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# DESIGN AND IMPLEMENTATION OF AN AUTOMATIC IRRIGATION SYSTEM BASED ON MONITORING SOIL MOISTURE.

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***Abstract:*** *An automatic irrigation control system has been designed to facilitate the automatic supply of adequate of water from a reservoir to field or domestic crops in all agricultural seasons. One of the objectives of this work is to see how human control could be removed from irrigation and also to optimize the use of water in the process. 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. The work can be grouped into four subsystems namely; power supply, sensing unit, control unit and pumping subsystems which make up the automatic irrigation control system. A moisture sensor was constructed to model the electrical resistance of the soil; a regulated 12 volts power supply unit was constructed to power the system; the control circuit was implemented using operational amplifier and timer; and the pumping subsystem consisting of a submersible low-noise micro water pump was constructed using a small dc-operated motor. System response tests were carried out to determine the time taken for the system to irrigate potted samples of different soil types having different levels of dryness. The results obtained showed that sandy soils require less water than loamy soils and clay soils require the most water for irrigation.*

***Keywords***: *Automation, irrigation, control, pumping, soil moisture*

## 1. Introduction

Micro Irrigation, According to [1] is an artificial supplying of water to the root of plant. Irrigation has been 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. In crop production, irrigation helps in protecting plants against frost, suppressing weed growth in grain fields and preventing soil consolidation. Irrigation systems are also used for dust suppression, disposal of sewage, and in mining. The old method used for irrigation was the use of watering cans, water channels that have to be opened and closed manually or backpack sprinklers. In this case, a lot of water is wasted in the process [2]. There is need for improvement on the existing or old forms of irrigation. An automated irrigation system needs to be developed to optimize water use for agricultural crops [3]. An intelligent automatic irrigation system has to have all the components that autonomously monitor and control the level of water available to the plants without any failure or human intervention [4]. The intelligent system should perform the following functions:

1. continuously monitor the amount of soil water available to plants (this is usually achieved using a sensing system).
2. determine if watering is required for the plants based on the information obtained from monitoring the soil water content.
3. supply exact (or approximate) amount of water required for the plants. This will be enhanced by how well it achieves requirement 1.
4. discontinue the water supply when the required amount has been delivered to the plants. This feature is important as the amount of water available for the irrigation system is not infinite, therefore water management is paramount.

The advantages of automatic irrigation to the plants include saving money, water, conservation of labour and overall convenience [5, 6, 7, and 8]. The water supply needed by the system to perform its irrigation function can be from any source, i.e. well, river, stream, pond, lagoon, etc. However, it is most desirable if a constant source of water is available to the system in order to ensure continuity of operation. The most preferred arrangement will be a water reservoir which is constantly maintained at full capacity or a large source of fresh water which remains continually available irrespective of variations in weather or climatic conditions.

There are about four categories of methods, according to [9], proposed for scheduling irrigation effectively:

- Entirely empirical method and without any kind of on-going measurement
- Method based on monitoring soil moisture
- Method based on estimates of water use from weather data, and
- Method based on tracking the condition of the crop usually referred to as crop water stress.

The method of monitoring the soil moisture is employed in this project work. By this method, the amount of water applied to the agricultural products is minimized and it reduces crop production cost. Irrigation methods, according to [10, 11] are based on the following; the experience of the farmer, the soil properties and environmental conditions. A better way to monitor the environmental conditions and effective use of water to avoid wastage is by the use of sensor network.

## 2. Methodology

The automatic irrigation system was designed to continuously sense the moisture level of the soil. The system responds appropriately by watering the soil with the exact required amount of water and then shuts down the water supply when the required level of soil moisture is achieved. The reference level of soil moisture content was made to be adjustable for the three most common soil samples (sandy, loamy and clayey soils – the samples used for this project were taken from around the Covenant University EIE building, Nigeria). Also the amount of irrigation, i.e. the volume of water delivered to the soil, will be adjustable by the system operator (mild, nominal and high levels). The block diagram of the system developed is shown in figure 2.1

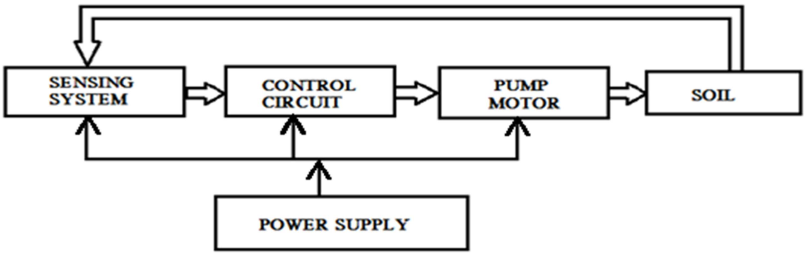

Figure 2.1: The system block diagram

The moisture sensors were designed using probes made from corrosion-resistant material which can be stuck into soil sample. Voltage levels corresponding to the wet and dry states of the soil sample were computed by measuring the resistance between the moisture detector probes and matching them to output voltages of a comparator circuit. A submersible low-noise micro water pump was developed to deliver the water to the appropriate parts of the soil (the base of the plants). The volume of water required for irrigation per time was computed by considering the capacity of the water pump and the water channels. The required irrigation time was determined by considering the response time of the water pump and the water volume required per irrigation instance. A timing circuit was designed to use the required irrigation time to control the duration of each irrigation instance. Simulations were done using Proteus™ circuit simulation software.

Circuit construction was done on a Vero board.

## 3. System design / components

### 3.1 The power supply circuit

A step-down transformer with turns ratio of 16:1 was selected to transform the 240V mains supply voltage to 15V for the power supply. The 15 V ac was converted to dc voltage using a full wave rectifier circuit. The circuit was designed as follows:

$V_{dd}$ = diode forward conduction voltage drop
$V_b$ = voltage drop across the diode bridge at any instant
$V_s$ = transformer secondary voltage
$V_{s_p}$ = peak value of transformer secondary voltage
$V_m$ = peak output dc voltage from the diode bridge
$V_{ac}$ = average value of the diode bridge output voltage
$V_{dc}$ = rms value of output dc voltage of the diode bridge
$\gamma$ = ripple factor for a full wave rectification process using a diode bridge
$V_r$ = ripple voltage

$C$ = capacitance value

$I$ = required output current from power supply circuit

$f$ = frequency of the ac mains supply voltage

$t$ =time taken for filtering capacitor to discharge in compensation for the ripple in the dc output

$q$ =charge on filtering capacitor

$$V_b = 2 \times V_{dd}$$

$$V_{s_p} = 1.414 \times V_s$$

$$V_m = V_{s_p} - V_b$$

$$V_{ac} = \frac{2}{\pi} \times V_m$$

$$V_{dc} = \frac{V_m}{1.414}$$

$$\gamma = \frac{\sqrt{V_{dc}{}^2 - V_{ac}{}^2}}{V_{dc}} \qquad 3.1$$

$$V_{dd} = 0.7\,V$$

$$V_b = 2 \times 0.7 = 1.4\,V$$

$$V_s = 15\,V$$

$$V_{s_p} = 1.414 \times 15 = 21.21\,V$$

$$V_m = 21.21 - 1.4 = 19.81\,V$$

$$V_{ac} = \frac{2}{\pi} \times 19.81 = 12.611\,V$$

$$V_{dc} = \frac{19.81}{1.414} = 14.01\,V$$

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

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

$$q = I \times t = C \times dV_{s_p} \qquad 3.2$$

$$t = 2 \times f$$

$$dV_{s_p} = V_r$$

$$V_r = \gamma \times V_{s_p} \qquad 3.3$$

$$2 \times I \times f = C \times V_r$$

$$C = \frac{I}{2 \times f \times V_r} \qquad 3.4$$

For the power supply to output a current of 2.5A, $I = 2.5\,A$

$$f = 50\,Hz$$

$$V_r = 0.48 \times 21.21 = 10.1808\,V$$

From eqn.(I),

$$C = \frac{I}{2 \times f \times Vr} = \frac{2.5}{2 \times 50 \times 10.1808}$$

$$= 2{,}456\,uF$$

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

A 12 V regulator, $\mu A$7812 to regulate the output is due to its capability to limit the current in order to prevent excessive current and also reduce the amount of power lost as heat in the circuit. 0.1$\mu$F 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.

### 3.2 The sensing circuit

The sensor designed was made up of two conducting metal probes placed in a block of varnished wood. The distance of separation of the probes was 4cm. The probes had conducting wires attached to them at the end above the block.

### 3.3 The pump

A 12 V dc-powered motor was used in designing the pump. The motor was powered from the 12 V dc output from the power supply circuit. The pump was able to supply 250 $cm^3$ of water in 10 seconds. The required irrigation time was calculated as follows:

$P_c$ = Pumping capacity of the pump

$V_p$ = Volume of water pumped

$T_v$ = Time taken to pump $V_p$ in seconds

$V_{irr}$ = Volume of water required for irrigating the soil from dry point

$T_{irr}$ = Required time for irrigation (length time for which the pump must be active)

$$P_c = \frac{V_p}{T_v} \qquad [3.5]$$

$$T_{irr} = \frac{V_{irr}}{P_c} \qquad [3.6]$$

$$V_p = 250\ cm^3$$

$$V_{irr} = 200\ cm^3$$

$$P_c = \frac{250}{10} = 25\ cm^3/s$$

$$T_{irr} = \frac{200}{25} = 8\ s$$

It is with this time $T_{irr}$ in mind that the control subsystem was designed.

### 3.4 The control circuit

One of the most important components of an automatic irrigation system is the irrigation controller also called a timer or clock [12]. A 555 timer was used as the brain of the control circuit due to its operational characteristics in the monostable mode. The timer was used to produce 11.01 V to energize the relay coil, consequently activating the pump motor circuit for about 5 seconds, which is the time needed for irrigation $T_{irr}$. Connected in the monostable mode, the parameters of the 555 timer are as follows:

$V_{cc}$ = supply voltage to the timer = $V_{dc}$

$R_t$ = resistance tying the discharge and threshold pins to $V_{cc}$

$C_t$ = capacitance tying the discharge and threshold pins to ground

$C_1$ = decoupling capacitor for noise voltage filtering. Standard value is 0.1 $\mu$F

The reset pin is tied directly to $V_{cc}$ and the ground pin connected to ground. The output pin is connected to the relay. The values of $R_t$ and $C_t$ are calculated below

$C_t$ = 100 $\mu$F (selected for convenience)

$$T_{irr} = 1.1 \times R_t \times C_t \qquad 3.7$$

$$R_t = \frac{T_{irr}}{1.1 \times C_t} = \frac{8}{1.1 \times 100 \times 10^{-6}} \qquad 3.8$$

$$= 72.8 k\Omega$$

In place of a single resistance value, a potentiometer is used for selecting values of $R_t$. This was done so that $T_{irr}$ may be extended or shortened based on the water requirements of the particular crops or plants on the soil being irrigated.

A normally-open relay was used as the actuator to implement the triggering of the pump-motor circuit. A free-wheeling diode was connected across the relay coil to allow for current dissipation due to stored energy when the relay coil becomes de-energized.

The circuit diagram for the sensing and control circuits in shown in figure 3.1

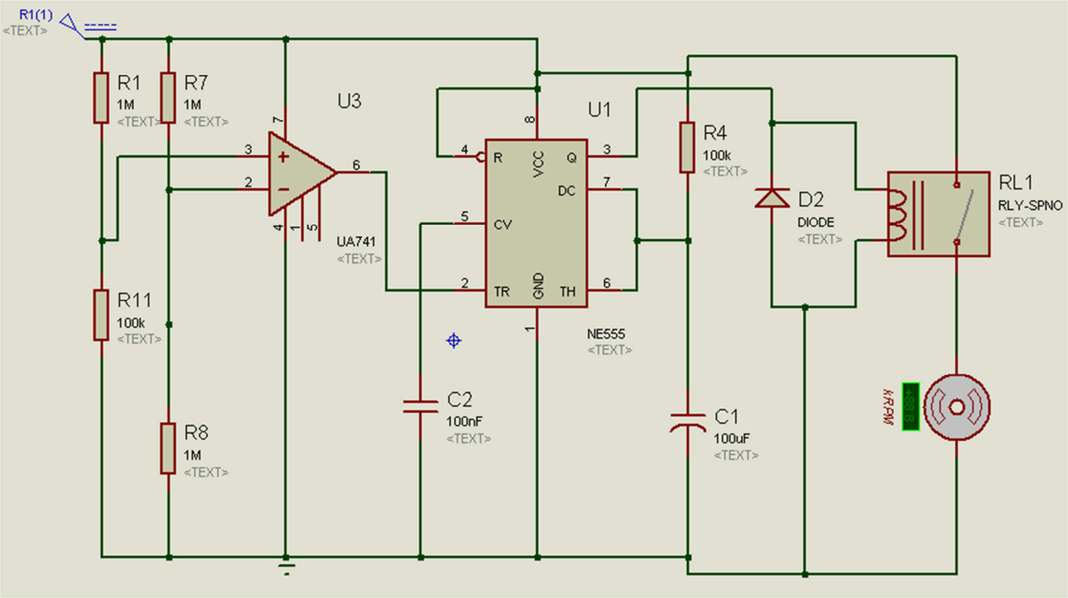

Figure 3.1: The sensing and control circuits

## 4. System construction

### 4.1 The moisture sensor

The sensor was constructed using two cylindrical galvanized metal probes. The probes were slotted firmly into a block of varnished wood with a spacing of four centimeters between them in the wood block. An insulated conducting wire was attached to each probe. The wires were held firmly, beneath the probe heads, to the wood block. A second wood block was then attached using metal studs to the wood block holding the probes in order to ensure absolute firmness of the assembly (i.e. to prevent the probes from popping out of the holding block). The opposite sides of the holding block were also secured together with studs. Cylindrical rubber bungs were attached to the base of the holding block for elevation above the soil surface and also to prevent excessive contact of the wood block with soil moisture. The rubber bungs were also secured to the holding block using metal studs. The whole assembly was seven centimeters long, two and half centimeters wide and eight centimeters in height.

### 4.2 The pump

The pump used was constructed using a miniature dc motor powered by the output of the power supply unit. The mechanical output point of the motor was loaded with miniature bi-directional fan blades and secured firmly using glue. The pumping was achieved by placing the fan blades in an enclosure made from two cylindrical plastic stoppers. The motor was also inserted into a stopper to protect it from contact with water. The electrical connections to the motor were passed through a tight hole in the side of the stopper. The stopper containing the motor was then taped with a water-tight cellophane tape to the pumping enclosure to make the pumping system one single unit. When placed in water (the pump has to be lying horizontally) and connected to the power from the power supply unit, water is taken through the hole at the top of the pump, the blades attached to the rotor spin the water around in the pumping enclosure and the water exits through the pipe attached to the hole at the side of the enclosure.

### 4.3 Circuit implementation

The implementation of the electronic circuitry involved the computerized simulation of the system design, physical simulation of the circuit using a breadboard to ensure proper operation and the final implementation of the circuit on a Vero board.

## 5. System testing and result

The system was tested using different soil samples. Below is a table of the results obtained.

Table 5.1 shows the amount of time the system took to irrigate different soil samples in different initial states. Figure 5.1 is a graphical representation of the result.

**Table 5.1: The results obtained from operational test of the system**

| Soil Sample | Soil Type | Initial soil state (% dryness) | Irrigation time (seconds) |
|---|---|---|---|
| A | Sandy | 100 | 5.0 |
| B | Sandy | 70 | 3.0 |
| C | Sandy | 50 | 1.5 |
| D | Loamy | 100 | 12.0 |
| E | Loamy | 70 | 7.5 |
| F | Loamy | 50 | 2.0 |
| G | Clay | 100 | 15.0 |
| H | Clay | 70 | 8.0 |
| I | Clay | 50 | 2.5 |

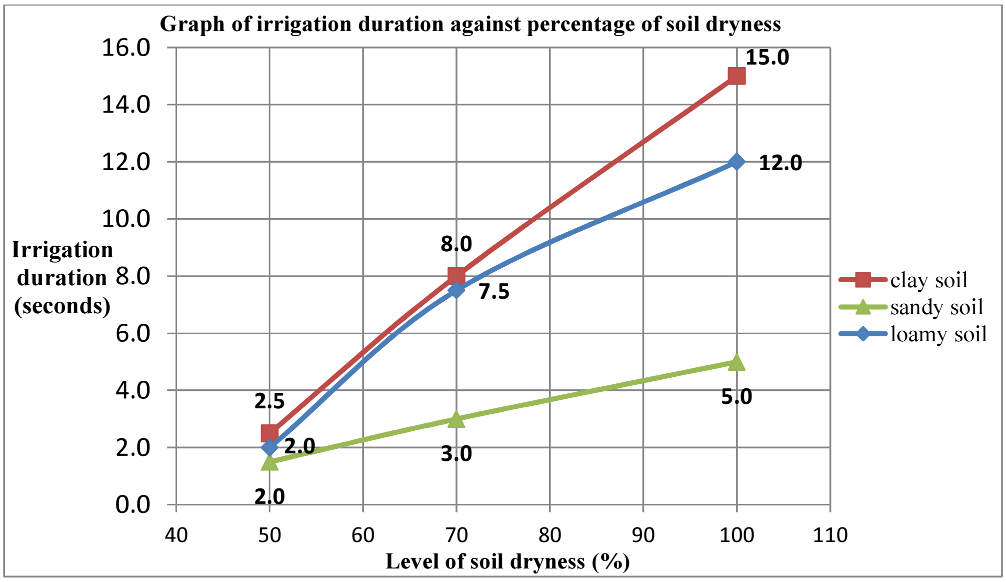

Figure 5.1: Graph of the system's response to soil samples of different conditions

## 6 Result Analysis

It can be seen from the results obtained that the system responded linearly with respect to the degree of dryness for the three soil types. There is a linear relationship between the degree of soil dryness and the time taken to irrigate the soil. At 50% dryness, irrigation durations were 2.0, 2.0 and 2.5 seconds for sandy, loamy and clayey soils respectively. While at 70% dryness, irrigation durations increased to 3.0, 7.5 and 8.0 seconds for sandy, loamy and clayey soils respectively. It is seen that irrigation in loamy soil generally took longer in loamy soil than in sandy soil, and clayey soil irrigation took longest.

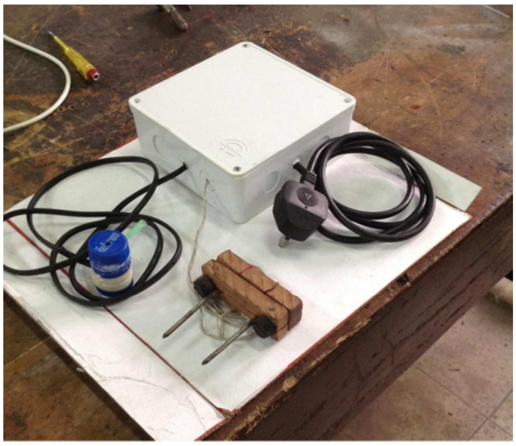

Fig 4: Picture of the complete project assembly

## 7 Conclusion

Automatic irrigation control system has been designed and constructed. The prototype of the system worked according to specification and quite satisfactorily. The system components are readily available, relatively affordable and they operate quite reliably. The system helps to eliminate the stress of manual irrigation and irrigation control while at the same time conserving the available water supply. Improving Irrigation efficiency can contribute greatly to reducing production costs of agricultural products, thereby making the industry to be more competitive and sustainable. The system was tested on three types of soil and from the result analysis sandy soils require less water than loamy soils and clay soils require the most water for irrigation.

For future work on this project, we recommend that for a large scale implementation a more powerful water pump can be used. Also a microcontroller should be used to accommodate more than one sensor input and also control different irrigation regimes independently. A wireless sensor and GPRS(General Packet Radio Service) based automated irrigation system can also be employed, which according to [13, 14], will help monitor the soil moisture and to control the application of water to the agricultural products thereby saving water[15].

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