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Soil Moisture Controlled Irrigation System for Enhanced Vegetable Garden Productivity and Water Efficiency

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Abstract: *The importance of irrigation in daily agriculture is highlighted, focusing on optimising water use through an automatic system. The research introduces a design utilizing capacitive soil moisture and DHT11 temperature/humidity sensors, ensuring minimal impact on plants. Components include ESP8266 WiFi modules for connectivity, an OLED display for local feedback, and infrared temperature sensors. Data on soil moisture is sent to a Blynk cloud account, allowing remote monitoring and control via a mobile app. The system triggers irrigation when soil moisture decreases, enhancing plant productivity by preventing water wastage and over-irrigation. This approach integrates real-time monitoring and global accessibility to optimize agricultural water management efficiently.*

Keyword: *sensor, blynk, moisture, irrigation and humidity*

1. Introduction

Irrigation is the controlled application of water to agricultural land to assist in crop growth. It has been practised for thousands of years, with historical records showing its use in ancient civilizations such as Mesopotamia13). Irrigation systems vary widely, including surface, sprinkler, and drip irrigation. Irrigation offers significant nutritional benefits by ensuring a consistent water supply to crops, which enhances their growth and yield. Proper irrigation can help prevent water stress and improve nutrient uptake, contributing to higher quality and more abundant produce 11). Irrigation involves careful scheduling and monitoring of water application, taking into account factors like soil type, crop type, and local climate. Techniques like furrow irrigation, where water is directed between rows of crops, and drip irrigation, which delivers water directly to plant roots, have been developed to optimize water efficiency 5). Irrigation played a pivotal role in the growth of civilizations by enabling agriculture in arid regions. The Sumerians in ancient Mesopotamia developed complex canal systems around 4000 BCE, facilitating crop production 6&7).

Cultivation methods for vegetables have evolved, from traditional practices to modern techniques that enhance yield and quality. Sustainable farming approaches, such as organic and agroecological methods, aim to minimize environmental impact while ensuring food security 1&11). The historical significance of vegetables dates back centuries. In ancient civilizations like Egypt and Mesopotamia, vegetables were integral to daily diets and even had medicinal uses4). Over time, their consumption patterns have influenced cultural traditions and culinary practices worldwide. The introduction of vegetables to the Americas occurred after the arrival of Christopher Columbus in 1492. Columbus brought tomatoes, potatoes, peppers, and other vegetables from the Americas back to Europe. Moisture is essential for the growth and development of living organisms, including plants and animals. In the context of plants, moisture refers to the presence of water in the soil, which is crucial for their survival. Adequate moisture levels provide plants with the necessary hydration to carry out various physiological processes, such as photosynthesis and nutrient absorption. moisture plays a vital role in ensuring the quality and edibility of fruits, vegetables, and other crops. Overwatering or under-watering can lead to adverse effects on plant health, emphasizing the importance of precise moisture control in modern agricultural practices. The availability of moisture has shaped civilizations and cultures. Ancient civilizations settled near water sources like rivers and lakes, enabling agriculture and providing water for daily needs. The Nile River's annual flooding, for example, facilitated fertile soil for farming in ancient Egypt (The Nile and Ancient Egypt" by Terry Deary). Additionally, historical texts often mention the significance of irrigation systems used to manage moisture for crop cultivation, such as the qanat systems in Persia ("Qanat - Ancient Water Systems" by Farrokh Mehr).

Soil moisture-controlled irrigation systems have gained significance in vegetable gardening due to their efficient water usage. Research by11), found that such systems can optimize water delivery, enhancing crop yield and quality. Vegetables grown with proper moisture levels have higher nutrient content. A study demonstrated that well-irrigated crops exhibited increased vitamin and mineral content compared to water-stressed crops – 3). Integrating moisture sensors and automated irrigation based on real-time soil data has proven effective – 6). This method ensures plants receive the right amount of water, preventing overwatering or drought stress. Controlled irrigation dates back to ancient civilizations like the Mesopotamians, who used canals to manage water for agriculture 9). Today, modern soil moisture control systems build upon these principles, offering sustainable solutions for vegetable cultivation.

2. Experimental Method

The design of irrigation systems utilizes different methods categorized into resistive and capacitive, based on sensor technology. This project employs a capacitive measurement technique, leveraging capacitance technology. Unlike resistive methods, capacitive sensors use a single probe without exposed metal, preventing rust and eliminating the risk of harm to plants from electricity in the soil. This approach is favoured for its reliability and plant-friendly operation, making it suitable for efficient irrigation system designs.

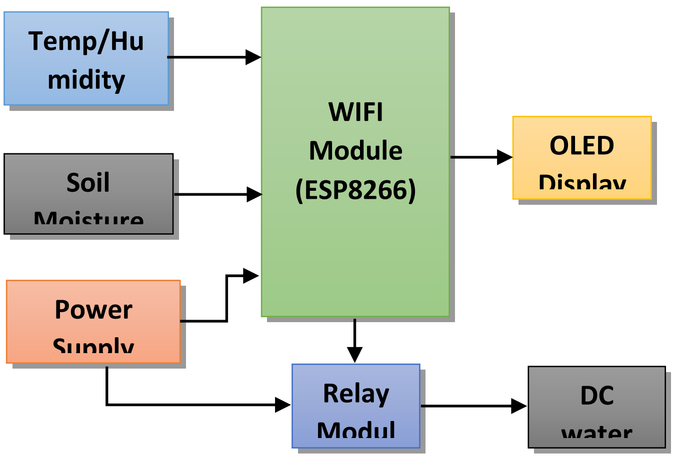

Figure3.7: *Block Diagram Smart Irrigation System*

3. CIRCUIT ANALYSIS

The major building block of the project comprises the power supply unit, microcontroller, OLED display section and an integrated infrared temperature sensor module, the sensor detects the change in environmental temperature and the object to be measured and then provides a signal to the microcontroller base on the measured value gotten from the environment and the object at which the measurement is done.

Fig 3.5 shows the complete circuit diagram for the IoT-based Agric Irrigation system. The control system is based on the ESP8266 WIFI module from Express if. The ESP8266 Module allows monitoring and controlling of the device remotely.The module is responsible for connecting to the WIFI Network and also acting as a server. In contrast, the Mobile Phone that runs the web-based user interface acts as the client. The web-based user interface is accessible via a web browser on the mobile device or laptop of the user using an IP address. Whenever the control buttons in the Application are clicked, the corresponding information will be transmitted to the Server (ESP8266) through a cloud environment.

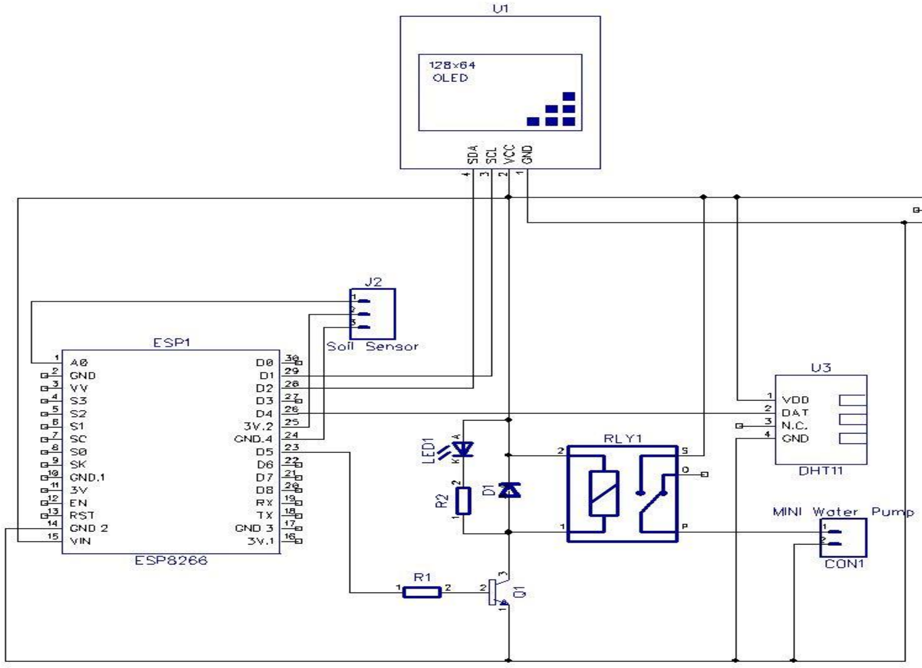

Figure3.8: *Circuit Diagram of Smart Irrigation System*

This information is further processed by the ESP module and then sent to the relay driver circuit which in turn controls the electric motor that is responsible for pumping water for the plant. The power supply for the system is derived from a 9V DC source through DCtoDC converter module voltage regulators connected to J3. The regulated output from the regulator is then fed to the power pins of the ESP8266’s Vcc and GND pins. the Digital Pins D5 of the ESP modules is configured as output and used in activating the relays.

Material

ESP8266 WIFI Module

Fig 3.1 shows that ESP8266 is a low-cost Wi-Fi controller board. It is an open-source platform used for building WIFI-based electronics projects. The ESP8266 is a low-cost Wi-Fi microchip with full TCP/IP stack and microcontroller capability produced by manufacturer Expressif Systems. The ESP8285 is an ESP8266 with 1 MB of built-in flash, allowing for single-chip devices capable of connecting to Wi-Fi.

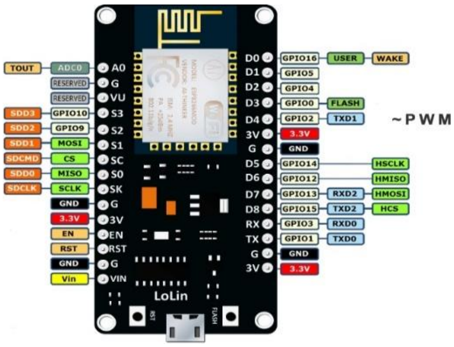

Fig3.1: *ESP8266 WIFI controller board*

The ESP8266 microcontroller integrates a Tensilica L106 32-bit RISC processor, which achieves extra-low power consumption and reaches a maximum clock speed of 160 MHz. The Real-Time Operating System (RTOS) and Wi-Fi stack allow about 80% of the processing power to be available for user application programming and development.

MT3608 DC to DC Step-Up Boost Converter Module

The MT3608 in Figure 3.2 step-up booster converter module is a small highly efficient and low-cost DC-to-DC converter module built for converting or boosting DC voltage as low as 2V to a maximum 28V DC with a maximum output current of 2A. The output voltage can be adjusted using the variable resistor used in the module.

Fig3.2: *MT3608 DC To DC Step Up Boost Converter Module*

The main component of this module is the MT3608 IC. It is a highly efficient voltage booster IC with many in-built features like overheat protection, low quiescent current, soft start function, low external components and overheat shutdown. Other components used in this module are two ceramic capacitors, a variable resistor, a fixed resistor, a Schottky diode and a 22µH inductor, which is an important part of all voltage booster circuits.

0.96″ I2C OLED (Organic Light-Emitting Diode) Display Module

An OLED is electroluminescent and therefore, emits its light. Its display has such high contrast and an extremely wide viewing angle. It offers low power consumption and high readability. On average the display uses about 20mA current, although it depends on how much of the display is on.

Fig3.3: *0.96" I2C OLED (Organic Light-Emitting Diode) display*

At the heart of the module is a powerful single-chip CMOS OLED driver controller – SSD1306. It can communicate with the microcontroller in multiple ways including I2C and SPI. SPI is generally faster than I2C but requires more I/O pins while I2C requires only two pins and can be shared with other I2C peripherals.

DHT11 Temperature/Humidity Sensor

DHT11 is a commonly used Temperature and humidity sensor that comes with a dedicated NTC to measure temperature and an 8-bit microcontroller to output the values of temperature and humidity as serial data. it is a low-cost digital temperature and humidity sensor, with a single-wire digital humidity and temperature sensor, which provides humidity and temperature values serially with the one-wire protocol.The sensor provides relative humidity values in percentage (20 to 90% RH) and temperature values in degrees Celsius (0 to 50 °C).

Figure3.4: *DHT11 Digital Temperature and Humidity Sensor*

Soil Moisture Sensor

Soil Moisture sensors make use of a 555 timer IC and operate by measuring how quickly (or slowly) a capacitor charges through a resistor, but in these sensors the capacitor is not a literal component but is formed by two PCB traces that are near one another. Their capacitance, and therefore their charging rate, changes in response to how much water is around them. The sensor includes an on-board 3.3V voltage regulator, making it suitable for 3.3V and 5V MCUs. Plus, it consumes less than 5mA of current. this sensor only provides a qualitative measurement of soil moisture. As the soil gets wetter, the output value decreases, and as it gets drier, the output value increases. When powered at 5V, the output ranges from about 1.5V (for wet soil) to 3V (for dry soil).

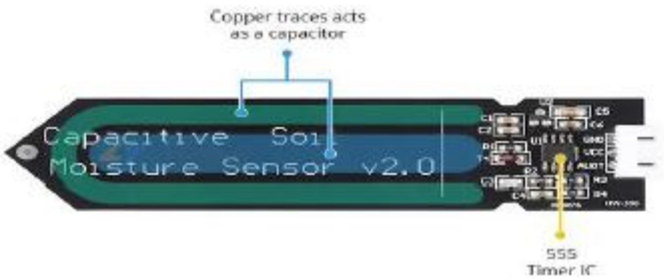

Fig3.5: *Capacitive Soil Moisture Sensors*

Relay Switch

A relay is an electromagnetic switch operated by a relatively small current that can control a much larger current. Typically, the relay has 5 pins, three of which are high-voltage terminals (NC, COM, and NO) that connect to the device you want to control.

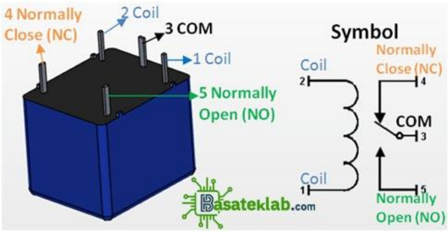

Fig3.6: *Physical and schematic representation of a relay*

4. Construction, Testing and Result

Being an electrically operated switch, Current flows through the coil of the relay allowing it to create a magnetic field which attracts a lever, thereby changing the switch contacts. relays have two switch positions making them either single pole single throw, single pole double throw or double pole double throw switches. In this project, the relay is designed for switching high-powered devices from a low-power system such as Microcontroller. The relay is rated up to 10A at 250VAC or 30VDC. There are two LEDs on the relay module indicating the position of the relay. Whenever a relay is activated, the respective LED will light up.

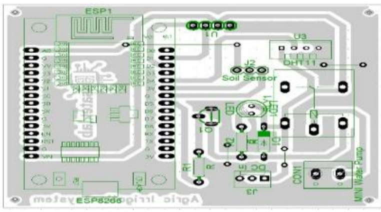

Fig4.1: *Layout diagram of Smart Irrigation system*

Designing of the Schematic and Layout Diagram

The jumper wires and resistors were first soldered into their respective holes, with care taken to place each in their correct position. In identifying the resistors, a digital Multimeter was used to check each resistor before they were installed. Next sockets for the ESP8266 and the power supply modules were installed, with care taken with their orientation. Female header connectors were used as sockets for the ESP8266 module. All polarized components were oriented as shown in the layout diagram above. Light emitting diodes, Buzzer and the relay were installed last. care was also taken to ensure that all the polarized components (e.g., LEDs, capacitors, buzzer and diodes) were soldered in the right way round.

Software and Programming

Fig 4.2 shows a screenshot of the application that was used in the development of the ESP8266 controller Firmware code. Here, Arduino integrated development environment IDE was used in writing the required firmware for the ESP module. The firmware program written in C allows control commands to be sent to the cloud server (thingspeak).

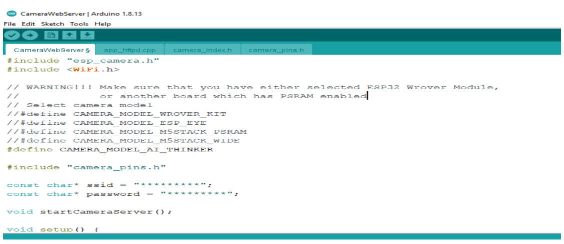

Fig4.2: *Arduino integrated development environment*

Arduino IDE providesa library for the ESP8266 module. These libraries contain the core initialization functions for the ESP8266 module. The controller digital pins were initialized and declared as output. to upload the firmware program into the module, an FTDI programmer was used.

Setting Up the Blynk web Dashboard and Mobile App

In other to monitor the system performance and status, a remote server was set up to allow communication between the user and the device remotely. this was accomplished by setting up a cloud account via Blynk,an account was created by visiting https://blynk.io./ after creating the account, a New template was created by Clicking on “add new template” & filling up the template details as shown in Fig4.3 below

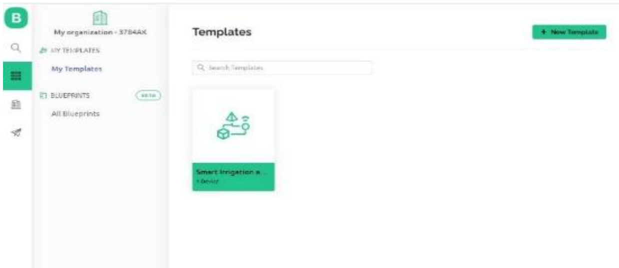

Fig4.3: *BlynkCloud Server Environment*

5. Testing & Results

In testing the project, the water pump needs to be fully submerged in water. The outlet pipe was kept in a field for irrigation. Similarly, the soil Moisture sensor was dipped into the soil. on powering on the device, the LCDgetsinitialized and starts displaying the real-time Data of the Soil moisture level, and the water pump status.

Figure: *Pictures of the complete system*

When the soil moisture content is reduced the water pumps turn on and irrigate the field until the required moisture is achieved. the real-time Data of the Soil moisture and water pump can be monitored online from any part of the world using Blynk Server. To do this, the Blynk app was accessed. the soil Moisture, and Temperature as well as relay status can be monitored remotely.

6. Operation

In operating the system, all that is required is to place the system by a door entry. When powering this system, First, the NodeMCU board connects to the Internet via a local IP address. Then, the system goes into activation mode. After which the LCD, displayed “System Loading” followed by the soil moisture level. The red LED turns ON to indicate the pump status. Whenthe red LED and the buzzer activate quickly to alert for possible intrusion within the Area. the display also shows a “Motor On” message on the screen and the mobile App as well. Then, the system returns to a normal situation, the green LED stays turned OFF, and the display shows “Motor OFF” on the LCD.

7. Summary

Farmers usually work on large portions of land to grow different types of crops. It is not always possible for one person to be able to keep track of the entire farmland all the time. Sometimes a given patch of land may receive more water leading to water-logging, or it might receive far less or no water at all leading to dry soil. In either case, the crops can get damaged and farmers may suffer losses.This project demonstrates the need for an irrigation system. It may not be possible for farmers to be continuously present in his/her gardens but they can use this project to keep track of 'soil moisture' and ensure proper water supply even from a distance.

8. CONCLUSION

This research was designed and constructed with a Wi-Fi-based soil moisture automatic irrigation system which is locally assembled. The operation of the system is straightforward with no ambiguity in operation. The system works perfectly andserves as soil moisture and temperature data logging for a particular environment. The system is effective and efficient and it's very avoidable to put together.

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