Design and Construction of a Microcontroller-Based Automatic Irrigation System

Aderemi A. Atayero and Adeyemi S. Alatishe, *Members, IAENG*

Abstract*—Agricultural produce and (consequently) the quality of harvest is adversely affected by prevailing draught in specific regions of the world in general and Africa in particular. The African Union has developed a set of *Aspirations* towards meeting its *Agenda 2063* – tagged 'The Africa We Desire'. The very first of these aspirations is concerned with Africa's prosperity, and there can be no sustainable prosperity without food security. Presently, the main themes in irrigation management are cost-effective technology and efficient water and labor management. This paper presents the design of a low-cost microcontroller-based irrigation controller capable of managing irrigation for a small area of land based on real-time values of soil moisture and temperature. The developed system allows for user setting of the desired soil moisture range suitable for the crop. It will display values of same parameters as well. There is also the added feature of water filling of a water-storage medium for such schemes where it will be required. The design presented in this paper has (to some) extent attempted to meet the present day requirements of irrigation management. By extension, it will aid in the achievement of a vital *Aspiration* of *Agenda 2063.

***Index Terms*—Agenda 2063, aspiration, irrigation, soil moisture, sensor**

I. Introduction

Crop production is a necessity for man's existence. We get most of the resources we use in our daily living like foods (e.g., cocoa, beans, rice etc.) and textiles (cotton, raffia, jute etc.) from crops, and therefore the practice of crop production attains great relevance. The practice of crop production from the soil is referred to as agriculture. Agriculture plays an important role in the economy of most nations. Agriculture forms the greater part of the source of revenue of most nations. Agriculture is a major branch of the economy in Nigeria, providing employment for 70% of the population [1]. Prospects for development in agriculture have recently emerged and the government has been giving more attention to developing the sector. If there can be any enhancement in the productivity of the sector, then it should be pursued. Irrigation has done this nationwide and worldwide in past years. Experiments have been carried out over the years, which have shown that the single most important parameter for control of crop growth is the range of soil moisture the crops maintain throughout their lifecycle. The prosperity of crops depends on their receiving adequate nutrition during seedtime as well as a good balance of exposure to the elements. For crops to thrive, they require water, sunlight and nutrients from the soil. It is water that helps to present the nutrients from the soil in a form that the roots of the crops can assimilate.

The crop roots must receive adequate water to dissolve and absorb the nutrients in the soil so that they can develop properly. However, with an over-supply of water, nutrients can be lost through run-off on the soil surface. Hence we don't only need to supply water to the soil but we need to keep the water level at the appropriate level to prevent surface run-off. The natural source of water is rainfall, but due to random distribution in the nation, some places receive more water supply than required, while others receive less than the amount of water required. Irrigation is the only means through which the latter can be compensated for successful cultivation of crops. Electronics in its versatility has found application in irrigation management and diverse designs have been implemented to achieve this. With the aid of knowledge in electronic engineering, we can introduce automation and control to irrigation and this will ultimately lead to increased productivity in the agricultural sector.

II. Literature Survey

Irrigation is the artificial application of water to the land for various purposes, which may include crop cultivation, re-vegetation of disturbed soils in dry areas and during periods of inadequate rainfall, and maintenance of landscapes. With the invention of sensors and transducers, a great opening has been achieved for the application of electronics to solving physical day-to-day problems. Through the invention of soil moisture sensors and transducers, the real –time soil moisture status can be electronically monitored and same information can be used to determine the water requirement and through actuators, induce irrigation. An actuator will induce a mechanical action from an electrical input. Different approaches have been undertaken to manage irrigation using electronics. G. K. Banerjee and Rahul Singhal [2] proposed a method for the control of temperature and relative humidity inside a poly house using a microcontroller. In the proposed method the greenhouse controller senses the change in temperature and relative humidity with the help of input sensors and process the output to take appropriate control action. The proposed system is a low cost and user friendly system with high stability and reliability.

Purna Prakash Dondapati and K. Govinda Rajulu [3]

Manuscript received July 07, 2015; revised August 20, 2015.

A. A. Atayero and A. S. Alatishe are with the Department of Electrical and Information Engineering (EIE), Covenant University, Ota, Nigeria
A. A. Atayero and A. S. Alatishe are with the Department of Electrical and Information Engineering (EIE), Covenant University, Ota, Nigeria (phone: +234-807-886-6304; e-mail: atayero@covenantuniversity.edu.ng).
A. S. Alatishe is currently with the Electrical Engineering Department, Salford University, UK, on leave from Covenant University, Nigeria. (e-mail: a.s.e.alatishe@edu.salford.ac.uk).

proposed a method in which the microclimatic parameters are monitored round the clock for cultivation of specific plant species which could maximize their production over the whole crop growth season and to eliminate the difficulties involved in the system by reducing human intervention to the best possible extent. When any of the climatic parameters crossed a safety threshold which had to be maintained to protect the crops, the sensors sensed the change and the microcontroller after having read this change then performed the specified actions through the use of relays until the strayed-out parameter has been brought back to its optimum level. The use of a microcontroller made the set-up low-cost and effective nevertheless.

III. System Architecture

The system is a simple circuit developed to control an irrigation scheme on a farmland. It is designed to manage irrigation based on response to the real-time status of the soil moisture. The system will cause the soil moisture to always be in a certain range suitable for proper crop development. The architecture of the system can be divided into two subsections based on function carried out. These are:

1. The irrigation controller and
2. The water-storage controller.

A. The Irrigation Controller

This section of the device performs the action of irrigation management. It does so by monitoring the moisture content of the soil continuously and comparing the values with two set reference values-the upper-limit and lower-limit moisture content values- and then inducing corresponding actions required. Provision is made through control knobs for the user to set these values as so desired. When the soil moisture content goes below the lower-limit value set by the user, the system observes this and begins irrigation action. The land section will be irrigated until the soil moisture level reaches the upper limit value set by the user. At this point irrigation action will cease until the soil moisture level is observed to fall below the lower limit value again. In this way, the soil moisture is kept within the desired range suitable for optimal growth of the crops and water is only supplied, as the crop requires.

There is also the option of including temperature sensing and control if the user so desires. When the temperature function is activated, the temperature is continuously monitored and whenever the temperature is observed by the system to surpass a certain preset temperature value, the irrigation action is terminated if it is in operation or else it will be prevented from commencing if it is required to do so (i.e. if the soil moisture level falls below the lower limit of soil moisture). In other words, the temperature sensing action bypasses the soil moisture-based irrigation operation. The temperature value above, which this operation occurs, is set in the firmware program code to represent the average afternoon temperature (36°C), which is considered unsuitable for irrigation by some users. What this means is that once the afternoon temperature is reached, irrigation action is suspended (even if the soil moisture level is below the lower limit) until the temperature falls below this set value - in the evening. Irrigation action will be resumed at this point, until afternoon temperature is reached the next afternoon. In this mode of operation, the soil will only experience stress due to absence of water, if ever, in the short period of the afternoon hence the optimal conditioning of the soil is scarcely compromised. This is an adaptive and optional function and is included for users who work with the principle of not irrigating under the high temperatures commonly obtained in the afternoons. It is made optional. It can be activated (if required by the user) or deactivated (if not required by the user).

B. The Water-Storage Controller

The system also includes the option of filling up a water storage medium (i.e. tank) used in the irrigation scheme and monitoring its water quantity to ensure that it does not go below a certain set water level (lower limit) by commencing filling action of the storage medium as soon as it falls below this level. It then refills the medium until the water level reaches another set water level (upper limit) at its full capacity. At this point, the water filling action is terminated. It will again resume the water filling as soon as the water level falls below the lower limit and the cycle would continue. This feature is made optional as well and can be activated - if desired by the user - or deactivated if the user does not require it. An operational block diagram for the device is presented in Fig. 1.

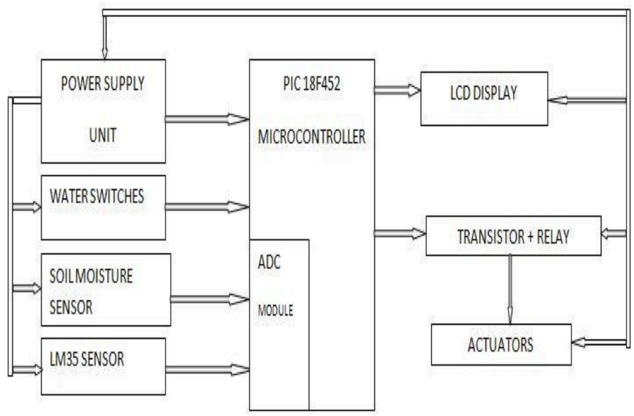

Fig. 1. Block diagram for the device operation

IV. Circuit Description

The developed circuit consists of several components like a power supply section through which regulated d.c. supply is provided for energizing the circuit, a microcontroller, soil moisture sensor, locally-made water sensor, relays, actuators, solenoid valves, two-way switches, variable resistors, connectors for power supply etc. To properly understand the circuit, the circuit can be subdivided into several units. These units are as follows:

1) The power supply unit
2) The sensor/transducer unit
3) The signal conditioning unit and peripherals
4) The control unit
5) The display unit
6) The actuators

A. The Power Supply Unit

The power supply unit (Fig. 2) supplies 12V D.C. and 5V D.C. for the microcontroller from mains of 220VA.C.

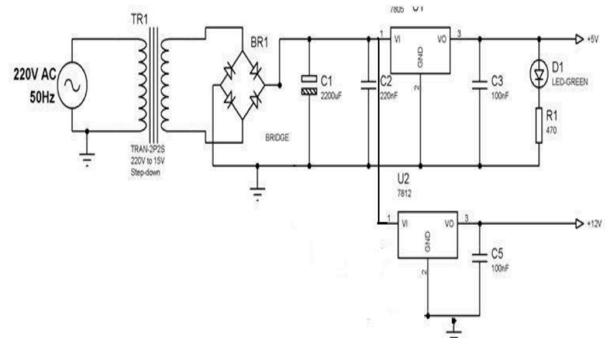

Fig. 2. Power supply circuit

B. The Sensor/Transducer Unit

This unit is the unit responsible for the detection of the presence of the physical parameters and converting same to electrical form for processing. The physical parameters of interest are the soil moisture, the ambient temperature and the presence of water in the tank.

The Soil Moisture Transducer

The soil moisture transducer used in this circuit was purchased from Amazon (Fig 3).

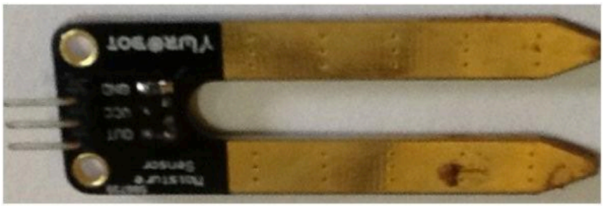

Fig. 3. Soil moisture transducer

Its voltage output is proportional to the quantity of water in the soil. There is no datasheet available for it and all information about it is given on Amazon's site. Its specified supply voltage is from 3.3V to 5V and with this supply, it gives an output voltage of between 0V to 2.3V for the full range of complete dryness to submersion in water. Its rating for maximum operating current is 15mA. The transducer is buried in the soil near the root zone of the crops for accurate monitoring. Its output is fed into the ADC input of the microcontroller.

The Temperature Transducer

The temperature transducer used in this circuit is the LM35 temperature transducer. It is a precision temperature transducer with a linear voltage output over the range of -55 oC to 150 oC. Its favorable property is its linearity and step-wise sensitivity. It has a sensitivity of 0.01V/oC starting from 0oC hence its temperature can easily be calculated. The output of the transducer is applied to the ADC segment of the microcontroller for processing.

The Water Switch

The water switch is a locally made sensor. It is constructed using a Vero board. It is simply an open circuit formed by a group of conductors separated by a little spacing to give room for water running through it to bridge it. If a voltage is applied to the switch, it is found to be short- circuited when water flows through it. We can therefore say it takes either of two states relative to voltage across its terminals - on or off - hence the name "switch". It is with this property that we are able to control the water filling of the tank.

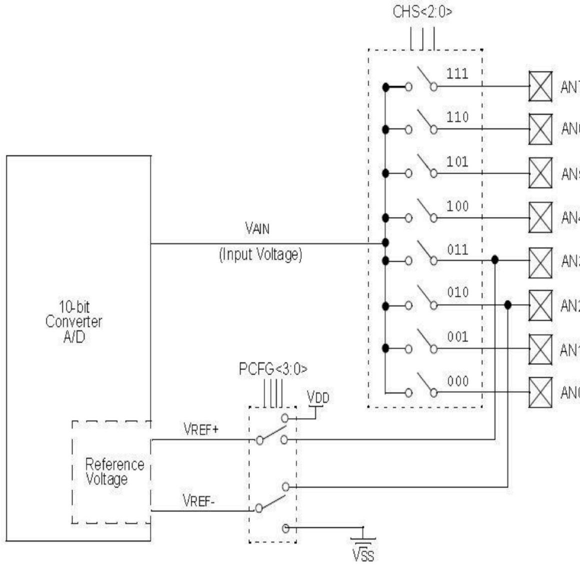

Fig. 4. Analog/Digital Converter Module

C. The Signal Conditioning Circuit and peripherals

This circuit consists of the all components, which are used to present the transducers' outputs in a form that the control unit or processing unit can process. The component included in this unit is the Analog/Digital Converter module of the microcontroller.

Analog/Digital Converter (ADC)

The analog/digital converter used in this work is a module embedded in the microcontroller. It produces discrete values from a continuous values fed into it which the microcontroller can process. The analog input charges a sample and hold capacitor. The output of the sample and hold capacitor is the input into the converter.

D. The Control Unit

This unit is basically the section that provides the control of the whole system. It consists of a microcontroller IC chip plus peripheral components and the control logic (firmware), which the chip functions with. The microcontroller chip is the central hardware component while the program/code written in Mikro-C language is the firmware component. The microcontroller used in this work is the PIC18F452. The PIC18F452 is a 40-pin, 8-bit microcontroller. The features of the PIC18F452 microcontroller make it a suitable choice for use in this automatic irrigation controller system. These features include: The microcontroller has 5 sets of input/output pins categorized into ports namely PORTS A, B, C, D, and E. PORT E is not utilized in this circuit.

The software

The software used for writing the control logic for the microcontroller processor is the Mikro-C software and the

Mikro-C compiler is used as a platform for storing and running the program. A programmer is used for the purpose of interfacing the code with the hardware chip. The program is first written as a flowchart before it is converted to a code in the Mikro-C language.

E. The Display Unit

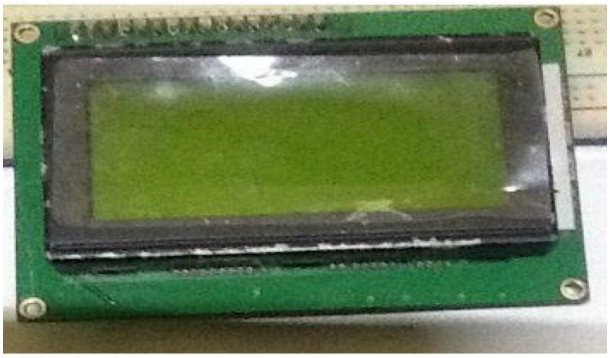

Fig. 5. The 16x4 LCD

The display unit is simply an output unit used for the purpose giving the user required information. The display unit is a simple 16x4 LCD module. This means it has sixteen columns and four rows. Each column can represent only a single character. The device can display the ASCII alphanumeric characters, some Japanese characters, and some symbols. The information to be displayed are the current soil moisture - on a percent base of which submersion in water is a 100% and in dry air is 0%, the lower limit soil moisture, the upper limit soil moisture, the current temperature, the state of the system (whether irrigating, or filling the tank) etc. The LCD screen is powered by a 5V supply voltage, and has backlight to enable the user to see the character that may be displayed on the screen where external light may be insufficient. The contrast of the display can also be controlled using a simple potentiometer or variable resistor with the sweep terminal connected to the V_{EE} pin of the LCD screen. When the device is used in the 4-bit mode, the pins D0, D1, D2 and D3 are left unconnected, while D4, D5, D6 and D7 are connected to corresponding output pins of the microcontroller.

F. The Actuators

The actuators used in this work consist of the solenoid valves, the low-power D.C. motor and all the relay switches used to energize and de-energize them.

V. METHODOLOGY

The circuit was designed and simulated using the circuit diagram of Fig. 6, on the Proteus design suite. However, the outputs Q1, Q2, and Q3 were replaced with the red, green and blue LEDs for demonstration purposes only. The programming code was written and built for simulation - with the Proteus Design software using Mikro-C compiler software.

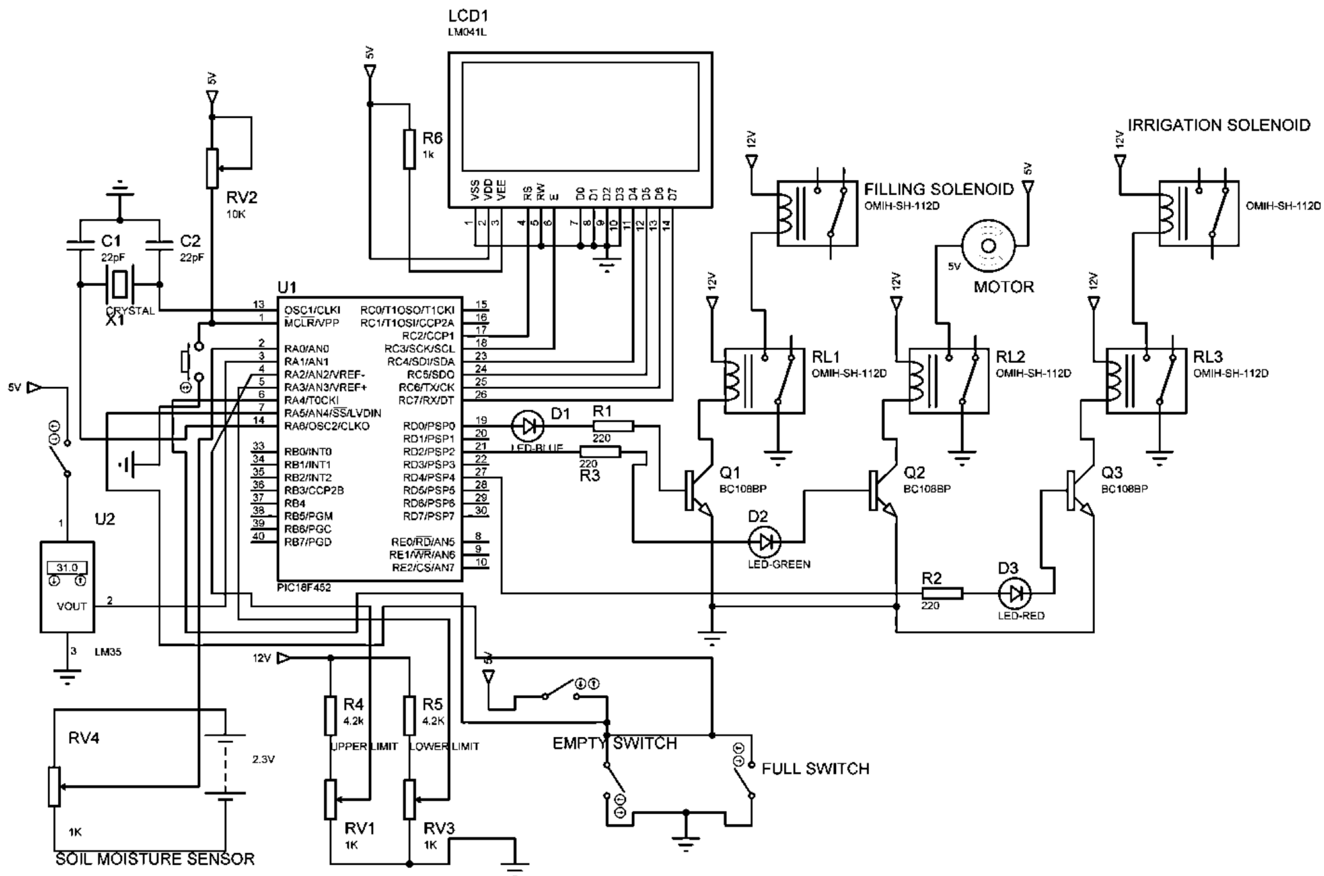

Fig. 6. System Circuit

ISBN: 978-988-19253-6-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

VI. Testing

Several tests were made to ensure the proper functioning of the system. The physical model was tested using the actual components on a breadboard, as the components were interconnected just like in the software simulation. During the physical testing, measurements were taken and a number of observations were made. The overall response and performance of the system were checked.

A. Transducer Testing

For the moisture sensor, in order to understand its voltage output characteristics, it was immersed in water and biased to give the output of 2.3V and less than 15mA current given inits specifications and then submerged in a soil sample initially filled to its capacity. Readings were taken at intervals, and the results shown in Table I.

TABLE I
Output Voltage of the Soil Moisture Transducer

Duration (Hrs)	Voltage (V)
0	2.3
6	2.21
12	2.03
18	1.87
24	1.65
30	1.31
36	0.70
42	0.45

C. Continuity Test

Continuity testing was carried out to ensure that there were no connections between isolated sections and components and that all connected points were connected.

D. Power-On Test

This test is performed to check whether the voltage at different terminals is according to the requirement or not. It is carried out before inserting the microcontroller.

VII. Conclusion

The system was developed successfully, meeting the aims of functionality, low-cost design and simplicity of operation. Hence irrigation can be automatically controlled in the rural areas of the country for low-earning farmers leading to greater productivity of crops and efficiency of irrigation management. This work could be developed to meet the requirements of irrigation in agriculture in the following ways:

1. The system could be developed for larger farmlands by integrating into the system a wireless transmission system of range suitable for the size of the land so that wires will not have to be run on the farmland for long distances, which will make the system bulky and difficult to implement in a large irrigation scheme.
2. The system can also be developed to meet farming practices like crop rotation by making the system have a separate sensing unit per section, so that each section can have different set soil moisture ranges suitable for the crops in those sections. The different sensing units can then be interfaced to a single control unit.
3. This system can be programmed in assembly language to make the response of the system much faster.

References

[1] Agriculture in Nigeria, Online, available at: http://en.wikipedia.org/wiki/Agriculture_in_Nigeria, accessed 20.08.2015.

[2] G. K. Banerjee, Rahul Singhal, “Microcontroller Based Polyhouse Automation Controller”, ISED '10 Proceedings of 2010 International Symposium on Electronic System Design.

[3] Purna Prakash Dondapat , K. Govinda Rajulu . (2012, August). An Automated Multi Sensored Green House Management. International Journal of Technological Exploration and Learning. Volume 1 (Issue 1).