TECHNICAL DESIGN DOCUMENT

Autonomous Plant Maintenance System

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1. Front Matter

Title: Autonomous Plant Maintenance System
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2. Introduction

a. Overview / Problem Description

The main problems identified in plant cultivation were:

- Excessive water consumption
- Inefficient irrigation (overwatering and underwatering)
- Lack of automation in plant maintenance

Manual watering often resulted in inconsistent soil moisture, leading to plant stress and wasted water.

Proposed Solution

An **autonomous plant maintenance system** based on sensors, automated irrigation, and smart lighting was developed to:

- Optimize water consumption
- Improve irrigation efficiency
- Automate plant care processes
- Maintain ideal growing conditions

A **drip irrigation system** was implemented where a water hose is positioned below plant roots. Small holes were drilled along the hose and wrapped with sponge material to ensure:

- Even water distribution
- Prevention of hole clogging
- Reduced water usage
- Increased irrigation efficiency

This design significantly improves water efficiency and is one of the primary goals of the system.

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b. Context / Background

Plant maintenance requires constant monitoring of:

- Soil moisture
- Temperature and air humidity
- pH value
- Light exposure

Traditional watering methods waste water and are not precise.
This system introduces automation and sensor-based control to ensure optimal plant growth with minimal resource usage.

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c. Goals and Technical Requirements

System Goals

- Reduce water consumption
- Prevent overwatering and underwatering
- Automate irrigation and lighting
- Monitor environmental conditions
- Provide reliable plant growth conditions

Technical Requirements

- Automated irrigation using pump and relay
- Sensor-based monitoring
- Autonomous decision-making via ESP32
- Battery-powered operation
- Grow light support
- Efficient drip irrigation distribution

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e. Future Improvements

- Advanced air humidity control
- Automatic soil pH correction
- Rain water collection system
- High-end water filtering system

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3. System Overview

Hardware Specifications

Pump

- Power: 40W
- Lift height: 3m
- Flow rate: 20L/min

Battery

- Voltage: 12V
- Capacity: 7Ah
- Type: Lead-acid (Pb)

Water Tank

- Capacity: 25L
- Dimensions: 303 × 443 × 259 mm

Microcontroller – ESP-32S

- Connectivity: WiFi + Bluetooth
- Flash: 16 MB
- SRAM: 250 KB
- Clock speed: 240 MHz

Sensors and Modules

Component	Function
Soil Hygrometer HW080	Measures soil moisture
Rain Sensor HW028	Detects rainfall
pH Sensor E-201-C	Measures soil pH value
DHT 22 Sensor	Measures temperature & air humidity
Relay Module HW-383	Controls pump and lighting

Custom PCB Grow Light

A custom PCB board is used as a grow light source.

Specifications:

- 9 RGB LEDs
- Purple grow light (red + blue spectrum)
- Mounted above plants
- Controlled by ESP32 via relay
- Provides artificial light for plant growth

Purpose:

- Improve plant growth indoors
- Enable night-time lighting
- Ensure consistent light exposure

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4. Irrigation System Design

Drip Irrigation Implementation

To increase watering efficiency:

- A hose is placed below plant roots
- Small holes are drilled along the hose
- The hose is wrapped in sponge material

Advantages

- Even water distribution
- Prevents clogging of holes
- Reduces water consumption
- Improves root hydration
- Prevents overflow and dry zones

This upgrade significantly improves irrigation precision and system efficiency.

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5. System Operation

The system continuously monitors environmental conditions using sensors.

Automatic Irrigation

Watering activates when soil moisture drops below the defined threshold and no rain is detected.

Environmental Monitoring

System monitors:

- Soil moisture
- Temperature
- Air humidity
- pH level

Lighting Control

Grow lights activate when:

- Natural light is insufficient
- Night cycle begins

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6. Testing Plan

System testing includes:

- Sensor accuracy testing
- Pump activation testing
- Water distribution testing
- Battery endurance testing
- Full system automation testing

Goal: ensure reliable autonomous operation and optimal plant conditions.

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7. Monitoring and Reliability

System monitors:

- Water level
- Battery level
- Sensor functionality
- Pump operation

In case of failure:

- Pump stops automatically
- System prevents dry running
- Alerts can be added in future versions

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8. Conclusion

The Autonomous Plant Maintenance System provides an efficient and reliable solution for automated plant care.

Key improvements:

- Reduced water consumption
- Precise irrigation
- Automated plant maintenance
- Improved growth conditions
- Energy-efficient operation

The upgraded drip irrigation design and sensor-based control ensure maximum efficiency while minimizing manual work and resource usage.