| University Of Waterloo    **Plant Hydration System**  Project Proposal  Kushal Prajapati & Krish Prajapati  *ECE198*  David Lau  19 September 2024 |
| --- |

Table of Contents

1. The Problem………………………………………………………………………………3

Clients ……………………….……………….…….…3

Goals ………………………….……………….………4

Our Stakeholders ………….…………………….…4

1. Solution.……………………………………………………………………………………6

Overview …………….……….…….…………………6

System Plan …..……………….……….……………7

1. Initial Requirements……………………………………………………………………8

Sound(Alarm System) ……..………….……….…8

Light(Lux Measurement)…….………….…………9

Soil Moisture Measurement .……..….……....…10

LCD Display Update Rate …..…..………………11

1. Principles …………………………………………………………………………………12
2. Standards …………………………………………………………………………………13
3. References…………………………………………………………………………………16

## The Problem

Many students in university dorms and rooms enjoy keeping plants in their rooms for various reasons, including decoration, stress relief, and improving air quality. According to a study by the Identity Realization research group at the University of Exeter [1], research has shown that indoor plants can help increase productivity by up to an astonishing 47%. It has also been analyzed that plants help give a 20% percent boost in memory and concentration. There are many reasons for the effect, including the smell of plants and flowers, their look, as well as how they help improve the oxygen levels within a room by absorbing the carbon dioxide and producing oxygen. Overall, it is important for students to have plants within their rooms for their wellbeing.

However, students also often struggle to properly take care of their plants primarily due to:

* Busy Academic Schedules
* Lack of gardening knowledge
* Inconsistent room environments

Students often have a hard time managing school time, teams, family responsibilities, and other priorities, often making maintaining plants hard and easy to forget. In addition, most dorm rooms have varying light and humidity levels, making it challenging and sometimes even stressful to take care of plants, especially with inadequate experience [2]. All of these factors can make plants more of a difficulty to manage rather than helpful. In addition, this lack of proper plant care may result in dead or unhealthy plants, which would further frustrate students and waste resources.

### Our Clients/Customers

Our solution is primarily oriented towards residence students that attend university or college. For this case, we will be specifically targeting the students that are living within or near the University of Waterloo. The University of Waterloo has over 42,000 [3] full and part-time students, with a minimum of 20% (8,400) of them living near or within the university. We are focusing our product towards the students that live in or near the campus that are interested in or currently are keeping and maintaining indoor plants.

### 

### Goals

The goal of our solution is to give students an easier way to maintain plants without adding to the stress of their already demanding academic lives. We want to ensure that students can remember to regularly water their plants when their hydration levels are getting low, monitor their growth and health, as well alert them if the hydration or light levels are not healthy. By simplifying plant maintenance, we aim to help students truly enjoy the benefits of having plants in their living spaces, such as improved air quality and reduced stress, without the burden of constant monitoring or worrying about plant health.

Even though our solution will simplify the process, we will not automate the entire watering process, as it is important for the students to remain actively involved in maintaining their plants, and this hands-on approach helps foster a sense of ownership and connection.

### Our Stakeholders

**Residence Students (Primary Client):**

Needs: Since the residence students are the primary client, we will need to create an easy-to-use system that helps maintain their plants without constant attention, or maintenance. The system must be reliable, simple to set up, and well put together, and most importantly, portable, while maintaining a low manufacturing cost. Since students do not have much time to pay attention to their plants, the display and lights must be bright so that students can recognize when it is time to water the plants. The design must be straightforward and not use too many wires or be messy as it would make the whole process of watering the plants more tedious and time consuming. In addition, we also have to ensure that the system is made of quality parts to ensure that no faults occur within the system.

Concerns:

* The system should be made of quality parts so that the readings of the hydration and light sensors are accurate.
* The system should not interfere with the dorm policies regarding the electricity use, so it must be consuming a low wattage, and not impose any danger towards anyone. (careful with dealing with power and batteries)
* The system must be within an affordable price limit ($10 to $40) to manufacture to make it accessible to more students (most students don’t want to spend too much or too limited money).
* Safety: The entire system must be safe to use, especially around water. It is important to ensure everything is well insulated.

**University of Waterloo Residence Staff:**

Needs: A system that can help promote wellness among students that live within their residence, as plants as they help improve the health and stress levels of the students.

Concerns:

* System must be easy to use and set up so it can easily be sold
* System must be cheap to manufacture
* Must adhere to the dorm policies regarding the electricity use
* The size of the pot and wires must be portable and easy to carry due to the space limitations
* Ensure the system stays clean and well insulated (water should not short or dmg anything)

**Shadi Vandvajdi (Graduate TA):**

Needs:

* The system must be easy to use and well designed
* Should be able to solve the problem in an effective manner (no wastage of components or resources)
* System must function without technical errors or issues

Concerns:

* The system must follow key design principles (functionality, safety, reliability, and manufacturability)
* The system must effectively meet the specific clients’ needs
* The documentation must be clear and easy to follow

**Parents of Students (Indirect Client):**

Parents can be included as a potential customer as they may have an indirect interest in the system. Most parents are concerned about the well-being of their children, especially in a dorm environment, and so they encourage their child to keep plants within their space.

Needs:

* A system that helps students maintain their healthy live space, without the need of constant maintenance or attention
* Assurance that the system remains safe and reliable
* System must be easy to set up, and remain portable
* The system should be clean so that it does not create a mess within the space

Concerns:

* Potential costs (Parents need to ensure that the system remains affordable as most students are tight on money)

**Plant Experts (Excluded):**

Given that this entire project is targeted at beginners plant owners (students), it is not important to involve experienced gardeners. Instead of being more technical and advanced in features and measurements, our design seeks to cater towards students, though prioritizing simplicity and affordability, and focusing on the most important and basic traits of healthy plants. Thus, including experts would not be required in our scope.

## Solution

### Overview

To prevent the dehydration of indoor plants, we plan to integrate a soil moisture sensor inside the plant pot, connecting it to an alarm system. Additionally, we will monitor the plant's sunlight exposure using a light sensor. The user will be alerted when the plant's moisture level drops below a normal threshold, with buzzers and lights that will turn off once the moisture returns to normal. The system will also track the plant's daily light exposure and compare it with the standard value of 12 hours. Furthermore, moisture and light data will be displayed on an LCD screen at regular hourly intervals, making it useful for applications such as plant care or automated watering systems. **The moisture level will be shown as a percentage (%), and light intensity will be displayed in lux.**

### 

### System Plan

Communication Domain: The two STM32 boards will have a wired connection that communicates both plant luminosity and soil moisture data, over a distance of 1m and greater, for the information/reminders to be displayed. All code will be written and deployed from the STM32CubeIDE in the language C and C++

**STM32 Microcontroller 1 (Hydration Alarm & Sensor Units):**

Function: Reads soil moisture and light data in hourly intervals, and compares to predefined thresholds of dry soil.

Input: Soil moisture sensor, light sensor, user-set intervals.

Output: Sends alarm trigger and soil moisture data to the second STM32.

**STM32 Microcontroller 2 (Remote Display/Notification Unit):**

Function: Receives data from the first STM32 and notifies the user.

Output: Displays moisture and light data and sends reminders via LED or buzzer if moisture or light levels are too low or intervals are reached.

Power and Energy

The accuracy of the power and energy are not accurate, as they do not account for the program/code that the MCU faces or the energy utilization of all the devices on the microcontrollers. This is done to see the maximum power and energy our system will create, if all devices are active [4].

Power = v \* a

**Maximum Power Output (Active Mode)**:  
The STM32F401RE microcontroller operates at around 100mA at 3.3V in active mode, resulting in a **maximum power output** of approximately:  
P=V×I=3.3V×100mA=0.33W  
So, for two STM32 boards, the total power output in active mode is:  
2×0.33W= 0.66W(660mW)

**Power Output in Sleep Mode**:  
In sleep mode, the STM32 consumes significantly less power, around 20µA. The power output would be:  
P=3.3V×20μA=0.066mW

1. **Soil Moisture Sensor**: Operates intermittently, taking readings every hour. Turns off when not in use.
   * **Active**: 66mW (at 3.3V, 20mA)
   * **Off**: 0W
2. **LCD Display**: Keep the display off unless user interaction is required and 5 minutes every hour . When active, the backlight will be disabled to save power.
   * **Active**: ~9mW
   * **Off**: 0W
3. **Light Sensor (LTR-329)**: Powers up every hour for light readings, and switched off otherwise.
   * **Active**: 0.33mW (100µA at 3.3V)
   * **Off**: 0W
4. **Buzzer**: Used sparingly for alarms
   * **Active**: 33mW (at 3.3V, 10mA)
   * **Off**: 0W
5. **LED**: Only illuminates for status changes. Lowering the current reduces the power from 10mA to around 2mA.
   * **Active**: 33mW
   * **Dimmed**: ~6.6mW

By selectively toggling the STM32 Boards, and peripherals, the energy consumption will be significantly optimized, and consume less than 30W and 500mJ of energy:

| Component | Manufactuer | Distibutor | Cost |
| --- | --- | --- | --- |
| STM32 (Active Mode) |  |  |  |
| STM32 (Sleep Mode) [5] |  |  |  |
| Resistor  Soil Moisture Sensor |  |  | $10.80 |
| Buzzer (Piezo) |  |  | $1.26 |
| LED (single) |  |  | $0.25 |
| Small LCD Display ( HD44780) |  |  | $14 |
| Light Sensor (LTR-329) |  |  | $ 6.91 |
| Jumper Wires |  |  | $ 3 |
| USB A Male to Mini-USB B Male |  |  | Part of STM 32 Nucleo Board Kit |

As you can see, the total cost of the project is less than $50 dollars when not accounting for the 2 STM 32 boards, which cost $46 each

4. Next Steps (if time permits) :

Wirelessly connect STM32 1 and STM 32 2.

Define thresholds and responses based on moisture levels.

## Initial Requirements

### Sound (Alarm System)

**Functional Requirements:**

The alarm must notify the user when the soil moisture drops below a set threshold or when light levels are lower than normal with an audible alert. According to the Hearing Health Foundation guidelines, an audible alert should be between **60 dB and 70 dB** (at a distance of 1 meter), which is sufficient for attracting attention during typical household activities without causing a nuisance [6].

According to studies in PubMed Central [6] on the impact of light on adults, **moderate light levels around 700 - 800 lumens** are sufficient to draw attention and prompt a response without being intense enough to fully wake someone from sleep. Therefore, the alarm’s LED lights should produce **800 lumens,** which is comparable to a standard 60-watt incandescent bulb, ensuring visible light output even in bright environments.

**Technical Requirements:**

The alarm must produce a sound level of at least 60 dB at a distance of 1 meter [7].

According to the manufacturer, Led Lights Unlimited, The LED must operate at **2-3 volts** to prevent excess heat and voltage spikes which should produce at least **800 lumens** of light, ensuring sufficient visibility even in well-lit environments.

**Safety Requirements:**

Studies by the Hearing Health Foundation indicate that sound must not exceed 70 dB to prevent potential hearing damage.

The alarm system’s LEDs must operate at 2-3 volts to prevent excess heat[8].

### Light (Lux Measurement)

**Functional Requirement**:

According to an article by Vegetableacademy, the system should continuously monitor the amount of light the plant receives throughout **every hour** to provide sufficient data for determining whether the plant has received adequate light. It should compare this data with the recommended daily light exposure for the specific plant type with a tolerance range of **5%** to ensure the plant gets adequate light for healthy growth[9].

**Technical Requirement**:

According to an article by Jbdconcepts , indoor plants typically thrive in light levels ranging from **500 to 2,000 lux**, depending on the plant type. Therefore, the light sensor should measure between **0-10,000 lux** (sufficient to cover indoor lighting to bright daylight exposure), with daily tracking for 12 hours [10]. Furthermore, the sensor must function effectively under outdoor lighting conditions and be able to withstand temperatures between **-30°C to 40°C as** according to data from the University of Waterloo, temperatures in Waterloo range from -20°C to 30°C.

**Safety Requirement**:

Light measurement accuracy should be ±5% of the light meter’s to ensure the readings are reliable without risking incorrect notifications.

The entire system must be enclosed to protect it from water, and no wires should be left exposed. Furthermore, it should be able to withstand temperatures between -30°C to 40°C[11].

### **Water (Soil Moisture Measurement)**

**Explaining the unit of percentages:**

Water is a good conductor of electricity, while dry soil is not. As the soil’s water content increases, its resistance decreases, allowing more current to pass through the sensor. The sensor outputs an **analog voltage signal (usually between 0V and 3.3V or 5V)**, which is converted to digital percentage, that corresponds to the soil moisture level.

**Functional Requirement**:

The system must accurately measure the soil’s moisture content and differentiate between dry, moist, and oversaturated soil conditions with the correct calibration. The moisture data should guide plant care by providing real-time feedback on hydration levels **every hour.**

According to an article by Acurite, the system must stop the alarm once the soil moisture exceeds **45%**, ensuring that the user does not overwater the plant. This ensures healthy plant care and prevents excessive watering [12] . Furthemore, the soil moisture sensor must function safely within a soil moisture range of **20-80%**, preventing malfunctions or sensor degradation in both drier and wetter soil conditions.

**Technical Requirement**:

According to the manufacturer of the sensor, Sunfounder, the soil moisture sensor should measure water content as a percentage from **0-100%**, with the analog voltage (V) accurately measuring voltage when dry or over-saturated. The alert will trigger when moisture falls below **30-40%** (depending on the plant type). With the conversion to a digital value, the permitted deviation from a commercially available soil moisture tester is no more than **5%** based on sensor comparison tests . Accuracy will be verified using a standard soil moisture meter.

**Safety Requirement**:

To ensure long-term durability, the soil moisture sensor must be **PCB-coated** to protect it from corrosion caused by prolonged exposure to moisture. This coating helps combat the typically short lifespan of soil moisture sensors in a moist environment, ensuring ongoing accuracy. Furthermore, as the light sensor, it should be able to withstand temperatures between -30°C to 40°C.

### 

### 

### 

### 

### **LCD Display Update Rate**

**Functional Requirement**:

The LCD must update sensor readings once ever**y 60 minutes (i.e., once per hour)**. This interval provides a reasonable time to update info while minimizing power consumption for both the sensors and the display. Low-power LCD displays usually consume between **10-20 mW** during operation, and periodic updates (once every hour) can reduce overall power usage.

Constantly measuring moisture and light levels can also degrade sensor performance over time[13], and research suggests that less frequent updates can help extend sensor life by up to **20-30%** in low-power environments, based on the industry data provided from low-power LCD product specifications [14] .

**Technical Requirement**:

The Low-power LCD display must consume between **10-20 mW** during operation, in every hour, and must be visible for 5 minutes for the user to see. According to ynsible.com[15], many commercially available low-power displays operate within this range, making it a widely accepted standard for energy-efficient designs. Furthermore, **five minutes** provides enough time for a user to check the moisture and light levels without rushing or having to react immediately after the update.

## Principles

Ohm’s Law for Voltage Measurement

Principle: Ohm’s Law states that the current through a conductor between two points is **proportional** to the **voltage** across the two points. In addition, it has to be **inversely proportional** to the **resistance**. This can also be applied to the soil moisture/hydration sensing, where the resistance of the sensor would change based on its moisture content. [16]

*Formula: V=I\*R*

V is the voltage, I is the current, 𝑅 is the resistance of the soil (which changes with moisture levels)

To see the power of each component and make sure that each component is given an adequate supply of power without overvolting, we would utilize the ohm’s law. As a result, we can put adequate resistance and prevent any of the components from heating up, or in a worse scenario, causing a fire, raising a risk to safety.

Interpolation of moisture values:

Standard: Since the sensor of the soil hydration outputs an digital voltage, we can use it to correspond/interpolate the values of hydration:

* Dry Soil: Higher resistance, lower current, resulting in a higher voltage
* Wet Soil: Lower resistance, higher current, resulting in a lower voltage

We can use the values to than interpolate the moisture % using the formula below using the ADC value (Analog to Digital) and output the readings:

* ***Moisture(%)= (V\_measured-V\_dry) / (V\_wet-V\_dry)\*100***

This formula is essentially a linear interpolation between the dry and wet conditions, and thus it is estimating a value within the two conditions. Essentially the first part of the equation, (V\_measured-V\_dry) / (V\_wet-V\_dry) will give us a proportion between 0(completely dry) and 1(fully wet). The percentage that will be outputted will be the main value to evaluate the hydration of the plant, and if it reaches a certain threshold, between 10% and 40% percent[17], the system can output that the plant is healthy, or else if it doesn’t pass the admissible values range, we can alert the system. [18]

## Standards

*Human-Centered Design (ISO 9241-210) :*

Human-Centered Design Standard focuses upon designing systems that have a user-centered approach. It ensures that the systems are easy to use, understand, and interact with for the user. It focuses on creating products that meet the needs and expectations of users, ensuring that they can interact with the system efficiently, effectively, and intuitively. [19]

**For our implementation in our project, we will utilize multiple sections:**

Section 4.2: The design is based upon an explicit understanding of users, tasks and environments

* Description: The section focuses on the significance of understanding the end users, and what tasks they perform, and the environment they will interact with in our system. As a result, we can specify the context of use and focus solely on our end users.
* The section states: “The extent to which products are usable and accessible depends on the context, i.e. the specified users, having specified goals, performing specific tasks in a specified environment”.
* In our product:
  + Our users are students living in dorms that do not have must experience with plant care
  + Our environment are dorm rooms, which are small indoor spaces with limited light
  + The tasks that our product will perform are to monitor plant health (moisture, light values), and then reacting based on system alerts

Section 6.3: Specifying the user requirements

* Description: This section focuses on the importance of defining the user’s needs and expectations in the entire design process
* The section states: “ For human-centered design, these user requirements must be explicitly addressed in relation to the intended context of use”.
* Using this standard, we must ensure that our user’s key requirements are prioritized. Specifically for the product we are creating, the follow requirements are key and must be met:
  + The system should be easy to understand and use without technical expertise
  + The system should be easy to handle and utilize
  + The system must be safe to use
  + The system must effectively and accurately monitor the health of the plant
  + The alerts must be clear and actionable (lights or notifications), without requiring complex instructions

Section 6.4: Producing Design Solutions

* Description: Design solutions must be created with the user's requirements and context of use in mind.
* For our project, we will be specifically implementing this section through:
  + Creating an interface that will provide feedback accurately
  + Our interface will use simple instructions or visual cues such as a traffic light system for moisture (green for healthy, red for water needed), and a light indicator that dims or brightens depending on how much light the plant is receiving

Overview of how HCD (human-centered design) standards will be applied and benefit the project:

Benefits:

* Increased usability of our product
* Higher user satisfaction

Overall, by following the guidelines by ISO on human centered design, we will ensure that the design prioritizes the usability and satisfaction of students first, as they are our primary client. We will tailor our product to our users' specific context of use by making sure that the user interface and interactions are as stress-free and intuitive as possible. This standard will ensure that our alerts, sensor readings, and interface are intuitive, concise, and our entire system is designed with the students’ limited time and stress levels in mind. We want to ensure that the plants stay healthy without them becoming a chore, and that inexperienced plant owners can have the confidence in knowing their health and status. As a result, our product can be more beneficial and focused around students, and resultantly gain more popularity and success.

## 

## 

## References

[1] “Plants and how they can help you study,” University of Sunderland, https://london.sunderland.ac.uk/about/news-home/growth-mindset/plants/ct (accessed Sep. 18, 2024).

[2] “Plants for college dorms,” Love Your Landscape.org, https://www.loveyourlandscape.org/expert-advice/little-landscapers/teens-and-tweens/plants-for-college-dorms/#:~:text=Plants%20provide%20oxygen%20and%20keeping,especially%20beneficial%20for%20air%20purification (accessed Sep. 18, 2024).

[3] “Quick facts: About Waterloo,” About Waterloo | University of Waterloo, https://uwaterloo.ca/about/facts (accessed Sep. 18, 2024).

[4] UM2470 user manual - discovery kit for STM32F7 series with ..., https://www.st.com/resource/en/user\_manual/um2470-discovery-kit-for-stm32f7-series-with-stm32f750n8-mcu-stmicroelectronics.pdf (accessed Sep. 18, 2024).

[5] 5591 DigiKey, https://www.digikey.ca/en/products/detail/adafruit-industries-llc/5591/16733167 (accessed Sep. 18, 2024).

[6] N. D. Dautovich et al., “A systematic review of the amount and timing of light in association with objective and subjective sleep outcomes in community-dwelling adults,” Sleep health, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6814154/ (accessed Sep. 18, 2024).

[7] “Keep listening: What are safe decibels?,” Hearing Health Foundation, https://hearinghealthfoundation.org/keeplistening/decibels (accessed Sep. 18, 2024).

[8] LED Lights Unlimited, “What happens if you put too much voltage through an LED,” LED Lights Unlimited, https://ledlightsunlimited.net/2021/06/15/too-much-voltage-led-light/ (accessed Sep. 18, 2024).

[9] J. Regier, “A definitive grow light study,” Vegetable Academy, https://www.vegetableacademy.com/post/a-definitive-grow-light-study (accessed Sep. 18, 2024).

[10] “How many lumens do my plants need? an expert guide on adequate light for plant growth!,” JBD Concepts, https://jbdconcepts.com/blogs/guides/how-many-lumens-do-my-plants-need/ (accessed Sep. 18, 2024).

[11] “Waterloo Weather Data,” Weather.uwaterloo.ca, https://weather.uwaterloo.ca/download/historical/2021/2021-annual\_temperature.png (accessed Sep. 18, 2024).

[12] A. Team, “Guide: Soil moisture recommendations for flowers, plants, and vegetables,” Welcome to AcuRite.com, https://www.acurite.com/blog/soil-moisture-guide-for-plants-and-vegetables.html/(accessed Sep. 18, 2024).

[13] LCD-016N002B-CFH-ET 16 x 2 character LCD, https://www.vishay.com/docs/37484/lcd016n002bcfhet.pdf (accessed Sep. 18, 2024).

[14] S. Dahal et al., “Degradability of biodegradable soil moisture sensor components and their effect on maize (*zea mays* L.) growth,” Sensors (Basel, Switzerland), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7663592/ (accessed Sep. 18, 2024).

[15] “An essential guide to low power display technology,” Ynvisible, https://www.ynvisible.com/news-inspiration/low-power-display-technology (accessed Sep. 18, 2024).

[16] Libretexts, “20.2: Ohm’s law - resistance and simple circuits,” Physics LibreTexts, https://phys.libretexts.org/Bookshelves/College\_Physics/College\_Physics\_1e\_(OpenStax)/20%3A\_Electric\_Current\_Resistance\_and\_Ohm’s\_Law/(accessed Sep. 18, 2024).

[17] “Soil moisture recommendations for flowers, plants, and vegetables,” Welcome to AcuRite.com, https://www.acurite.com/blog/soil-moisture-guide-for-plants-and-vegetables.html (accessed Sep. 18, 2024).

[18] Light and moisture requirements for indoor plants, https://sustainablecampus.unimelb.edu.au/\_\_data/assets/pdf\_file/0005/2839190/Indoor-plant-workshop-Light-and-Moisture-Requirements.pdf (accessed Sep. 18, 2024).

[19] ISO 9241-210, https://richardcornish.s3.amazonaws.com/static/pdfs/iso-9241-210.pdf (accessed Sep. 18, 2024).

[20] Project Outline, https://learn.uwaterloo.ca/d2l/le/content/1062117/viewContent/5650397/View (accessed Sep. 18, 2024).