Automated Irrigation System (Water & Herbicide) Interfaced With GSM Remote Monitoring System

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Abstract-In view of increased agricultural production targeted at national and global food security, it is necessary to increase the overall efficiency of irrigated agriculture through optimized automated systems. Uncertainty in climatic condition is of key concern to farmers all over the world, since the availability and cost of irrigation water is likely to be compounded by increased regulations and competition. Given the increasing competition of limited resources for farmland irrigation, it is necessary to initiate measures to adapt to these changing conditions. This work is aimed at automating a sprinkler irrigation system and also to optimize the use of water by providing information about storage water level and soil moisture condition using GSM technology. The method employed is to continuously monitor the soil moisture level to decide whether irrigation is needed, and how much water is needed in the soil. A pumping mechanism is used to deliver the needed amount of water to the soil and the water level is also monitored and sent to the farmer through a GSM device which would inform the farmer when to refill the water reservoir.

Keywords: Automatic Irrigation, Soil moisture sensors, GSM, SMS, Arduino, microcontroller.

1.0 Introduction

Water is a precious natural resource, a prime national asset and one of the basic requirements for human existence. The use of water by plants and animals are universal, without it the existence of life will be futile. Man and animal not only consume water but also consume vegetation for their food. Vegetation in turn cannot grow without water. Growth of vegetation also depends upon bacterial action while bacterial need water in order to thrive. The bacterial action can convert vegetation matter into productive soil. New plants, which grow in this soil grows by sucking nutrients through their root system in the form of solution. Thus an ecological chain is maintained. Water maintains an ecological balance in the relationship between living things and environment in which they live [1]. Similarly, the plants with the aid of water utilize the decomposed dead animals and man for its manure.

There are competing demands of water, for irrigation, industrial production, domestic water supply, hydro-power generation and environmental requirements of water for transport, recreation and fresh water fisheries also require adequate provision for water. The extent to which water is plentiful or scarce, clean or polluted, beneficial or destructive, profoundly influence the extent and quality of human life. The relentless increase in human population and resulting spurt in the demand for water require careful planning and management of limited water resources. Also, the presence of weed in the farm is also a factor that can hinder the proper growth of plants by competing with the plants for available nutrients; hence adequate measure is required to eradicate the presence of weed in the farmland, in order to boost production and reduce water and nutrient competition.

Increasing demands for water, limited availability, and concerns about water quality, make effective use of water essential [2]. This effective use of water becomes imperative as irrigation is a major water user. High amount of the world's finite water resources are wasted through irrigation.

The use of automated control system and digital technology has become rampant as their application cuts across all aspects of human endeavor which ranges from industrial control system, robotics, weather forecasting, military, ease of enhancement and programming modification. Also there is an increase in the ease at which complex control systems are handled and controlled. This work is aimed at providing a microcontroller based automatic sprinkler system capable of applying water and herbicide automatically when required and also to provide information on storage water level and soil moisture condition to the farmer via SMS (Short Messaging System).

2.0 Review of Related Works

Irrigation is the artificial application of water to the land or soil. It is used to assist in the growing of agricultural crops, maintenance of landscapes, and re-vegetation of disturbed soils in dry areas and during periods of inadequate rainfall. Additionally, irrigation also has a few other uses in crop production, which include protecting plants against frost [3], suppressing weed growing in grain fields [4] and helping in preventing soil consolidation [5]. Water used for irrigation could be sourced from rivers, groundwater, inundation canals, tanks, wells, rain water harvest etc. There are several types of irrigation. Various types of irrigation techniques differ in how the water obtained from the source is distributed within the field. In general, the goal is to supply the entire field uniformly with water, so that each plant has the amount of water it needs, neither too much nor too little. The modern methods are efficient enough to achieve this goal, they include:

- Surface irrigation: water moves over and across the land by simple gravity flow in order to wet it and to infiltrate into the soil. Water is applied directly to the soil surface from a channel located at the upper reach of the soil [6]
- Sub-irrigation: This is the application of water below the soil surface by maintaining a water table that allows water to move up through the root zone by capillary action.
- Sprinkler irrigation: water is piped to one or more central locations within the field and distributed by overhead high-pressure sprinklers or guns.
- Drip Irrigation: This method minimizes the use of water and fertilizer by allowing water to drip slowly to the roots of plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing, and emitters [7]. This method can be the most water-efficient method of irrigation [8] if managed properly, since evaporation and runoff are minimized.

An intelligent automatic irrigation system should have all the components that autonomously monitor and control the level of water available to the plants without any failure or human intervention [9]. Drip irrigation was employed by [10], the circuit comprises of sensor parts built using op-amp IC LM324.The Op-amps are configured here as a comparator. Two stiff copper wires are inserted in the soil to sense the whether the Soil is wet or dry. The voltages from the copper plates are fed to a comparator operational amplifier LM324 to compare with a reference voltage. The result can either give a logic output of false (logic zero "0" i.e. 0v) or true (logic one "1" or 5v) depending upon the copper sensing voltages from the conductivity in the earth due to the presence or absence of enough water in that location. A Microcontroller was used to control the whole system, it monitors the sensors and when more than two sensors connected to the system sense the dry condition of the farm land, then the microcontroller will switch on the motor to enable the irrigation of the land and it will switch off the motor when all the sensors are wet. The important parameters [11] measured for automation of irrigation system are soil moisture and temperature. The entire field is first divided into small sections such that each section should contain one moisture sensor and a temperature sensor. RTD like PT100 is used as the temperature sensor while Densitometer is used as the moisture sensor to detect moisture contents of soil. These sensors are buried in the ground at required depth. Once the soil has reached desired moisture level the sensors send a signal to the micro controller to turn off the relays, which control the valves. The signal sent by the sensor is boosted unto the required level by corresponding amplifier stages. Then the amplified signal is fed to A/D converters of desired resolution to obtain digital form of sensed input for microcontroller use. A 16X1 line LCD module is used in the system to monitor current readings of all the sensors and the current status of respective valves. The solenoid valves are controlled by microcontroller though relays. A Chemical injection unit is used to mix required amount of fertilizers, pesticides, and nutrients with water, whenever required. A flow meter is attached for analysis of total water consumed. The microcontroller unit has in-built timer in it, which operates parallel to sensor system. In case of sensor failure the timer turns off the valves after a threshold level of time, which may prevent the further disaster. The microcontroller unit may warn the pump failure or insufficient amount of water input with the help of flow meter.

The work by [12] presents a GSM based irrigation control system, which helps in maintaining environmental conditions uniformly. For this purpose an android phone is used. In this system the connection between two mobiles are done using GSM. The microcontroller and GSM module are connected using MAX232. The moisture sensor is used to sense the moisture of the soil; if the moisture of the soil becomes low then it gives signal to microcontroller. The microcontroller sends this signal to a mobile phone then the remote mobile phone activates the buzzer simply by pressing a button in the remote phone and the signal is sent back to microcontroller. The microcontroller sends this signal to valves which causes it to get open. After certain interval moisture content of the soil increases then the valve is turned off automatically. The power supply +5V are required for controlling system.

3.0 Proposed System

The proposed system comprises of a water and herbicide reservoir where water and herbicide are stored. A microcontroller acts as the central control unit that controls the whole activity of the system. The humidity sensor detects the presence of water in the soil. Temperature sensor is used to detect the environmental temperature. The buzzer sounds an alarm to alert when it is time for herbicide to be applied to the farm. An AC-pump helps to draw out water and liquid herbicide from the reservoir to the sprinkler system and the sprinkler sprays the liquids on the farm.

When the system is turned on, it checks if it is time for herbicide to be sprinkled, if yes, it triggers the buzzer to blow an alarm that signifies that it is time to sprinkle herbicide, it also triggers the electric motor to pump herbicide to the sprinkler so that herbicide will be sprinkled, then the LCD displays 'herbicide sprinkling', this will sprinkle the quantity of herbicide required and stops after sprinkling that stipulated quantity. If No, then it goes further to check the humidity and temperature condition of the soil using the humidity and temperature sensor and displays it on the LCD. If there is 'Normal' temperature and 'Low' humidity of the soil, it triggers the pump to pump water to the sprinkler so that water will be sprinkled, the LCD displays 'water pumping', then sprinkler sprinkles water on the farm until the humidity sensor sends 'logical low' signal that the humidity of the soil is 'normal' and the pump stops. There would be no sprinkling of any substance when the temperature is 'high'. This is because sprinkling of any liquid substance on plants on a sunny day can lead to death of the plant. Similarly at 'low' temperature it would not spray irrespective of the humidity sensor reading because a low temperature signifies a humid environment and hence the presence of water in the air. When the tank is empty an SMS is sent to the farmer indicating that the water reservoir is empty. The farmer sends an SMS that triggers the pump to refill the tank.

4.0 System design / components

a) **Power Supply Unit:** This consists of a 15V step down transformer which steps down the 220V AC to 15VAC. 15V is used here because the project sections require 12V for driving the relay and 5v for driving the entire digital circuit. 12V output voltage was chosen because that is the value for a standard step down transformer and it is meant to be higher than the 5V voltage regulator due to the fact that voltage regulator cuts one volt while it is stepping down. The circuit was designed using the following equations;

$$V_b = 2V_{dd} \quad (1)$$

$$V_{sp} = \sqrt{2}\,V_s \quad (2)$$

$$V_m = V_{sp} - V_b \quad (3)$$

$$V_{ac} = \frac{2}{\pi} \times \mathrm{V_m} \quad (4)$$

$$\mathrm{V_{dc}} = \frac{\mathrm{V_m}}{1.414} \quad (5)$$

$$\gamma = \frac{\sqrt{V_{dc}{}^2 - V_{ac}{}^2}}{V_{dc}} \quad (6)$$

Where:

V_{dd} = Diode forward conduction voltage drop = 0.7v

V_b = Voltage drop across the diode bridge at any instant = $2 \times 0.7 = 1.4v$

V_s = Transformer secondary voltage = 15v

V_{sp} = Peak value of transformer secondary voltage = $1.414 \times 15 = 21.21v$

V_m = Peak output dc voltage from the diode bridge = 21.21 – 1.4 = 19.81v

V_{ac} = average value of the diode bridge output voltage = $\frac{2}{\pi} \times 19.81 = 12.611$v

V_{dd} = rms value of output dc voltage of the diode bridge = $\frac{19.81}{1.414} = 14.01$v

γ = ripple factor for full wave rectification process using a diode bridge is given by

$$\frac{\sqrt{14.01^2 - 12.611^2}}{14.01} = 0.48$$

The ripple in the output voltage is directly proportional to the output current and is related to the filtering capacitance by the following equations:

$$C = \frac{I}{2 \times f \times \mathrm{V_r}} \quad (7)$$

Where:

V_r = ripple voltage = $\gamma \times \mathrm{V_{sp}} = 0.48 \times 21.21 = 10.1808$v

C = capacitance value

I = required output current from power supply circuit = 2.5A

f = frequency of the ac mains supply voltage = 50Hz

$$C = \frac{I}{2 \times f \times \mathrm{V_r}} = \frac{2.5}{2 \times 50 \times 10.1808}$$
$$= 2456\mu f$$

The closest available capacitor value to this is the 2200μf capacitor which is still acceptable as it will further reduce the ripple in the output voltage.

A 12 V regulator, LM7812 is used to regulate the output due to its capability to limit the current in order to prevent excessive current and also reduce the amount of power lost as heat in the circuit. Also, 0.1μF noise filter capacitors are used to ground the external or environmental noise voltages that the circuit may pick up. This ensures that the circuit produces an almost pure dc voltage of 12 volts.

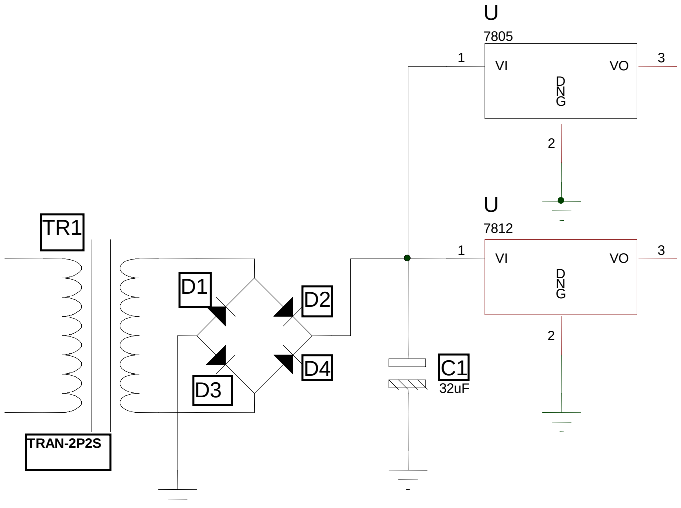

Figure 1 DC Power Supply.

b) Humidity Sensor: This is made by molding gypsum around two metal probes. As the gypsum gets wet (i.e. as humidity increases), the resistance between the two probes drops and vice versa.

$$V_0 = 5v\left(\frac{R_b}{R_h + R_a + R_b}\right)$$

Where 5v = input voltage.

R_h = Resistance of the Humidity Sensor.

$R_a + R_b = 50k\Omega$ (Variable resistor).

c) Temperature sensor: An LM35 temperature sensor calibrated in degree Celsius is used. 1°C rise in temperature results in 1mV rise in its output.

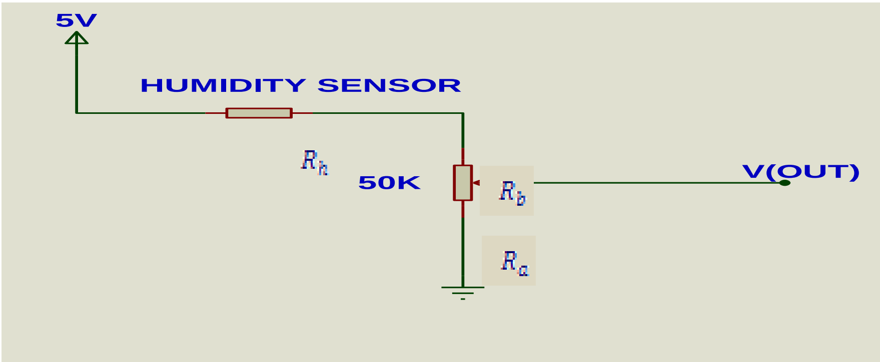

Figure 2 Circuit diagram of humidity sensor.

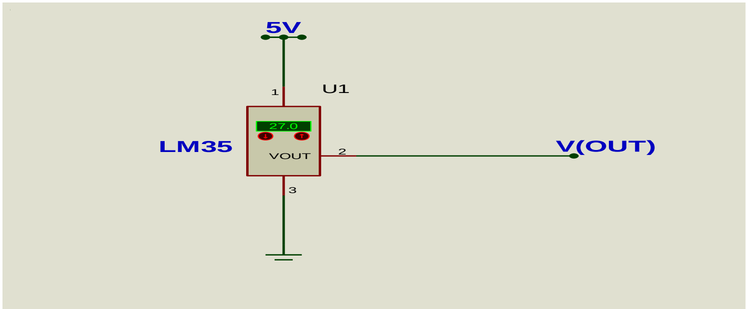

Figure 3 Schematic capture of temperature sensor circuit.

d) **Comparators:** LM358 which contains two comparators in one package is used because two elements (humidity and temperature) are being considered in the project.

i. **Comparator 1 for Humidity sensor**: This compares the voltage output from the humidity sensor with a set reference voltage of the zener diode which is 2.4V. The Zener diode was used because it provides a constant voltage and acts as a voltage cutoff. The value was made to be at most half of the input voltage so that any variation will be significant. Once the voltage output of the sensor exceeds that of the reference voltage, the output voltage of the comparator becomes 'logically high' signaling normal humidity to the controller. And when the reference voltage exceeds the output voltage from the humidity sensor, it sends a 'logical low' signal to show low humidity.

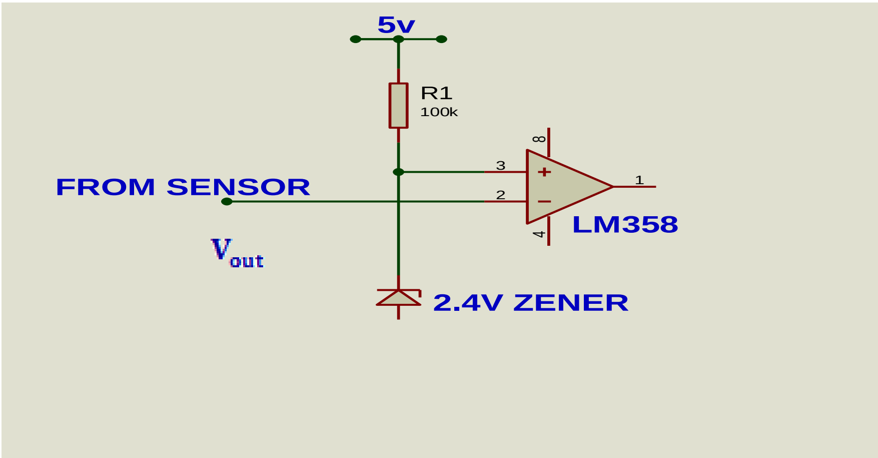

Figure 4 Schematic capture of humidity sensor comparator circuit.

ii. **Comparator 2 for the temperature sensor**: This compares the voltage output from the temperature sensor with a set reference voltage of 2.4V. If the output voltage from the temperature sensor exceeds the set reference voltage (it sends a 'logical low' signal i.e. 0), it signals no sprinkling. If the set reference voltage exceeds the output voltage, (it sends a logical high signal i.e. 1) shows 'normal temperature'.

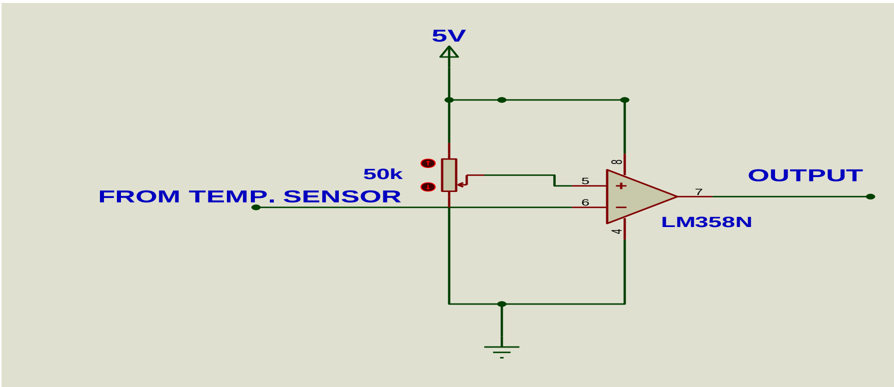

Figure 5 Schematic capture of temperature sensor comparator circuit.

e) **Alarm:** This alarm is used to indicate that it is time for the herbicide to be sprinkled. The alarm is used to indicate this period because the herbicide is to be sprinkled at a stipulated time depending on the crop being considered, it is not sprinkled always because of the harm excess of it can cause to the crop.

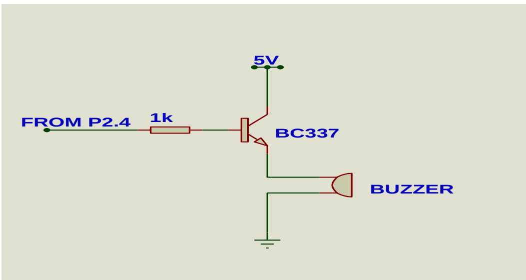

Figure 6 Schematic capture of alarm unit circuit.

f) **Display:** This is made up of 16 × 2 LCD display. It is used in this system to monitor current status of the sensors (whether high or low) and the current activity taking place or about to take place in the system.

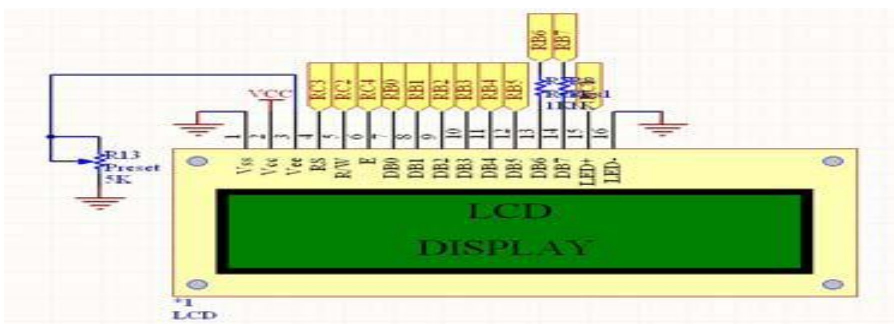

Figure 7 The LCD display unit.

g) **Pump:** This consists of the AC 0.5hp electric motor (pump), the relay and transistor circuitry. The transistor circuitry is used to activate or deactivate the pump while the relay is used to switch on or off the pump for interfacing the pump and the transistor since the output of the transistor cannot operate an AC pump. The diode prevents flow back of voltage from the inductor to the transistor immediately supply of voltage is cut off from the base.

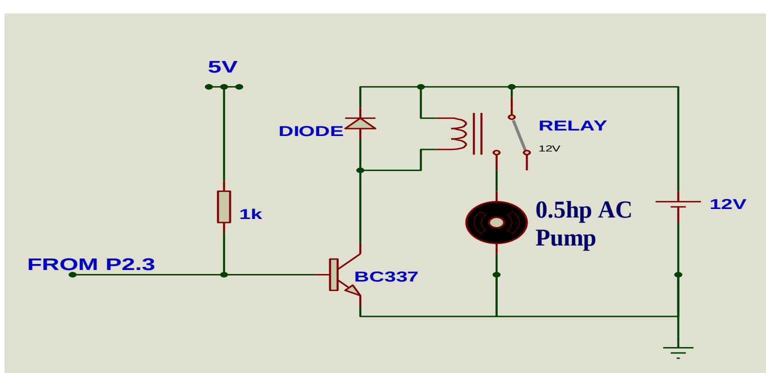

Figure 8 Schematic representation of electric motor circuit.

h) Controller: The controller is based on Arduino Uno which is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board.

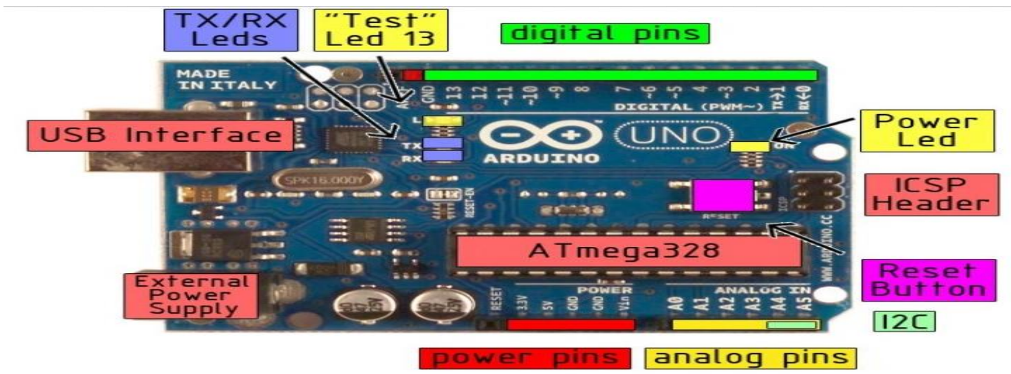

Figure 9 Block diagram of the Arduino Board

i) The Arduino GSM Shield/Module

The Arduino GSM Shield is used to enable the Arduino board to make/receive voice calls and send/receive SMS messages as well as connect to the internet. It is a Quad-band GSM/GPRS modem that works at frequencies GSM850MHz, GSM900MHz, DCS1800MHz and PCS1900MHz. AT commands are used to initiate communication with the board.

Figure 10 Pin Outs of The Arduino GSM Shield

The shield uses digital pins 2 and 3 for software serial communication as it is equipped with standard communication interfaces like RS-232 (Serial Port), USB etc. The power supply circuit is also built into the module and can be activated using a suitable adaptor. The GSM modem requires a SIM card from a wireless carrier in order to operate.

j) Water Level Sensing Unit: The water level sensing unit consists of a resistor ladder circuit R1, R2, R3, R4,R5, and R6 of 47k each, and six inverters(74HC04 NOR gates) connected as shown in fig 11. When there is no water at the various levels (10 liters, 8 liters, 6 liters, 4 liters and 2 liters), the input to the inverter is low, and therefore, a high is produced at the output.

Whenever the outputs of the five inverters connected to the tank are high, and the sixth connected to the well is high as well, it indicates that there is water in the well and the tank is empty, and an SMS is sent to the farmer indicating that the water reservoir is empty. The farmer sends an SMS that triggers the pump to refill the tank. Water is pumped into the tank until it gets to the brim level, in which case, the outputs of five inverters connected to the tank are low, indicating the tank is full, hence, the pump is switched off automatically by the microcontroller.

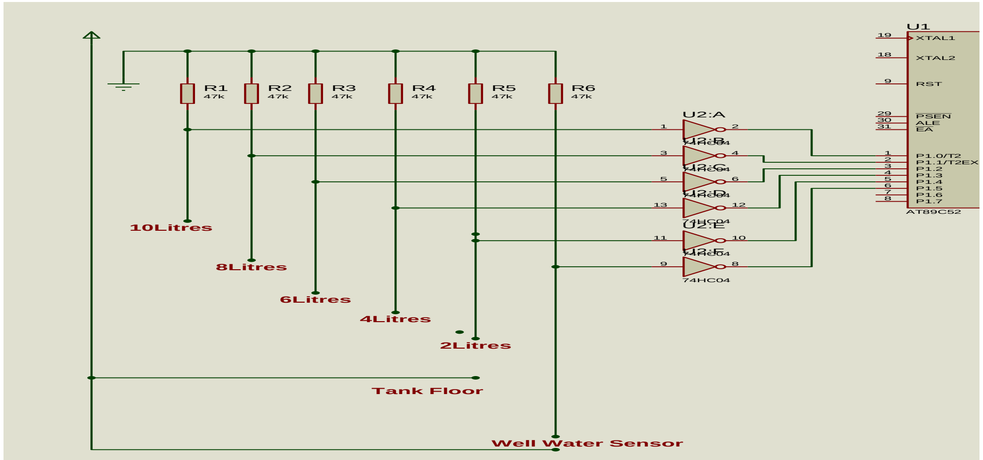

Figure 11 Water Level Sensing Unit

k) Mobile User: The mobile user is simply any GSM mobile phone owned by the farmer that is able to send and receive an SMS. Control signals are sent by the microcontroller which instructs the GSM Module to send an SMS remotely over the GSM network to the GSM Mobile phone which receives the message sent to it. This provides the farmer on information about the water level.

5.0 System Testing and Result

After the execution of the work the system was subjected to different tests to ascertain if the system is working according to specification. The tests and the results obtained are shown and analyzed in this section.

I. **Saturation test:** The purpose of this test carried out on the humidity sensor is to derive the relationship between the quantity of liquid present in the soil and resistance values obtained from the sensor. The graphical representation of the result is as shown in Fig. 12:

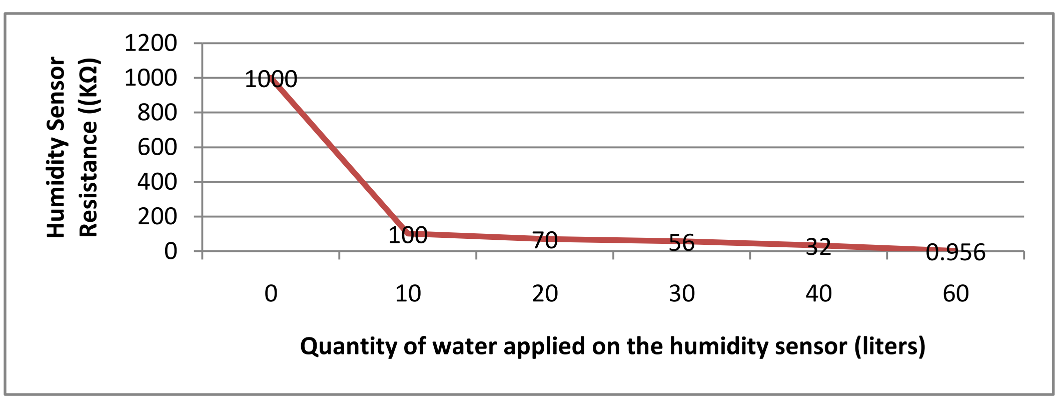

Figure 12 Graph of humidity sensor resistance against the quantity of water applied on the gypsum.

From the graph, it could be deduced that the 'Resistance of the humidity sensor varies inversely to the quantity of water applied'.

II. **Flow rate test:** A test was also carried out on the flow rate of the pump; in order to know the time it takes for the sprinkler to apply a certain quantity of herbicide on the farm. The aim of this experiment is, since different crops have different quantity of herbicides they require, this information will therefore help the farmer to deduce the quantity of herbicide in order to avoid sprinkling excess that will harm the plants. Also this information will help the farmer to know the programming time to set for herbicide sprinkling for a required quantity of herbicide. It was observed that 15litres of herbicide was sprinkled in 60seconds. With this the data shown in Table 1 was deduced.

Table 1 Quantity of Herbicide and Time Taken to Sprinkle

Quantity of herbicide (litres)	Time taken (minutes)
15	1
75	5
150	10
225	15
300	20
375	25

It was deduced from Table 1.0 that more herbicides is sprinkled with more time. The time gotten here can be used to program the microcontroller on how long to spray the herbicide knowing the relationship between time and the quantity of herbicides expelled.

Figure 13: Image of the completed work

6.0 Conclusion

The need for efficient utilization of water which is one of the major elements required for plant growth and also proper application of herbicides as at when due so as to reduce competition between the plants and weed is of utmost importance. Improving Irrigation efficiency can contribute greatly to reducing production costs of agricultural products, thereby making the industry more competitive and sustainable. This system when installed in a farm has the ability to sense the temperature and humidity condition of the soil and automatically irrigate the farmland as well as sprinkle herbicide on the farm depending on the value obtained from the sensor and on the microcontroller's decision. This system helps to eliminate the stress of manual irrigation at the same time conserving the available water supply. This system is cost effective and user friendly and serves as a great improvement over other conventional monitoring and alert systems.

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