

IoT-Based Soil Moisture Monitoring And Automatic Watering System

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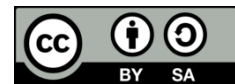
Automatic Watering

Remote Monitoring

ABSTRACT

This research aims to design and implement an Internet of Things (IoT)-based soil moisture monitoring and automatic watering system using an ESP32 microcontroller. This system was developed to improve the efficiency of plant watering by reducing water usage, time, and human effort. A soil moisture sensor is used as the main input to detect soil moisture levels, while the ESP32 serves as a control center and data processor. Soil moisture data is sent in real-time to the IoT platform and can be monitored and controlled remotely through the Blynk application. A relay module is used as a connection between the ESP32 and the water pump to regulate the automatic watering process. All hardware components are housed in an acrylic casing and the system is powered by a 9V battery to operate the water pump. Test results show that the soil moisture sensor has a good level of accuracy in detecting soil conditions. The automatic watering system is able to respond quickly to changes in humidity, where the water pump is active when the humidity is below the threshold and stops when the soil conditions are optimal. Based on these results, the developed system is declared to work well and is suitable for use as an IoT-based smart irrigation solution.

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1. Introduction

Soil moisture monitoring and automatic watering systems based on the Internet of Things (IoT) are increasingly being implemented to improve the efficiency of crop management, particularly in agriculture and gardening[1]. The use of IoT enables automated, real-time monitoring and control of soil conditions, thereby increasing productivity and resource efficiency.

Soil moisture is a critical factor that significantly impacts plant growth and health. Soil that is too dry can cause plant stress and nutrient deficiencies, while soil that is too wet can inhibit root respiration and lead to rot. Therefore, proper soil moisture management is essential to create an optimal growing environment for plants.

In traditional agricultural practices, soil moisture monitoring is generally performed manually. This method is labor-intensive and time-consuming and ineffective, especially for large areas. Furthermore,

manual monitoring cannot respond quickly to changes in soil moisture conditions, potentially reducing the quality of plant growth.

Developments in Internet of Things (IoT) technology provide a solution to this problem through the use of soil moisture sensors connected to the internet. These sensors allow for real-time monitoring of soil moisture data without the need for direct field inspection. The information obtained can be accessed via devices such as smartphones or computers, making it easier for users to monitor soil conditions.

The integration of a monitoring system with IoT-based automatic watering also simplifies crop management. This system works by automatically activating watering when soil moisture falls below a predetermined threshold. This ensures plants receive the water they need without having to rely on manual watering.

In addition to increasing energy efficiency, an IoT-based automatic watering system can also save water and reduce operational costs. Targeted watering can reduce water waste, which often occurs with conventional irrigation systems. This is especially important in areas with limited water resources.

Overall, the implementation of an IoT-based soil moisture monitoring and automatic watering system not only benefits farmers and plant enthusiasts but also supports sustainable agriculture. This system enables more efficient, environmentally friendly, and data-driven crop management, contributing to increased productivity and the sustainability of natural resources in the future.

2. Research Method

2.1 Research Flowchart

The steps I followed in this research were defined by a flow diagram, often referred to as a flowchart. In this research, I designed and developed an Internet of Things (IoT)-based soil moisture monitoring and automatic watering system.

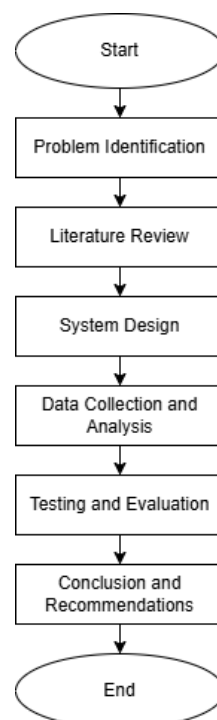


Figure 1. Research Flow Diagram

2.2 System Block Diagram

Data collection can be seen from the block diagram itself, where a block diagram is a method of designing and building tools to clarify the overall working principles of the tool being tested. The following is an illustration of such a block diagram:

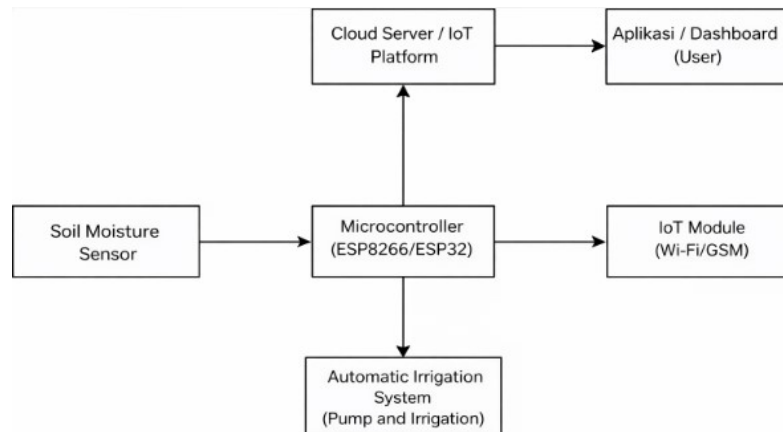


Figure 2. System Block Diagram

- a. Soil Moisture Sensor
The soil moisture sensor detects the moisture level in the growing medium. This sensor generates data in the form of moisture values that indicate the condition of the soil, whether it is dry, moderately moist, or wet. This data serves as the primary basis for making decisions regarding the irrigation system.
- b. Microcontroller (ESP8266/ESP32)
The microcontroller acts as the system's processing and control center. Data from the soil moisture sensor is read and processed to determine the appropriate action, such as turning the water pump on or off. In addition, the microcontroller also manages data transmission to the IoT server and receives commands from the user.
- c. IoT Module (Wi-Fi/GSM)
The IoT module connects the system to the internet. Through this module, sensor readings are sent to a cloud server, and user commands or settings can be relayed back to the microcontroller remotely.
- d. Cloud Server / IoT Platform
The cloud server serves as a data storage and processing platform. Soil moisture data received from the microcontroller is stored and displayed in real time. The cloud also serves as a link between field devices and the user's application or dashboard.
- e. Application/Dashboard (User)
Users use the application or dashboard to monitor plant conditions. Users can view soil moisture information, historical data, and adjust the irrigation system, both automatically and manually, through an easily accessible interface.
- f. Automatic Watering System (Pump and Irrigation)
The automatic watering system consists of a water pump and irrigation channels controlled by a microcontroller. The pump will turn on when the soil is detected as dry and will turn off when sufficient moisture is present, ensuring efficient and effective watering.

2.3 Hardware Design

The hardware design in this study aims to build a smart irrigation system that operates automatically based on soil moisture levels. This system is designed to improve the efficiency of plant watering in terms of time, energy, and water consumption, while also enabling remote monitoring and control through Internet of Things (IoT) technology.

The ESP32 is used as the main control center due to its Wi-Fi connectivity and robust processing capabilities. This microcontroller reads data from the soil moisture sensor, automatically controls the water pump, and transmits the data to the IoT platform for real-time monitoring. The soil moisture sensor serves as the primary input source, detecting soil moisture levels to determine watering needs. The system hardware design is shown in Figure 3, and the component paths are described in Table 1.

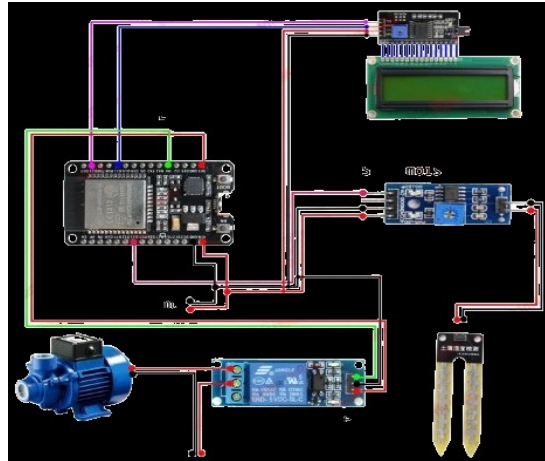


Figure 3. Hardware Design

Table 1. Component Path

Component	Pin/Output	Connection
ESP32 Power Supply	VCC (5V) GND	External 5V DC power supply External power supply ground
Soil Moisture Sensor	VCC GND Output Data (AO/DO)	ESP32 3V3 ESP32 GND ESP32 GPIO (e.g., D34)
Relay Module	IN Pin VCC GND	ESP32 GPIO (e.g., D5) ESP32 3V3 ESP32 GND
Water Pump	COM Pin (Common) NO Pin (Normally Open) Ground	Power input terminal AC/DC power source according to pump specification AC/DC power source ground
I2C Module & LCD	VCC GND SDA SCL	ESP32 3V3 ESP32 GND ESP32 D21 (SDA) ESP32 D22 (SCL)

2.4 Software Design

The software I developed acts as the mastermind for managing the entire physical system and integrating Internet of Things (IoT) technology. With the help of relays, this software automatically controls soil watering through the following steps:

1. Reading data from the soil moisture sensor.
2. Processing the data based on the logic I defined.
3. Displaying the data on an LCD screen.
4. Connecting the system to an IoT platform to enable remote monitoring.

After writing the program, I compiled and uploaded the code to the ESP32 to enable its functionality. During the compilation process, I could see the connection code displayed in the UI output by pressing the BOOT button on the ESP32 board.

In this system, I used several software tools to support development:

1. CorelDRAW – to design the component circuit diagram.
2. Arduino IDE – to program the ESP32.
3. Blynk IoT – to control and monitor the device in real time.

The ESP32 program flowchart can be seen in Figure 4.

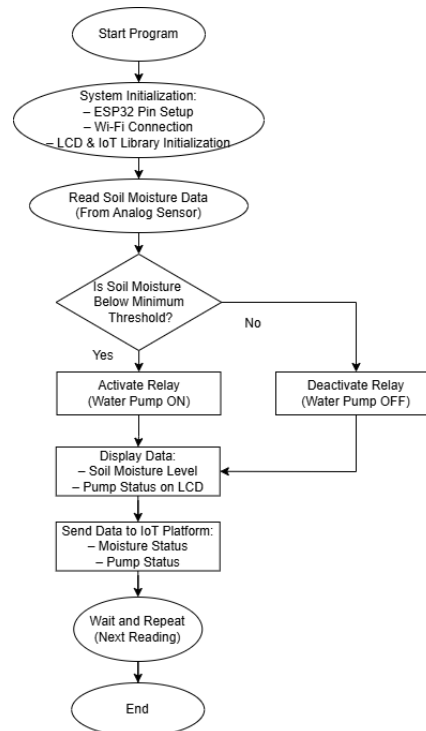


Figure 4. ESP32 Program Flowchart

2.5 Test Method

Before this machine can be used, testing must be conducted to ensure it can be used for the IoT-based soil moisture monitoring and automatic watering system. Testing aims to ensure that each hardware and software component functions according to expected specifications. This testing is necessary as one of the stages to verify the minimum error rate and accuracy of the designed tool. The following testing methods will be performed:

1. Soil Moisture Sensor Testing

Ensure that the soil moisture sensor is functioning properly and providing accurate data. The expected result is that the sensor provides different values for each condition (dry, humid, wet) with good accuracy.

2. Relay and Water Pump Testing

Ensure that the relay can control the water pump based on data from the soil moisture sensor. The expected result is that the relay automatically turns the water pump on and off according to the program logic.

3. Result and Discussion

3.1 Design Results for Soil Moisture Monitoring and Automatic Watering Machine

Figures 5 through 6 illustrate the design results obtained from the method that was previously developed and refined for the Humidity and Irrigation machine. The design process focused on ensuring that all essential components could be integrated efficiently while maintaining functionality, reliability, and ease of operation. Several adjustments were made to accommodate the placement of sensors, control modules, power supply units, communication devices, and irrigation-related components within the machine structure. These modifications were intended to optimize the internal layout, improve accessibility for maintenance, and enhance overall system performance.

In addition to its physical design, the device was developed with Internet of Things (IoT) capabilities, enabling seamless connectivity to the internet. Through this connectivity, users and operators can remotely monitor environmental conditions, receive real-time data, and control irrigation operations using a smartphone or other connected devices. This feature increases operational flexibility and allows timely responses to changes in humidity levels and irrigation requirements. Furthermore, the integration of wireless communication technologies improves user convenience and supports automated agricultural management. The final appearance of the device, including its conditions when powered on and powered off, is presented in the figures below to provide a clear visualization of the completed system design.:

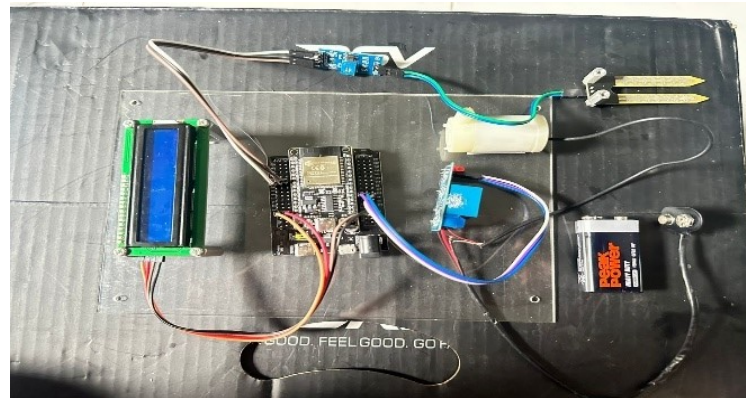


Figure 5. Front View of Soil Moisture and Watering Machine When Off

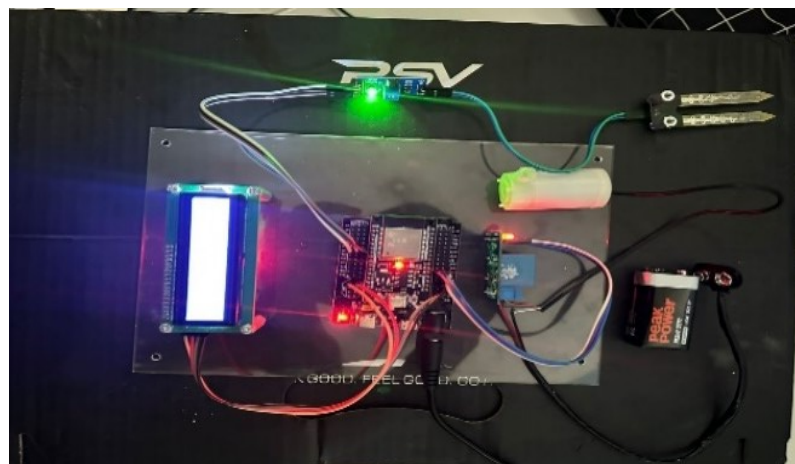


Figure 6. Front View of the Soil Moisture and Watering Machine When it is on

3.2 Blynk IoT Design Results on Smartphones

The Blynk IoT design is the most important part of the automatic watering machine's humidity control system. Blynk works by allowing users to easily control and monitor humidity and watering. If the humidity is too low or too high, the watering will be activated. Blynk can also be controlled remotely without having to visit the humidity machine. This system makes it easier for users to monitor the machine if conditions prevent them from visiting the humidity machine. The Blynk design can be seen in Figure 7.

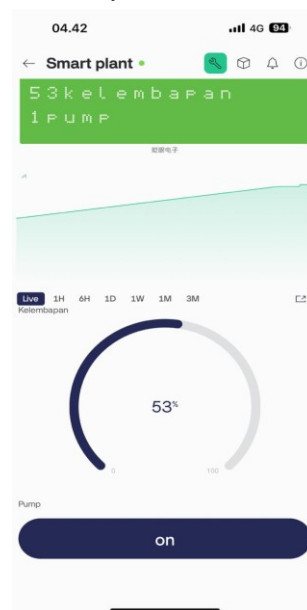


Figure 7. Blynk Design View

3.3 Soil Moisture Test Results and Automatic Watering

The results of the Soil Moisture and Automatic Watering tests can be seen in Table 2.

Table 2. Humidity and Watering Sensor Data

No.	Time	Soil Moisture	Water Pump Status	Description
1.	06:00	30%	ON	Soil is very dry; the pump is activated via Blynk.
2.	07:00	35%	ON	Soil is very dry; the pump is activated via Blynk.
3.	08.00	45%	OFF	Soil is moist; irrigation is stopped via Blynk.
4.	09.00	50%	OFF	Soil is sufficiently moist; irrigation is not required.
5.	10.00	65%	OFF	Soil is wet; the pump remains off.
6.	11.00	38%	ON	Soil starts to dry; irrigation is initiated via Blynk.
7.	12.00	42%	OFF	Soil is sufficiently moist; the pump is turned off.
8.	13.00	25%	ON	Soil is very dry; irrigation is initiated via Blynk.
9.	14.00	50%	OFF	Soil becomes moist again; the pump stops.

Soil moisture sensor data is used to measure the water content in the soil. This sensor provides crucial information for understanding soil conditions and assisting in irrigation management or plant watering. Below is a more detailed explanation of soil moisture sensor data and watering. Soil moisture sensors work by measuring the resistivity or conductivity of the soil, which changes according to the water content in the soil.

The data generated by a soil moisture sensor is generally a numerical value indicating the soil moisture level, usually expressed as a percentage or in volumetric units (m^3/m^3). For example, a soil moisture sensor reading of 30% means that 30% of the soil volume is water.

3.4 Water Pump Test Results

Water pump test results based on the material previously explained. This table includes test results for pressure, flow, power consumption, temperature, noise, and leakage to facilitate pump performance analysis.

Table 3. Water pump test data

No.	Testing Time	Measured Pressure	Specified Pressure	Description
1.	1 Minute	45	50	Pressure is slightly lower than the specification.
2.	5 Minutes	48	50	Pressure approaches the specified value.
3.	10 Minutes	50	50	Pressure meets the specification; soil is moist and irrigation is stopped via Blynk.
4.	15 Minutes	52	52	Pressure is slightly higher than the specification.

- 1 Minute: Pressure is 45 psi, slightly below specification (50 psi), likely due to initial pumping conditions or a light load.
- 5 Minutes: Pressure reaches 48 psi, close to specification, indicating the pump is stabilizing.
- Steady Point: Pressure reaches 50 psi, within pump specifications.
- 15 Minutes: Pressure increases slightly to 52 psi. A 2 psi increase is within tolerance, but should be monitored for potential control issues.

3.5 Overall Test Results

Table 4. Overall Test Data

No	Test	Initial Condition	Expected Result	Description	Status
1.	ESP32 input voltage test	5V DC power supply connected	ESP32 powers on and is ready for use	ESP32 powered on	Pass
2.	Soil moisture sensor reading test	Sensor placed in water	High moisture value (Digital: 80)	Value matches expectation	Pass
3.	Soil moisture sensor reading test	Sensor exposed to air (dry soil)	Low moisture value (Digital: 0)	Value matches expectation	Pass

4.	I2C communication test with LCD	LCD connected via I2C	Data displayed on LCD	Data shown on LCD screen	Pass
5.	Relay test in OFF condition	LOW signal sent to relay	Pump remains off	Pump turned off	Pass
6.	Relay test in ON condition	HIGH signal sent to relay	Pump turns on	Pump activated	Pass
7.	System test under high moisture condition	Sensor placed in wet soil or water	Pump remains off; LCD displays correct data	Results as expected	Pass
8.	System test under low moisture condition	Sensor placed in air or dry soil	Pump turns on; LCD displays correct data	Results as expected	Pass
9.	Electrical test: power disconnected	All systems powered off	All modules turn off	All modules powered off	Pass
10.	System stability test	System operated continuously for 1 hour	System remains stable without interruption	Stable without interruption	Pass

Table 5. Function Data and Description

No.	Component	Function	Description
1.	ESP32 Board	Acts as the central controller to read sensor data, process information, and control the relay and LCD.	The main component used to manage system logic and communication with other modules.
2.	Soil Moisture Sensor	Measures soil moisture and provides digital output (wet: 1, dry: 0).	Sensor output is used as a reference to activate or deactivate the water pump.
3.	Relay Module	Controls the electrical current to the water pump based on signals from the ESP32.	Functions as an automatic switch to turn the water pump on or off.
4.	AC/DC Water Pump	Delivers water to required areas based on relay signals.	The pump is activated when the soil is dry and turned off when sufficient moisture is detected.
5.	I2C Module	Enables communication between the ESP32 and LCD using the I2C protocol.	Mengurangi jumlah kabel yang Reduces the number of wires required for LCD communication.
6.	LCD Screen	Displays data such as soil moisture level and pump status.	Provides real-time visual feedback to users regarding system conditions.

Based on the data in Tables 4 and 5, it can be concluded that all components of the Soil Moisture tool have several components that perform poorly. First, the Water Pump is considered to be less effective at discharging water. Furthermore, because it uses batteries, the Water Pump has a slight delay and is less powerful.

The second component is Blynk. This application is still under development, so its performance is less than optimal. However, automatic and manual monitoring and control can run smoothly depending on internet connectivity.

4. Conclusion

The development of an IoT-based soil moisture monitoring and automatic watering tool using ESP32 was successfully realized. The system uses a soil moisture sensor, a relay module, and a water pump packaged in an acrylic casing and powered by a 9V battery. Soil moisture data can be monitored in real-time through the IoT platform, while the relay functions effectively in controlling the water pump automatically. Test results show that the sensor has a good level of accuracy and the system is able to respond quickly to changes in soil moisture. The water pump is automatically activated when the moisture is below the threshold and stops when the soil conditions are optimal, so the system is considered to be running effectively and in accordance with the design objectives.

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