Automated Hydroponics System

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***Abstract* — In recent times it has been brought to everyone's attention that the current farming practices used to grow the crops that feed us on a daily basis are somewhat outdated. These practices have been found to be wasteful and to some capacity harmful, wasteful because they waste large amounts of water on a daily basis and harmful because in some cases harmful chemicals inside of pesticides have been used to get rid of insects and rodents that threated the growing crops. A solution to this problem would be hydroponics systems, they are about 90 percent less wasteful, and crops can be grown around 10-times fasted given a good and controlled hydroponic system. In this paper we will discuss some research being done around the world as well as specifics of our own hydroponic design.**

***Index Terms* — Irrigation, Hydroponics, Mixed Cultures**

I. Introduction

There is worldwide talk about the environment and we could do as a society in order to contribute to its well-being rather than to contribute to its demise. The STEM community has increased its research to create technology that would reduce carbon footprint and toxic waste into our environment. One of these technologies is hydroponic systems. There are various types of hydroponics, and they all have their own requirements as well as criterium of the plants they can grow but overall, they work more of less the same.

Currently in most places crops are grown in vast amounts of lands that also require large amounts of water that is mostly wasted as it filters through the soil till it gets to the roots of the crops. Climate is also something to take into consideration as there are places with certain geographic locations where climate doesn't allow for the growth of crops, there is also the seasonal aspect of growing certain crops. Lastly, we can also attest to the fact that fertilization of the land can pose and has posed in the past a serious health concern. There have been numerous occasions where, for example, lettuce has been recalled because of e. coli. which is a bacterium that can result in being deadly.

Hydroponic systems bring a solution to all of these problems and more. Using hydroponics, especially vertical hydroponics can help us grow up to 10-times the number of crops with the same amount of space, there is also about 95 percent less need for irrigation than the plants that are grown in soil because the water is in direct contact with the roots of the crops and the water is also recycled through the hydroponics system several time before it needs to be changed out for new water. There is also research that supports that crop grown in hydroponics are ready to harvest 30 to 50 percent faster than soil grown crops. Overall, the future points to the use of massive hydroponic systems in controlled environments for industrial farming.

II. Types of hydroponics systems

There are several types of hydroponic systems our in the market. Each type can be used for different types of crops, for examples some systems can support the growth of lettuce, and some can support the growth of heavier crops such as zucchini and strawberries. Currently we have:

- Nutrient Filled Technique (NFT)
- Deep Water Culture (DWC)
- Wick Systems
- Ebb and Flow
- Drip System
- Aeroponics
- Vertical Hydroponic
- Dynamic Roots Floating Technique

The most commonly used hydroponics for mass commercial growing is the vertical system as it allows us to grow around ten times the crops in the same amount of space, we would get with soil grown plants, the vertical structure was our original design for our system but instead we decided to go with the Dynamic Roots Floating Technique. This is the main structure we will be using for our hydroponic system:

Figure 1: Hydroponic Structure

III. REQUIREMENTS & SPECIFICATIONS

For our hydroponic system we wanted it to be small and easily transferrable for the purpose of use being able to work on it without it being stationary. We also wanted to be user friendly so that more people could a system such as this one in their homes or outside in balconies. The system had to be low cost and low in power consumption. The following is a table of requirements we wanted to keep within for the design of our hydroponic system.

A. Hardware Diagram

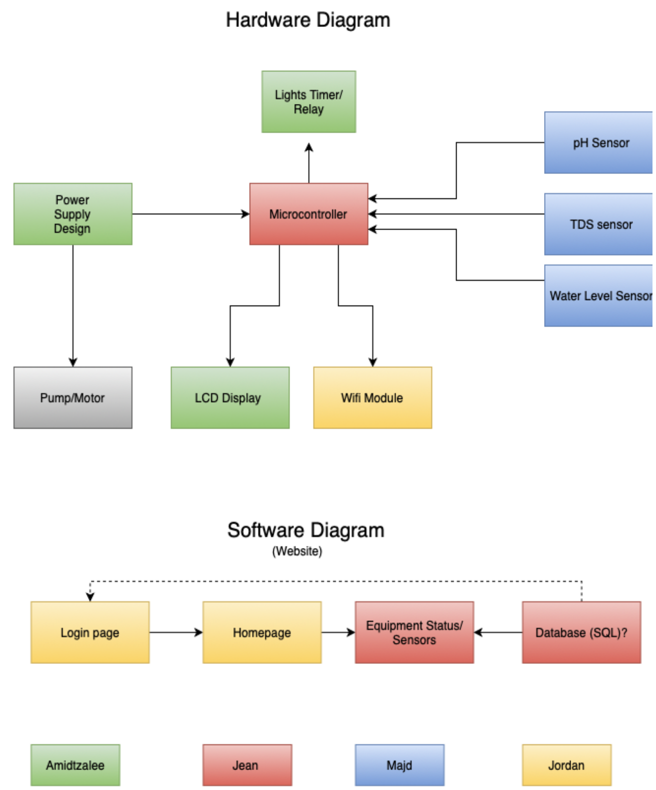

Figure 2: Hardware Diagram

B. Work Split

Shown above you will see an image of the block diagram which is also color coded to highlight what each of the group members worked on throughout the Senior Design course. We also split our work between primary and secondary work.

Table I: Requirement Specification

No.	Requirements	Specifications	Description
1.	Water pump	½ gallon per minute	This is done so there is appropriate water flow, and the nutrients can properly reach the plants.
2.	Ph of the water	Range from 5.0 and 7.0	The water needs to stay on this pH level for the plants to grow healthy
3.	Sensor updates	1 minute	The sensor should send the information to the microcontroller every 1 minute, so the system can be closely monitored.
4.	Communication module	50ft range	The communication module should have a reasonable range to access wireless internet connection
5.	Water Level	12 inches	The tank should be filled with water at 12 inches at all times.
6.	Microcontroller Voltage	Input ranges from 2.5 to 7.5 Volts	The input voltages should stay between this range for correct operation
7.	Light intensity	Up to 80,000 Lux	Exceeding the Lux of 80,000 can damage the plants, so we don't want to exceed it.

IV. Components used

For our system there are several components that we researched in order to implement them into our system. The components that were used were the following:

- Lights Strip
- pH Sensor
- TDS Sensor
- Water Level Sensor

A. Lights Strip

For the lighting portion of our project, we decided to go with the WS2811 LED Strip. The main reason was because this strip can be bent and cut into different ways, and we thought this to be beneficial for our design as we could shape and place them in any way we wanted. The LEDs are also individually addressable and can change color. This is good because there is research supporting that plants grow healthier and stronger given a specific light spectrum. The main parameters for this product are:

- Working Voltage: DC 5V
- Color: 24-bit full color
- Max Current: 1.8A per meter, 9A per roll
- Max Power: 9W per meter, 45W per roll
- Working Environment: -20°C -> +50°C

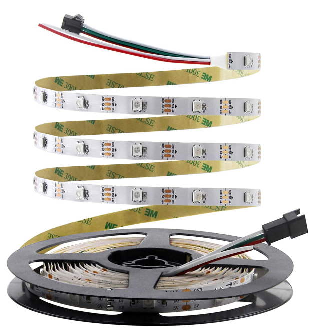

Figure 3: WS2811 LED Strip

B. pH Sensor

A pH sensor is necessary in our system because the water used throughout the system is recycled through it several times and a nutrient solution is added to it for the plants since there is no soil filled with nutrients, the nutrients must be added to the water directly. As the water goes through the system several times the water becomes more and more acidic, so it is important that we keep track of its pH so that it does not harm or slow down the growth of the plants. For the pH sensor we decided to go with the Liquid pH-14 Value Detect Sensor Module + pH Electrode Probe BNC for Arduino. The main parameters for this product are:

- Working Voltage: 5V
- Working Current: 5-10mA
- Detection Temperature Range: 0-80°C
- Working Temperature: -10° -> 50°C
- Max Response Time: 60 Seconds

Figure 4: pH sensor and Valve Detect Module

C. TDS Sensor

The TDS sensor is a water quality sensor, it stands for Total Dissolved Solids, and it checks the overall cleanliness if the water. This sensor detects the number of solids in a water solution which in our case it is very important because if the water has too many solids in it this will inevitably affect the growth and healthy development of our plants. The TDS detects the combination of all organic and inorganic material in the water, therefore the higher the value the less clean the water is, and this could pose a threat to the plants. The main parameters for this product are:

- Working Voltage: 3.3V – 5.5V
- Working Current: 3-6mA
- TDS Measurement Accuracy: ±10% F.S.
- TDS Measurement Range: 0-1000ppm

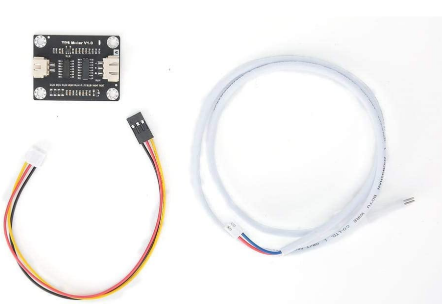

Figure 5: TDS Sensor & Module

V. PCB Connectivity

For our hydroponic system to work properly we have to bring all the parts together and ensure they are working properly. In order for our system to work unified as one we will have to create a printed board circuit. The PCB my group designed for this project will have several components attached to it. We actually were able to design more than one PCB, one was easier than the other as well as cheaper than the other. We made sure to design the PCB, send it to print and purchase the components separately because this would greatly lower the cost of the PCB as well as lower the lead time for the PCB to be printed soldered and sent back to us. One of the greatest challenges that we came across was the fact that some of the components that we needed were either out of stock or the lead time was too far ahead and might not get to us on time. We had to make lots of design changes to accommodate for the fact that some of the components we needed might not be available on time so there was plenty of research done to replace these necessary components with their equivalents that could both available and can get to us on time. Our PCB will have the following components attached to it:

A. *ESP32-E Microcontroller Chip*

The ESP32 Arduino chip is great for the use of our hydroponic system.

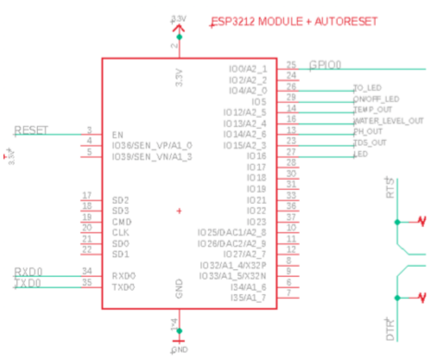

Figure 6: Microprocessor Schematic

This microprocessor has just enough features for us to complete our PCB design. To it we connected the LEDs, the TDS sensor, the Water Level Sensor and the pH sensor. Most of the components we have need a 5V input voltage and this chip provides both 5V and 3.3V. The ESP32 also includes the WIFI MODULE, and it has much better capabilities than its predecessor. Some of the main specs for this microcontroller chip is that is has a WIFI-Module which is something we need to transmit the data into our website. It also includes 2Mib to 4Mib, 520 KiB SRAM, Two Tensilica LX6 Cores.

B. *Power Supply Design*

For the power supply design, we used the Power Supply Solderless board for Arduino as our footprint to design our power supply into the PCB. The power supply needed to provide at least 5V into the board to power up all of the components. We made sure to add both a Micro-USB connection as well as a power supply connector for the board, these connectors will attach to a wall plug. The Micro-USB can take up to 5V and the power supply connector can take up to 12V. The following is an image of the schematic for it:

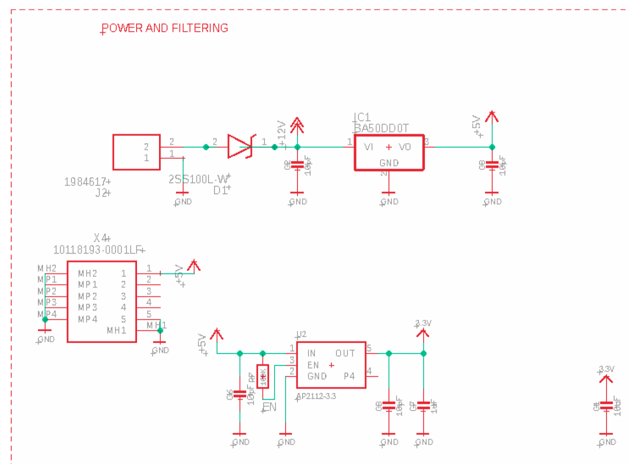

Figure 7: Power Supply Schematic

C. *TDS Sensor*

The TDS Sensor we choose requires a 3.3V input voltage. This sensor module board goes into the PCB at Pin 23. Once again, this sensor stands for Total Dissolved Solids and is needed to determine the cleanliness of the water solution in our system. Out of all the connection the TDS schematic is the simplest one. On the TDS sensor module, the first pin is connected to the microcontroller chip, the second pin is connected to the 3.3V input voltage and the third pin is connected to the ground. The following is an image of the TDS sensor schematic:

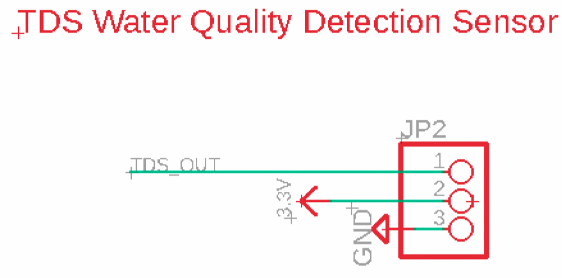

Figure 8: TDS Sensor Schematic

D. *Water Level Sensor*

The water level sensor is required for us to make sure there is always enough water to go through the system. The roots of the plants must be constantly submerged into water or else the roots dry up almost immediately and this would of course not be good for them. There are two water level sensors we have been looking into, the eTape and the rain water level sensor module. Either one works for our hydroponic system, and both have the same connections that could fit into our schematic, the sensor itself is connected to Pin 16 in our microcontroller and it has a 560Ω resistor between the sensor and the 3.3V input power. The water level module has 6 pins on it. The first pin is attached to the board, the second pin on the module is attached to the ground. The third pin goes to a resistor which then goes into the 3.3V input power. This sensor requires a 5V input voltage and the following is an image of the schematic:

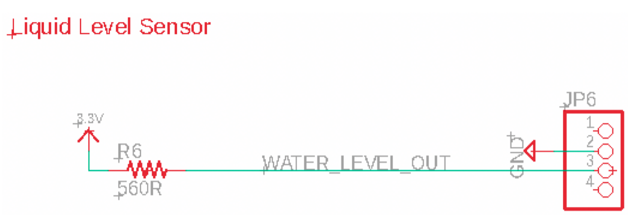

Figure 9: Water Level Sensor Schematic

E. *pH sensor*

The pH level sensor is the last sensor, this once is again very important to the system as it determines the pH of the water since the water solution is recycled through the system repeatedly. This pH sensor requires 5V of input voltage and it is connected to the microcontroller chip to Pin 13. The pH module itself has 6 pins, the first one is connected to a series of two resistors that connect to the microcontroller on Pin 14 and then to ground. The second pin is not used as it is optional on this module. The third pin has an almost identical connection configuration as the first pin but this one connects into the microcontroller on Pin 13 and then to ground. The fourth pin is connected to the general ground, the fifth pin is also connected to the general ground, and lastly the sixth pin is connected to the 5V input voltage as it is required to be able to power on the module for the pH sensor.

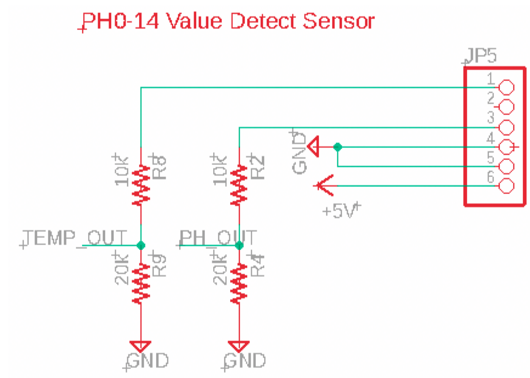

Figure 10: pH Sensor Schematic

F. *LED Strip*

The LED Strip we are using is a WS2811 LED strip that can be cut and fashioned in different way to fit our design. These lights require a 5V input power and a 3A output current. Out of all of the previous schematics, the LEDs is the most compounded of them all. Each LED can be individually addressed and the strip itself can be cut at any length. The lights have three pins that are connected to the microcontroller. The first pin goes into the 5V input voltage in the microcontroller. The second pin goes through two parallel 10kΩ resistors that are connected together by a Mosfet which is used as a level shifter circuit. Eventually the connection goes into the microcontroller chip at pin 26. The last pin on the lights is to turn them ON/OFF and it goes into the microcontroller chip at pin 29. This last pin is connected in series with a transistor and then to ground.

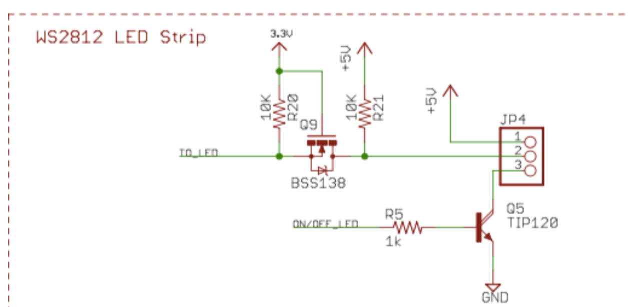

Figure 11: LED Strip Schematic

VI. Testing The components

Test Case	**How Testing Was Done**	**Acceptance Criteria**
Microcontroller	Testing correct input of sensors with constant values.	Correct values are returned.
Web Based Application	Ensuring that data displayed on the website matches those on the physical location of the hydroponic system.	Correct data is being displayed to the user.
MySQL Database Functionality	Inserting different values into the data tables of the database and also ensuring that values being returned from the database match those being deposited into the tables.	Correct information is stored in the correct slot on the tables, and the correct data is being pulled from the corresponding slot.
Sensor Feedback	Ensuring that the values being returned to the microcontroller match the constant values being tested on the sensors.	Values being returned from the sensors are accurate to the constant values being given to the sensors.
Wi-Fi Module	Testing was conducted by connecting to a network via SSID and password and running a simple program that remotely turns on the LEDs on the microcontroller via a remote connection on a server.	LED's turn on when interacted with via remote location on a web-based application

Table 2: Testing case for all components

VII. WI-FI Module & Website

In WI-FI there are several standards that are used. We focused on specification, quality and test method standards for our project. A specification standard is often a well-documented requirement that satisfies a service, product, or design. A test method standard lays out a procedure that produces a result. A public or private organization can develop it. The use of a standard is to make more accessible and straightforward the use of many goods and services by companies, engineers, businesses, manufacturers. When thinking about a product or project, it is essential to consider standards for doing it. This project will be dealing with multiple standards in WIFI, Electricity, water, and a food quality standard. For our project, we will be using ESP32 that includes wireless connectivity WIFI 802.11 b/g/n.

There are different types of WIFI standards, and their acronyms usually give information about the strength, data, and compatibility with other standards. IEEE (Institute of Electrical and Electronics Engineers) is the institution that decides on the standards like how much data they send and the standards for encryption. Companies participate in these standards, so their technologies work well together. A network can be broken down in speed and frequency.

The back end of the entire system will have to be the database. The ESP32 microcontroller chip has a WIFI component to it which allows us to use the chip directly for the WI-FI without the need to add an additional component to it for the WI-FI. The database we will be storing all of the systems vital information for optimal plant growth. This data can be stored and will give us the ability to analyze old data such as the history of the pH levels, water levels etc. We went with the MySQL database for this since it is user friendly. The following is an image of the database design:

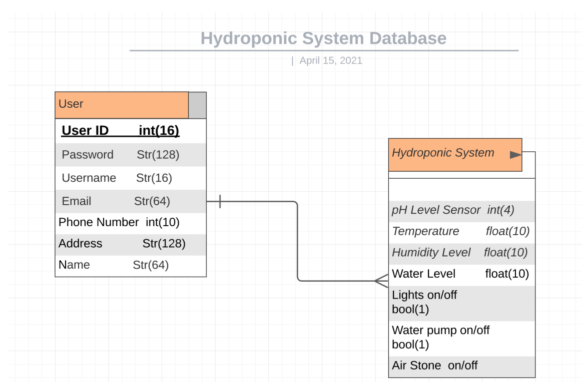

Figure 12: Hydroponic System Database

Because the ESP32 chip has a WI-FI component to it this makes it easier to create the website that will hold all of the data collected by the modules attached to the PCB. But it can also hold data like the user's information such as their first name, last name, email, and password. The following is a flow diagram of the website application:

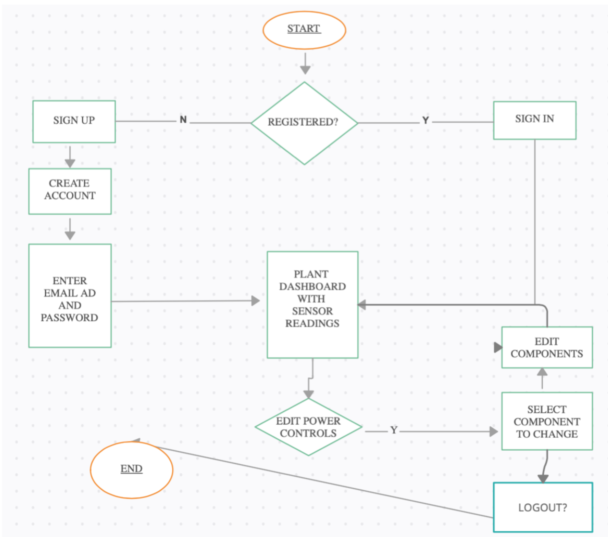

Figure 13: Website Application

VIII. Similar Projects and Products

Hydroponics is known as the act of growing plants in water (whether it be herbs, vegetables, fruits, or even medicinal plants). The meaning of the word hydroponics comes from the following two words:

- *HYDRO = MEANS WATER*
- *PONIC = MEANS LABOR*

During our research of hydroponic systems, we came across other very important applications in which hydroponic systems are being applied to. A good hydroponic system allows for temperature control which means one could grow crops all year round since conditions such as heavy rains or snow does not apply to indoor hydroponics. The issue of pests and rodents is taken care of since the environment of the crops can be more closely monitored. There is also the benefit of no-soil related diseases, and one is able to use the precise amount of nutrients for optimal crop growth. All of these benefits have attracted the attention of NASA as well as Ocean Reef Group. Both of these companies are working separately on research that could benefit the mass population since hydroponics is the future way of farming crops.

A. *Under the Sea Hydroponics*

Under the Sea Hydroponics is a project located about a hundred meters off the coast Noli, which is located in Italy. This project is a collaboration between scuba divers and expert agricultural experts to grow certain crops within these pods that are submerged about 15 meters in water. Within these balloon-like pods they team is growing both frits and vegetables including, lettuce, beans, strawberries, basil, red cabbage.

Figure 14: Nemo's Garden Research Lab

There about seven pods that create their own biospheres Each pod can hold around to ten trays of plans, each of these tray holds about 22 small pots for each of the plants overall. The pods have a a heating system, and cooling system, and the LED lights used because there is not direct sunlight at around 15 meters below water. Currently the project has been successful in showing that crops can also be grown underwater without the need of land space at all but the net experiment to try is how deep underwater can these under the sea hydroponics go.

B. *Interstellar Space Hydroponics*

In recent years there has been plenty of talk of sending humans to experiment in interstellar space travel. Many issues and concern have arisen from traveling in space, but a main concern is what will the humans on board of the chip eat. A healthy balanced diet is not only comprised of dehydrated foods such as those that current astronauts eat at the international space station, but we want to put humans in long duration space travels then we must develop a way to grow food on board since the food storage capacities will also be limited. Hydroponics can solve this issue since there is no need for a lot of space to grow food and there is no need for soil. Scientist at the Kennedy Space Center are currently studying the growth of plants including radishes, green onions and lettuce. They use a controlled environment where the temperature, lights and carbon dioxide levels are carefully monitored. They also experiment with something called mixed cultures; it is known that some plants give off different chemical compounds that can be poisonous to other plants around them. Investigating this has given more context to the issue of aggressive plant spread which could potentially cause an issue with the healthy development of the crops.

VIIII. Conclusion

The project overall was completed but not without its setbacks. One of the major setbacks was of course the fact that we had to take the course remotely. Senior Design is a class that is very much hands on and requires people to be able to meet at a set time and work together through research and problems that might arise when working on the Cap Stone project. The second major setback was that a lot of the materials and components come imported from other countries, mostly from china. The component materials that we needed for our project were constantly changed because the lead time for these materials were not available and or the lead time was too long for us to wait on the components. We also had to resort to ordering materials from many different companies depending on who had what we required for our project. This portion required more research for us to find the equivalent components for us to find the equivalent components for what we needed and lots of redesigning on the PCB to fit the components we were able to get. But overall, we were able to complete the project with the allotted time. Our hydroponic system is small, easily transportable, and user friendly.

Acknowledgement

We as a group would like to acknowledge the assistance and support of Quality Manufacturing Services Inc. for their help and assistance in soldering the components into our PCB design. As well as the UCF ECE faculty for providing us with testing materials and lab access.

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Bibliography

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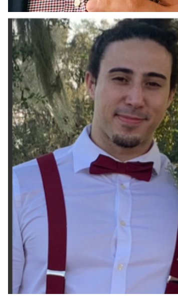

Jordan Sole is a senior student in Computer Engineering. Currently interested in working the design and development of several technological devices. His main goal is to work for a large company such as Microsoft, AMD, Space X to name a few.