Development of an Intelligent Condition based Soil Moisture Control System

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Abstract

The main theme of this paper is to explain the design and implementation of an Intelligent Condition based Soil Moisture Control System to overcome the prevailing problems in Indian agricultural irrigation system. The system is low cost and reliable in its operation giving the user the flexibility to monitor and control the soil moisture either being near to the system or through remote access using a DTMF decoder circuitry. A remotely located visual studio based GUI software ensures proper statistical and graphical analysis of the sensor outputs acquired by the microcontroller. A radio frequency communication link allows wireless data transactions between the designed system and the remotely located GUI software. The remotely acquired data by the GUI application over a RF communication link can be further preserved in databases like Microsoft Excel, Access etc. and can be logged on to the internet for global access.

Keywords: Irrigation System, RF Communication, Intelligent Soil Moisture Control, Low Cost

I. INTRODUCTION

Embedded technology has been advancing very fast from last two decades to such an extent that the world can't think of automation in any field without embedded controllers also called an embedded computers. An embedded controller is a reprogrammable and re-configurable single chip uni-purpose or application specific processor designed to perform specific operations, like controlling of greenhouse, home automation, industrial automation etc.

In India about 70% of the population earn their livelihood through various agricultural practices like plantation, irrigation and harvesting. To improve and enhance the overall productivity of the agricultural products, it is necessary to employ automation in the agricultural field through various steps of cultivation. The most important and widely used practice for enhancing the overall productivity is to properly monitor and control the soil moisture of the field and irrigate it at proper intervals without using excess water resources. The use of excess water resources not only damages the crop productivity but also causes soil erosion which ultimately leads to the degradation and devastation of the agricultural land. Soil moisture or the amount of water content in the soil has a vital impact and determines the exact growth rate of the plant, their reproduction and the rate at which the plants make their own food i.e. photosynthesis. Therefore, achieving the correct information about soil moisture content in real time accurately, timely and effectively plays a vital role in taking initiatives for proper water saving irrigation on high altitude farmlands and for crop cultivation in urban areas [1].

Most of the problems highlighted above are directly or indirectly prevailing in our country. In order to overcome these problems an agricultural irrigating system (soil moisture monitoring and controlling system) is developed by integrating various sophisticated electronic modules to ensure proper and error free operation of the system. The system designed is computationally powered by a high performance PIC microcontroller unit 16f877a [1][2]. PIC16f877a is a 40 pin DIP integrated circuit integrated with on chip flash type program memory of 14 Kbytes. The device supports a desired throughput of 5MIPS and operates between 2 to 5.5 volts. It also supports a number of digital communication peripherals like UART, A/E/USART, SPI, I2C1-MSSP (SPI/I2C) which enables the user to operate and control the system digitally from any remote location.

II. SYSTEM DESIGN

The system aims in real time monitoring and controlling of the soil moisture content for different types of soil using the moisture sensors. The data is digitized and stored in the data memory of PIC 16f877a and proper comparisons of the moisture data obtained from the sensors are made with the preset or the threshold values (Sn's) already stored in the data memory[2][3]. If the sensed moisture value is less than the threshold value, the MCU turns on the motor and turns off the motor if vice versa. The variation of the soil moisture w.r.t to time can be clearly visualized on your PC monitor using a visual studio based application program. The application program has been designed in such a way that the designed system communicates with the PC via RS-232 communication protocol at a baud rate of 9600bps. Broadly speaking the system design is divided into hardware and software design as follows

III. HARDWARE ASSEMBLY

Hardware of the system is divided into two sections: The transmitter section and the receiver section. Both the hardware sections communicate with each other wirelessly using RF data connectivity in the frequency band of 433 MHz, the fundamental importance of using RF data connectivity is to achieve an easy and affordable data transactions between the transmitter section installed near the target field under consideration and the receiver section connected to the personal computer at the controlling station. The RF data transmitter modulates the USART data over the radio frequency carrier and transmits in free space, on the receiver side, the receiver RF module receives the data and forwards it to the personal computer via RS 232 communication protocol.

A. Transmitter Section:

The transmitter section hardware block diagram is shown in fig 1. The system consists of PIC 16f877a MCU with the following on chip peripherals, two timers, a 10bit ADC with 4 selected inputs, internal crystal oscillator, analog comparator, 64bytes of RAM, 128bytes of EEPROM, and an external crystal of up to 20 MHz to boost the system performance.

Pure silver metal plates which function as the soil moisture sensors whose output voltage is proportional to the conductivity of the target field under consideration. The change in sensor output voltage as a result of soil conductivity is called galvanic soil response (GSR) which is related to the fact that a small current flows between the two silver plates on account of the soil moisture present.

Three push to on switches to load the threshold values in to the data memory. A DTMF decoder circuitry that enables a user to operate the system remotely from anywhere in the world through a GSM based mobile handset, A 2x16 liquid crystal display is programmed to provide all operation related messages like sensor values, time of start, threshold values, motor on and off timing etc. [4]. An alarm circuitry is employed for alerting the user specifying the completion of the irrigation process.

The RF module ensures a very economical and error free wireless communication with the receiver section as will be highlighted in the next sessions of this paper. More importantly the system is powered by a nonrenewable source of energy i.e. solar energy [5]. The motor driver circuit and the motor forms the actuator part of the system that turns the mechanical water valves on and off based on the comparisons as mentioned below.

```
If (Sn1>GSR1 and sn2>GSR2);
{
Turn motors on;
}
Else
{Turn motors off;
}
End if;
```

Where Sn's are the threshold values and GSR's are the real time sensor values.

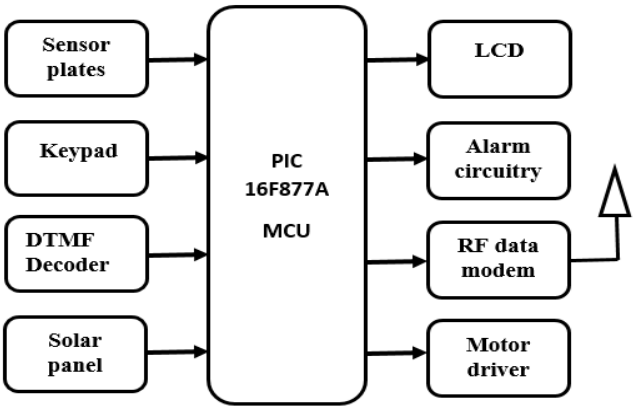

Fig. 1: The transmitter section hardware block diagram

B. Receiver Section:

The receiver section block diagram is shown below in fig 2. The receiver section simply consists of RF data receiver that demodulates the radio frequency modulated data transmitted by the transmitter section into the baseband data frames which are TTL compatible [6]. However to communicate with the PC based application software the TTL data frames needs to be transformed into the RS-232 logic. This function is accomplished by the MAX-232 line driver also referred to as the line converter or voltage converter. Internally MAX 232 consists of two sets of line drivers. The pins 11,12,13 and 14 consists of one set of line drivers while as pins 7,8,9 and 10 consists of another set. Only one set is used at a time.

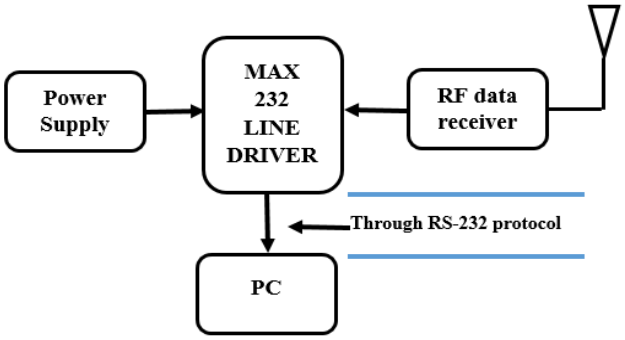

Fig. 2: The Receiver Section Block Diagram

IV. SOFTWARE DESIGN

Like the hardware design the system software design is also divided into two portions which consists of the firmware design for the MCU 16f877a and the PC based application software.

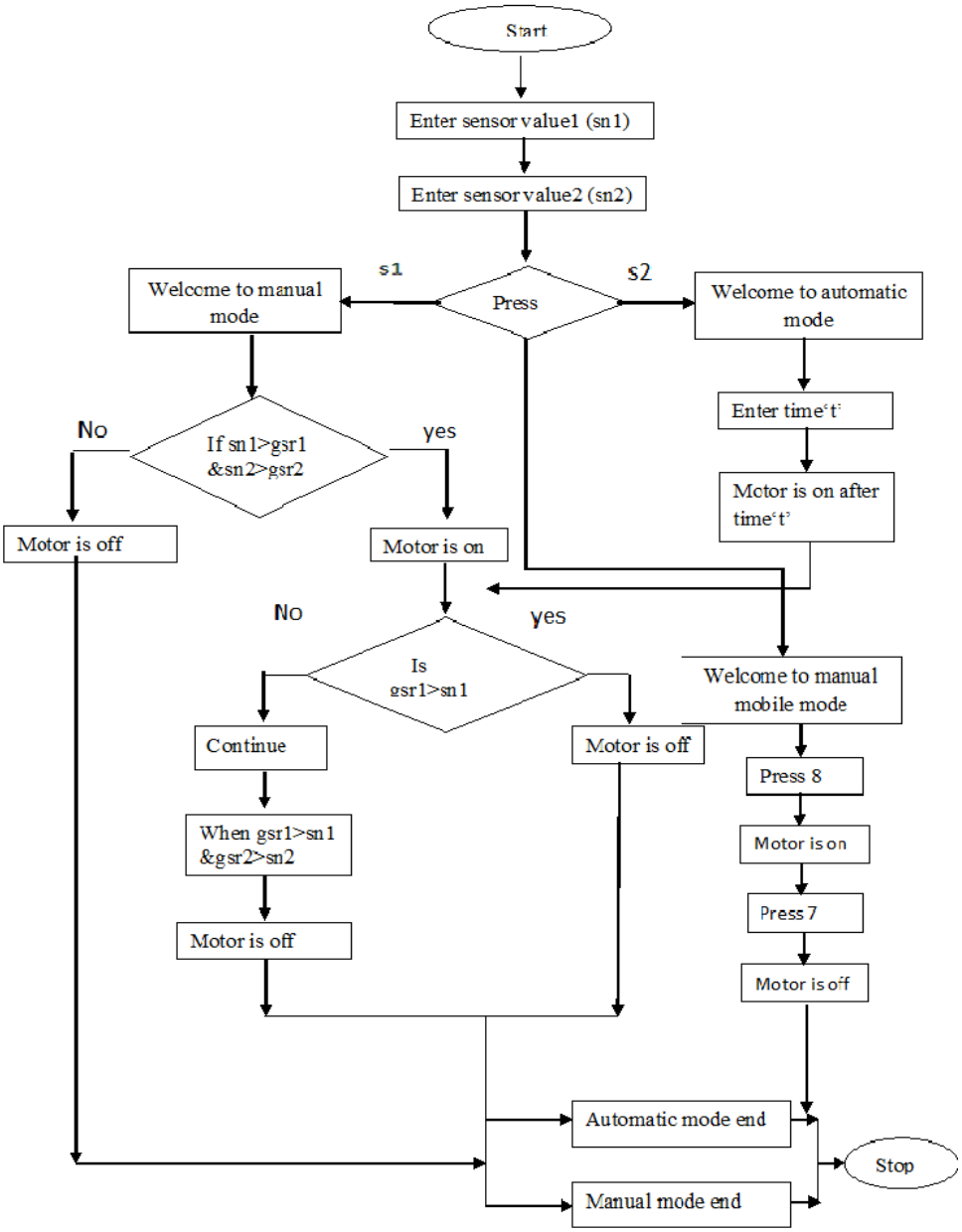

Fig 3: System Flowchart

A. MCU 16f877a Firmware Design

The firrmware for the microcontroller has been designed keeping in view the automaticity of the system. The software code has been writen using the C language which is prrobably the most flexible and easy high level language for writing firmwares for microcontrollers. The dynamicity of the code makes the system operation robust and fast to respond to the external stumuli and react to the environmental changes rapidly.

The PIC 16f877a MCU hosts a 14 Kbytes of flash program memory and the designed firmware is just about 200 lines of code. Thus PIC 16f877a can fully meet the memory requirements without overloading the flash. This would make the system work properly and ensures error free hardware and software interaction. The fig 3 below depicts the flowchart of the system.

First of all the system runs various types of the initialization functions like LCD initialization, on chip EEPROM initialization for data read and write cycles, Set the threshold values of the soil moistures (Sn's) and continuously look for the interrupts to occur in the form of keypad and DTMF inputs.

B. Modes of Operation

The system software enables the system to operate in three separate modes. Manual mode, automatic mode and the manual mobile mode.

In Manual mode the system makes comparisons based on the threshold values and the sensor values. If the sensor values (GSR'S) are less than the threshold values (Sn's) the motors are turned on and motors are turned off if vice versa.

In automatic mode the system prompts to enter the time (t) for which the motors are turned on, for example if t=1hr the system will automatically turn the motors off after exactly one hour.

In manual mobile mode the DTMF decoder inputs the commands to the system to turn the motors on and off as illustrated in the flowchart.

C. Remote Monitoring of the Moisture Level:

This PC application software is highly efficient and flexible in terms of data captures from the PC's COM port. The communication between the receiver section and PC's COM port is established at a baud rate of 9600 bps. The graphical user interface (GUI) software is designed using visual studio. Visual studio is an integrated development environment (IDE) build by Microsoft for creating computer programs as well as web based applications. The fig 4 below depicts the screenshot of the application software.

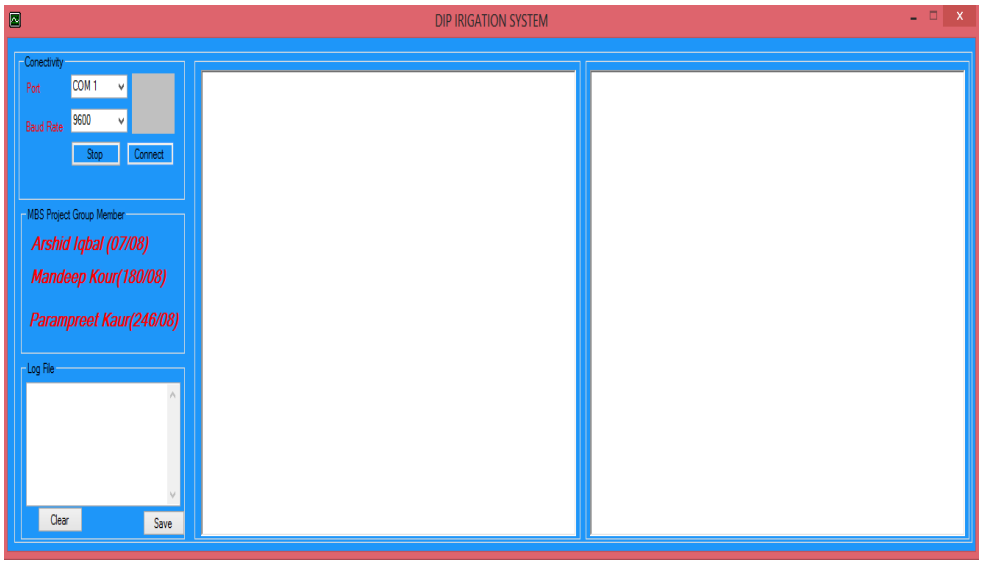

Fig 4: Screenshot of the application software.

V. RESULTS AND DISCUSSIONS

In order to check the reliability of the real time soil moisture content monitoring and controlling system, the system was put through various tests. All the results are obtained at a room temperature of 298 kelvin with a tolerance limit of ±0.2v. The table 1.below shows the sensor output voltage for different conditions of the soil.

Table - 1
Soil moisture sensor readings

Soil condition	*Transducer optimum value in volts*
Dry soil	*0-1.5*
Moist soil	*1.85-3.50*
Slurry soil	*More than 3.5*

While installing the system it is necessary to put up the sensors at proper depths which may vary for different crops to measure the soil moisture properly, the table 2. Below depicts the recommended depths of the moisture sensors for different crops.

Table – 2
Recommended sensor depths

Crop	*Shallow sensor (inches)*	*Deep sensor (inches)*
Alfalfa *Corn* *Sorghum* *Sugar beets* *Tomatoes*	*18*	*36*
Field beans *Potatoes* *Small grain*	*12*	*24*
Pasture	*12*	*18*

During the initial stages of the growing season consider the shallow sensor readings and moderately irrigate the fields while as in the later session consider the deeper sensor and heavily irrigate the fields. The table below gives the exact interpretation of the sensor plate readings.

Table – 3
Interpretation of the sensor plate readings.

Moisture content (atm)	*Soil type*	*Moisture status*
0-0.05 *0-0.10* *0-0.20*	*Coarse* *Moderate* *Fine*	*Nearly saturated*
0.10-0.20 *0.30-0.40*	*Coarse* *Moderate* *Fine*	*Field capacity*
0.30-0.50 *0.40-0.80* *0.50-1.50*	*Coarse* *Moderate* *fine*	*Irrigation range*

D. Results from Data Acquisition Software:

The required soil moisture is solely dependent on the kind of plant, type of growth, type of land and type of soil. The required soil moisture is calculated according to the above mentioned factors. An assumed graph representing a time variation of soil moisture is depicted below in fig 5. The x axis represents the time and the y axis represents the soil moisture in atmospheres [6].

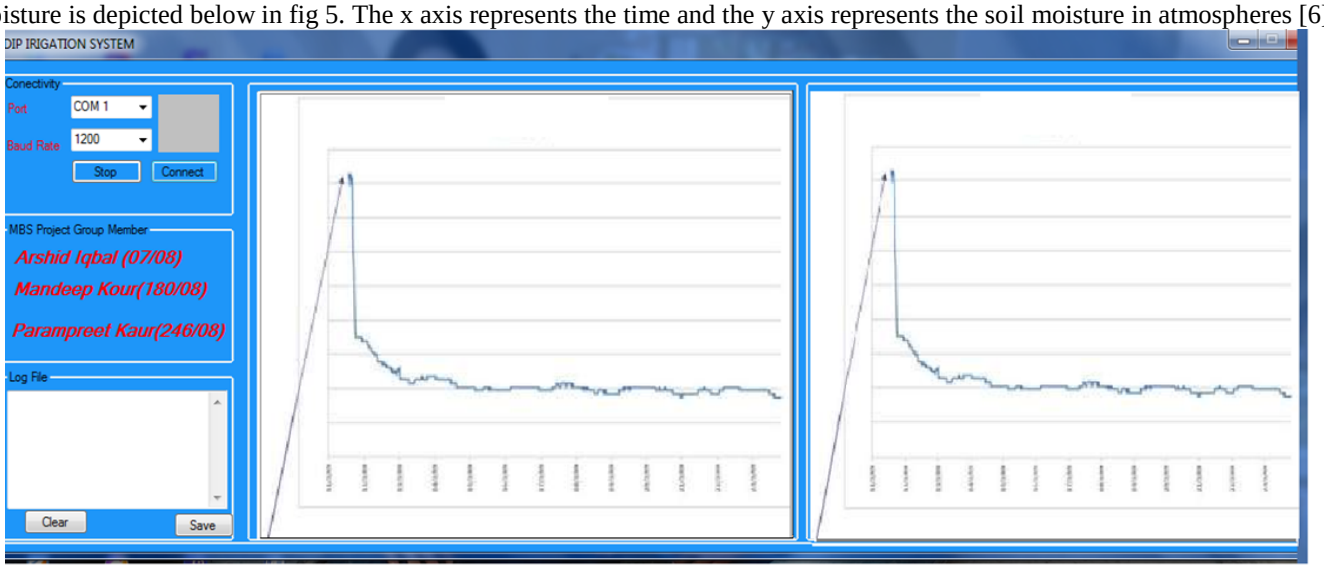

Fig 5: Results from data acquisition software

VI. CONCLUSION

Throughout the designing of the system titled "Development of an Intelligent Condition based Soil Moisture Control System", a step by step and hierarchical approach was followed. All the results obtained during the tests and implementation of the system has shown the system operation and performance to be reliable and accurate. The system was found to respond well to the analog signals from the sensors and the signal conditioning done was accurately calibrated as per the results obtained. The system is

reliably good for irrigation in urban areas and high altitude lands where timely human intervention is very tough and hectic. The main advantages of this system are:

- Accurate and fast in performance.
- Solar powered with auto backup and hence its working doesn't get effected due to power failure.
- The output of the sensors can be stored for future use and statistical research can be done.
- The pc based application software can store years of the sensor data in the form of spreadsheets.

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