Senior Design Research Document

Senior Design I

EEL 4914

Home Hydroponics Systems

Group 18 – Members

Joshua Casserino | Computer Engineering

Richard Charmbury | Electrical Engineering

Alexander Costello | Computer Engineering

Ernest Inman | Electrical Engineering

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1 Executive Summary

Every society, past, present and future is depended on its food production and water supply. Without a steady reliable source, all civilizations would collapse. Advancement in agriculture techniques has increased the amount of food able to be produced but modern agriculture is starting to run into major problems, it's this groups opinion that hydroponics can be the solution to some of those problems. Hydroponics is the practice of growing plants using only water, nutrients and a growing medium. This makes it possible to grow plants without soil, seems very innovative but it's not.

This project looks at making a home hydroponic system more user friendly by taking care of the day to day checks that are required to grow indoors. Today everybody is so busy that it is often overlooked to check your hydroponic system. Our aim is to make the hydroponic system easier and fun by collecting this data that you would normally have to do by hand and place the collected information on your smart device via the internet. Using an array of sensors and Wi-Fi, this information will be collected and stored on an online data base, and the data can be viewed live, this way the user can be more interactive with the system and respond when something goes wrong. The data that our system will be collecting is light levels, pH, water level and total dissolved solids. The first system will be robust enough that in the future more subsystems can be added without the fear of not enough memory or digital pins available. Our light sensor will detect when normal window light is not enough for the plants growth and will activate an array of LED's to supplement the natural lighting. The pH and TDS sensors will check the current levels in the hydroponics' water tank and will make corrections using peristatic pumps from stored solutions. In these ways, we hope to make indoor growing more user friendly with better results come harvest time.

2 Project Description

2.1 Introduction

Hydroponic techniques have been around for thousands of years, since the Hanging Gardens of Babylon and the Floating Gardens of China. While the general theory hasn't changed very much, modern technology has enabled for plants to grow stronger, faster and healthier. Even with these improvements hydroponic systems are able to increase the yield of each harvest and shorten the time between harvests. Even though these improvements may seem like enough the most important aspects are that it;

- Uses less water than conventional farming
- Uses less space than conventional farming
- Gives farmers more control over their plant growing cycles
- Farmer have complete control of the nutrients the plant receives
- Affordable

The let's discuss the benefits of each of these points separately.

2.1.1 Uses less water than conventional farming

Since hydroponic system are closed systems they will automatically use less water. As an example of the differences of conventional farming and a hydroponic system to help and example how these systems will always use less water. A conventional farm plants the crop in soil provide the water needs to grow the plants by either spraying water over or by using a drip method. The spraying of crops doesn't ensure that each plant receives the proper amount of water needed so to compensate farmers will spray more then what is required. Many factors can prevent the plant from receiving the sprayed water, such as;

- Wind blowing the spray away from the crop
- Crops blocking other crops from the sprayed water
- Water runs off before the soil can absorb the water
- The sprayed water being dispersed before reaching the crop

Because of these reasons conventional farming using spraying crops will always use more water than the crop requires. The other popular method of watering crops is using a drip method. In order to use this method a hose or pipe is run along the length of each crop row. The hose or pipe will have holes along its sides that are small enough so that only a small amount of water will escape, i.e. drip, from the hose or pipe. The pipe or hose must be fed a steady stream of water so that the water will reach the end of the object. Using a drip method removes some of these issues but has its own issues, such as;

- Water runoff is still an issue
- In order to reach all crops along the pipe or hose a steady supply of water will be pumped into the object and has to be more than enough so that water will reach the end of the pipe

- Since the hose or pipe is exposed to the sun it will heat up which will also heat the water making it more likely for it to evaporate once it leaves the hose or pipe
- Since the water is flowing slowly out of the hose or pipe it will stand on the surface of the ground longer and is more likely to evaporate.

These are the major issues with conventional farming methods, and adding to them is the ever-present water cycle that will try its best to absorb and evaporate any and all water that is exposed to the air. Hydroponic systems don't have these issues because it is a closed system and the only water leaving this system is the water that is absorbed by the plants. Since the plants will only absorb what they need, only that amount is used and the rest will stay in the system to be reused. Per luckyroots.com, this turns into a water savings of up to 2/3rds less water used [1]. This is an amazing amount when you think of the volume a normal farm will go through.

2.1.2 Uses less space than conventional farming

Again, to aid in explaining the benefits of a hydroponic system verses conventional farming. Conventional farming habits uses a standard method of laying out crops along the group in rows. This method consumes a lot of land as each plant requires a clear area around it to maximize the potential growth of the plants. On the other hand, a hydroponic system isn't limited to the surface of the ground. A hydroponic system can be set up in any configuration if the plants receive sunlight, or even suppled light. Below is a few pictures, one of the conventional farm planting method and some examples of different hydroponic system plant layouts.

- This is the standard crop layout on most farms currently.

Figure 2-1 Conventional Farm Crop Layout

- This layout uses layers to simulate the Earth's surface but can be stack so that each layer is increasing the area but the original area

Figure 2-2 Vertical Layering System

- This system uses a shift row configuration to maximize sunlight exposer to each row.

Figure 2-3 Shifted Row Configuration

- This configuration is less efficient than the previous two but is maximizes space saving so that it's possible to store in areas that are normally unusable.

Figure 2-4 Space Saving Configuration

These are just examples of the, almost, infinite ways of laying out different hydroponic systems. As anyone can see these layouts are far more efficient then the convention farming layout shown above. Per Lucky Roots, "Hydroponic gardens can produce the same yield as soil gardens in about 1/5 the space" [1]. This is a major space savings when it is reported, per Lucky Roots, that "As the amount of arable land continues to decrease (over 10 million hectares per year are lost)" [1]. This makes it possible for a civilization to eat more people by using less space.

2.1.3 Gives farmers more control over their plant growing cycles

Since artificially lit hydroponic gardens are not dependent on growing seasons, they can produce yields several times a year rather than just once. This will enable farmers to always grow crops that are in demand no matter the time of year. For example, if the current farming market is flooded with potatoes, farmers will be able to grow another crop immediately instead of waiting until the nature growing period of that crop.

This has major advantages, because it will not only make growing of crop possible during off season but it we extend this idea it makes it possible to grow in areas that would normally not have the seasonal requirements for specific crop growth.

2.1.4 Farmer have complete control of the nutrients the plant receives

Since hydroponic systems are a closed system farmers can control exactly what the plants are exposed too. While the chemistry of soil composition has advanced greatly over the last century, it is still impossible to control the exact nutrients the plant will be exposed too. Either because of uneven distribution or just normal environmental effects (i.e. erosion), the soil may contain the nutrients need but that doesn't guarantee the plant will receive them.

On the other hand, a farmer can place the nutrients the plant need in the close system and monitor that nutrient to ensure it is always available to the crop. This is just another way that these systems can aid farmers, and hobbyist, from removing an extra variable in the farming process.

2.1.5 Affordable

Hydroponic systems are much cheaper to start and maintain then the conventional farm that will product an equal crop yield. The above benefits to hydroponic systems alone it's already apparated that a hydroponic farm will cost less in the areas of;

- Land size required
- Water Use
- Cost of nutrients
- Cost of Soil (No cost in a hydroponic system)
- Protection from the elements

There is a major down size to hydroponic farming though. The cost of electricity is much higher per year. Per Eric Siegel,

"The initial investment is still steep. For $60,000 a new farmer gets an 8'x40' shipping container filled with everything he needs to start farming on the spot. "A tablet computer inside controls everything — the lighting, the pH and the temperature," Liebman says. In an area smaller than the footprint of three parking spaces, a single person working eight hours a week can grow one acre's worth of leafy greens. Liebman says that the "freight farm" pays for itself in 9 to 12 months because the farmer harvests high-quality produce every week, year-round. After the initial investment, which is likely less expensive than the cost of an acre of land, annual costs remain under $5,000 dollars." [2].

This is a great example of how a hydroponic system is cheaper than conventional farming because while the initial cost may seem high, it is still cheaper the initial cost of conventional farms due to having to purchase the land for the farm. As we all know, land prices will always increase as the amount of land required for cities and towns expands. This doesn't even take in account that with the same number of crops the average hydroponics system will provide a greater yield then conventional farming.

2.2 Project Motivation and Goals

2.2.1 Motivation

A simple home hydroponic system will enable people to become less dependent on large farms for simple and daily food needs. Large farms will always focus on crops that will turn the highest profit. This business model has created a supply and demand cycle of food goods, and to fill this demand, businesses have lowered the quality of their products. The need to grow crops faster or harvest more from each crop has made farmers turn to cross breeding plants at the cost of flavor, nutrition, and overall value. This kind of system will remove some of the demand on the market for simple, easy to grow, crops.

This will be a system that the average person can run and maintain with a minimal time investment and cost. It will improve the standard of living for people of low income levels. The current moderate-cost food plan of a family of 4 (Male/Female 19-50 years old, one 2-3-year-old child and one 4-5-year-old child) in America is $880.30 a month. If this system could remove just one-quarter of that cost, it would save that family $220 a month. For a low-income family, this money could now be spent on other household needs; which in turn will improve their quality of life.

This kind of device will also make it possible for people living in harsh climate areas (i.e. deserts, arctic, mountainous, etc.) to have a much more varied diet. Thus, it will improve the health of those individuals. By improving their health, the healthcare systems can now focus more on illnesses that are more serious. This will also help limit the spread of diseases. If there is less risk of contracting a disease or illness, people will be able live together in larger numbers. This will empower the growth of cities and society around the world.

2.2.2 Goals

The main goal of this project is creating a working prototype of a home hydroponic system that at least meets the minimal requirements needed to maintain and grow plants. In the process this group hopes to gain more experience with;

- the overall engineering process
- software design
- hardware design
- circuit design
- resource management
- working on an engineering team
- PCB design.

While the individual members in this group have a theoretical understanding of the many different aspects this task requires. Combining and executing those elements will become our greatest challenge. As each element is designed separate from the each other, the group must always remember and design that piece to fit into the project seamlessly. It is this group desire to become much more rounded and knowledgeable engineers. This project provides that opportunity.

Even though there are many benefits to hydroponics systems it still isn’t the main method of growing plants currently. The main issue with hydroponics currently is the volume of energy it requires to maintain. Finding a way to cut down on this cost is a major goal for this group. Even if this group isn’t able to cut the energy for a hydroponic system to run, the group aims to create ways to cut cost outside of the circuit design. Since there have been many ingenious and creative engineers working toward making circuits and architectures more efficient, this group would like to think outside of the box and maybe find a way to cut the cost by using the available resources of the Earth. An initial thought is to use the natural sunlight for the system instead of always using lighting. As well as using supplemental lights to aid in growing of crops but just offsetting the sunlight on days that it isn’t providing enough light.

2.3 Objectives

This project’s main objective is to create a hydroponic system that can be used and maintained by the average person. The system should be able to wirelessly connect to the internet which will enable the user to monitor of the current state of the system. This will also make it possible for users to be alerted to potential dangers to the system (i.e. low water level, wrong pH levels, etc.). To make automation and tracking possible, the system will have several sensors to test the water, this will enable the system to.

2.4 Requirements Specifications

This section covers what this project base requirements and specifications are. It is this groups goal to make sure that each one of these specifications are met and/or exceeded.

- Housing of Hydroponic Monitoring System
  - Dimensions - No larger than XX” L by XX” W by XX” H
  - Weight - No heavier than XX pounds
  - Enclosure - Water Tight Enclosure / Plastic Box
- Power Source for Project
  - AC/DC Conversion from Main
  - Voltage Regulation and Current Supply Circuitry
- Microcontroller
  - Input Voltages - 2.5 to 7.5 Volts
  - Digital Input/Output Pins - 10 to 30 Pins
  - Analog Input/Output Pins - 5 to 10 Pins
- pH Sensor
  - pH Range - 0 to 14
  - Offset - +/- 0.20 pH
  - Output - Serial Communication with Microcontroller
- Peristaltic Pumps
  - Control of pH Levels
  - Voltage Input - 12 Volts

- Environmentally Friendly - Chemicals do not encountered motors.
- How Many - Two - One each for pH up and pH down corrections
- Flow Velocity - 6 to 24 mL/min
- High Dynamic Range Light Sensor
  - Accuracy - Approximates Human Eye Response
  - Dynamic Range - 1 to 600,000,000 Counts
  - Lux Range - 188 uLux sensitivity, up to 88,000 Lux input measurements.
  - Dimensions - 19mm x 16mm x 1mm
  - Weight - 1.1 grams
- Wi-Fi Module
  - Input Voltage - 3.3 Volts
  - Wi-Fi Standard - 802.11 b/g/n
  - Dimensions - 51mm x 23mm x 8mm
  - Weight - 9.7 Grams
- Software Considerations
  - Processor will be coded using C
  - Website-Database interactions will be written using PHP
  - SQL will be used to create the Database
  - Website will be written using, at a minimum, HTML
- Web Page Hosting
  - Website will be written to work on, at a minimum, Google Chrome browser
  - Database will be able to be modified by multiple users

2.5 Quality of House Analysis

As this system is designed it was important to have an understanding the tradeoff between market needs and engineering requirements. During the design and building process there needed to be a clear path for making the best decision for a successful project. This will be the guide for making decisions for the design and implementation. The main goal is to be able to provide the highest quality product while considering market needs.

Engineering Requirement

- ↑ Positive correlation
- ↑↑ Strong positive correlation
- ↓↓ Strong negative correlation
- \+ Positive polarity (Increasing the requirement)
- \- Negative correlation (Decreasing the requirement)

Below is a table showing the engineering and marketing requirements that this group thought was the most important as well as relevant to the system;

			Engineering Requirements			
Marketing Requirements			Quality	Efficiency	Install Time	Cost
			+	-	+	-
	Lighting	+	↑	↑	↓↓	↓↓
	System Use	+	↑	↓↓	↑	↑
	System Setup	-	↓	↓		↓
	Portability	+	↑	↓	↓	↑
	Cost	+	↑↑	↑	↑	
	Target for Engineering Requirements			< 20%	< 2 hours	< $500

Table 2-1 House of Quality Table

3 Research related to Project Definition

This chapter covers similar projects and current technology that is useful to this senior design project. First, it covers similar projects and products completed by the time this paper was written. Next it will cover the available relevant technologies that can aid in these types of systems. Following that, components that are useful to the specific project. Then is covers, the different possible architectures for creating this system. Lastly, the part selection summary which will explain what components were chosen and why those components where picked other the other available components.

3.1 Existing Similar Projects and Products

As the idea of a hydroponic control system for an indoor system became the topic of this project there subsist plenty of other control system to investigate to visualize what ideas constitute good features to add value to this controller. Of all the systems, out there the following systems were worth using for motivation and to see what was not on the systems.

This section will cover various project or products that are related to this groups senior design project. Some of these systems were used as an aid the group, either by providing information that wasn't originally thought about. While others help the group escape issues that would've cause problems later in the design, development, and implementation process. There are many different hydroponic controllers on the market and all the features so far create a way for people to grow plants without having to do everything manually. With the consideration of all the systems the hydroponic system of this project will utilize features from each of these systems to maximize the benefits of what has already been done. There is one main feature this projects controller will implement that has not been seen and that is the ability to dim the lighting system automatically. The projects controller will monitor pH, TDS, water level, adjust pH, adjust nutrients, measure light intensity, and dim the lighting system. The microcontroller will take all the measurements and with user inputted settings will make the necessary adjustments automatically. The main feature the microcontroller will provide is to measure the light provided from the sun and it will utilize artificial lighting to make sure the plants receive the proper intensity of light and in the end, will save the user money from their utility bills.

3.1.1 Hyduino

Hyduino is hydroponic system that has a lot of documentation of the web. Its system uses the ATMEGA 2560 microcontroller to control its various systems. This system was created to control its lights and, the pH levels using peristaltic pumps similar to our system. A light sensor to control its lights and a LCD touch screen to control the pH, water level, and temperature control. This system also used relays to control the different systems from the pins of the ATMEGA microcontroller unit. While this system is very like our system, we will improve on this design by also including a total dissolved solids sensor to control the quantity of nutrients that our system gets. Another way we are looking to improve on this system is with Wi-Fi and the internet. Our data while being read on a LCD screen will also be uploaded to an online database through a Wi-Fi module connected to the internet. This will allow us to monitor the hydroponic system from any location with internet access.

3.1.2 LeafAlone Hydroponic System

LeafAlone Hydroponic System is a system that was designed at UCF by senior design students in 2014. Their system was designed to run on solar and battery power to conserve energy. While their system was eco-friendlier, the cost of the solar system was costly. Their system used the ATMEGA 328 as the microcontroller to control all their subsystems. Their system all used the use of Wi-Fi to communicate real time data to the web where it could be read in graphs or charts. In their system, they were interested in collecting data from pH sensor, electrical conductivity sensor, water and temperature sensors. One aspect of their system which is not included in ours was the use of a camera to remotely monitor their system by visually inspecting the progress of their system. We believe that this aspect is not necessary now and is something that would be in consideration in future revisions of the system. One way we intend to improve on this system is the implementation of a LCD screen in our system. This will give the user visual implementation that the system is working.

3.1.3 Autopilot Greenhouse Master Controller (GMC)

This system was designed to precisely control temperature, humidity, and CO_2 levels in the growing system. This system is designed to be user friendly with controls directly on the front of the unit to control the various functions. Also, there are easy to read error warning lights on the unit to warn when something in the system is not right. Instead of this system sending its data to an online database it has a built-in data-logger to store the sensors data. This might be convenient for the systems that are off the grid and have no way to access the internet. Also, this system has been designed to resist EMI / EFI interferences from subsystems such as relays and light ballasts. While this system is a simple plug n play type system it lacks the needed sensors of pH and TDS which will be in our system. While it does lack these types of sensors which we need in our system, it does have appeal to the beginning hydroponic system user.

3.1.4 NIWA Hydroponics Systems

NIWA system idea is to allow the everyday consumer to be able to grow in home with the simplicity of using an app on a smartphone. Whether you are a just beginning grower or a green fingered enthusiast. Their intention in their design is to make growing fun and incredibly simple. All the care that the plants need comes directly from interactions through the app on a mobile device. The app can control the irrigation, heating system, lighting, ventilation, and climate control. Through this app you can monitor the growth of your plants and adjust when necessary. The app also allows you to connect with other NIWA system growers to broaden your understanding on what is needed for good plant growth. This system is designed to be an all in one system which runs quietly, efficiently with minimum maintenance. The biggest plus to this system in a residential home is that it is simple and such a neat little package that you would not even notice it is there, and when you need to know the conditions of your system all you must do is look at your smart device.

Figure 3-1 NIWA Hydroponic System

3.1.5 Cloudponics

This system also like the NIWA system uses a remote app on your smart device to monitor and control your system from anywhere in the world with their Cloudponics app. This system uses peristatic pumps to control the pH, nutrients, and fresh water needs. With the peace of mind of your plants getting the needed requirements daily you are free to not worry when away for extended period. This system monitors the air temperature, humidity, and light intensity that your plants are receiving. When needed, it can control fans and humidity to bring them within the proper specs of your plants. Three separate peristatic pumps can be custom designed to inject custom designed nutrients to your plants depending on the stage of your plants at a touch of a button. By experimenting with three different types of nutrients and the mix needed for your plants, you can see what works and what doesn't and are able to change what your plant needs during the different growing cycles.

Figure 3-2 Cloudponics

3.1.6 Growtronix

Growtronix has a clean and professional looking system and their focus is on automation. The hydroponic controllers on the site are very clean looking and what looked appealing with their system were the following components. In figure 3-3 they designed a TDS sensor that will read the salinity in the water for the user to interface and know when the system needs to have more nutrients added. In figure 3-4 they designed a pH system to measure the pH of the water. If the solution the plants are growing in does not have the correct pH the plants will not be able to take in the proper nutrients. The pH sensor is equally a must have feature for a grower who wants to automate the hydroponic system. To go along with these sensors, they designed a controller as seen in figure 3-6 to be able to control the addition of nutrients, pH up, and pH down. With the dosing pump the user can let the controller handle the balance of the growing solution to produce a plentiful yield for the end user. The final product that they designed of interest is the ability to control a power supply. In figure 3-5 Growtronix displays the controllable power supply. A huge advantage that this company is offering is the ability for the user to interface with these devices electronically. The system interfaces with the user via computer or an app. For the grower to be able to get data in their hands anytime they need. With the electronic system, the user can control the set points of the pH, TDS, and lights depending on the needs of the plants. Over this system has provided some great ideas that will be of interest to the hydroponic controller to be designed in this project.

Figure 3-6 TDS sensor

Figure 3-6 pH System

Figure 3-6 Controllable Power Supply

Figure 3-6 Sensor Controller

3.1.7 AGROWTEK

AGROWTEK has designed a complete hydroponic control system for a grower to purchase to automate their grow operation. This hydroponic control system is like the previous one reviewed with a couple of interesting topics that will be considered into the upcoming design of this project. This system has the typical pH sensor, TDS sensor, pump control, and power controlled timers, however; the addition of a LCD screen on the wall mount controller is very interesting. It is one thing to have the information available on a computer or phone, but to have a LCD screen adds the ability to visualize and control the system in the event the user is in the grow room and does not have their electronic device on hand. Another advantage of having a LCD screen is to be able to adjust the system if there are any issues with internet connectivity. As figure 3-7 shows the package is a desirable look too. Another interesting feature of ARGTOWTEK it the ability to control the climate. They have added temperature sensors that can control fans or an air-conditioning system. The down side of AGROWTEK is the cost. The cost of their controller is around $1,700 for a full controlled system. This is a complete system that is more geared to a large growing operation such as a nursery

Figure 3-7 AGROWTEK System

setting. The design of those project is focused on the average person that wants to grow inside their home to know the quality of the food that they are eating so from this system the one feature that will be utilized is the LCD display.

3.1.8 Huertomato

The Huertomato hydroponic controller was the final system that under consideration. The difference this hydroponic controller offers are the utilizing of a microcontroller to monitor the system. The ability to control the system from one interface is a feature that makes sense. The Huertomato controller does the same functions as the other two systems such as monitor pH, TDS, Humidity, and temperature, however; an interesting feature that makes this system stand out is a light sensor. The Huertomato system utilizes a light sensor to measure light intensity. The microcontroller monitors the system and will monitor ambient light by measuring light intensity with a sensor. When it is, light intensity drops below a set value the microcontroller controls the ability to water the garden at that time. The utilization of a light sensor is a great feature that will be considered for this project.

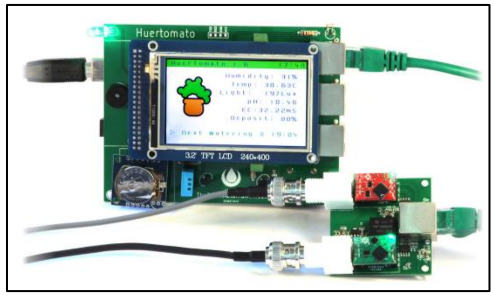


Figure 3-8 Huertomato

3.2 Relevant Technologies

3.2.1 Other Types of Hydroponic Systems

Besides nutrient film technique which we used in our project, there are several other type systems available for the home hydroponic user. There are many pros and cons for these other type systems, and where one system may work better for one type of crop, there may be a choice built around what you are going to harvest. Below are some of the other systems that are being used by hydroponic farms around the world.

- Wicking Systems
- Deep Water Culture (DWC) Systems
- Nutrient Film Technique (NFT) Systems
- Ebb and Flow / Flood and Drain Systems
- Aeroponics Systems

Wicking systems has been around for thousands of years and were not thought as hydroponic systems until recently as seen in Figure 3-9. Basically, a pump from the containment system brings the water solution to the roots, which are in large square configuration containers. Once the water reaches a certain level, say halfway up the container, the liquid hits overspill tubes which recycle the fluid back into the storage container. This is like our

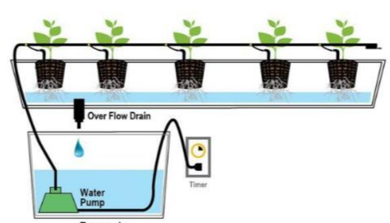


Figure 3-9 A Wicking System

system, in that the pumps are running continuously. The roots in these plant containers are only soaked in the part of the container which holds the solution, the top portion of the roots are free hanging in air. In this way, the roots are able to obtain the oxygen they need directly from the roots that are in the air. In the beginning the roots are connected by a wick or a piece or rope to get the nutrients and water up to the roots, but once the roots are long enough, the piece of rope is removed.

Deep water culture defers from the above system by instead of moving the water around and letting the roots get the oxygen by their roots, deep water culture the roots are always submerged in the hydroponic solution and an air stone is added to the hydroponic solution to provide the oxygen the plants need to survive. This is a very simple system to set up and is easy for a first type hydroponic grower. These buckets that is seen if Figure 3-10, can be daisy-chained together to provide air by splitter value, and as many as needed can be hooked together when more is needed, providing the air source has enough power. What makes this so simple is all you need is a bucket and air source and air stone and you are up and running.

Figure 3-10 Deep water System

Nutrient film technique is the system that we ended up going with in this project as to it was simple to set up and is the most common setup for small area growing. This system also used a water pump to provide the plants with water and nutrients. In this system the water is always being pumped to the roots. The difference with this type of system is that the pump provides not only the nutrients, but also the air that has been defused into the hydroponic solution by an air source and a stone. The water is generally pumped to the highest location of the grow rack and gravity draws it back down and into the containment container. This system is always bringing nutrients to the plants and is a very efficient system. In the tubes the roots are exposed to nutrients which are running down the tubes in a film technique, this means that the roots are exposed to the solution but more importantly, they are exposed to oxygen where the roots do not make it to the bottom section of the tube, in Figure 3-11 you can see this technique.

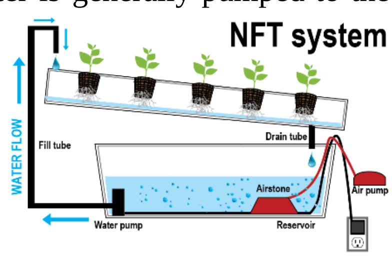


Figure 3-11 NFT System

Ebb and Flow systems, are becoming very popular among hydroponic solution growers for many reasons. Like the nutrient film technique, the solution is pumped from the containment chamber to the plants. What this system doesn't need is an air source, this is because the roots are only submerged in the hydroponic solution on time intervals. On the solution cycle the roots are provided under pressure to fill the plant container with solution up to the overflow tube, at which time the excess is placed back into the solution reservoir seen in Figure 13. This set time is dependent on what is being grown, but 30 minutes is usually more than enough. The next part of this cycle is when the pump is shut off, the remaining solution that remains in the grow tray is then slowly drained back to the storage reservoir and the roots can absorb oxygen through the roots which are now exposed to the air. These two cycle then repeat based on the time sequence for best plant growth, this is seen in Figure 3-12.

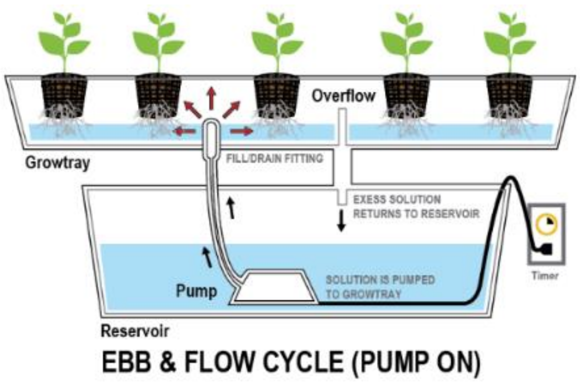


Figure 3-13 Ebb & Flow Cycle (Pump On)

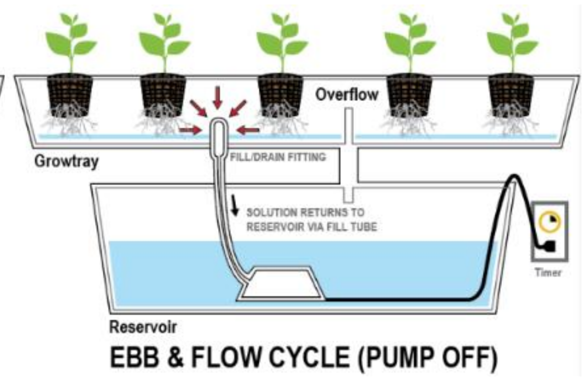


Figure 3-13 Ebb & Flow Cycle (Pump off)

Aeroponic systems are another relevant technology for providing the plants with nutrients. These systems are very easy to build and very little that can go wrong with them. In this system, the plants sit directly above the nutrient solution. The solution is pumped up and sprayed directly on the roots in timed intervals. In this way, the roots can get the solution they need and the oxygen they need from the air as seen in Figure 3-14. Some of these systems are even equipped with ultrasonic sprayers; these sprayers provide a very fine mist of solution the roots which is easy for the plants to absorb.

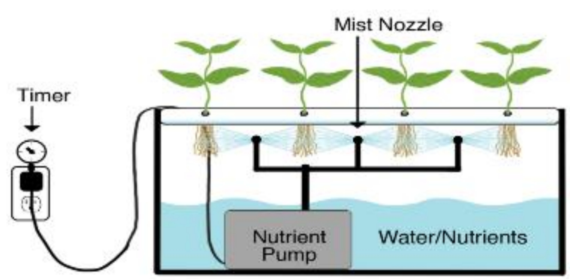


Figure 3-14 Aeroponic System

3.2.2 Solar Power

Instead of power from main to power our lights and system, another relevant system that could have been used is solar power as seen in Figure 3-15. Solar power dates to the mid 1800's, where solar power was used to heat water than create steam to drive machinery. It wasn't until 1941 that solar power was realized after the creation of the bi-junction transistor. Using semiconductors there was a way to have light strike a semiconductor material which caused electrons to flow, and thereby create electricity. This effect was called the photo-electric effect. This power which would have been more than enough for our system using

Figure 3-15 Example of a Solar Panel

LED's and low power microcontrollers would have been suitable for this design, but was not chosen. During the day these photo cells would produce electricity and would power the LED array needed to grow the plants, and run the various other 12-volt DC systems. This 12-volt power would then be reduced to lower voltages for our microcontroller and sensors. The excess power would be stored in a bank of batteries, enabling the system to have power throughout the night and during days of low light levels due to clouds. In most case, solar is not the way to go, this is because the amount of energy needed by high intensity discharge or fluorescent lighting. The number of solar panels needed is too high to be affordable by average home owner.

Solar cells which were invented after the creation of BJT and mosfet when it was observed that striking one of these devices with solar light an electric field was discovered as seen in Figure 3-16. Solar cells are constructed with a metallic conducting strip on the surface of the semiconductor material with an anti-reflective coating that allows the sun's rays to penetrate the semiconductor material. The element silicon has 14 electrons arranged in three different layers. The outer shell only has 4 electrons in its shell, so silicon is always trying to get rid of its outer shell or fill it up. It is this configuration that allows silicon to take on the crystalline structure. All the silicon atoms are thus held together by its four neighbors to make a structure similar to that of a diamond. Silicon in its natural state is a poor conductor but by intruding impurities to the pure silicon by using elements from the neighboring elements, it is possible to make the structure either partly positive or negatively charged. When the sun strikes the N-type semiconductor layer which is negatively charged it causes electrons to jump across the depletion region to the P-type which is positively charged. This extra electron causes a hole or a positive charge to flow back to the other side creating a current within the two-layer semiconductor material. These cells are connected to each other in a similar way a line or diodes are connected where electricity can only flow in one direction.

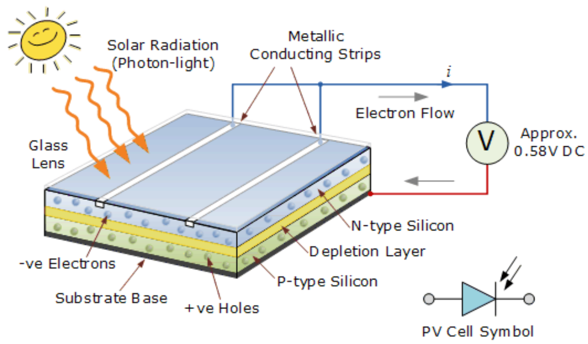


Figure 3-16 Solar Cell

3.2.3 High Intensity Discharge and Fluorescent Lighting

High intensity discharge or (HID) are lights that have been used in hydroponics for decades. These lights are intense as their name implies and basically come in two different types, metal halide (MH), or HPS which is preferable for the flowering or fruiting stage of the growing cycle but is not necessary. If price is a constraint your indoor garden can grow just fine with a metal halide (MH) and these systems give the plants the full

Figure 3-17 HID Bulb

spectrum of light that they need. The second type of growing lights is fluorescent lamps, especially high-output fluorescent as seen in Figure 3-19. Not only are they more efficient than incandescent the cost of electricity is much less.

Metal halide lighting systems consists of four parts. These parts are the bulb itself, a reflector hood, and a ballast. Most of the time these systems are sold together, because they need to be compatible with each other, you cannot mix and match different systems together. One downside to HID lights are the enormous amounts of heat the produce can cause damage to your plants if they are not properly cooled. One of the most common ways today of cooling the air around the bulb is to have the reflector that is vented to a ductwork section the blows the hot air outside the grow are using a fan seen in Figure 3-18. This process of controlling the high heats of the metal halide bulb is the reason that we went with LED which produce little to no heat byproduct. The second downside is the large cost to the electric bill, these bulbs are very inefficient, and unless you are growing a high product produce they are not feasible for the home hydroponic system, or for the person who just wants to grow some herbs by the window as our system as set to do.

Figure 3-18 Cooling Fan

Fluorescent lighting works fine for lettuce and for starting clones out as they do not produce the same amount of heat that HID bulbs do Figure 3-19. They also are cheaper and last longer than the HID bulbs also saving cost. Their main drawback is that they do not have the full spectrum of lighting needed to grow plants that flower and produce fruits. Although great strides have been made to improve these bulbs with a better spectrum and higher intensity of light per bulb, the technology is still not there yet. And yet they are still a choice for people who are only interested in growing leafy products that don’t need to flower and produce vegetables. Also, they are still in high demand for the hydro culturist that wants to grow clones or juvenile plants, because the bulbs cans be moved into a position that is just over the plants without the worry of scorching the plants or removing all the hot air a HID produce. Many times, growers will use both systems, in a way that the juvenile plants use the fluorescent lights and then are slide over to the HID bulbs once the plants are mature enough and need the extra light to produce fruit or flowers.

Figure 3-19 Fluorescent Lighting

3.2.4 Space Hydroponics

Unlike farming her on earth, farming in space or zero gravity has some serious drawbacks. The importance for astronauts to grow produce during long space flights has always been a concern to NASA and other space organizations. How to contend with having no gravity for long periods of time. And since food is needed and the removal of carbon dioxide from the air and fresh air produced by the plants it's a wining situation, if they could work out all the kinks. As seen in Figure 3-20, space available to grow in a space vehicle is very limited. But it is very clear that some type of hydroponic system is the key as space and heat are main concern of a space vehicle. And the heat is much of a concern to LED arrays will probably be the future. The LED technology is becoming a better solution to the problem than fluorescent lighting. Hopefully in our next missions to populate a station on the moon that we will develop the necessary tools to make this a possibility. It's not a matter of when it's a matter of we have too, to keep humanity from dying from some type of global catastrophe.

Figure 3-20 Hydroponics In Space

Scientists are looking at the different factors in growing space, namely the lights, temperature, and carbon dioxide levels the plants can absorb. Also, what happens when different types of produce are brought together near each other. Any type of liquid on a space vehicle would also come into a key factor when designing a space hydroponic system. A lot of research seems to be looking at potatoes as one of the spaces first crop. This is because they are one of the foods that produce a lot of carbohydrates which will be needed for deep space exploration. Even if we were able to get to Mars and set up a hydroponic system in a grow house, the light that mars receive is about 43% of what we get on earth. As seen in Figure 3-21, of an artist imagination of what a grow house would look like, LED or some other light source would be needed to supplement the light that Mars receives.

Figure 3-21 Artist's Vision of Space Hydroponics

3.3 Strategic Components and Part Selections

This section will cover the strategy the group used to aid in the selection process, this was one of the first processes the group sat down and discussed. It was important to the group, how the selection of components was going to preformed. Once the group agreed on what the system's basic design and requirements were then we had an idea of what components this system was going to require. After that the group set up a couple of rules to eliminate the huge number of components that are available on the market. In no particle order the first constraints used for the first round of eliminations was;

- Cost
- Ease of use
- Ease to integrate into the system
- Meets the minimal requirements
- Energy cost
- Delivery Time

Using these factors the group could eliminate the main bulk of components available. Even after this round of eliminations the number of components available with too much. So, the second round of eliminations was performed with the following factor in priority from top to bottom;

- Cost
- Delivery Time
- Ease to integrate in the system

After this round of eliminations, the group could order the components required to start building the prototype. The following section will talk about specific characteristics of the individual components.

3.3.1 Circulatory pump

Figure 3-22 Pump

Our system is going to use a circulatory pump to circulate the nutrient solution to the plants. In our first system design, we will be using a nutrient film technique (NFT). This technique requires the pump to be on constantly, therefore is will be a separate subsystem which is not controlled by the microcontroller. One of the major concerns in choosing a circulatory pump for the system is that it does not interfere with the sensors in the circulatory chamber. Because this pump is to be submerged into the nutrient solution this interference is a constraint that might have to be dealt with by a voltage isolation circuit which will be discussed in another section. The pump that has been donated to our system is the Eco Plus 264 submersible pump which can produce a flow rate of 290 GPH and is well known as a functional pump in the hydroponic growing community. This pump is oil free so contamination between the pump and the nutrient solution is not a concern. The pump uses ceramic shaft and bearing which insures reliably and corrosion free operation while be submerged in the nutrient solution. Because there is only one moving part this pump is trouble free and not prone to breakdowns. The pump contains a strainer which may need to be checked for obstructions of plant material from time to time, but overall has very high ratings.

3.3.2 LCD Screen

Having a LCD (liquid crystal display) screen for this project will not only help us in testing the system while in development, but will also provide the end user with a quick and easy way to see what the system sensors are reading and what it’s doing to correct the problem. For example, when the pH is to low or high the LCD screen could mention that the peristatic pump is activated for either pH up or down. Another advantage would be that if something was wrong in the system a warning sign could flash on the screen to bring attention to the problem before things get worse. This system will display things such as the pH value, TDS (total dissolved solids), water level, and light illumination. The LCD screen could also help with Wi-Fi connection to the internet and show that proper connection has been established.

Liquid crystal display screens come in an assortment of colors shapes and sizes. For our purposes, we will start with a small screen that will display information in a cycle. To save money this is a good option, because the larger screens are very expensive and this is our first prototype, in the future we may expand to a larger LCD screen which could even be touch sensitive, but for now we just need a way to monitor the system in case the internet goes down and then there would be no other way to monitor the system. For this reason, having a LCD screen will make our system more robust to problems with the internet and Wi-Fi connection. Green and blue LCD screens seem to be the most cost effective so we will probably choose between these two colors. The screen is hooked to our microcontroller by six data pins and a ground and power pin for a total of 8 wires. For this reason, we may need to upgrade our microcontroller to one with more data pins to accommodate this screen, because we are already using a log of pins on the Atmega328 with the other sensors. Adding a potentiometer to the power supply of the screen will allow us to dim the screen when not in use and brighten it up when a reading needed.

Figure 3-24 LCD Screen

In future revisions of this project a LCD touch screen can be implemented which will require even more pins than these simple types displayed above. Although they require more pins they can display different colors compared to the mono tone ones pictured above. Also, they can rely information by touch a lot like how our smart phones work to the micro controller and change setting on

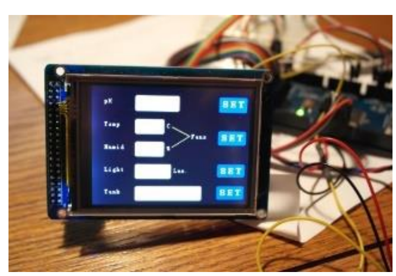


Figure 3-23 LCD Touch Screen

where pH or light cycles are set. This will give the user a way to change settings in case the internet or the Wi-Fi service somehow becomes disconnected allowing the user to keep the system in working condition until the problem is resolved.

3.3.3 LED and Dimmer Array

The main source of nutrients for plants to grow comes from the sun. As more gardens are being grown indoors the need for adequate lighting is imperative. There are multiple sources for indoor lighting systems. The different lighting sources available are:

- High intensity discharge
- Fluorescent
- Incandescent
- LED
- Sunlight

High intensity discharge lamps are a type of lamp that produces enough light to grow plant indoors. There are two different types of high intensity discharge lights. The different lights are metal halide and high pressure sodium. Metal halide bulbs produce more blue spectrum and these are utilized during the vegetative growing stage. High pressure sodium bulbs are utilized during the flowering stage. High intensity discharge bulbs come in 250w, 400w, 600s, and 1000w. There are a few advantages that make these lighting systems the most utilized for indoor gardening and these are:

- They produce intense lighting to allow a deeper penetration of light into the garden.
- Produces a wide spread so the light covers more space
- Widely available

The disadvantages of high intensity discharge bulbs are:

- They are not energy efficient
- Produce a lot of heat
- Need extra fans to help keep plants cooler
- Need a large exhaust fan to remove the unwanted heat
- The need for ducting to route heat out of the room
- Need more amperage to the overall power in the room

Due to the complexity of these lights and they will not be energy efficient these types of lights will not be used for this design.

Fluorescent lighting systems are the second most commonly utilized lighting systems currently implemented. These types of lighting systems come in several different sizes and wattages for the user to choose from there are advantages and disadvantages to fluorescent lighting systems. Some advantages to fluorescent lighting systems are:

- Energy efficient
- Produces low heat
- Several bulb types for vegetative and flowering cycles

- No need for complicated ventilation systems

The main reason this system was not utilized is the consumption of energy. Some of the disadvantages are:

- Do not have a wide spread of lights (plants must be directly under fixture)
- Does not have depth of penetration
- Cannot dim the lighting system

The main reason this lighting system was not utilized is the inability to dim the lights. As the research was conducted the use of incandescent lights were considered for the source lighting. While there are incandescent lights that can be used for growing plants the lights are inefficient and are a poor source of lights for plants to utilized for nutrients for growth.

The final lighting system to be utilized is the use of an LED array. LED lighting is still the newest lighting system on the market for growing indoor plants. There is a lot of research being The LED array lighting system is very efficient and produces minimal heat. Due the array not producing heat it eliminates the need for additional fans and an exhaust system. The LED lighting systems are where most of the lighting research and design is being focused. The trend of indoor growing lighting systems is focused on LED arrays. There advantages are:

- Full spectrum lighting
- Will produce infrared light to promote cell generation
- Energy efficient
- Low heat generation
- Dimmable

Due to the future trends of LED lighting systems, all the advantages, and the systems dimming capability this project will be focused on utilizing the LED array to grow the indoor garden.

Now the type of lighting was researched and decided on, the focus went to figuring out what circuit components are needed to control the dimming of the lights. There were a few parameters to make sure were met as the circuit design was being considered.

- Ability to control the dimming in small increments
- To be able to digitally control the lights
- The proper sizing to fit on the PCB

One important aspect of the project is to be able to autonomously control the dimming of the LED array. There were a couple of options that were researched while considering how to control the LED array.

The first option that was considered involved utilizing the mcu. The system is a viable option however, as the array is turned on for an extended period it would put a strain on the microcontroller which is an undesirable design. The second option that was explored was utilizing the MCP4131 digital potentiometer. This chip can use 127 bits to control the dimming of the lights and it can handle current flowing through it for an extended period. It is also a relatively simple design. This chip utilizes the 5 volts from the power supply and the main ground. Otherwise the microcontroller sends the signals to control the system through one pin.

3.3.4 Light Sensor

For the system to be autonomous and energy efficient the use of a light sensor will be implemented in the circuit. There are several factors that were considered during the research of the light sensor.

- Light reading range
- Lux readings and output
- Ability to communicate with the MCU
- Programmability

After looking at many different light sensors the TSL2591 dynamic range light sensor was chosen. This light sensor reads lux, full spectrum, infrared, and visible light. These will be needed for the implementation of the lighting sensor. The mcu will need to distinguish the difference between the sunlight and the LED array to know when to adjust the brightness of the array. This light sensor is compatible with the MCU and the coding is flexible.

3.3.5 Logic Level Shifting

Because different subsystems communicate in different voltages, a logic level shifter will be required for the different subsystems to be able to communicate. Basically, in the world of digital signals there are two states on or off. These two states can be represented by different voltage differences. Usually these include 5V or 3.3V. These devices either connect a pin to its high voltage or connects it to ground to represent its low value. The problem is not all devices use the same voltage levels. To get around problem logic level shifting is needed to deliver proper communications between the two devices.

Figure 3-25 Logic Level Shifter

Logic level shifter converts the binary data in one voltage to another, this is done by hooking the converter up to both the voltage levels that are needed. Then when the microcontroller is hooked up to the converter it converts it to the needed voltage on the receiving end. When it receives a high 5 volts from the MCU it changes this high to 3.3 volts which can be read at the component on the other end.

3.3.6 Microcontroller

This system will require a microcontroller to run the system. The microcontroller takes the inputs from the various sensors and makes use of the serial information and then makes decisions based on these reading. This might be to turn the system lights on and off, or to add pH up or down solutions to control the pH, or to add nutrients when the system is running low on nutrients. This information is then relayed to a WIFI unit which then uploads the information to an online data storage site which can be used to remotely see what is going on when away from the system.

There are many considerations in picking the best microcontroller for the system you are working on. Does the microcontroller have enough input/output pins to run the system? Does the microcontroller have enough memory to hold all the libraries and the code that is needed to keep the system running?

Input/output pin consideration in our system is very important because of the number of subsystems controls and sensors that are connected to the system. Our system may need as many as 20 pins to be able to run correctly. Without having the correct number of pins other components would be needed making the system more complicated, while in practice this is not impossible it is most often easier to just go with the next bigger size microcontroller as power is not a main concern in this projects.

Another main concern is to make sure that our microcontroller will have enough memory to hold the libraries that many of the sensors need to run correctly and the code to control the whole system. This must be considered still when writing the code and may require that we got up to the next size microcontroller even though the required number of input/output pins is within the required specifications.

Power consumption is always a constraint in many systems but in this system because so much power is going to be used in other subsystems, the power that is being used by the microcontroller is trivial compared to all the other subsystems.

3.3.7 Nutrient Sensor

The system will implement a nutrient sensor to read the solution in order to read the nutrient levels in the solution. Once the readings are taken the information will be used to control the pumps to add the nutrients needed to the solution. There were only two options that was found for this sensor. The options were to design one or purchase the AtlasScientific conductivity K 1.0. This sensor can read the total dissolved solids or electro conductivity of the solution. A big advantage of utilizing the sensor from AtlasScientific is it comes with the module to convert the current reading into a digital readout for the MCU to utilize. If a sensor was designed and manufactured it would be challenging to figure out how to convert such small current flow to actual information for the MCU to decipher. The use of the AtlasScientific sensor is the best option for this autonomous system.

3.3.8 Oxygen air pump

Unlike soil based plant system, in hydroponics if you don't have dissolved oxygen in your hydroponic solution your plants will die. For this reason, we need to make sure our plants are getting the proper oxygen level they need to thrive. A simple way to ensure they have enough oxygen in the nutrient solutions is by using an air pump connected to an air stone in the hydroponic solution reservoir. This will dissolve air into the nutrient solution, it then will be delivered to the roots in a nutrient film by the circulatory pump, where it will be absorbed by the roots of the plants. In this first revision system, we will run the air pump 24/7 supplying the nutrient water solution with dissolved oxygen and monitor the amount of oxygen our plants are receiving. In future revisions, we may add an oxygen sensor to the system so we can turn the pump on and off when needed and to see when or if the system is in trouble due to a down air pump. This information would be added to our online database and send an alert either by app or text message allowing you to fix the problem before the hydroponic system fails. The pump we have for our system is the EcoPlus commercial air pump. This pump runs without oil and is very quiet; meeting the constraints of noise pollution for the in-house design and is designed to run for long periods of time without failure.

Figure 3-27 Air Pump Example 1

Figure 3-26 Air Pump Example 2

3.3.9 Peristaltic pumps

This hydroponic system is going to check the pH of the nutrient solution and when it finds that the pH has either dropped or risen to an unproductive value for the plants it will implement one of two peristaltic pumps to correct the problem. Keeping the right pH for the type of crop you are growing is important because when the nutrient solution is at the correct pH, the crop will be able to absorb more nutrients from the solution and grow at a more productive rate, therefore producing a larger crop. These two pumps will either deliver a base or an acid solution to the nutrient solution to correct the pH value. Also, there will be a peristaltic pump in conjunction with the TDS sensor to add nutrients to the solution when needed.

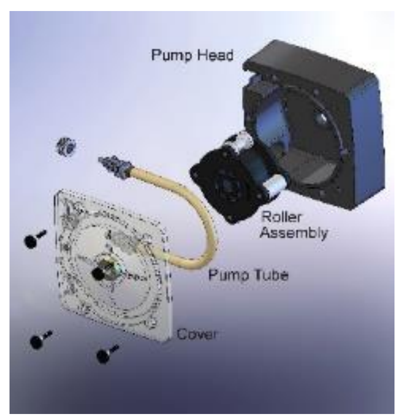


Figure 3-28 Exploded View of Pump

Peristaltic pumps are used to move all kinds of fluids. These fluids are contained within a flexible plastic hose which is fitted through a circular pump casing in front of the actual motor. Inside the circular pump casing the motor drives rollers to compress or pinch the plastic tube and occludes the liquid from the storage reservoir to the hydroponic nutrient reservoir. Typically, there are three rollers in the circular pump casing and once the liquid

Figure 3-29 Actual Picture of Pump

makes its way past these rollers the tube is free from the rollers and the tube returns to its natural state. Once free from the pump the fluid is free to travel down the other side into the solution container. Because of the way the tube is pinched in the rotor, this prevents any backflow or syphoning which is possible in regular pump operations, which would be disastrous to both the hydroponic solution and the solution reservoirs. The tubing in these pumps needs to be elastomeric to maintain its cross-sectional shape after the millions of cycles that it will endure being squeezed by the rollers of the pump. Because there is no metal to liquid contact, there is no contamination to the liquids and there is no corrosion to pump parts due to the caustic liquids. Another advantage to using these pumps is low maintenance, because they have two valves, seals, and glands make them inexpensive to maintain.

3.3.10 pH Sensor

Perhaps one of the most overlooked aspects of a hydroponic system is the importance for the pH of the solution to stay within a certain range. If this pH is not within the required range the plants may not get the nutrients they need to survive or even worse cause the nutrients in the solution to precipitate out, as these nutrients will begin to adhere to the walls and anything placed in the tank causing money loss and unneeded system maintenance. For example, at a pH of 7.3 the iron will start to precipitate out of the solution and at 8.0 there will be no iron left in the suspended solution and the plants will suffer or die. Generally, the target pH will be in the range of 5.0 and 7.0 making the solution a little on the acidic side. Keeping the proper pH and being able to read the data on a daily report will help keep our plants healthy and strong and save money at the same time.

Technically speaking pH stands for potential hydrogen-hydroxyl ion content in the solution. The range of pH is on a logarithmic scale from 1.0 to 14.0, where pH values less than 7.0 are more base and greater than 7.0 are more acidic. Because pH is read on an algorithmic scale a reading of 6.0 to 7.0, the 7.0 reading is ten times more acidic than 6.0

Checking pH can be done several ways, the simplest way would be paper test strips which are impregnated with a sensitive die and be comparing to a color swatch the pH can be determined. This method is not advantage to our system because of the need to be able to store this information electronically and adjust as needed. Another way is to use liquid drops and depending on how many drops are added to a sample solution the pH can be determined. Many home hydroponic systems owners use a small hand held sensor which reads the pH on a digital screen for quick and easy reading. This simple pH measuring probes are cheap and easy but trying to retrieve this information from the device for data storage could be extremely difficult, if not impossible

Figure 3-30 pH Sensor

for our needs. Because we are creating an autonomous system for hydroponics we will be focusing on the last solution which is a submersible pH probe, which uses a small electric current to read the pH of the hydroponic solution. This will be our choice because of its extreme accuracy and its ease of data retrieval by a microcontroller to read the pH and adjust for any discrepancies by adding acid or base to the solution to keep it within the parameters set by the plants being grown in the system.

Because of the need for tracking the pH levels in the system this data needs to be uploaded to a monitoring data website which can be viewed from anywhere there is internet access, because of this the rest of this discussion will be focused on the pH probe that is submerged is the hydroponic solutions which gives real time and constant feedback to the microcontroller which will be uploaded via Wi-Fi to the internet. Basically, most of these sensors are composed of two parts, the glass probe which houses the two electrical metals and the module which translates the conducted electricity. One of the electrodes in the probe is held at constant voltage potential while the second reads the conductivity between the two probes and relays this information to the analog to serial module. So, it is this potential difference through the solution from the probe held at a constant voltage to the one which is doing the reading. Since this data will be able to read of graphed in real time on a website, the user will see what causes the pH to swing and why it happens. Although our system will restore the pH to the proper levels in other subsystems discussed elsewhere, the user will be able to see what and why the pH levels are changing in a daily report which can be viewed in a graph time view for ease of understanding.

One aspect of many outdoor hydroponic systems is the variations in temperature. When temperature goes up our down so does the pH of the solution. Because we are developing an indoor monitored hydroponic system where the temperature of the house is kept within a few degrees' year around, this will not be a problem for the design aspect of this projects.

Most pH sensor probes can have an accuracy of 0.01. This accuracy will not be a needed requirement in this system because the plants we are targeting do not need the accuracy to the hundreds place, the tenth place is more than enough for what we need. We will be searching for a pH probe that has the readout capability range from 0.0 to 14.0. These probes produce an analogue signal based on the voltage difference between the two probes and is sent to its manufacturer module which converts the analog signal into a digital serial signal which the microcontroller can read and understand as a pH value. Once this periodical data is read by the microcontroller it can be checked and adjusted by other components of the system to regain the proper pH or do nothing if within the desired measurements.

When the probe reads measurements below the desired threshold an acid solution will be added by another subsystem, likewise if the pH reads above the desired threshold the system will react and add a base solution. The period at which the probe reads the solution must be of a sufficient and predetermined period that the added medium will have time to be thoroughly mixed within the tank reservoir. At which point another reading will be made and further adjustments being made to continue towards the desired pH level.

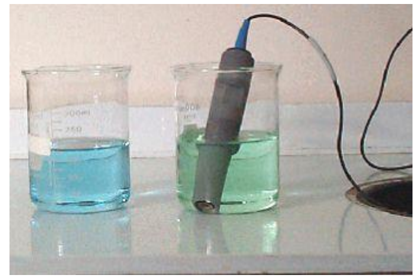


Figure 3-31 pH Sensor being used

One problem with the pH probe sensor is the need for the owner to conduct calibration and cleaning of the glass probe which is suspended in the nutrient solution. Although the probe provides security for the metal wires within, the nutrients do build up on all surfaces in the tank and anything suspended into the solution and does require cleaning for proper measurements. Cleaning the probe periodically will solve this problem and should be done on a regular schedule. By placing the probe as far away as possible from where the nutrients that are being delivered to the tank will help reduce the need for constant cleaning. Calibrating the sensor requires removing the sensor from the hydroponic solution and then after cleaning place the sensor in one of two different known pH solutions and then taking a measurement and reading it back from the microcontroller either thru the website or in a UART terminal on the computer and then calibrating the microcontroller to the correct measurement of the known sample. This technique is then done with the second solution and the calibration is complete and the probe can be placed back into the hydroponic system. Careful cleaning of the probe and handling with plastic gloves to avoid any outside contamination during this calibration is mandatory or your system pH values can be way off.

3.3.11 Power Supply AC to DC 12 volt

When it comes to power supplies our system is going to have both a AC to DC 12 Volt subsystem and it will require DC to DC regulated voltages for our other subsystems which will require 5 and 3.3 volts regulated low ripple DC. There are three main types to consider when choosing which power supply to choose, these are unregulated also known as brute force, linear regulated and switching power supplies. There is a fourth type which is a hybrid of the two previous systems of brute force and switching design, this system is known as the ripple-regulated power supply, but we will focus on the first three. There are many things to consider when designing your power supply and these include but are not limited to efficiency, overvoltage protection, maximum power, and continuous and peak power needs.

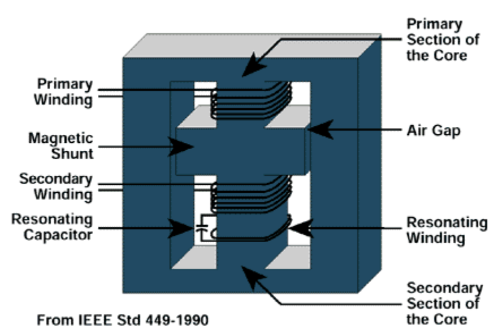


Figure 3-32 Transformer

Brute force power supplies or often called (unregulated power supplies) provide an approximate output voltage which is dependent on the load and input voltages. These power supplies are simple but they are often not used in electronics which require a certain level of accuracy and low ripple. These power supplies start with either a step up or step down transformer which are quite heavy and are made by strong magnets and coils of copper wire. After the transforming of the voltage the current passes through a series of diodes and a filter capacitor. Because the voltage does not remain constant depending on changes in the load, this type of power supply will not be considered for our 5 and 3.3-volt power needs which will have different loads depending on the action they are performing in the system. This brute force power system may be used in our AC to DC conversion which produces a 12-volt output and will be good enough to run our 12 volt pumps and then use either the linear or switching power supplies to run our more sensitive electronics in the rest of the system.

Linear voltage regulators convert often an unregulated DC voltage which has been converted from AC to DC in another subsystem and convert and regulated to a needed DC power supply. These regulators take the ripple out of the higher DC voltage and produce a constant voltage without the fluctuations of the higher voltage subsystem. Not only do linear voltage regulators reduce this ripple in the voltage they also reduce the noise that is present when converting from AC to DC power system. These power systems are very simple to create by their main drawback is their power efficiency. These linear voltage regulators were the mainstay of power conversion until the late 1970's and are still in use today as the component parts are very cheap and easy to build.

Figure 3-33 Linear Voltage Regulator

From the 1970's on switching power supplies have been the most popular form of DC power supply because of their exceptional power supply efficiency. In today's market being efficient is one of the number one concern in power design supplies. Switching DC power supplies also known as (switch mode power supply) regulate a higher subsystem voltage by a process called PWM (pulse width modulation). Because these systems are more efficient heat dissipation is less of a concern as with the linear voltage regulated systems. This efficiency is achieved by the switching transistor dissipates very little power when acting as a switch. This switching turns the voltage on and off and is achieved by varying the ratio in its on to off time. Texas Instruments web-bench does a good job of optimizing these qualities and providing a constant DC voltage which has excellent load and line regulation. These systems can produce more noise than the linear voltage regulators, but this noise can be suppressed in a good design. Because of the complexity in designing a good switching power supply we will most likely stick with the linear voltage regulation in our first revision.

Figure 3-34 Voltage Regulator

3.3.12 Power Supply DC to DC regulation

Once the power supply was stepped down and rectified the signal was ready to be sent through a series of voltage regulators to provide the necessary voltages to the circuit. There are several options that were considered during the research process. The voltage regulators that were considered were:

- Buck converter
- Linear voltage regulator

- DC to DC converter

The buck converter seemed to be a good direction to control the different voltages but there was a little too much delay time for what this circuit needed and since this design is a lower power system the buck converter would have caused more problems than was worth the effort. The DC to DC converter tends to be less efficient so that was not the ideal regulator to use. Finally, for this project the linear voltage regulator was the best choice. There will be three different voltage regulators utilized in this circuit design:

- 12-volt to 12-volt for a consistent source
- 12-volt to 5 volts
- 12-volt to 3.3 volt

With all the research these components will be sufficient to produce a constant DC voltage source.

3.3.13 Relays

Relays are electromagnetic switches that operate on a small voltage level that our microcontroller can produce and as simple as turning on our off a pin on the microcontroller we will be able to control voltages and currents for any of our subsystem components. Inside a relay is an electromagnet which consists of a magnet and a coil of wire. These switches are normally in an open configuration which means no current can flow to the subsystem device. When a small voltage is applied to the pin of the relay it maintains this normally open position. When the pin is connected to ground the voltage in the electromagnet is activated and the switch is closed allowing whatever voltage and current connected to the relay to activate the desired component. So, in this configuration we will be able to turn on and off the peristatic pumps which run on 12 volts to control the pH level. Also, the relay allows us to go from the ground and VCC conditions on the pins of the microcontroller to AC current which will turn our light on and off in a daily cycle. Basically, these relays bridge the possibilities of many power conditions to components which cannot run on 5 volts and low current conditions that the microcontroller produces.


Figure 3-35 Relay

3.3.14 Water Supply Pumps

For a hydroponic system, it is important for the solution to be circulated to avoid unwanted bacterial from building up in the solution. There are multiple options for pumps to be utilized in a hydroponic system. There were a couple options that were considered to for this system.

The first consideration was an external pump. This pump would sit on a platform and then the container would need to be modified to allow access to the nutrients. The container would need a hole drilled into it for the pump to circulate the water. In the long run if a residential setting could cause a problem if the system started to leak. Due to this consideration, this type of pump will not be utilized.

The second consideration was a sump pump. This pump will be submerged into the tank and will take solution directly into the input and pump it to the tubes and it will flow back to the holding tank using gravity. The pump selection will need to be able to pump the solution to whatever height is needed. The only down side of this type of pump is if the pump emits any voltage to the water. Due to this the use of a voltage isolator circuit will be designed to get rid of this extra voltage.

3.3.15 Water Level Sensor

This system is going to need a water level sensor to monitor and to make sure that the level of water in the containment system does not become too low. This information will be relayed to an online database, so that the system user can monitor and add water as needed. Because this information is going to be needed for the data bank and be monitored or possible graphed on a daily or weekly report, a digital water sensor will be needed. If possible we will be searching for a water sensor that has at least one inch of accuracy or better, so that we will be informed of the drop of less than this amount. Another major consideration in having a water level sensor in this system is that our PH probe and TDS sensor must stay in contact with the solution of the reservoir or permanent damage could occur to these sensors.

For now, we plan on just monitoring this level and adding water to the system manually by adding water into the system by hand, in future revisions a supply line may be connected and a control value installed. Most of these water sensors on the market are very cheap, so price is not much a consideration as is accuracy or durability in our case. Since the water level is not going to drastically change from minute to minute, the water level sensor may only need to be checked a few times per hour and then that information being relayed through the microcontroller to the WIFI unit and then eventually being transmitted to our online database to be stored and viewed by the user. Another aspect of the sensor is to notify the user that continuous pump that supplies the plants with water in our NFT system (Nutrient Film Technique) has stopped working, this will be seen by a significant increase in the water level. Being able to monitor and warn about this condition will give us time to get back to the system and fix the problem. The system for water monitoring that this system will need will not only need to have a decent accuracy level but will also be able to monitor when the system becomes too low or too high.

Figure 3-36 eTape water sensor

Because of these requirements, we need a sensor called a liquid level sensor tape. These sensors do away with the clunky metal float type sensors, which usually interfere with other sensors in the system. These tape sensors work by hydrostatic pressure of the fluid acting on it. This results in a change in resistance from the top of the sensor to the location on the sensor which is contact with the liquid. This resistance is inversely proportional to the height of the liquid, i.e. the lower the liquid level the higher the output resistance, the higher the liquid level the lower the resistance. This output resistance will range from 1500 ohms when empty to 300 ohms when full and have a resolution of 0.01 inches which is more accurate than our requirements.

3.3.16 Wi-Fi Transmission

Our system will require the standard of Wi-Fi 802.11 b/g/n communication between the microcontroller sensors and an online database. This standard utilizes spread spectrum radio waves. This type of communication is one of the most popular wireless transmission used today and is the standard for most projects with home router systems. Depending on what system is chosen ranges of 100 to 300 feet from the system to the router is possible and is needed in this house designed hydroponic system. This Wi-Fi subsystem will transmit to a local router which is then send to an online databank webpage. This information can then be routed to an app on a smart phone where the data can be read or seen visually by the owner of the system. These transmissions will send data and alerts when the system is not at optimal running conditions. These Wi-Fi units are low cost and able of two-way communication between the system and the database. This means that not only are there ways to monitor the system remotely, there will be a way to change the system as needed. This subsystem will relay information obtained by the microcontroller and sensors in the system.

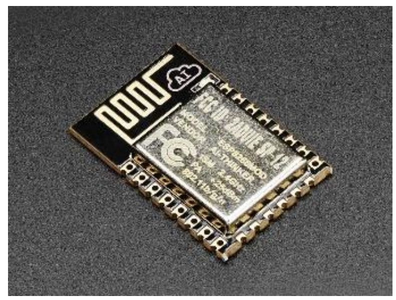


Figure 3-37 Wi-Fi module

3.3.17 Wireless

When our group decided on doing a hydroponics system, we wanted to make sure we not only had a functioning system, but that we innovated and improved upon previous projects and products that are currently available on the market. Many of these systems are automated, as ours will be, but none of them had auto-dimming lighting like our, nor did they have internet-accessible monitoring. We wanted to make sure that no matter where the user is, they will be able to check the sensor readings from anywhere that has internet access.

Having the sensor data available over the internet brings up several very important questions for us: how will we get the information on the internet? How will we organize and host this information? How will we secure this information? How will the networking be architecture? To begin with, let’s examine how we decided to structure our system:

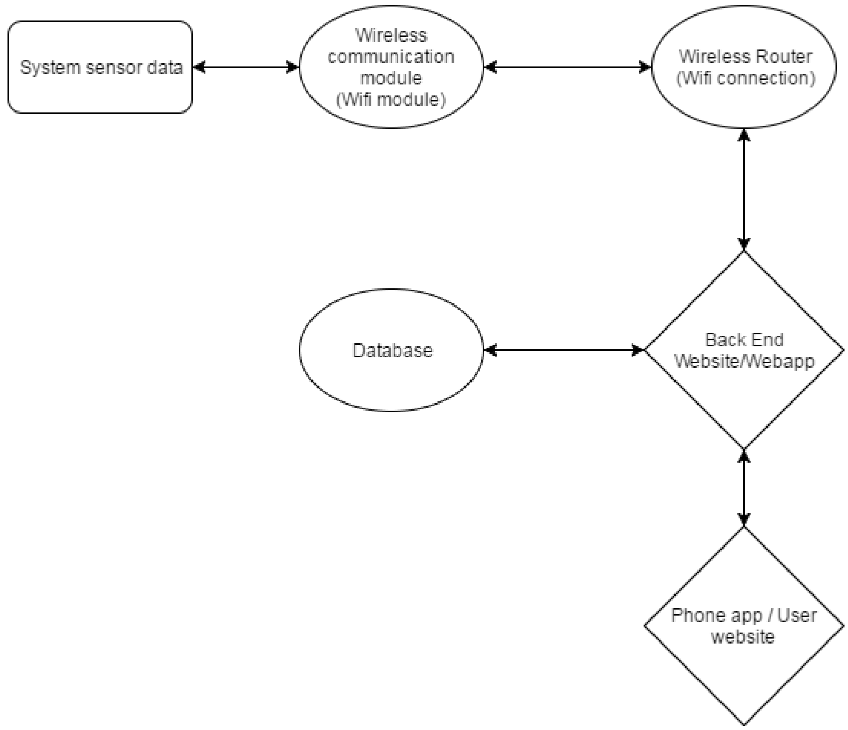


Figure 3-38 Wi-Fi Data Flow

The system shown above in Fig. W1 is the one that we ended up with, but before we get into that let's discuss how we elected this one from several other options. The first thing we had to decide on is the wireless communication that we would use to transmit information from the microcontroller to the internet. At first, we thought that we would maybe use Bluetooth to directly connect the microcontroller to the user's phone, but we quickly realized that this method would require the user to be physically close to the system, but this wouldn't allow the user to access current sensor readings from the internet. Using Bluetooth to connect to another device, and then the internet seemed excessive after we became aware of the ESP8266 Wi-Fi module. Also, going with an Ethernet connection seemed outdated.

The ESP826 Wi-Fi module was an attractive option to us because of its high performance at a low price. With each module being less than $5 per piece it was a solid choice. Considering the other components in our system are comparatively pricy, with 3 components being over $100 per piece, we wanted something that wouldn't raise our expenses exorbitantly. A development board with the ESP8266 was around $10 and let us get familiar with the different firmware's that the ESP8266 chip supports before we solder the module to a PCB.

The development board we used for initial coding and testing is the Adafruit HUZZAH ESP8266 Breakout board, soldered with pins for breadboard use. It is available at the Adafruit website [3] or $9.99 plus shipping. There are many ESP8266 development boards like this that are purchasable from similar companies and websites but we went with the Adafruit board because of their good reputation and our previous purchase experiences with the site.

This board comes preloaded with the NodeMCU firmware which runs a scripting language on the ESP8266 based off LUA [4]. You execute LUA style scripts over serial to the ESP8266 and it will run the scripts. There is also the option of saving script files onto the device which can be run like functions later. The support for this firmware is very limited however and the 3rd party tools we could find for loading, updating, and testing the LUA style scripts was shoddy at best, and annoyingly difficult at worst. Saving script files to the device proved to be unreliable, which means we'd have to send the whole script over serial every time we wanted to run it which seemed ridiculous and turned us off this choice for the firmware. On top of all the before mentioned issues, none of us had much experience in LUA scripting and so it would require lots of extra research on our part to create well-written code for this firmware.

Most of the ESP8266 variant development boards come preloaded with AT-command firmware available at the Expressif website [5]. From our research, it seems many people appreciate the simplicity of this firmware for testing and simple programming, but it lacks elegance. Writing code for it would present much of the same problems as with NodeMCU. Another option for firmware we came across was MicroPython, a stripped-down version of Python for the ESP8266. It's a firmware that while growing in popularity, once again ran into support issues like the NodeMCU firmware. Scouring the internet for buggy tools to flash and update this firmware was a hassle. Ultimately, we decided to go with the popular Arduino firmware which was a library for the ESP8266. We are all familiar with the Arduino platform and it seems to be by far the most popular choice for the ESP8266. Down the road, this factor should make troubleshooting any problems we encounter that much easier.

Getting back to the architecture in the system, shown in Fig. W1, you can see that we went with a three-tier architecture for the client server relation. The ESP8266 will communicate with a backend website through HTTP, and that website will then store the data in a SQL database using PHP. Using this backend website will give us versatility should we decide to change database software, design, or connection options without having to go back and reprogram the ESP8266 firmware. Similarly, the user can check the sensor data through a user-friendly front end site which will serve the data from the database. Likewise, the phone app will also serve the data from the database through a similarly designed front end website.

We've tried to develop the wireless software and hardware architectures to be as modular as possible. This will make updating and maintaining these systems as easy and efficient.

3.4 Possible Architectures and Related Diagrams

When this group first started making plans to develop the Home Hydroponic system we went through the many different types architectures we could use. It was decided that the system would use the Atmega328 since most group members have experience with this board. The system will operate using two Atmega328s, one to act as the MCU and the other to function with the LED display. This had to be done due to the increasing pin count as the project progressed and more components were added. A voltage and data insulator were added between the TDS and pH sensors, and the MCU. This was done to protect the signal from large increases in voltage. The next chapter will discuss and explain the different components that were added as the systems design process continued. This changed the basic layout of the MCU but the original architecture stayed the same.

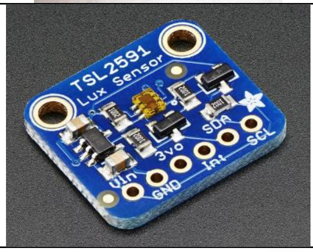
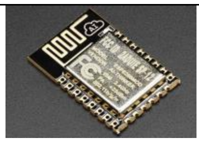
3.5 Parts Selection Summary

This section the group will discuss and explain what components were chosen and why these specific components were picked from the available technology. This section was the hardest and potentially the most important part of the beginning senior design project process. The first step of this process was to search online for any available equipment that would be helpful in creating this hydroponic system. After gathering all that information, the next step was to eliminate individual components based off several characteristics. The eliminating characteristics is as follows (not in order of priority);

- Cost
- Ease of purchase
- Delivery time
- Meeting the required specifications for that subsystem
- Ease of integrating into the current selected parts
- Ease of making it operational
- Total improvement of the overall system

By using these eliminators only a few parts were remaining, and in some case only one was remaining. The remaining products were then compared again, this time by giving them a priority of cost and delivery time. The component was then chosen and used in the system. We used this system for most main component and all small components (wire, capacitors, resistors, etc.).

The chart below shows a brief description and summary of the actual components chosen for this hydroponic system. All the components were extensively research and were chosen based on the functionality, efficiency, safety, and the ability to perform within the parameters of the circuit. All the components for the electronic circuits will be rated to double of what the system demands ex… if the circuit has the need for 5 volts all the capacitors and resistors will be rated for a minimum of 10 volts. Here is a quick break down of all the components;

Device	Type	#	Price per Unit ($)	Description	Picture
12V Dosing Pump	Peristaltic Pump	4	4.65	Used to deliver pH up and down and nutrients to hydroponic solution.	
Adafruit TSL2591 High Dynamic	Light Sensor	3	6.95	Reads the available light from the LED array and natural lighting.	
Atlas Scientific pH Probe Kit	pH Sensor	1	149.15	Reads the pH from the hydroponic solution.	
Atlas Scientific Kit K 1.0	EC sensor	1	195.71	conductivity Probe Kit	
Galaxy Pro 300 Watt	LED lights	1	109.99	LED lighting system will be controlled digitally	
Adafruit ESP8266 SMT Module	Wi-Fi Module	3	6.95	Transmits the sensor data to an online data base.	
FT232RL FTDI USB to TTL Serial Adapter	USB to Serial Adapter	3	1.85	Used to program the Atmel microcontroller on the PCB	
Adafruit ATMEGA 328P	Micro-Controller	3	5.95	Microcontroller for the system.	
China ATMEGA 2560	Micro-Controller	3	5.08	Microcontroller option in case of digital pin or memory issues.	

Adafruit Assembled Standard LCD 16x2	LCD Screen	1	18.18	LCD screen to display system data and warning on unit.	
Jameco Valuepro 112512-R Transformer, 2 amp	Transformer	1	15.00	Step down AC to DC transformer	
821-1N4007	Diode	4	0.18	Diode for the full bridge rectifying circuit	
TECH CAP 4700 50 VDC	Capacitor	1	4.86	To smooth out the signal after the rectifying circuit	
UXCell .1 uF 50V low voltage	Capacitor	2	0.50	To remove and EMI interference	
	Capacitor	1	0.53	Output capacitor	
LM7812	Voltage Regulator	1	0.57	Linear 12-volt regulator	
L7805CV	Voltage Regulator	1	.043	Linear 5-volt regulator	
LD1117V33	Voltage Regulator	1	0.55	Linear 3.3-volt regulator	
4131-103	Digital Potentiometer	1	4.50	Potentiometer to digitally control LED lighting system	
RECOM	DC – DC converter	2	8.20	DC-DC 5-volt isolated converter for the voltage and data isolation circuits	

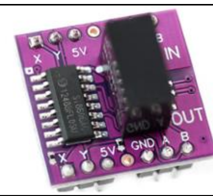
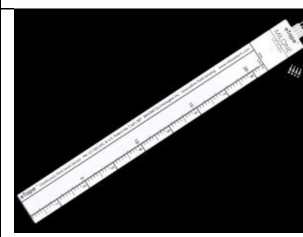
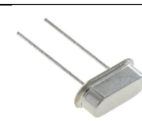
336 -2054-5-ND	Integrated circuit	2	4.00	This is the digital isolator that we will use to design and implement for the voltage and data isolation circuits	
To be designed on the PCB	Voltage isolation circuit	2		Voltage / Data isolation circuit for PH and conductivity circuits	
Variety	Resistors			Resistors for multiple circuit implementation on PCB	
Variety	LED			LEDs to be able to see when systems are running and troubleshooting codes	
8" Etape	Water level sensor	1	39.95	The water level sensor will be used to alert the user when the water level is to low and needs to be replenished	
774-ATS16B	Crystal	1	0.36	16 MHz crystal for the microcontroller to run its timing from	

Table 3-1 Selected Component Table

3.5.1 12 V Power Supply

The main power to control the LED array needed to be to be converted from ac to dc for the circuit to function properly. The circuit components were all evaluated for power consumption utilized and recorded in Table 3-2. Once the total power needs were calculated the power supply was ready to be considered. There are several components that needed to be researched. The following are what was considered:

- Transformer
- Diodes
- Voltage regulators
- Capacitors

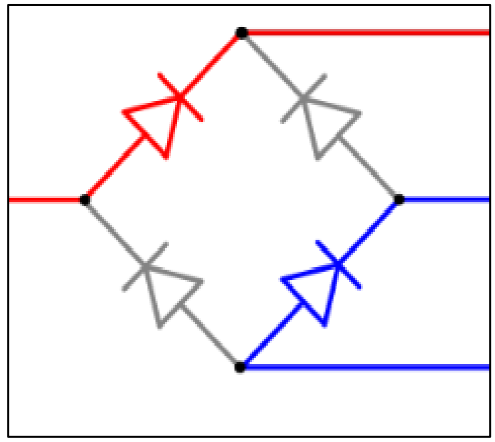


Figure 3-39 Full bridge rectifier

The first consideration was the transformer. The transformer will need to deliver at 1 ampere of current for the total component needs. After research, it was found that if the circuit needs 1 ampere of current the transformer needs to be able to supply at least 2 amps of current. The max voltage the circuit needed to operate properly is 12-volt DC. The transformer selected was 120-volt input to 34-volt output. Once the voltage was stepped down to 34 volts the first step was to rectify the input signal.

The input signal supplied to the circuit came in as a full sign wave. Once the signal came in through the transformer the initial step was to rectify the circuit. The decision was made to utilize a full bridge rectifier to rectify the circuit. The full bridge rectifier will utilize 4 1N4007 diodes. The circuit is shown in Figure 3-39. Once the sinal was stepped down it was neseccarry to correct the ripple in order to achieve a solid DC converted signal. In order to remove all of the ripple the use of a capacitor was needed. After reseach and carefull consideration the 4700 µF capacitor wsa found to remove most of the ripple. This will be discussed in further detail in section 3.3.12.

Quantity	Component	Current (mA)	Voltage (DC)	Power consumption (mW)
1	pH sensor	18.3	5.0	91.5
1	TDS sensor	22.5	5.0	112.5
1	Water level	100.0	5.0	500.0
3	Pump	80.0	12.0	960.0
1	Arduino circuit	50.0	12.0	600.0
1	Power isolation	200.0	5.0	1.0
1	Data Isolation	7.6	5.0	38.0
1	wifi	500.0	3.3	1.7
1	Light Sensor	0.4	5.0	2.0
1	Light dimmer	25.0	5.5	137.5
1	LCD	70.0	5.0	35.0
Total needs per subsystem				
Vaoltage (DC)	Current (Amp)		Power (watts)	
5	0..373		2.0	
3.3	0.5		1.7	
12	0.13		1.6	
Total	0.97		2.5	

Table 3-2 Power Consumption

Finally to provide the proper voltages for the different circuts the use of a voltage regulator was neccessarry to provide a steady voltage supple to prevent any failure to all of the circuitry. This research allowed the proper decisions to be made to create a quality power supply.

3.5.2 Data and Voltage Isolator

The TDS and PH sensors will be in the solution along with the circulation pump. These devices emit current and/or voltage into the solution. These unwanted currents and voltages will interfere with the TDS and PH readings. Due to this interference, the stray current and voltage needs to be dealt with. During the research AtlasScientific recommended to utilize a voltage and isolator circuit. This circuit will consist of the following components:

- SI8600 digital isolator with two bi-directional channels for data isolation
- SI8606 digital isolator with two bi-directional channels for voltage isolation
- Pull up resistors
- ROE-0505s isolated DC/DC converter
- 5-volt regulator on the output pin

Two of these circuits will be utilized to make sure the TDS and PH sensors both provide accurate readings. One will go with the TDS sensor and one will go with the PH sensor. One will be a date isolator circuit and the other a voltage isolator circuit.

3.5.3 LCD Screen

There were many different directions we could have taken when it came to choosing our LCD. After much deliberations, we decided not to go with a touchscreen display because of its complexity and much higher price point. The cheapest touchscreen display we could find was roughly four times the cost of our 16x2 character LCD that we settled on. The complexity of our hardware and software also goes up substantially when we considered touchscreen displays. Many of the ones we could find required their own microcontroller and that’s an entire additional PCB we would have to build just for the display.

The LCD we chose is the Adafruit Standard LCD 16x2. It is a basic LCD with two 16 character rows for display. It runs on 5v power and logic, so it is perfectly compatible with our Arduino microcontrollers. The LCD also has adjustable contrast so that you can make sure the characters on the display are visible. It only requires 6 data pins, which is much more convenient than adding an entire other microcontroller. It displays white characters and has blue backlighting. Arduino also already has a built in Liquid Crystal Display library that makes development and programming on this LCD much easier. The

PCB dimensions are 36mm x 80.6mm x 1 mm, while the screen dimensions are 24mm x 69mm. The total height of both the PCB and screen is 8.4mm.

Figure 3-40 A picture of the LCD we chose to use

3.5.4 Light Sensor

One of the defining features of our hydroponics system will be the automated light adjustment. A key component of the automation is the sensor. It needs to be both accurate and precise. After researching several sensors, we decided on the TSL2591 HDR Digital Light Sensor from Adafruit. Adafruit offers Arduino compatible sensors and devices that make development very pain free, and so we took advantage of using yet another of their products.

The TSL2591 uses 3.3V logic and power, but has onboard regulators so that you can hook up 5V logic and power, like that found on most Arduinos, and not worry about logic level shifting. It also features a 3.3V output, which is fed from the onboard regulator, as well as a

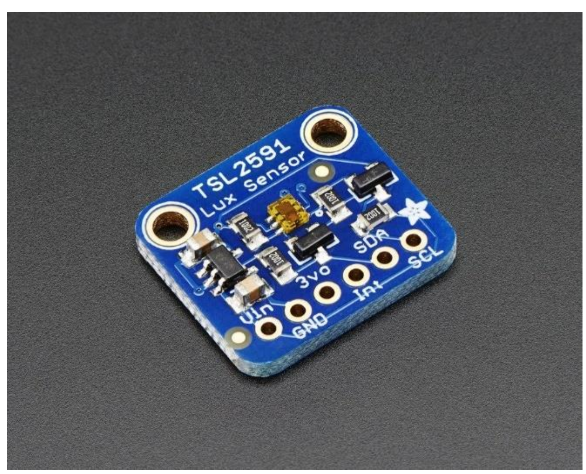


Figure 3-41 TSL2591: The light Sensor

grounding pin. It offers 2 I2C pins: a clock pin and a data pin. With these pins, you can communicate with other devices over an I2C connection. The last pin available on this sensor is a programmable interrupt pin. The device's dimensions are 19mm x 16mm x 1mm and weighs 1.1g.

The TSL2591 has 4 gain settings, so that you can adjust your measurements depending on how much light you are dealing with. When you establish an I2C connection, you can configure the module to transmit and combination of IR, Full spectrum, Visible, or Lux light readings. You can also change the integration timings from 100 to 600 ms in 100 ms increments. A longer integration time will lead to more accurate results in low light situations.

3.5.5 Microcontroller

Our automated hydroponics system has a lot of complex sensors in it and need to be read and controlled by a microcontroller. These sensors can take up many pins on a microcontroller so it is important to get one with enough of them. Following this logic, we originally thought that would go with the larger Atmega2560 due to its increased pin count, but after some initial tests we learned we only went slightly over what the Atmega328 offered in pin count. We already had several Atmega328s and were familiar with them, and decided to just use a second Atmega328. The second Atmega328 would just be used similarly to a multiplexer. We could transmit the sensor data to the second microcontroller using only 2 pins, and then that controller could send the relevant data to the LCD and the Wi-Fi module. This moves the pins for these two devices to the second microcontroller and it still has pins to spare should we need to add more devices.

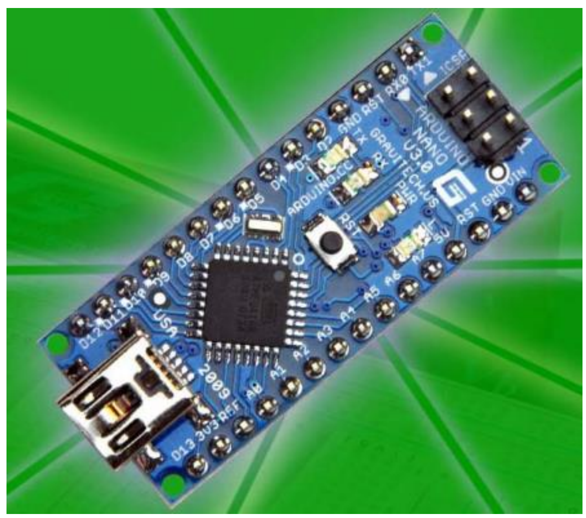


Figure 3-42 Arduino Nano v3

The Atmega328 that we have been developing on is the one found in the Arduino Nano v3. It is a small open source development board that is available from many different electronics websites. It has an attached mini USB connection that can power the device and allow serial communication with the Arduino software. A reset button is also present on the board. The board offers 14 digital IO pins as well as 8 analog inputs. The analog pins can function as digital IO pins of necessary. The board also features two reset pins (which are active low), a 3.3V output pin, an ADC reference pin, a 5V input/output pin (dependent on if the USB power is connected), and a power input pin for connecting a 5V power source if you do not wish to use the USB power. In our final design, we will implement two

Atmega328s onto our PCB, but for prototyping and testing, these development boards are sufficient

3.5.6 Nutrient Sensor

Hydroponic systems use liquid fertilizer that contains nitrogen, potassium, and phosphorus which are all salts. When the nutrients dissolve in the water there is a specific salinity that needs to be kept in balance to allow the plants to take in the nutrients to grow and produce a yield. When the salts dissolve in the water it will allow current to travel and we can measure the conductivity to determine the proper nutrient level of the solution. To be autonomous, the system will be designed to include an electrical conductivity (EC) sensor to read nutrient levels, supply information for the microcontroller to control the dosing pumps, and have longevity.

To begin with, the system will need to measure the amount nutrients in the solution. One way to do this is to measure the EC of the solution. For the sensor to measure the EC of the solution it sends a small current through the water and it will use the time it takes for the charge to travel from the output to the input of the sensor to calculated the conductivity of the water. This method essentially measures the amount of salts in the water which is what the nutrients are composed of. Another consideration that was thought about was the power consumption of the sensor. One of the reasons for the selection of AtlasScientific conductivity kit k 1.0 was the fact it uses low power and the software can be developed to only have the sensor turn on when the readings are needed.

Figure 3-43 pH Sensor Kit

In the same fashion, as the plants take up nutrients the solution will be diluted and more nutrients will need to be added. This sensor will read the EC of the water then send the information to the microcontroller. Once the microcontroller receives this information then it will compare it to the EC value that was set for the plants that are grown to be able to make the decision to add nutrients or not. The measurement will be taken once per day. To adjust the nutrients, the microcontroller will send voltage to the peristatic pumps to add a minimum amount that was tested in the lab. Once the pumps stop running the system will wait a predetermined period to allow the nutrients to disperse in the solution then it will take another reading to make sure the solution has the correct number of nutrients.

Important to realize, was over time the sensor will need to have regular maintenance performed due to the nutrient content in the solution. As the sensor is submerged in the solution it has been found calcium will tend to build up on the plastics. AtlasScientific has been in the industry for many years so they have created the sensor to withstand the elements as best as possible so in the probe data sheet once the probe is calibrated it does not need to be calibrated again. As best practice tips, due to the elements the probe needs to be cleaned as needed with soap and water and a soft cloth. Due to the low maintenance of the probe the used will be able to put the probe in the solution and all they should do is clean it in soap and water when they see build up on it.

In contrast, as the system was being researched there was very few sensors found to measure the nutrients in the water. One of the considerations was to build a custom sensor. There was information on the internet that showed how to build one. The benefit of building a sensor would have been cost. The cost to build a sensor to measure the nutrients would have been a quarter of the cost. However, it was discovered the custom-built sensor would be very challenging to get the probe built and get accurate measurements from it. There were two main issues that come with this method and these issues were the possibility of allowing too much current in the solution which would interfere with other sensors in the water. The other issue was to keep the sensor tips clean. The tips would be made from a metal such as copper, however; over time these tips would be covered with contaminants and would need more maintenance from the end user.

3.5.7 Oxygen air pump

The hydroponic solution includes water and nutrients for the plants. The nutrients consist of living bacterial that is necessary for the pants to breakdown the nutrients in the water for internal use. If this bacterial is left stagnant it can become toxic to the plants and will cause the bacteria to attack the roots and the plants will die. One way to prevent this is to add an air pump and aerating stone to the main tank. The additional oxygen added to the water will prevent the bacterial from becoming hazardous to the plants.

3.5.8 pH Sensor

The pH sensor we chose to use with our system is the Atlas Scientific pH kit. The kit comes with a probe, a BNC connector for the probe, a module to communicate with the probe, and 4 pH solutions for calibration and pH adjustments. The probe has a maximum pressure of 960kPa, a maximum depth of 60 meters and a weight of 49 grams. When the pH sensor has been connected properly, it will transmit the pH reading over its serial pins. You can configure it to either take a reading once per second, or to run in low power mode until you send it a read command over the serial connection.

Figure 3-44 Atlas Scientific pH kit

3.5.9 Water Level Sensor

The most basic measurement you need to keep track of in any hydroponics system, or practically any system involving water, is the water level of the system. Low levels of water can damage or kill the plants due to low circulation or even stagnation. We knew that keeping track of the water level would be important for our system. We deliberated on which kind of sensor we would use to keep track of the water level and in the end, we chose the eTape Liquid Level Sensor from Milone Technologies. We purchased the 8" version. The way it works is that there is an envelope down the center of the tape, connected to a pin at the top. There is also a reference resistor on the top of the tape. When water contacts the envelope, the pressure changes the resistance of the pin it is connected to. From here you can read the water level accurate by comparing the envelope pin resistance with the reference resistor and doing the correct calculations.

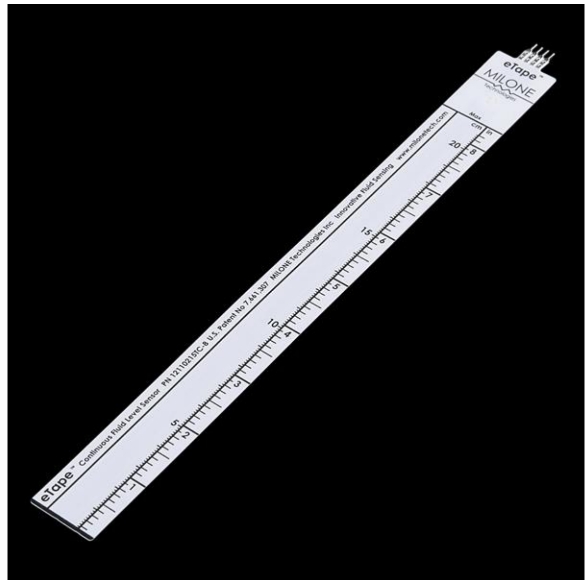


Figure 3-45 eTape Liquid Level

4 Related Standards and Realistic Design Constraints

This chapter will cover the some of the standards and design constraints that this group had to deal with during the creation of the Home Hydroponics System. This group understands that there's more standards and constraints then what is written about below but due to time constraints and cost it isn't possible to list all the associated standards and constraints.

4.1 Standards

The following sections are standards that this goal had to keep in mind during the development and building process. Standards are a way to help designers to develop projects and components that will work with previously created systems and interfaces. Due to the cost of the IEEE standards, this group could access and discuss every possible standard that implies to this system.

4.1.1 Electromagnetic Interference

When dealing with electronic circuitry there are standards that need to be followed to protect people and the electronic circuits. One thing that is a big issue is electromagnetic interference. What is electromagnetic interference and when did this start to be an issue? These specifications started with the military, however; as electronics, have grown and entered the homes all over the United States these standards have been adapted by all electronic manufacturing processes. There are several ways to protect the system from emitting or being affected from electromagnetic interference. The main areas of interest that will be explored here are what devices create the interference, understanding the frequencies have the greatest affect, and how to protect the system from electromagnetic interference. Due to this large growth of electronics and some tragic events that have occurred there have been some standards that manufacturers and the government use to make sure these devices are safe.

First, most homes are filled with electronic devices that produce energy fields that often will affect another nearby devices, for an example check out Figure 4-1. The effect on a device from the electromagnetic fields of another can cause noise to enter the affected device. There are a couple of components especially dominant in emitting these waves. Due to the large magnet and the windings involved in creating an inductor is one of the major contributors of emitting electromagnetic waves. One of the largest inductive components are the large AC to DC transformers. These large transformers are some of the necessary devices that convert the voltage so that small electronic devices can operate within the safe DC

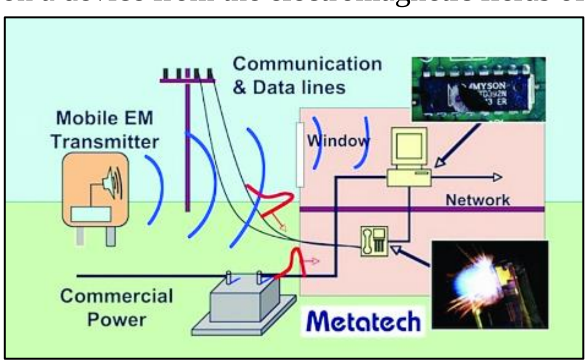


Figure 4-1 Example of Electronic Noise

voltage range they were designed for. Another device that sometimes also contributes to the electromagnetic interference is a capacitor. [6]This noise can sometimes be heard by the user or can be injected into nearby components. Figure 4-2 is an image of noise that was measured in a device on an oscilloscope. When trying to transmit data, this noise could cause a lot of problems to at the receiver so it is especially important to design an electronic system following some of the techniques that can protect against this interference. Most devices that are produced and sold in mass production will be tested by an electromagnetic comparability engineer before it gets sold to the public.

In addition, as devices have emerged and with them getting smaller the frequencies have increased dramatically. Back in the 60’s and 70’s low frequencies were used and the devices were much larger. The AM radio signals were greatly affected by this interference due to the system operating at a lower frequency range. Today devices operate at much higher frequency ranges so the need for electromagnetic interference protection greatly increased. Most computer systems that are sold today are operating in the 3.4 GHz range. Most of the devices being developed have many capacitors and inductors in then so the electromagnetic interference problems must be thought about in the design process. Another consideration that will add to the EMI are the power cords that run to these devices. EMI can enter a system through the cables and add noise to the system. An area known for EMI to enter a system is through the connectors. EMI engineers have found that one way the cables contribute to the EMI problem is through the cable connectors. EMI signals in the air can get into a system through the connectors so it is important to make sure these terminators are proper for designed piece of equipment depending on the device sensitivity to EMI.

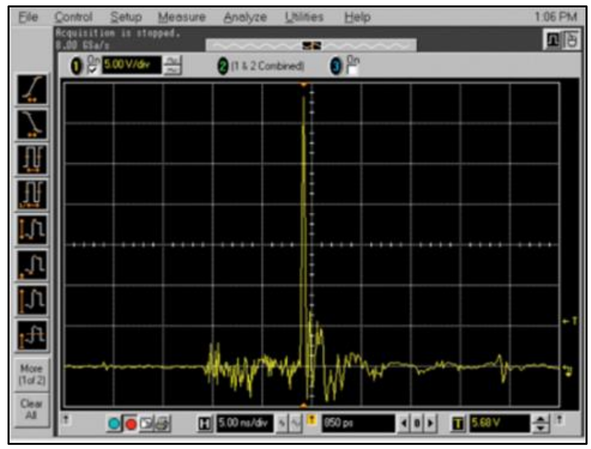


Figure 4-2Measured Electronic Noise

Now that EMI information is understood, the engineer designing electronic or power devices can make the necessary design specifications to protect the device and other nearby devices from EMI waves that are present. A transformer is sensitive to EMI due to the magnetic fields being produced. Transformers [7] are often shielded see figure 4-3 due to the sensitivity of the device and the magnetic waves. One wat to shield a device is to cover it in a metal container and ground the metal box so the EMI wave can be dispersed to ground and not affect the device. When an electronic device is housed in some manner the cables to supply the device will need to be connected. It is important to make sure the connectors match the needs of the device protection as well to be attached properly. In highly sensitive devices the connect to and from it will need to be grounded so custom cable may be necessary to accomplish this. Another

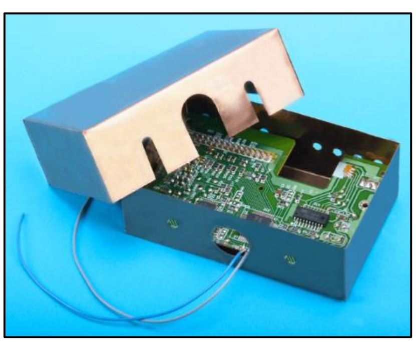


Figure 4-3 Examples of Shielding

consideration of the cabling is to shield the cables that supply the device. There are several ways to shield a cable. The following is an extract from Ott [6]:

1. Shields are made of nonmagnetic materials and have a thickness much less than a skin depth at the frequency of interest.
2. The receptor is not coupled so tightly to the source that it loads down the source.
3. Induced currents in the receptor circuit are small enough not to distort the original field. (This does not apply to a shield around the receptor circuit.)
4. Cables are short compared with a wavelength.

If the electronic circuit is very sensitive to EMI, the I/O connections can be filtered to make sure the system is protected. Now to consider the internal protection from EMI waves. On an electronic power transformer circuit, another way to shield the system from the EMI waves is to filter it out with capacitors on the voltage regulators. This technique allows the EM waves to travel to ground instead of entering the electronic system. For in circuit possible problems the use of capacitive filtering may be necessary for EMI protection. In other circuitry, certain type of capacitors can lead to an adverse effect to the system. If a system is transmitting RF signals the use of Mica and ceramic capacitors are used a filter due to the low series resistance and inductance of these capacitors.

EMI is a very important consideration when designing an electronic circuit. If an engineer does not consider this during the design phase, then there is a possibility of problems in the circuit or other nearby devices. There are multiple ways to shield a device and it will be up to the engineer designing the system to consider the design specifications and the budget available for the design. There are numerous methods to shielding an electronic circuit and some of the methods are very labor intensive.

4.1.2 IEEE 802: LANS

This standard covers the use of 802 wireless devices, this standard sets defining key specifications for the physical data links as well as the networking data link layering. The aspect of this standard that applies to us is the 802.11 wireless LANS chapter. Since the group in using the Arduino Wi-Fi module and its code libraries, this project follows all the guidelines and regulations in this standard.

4.2 Realistic Design Constraints

4.2.1 Wi-Fi Constraints and Protocols

Wi-Fi is typically used as a means of extending a traditional wired LAN to a device wirelessly, through the air using radios. So many different devices use this method of transmission that different frequency bands can often become convoluted and cause interference with other devices. Things like FM and AM radio, satellite transmissions, TV, wireless phones, etc. all use some part of the spectrum, and the development of standards helps to keep these broadcasts from intertwining and causing problems.

Wi-Fi is a trademark for the Wi-Fi Alliance. The Wi-Fi alliance is a non-profit company that helps promote Wi-Fi technology and certifies devices that conform to the IEEE 802.11 standard. You should note however, that there can be devices that conform to the IEEE standards that are not Wi-Fi certified. The IEEE has released multiple versions of the 802.11 standard, and they differ in various ways. The original 802.11 standard was established in 1997, but has been improved over time. For students, copies of the different 802.11 standards are available for free from the IEEE standards website below;

Figure 4-4 Wi-Fi ™ license free logo

- https://standards.ieee.org/about/get/802/802.11.html

Our Wi-Fi module, the ESP8266 can be configured to run on one of three different protocols: 802.11b, 802.11n, and 802.11g. These all function at a frequency of 2.4GHz, except for 802.11n which can function at 2.4 and 5GHz. These protocols offer different advantages and disadvantages. Chronologically the protocols were established in the order: 802.11b, 802.11g, and then 802.11n. As one might expect, the main improvements in the releases were speed, throughput, and range.

The oldest protocol that the ESP8266 supports is 802.11b. This has a maximum transfer rate of 11 Megabits per second. It is an aging protocol, released in 1999, and devices like routers are starting phase out support for it. It functions at 2.4GHz and has a bandwidth of 22MHz. The range for this is dependent on the antenna but generally it has the lowest range of the three. A positive aspect of this protocol is that devices can implement it cheaply since it is older, and it can typically run with lower power draw. Another benefit is that it is compatible with its successor: 802.11g.

802.11g was released a few years after, in 2003. This comes with a maximum transfer rate of 54 Megabits per second. It still functions at 2.4GHz and a band width of 20MHz. Again, the range is heavily reliant on the antenna, but in general offers small range improvement over 802.11b. As previously stated, 802.11g is backwards compatible with 802.11b devices. This makes implementing and upgrading to 802.11g easy, as you wouldn't have to upgrade all your 802.11b devices necessarily. Bigger changes came with the introduction of 802.11n.

802.11n offered large improvements over its predecessor. It added support for multiple-input multiple-output antennas. 802.11n also offered the option to operate at 2.4GHz with a 20MHz band as well as 5GHz with a 40MHz band. This protocol can achieve a transfer rate of 72.2 Megabits per second on 2.4GHz and 150 Megabits per second on 5 GHz. This is the fastest of the three protocols supported by our ESP8266.

The ESP 8266 is a small device. Running the different protocols on it can make a difference in power consumption. Given that we are only transmitting small strings of data we can easily use the lowest compatible protocol and save power where we can.

4.3 Economic and Time constraints

Any project or development needs sufficient planning. When setting goals and milestones it’s important to have realistic estimates and efficient time management. You don’t want to set the bar for performance too high or too low, it is a delicate balance. If you pay too little, require too much work, or try to rush something unrealistically, then the quality and quantity of work being done will be severely hindered. On the other hand, do the opposite and you are wasting resources and not functioning optimally.

When we founded our group for Senior Design we had brainstorming meetings once or twice a week for the first few weeks, at the suggestion of Dr.Wei. Many good ideas were thrown around in discussion of what we wanted to create. Our brainstorming sessions quickly helped us filter out unrealistic projects that would take much longer than the two semesters allotted, would require specialties outside of our fields of study, or were financially out of our reach. Finally, we settled on an automated hydroponics system.

For the first several weeks we met in the UCF library to discuss the design of the system. We settled on what aspects of the system would be monitored, such as pH, EC, water level, and light levels. We also discussed which aspects of the system should be automated, and decided on pH, EC, and the LED lights. Automation of the water level was also discussed but a member of our team has experience with hydroponics systems and assured us that given how infrequently you need to add water, the extra work of designing and implementing a filling system wouldn’t be an efficient use of our time. Building a filling system would be mostly mechanical and while it might not be difficult, it doesn’t really highlight the aspects of our degree majors.

From this point, we spent a week researching the different components we would need to get an idea what we could feasibly build ourselves and what we would have to buy. After researching our major components, we discovered that our pH and EC sensors would be a couple hundred dollars. Building these sensors ourselves was also out of the question. We do not have the expertise required to design let alone implement and produce such high precision equipment. We would have spent possibly just as much trying to create these probes ourselves as we would have if we just spent the money on them. We do not have funding for this project so we discussed setting a maximum budget, and putting all the money on a prepaid card upfront so that there would be no awkward conversations about money. We agreed on a $1000 total, with $250 being contributed from each member. One member, Beau, wants to keep our project after we are done with it and offered to cover any costs that exceed this $1000 total and we all deemed that fair.

After the design aspects were agreed upon we split up the project responsibilities to our different group members. We decided on a leader, a treasurer, an editor for this paper, and then further divvied the component designs and programming duties. After we ordered our parts and got them in the mail we moved our weekly meetings to the Senior

Design lab in Engineering 1, room 456. Our meetings every Friday have been spent here designing, prototyping, and testing our components and subsystems.

Dr. Wei stressed that we should have our system completely designed and have the individual components tested by the end of our first semester. Most electrical component websites / companies operate overseas and this can lead to shipping taking up to a month in some cases. Considering most electrical components are very cheap, we took Dr. Wei's advice and ordered 2-3 times the number of components we required. This was done in case we received faulty components, or damaged the components ourselves, we would have spares to use that wouldn't take weeks to come in. Shipping time is something that needed to be factored in to our project time if we were to receive everything and test it before the end of the semester.

Further down the road, allotting sufficient shipping time will also apply to ordering our PCB. Many PCB manufacturers are also overseas with similar turnaround times. An added caveat is that PCBs can be very finicky and a bit difficult to troubleshoot. Even if your design is perfect, the PCB can have errors in its manufacturing. It takes a considerable amount of time to discover the cause behind a faulty PCB, makes the fixes to the design, order another, and wait for the overseas shipping. At the very least we need to allocate ourselves several 2-3 week cycles for PCB ordering and shipping if we go with an overseas manufacturer so that we have time to get our final project put together even if we must reorder a few times.

As of writing this, the end of the first semester is approaching rapidly. We have ordered all our parts needed for a prototype. Not only that, but we have tested these components individually and confirmed their functionality. We have also even started to integrate some of the sensors together, and are close to having a full prototype breadboarded. In this regard, I believe we are very far ahead of schedule as most other groups we have talked to either haven't ordered parts yet or they have not yet arrived. We also see many groups form Senior Design II in the lab and they always tell us how much further ahead we are than even most groups in Senior Design II. In addition, we have drawn the schematics for all for the system and have begun combining them for our final PCB design.

All that will be left for us to do next semester is finish integrating the parts, tune the functionality, and order our PCB. We should have plenty of time for tinkering and adding, should we meet all our core requirements in a timely manner. Even if we wind up running into problems with tuning the automation of the pH, or EC we should have plenty of time to iron out any foreseeable problems. Likewise, we should have plenty of time to work on and fix erroneous PCB designs or faulty PCB boards. Our budget still has several hundred dollars left for PCB and surface mount component purchasing and believe our budget estimate was a good one.

4.4 Social constraints

Designing a system for home gardening tends to have a negative view in the past. In the past hydroponic systems for the home were used mainly for growing marijuana.

Because of this, hydroponic systems are associated with illegal actions but lately the cultural stigma of marijuana is decreasing. As the view on marijuana is shifting, it's making it possible to have a conversation that includes hydroponic farming without people thinking of drug use. This group is aiming to make everyone understand that hydroponic farming is the future of farming and with systems, like the Home Hydroponic system, it's possible that everyone can grow their own crops.

4.5 Ethical, Health, and Safety constraints

Hydroponics systems are often viewed in a positive light. They are often associated with the health benefits of eating fresh, organic, pesticide free produce. They are also affiliated with self-sustainability and efficient space utilization, all while being an easier, more elegant alternative to traditional soil growing. These positives would be hard to argue against but as with anything in life, there are pros and cons. These pros and cons consist of but are not limited to the ethical, health and safety concerns of a home hydroponics system.

To begin with, what are the ethical implications of such a system? Hydroponics systems can be used to grow your own food. What could possibly be ethically wrong about that? Well other than food, most hydroponics system can be easily adjusted to grow almost any type of traditional soil-grown plant. This brings us to the most obvious ethical concern: will users be able to grow illegal or illicit drugs with our system? To go further, does a plant being illegal mean it is ethically wrong to grow it? Is a harmful plant that isn't illegal still ethical to grow? These are mostly political and personal questions that will differ highly between individuals. We will examine the most relevant controversial plants in modern society: marijuana.

Marijuana has been gaining increased acceptance in the United States, with states like Colorado, Oregon and Washington legalizing it for recreational use. There are also over 20 other states that have legalized it for medicinal use. Besides those, there are even more states with specific counties or cities that have decriminalized marijuana use. Per Time Magazine's website [8] Colorado netted $69 million in tax revenue in the 2015-2016 fiscal year, ending in June 2016. This was through just Marijuana based taxes, and did not include state or local sales tax revenue from the sale of marijuana.

While these legal marijuana states continue to make so much money the idea of recreational and medical marijuana will surely spread in the coming years. Colorado at least, does not constrict its citizens to purchasing marijuana from distributors: it allows its residents to grow their own. Per Amendment 64 of the Constitution of the State of Colorado, a resident can grow up to six marijuana plants at their home, with up to 3 mature plants at a time. Some of these residents

Figure 4-5 Example of Marijuana Use

might choose to grow hydroponically, with a system like ours. This is a growing legal market that extends the use of hydroponics system beyond that of simple produce.

The reality is, once we sell our product to an end user, we have virtually no control over how they intend to use it. A hydroponics system can easily be used to grow marijuana or other illicit or illegal substances but that doesn’t overshadow its legitimate use for home produce, flowers, herbs or other types of plants that it can be used for. We believe the positive benefits people could reap from growing their own food and plants ethically outweighs those who would use our system for illegal activities.

Moving on, this brings us to the health and safety concerns of using a home hydroponics system. The system we will create automatically controls pH, TDS, and lighting. We feel that this creates some ethical obligations to the safe operation of these systems within or product. We believe that by having these systems be automated, we can reduce the risk of operation for the end user.

For safety, lets first examine the risks with adjusting pH levels. The most obvious risk is to the plants themselves. Per Howard M. Resh [9] healthy food plants have pH ranges anywhere from 5 to 7 depending on the plant. If the pH dips above or below the pH values of the specific plant, the plant could be malnourished and have stunted growth or even could die. When the end user of our product sets the pH level correctly for the plant they are growing, we have a responsibility to maintain that level accurately to ensure their plants are healthy.

Other than risk to the plants themselves, there are inherent risks for storing the solutions required to adjust pH levels. The acidity or basicity of the water can have impacts on the storing containers, pumps, plant holders and anything else they encounter. We have a responsibility to ensure the parts of the system exposed to these materials is resistant to deterioration from them.

Additionally, we need to responsibly control the lights. Prolonged exposure to too much light could dehydrate or even burn the plants. This could lead to dead plants if the control system is compromised. Less severely, a compromise of the light control could lead to incorrect day/night cycles for the plants which could stress the plants unnecessarily. We need to be sure to set correct light settings for the type of plant to maximize growth efficiency.

Figure 4-6 Examples of Mold growing on plants

As with anything that meets water, mold and mildew are another serious concern. All parts and components need to be sufficiently protected or isolated from moisture and water to ensure correct functionality of the system. To expand a bit, the housing for the electrical components needs to be sufficiently isolated from the system to ensure no water contact which could result in the damage of components or plants. Pumps, housing, fittings, etc. will also need to be sufficiently sealed to ensure no leaking, which could result in damage to its surroundings as well as deny that water to the plants.

Moreover, we should provide clear and comprehensive instructions for use and maintenance to ensure that user error is minimized. Most components might seem simple and straightforward but ethically, and probably legally, we should provide comprehensive instructions so that users that might be unfamiliar with certain aspects or parts of the system will be able to educate themselves on the proper usage and maintenance of the system so that they can confidently and safely setup and run the hydroponics system.

We as a group take ethics, health and safety very seriously and want our product to be well respected and safe to use. It is important to minimize risk of operation and maintenance, while maximizing safety and ease of use. We envision our system as well designed, safe, product that has a positive impact on the lives of our audience and customers.

4.6 Manufacturability and Sustainability constraints

Perhaps the biggest feature of our hydroponics system that offers our product an advantage over other systems that are already in the market is the adaptable lighting that we will be implementing. There are several systems that automate pH, EC, and water level but none that will also adjust your lights depending on time of day, the amount of light the plants are getting naturally, etc. This gives us a unique position in the market.

The biggest drawback to production for our system would be our pH and EC sensors as well as our LED array. These components are by far the most expensive part of our hydroponics system. The probes and circuitry are packaged together nicely but that is what drives the cost up for them, naturally. I think long term if we were to continue production of these systems it would behoove us to spend the extra time to develop our own circuitry and maybe even our own probes, something that our time and financial constraints for this Senior Design project prevents us from doing. The same applies to our LED array. I believe if we had the time to develop our own and implement it we could save lots of money in this area as well.

If we were to develop these probes and circuitry for the pH/EC/LED array ourselves it would cut production costs by a large margin, potentially several hundred dollars. In a similar vein, after we finish our programming and PCB schematics, assembly time would obviously be cut back by a large margin as well since we wouldn’t be testing and developing from scratch like we are for this project.

If we did not develop our own probes and circuitry for the pH/EC/LED array we would of course be constrained by cost, availability, and turnaround time from the manufacturers of these parts and our business model would have to keep this in mind. In kind, our microcontrollers and Wi-Fi chips were so cheap because we ordered them from overseas companies. There is a long shipping time, sometimes up to a month or two. We would need to stockpile ample amounts of them, because if we were to run out it would not only delay our product but we would likely have to pay a premium for quicker shipping or for buying from a closer source.

Shipping is another thing to consider. Our systems would be rather large for shipping and would need to be well packaged considering the sensitive materials included such as the probes and the pH solutions. We would need to make sure our instructions on setup and installation were clear and precise so that users would feel comfortable and safe with installing it themselves.

A final consideration is the modularity of building a system like this. Depending on customer needs we could create custom setups that can fit more plants, have different water flow configurations, etc. Things like the internet services for the system are also something to be taken into consideration. We would have to decide on if we would handle the hosting and web services or if we would make the software available to the customer who could then do it themselves. For the internet connectivity to remain functioning someone is going to have to pay for the hosting and maintenance. As with any business, developing the product is the first step that is usually the most expensive and the most time consuming. After that, it’s all about minimizing costs and maximizing efficiency, customer satisfaction, quality, and profitability.

5 Project Hardware and Software Design Details

Chapter 5 will cover the design of the hardware and software aspect of this project. Section 5.1 will cover the initial designs and architectures the group came up with for several of the components. The next section 5.2 will cover the subsystems of this project and the groups initial bread board design for the various components of the system. After that, section 5.3 will cover the software design of the system. This section will split the different software interfaces and then speak about each individually. Lastly, section 5.4 will give a summary of the entire system.

5.1 Initial Design Architectures and Related Diagrams

5.1.1 Dimmer Control

In order to digitally dim the lighting system the digital circuit will need to be designed on the breadboard and tested. The digital dimmer will utilize the MCP4131 chip Figure 5-2 to control the voltage that is going to the LED drivers on the lighting system. The initial breadboard testing will utilize a single White LED and a 220 Ω resistor and will be dimmed it at least 10 steps. Once the chip, LED, and resistor are assembled on the breadboard the circuit will be wired to the microcontroller as in Figure 5-1. The chip suply voltage will be 5 VDC and the circuit needs to be grounded to the microcontroller. The microcontroller will be plugged in using a seperat 9 volt power supply so that it will provide the correct current and voltage to the chip.

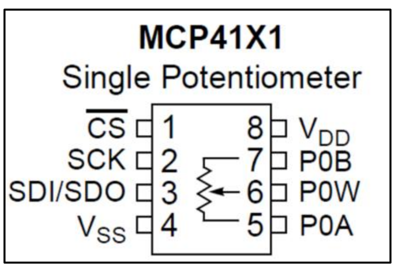


Figure 5-2 MCP41X1

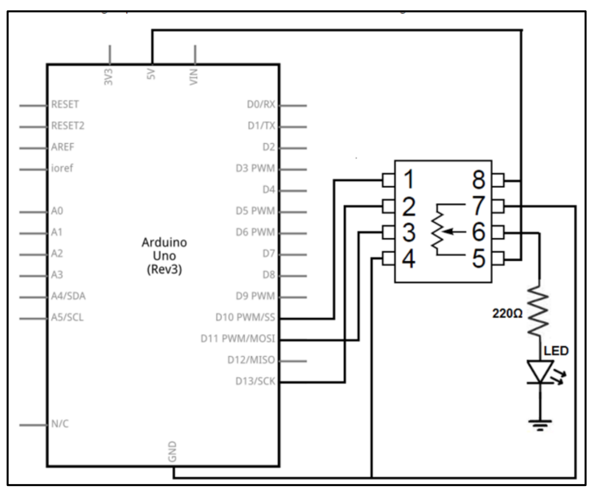


Figure 5-2 MCO41X1 connected to an Arduino Uno

5.1.2 LED

LED lighting can provide the needed supplemental lighting to grow plants inside of the home. The lighting provides the following features:

- Dimmable led grow light from 0 – 100 %
- Light weight

- Can be daisy chained for multiple lights
- 9 band of lighting for the plant needs
- UV 380-400nm, 470nm
- IR(730nm)
- Primarily produces the red and blue spectrum of lights

Figure 5-3 Parts of the LED Array

To control the dimming of the lights the following architecture the MCP 4131 integrated circuit will provide the needs for this system. The following parameters meets the system parameters:

- Single or dual resistor network options
- Potentiometer of rheostat configuration options
- Zero to full scale options
- SPI interface of 10 MHz
- High voltage Tolerant digital input pins of 12.5 Volts
- Wide bandwidth -3dB operation (2MHz)
- Maximum current 25mA

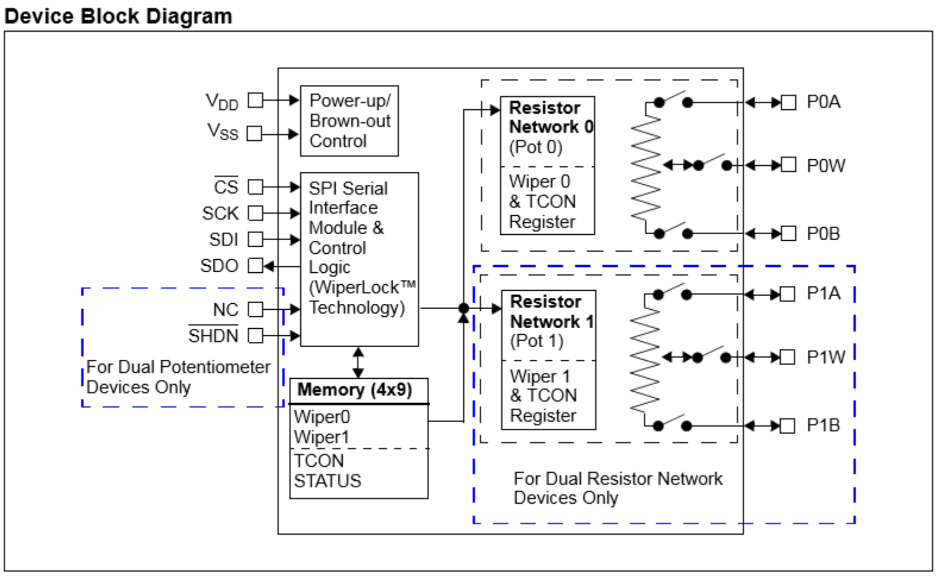


Figure 5-4 LED Device Schematic

5.1.3 Light Sensor

The light sensor in the project is the TSL2561 light sensor as seen in Figure 5-5. The communication between the MCU and the light sensor module also uses the I2C communication, like the MCU master/slave configuration. It used two pins on the MCU in this projects case A3 and A2, and connecting the necessary power and ground pins as seen in Figure 5-6. Initially the testing phase of this light sensor was to connect it directly to the breadboard design of the microcontroller unit. Testing was done by giving it light from the LED array on low, medium, and high settings. The module would relay the serial information through the two analog pins on the microcontroller and reading could be seen visually on the serial monitor on the laptop. By adjusting the light levels and or by using an object to block some of the light simulating cloud coverage, we could see that the light sensor was functional.

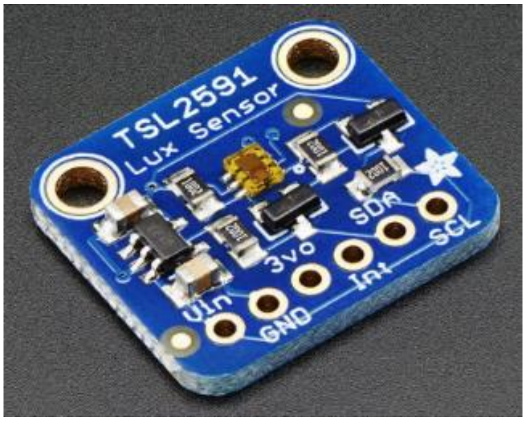


Figure 5-6 Light Sensor

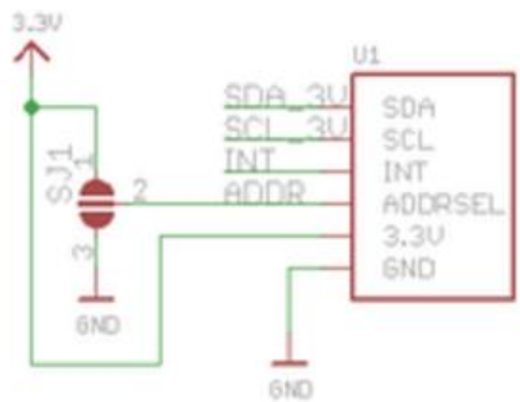


Figure 5-6 Light Sensor Circuit

5.1.4 MCU

The initial microcontroller that will support the needs of the system is the ATMEL ATMEGA 328P. Figure 5-3 displays the internal architecture for the processor. The ATMEGA 328P is designed for low power operations so it is energy efficient. The chip provides the speed and the amount of input pins that are desired. The following is a small list of specifications that was used to decide on using this microcontroller:

- CMOS 8-bit system
- 32 Kbytes of flash RAM. 20 MHz crystal
- 23 programmable I/O pins
- .2mA of current during the active mode

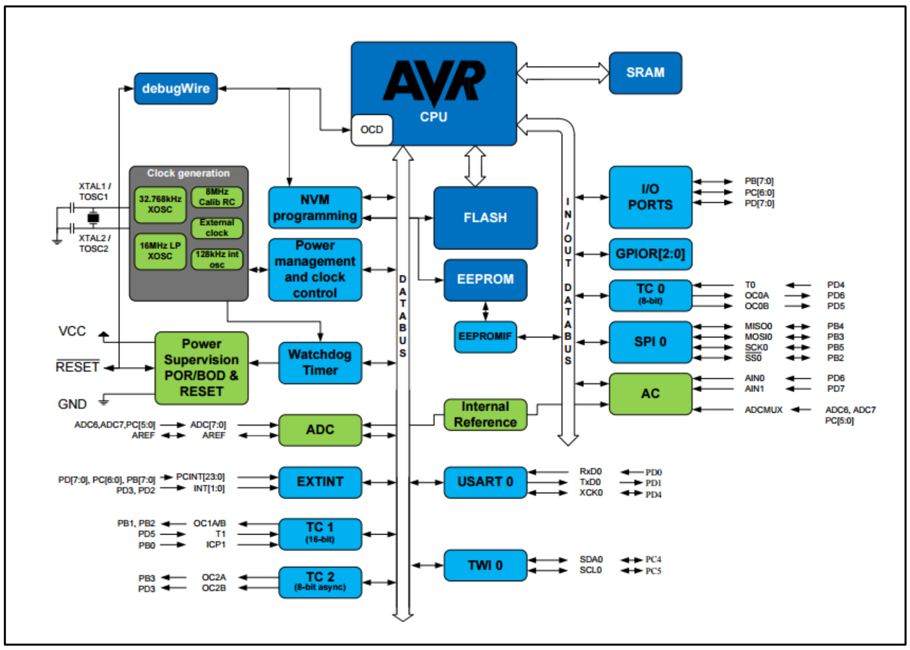


Figure 5-7 MCU Wiring Diagram

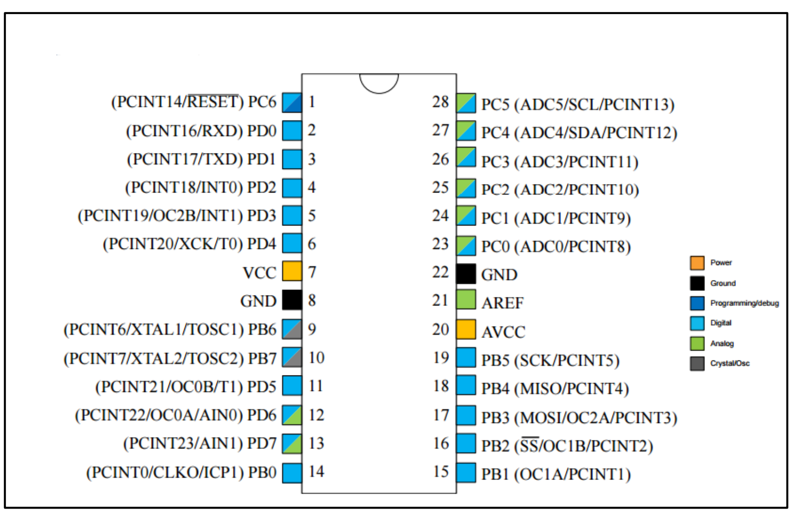


Figure 5-8 MCU Pin Assignment

5.1.5 pH Sensor

The pH sensor to be used is AtlasScientific. This sensor will take up 2 pins on the microcontroller and from the data sheet the following specifications will meet the needs of the controller:

- Full range pH reading from .001 – 14.000
- Accurate reading to =/- 0.02
- Flexible calibration and supports single point, 2 point, and 3-point calibration
- Calibration only needs to be done once per year
- Single of continuous reading modes
- I^2C data protocol
- Sleep mode power .0995 mA at 3.3 V

5.1.6 Power Distribution

The circuits are to run on a DC source so the input signal seen in Figure 5-10 is the sine wave from the output of the transformer. Once the signal was stepped down it then needed to be rectified. In Figure 5-11 the signal passed through the full bridge rectifier. Once the signal was rectified then the capacitor was added to remove the ripple and to create a 36-volt dc signal ready to be utilized by the voltage regulators. Figure 5- 13shows the 12-volt DC source from the output of the voltage regulator. The next Figure 5-9 is of

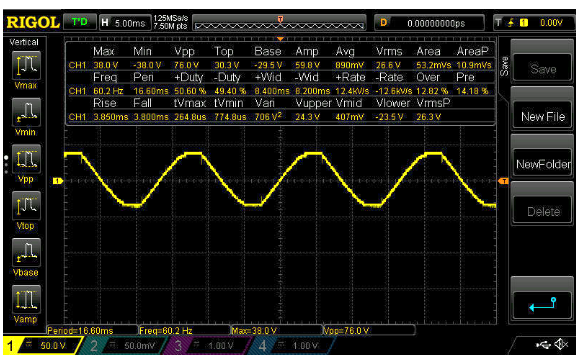


Figure 5-12 Input Signal

Figure 5-12 Rectified circuit

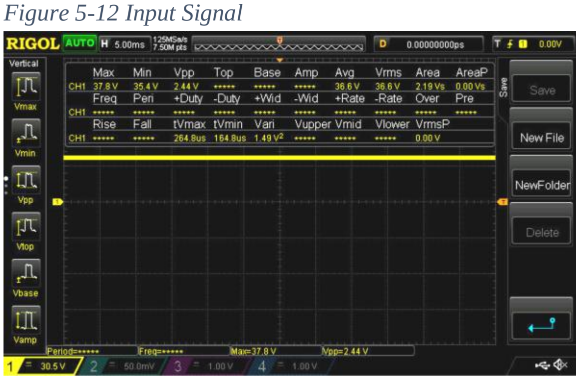


Figure 5-12 12-volt DC signal

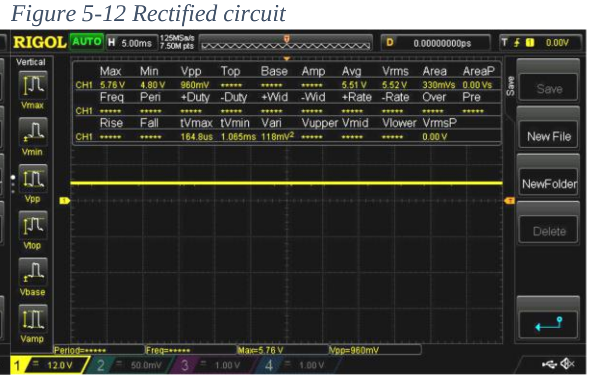


Figure 5-12 5-volt

Figure 5-13 3.3-volt DC

the 5-volt DC source. The final Figure 5-12 is the 3.3-volt DC source measured at the output of the 3.3-volt regulator.

All the signal measured are consistent and when put under load they all performed as expected. This power supply and distribution will be sufficient for the hydroponic controller.

5.1.7 Power Supply

The first step in designing the power supply is to consider the power consumption needs of the entire hydroponic system. There are several sub power systems to consider during the design stage. The three main systems that are needed to run the hydroponic system include 12 VDC, 5 VDC, and 3.3VDC. Table 5-1 displays all the voltage, current, and power needs.

Quantity	Component	Current (mA)	Voltage (DC)	Power consumption (mW)
1	pH sensor	18.3	5	91.5
1	TDS sensor	22.5	5	112.5
1	Water level	100	5	500
3	Pump	80	12	960
1	Arduino circuit	50	12	600
1	Power isolatior	200	5	1
1	Data Isolation	7.6	5	38
1	Wi-Fi	500	3.3	1.7
1	Light Sensor	0.4	5	2
1	Light dimmer	25	5.5	137.5
1	LCD	70	5	35
Total needs per subsystem				
Voltage (DC)	Current (Amp)		Power (watts)	
5	0.373		2	
3.3	0.5		1.7	
12	0.13		1.6	
Total	0.97		2.5	

Table 5-1 System Power Needs

With these power consumption needs the system will require a power transformer that will supply a minimum of 2 amperes to prevent the devices from receiving enough current during high demand periods. Figure 5-14 is the diagram that needs to be followed during the testing and implementation phase of development.

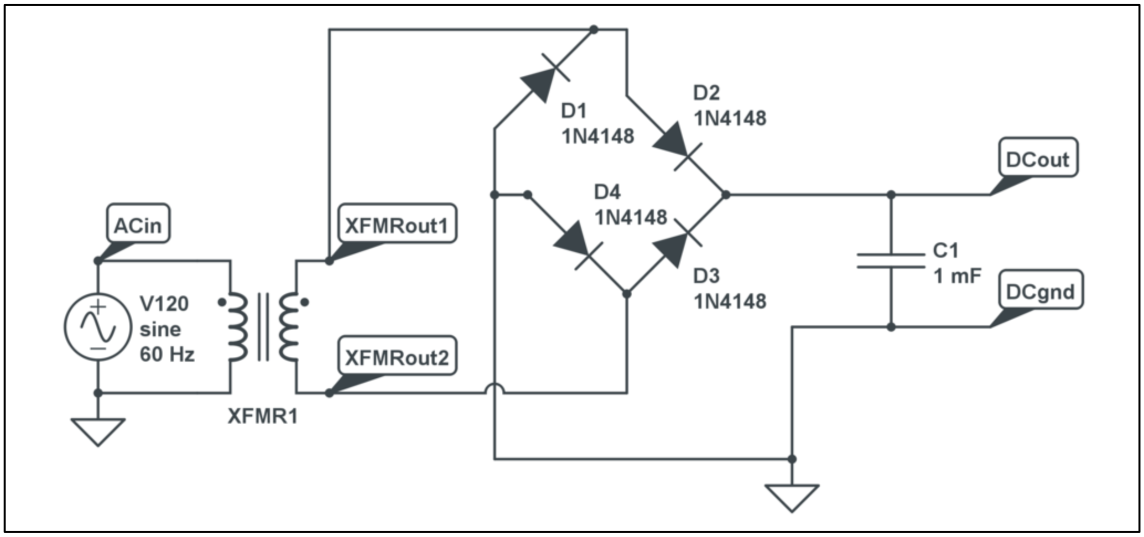


Figure 5-14 Power Circuit

5.1.8 TDS and Voltage isolator

The TDS sensor to be used is AtlasScientific conductivity kit K1.0. This sensor will take up 2 pins on the microcontroller and from the data sheet the following specifications will meet the needs of the controller:

- Reads conductivity
- Practical salinity of the solution
- Accuracy +/- 2%
- Full range from 0.07µs/cm – 500,000µs/cm
- Provides single point or dual point calibration
- Calibration only needed once per year
- Operating voltage 3.3V – 5.0V
- Sleep mode of 0.4 mA at 3.3V
- I^2C data protocol
- Single of continuous reading modes

5.1.9 Wi-Fi

The Wi-Fi module we purchased for development is the Adafruit HUZZAH ESP8266. It is a breakout board that features useful components on it for testing such as logic shifters on some of the pins, push buttons for ease of programming the board, and LEDs again for ease of programming and diagnostics. The ESP8266 chip uses 3.3V logic and therefore needs a logic-level shifter to interface with Arduinos and most Arduino related sensors and modules. This breakout includes diodes on the communication pins that act as logic level shifters so that for development we don’t have to worry about doing the shifting ourselves.

This is a well put together module and we don’t need to do much to start testing and developing on it. All that is needed for setup is to solder some headers to the broken-out pins and you’re reading to go on a breadboard. There are six headers on top that can use an FTDI cable connection to not only power the device but interface with the Arduino software as well, providing serial communication monitoring and easy programming.

The board itself can run Arduino software and, in addition to the Wi-Fi communication it provides, can function like any other Arduino based microcontroller and even features 9 GPIO pins that can be used for interfacing with other hardware. For initial development, this board is nice and easy to use, but should we decide to mount an ESP8266 to our PCB we need to be careful to include level shifters on the logic pins, a stable 3.3V power connection, and the push buttons that are required to toggle boot loading mode.

5.2 Subsystem and Breadboard

This section will include the results of breadboard testing on the individual subsystems. While each subsystem was tested to see if it was working when it was first received, it wasn’t tested in any specific means. These subsystems will now be tested and the results will be recorded. The testing process this group tried to preformed was to match the environment that they would be running once the total system is completely assembled. If those tests passed, we next would test them in extreme situations so that the group can feel secure with this product working in the real world working environment. If the subsystem could perform well in these test, the group then tried to correct the wire/circuit designs so that it could pass. Currently all subsystems are working per the groups goals.

5.2.1 12 V Power Supply

How do all electronics can function? The basis of any electronic system is to have a power supply that can supply the correct amount of power for the system to perform within tolerance that is was designed for. The hydroponic control system main power supply needs to convert 120 AC (v) to 12 DC (v). The power system needs to supply enough power, be within safety constraints, and be efficient for the system needs.

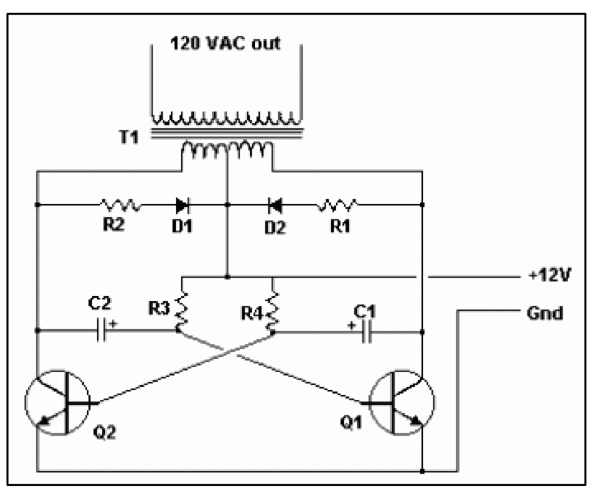


Figure 5-15 Complete System

To start with, the power supply needs to convert AC to DC voltage to provide the power needs for the control system. Figure 5-15 shows the complete system that is being implemented for the control system. After evaluating the complete control system, it needs to be stepped down from 120 ACV to 12 VDC and to supply a total of one

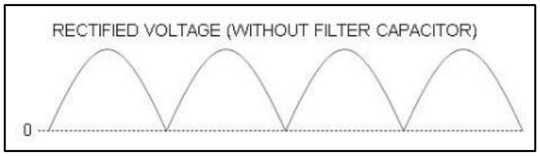


Figure 5-18 Rectified Voltage w/o capacitor

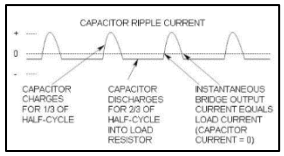


Figure 5-18 Rectified Voltage with Capacitor

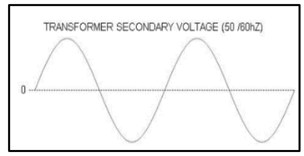


Figure 5-18 Transformer Secondary Voltage

ampere of current. The fist component to do this is the transformer. The sine wave that comes in is at 60Hz and is displayed in Figure 5-18. The wave is rectified using the full bridge rectifier and is displayed in. Then the 4700 µF capacitor smooths out the ripple to allow the voltage regulator to control for the rest of the to use as the main supply seen in Figure 5-16. The final DC voltage will be stepped down to the 5V and 3.3 V that is needed for the subsystems.

Equally important, is the safety of people and the circuit components that will be used for this implementation. To protect the circuit there will be a 240 V 1-amp fuse placed in line just past the transformer but before full bridge rectifier. This will protect the system for any shorts that could possibly happen during operation of the system. To protect the user from electrocution, the system will have sufficient grounding in accordance to 295-1969- IEEE standard for electronics power transformers *[7]*. The two .1 µF capacitors are placed in the power system to filter the electromagnetic interference that is created in the electronic power system.

All in all, the design of the hydroponic controller power system needs to be continence of the environment and make sure it is efficient for the needs of the system. In today's time, most medium to high power applications typically use switching techniques, however; the subsystems are designed to operate with low power so this low power system will use linear components to provide stable DC voltage and current for the needs of the system. Most of the sensors in the system can go into sleep mode when they are not in use and the software will engage the sensors to turn on only when the readings are needed.

Finally, the sub systems will operate within three different voltage ranges. The peristatic pumps will operate with the 12-volt system, the sensors will operate with the 3.3-volt subsystem, and the microcontroller will operate with the 5-volt subsystem. Every effort will be made to keep noise and heat reduced so the electronic circuits will run properly. The power system will be housed in a separate insulated container with proper ventilation to prevent any issues that could possibly come from the power system.

5.2.2 Dimmer Control

Once the voltage needs were measured from the dimmer control that came with the LED array the digital potentiometer was ready to be implemented. The use of the MCP4131 was determined to be a good fit for this design. The circuit was designed as in Figure 5-19 to be bench tested and programmed. There were a few tests that needed to be completed before the circuit was to be implemented. The relevant tests were:

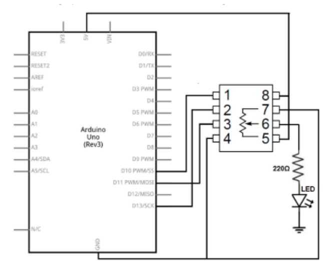


Figure 5-19 MCP4131 Digital potentiometer

1. Voltage range
2. Resistance of the chip
3. Proper functionality

5.2.2.1 Initial testing

Once the chip was connected to the microcontroller as in Figure 5-19 the initial testing was ready to be voltage was measured. It was important to measure the output voltage range in order to verify the max output voltage was in the range of zero to five volts. Once the circuit was designed the microcontroller was programmed and the circuit was tested measuring the voltage out of pin 6. The first measurement was performed at the lower end and was recorded at .059 volts. The code was adjusted to produce the maximum voltage and was recorded at 4.98 volts. This was within the range that was expected. Once this testing was complete the single LED was attached to pin 6 and the code was executed to visually see the dimmer working with the light and resistor.

5.2.2.2 Testing after the circuit was designed.

To make sure the LED array was not going to be damaged the digital potentiometer was set up to control a single LED and measurements were taken. The digital potentiometer controlled the LED light as expected. Once the testing of the single LED was complete the LED array was connected to the digital potentiometer and the array worked as expected. Now that the array works the LED array was taken back apart to design the wire routing to the digital potentiometer.

During the initial inspection of the LED array it was discovered the fans that cool the electronics was also controlled by the manual potentiometer. With the current design the fans will need to be controlled separately. The three fans will require a constant twelve-volt source and it will need to only come on when the lights are on. As the thoughts of different designs were considered on thing that was important is not to drain the mcu unnecessarily. The fans need to meet the following criteria:

- 12-volt supply
- 100 mA current to drive the fans
- 12 mW of power

After careful consideration, the decision was made to use the following circuit Figure 5-20 to control the fans in the array. The PN2222a transistor will be utilized to act as a switch to allow current to flow and control the fans. The other component to be used is the 1N4001 diode. This circuit was supplied the necessary voltage and ground and worked as the MCU code was written.

Figure 5-20 fan control circuit

5.2.3 LCD Screen

The hydroponics system we decided to build automates the LED lighting, pH, and EC sensors. It uploads the readings to the internet where the user can check the data for their system. That is convenient for the user when they are not physically close to the system, however it might seem like a hassle to pullout a phone or computer to check readings when they are standing right in front of it. For ease of use, we decided to use a simple LCD screen to display the sensor readings to users who are next to the system.

We selected a simple LCD that was on the cheaper side, being around $10. It is a 16x2 display with adjustable contrast via wiring a potentiometer to it. It runs off a 5v power supply and uses 5v logic. Initially we thought we would require 8-10 pins on our microcontroller to have in functioning correctly.

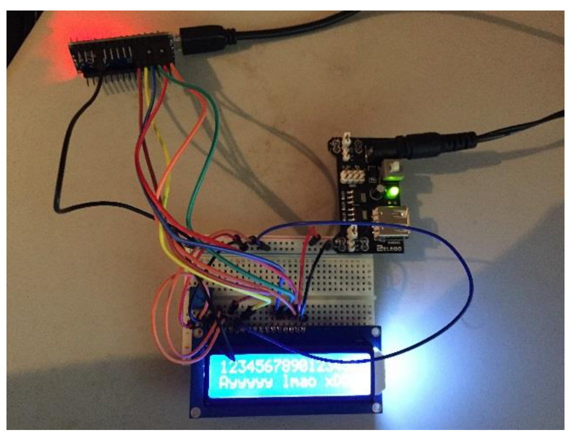


Figure 5-21 Working LCD Screen

Thanks to some wonderful documentation and examples on the adafruit website [10], we learned that the LCD would actually only require 6 pins on out microcontroller.There is a pin that controls the direction of the data (whether we are writing to the LCD or reading from it) and since we don't need to read from it, we can wire this pin (pin 5) to ground. Next we wire a control pin (pin 4) which controls whether the incoming data is a command or if it is information to display. The next wire is an enable wire (pin 6) which lets the LCD know when data is ready to be transmitted. The other four pins we connect to the microcontroller (pins 9-12) are for data transmission, for a total of only 6 wires.

Besides the microcontroller pins, we also have to wire a potentiometer (the little blue dial in the picture) to 5v power, ground, and pin 3 of the LCD. This allows us to tune the contrast of the screen to make sure it is readable. To power the logic section of the LCD, we must also connect 5v power and ground on pins 2 and 1 respectively. Likewise, we power the screen itself with 5v power on pin 15 and ground it on pin 16.

Arduino has a built in library called LiquidCrystal for interfacing with LCD displayed. You instantiate a LiquidCrystal object that ties itself to the 6 connected pins. After that you can start the display in the Arduino set-up loop with the .begin method which takes the screens character length and number of lines (so (16,2) in our case) as input. Then displaying characters is as easy as printing a line of text, with the .print method. The only thing that a programmer need to be careful of is that the lines do not wrap around. For example, if you write 20 characters to the first line, the extra 4 will not wrap to the second line, they will just no be displayed. The result of this is that after you write 16 characters to the display, you need to move the "cursor" to the second line so that you can continue writing on the second line. This is done with the .setcursor method which takes the columns and rows as input (in our case it would be (0,1) when we want to switch to the second line of the LCD).

5.2.4 LED

The LED array that came in was set up from the manufacturer with the ability to manually dim the lighting. Once the lighting system came in it had to be disassembled to figure out how to digitally control the dimming of the array. The current potentiometer was measured with a multi-meter to find out the voltage range of the controller. The manual potentiometer controls the voltage to the LED drivers. The voltage going to the LED drivers ranges from zero to five volts. The digital potentiometer can handle the voltage range to control the diming of the lighting and will be discussed in detail in the following section.

Now that the controller was figured out the LED lighting needed to be looked at to know if it will be sufficient. The main power to run the lighting system will be 120 volts A/C. The power outlet will be controlled by the microcontroller so that the lights are on for the specific time that the plants need. The plants will need the lights on for eighteen hours during vegetative growth and twelve hours for flowering stage. The main controller will be designed to control the outlet and only provide the array with power when needed. To control the main A/C power supply a relay will need to be implemented for the micro-controller to automatically turn the lights on and off.

Once the lighting system was set up it was plugged in so we could take readings with a light meter. At this stage, an app to measure the available lux the lighting array produces was used. Two things that needed to be determined from the array lighting, the max lux the array can produce and the distance away from the where at least 30,000 lux is available. The minimum lux the plants will need is 30,000 lux. The lighting system produced a max of 45,000 lux and at eight inches away it measure 30,000 lux. The lighting sensor that is used to take readings will be designed to be eight inches away. The lighting sensor will give the end user the gage to have the lights at the correct height always. As the plants grow the LED array will be raised manually by the user.

The final test to be performed needed to take place outdoors. Once a spot was located on campus that had a power outlet outside the LED array was set up with the lighting sensor and micro-controller. When the LED array is matched with the sun eight inches still was a good height for the lighting system for the plants to receive sufficient lighting and not be shaded by the light fixture.

5.2.5 Light Sensor

The sun produces the full spectrum of light that reached the plants and can produce light intensity up to 98,000 lux. Per dictionary.com [11] lux is defined as:" a unit of illumination, equivalent to 0.0929 foot-candle and equal to the illumination produced by luminous flux of one lumen falling perpendicularly on a surface one meter square'. The variety of plants require different amount of lux; however, for the typical garden plants need at least 30, 000 lux to produce any meaningful growth. This system is designed to use ambient light mixed with artificial light to produce the minimum lux needed. This system is going to utilize a light sensor to be energy efficient, easy to set up, and have the quality to last the conditions.

The light intensity for this system is going to be energy efficient by blending ambient light with the LED lighting system. The sensor that will be used to measure the light is Adafruit TSL2591 High Dynamic Range Digital Light Sensor. To be energy efficient, the system is designed to be:

- Dimmable
- Energy friendly with a sensor that has low power consumption
- Autonomous
- Easy accessibility

In addition, for a home user the system is designed to be easy to set up. The controller will hold the computer program that will allow the user to just plug it in and use it. Part of the sensor design will be to create a housing that will attach to the lighting rack and to make sure the sensor will be in the proper position. This will also make sure the lighting rack is the proper distance from the plants to provide efficient lighting intensity as needed.

In like manner, it is important to have a quality lighting sensor to provide long term use. This chip was selected due to the fact it can:

- Detect light ranges from 188µlux to 88,000 lux continuously
- Flexible operation
- Has low power sleep mode
- Fast mode compatible interface

Equally important, was to consider the Adafruit TSL2561 digital luminosity/lux/light sensor. This sensor utilizes similar parameters. It provides for flexible operation, similar voltage needs, it is similar in size and has similar power consumption sleep mode. This sensor can read lux ranges of .1 to 40,0000 lux. This is within the range that is needed for most plants to survive. Most plants can survive within this range of lux; but, the system needs to provide the ability for the end user to grow any plants they choose and to provide a plentiful result in growth. At the end the decision was made to not use this sensor because the TSL 2591 has a broader range to read the lux provided to the plants. As mentioned earlier the more lighting a plant receives the greater the harvest and the goal of the system is to provide the highest quality at an affordable cost.

5.2.6 Lighting System and Sensor

As the food, we consume may not be as nutritious there are a group of people that would like to grow their own food and one way that these people are growing their food is hydroponically. As these systems are considered the lighting systems consume a lot of power. As the cost of power goes up this may deter people from growing inside of the home. This system considers this cost and will be designed to blend ambient light with the use of an efficient LED lighting system that will be dimmable and provide the correct amount of lighting to the plants.

To be energy efficient, the use of an LED lighting system will be implemented. Since the goal is to blend ambient and artificial light to grow healthy plants and achieve the highest yield the use of a lighting system that is dimmable is needed. As the research was done the decision was made to utilize Galaxyhydro 300W dimmable LED lights. This lighting system only consumes a maximum of 150 watts which will be approximately fifty percent of what another lighting system would use. The way for plants to produce the highest yield is to make sure the get the correct spectrum of lighting. To grow plants indoors the main lighting needs that need to be supplemented are mostly red and blue spectrum. This lighting system is focused on the red and blue and it also includes infrared spectrum which helps with cell division to increase crop yield.

In like manner, the system needs to have the correct light intensity to grow healthy plants. Utilizing LED lighting produces less heat so this will allow the lighting system to be placed closer to the plants. The lighting sensor will be mounted to the frame of the lighting system at the height that will allow for maximum light penetration to the plants.

Equally important, to be energy efficient the system needs to be dimmable. Once the lighting system came in it was taken apart to observe how the dimmer was utilized. The system came in with a manual potentiometer that controls two LED drivers. Once the lighting system is plugged in the dimmer is utilized to turn on the LED lights and the fans to keep the electronics within the housing in the range for safe operation. With this system being autonomous it is going to need to be controlled digitally through the microcontroller. There were three options considered to control the lighting system. The first component considered was an IRF830A which is a MOSFET controlled dimmer control. After investigation, there was not a smooth enough control and not enough range. Most of the applications used this chip with four setting so it will have the dimming levels of 25, 50, 75, and 100 percent. This is not desirable for this design. The second option considered was an AD5171 digital potentiometer. This circuit design seemed promising; however, this chip utilized two of the analog input pins. Utilizing the analog pins is a valid option other than the fact that there were other sensors in the system that needed to utilize the analog pins. The final chip that was considered was a MCP4131. This chip utilizes two digital pins and has a very dynamic range of controllability. This chip has the following specs:

- 7bit: 128 Resistors with 129 taps to Vss and VDD

- SPI compatible interface
- Low power operation: 1µA
- Wide operating voltage: 1.8V to 5.5 V

With the seven-bit system this will allow for one hundred twenty-eight steps to control the dimming system. With the low power consumption and dynamic range this was a good fit for the system.

5.2.7 Logic Level Shifting

The atmega328 in this project uses a voltage of 5 volts for a high signal and GND for its low. Which is good for serial communication for most cases, but through experimentation it was learned that our Wi-Fi unit needed 3.3 volt high and GND. Because of this we tested several methods to shift the logic level to the needed voltages. Our first experiment was done on a module to do the shifting as seen in Figure 5-23. In Figure 5-22 below the results of using this module are displayed. Using a signal generator connected to the module as seen in the input of the oscilloscope as the blue line and the output as seen in the green line. This module produced a nice test response but as we didn't want to use a module on our PCB, we explored other alternatives.

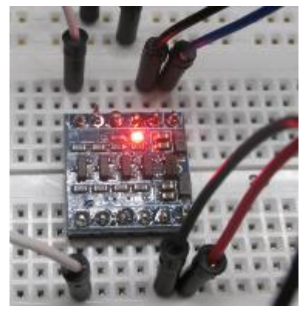


Figure 5-23 Module test

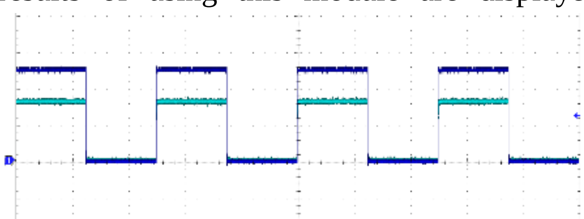


Figure 5-22 Test Results

The next strategy was to try a resistor voltage divider, which are common in many circuits and see what the result would be. Because 3.3 volts is 2/3 of 5 volts, different values of R as seen in Figure 5-25 can be used. By experimenting with different values of R, the results can be seen in Figure 5-24.

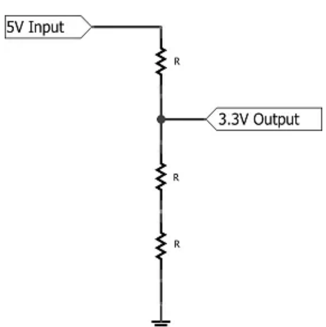


Figure 5-25 Module Circuit

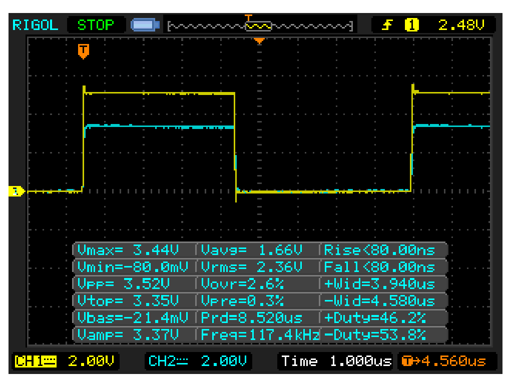


Figure 5-24 Module Test Results

The last strategy was to use a Zener diode as seen in Figure 5-27. This produced a very nice response in the logic level conversion as seen in Figure 5-26. The simplicity of this design made it a choice for our project and the module that we experimented with in the first section would not be used in the project.

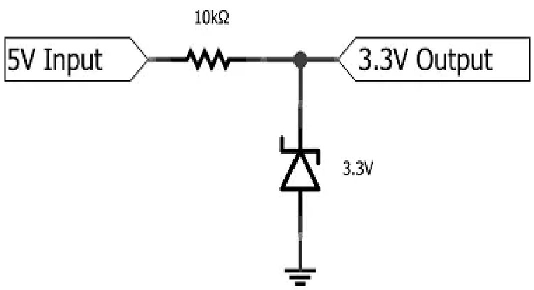


Figure 5-27 Zener diode Circuit

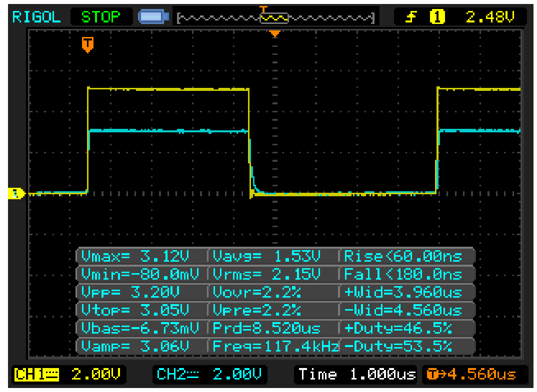


Figure 5-26 Zener diode Test Results

5.2.8 Microcontroller

During the process of experimentation of our first subsystem breadboard test, we soon discovered that just one atmega328 microcontroller would not be enough input/output pins to accommodate our design. It was now through research that we decided to go with a master/slave configuration as seen if Figure 5-28. Not only would this give us more pins to work with, but also allow the LCD screen and Wi-Fi unit to have their own dedicated microcontroller. This was done by connecting pins A5 and A4 together on both microcontrollers with pull up resistors connected to VCC. This communication is called I2C and is a multi-master bus which can communicate between the master MCU and the slaves that are connected to it. This configuration requires only two analog pins on each microcontroller and are connected to both MCU as seen below. These lines are two bidirectional open-drain lines. Serial Data (SDA) and serial clock (SCL). In this way, up to 112 nodes can communicate with each other and in future revisions additional MCU can be added to the design. Thus, not limiting this design to just a few pins which the MCU has available, but as many as needed in the design.

Our testing of this MCU I2C configuration on the breadboard is to see if the communication of one device could indeed communicate with the other MCU. The design was laid out on a breadboard and connected to the proper voltages and grounds as needed by this design. Then by uploading a simple code to the master MCU and coding the slave MCU to receive this information. The test was to see if information could be moved from the master to the slave and the results to be displayed on a serial monitor. The test passed the testing phase and was deemed suitable for this design project.

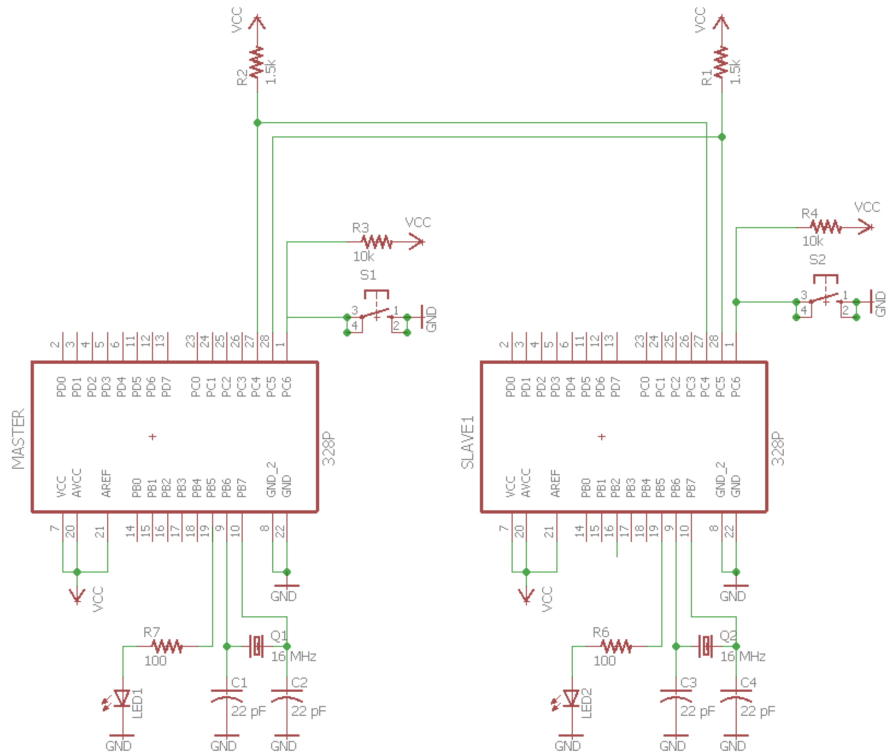


Figure 5-28 MCU Schematic

5.2.9 pH Sensor

The testing of the pH sensor involved connecting the sensor to its module and connector port, seen if Figure 5-30. This part of the system will be included on its own separate PCB along with the TDS modules and one extra slot for future revisions if needed. Before testing the sensor in different pH levels, the sensor needed to be calibrated first. The solution that we calibrated the sensor to was the 7.0 solution. At first readings on the serial monitor showed that the sensor was reading 7.2 pH. By sending a command through the

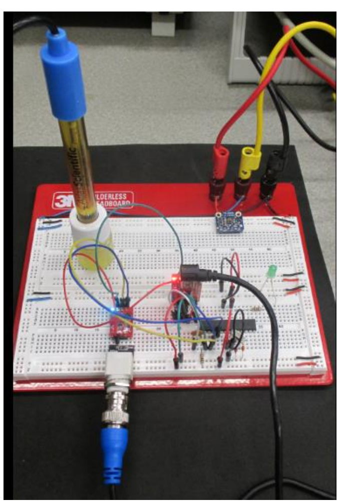


Figure 5-30 Testing Set of pH Sensor

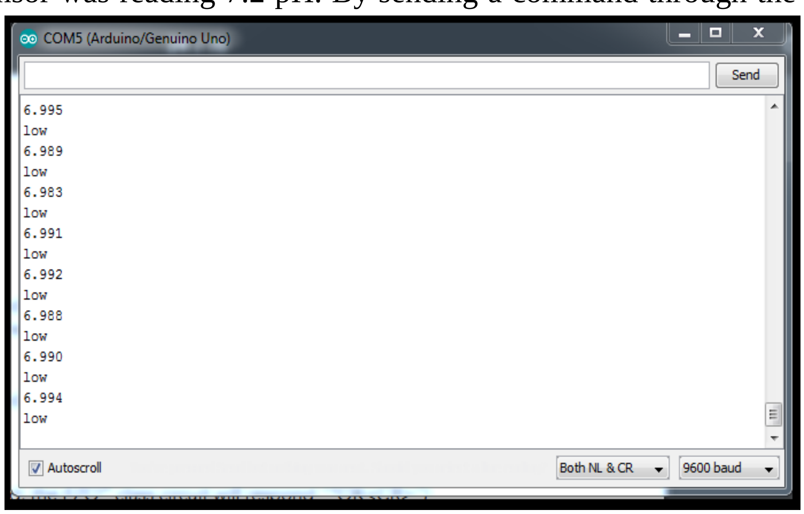


Figure 5-30 Arduino Monitor with the pH Sensor Readings

serial port on the laptop the measurement was set to 7.0 and the results can be seen in Figure 5-29 above. Several more tests were made and the testing of the pH senor was a success.

5.2.10 Power Supply AC to DC 12 volt

For the circuit control of this system to function properly the supply voltage needs to be stepped down from 120 VAC to 12 VDC and it needs to safely provide 1 ampere of current. The first step to reduce the voltage is the utilization of a transformer. The transformer will step the 120 VAC down to approximatley 17 VAC. First a power cord needs to be wired to the transfomer following the *IEEE power transformer standard C57* [7]. Once the transformer is wired properly then the circuit in Figure 5-31 needs to be assembled on the breadboard. In order to convert the AC to DC the AC voltage needs to be rectified. Use the 4 1N007 diodes to assemble the full rectifying circuit. The next step is to decrease the ripple voltage using the 4700 µF capacitor to design the full bridge rectifier. Now to be able to deliver a constant 12VDC to the circuit the output from the rectifier needs to connet to the intout of the LM7812 linear regulator. Connect the center pin of the regulator to ground. Finally on .1µF capacitor will be attached to the input and the output of the linear regulator. These 2 capacitors will eliminate the electromagnetic interference that can be produced from the large inductive transformer. Once the circuit is fully assembled then the power transfomer can be attached to the circuit then plugged into the wall. **Caution this is a high voltage input so all safety precautions need to be takem during this design process.**

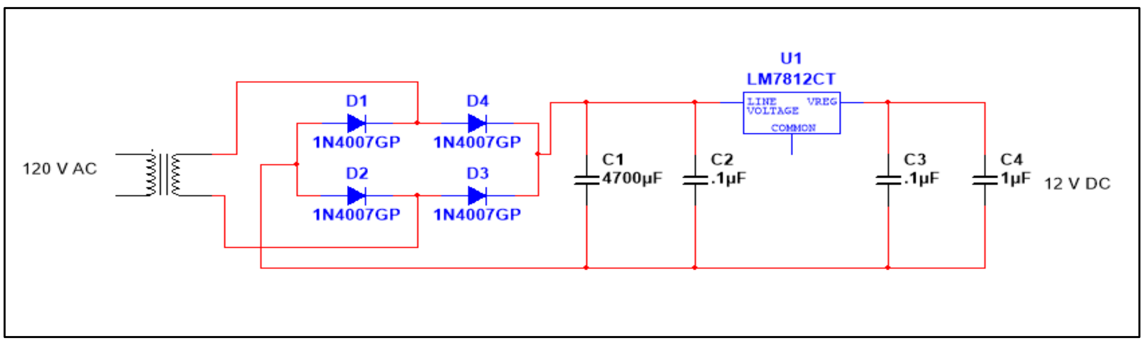


Figure 5-31 Power Circuit

5.2.11 TDS and Voltage Isolation Circuit

The EC sensor is a very sensitive device which requires the upmost care when building the circuit to prevent damage. The sensor is designed to inject a very small current into the water within a small hole in the lower end of the probe. This is such a very small current and the module circuit that came with the sensor will take in the values and do the calculations and send it to the microcontroller to be displayed to the user. The module is seen in figure 5-33 and the circuit will be assembled on the breadboard first. There will be multiple sensors in the solution and with the sensitivity of this sensor these other sources may cause inconsistent readings. To avoid the inconsistent readings, the system will utilize a voltage isolation circuit in series with the module. Figure 5-32 is the breadboard with the complete circuit attached to the bread board. design. Once assembled and attached to the microcontroller 5 VDC is to be applied to VCC ground needs to come from the microcontroller and the Rx and Tx will also be attached to the microcontroller. Once the microcontroller is up and running the next step will be to calibrate the EC sensor to make sure the correct value is displayed on the computer to verify that the sensor is working. There is two different total dissolved solids solution that needs to be utilized for calibration. This will also be a bench mark since this is a known value to an accurate TDS value. For calibration procedure see page 17 in the data sheet for the AtlasScientific EC EZO.

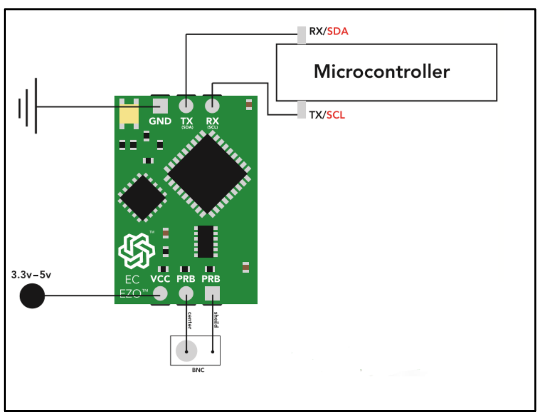


Figure 5-33 TDS Sensor design

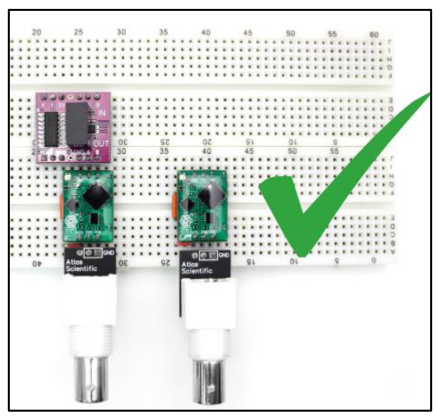


Figure 5-33 TDS Proper Positoning

5.2.12 Water Level Sensor

This liquid level sensor is a solid state continuous (multi-level) fluid sensor for measuring the amount of hydroponic solution in the containment container as seen in Figure 5-35. This sensor provides a resistive output which is inversely proportional to the liquid level. This corresponds to high resistance levels when the tank is low and a low resistance when the tank is full. With this information, we should be able to read low

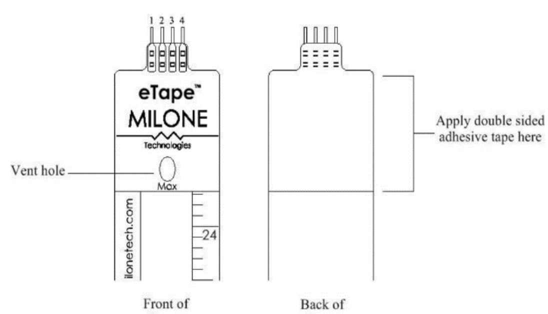


Figure 5-34 eTape Diagram

voltages when the level of solution is low and higher voltage levels when the level of the solution is high.

In Figure 5-34 we used a simple voltage divider using the internal resistors in the eTape to complete the circuit. The connections were made to our MCU by connecting pin1 to ground, and pin2 to VCC. Next by connecting pin3 and pin4 together to become our voltage out which would be read by pin A1 on the microcontroller. This type of connection produces a simple voltage divider using the internal resistors of the eTape liquid level sensor. Now that the connections have been made to the MCU, testing could be done by using a multi-meter and reading the voltage levels with different amount of liquid in our test chamber. Table 5-2 below shows the voltage levels produced by adding more liquid to the test chamber one inch at a time. It was noted that between 0 and 1 inch there was no change in voltage and would have to be considered when placing the sensor in the final system.

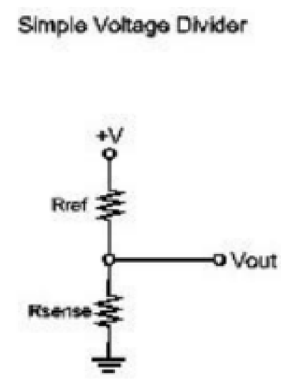


Figure 5-35 Voltage Divider Circuit

Liquid Level (inches)	Voltage Out (V)
0	2.51
1	2.51
2	2.59
3	2.72
4	2.79
5	3.05
6	3.26
7	3.52
8	3.77

Table 5-2 Water Level Test Results

5.2.13 Wi-Fi Breadboarding

One of, if not the most, attractive things about our automated hydroponics system will be the internet connectivity of it. Users will be able to check the sensor readings online, either with their phone or a computer. To accomplish this task, we went with the very attractively priced ESP8266 chip. The modules we will end up putting on our PCB will need to be surface mounted so in the mean time we purchase an Adafruit HUZZAH ESP8266 development board for about $10. It is a simple breakout board with some LEDs and pushbuttons that make development on this board a bit easier. It should be noted that the version of the ESP8266 on this board is the ESP12E, but the chips we purchased for our PCB is the ESP12F. The only difference between these two chips is an upgraded antenna. All the pinouts, power requirements, functionality, etc in regards to wiring and programming are the same between these two.

The ESP8266 has onboard memory and we will be using this to run the Arduino software for controlling the board. The development board we have has an FTDI pin breakout which allows for serial to USB conversion as well as powering the board off the same USB port connection. The ESP8266 chip that we will be surface mounting to our PCB will have the same breakout on the PCB so that we will be able to reprogram the chip without unsoldering it from the PCB, should we have to. The only difference will be the power form the USB port will obviously not be needed as it will be powered from the PCB.

The breadboard setup, as you can see is very simple. The FTDI breakout allows us to program and power it all from the one FTDI to USB cable. As previously mentioned, we will be using Arduino to program it and do this initial testing with it. Adafruit supplies some sample code that connects the device to a simple text website so that you can verify a connection has been made. The sample code prints the website contents over serial via the FTDI connection and you can view it in the Arduino serial monitor.

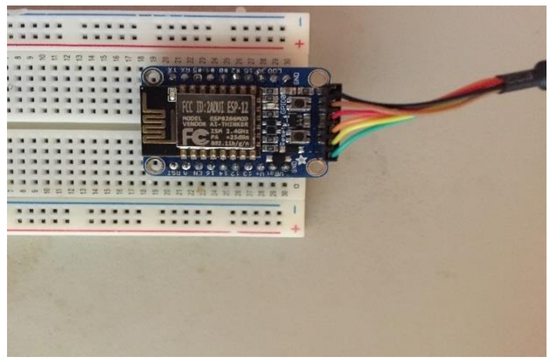


Figure 5-36 ESP8266

Setting up the Arduino IDE for development with this board was easy. All that needed to be done was to go to the Library manager in the application and to search for ESP8266 which presents a library not only for this development board, but for other development boards as well as generic ESP8266 modules that are presumably wired manually. The only thing to be careful of with this development board is that for the Arduino IDE to upload code correctly, you must hold down the GPIO button and then press the reset button. Doing this puts the board into boot load mode and allow you to upload code to it. We took this into consideration when designing our PCB circuit so that we would be able to mimic this functionality for ease of use.

After setting up the Arduino environment and learning of the boot load mode requirement for uploading code, testing and development went smoothly. The only thing required for running the sample code available at the Adafruit [12] was for us to change the SSID and password fields in the code to match the router we were using for development to ensure the Wi-Fi connection was established. Within a couple minutes we had the board printing the sample website out over our serial connection.

The next step was to try modifying this sample code to see if we would be able to use the ESP8266 on custom websites like we intended. To accomplish this goal, we set up a simple website that was locally hosted on our network. In the final design and presentation of our project we will need this website (and out planned back-end database) to be hosted on the internet so that it will be accessible anywhere. Internet hosting is not free however and we believe that using a locally hosted website and database is fine for the development stage and we can transition to an online host later in our project.

This where another roadblock presented itself. Configuring the IP and port number that we would use locally took a bit of setup, and depending on your computer and network configuration, the IP can change at times. A statically hosted website should encounter none of these issues but for developing we had to frequently check the code and local hosting settings and make sure our connection was being made.

Creating a simple html page at first worked well. The ESP8266 could connect to it and print the contents of the page over the serial connection without any problems. The next step was then figuring out how to transfer data to this website considering that we would need to do this to get it into our database later. This was accomplished by using HTTP and sending the data in the URL via a POST request. First, we had it mirror the information back into the HTML page to confirm that the website was correctly receiving the data form the ESP8266. Later we made a locally hosted database to test storing the data. Using PHP, we then tested that we could put the data from the POST into our locally hosted database. Finally, we could transmit data from the ESP8266, of the Wi-Fi, into our website, and finally into our database. This was a working prototype. The only thing that remains is to finalize the formatting for all the sensor data, improve our website to make it more user-friendly, and migrate the website and database to an online host.

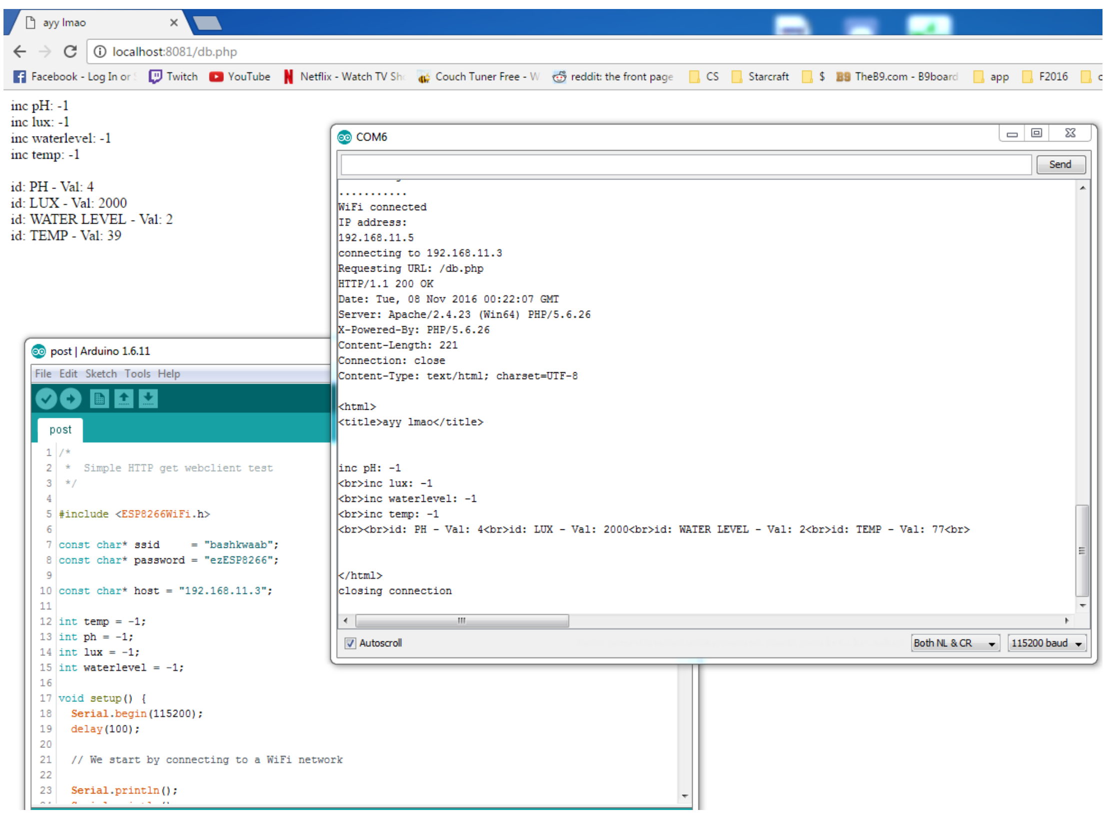


Figure 5-37 Wi-Fi System Test

The only aspect that was not tested was transmitting data to the ESP8266 over serial. In our PCB configuration, the main microcontroller will be reading the different sensor values and transmitting them to the ESP8266 over serial. After that the ESP8266 will transmit the data over the internet. The reason we did not bother testing this is because we have done serial communication between microcontrollers several times, not only in school but in our personal lives. We concluded that there was no reason to believe this wouldn't work and when we get our whole system put together on a breadboard we will test this feature to make sure it is functioning correctly. Once our full system is working together on breadboards we will finally be able to migrate our website and database over to the internet and iron out any potential issues that crop up along the way.

5.3 Software Design

This section will cover the overall software design of the system by splitting the software into four subsystems;

- Database
- Mobile App
- PCB
- Website

Each section will go into depth on the coding and plan for its functions as well as the intended design. The next section will look at the overall system by explaining and showing the interactions of the various subsystems. This is of course being the intended design of the system and is subject to change based on how the final subsystems are coded/designed and thus how they interact with each other.

5.3.1 Database

The database for this system will be written in SQL and, at first, stored on a personal computer. Once the first round of testing is complete the group will look for an internet service to load the database too. This database will be simple in its design and the group will try and remove any third-party processes that maybe needed to maintain data verification. Below is a figure showing the database relation diagram;

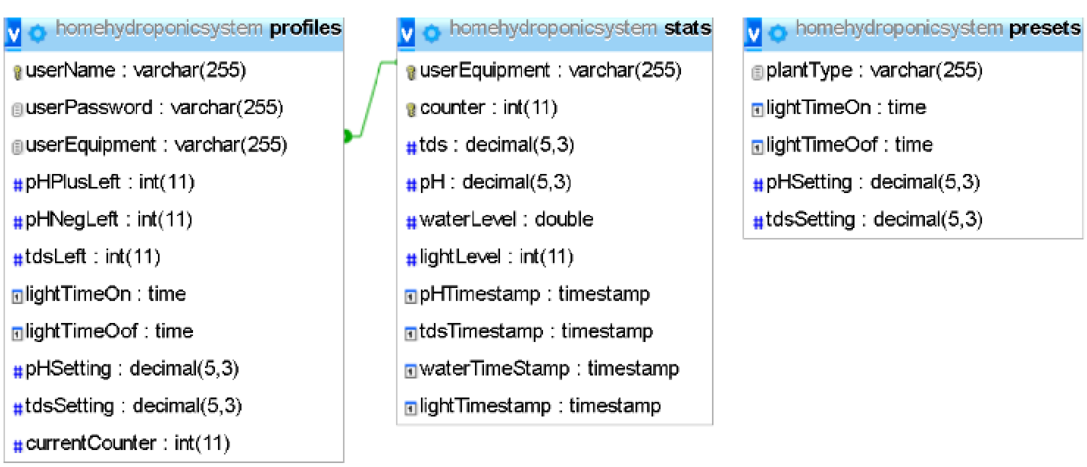


Figure 5-38 Database Relation Diagram

As can be seen, the table relationships are very simple and direct. Doing it this way will increase query speeds to and from the website. Each profile will have multiple equipment stat tables, using the counter to know the position and location of all the stats. These stats can be looked up and referenced to know the history of the system.

5.3.2 Mobile App

One of the aspects of our system in a mobile device application. This application will also be one of the defining characteristics of our project. Many automated hydroponics systems have been developed in the past but we felt that many of them lacked the ability to be able to check your sensor readings on the go and have accurate information. A mobile application allows the user to check these settings any place that he has internet access.

We discussed which platforms to develop this mobile application for and in the end, we settled on developing for Android. There are many different operating systems on phones today, with some of the more popular ones being Android, iOS(Apple), and Windows Phone. None of us had developed for iOS or Windows Phone before and we decided that Android was popular enough that just doing an Android application for our prototype would be sufficient. The official, and most popular IDE, for Android is Android Studio. Android Studio is based off the popular JetBrains IntelliJ IDEA software that is used for Java development.

Android Studio makes use of a combination of technologies for the development of Android. It combines Java, eXtensible Markup Language (XML), Gradle, and other technologies for ease of development. Not only does it aid in development but also coordination, with built-in support for popular version control software like Git. A particularly useful tool that is included in the IDE is its design tab for activities that allows you to preview the look of the activity and drag and drop common components like text boxes, buttons, pictures, etc. These are but a few of the reasons we went with Android Studio.

The way Android works is a bit different to Java, but at its core shares many things with Java such as the way data is handled and manipulated. A major difference however is the way GUIs and windows are handled. When an app launches, the app creates an intent. This intent creates a window and from there you can link buttons and various actions to navigate to other screens, or intents. While functionality and syntax might differ slightly, for most intents and purposes Android can be thought of in the same was as most other object oriented development languages.

As far as functionality goes, when the user opens the application they should be presented with a log in screen. After entering their information, they will be presented with the readings from the different sensors in the system. Depending on how much we will be able to implement in our given time over the second semester of our Senior

Design, we also planned on possibly adding a settings menu where users could change profile settings. These profile settings would set different acceptable levels of pH, EC, etc. based on different plant types and maybe even things like season, time of day, light level, etc.

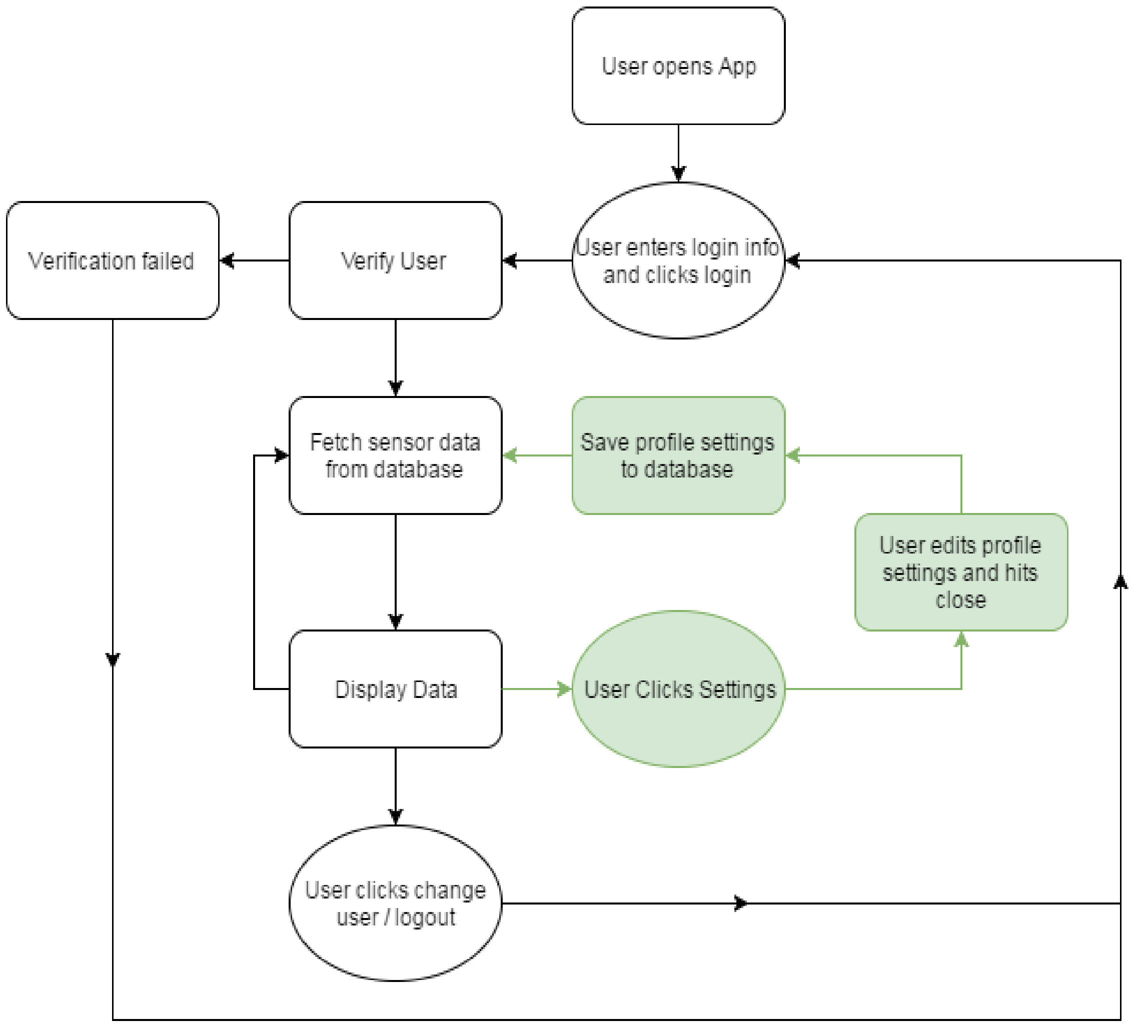


Figure 5-39 Mobile Application Design Flowchart

A simple flow chart of how the application would function can be found below in Figure 5-39. As you can see the features that we plan on implementing should time allow are in green. The basic checking of sensor data is something that is a baseline for implementation and will be in the final project no matter what. We had so many great ideas for what the system and mobile application could do in conjunction that we had to be realistic about our time constraints and pick a good list of requirements that could be met. There is no shortage of things we can add to the application and system should we find that we have spare time on our hands.

The sky is really the limit with what we could do with this app if we weren't also designing the entire hydroponics system from scratch. Much of what we are going to implement in the mobile application will be limited, hindered, or even made impossible by the configuration our hardware. In addition to requiring the right hardware functionality, our backend website and database design and architecture will determine the effectiveness of communication between our hardware and the mobile application.

As an example, if we configure the Wi-Fi module to only send out the sensor readings, there would be no way for us to send selected profile settings back to the hardware so that it would adjust accordingly. We would need to program the functionality into the hardware to receive that information which is much more difficult to do, but might take more time than we have. Likewise, the website that we are using as a medium for the database, Wi-Fi module, and Android application would have to have the correct coding as well for this added functionality.

5.3.3 PCB

Our system is an automated hydroponics system. Whenever you take a system such as this, and automate it, by necessity there will be lots of code. You need to be able to control the hardware and devices appropriately and react to as many different situations as possible. With so many sensors, and adjustments to make, I would assume our code is going to be on the larger side than most projects. Our software is going to be broken into 2 major components, the first being he microcontroller and Wi-Fi modules, and then the website and database backend.

To begin with the microcontroller section, the code for the pH and EC sensors is simple considering the circuits that we will use with the sensors. Once a serial connection has been established with the Arduino software, all we must do is transmits an “R” character over the serial connections and the sensors will respond with their readings. The pH will transmit the pH reading back in X.XX format where a reading of 7.5 on the pH scale will be represented as 7.50. While not transmitting, these sensors will run in a low power state. Should the need arise, there are other commands we can send to them via serial so that they could run in continuous reading mode, where it will repeatedly transmit the readings. When we read the pH or EC sensors and see that the values are unacceptable, we will adjust the levels accordingly.

To do this, we will use peristaltic pumps which are controlled via relays. These simple 12v pumps have bearings that squeeze the tubing used to pump liquid to ensure that each time it rotates it releases the same amount of liquid. Once we figure out how long the pump need to be on for one rotation, we can program the relays to leave the pump on for that amount of time. Similarly, we can keep track of the number of rotations and accurately know when the solutions we are pumping are running low, given we know the size of the solution’s container. Given the nature of hydroponics systems, after adjusting the pH or EC we will wait for the added solution to permeate the water and stabilize. This will take a few minutes and we will keep track of this with the microcontrollers built in timer that tracks how long since it has been reset.

The lighting sensor is a bit different. It similarly transmits its readings over serial, but there’s more that we must do. Our system will dynamically adjust the LED light array to supplement the natural light until it is at an acceptable level. This will be done through a digitally controlled potentiometer. When the system needs more light we will increment the LED array's intensity by use of the digitally controlled potentiometer, and then take another reading the next time the microcontroller loops. Every time the microcontroller loops, it will keep adjusting the LED array up or down until the light level is acceptable.

The last sensor we are using is a water level sensor. This is the one area that we will not automate since the time required to do so is a bit out of our reach. We would have to have a sizeable reservoir and considering the only water lost by the system should only be evaporation, low water levels should be infrequent. So instead we will send a notification to the user. In the code, we will just have a flag and when the water level is too low, we will enable this notification to be sent.

The software we will use to control our system will be written in Arduino. If you have used it before, you know the basic structure of code written in this IDE. There is a setup loop that runs whenever the microcontroller is turned on or reset. The rest of the main code runs in a continuous loop. Let's look at 5-40:

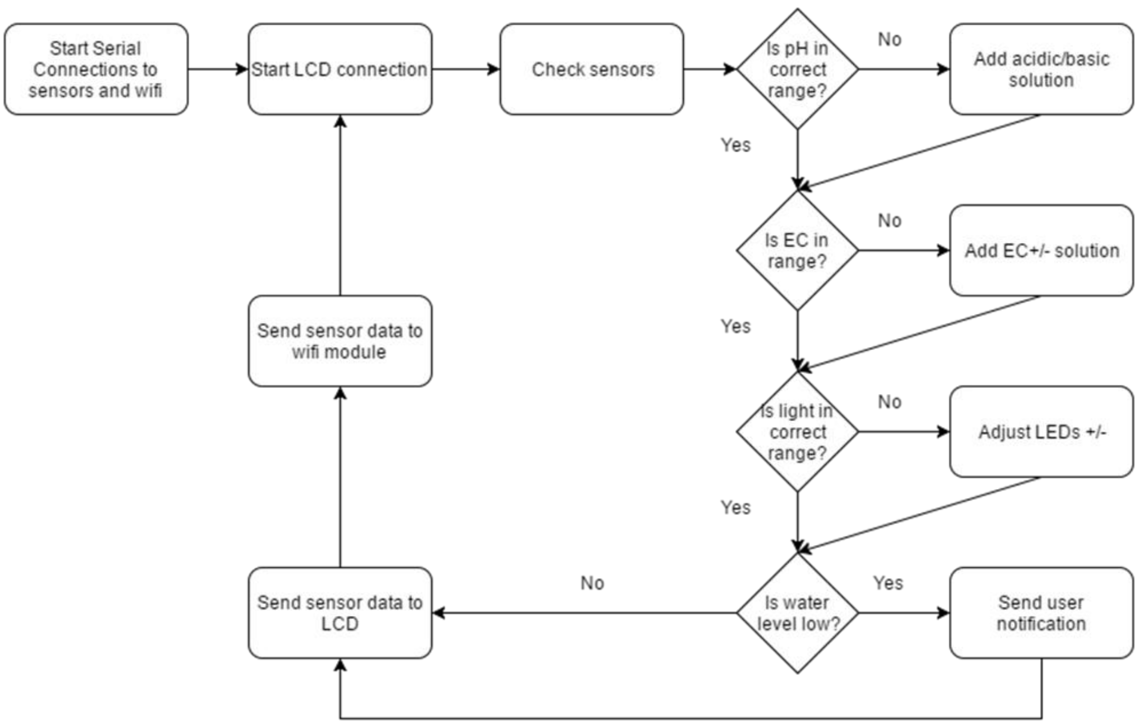


Figure 5-40 Microcontroller Flowchart

In the setup loop, we establish the serial connections that we will use for communication with our sensors. As previously mentioned, this can be a call land return type connection or one where readings are just constantly streamed from the sensor. In the interest of saving power, we have elected the call and return type of communication so that the pH and EC sensors can sit in low power mode when not in use. We also start the LCD connection and Wi-Fi connection so that we can interface with them accordingly.

While the actual code and the way certain tasks are accomplished are subject to change (such as how to control pumps, etc.). This diagram for the microcontroller should hold true. The descriptions in the boxes of Figure 5-40 aptly describe what we intend to happen under the condition we want it to happen. While the method for arriving at these intended functions might be altered along development, the outcome should remain the same.

5.3.4 Website

Moving on, we can discuss the website and backend database. The website portion will be broken down into 2 different pages. The first page will be a backend page that the ESP8266 can transmit data to, and the second page will be the frontend page that shows the data from the database to the user's web browser or phone app. Both the frontend and backend pages will need to have safety precautions set in place so that the system's data can't be tampered with.

The way we've designed the backend page to work is for the ESP8266 to transmit data to the website using a POST call. The website has PHP code that then takes the data form the POST and verifies and formats this data. Then using the mysqli library, connects to our database and updates the relevant information. We spent time thinking about how to establish this connectivity and ultimately decided on PHP since we have experience using it in other classes and that PHP scripts on websites are typically hidden form users so that helps with security. Figure 5-41 will represent how our backend website will function:

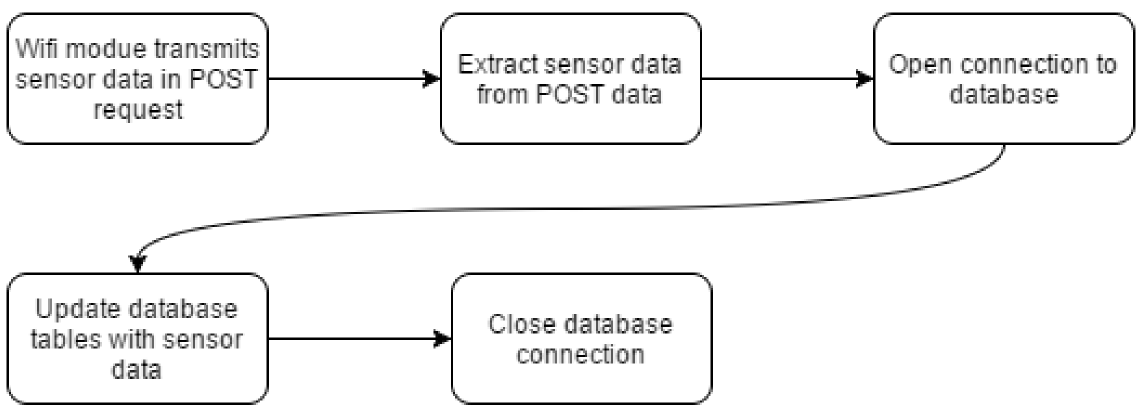


Figure 5-41 Website Dataflow

As you can see, this backend website will be simple in terms of coding. The main purpose it will fulfill is getting the incoming data into the database, other than that it will just do some simple data verification and error handling. There won't be much processing going on. Given that this webpage is not meant to be seen by the user, its biggest use will likely come in development and maintenance. This also means the website does neither has to look nice or be the easiest to use. The one thing it does have to be however, is functional and thorough in reporting what possible problems could be. For example, all from this one page we should be able to know if the data we are receiving is valid, if our database connection is functioning properly, and can troubleshoot these problems with relevant error handing.

5.4 Summary of Design

The automated hydroponics system we designed will automate pH levels, EC levels, light levels, as well as monitor water levels and make the readings available to the user whoever there is internet access, either from an Android phone or computer. To achieve this, we needed to integrate a pH sensor, EC sensor, LED lights, light sensor, LED dimmer control, water level sensor, and the LCD screen. These components needed to be attached to our microcontroller and programmed accordingly. As mentioned in other sections, we opted to use an additional Atmega328 when we learned we required new pins, as opposed to switching to a larger chip. The main microcontroller will have all the sensors attached to it while the secondary controllers will have the LCD and Wi-Fi module attached to it. The two devices are connected by an I2C connection.

The pH and EC sensors were simple to design and integrate since they both use a serial connection to communicate with the main microcontroller. For prototyping, we just configured them to repeatedly transmit their readings every 1 second. In the future, we plan to switch it to a call-and-response type connection so that we can keep them in low power modes when they are not being used. We configured the system so that the readings would be displayed on our LCD, as you can see in our latest prototype below, in Figure 5-42.

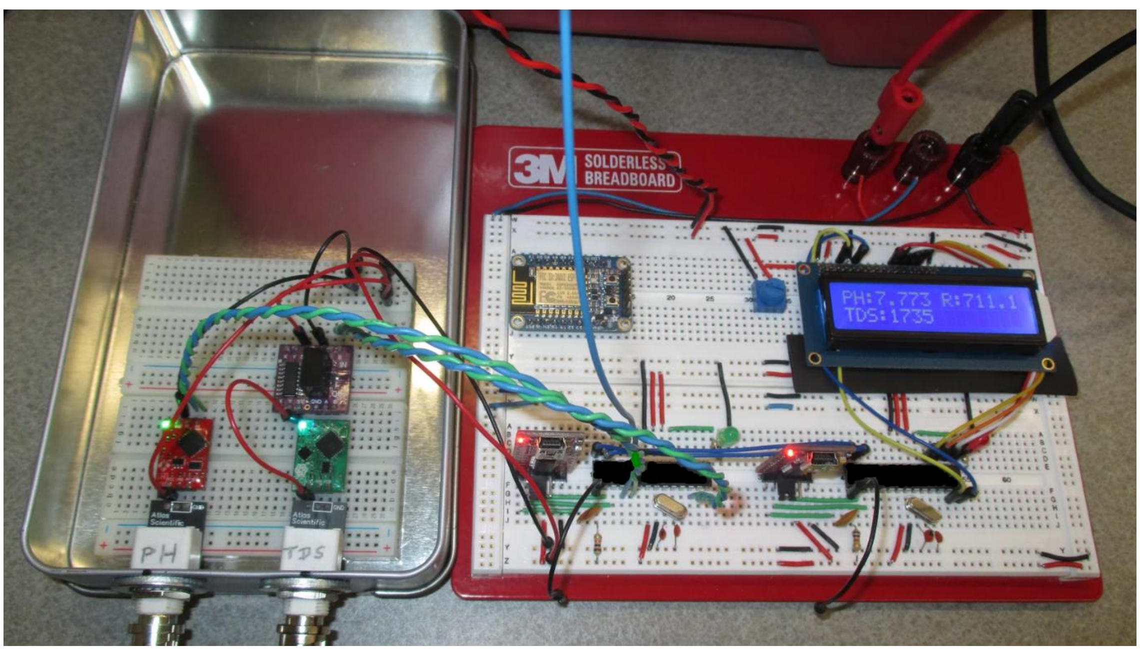


Figure 5-42 Integration and testing of our two microcontrollers with other components

As you can see, we also integrated the water level sensor, but haven't finished the programming to convert the resistance into an actual water level. We decided to just display the resistance to the LCD for now, and we verified that it went up and down with the water level. In the final version of the project it will be an actual water level in inches. Below you can see our water sensor array, in Figure 5-43.

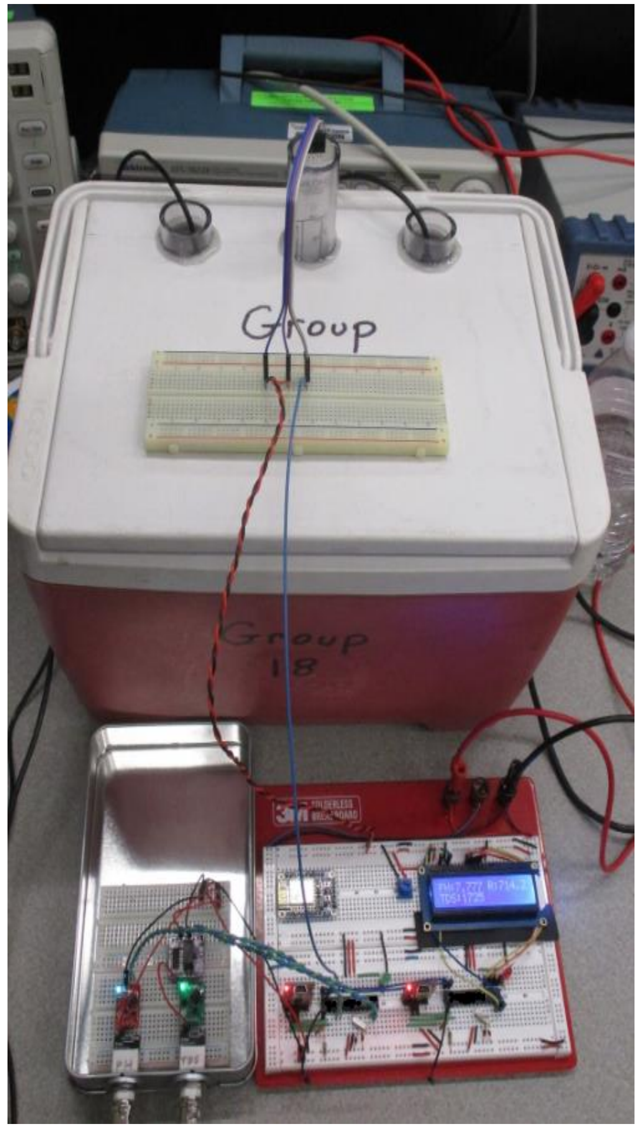


Figure 5-43 A view of the container that houses the pH, EC, and water level

The Wi-Fi module on the breadboard is obviously not connected in these photographs. We tested the Wi-Fi module with a team member's wireless hotspot function on their phone and verified we could connect to the internet with this device. After that, all the Wi-Fi module, mobile phone application, website, and database programming was done at home where we had access to locally host these things, something we could not do in the Senior Design lab without creating a new network.

In the final design of the system, the Wi-Fi module will be attached to he secondary microcontroller along with the LCD, since the information going to both of these devices is virtually the same. The Wi-Fi controller will then upload the sensor data to our website, which will store it in our database. The end-user will then be able to access this data either through our website or our Android application.

Additionally, two components of our system not integrated into the main prototype are the LED light array and light sensor. The light sensor will read that light levels, and if they are above or below our threshold for acceptable light levels, will adjust the LED lights up or down accordingly. We have breadboarded and tested these two components in conjunction with a separate microcontroller, but in the final prototype will be integrated and attached to the main microcontroller that the other sensors are on as well. You can see our sensor attached to a microcontroller under our LED light in Figure 5-44 below.

In summary, we have breadboarded and tested all the components individually, and even integrated most of them into one system except for the Wi-Fi module, light sensor, and LED array. The sensors we have on our two main microcontrollers are displaying their readings on our LCD. Once we finish integrating all the components to the main microcontroller and finish the website/database programming, we will be ready to focus on finalizing and ordering our PCB for the final system.

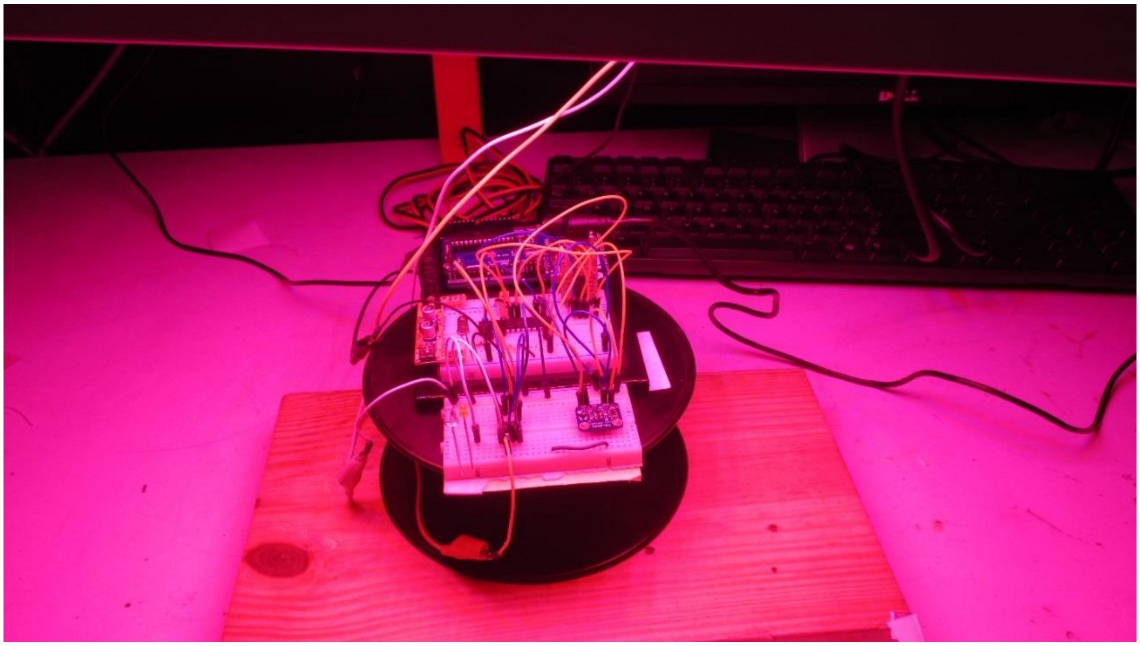


Figure 5-44 Light sensor and LED array testing with a separate microcontroller.

6 Project Prototype Construction and Coding

This chapter will cover the process in which this project was taken from the theoretical process into a working prototype. This was a new experience for most of the group members. It was also the process in which we learned new limitations on the system and the group had to revisit some of the earlier processes.

6.1 Integrated Schematics

In this section of the report the current schematics of the system will be posted with a title of that circuit.

6.1.1 FT232RL Female Pin Connectors Schematic

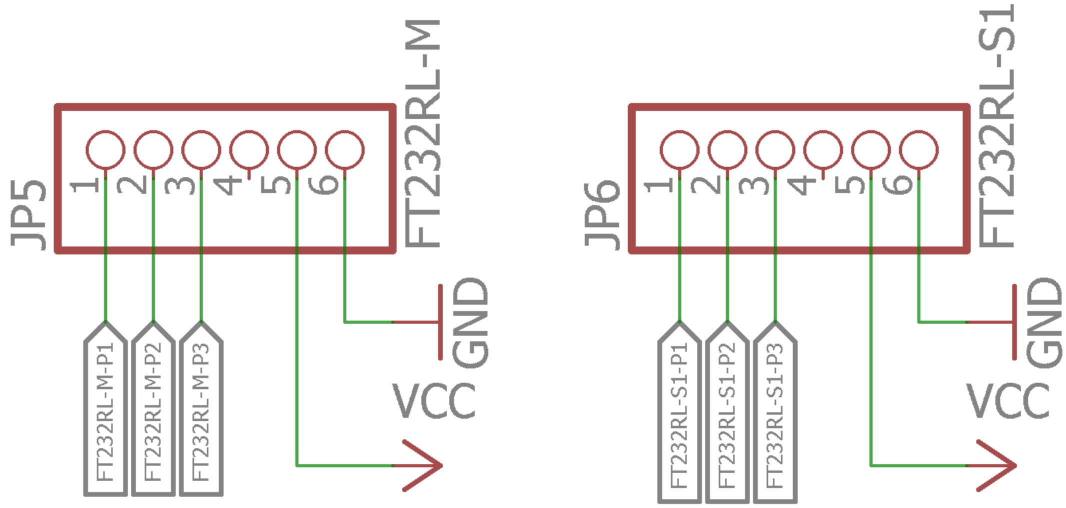


Figure 6-1 Female Pin Connectors Schematic

6.1.2 Sensor JST connector Schematic

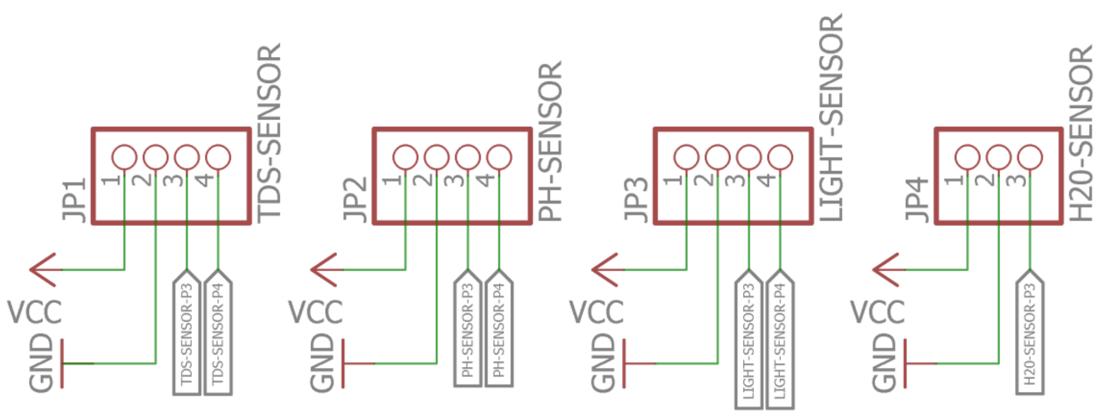


Figure 6-2 Sensor JST connector Schematic

6.1.3 Transistor Switches Schematic

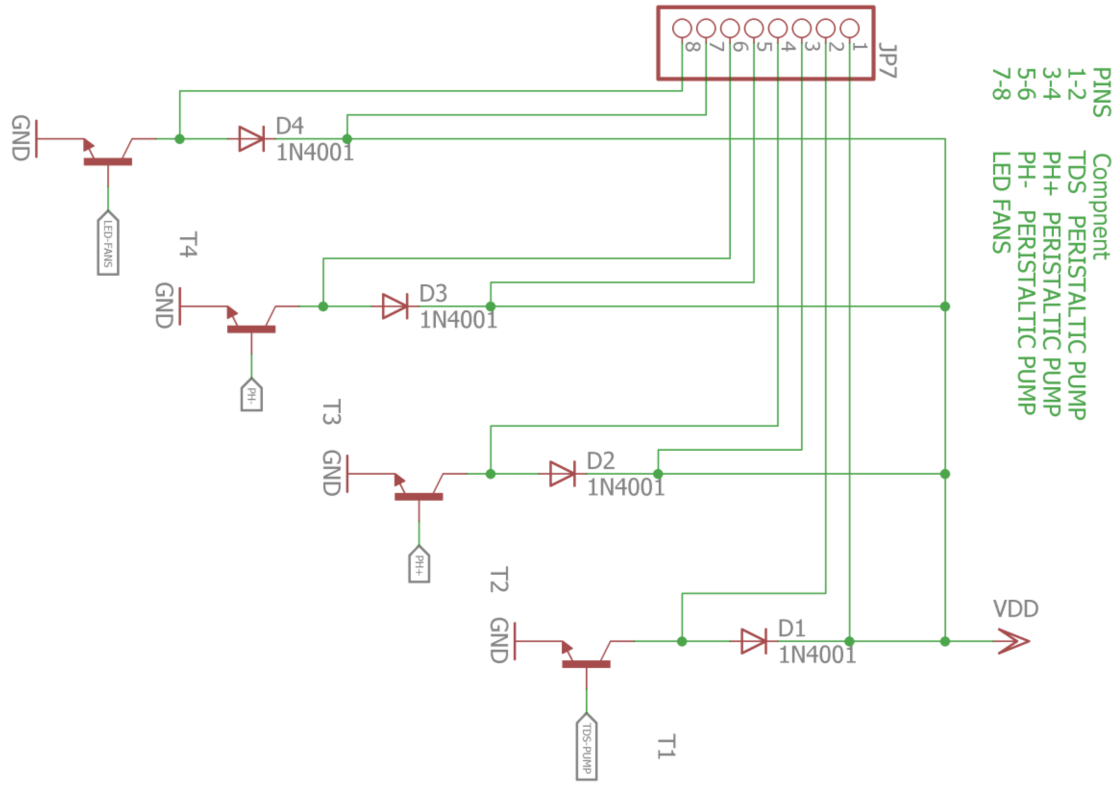


Figure 6-3 Transistor Switches Schematic

6.1.4 Powerport JST Schematic

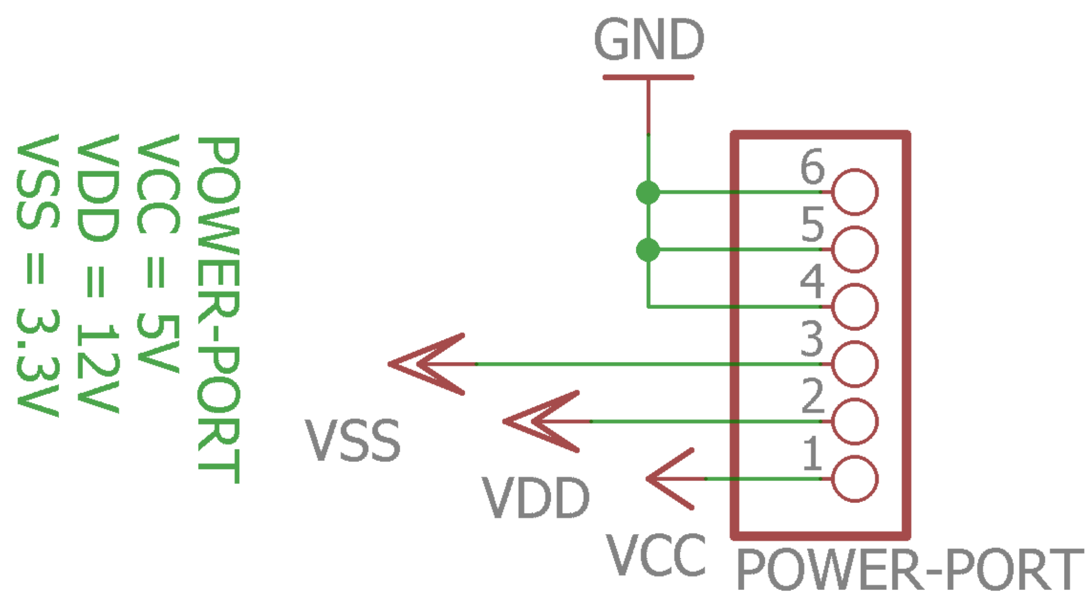


Figure 6-4 Powerport JST Schematic

6.1.5 LCD and JST connector Schematic

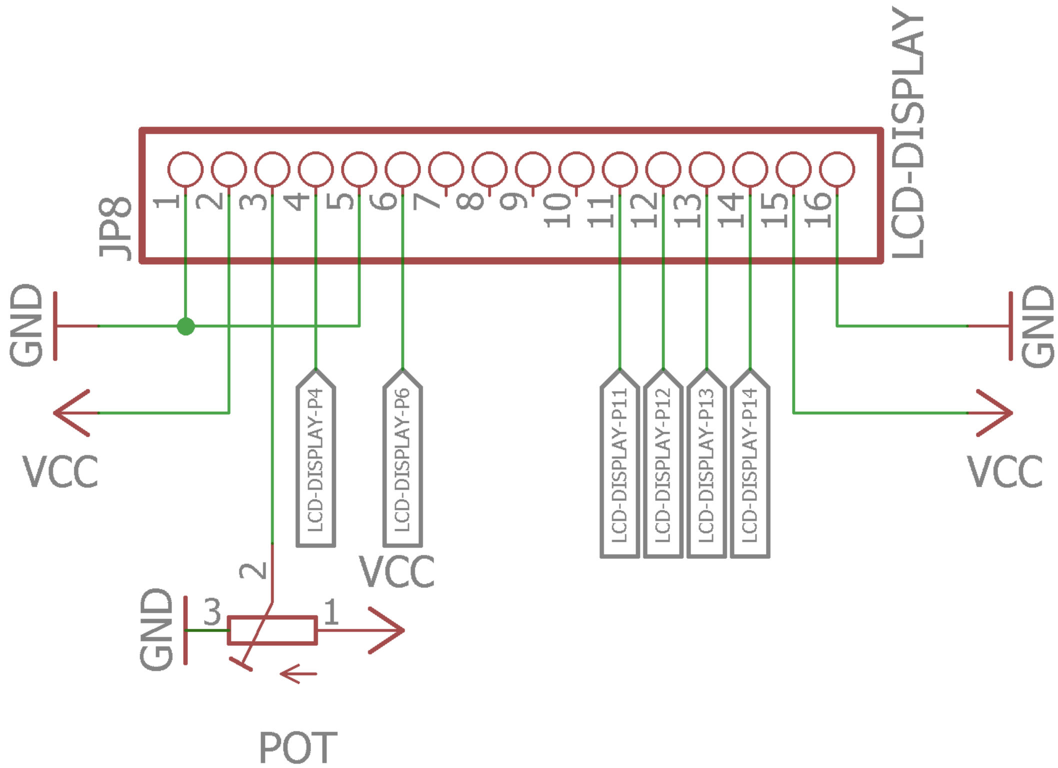


Figure 6-5 LCD and JST connector Schematic

6.1.6 Wi-Fi Schematic

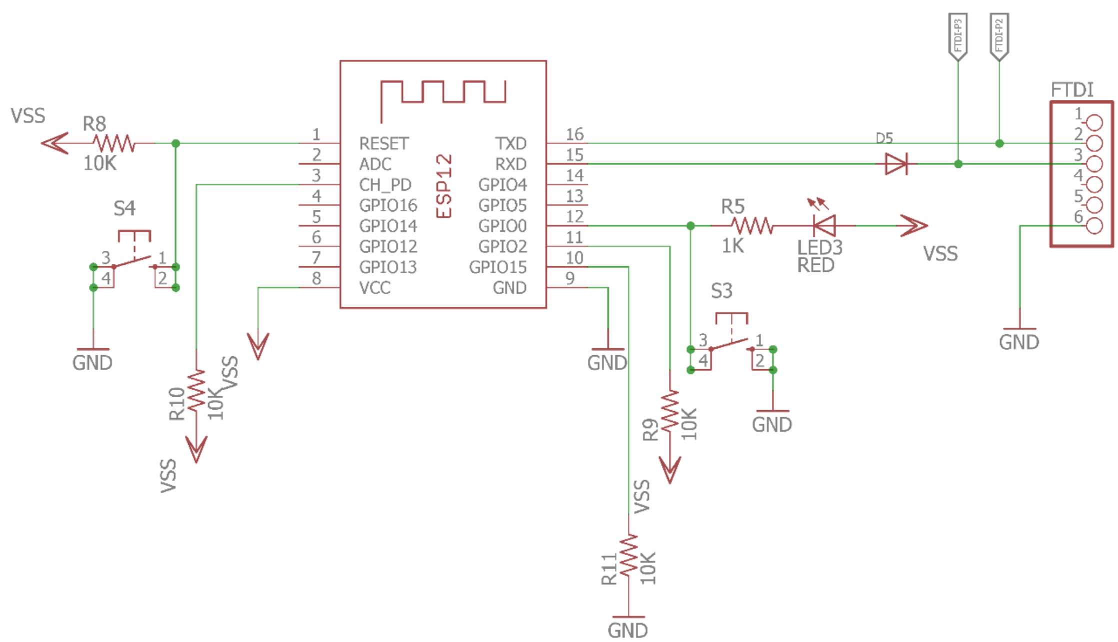


Figure 6-6 Wi-Fi Schematic

6.1.7 Digital Potentiometer Schematic

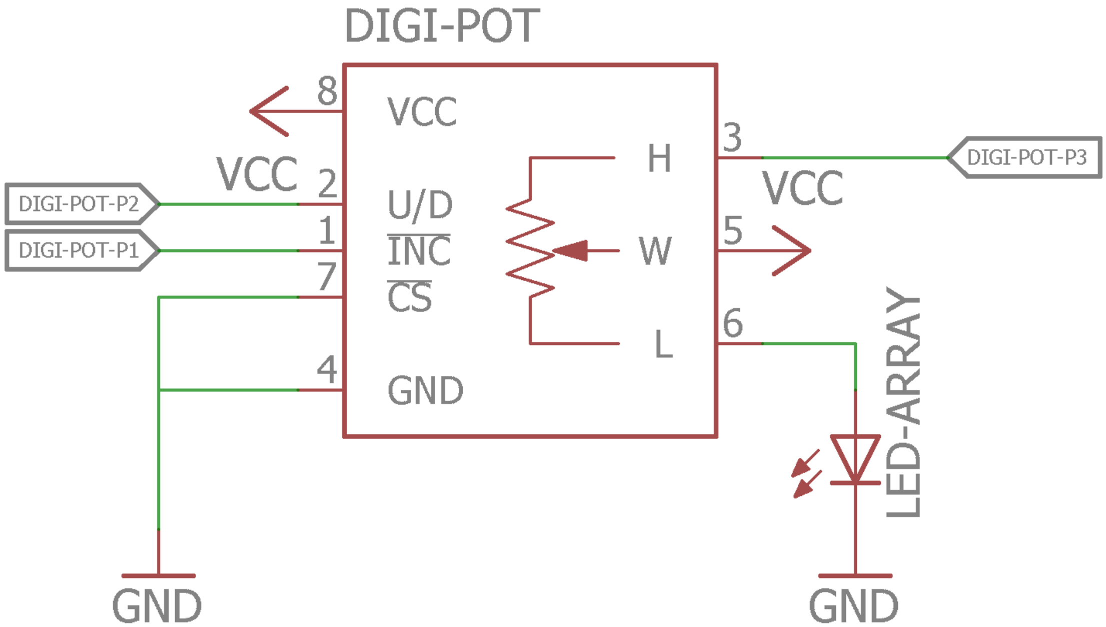


Figure 6-7 Digital Potentiometer Schematic

6.1.8 MCU Schematic

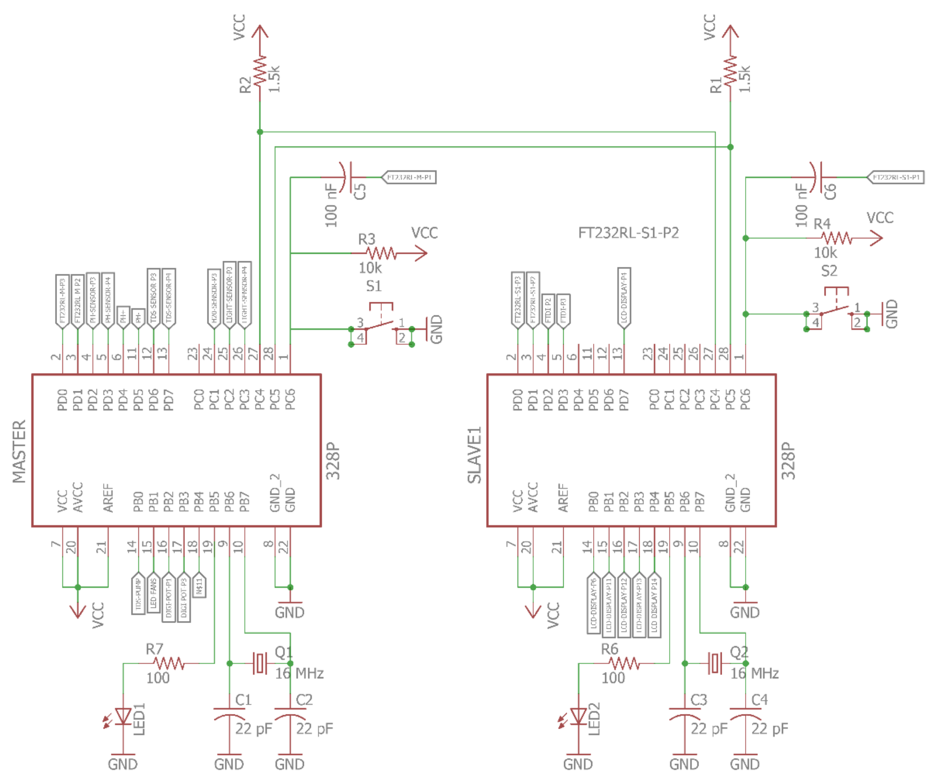


Figure 6-8 MCU Schematic

6.1.9 Total System Schematic

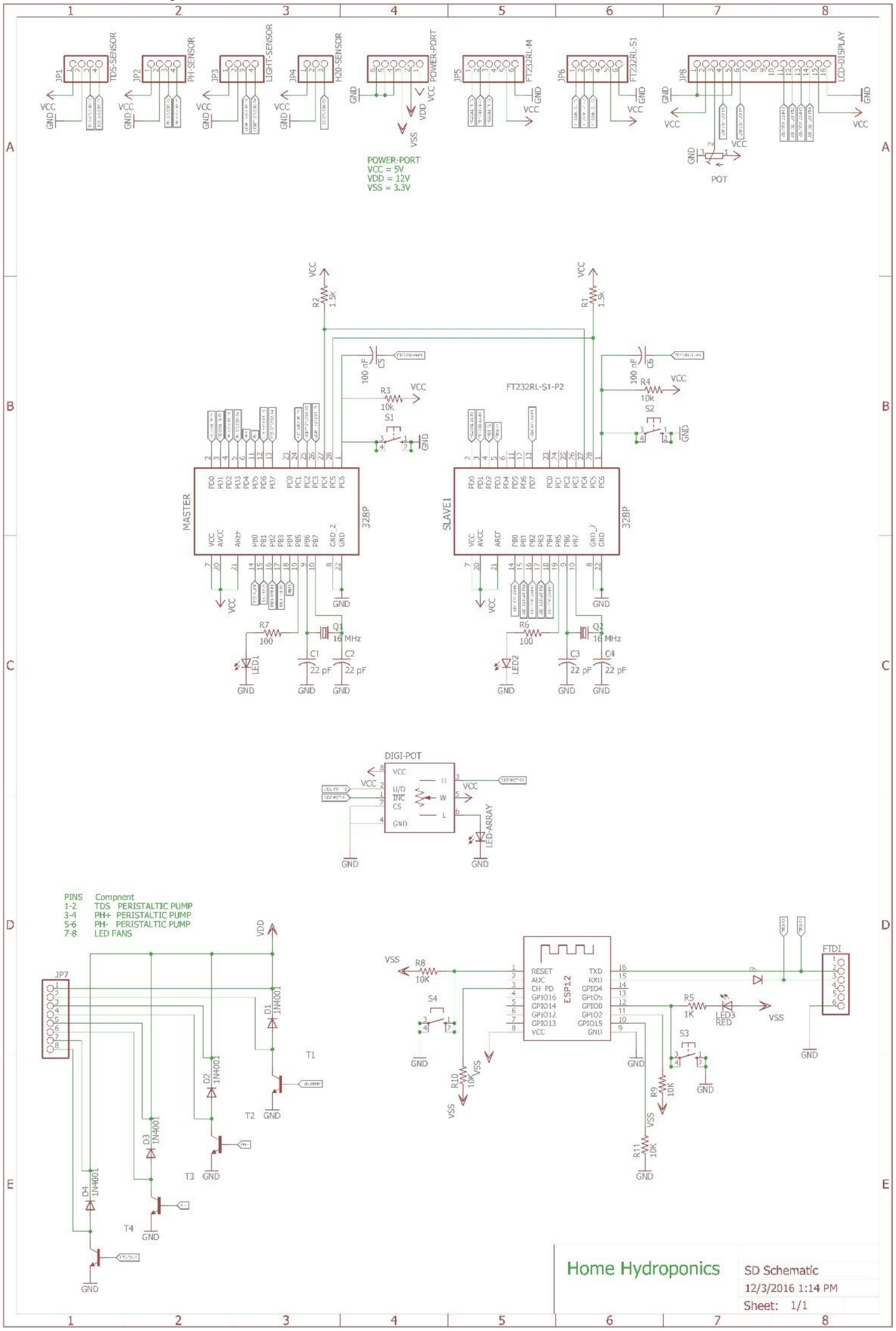


Figure 6-9 Total System Schematic

6.2 PCB Vendor and Assembly

One of the biggest goals of this project is to bring the micro controller and all the sensors and components together on a PCB (printed circuit board). This PCB does away with the tangled mess of wires that are necessary for power and communication between the different devices that make up this hydroponic system. Not only does this help by consolidating all the components into a neat and small package, but helps reduce the risk of shorting out the system when a wire pulls loose. There are many steps in this process and the first is to design a wire schematic of the system. This may be done in several steps, the first being the microcontroller on a standalone circuit with female pin headers so testing and experimentation can be done. After this testing process is done the next step would be to start adding the components which can be added to the PCB, for example the Wi-Fi module and the components which go with it.

There are many things to consider when designing a PCB, how wide should we make the trace lines, how close can the trace lines be to each other, where to place component as to they don't interfere with other components. All these things must be considered before going from the schematic which doesn't care about the placement of components to the actual PCB design where components can be moved, trace lines increased or decreased in size depending on current needs, or how far apart trace lines need to be for high speed communication. Any of these things could cause the PCB to fail and needs to be considered in high detail as to not have to repeat the process several times. Each PCB can take one to two weeks to be delivered so each revision adds more time to completing the job. Because we have a deadline and want to make sure we have plenty of time for revision, we have started this process in senior design one. If we can get a working through hole version of our system well before the deadline, we plan on going the extra step for a surface mount version.

There is many design software on the market for generating Gerber files which the PCB manufacturers use to create your PCB. The one we will be using and most other groups have chosen is Cadsoft EAGLE which is available online in a free version that allows you to make a 2-layer PCB which is all we will need for this project. This software is very popular due to all the help videos that you can find online about how to use it, and its connection with Element 14 and part selection. This software allows the beginning engineer design with relative ease a PCB without the knowledge of AutoCAD which is very expensive.

EAGLE software allows you to move your component to the locations on the PCB which allows the air trace wires to be untangled as much as possible by trying different locations and spinning the component. Once we reduce as much detangling of the air trace wires the next step is to route the wires. Because of the PCB being a 2-layer design, this allows you to use a via, a via allows you to drop a trace line from one side of the PCB to the other and then by another via come back to the top of the board to complete a trace. This allows you to untangle the mess of wires in such a way that two wires do not cross on the PCB. Once all the trace wires have been configured in a way that there are no more air trace wires then the next step is to flood one side of the board with copper which will be used as a ground plate, and all the ground connections will be connected to this copper plate which minimizes the ground trace wires. Not only does this copper fill plate reduce the number of trace wires, but it also helps in electrical disturbances between the separate components.

The last step in the EAGLE software is to produce the Gerber files for the PCB manufacturer. These Gerber files break up your design into separate files. Some of these files include things such as bottom copper, top copper, bottom soldermask, top soldermask, top silkscreen, NC drill files. These files are then generally zipped together into one file and then sent to the PCB manufacturer for review. After their review, they will email back any problems that they man foresee and correction can be made and the new Gerber files zipped and sent again. After all the problems, have been worked out they will then create the PCB.

Our design for this hydroponic system will have multiple PCB designs. The first PCB design will be for the microcontroller and the components and connections it will need to run the rest of the system. This main PCB will also have the communications through Wi-Fi to our online database storing the data that is collected from the various sensors in the system. Through the connections of this PCB we will connect two other PCB systems. The first of these is the power supply from main to 12 volts DC, and its subsystems of voltage regulation from 12V DC to 5V and 3.3V DC. By keeping this on a separate PCB we hope to not melt down our microcontroller unit and if a problem occurs we can replace the power supply with a new one. The second PCB design will be for the sensor connections and modules that go with them. These components list that there be no wire connections between them so by placing them on a separate PCB we will provide the best connection between the various parts.

The main constraint in this project is the deadline, but this must be weighed with price, because a PCB which has a fast turnaround usually comes at a cost. The chart below looks at several PCB manufacturers and lists their costs and requirements. These prices are based on a 10mm by 10mm PCB, two layer, with silkscreen printing on the top of the board. Also, these prices are for the general delivery option, many of these sites offer faster shipping which comes at a much greater cost, usually at twice or three times the actual cost listed in the chart which is located on the next page.

Vendor	Website	Min. Order	Turn Around Time	Cost per Board
Elecrow (China)	http://www.elecrow.com/	5	26 days	$5.10
PCBCART (China)	http://www.pcbcart.com/	5	12 days	$6.04
Dirty PCBs (China)	http://dirtypcbs.com/	8	48 days	$4.88
PCB-Pool (Germany)	http://www.pcb-pool.com/ppuk/index.html	99	16 days	$0.85
Eurocircuits (Belgium)	http://www.eurocircuits.com/	5	9 days	$17.64
Sunstone (USA)	https://www.sunstone.com/	5	10 days	$35.00
Bay Area Circuits (USA)	http://store.bayareacircuits.com/	580	14 days	$0.37
Advanced Circuits (USA)	http://www.4pcb.com/	5	5 days	$33.00

Table 6-1 Vendor List

Our first revision of the system will be though hole design. Through hole is the standard resistors, capacitors and inductors that we used in all our electrical engineering classes. These will be used in our first version because they are easier to solder to the PCB than the smaller and more compact surface mount versions. Solder is used to make the electrical connections between the PCB and the components. Solder often is composed of a mixture of tin and lead with a flux at its core. This flux dissolves oxides to provide a durable connection without the fear of cold solder joints which could cause all kinds of problems in the circuit with noise. If solder with flux is not available, flux can be applied manually to all the connections on the PCB manually and then flux less solder can be used instead.

What the flux does is remove any unwanted impurities that may be found on the board during the manufacturing process, for example oils, wax or even grease from our fingers. Some components are very sensitive to heat from the soldering iron so using low wattages of 25-40 watts on these components is critical. Usually the cheap soldering irons you can get at your local hardware stores run much hotter and can destroy components before you even start, so this is a major concern to be looked at. Also with through hole components you have the option of using a heat sink to dissipate some of this heat through a clip-on device, with surface mount this is not an option, so soldering surface mount devices with a soldering iron is not recommended.

If we are successful with time to spare before our deadline, the last revision will be to implement a surface mount design for a microcontroller PCB. Additional components will be added and a surface mount design will be implemented. Due to the complexity of placing components surface mount style we will be looking for an outside source that can create our PCB and place the components by placing a paste at the desired locations on the PCB which is also generated by EAGLE software in the Gerber files and then baked to create the electrical connections. This would be only after having a complete working version of the system with the through hole design. By going to surface mount the overall size and weight of the PCB will become smaller allowing for an overall smaller and neater design for our peer review.

6.3 Final Coding Plan

This section will cover the overall system interactions of the multiple subsystems. The microcontroller will send data directly to the website, the same is true for the mobile app, and the website will communicate with the user database. Using this structure, the system can ensure that the database will only be interacted with from the website and thus, this will provide an extra layer of protection. The total system data flow charts is as follows;

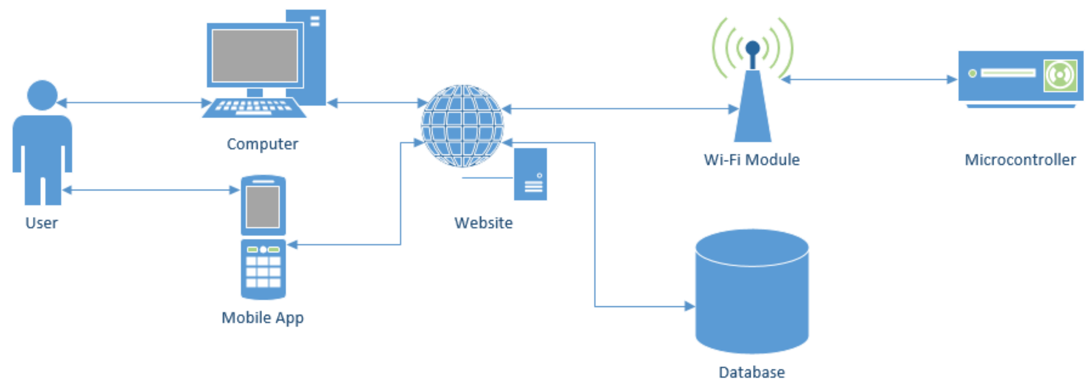


Figure 6-10 Total System Flow Chart

As is visible from the flow chart the user can either interact with the system from computer or the mobile. Using either will have the same results, interacting with the database and the microcontroller. Once the user has set their chosen settings for the system, the website will update the database and send the new information to the microcontroller. From that point the microcontroller will do a series of actions to make the system function properly. Below is the flow chart for the overall micro controller loop;

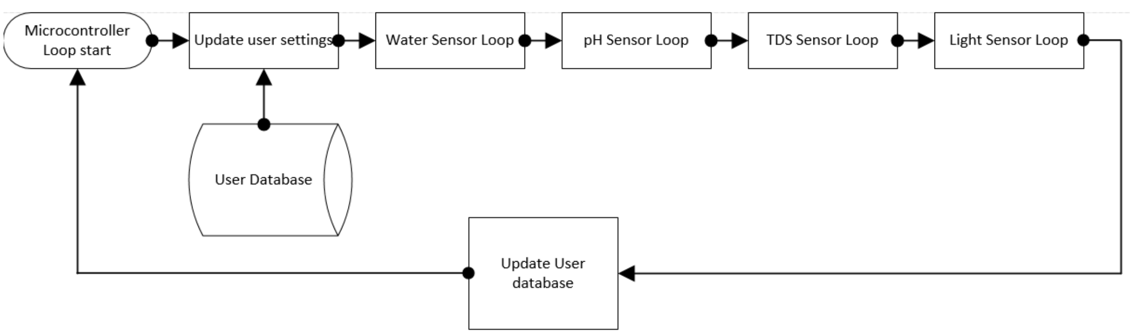


Figure 6-11 Microcontroller Flow Chart

To aid in readability of the microcontroller loop flow chart it was split in smaller flowcharts for each loop. The first action the microcontroller will perform is to check if the user has changed their settings and update any changed values. Then it will enter the water sensor loop. That loops flow chart is as follows;

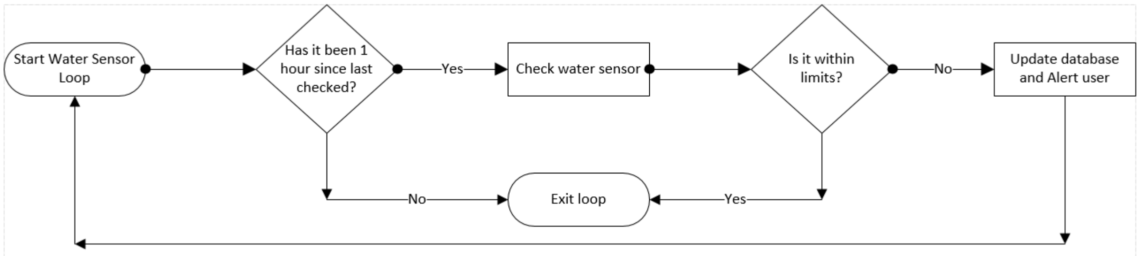


Figure 6-12 Water Sensor Loop Flow Chart

The water loop will first check the last time the water level was checked. If it was within the last hour of last check the microcontroller will exit the loop and move onto the next loop. Otherwise the microcontroller will check the water sensor readings. If the water is low then it will send an alert to the database, with will in turn alert the user. If the water level is fine the loop will be exited. We placed this loop first in the microcontroller loop because it is the most important safety feature for the system. If the water level gets too low the water pump will get damaged and must be replaced. With the planned alert system, this should never be a problem and is one of the safety precautions this group has installed into the project.

The next loop the microcontroller will enter is the pH sensor loop. The microcontroller will again first check the last time the pH was measured. If it was within the last hour of last check the microcontroller will exit the loop and move onto the next loop. Otherwise the microcontroller will check the pH sensor readings. It then checks if the pH of the water in the system is too high or low. These limits will be set by the user from either the website or the mobile application. If the level is not within limit the system will then activate the assigned pump for either the pH+ or pH- solution. The pumps will be activated for a set amount of time to increase, or decrease, the pH level of the tanks. This time frame must be calculated and experimented with during the final testing phase of the project. Once the pump is finished running the system will wait 5 minutes and repeat the loop from the check the sensor spot. This will continue until the pH is within limits. The flow chart is as follows;

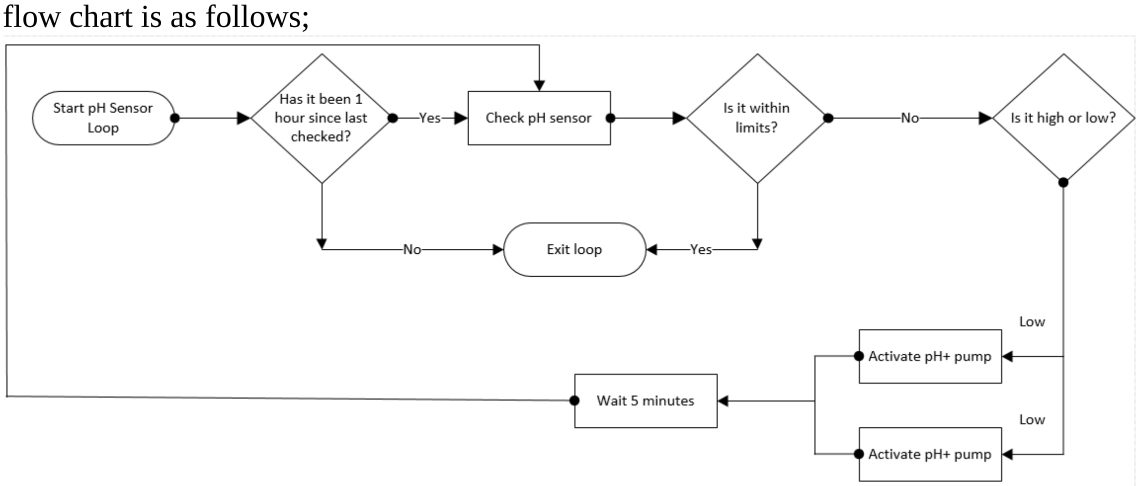


Figure 6-13 pH Sensor Loop Flow chart

Once the pH is correct the loop will be exited and the microcontroller will move onto the next loop. This loop is very important for the health of the plants in this hydroponics system. If the pH levels aren't correct the plants will die, thus making the system useless. Will be checked multiple times a day just to make sure the plants are receiving exacting what they need to survive. The next loop is the TDS subsystem and the flow is as follows;

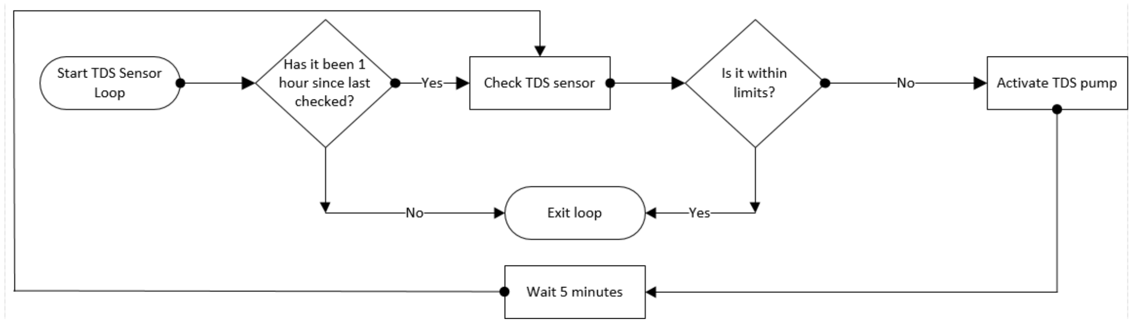


Figure 6-14 TDS Sensor Loop Flow Chart

Once the microcontroller enters this loop it will again check the last time the sensor was read. If it was within the last hour of last check the microcontroller will exit the loop and move onto the next loop. Otherwise the microcontroller will check the TDS sensor readings. If the measurement is within the limits set by the user then the loop will be exited, otherwise a pump assigned to the TDS solution will activate to add nutrients to the system. The loop will then wait 5 minutes and check the TDS levels of the water again. If it is still low the loop will be repeated from the check the sensor point otherwise the loop will be exited. The is just as important as the pH levels of the water for plant health. The group placed this loop after the pH loop because plants can survive longer without proper nutrient level then they can with the wrong pH level.

The last subsystem loop to be enter is the light sensor loop. The flow chart for this loop is as follows;

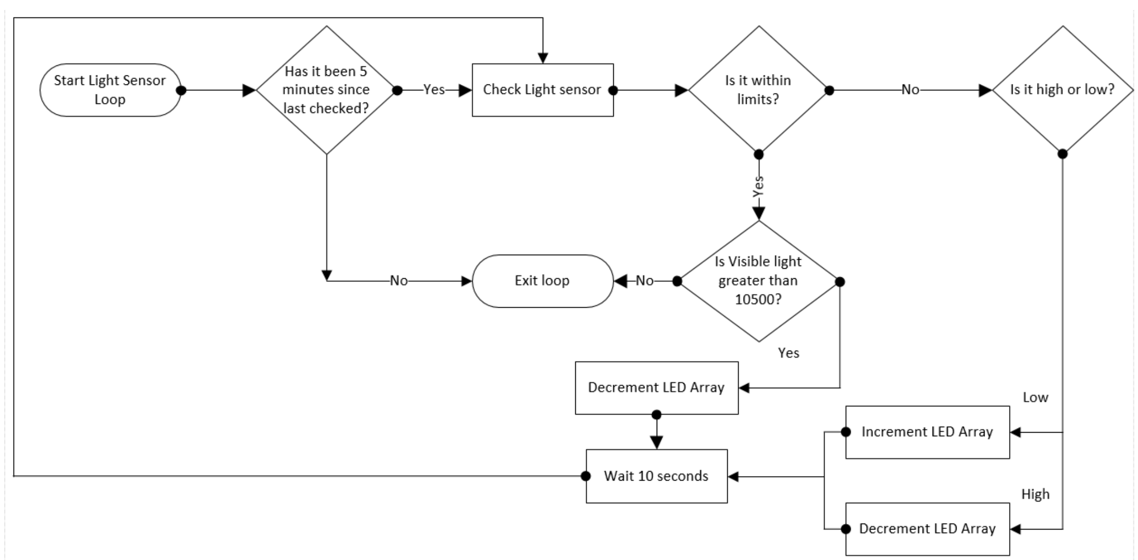


Figure 6-15 Light Sensors Loop Flow Chart

The loop will first check again check the timestamp of the last light sensor measurement. If it was within the last 5 minutes then the loop will be exited, otherwise the microcontroller will continue down the loop. Next the microcontroller will check the current readings of the light sensor. This were this loop is different from the other loops, if it is within limits of the lux spectrum if will check the visible light spectrum. This is done to check how much sunlight the system is currently getting, if the visible light spectrum is greater the 10,500 nm (nanometers) then we know that it is getting direct sunlight. This measurement was found from testing the LED array at its highest setting without sunlight but with normal room lighting, and then again at its highest setting with sunlight. The highest visible light the LED array created without sunlight was 10,472 nm. Anything greater is known to be from an external light source, and sense this system is design to not require an external light source, it will be believed that extra light is from the sun.

To aid in saving power cost and consumption, a group requirement for this system, if the visible light if greater than 10,500 nm then the LED array will be dimmed one increment of the LED array setting. The loop will then wait 10 seconds and repeat from the check light sensor position.

If the sensor measurement isn't within user defined limits, then the microcontroller will check to see if the measurement was too high or low. If too high then the LED array will be decremented by one level of the LED array's setting, otherwise if it was too low the LED array will be incremented by one level of the LED array's setting. The loop will then repeat from the check light sensor position. This loop will be, by far, the most ran loop on the microcontroller but it is also the greatest feature of this system. By checking the amount of light the system is getting this program can save on energy cost and consumption, while still ensuring healthy plant growth.

The light sensor loop is the last part of the microcontroller loop and once complete the system will then update the database, through the website, with the new timestamps and measurements of the system.

The next part of the system that will be discussed is the database system. The database is very simple, by using foreign and primary keys it can have data verification within third party programs. Below if the relation table for the current database;

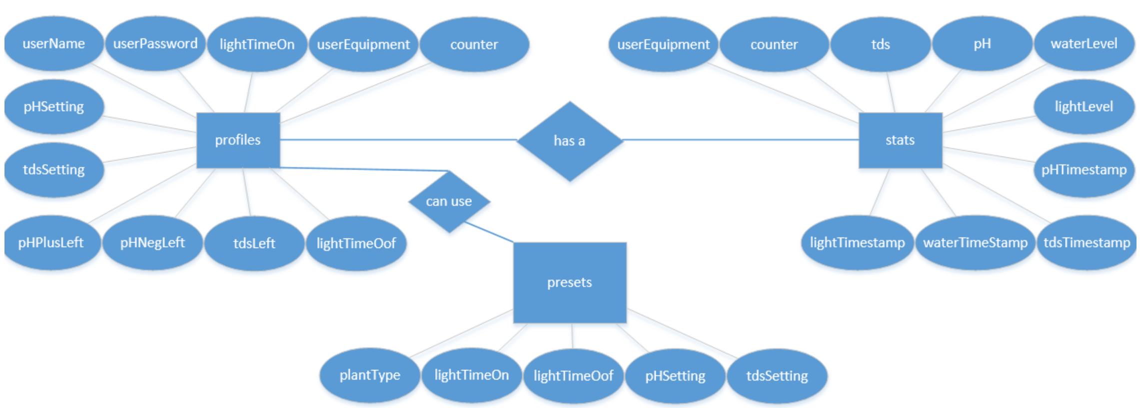


Figure 6-16 Database Relation Chart

As can be seen from the figure above the database is simple, it only currently has three tables. Each user profiles will have multiple stats tables that will each hold the sensor data received from the MCU. The counter attribute in the user's table will keep track of that users current stat table location and the counter in the stat table will be indexed so that past sensor data can be stored. The counter attribute in stored as an integer value so that a total of 4,294,967,293 stat tables that will store sensor data for each profile. The group feels that will be enough for the currently plan system.

The next topic in this section will be the website's base design. As mentioned before this website will be simple in design to aid in the ease of flow for the user. It was important to the group's website designer to make to functional for the user without making it overly complicated. To add to this design, protecting the database was the utmost importance. The database is what makes this system work with both the app, website and the actual hydroponic system. Without a working database, none of these systems will work together or even store the required data.

The first stage in the website design was to layout the flow the user will go through to use the system, below is the flow this group decided on;

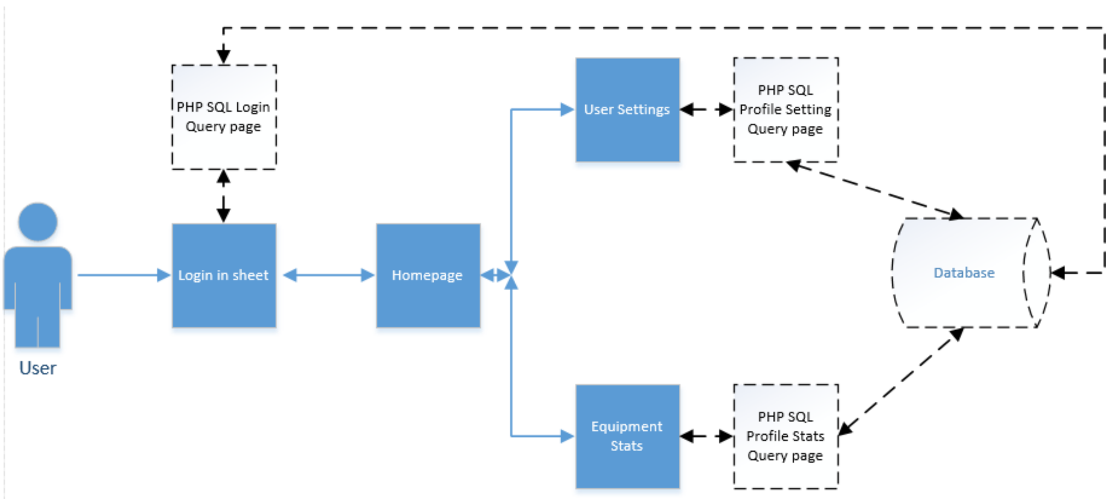


Figure 6-17 Website User Flow Diagram

To help explain the above figure;

- The solid blue boxes are the pages the user will see
- The dotted black line boxes are the PHP pages that will access the database directly and work in the back ground without the user's knowledge
- The dotted black lines are the data paths that connect to the database
- The solid blue line are the changes in the screens depending what the user choses to follow.

The user will first be greeted with a login in screen that will prompt the user to either, input their user name and password or, register a new equipment and create a new account. Once the user has entered the required information, the login page will load a PHP page. This page will contain several SQL queries for the database, these queries will return a true value if the information was accepted. Otherwise it will return a false value if;

- The password and username don't match
- The equipment ID is already in use
- The user name and password doesn't meet the required values

If the database returned a false value, the user will be prompted again to input their information. Otherwise the website will load the next page which is their home page. From the home page the user will have access to some general information about their Home Hydroponic System. As well as have two options, either accessing their profile settings or to view their equipment stats that have been stored onto the database. The user profile settings will include options to change the range values for;

- The hours of sunlight the system needs to measure
- The high and low pH range
- The high and low TDS range
- The water sensor empty range

Once the user has make any changes they wish to make on this page, they can follow a link back to their profile home page. Now if they wish they can access the equipment statistics page. This page will display a range of data on the system. The user will be prompted to select the time range and the statistic that they wish to view. They will have access to the past;

- TDS Sensor readings
- pH Sensor readings
- Light Sensor readings
- Changes made to the TDS levels of the system
- Changes made to the pH levels of the system
- Changes made to the LED array
- Amount of TDS solution that is remaining
- Amount of pH solution that is remaining
- Last recorded level of the water.

These statistics have been saved in the database along with the timestamps of the sensor readings. The TDS and pH solutions will be tracked by knowing the amount the system has added to the water tank. This will be a measurement that the group will experiment with once the prototype system is complete and testing can be performed on it as a complete system. One of the goals of the group to make the lay out of the system easy for the casual user run without need a lot of instruction. To do this the website will try to use graphs as vision aid, along with the raw data collected. It is also important for the data to be laid out in a manner that is easy for the user to read, so it will be required to the data to be parsed and organized to match cultural reading habits. This page will be the main access to the database for the user to obtain the equipment sensor readings.

Both the user settings page and the equipment stats page have a PHP query page that will retrieve or send this data to the database. This is another fail safe for the website to prevent the user from directly manipulating the database. By having these PHP pages in the background without user knowledge it will ensure any data entered will match all required datatypes and avoid any extra data from being available to the wrong user.

The last topic in this section will be the mobile app for the Home Hydroponic System. The will follow the same layout as the mobile app;

1. User opens application.
2. User enters login data or registers new account.
3. The mobile app will access the database to check if data is valid.
4. If the information was correct then move to option 5, otherwise return to option 2.
5. The User now view the home screen which will display general system statistics.
6. The User can follow a link to view specific system information.
7. The app will access the database to retrieve more information on the system based off the options the user selected.
8. The User is also able to access a page to change their use profile setting for the system.
9. The app will access the database to update the profile settings.
10. When the user is finished using the app they can just close.

The mobile app is just another way for the system to be user friendly and give them more access to the system data. The most important feature that the app will provide that the website won't, is the alert for low water in the tank. It is very important for the system users to have information for the water level since if the water level is too low the water supply pump can be damaged and will need replacement.

As can be seen from this section the Home Hydroponics System software will be robust and will offer users many different options to interact with the system. It is this groups hope that the software for this system be as easy to use and useful to user as possible.

7 Project Prototype Testing Plan

This chapter will cover the test plans this group has created to test the current prototype as best as possible. Since this project's prototype isn't completely completed there will many more test cases as the project continues. The tests cases will also increase in difficulty as the system continues to be built since the completed prototype will have to handle more real world situations.

7.1 Hardware Test Environment

U.C.F. has two locations for testing electrical components located at the Central Florida location. These locations include the senior design lab on the fourth floor of engineering one, and on the first floor between engineering one and two at the Texas Instruments Innovation lab. While the Texas Instruments lab had normal business hours, the senior deign lab is open 24/7, giving students flexible hours and time to work on and debug their projects. Both locations offer help either in the form of a T.A. or lab assistant to help you resolve any problem which you may encounter. The senior design lab is run by David Douglas which is located just down the hall from the lab. He assists by loaning out the cords and tools needed for testing. He also has an array of common resistors, capacitors, inductors that may be needed if we get stuck not having the right value component.

Both labs have the equipment to test our projects and include triple output power supplies, multi-meters, oscilloscope, and function generators. By having these power supplies on hand, testing of the subsystem components can begin while the development of our system power supplies is being created. Security in the senior design lab is at an upmost importance and that is why the room is recorded by several camera's and access to the room is by passkey only. In this way people that are not aware of the severity of touching someone else's project is not allowed in the room. With all this security and lockers to store our supplies located close to the hardware test benches, one can feel safe that their projects are safe and will not be messed with while attending a lecture in another class.

7.2 Hardware Specific Testing

The following section describe a summary of the test plan to be completed on the individual components and subsystems. These tests will be made to make sure the purchased components will meet the desired requirements or constraints as planned for this project. This section must be updated as the project continues the development process since unforeseen troubles and changes will arise.

7.2.1 Logic Level Shifting Testing

Our system uses a logic level shifter to change the 5V logic level of the microcontroller to 3.3V logic level of our Wi-Fi component. The testing of this unit will be done on the test bench with a function generator, generating a 5Vpp square wave and a DC offset of 2.5 volts. This will create a square wave with a 5V high and a 0V low logic level for testing. This signal will simulate the conditions found on the microcontroller in binary logic serial communications. This signal will be monitored by the input signal on the oscilloscope and the output of the logic level shifter will be connected to oscilloscope to see the two signals side by side and checked for accuracy and noise problems. The output signal should follow the input signal closely without much ramping to be a successful test.

7.2.2 Light Sensor Testing

The light sensor will be tested alongside a hand held light sensor used in hydroponic systems. The reading will be checked against this know accurate hand held device to see if the reading is accurate. The light sensor needed to be calibrated for bright light conditions, because when we tested it the first time it read reading way off the chart. It was found that a variable had to be set to read these extremely bright conditions that were being produced by the LED array.

7.2.3 Ph Sensor Testing

Testing of the pH sensor includes checking and calibrating the sensor with the three pH solutions that came with the sensor. The first solution checks the calibration of the sensor to the base side of the pH scale; a second solution checks the calibration of the acid side of the pH scale and the last checks the middle of the pH scale. These measurements from the sensor are relayed to the serial terminal on our computer where they can be visually seen in a value to the hundreds place. At which time the value on the serial monitor does not match that of the solution a command is sent to the sensor module to reset either the high, low or mid-range pH. This will set the sensor to the correct pH level ensuring proper readings of the hydroponic solution. The pH sensor will need to be calibrated at least once a year for accurate and consistent readings.

7.2.4 Nutrient Sensor Testing

The nutrient sensor well be tested in a similar way that the pH sensor was tested. It came with two known total dissolved solids solutions that could be used to check the sensors accuracy, once these solutions are tested with the sensor, a reset can be sent the module to dial in the results to that of the testing solution.

7.2.5 Solution Level Testing

Our solution level or water level testing will be conducted by filling the nutrient tank to the proper level. Then by taking away water from the system and adding more water to the system the water level will be tested by comparing actual hand measured differences in the water level to those reading calculated by our water level sensor. This sensor has the ability to read how many inches above or below the norm that exists in the tank. This information is fed to the UART for readout on the computer.

7.2.6 LED Lighting Testing

Our LED array will be tested to see if we can turn the lights on and off by the code in the microcontroller. We will also see if this lighting system works in conjunction with our light sensor. When more light is added from an outside source, our digital potentiometer will dim the LED lights or turn them off completely if there is enough natural lighting for the plants to healthy. When the natural lighting goes away the LED array will go to 100%. This testing will be in conjunction with the light sensor and the digital potentiometer that we're substituting for the manual one that comes with the LED array.

7.2.7 Peristatic Pumps

Our pumps will be tested once the pH and TDS sensor have been fully tested and deemed to be in working condition. To test the peristatic pumps, the microcontroller will send a signal to a bank of relays that will turn on the desired pump for a set period. Once this time has expired the system will wait for the added solutions to completely mix in the hydroponic reservoir. At this time, the sensors will take another reading and decide if another dose is necessary

7.2.8 Power System Testing

Our power systems will need to be tested for consistent voltages without any excess noise or ripple. These tests can be performed with a volt meter for rough measurements. Once these measurements are close to the desired values, and second test with the oscilloscope will check to see if the ripple current is small enough for the component needs. Ripple is the small plus or minus values of the DC voltage that are not desirable in microelectronics. The next step will be to check these voltages again once the system is under full load.

7.3 Software Test Environment

The complexity of an automated system is often underestimated. For something that might seem simple, like an automated hydroponics system, there is much that could be overlooked. Not only must the hardware be configured correctly, but the software running it must be designed and implemented well. This is the case with our system as well. Configuring all our complex sensors together is something that is vital and can take time.

All testing has taken place in, and will continue to take place in the Senior Design Lab on the fourth floor of the Electronics I building, room 456. It restricts access to those taking part in Senior Design and offers testing equipment as well as a peaceful place to experiment, test, and implement. It also provides lockers to keep your belongings locked up while you are not there so that there is no interference from other people, should you elect to leave your project there.

The two pieces of hardware that control all the sensors and other hardware are the Wi-Fi module and the Microcontroller. Both devices are programmed with the Arduino software. This makes development and testing with these devices simple and familiar. When testing software and different hardware we can print things over serial to the computer so that the serial connection acts like a console window found in most IDEs. This allows for quick and efficient bug solving and troubleshooting.

Arduino handles many of the issues you can run into when working with microcontrollers or any other types of hardware. It is a strongly community driven platform and allows users to benefit from the hard work other community members have put in so that you needn't waste time on writing common libraries or finding examples. Arduino has a huge built-in library of sample code and examples but also allows users to create, share, search, and download custom libraries through their software. In a similar vein, it installs drivers for common microcontrollers automatically and again lets users search and download ones that might be a bit more obscure.

All testing that has been done has been conducted using the previously stated method of printing messages and outputs to the serial connection that acts like a console so that we can see on our computer screen any hiccups or red flags that arise in the code. As our project advances we can display the messages to our LCD screen once it has been connected properly to our breadboarded project.

Our system is not going to be doing any complex computations, the only thing to really test to get right is the communication between all the components. The biggest variable in our code will be learning how long to activate the pumps when adjusting pH or EC in the system. Other than those two things, the only parts that need extensive testing and evaluation is the communication of all the different subsystems. For example, we need to make sure the values form the sensors make it through the microcontroller, Wi-Fi module, website, into the database, and then again to the mobile application or user website. This is very binary, as in it either works or doesn't. There isn't much algorithmically or programmatically to adjust from prototype to production level.

7.4 Software Specific Testing

7.4.1 Database

7.4.1.1 Installation

The source code should be placed in the main folder of a web server that is running PHP and preferably be configured with a compatible database such as SQL (ours were configured with XAMPP localhost instances). The database should have a localhost account with account name “root” and password “”. This was configured for the sake of simplicity and would be modified to use a configuration file before being deployed for real-world use. A database should be created with the name "HydroponicsDatabase". From there, the populated script file contents (HydroponicsDatabase.sql file) should be copied and ran through the myAdmin SQL option to create the tables within the database.

7.4.1.2 Testing Procedure

To test the database, the group had to simulate all data input because at this time the hardware was not completely merged with website, app and database. The test produces the used will follow this paragraph in the form of test cases;

Test case 1 plan – Adding name user information

- Test Objective: To add new user information to the database
- Test Description: A SQL query will be written to add the user's information
- Test Condition: This test will be done from the myAdmin function of the database since currently the website and app aren't connected.
- Expect Results: The user's information will be added to the profiles table in the database.

Test case 2 plan – Trying to add Identical Equipment ID to the database

- Test Objective: To try and add an Equipment ID that already exist in the database
- Test Description: A SQL query will be written to add a user's information that has an equipment ID that has already been used.
- Test Condition: This test will be done from the myAdmin function of the database since currently the website and app aren't connected.
- Expect Results: The database will deny the request and the information won't be added to the database.

Test case 3 plan – Update user settings for Ph Level

- Test Objective: A user will try and update their pH setting limits
- Test Description: A SQL query will be written to update a user's profile that will change the original pH settings.
- Test Condition: This test will be done from the myAdmin function of the database since currently the website and app aren't connected.
- Expect Results: The new pH setting will be added to that person's profile.

Test case 4 plan – Update user settings for TDS Level

- Test Objective: A user will try and update their TDS setting limits.
- Test Description: A SQL query will be written to update a user's profile that will change the original TDS settings.
- Test Condition: This test will be done from the myAdmin function of the database since currently the website and app aren't connected.
- Expect Results: The new TDS setting will be added to that person's profile.

Test case 5 plan – Receiving "Sensor" data

- Test Objective: The database will be fed sensor data.
- Test Description: A SQL query will be written to update a user's profile that will change the original sensor data. Since the hardware hasn't been merged with the software yet to test this the group will be fed a query directly to simulate sensor data coming from the MCU.
- Test Condition: This test will be done from the myAdmin function of the database since currently the website and app aren't connected.
- Expect Results: The data will be added to the database.

Test case 6 plan – User tries to access sensor data

- Test Objective: A user all try and view the current sensor data
- Test Description: A SQL query will be written retrieve sensor data stored in the database.
- Test Condition: This test will be done from the myAdmin function of the database since currently the website and app aren't connected.
- Expect Results: The user will be able access the data that they wish to view.

7.4.1.3 Results

Test case 1 results – Adding name user information

- Test Results: The user "Test User", equipment ID "01" and password "password" was input in the query and the SQL was accessed. The user name was then added to the database.
- Ran by: Joshua Casserino on 11/25/2016

Test case 2 plan – Trying to add Identical Equipment ID to the database

- Test Results: The user "Test User", equipment ID "01" and password "password" was input in the query and the SQL was accessed. The user name was then blocked from being added to the database.
- Ran by: Joshua Casserino on 11/25/2016

Test case 3 plan – Update user settings for Ph Level

- Test Results: The user data pH "6.0" was put into the query and the SQL was accessed. Under that user's profile the pH setting was changed.
- Ran by: Joshua Casserino on 11/25/2016

Test case 4 plan – Update user settings for TDS Level

- Test Results: The user data TDS "99" was put into the query and the SQL was accessed. Under that user's profile the TDS setting was changed.
- Ran by: Joshua Casserino on 11/25/2016

Test case 5 plan – Receiving "Sensor" data

- Test Results: A query was written to act as sensor data from the MCU. The data was set was;

  TDS = 50

  pH = 8.0

  Waterlevel = 0

  Light = 30000

  Once the query was running the database was accessed to check if the database was updated with new data. The user profile was updated correctly.

- Ran by: Joshua Casserino on 11/25/2016

Test case 6 plan – User tries to access sensor data

- Test Results: A query was written to pull the sensor data from that user's profile. Once the query was submitted the command prompt return the current data in the user's profile.
- Ran by: Joshua Casserino on 11/25/2016

7.4.1.4 Observations of Testing

During testing the database performed well. The response time for queries, while not formally recorded and averaged, was deemed satisfactory for the scope of the application. Real-world performance would be difficult to estimate due to the development team's use of local databases rather than a deployed production database and lack of experience with such systems. Despite this, the team is confident the database was designed efficiently and would be satisfactory for a deployed application. The project makes use of one index, one on plant name in the setting table, which was used to order the data and treat it as a foreign key without designating it as a primary key. Due to the minimal nature on the schema the development does not have many recommendations for indexes because most data can be ordered by primary key. One possible beneficial index would be on counter name since presenting the numerical data would be a huge aid if there was more data and performance improvements would be good for the UI.

There were several additional features that would be desirable expansions to this project. The most obvious aspect of the site's design that could be improved upon is security. Certain assumptions were made for simplifying the scope of the project such as assuming certain pieces of input would be correct, assuming no malicious intent, and assuming the database contents would not be compromised. In expectation of deployment and real world use the application's security would need to be strengthened, such as sanitizing all input before being passed to queries and ensuring all pages and functions are limited to users with required access. Weather media integration was also not fully configured for the application as well as the ability to pull events from an RSS feed.

The development of this application was not without problems, the most serious of these being the result of serious issues with source control. During a crucial merge of very large components the branches refused to commit and the merge could not be accomplished. This meant a large portion of the code written could not be added to the application. To continue working the team accepted the copy with the largest changes made as the newest version and rewrote the missing UI components and features on top of it. The time constraint for the project also made it challenging. This difficulty was further compounded by the variety of technologies the team needed to become competent with in such a short time.

8 Administrative Content

The administrative aspect of this project will be covered in this section of the document. This project has shown the group members how much more to designing and researching a project then was previously plan. The amount of documentation required for a project of this size is shocking to say the least. The project manager write about the difficulties of handling a group of this size. The documentation manager will write about the troubles of dealing with the various problems of organizing and compiling different documents required for a project of this size.

8.1 Project Management

Group 18 has chosen to assign Ernest Inman as the Project manager for this senior design project. This section will be written from his perspective on the Project management process.

As ideas were discussed of what the group wanted to do for the final senior design project it was clear that to get this completed with the least amount of stress as possible someone needed to lead and direct this project. Once the group decided the idea then they elected me to lead the group. The first thought was I knew we had four good people for the group that this should not be too bad to lead. The people seemed good and the idea did not seem too difficult in the initial stage of the idea. The idea of project manager seems like an easy thing until reality of managing people, component selection and making final decisions sets in.

A huge learning part of this class was in managing people that all have different personalities, vision of what the project should be and schedules. As a leader one must be able to evaluate a situation and can decide for what is best for the group without getting to emotional about upsetting the other group members. The overall vision is to create a hydroponic controller that allows a person to grow their own vegetables with the least amount of effort. Knowing what the product needed to be is what all the executive decisions to manage this group. There were times where it was very challenging to deal with strong personalities; however, keeping the goal in mind allowed me not to be overly concerned with making the decisions. During this process, I learned how to manage and lead different types of people as everyone is motivated by something different.

Once the initial idea was agreed upon the group started discussing the components that were going to be needed to end up with a valid design. During the process of deciding the best components that were to be used proved to be more challenging than initially thought. Each major component had a lot of variability and needed to be carefully thought about before implementing them. It was quickly realized of how important it was going to be to make the proper decision on all the needed components. If the project does not work, then we all do not graduate so there was a lot of pressure for this part of the project management.

In the end this class project will decide if we graduate on time and to create a great learning experience for the new careers to be embarked upon. There were times where an agreement could not be reached and the overall final decision needed to be made. As these decisions were made the utmost importance was kept on what the end project needed to be. This was the most challenging areas of project management. In the group, there were times were a consensus was not met and the executive decision was made.

As the components came in the group started testing all of them to make sure it was really going to work for the application. With all the research and careful selection most of the components performed as expected. The group did a good job at making sure the correct components were ordered.

This ended up being a great experience. After all the testing and prototyping was completed the vision was coming to fruition. The group worked together very together well during testing and prototyping process. If things did not work properly everyone got involved during the troubleshooting to arrive at a working component.

8.2 Documentation Management

Group 18 has chosen to assign Joshua Casserino as the documentation manager for this senior design project. This section will be written from his perspective on the documentation process.

The documents required for this project at first, appeared easy and could be quickly done, but this was completely the wrong perspective to have. This was the first time I had to document such a large project from step one. Having served in the military for over 9 years and being in a supervisor role for half of those years, I had seen my fair share of paperwork. This projects report was paperwork on a whole new level.

In the beginning of the semester of Senior Design 1, we (Group 18) started strong and tried our best to tackle all the issues early on. This gave us a head start, but it wasn't in documentation. We started with the design process, then moved onto component selection process, and then ordering. Since day one, we were great about sharing documents and recording our meeting but these documents didn't translate into the final document as well as we hoped for. While the component selection process was a great aid in writing this paper, the other documents weren't. Not knowing that, we had a false sense of security. When the rough draft layout was explained to us, we finally realized that we had to start writing immediately.

The group split up the different sections of the paper and decided to have me combine them as we went along. As of writing this, it worked out well but it takes such a larger amount of time to combine then previous planned. I know, how many times will I underestimate the volume of work this is. The report writing process has, for me, been the hardest part of this semester.

Let me explain the process of writing this group has decided on to write the report. As I said we each split the sections up among the group members, trying our best to split the page count evenly. At first this worked out well, but as the semester went on we started to understand that the page count will not be evenly distributed as some each member has an area of expertise. A group member writing outside this area of expertise proved difficult and that required other student to help, or even take over that sections writing. Once most of the paper was written I started to combined and format the sections together. To do this I had to learn the proper writing style for IEEE papers, which in itself was a challenge as most IEEE documents are written in the same manner that this class required. So, I have to do a lot of research on the web to find example of report like this, which of course turned out to be other senior design papers. Even using them as a reference was troublesome because every group had its own opinion on how the paper should be written. In the end, I spoke with our professor Dr. Lei Wei to get a better understanding. This helped me greatly and without that help I couldn't have formatted this report properly. The formatting process of the report was slow at the start but toward the end I could quickly add and format the different pieces quickly.

8.3 Milestone Discussion

The section will cover the group milestones for class, hardware and software aspects. Because of the live nature of this document these milestones will change to reflect the current plan. As of now this group has stayed within the planned time limits for all sections. New milestones are going to have to be added to the hardware and software sections as the project continues in development because new systems may have to be added. Currently, the group is ahead of schedule on the hardware and senior design sections. While the group isn't behind the time limits set in the software section, it has come to the attention of the group that the software will be held back until most of the hardware goals are met. The requirements of the senior design document also seem to require more time than this group previously plan.

8.3.1 Senior Design 1 Milestones

Task Name	Start	Duration	End
Senior Design 1 Project Idea	8/22/2016	6	8/28/2016
Project Discussions	8/29/2016	67	11/4/2016
Divide and Conquer Document	9/5/2016	4	9/9/2016
Initial Project Documentation	8/22/2016	18	9/9/2016
Research Past Projects	9/12/2016	13	9/25/2016
Individual Research Writing	9/26/2016	27	10/23/2016
Group Collaboration Writing	10/24/2016	11	11/4/2016
Individual Research Writing	11/5/2016	8	11/13/2016
Prototype & Code Development	11/14/2016	13	11/27/2016
Finish Project Documentation	11/28/2016	6	12/4/2016
Review Documentation	12/5/2016	1	12/6/2016

Table 8-1 Senior Design 1 Milestones

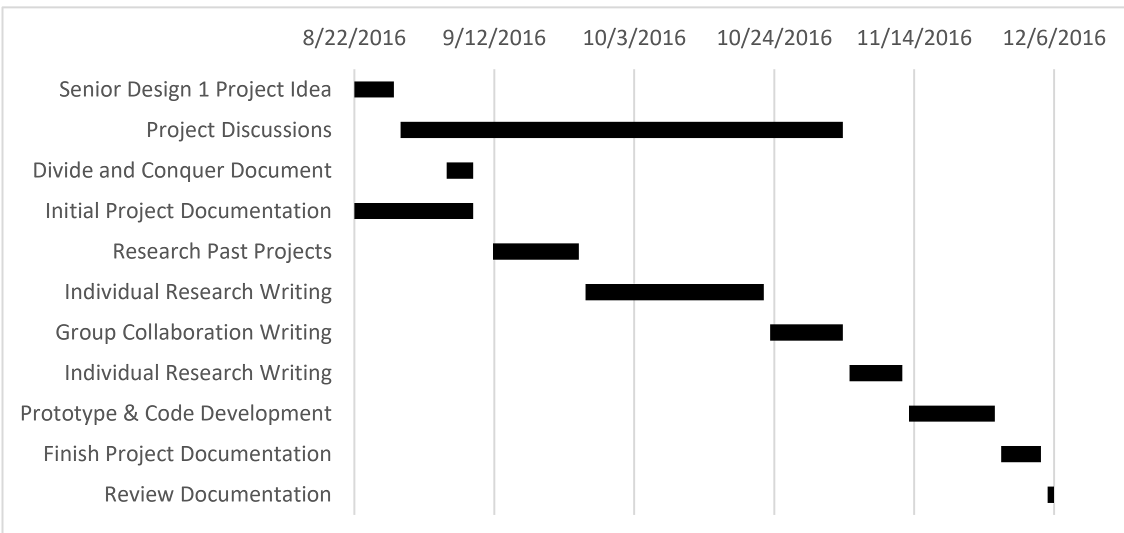


Figure 8-1 Senior Design 1 Milestones

8.3.2 Senior Design 2 Milestones

Task Name	Start	Duration	End
Test Components	12/7/2016	46	1/22/2017
Build Prototype / Program MIC	1/23/2017	55	3/19/2017
Test Prototype	3/20/2017	27	4/16/2017
Finalize Project	4/17/2017	6	4/23/2017
Prepare for Presentation	4/24/2017	7	5/1/2017

Table 8-2 Senior Design 2 Milestones

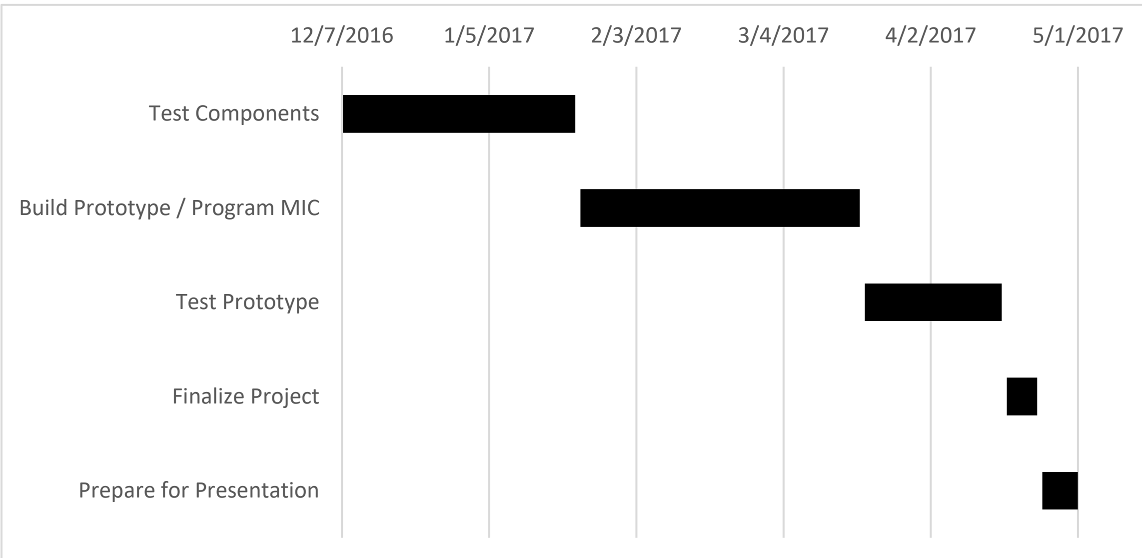


Figure 8-2 Senior Design 2 Milestones

8.3.3 Hardware Milestones

Task Name	Start	Duration	End
Sensor Research and Selection	9/9/2016	7	9/16/2016
Pump Selection	9/16/2016	7	9/23/2016
Power Supply Design	9/30/2016	7	10/7/2016
Analog Digital Converter	9/27/2016	10	10/7/2016
Wi-Fi design	9/30/2016	14	10/14/2016
Microprocessor Selection	10/7/2016	7	10/14/2016
Circuit Simulation	11/11/2016	7	11/18/2016
PCB layout	11/15/2016	21	12/6/2016
Build Prototype	11/6/2016	30	12/6/2016
Schematic Design	11/6/2016	30	12/6/2016
Run Prototype	12/7/2016	136	4/22/2017
Test / Design Updates	12/7/2016	136	4/22/2017
Finalize Prototype	12/7/2016	136	4/22/2017
Finalize PCB	12/7/2016	136	4/22/2017
Packaging Design	12/7/2016	136	4/22/2017

Table 8-3 Hardware Milestones

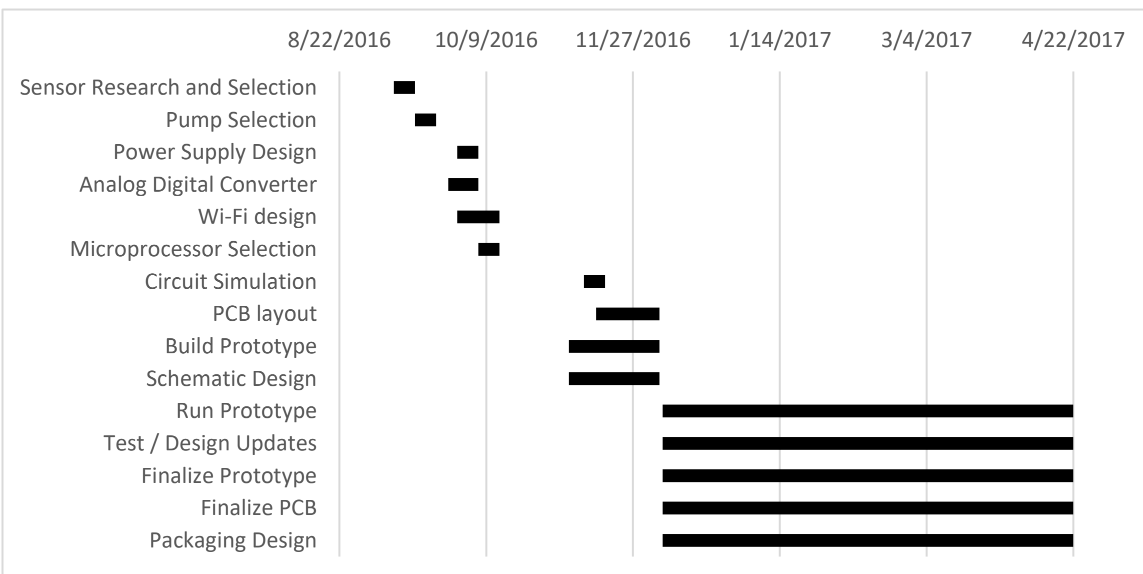


Figure 8-3 Hardware Milestones

8.3.4 Software Milestone

Task Name	Start	Duration	End
Website Design and Layout	10/1/2016	61	12/1/2016
Database Management System Design	10/1/2016	61	12/1/2016
Mobile App Design and Layout	10/1/2016	61	12/1/2016
Coding Website	12/2/2016	87	2/27/2017
Coding Database	12/2/2016	87	2/27/2017
Coding Mobile App	12/2/2016	87	2/27/2017
Microprocessor System Design	10/15/2016	31	11/15/2016
Coding Microprocessor	11/16/2016	20	12/6/2016
Testing System Interactions and Debugging	12/7/2016	121	4/7/2017
Fine Tuning User Experience	4/8/2017	14	4/22/2017

Table 8-4 Software Milestone

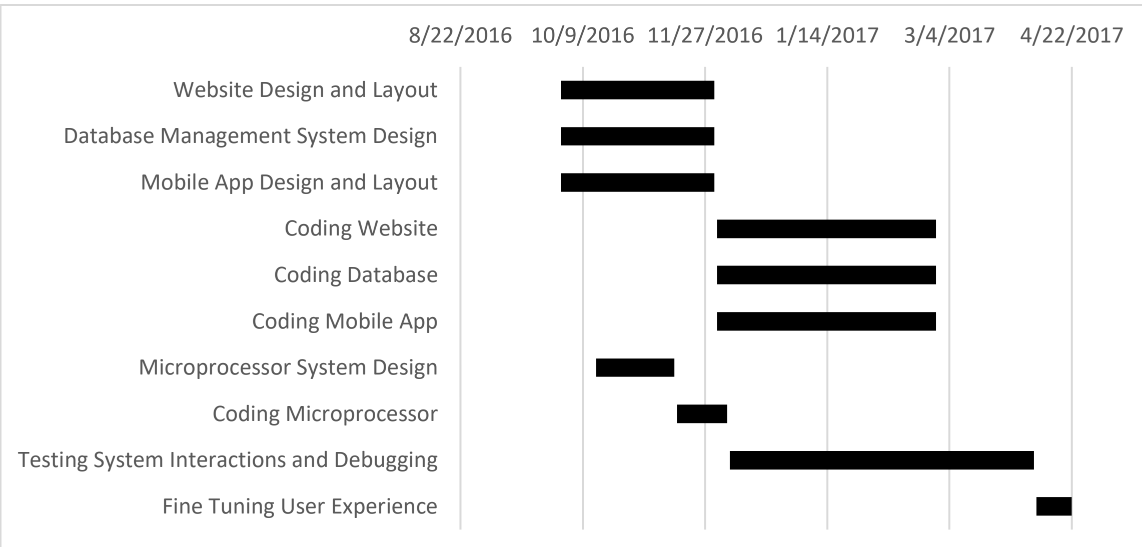


Figure 8-4 Software Milestones

8.4 Budget and Finance Discussion

Hydroponics systems are very intricate. Even a basic system requires the user to monitor pH, TDS/EC, and water levels. The measurements required to do this monitoring depend upon some sophisticated devices. Besides the pH, EC, and water level monitoring of a more basic system, our solution also involves measuring the light the plants are receiving and supplementing it with an LED light array, and of course the ability to check these readings on a website and phone application. Our system will also automatically adjust the pH of the water in the system so that the user doesn't have to.

The pH and EC sensors require not only circuitry, but specially designed probes to do the readings. We researched these probes and determined as a group that to design the probes ourselves would not be feasible. These devices need to be high precision and the amount of research, testing, and implementing time would hamstring our project. On top of these other problems, it didn't seem financially worth it either. We would of course however need these devices and we spent some time researching our options.

Once doing preliminary research and getting a rough idea of the cost for our components, we decided on a budget for the project. When we decided to do an independent project, we realized that money would be an issue from the beginning. We decided that each of us would put $250 each on to a prepaid card that would be used for the project's expenses, for a total of $1000 for the project. One of our group members, Beau, plans on keeping the hydroponics system and he has agreed that should we go over budget, he will cover the extra expenses incurred. We all felt this was fair and so this was the arrangement for our funding.

Moving forward with our project, we realized form our preliminary research that the pH and EC sensors would be our biggest expenses by far. The cheapest probes we could find that could interface with our Arduino microcontroller were still well over $100 each. Again, we felt that with all the other features of our system, that building the pH and EC systems ourselves would be aiming for the moon. We accepted this as a cost that couldn't be avoided and moved on.

The third most expensive item was our LED light array. This again came in at just over $100. We had already decided on building a power supply for our system, and once more thought that designing and implementing a high-power LED array for plant growing was too big of a task to take on with everything else we had put on our plate. Given that we planned on adjust the light intensity with our microcontroller depending on light conditions, we also had to have a LED array that was adjustable. The LED array we settled on was an adjustable one that was controlled by a potentiometer and we thought that we could modify this to be digitally controlled by the microcontroller. We conceded to accepting this as an unavoidable expense.

Not everything was so expensive however. For example, the light sensor we would need to determine how bright to turn the LEDs was priced reasonably at around $10. The microcontroller and Wi-Fi chips we settled on using were cheap as well, being only a couple dollars per chip. This is also where we thought that we could implement the microcontroller chip itself on to a PCB and not have to use a pre-built development board. Similarly, we felt that the Wi-Fi chip we selected could also be integrated into the PCB in the same fashion.

For automating the pH and EC adjustment, we needed to find digitally controlled pumps. We found some small, cheap peristaltic pumps for pumping the pH and EC solutions into our water as needed. They were about $5 each and we felt comfortable with this price point. We looked at several all-in-one pH and EC monitor and pumping systems but we felt like automating our system ourselves was the entire point of our project. Not only that, but those all in one automated pump/sensor combos are extremely expensive for a good one, easily being over $500 by itself. We felt the main body of work for our project would be taking our light/pH/EC readings and configuring the system to auto adjust with our microcontroller.

Rounding up our main components, we also needed an electronic water level sensor. We found one moderately priced at around $40 but felt like its quality would be long lasting, something that Beau had wanted since he would be keeping our system, and we agreed on it. As a group, we also deiced on implementing a basic 16x2 LCD screen onto the system so that the user can see the readings of the system without having to pull out their computer or phone. This was cheap as well, and only ended up costing us around $10.

These components took up a good chunk of our budget, but not all of it. After these purchases, we still had a couple hundred dollars to order our PCBs and the electrical components for them. With only this outstanding expense, everything else that was needed for the project was provided by the members personally. For example, breadboards, some electrical components, our tank for the system, etc. we already had and didn't mind using for the project. This saved on some of the costs as well. I believe our budget will be more than enough to cover our estimated expenses, and barring some unforeseen circumstance we should come in under budget. In the case that we don't spend all the budget, we are going to divide up the remaining balance equally between all the members. Below you will find Figure 8-5, a breakdown of our expenses so far:

Bearing rotary pumps x 4	$27.56
Atmega2560 Microcontroller Chips x 3	$17.57
AdaFruit TSL2591 HDR Digital Light Sensor x 3	$29.44
pH Sensor Kit x 1	$149.95
ESP8266 12F Wifi Chips x 5	$13.19
Water Level sensor x 1	$45.04
LCD x 1	$18.18
LED Lights x 1	$109.99
TDS Sensor x 1	$233.91
Assorted electronic parts	$23.56
Additional Wires,Transistors,Capacitors	$19.85
Total	$688.24

Figure 8-5 Breakdown of Expenses

I. Appendices

a. Appendix A – Abbreviations

Here is a list of all the acronyms used in this report;

Abbreviations	Meaning
A	Amperage
AC	Alternating Current
DBMS	Database Management System
DC	Direct Current
EC	Electrical Conductivity
EMI	Electromagnetic interference
FTDI	Future Technology Devices International
I	Current
I/O	Input output
IDE	Integrated Development Environment
IEEE	Institute of Electrical and Electronics Engineers
LAN	Local Area Network
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
nm	nanometers
PCB	Printed Circuit Board
pH	potential of Hydrogen
PHP	recursive acronym for PHP: Hypertext Preprocessor
RF	Radio frequency
TDS	Total Dissolved Solids
URL	Uniform Resource Locator
V	Voltage
Wi-Fi	Wireless Fidelity
XML	eXtensible Markup Language

b. Appendix D – Datasheets

All Datasheet on the components of this project can be found by following the link below;
https://drive.google.com/open?id=0B_VXPmkEv-QZVlRhWHRjNEtNZDQ

II. References

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