Autonomous Vertical Hydroponic Drip System

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Group 13

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I: Project Description

A fully automated hydroponic system that functions as both a stylish in-home decoration and a space efficient way to grow leafy greens. The system will be able to be controlled wirelessly, allowing for nutrient dosing amounts and schedules, light cycles, and water flow to be customized.

- What is a hydroponic system?
    - Hydroponics is the art of growing plants without soil. The main advantages of hydroponics are its very low water and space consumption, higher plant yields, and its ability to grow plants in harsh environments at the cost of power and nutrient management.
    - The soil is often replaced with another physical medium to allow the roots to grow and expand as if it were growing in natural soil. Without soil, certain natural ion exchanges aren't possible in replacement mediums. More complex nutrient mixtures are necessary for the plants' health.
    - The climate is getting warmer. If sea levels rise, the availability of arable land and fresh water will decrease. In a warmer climate there will be less options for plants that need a cooler climate to grow. A small farm people can use in their own home means families will be less dependent on traditional farming techniques while conserving a diminished fresh water supply.
- Why automate it?
    - Hydroponic plants need maintenance and monitoring to ensure the plants grow properly. The roots of each plant need constant water and sufficient light to survive and thrive.
    - This means a water-nutrient solution delivery system to the plants is necessary. Doing this work manually is cumbersome and using machinery will help get the most plant growth we can out of our hydroponic system.
    - Constant lighting can be detrimental to the growth of some plants. By providing a timer, we can be sure that the plants are getting the correct amount of light each day.
    - Nutrients also have to be mixed in water before being delivered to the plants. An uneven mixture can be toxic to hydroponic plants. Using a mechanical solution, we can ensure the nutrients being delivered to plants is what is desired.
    - Lastly, we can monitor the current state of the hydroponic system with a variety of sensors and keep a record of it. By having a record of pH balance in the nutrient water, amount of light the plants received, and the amount of water the plants received, we can give our users the data to make informed decisions on how to take care of their plants.
- Why a wall decoration?
    - Many hydroponics units currently on the market are limited in the styles available, such as tower and horizontal rack formats. Often, these units have exposed pipes or have industrial appearances, both of which may not be attractive qualities to a customer looking for an in-home hydroponics solution. By designing a system with an enclosed vertical wall style (kinda wordy here), customers will now have a more aesthetically pleasing and unique product to choose.
    - By using an upright, against-the-wall format, the customer will be able to save room in their home by avoiding the large space requirement of tower and rack style hydroponics units.

II: Project Motivations

- Goals / Objectives
  - Build a system that delivers water to plants.
  - Build a system that mixes nutrients in water.
  - Build a system that logs data collected from sensors.
  - Build an aesthetically pleasing structure for walls that plants can grow in.
  - Build an application that interfaces with the operations of the automated hydroponic system.
  - The hydroponic system should sustain the life of the plants with the correct settings.
- Personal Motivations
  - David - To start, I want to demonstrate competence that I can program a microcontroller for a system of this complexity. Secondly, I want more experience building interfaces for internet and phone applications. Lastly, I want more experience working in a successful team setting.
  - Marco - Be able to apply my knowledge I have learned over the past 4 years in a practical manner within a group. This will push me to maintain engagement and push my creativity in order to finish successfully. This will teach me the necessary skills that I can use as a supplement to knowledge in the workforce.
  - Max - Acquire more hands-on experience with the software and hardware development process, further educating myself in the computer engineering field and adding to my professional marketability. Learn how to better contribute to a group engineering effort and maintain a healthy team-based workflow. Further develop interpersonal communication skills and organizational habits.
  - Jacob - Equip myself with new skills working with microcontrollers and full-stack software development. Learning how to bridge the gap between connecting a complex device to the internet for management is a great challenge that will give me some solid experience as a computer engineer. I also have a vested interest in the evolution of the agricultural landscape as technology becomes more powerful.

III: Requirements / Specifications

- Product Dimensions
  - The unit shall have the target dimensions of 3ft wide by 5ft tall, with a minimized thickness that will not exceed 1.5ft. Being that the thickness will have the greatest impact on the space efficiency of the unit, it is highly beneficial to design the unit to be as thin as possible.
- Power Requirements
  - The unit shall use one primary power supply that will meet the total power requirements of the system, with several step-down voltage circuits being used to provide the individual voltage rails. These step-down circuits will be designed using Webench.
- Hardware Requirements - Jacob/Marco
  - The pH, flow, and water level sensors should:
    - Take accurate measurements within a 5% margin of error

        - Read input data every hour
        - Be able to withstand long amounts of time submerged in a water-based nutrient solution
    - When handling water flowing throughout the system:
        - No water should leak anywhere in the system
        - A pump will send water through each hydroponic tower evenly
        - Water flow will be great enough to keep plant roots wet whenever the system is on
        - Water will be dispensed to each tower from a small reservoir pipe at the top of the frame with flow restrictors directed at each tower
        - The water tank will have an easy drainage valve for convenient water replacement
        - Relay controlled pump actuation through the system
        - Pump water 5 feet from the bottom to the top tank (~200-500 GPH)
        - Water falling down the towers will drain into the main recirculation tank
        - Water will be mixed every hour to ensure nutrients aren't stagnant at the bottom of the recirculation tank
    - To maintain proper nutrient and pH levels in the system:
        - Dosers will provide small amounts of pH adjustment fluid to the nutrient solution daily at a rate of 1 mL of balancing fluid per liter of water if it is out of proper pH range [5.5, 6.0]
        - Upon replacement of water in the main tank every 2 weeks, the dosers will dispense ½ tbsp of nutrient mixture per gallon to the tank and mix the fresh water together with it
    - To prevent bacteria buildup in the system:
        - There will be minimal light leaks in the system
        - The frame will have a covering that can open and close the front face of the system.
        - Pipes that have water running through them must be completely opaque
    - To monitor the system locally:
        - A liquid crystal display attached to the frame will display current sensor readings
        - A button on the frame of the system will be able to pause / restart the pump
    - Plant handling of the system:
        - Plants should have sufficient root and leaf sprouting space.
        - Plants should get at least 32 Watts of light through a natural day-cycle via LED strips.
        - A constant flow of water and nutrients mix should be maintained through water pumps.
        - Flow sensors will be in place to monitor flow, an alarm/notice will be sent to the user if flow stops to prevent prolonged water deprivation to the roots.
        - Dosers will control the fertilizer mixture ratio that will be provided depending on the plant type.
        - Liquid levels from the two main tanks will be monitored through electronic water levels sensors and sight gauge.

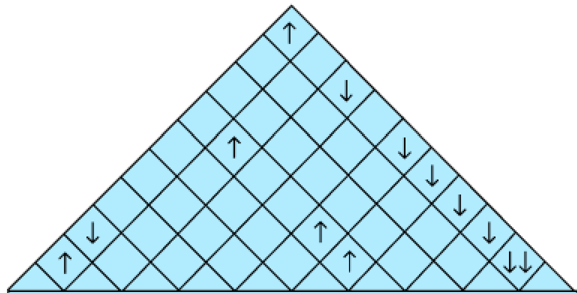
- Supporting structure:
    - Tanks will be based on plastic or PVC material.
    - The main structure supporting the tanks will be a combination of wood ¼” sheets and PVC material.
    - Electronics and connections enclosures will be weather proof to prevent moisture intrusion.
    - Plant bases will be based on PVC piping.
    - Pipe connections and joints will have watertight grommets.
    - Overall structure will be held by a combination of glue, nuts and bolts.
    - Wood materials will be paint sealed.

- Software Requirements
    - The microcontroller unit program should:
        - Turn water pumps, lights, nutrient dosers, and mixer on and off.
        - Balance pH of nutrient water with an accuracy of 90%.
        - Collect sensor data. (Water levels, water flow, and pH balance of the water)
        - Send and receive sensor data to the internet application via Wi-Fi.
        - Displays water levels, water flow, and pH balance of nutrient water on an LCD screen.
    - There will be a phone application to interact with the hydroponic system, which includes:
        - Displays water levels, water flow, and pH balance of nutrient water.
        - Controlling light schedule, pH, and water pumps.
        - External database of collected sensor data from the hydroponic system.
        - Showing graphs of collected time-series data.
        - Log In / Sign up
        - Should pair the user with their login credentials with their specific hydroponic system.

Milestones

8/3/2021	8/21/2021	10/1/2021	10/20/2021	11/22/2021
Complete design sketch and project requirements	Acquire all components / sensors	Complete first prototype design with minimal flaws	Complete quality assurance and testing	Complete final project iteration
Calibrate sensors and test individual components	Begin construction of 1st hydroponic prototype	Have database models set up and connected to prototype	Have a working method for displaying data to user device	

House of Quality



User Requirements		Power Consumption	Water Flow Optimization	Light Satisfaction	Unit Dimensions	Nutrient Balance Accuracy	PH Balance Accuracy	Sensor Accuracy	Sanitation	Enclosure Quality	Cost
		−	+	+	−	+	+	+	+	+	−
Cost	−	↑		↓	↓			↓	↓	↓↓	↑↑
Space Efficiency	+				↑↑						
Physical Maintenance	−					↑	↑	↑	↑		
Noise	−	↑	↑							↑	↓
Plant Yield	+		↑↑	↑		↑	↑	↑	↑↑		↓
Weight	−				↑					↓	
Ease of Use	+					↑	↑	↑			↓
Visual Appeal	+				↑↑					↑↑	↓↓
Structural Stability	+				↓					↑	↓
		In Research Phase	In Research Phase	> 32 Watts per Sq. Ft.	3' x <= 1.5' x 5'	1ml per Liter, 90% Accuracy	pH: 5.5 - 6.0, 90% Accuracy	>= 90% Accuracy	Negligible Bacteria Growth	Furniture Grade Appearance	< $1,0000

Legend:
- + Positive Polarity
- − Negative Polarity
- ↑ Positive Correlation
- ↑↑ Strong Positive Correlation
- ↓↓ Strong Negative Correlation
- ↓ Negative Correlation

Figure 1: House of Quality

Block Diagrams / Illustrations

Hardware Flow

- David
- Jacob
- Marco
- Max

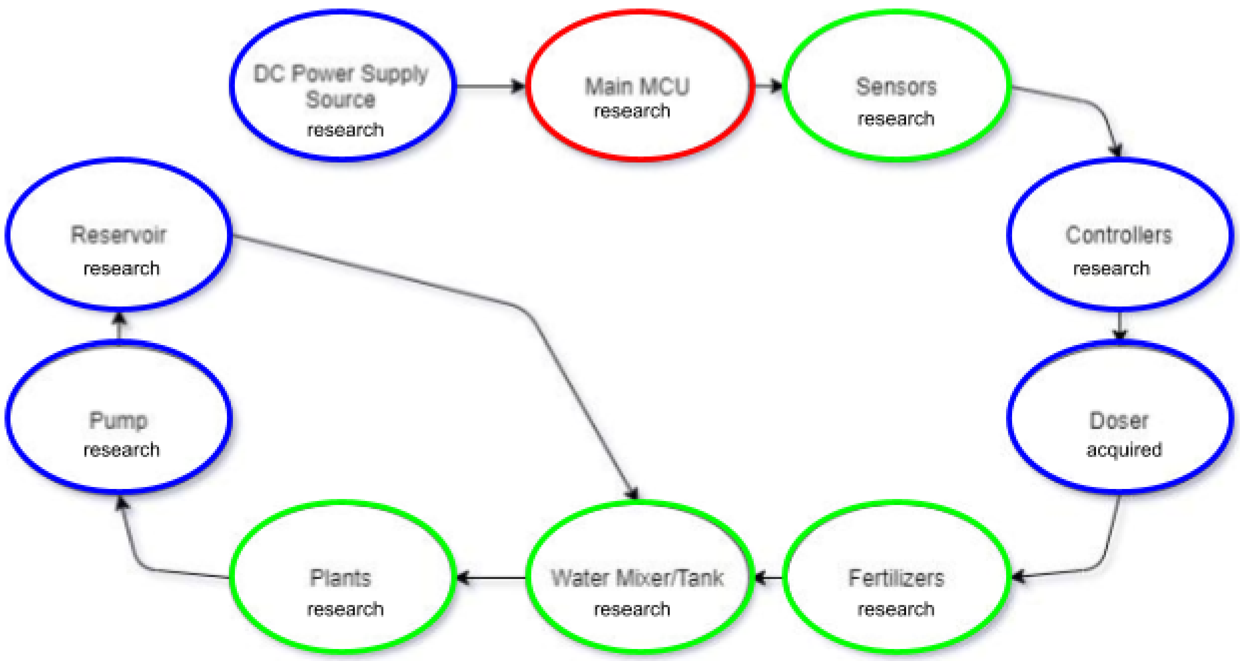


Figure 2: Hardware Block Diagram

Software Flow

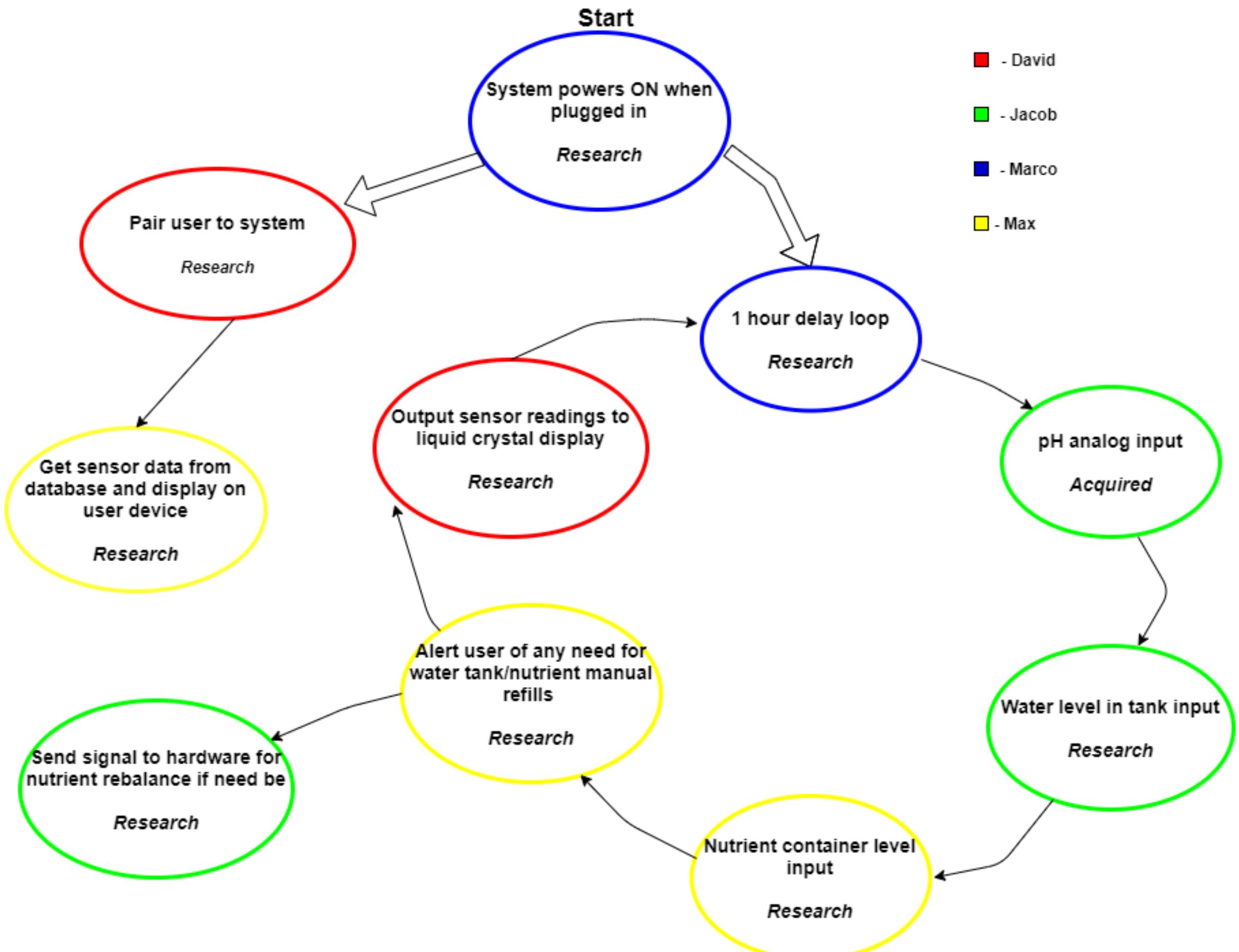
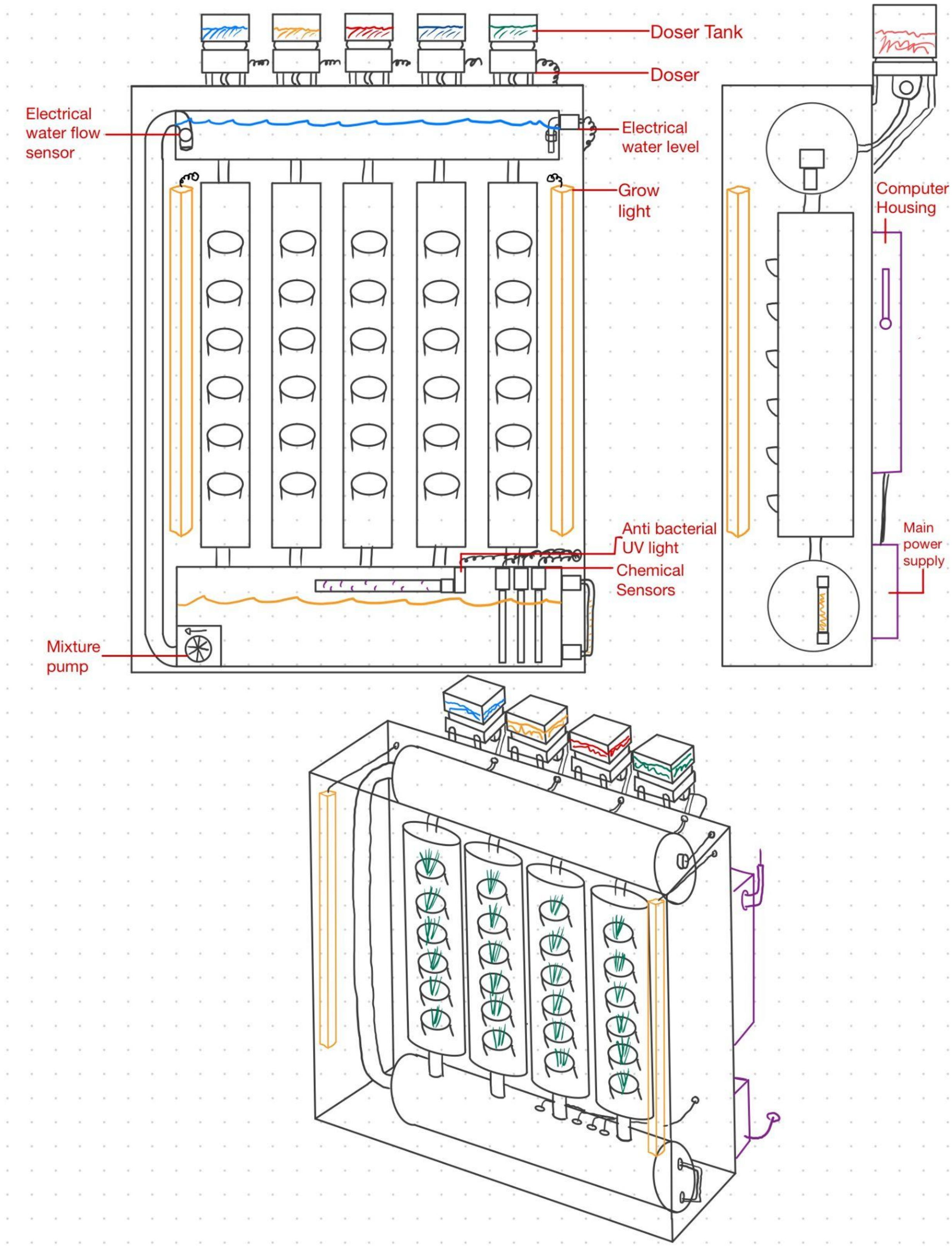


Figure 3: Software Block Diagram

Illustration



Budget Analysis

Item	**Quantity**	**Price Estimate**
PCB	1	\$30 - \$80
System Controller & Development Board	1	\$70
Power Supply	1	\$20 - \$30
Water Pump	1	\$25 - \$40
PH Sensor	1	\$80
Electrical Conductivity Sensor	1	\$50 - \$60
Temperature Sensor	0-1	\$0 - \$15
Flow Sensor	1	\$10
Water Level Sensor	2	\$50
LED Grow Lights	2-4	\$30 - \$80
Dosers	4	\$60
Underwater Mixer	1	\$10 - \$20
Display Panel	1	\$15
PVC Frame & Piping	Variable	\$50 - \$150
Water Tanks	2	\$30 - \$60
Plants/Seeds	Variable	\$5 - \$10
Nutrient Solutions	2	\$20 - \$50
PH Control Solutions	2	\$20 - \$50
Enclosure Panelling	Variable	\$20 - \$100
Miscellaneous	Variable	\$50 - \$150
Total Cost		\$595 - \$1120

The project will be self-funded with a target budget of no more than \$1,000. As some materials and design solutions are still in the research phase, a wide range of prices have been accounted for.