

HYDROFLORA (A CONTEXT-AWARE WATERING CAN)

By

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1. Introduction

1.1 Problem

Many people care for multiple houseplants with different watering needs, but watering is typically done by intuition and inconsistent habits. Because plant type, pot size, soil type, and moisture all affect how much water a plant actually needs, manual watering often results in overwatering or underwatering. Overwatering can lead to root rot, fungus gnats, and wasted water, while underwatering causes plant stress, slowed growth, and wilting. However, existing reminders or generic schedules don't adapt to real-time soil conditions, and fully automated irrigation systems can be too expensive, complex, or impractical for small indoor plant collections. Thus, there is a need for a simple, low-effort tool that helps users deliver the correct amount of water per plant based on measured soil dryness and plant/pot-specific requirements, without requiring a permanent installed system.

From a broader perspective, our project addresses environmental sustainability by reducing water waste because only the exact optimal amount of water needed for the plants will be dispensed to avoid overwatering. This project also relates to economic efficiency by preventing the loss of expensive indoor greenery as problems relating to watering that might cause the death of plants can be avoided. Furthermore, studies [11] have shown that indoor gardening has become a vital component of psychological well-being. By providing a tool that ensures plant health, our project directly supports the mental wellness of the society.

1.2 Solution

Our solution is a Smart Watering Can System. We say that the watering can is context-aware because it does the watering job based on the feedback received from the components surrounding it. The project consists of modular, low-power sensor nodes and a centralized intelligent dispensing unit. The sensor nodes are placed permanently in plant pots to monitor soil moisture levels using capacitive sensing, which avoids the corrosion issues typical of resistive probes. These nodes broadcast real-time data to the watering can via a wireless protocol (Bluetooth/WiFi).

The user interacts with a microcontroller-based interface on the watering can. When the user selects a plant through the buttons/rotary knob, the system compares the current moisture

reading against a pre-set threshold for that specific plant species. Upon activation, a peristaltic pump dispenses a precise, calculated volume of water. This implementation moves plant care from being “scheduled-based” to "data-driven", ensuring that the exact lack of moisture is replenished with accurate calculations instead of human estimation.

1.3 Visual Aid

Below is the diagram of how different components will be placed in our system, with the sensor nodes attached to the plants, and the control unit on the watering can.

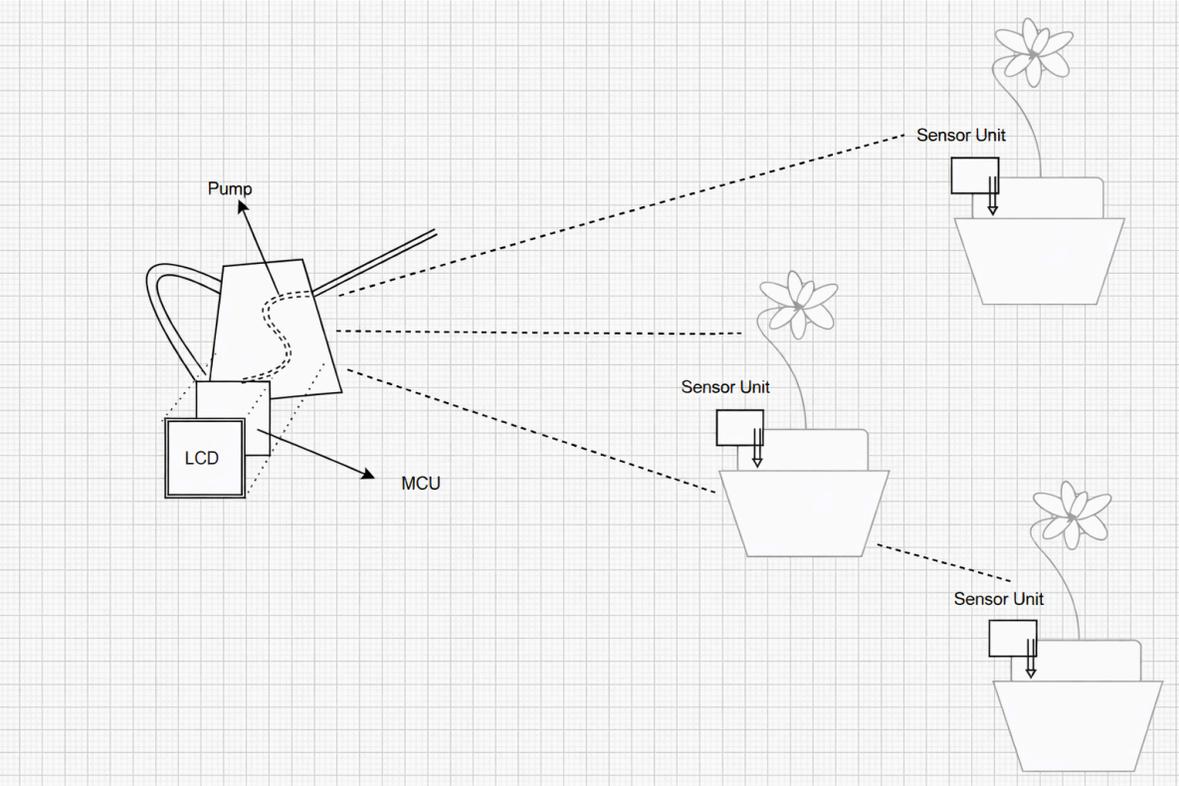


Figure 1: Visual aid of solution

1.4 High-level Requirements

- **Accuracy:** The system must dispense the calculated volume of water with a precision of $\pm 20\%$ of the target volume.
- **Connectivity:** The sensor node must maintain a reliable wireless connection and update soil moisture data to the Main Control Unit at a range of at least 3 meters in an indoor environment.
- **Longevity:** The sensor node must operate continuously for a minimum of 24 hours on a single battery charge while broadcasting data at 5-minute intervals.

2. Design

2.1 Block Diagram

Below is the block diagram for our system which is broken down into two main blocks serving different subsystems, namely the sensor node block and the main control unit at the watering can.

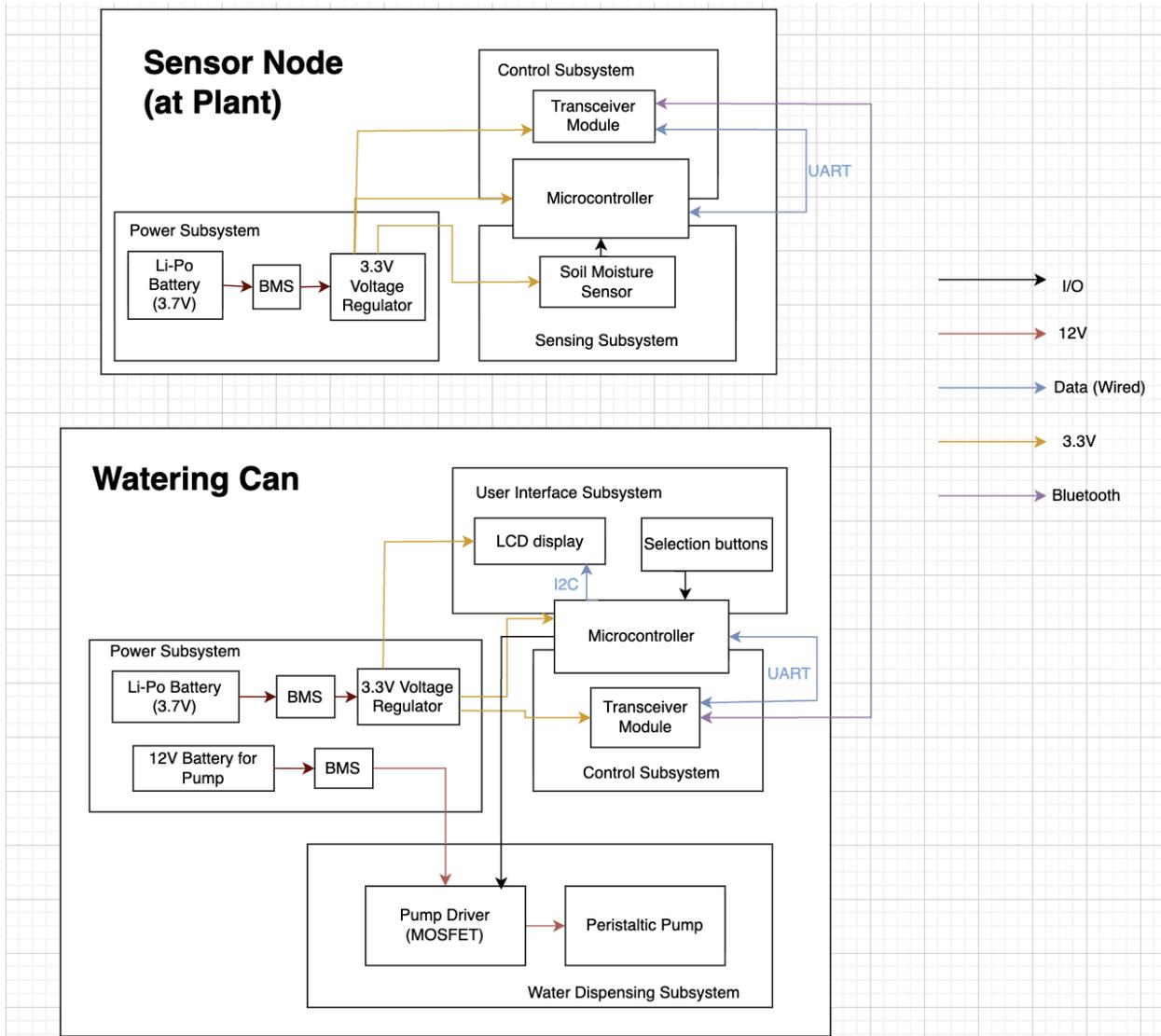


Figure 2: System block diagram

2.2 Subsystem Overview

2.2.1 Sensing Subsystem

This block is located in the plant pot, and is the source of all system data. It measures the soil moisture using a capacitive probe and converts it into a digital value via the ESP32-C3's internal ADC. It then broadcasts this data wirelessly to the main control unit on the watering can. Without the sensing in this block, we cannot get the accurate moisture level, thus will fail to determine the amount of water a plant needs.

2.2.2 User Interface Subsystem

This block is located on the watering can, and handles all the interactions with users. It consists of an LCD to display plant types and soil moisture levels corresponding to the pot, and buttons/rotary knobs for user selection. It ensures the system is applicable for multiple plants in order to determine how much water should be dispensed.

2.2.3 Control Subsystem

This is a dual-part system. For the sensor node, this subsystem receives data from multiple sensors on the pots and broadcasts it to the watering can's control subsystem (the main control unit). For the watering can, this subsystem stores plant-specific calibration data, and calculates the precise PWM/Logic timing for the pump based on the received sensor data.

2.2.4 Water Dispensing Subsystem

This block is the physical actuator. It takes the low-power logic signal from the Control Subsystem and uses a power MOSFET to switch a 12V supply to the peristaltic pump, moving water from the reservoir to the spout.

2.2.5 Power Subsystem

This is a dual-part system. The Sensor Node uses a 3.7V Li-Po battery with a LDO (Low Dropout) regulator, while the Watering Can uses a larger 12V Li-Po for the pump and a 3.7V Li-Po battery for the microcontroller.

2.3 Subsystem Requirements

2.3.1 Sensing Subsystem

Requirements:

- The sensing node shall remain operational for at least 24 hours without recharge under normal sampling conditions (5-minutes interval).
- The sensing probe shall resist water-induced degradation for at least 30 days of continuous exposure.
- The subsystem shall convert soil moisture into a digital measurement.
- The sensing node shall transmit a valid moisture reading within an indoor range of at least 3 meters.

2.3.2 User Interface Subsystem

Requirements:

- The display shall show the current moisture percentage and selected plant name.
- The display shall remain readable under typical indoor lighting conditions.
- The subsystem shall not cause unintended pump activation during input interaction.
- The subsystem shall allow the user to select between at least 3 plant profiles.

2.3.3 Control Subsystem (Watering Can Controller)

Requirements:

- The controller shall store and manage data for at least 3 independent sensor nodes
- The controller shall compute water level based on the difference between target moisture and measured moisture.
- The pump activation shall be within 3 seconds of control signal inception.
- If communication with a selected node fails, the pump shall remain disabled.
- Wireless reception shall reliably operate at 3 meter indoor range.

2.3.4 Control Subsystem (Sensor Node Controller)

Requirements:

- The sensor samples every 2 seconds and then samples for 2 seconds.
- If communication fails, the node shall return to sleep within 5 seconds.
- The node shall maintain periodic measurement operation without requiring external reset.

2.3.5 Water Dispensing Subsystem

Requirements:

- The dispensed volume should be stable around plus or minus 20 percent volume accuracy.
- Water shall begin flowing within 3 seconds of activation.
- The subsystem shall operate continuously for up to 60 seconds without overheating or shutdown.

2.3.6 Power Subsystem

Requirements:

- The system shall operate safely from a rechargeable battery source.
- The logic supply voltage shall remain within plus or minus 5 percent of nominal during operation, including pump activation.
- The sensor node supply shall maintain low standby current to preserve battery life.

2.4 Tolerance Analysis

2.4.1 Pump Dispense Accuracy

A significant risk to project success is the accuracy of the water volume dispensed. Peristaltic pumps are generally consistent, but flow rate can vary based on battery voltage and tubing friction. To ensure the +/- 20% requirement, we must calculate the required timing required to dispense the required volume.

$$Q = 100 \text{ mL/min}$$

$$Q = \frac{100}{60} \text{ mL/s} \approx 1.66 \text{ mL/s}$$

$$t = \frac{V_{\text{target}}}{Q}$$

$$t = \frac{50 \text{ mL}}{1.66 \text{ mL/s}} \approx 30 \text{ s}$$

We can then measure the accuracy using the following formula:

$$\text{Accuracy} = \frac{V_{\text{actual}}}{V_{\text{target}}} \times 100\%$$

This will allow us to see the current performance of the pump control and figure out if we need to improve motor output and other peripherals.

3. Ethics, safety, and societal impact

According to the IEEE Code of Ethics 1.1 [1], our design prioritizes the safety and health of the public. For safety concerns, we will apply protection to the components to provide isolation between water and electronics. We will use a waterproof enclosure to house all the circuitry on the watering can.

Aligning with IEEE Code of Ethics 1.4 [1] and ACM Code of Ethics 1.3 [2], we will avoid unlawful conduct and provide full disclosure of all systems capabilities and limitations while doing our project. We are committed to honest representation of our sensor data and avoid ethical breach of falsifying data or hard-coding success values. We should always report true soil moisture levels and this will be shown by implementing transparent calibration procedures.

Furthermore, one of the regulatory standards that is relevant to our project is the UL1642 standard [3] where the Li-Po batteries used will be equipped with a BMS (battery management system) to prevent overcharging and short circuits.

As for the societal impact, by encouraging water conservation, our project promotes environmental stewardship according to the National Oceanic and Atmospheric Administration (NOAA). Besides, by providing a solution that makes plant care easy, we are promoting indoor gardening which helps in an individual's mental well-being. From an economical perspective, this project provides a low-cost solution for plant hobbyists and can even extend to small-scale farmers who cannot afford industrial irrigation.

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