Simulation and Construction of a Microcontroller based Plant Water Sprinkler with Weather Monitoring System

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ABSTRACT
Plants water sprinkling is the most important usual practice and one of the labor intensive tasks in daily farming operation. Since excess watering of plants is as harmful as insufficient watering, knowing when and how much to water is of vital importance in agricultural practice. In this study, simulation and construction of a microcontroller based plant water sprinkler with weather monitoring system was carried out using Arduino Nano ATmega328 microcontroller. The circuit was simulated using Proteus ver8.0 consisting of regulated power supply, soil moisture sensor, DHT11 temperature and humidity sensor, microcontroller, 16x2 LCD, and relay/motor output driver unit. A prototype of the circuit was constructed on a Vero board and tested for continuity, power ON and pump status under different soil conditions; wet and dry soils. Results shows that, the circuit senses the moisture level of the soil, temperature and humidity then supply water when required by the plants when the voltage (conductivity) of the soil goes below 3v. The motor will trigger to pump water when the resistance of the soil increases and the conductivity or the voltage decreases. This device can be used to maintain the soil moisture content while conserving water for effective plants growth, improved yield and food sustainability.

General Terms
Simulation studies

Keywords
Water sprinkler, weather monitoring system, microcontroller, Proteus design suit, Arduino Nano, implementation

1. INTRODUCTION
Water is one of the most vital substances on earth. All plants and animals require water to stay alive. It constitutes a greater part of human body weight, and is involved in many key functions including flushing out waste from your body, regulating body temperature, aiding digestions, and improving blood oxygen circulation [1]. In farming two things are very important, first to get data on the fertility of soil and second is to know the level of moisture content in soil. Water is an importance requirement for the growth and development of crops. They use it to keep their cells from drying out and to convey nutrients and raw materials throughout their system to area where photosynthesis and seed production take place. Plants desires water constantly during their life and in a regulating quantity to control photosynthesis, respiration, absorption, transportation, translation and use of mineral nutrients and cell division, as well as some other processes [2, 3].

Both scarcity and excess of water affect the growth and development of the plant directly and as a result, low yield. Lack of water to plants may leads to wilting, reduced photosynthesis, reduced respiration, reduced transportation and evolutionary developments [4]. Over-watering results in waterlogging and can severely limit the supply of oxygen that roots depend on to function properly [5]. It can result to foliar diseases, root rot diseases, plants wilted, yellow leaves, young leaves turn brown and fall, leaching of fertilizer and pesticides, and stunted growth [6, 7]. The use of controlled amount of water to land to assist in production of crops at the required spans is refers to as irrigation [2, 4]. Automatic irrigation system distributes water to crops and nurseries automatically and does not require any human support to perform the operations of watering but however, they are very expensive and complex in their design [4]. The common problem for farmers who have domestic's plants is to be sure if the plants receive the right amount of water and at the right time. It is also difficult to avoid wasting water in trying to fulfill this task manually since water required by plant needs specific volume.

Microcontroller base automatic plant water sprinkler uses intelligence embedded technology in plant watering which replaces the conventional manual plant watering with automatic processes [8]. Weather monitoring plays an important role in agriculture and human life in general, so the collection of information about the temporal dynamics of weather change is very important to plants [9]. Monitoring weather parameters manually is difficult, as such, implementation of automatic systems that monitor weather conditions like temperature, humidity and soil moisture content is very significant in agriculture and day to day activities [10, 11]. Agriculture is one field where water is required in high quantity, however, water shortage is one of the major problems in Nigeria agricultural practices [12]. A number of techniques are available to save or control wastage of water but microcontroller based automatic plant watering system has proved to be very cost effective, can give required amount of water to the plants at the targeted area and promote water conservation [11]. In view of the above, the main objective of this study is to simulate and construct an automatic microcontroller based plant water sprinkler with weather monitoring system. The device will be of great significance to commercial and local farmers especially in Nigeria, where there is diversification of economy to agriculture and the climatic condition is mostly isotropic with scarcity of rain. The device can be used to control the soil moisture content of plants and at the same time monitor the weather condition for effective plant growth and improve yield.

2. MATERIALS AND METHODS

2.1 Materials

The materials and their specification that were used for the simulation and construction of a microcontroller based plant water sprinkler with weather monitoring system includes ATMega328 microcontroller, DHT11 temperature and humidity sensor, motor, soil moisture sensor, LM7812 voltage regulator, 12-30A relay, 16 x 2 LCD display, transformer, Proteus 8.0 software.

2.2 Methods

The methods for implementation of the microcontroller based automatic plant water sprinkler with weather monitoring device include simulation, flowchart, algorithms, choice of programming language, hardware construction, and circuit analysis (testing) method.

2.2.1 Simulation

The microcontroller based automatic plant water sprinkler with weather monitoring device circuit was simulated using Proteus ver8.0 software. The stages in the software simulation includes power supply unit, soil moisture sensor unit, microcontroller unit, DHT11 (temperature/ humidity) sensor, LCD unit, and pump/ motor/ sprinkler unit. The block diagram of the proposed system is shown in Figure 1.

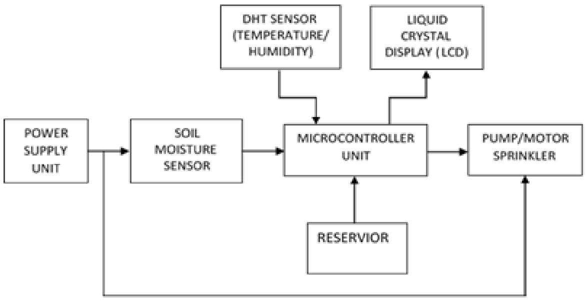

Fig 1: Block Diagram of the proposed system

2.2.1.1 Power Supply Circuit

The power supply is the circuit after which a selected dc voltage to operate the additional circuits are achieved. The voltage from the main source was 220V AC but some sections of the circuit needed 5V DC. Therefore, a step-down transformer was used to get 12V AC from 220V, which was rectified to 12V DC using a rectifier. The result of the rectifier still comprised of some distortions despite that it was a DC signal and as such called fluctuating DC. The ripples were removed to realize a smoothened signal using DC power filter circuits. 12V was used to power the relay/motor unit but regulated to 5V to power the microcontroller. The Power Supply unit is shown in Figure 2.

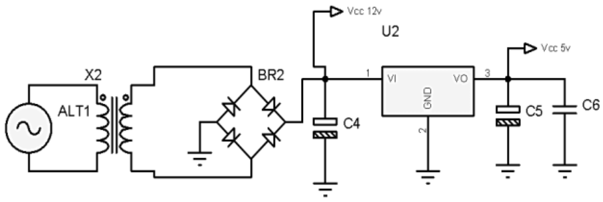

Fig 2: Regulated power supply unit

2.2.1.2 Soil Moisture Sensor Unit

The soil moisture sensor senses the moisture content of the soil (quantity of water in the soil) and sends signals to the microcontroller to act accordingly. The distance to which the sensor is hidden in the soil depends on where the system is to be used. Soil moisture sensors measure the water content in soil. A soil moisture probe is made up of numerous soil moisture sensors. Moisture sensor measures and gives Analog output variations from 0.6volts - 12volts. Input Voltage 12V DC, this output is converted into a form that can be interpreted by the microcontroller [13]. Figure 3 shows the circuit diagram of the Soil Moisture Sensor unit.

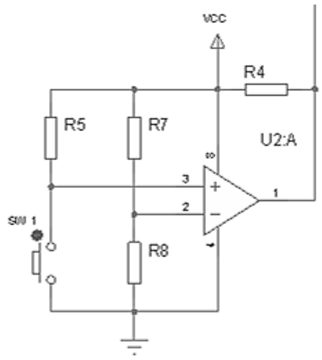

Fig 3: Soil Moisture Sensor Unit

2.2.1.3 DHT11 Unit

The DHT11 is a low cost temperature and humidity sensor, which generates calibrated digital output. It can be interface with any microcontroller like Arduino, Raspberry pi etc. and get instantaneous results which provides high reliability and long term stability. DHT11 sensor was connected with Arduino in this study to monitor weather. It consists of three main components; a resistive type humidity sensor, an NTC (negative temperature coefficient) thermistor (to measure the temperature), and an 8-bit microcontroller, which converts the analogue signals from both the sensors to digital signal which can be read by any microcontroller or microprocessor for further analysis [14]. DHT11 consists of 4 pins: Vcc, data out, not connected (NC) and ground (GND). The range of voltage for Vcc is 3.5V to 5.5V. In this study, a 5V supply was used. DHT11 sensor can measure humidity in the range of 20 - 90% of relative humidity and a temperature in the range of 0 - 50°C. The circuit diagram of the DHT11 is shown in Figure 4.

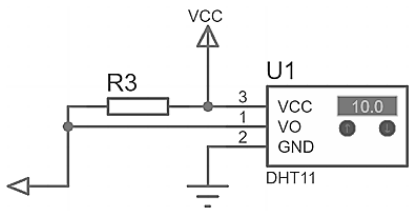

Fig 4: DHT11 Sensor Unit

2.2.1.4 LCD Unit

The LCD (Liquid Crystal Display) screen is an electronic display module. A 16x2 LCD display is a very basic module used to display 16 characters per line and there are 2 such lines. Each character is displayed in 5x7 pixel matrix. The 16 x 2 intelligent alphanumeric dot matrix display is capable of displaying 224 different characters and symbols. This LCD has two registers, namely, Command and Data registers. Command register accepts and stores various commands or instructions given to the LCD while data register stores data to be displayed by the LCD. In Arduino project, Liquid Crystal Library simplifies the process of controlling the display, hence, there is usually no need to know the low-level instructions [15]. However, the contrast of the display can be adjusted by adjusting the potentiometer to be connected across VEE pin. The LCD was used in this study to displays the state of the motor and to measure relative humidity and temperature. Figure 5 shows the 16x2 LCD unit.

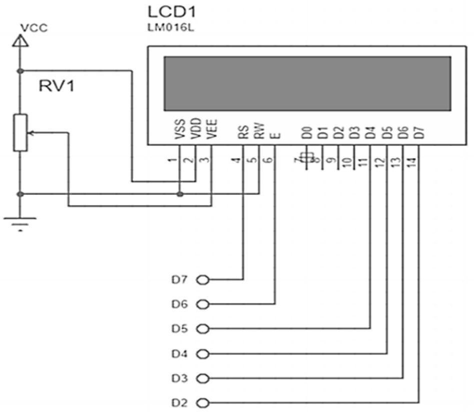

Fig 5: LCD1 LMO16L Unit

2.2.1.5 Microcontroller Circuit

The Arduino is an open source platform used for building electronics projects, it consists of a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board. The Arduino IDE uses a simplified version C++, making it easier to learn the program [16]. In this work, the Arduino Nano based on ATmega328 was used. It contains a chip central processing unit (CPU), Read Only Memory (ROM), Random Access Memory (RAM), input/output unit, interrupts controller etc. Figure 6 shows the circuit diagram of the microcontroller unit.

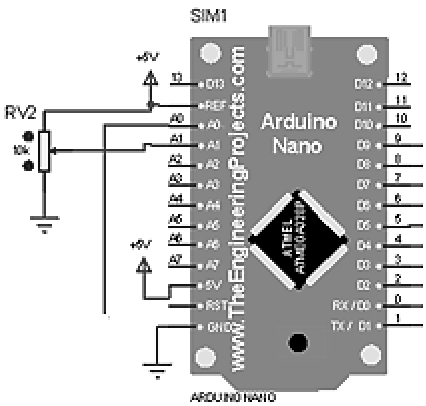

Fig 6: Microcontroller unit

2.2.1.6 Relay/Motor Output Driver Unit

The relays are electrical shifts or switches that open and close below the control of added electrical circuit. In the original form, the shift is operated by an electromagnet to open or close one or many arrays of contacts. Since a relay is capable of controlling the output circuit of higher power than the input circuit, it can be well-thought-out to be in a wide sense a form of an electrical driver used to provide enough current for the pump [16]. The pump capacity in this work needs a spray of a distance of about one meter. But larger pump could be required for large spray range or even high pressure device to make the projectile even farther. The circuit diagram of the relay/motor output driver is shown in Figure 7.

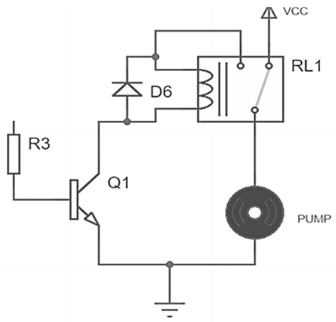

Fig 7: Relay/motor output driver unit

2.2.2 System Flowchart

The flow chart for the microcontroller based automatic plant water sprinkler with weather monitoring system is as shown in Figure 8.

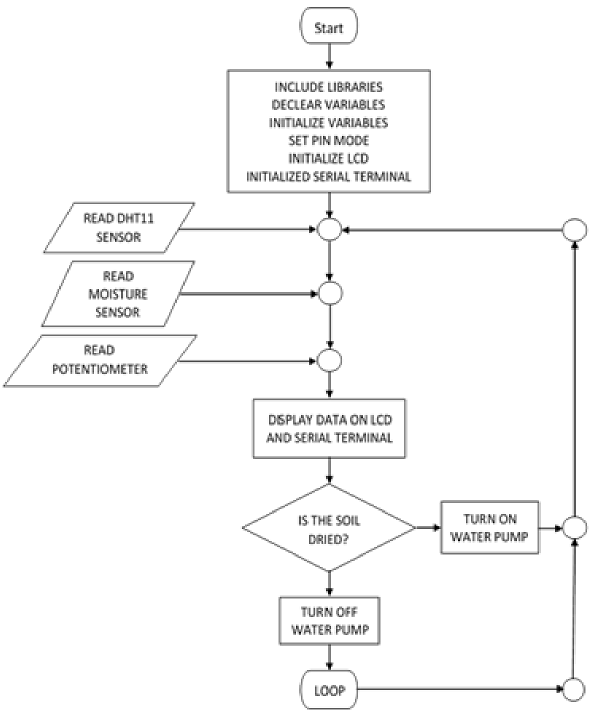

Fig 8: Flowchart for the proposed system

2.2.3 The Algorithm

The algorithm that explains the flowchart for the microcontroller based automatic plant waterer with weather monitoring system is presented as follows:

1. Choose the microcontroller system

2. Include libraries

3. Declare and initialize variables

4. Setup pin modes

5. Setup LCD and Serial communication

6. Read DHT11 sensor

7. Read soil moisture sensor

8. Read potentiometer

9. Turn on pump if soil moisture value is higher than potentiometer value else turn off pump.

10. Display data on LCD and serial terminal.

2.2.4 Choice of Programming Language

The basic software program was written using the Arduino language program. The choice of Arduino C language programming was chosen because it is more compatible with the Arduino programming software. This is widely used in programming language for embedded microcontrollers. C language was also used mainly to implement those portions of the code where very timing, accuracy and code size efficiency are key requirements.

2.2.5 Hardware Construction Method

The circuit construction was carried out in stages according to the block diagram shown in Figure 1. The components were first assembled on electronics breadboard to ensure proper terminal connections and then transferred on to a Vero board for permanent soldering, using the soldering iron and MBO 1mm wire lead solder at +183°C melting point. However, too much Lead was avoided to prevent clumsiness and bridging of the component to each another.

2.2.6 Circuit Testing Method

The components testing was carried out before fixing them on the Vero board. Also Continuity test and Power ON test were carried out during construction to ensure proper functioning of the circuit and to ensure that no components in the circuit undergo heating when the device is in use and also to avoid loading and impedance mismatch of one stage and another.

2.2.6.1 Continuity Test

This test is performed to find any electrical open paths in the circuit after the soldering. The continuity test was carried out to make sure no cable or line jammed and all lines have free flow of electrons. It helped the researcher to check and see if current flows in the constructed circuit or the lines are continuous. The test can be performed by using a multi meters which measure current and specialized continuity testers which are cheaper, or generally with a simple light bulb that lights up when current flows or even a piezo electric speaker. If electron flow is inhibited by broken conductors, damaged components, or excessive resistance, the circuit will be "open". The multi meter was used to perform this test in this study.

2.2.6.2 Power ON Test

This test was carried out to ascertain whether the voltage at the different terminals were according to the requirement or not. It was carried out without microcontroller to protect the microcontroller from damage by any excessive voltage and possible heat [17]. In this study, a multi meter was used to carry out this test.

2.2.6.3 Performance Evaluation Test

The performance evaluation was carried out to ascertain the functionality of the constructed device. This was carried out to test the working condition of the relay/motor for various soil moisture conditions. The device was tested when there was presence of water in the soil and when the soil was in dry state.

3. RESULTS

3.1 Simulation Results

The simulation was carried out in stages according to the block diagram in Figure 1 and the results are presented in Figures 9 to 11.

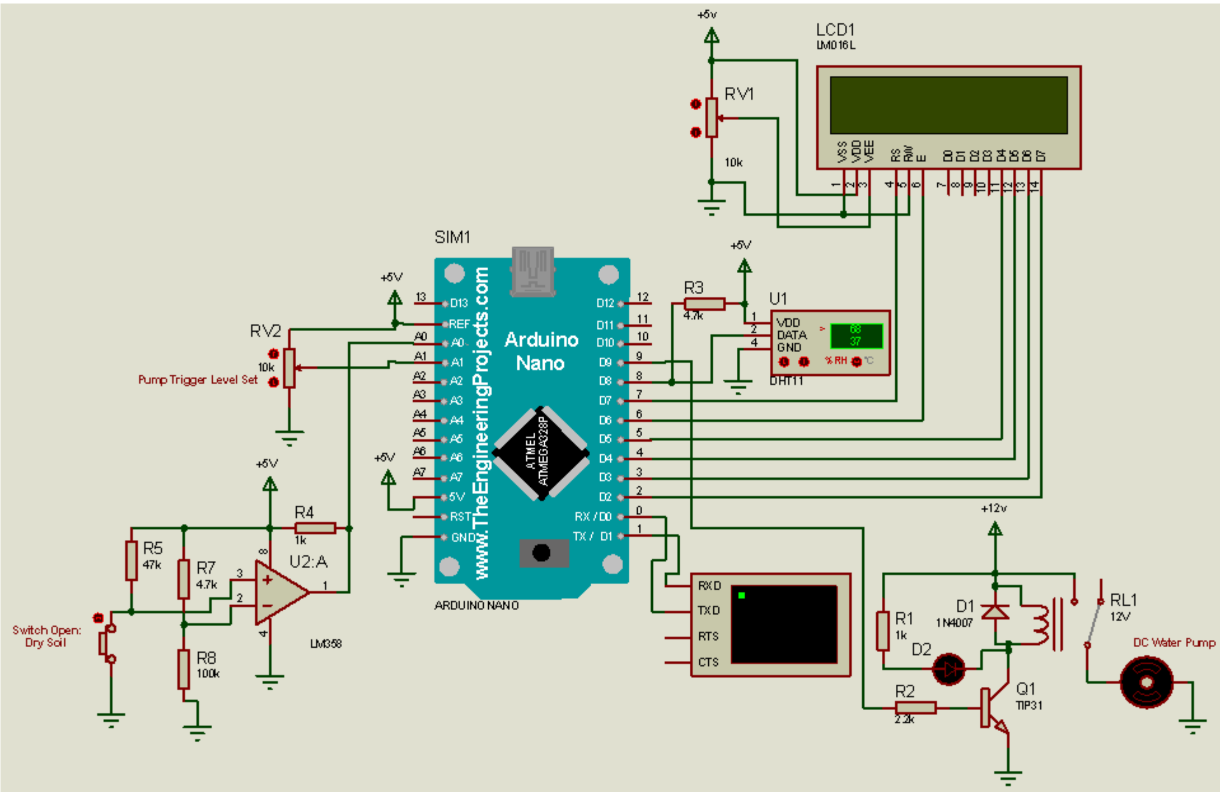

Fig. 9: Simulated result general circuit idle state initializing

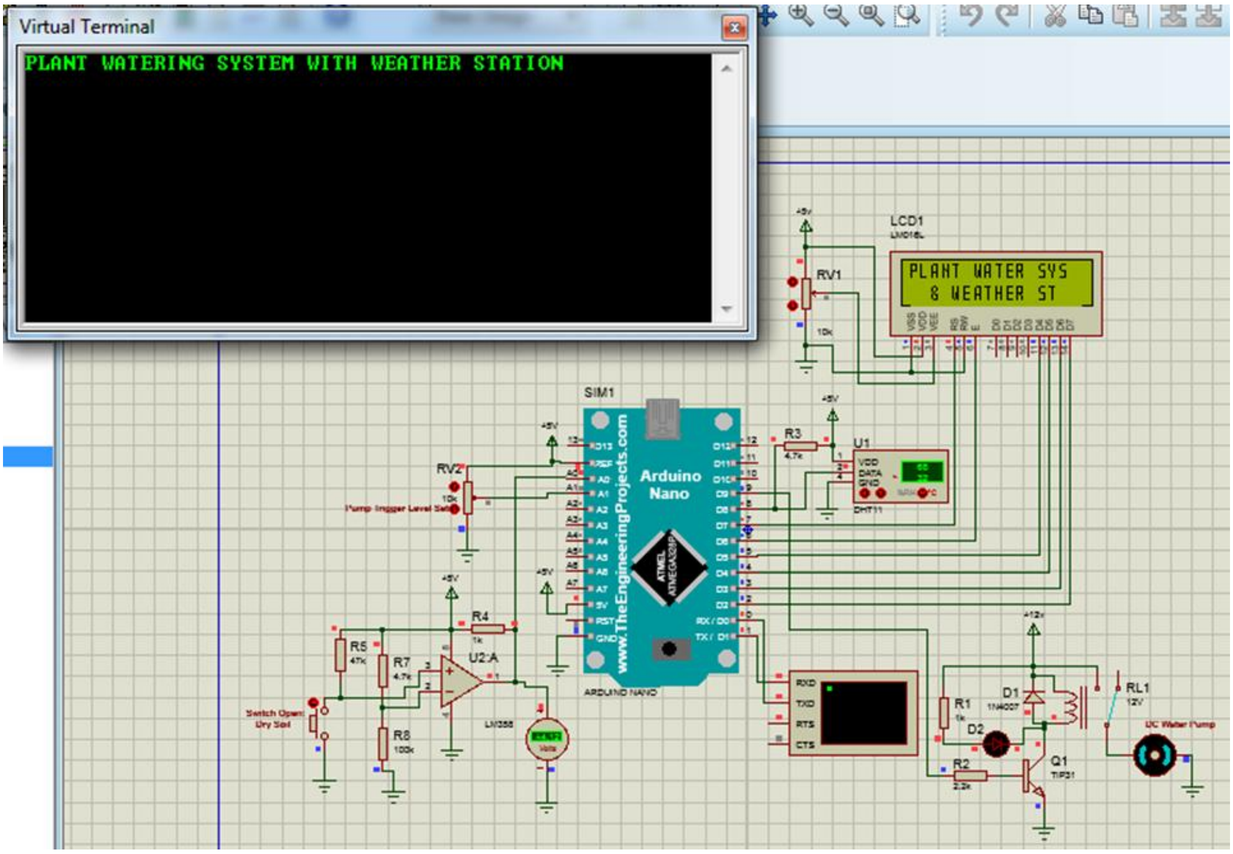

Fig 10: Pumping state with virtual terminal display

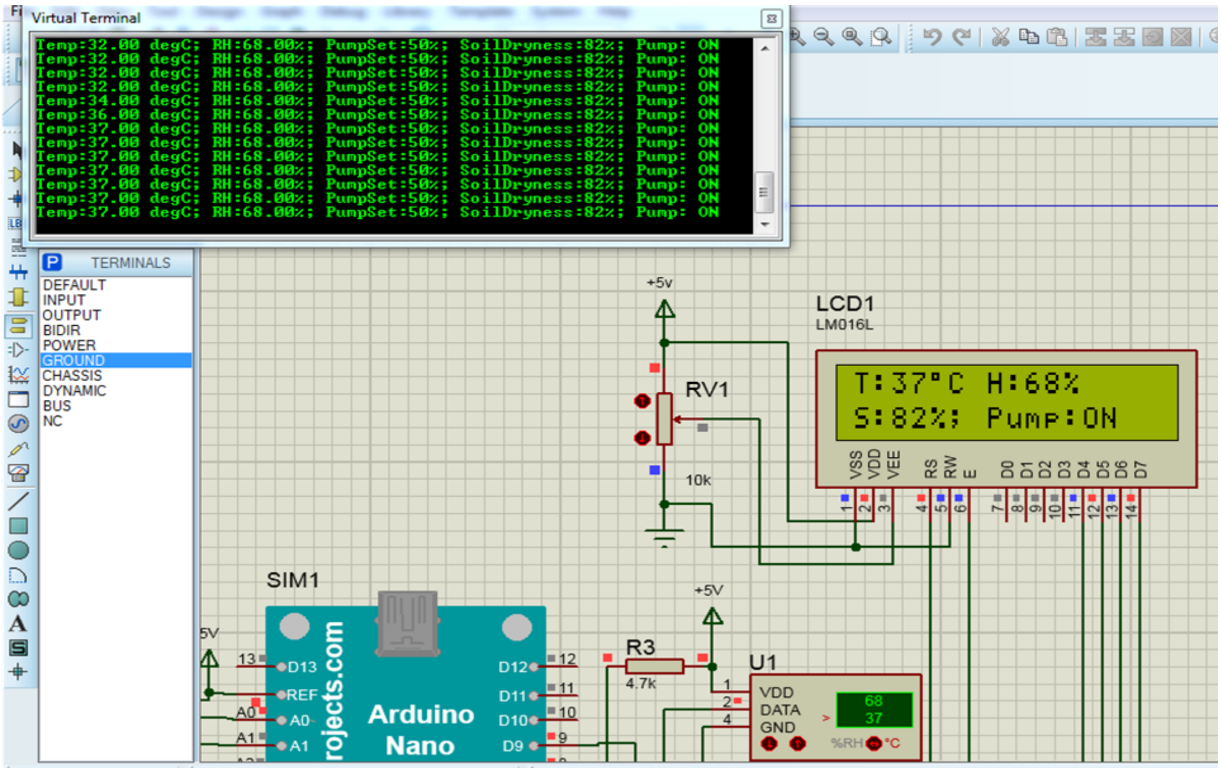

Fig 11: Pumping state with weather condition

Figure 9 presents the simulated result of the general circuit of the automatic plant water sprinkler with weather monitoring system showing the idle state when the system is initializing.

Figures 10 presents the simulated result of the behavior of the circuit at pumping state showing virtual terminal display. The system after initializing displays "Plant waterer system with weather station". Figure 11 presents the simulated result of the circuit pumping state displaying weather condition which includes relative humidity, temperature, soil moisture content, and the pump status (H: 68%, T: 37°C, S: 82% and Pump: ON).

3.2 Hardware Construction

3.2.1 Circuit Construction

The construction was carried out first on a bread board to ensure that the circuit is working as required, then transferred to the Vero board for permanent soldering. The microcontroller and the Arduino Uno exists as a component while the soil moisture sensor, The DHT1 (temperature/humidity) sensor, the LCD, the relay/motor driver unit and every other component in the system were interfaced with the microcontroller and Arduino board. The shunt and limiting resistors were also connected to limit and control the flow of current to the input terminals of each component. The constructed circuit showing the top view of the device on Vero board is shown in Figure 12.

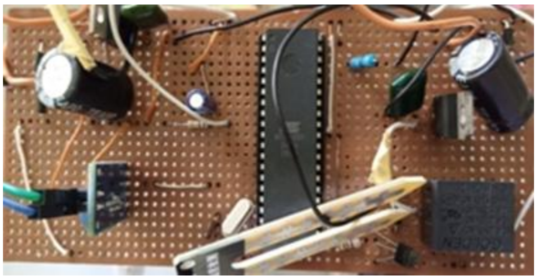

Fig 12: Constructed device on Vero board

3.2.2 Casing and Packaging

The constructed device was packaged in a casing measuring 15cm x 15cm x 3cm provided to the system for mechanical protection. It is provided with 8 numbers of 1cm diameter hole (4 each at front and back side), out of which 6 are for ventilation and 2 for input and output pipe respectively. It is provided with a 1cm x 3cm opening for LCD. It is also provided with 4 numbers 4 of 0.25cm diameter hole within 0.5cm diameter groove at the edges of its top side for screw lock. The complete isometric diagram of the casing showing its three views (Front, Side and Top) and the various dimensions is shown in Figure 13, while the complete packaged device with full casing showing its top and side view is shown in Figure 14.

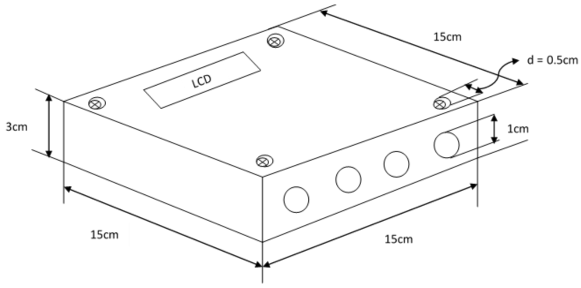

Fig 13: Isometric diagram of the casing

Fig 14: Complete packaged device with full casing

3.3 Analysis and Testing

3.3.1 Continuity Test

In this study, the multi meter was used to perform this test. The multi meter was set at the continuity mode and the two ends of the probe was placed at the ends of a particular wire that was being checked for continuity, if there is a negligible resistance between the ends of the wire or path or the multi meter buzzer sounds then, the ends or path is continuous. Test results shows that the soldering was perfectly done as there were no short circuits along the paths, or broken conductors, damaged components, or excessive resistance along the circuit.

3.3.2 Power ON Test

In this test, the multi meter was put in voltage mode and the output of the transformer was checked for 12V AC. This voltage was then applied to the power supply circuit (without the microcontroller to avoid damage to the controller in case the voltage was above 12V). The power input to the voltage regulator was also checked and ascertained to be 12V input and 5V output. This 5V output was fed to the microcontroller at the 40th pin. The voltages at the other terminals were also checked and ascertained to be as required from the specification in the simulated circuit.

3.3.3 Performance Evaluation Test

To ascertain the functionality of the constructed device a performance evaluation was carried out for various soil moisture conditions i.e. wet and dry soil. However, the number of times the device continues to run or pump until the soil is wet enough for plants i.e. the working condition of the relay/motor for various soil moisture conditions was recorded and presented in Table 1.

Table 1. Operation of relay for various soil moisture conditions

S/N	Voltage Range	Soil Condition	Q	Amplifier Output	Relay Ref. Pin Voltage	Relay 'NO' Contact	Water Pump Operation
1	>5V	Excess Wet	0	1	1	Open	OFF
2	<5V & >3V	Optimally Wet	0	1	1	Open	OFF
		Optimally Dry	1	0	0	Closed	ON
3	<3V	Dry	1	0	0	Closed	ON

4. DISCUSSION

The constructed microcontroller based automatic plant water sprinkler with weather monitor subjected to various test have revealed vital information that ascertain its functionality. The continuity test revealed that the circuit was continue with no short circuits along the paths, or broken conductors, damaged components, or excessive resistance along the circuit and the soldering was well done. While the power ON test showed that, the voltage at the different terminals was according to the requirement and specification of the simulated circuit. This is similar to that of Garnesh [18] who presented an efficient automatic plant irrigation system using ATMega Microcontroller, though he uses GSM for feedback, Alemu et al. [13] who presented a low cost microcontroller-based automated irrigation system for two Ethiopian crops in a dry area, Kumar et al. [11] who presented a microcontroller based automatic plant irrigation system though his work was powered by solar, Bhattacharyya et al. [19] who carried out a design and implementation of automated plant watering system but used a H. bridge motor, Atayero and Alatishe [15] who also designed and Constructed a microcontroller-based automatic irrigation system though his work differs in the type of switch used and Jagdeep and Daljit [8] who implemented a microcontroller based automatic sprinkler irrigation. The present study differs from all the previous studies in the addition of weather monitoring device to monitor the environmental temperature and humidity which is very significant for plant growth and improve yield. This reveals the additional contribution of this work to the existing literature. In the short period over which this system has been tested, virtually no human intervention was required. The user must only verify that the system is operational with constant supply of power and that the water tank is not empty. On the other hand, there is no way to inform the user of emergencies such as overflow, empty tank, component failure, etc. Further testing should be done in an environment with a sprinkler to assess the reliability and durability of the system. These tests should also be prolonged to determine the significance of the savings in water and labor. Different plants have different water requirements and are unequally resistant to deficiencies in the water supply. All the components were selected to achieve some degree of power efficiency. Regular maintenance of the irrigation system is not required, except to refill the water tank (if used), to clean the pipes and valve, and to replace parts when broken; if used on a large scale. Most replacement components can be found in an electronic shop or a hardware store.

5. CONCLUSION

The microcontroller based automatic plant water sprinkler with weather monitoring system has been simulated and tested successfully and it function automatically. It has been developed by integrated features of all the hardware components used. Presence of every section has been reasoned out and placed carefully, thus contributing to the best working of the system. The moisture sensors measured the moisture level (water content) of the soil for different soil. If the moisture level is found to be below the desired level, the moisture sensor sends the signal to the Microcontroller, which triggers the Water Pump to turn ON and supply the water to the plant using the Rotating Platform/Sprinkler. When the desired moisture level is reached, the system halts on automatically and the Water Pump is turned OFF. The entire system will act as a crop, garden and farm insurance system, as it will protect the crops by shielding it from untimely rain, hail stones, and temperature, thereby helping the farmers to get optimum cultivation. Also, it will help to make proper use of water, as the soil moisture level differs from crops to crops and this will be taken care of by the soil moisture sensor.

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