

A Low Cost Design & Monitoring Of Automatic Irrigation System Based On Zigbee Technology

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Abstract

Indian agriculture is dependent on the monsoons which is not a reliable source of water, so there is a need for an automatic irrigation system in the country which can provide water to the farms according to their moisture and soil types. Modern drip Irrigation is today's need because water resources are very limited, diminishing day by day and most of them depend upon monsoons. The one and only one solution to this problem is automated Drip Irrigation system. In the field of agriculture, use of proper method of irrigation is important and it is well known that irrigation by drip is very economical and efficient.

In the conventional drip irrigation system, the farmer has to follow a schedule for watering, which is different for different crops. In the automatic microcontroller based drip irrigation system, irrigation will take place only when there will be intense requirement of water.

A variety of drip irrigation methods have been proposed, but most of them have been found to be very expensive and complicated to use. In future each and every farmer, whether poor or uneducated might wake up in need of such a system, therefore the proposed applications targeting an automatic irrigation system with minimal cost, time and human-computer interaction.

1. Introduction

This paper work represents the prototype design of microcontroller based automatic irrigation system which will allow irrigation to take place in areas where watering is required, while bypassing those areas where adequate soil moisture is indicated. This system has a wireless sensor network for real time infield sensing and control of an irrigation system. Too much watering causes diseases to plants and even they die out. This system provides uniform and required level of water for both plain and slope areas and therefore it avoids the water overflow at the slope areas which saves the plant and also water. This system has software for real-time in-field sensing and control of an irrigation system. Field conditions are site-specific monitored by in-field

sensor stations distributed across the field and then wirelessly transmitted to a base station. This irrigation system updates solenoid valves for specified location of mist emitters automatically according to the set point of temperature, humidity and soil moisture. This system also senses the water level of the tank and whenever the water level is too low then the system immediately provides a sound alarm and then it automatically switches ON the motor. When the water level reaches 90% of the tank then the motor is switched OFF through the remote system. Communication signals from the sensor network and irrigation controller to the base station interfaced using ZigBee communication and this technology is a low-cost, low-power wireless sensor network. The modules operate within the 2.4 GHz frequency band and range up to 30 meters indoor and outdoor RF line-of-sight range up to 100 meters and RF Data Rate 115kbps.

This system can be used in greenhouses as well as open fields. The real time values of soil moisture, air humidity, temperature and water level in the tank are wirelessly transmitted using Zigbee technology from field to base station which controls the state of the motor and irrigation valves according to the desired levels set by the user. A flow sensor can also be interfaced to the main water supply which continuously tracks the water applied to the field. All the information viz. temperature, current soil moisture level in field, upper and lower moisture levels to be maintained in field (set by user), motor status, water usage and flow rate are displayed on LCD.

2. Objectives

- a) To save water, energy and man power in the agriculture field.
- b) Remote control access of the system as well as handle the system manually.
- c) Monitoring water level, status of sensors and warning indication at critical situations.
- d) To design, which will be less costly, easy to handle, efficient and putting minimal efforts of the farmer?

3. System Architecture

The Architecture level is a plan for overall system that will be used to design the components that make up the architecture. Fig.1 shows the architecture of the field-station in which different sensors status is continuously updated by microcontroller and then transmitted through wireless ZigBee transceiver to the base station, the base station process these signals, update status and transfer the decision control signals back to the field station, which in turn switches the relays on/off according to the required irrigation conditions. The components which are involved in the designing of the Field-Station are shown below:

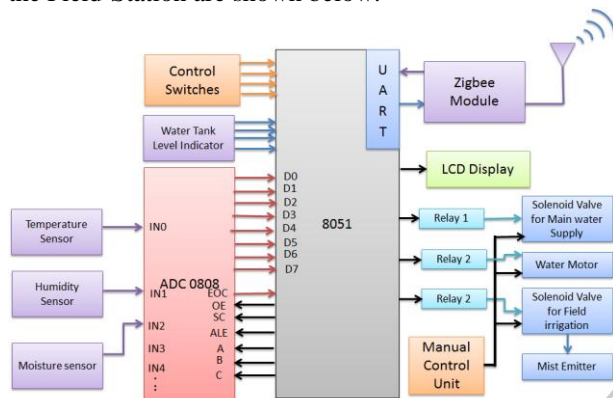


Figure 1. Architecture of the Field-station

The ZigBee transceiver module is connected through UART serial interface with the microcontroller which transmits the data from the field station to the base station where the receiver ZigBee module receives the data, check the required irrigation conditions, display the output and then resend the control signals to the field station.

In the field-station, The information data is collected from different sensors such that environmental humidity, temperature conditions, soil moisture, water level of the tank and then it is fed to the microcontroller through data collection interface. All these analog signals values are converted into suitable digital form by using Analog to digital convertor interface and then these signals are fed to AT89S51 microcontroller. The microcontroller displays the sensors output in the LCD, simultaneously transmitted this information to the base station using ZigBee transceiver [4]. We can manually adjust the set points according to the climate to provide proper irrigation to different aged and different areas of the field by using manual control unit.

Base station which is shown below in fig.2 receives the information data from field using ZigBee module and checks whether the limits are exceeding the set point or

not[3]. On the basis of that it sends the control signal back to the field station where corresponding irrigation condition is applied. Base station also maintains the database and displays the current sensor readings. The components which are involved in the designing of the Base-Station are shown below:

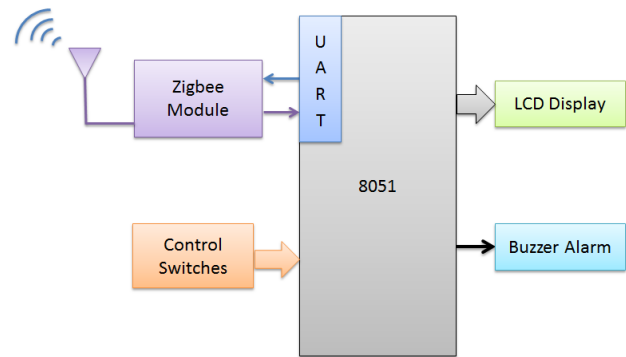


Figure 2. Architecture of the Base station

4. Design Methodology

In this paperwork, overall steps that are taken to be carried out to successfully achieve the objectives are:

- i. Testing and configuring ZigBee module.
- ii. Choosing a microcontroller.
- iii. Testing and configuring ADC0808 with microcontroller.
- iv. Testing of water level indicator.
- v. Testing of temperature sensor.
- vi. Testing of humidity sensor.
- vii. Testing of moisture sensor.
- viii. Testing the solenoid valve.
- ix. Testing of relays for water motor control and sound alarm.
- x. Testing of switches control over system.
- xi. Testing of L.C.D with microcontroller.
- xii. Power supply unit.
- xiii. Software design.

The main objective of this research is to investigate the development of a low cost irrigation system, which can be used in a ZigBee mesh network. ZigBee is a new mesh networking standard, which places emphasis on low cost sensor networks and energy conservation. The development focus for ZigBee is remote monitoring and control applications. This research has successfully achieved its objectives and identifies areas for future development.

5. Testing And Implementation

The various unit which are combine to form a complete systems are described step by step as follow:

5.1 Zigbee

The ZigBee and ZigBee Pro radio is made by Digi (formerly Maxstream). These modules use the IEEE 802.15.4 networking protocol for fast point-to-point or peer-to-peer networking. However, the most different part between ZigBee and ZigBee Pro is they have different cover distance range for communicate with own module. ZigBee can be covers around 30m at indoor and 100m at outdoor. Inversely, ZigBee Pro can cover higher distance range than ZigBee which is 100m at indoor and 1500m at outdoor[4]. Both devices that have a UART interface so can be connected directly from microcontroller to pins of RF Module (ZigBee/ZigBee Pro). Using UART interface, we can use this wireless devices to communicate between microcontroller to microcontroller (two 8051's) or between PC to microcontroller or between PC to PC. Here, we will discuss how to use two ZigBee/ZigBee Pros to interface with microcontroller and how to send command for configuration ZigBee/ZigBee Pro Module. The role of the Zigbee module is to be as transparent as possible. It should be as if a wire was connecting the input to the output and connectivity is never lost. While this sounds simple, it's actually a very hard task to accomplish and error correction is a must, which the Zigbee's role in offering sound and reliable wireless communication[5]. ZigBee pin diagram is shown below:

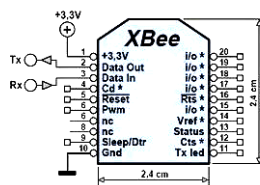


Figure 3. ZigBee Pin description

Looking at the ZigBee pinout we can see right away the different types of input that can be translated and transmitted wirelessly:

- Digital I/O
- Analog I/O (10 bit resolution)
- Pulse with Modulation
- Serial Communication (SPI/RS232/I²C)
- CTS/DTR Control Signals

5.1.1 ZigBee/ZigBee Pro Hardware Interface Between Pc

Here we have used two different ZigBee starter kit one is USB compatible kit with PC and other one is RS232 protocol compatible with PC. We have connected one of the starter kit with the USB port and the other one with Serial Com port of same or different PC (depends upon choice). Bear in mind, ZigBee is designed for 3.3V system, this starter kit have inbuilt 3.3V regulated power supply so we don't need to worry about this. Those system in which we want to connect ZigBee as a stand-alone device will require extra work and component before ZigBee module could be embedded in the system. Next step is to set ZigBee Module Source address and Destination address, it is very important for us to transfer data by transparently from one ZigBee module (Source) to another ZigBee module (Destination) so that it don't interfere with other module in the same network. Two ways to setting ID address which is using [X-CTU software](#) or using programming code to send specified command for ZigBee ID address setting. We will discuss only one way of configuring ZigBee module by using X-CTU software only since this is sufficient for our research paper work. X-CTU which is a computer based software to communicate with XBee, to change configuration or Transmit/Receive data. Double click the "setup_x-ctu.exe" file to install this Software.



Figure 4. Using X-CTU Software to Setting Source Address and Destination

Launch the X-CTU Software and connect the USB cable from USB compatible starter kit to any of the USB port (without connecting to microcontroller board). Select "PC Setting" tab under X-CTU software window -> select *USB Serial Port* (Here it is COM 12 appeared and unaltered all the other settings) -> Now click "TEST/QUERY" as shown in Fig. 5.1. All the other settings like -Baud rate: 9600- Data bits: 0 - Parity: NONE - Stop bits: 1 and others are unchanged or could be changed according to data transmission rate required[6].

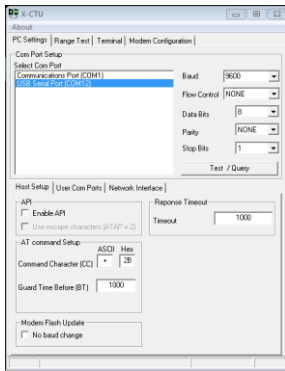


Figure 5.1

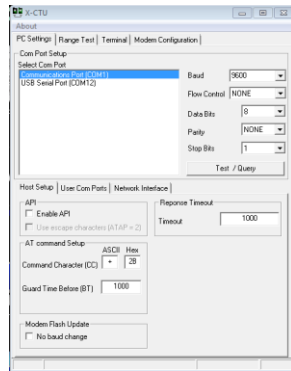


Figure 5.2

ZigBee Coordinator ZigBee Router (End Device) Configuring By Using X-CTU Software.

If everything is fine, a dialogue box will appear as shown below in Fig.6.1, click “OK” to close this box:

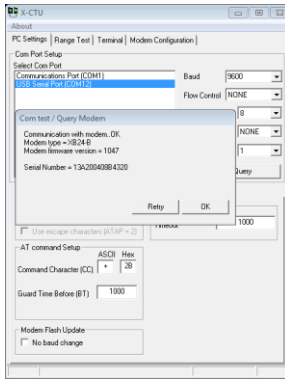


Figure 6.1

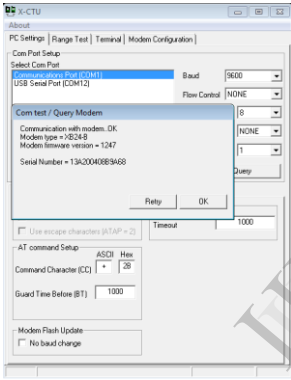


Figure 6.2

ZigBee Coordinator ZigBee Router (End Device) Configuring By Using X-CTU Software

Now repeat the same steps with the other serial com port compatible starter kit. Connect the cable of starter kit with the com port of PC. Run the X-CTU software. Select “PC Setting” tab under X-CTU software window→ select serial COM Port (Here it is COM 1 appeared and unaltered all the other settings) → Now click “TEST/QUERY” as shown in Fig.5.2. If everything is fine, a dialogue box will appear as shown in Fig. 6.2, click “OK” to close this box[7]. Here we have used the single PC Serial Com Port and USB port for the testing purpose. As shown in the Fig. 7.1. the modem type is XB 24-B so click now on the Modem Configuration Tab.

- Select modem XBEE type (as it is XB 24-B)
- Click on the Function set and select Coordinator AT (For point to point

communication AT command mode is simplest)

- Choose always update firmware
- Click on write.

Within a few seconds the new firmware will be installed on ZigBee. Keep the other settings unchanged as a shown in Fig.7.1.

Similarly go to second X-CTU window here again the modem type is XB 24-B so click now on the Modem Configuration Tab.

- Select modem XBEE type (as it is XB 24-B)
- Click on the Function set and select Router/End Device AT
- Choose always update firmware
- Click on write

Within a few seconds the new firmware will be installed on ZigBee. Keep the other settings unchanged as shown in below Fig.7.2.

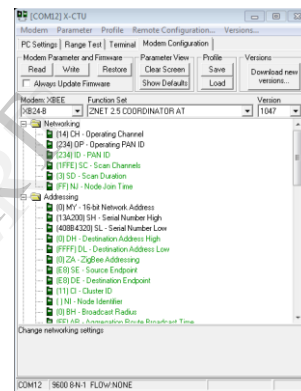


Figure 7.1

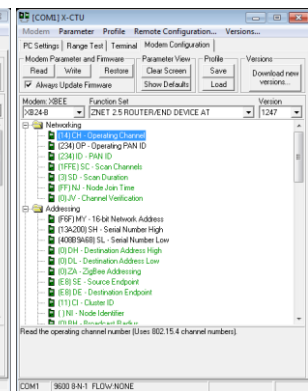


Figure 7.2

ZigBee Coordinator ZigBee Router (End Device) Modem Configuration

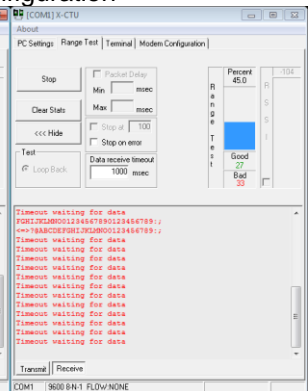
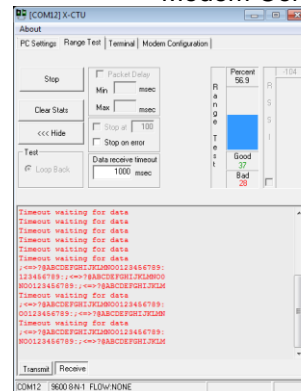


Figure 8. Range Test Between Co-ordinator and Router/End Device

Now go to Range Test Tab and in both X-CTU windows click on start if everything is done correctly the both ZigBee start communicating each other. Now both the ZigBee module are configured successfully and can be attached with remote station and base station microcontroller board. The range test is shown above in Fig.8.

5.1.2 Zigbee/ZigBee Hardware Interface Between Microcontrollers

If we want to use coding to send the command to ZigBee, we have to ensure the hardware connection between Zigbee to microcontroller is complete. Any microcontroller with UART peripheral can be used to interface with ZigBee as shown below:

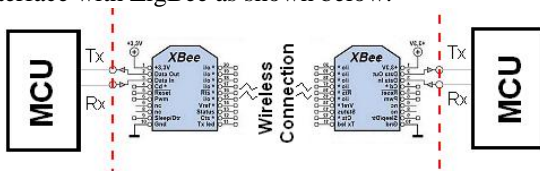


Figure 9. Standard ZigBee wireless communication link with microcontroller

The way we will be using the Zigbee is far easier. Straight out of the box, the Zigbee is normally configured for 9600bps serial communication and so to make things easier, we haven't change any of the configuration options[8]. This means we will only be using the Vcc, GND, Din and Dout pins and left other pins unconnected. In Fig.9 we have connected RXD pin no.3of ZigBee to TXD pin of microcontroller and ZigBee TXD pin no. 2 to RXD pin of microcontroller.

5.2 Microcontroller 8051

Since the project's focus is on embedded hardware and software control, the microcontroller is the heart of the system. The microcontroller selected for this project must be able to read values from sensors through analog to digital convertor, send and receive signals from RF module and must be able to display them to LCD[9]. Any 8-bit microcontroller can be chosen for this purpose. The AT89S51 was selected as it satisfies these requirements

A 11.0592 MHz crystal oscillator was also used in conjunction with the 8051 to provide the necessary clock input[10]. This speed is sufficient for the application. A pin diagram of the AT89S51 is provided in Fig.10.

The inbuilt capabilities of 8051 microcontroller (AT89S51) are

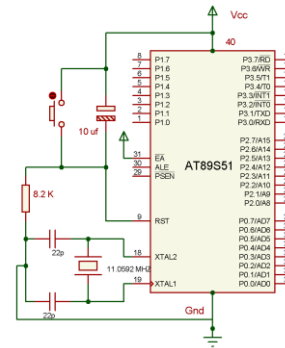


Figure 10. 8051 Microcontroller with basic connection

- It is a full static CMOS controller
- 8k Flash memory
- 256 bytes RAM
- 4 I/O ports of 8 bit wide
- 3 timers/counters
- 8 interrupt sources etc.

5.3 Testing And Configuring Analog To Digital Convertor

Here we have used ADC0808 (8 channels, 8-bit data output) to get the data from different sensors and convert these values in digital form which is suitable to be processed by microcontroller[2]. The 8 analog channels are multiplexed and selected by using three address pins A,B and C.

Since ADC0808 has no self-clocking so the clock is provided by external source such as 555 timer in astable mode. An Astable Multivibrator, often called a free-running Multivibrator, is a rectangular-wave generating circuit. An Astable Multivibrator can be produced by adding resistors and a capacitor to the basic timer IC 555. The timing during which the output is either high or low is determined by the externally connected two resistors and a capacitor and this timing cannot be faster than 100 microseconds for ADC0808.

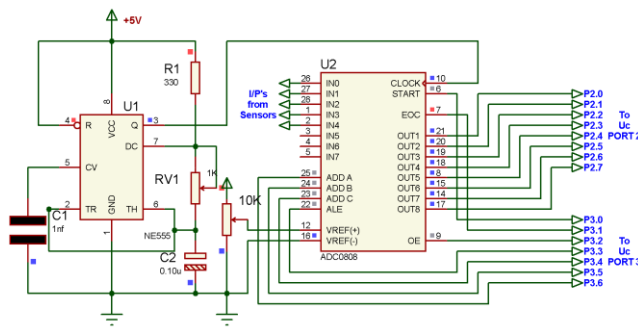


Figure 11. 8051 connection to ADC with clock from 555 timer

A maximum of 8 sensors could be connected with the ADC0808 which is enough for our design work. The schematic diagram of ADC with microcontroller and frequency generator circuit is shown above.

5.4 Water Level Indicator

The water level in the tank is sensed by the sensor assembly, which is connected to a 4-bit data line (any 4 pins) of microcontroller through transistor. Depending upon water level in the tank, BC547 n-p-n transistors (Q1-Q4) conduct to generate a 4-bit code, shown as in table 1.

Water Level	4-Bit Code	Message On LCD	Buzzer Status
Less than 25%	0000	Water Level low	Buzzer Ring (Time to On the Water Motor)
25%	0001	Water Level 25%	-
50%	0011	Water Level 50%	-
75%	0111	Water Level 75%	-
90%	1111	Water Level 90%	Buzzer Ring (Time to Off the Water Motor)

Table 1. 4-Bit Code With its Significance

This four bit code is fed to the microcontroller which then takes decision of either to on/off water motor for irrigation. The block diagram of water level indicator connection to microcontroller is shown below.

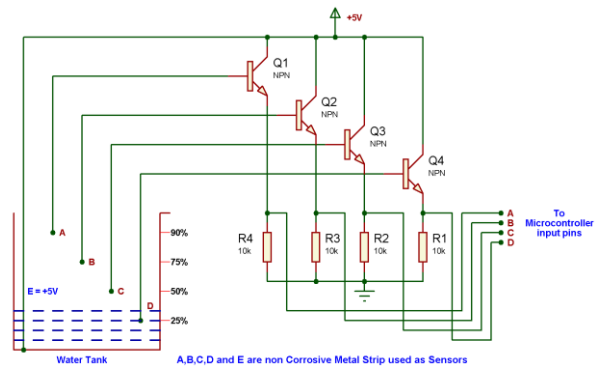


Figure 12. 8051 connection to Water Level Indicator

5.5 Temperature Sensor

The LM35 series are precision integrated-circuit temperature sensors whose output voltage is linearly proportional to the celsius (centigrade) temperature. The operating temperature range is from -55°C to 150°C. The output voltage varies by 10mV in response to every °C rise/fall in ambient temperature, i.e., its per size is 0.01V/°C.

This sensor senses the field temperature and it is interfaced with the microcontroller as shown in the figure 13.2.

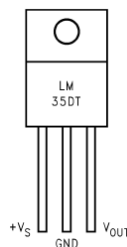


Figure 13.1 LM35 Pin Diagram

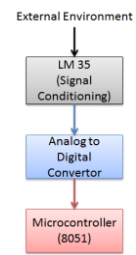


Figure 13.2 Interface with microcontroller

5.6 Humidity Sensor

To measure amount of water molecules dissolved in the air, a smart humidity sensor module SY-HS-220 is opted for the system design. The diagram of humidity sensor is shown in the figure 14. The humidity sensor used in this system is highly precise and reliable. It provides analog voltage depending upon humidity of the surrounding in RH%. It works with +5 Volt power supply and the typical current consumption is less than 3 mA. The operating humidity range is 30% RH to 90% RH[1]. The standard analog output voltage provided at 25°C is 1980 mV and 60% RH. The accuracy is ± 5% RH at 25°C. It has three output pins

recognized as B, W and R. The pin labeled W provides the analog output voltage which is sampled to ADC through instrumentation amplifier and offset voltage compensator for measurements, whereas the pin labeled B is ground. A +5V is applied at the pin R. The humidity sensor module is shown in figure 14.1

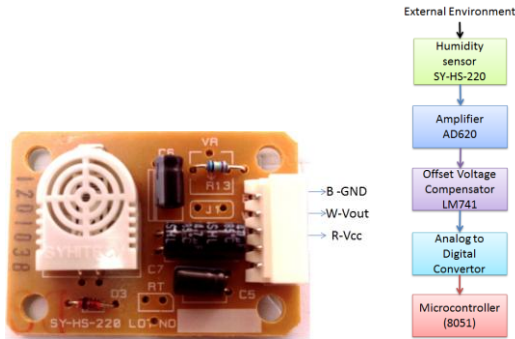


Figure 14.1 Humidity Sensor Module

Figure 14.2 Overall Design of the Sensor Unit.

The humidity sensor provides the analog output voltage in mV which is linearly proportional to the humidity in RH%. To pick up this signal it is amplified by an instrumentation amplifier AD 620.

It is found that humidity sensor SY-HS-220 produces the analog output voltage 1980 mV at 25°C and 60% RH. This voltage is the offset voltage, therefore it is required to compensate. The offset voltage compensator is designed about operational amplifier 741. The block diagram of overall sensor unit is shown in Figure 14.2.

5.7 Soil Moisture Sensors

Soil moisture sensor measure the water content in the soil. In this sensor we are using 2 probes to be dipped into the soil as shown below. As per moisture we will get analog output variation from 0.60V-12V, input supplied voltage is 12V.

Soil moisture levels can be expressed in terms of soil water content. A predefined moisture threshold is used as a reference to control the water pumping if needed. If the water level is less than a predefined value then our sensor will detect this and will inform the system to pump the water. On the other hand if it exceeds the threshold value and the water pump is ON then our system will switch OFF the water pump. This will allow efficient usage of water.



Figure 15.1 Soil Moisture Sensor

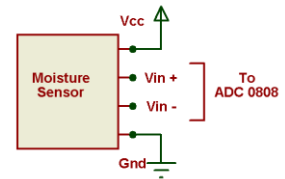


Figure 15.2 Overall Design of the sensor unit.

5.8 Solenoid Valve

Solenoid valves are power-operated devices used to modify fluid flow or pressure rate in a process system. A Relay is used to connect the solenoid valve with the microcontroller. The solenoid valve is shown in figure 16.1 and its connection detail in 16.2.



Figure 16.1 Solenoid Valve



Figure 16.2 Overall Design of the Actuator Unit.

5.9 Relay Switch

In this paper work relay is used for connecting the solenoid valves, water motor and buzzer to a microcontroller. A single relay switch connection to microcontroller is shown below. A buzzer can also be connected by applying +12V at the common terminal of relay

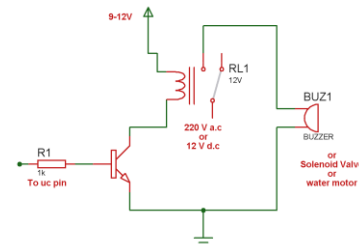


Figure 17. Relay Switch interfacing circuit

5.10 Control Switches

Control switches are provided in the field station to manually adjust the set points according to the climate to provide proper irrigation to different aged and different areas of the field.

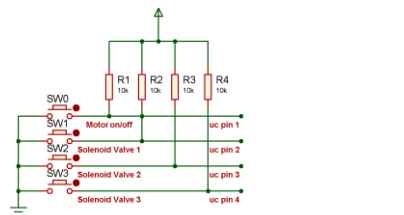


Figure 18. Manual Switch Control Unit

5.11 Liquid Crystal Display (Lcd)

Here we are using a 16 x 2 LCD for displaying the values on the screen. It has 16 pins. It support 16 characters per rows and total no of rows are 2. It means that it can support up to 32 character at a time, which is sufficient for data display purpose. RS, R/W and Enable pins of LCD are connected with the receiving end microcontroller port pins[11]. Data lines D0-D7 are connected to one of the output port of microcontroller. The basic connection of LCD is shown below in Fig.19. Here V_{DD} (contrast voltage) is adjusted by using a variable resistor connected with it.

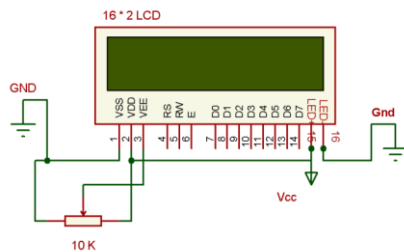


Figure 19. LCD Basic Connection Diagram

5.12 Power Supply Unit

In the power section a simple 9-12V battery is connected with the transmitting end as well as receiving end. Since the microcontroller which is the central processing unit works on regulated +5V power supply so this can be achieved by connecting a +5 volt regulator at the output of battery. This is shown in Fig. 20.

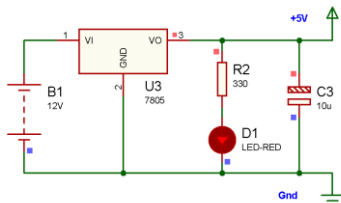


Figure 20. Battery operated +5V power supply

6. Software Design

Software design includes

- transmission and reception of wireless signal using ZigBee transceiver.
- read the sensors values through analog to digital convertor.
- update the status of relay switches to on off solenoid valves and water motor.
- display the status on LCD display accordingly.

The main program for this system is written by using the embedded C programming language[12]. The schematic diagram for this system which consists of all the components was designed by using the proteus ISIS 7 professional editions. The main program was developed in the keil Integrated Development Environment by using the embedded C programming language. The .c program was converted into .HEX file in this IDE and burned into the ROM part of the AT89S51 microcontroller.

The software flow of the entire system including base station and field station is displayed below.

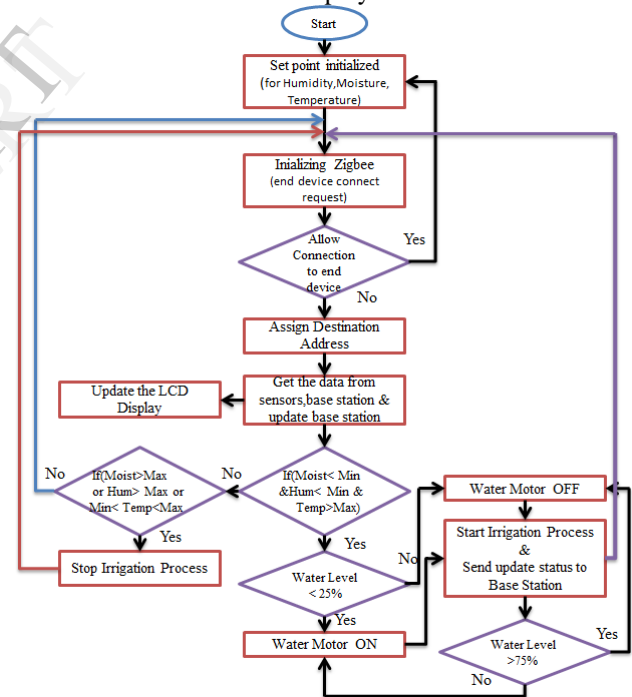


Figure 21. Field Station Software Flow-chart

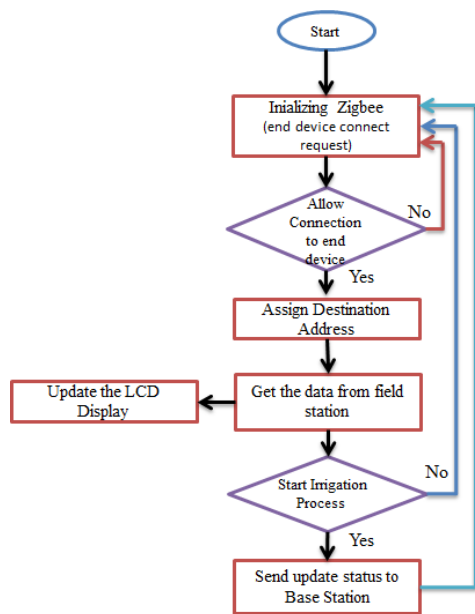


Figure 22. Base Station Software Flow-chart

6. Scope And Conclusion

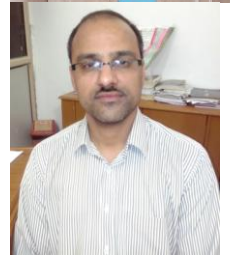
It is found that the combination of hardware and software provides an automatic irrigation system that can be implemented at relatively low cost and which is extremely user friendly with the use of ZigBee network. We can eliminate the complication of wiring in case of wired irrigation and ZigBee based automation system provides operating range much higher as compared to Bluetooth or other wireless standard. With the use of ZigBee based automation circuit considerable amount of power saving is possible and it is flexible and compatible with future technologies so it can be easily customized for individual requirements.



Dhawan S. Thakur is presently working as Lecturer in the department of Electronics and Communication Engineering, Eternal University, India. His areas of interest are Microcontroller & Embedded System.



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Dileep Kumar Sharma is presently working as Asst. Professor in the department of Electronics and Communication Engineering, Eternal University, India. His areas of interest are Embedded systems, Microwave & Data communication

8. References

1. B. P. Ladgaonkar And A. M. Pawar, "Design And Implementation Of Sensor Node For Wireless Sensors Network To Monitor Humidity Of High-Tech Polyhouse Environment", *International Journal of Advances in Engineering & Technology*, ISSN: 2231-1963. July 2011.
2. Zacharia Mzurikwao, Dr. Wang Liqiang, "Zigbee And Gsm Technology Based Irrigation Control System", *International Journal of Engineering Research & Technology (IJERT)*, ISSN: 2278-0181, Vol. 2 Issue 3, March – 2013
3. Zulhani Rasin, Mohd Rizal Abdullah, "Water Quality Monitoring System Using Zigbee Based Wireless Sensor Network", *International Journal of Engineering & Technology*, IJET Vol: 9 No: 10
4. ZigBee Alliance Official Site, [online]. Available: www.zigbee.org
5. Prof. Jitendra R. Rana, Prof. S.N.Pawar, "ZigBee Based Home Automation", <http://ssrn.com/abstract=1587245>
6. "XBee-2.5-Manual," ZigBee RF communication protocol. (2008). Minnetonka: Digi International Inc.
7. XBee OEM RF Modules- ZigBee - v1.x1x [2007.06.01] © 2007 Digi International, Inc. www.digi.com
8. http://www.pyroelectro.com/tutorials/xbec_wireless_interface
9. Lakhya, Inder, Emanuel, Abhijit, Lalan, Debraj, Er. M. Sujitha, "Home Automation System Based On Arm And Zigbee", *Undergraduate Academic Research Journal (UARJ)*, ISSN: 2278 – 1129, Volume-1, Issue-3,4, 2012.
10. Muhammad A Mazidi, Janice Mazidi, "The 8051 Microcontroller And Embedded systems", *person Education second Edition*, printed in India by Gopson papers Ltd.
11. Dhawan S. Thakur and Aditi Sharma, "Wireless Solar Irradiance Meter", *International Conference On Renewable Energy*, 5th-6th May., 2012, Eternal University, H.P., INDIA
12. V. Ramya, B. Palaniappan, Bobby George, "Embedded System for Automatic Irrigation of Cardamom Field using Xbee-PRO Technology", *International Journal of*

Computer Applications (0975 – 8887) Volume 53–
No.14, September 2012.

13. Mahir Dursun and Semih Ozden, “A wireless application of drip irrigation automation supported by soil moisture sensors”, *Scientific Research and Essays* Vol. 6(7), pp. 1573-1582, 4 April, 2011

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