F.L.O.W.E.R.S.

Functioning Lighting and Optimal Watering for Environmental Regulation System

Group 20

Meet the Team

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Motivation and Background

- Ease of Use for Non-Gardening Experts
  - Many people are discouraged from plant care due to a lack of knowledge or confidence. This system lowers the barrier to entry by automating key tasks, making gardening approachable for beginners.
- Benefits of Automating a Home Growing System
  - Automation reduces the time and effort needed to maintain healthy plants, allowing users to enjoy the therapeutic and aesthetic benefits of greenery without daily oversight.
- Resource Management/Efficiency
  - By monitoring light and moisture conditions, the system optimizes water and energy usage, reducing waste and increasing sustainability.
- Indoor Accessibility
  - The smart garden system enables successful plant growth indoors, even in environments with limited natural light or irregular maintenance schedules.

Objectives

Objective 1: Create an Optimized Indoor Growing Environment

- Automatically deliver species-specific water amounts using a pump and solenoid valve system.
- Provide optimal spectral light output for plant growth, including the use of programmable LEDs.
- Use sensor data from light sensors and moisture sensors to create a feedback loop that controls each environment individually
- Simulate natural light cycles through duty cycling and on/off scheduling.

Objective 2: Develop a User Friendly Mobile Application

- Allow users to manually input target values for soil moisture and lighting.
- Display real-time sensor data, including moisture and temperature readings.
- Provide preset growth profiles for Florida plants commonly grown indoors.

Goals and Stretch Goals

- Measure real-time temperature and humidity for updating the user via the app.
- Transmit multiplexed sensor data to the MCU
- Notify the user when sensor values exceed or fall below critical thresholds.
- ***Stretch Goal:*** Use ultra-low-power sensors that require infrequent battery replacement; only twice a year under constant use.
- ***Stretch Goal:*** Implement individual ESP32 modules on the soil moisture sensor for wireless communication to the main PCB, using the ESP-NOW protocol for communication
- ***Stretch Goal:*** Adapt watering schedules based on plant growth stage (e.g., seedling, budding, flowering).

Engineering Specifications

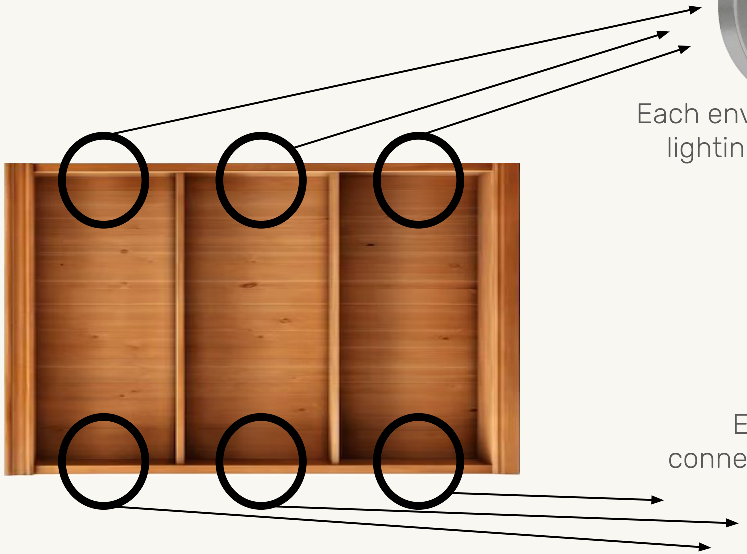
Specifications Table	
Parameter	**Requirement**
App Data Refresh Rate	At least once every hour
Web Server Refresh Rate	At least once every minute
Soil Temperature Polling Rate	At least once every hour
Soil Moisture Polling Rate	At least once per minute
Light Sensor Polling Rate	At least once per minute
Number of Environments Maintained Simultaneously	At least 3
Light Sensor Relative Accuracy	No more than 3 percent difference between values under identical lux
Temp Sensor Accuracy	Within 2 percent between the Ambient Temperature range of 0 degrees Celcius and 35 degrees Celcius
Power Consumption (12V LED lights)	Less than 200 Watts
Electronic Solenoid Valve Response Time	Less than 5 seconds
Water Pump Flow Rate	At least 1 GPM (Gallon per Minute)
Water Pump Pressure	At least 40 PSI
Water Pump Power Consumption	Less than 75 watts
Maximum Shelf Size	4'x 6'x3'
15A Breaker Trip Time (12V)	Less than 1 second

- Feedback sub-systems that control the environments frequently update
- Sensor polling the environment and sending back to MCU
- Three environments that are maintained simultaneously
- Safety features like the breaker trip time

F.L.O.W.E.R.S. : The Physical Unit

How F.L.O.W.E.R.S. Operates: The Physical Unit

Each environment contains a lighting source at the top



The physical unit can simultaneously maintain 3 individual environments, meeting each environment’s own needs for watering and lighting

Each environment has a connection to the watering source

How F.L.O.W.E.R.S. Operates: The Physical Unit

x3

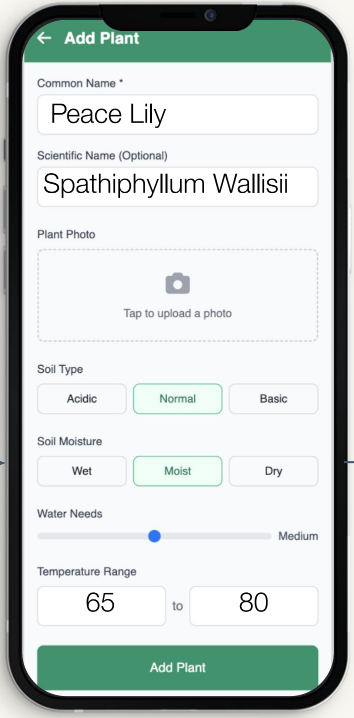
3 capacitive soil moisture sensors will be used, one for each environment

<u>User input</u>

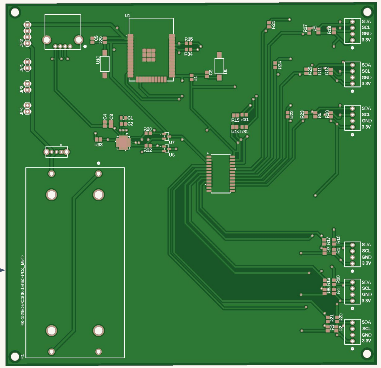
- Placing the sensors into pot
- Switching sensors into new pot
- Entering environmental needs for plant within app

How F.L.O.W.E.R.S. Operates: Incorporating the Software

1 The user places the plant into the environment, and inserts the soil moisture sensor

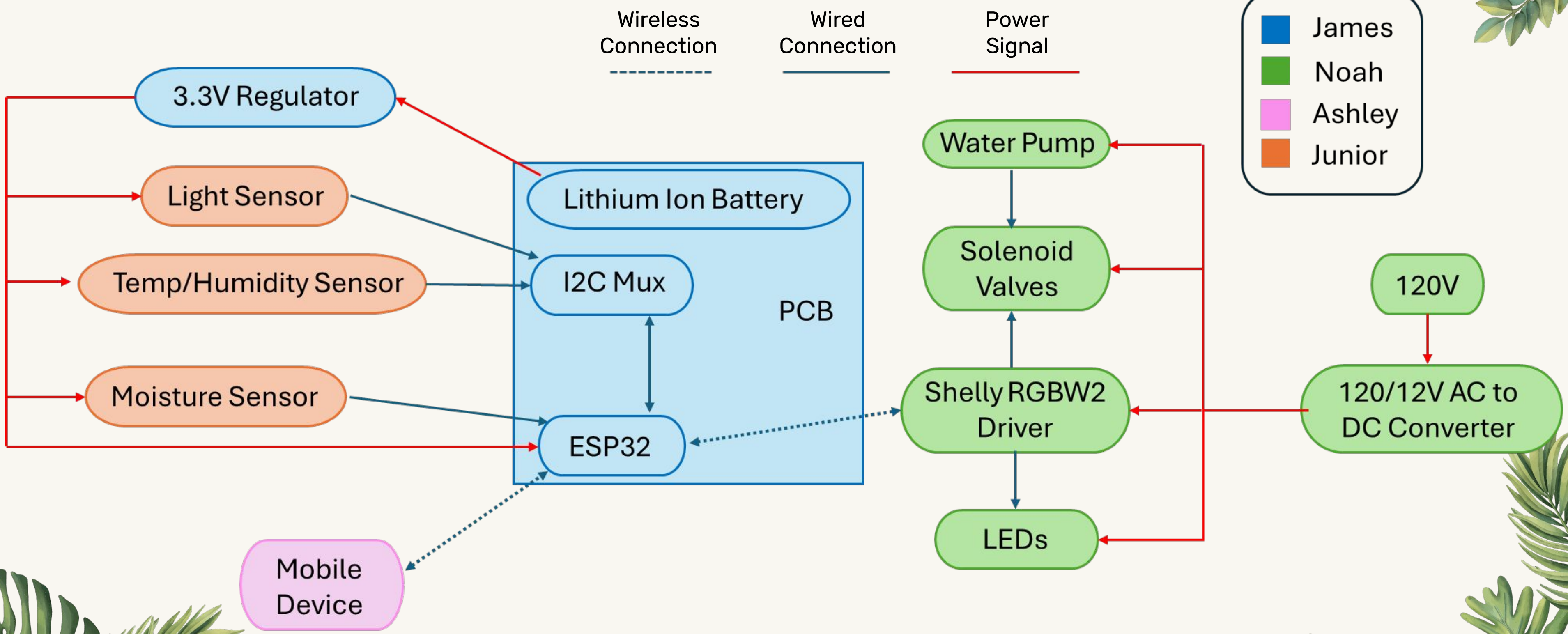


2 The user enters the environmental needs including soil moisture



3 The info is sent to the main PCB and the ESP32 will handle polling the soil moisture sensors and sending the water, if needed

Hardware Block Diagram Overview



Technology Selection: Main PCB MCU

Features	*ESP32-Wroom-32*	*ATmega328P*	*MSP430*	*RP2040*
CPU Cores	Dual-Core Xtensa LX6	Single Core	Single Core	Dual ARM Cortex-M0+
I/O Pins	38 GPIO	23 PIO	24 PIO	30 GPIO
Analog Inputs	18 channels (12-bit ADC)	8 channel (10-bit ADC)	8 Channel (10-bit)	3 Channel (12-bit ADC)
PWM	16 Channels	6 Channels	8 Channels	16 Channels
Communication Protocols	SPI, UART, I2C, I2S,	UART, I2C, SPI	UART, I2C, SPI	UART, SPI, I2C
Wi-fi capability	802.11 b/g/n	N/A	N/A	N/A
Bluetooth Capability	BR/EDR and Bluetooth LE	N/A	N/A	N/A
Power Consumption	10μA Deep Sleep	0.2mA Active Mode	230μA Active Mode	30mA Active
Memory	4M Byte	32Kbyte	16K Byte	2M Byte
RAM	4M Byte	2KByte	512 Byte	264k Byte
Operating Voltage	3.0V-3.6V	1.8V-5.5V	1.8V-3.6V	3.3V

<u>ESP32-Wroom-32</u>

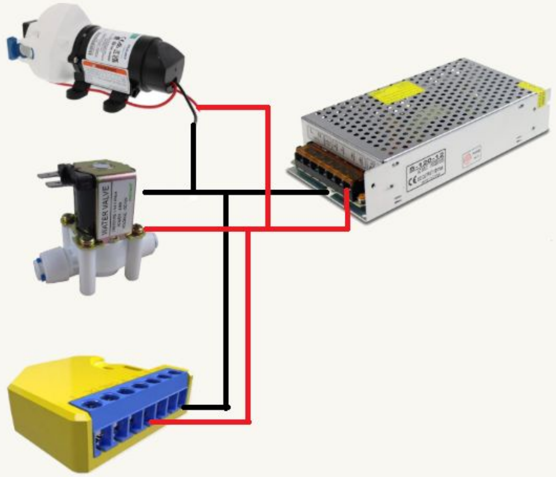
- High Performance
- Advance Communication
- Low Power Mods
- Built-in Connectivity
- Rich I/O
- Ample Memory
- Flexible Voltage Range

Technology Selection: Soil Moisture Sensing

	VWC	Water Tension	Single-Point	PCB Design
Water calculation	Uses dielectric permittivity of the soil	Uses tensiometer to measure soil suction	At a specific point takes the conductivity of soil	Uses traces as capacitor plates to measure soil moisture
Sensitivity	Affected by soil type and salinity	Soil texture	Contact to soil and soil	Soil make up and salinity
Output Value	Percentage	kPa	Binary or Resistance Value	Voltage or Digital Signal
Measurement Depth	Multiple depths	Near roots	Fixed at a single point	Few cm depth
Accuracy	High	N/A	Low	Moderate can improve with calibration
Cost	High	High	Low	Low

Hardware Selection: AC to DC Converter

- 4 unique devices that require 12V power, being the solenoid valves, the Shelly RGBW2, the LED lights, and the water pump.
- Battery size limitations, we found it most practical to use wall power to power these devices
- Therefore, an AC to DC converter would be needed to both bring down the 120V wall power to 12V, and also rectify it to DC



Specific AC to DC converter	XINCOL AC to DC Converter 12V 500W	inSharePlus 12V 500W Power Supply	Makerele MS-500	MEAN WELL SE-600	ALITOVE 12V 50A 600W Power Supply
Meets Power Reqs?	Yes	Yes	Yes	Yes	Yes
Heat Diss.?	Poor	Excellent	Excellent	Excellent	Moderate
Footprint	11.43" (L) × 6.18" (W) × 2.57" (H)	10.2" (L) × 3.39" (W) × 2.16" (H)	8.61" (L) × 7.43" (W) × 4.88" (H)	9.72" (L) × 5.00" (W) × 2.50" (H)	9.41" (L) × 6.05" (W) × 2.93" (H)
Supports 120V AC at input?	Yes	Yes	Yes	Yes	Yes

Hardware Selection: Battery

	18650 Lithium Ion	9V Alkaline	NiMH AA
Nominal Voltage	3.7V	9V	1.2V
Capacity	5000mAh	~1500mAh	2000mAh
Cost	$2.49	$4.46	$1.20

PKNERGY

Hardware Selection: I2C Bus Multiplexer

	PCA9547D	MCP23018	MAX7356
Channels	8	16	8
Operating Voltage	2.3-3.6V	1.8-5.5V	2.3-3.6V
Current Draw	20uA (typical)	100uA (typical)	30uA (typical)
Stand By Current	0.1uA (typical)	1uA (typical)	0.1uA (typical)
Cost	$1.79	$2.04	$7.69

Hardware Selection: Temp/Humidity Sensor

	AHT 20	SHT 45	DHT 11
Temp Range	-40 to 85 °C	-40 to 125 °C	0 to 50 °C
Humidity Range	0 to 100% RH	0 to 100% RH	20-80% RH
Voltage	2.2V to 5.5V	1.08V to 3.6V	3.3V to 5.5V
Interface	I2C	I2C	Single Wire
Response Time	~8 sec	<0.5 sec	~10 sec
Accuracy	±0.3 °C/±2%RH	±0.1 °C/±1%RH	±2 °C/±5%RH

SHT 45

- Wide Temperature Range
- Full Humidity Range
- High Accuracy
- I2C Interface
- Low Voltage Range
- Fast Response Time

Hardware Selection: Light Sensor

	BH1750	VEML7700	TSL2591
Range (lx)	0-100k	0-120k	0-88k lux
Resolution	1 lux	0.0036 lux	0.000377 lux
Power	~0.36 mW	~0.51 mW	~0.6 mW
Current Draw	0.12 mA	0.17 mA	0.2 mA
Standby Current	0.01 µA	0.8 µA	2 µA
Cost	$3.29	$1.25	$1.67

VELM7700

- Wide Lux Range
- High resolution
- Low Power Consumption
- I2C Interface
- Cost Effective

Hardware Selection: Capacitive Sensor

	Resistive Sensor	**Capacitive Sensor**
Measurement method	Measures the soil resistance between two probes	Measures capacitance from soil permittivity
Output Type	Analog	Analog
Voltage	3.3V to 5V	3.3V to 5V
Accuracy	Low	Medium

Capacitive Sensor

- High accuracy
- Non-corrosive
- Stable readings
- Long lifespan
- Analog output

Hardware Selection: Water Pump

Water Pump Selection Summary:

- Selected Pump: Model R3526144D
- Supply Voltage: 12V DC – consistent with overall system requirements
- Flow Rate: Delivers 3.0 GPM – Beyond Sufficient for needs
- Pump type- Demand Pump
- Maintained Pressure: 50 PSI – sufficient for our vertical planter system
- Cost: $49.99 – lowest-cost option
- Trade-offs Considered: Slightly lower pressure compared to others, but acceptable within design limits. In fact, a flow regulator will still be used
- Rationale: Chosen for its optimal balance of performance, simplicity, and budget compatibility

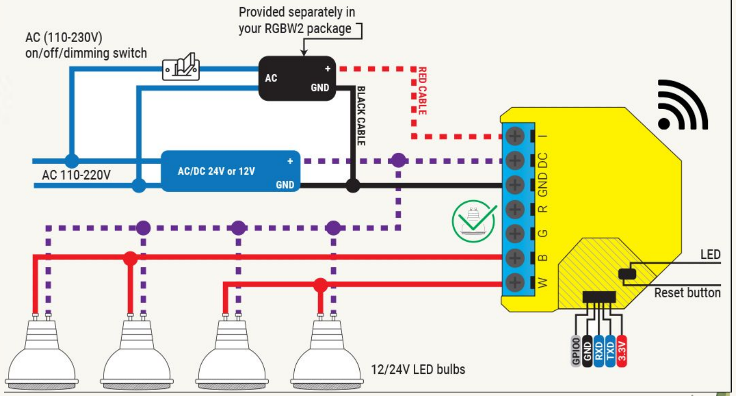
Model Number	R3526144D	Delavan Powerflo 7822FS	Everflo EF2200
Cost	$49.99	$81.37	$77.47
GPM	3.0	2.2	2.3
Sustained PSI	50	60	70
Supply Voltage	12V	12V	12V

LED Driver/ Wireless Relay

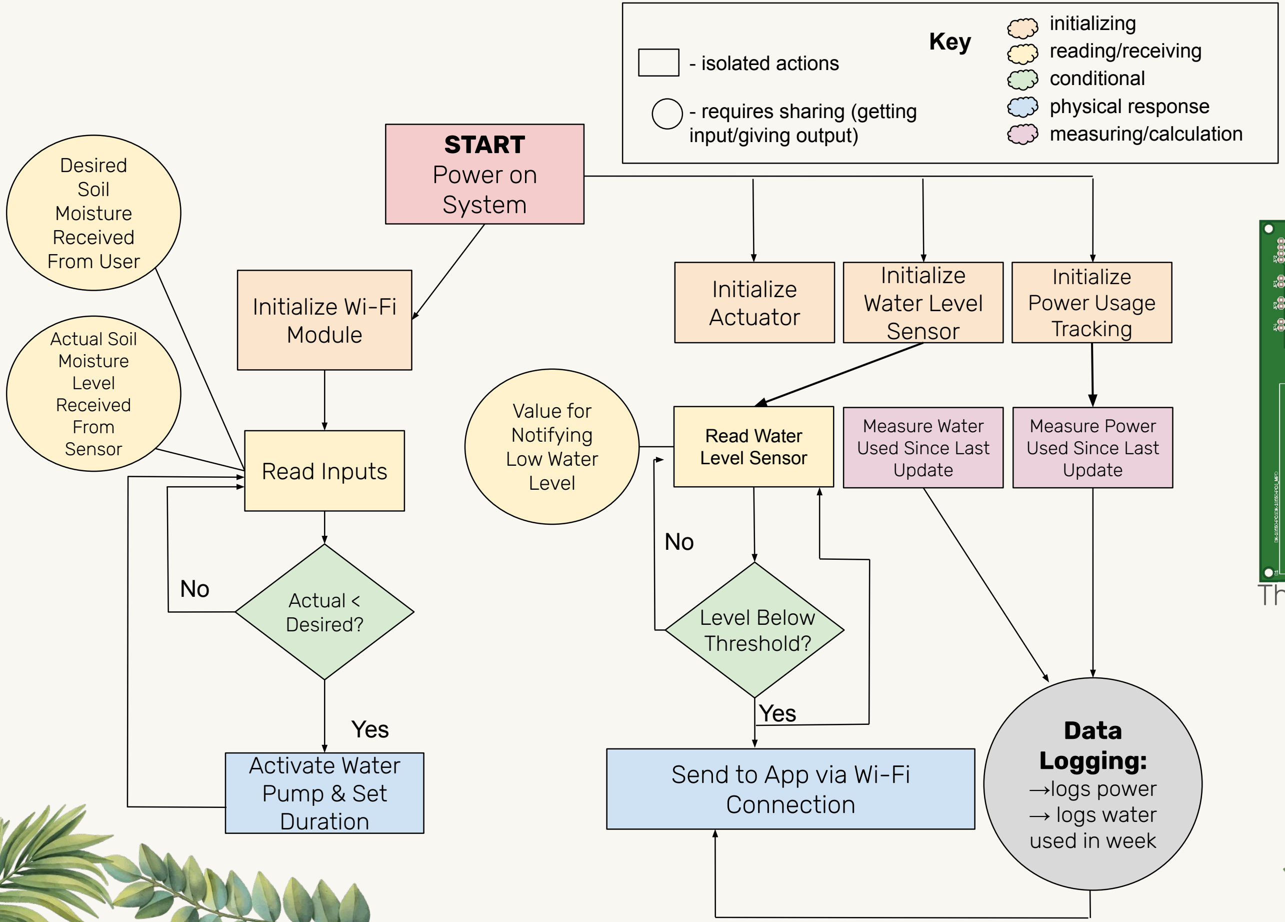
- Provides the wireless control for the lights and solenoid valves
- Chosen for flexibility in light/valve placement
- Gives a convenient way to dim the lights and set automation schedules
- The Shelly RGBW device was a natural selection for this use case, as other devices require proprietary lights or software

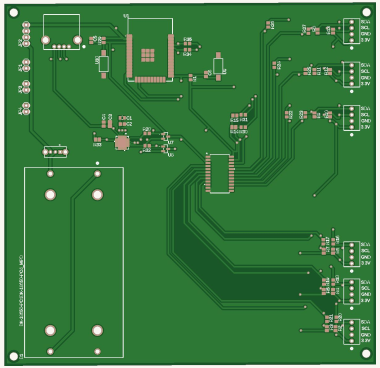
Issues Faced: Connectivity Issues; the device would default to turning the valves on as soon as it received power, causing unwanted water to flow momentarily

Solution: Configured Shelly boot process to not automatically turn on the valves after receiving power



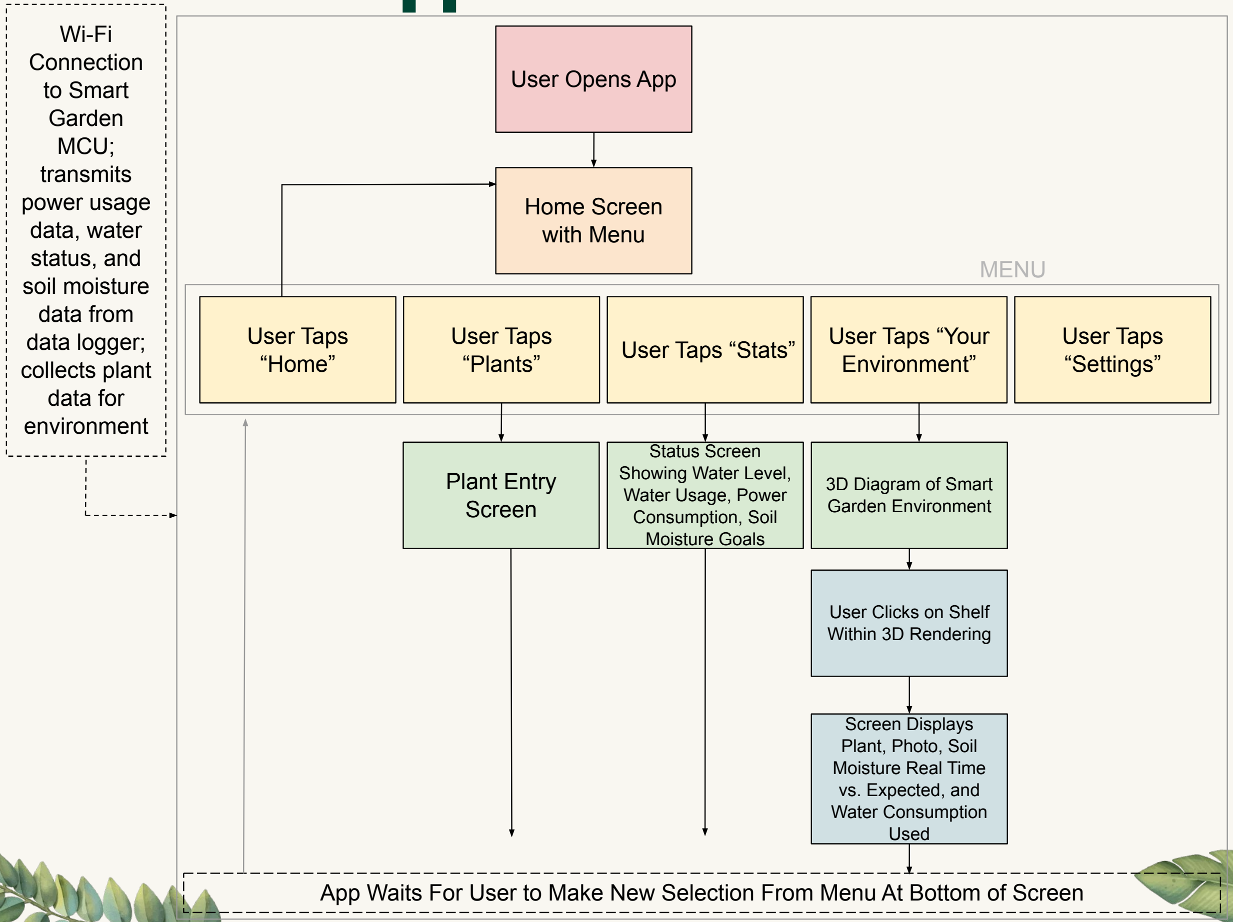
Embedded Software Flowchart



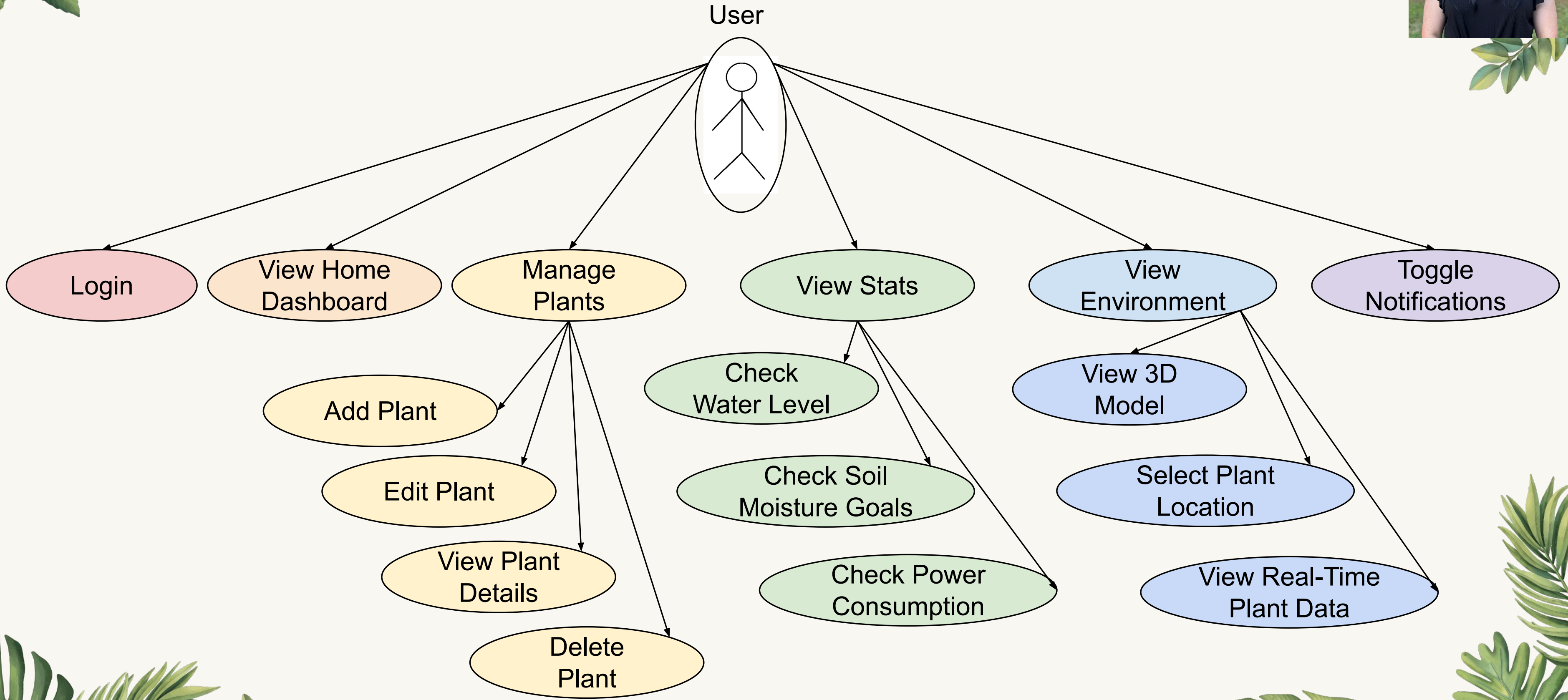


This is the logic which drives the main ESP32

Mobile App Software Flowchart



Mobile App Use-Case Diagram



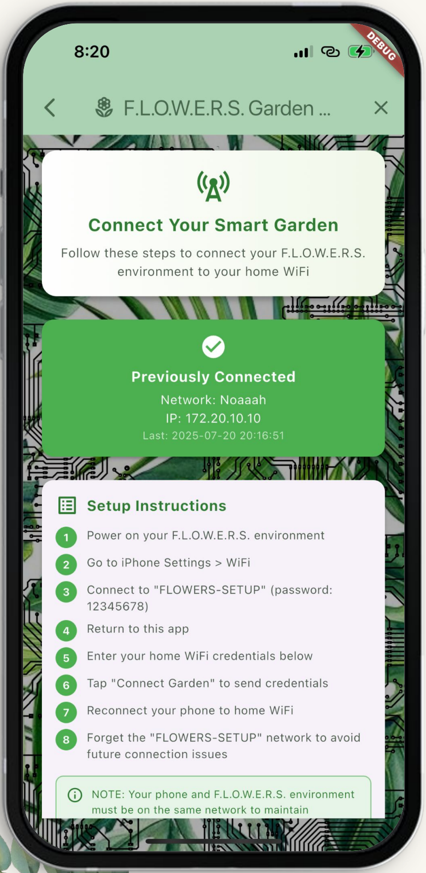
ESP32 Communication - Mobile App

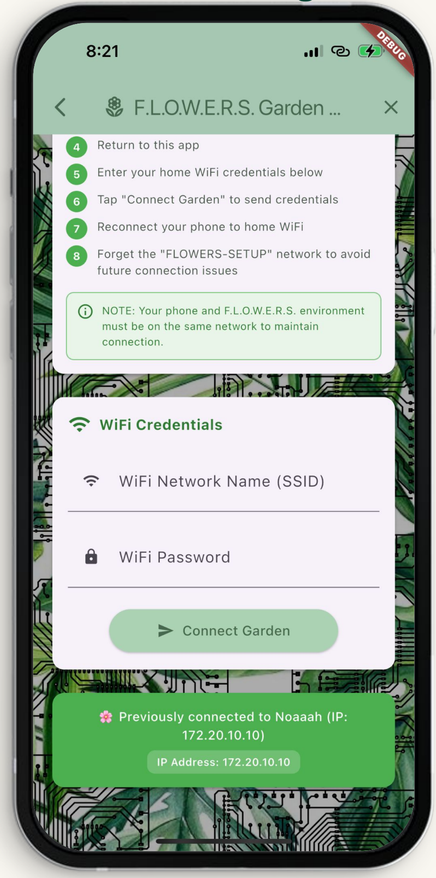
Initial Wi-Fi Connection and Setting Up Two-Way Communication for the MCU and app

- The ESP32 powers on
- While no WiFi connection is established, it holds in access point mode
- The user will be prompted to share the password or enter the credentials on the mobile app
- The ESP32 connects to WiFi successfully and initializes an HTTP server at its IP address to send the app readings

ESP32 Communication - Mobile App

The User's View for WiFi Configuration



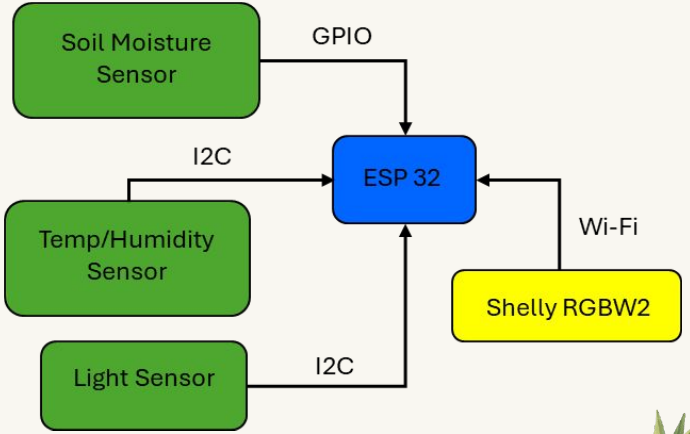


ESP32 Communication - MCU

- I2C is used to relay communication from Temp/Humidity sensors and Light sensors to I2C bus to ESP32.

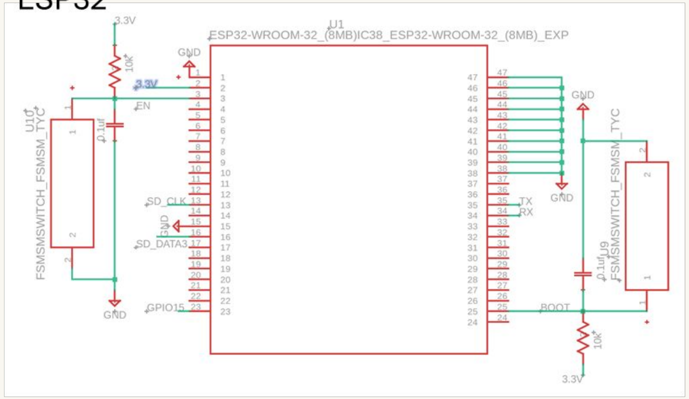
- The capacitive moisture sensor will be wired directly to the ESP32 GPIO pins, and the raw voltage values will be converted to digital readings by the on-chip ADC.

- The ESP32 will control both the water pump and the LED light strips using the Shelly RGBW2. Communication between the ESP32 and the Shelly will be through Wi-Fi.

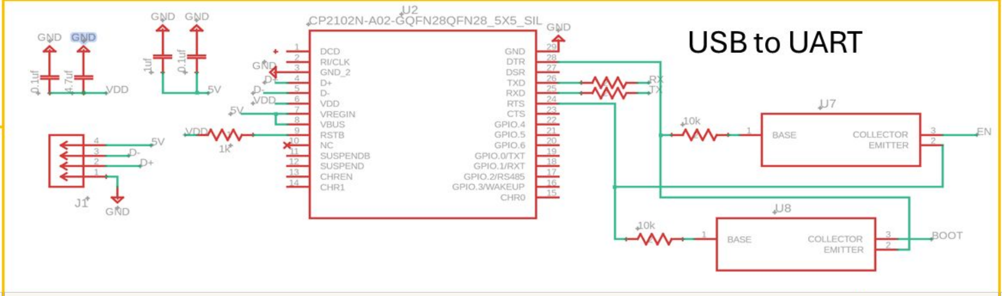


Main Board/3.3V Reg

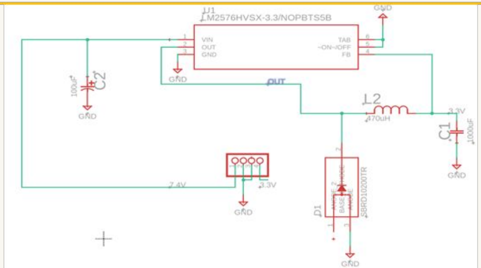
ESP32



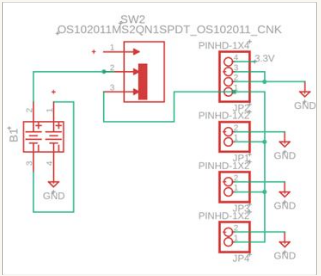
USB to UART



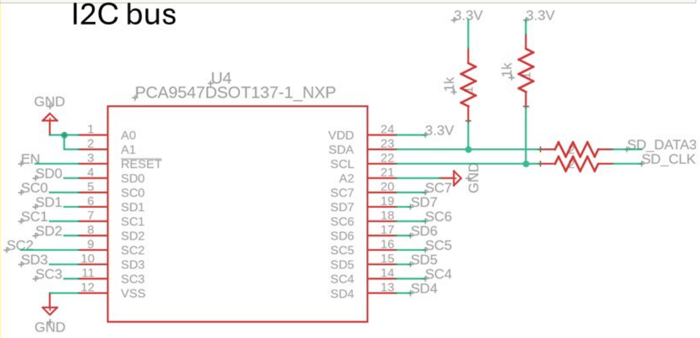
3.3V Regulator

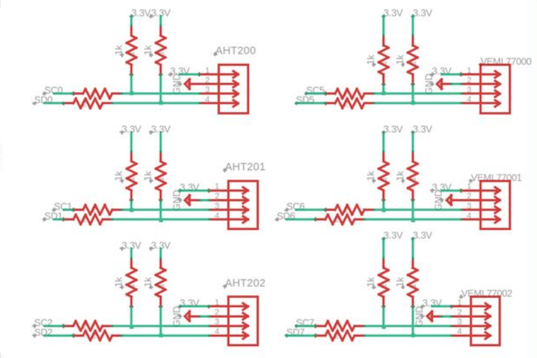


3.3V Jumper Connections



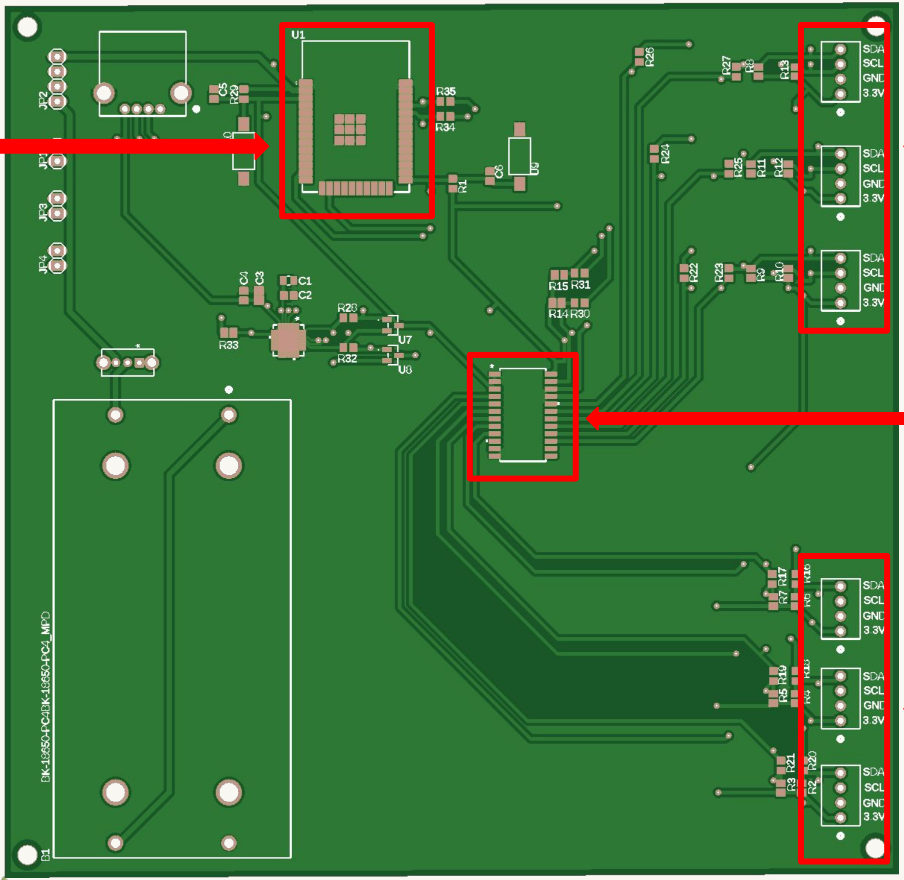
I2C bus





Main Board Layout

ESP32

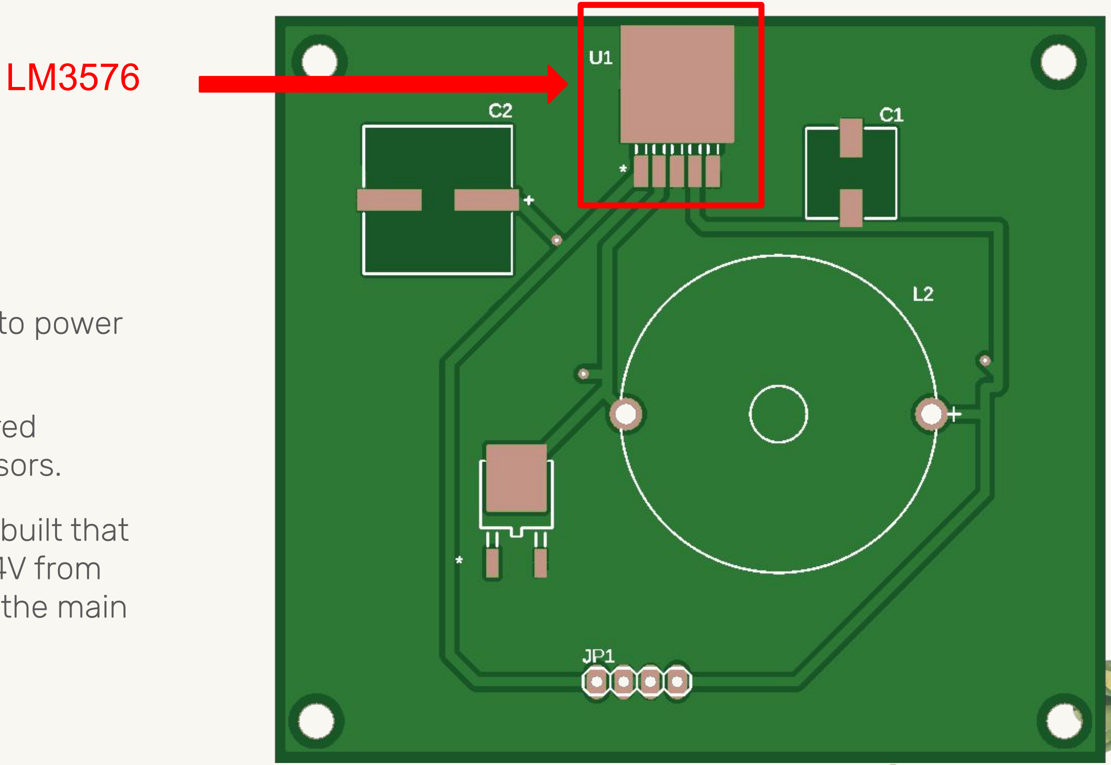


Pin headers for light sensors

PCA9547D (I2C Mux)

Pin headers for temp/humidity sensors

3.3V Regulator Layout



- One 3.3V regulator will be used to power the ESP32 on the main board.
- Three 3.3V regulators will be wired directly to the soil moisture sensors.
- A total of four regulators will be built that will each be supplied a Vin of 7.4V from the two lithium ion batteries on the main board.

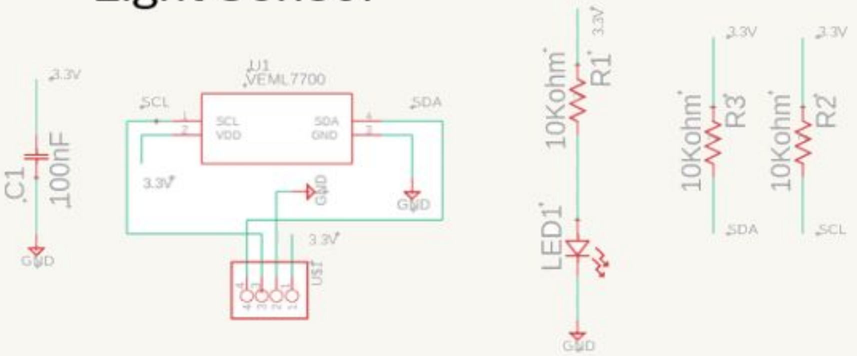
3.3V Regulator Testing

Input: 8.4V

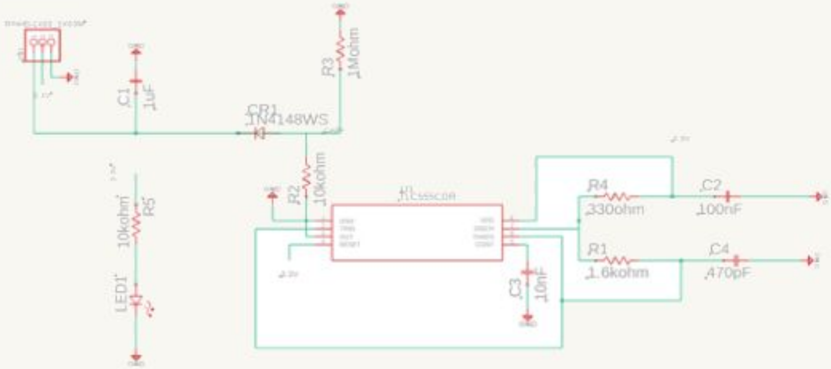
Output: 3.3V

Sensors

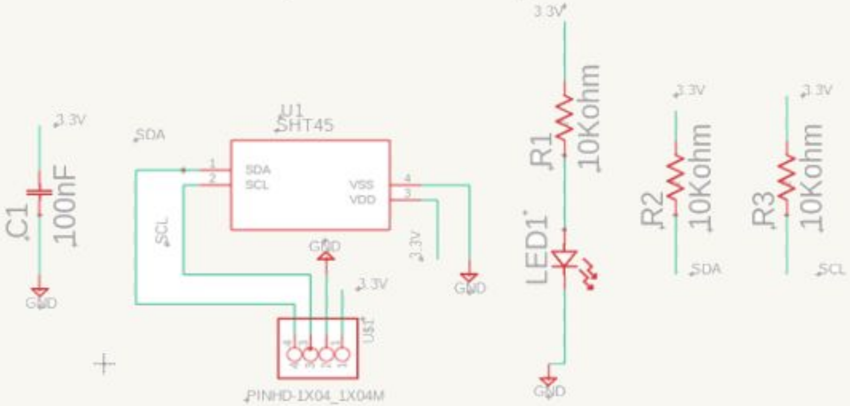
Light Sensor



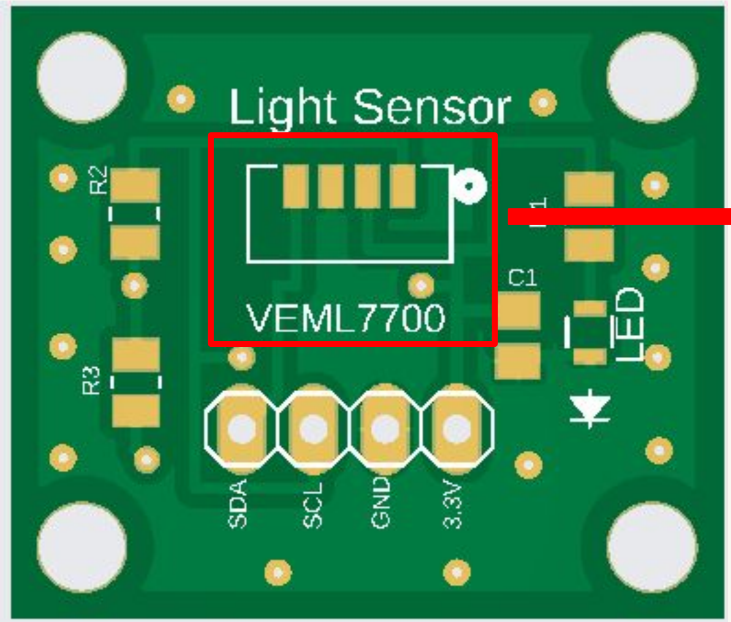
Moisture Sensor



Temp/Humidity Sensor

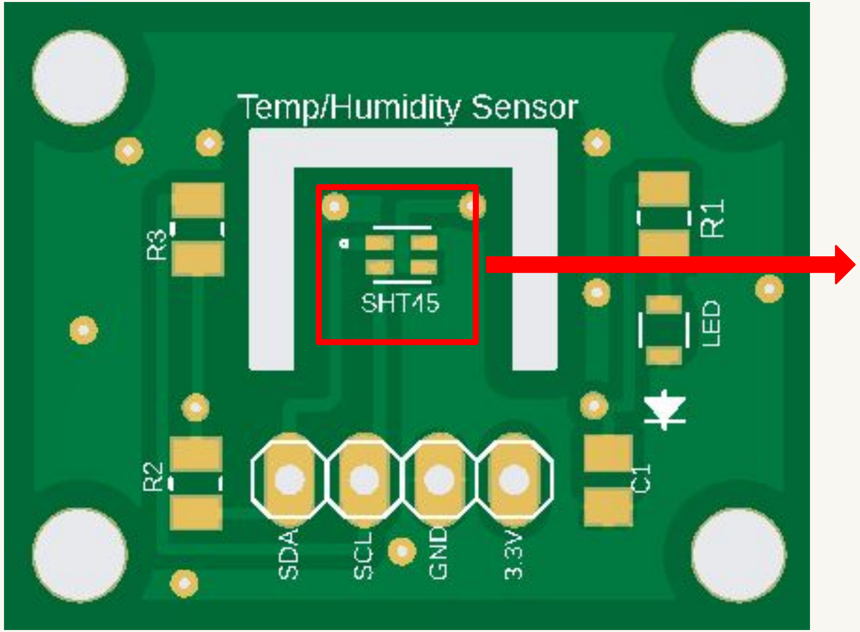


Light Sensor Layout



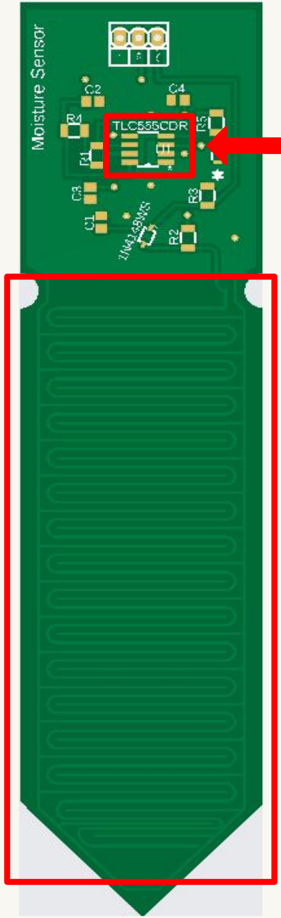
- VEML7700 light sensor
- 10nF capacitor
- LED
- 10k resistor

Temp/Humidity Sensor Layout



- SHT 45 temperature and humidity sensor
- 10k resistor
- 100nF capacitor
- LED

Moisture Sensor Layout



- 555 Timer
- Diode
- Resistors
- Capacitors
- LED

- Capacitive trace lines
- Charges then discharges and we measure that with a timer

Light and Temp Sensor Testing

Issues faced:

- Initial problem with I2C mux communication because of wrong pull-up resistors.
- Temp sensor worked but light sensor didn't, this was a library issue.

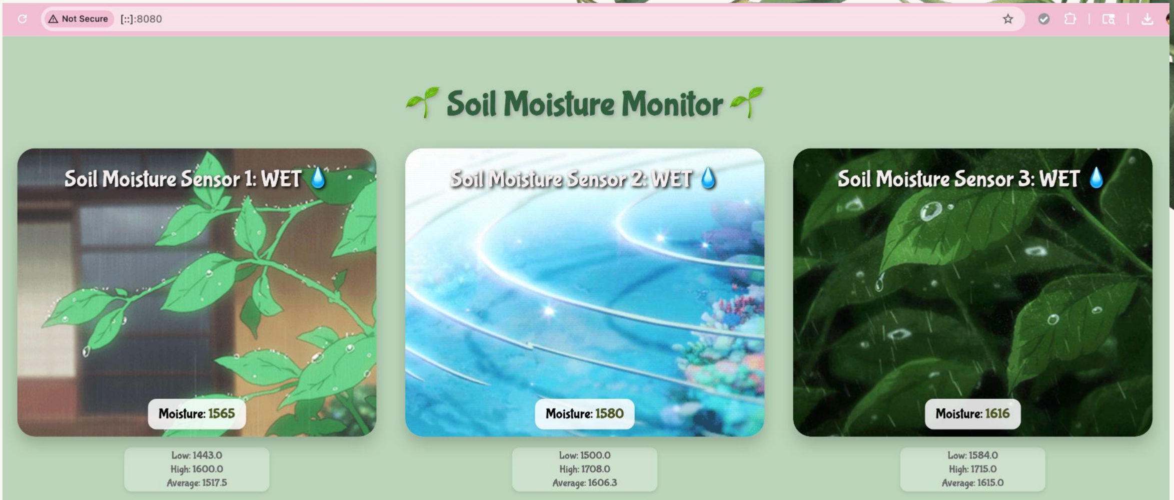
```
SHT45 Sensor Data (Channel 0):
  Temperature: 23.80°C (74.84°F)
  Humidity: 47.52%
  Raw data: 0x64 0xA4 0x6F 0x79 0xA7 0x12
VEML7700 Light Sensor Data (Channel 7):
  Ambient Light: 0.00 lux
  ALS Raw: 0
  White Raw: 0
  Light Level: Very Dark
```

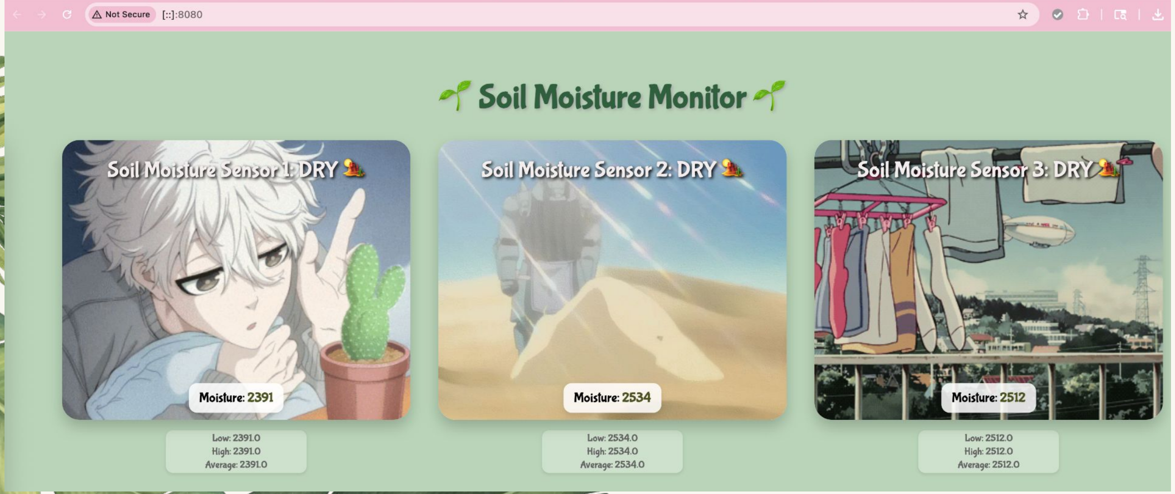
```
=== Reading All VEML7700 Sensors ===

Reading VEML7700 on Channel 5:
  Raw ALS: 5159 (0x1427)
  Raw White: 6807 (0x1A97)
  Lux: 297.27
  Light Level: Normal Indoor

Reading VEML7700 on Channel 6:
  Raw ALS: 4930 (0x1342)
  Raw White: 6851 (0x1AC3)
  Lux: 283.91
  Light Level: Normal Indoor

Reading VEML7700 on Channel 7:
  Raw ALS: 4934 (0x1346)
  Raw White: 6928 (0x1B10)
  Lux: 284.14
  Light Level: Normal Indoor
```

Software Technologies

These were the largest contributors to our project, helping us push F.L.O.W.E.R.S. to continue growing.

Testing – Soil Moisture Values





- Temporary localhost gathered sensor ranges for both wet and dry soil for all 4 types of soil
- The page keeps track of lows, highs, and averages to track the best range cutoffs

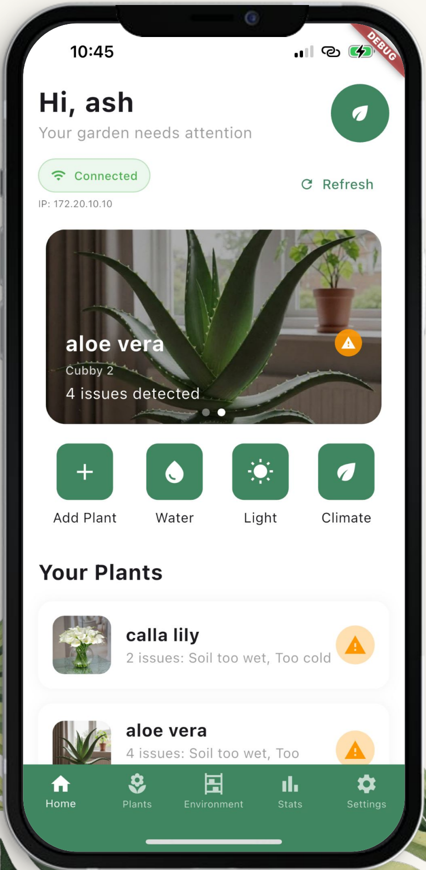
Testing – Soil Moisture Values, Cont.

	Left Soil Moisture Sensor	Center Soil Moisture Sensor	Right Soil Moisture Sensor
Coarse Soil	Drenched: < 1615 Wet: 1616 - 1925 Moist: 1926 - 2235 Dry: > 2236	Drenched: < 575 Wet: 576 - 1075 Moist: 1076 - 1574 Dry: > 1575	Drenched: < 1712 Wet: 1713 - 2040 Moist: 2041 - 2364 Dry: > 2365
Rough Soil	Drenched: < 1535 Wet: 1536 - 1819 Moist: 1820 - 2099 Dry: > 2100	Drenched: < 457 Wet: 458 - 710 Moist: 711 - 954 Dry: > 955	Drenched: < 765 Wet: 766 - 1440 Moist: 1441 - 2109 Dry: > 2110
Normal Soil	Drenched: < 1525 Wet: 1526 - 1680 Moist: 1681 - 1839 Dry: > 1840	Drenched: < 465 Wet: 466 - 715 Moist: 716 - 959 Dry: > 960	Drenched: < 1615 Wet: 1616 - 1830 Moist: 1831 - 2039 Dry: > 2040
Fine Soil	Drenched: < 1520 Wet: 1521 - 1764 Moist: 1765 - 2004 Dry: > 2005	Drenched: < 465 Wet: 466 - 635 Moist: 636 - 799 Dry: > 800	Drenched: < 1655 Wet: 1656 - 1885 Moist: 1886 - 2114 Dry: > 2115

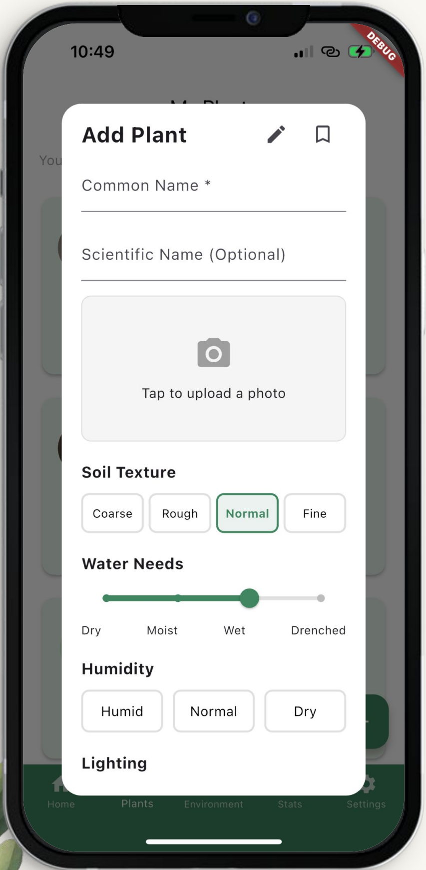
- For each soil type, the value range was gathered as specific to each unit's assigned sensor
- The values above are the ADC readings gathered from testing on the html page, as shown on the previous slide.

Mobile Walk-Through

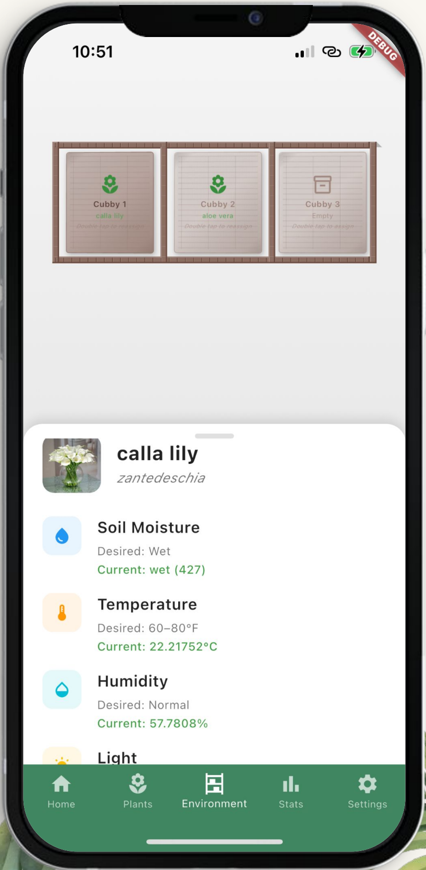
Home Page (on App open)



User Taps "Add Plant" Quick Key, Fills out Info, and "Add Plant"



The Plant is Added to the "Environment" page in the designated environment.

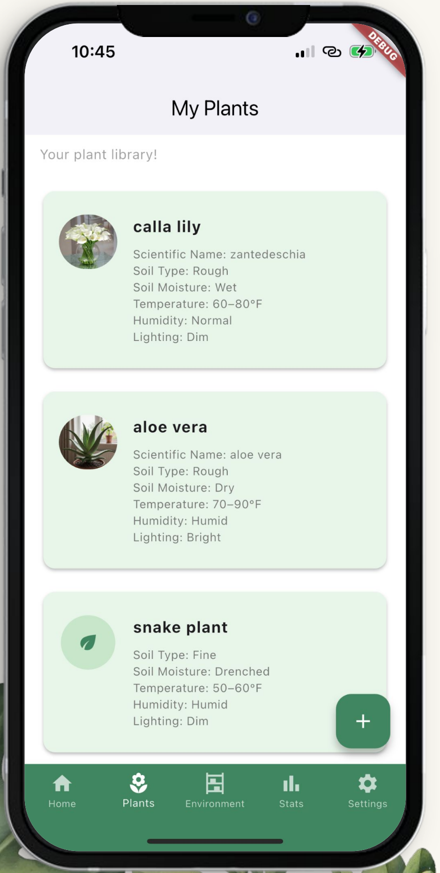


The User double taps the cubby within the environment where the plant will be stored

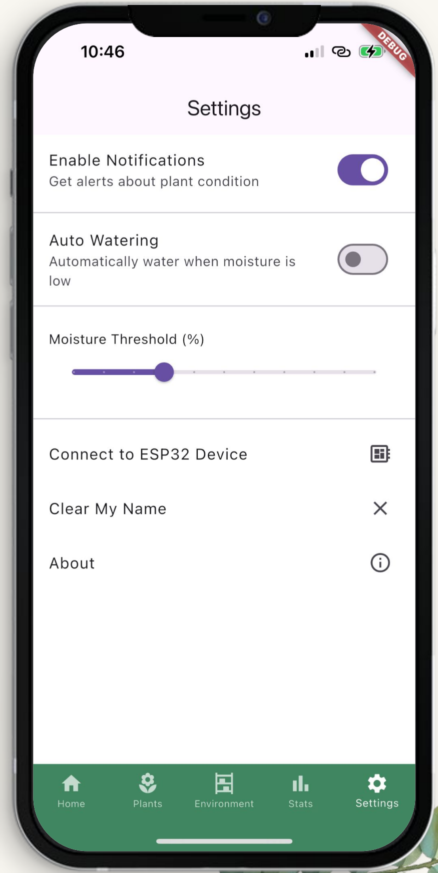
With a single tap, the plant profile will come up

Mobile Walk-Through

The User's Plant Library



User Settings



Work Distribution Table

Ashley	Mobile app Wifi configuration and bidirectional communication with the app Embedded programming for soil moisture sensors
James	Designed PCB for main board and 3.3V regulator, troubleshoot I2C mux and general I2C issues, assisted in shelving assembly and wiring
Noah	Shelving Assembly, Water pump/solenoid valves implementation, Lighting implementation, Shelly RGBW coding for lights and valves
Junior	Designed PCB for the light sensor, temperature/humidity sensor, and moisture sensor

Budget Table

Item	Projected Cost	Actual Cost
Circuit Components	$150	$300
PCBs	$100	$200
Shelving unit for plants	$165	$175
PVC/Solenoid valves/Pump	$125	$150
LEDs/LED Driver	$80	$90
120V/12V AC to DC converter	N/A	$50
Dev boards	$30	$40

Improvements for the Future

- Use SPI or another communication protocol instead of I2C for the sensors.
- Instead of using batteries to supply power to the main board, use the AC/DC converter as the power supply.
- Only need one regulator for all of the moisture sensors and the ESP32, instead of individual regulators for each.

Thanks !

Thank you for your time and for listening to how our project has **grown**.