ECE 198 Design Document

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Customer Definition

The customers for our project are those who have home gardens and also companies/businesses that have gardens and wish to take care of them properly[1]. Those who do not want to know the exact amount of water needed for their plants due to being busy would also find this useful as they would not have to worry about overwatering and underwatering [2], [3], [4]. Companies often have gardens in their buildings and an automatic irrigation system would be more ideal to use to maintain them instead of hiring someone to do it. Companies and businesses related to agriculture and farming would also be a large demographic of our customers due to their need for an automatic irrigation system[5]. A geographic attribute of the customer base is that in the United States, the most suited areas for gardening are in the Southeast and Southwest regions of the country[6], which is where the majority of gardeners live in the United States. 29% of the population in that region have home gardens, which amounts to a customer base of around 36000000 people. An economic attribute of the customer base is that the average home gardener in the United States is a part of the middle class[7]. A demographic attribute of the customer base is that 71.6% of home gardeners are married in the United States[7].

Competitive Landscape

A social system that addresses the problem is public gardening services, where the customer can rely on professional gardeners to take care of and maintain their gardens, due to the customer not having enough time to do so themselves. Shortcomings of this system are the cost of hiring someone to come in and the customer might have a different style that the person hired might not fully be able to see and implement[8]. A technological system that addresses the problem are drip irrigation systems, which allow for plants to be watered through a system of pipes and valves and do not require the customer to spend time every day taking care of their plants. Shortcomings of this system are the expensive initial cost, the possibility of pipes being clogged and it can take a lot of time to install the system in the initial stage[9]. Another technological system that addresses the problem are sprinkler irrigation systems which simulate natural rainfall to water plants. This system also does not require the customer to spend a lot of time out of their day taking care of their plants. Shortcomings of this system are that water can be lost due to winds and evaporation, and can lead to fungal disease from the overhead watering[10].

Requirement Specification

Functional Requirements:

- One of the system's functional requirements is the amount of water needed for each plant. From a published source online[11], the plants will be pumped out about a 3rd of a cup worth of water, around 80 milliliters.
- The electric-powered water pumps used to dispense the water will have a noise level range of 80-85db[12].
- A 16X2 character LCD screen will display a reading of the current temperature in the room[13].
- The water tank that will be used to dispense water for the user will have a maximum capacity of 5 liters[14]

Technical Requirements:

- The input voltage of the soil moisture sensor is one of the requirements that is needed for our product. From a source online[15], the input voltage of the soil moisture sensor is 4.4-6V. The moisture sensor will output a value between 3.15V to 1.9V depending on the level of moisture in the soil.

- The STM32 microcontroller should operate at a core voltage of 1.8V to 3.6V, and handle an analog-to-digital conversion resolution of 12 bits[16]. The Board that we are using should have about 20 I/O pins on it, as we will need to support up to 5 moisture sensors, 1 ultrasonic sensor, a motor driver for the water pump, humidity, temperature, and LCD.

- The ultrasonic sensor used in this project must be able to measure a distance from 2 cm to 200 cm with a resolution of 3mm to provide as much accuracy as possible. The ultrasonic sensor will require a 5V DC voltage to run and will need a trigger pulse input, echo pulse output, and a ground connection[17].

- The water pumps that we will be using will be running at 5V and and a current of 0.18A. With this much power to the water pumps, they will be able to pump 80 L/hour.

Safety Requirements:

Our system will not require the need for more than 30W of any form of power during any point of its usage. Additionally, it will not require the need to have more than 500mJ of any form of energy during any point of its usage. We can implement these safety requirements into the system by adding an automatic shut down mechanism, which will trigger if either the 30W power or 500mJ energy threshold is met. When the mechanism triggers, the system will shut down and stop performing its current task, to ensure that the user is not put in any dangerous circumstances. Since we are working with a lot of water, a safety requirement would be to waterproof the system so that no short-circuiting is caused. We can implement this by applying clear nail polish to the boards, which acts as a waterproofing agent. Another safety requirement is to ensure that the water pump do not overheat. To implement this, the system will run periodically(once every hour), so that water is not being pumped out continuously for long periods of time. This will allow for the water pump to cool down until it begins functioning again, which ensures the safety of the user.

Design

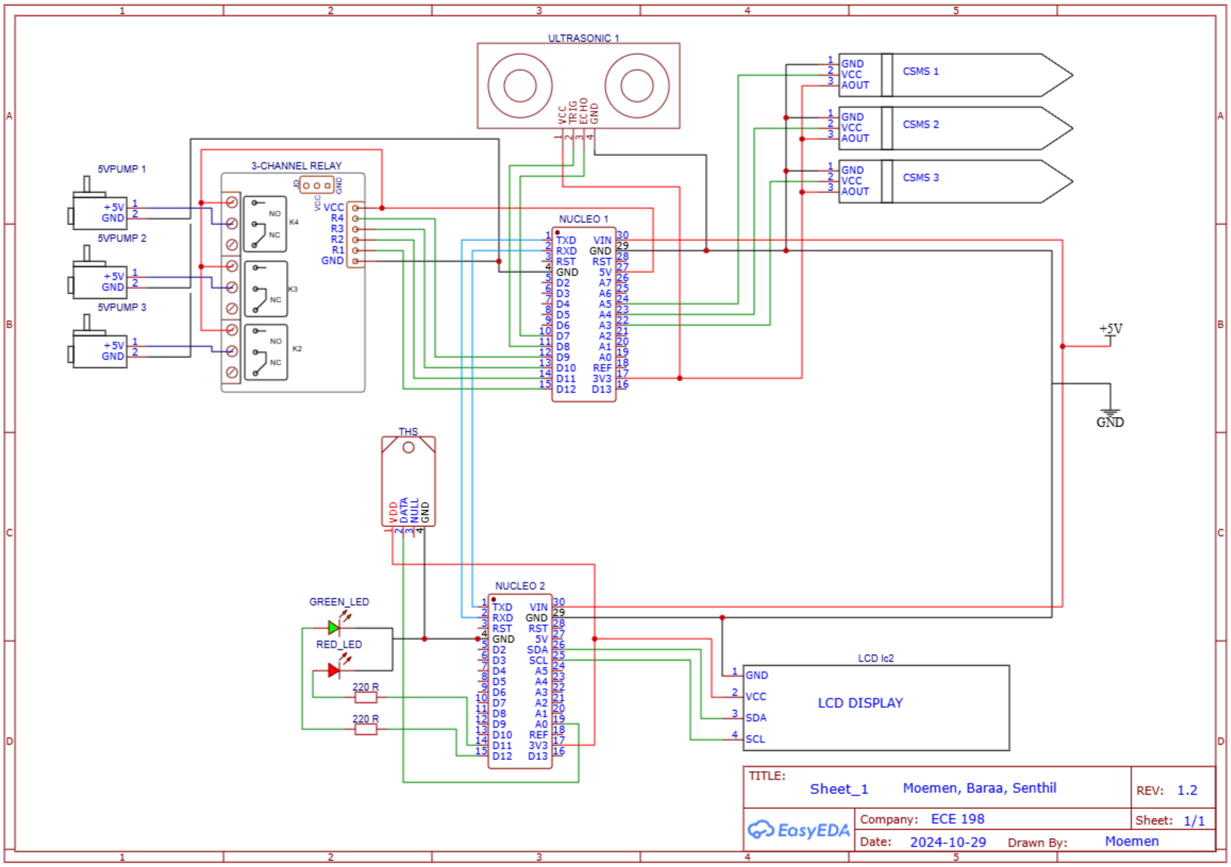
ULTRASONIC 1
5VPUMP 1
3-CHANNEL RELAY
5VPUMP 2
5VPUMP 3
NUCLEO 1
CSMS 1
CSMS 2
CSMS 3
+5V
GND
THS
NUCLEO 2
GREEN_LED
RED_LED
220 R
220 R
LCD Ic2
LCD DISPLAY
TITLE:
Sheet_1
Moemen, Baraa, Senthil
REV: 1.2
EasyEDA
Company: ECE 198
Sheet: 1/1
Date: 2024-10-29
Drawn By: Moemen

Figure 1

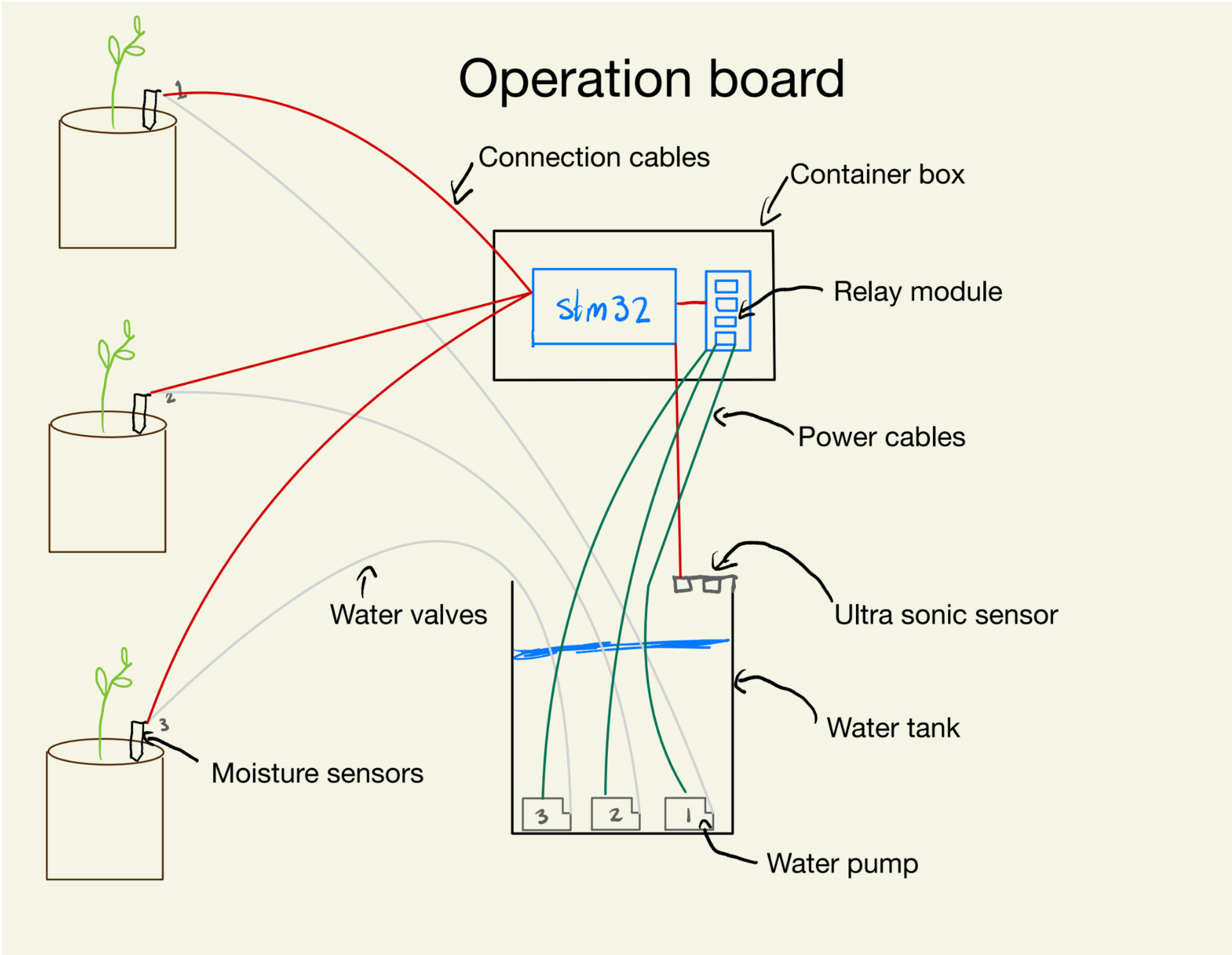
Operation board
Connection cables
Container box
stm32
Relay module
Power cables
Ultra sonic sensor
Water valves
Water tank
Moisture sensors
Water pump
1
2
3
3
2
1

Figure 2

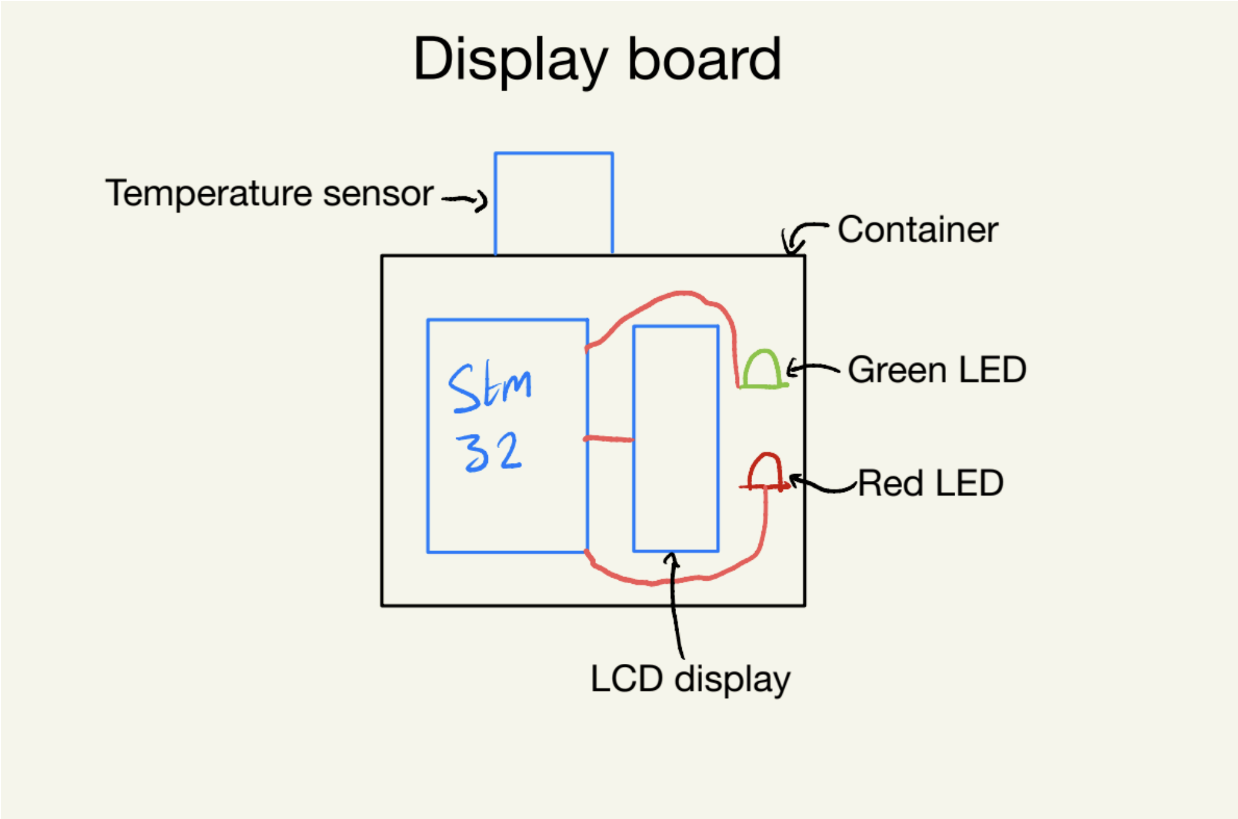

Figure 3

The water tank will have three water pumps(5V, 0.18A) inside of it which will be connected to the plants through the water valves and to the relay module on the 1st STM32 microcontroller through power cables(Figure 2), which is placed inside of a container box. The ultrasonic sensor(5V) will be placed above the tank attached to the top of its side and connected to the 1st STM32 microcontroller through a wire(Figure 2). The LCD display and LEDs will be connected to the 2nd microcontroller to display the output of the system(Figure 3). The temperature sensor will also be connected to this microcontroller(Figure 3). The first STM32 will be connected to the second STM32 through a wire, the soil moisture sensor(input: 4.4-6V, output: 1.9-3.15V) inside of the soil where the plants are laid, and also connected to the water pumps inside of the water tank.

All of the components with quantified requirements from the previous section are included in Figure 1, Figure 2 and Figure 3.

An alternative solution we considered was to implement solenoid valves into our design instead of the 3 water pumps. We ultimately decided to not include the solenoid valves and instead use 3 water pumps as the solenoid valve would have used 1 high powered water pump compared to using 3 water pumps. Using the solenoid valve with higher voltage would result in more power and energy being used, which increases the safety risks, so using the 3 low voltage water pumps allows for a more safe design[19].

Technical Analysis

Analog to digital conversions:

This concept is used when converting signals from various sensors (e.g. soil moisture, temperature) into digital signals, which the STM32 microcontroller can process. The sensors usually output specific voltages that correspond to the physical qualities such as water level, and temperature, and these voltages must be converted into a digital form to be interpreted by the microcontroller.

The formula for ADC (Analog Digital Conversion) is:

Digital value = (Analog Signal (voltage) * 2^n -1)/ Reference Voltage

n is the number of bits (e.g. a 12-bit ADC converts the analog signal into a number from 0 and 2^{12} - 1= 4095[20].

This principle is crucial in converting the environmental conditions such as (soil moisture, and temperature) into digital data, allowing the microcontroller to make decisions on whether to water the plants or provide shade.

Flow rate:

Flow rate is a crucial concept in fluid dynamics, which measures the volume of fluids, (in this case water) moving through a pipe per unit of time. This concept is essential for determining how much water is being delivered to the plants, and it directly affects the efficiency of the irrigation system.

Equation: The flow rate Q is defined as:

$$Q = A * v$$

v is the flow velocity of the fluid in m/s and A is the cross-sectional vector area of the fluid in m^2, which gives Q units of (m^3)/s[21].

To determine the Optimal flow rate for our project, we first measure the cross-sectional area of the pipe through which the water will flow. We can calculate this based on the diameter of the tubing used. Next, we factor in the speed at which the water will flow, which will depend on the pump's power.

Calculating the optimal flow rate for this small low-power project allows us to pick out a water pump which would be best fit for the specifications and requirements that we have. By monitoring and controlling this rate, we can ensure that the correct amount of water reaches the plants without waste. Additionally, knowing the pump's flow rate allows the system to adjust irrigation durations to meet the water needs of the plants accurately. Additionally, knowing the flow rate will allow us to precisely track how much water is being used, which is important for conserving water in a resource-efficient way.

Ultrasonic Sensor:

To calculate the depth of the water, an ultrasonic sensor will be used. It will be used to calculate the height from where the sensor is to the surface of the water. The sensor will give us the time in nanoseconds for the wave to reach the surface of the water and back to the sensor. The distance can then be calculated using the following formula:

Equation: Distance = (time)(speed of sound)/2

Since the ultrasonic sensor returns the time it takes to travel to the surface of the water and back, we have to divide by 2 to account for this so that it gives us the distance between the sensor and the surface of the water only[22]. This principle will be used to track the water reserve and notify the user when the water level reaches a certain amount.

Manufacturing & Implementation Costs:

Part	Quantity	Price	Distributor
NUCLEO-F401RE	2	$19.69	https://www.digikey.ca/en/products/detail/stmicroelectronics/NUCLEO-F401RE/4695525
DHT11	1	$1.82	https://ca.robotshop.com/products/dht11-temperature-humidity-sensor-module-breakout
HC-SR04	1	$4.79	https://ca.robotshop.com/products/hc-sr04-ultrasonic-sensor
LCD1602A	1	$3.78	https://www.ebay.com/itm/145883485729?chn=ps
4pcs Capacitive Soil Moisture Sensor, 4 Channel 5V Relay Module, and 4pcs Water Pump + 4M Vinyl Tubing	1	$33	amazon link
Red LED	1	$0.25	https://bc-robotics.com/mm-red-led-624nm/
Green LED	1	$0.25	https://bc-robotics.com/shop/5mm-blue-led-basic/

- **Stm32 microcontroller:** The manufacturing and assembly of the stm32 happens worldwide with factories in France, Singapore, and Italy[23].

- **DHT 11:** The DHT11 is a humidity and temperature sensor module which is manufactured by Aosong Electronics, in Guangzhou, China[24].
- **HC-SR04:** The HC-SR04 is an ultrasonic sensor provided globally by Kuongshun Electronic, one of the international well-known manufacturers and suppliers of hc-sr04, located in Shenzhen, China[25].
- **4pcs Capacitive Soil Moisture Sensor, 4 Channel 5V Relay Module, and 4pcs Water Pump + 4M Vinyl Tubing:** These components are all manufactured and distributed by WayinTop, a company located in the USA[26].
- **Red and Green LEDs:** The LEDs that we are buying will be manufactured by Vorlane, a company located in Zhongshan, China[27].
- **LCD1602A:** We will be using the LCD1602A as our display. This LCD is manufactured by KeyGree, a company located in Chengdu, Sichuan, China [28].

Installation Manual:

1. Remove the product from the packaging
2. Put the 4 AA batteries into the battery pack
3. Put the Soil moisture sensors into the plant pots (figure 2)

4. Plug the one of the 3 water valves into the water pumps, then put it into the plant pot with the corresponding number on the moisture sensor and water pump (figure 2)
5. Fill the water tank to the marked line (figure 2)

User Guide:

1. Inspect the product for any damage upon arrival
2. Follow the installation guide to set up the device
3. To see the current temperature of the room check the LCD for information(figure 3)
4. The two LEDs connected to the beside the LCD display will inform you of there is water in the tank(figure 3)
5. If the green led is on then your product is fully operational(figure 3)
6. If the red LED is on the you need to refill the tank with water (the device will not operate without sufficient water in the tank)

Energy Analysis

The reference standard for the product for baseline power levels will be coming from the 6V battery. This component of the product uses a maximum of 6V and has a current of 750mA = 0.75A, which produces the maximum amount of power out of all of the components. The amount of power produced by the battery is given by:

Watts = Voltage x Current = 6V x 0.75A = 4.5W

From this, it is seen that the product will not exceed the maximum power output allowed of 30W.

Our product is using a 6V battery, which has a maximum capacity of 6Ah. The energy in watt-hours is given by:

Energy = Voltage x Capacity = 6V x 6Ah = 12Wh

The energy in millijoules is 12 x 3.6 x 10^6mJ.

This exceeds the limit of 500mJ, so to prevent this issue, we will be using an external cable to supply extra power into the device to make up for the excess energy.

Risk Analysis

A possible negative consequence of using the design as intended for the user's safety is a potential short circuit in the system, as well as the water pumps overheating too quickly, which could cause physical harm to the user.

A possible negative consequence of using the design incorrectly on the user’s safety is the scenario where the user unknowingly damages a component of the system believing that no harm is being done, which could pose a danger. This could lead to a short circuit, or causing the system to malfunction and an issue occurring within the water pumps which has the potential to cause harm to the user.

A possible negative consequence of using the design not as it was intended is if the user attempts to use the system to water different plants as if it were a hose. The user might attempt to remove the water pumps and use them to water plants from above. This raises safety issues as the user attempting to disassemble the system poses a danger to their safety and could cause the product to malfunction, further raising the risks and dangers.

The most likely way the product will malfunction is due to a short circuit. As the product involves a water tank, the wires will be in close proximity to water, and potentially drops of water will land on the wires, leading to a short circuit. If a short circuit occurs, it can also damage other components of the system, leading to a malfunction of the overall product. This raises a safety concern as short circuits are very dangerous towards the user and can cause burns, internal damage, and cardiac arrest[29].

Testing and Validation

Soil Moisture Testing:

Test specification: The soil moisture sensors will be tested by inputting each of the three sensors into pots of soil with different levels of moisture. The first one being completely wet, and the second being a little wet. All this will be done with no water in the tank, just to avoid messiness.

The main measurement will be in the output of the soil moisture sensor, the sensor will output a voltage which will either indicate a "high" or "low", with high voltage being around 3.15v and low being around 1.9v.

Pass criteria: If the sensor is in a wet environment, then it should output "low" with a voltage of 1.9v. If the sensor is in a dry environment, then the output should be "high" with a voltage of around 3.15v

Water level detection:

The ultrasonic sensor will input a value of a distance, this distance will be used to determine the water level in the bucket of water. The bucket of water will have a height of H cm , the stm32 will calculate (H - distance). For a tank to be considered "empty" the water level needs to be under 4 cm, and for it to have water, the water level needs to be above 4 cm. The 4 cm mark is to make sure that the water pumps are fully submerged in the water.

Pass criteria: If there is no water in the tank, the red led should light up, indicating that water needs to be refilled, and if there is water above the 4 cm mark, the green led should light up indicating that there is sufficient water available.

Water Pump Testing With green led on:

This test will determine the functionality of the water pumps, each will be receiving an output which will be into the relay, which will activate the specific pump which we want to turn on. To test, we will put the corresponding moisture sensor in a wet plant pot, which will trigger the pump.

The pumps should turn on for a total of about 3 seconds and pump a total of about 80 ml out, which is about a third of a cup.

Pass criteria: Each water pump should pump out about a third of a cup of water or around 80 milliliters when the corresponding soil moisture sensor is placed in water.

Water pump with red led on:

The red led is on here, this means that there is no water available in the tank. This test will validate that the pumps will not run when there is no water available. This will conserve energy and will not keep constantly testing the moisture and turning on the pumps with each cycle. The moisture sensor will test for moisture every 20 minutes, so if water wasn't available, then the pumps would keep pointlessly turning on every 30 minutes.

Pass criteria: If the red led is on, and the corresponding soil moisture sensor is inserted into dry soil, then the corresponding water pump should not activate.

Temperature inputting and display:

The temperature sensor will input a temperature into the stm32 and the stm 32 will output that temperature through the lcd. The LCD will print it in the form of "Temperature: ##" the "#" represent numbers. To test if it changes as the temperature simply light a flame from a lighter near the sensor and the temperature reading should increase.

Pass criteria: The demonstration will be performed in a closed indoor insulated space, therefore the space's temperature will be at “room temperature” which is around 20- 22 degrees celsius, as long as the output on the LCD is close to that number then it passes. If the temperature also increases when a flame is brought near the candle then it also passes.

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