro controllers. And performance of the PIC is very fast because of using RISC architecture. And when we see in the programmatic point of view interfacing is very easy [24].

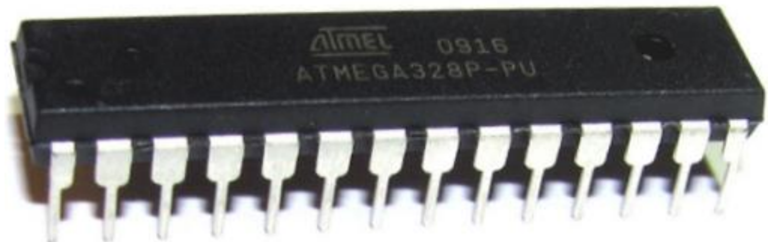

Figure 3.21:ATMEGA 328P.

3.1.3.3. Timer and Contactor:

It was used in this project as a controller for a irrigation water pumping, LED grow lighting and air exchanger fans. Because the plant goes through stages, and each stage needs a different duration and number of irrigation times than the other.

Figure 3.22: Digital Timer.

Figure 3.23: Contactor.

3.2.Software:

The overall behavior of **(climate device)** system is described by a flowchart shown in Figure 3.20.

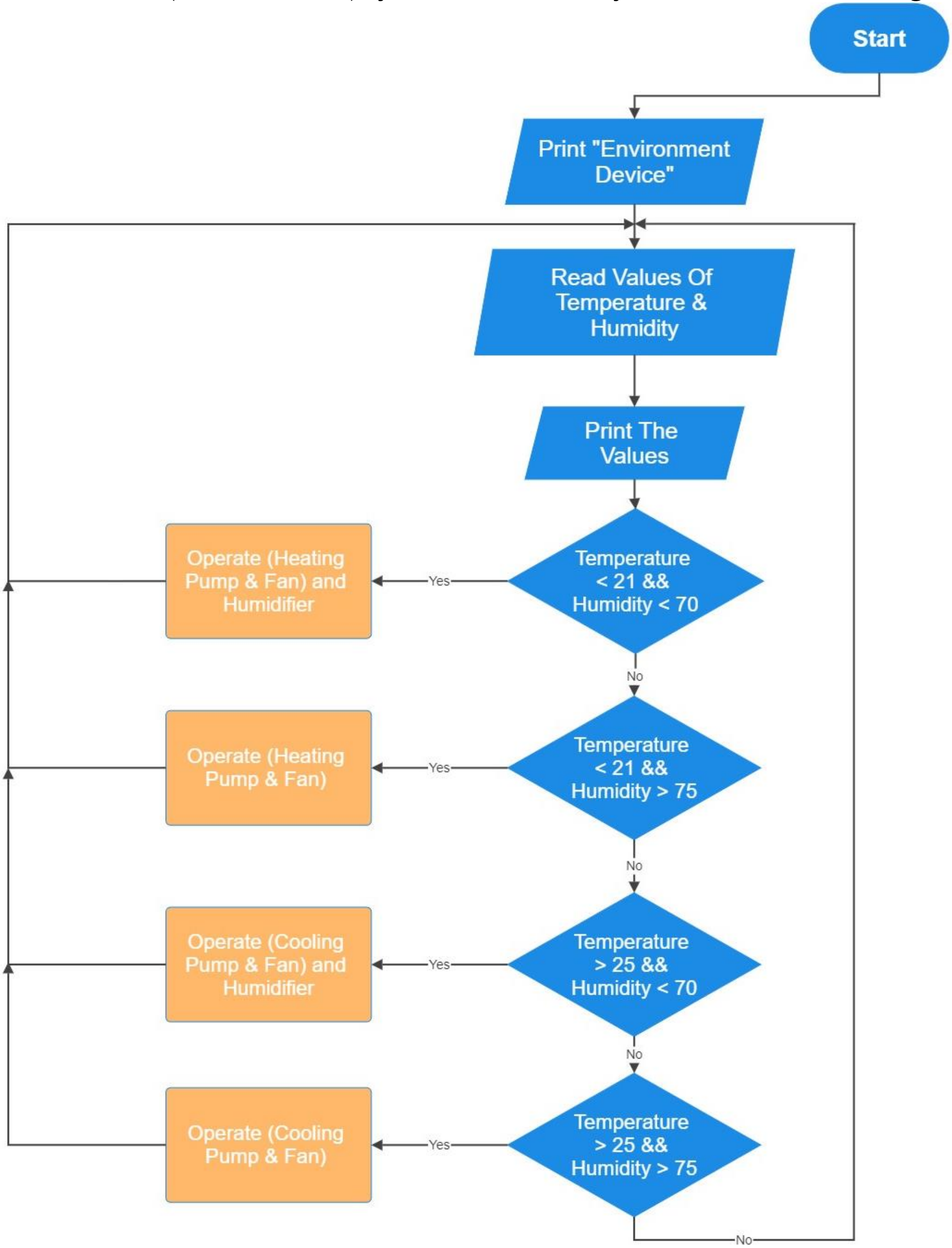

Figure 3.24: Flowchart of (climate device) software.

The overall behavior of **(injection device)** system is described by a flowchart shown in Figure 3.21.

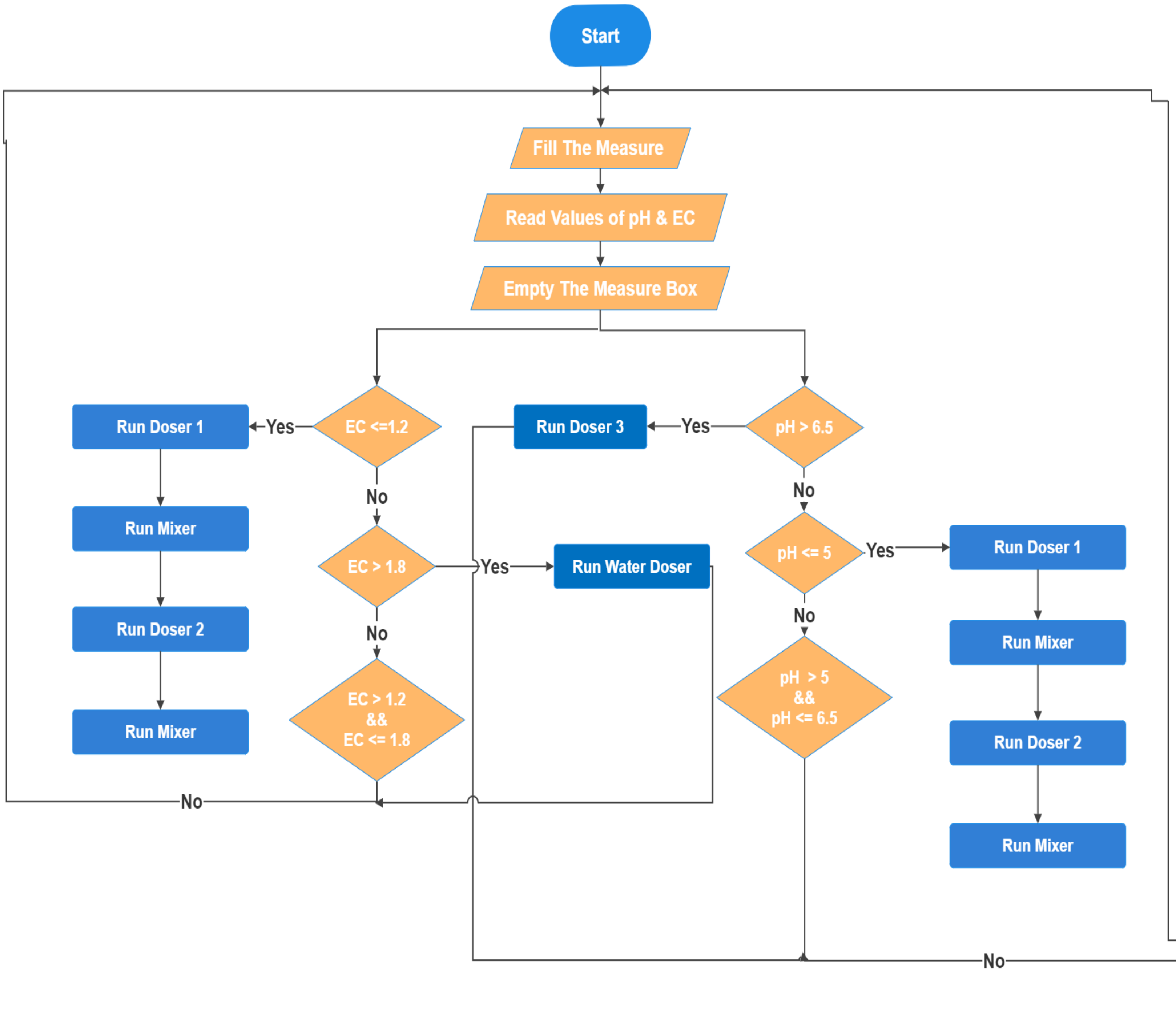

Figure 3.25: Flowchart of (Injection device) software.

Chapter 4

Result & Discussion

4.1. Closed Room and Internal Structure:

Figure 4.1: Side View of The Greenhouse.

Figure 4.2: Front View of The Greenhouse.

Figure 4.3: Internal Structure of The Greenhouse (Farming Towers).

4.1.1. The Result of Internal Structure:

Figure 4.4: Farming Towers.

4.2.EC &PH Sensors Parameters:

Each plant has a specific food and a proportion of solutions that suit it. This is done by mixing the solutions. The pH and IC value that is appropriate for the plant is determined. This means that several solutions and nutrients that the plant needs were mixed until the parameters reached this point by reading the sensors. If we take the strawberry plant as an example (which was experimented on in this project), the pH and EC coefficients for strawberries are:

pH : 5.5 to 6.5.

EC: 1.2 to 1.8 [25].

How are these parameters accessed?

There are 3 main tanks (Tank A , Tank B , Tank C), each tank containing its own solutions:

Table of solutions per Tank 4.1[33].

Tank A	Tank B	Tank C
• Calcium nitrate • ½ of potassium nitrate • Iron chelate • (Nitric acid)	• ½ of potassium nitrate • Potassium sulfate • Monopotassiumphosphate • Magnesium sulfate • Monoammoniumphosphate • Ammonium nitrate • All micronutrients except iron chelate • sulfuric acid or phosphoric acid	•Acid, used to drive down pH (sulfuric, nitric, phosphoric, citric, etc.)

Steps to calculate the nutrient solution:

Each fertilizer salt we use contains two different important elements. This means that if we want to add calcium

For example, we will also add chloride, nitrate, sulfate, etc. depending on the fertilizer source you are using.

We use it. Therefore, a fairly specific order is followed to ensure that we do not add an excess of a nutrient when trying

Reaching the target value for another nutrient.

1. We use calcium chloride (CaCl, Calcium chloride) or potassium chloride (KCl) to add chlorine (Cl).

It should be noted here that it is possible to replace potassium chloride fertilizer with another fertilizer, and the reason for this is due to the content of potassium chloride.

Chlorine in special water to prepare the nutrient solution.

2. We use calcium nitrate as a source of calcium.

3. We use ammonium nitrate (3NO4NH) or monoammonium phosphate (ammonium phosphate-Mono, MAP).

To compensate for the deficiency in ammonium 4NH.

4. We use mono-potassium phosphate (4PO2KH, phosphate potassium-Mono) to compensate for the deficiency in phosphorus.

.(P)

5. We use magnesium sulfate (4MgSO, Magnesium sulfate) to complete the demand for magnesium (Mg) or

Sulfur (S).

6. Add magnesium nitrate (2(3NO(Mg), Magnesium nitrate) (if more magnesium is needed,

Or we replace magnesium sulphate (4MgSO) with magnesium nitrate (2(3NO(Mg)) if a smaller amount is needed.

Sulphate (S).

7. We use potassium sulfate (4SO2K, Potassium sulfate) as a source of sulfate in case the concentration is incomplete.

Sulfate required as magnesium sulphate (4MgSO).

8. Use potassium nitrate (3KNO) to complete the demand for 3NO and K [25].

Table of solutions per Tank 4.2[33].

Element	Strawberry stage 1 ppm	Strawberry stage2 ppm	Strawberry stage3 ppm
N03-N	90	120	190
NH4-N	0	0	0
p	47	47	47
K	144	350	350
Ca	104	160	200
Mg	40	60	60
s	116	116	116
Cl	89	89	89
Fe(EDTA)	2	2	2
Mn	055	055	055
Zn	033	033	033
Cu	005	005	005
B	034	034	034
Mo	005	005	005

For example and referring to the table above:

To prepare 89 ppm of Cl

(KCl: 47.6% Cl and 52.2% K) Potassium Chloride Fertilizer We Use

The percentage of 47.6% means that every 100 mg of KCl fertilizer contains 47.6 mg of Cl

$$\frac{100 \times 89}{47.6} = 187mg\ KCl\ (dissolve\ 187\ mg\ KCl\ in\ 1L\ water)$$

We dissolve 187 mg potassium chloride in 1 liter of water to obtain ppm89 of C.

Using the equations in Reference [25], the plant’s nutritional needs are known.

PH probe module Offset and how to use it.

This board have the ability to supply a voltage output to the analogue board that will represent a PH value just like any other sensor that will connect to an analog pin. Ideally, we want a PH 0 represent 0v and a PH of 14 to represent 5V**.**

but there is a catch……, this board by default have PH 7 set to 0V (or near it, it differs from one PH probe to another, that is why we have to calibrate the probe as you will see later on), This means that the voltage will go into the minuses when reading acidic PH values and that cannot be read by the an alog Arduino port. The offset pot is used to change this so that a PH 7 will read the expected 2.5V to the Arduino analog pin, the analog pin can

read voltages between 0V and 5V hence the 2.5V that is halfway between 0V and 5V as a PH 7 is halfway between PH 0 and PH 14،

You will need to turn the offset potentiometer to get the right offset, The offset pot is the blue pot nearest to the E-201-C BNC connector**.**

To set the offset is easy. First, you need to disconnect the probe from the circuit and short-circuit the inside of the E-201-C BNC connector with the outside to simulate a neutral PH (PH7). I took a piece of wire, strip both sides, wrap the one side around the outside of the E-201-C BNC connector and push the other side into the E-201-C BNC hole. This short-circuit represents about a neutral PH reading of 7.

Figure 4.5: connection of calibration.

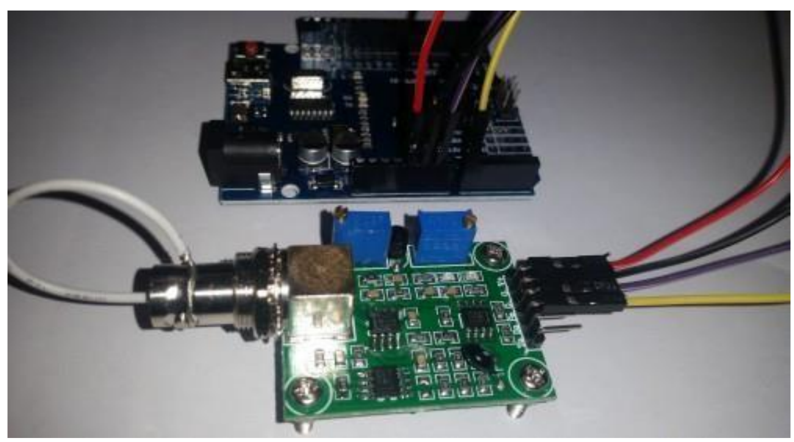

Figure 4.6: whole connection of calibration.

The Adjustment: -

If you have a multimeter handy you can measure the value of the PO pin and adjust the offset potentiometer until PO measures 2.5V. We prefer to just use the sketch below. Just download it to your Arduino as you will with any other sketch, open serial monitor and view the reading there. All this sketch does is to print the volts it receives from the analog pin and print it to the serial monitor. It of course first changes the digital value to volts to make it easier. Now simply turn the offset pot until it is exactly 2.5V.

Table 4.3:Showing voltage versus pH value.

pH	Voltage
4	**3.071**
7	**2.535**
10	**2.066**

4.3. Electric Design:

4.3.1. Climate Device Proteus Design:

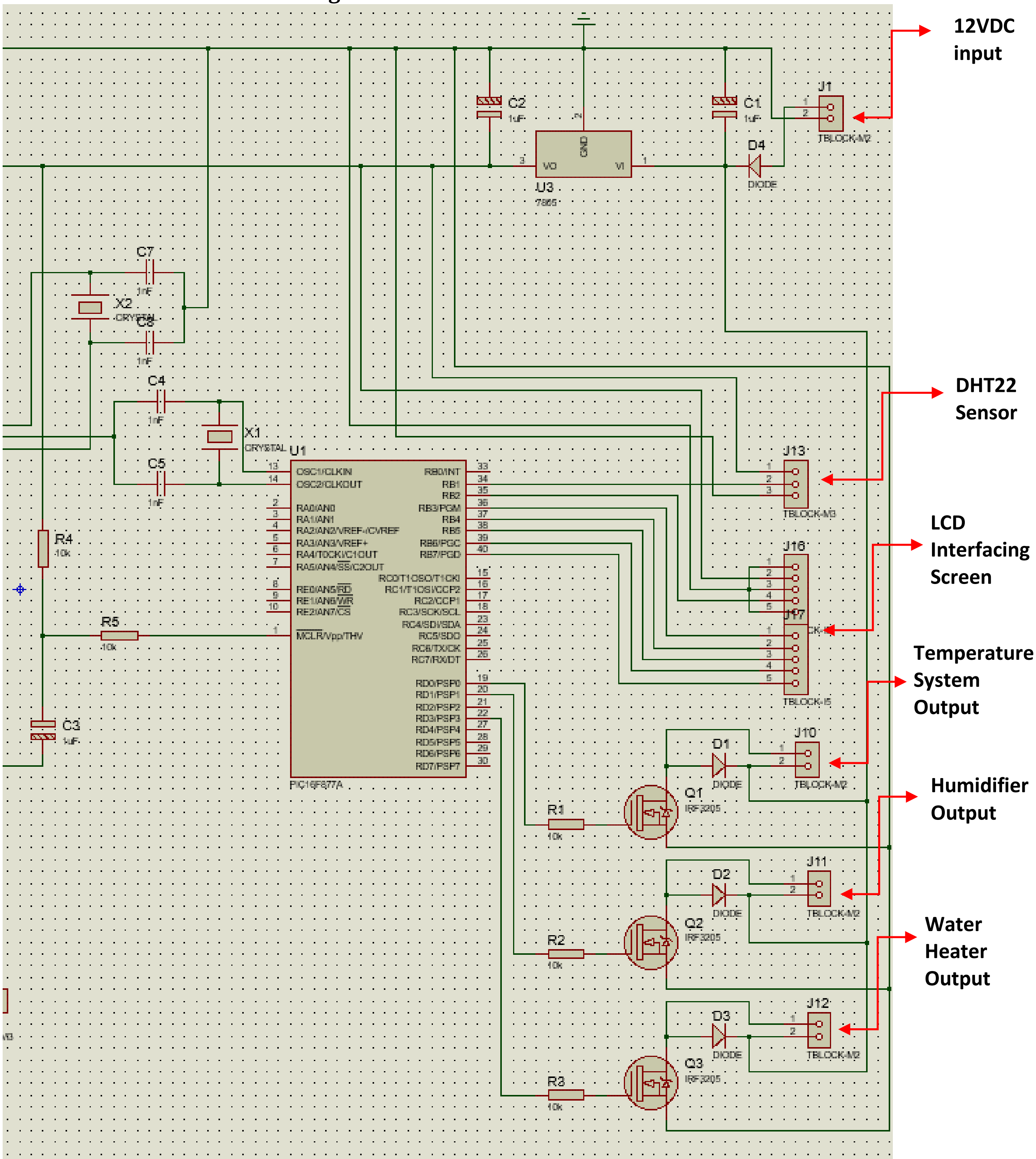

Figure 4.7: Climate Device Design.

4.3.2. Injection Device Proteus Design:

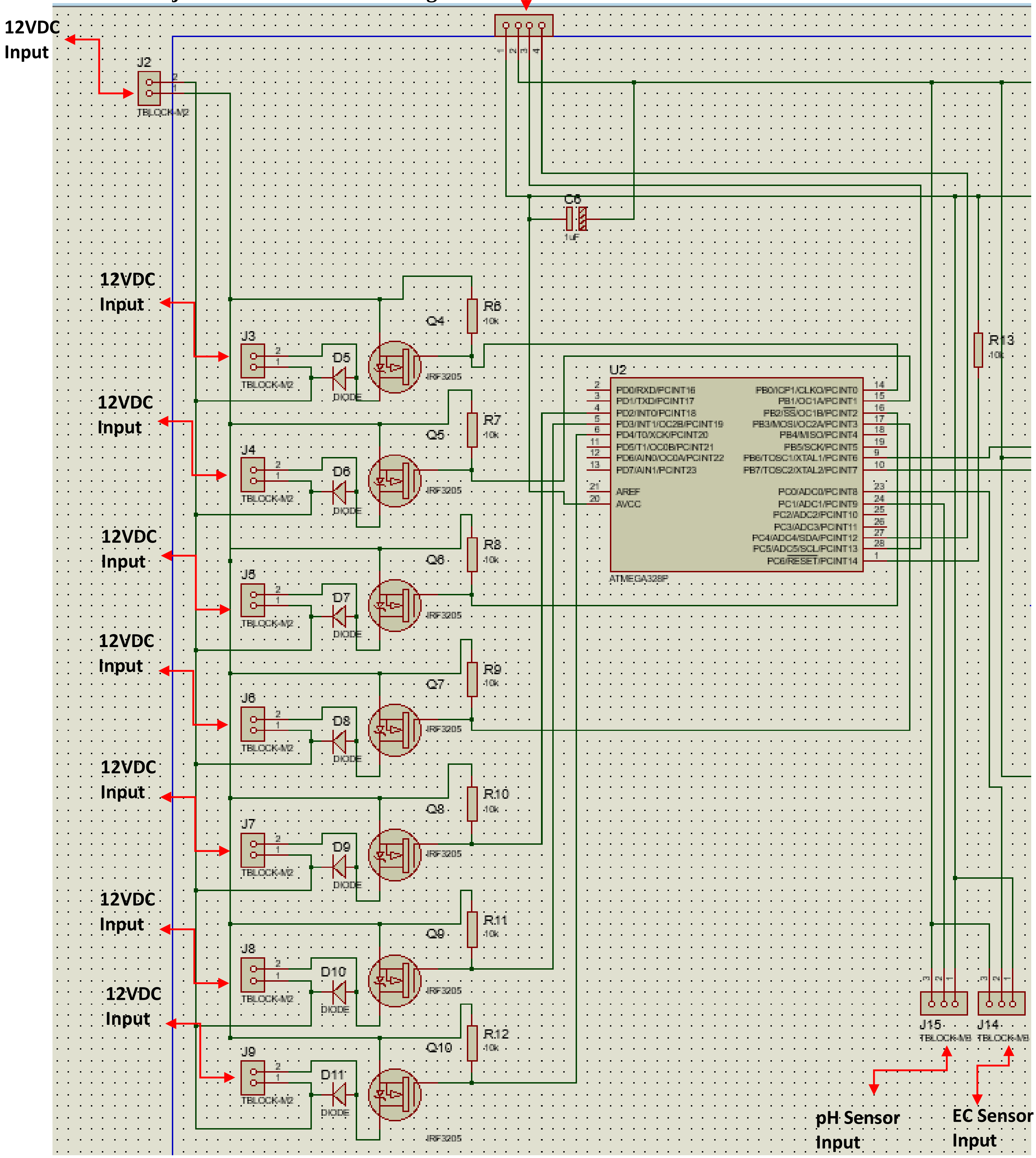

Figure 4. 8: Injection Device Design.

4.3.3. Overall Proteus Design:

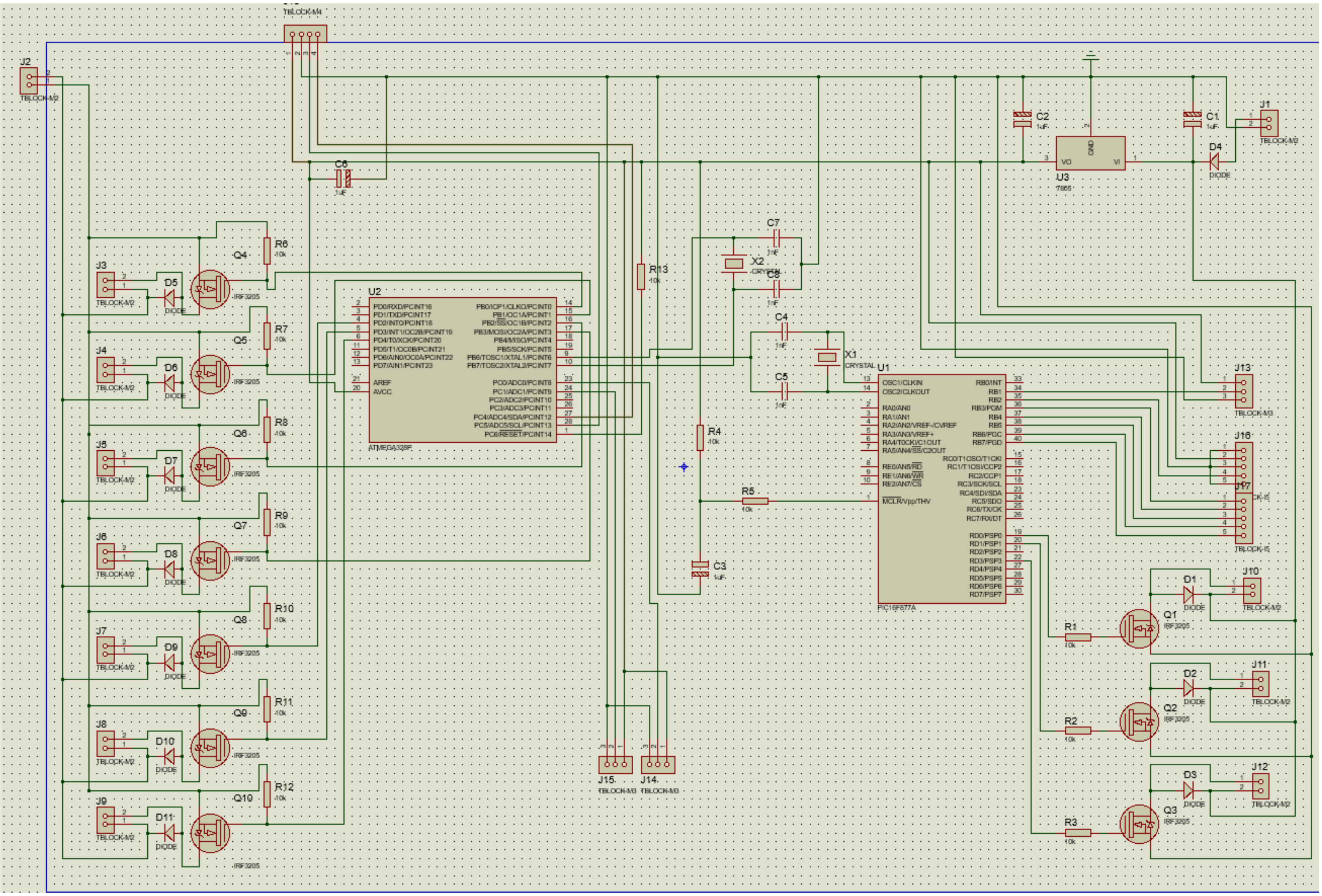

Figure 4.9: Overall Electric Design.

4.4. Converting Electric Design to PCB Board:

4.4.1. PCB Circuit Design:

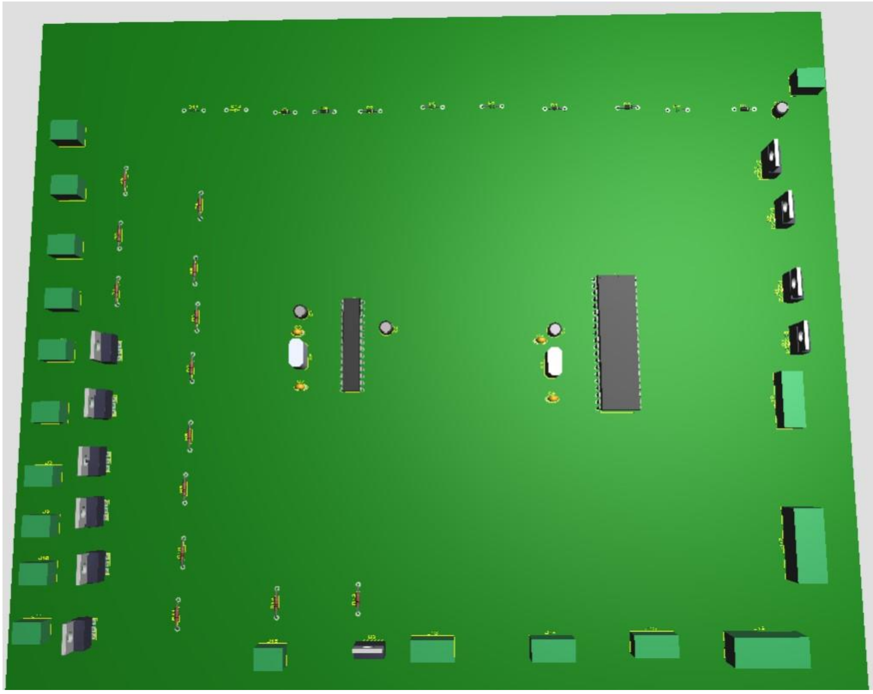

Figure 4.10: PCB Circuit Design.

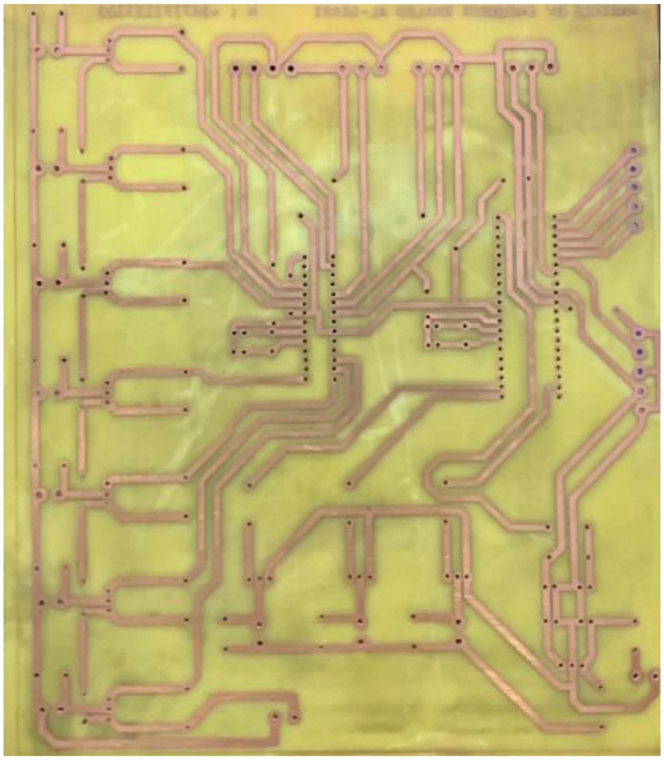

Figure 4.11: PCB Circuit After Printing.

The following picture shows the printed circuit board after the electronic parts have been soldered.

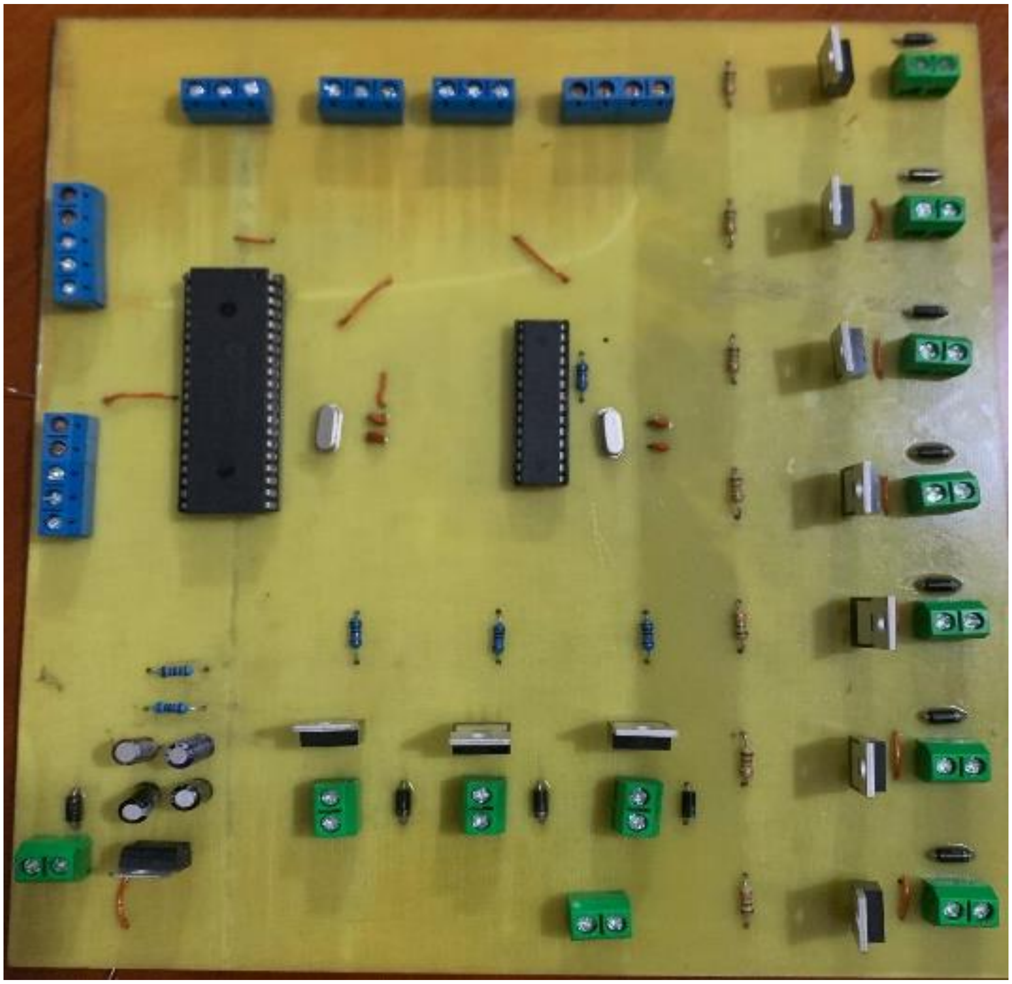

Figure 4.12: Board after soldering the electronic parts.

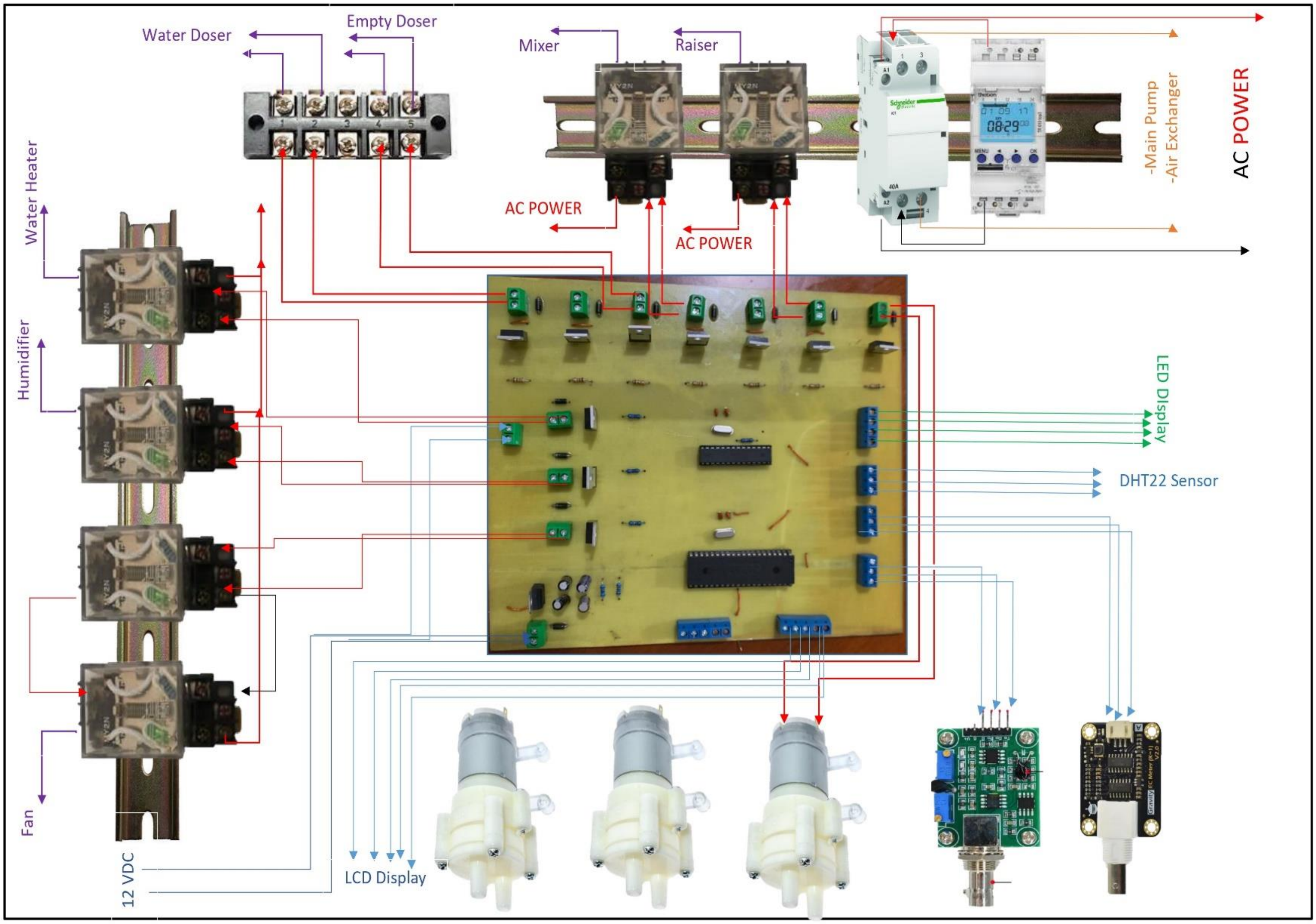

Figure 4.13: Box Wiring Diagram

Insert the printed board into the control box:

Figure 4.14:Insert Printed Board into Control Box.

Final control box shape:

Figure 4.15:Final Control Box.

4.5. Irrigation, Air exchanging and Lighting Process:

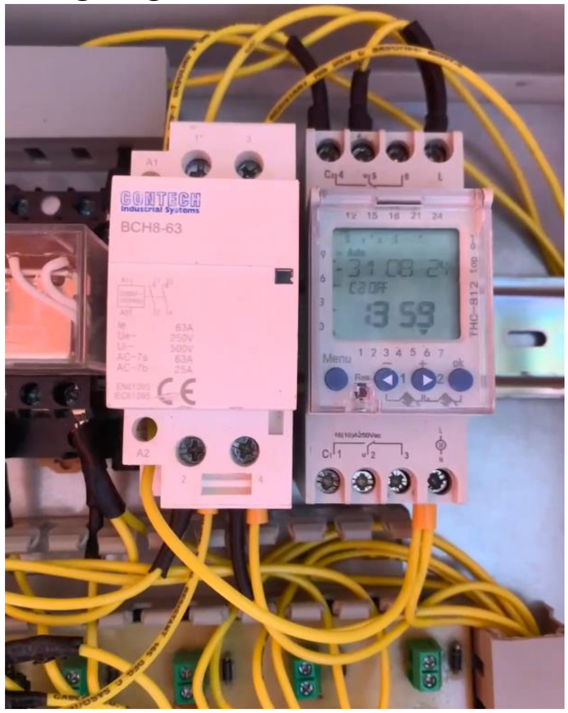

Figure 4.16: Over View of (Irrigation System).

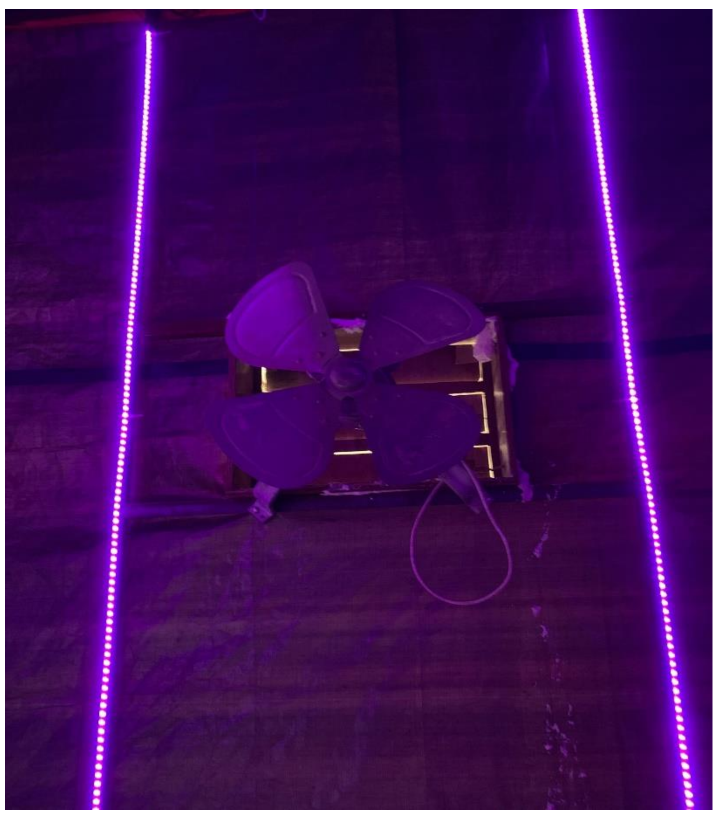

Figure 4.17: Over View of (Lighting).

Figure 4.18: Over View of (Air Exchanger).

Chapter 5

Conclusion & Future Work

5.1. Conclusion:-

Hydroponics classification is a good method of cultivation and provides better yield and faster growth rate compared to (conventional) soil-based farming. The main concern, which was also the main objective, was to automate the process for the entire environment to enhance productivity and efficiency by introducing a controlled automated system so that every simple farmer would take advantage of engineering techniques and create their own hydroponic systems at the lowest possible cost beyond what competitors offer.

Hydroponics classification is a good method of cultivation and provides better yield and faster growth rate compared to (conventional) soil-based farming. The main concern, which was also the main objective, was to automate the process for the entire environment to enhance productivity and efficiency by introducing a controlled automated system so that every simple farmer would take advantage of engineering techniques and create their own hydroponic systems at the lowest possible cost beyond what competitors offer.

This research also gave us an opportunity to contribute to the development of agriculture in our country by inspiring farmers with modern agricultural engineering techniques in order to enhance production and efficiency and support the national economy.

It was also very useful how to design and implement the project along with the control devices in a commercial way. We've also learned that hydroponics is more efficient when grown in greenhouses or indoors than outdoors because temperature control will be difficult and expensive. We have also learned that plants are quickly affected by any factor that may cause diseases, and that is why it must be dealt with carefully and carefully. This research also gave us an opportunity to contribute to the development of agriculture in our country by inspiring farmers with modern agricultural engineering techniques in order to enhance production and efficiency and support the national economy. It was also very useful how to design and implement the project along with the control devices in a commercial way. We've also learned that hydroponics is more efficient when grown in greenhouses or indoors than outdoors because temperature control will be difficult and expensive. We have also learned that plants are quickly affected by any factor that may cause diseases, and that is why it must be dealt with carefully and carefully. One of the key advantages of indoor vertical farming is its ability to achieve significantly higher crop yields compared to traditional soil-based farming. By stacking multiple growing levels vertically, the same footprint of land can produce up to 10-20 times more food. This is particularly beneficial in areas with limited arable land, as it allows for more efficient use of available space. The precision control of the growing environment in indoor vertical farms also enables the optimization of growing conditions for each crop. Factors such as temperature, humidity, lighting, and nutrient delivery can be fine-tuned to create the ideal conditions for rapid plant growth and maximize productivity. This level of control is simply not possible in open-field agriculture. Another important aspect is the reduction in water usage. Aeroponics, the core technology used in indoor vertical farming, delivers water and nutrients directly to the plant roots in the form of a fine mist or aerosol. This eliminates the need for soil, reducing water consumption by up to 95% compared to traditional soil-based irrigation. The closed, climate-controlled nature of indoor vertical farms also provides protection against external environmental stressors, pests, and diseases. This allows for the implementation of organic and pesticide-free growing practices, producing healthier, more nutritious crops while reducing the environmental impact. Furthermore, the proximity of indoor vertical farms to urban centers significantly reduces the distance food has to travel from farm to fork. This "hyper-local" production model decreases the carbon footprint associated with long-distance food transportation, contributing to a more sustainable food supply chain. While the initial capital investment for setting up an indoor vertical farm can be high, the operational costs are often lower compared to traditional farming due to factors such as reduced water and land requirements, as well as the potential for automation and energy optimization.

As the technology continues to evolve, we can expect to see further advancements in areas like LED lighting, robotics, and control systems that will drive down costs and improve the overall efficiency and scalability of indoor vertical aeroponic agriculture. This, in turn, will make this innovative approach more accessible and widespread, transforming the future of food production.

5.2.Future Work:

Through future work, we plan to:

1. Improving lighting systems:

   Exploring the use of advanced LED lighting technologies to improve energy efficiency, spectral control and lighting requirements of crops. In addition to adding renewable energy, such as solar panels, to operate lighting and control systems and reduce total energy consumption in indoor vertical farms.
2. Adding artificial intelligence, machine learning algorithms and computer vision to the control system and making the system make decisions to better manage and detect problems and diseases in the plant.
3. Crop diversification and breeding:

   Expanding the range of crops that can be successfully grown in indoor vertical farming environments, including fruits, vegetables, and even staple crops .Collaborating with plant breeders to develop cultivars specifically adapted to the unique growing conditions of indoor vertical farms.
4. Exploring innovative building designs and insulation materials to enhance the energy efficiency of indoor vertical farm facilities.
5. Economic and business model analysis:

   Conducting in-depth feasibility studies and cost-benefit analyses to identify strategies for reducing the capital and operational expenses associated with indoor vertical farming.
6. Developing, improving and evaluating sustainability in this type of modern agriculture.

5.3. Block Diagram:

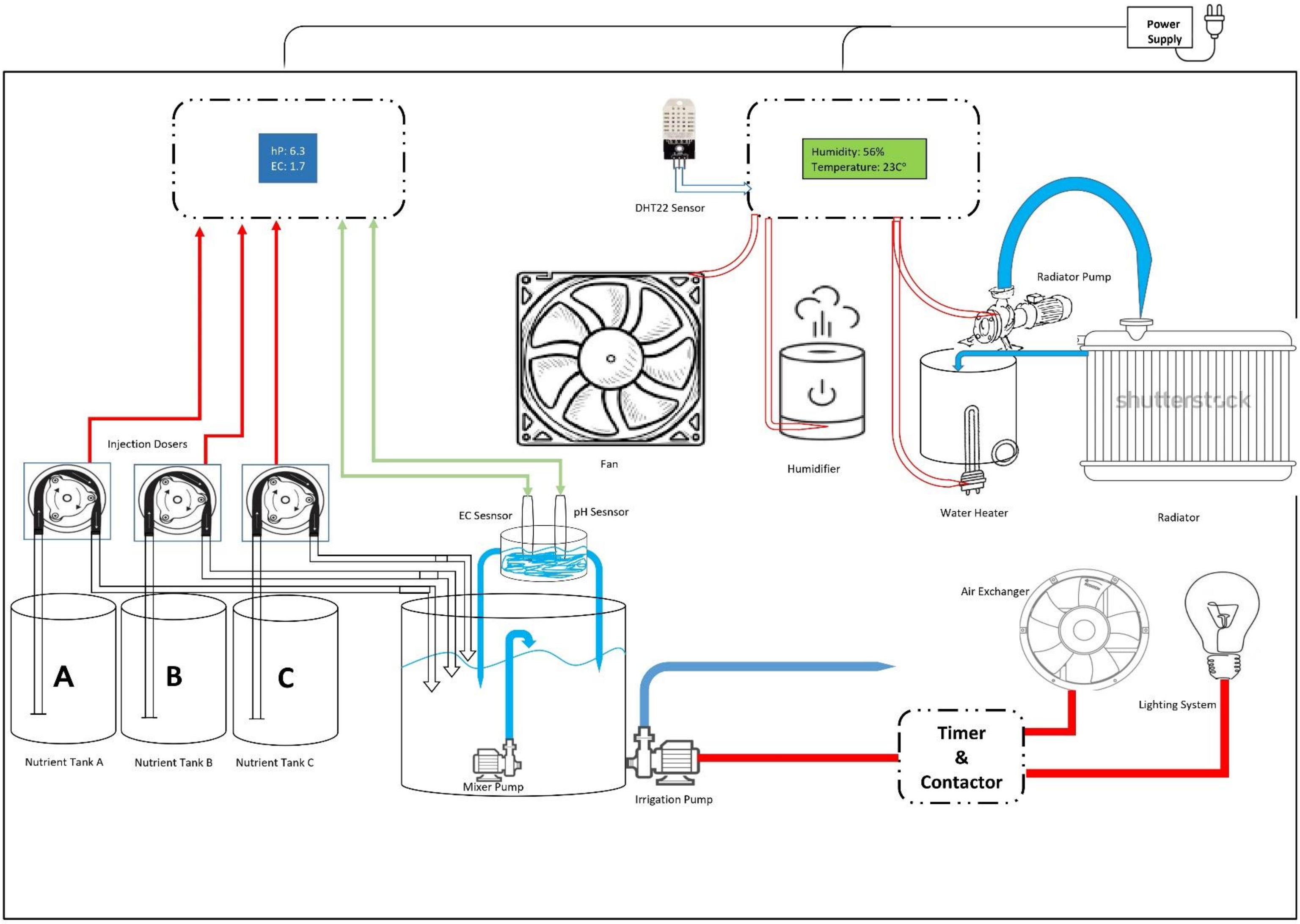

Figure 5.1: All System Block Diagram.

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APPENDIX