Brown University

School of Engineering

ENGN 1650 / AY 24-25
Embedded Microprocessor Design
Product Requirements Document

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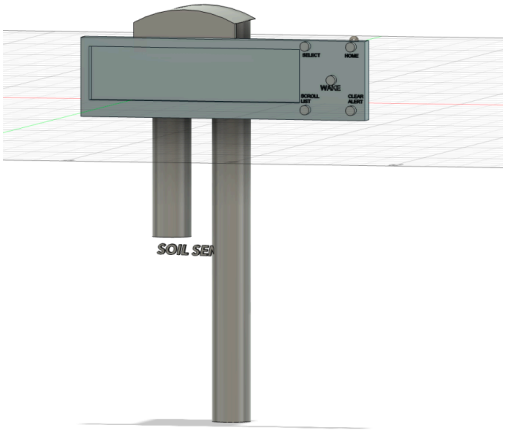
Project Concept: SoilSense
Building a sensing system for plants to keep them healthy.



I. Revision Block

Version	Date
V1	10/25/2024

II. Scope

SoilSense is aimed at everyday plant owners who often struggle to keep their plants healthy due to busy schedules or simply not knowing when their plants need attention. It's also great for anyone who enjoys gardening indoors, people living in apartments or urban areas with limited space, and even tech enthusiasts who want to integrate more smart devices into their homes. The idea is to create a simple, easy-to-use gadget that helps people take better care of their plants by tracking light intensity, moisture, humidity, and temperature. The main goal is to make plant care less of a guessing game and more about giving your plants exactly what they need.

What Is This For?

- Market Product: This could definitely become a retail product, considering how many people struggle with plant care and how popular smart home gadgets are becoming.
- Personal or Academic Use: It's also a solid project for anyone looking to learn about IoT, smart sensors, or even just experimenting with electronics. It could be used in a class project, lab work, or as a research tool.
- Just for Fun: And, of course, it's perfect if you're just someone who likes tinkering with tech and wants a cool, practical project to build.

Who Would Benefit?

- Plant Owners: Obviously, anyone with a houseplant could benefit from this. It's going to make keeping your plants alive a lot easier.
- Smart Home Fans: This could be a neat addition to a smart home setup, making plant care feel more high-tech and hands-off.
- Students and Learners: It's also a great educational tool for anyone interested in learning about electronics, IoT, or environmental science.

In a nutshell, SoilSense aims to make plant care simpler, more efficient, and maybe even a bit more fun, whether you're an experienced gardener or someone who just wants their plants to stop dying.

III. General Description

Soil Sense is an intuitive soil monitoring device designed specifically for medium-sized household plants, offering plant enthusiasts an easy and effective way to understand their plant's needs. Unlike many products on the market that require smartphone connectivity, Soil Sense comes with its own built-in display, providing real-time readings of soil moisture, temperature, and nutrient levels right at your fingertips. This means you can instantly check on your plant's health without any extra gadgets or apps, making plant care accessible and stress-free.

What sets Soil Sense apart is its user-friendly design and precise monitoring capabilities. Whether you're a seasoned plant parent or just starting your indoor garden, Soil Sense helps you take the guesswork out of plant care, ensuring your plants receive the right amount of water, warmth, and nutrients to thrive. It's perfect for those who want to avoid common pitfalls like overwatering or neglecting their plants. Our target audience includes urban dwellers, plant enthusiasts, and anyone looking to maintain a healthy, green space in their home. As we move forward, we plan to expand Soil Sense's reach, offering a variety of models tailored to different plant types and environments, making it the go-to tool for every indoor gardener.

IV. Functional Description

The purpose of SoilSense is to provide low-cost, real time soil monitoring to consumer plant hobbyists who want to ensure their plants stay healthy. The plants that we service will be predominantly indoor plants whose size does not exceed 24" in diameter and 24" in depth. As the project progresses, these restrictions may change. The following features are essential to the product functionality:

- Monitor soil moisture levels and alert user when to water the plant
    - Tell user to water the plant
- Monitor room temperature and humidity and alert the user of poor conditions
    - It's too hot/cold/humid/dry
- Monitor light intensity and time and alert user of poor conditions
    - Brighter/darker and more time in light/less time in light
- Alert user when it is time to fertilize plant, change soil, and remove dust from plant
- Display these alerts on the LCD screen and allow user to clear alerts with a button
- Attach to side of pot
- LED indicator for alert and charge
- Allow user to select type of plant to properly calculate health parameters
- Display controls:

Button	Setup Mode	Operation Mode
1	Select/ok	Open plant select
2	Calibrate	Clear alert
3		Screen on/off
4	Back	
5	Next	Toggle alert

The second phase of the project will involve:

- Incorporate a self-watering system

V. Market Positioning

The market for smart plant health monitoring systems is steadily growing as consumers show increasing interest in urban farming, indoor gardening, and sustainable plant care. Some of the key competitors across the smart plant monitoring market include:

- Click and Grow offers an all-inclusive home gardening smart system for $249.95 that features automatic watering, grow lighting, and fertilization. Their companion app allows users to monitor their gardens, receive helpful gardening tips, and see general information about the plant species they are growing. The app also allows users to control the lighting or change the cycle of their garden.
- Sage Sill offers a premium version of their plant monitoring probe with smart app connectivity for $160.97 and a base version with just an LED indicator for $128.99. Sage Sill interfaces with users via the Flower Care app to share data about temperature, light intensity, soil moisture, nutrient levels, and give users access to the Cloud Plant Database. The LED indicator light communicates notification of low moisture, low nutrients, high nutrients, and low battery.
- Flora Pod offers an AI plant monitoring system for $63.99. Their Flora App interfaces with the user to communicate data about temperature, moisture, humidity, and light intensity and to provide data-based suggestions. For a premium, users can subscribe to Flora Plus to gain access to unlimited AI photo recognition to identify or diagnose plants.

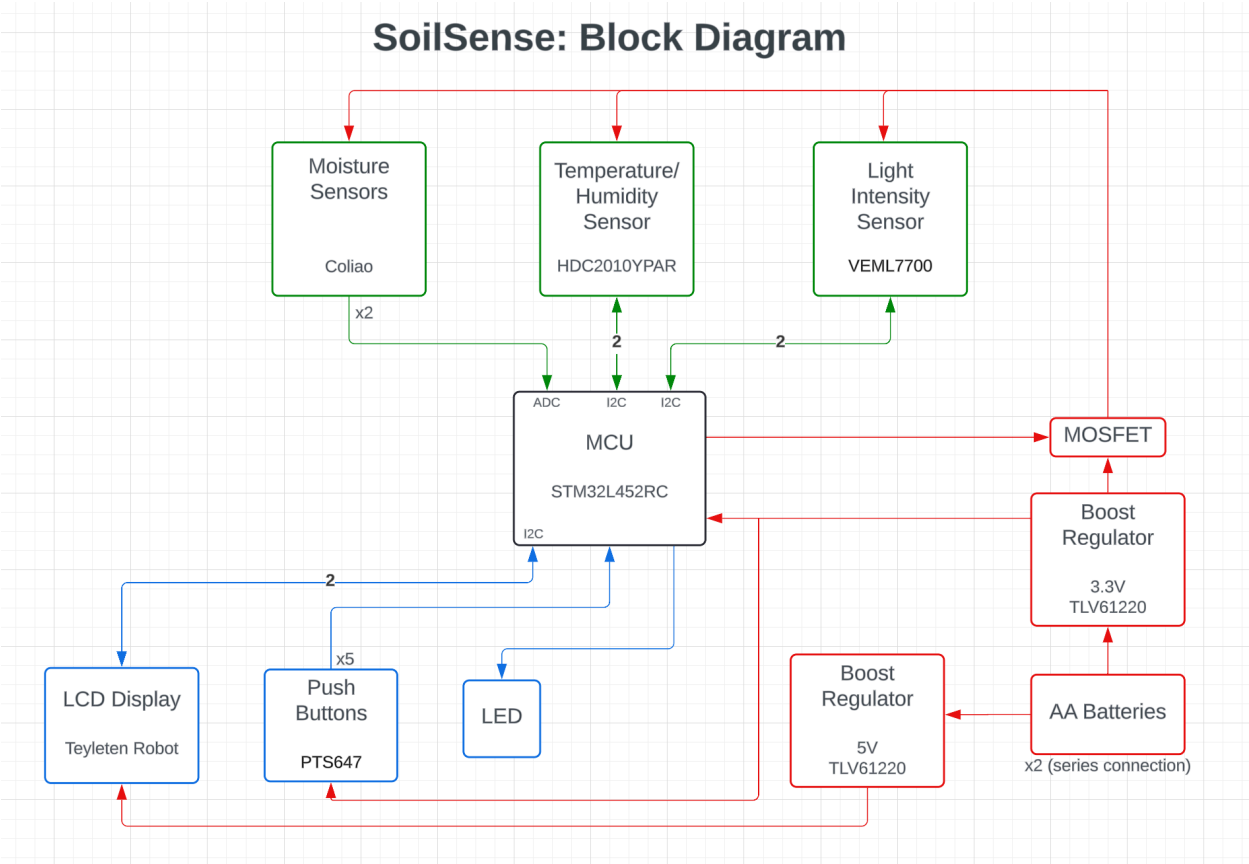
These products tend to use app connectivity as means of interfacing with the user, leaving room for SoilSense to simplify the process by utilizing an onboard display to communicate directly to the user. SoilSense will fill a few gaps in the current market:

- Most smart gardening solutions are dependent on mobile app monitoring. SoilSense cuts out the need for this, regrounding the user with the plant and encouraging a more hands-on, tactile experience with the product.
- Many of the current products boast complicated app ecosystems or advanced functionality that is not necessary for most applications. SoilSense could appeal to more budget-conscious plant owners who want affordable yet effective solutions.
- Value proposition: SoilSense empowers plant owners to easily monitor their plants' health by providing feedback through an intuitive, attachable display. SoilSense simplifies care by tracking essential markers such as moisture, temperature, light intensity, and humidity – all at an affordable price.

With entry to mid level pricing, we believe that the set of features and lack of reliance on app connectivity will offer a compelling alternative to other options on the market. A retail price around $50 will stay competitive and remain accessible to plant owners who may be reluctant to spend more. A target cost of production would ideally be under $20 per unit to allow for proper margins and will be heavily driven by:

- Component Cost: Moisture, temperature, and humidity sensors are all relatively inexpensive but components like the battery and a display will drive up costs significantly.
- Enclosure Design: A sturdy and inexpensive enclosure with a reliable mechanism to clip the device onto a pot will constitute a significant part of the manufacturing cost. Ensuring that the probes can be properly positioned without risk of damage will likely drive up costs when designing the final product.

Block Diagram



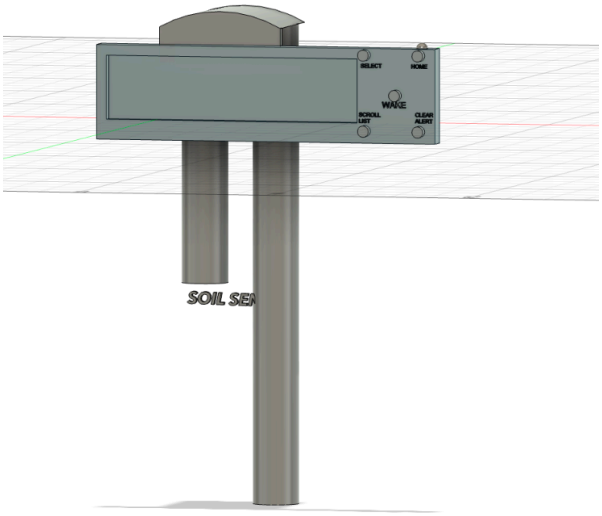
VI. Standards Adherence

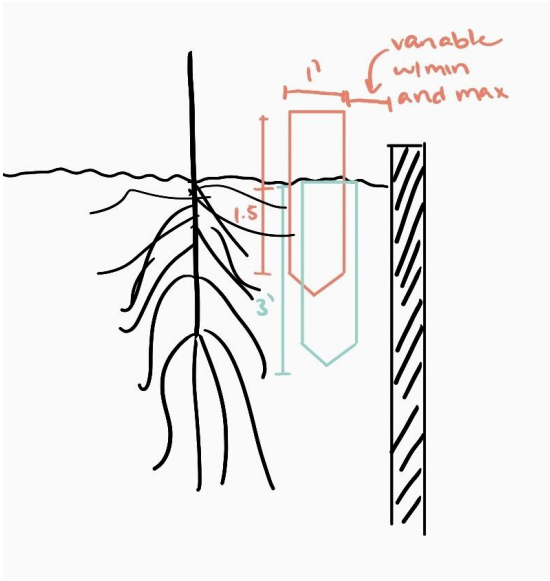
SoilSense will adhere to many industry standards through the design process. This will help the product integrate with pre-existing technology like chargers, but meet regulatory requirements that will ensure the safety of users. The following standards are essential to meet:

- Ingress Protection Rating: IP compliance will be upheld given the exposure to water. A rating of IP67 would ensure full dust protection and immersion for 30 minutes at a depth of 1 meter, which would ensure the durability of the product in normal indoor gardening conditions.
- RoHS Compliance: Design will be guided by the RoHS directive to ensure the device is free from harmful chemicals like lead and mercury. It would ensure environmental and user safety and allow the product to be marketed in the EU.
- Underwriters Laboratory Certification: The UL certification would verify that SoilSense meets electronic safety standards. Particularly pertaining to fire hazard, the certification would involve testing for device and power system integrity (like checking short-circuit protection and product durability).

VII. Industrial Design

We want a sense of style. The whole case will be waterproof. The two cylinders will look like stakes towards the bottom. They are different lengths because we will house two moisture sensors there at different heights in the soil.





VIII. Component Breakdown

Microprocessor:

- STM32L452RC available from Digikey

Environmental Sensors:

- Light intensity sensor: VEML7700 available from Digikey.
- Temperature and humidity sensor: HDC2010YPAR available from Digikey
- Moisture sensor: Coliao Capacitive Soil Moisture Sensor (Corrosion Resistant)

Display:

- Teyleten Robot LCD1602 LCD Display ($2.78)

Power:

- Runs on 2 AA batteries supplied by user

IX. Power Budget

Device	#	Standby Current (mA)	Operating Current (mA)	Operating Voltage	Standby Cons. (mW)	Operating Cons. (mW)	Time on/day (h)	Daily mAh
STM Chip Run Mode	1	0.000375	0.036	3.3	0.0012375	0.1188	1.3	0.0553125
Moisture Sensor (x 2)	2	0	5	3.3	0	33	0.2	1
Humidity/Temp Sensor	1	0.0001	0.00055	3.3	0.00033	0.001815	0.4	0.00258
Display	1	0	1.5	5	0	7.5	0.1	0.15
Light Sensor	1	0.0005	0.00045	3.3	0.00165	0.001485	0.4	0.01198
Battery @ 700 mAh				1.2				
Total					0.0032175	40.6221		1.2198725
			Battery Rating (mAh)	**Days Without Charge**				
		Battery Life Calculation:	700	573.8304618				

Fundamental Requirements

- Waterproof: both protecting sensors in the soil and protecting all electronic components from watering
- Readability: Display must be visible from a distance including the alert LED
- Minimum pot diameter: 4 inches
- Minimum pot depth: 4 inches
- Battery must last for at least 3 months without charge

X. Safety Requirements

By prioritizing safety measures, SoilSense will deliver peace of mind to users that the product is not only effective but also safe for everyday use in their homes. To achieve that goal, the following safety conditions will guide the design of the product:

- Fire Safety: Components will meet standards to prevent the possibility of overheat or ignition. Internal circuits should be protected from short circuiting, overheating, and overdrawing current.
- Material Safety: The materials used will be non-toxic and safe for the plants. Under normal operation conditions, the product should not leach chemicals into the soil that could be harmful.
- Water Resistance: Because the product will be used in close proximity to water, electronics will be properly protected from the moisture to avoid failure or hazard. Meeting IP standards could ensure the unit is safe for consumer use.

XI. Risk Items

In this early phase, it is important to identify potential risks that could inhibit the product development timeline. The following are the main risks that need to be addressed before advancing into the design and manufacturing phases:

- Sensor Accuracy: Ensuring that the light, moisture, humidity, and temperature sensors are accurate and reliable is essential in collecting data. With uncalibrated sensors, the device may give incorrect recommendations that could harm the plant. Factors like

manufacturing variability, soil type, and general usage will need to be considered. Early testing of the components will mitigate errors and ensure durability of the product.

- Power Management/Battery Life: Some of the components require input voltages of 5 V while others require 3.3 V. Ensuring that the components receive the stable voltages they need will be paramount to the success of the product. Our use case is one in which frequent charging is not ideal, so finding cheap and low power solutions is crucial.
- Weatherproofing: Finding materials to create the product casing will present a significant challenge in the design process. The material will need to endure daily use (especially the buttons) and exposure to moisture, so prototype testing will be necessary to ensure we choose a material that is sufficiently durable but will not drive up production cost. Despite being indoors, the product will also be exposed to sunlight, dust, dirt, and various temperatures. We have to ensure the material used for the casing can withstand these obstacles.

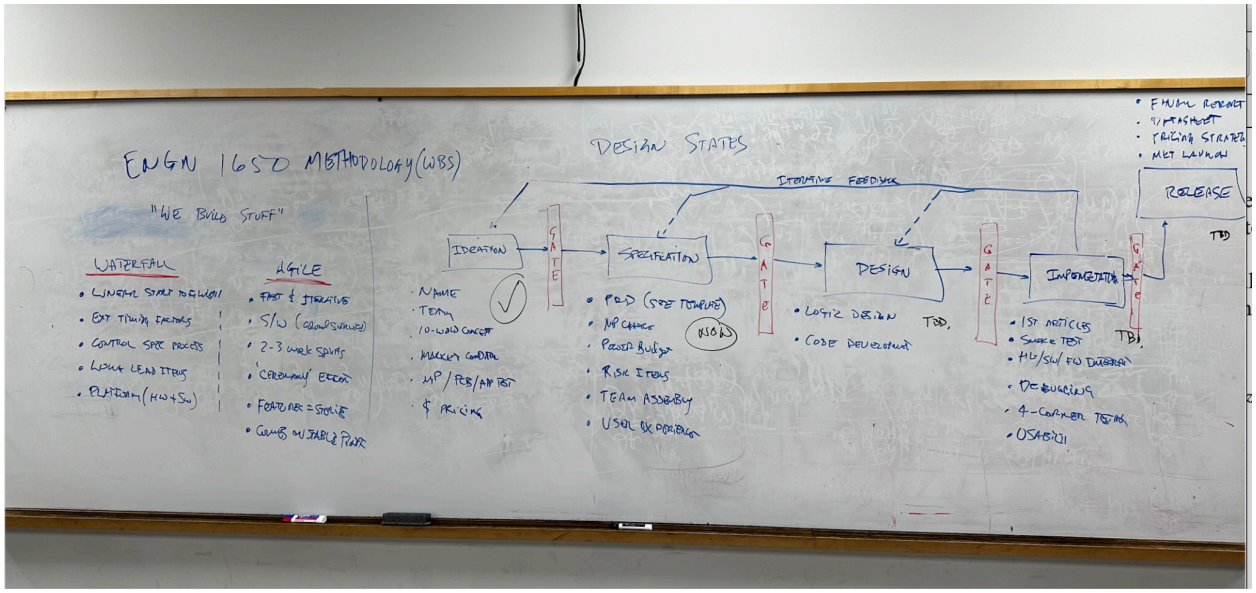
XII. Schedule

Stage	Tasks	Date Completed	Roles
~~Ideation~~		~~Completed~~	
Specification	PRD	In Review	
	Power Budget	In Review	
	Risk Items	Completed	
	Team Assembly	Completed	
	User Experience	Completed	
	Prototypes	In Progress	Gianna
Design	Logic Design	Completed	
	Code Development	11/6	
Implementation	Debugging		
	Parts Development		
	Smoke Tests		
	First Demo		
	PCB Fabrication	11/10	
Release	Final Report	12/17	
	Data Sheet	12/17	
	Finalized Schematics	12/17	

You are welcome to add other key information about your concept to this specification, but this will cover 90% of what you need and will be a good start! We will continue to refine this document as we go.

Appendix I

"We Build Stuff" (WBS Methodology)



WBS Product Phases or States

Ideation - concept is vetted with a brief description of what we are trying to achieve. Target market and use. Why it is cool and innovative.

Specification - Create a PRD (Product Requirements Document) to outline all the fundamental requirements for the design. Includes separate prototype efforts to make sure the fundamental risks for the product are identified and vetted out accordingly.

Design - Logic design for the circuitry and all the real-world IO that is associated with the product concept. Includes board layout requirements as well.

Implementation - Build the first articles for the concept. Parts development. PCB fabrication. Smoke tests. First debugging attempts, etc. First demo.

Release - Final documentation of the project. Finalized schematics. BOM.