SEMINAR REPORT
ON

HYDROPONICS BASED PRECISION FARMING WITH FEATURE OPTIMIZATION

SUBMITTED BY

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Academic Year: 2023-2024

CERTIFICATE

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of B.E. (E&TC) have successfully completed the seminar titled '**Hydroponics Based Precision Farming with Feature Optimization**' during the academic year 2023-2024. This report is submitted as partial fulfillment of the requirement of degree in E&TC Engineering as prescribed by Savitribai Phule Pune University.

Dr. Mrs. K. R. Joshi	**Dr. Mrs. R. S. Kamathe**	**Mr. Ramgopal Sahu**
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ACKNOWLEDGEMENT

We would like to express our sincere appreciation to all the individuals who contributed to the success of our project "Hydroponics Based Precision Farming with Feature Optimization".

First and foremost, We would like to thank **Mr. Ramgopal Sahu** for his invaluable guidance and support in PCB design, enclosure design, component choices, and modifications. His expertise and experience played a crucial role in the successful implementation of our project. His suggestions on plant choices were also very helpful in achieving our goals.

We would also like to extend our heartfelt thanks to **Mrs. Shreyasi Watve** for her brilliant ideas on the farm field and modifications in the report. Her contributions have greatly enhanced the quality of our project. Furthermore, we would like to express our gratitude to our HOD **Dr. Mrs. R. S. Kamathe** for her constant support and encouragement throughout the project.

We would also like to thank the industry expert **Mr. Jayesh Ranjare** who provided valuable suggestions for this project. Their insights and knowledge have been immensely helpful in achieving our objectives.

We would also like to express our gratitude to our principal **Dr. Mrs. K. R. Joshi** for provision of state-of-the-art infrastructure, access to necessary resources and college's commitment to fostering an environment that encourages innovation, creativity, and hands-on learning.

Lastly, we would like to thank **Mr. Chandrakanth Bhode**, a certified fertilizer shop owner, for providing us with the best knowledge about fertilizer choices for hydroponics systems. His inputs were very valuable for the success of our project.

- Janhavi Bhor
- Varad Chaskar
- Sahaj Chaudhari

ABSTRACT

The world is changing rapidly, bringing both innovations and problems. As the population grows, land and water resources are shrinking. Conventional farming methods are becoming unsustainable due to climate change and harmful environment. Hydroponics offers an innovative solution that uses less space and water and produces more food with fewer chemicals than soil based farming. Furthermore, hydroponics can grow food in any location and season, providing fresh, local, and nutritious vegetables to consumers. The proposed system aims to enhance the hydroponics concept by not only automates crucial aspects of hydroponic systems such as water and nutrient supply but also incorporates features like machine learning algorithms, IoT, cloud computing, M2M communication, and image analysis and controlling environmental parameters in plant growth but also verifying whether the system functions as intended. The system is in product-ready form that may be used commercially or domestically.

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1. INTRODUCTION

With the world's population projected to reach 9.8 billion by 2050,[1] the agriculture sector faces immense pressure to double its food production to meet this demand.[2] Automation in agriculture becomes imperative due to several factors including the scarcity of arable land,[3] fluctuating climate patterns, and the need for increased efficiency and productivity. By automating tasks such as planting, watering, harvesting, and monitoring crop health, we can optimize resource utilization, minimize waste, and enhance yields. Additionally, automation can mitigate the challenges posed by labor shortages[4] and provide opportunities for more sustainable farming practices, ensuring food security for the growing global population while conserving natural resources for future generations.[5]

1.1 Need for Hydroponics

Indoor hydroponics presents numerous advantages over traditional soil farming methods, particularly in the context of addressing the challenges posed by limited land availability, water scarcity, and climate variability. Hydroponic systems enable cultivation in controlled environments, allowing for year-round production regardless of external conditions. By providing precise control over nutrient delivery and environmental factors such as temperature, humidity, and light, hydroponics maximizes resource efficiency, minimizes water usage, and reduces the reliance on harmful pesticides and fertilizers. Furthermore, indoor hydroponic setups can be tailored to fit various spatial constraints, making them suitable for urban areas and regions with limited arable land, ultimately offering a sustainable and scalable solution to meet the growing global demand for fresh produce.[6]

1.2 What is Hydroponics

Hydroponics is a method of growing plants without soil, where plants receive essential nutrients dissolved in water. This soilless cultivation technique utilizes various systems such as nutrient film technique (NFT), deep water culture (DWC), or aeroponics, allowing for precise control over nutrient levels, pH, and environmental conditions. Hydroponics can be used in diverse applications, including commercial agriculture for growing vegetables, fruits, and herbs in controlled environments, urban farming to maximize space efficiency and enable year-round production, research institutions for studying plant biology and optimizing growth conditions, as well as in areas with poor soil quality or limited access to arable land, providing a sustainable solution for food production.[7]

1.3 Automating Hydroponics

Automation of hydroponics using technology involves integrating sensors, actuators, and control systems to monitor and regulate key parameters such as nutrient levels, pH, temperature, humidity, and lighting. This can be achieved through the use of IoT (Internet of Things) devices and smart controllers that gather real-time data from the hydroponic system and adjust environmental conditions accordingly. Automated nutrient dosing systems ensure precise delivery of nutrients to plants, while automated irrigation systems maintain optimal moisture levels. Additionally, automated lighting systems can mimic natural sunlight cycles to promote healthy plant growth. By automating these processes, technology streamlines hydroponic operations, increases efficiency, minimizes labor requirements, and enables remote monitoring and management, ultimately enhancing crop yields and sustainability.[8]

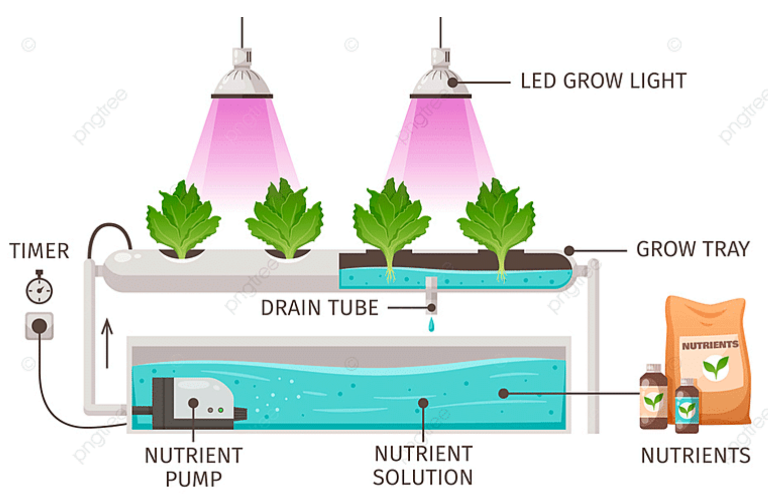


Fig. 1.1: Concept of Hydroponics

Source: https://www.greenlivingoffgrid.com/hydroponic-gardens-pros-and-cons

2. LITERATURE SURVEY

2.1 Literature Survey of the Reference Papers

“Nutrient Film Technique (NFT) Hydroponic Monitoring System Based on Wireless Sensor Network,” by Helmy, Marsha Gresia Mahaidayu, Arif Nursyahid, Thomas Agung Setyawan, Abu Hasan (2017), highlights urban development challenges such as agricultural land conversion, prompting interest in hydroponic cultivation. Hydroponics replaces soil with water, nutrients, and oxygen, crucially defining success in techniques like Nutrient Film Technique (NFT).

“A Controlled Environment Agriculture with Hydroponics: Variants, Parameters, Methodologies and Challenges for Smart Farming,” Srivani P, Yamuna Devi C and Manjula S H (2019), discusses urbanization, food scarcity, and climate unpredictability, advocating hydroponics as a sustainable alternative. It enables precision agriculture, conserves resources, and supports urban farming while avoiding pesticides and GMOs.

“Technological Influences on Monitoring and Automation of the Hydroponics System,” by Geetali Saha (2021), explores hydroponics' components and challenges. It emphasizes the need for comprehensive data collection, automated control systems, and interfaces to mitigate weather disruptions and power failures. The study aims to advance hydroponic technology in addressing land scarcity and climate change impacts on traditional farming.

2.2 Brief Findings From Research Literature

- New technologies are currently under research and development, particularly in areas such as nutrient composition, supply mechanisms, growth mediums, and the impact of environmental factors such as light, temperature, humidity, and pH levels. These factors have demonstrated a direct correlation with plant growth outcomes.

- Despite longstanding discussions about the integration of automation and AI in hydroponics, much of the progress has been confined to simulated environments, whether physical or virtual, typically facilitated through platforms like MATLAB. While AI models have been constructed based on real-life data, their practical application in agricultural settings remains largely unexplored.

- The majority of research efforts in this field have failed to employ methodologies conducive to transforming AI and automation into viable products capable of demonstrating efficiency and effectiveness beyond mere plant growth optimization. Our focus is on bridging this gap by implementing research techniques aimed at showcasing the practical benefits of these technologies in real-world farming scenarios.

2.3 Literature Survey Of Similar Products Available In The Market

2.3.1 Automation kit by Growtronix

The Hydroponic Automation Kit by Growtronix and the Hydroponic Starter Kit by General Hydroponics are two comparable products on the market. Growtronix offers a comprehensive automation solution, including temperature/humidity sensors and nutrient dosing systems. In contrast, General Hydroponics provides a simpler kit featuring a water pump, air pump, and air stone for use with a 5-gallon bucket.

Fig. 2.1: Automation by Growtronix
Source: growtronix.com/cart/blog/how-growtronix-works-n5

2.3.2 City Greens

City greens provide low-cost hydroponic solutions for farmers who are on budget and would like to grow seasonal and local crops, but at the same time enjoy higher yields and improved profits as compared to what is possible in traditional farming. They are currently serving 18+ states right now. They provide setup, support, and automation to farming systems.

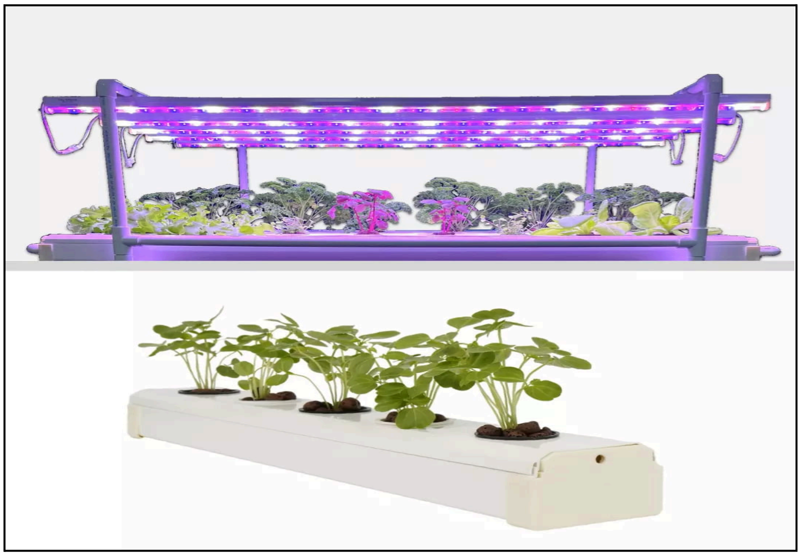


Fig. 2.2: Product by City Greens
Source: https://www.citygreens.shop/Images/202211/1080x1080/Kits.webp

2.4 Comparison With Various Technologies Available

Hydroponic systems offer advantages over traditional soil-based farming, including higher crop yields and reduced water usage, with automation further boosting efficiency. Various technologies exist for hydroponic automation, each with its own advantages and drawbacks.

Automated dosing systems ensure precise nutrient delivery but can be costly and require regular maintenance, while simpler timer-based systems with water pumps may be more affordable but lack precision. Notably, there's no existing system that simultaneously operates UV lights, fans, air pumps, and water pumps, nor the technology to verify their functionality, making this system distinctive in its approach.

2.5 Market Survey Based On Economy Literature

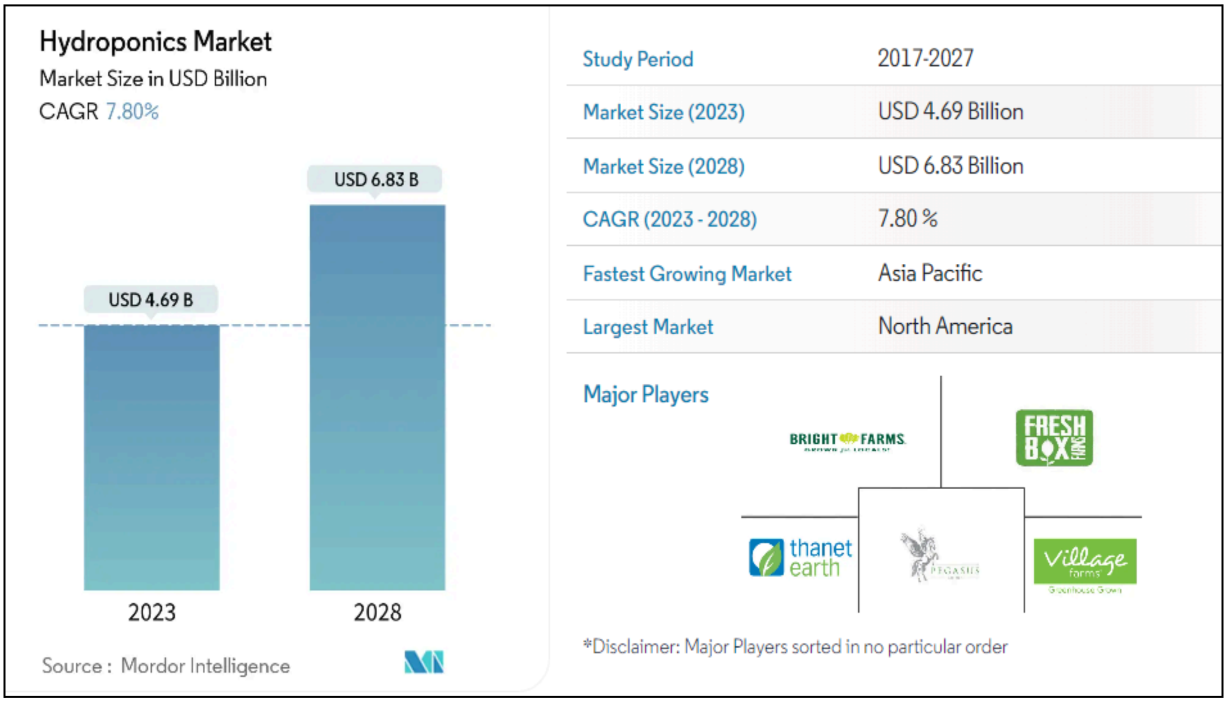


Fig. 2.3: Hydroponics Market Size

Source: https://www.mordorintelligence.com/industry-reports/hydroponics-market

- The Hydroponics Market is projected to grow from USD 4.69 billion in 2023 to USD 6.83 billion by 2028, with a CAGR of 7.80% during 2023-2028. North America leads the market, while Asia Pacific shows the fastest growth [4].
- Rapid growth is expected, driven by increased adoption in Australia, Japan, India, and China [5].
- The global market is fragmented, with many companies focusing on R&D to develop advanced techniques for sustainability and cost reduction [6].
- In March 2021, Ahmedabad's state government announced plans to promote hydroponic farming in cities, offering hands-on training and DIY videos to encourage household vegetable cultivation.
- Key players in the hydroponics market include Argus Control Systems Ltd. (Canada), Signify Holding B.V. (Netherlands), The Scotts Miracle-Gro Company (U.S.), and others.

3. SPECIFICATIONS

3.1 Actuator Module Features

- Operates LED violet light using 2 PC817 optoisolators.
- Controls up to 4 motors with adjustable speed using 2 L293D motor drivers.
- Integrates Wemos D1 mini microcontroller for WiFi connectivity.
- Allows system operation through web and app interfaces.
- Operates on 5V power supply.

3.2 Actuator Module Input Specifications

Parameter	Description
Power Supply Voltage	5V
Control Signal	Logic High (3.3V), Logic Low (0V)
Motor Speed Control	Adjustable via PWM signal (0-255)
Communication	WiFi connectivity

Table 3.1: Input Specifications of the Actuator Module

3.3 Actuator Output Specifications

Parameter	Description
LED Voltage	Collector Current: 50 mA, C-E Voltage: max. 35V
Motor Voltage	Up to 5V, Peak Output Current: 600mA, Continuous Output Current: 200mA
Motor Control	Speed control (adjustable PWM)

Table 3.2: Output Specifications of the Actuator Module

3.4 Actuator Module Status/Control

- Status Indication: LED status indicator.
- Control Interface: Web and app-based control through WiFi.
- Motor Activation: Controlled via microcontroller logic.

3.5 Actuator General Specifications

Parameter	Description
Microcontroller	Wemos D1 mini
Optocoupler	PC817
Motor Driver	L293D
Communication Protocol	WiFi (802.11 b/g/n)
Operating Voltage	5V
Dimensions	7cm x 8cm x 2.5cm
Operating Temperature	-40°C to 85°C

Table 3.3: General Specifications of the Actuators

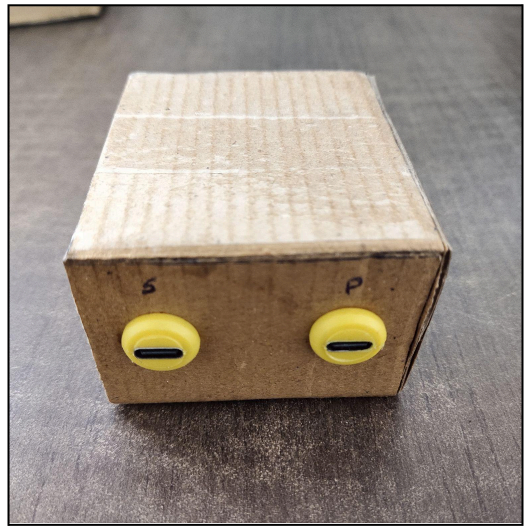


Fig. 3.1: UPS Module (5V 2A)

3.6 Sensor Module Features

- Monitors temperature and humidity using DHT11 sensor.
- Detects light status using an LDR (Light Dependent Resistor).
- Monitors water level depth using a water level sensor.
- Integrates Wemos D1 mini microcontroller for WiFi connectivity.
- Sends data to the cloud through WiFi.

3.7 Sensor Module Input Specifications

Parameter	Description
Power Supply Voltage	5V
Communication	WiFi connectivity
Temperature Range	0°C to 50°C (DHT11 sensor)
Humidity Range	20% to 90% RH (DHT11 sensor)
Light Detection	Analog Voltage Output (LDR)
Water Level Depth	Analog Voltage Output (Water level sensor)

Table 3.4: Input Specifications of the Sensor Module

3.8 Sensor Module Status/Control

- Status Indication: LED status indicators for sensor readings.
- Control Interface: WiFi for data transmission to the cloud.
- Data Transmission: Periodic updates to cloud server.

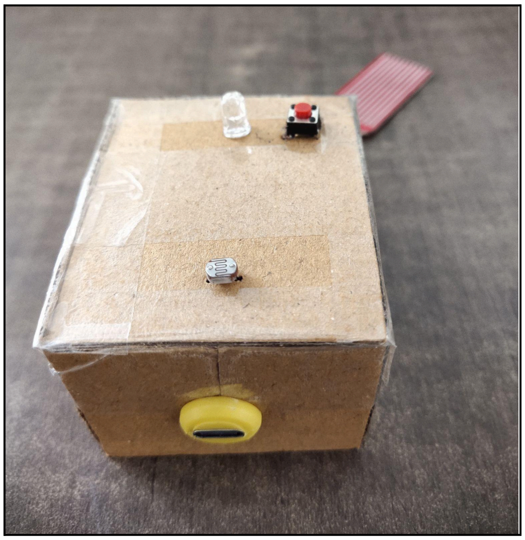


Fig. 3.2: Sensor Module

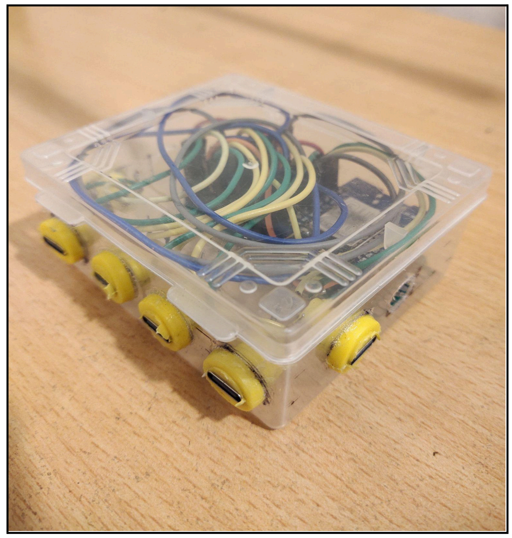


Fig. 3.3: Actuator Module

3.9 General Specifications

Parameter	Description
Microcontroller	Wemos D1 mini
Temperature/ Humidity Sensor	DHT11
Light Sensor	LDR (Light Dependent Resistor)
Water Level Sensor	Analog Water Level Sensor
Communication Protocol	WiFi (802.11 b/g/n)
Operating Voltage	5V
Dimensions	7 cm x 8 cm x 2.5 cm
Operating Temperature	-40°C to 85°C

Table 3.5: General Specifications of the Sensor Module

3.10 External system specification

3.10.1 LED Violet light

- Type: USB
- Adjustable intensity
- Adjustable color (red, blue, violet)
- Voltage at Max. Brightness: 5V, DC
- Current at Max. Brightness: 1.45A

3.10.2 Air pump

- Type: USB
- Voltage consumption: 5 – 5.1V, DC
- Current consumption: 0.15A

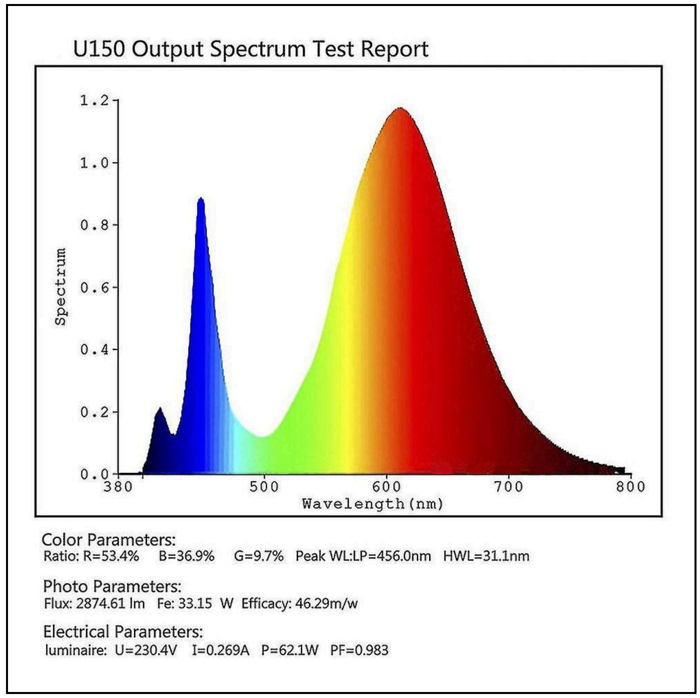


Fig. 3.4: LED Violet Light Spectrum
Source: https://www.amazon.com/dp/B07312WKX2

3.10.3 Fan

- Type: USB
- Voltage consumption at maximum speed: 5V, DC
- Current consumption at maximum speed: 0.91A

3.10.4 Water pump

- Voltage consumption: 5V
- Current consumption: 0.31A

3.11 Camera: ESP32

- FPC connector.
- Support for OV2640 (sold with a board) or OV7670 cameras.
- Image Format: JPEG(OV2640 support only), BMP, grayscale.
- Built-in LED flashlight.
- Temperature Range: Operating: -20 ℃ ~ 85 ℃
- Power Supply: 5V via pin header.
- External Storage: micro SD card slot up to 4GB.

4. BLOCK DIAGRAM AND DESCRIPTION

4.1 Block Diagram

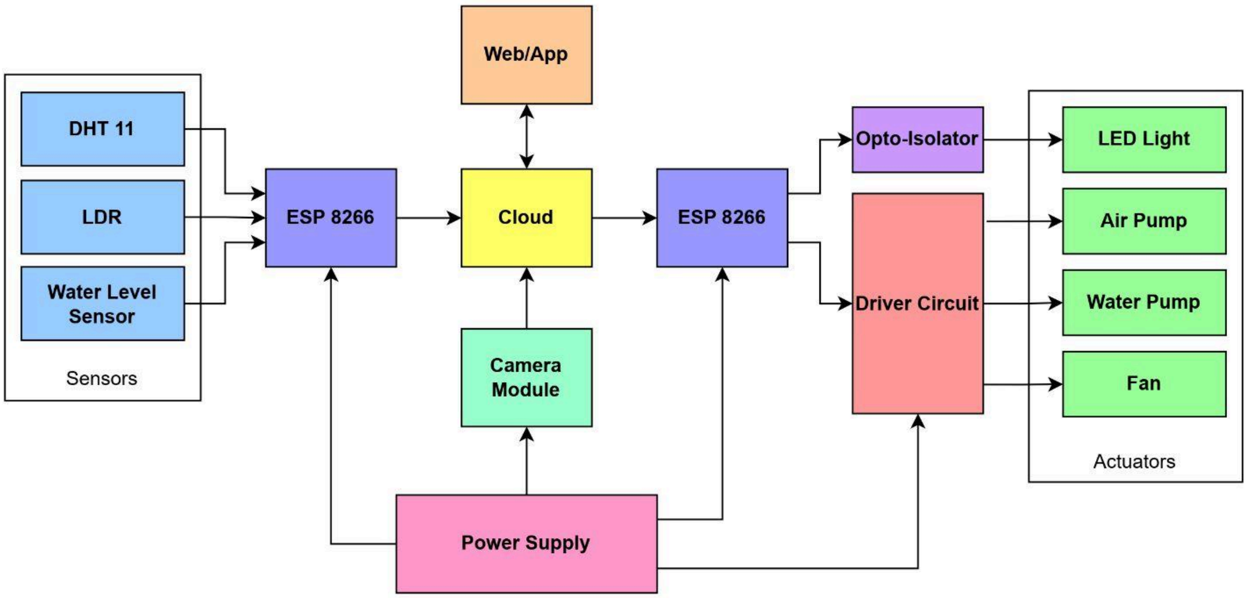


Fig. 4.1: Block Diagram of the System

4.2 Description of the block diagram

4.2.1 Sensors Block

- **Water Level Sensor:** Measures the water level in the hydroponic system to ensure it remains within the desired range and expected setup.
- **Temperature Sensor:** Monitors the temperature within the hydroponic environment for optimal plant growth. And measures the humidity levels to maintain an ideal atmosphere for plant growth.
- **LDR (Light Dependent Resistor):** Checks the light status to determine if additional artificial light is needed.

4.2.2 Controller Block

Wemos D1 mini Microcontroller: It is a compact and cost-effective WiFi module based on the ESP8266 microcontroller, enabling wireless connectivity for IoT and embedded systems.

4.2.3 IoT & Cloud Block

IoT Protocols of Communication: Enables communication with external networks or devices, allowing remote monitoring and control. MQTT and HTTP protocols are used to send and receive the data through the cloud.

4.2.4 Web/App Block

Smartphone/Web UI: Provides a user-friendly interface on a mobile app or web application for users to monitor and control the hydroponics system remotely.

4.2.5 Actuator Block

- **LED Light:** Controls the artificial lighting system to supplement natural light as needed.
- **Fan:** Regulates ventilation and air circulation within the hydroponic environment.
- **Air Pump:** Manages aeration of the nutrient solution for plant roots.
- **Water Pump:** Controls the flow of nutrient-rich water to the plant roots.

4.2.6 Camera Block

ESP32-CAM: It is a compact, Wi-Fi and Bluetooth-enabled module with a built-in camera, suitable for various IoT and image-capture applications.

4.2.7 Power Supply Block

The system requires 5V 2A power supply which we can get using mobile adapters or USB ports.

5. HARDWARE SYSTEM DESIGN

5.1 Simple Circuit Diagram

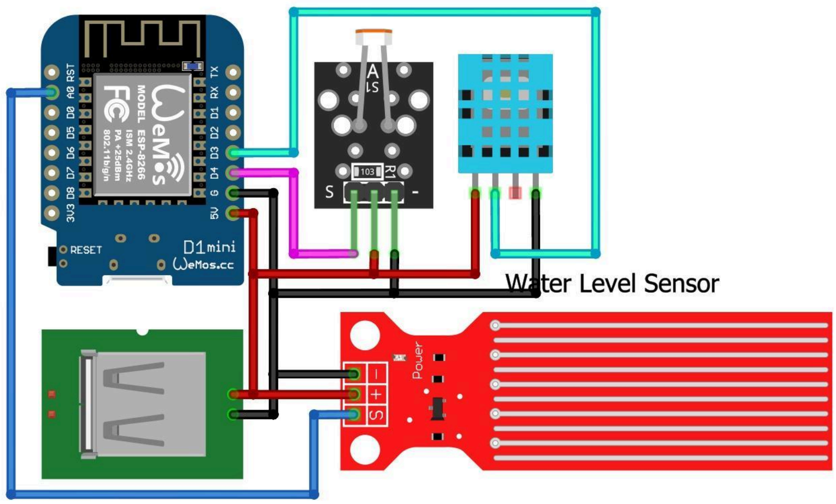


Fig. 5.1: Simple Circuit Design of the Sensor Module

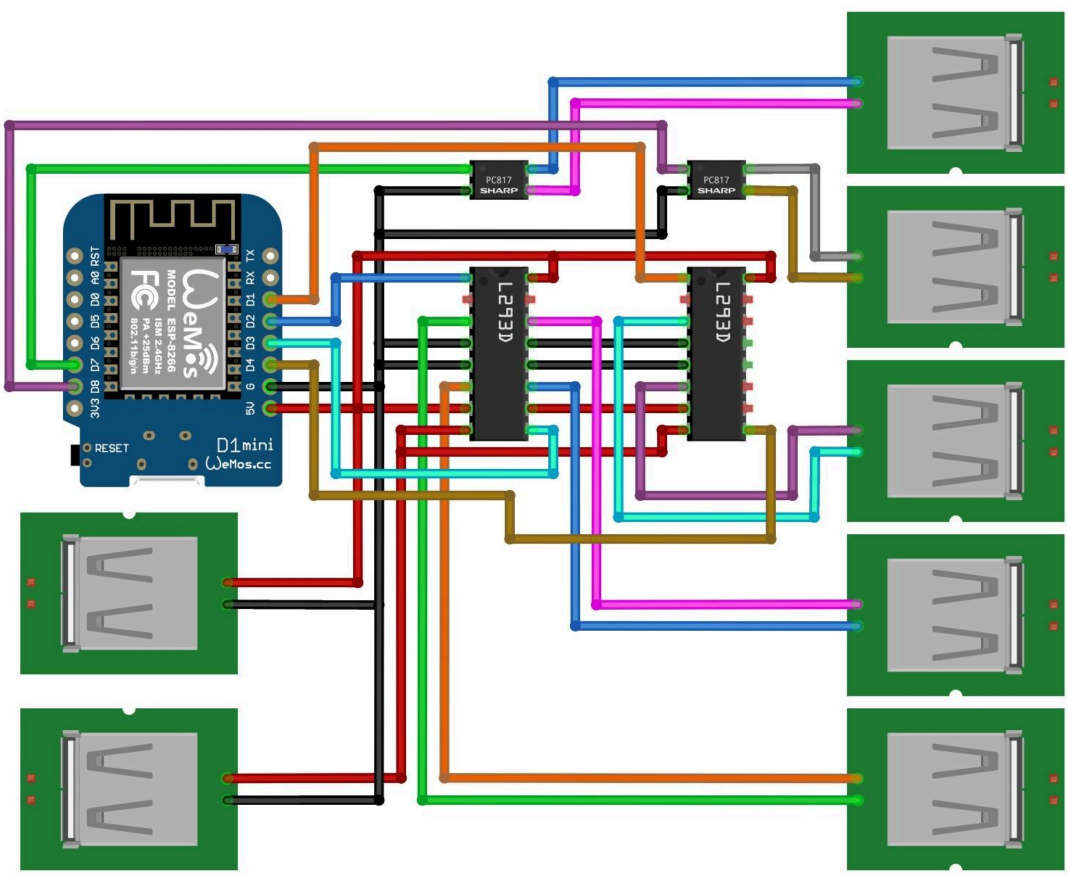


Fig. 5.2: Simple Circuit Design of the Actuator Module

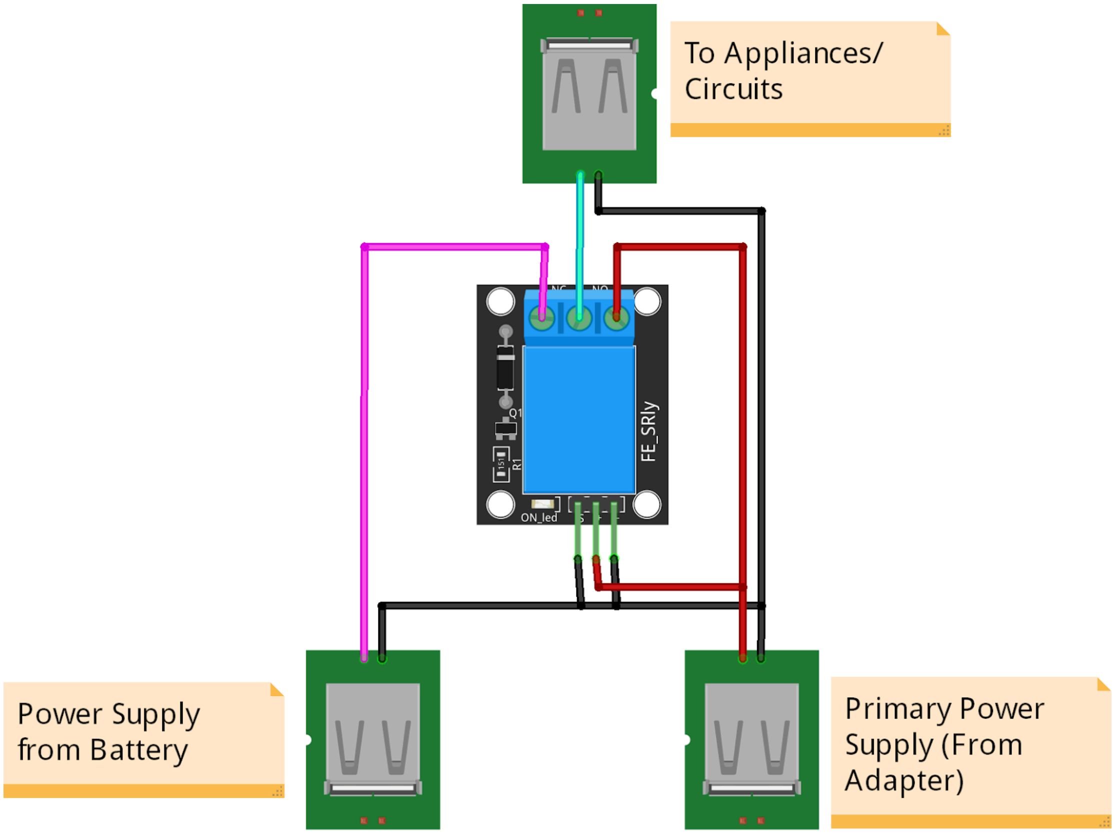


Fig. 5.3: Simple Circuit Diagram of UPS Module

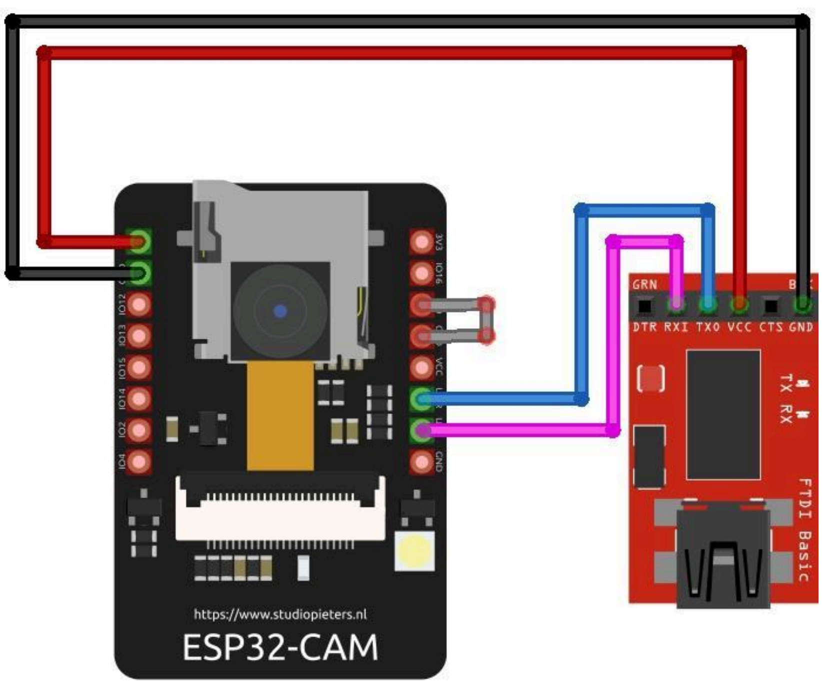


Fig. 5.4: Simple Circuit Diagram of ESP32-CAM

5.2 Schematic Circuit Diagram

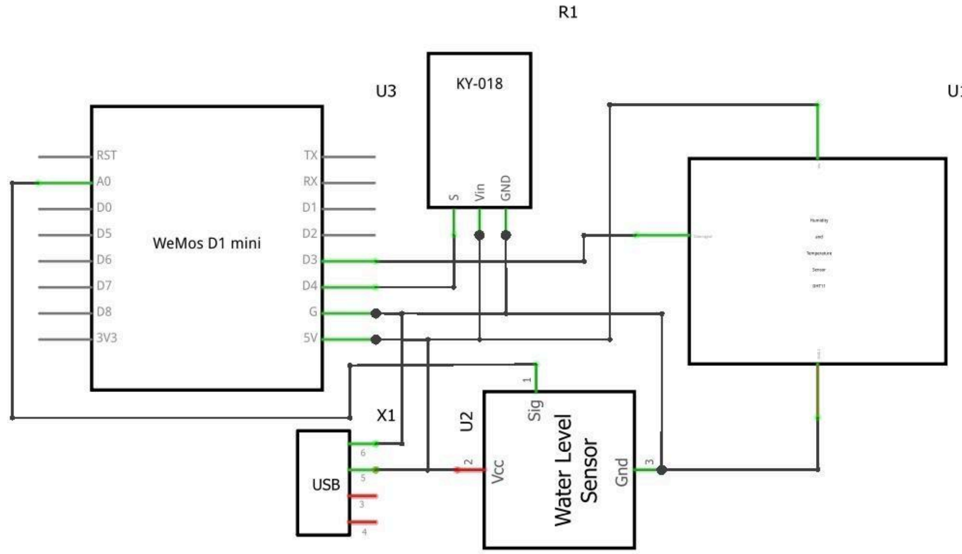


Fig. 5.5: Schematic Circuit Diagram of Sensor Module

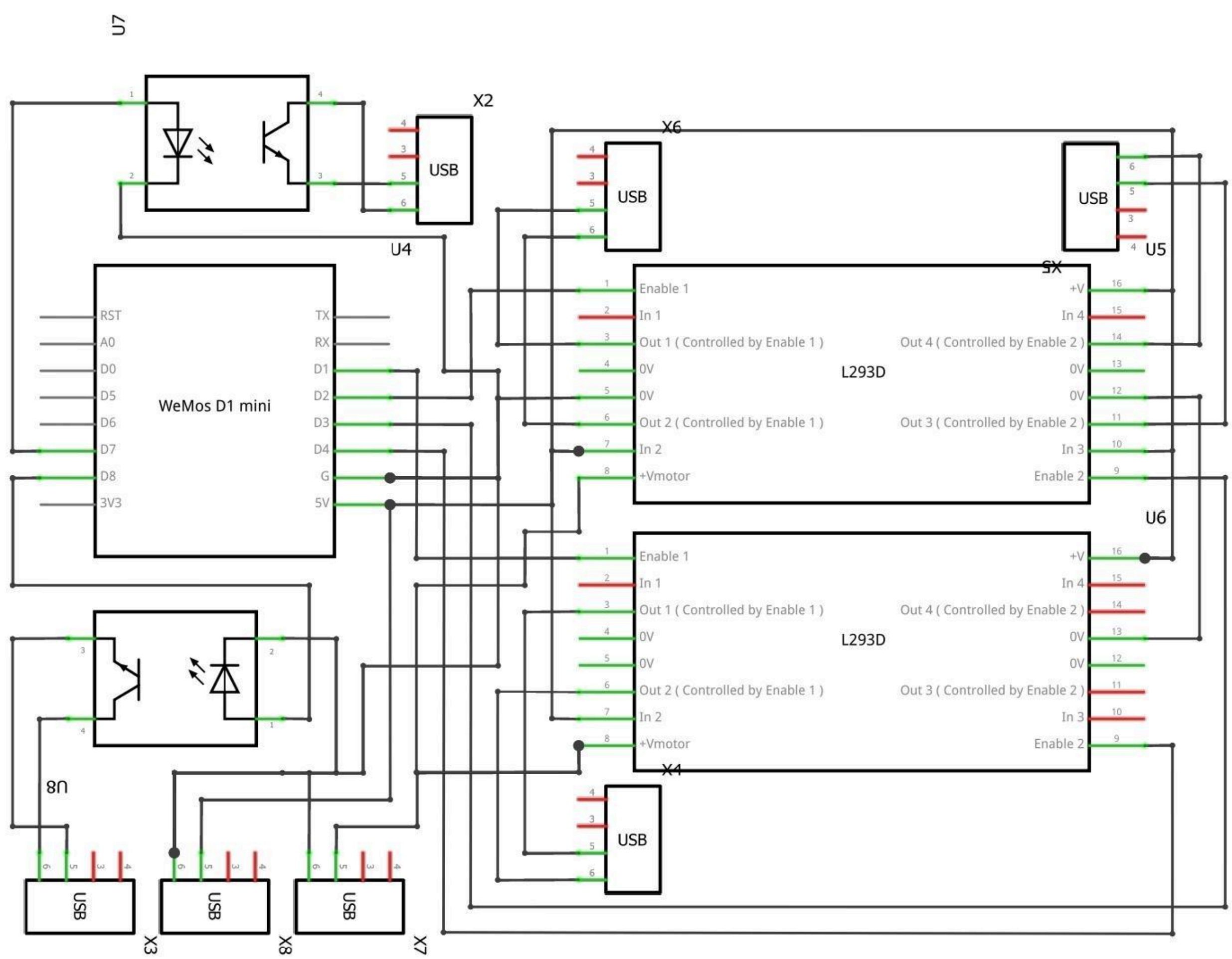


Fig. 5.6: Schematic Circuit Diagram of the Actuator Module

5.3 PCB Designing

Layers: Single Sided
Material: FR2 A Grade Material
Surface Finishing: Copper Clad
View from: Top
Wiring layer: Bottom

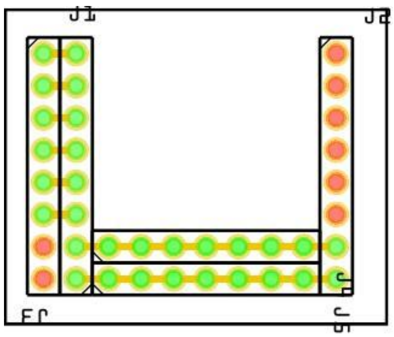
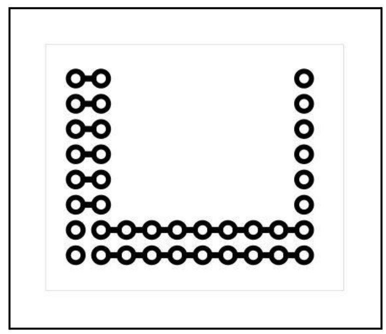
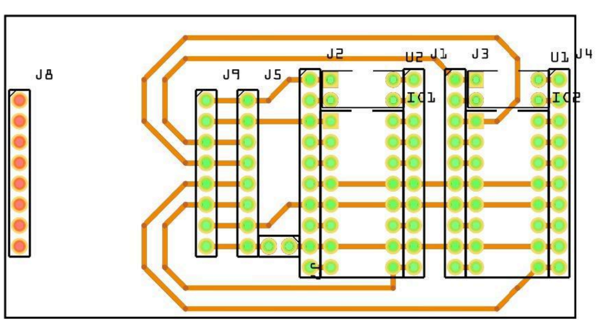
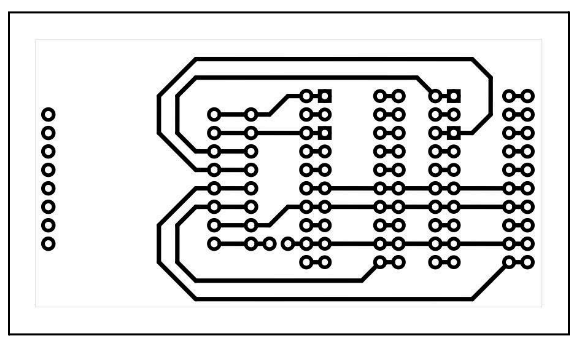
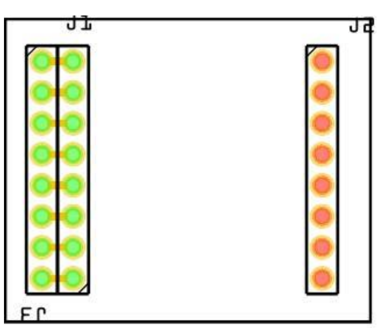
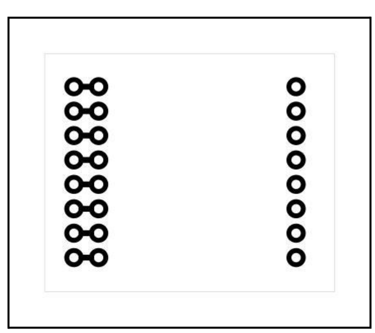
Sensor Module 	
Actuator Module 	
Camera Module 	

Table 5.1: PCB Designs

5.4 Bill of Materials

Sr. No.	Label	Part Type	Part Description	Qty/ Set	Unit Price (INR)	Total Price (INR)
1	R1	KY-018 Photoresistor Module	output type analog; pins 3;	1	22	22
2	U1	Humidity and Temperature Sensor DHT11	±5%RH ±2°C; 20-95%RH; 3.3-5.5V DC;	1	58	58
3	U2	Water Level Sensor	-	1	21	21
4	U3, U4	WeMos D1 Mini	no headers; ESP-8266EX	2	152	304
5	U5, U6	L293D	L293D; package THT	2	21	42
6	U7, U8	Sharp PC817	package THT	2	6.5	13
7	U9	ESP 32 CAM	OV2640 Module 2MP	1	439	439
8	U10	1 channel Relay Module	5V SPDT	1	33	33
9	X1 to X12	USB Connectors	target USB-A;	12	5	60
		Hardware Cost				**992**

5.4.1 Setup Cost

Sr. No.	Components	Qty	Unit Price	Total Price
1	UV light	1	1799	1799
2	Air Pump	1	499	499
3	Water Pump	1	90	90
4	Fan	1	240	240
5	Hydroponic Starter Kit	2	1599	3198
	Setup Cost			**5826**
	Total Cost			**6818**

5.5 Specifications of the Components

<table>
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Wemos D1 mini

Microcontroller: ESP8266EX
Operating Voltage: 3.3V
Digital I/O Pins: 11 (can be used as GPIO, PWM, I2C, and more)
Analog Input Pins: 1 (3.2V max)
Flash Memory: 4 MB
Wi-Fi: 802.11 b/g/n (2.4 GHz)
USB-to-Serial Converter: CH340G
Built-in LED: GPIO 2
Reset Button: Yes
Temperature Range: -40°C to +125°C
Dimensions: 34.2mm x 25.6mm

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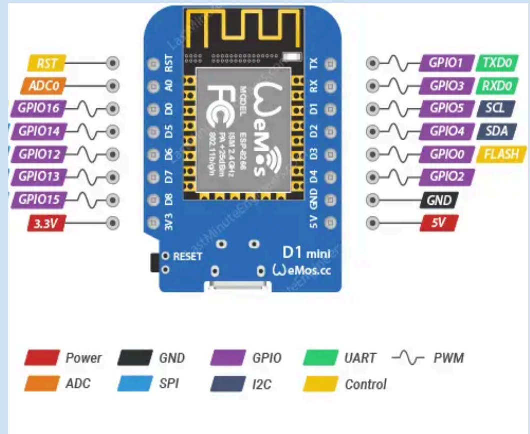

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L293D Motor Driver

Motor Supply Voltage (VS): 4.5V to 36V
Logic Supply Voltage (VSS): 4.5V to 7V
Output Current (per channel): 600 mA (1.2A peak for short durations)
Total Output Current (all channels combined): 1.2A (2.4A peak)
Number of Channels: 4 (two H-bridges)
Enable/Disable Feature: Yes (enable pin for each H-bridge)
Operating Temperature Range: 0°C to 70°C

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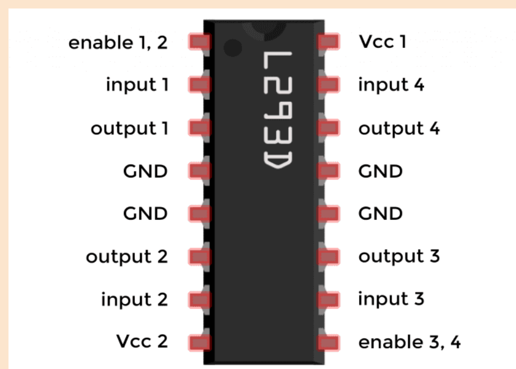

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DHT11 Sensor

Operating Voltage: 3.3V to 5.5V
Temperature Range: 0°C to 50°C
Temperature Accuracy: ±2°C
Humidity Range: 20% to 80%
Humidity Accuracy: ±5%
Communication Protocol: Single-wire digital signal
Response Time: 2 seconds
Calibration: Factory calibrated
Low Power Consumption: 0.5 mA (average)
Dimensions: 15.5mm x 12mm x 5.5mm

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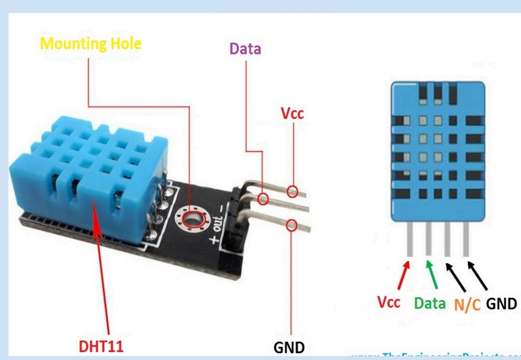

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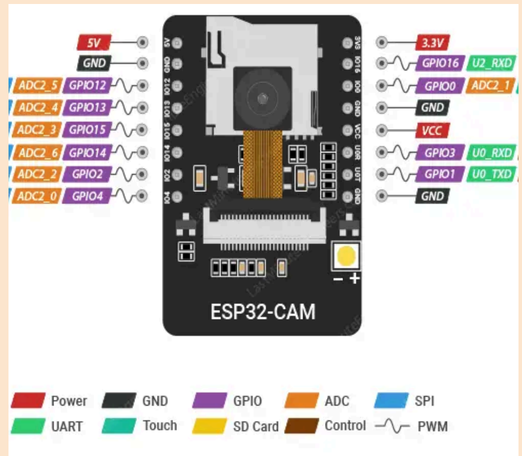
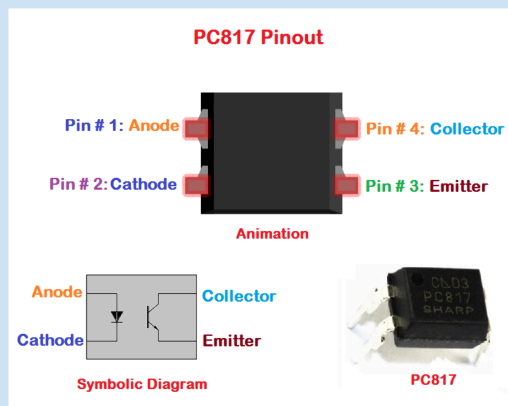
ESP 32- CAM

Microcontroller: ESP32-S Module (Dual-core Tensilica LX6 microprocessor)
Operating Voltage: 5V
Flash Memory: 4 MB
Camera: OV2640 (2 Megapixels)
Wi-Fi: 802.11 b/g/n (2.4 GHz)
Bluetooth: Bluetooth v4.2 BR/EDR and BLE
Digital I/O Pins: 10 (can be used as GPIO, PWM, I2C, etc.)
UART/I2C/SPI Interfaces: Yes
USB-to-Serial Converter: CP2102
Operating Temperature Range: -40°C to +125°C
Dimensions: Approximately 27mm x 40.5mm
</td>
<td>


</td>
</tr>
<tr>
<td>
PC 817 Opto-Isolator

Isolation Voltage: 5000Vrms (minimum)
Collector-Emitter Breakdown Voltage (VCEO): 80V (minimum)
Collector Current (IC): 50mA (continuous)
Collector Current (IC): 150mA (peak, 10% duty cycle)
Emitter-Collector Breakdown Voltage (VECO): 7V (maximum)
Forward Current (IF): 60mA (maximum)
Power Dissipation (PD): 150mW (total package)
Operating Temperature Range: -55°C to +110°C
Package Type: DIP-4 (Dual In-line Package with 4 pins)
</td>
<td>


</td>
</tr>
<tr>
<td>
Light Dependent Resistor

Dark Resistance (R_dark): 1 M ohm
Light Resistance (R_light): 10 k ohms
Sensitivity: 100 ohms per lux
Spectral Response: 400 nm to 700 nm (visible light range)
Operating Temperature Range: -40°C to +70°C
Response Time: 20 milliseconds (typical)
</td>
<td>

</td>
</tr>
</table>

Table 5.2: Specification of the Components

5.6 MATLAB Emulation

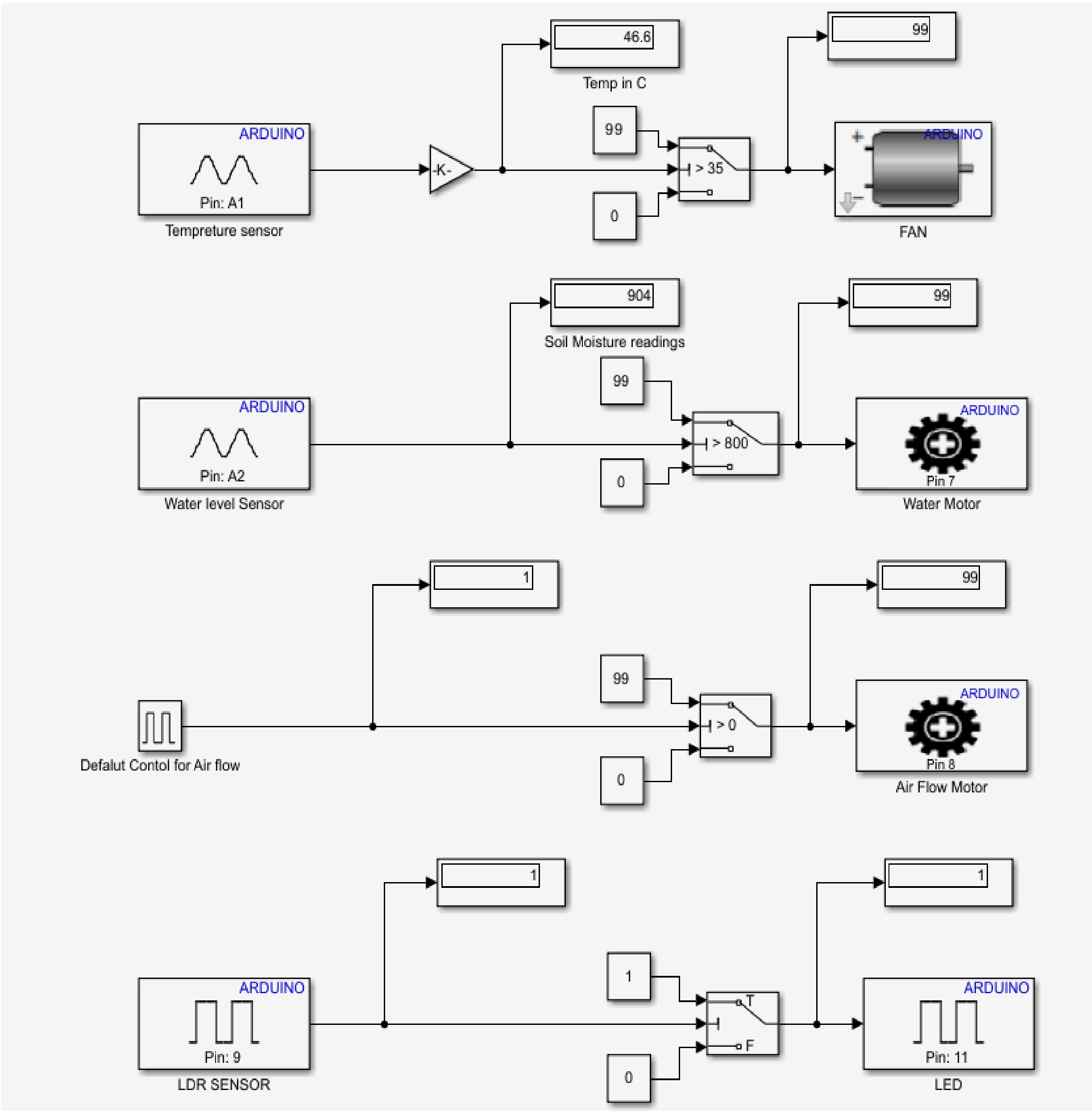


Fig. 5.7: Matlab Emulation of the System

5.7 Enclosure Designs

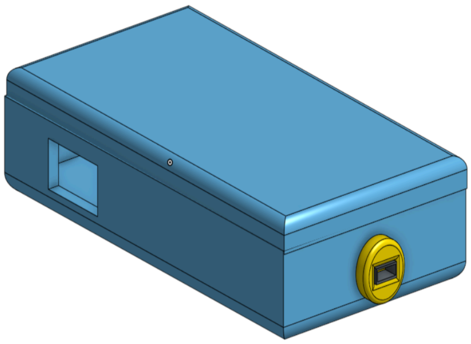


Fig. 5.8: 3D Enclosure Design of the Sensor Module

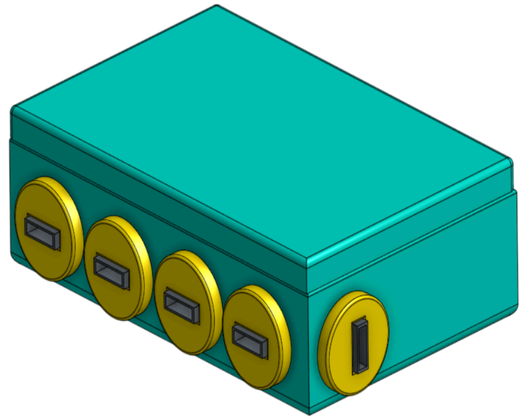


Fig. 5.9: 3D Enclosure Design of the Actuator Module

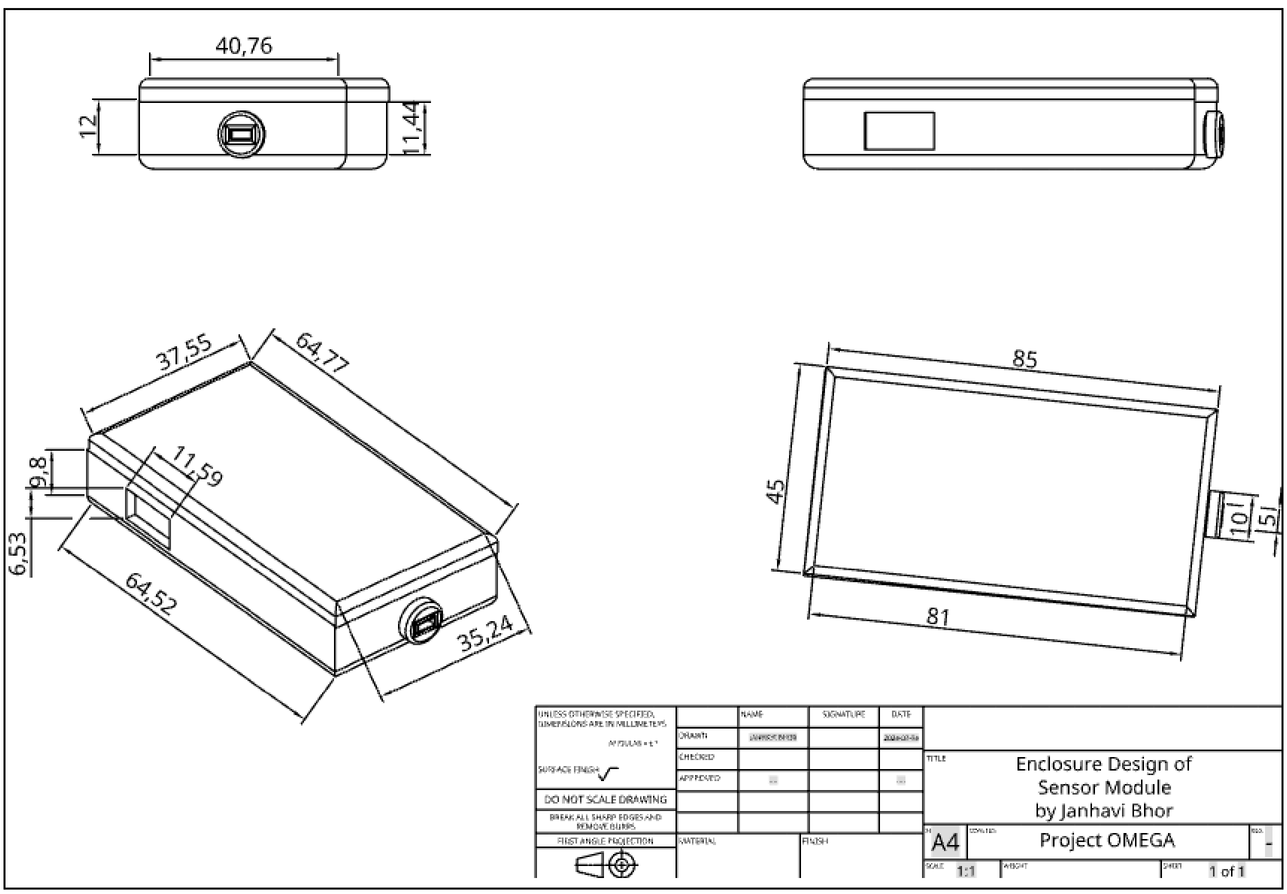


Fig. 5.10: 2D Design of the Sensor Module

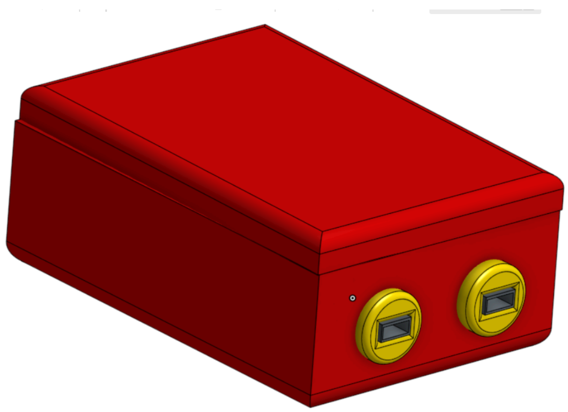


Fig. 5.11: 3D EnclosureDesign of the UPS Module

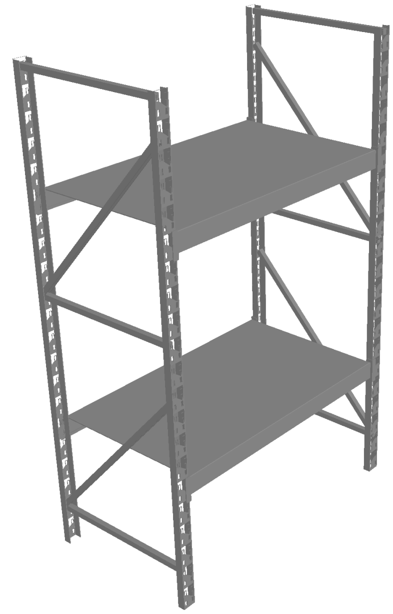


Fig. 5.12: 3D EnclosureDesign of the Stack

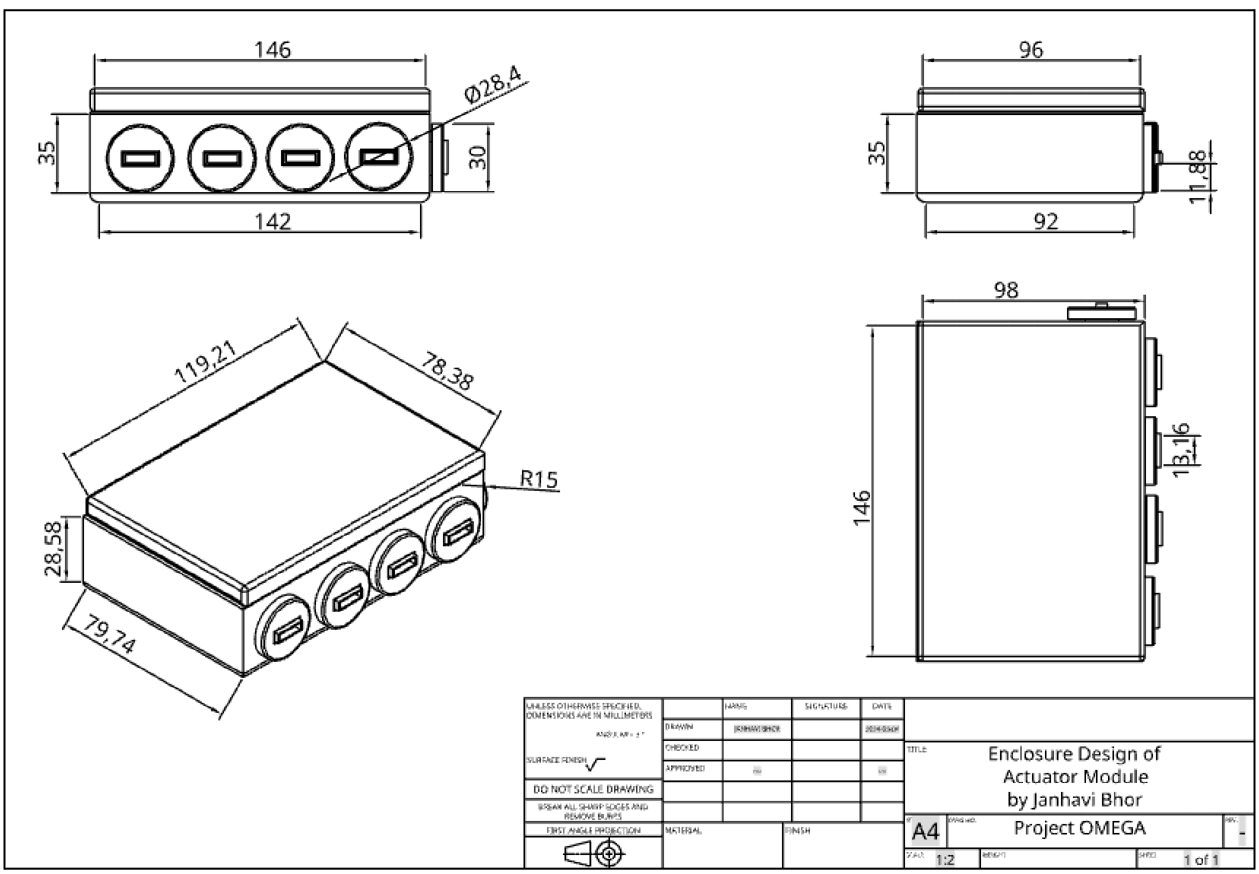
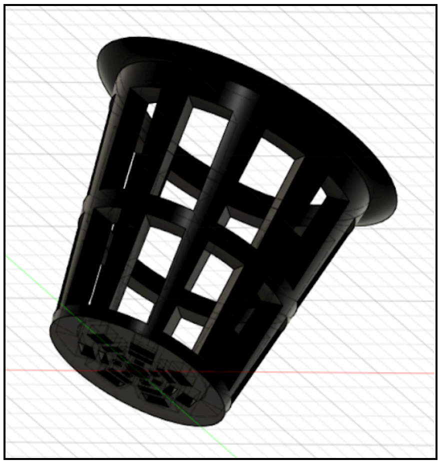


Fig. 5.13: 2D Design of the Actuator Module



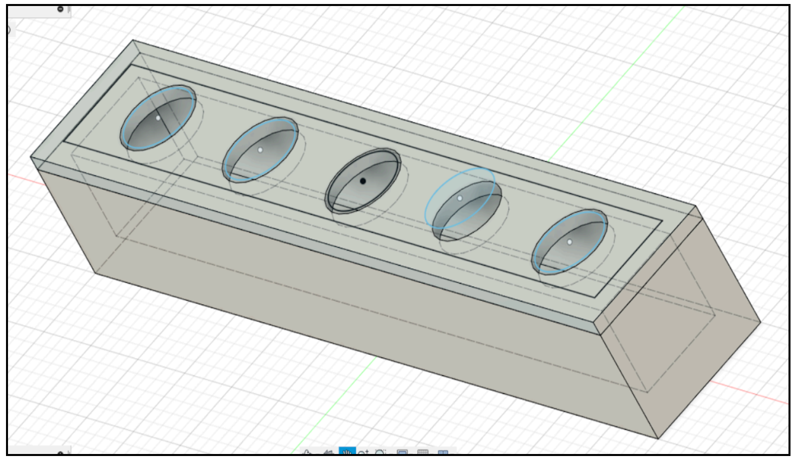


Fig. 5.14: 3D Enclosure Design of the NetPot

Fig. 5.15: 3D Enclosure Design of the Hydroponic Tank

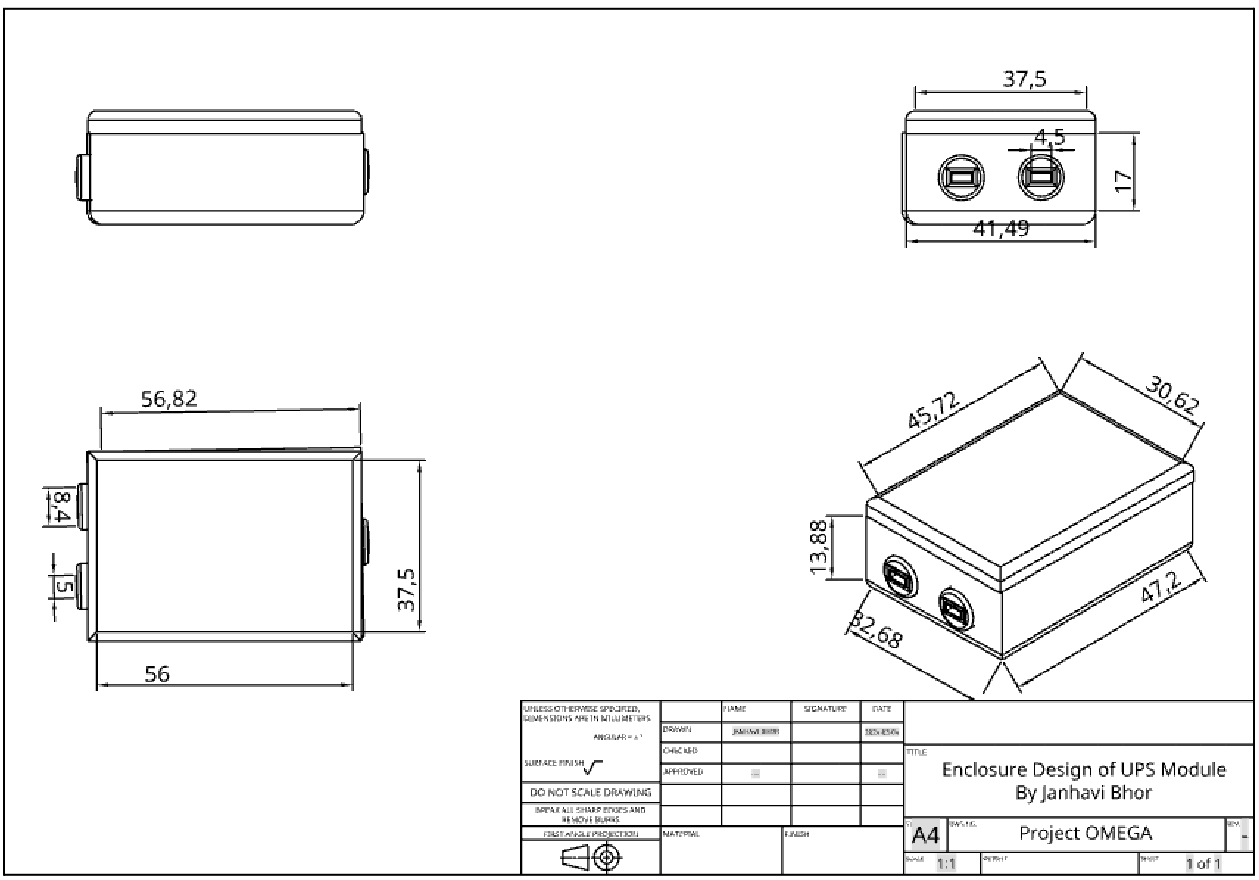


Fig. 5.16: 2D Design of the UPS Module

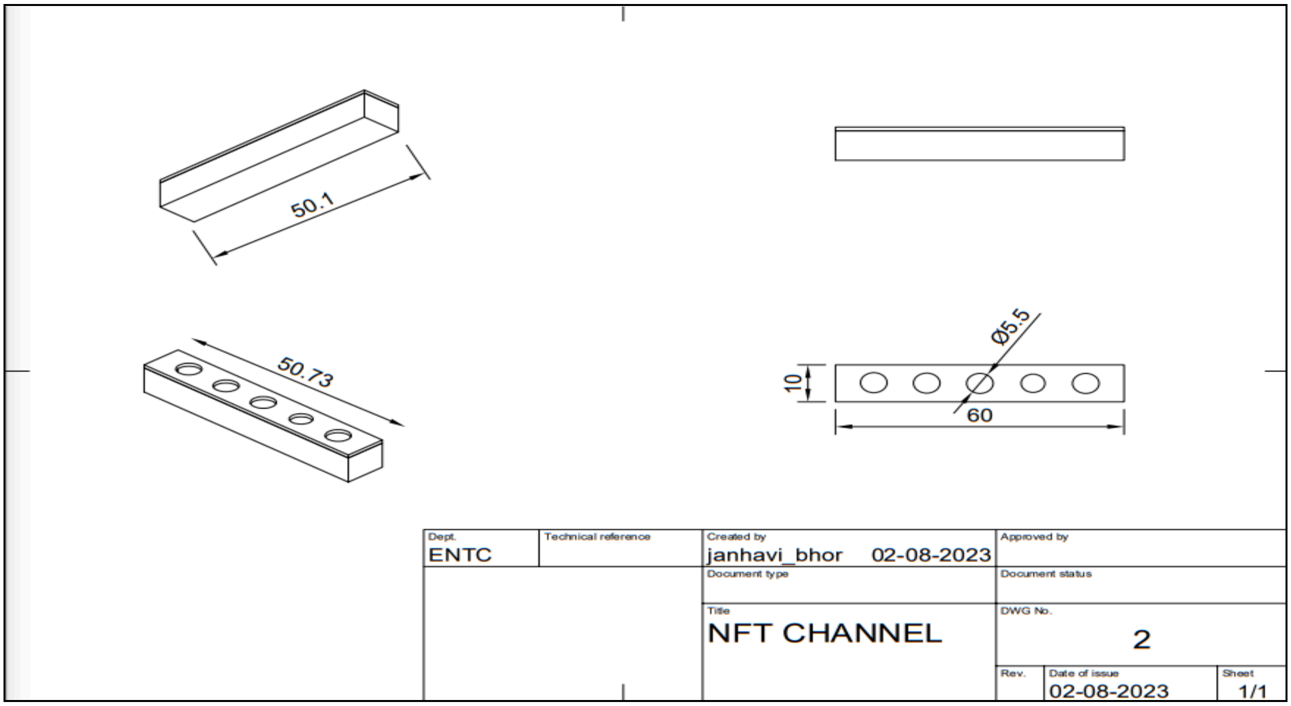


Fig. 5.17: 2D Design of the Hydroponic Tank

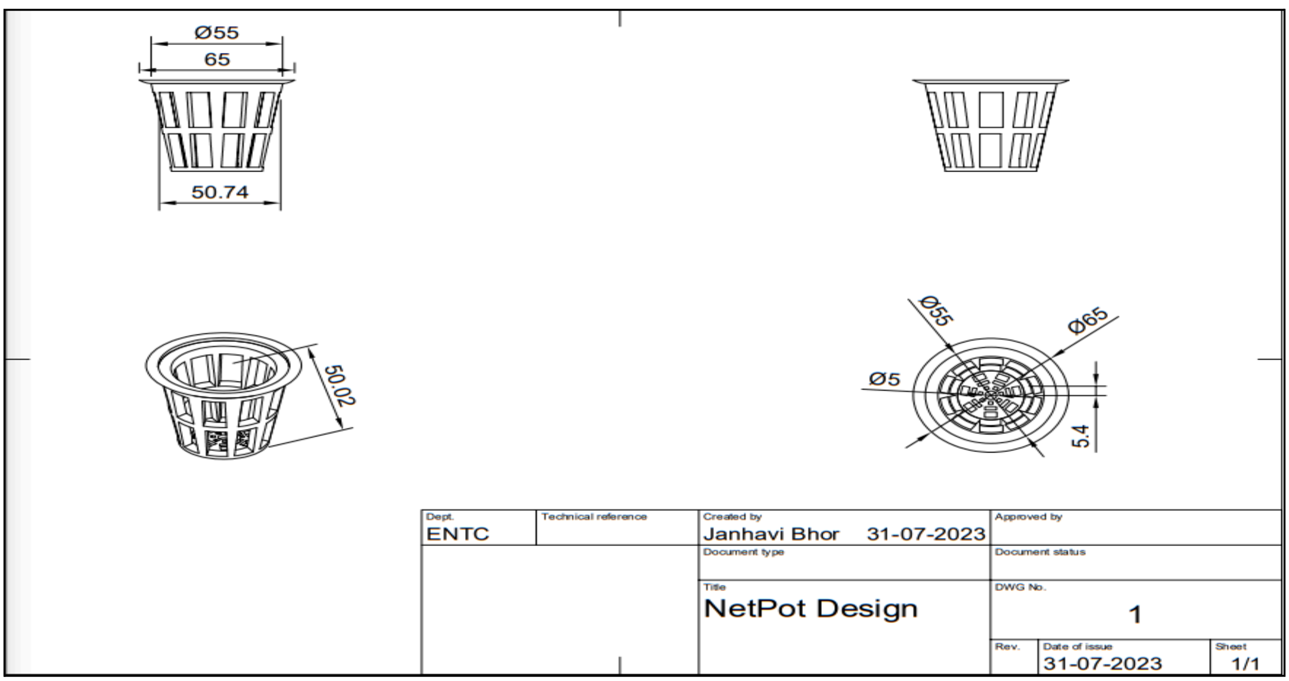


Fig. 5.18: 2D Design of the NetPot

6. SOFTWARE SYSTEM DESIGN

6.1 Flowchart of the Sensor Module

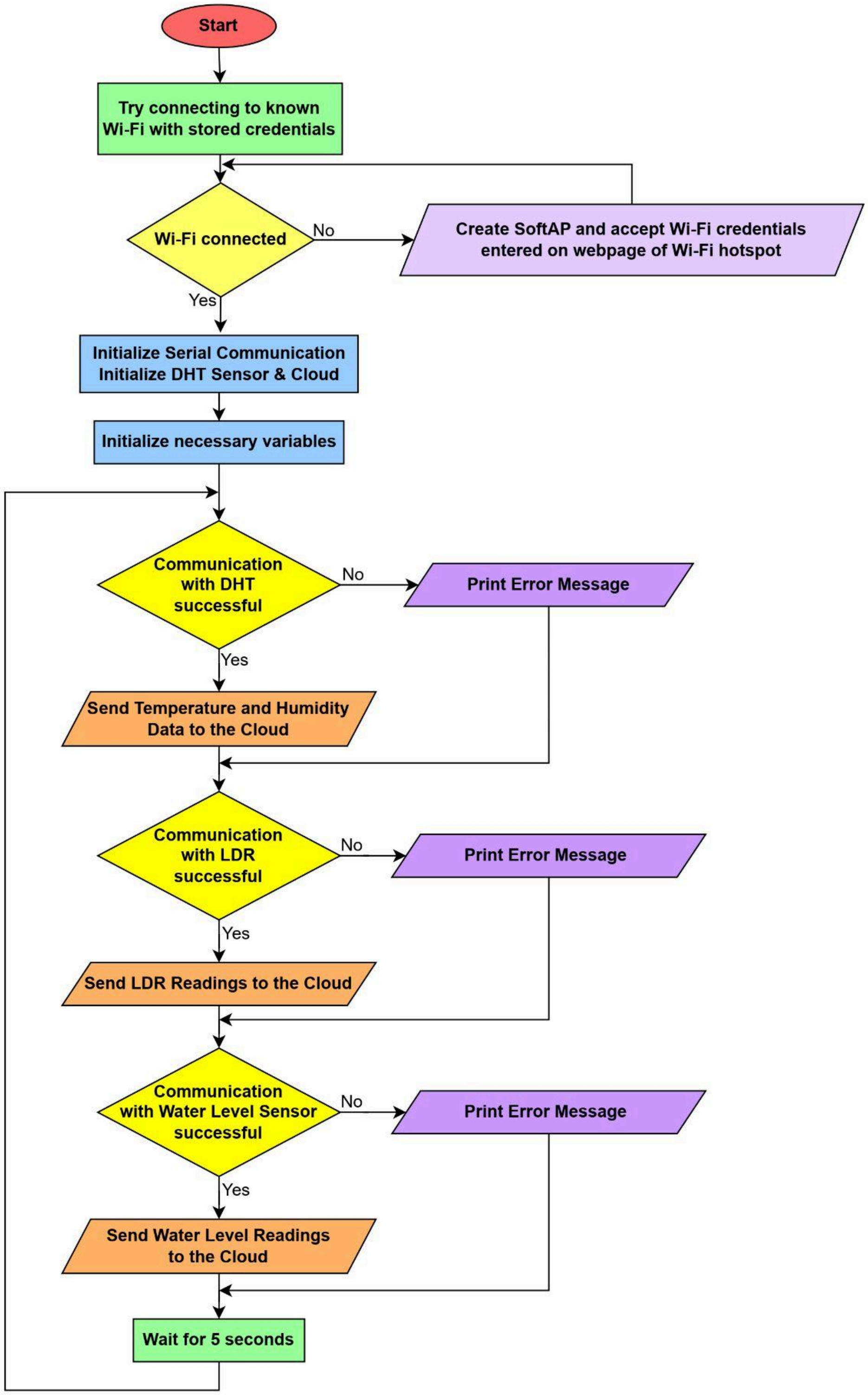


Fig. 6.1: Flowchart of the Sensor Module

6.2 Flowchart of the Actuator Module

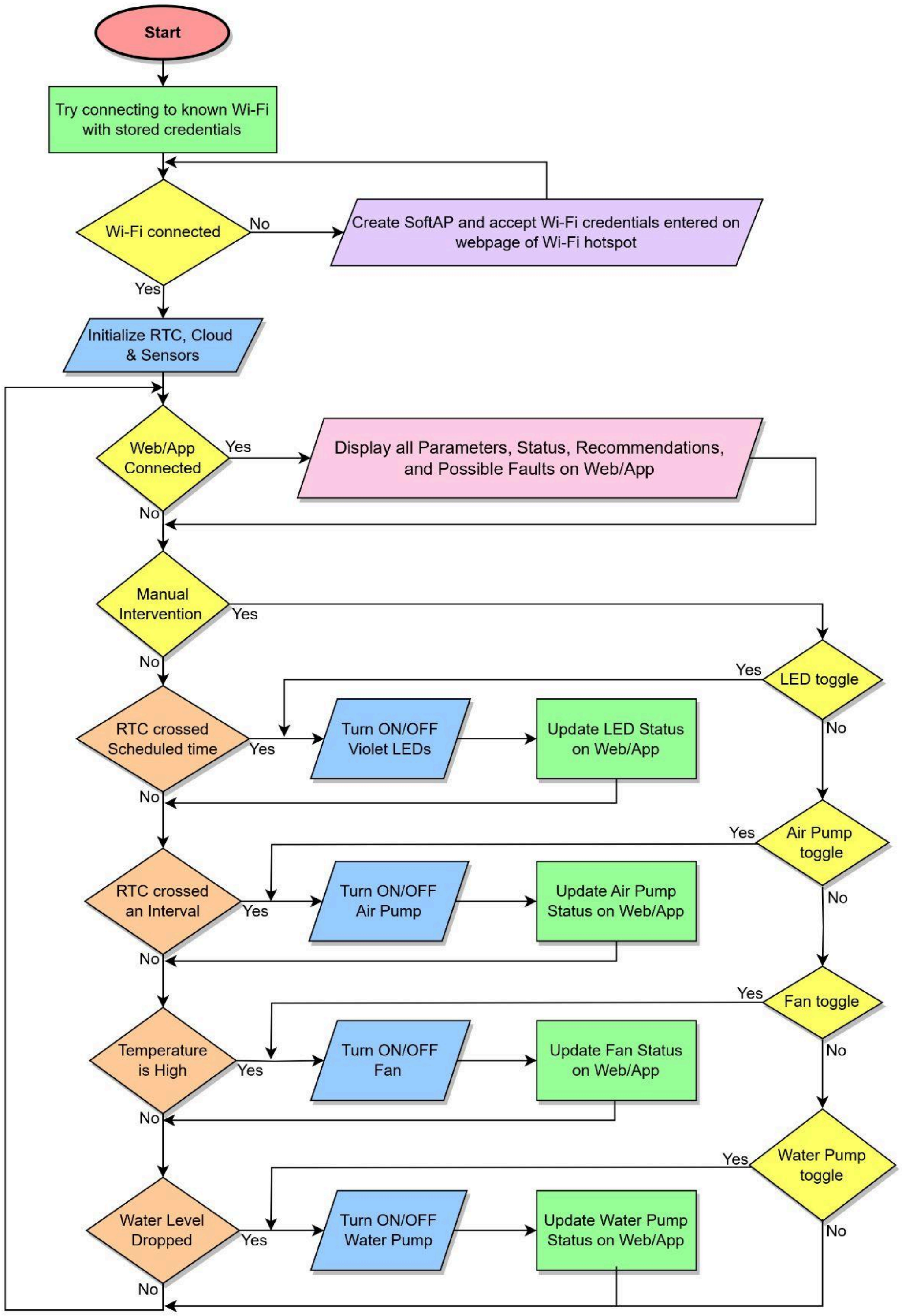


Fig. 6.2: Flowchart of the Actuator Module

6.3 Cloud Architecture

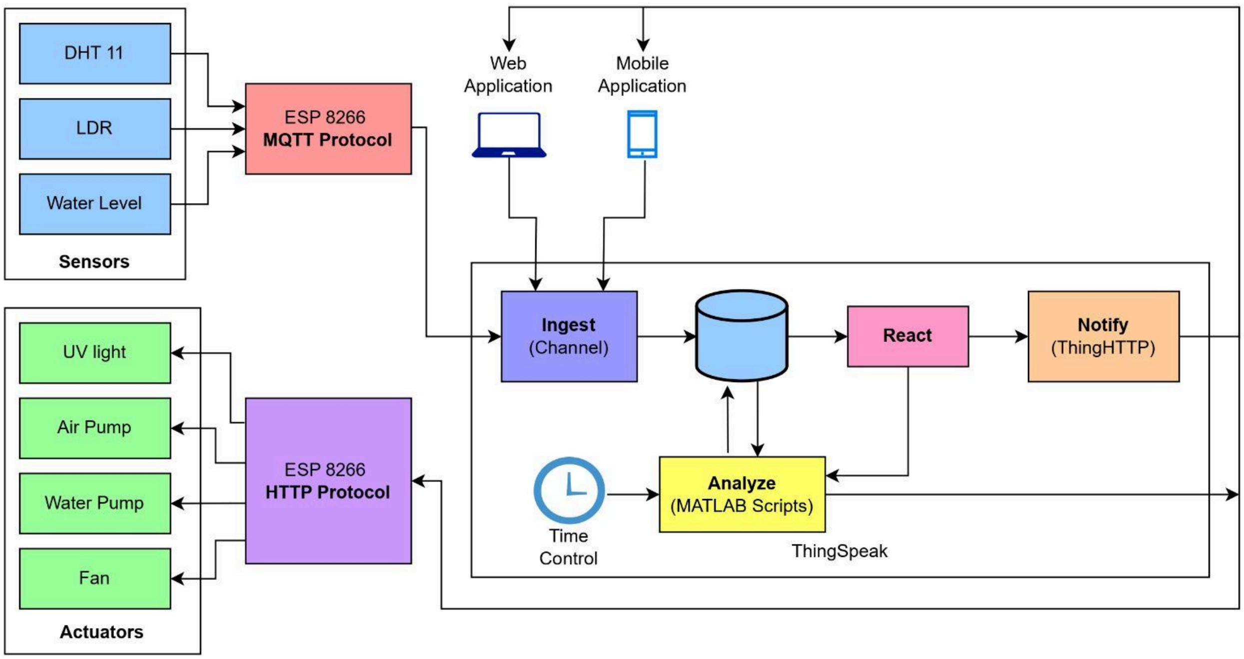


Fig. 6.3: Cloud Architecture

6.4 Power Optimization using Time Slotting

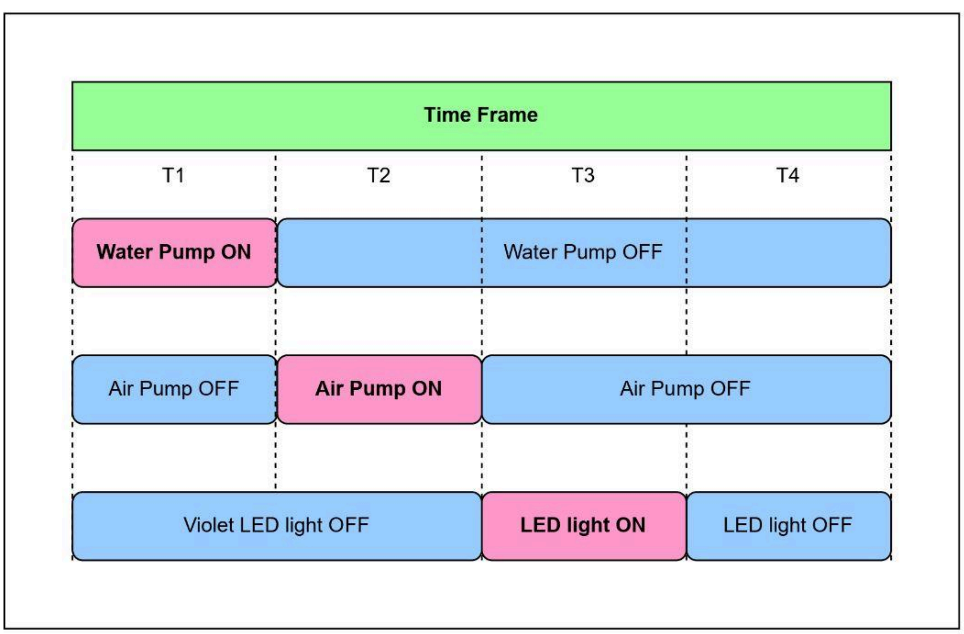


Fig. 6.4: Power Optimization using Time Slotting

6.5 Unit & Integration Testing

6.5.1 Unit Testing of the Actuator Module

Test Case	Description	Expected Result	Actual Result	Pass/Fail
1	Verify WiFiManager setup	WiFiManager initializes successfully	Initialization successful	Pass
2	Check the initialization of ThingSpeak	ThingSpeak client initialized without errors	Initialization without errors	Pass
3	Test WiFi connection	Successfully connect to the WiFi network	Connected to WiFi	Pass
4	Verify GPIO pin modes	Ensure correct initialization of GPIO pins	GPIO pins initialized correctly	Pass
5	Check LED control logic	Validate the control logic for LEDs based on ThingSpeak data	LED control logic functioning as expected	Pass

Table 6.1: Unit Testing of the Actuator Module

6.5.2 Integration Testing of the Actuator Module

Test Case	Description	Expected Result	Actual Result	Pass/Fail
1	Verify end-to-end functionality	Actuator Module successfully connects to WiFi, reads ThingSpeak data, and controls actuators accordingly	All steps completed successfully	Pass
2	Test error handling	Simulate WiFi connection failure and ensure proper error handling and recovery	WiFi connection failure handled, and recovery successful	Pass
3	Check for correct ThingSpeak integration	Confirm that the Actuator Module reads data from the specified ThingSpeak fields and performs as expected	Data read from ThingSpeak and actuators controlled correctly	Pass

4	Validate actuation scenarios	Test various scenarios for actuation based on different values of ThingSpeak fields	Actuators respond appropriately to different scenarios	Pass
5	Test restart functionality	Verify that the Actuator Module restarts if WiFi connection issues persist	Module restarts when WiFi connection issues persist	Pass

Table 6.2: Integration Testing of the Actuator Module

6.5.3 Unit Testing of the Sensor Module

Test Case	Description	Expected Result	Actual Result	Pass/Fail
UT-001	Verify successful initialization of WiFiManager	WiFiManager connects successfully to WiFi	Connected to WiFi	Pass
UT-002	Check DHT sensor initialization	DHT sensor is initialized without errors	Sensor initialized without errors	Pass
UT-003	Read temperature from DHT sensor	Temperature reading within expected range	25.5°C	Pass
UT-004	Read humidity from DHT sensor	Humidity reading within expected range	55%	Pass
UT-005	Read analog input from LDR	Analog value is read successfully	450	Pass
UT-006	Read the water level from ThingSpeak	Water level reading retrieved successfully	1	Pass
UT-007	Write temperature data to ThingSpeak	Temperature data successfully written to ThingSpeak	Data written successfully	Pass
UT-008	Write humidity data to ThingSpeak	Humidity data successfully written to ThingSpeak	Data written successfully	Pass
UT-009	Write LDR value to ThingSpeak	LDR value successfully written to ThingSpeak	Data written successfully	Pass
UT-010	Write water level data to ThingSpeak	Water level data successfully written to ThingSpeak	Data written successfully	Pass

Table 6.3: Unit Testing of the Sensor Module

6.5.4 Integration Testing of the Sensor Module

Test Case	Description	Expected Result	Actual Result	Pass/Fail
IT-001	Ensure WiFi connection and ThingSpeak initialization	WiFi connection and ThingSpeak initialization successful	Connected to WiFi and ThingSpeak initialized successfully	Pass
IT-002	Verify seamless data transmission to ThingSpeak	Data is transmitted to ThingSpeak without errors	Data transmitted without errors	Pass
IT-003	Check correct execution of loop() function	Loop function executes without errors	Loop function executed successfully	Pass

Table 6.4: Integration Testing of the Sensor Module

6.6 Wireframe

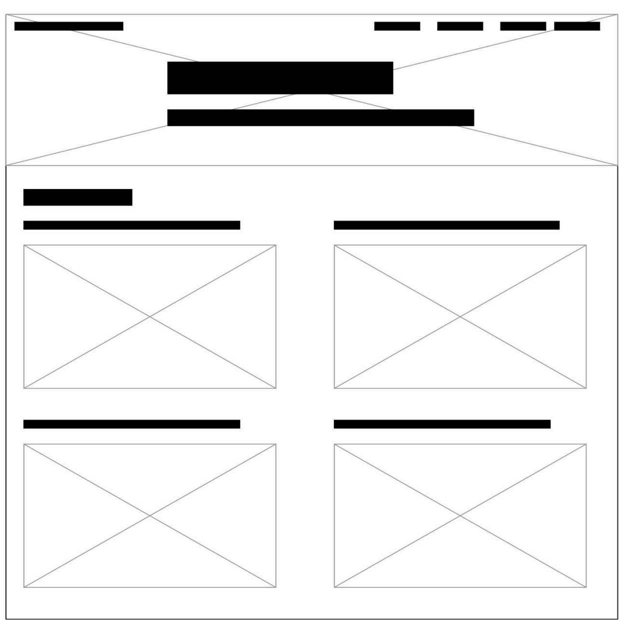


Fig. 6.5: Wireframe Design to Display the Sensor Data

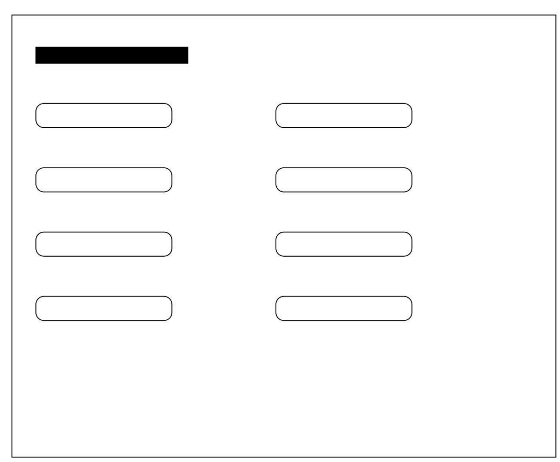


Fig. 6.6: Wireframe Design to Control the Actuators

6.7 Flowchart of the Webpage/Application

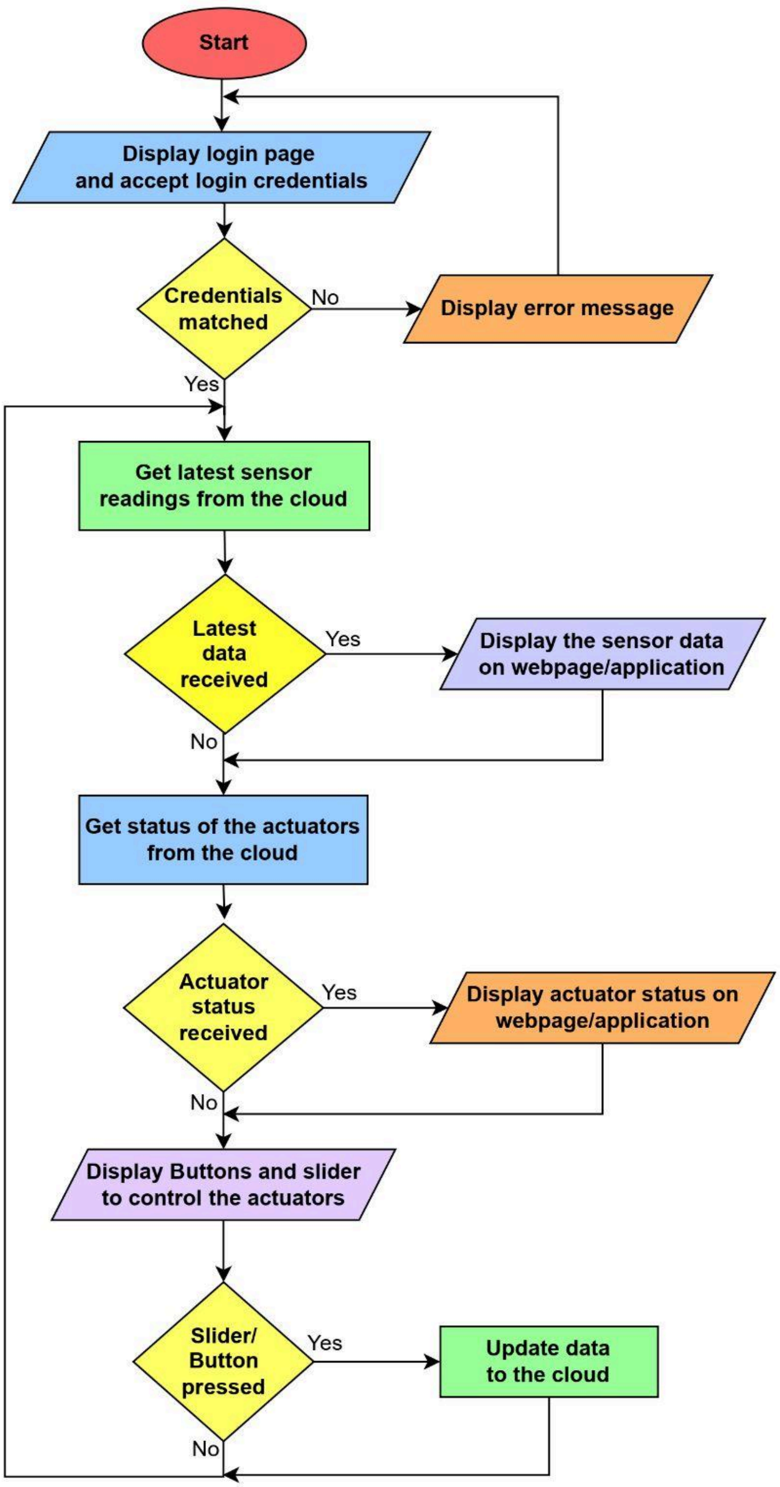


Fig. 6.7: Flowchart of the Webpage/Application

6.8 Steps to Train AI with Images

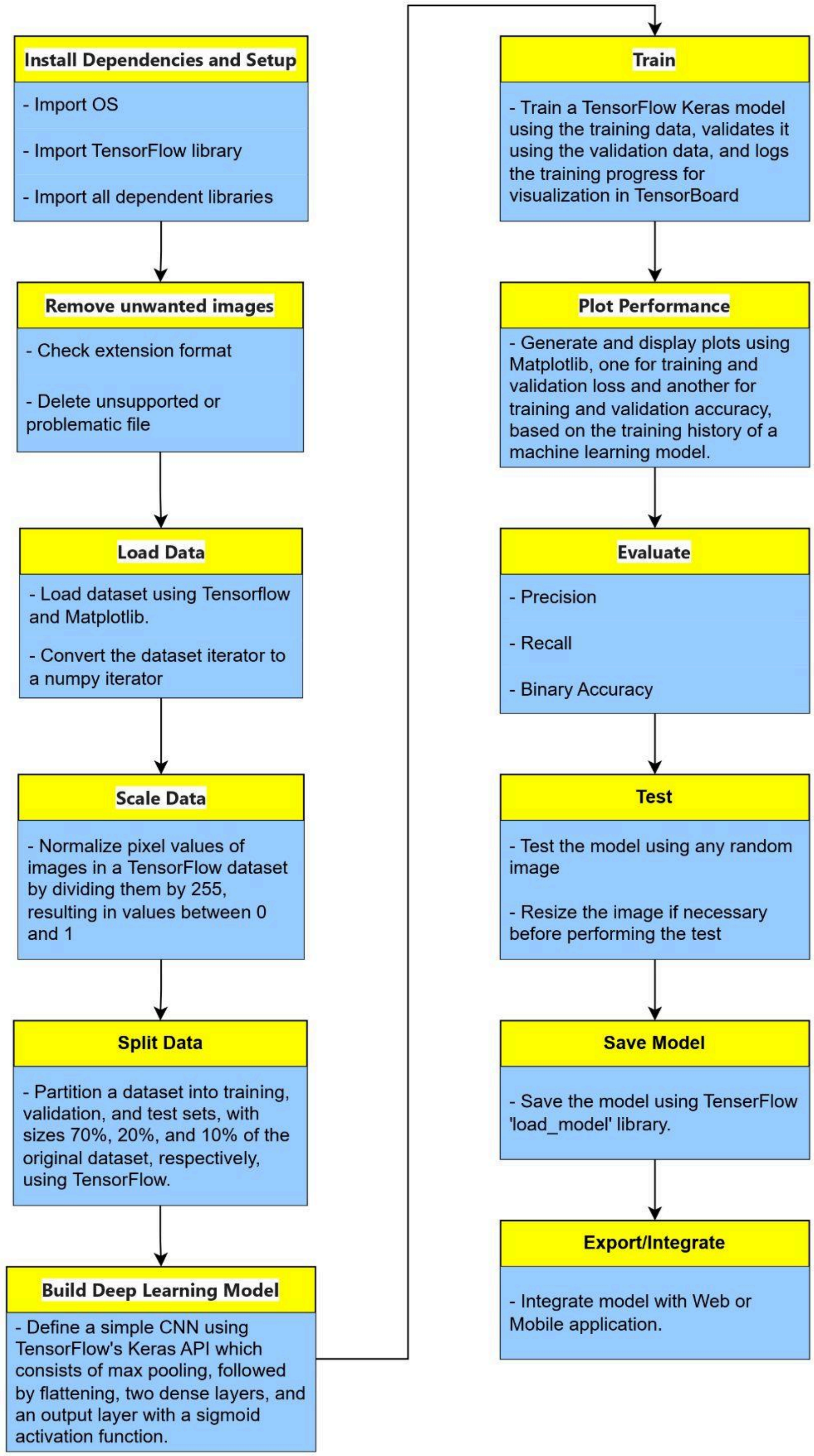


Fig. 6.8: Steps to Train AI with Images

7. RESULT & DISCUSSION

7.1 Final Setup

Fig 7.1: Final Setup with Lights OFF

Fig 7.2: Final Setup with Lights ON

The two-stack hydroponic automation system integrates LED violet lights, an air pump, a water pump, and a fan, all managed by sensor and actuator modules alongside a UPS module for uninterrupted power supply. This setup optimizes plant growth by providing consistent light, proper aeration, and hydration. Additionally, a time schedule control feature schedules the activation of UV lights and the air pump according to preset timings.

The sensor module regulates environmental conditions, while the actuator module adjusts settings accordingly, ensuring optimal growth conditions. A UPS module guarantees continuous operation, safeguarding against power interruptions. A photo of the system reveals thriving plants on the 22nd day after sowing seeds, highlighting the effectiveness of the automated hydroponic setup in nurturing plant growth.

7.2 Wi-Fi Credentials Change

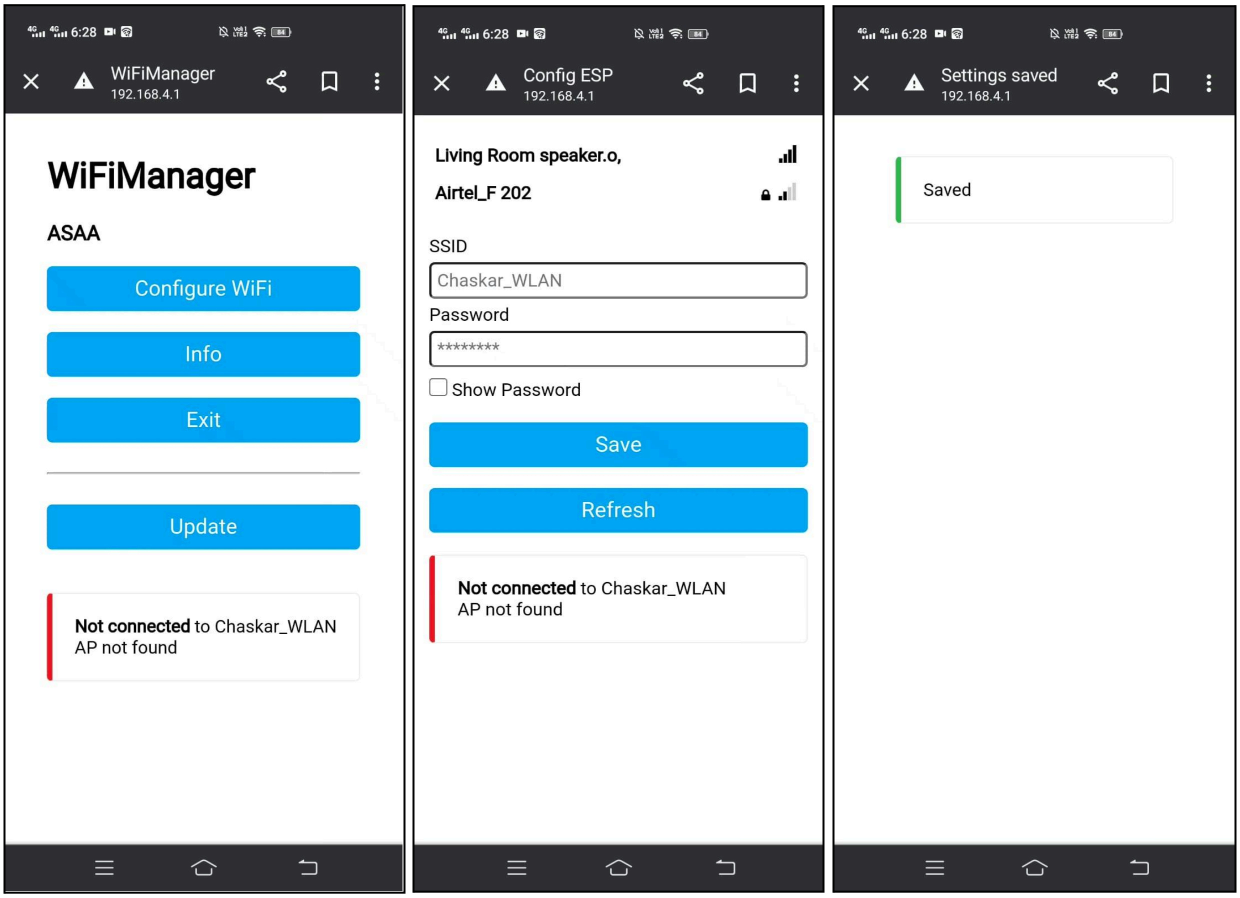


Fig. 7.3: Screenshots taken while changing the Wi-Fi credentials

This hydroponic automation system offers the flexibility of configuring Wi-Fi credentials for both sensor and actuator modules, akin to setting up new products from the market. Employing softAP technology, the system enables seamless integration into existing Wi-Fi networks. Screenshots detailing the process of changing credentials are provided, showcasing the user-friendly interface.

The implementation utilizes the Wi-Fi manager library, streamlining the configuration process. This feature enhances accessibility and adaptability, allowing users to easily connect the automation system to their preferred Wi-Fi networks with minimal hassle.

7.3 Web Interface

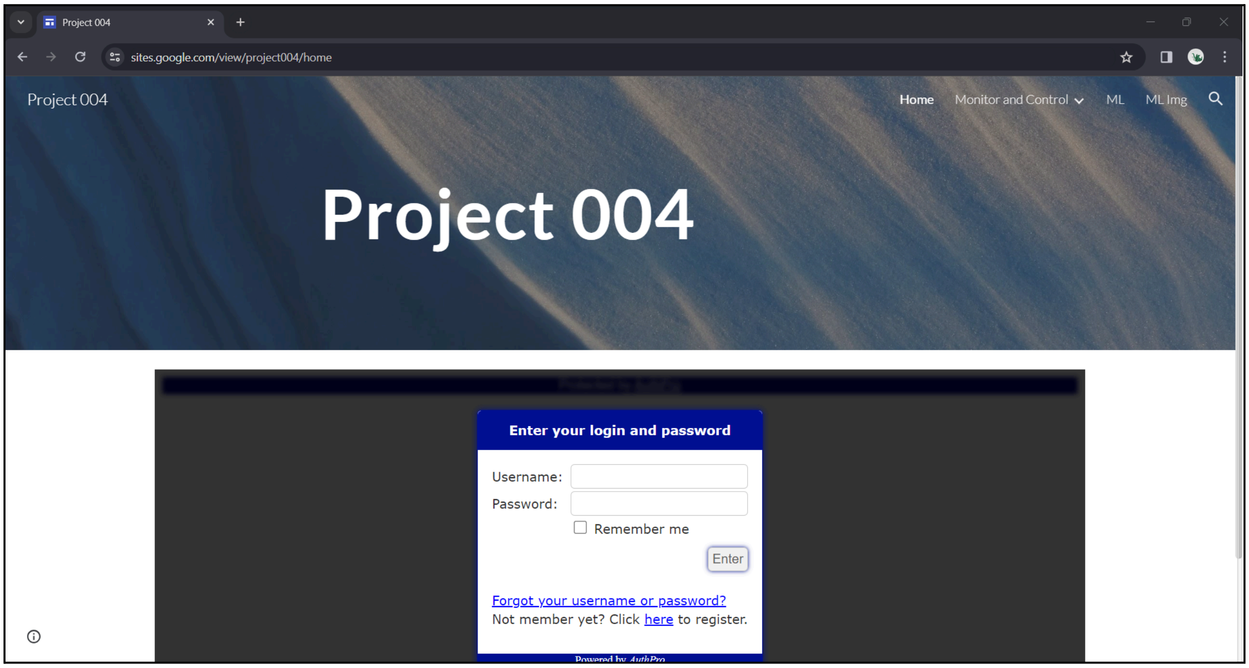


Fig. 7.4: Web Interface with Login and Password

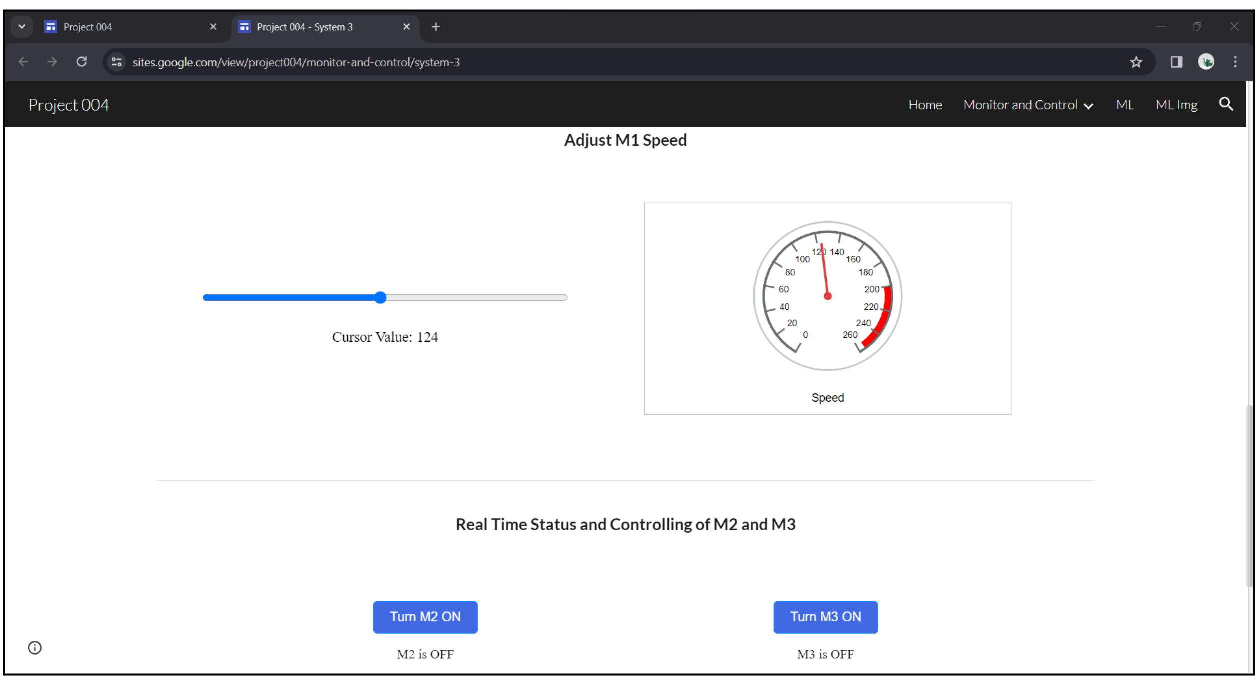
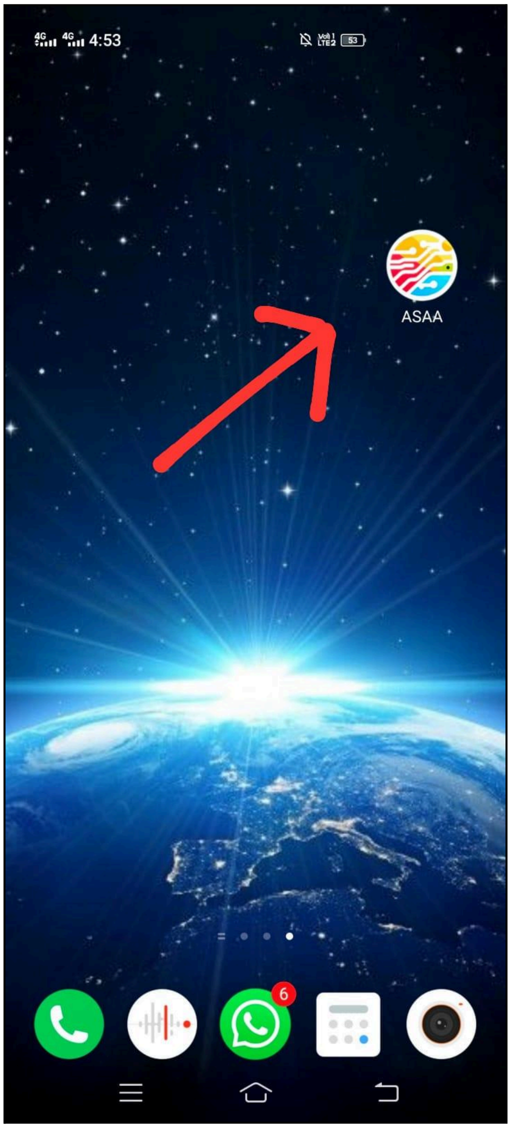


Fig 7.5: Web Interface to Control the Actuators

7.4 App interface



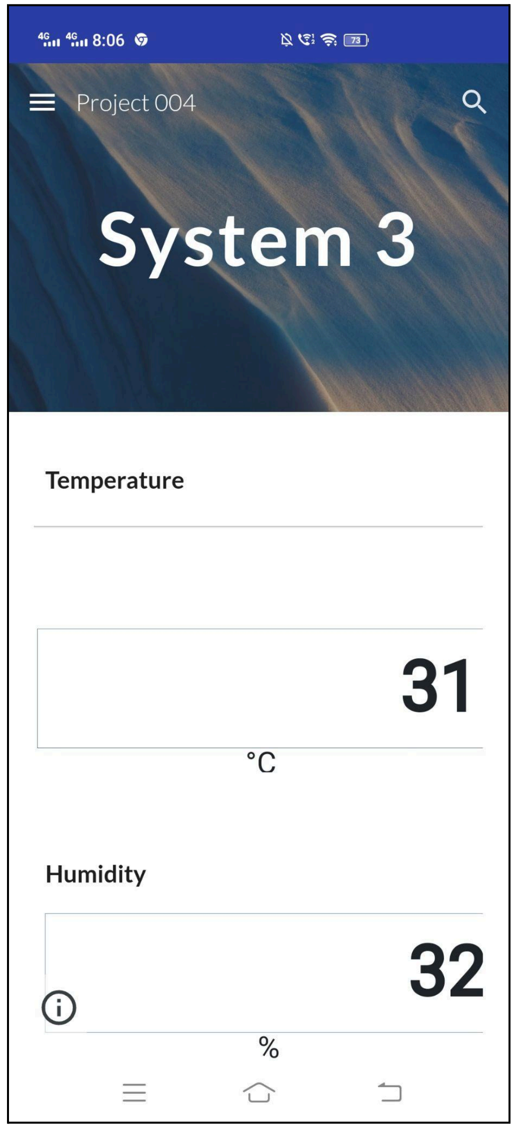


Fig. 7.6: Android App Icon **Fig. 7.7: Android App Interface**

The web and app interface screenshots depict a user-friendly control panel for managing the hydroponic automation system. Notably, a key feature ensures that any data modification made through either the web or app interface is promptly updated in the cloud, thereby synchronizing data across all connected devices in real-time. This seamless integration enables users to monitor and adjust settings remotely from anywhere in the world.

Whether it's adjusting light intensity, or monitoring environmental conditions, users can efficiently control the system's operations with ease and convenience, fostering optimal plant growth regardless of location.

7.5 TDS Research

Fig. 7.8: Difference with nutrient control

Fig. 7.9: Experiment Setup with Different TDS on different pots

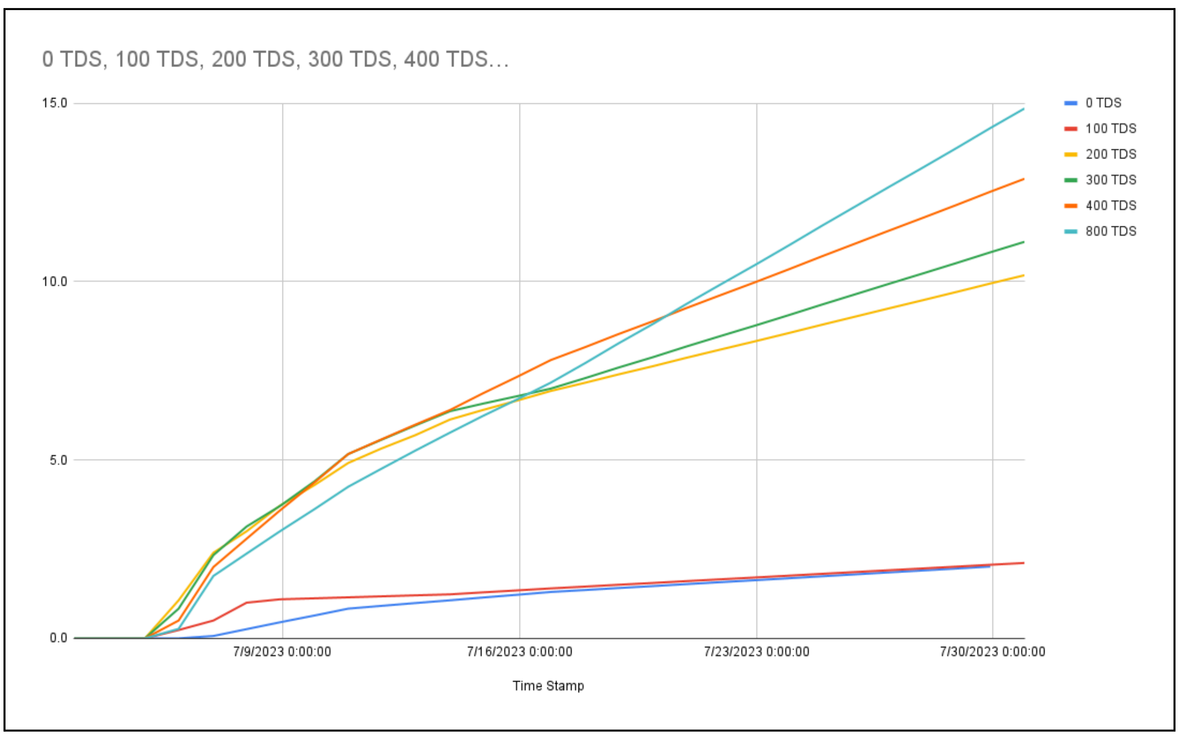
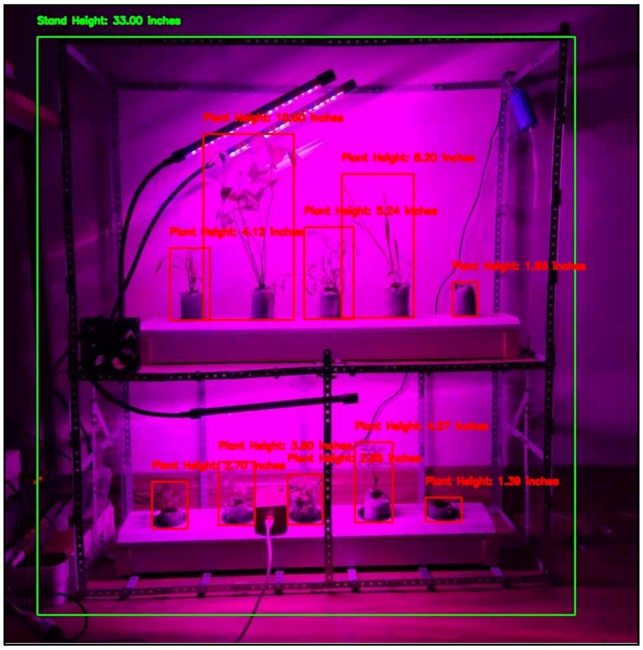


Fig. 7.10: Plant Height over Growth at Different TDS

The experiment showed that small plants thrive with low TDS levels, while medium-sized ones grow best with around 400 TDS for optimal growth. At the harvest stage, plants need about 800 TDS for faster growth, neither too high nor too low. This TDS consists of one-third each of nitrogen (N), phosphorus (P), and potassium (K) for balanced nutrition and healthy development.

7.6 TDS Recommendation using Camera



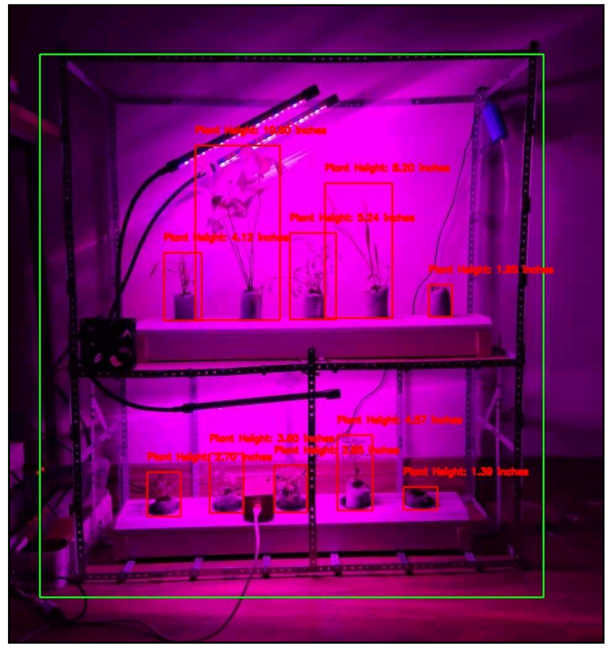


Fig. 7.11: Output of Model v1 **Fig. 7.12: Output of Model v2**

The Hydroponic Automation system integrates a camera module to capture images of the plants within the system, sending them to a local web server for analysis. Using advanced algorithms, the system accurately predicts the Total Dissolved Solids (TDS) required for optimal plant growth based on the height of the plants. On accessing the webpage, users are presented with a clear indication of the TDS needed – whether it's 200 TDS, 400 TDS, 600 TDS, or 800 TDS. Alongside each TDS value is a measure of prediction accuracy, displayed on a scale from 0 to 1, allowing users to gauge the reliability of the system's recommendation. With this seamless integration of imaging technology and predictive analytics, users can effortlessly maintain the ideal nutrient balance for their hydroponic setup, ensuring healthy and thriving plant growth.

By leveraging the camera module and predictive capabilities, the Hydroponic Automation system revolutionizes the way growers manage their hydroponic environments. With just a glance at the webpage, users can make informed decisions about adjusting TDS levels and enhancing efficiency and productivity in their cultivation process. The simplicity and accuracy of the system empower growers of all levels to achieve optimal results, fostering a more sustainable and efficient approach to hydroponic farming. With real-time insights at their fingertips, users can confidently nurture their plants, knowing they are providing the precise nutrients needed for vibrant and robust growth, ultimately maximizing yield and quality.

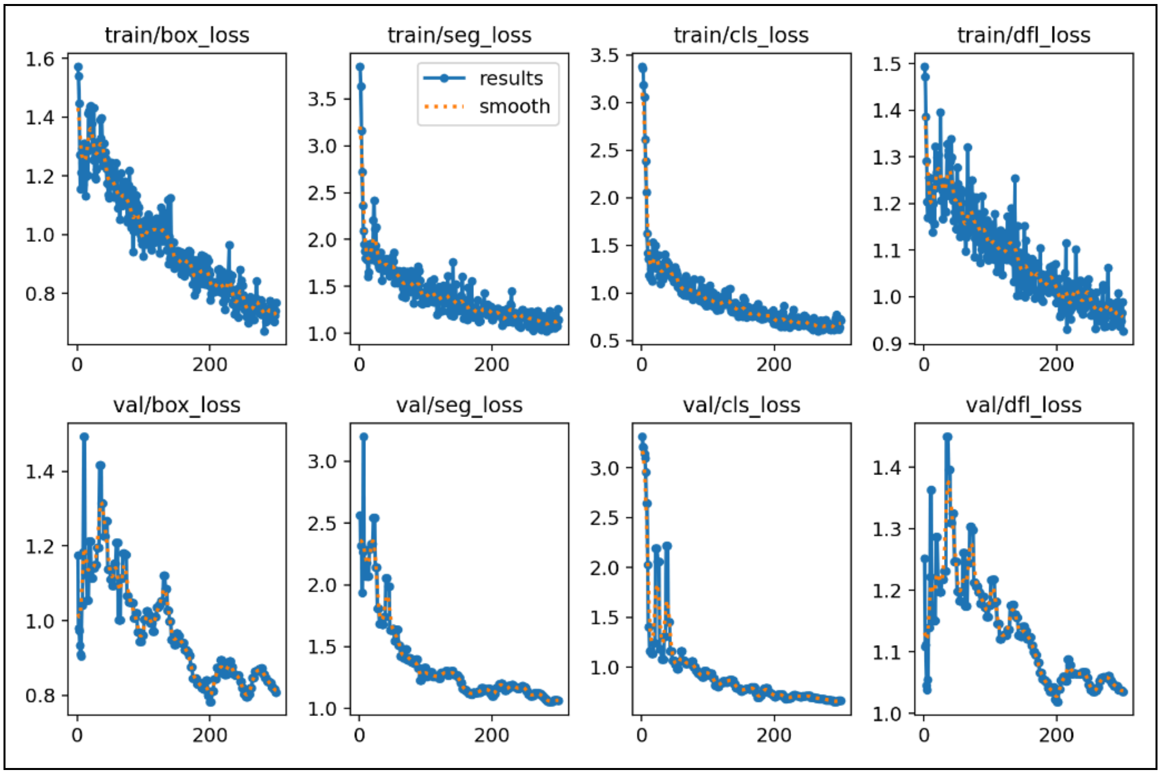


Fig. 7.13: Plot Performance of AI model

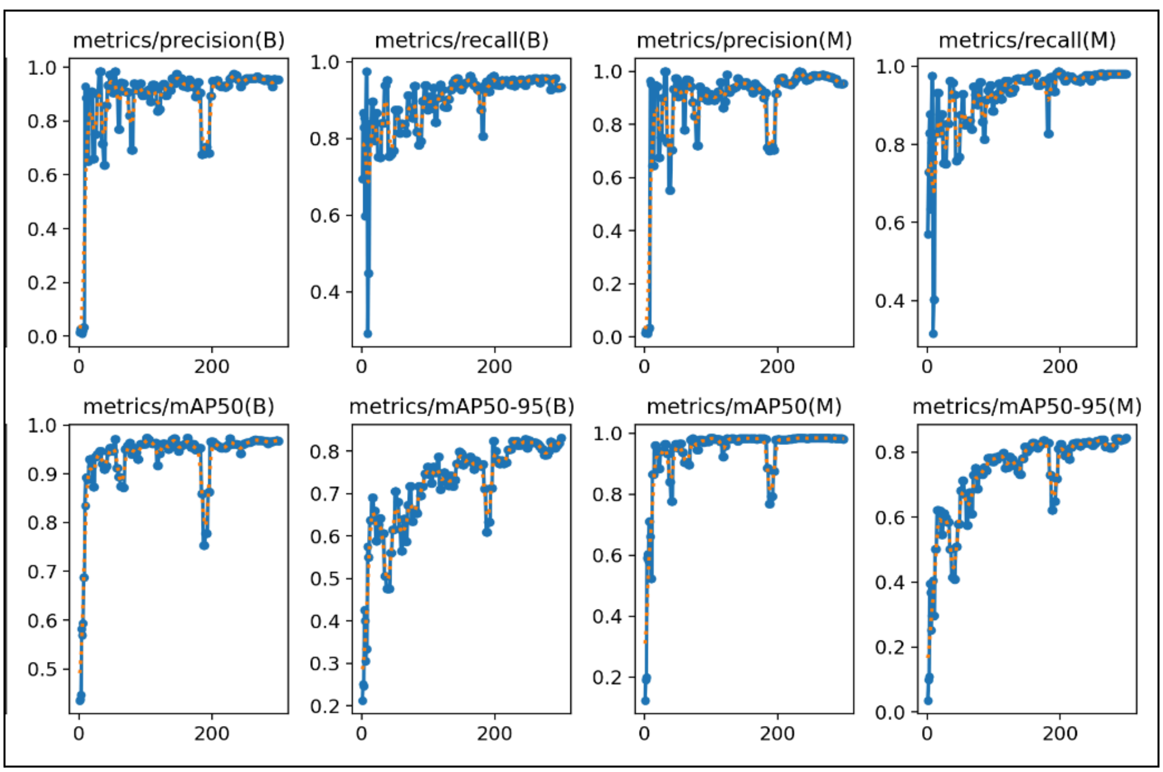


Fig. 7.14: Evaluation of AI model

7.7 List of plants grown using our setup

1. Wheat
2. Chickpea
3. Mung Bean
4. Safflower
5. Bajra
6. Marigold Scarlet
7. Marigold Orange
8. Mesembryanthemum
9. Ornamental Kale Fringed
10. Amaranthus

Fig. 7.15: Mung Bean Plant

The hydroponic automation project has been successful, enabling the cultivation of various plants, from flowers to herbs, effortlessly. By precisely understanding the nutrient needs during different growth stages, we can efficiently nurture multiple plant varieties in hydroponic systems. This advancement simplifies the process, making hydroponic gardening accessible to all.

Fig. 7.16: Wheat Plant

Fig. 7.17: Chickpea Plant

7.8 Time Scheduling and React Control

The indoor hydroponic automation system demonstrated promising results in effectively managing the cultivation environment. Time scheduling provided convenient control over LED lights and the air pump, ensuring plants received adequate lighting and aeration at optimal times. This scheduling capability, integrated with the ThingSpeak Cloud, enabled users to program specific timings for these essential components, promoting healthy plant growth and resource efficiency. Additionally, the system offered flexibility through a user-friendly webpage interface, allowing for manual initiation of countdown timers, and enhancing accessibility and adaptability to varying cultivation needs.

Furthermore, the implementation of react control proved to be a valuable feature in maintaining ideal conditions within the hydroponic environment. By enabling users to set temperature thresholds through the webpage interface, the system effectively regulated environmental parameters such as temperature and water levels. For instance, when the temperature exceeded the user-defined threshold, the fan automatically activated, efficiently mitigating heat stress and ensuring optimal growing conditions. Similarly, the react control facilitated automatic activation of the water level motor when water levels dropped below the designated threshold, guaranteeing consistent hydration for plants without requiring constant monitoring. Overall, the integration of time scheduling and react control functionalities contributed to the automation and optimization of indoor hydroponic cultivation, simplifying management tasks and enhancing yield.

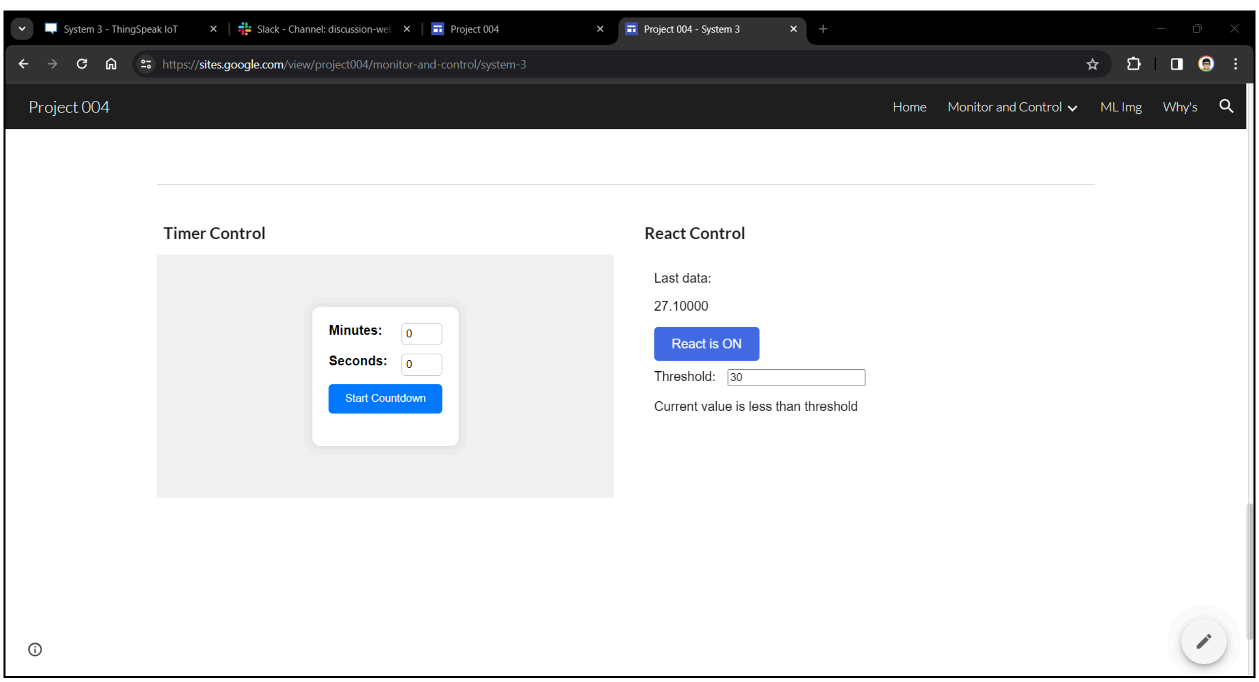


Fig. 7.18: Time Scheduling and React Control Web Interface

7.9 Email Alerts

The email alert facility incorporated into the indoor hydroponic automation system demonstrated significant utility in enhancing user convenience and ensuring timely intervention when necessary. This feature enabled users to receive real-time notifications via email regarding critical events or irregularities detected within the cultivation environment. For example, if the water level in the hydroponic system fell below a certain threshold or if there were any malfunctions in the equipment, the system promptly generated an email alert, notifying users of the issue. This proactive approach to monitoring helped prevent potential damage to plants and equipment by allowing users to address issues promptly, even when they were not physically present.

Moreover, the email alert facility served as an invaluable tool for remote monitoring and management of the hydroponic setup. Users could stay informed about the status of their cultivation system regardless of their location, facilitating peace of mind and enabling efficient troubleshooting. Whether users were away from home or occupied with other tasks, they could rely on email alerts to keep them informed about the well-being of their plants and the overall functionality of the system. This remote accessibility empowered users to take timely actions to maintain optimal growing conditions, ultimately maximizing the success of their indoor hydroponic system.

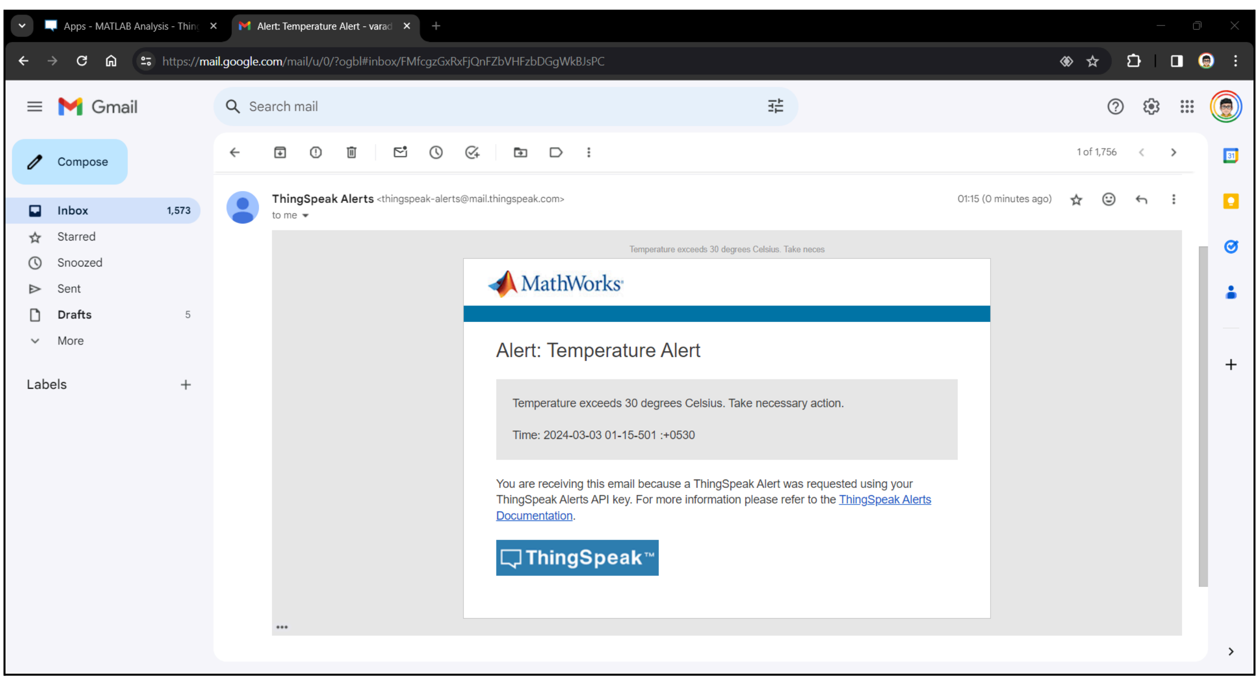


Fig. 7.19: Email Alert

7.10 Data Storage

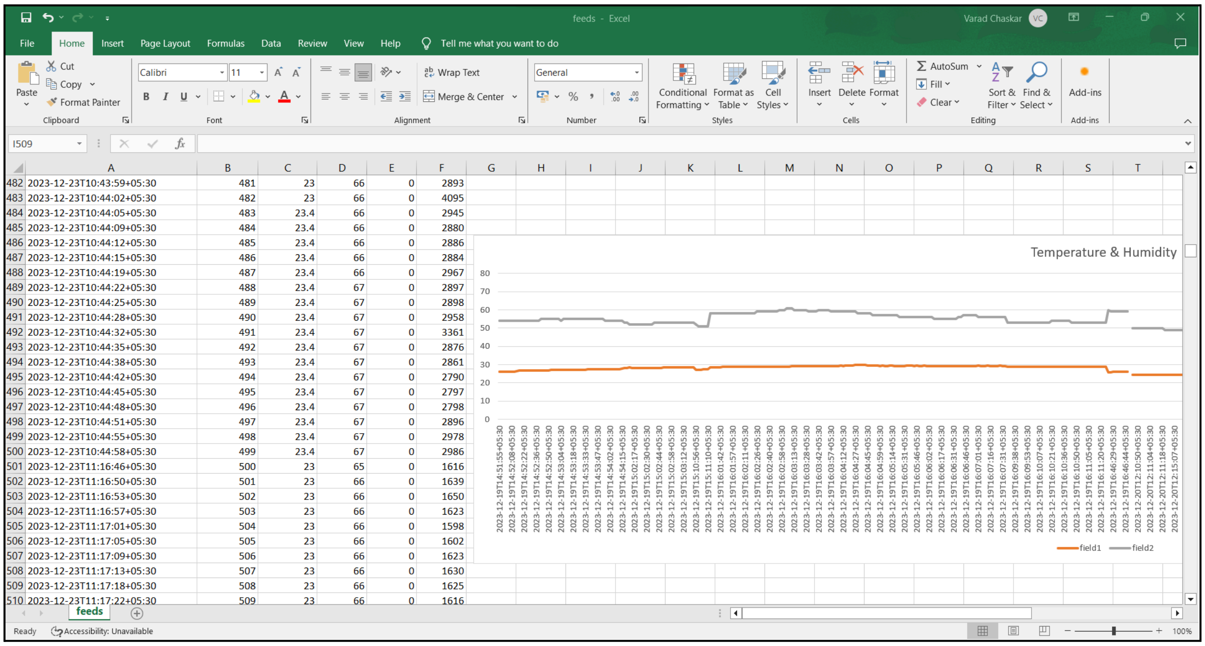


Fig. 7.20: Data Exported from the Cloud in Excel

The system integrates sensor data storage, enabling convenient exportation in CSV or compatible formats. This facilitates seamless data analysis and retrieval for specific days. With this capability, users can easily track and optimize environmental conditions for optimal plant growth and yield.

7.11 Simulation

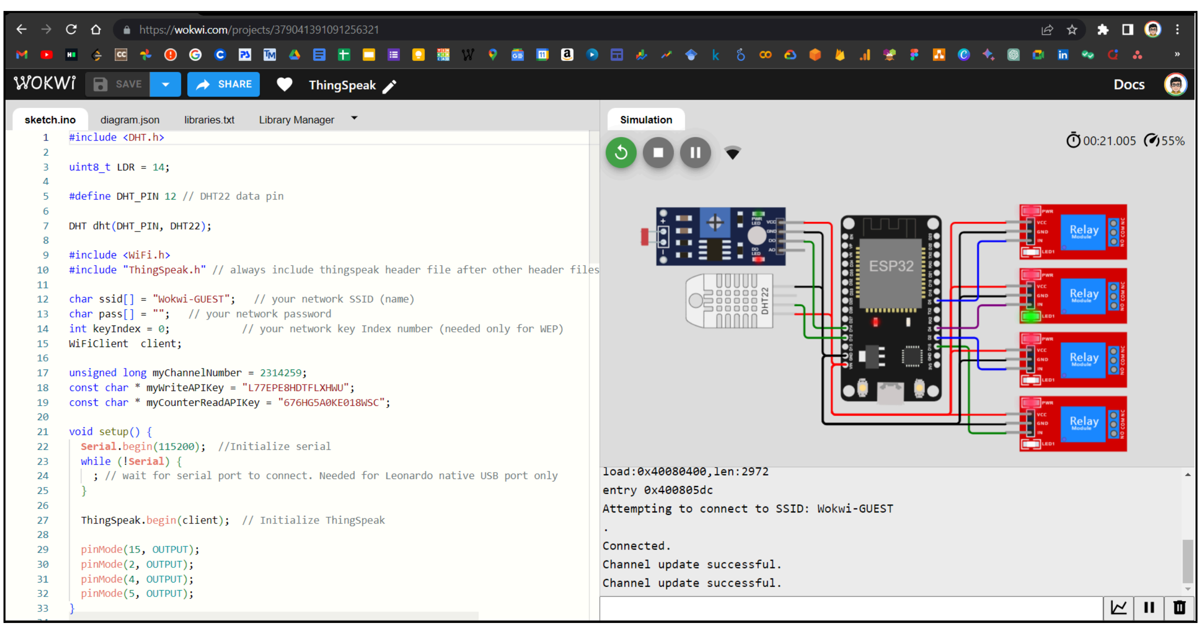


Fig. 7.21: Screenshot of the Simulation Done on Wokwi

8. APPLICATIONS

8.1 Detailed Relevant Applications of the System Designed

- **Home gardening**: NFT hydroponics is an ideal method for home gardening, as it allows for year-round cultivation of fresh herbs, vegetables, and fruits. The system can be set up in a small space and can be easily maintained, making it a convenient and cost-effective option for home gardeners.

- **Commercial agriculture**: NFT hydroponics is also used in commercial agriculture for growing crops such as lettuce, herbs, and strawberries. The system is highly efficient, as it requires less water and space compared to traditional farming methods, leading to higher yields and reduced costs.

- **Urban farming**: NFT hydroponics is becoming increasingly popular in urban farming, as it allows for the cultivation of fresh produce in urban areas with limited space. The system can be set up in rooftops, balconies, or indoor spaces, providing a sustainable and efficient method for urban farming.

- **Research and education**: NFT hydroponics is used in research and education to study plant growth and development in a controlled environment. The system allows researchers and students to manipulate the nutrient composition and environmental factors to study the effects on plant growth and development.

Overall, the NFT hydroponics system has a wide range of applications in home gardening, commercial agriculture, urban farming, research and education, and medical cannabis cultivation, making it a versatile and efficient method for indoor plant growth.

8.2 Future Modifications

- **Integration with Robotics:** Incorporation of robotics for tasks such as planting, harvesting, pruning, and monitoring. Robotics can increase efficiency, reduce labor costs, and ensure precision in crop management tasks, ultimately leading to higher yields and better resource utilization.

- **Expansion in Space:** Exploration and development of hydroponic farming systems for extraterrestrial environments such as space stations, lunar bases, or Mars habitats. These systems would need to be adapted to operate in microgravity or reduced gravity conditions, utilizing closed-loop life support systems and advanced technologies for water recycling, nutrient delivery, and environmental control to sustain food production for long-duration space missions.

- **Automated Nutrient Delivery:** Implementation of automated nutrient delivery systems that precisely dose and adjust nutrient solutions based on plant growth stages and requirements, ensuring optimal nutrition uptake.

- **Climate Control and CO2 Enrichment:** Enhanced climate control systems to regulate temperature, humidity, and CO_2 levels, providing an optimal growing environment for plants to thrive and maximizing photosynthetic efficiency.

- **Advanced Pest and Disease Management:** Integration of biological control methods, such as beneficial insects or organic pesticides, and the use of data analytics to detect and prevent pest and disease outbreaks before they can damage crops.

- **Integration with Renewable Energy Sources:** Incorporation of renewable energy sources such as solar or wind power to supplement or replace traditional energy sources, reducing carbon footprint and operating costs.

- **Nutrient Monitoring and Management Systems:** Implementation of advanced nutrient monitoring and management systems that analyze plant nutrient levels in real-time and automatically adjust nutrient solutions accordingly, ensuring optimal plant health and productivity.

- **Genetic Engineering for Crop Improvement:** Continued research into genetic engineering techniques to develop crops with enhanced traits such as disease resistance, nutrient efficiency, and yield potential, tailored specifically for hydroponic cultivation.

9. CONCLUSION

The Hydroponics Based Precision Farming With Feature Optimization, based on indoor farming with temperature, UV light, water level, and air pump control, has several benefits in addition to faster growth and reduced water consumption. Firstly, the system eliminates the need for large land areas, making it ideal for urban and suburban regions where space is limited. By precisely controlling temperature, light, and water levels, plants receive optimal growing conditions, leading to higher yields and healthier crops. Furthermore, automation reduces the risk of human error, ensuring consistent production to the highest standards.

The Hydroponics Based Precision Farming With Feature Optimization project is a highly effective and efficient system for growing plants. The system can lead to 30 to 50% faster growth than soil-based farming while reducing water consumption by 70-85%. With the entire system operating on its own, there is no need for human intervention, making it an ideal solution for individuals or businesses seeking to maximize crop yields while minimizing labor and resource costs. Moreover, it has been designed for Scaling by utilizing M2M and cloud. Overall, the Hydroponics Based Precision Farming With Feature Optimization project represents a significant advancement in sustainable farming practices, and its potential to revolutionize the agriculture industry cannot be overstated.

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