DESIGN AND IMPLEMENTATION OF RF BASED IRRIGATIONSYSTEM CONTROL

M.SC THESIS PROJECT REPORT

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF ELECTRICAL ENGINEERINGAND COMPUTING

SPECIALIZATION ON INDUSTRIAL AUTOMATION AND CONTROL TECHNOLOGY MANAGEMENT

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June-2015 G.C.

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CERTIFICATE

The project **Design and Implementation of RF basedirrigation system control** by AmenuDida, BereketTesfaye, Friat Y/Wendm, GashawNigussu and ZewduMekonnen has been carried out under my supervision and that this work has not been submitted elsewhere for a degree. This project has been submitted for examination with my approval as a University advisor.

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DECLARATION

We AmenuDida, BereketTesfaye, Friat Y/Wendm, GashawNigussu and ZewduMekonnen hereby declare that this project entitled **Design and Implementation of RF basedirrigation system control** is entirely our own work and to our knowledge it has not been done or presented by other person. The result of our own work carried out under the supervision of S.Sateesh and Feleke Fanta.We swear that all the material used has been properly referenced.

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ABSTRACT

In crop production a healthy water balance is essential for high quality yields. Under-watered crops suffer from nutrient deficiencies while over-watered plants are more susceptible to diseases pressure and can in some cases lead to root death through suffocation. Also over-watered plants are not able to withstand dry spells during dry season, because the existing irrigation systems are mostly based on traditional and rarely with electrical control system. For this reason, we use control engineering principles and concepts to provide a RF based automatic irrigation system control. The automated irrigation system is controlled using AT89C52 microcontroller based on RF transceiver. The system is programmed via the microcontroller to give interrupt signal to the irrigation system (drip, sprinkler, ditch etc) depending on the soil moisture levels. The soil moisture levels are checked using soil moisture sensor. Whenever there is a change in moisture in the soil these sensors senses the change and transmit it through RF transmitter, and gives an interrupt signal to the micro-controller through RF receiver and thus the watering system is activated or deactivated via switching relays. This system will help in saving money and water and at the same time increasing crops production.

Key words: high quality yields, automatic irrigation system, AT89C52 microcontroller, soil moisture sensor, RF transceiver.

ACKNOWLEDGMENT

Praise GOD for his Almighty and Graciousness, we were able to complete this project report in the dateline given.

First and foremost, we would like to thank our respective advisor S.Sateesh for the guidance and brilliant ideas from him. Moreover, thank you so much to our co adviser Feleke Fanta for his concern.

Furthermore, other lecturers at Electrical and Computer Engineering Departmentas involved with our project by providing full support since proposal phase and laboratory assistances for their cooperation at practical section.

Last but not least, thank you so much to our beloved parent and friends that gave us encouragement and morale support from behind.

Thank you so much.

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ACRONYM

SMS	Soil Moisture Sensor
VWC	Volumetric Water Content
PIC	Programmable Interface Controllers
LCD	Liquid crystal Display
LED	Light Emitting Diodes
PCB	Printed Circuit Board
IC	Integrated Circuit
PLD	Programmable Logic Devices
RAM	Random Access Memory
RF	Radio Frequency
ROM	Read Only Memory
Rx	Receiver Module
MCU	Central Control Unit (microcontroller)
CAD	Computer Aided Design
GND	Ground
CKT	Circuit
ADC	Analog to Digital Converter
SDLC	System Development Life Cycle
SPLD	Simple Programmable Logic Devices
Tx	Transmitter Module
SPDT	Single Pole Double Throw
DPST	Double Pole Single Throw
WLANs	Wireless Local Area Network
WSN	Wireless Sensor Network
FPGA	Field programmable get array

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CHAPTER ONE

INTRODUCTION

1.1. Background

Traditionally electrical motors in a home or at fields are controlled via switches that regulate the electricity to these devices. As the world gets more and more technologically advanced, we find new technology coming in deeper and deeper into our personal lives even at home. This automation is becoming more and more popular around the world and is becoming a common practice. The process of home automation works by making everything in the house automatically controlled using technology to control and do the jobs that we would normally do manually.

Agricultural irrigation is highly important in crop production everywhere in the world. In turkey, 75% of the current fresh water is consumed in the agricultural irrigation[1].

Ethiopia, our country with 12 river basins, is considered as 'the water tower' in the north east Africa. Most of the rivers in these basins cross the national boundary. According to various studies the total available water (mean annual flow) is estimated at 122 billion cubic meters and the ground water potential is about 2.6 billion cubic meters while the potentially farmland in the country has been estimated at 3.7 million hectares. Although Ethiopia's water resource is enormous, very little of it has been developed for agriculture, hydropower, industry, water supply and other purposes. Of the total flow only about 1.5% is utilized for power production and 2% for irrigation [2].

Therefore, efficient water management plays an important role in the irrigated agricultural cropping systems[3]. The demand for new water saving techniques in irrigation is increasing rapidly right now. In order to produce "more crop per drop", growers in (semi) arid regions currently explore irrigation techniques in the range from using less fresh water[4]. One of them is making agriculture in a manner of sense, which uses different type of sensors. A site-specific wireless sensor-based irrigation control system is a potential solution to optimize yields and maximize water use efficiency for fields with variation in water availability due to different soil characteristics or crop water needs and site-specifically controlling irrigation valves[5][6]. Decision making process with the controls is a variable option for determining when and where to irrigate, and how much water to use. Temporal monitoring of soil moisture at different growth stages of crop could prevent water stress and improve the crop yield[6].

After the usage of wireless technology began in agricultural irrigation, a trial was made to involve different types of equipments in such instrumentations. In terms of controllers, were designed microcontroller site-specific irrigation, wireless monitoring system was implemented with a field programmable gate array (FPGA). In terms of protocols, infra-red, GSM/GPRS WPANs (Wireless Personal Area Networks), Bluetooth, WLANs (Wireless Local Area Networks) have been put to different utilities to implement wireless sensors in precision agriculture[6][7].

This project we propose a unique System for motor start and stop utilizing Radio Frequency that is paired with a wireless module to provide seamless wireless control over many devices in our houses and fields. The RF transmitter transmit signal and this signal will be received by RF receiver and fed into the microcontroller for final control action based up on this the motor is triggered.

1.2. Statement of the problem

Currently, existing irrigation systems are mostly based on traditional, open ended and rarely with electrical control system. Even the existing electrically driven pumps are not yet efficient in their water usage and electric power consumptions. And these are also limited to some Sugarcane plantation areas.

Well relying on this existing mode of irrigation system incurs, extra electric (fuel) power consumption, and untimely operation of the system in general which is followed by the misuse of water and energy. These unnecessary costs incur a huge running cost and usually unaffordable for some private sectors.

And the sole target of this project is to design and implement an automated RF based irrigation system that takes into account the moisture level and operation time of pumps, where by the overall running costs of the production will be plummeted down, incredibly than time based manually operated irrigation system controlled using pivot and sprinkler in wonji shoe sugar factory sugar cane plantation irrigation control.

1.3. Objective of the project

1.3.1. General objective of the project

The General aim of the project is to build and implement a wide area coverage irrigation automation control system that has a capability to communicate with the central control unit.

1.3.2. Specific objective of the project

- To control the flow of water so that it can be effectively used in the irrigation system this leads us to the term irrigation scheduling.
- To improve water usage efficiency by measuring the humidity of farm land soil during irrigation.
- To control the distribution of optimum amount of water to various areas, as considered necessary by them according to their requirements.
- To reduce the manpower required for monitoring and performing irrigation activities.

1.4. The scope of the project

As the name implies, RF based irrigation control system is a system used to control the irrigation components and sub modules with the aid of RF signals. Being an RF it has many merits over wire cabling.For instance the complexity of the system and wiring costs and communication signal degradations are all avoided because of the neat RF communication phenomenon.And the prime scope of this project is to build and execute a programmed microcontroller reads in the moisture of different sensors and actuates the respective region solenoid valves and electric pump.

For the sake of convenience the RF transmitter and receiver to be designed and build in this project can communicate to one another with in distance, under no obstructions. And the scope of the project is not limited to reveal the RF signal communication with microcontroller. The scope of this study to design an RF based irrigation control system that can accommodate about 255 different sensors and signal coverage a distance.

1.5. Methodology

Systematic design methods (called design methodologies) are necessary for successfully designing a complex digital hardware. There may be specific tasks involved with system development. Although the arrangement and order of these tasks may vary from organization to organization, a system development project typically consists of six steps – problem analysis, program design, program coding, and program debugging, testing and program maintenance.

As each critical development activity is taking place, documentations are generated. Documentation consists of details about what the program does and how it works. During the first few steps of the system development life cycle (SDLC), the systems analyst develops a set of specification's indicating exactly what the new system should do and how it will work. These specifications include data flow diagrams, system flow charts, input and output designs, and so on.In this step of the SDLC, the specifications developed during the problem analysis step are used to define a precise description of the nature of the required program.In this project two main methods considered in designing the system: Hardware design methodology and software design methodology.

In hardware designing different types of the components were selected according to their specifications and connected to together to build the complete system. The complete system circuit was drawn using different circuit making software. But, in this project proteus7.6 ISIS Professional is used to draw and to build the PCB of the system.In software designing the control algorithm was written in the form of flow chart and the program was written in Keil version 4 using C-Language. Then the entire program can be built and simulated on Proteus7.6 ISIS professional window.

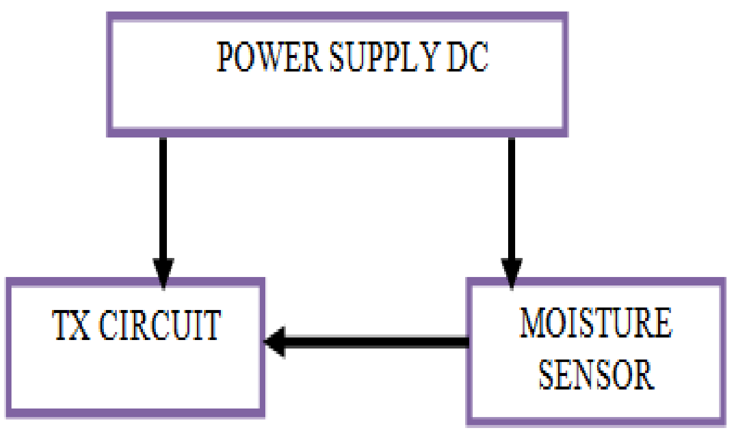


Figure 1.1 block diagram of Moisture sensor and Tx module

In figure 1.1 a moisture sensor detects the actual level of the moisture in the soil in terms of the voltage across the rod (sensor). The sensor senses and transfer to the radio transmitter. The transmitter transmits the signal and received by the radio receiver and feeds it in to the microcontroller then the control action generated by the microcontroller is amplified through a suitable amplifier that actuates the actuator (the pump) and finally controls the flow output of the pump via the dedicated electrical valves, as shown in figure 1.2 below.

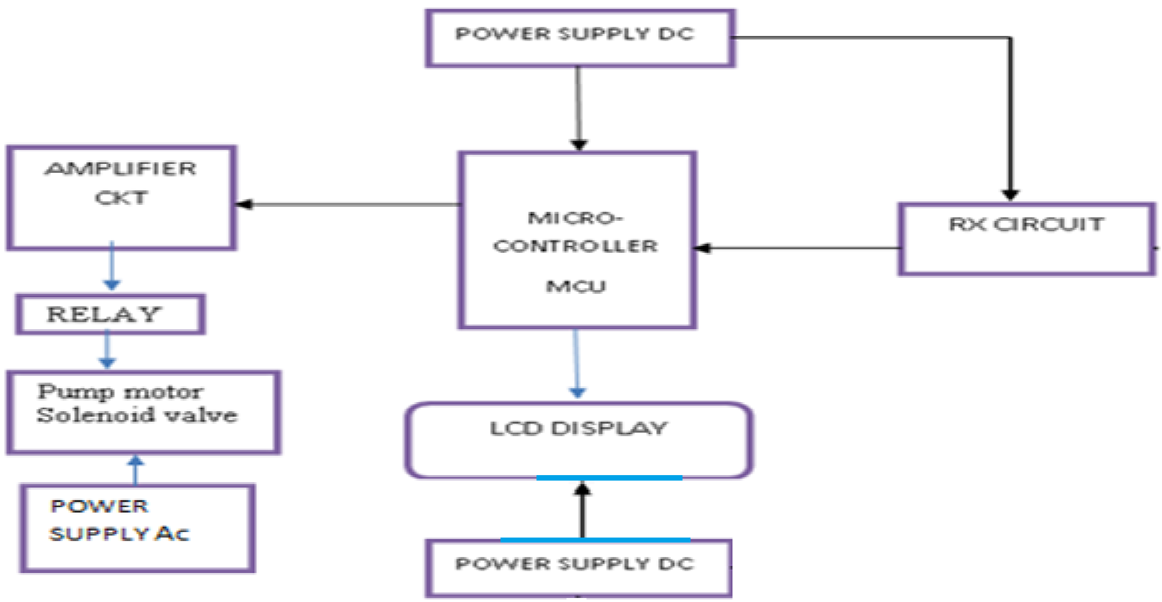


Figure 1.2 block diagram of main circuit

1.6. Significance of the Study

This project RF based irrigation system control that takes in to account the moisture level of soil and reacts accordingly. Different numbers of sensors are situated at different locations of the plot of land and communicate with the central control unit. The number of sensors is limited based on the size of plot of land. By using this technique the customers will benefit a lot.

Thus, the significances of this project are:

- optimize yields and maximize water usage efficiency
- Improve electric power consumption
- reduce the human work load
- Precision irrigation system.

1.7. Thesis Outline

Chapter 1 Introduction to the project

Chapter 2 Literature reviews of this project based on journals and other references.

Chapter 3 System design of the project. Details on the progress of the project are explained in this chapter.

Chapter 4 System hardware and soft ware implementation

Chapter 5 Results of the project and conclusion. The discussion focused on the result based on the experiment. Obstacle faced and future recommendation is also discussed in this chapter.

CHAPTER TWO

LITERATURE REVIEW

2.1. Principles

Irrigation is particularly a science of planning and designing a water supply system for agricultural land to protect the crops from bad effect of drought or low rainfall; The process of artificial application of water to the soil for the growth of agricultural crop is termed as irrigation It includes the following structures for the regular supply of water to the required command area the construction weir/barrage, dam/reservoir and canal system [5].

Distribution of irrigation water is taken from the sources by any of the techniques (Diversion from river or reservoir or pumped from the ground sources etc), it can be distributed to the agricultural field by different methods Surface Method of Irrigation, Sub-Surface Method/ Drip Irrigation and Sprinkler Irrigation Method [14].

Good irrigation water management will increase yields, improve crop quality, conserve water, save energy, decrease fertilizer requirements, and reduce non point source pollution. Using soil moisture measurements is one of the best and simplest ways to get feedback to help make improved water management [4].

The irrigation system is use only when there is not sufficient moisture in the soil and the microcontroller decides when should the pump be turned on/off, saves a lot time and water for the farmers. As there is no unanticipated usage of water, a lot of water is saved from creature wasted. This also gives much wanted rest to the farmers, as they don't have to go and revolve the pump on/off automatically [12].

2.2. Irrigation system control Technologies

There are several technologies associated with irrigation system control. To understand the different technologies and monitoring schemes properly, the systems studied can be broadly classified under different heads as below the classification of the existing systems based on different criteria: Technology Used, Processors Embedded, Sensors Incorporated and Crop fields Monitored.

2.2.1. Technology Used

In [8], Chandrika et al surveyed several GSM based farm irrigation systems and compared them. The result of the survey conducted has lead to a very positive approach on the impact of GSM technology in farm irrigation methods and techniques. With technology advancing everyday new techniques have been implemented for further minimizing the irrigation process like using prebuilt mobile phone or standalone application software for conduction the irrigation process. In [9], Mahesh focused on automizing the irrigation system for social welfare of Indian agricultural system and also to provide adequate irrigation in particular area. The set up consists of GSM which serves as an important part as it is responsible for controlling the irrigation on field and sends them to the receiver through coded signals. GSM operates through SMS and is the link between ARM processor and centralized unit. The project aims to implement the basic application of automizing the irrigation field by programming the components and building the necessary hardware. This project is used to find the exact field condition. GSM is used to inform the user about the exact field condition. The information is given on user request in form of SMS. GSM modem can be controlled by standard set of AT (Attention) commands. These commands can be used to control majority of the functions of GSM modem

In [11], Nirmal et al. Proposed idea about monitoring the crop field area without man power. The fundamental concept of this paper is to provide a highly enabled monitoring of paddy crop field. In this paper they have detailed how to utilize the sensors in paddy crop field area and explained about Wireless Sensor Network (WSN), Zigbee technology, Protocol stack of zigbee. They checked out the zigbee technology with two different commercial modules (Xbow and Xbee and analyze battery life under sensor deployed in the wet conditions and evaluate the reliability of communications and measurements.

In [13] Chavez et al. (2009) discussed limitations of the conventional PLC based irrigation control systems and a new approach to automate the irrigation is presented which uses a Single Board Computer (SBC) using the Linux operating system to control solenoids connected to individual or groups of nozzles based on prescribed application maps. The main control box houses the SBC connected to a sensor network radio, a GPS (Global Positioning System) unit, and an Ethernet radio creating a wireless connection to a remote server. A C-software control program control the overall working of system. A wireless drip irrigation system using soil moisture sensors is presented in [14] by MahirDursun et al (2011) and in [15] by V.I. Adamchuk.

This paper describes an application of a wireless sensor network for low-cost wireless controlled irrigation solution and real time monitoring of water content of soil based on soil moisture sensors. Data acquisition is performed by using solar powered wireless acquisition stations for the purpose of control of valves for irrigation. The designed system has 3 units namely: base station unit (BSU), valve unit (VU) and sensor unit (SU). The system is energy efficient.

2.2.2. Processors Embedded

In [10], Wenbin et al. introduced a WSN used for an intelligent temperature measurement system. In the system, temperature signals are acquired by digital multipoint thermometers, and transmitted to the advanced RISC microprocessor (ARM) by using WiFi technology. Then they are stored in SD card which is controlled by the microprocessor. The software design of data acquisition and the progress of transplanting Linux operating system to the ARM hardware platform is described. The system fully makes advantage of SD card's characteristic of huge and long-time storage, remedying the defect of Nor Flash's small storage in ARM. Long-distance control is accomplished; the huge data stored in SD card can be transferred to the control center.

[18][19][20] Used a 16-bit MSP (mixed signal processing) microcontroller. Its peripheral circuits include Liquid crystal display, keyboard functions, A/D converter and so on and it is suitable for applications that requires extremely low power consumptions.

In [21], Purnima et al. gives a review of the systems based on existing technologies and also proposes an economical and generic automatic irrigation system based on wireless sensors with GSM-Bluetooth for irrigation system controller and remote monitoring system. This system has simpler features designed with the objective of low cost and effective with less power consumption using sensors for remote monitoring and controlling devices which are controlled via SMS using a GSM module. A Bluetooth module is also interfaced with the main microcontroller chip. This Bluetooth module eliminates the usage charges by communicating with the appliances via Bluetooth when the application is in a limited range of few meters. The system informs user about any abnormal conditions like less moisture content and temperature rise, even concentration of CO_2 via SMS from the GSM module or by Bluetooth module to the farmer's mobile and actions are taken accordingly by the farmer.

2.2.3. Sensors Incorporated

In [12], Neelam R. et al presented a closed loop automatic irrigation system along with the temperature and water usage monitoring. The system can be used in greenhouses as well as open fields. The real time values of soil moisture, temperature(useful in greenhouse cultivation) are wirelessly transmitted using Zigbee technology from field to substation which controls the state of the motor and irrigation valves according to the desired moisture levels set by the user. A flow sensor is also 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. They discussed on sensor and substation module in detail and recorded the results for five different crops by measuring Soil Matrix Potential to initiate or terminate the irrigation process.

Dukes et al. (2003) used a commercially available dielectric sensor for lawns and gardens to control irrigation on green bell pepper. They found 50% reduction in water use with soil-water-based automatically irrigated bell pepper when compared to once daily manually irrigated treatments that had similar yields; however, maximum yields and water use were on the farmer treatment that was irrigated 1-2 times each day [17].

2.2.4. Crop fields Monitored

Rafael Muñoz-Carpena [16] et al. in Automatic irrigation based on soil moisture for vegetable crops studied the water conservation and new irrigation technology. They surveyed on the various types of sensors used. They focused on ways to minimize environmental effects caused by excess water supply. They focused on studying and comparing different tensiometric techniques which includes Tensiometers sensors and Granular Matrix Sensors. They also studied the effect of volumetric sensors that are suitable for irrigation by measuring Dielectric Constant in the field. They concluded that as water supplies become scarce and polluted, there is a need to irrigate more efficiently in order to minimize water use and chemical leaching. Recent advances in soil water sensoring make the commercial use of the technology possible to automate irrigation management for vegetable production. However, research indicates that different sensors types may not perform alike under all conditions. Reductions in water use range as high as 70% compared to farmer practices with no negative impact on crop yields.

2.2.5. Analyzing the existing systems

The existing systems studied are well equipped for Remote Monitoring of crop field depending upon the techniques used and the field requirements. Systems based on PC as the main controlling device make it possible to control remotely from any part of the world provided internet access is available to user. The system is of high cost due to the requirement of a computer. And special hardware and software installation is required to control the devices in a particular design. It is difficult to monitor and control the status of different sensors and devices in case of power failure unless you have a battery backup which is an additional cost. Zigbee based systems are better because they offer low power consumption, high reliability and has a place in the short distance wireless transmission technology and is the most suitable wireless technology for agriculture applications. It allows the administrator to instrument, observe and react to events and phenomena in an agriculture environment. Zigbee can also work on different networks like star, cluster tree, and mesh. However, in each of these cases, Zigbee will provide data exchange when nodes are down because the signaling information can be re-routed to other nodes easily. In fact, Zigbee can support 65,000 nodes. This makes it available for very large networks. GSM based systems offer advantages of being controlled from far flung places and simplicity of command. In GSM based system, the information is exchanged between far end and designed system via SMS on GSM network. A Bluetooth module is also interfaced with the main microcontroller chip which eliminates the SMS charges when the user is within the limited range of few meters to the designated system. The system informs users about many conditions like status of electricity, dry running motor, increased temperature, water content in soil and smoke via SMS on GSM network or by Bluetooth. Sensors based classification helps in selecting the crop specific and season specific sensors. Processors based on AVR, the Programming hardware is easy and Learning Curve is shorter compared to any other chip. High Performance to Cost ratio is there when compared to microcontroller 8051.Also 8051 consumes more power than AVR and PIC which are RISC based but their instruction Sets are entirely different.

From Programming point of view: 8051s are easy to code, next come PICs and last comes AVRs. 8051 has very powerful instruction set; it has commands which do more complex calculations. Whereas PICs and AVRs have simple single instructions but the programmer has to tell each and every step to get the results. 8051 is still in use because of its simplicity and popularity and less cost. AVRs and PICS are costly and come with many on chip peripherals like: hardware SPI, ADC, I2C, USART, Analog comparator, internal RC oscillator etc.PIC micros are also pretty good and for applications with demanding analog input requirements they are probably better than AVRs. They have ADCs that have high sampling speed as compared to the AVR [22].

2.3. Trends

The general direction of under-irrigation and over-irrigation they can provide irrigation to larger areas of plants with less water spending and inferior pressure. Using this system, one can save manpower, water to get better manufacture and eventually income. Advanced soil moisture level sensor will use in these we can measure different parameter that is pressure, temperature and humidity of soil. Different amount of water requirements for different types of soil in this according to the type of crop, and water resistance capacity in different seasons, system provide definite amount of water to the plant hence, we can save large amount of water.

CHAPTER THREE

SYSTEM DESIGN AND ANALYSIS

3.1. Structured Analysis and Design Method

This is a problem-solving technique that decomposes a system into component pieces for the purpose of studying how well those component parts work and interact to accomplish their purpose. Structured analysis is a model-driven, process-centered technique used to either analyze an existing system, define requirements for a new system, or both. The models are pictures that illustrate the system's component pieces: processes and their associated inputs, outputs, etc.

System design is a complementary problem-solving technique (to system analysis) that reassembles a system's component pieces back into a complete system-hopefully, an improved system.

3.1.1. Top-Down Decomposition

It is easier to understand the operation of the whole by looking at its pieces and their interactions. We "divide" a system into subsystems and components in order to more easily "conquer" the problem and build the larger system.This is a good strategy for constructing any kind of complex system. The process of top-down decomposition starts with the description of a whole system and replaces it with a series of smaller steps- each step is a more primitive subsystem.

Figure 3.1 shows one of the possible decompositions of the RF irrigation control system. It is broken down into input subsystem, control unit, output unit. Here control unit is responsible for the actual irrigation control system. Output subsystem displays the control action to the viewers. Input unit can produce different information for the control unit by using various sensors for detecting real time situation of the soil moisture status.The decomposition of the design into its subsystems is its structural representation. The approach can continue to any finer level of detail.

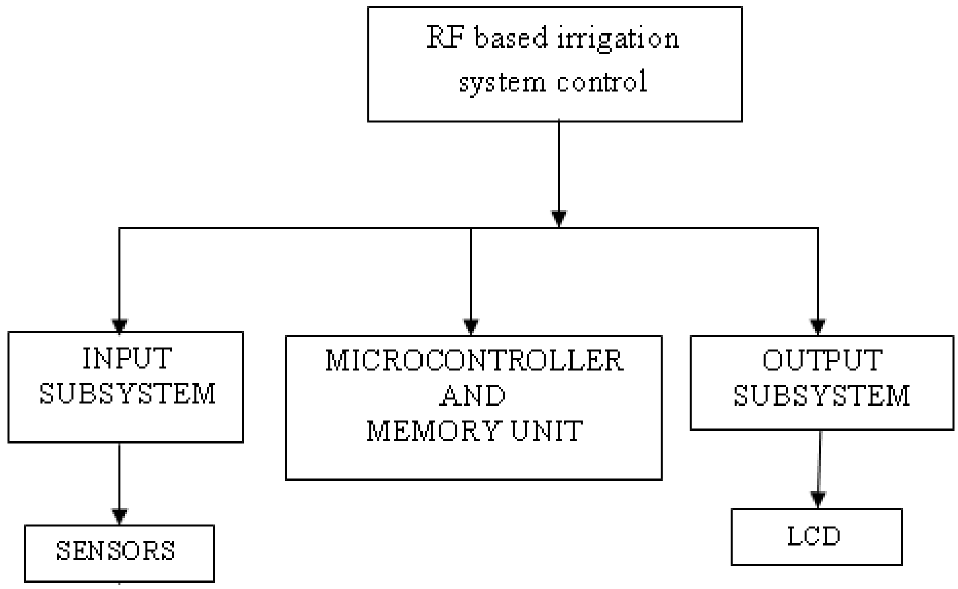


Figure 3.1 RF based irrigation system control

3.2. The Design Process

Any design process comprises a basic sequence of tasks that are performed in various situations. This sequence is presented in Figure 3.2 Assuming that we have an initial concept about what should be achieved in the design process, the first step is to generate an initial design. This step often requires a lot of manual effort because most designs have some specific goals that can be reached only through the designer's knowledge, skill, and intuition. The next step is the simulation of the design at hand.

There exist excellent CAD tools to assist in this step. To carry out the simulation successfully, it is necessary to have adequate input conditions that can be applied to the design that is being simulated and later to the final product that has to be tested. Applying these input conditions, the simulator tries to verify that the designed product will perform as required under the original product specifications. If the simulation reveals some errors, then the design must be changed to overcome the problems. The redesigned version is again simulated to determine whether the errors have disappeared. This loop is repeated until the simulation indicates a successful design. A prudent designer expends considerable effort to remedy errors during simulation because errors are typically much harder to fix if they are discovered late in the design process. Even so, some errors may not be detected during simulation, in which case they have to be dealt with in later stages of the development cycle.

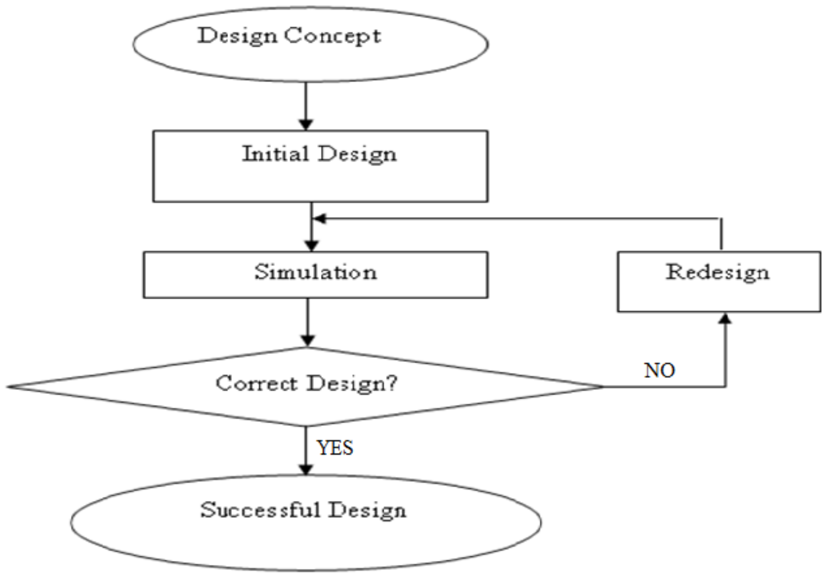


Figure 3.2The Design Loop

3.3. Analysis

The design of any new electronic system or device equipped with microcontroller needs premeditation at the beginning and the subsequent design of the electric circuit, printed copper board and the development of the microcontroller's software of course.

The RF based irrigation control system should consist of an input subsystem, basically moisture sensors are used in this system, the first sensor is responsible for detection of the region number one and other sensors are responsible for another region. So that the microcontroller give message to the motor for watering a given region, So this system solves such problem by detecting the moisture level of soil at the regions, Hence moisture sensors are used for input subsystem.

As embedded system, the control subsystem requires an efficient microcontroller device to make reprogramming possible. AT89C52 microcontroller is used as a brain of RF based irrigation control system.

Lastly, since the irrigation control system will have an embedded microcontroller, an embedded driving software program is needed to be written for it. Such software program will requires any of the embedded software languages understandable to the processor device of choice. Typically, C- language which can be converted to hex code using anKeil vision 4 compiler is chosen for this project.

3.4. Hardware Subsystem Design

Figure 3.3 below is the same diagram as shown in Figure 1.1 and Figure 1.2 of chapter one except that related blocks combined in their respective subsystem block. We are to deal with the design of the input, control and output subsystems of the irrigation control system in relevant sections.

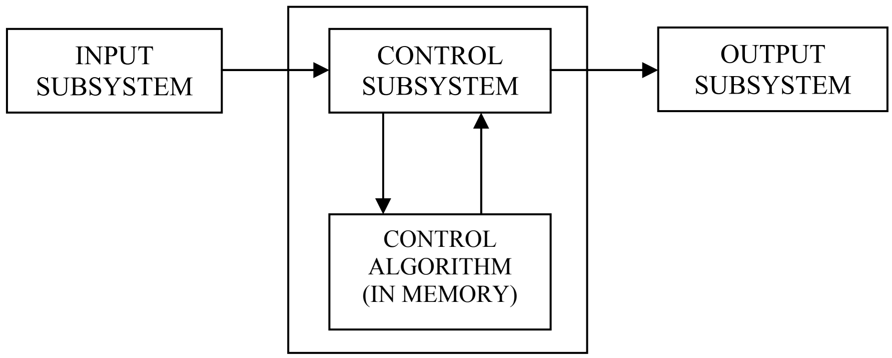


Figure 3.3 RF based irrigation control subsystem block

From figure 3.3 RF based irrigation control subsystem block has the following basic parts.

- The control algorithm which is embedded in the system's memory.
- The processing unit which contains the control logic for the input/output coordination using the resident control program in the chip's memory.

The input subsystem is interfaced with the control unit so that one can configure the control system by means of input. The control subsystem should have an output unit attached to it so that the control operation of the unit can be view externally. The various details of the hardware design shall be discussed under the relevant sections.

3.4.1.LM393 comparator

A comparator is an electronic device that compares two voltages or currents and gives a digital signal as the output. It indicates which of the two compared quantities is large. A comparator has at least two input pins and one output pin. Operational amplifier operating in open loop configuration and without negative feedback can be used as a simple comparator.One of the most commonly used comparators is LM393 and its circuit symbol is shown in Figure 3.4. It is available as an IC, figure3.5.

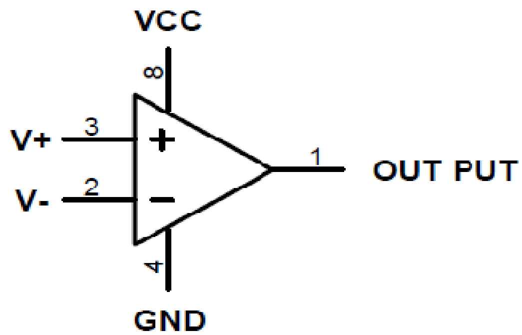


Figure 3.4 LM 393 Comparator Circuit

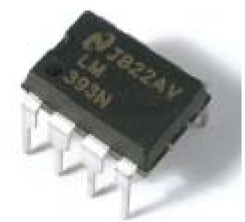


Figure3.5 LM 393 Comparator IC

It is preferred due to the following characteristics, listed on table 3.1:

Table 3.1 LM 393 Comparator specifications

Supply Voltage	2 V t0 36V
Supply	Single or Dual(±1.0 to±18)V
Current drain	0.4mA
Biasing Current	25nA
Offset Current	5nA
Saturation Voltage	3mV
Compatibility	TTL,DTL,ECL,MOSand CMOS logic

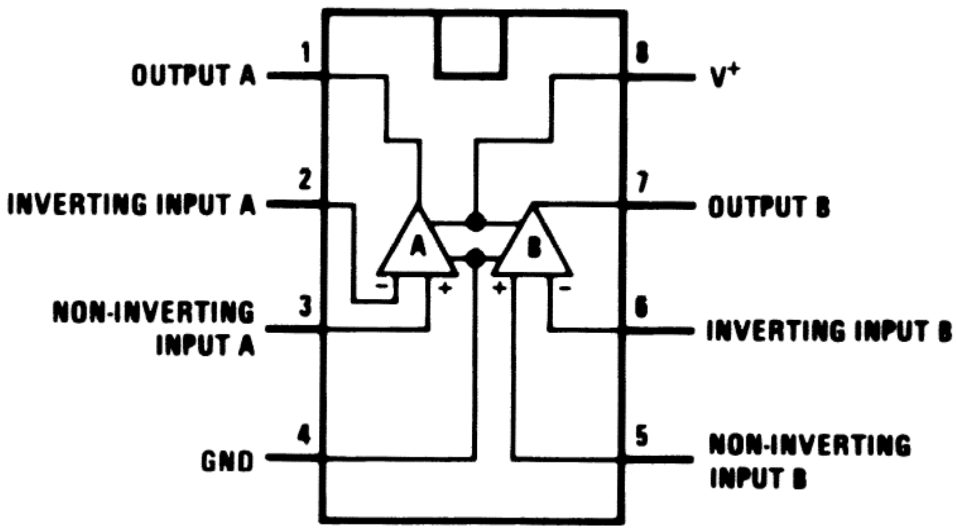


Figure 3.6 LM393 pin configuration

LM393 finds application in limit comparators, simple ADC, time delay generators and square wave generators among others. The capability of LM393 to interface with low power drain is an advantage over other types of comparators. LM393 is a dual comparator and its pin configuration is shown in figure 3.6.

3.4.2. Microcontroller

A microcontroller is a single on chip computer which includes number of peripherals like RAM, EEPROM, Timers etc, required to perform some predefined task [23]. There are different microcontroller families including: 8051, PIC (Programmable Interface Controller) and AVR. Microcontrollers are used in digital applications as control units [24]. Some microcontrollers come with their in-build circuits like Analog to digital convertors or digital to analog convertors. Microcontrollers are mostly programmed using assembly language but in recent year's high level languages like C, C++, PASCAL and Java have been used [25]. High level programming of microcontrollers brings the advantage of not having a different program for each microcontroller manufacturer. High level programming is also neat, easy to document and maintain and user friendly.

A microcontroller is a compact microcomputer designed to govern the operation of embedded systems in motor vehicles, robots, office machines, complex medical devices, mobile radio transceivers, vending machines, home appliances, and various other devices. A typical microcontroller includes a processor, memory, and peripherals.

The simplest microcontrollers facilitate the operation of the electromechanical systems found in everyday convenience items. Originally, such use was confined to large machines such as furnaces and automobile engines to optimize efficiency and performance. In recent years, microcontrollers have found their way into common items such as ovens, refrigerators, toasters, clock radios, and lawn watering systems. Microcomputers are also common in office machines such as photocopiers, scanners, fax machines and printers.

Figure 3.7 AT89C52 Microcontroller photo

AT89C52, figure 3.7,is an 8-bit microcontroller and belongs to Atmel's 8051 family. AT89C52 has 8KB of Flash programmable and erasable read only memory (PEROM) and 256 bytes of RAM. AT89C52 has an endurance of 1000 Write/Erase cycles which means that it can be erased and programmed to a maximum of 1000 times.Though very slight difference between the features of AT89C51 and **AT89C52**, they are very similar in their pin configurations and operations. The differences between AT89C51 and AT89C52 have been tabulated below in table 3.2.

Table 3.2differences between AT89C51 and AT89C52

	AT89C52	**AT89C51**
RAM	256 Bytes	128 Bytes
Flash	8 KB	4 KB
Number of Timers/Counters	3 (16-bit each)	2 (16-bit each)
Number of Interrupt Sources	8	6

The pin configuration of AT89C52 is exactly similar to that of AT89C51 except that the first two pins, P1.0 and P1.1 are multiplexed to correspond to Timer2 operations as given in the following table 3.3.

Table 3.3AT89C52 timer/counter pin configuration

Existing	Alternate	Function
P1.0	**T2**	Timer/counter 2 External Count input
P1.1	**T2 EX**	Timer/counter 2 Trigger input

While AT89C51 has two timers (Timer0 & Timer1), AT89C52 also has Timer2. Corresponding to Timer2, there are extra SFRs (Special Function Registers) T2CON and T2MOD. Also there are registers RCAP2H and RCAP2L to configure 16 bit Capture and Auto-reload modes of Timer2.

Therefore AT89C52 is selected based on above comparison. The pin diagram and the pin description of AT89C52 are shown in figure 3.8 and Table 3.4.

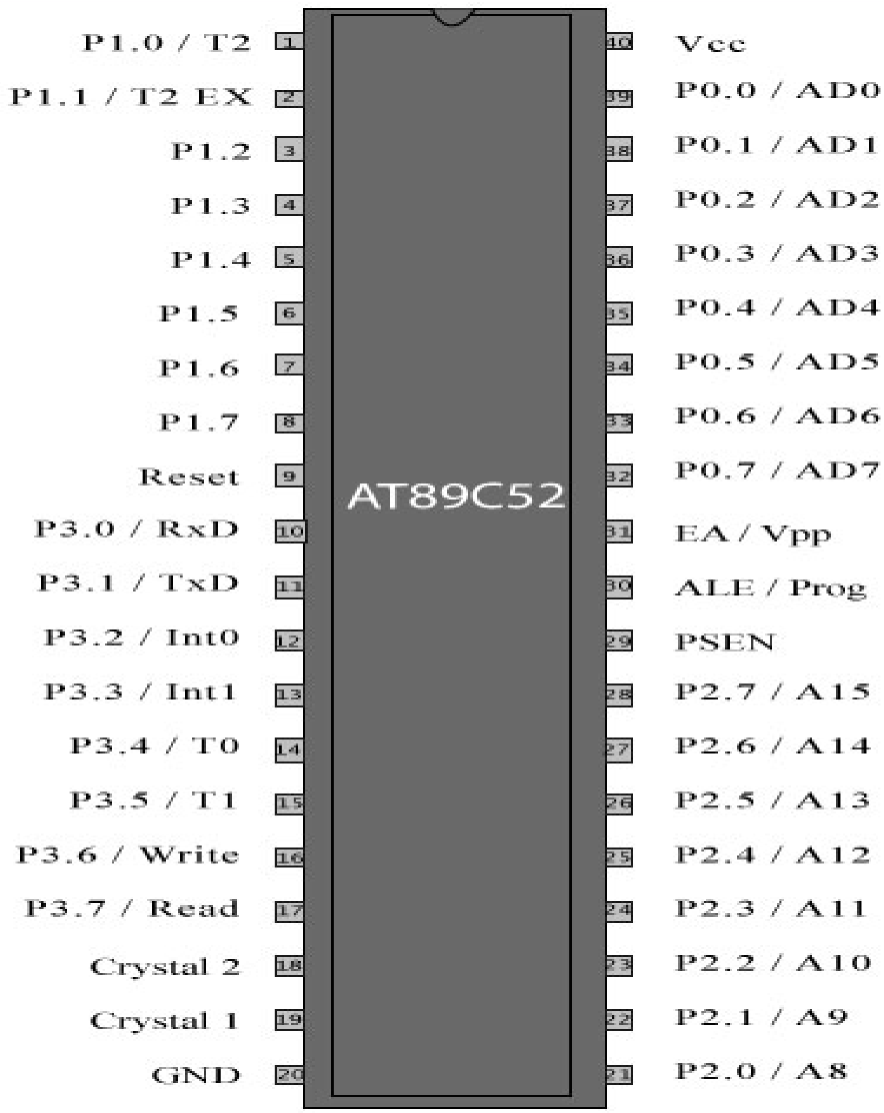


Figure 3.8 AT89C52 Pin Diagram

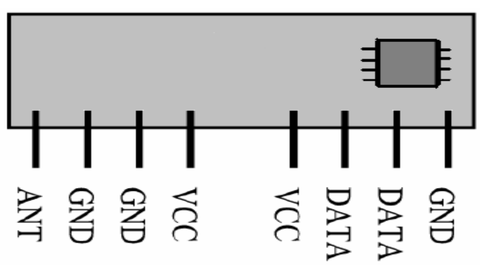
Table 3.4AT89C52 Pin Description

	Function			Name
1	External count input to Timer/Counter 2, clock-out	T_2		$P_1.0$
2	Timer/Counter 2 capture/reload trigger and direction control	T_2 EX		$P_1.1$
3	8 bit input/output port (P_1) pins			$P_1.2$
4				$P_1.3$
5				$P_1.4$
6				$P_1.5$
7				$P_1.6$
8				$P_1.7$
9	Reset pin; Active high			Reset
10	Input (receiver) for serial communication	RxD	8 bit input/output port (P_3) pins	$P_3.0$
11	Output (transmitter) for serial communication	TxD		$P_3.1$
12	External interrupt 1	Int0		$P_3.2$
13	External interrupt 2	Int1		$P_3.3$
14	Timer1 external input	T_0		$P_3.4$
15	Timer2 external input	T_1		$P_3.5$
16	Write to external data memory	Write		$P_3.6$
17	Read from external data memory	Read		$P_3.7$
18	Quartz crystal oscillator (up to 24 MHz)			Crystal 2
19				Crystal 1
20	Ground (0V)			Ground
21	8 bit input/output port (P_2) pins/ High-order address bits when interfacing with external memory			$P_2.0/ A_8$
22				$P_2.1/ A_9$
23				$P_2.2/ A_{10}$
24				$P_2.3/ A_{11}$
25				$P_2.4/ A_{12}$
26				$P_2.5/ A_{13}$
27				$P_2.6/ A_{14}$
28				$P_2.7/ A_{15}$
29	Program store enable; Read from external program memory			PSEN
30	Address Latch Enable			ALE
	Program pulse input during Flash programming			Prog
31	External Access Enable; Vcc for internal program executions			EA
	Programming enable voltage; 12V (during Flash programming)			Vpp
32	8 bit input/output port (P_0) pins Low-order address bits when interfacing with external memory			$P_0.7/ AD_7$
33				$P_0.6/ AD_6$
34				$P_0.5/ AD_5$
35				$P_0.4/ AD_4$
36				$P_0.3/ AD_3$
37				$P_0.2/ AD_2$
38				$P_0.1/ AD_1$
39				$P_0.0/ AD_0$
40	Supply voltage; 5V (up to 6.6V)			Vcc

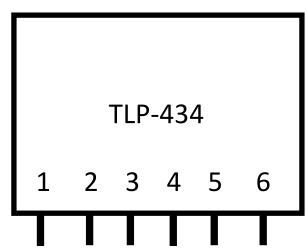
3.4.3. RF Modules (434MHz)

Radio frequency is a frequency or rate of oscillation within the range of about 3Hz to 300 GHz. This range corresponds to frequency of alternating current electrical signals used to produce and detect radio waves. Since most of this range is beyond the vibration rate the most mechanical systems can respond to, RF usually refers to oscillations in electrical circuits. RF is widely used because it does not require any line of sight, less distortions and no interference.

This RF transmission system employs Amplitude Shift Keying (ASK) with transmitter (TLP)/receiver (RLP) pair operating at 434 MHz The transmitter module (TLP-434) takes serial input and transmits these signals through RF. The transmitted signals are received by the receiver module (RLP-434) placed away from the source of transmission. The system allows one way communication between two nodes, namely, transmission and reception. The pin diagram of receiver (RLP-434) and transmitter (TLP-434) module along with pin description table is shown in figure 3.9 and table 3.5 and 3.6 respectively.



(a) Receiver Module (RLP-434)



(b) Transmitter module (TRP-434)

Figure 3.9 RF Pin Diagrams

Table 3.5 Transmitter Module pin description (TRP-434)

Pin Number	Function	Name
1	Supply Voltage (5V)	VCC
2	Supply Voltage (5V)	VCC
3	Ground (0V)	GND
4	Ground (0V)	GND
5	Antenna output Pin	RF Output
6	Digital data input	Data

Table 3.6 Receiver Module pin description (RLP- 434)

Pin Number	Function	Name
1	Ground (0V)	GND
2	Digital Data Output Pin	DATA
3	Linear Output Pin	NC
4	Supply Voltage (5V)	VCC
5	Supply Voltage (5V)	VCC
6	Ground (0V)	GND
7	Ground (0V)	GND
8	Antenna Input Pin	ANT

3.4.3.1. Working of RF module

This RF module comprise of a RF Transmitter and an RF Receiver. Radio Frequency (RF) transmission system employs Amplitude Shift Keying (ASK) with transmitter/receiver (Tx/Rx) pair which operates at 434 MHz .The sensor senses and transfer data to the radio transmitter and the transmitter transmits the signal through RF and the transmitted signals are being received by the receiver module operating at the same frequency like the transmitter and placed away from the source of transmission. The data out from RF receiver circuit feeds it in to the microcontroller then the control action generated by the microcontroller. The system allows one way communication between two nodes that are known as transmission and receiving, as shown in figure 3.10.

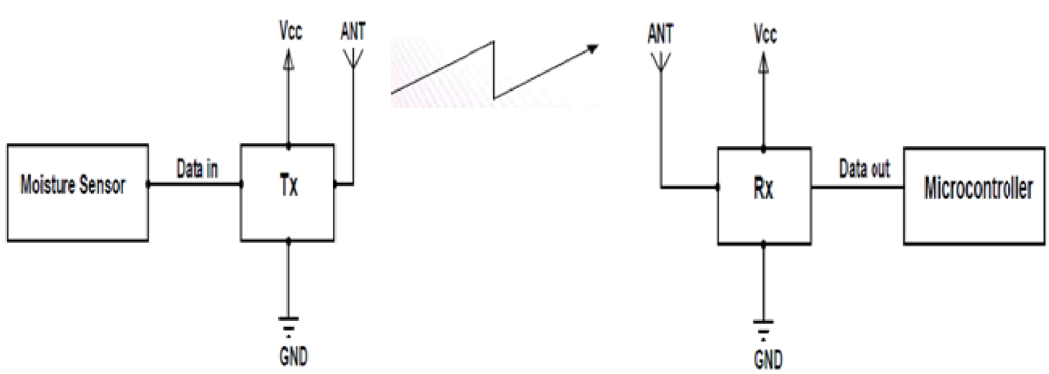


Figure 3.10 Block diagram for RF communication

3.4.4.Liquid Crystal Display (LCD)

Liquid Crystal Display (LCD) screen is an electronic display module. An LCD has a wide range of applications in electronics. The most basic and commonly used LCD in circuits is the 16x2 display, figure 3.11. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on.

A **16x2 LCD** means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The pin configurations of LCD (16x2) described in table 3.7.

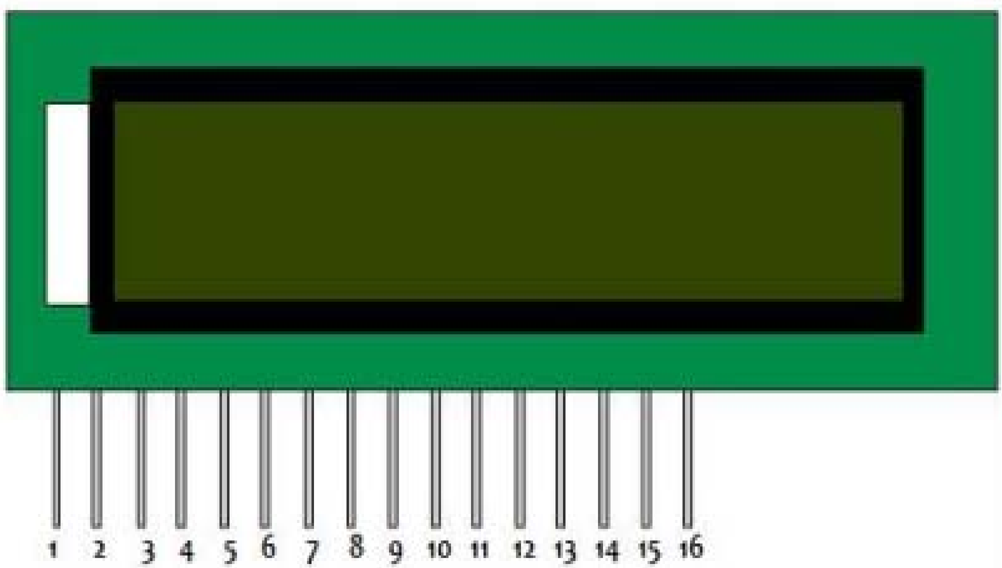


Figure 3.11 LCD (16X2)

Table 3.7 LCD (16x2) Pin configurations

Pin number	Function	Symbol
1	Ground (0V)	VSS
2	Supply voltage (5V)	VDD
3	Contrast adjustment; through a variable resistor(potentiometer)	V0
4	Selects command register when low; and data register when high	RS
5	Low to write to the register; High to read from the register	RW
6	Sends data to data pins when a high to low pulse is given	E
7	8-bit data pins	D0
8	8-bit data pins	D1
9	8-bit data pins	D2
10	8-bit data pins	D3
11	8-bit data pins	D4
12	8-bit data pins	D5
13	8-bit data pins	D6
14	8-bit data pins	D7
15	Backlight Vcc(5V)	A
16	Backlight Ground (0V)	K

When using 8-bit configuration all 8 data pins (DB0-DB7) are used while only 4 data pins (DB4-DB7) are used in a 4-bit configuration.

3.4.5. Relay switching circuit

This is an electromagnetic switch which is activated when a current is applied to it. A relay uses small currents to switch huge currents. Most relays use principle of electromagnetism to operate but still other operating principles like solid state are also used. A contactor is a type of relay which can handle a high power required to control an electric motor or other loads directly. Solid state relays have no moving parts and they use semiconductor devices to perform switching. Figure 3.12 shows 5VDC relay and its pins.

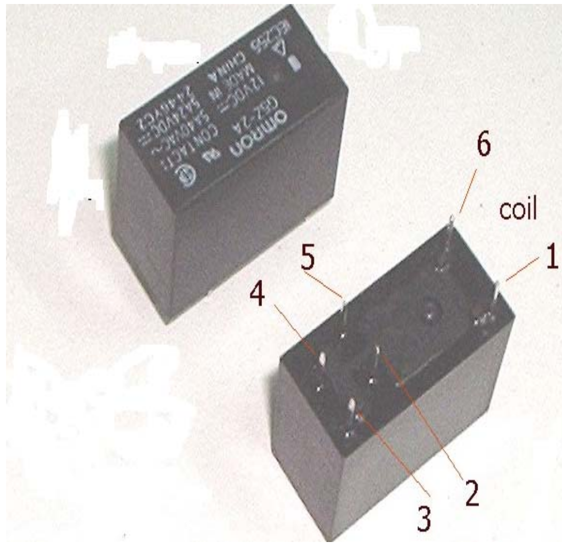


Figure 3.12Relay

Relays are switches and thus terminologies applied to switches are also applied to relays. A relay switches one or more poles, each of whose contacts can be thrown by energizing the coil in one of three ways.

- NO contacts connect the circuit when the relay is activated; the circuit is disconnected when the relay is inactive.
- NC contacts disconnect the circuit when the relay is activated; the circuit is connected when the relay is inactive.
- CO or double-throw (DT), contacts control two circuits: one normally-open contact and one normally-closed contact with a common terminal.

A contact relay switches one or more poles each of whose contacts can be thrown by energizing the coil in three ways namely; normally open(NO), normally closed(NC) or change over(CO). DPST ± Double Pole Single Throw. This relay configuring has six terminals. It is equivalent to SPST in that it is actuated by a single coil. Figure 3.13 shows a contacts and coil terminal inside a DPST relay.

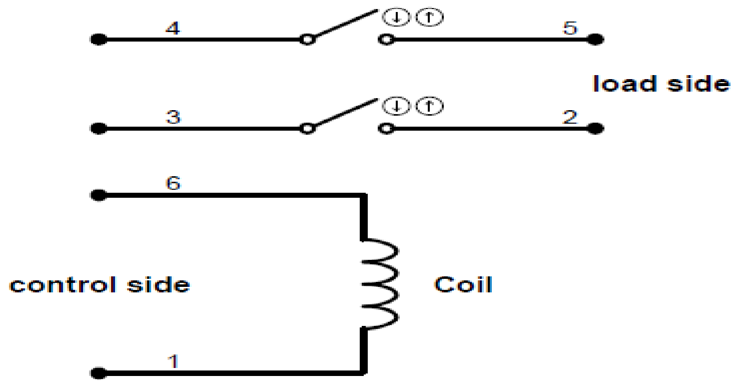


Figure 3.13Inside a DPST relay

A simple example, figure 3.14, of relay application is where a 5V DC circuit can be used to turn on/off a 220V AC motor.

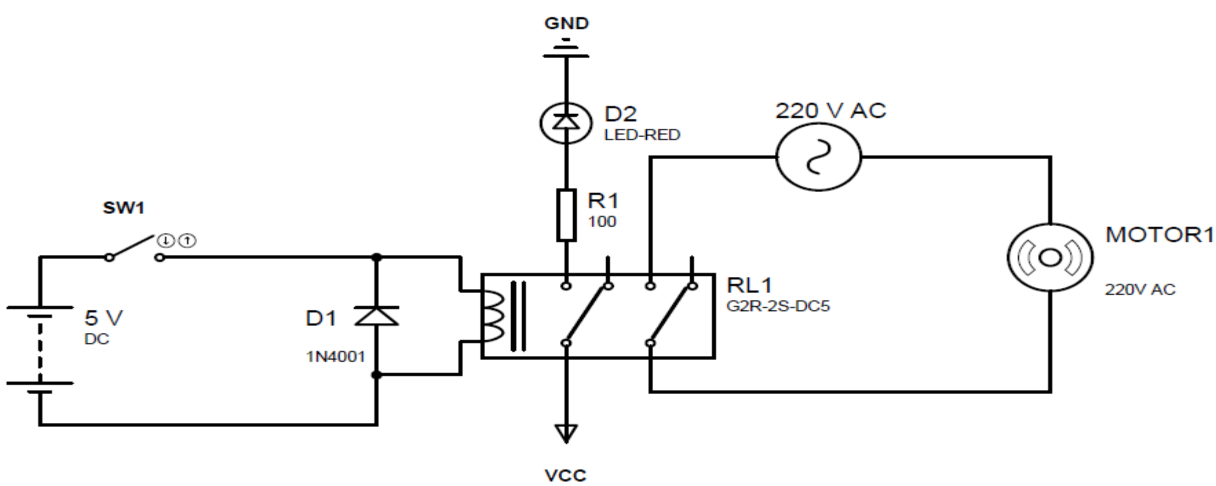


Figure 3.14 Simple relay interfacing

Whenever a relay is driven from a circuit that has delicate components such as integrated circuits or transistors, a diode is always included across the relay coil to prevent the relay from damaging the circuit.

3.4.6. Solenoid Valve

Solenoid control valves are electromagnetic valves that are used with both gas and liquid are controlled by the starting and stopping of electrical current through a solenoid. A solenoid is the coil in a wire that changes the state of the value. Solenoid control valves dictate the flow of water or air is used in fluid to perform both digital and analog operations. Solenoid valves may have two or more ports: in the case of a two-port valve the flow is switched on or off; in the case of a three-port valve, the outflow is switched between the two outlet ports. The inlet(s) and outlet(s) are also known as "ports".

3.4.6.1. Function of Solenoid Valve

Solenoid control valves are broken up into two main parts; they are the solenoid and the valves. The solenoid works to convert electrical energy into mechanical energy. This allows the valves to open and control mechanically. Solenoid control valves have metal seals that allow the electrical interfaces to be easily controlled. When the valves are not activated, a spring is used to hold the valve open or closed.

3.4.6.2. Operation Principle of solenoid valve

A solenoid valve is an electromechanical valve that is controlled by an electric current. An electrical source used 220V AC. The electric current runs through a solenoid, which is a wire coil wrapped around a metallic core. A solenoid creates a controlled magnetic field when an electrical current is passed through it. This magnetic field affects the state of the solenoid valve, causing the valve to open or close. Figure 3.15 shows the solenoid valve and its internal coil.

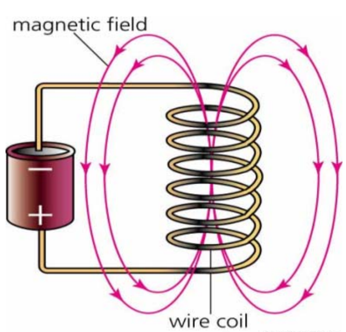


Figure 3.15Solenoid valve

Each of the two ports on a two way valve is alternately used to permit flow as well as close it off. A two way valve can be specified to be either “Normally Open" or “Normally Closed” in its operation. With a normally open valve, the valve remains open until some type of current is applied to close the valve. Suspension of the electrical power causes the valve to automatically re-open to its normal state. A normally closed solenoid valve is the most common, working in the opposite fashion, remaining closed until a power source causes it to open.

3.4.6.3 Direct Acting Valves

In a direct-acting solenoid valve, a coil magnetically opens the valve in a direct action, lifting the shaft and the seat of the valve without depending on outside pressure.

3.4.6.4 Application of solenoid valve

Solenoid valves are used to transport water and have a wide variety of applications. Solenoids offer fast and safe switching, high reliability, long service life, good medium compatibility of the materials used, low control power and compact design.

3.5. Water pump

The pump is used to provide sufficient pressure to move fluid at a required flow rate.The pump used in our case is 220 V AC, 50Hz. We can control the water pump by connecting it with an output pin of microcontroller via a motor driver circuit. When microcontroller sends a positive signal (+5v) or a ground signal (0v) to the motor driver circuit, then the water pump become on or off respectively. The overall water pump control circuit is shown below on figure 3.16.

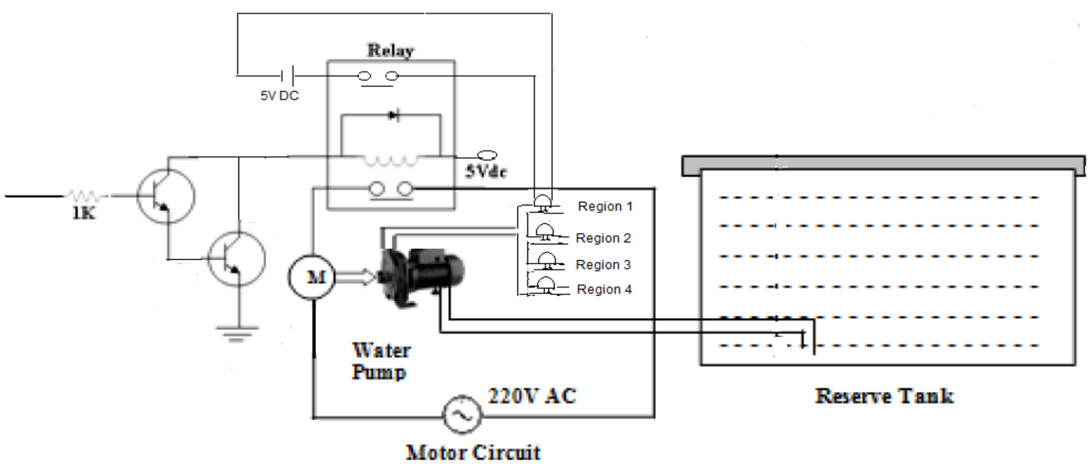


Figure 3.16 water pump control circuit

3.6. Printed Circuit Board (PCB)

A printed circuit board (PCB**)** is the board base for physically supporting and wiring the surface-mounted and socketed components in most electronics. In this project the PCB was mounted with resistors, LEDs, transistor, LCD, diode and the relay.

The following steps were followed in preparing the PCB.

1. The circuit's schematic was captured/designed using Express PCB software. Though not mandatory, this stage is very important in that it helps one in placing all the components correctly.
2. Using the same Express PCB application, the board layout with all the components and the power traces put were put in place. The circuit schematic was used to confirm all the components were placed correctly. Figure 3.17 shows the board layout of main circuit with its all components.
3. Then a MIRRORED image of the PCB layout of actual size was printed. The printout Printed only where traces are needed; blank or empty places on the printout will eventually contain no copper and be completely etched to the fiberglass under layer.
4. UV light was used to transfer the mask of the circuit layout from paper to the PCB.
5. The board was then developed by immersing in a basic and an acidic solution respectively. Two acids, ferric chloride (Eisen-3-Chlorid) and Sodium Per sulfate can be used at this stage (etching) .This stage took at least 20 minutes. When etching is done the board changes from opaque pink to transparent yellow.
6. Then the board was put into the rinse tank for a few seconds and then dried with a piece cloth.
7. Finally drilling of holes on the PCB was done and the board cut to the desired size.

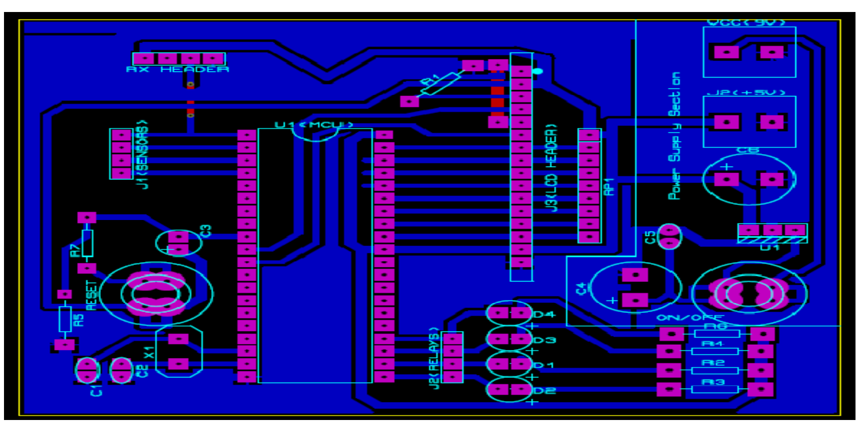


Figure3.17 Printed Circuit Board Main circuit

3.7. Software design

To be able to interpret the different states of the soil as prompted by the soil sensor the microcontroller was programmed. The program design expresses the algorithm set of steps needed to perform all the required tasks that the program must do. Coding is the process of writing the actual program steps in a programming language. The language of choice for this problem is c-language.

The irrigation regions of plot land to be controlled are software driven and thus require a software program to be written and embedded in the system's memory. Program flowcharts and pseudo-codes are used to show irrigation system control action. Therefore, the algorithm initially established and represented by a flowchart in figure 3.18. These flowcharts are then translated into C- language and compiled using a "Unipro" platform. The program in C- language can be referred in Appendix A.

3.7.1. Program Pseudo code

READ sensor value

COMPARE sensor value with set threshold

IF sensor value > maximum set value

TURN-ON pump

DISPLAY soil condition on LCD

LIGHT dry soil LED

ELSE IF sensor value < maximum set value > minimum set value

TURN-OFF pump

DISPLAY soil condition on LCD

LIGHT moist soil LED

ELSE IF sensor value < minimum set value

TURN-OFF pump

The entire program pseudo code is stated as flow diagram shown below in figure 3.18

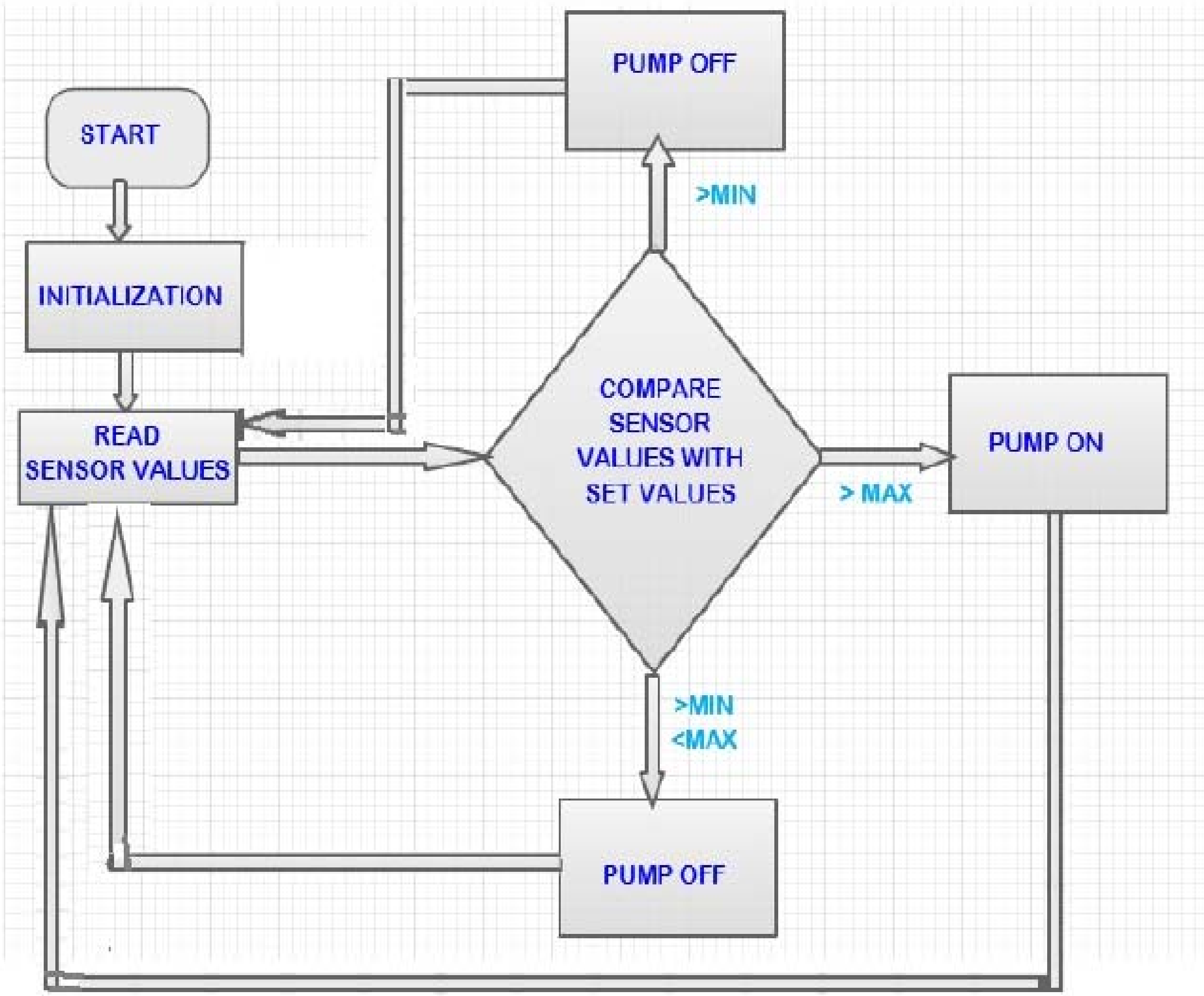


Figure 3.18.The program flow Diagram

CHAPTER FOUR

SYSTEM IMPLEMENTATION

4.1. Hardware Subsystem Implementation

The implementation of the hardware subsystem is done unit by unit. This is in line with the bottom-up implementation approach where each hardware module is implemented separately after which all are combined to give the entire system. The overall circuit diagram is given in figure4.1. The final circuitry was realized in the computer using a computer aided design (CAD) software tool Proteus ISIS. This enabled us to join all the separate parts of the system together and simulated the entire circuitry before carrying out the physical construction.

In order to reduce construction errors, the final circuitry was exported to another CAD software tool Proteus ARES, which guided in the production of all the tracks (signal lines) linking one pin to the other. The CAD tool makes it possible to easily layout the various components on board. Hence the components layout was properly positioned; each component before they are linked to one another by the traces.

By selecting the various device pins on the board, the CAD tool helped us to link the devices together as defined in the circuit diagram. With few manual alterations, the circuit track layout and traces were developed. This track layout is known as the printed circuit board (PCB) layout.

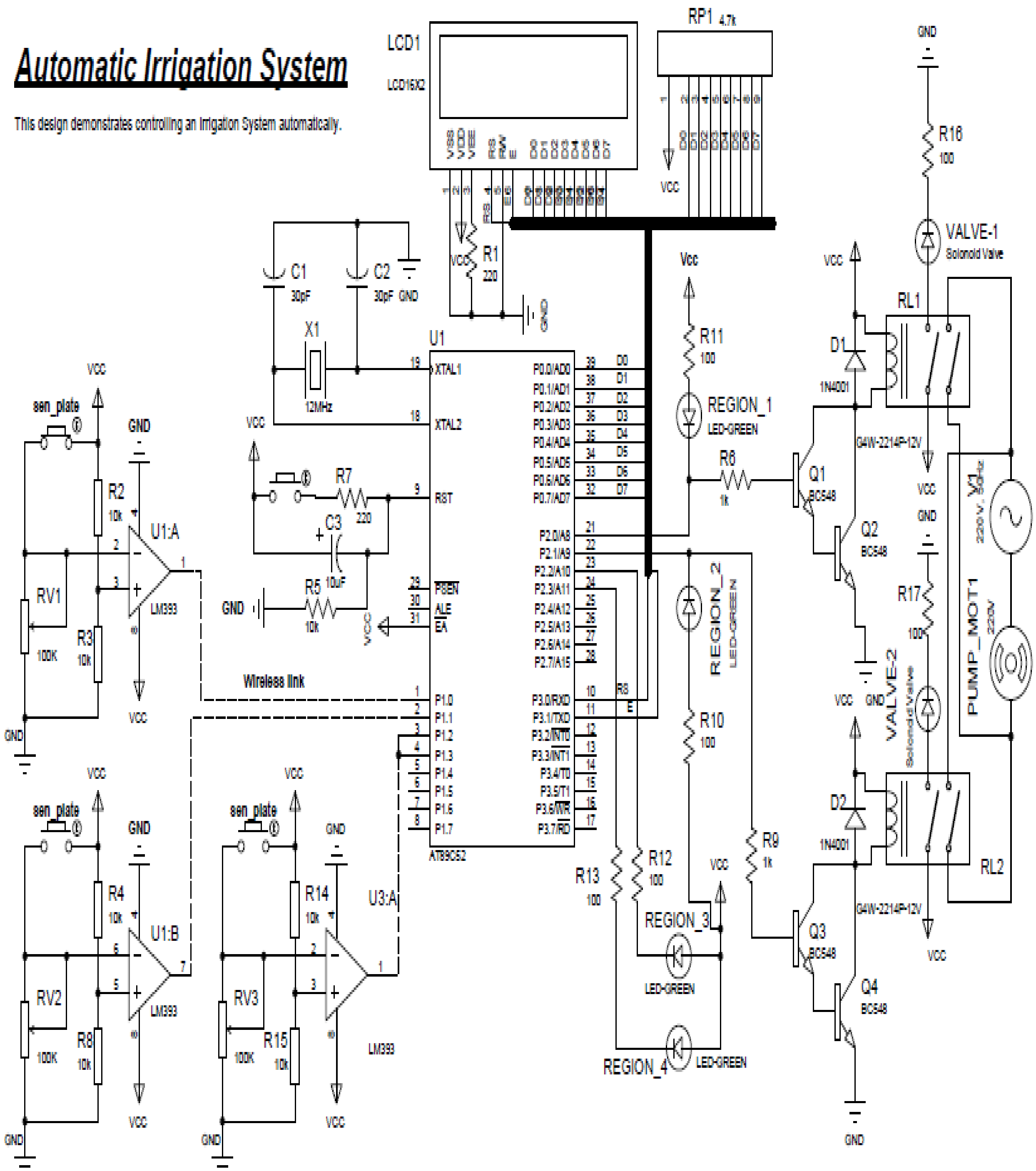


Figure 4.1 Project Circuit diagram

4.1.1. Working principle of the project

Soil moisture sensor circuit is used to monitor the moisture contained in soil. And send its data to microcontroller via RF transceiver circuit. According to that further action is taken by microcontroller as the output of circuit is given to the microcontroller. Indicator indicates whether the soil is dry or wet. Microcontroller is the heart of the system; it controls the overall irrigation system. It takes the input from moisture sensor 1, 2, 3 and 4. According to the written program it turns ON or OFF the motor pump as well as the solenoid valve. It also indicates the condition of soil. When soil is dry motor is on and when soil is wet motor is off. Thus microcontroller controls the operation of motor. On the basis of soil moisture detection, motor ON/OFF working will be done. Provision of water and considering the need of water to the crop is done by controlling motor. Along with this the valves are made on depending on the state of the soil. LCD is also used at field. It indicates message from the microcontroller like soil state, and motor state.

4.1.2. Sensor circuit

The present work comprises of development of a soil moisture sensor. The soil moisture sensor has been developed using the basic property that the resistance of the soil between two points decreases with the increase of water content in it. We know that water is a good conductor of electricity in the presence of ions. So, greater the amount of with electrolytes in the soil, greater will be the conductivity of the soil. This means that the resistance of the soil decreases. However, it has to be ensured that chemical fertilizers are not administered into the soil within a radius of 1m from the sensor. This will ensure that the conductivity of the soil will not change at the point of measurement due to application of chemical fertilizers. The developed sensor has two probes that are inserted into the soil. The distance between the probes is kept fixed. A resistance is connected in series with the probe and current is passed through it. The set-up works like a voltage divider and the voltage of the mid-point is given to the ADC of the microcontroller. The basic construction of probes and the circuit is given below.

The Probes are made using two metal rods tied together using an insulating tape. The two probes are separated by a small rubber block which keeps the two probes apart. The photograph of the soil moisture sensor probe is shown below in figure 4.2.

Figure4.2 soil moisture sensor probes

The circuit consists of a LM393 comparator, simple ADC, time delay generators and square wave generators among others, the capability of LM393 to interface with low power drain. The potentiometer is given to the one end of the probe. At the other end of the probe there is a series resistance and the output between these twoprobes is given to comparator followed by RF transmitter circuit. This setup gives the DC value depending on the resistance due to soil between the probes. The LM393 comparator is used to compare the voltages across the sensor probes and the set VCC voltage. The circuit diagram is shown below in figure4.3.

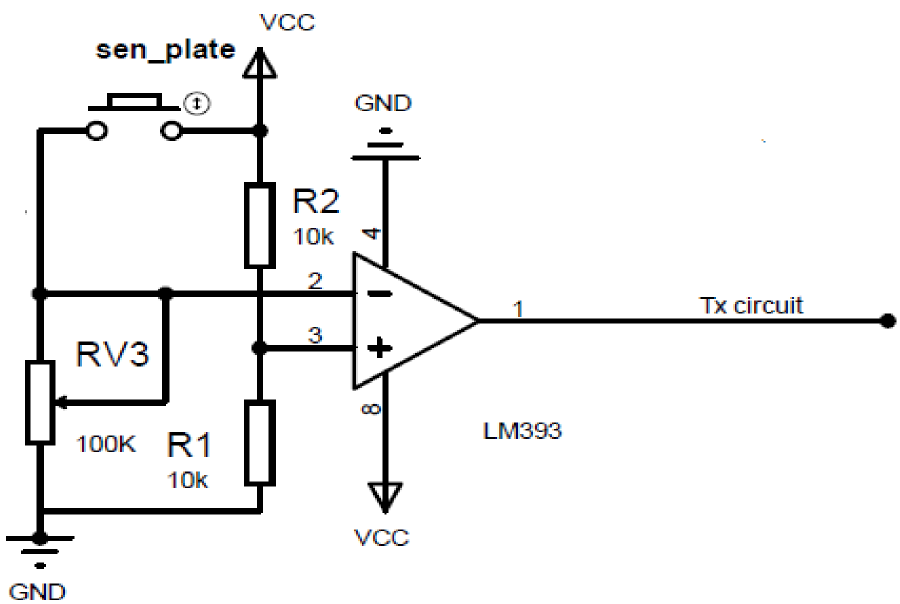


Figure4.3Moisture sensor circuit

The resistance to flow of current between the sensor probes changes with soil moisture level and soil type. The current passing through the sensor probes (Iout) for different soils and different soil moisture levels was calculated as shown below:

Iout = Vcc / {Soil Resistance value (RS)}

4.1.3. Microcontroller circuit

The microcontroller has a program running on it, which acts as a small Operating System. It has a user interface, and takes inputs from the user and accordingly takes actions. The signal transmitted from the sensor circuit using RF transmitter is received by RF receiver that is connected to microcontroller for control system. Pin 1, 2, 3and 4 were connected to the RF receivers individually, that receives RF signals transmitted from RF transmitters that were connected to soil moisture sensor circuit.

Pin 9 was connected to reset circuit. Pin 10 was connected to LCD's RS (Register Select). Pin 11 was connected to LCD's E (Enable). Pin 18 and 19 were connected to oscillator circuit. Pin 21, 22, 23 and 24 were connected to water pump drive circuit for the final control action. Pin 31 connected to VCC (+5V DC). LCD pins D0, D1, D2, D3, D4, D5, D6 and D7 were used as data lines in an 8 bit mode configuration. These pins were connected to RESPACK pins 2, 3, 4, 5,6,7,8 and 9 respectively; and connected to microcontroller pins 39, 38, 37, 36, 35, 34, 33, and 32 respectively.

4.1.3.1. Oscillator Characteristics

An oscillator is simply a signal generator converting its DC supply voltage into a continuously repeating AC output signal without any input signal. Oscillators play very important roles in communication systems. An oscillator generates the carrier or local oscillation signal used in any communication system [26].

XTAL1 and XTAL2 are the input and output, respectively, of an inverting amplifier that can be configured for use as an on-chip oscillator, as shown in figure below. Either a quartz crystal or ceramic resonator may be used. The clock circuit of AT89C52 composed of 18, 19 feet from the clock side (XTALI and XTAL2), and 12MHz crystal X, capacitor C1 and C2, and uses on-chip oscillator mode.

Note: C1, C2 = 30 pF ±10 pF for Crystals = 40 pF ±10 pF for Ceramic Resonators from data sheet.

4.1.3.2. Reset circuit

A good implementation of internal reset, besides having properly set trip voltage levels and Perhaps also fusible options for duration, may also after reaching proper supply voltage and expiring the delay, hold the microcontroller in reset for a number of oscillator clock occurs (to enable oscillator stabilization); and it should have an output to reset the surrounding circuitry. Uses a simple power-on reset circuit, and constitute of resistor R1, capacitor C3, and R3 connected to the AT89C52's reset input pin.

Note: R1=220Ω, R2= 10KΩ, C3= 10μF, VCC= +5V from data sheet.

Figure 4.4 shows the assigned pin of the microcontroller for input from sensor circuit, LCD circuit, and pump drive circuit, in addition with the oscillator circuit and reset circuit.

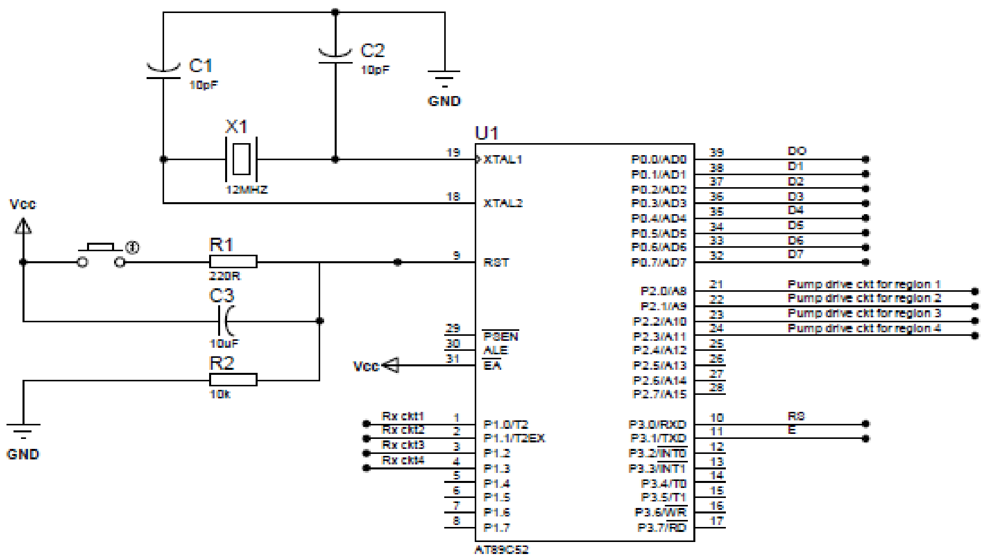


Figure.4.4 Microcontroller

4.1.4. LCD circuit

To affect display a 16x2 Liquid Crystal Display (LCD) was chosen. LCD pins D0, D1, D2, D3, D4, D5, D6 and D7 were used as data lines in an 8 bit mode configuration. These pins were connected to RESPACK pins 2, 3, 4, 5,6,7,8 and 9 respectively; and connected to microcontroller pins 39, 38, 37, 36, 35, 34, 33, and 32 respectively. Pin 15(A) was connected to VCC and pin 16 (K) was connected to GND. These pins (A and K) are for the LEDs integrated on the LCD circuit board. LCD’s pin E (Enable) was connected to pin 11 on the MCU. Pin RS (Register Select) on the LCD was connected to MCU pin 10. R/W pin of the LCD was connected to GND (ground). The pin connection of the LCD circuit with the resistor pack is shown in the figure 4.5 below.

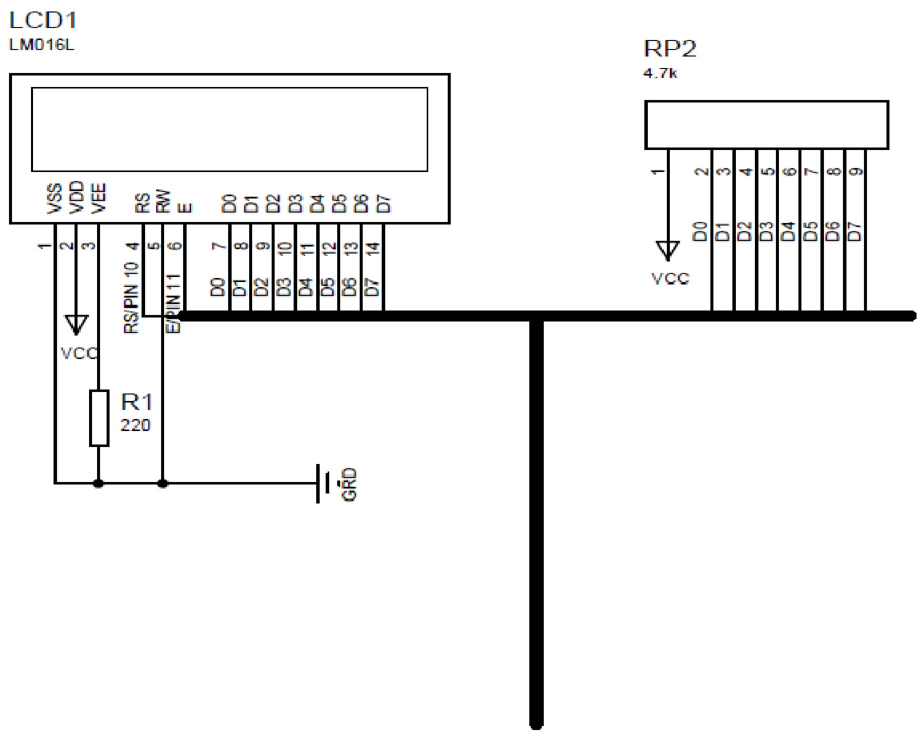


Figure 4.5LCD circuit

4.1.5. Water pump drive circuit

To implement the final bit of the automated irrigation system an electric motor (220VAC) was selected as the water pump. The first two units of the system i.e. sensing unit and the control unit (microcontroller) are powered by 5VDC. To interface the two units a 5VDC relay (G4W-2214P-5V) was used as the isolation unit. The microcontroller was connected to the relay via an NPN transistor (BC548). To protect the transistor; while turning it on, a resistor was used. The resistor limits the current flowing through the transistor. The maximum base current that the transistor could handle is 12mA.

R_B = (5 – 0.7) V / 12mA =358.33Ω.Since there are no available resistor of the computed value and the next higher value 390Ω resistor; We decide to use 1K Ω resistor just to limit the 5V that will applied to the transistor and thus the current through the transistor was limited to; 4.3V / 1kΩ = 4.3 mA. To protect the microcontroller from back e.m.f during switching a diode (1N4001) was connected across the relay. A 100 ~ 200 ohm resistor was connected in series with an LED, to prevent burning out the LED. Figure 4.6 shows the connection of water pump drive circuit with single sensor and figure 4.7 shows the connection of Water pump drive circuit with two sensors.

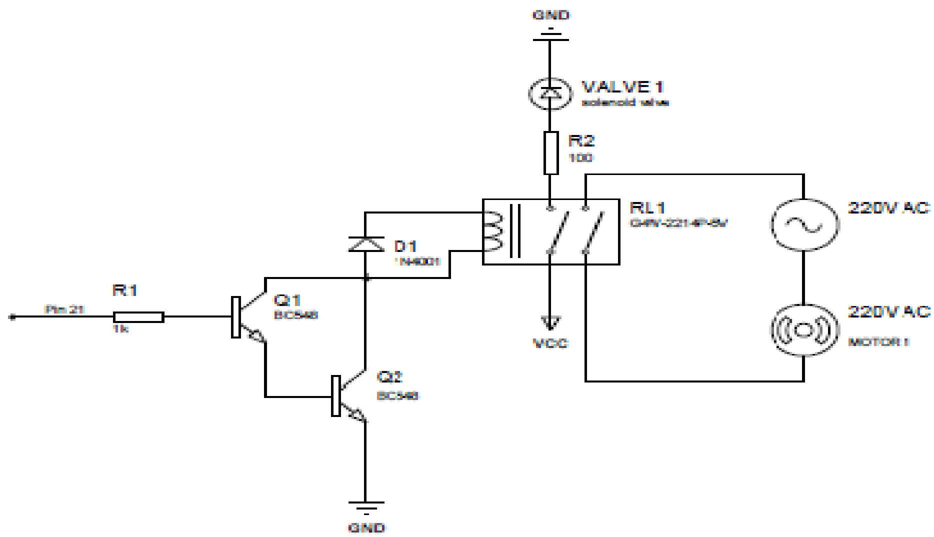


Figure 4.6 water pump drive circuit withsingle sensor

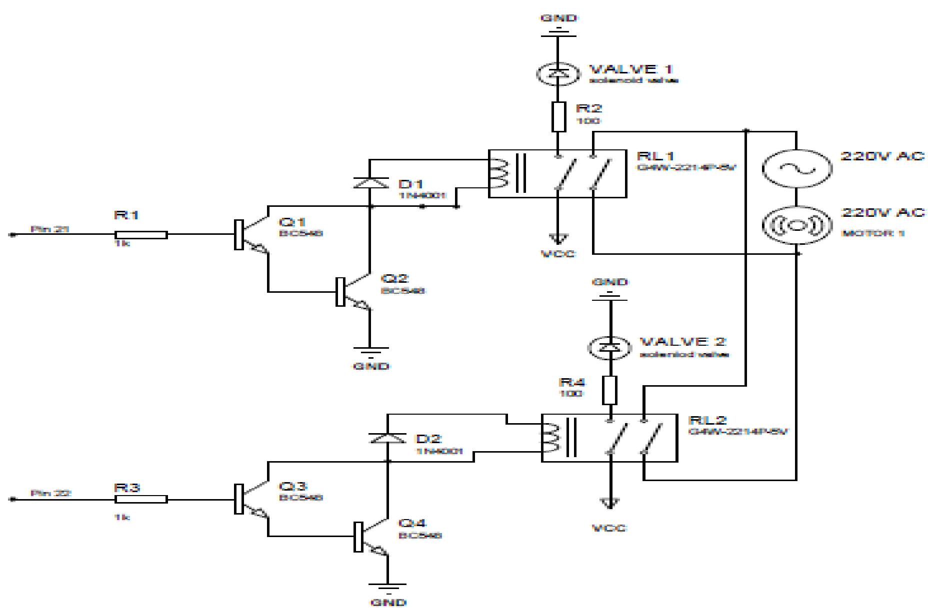


Figure 4.7 Water pump drive circuit with two sensors

4.1.6. Regulated DC Power Supply

A regulated power supply is very much essential for several electronic devices due to the semiconductor material employed in them have a fixed rate of current as well as voltage. The device may get damaged if there is any deviation from the fixed rate. The AC power supply gets converted into constant DC by a circuit shown in figure 4.8 below. By the help of a voltage regulator DC, unregulated output will be fixed to a constant voltage. The circuit is made up of linear voltage regulator 7805 along with capacitors and resistors with bridge rectifier made up from diodes.

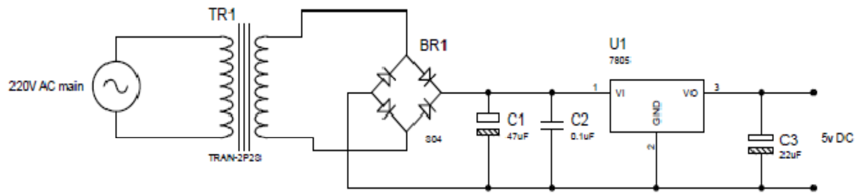


Figure 4.8 Regulated DC power supply

As we have made the whole circuit till now to be operated on the 5V DC supply, so we have to use an IC regulator for 5V DC. And the most generally used IC regulators get into the market for 5V DC regulation use is 7805. IC 7805, figure 4.9, is a DC regulated IC of 5V. This IC is very flexible and is widely employed in all types of circuit like a voltage regulator. It is a three terminal device and mainly called input, output and ground. The pin description of LM7805 is described on table 4.1 below.

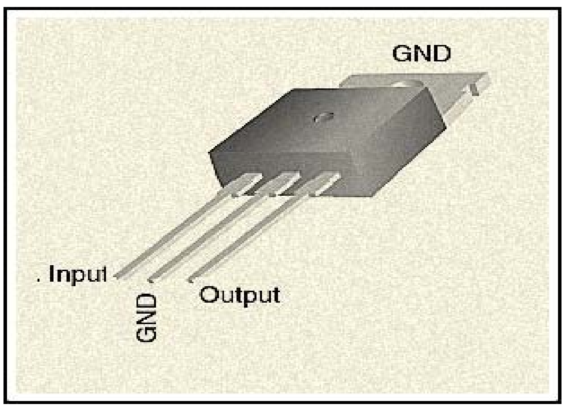


Figure 4.9 LM7805 IC Regulators

Table: 4.1 LM7805 Pin descriptions

PIN NO.	PIN	DESCRIPTION
1	INPUT	In this pin of the IC positive unregulated voltage is given in regulation.
2	GROUND	In this pin where the ground is given. This pin is neutral for equally the input and output.
3	OUTPUT	The output of the regulated 5V volt is taken out at this pin of the IC regulator.

The complete circuitry is operated with TTL logic level of 0-5V. It comprise of 0V to 9V transformer to step down the 220V AC supply to 9V AC. Further a bridge rectifier converts the 9V into 9V*√2 DC. It is further filtered through a 47µF capacitor and then regulated using LM7805 to get +5V. To isolate the output voltage of +5V from noise further filtering 22µF capacitor is done. But we can use a simple 9V DC power supply with the combination of IC LM7805 and capacitors to have a regulated 5V supply for our microcontroller.

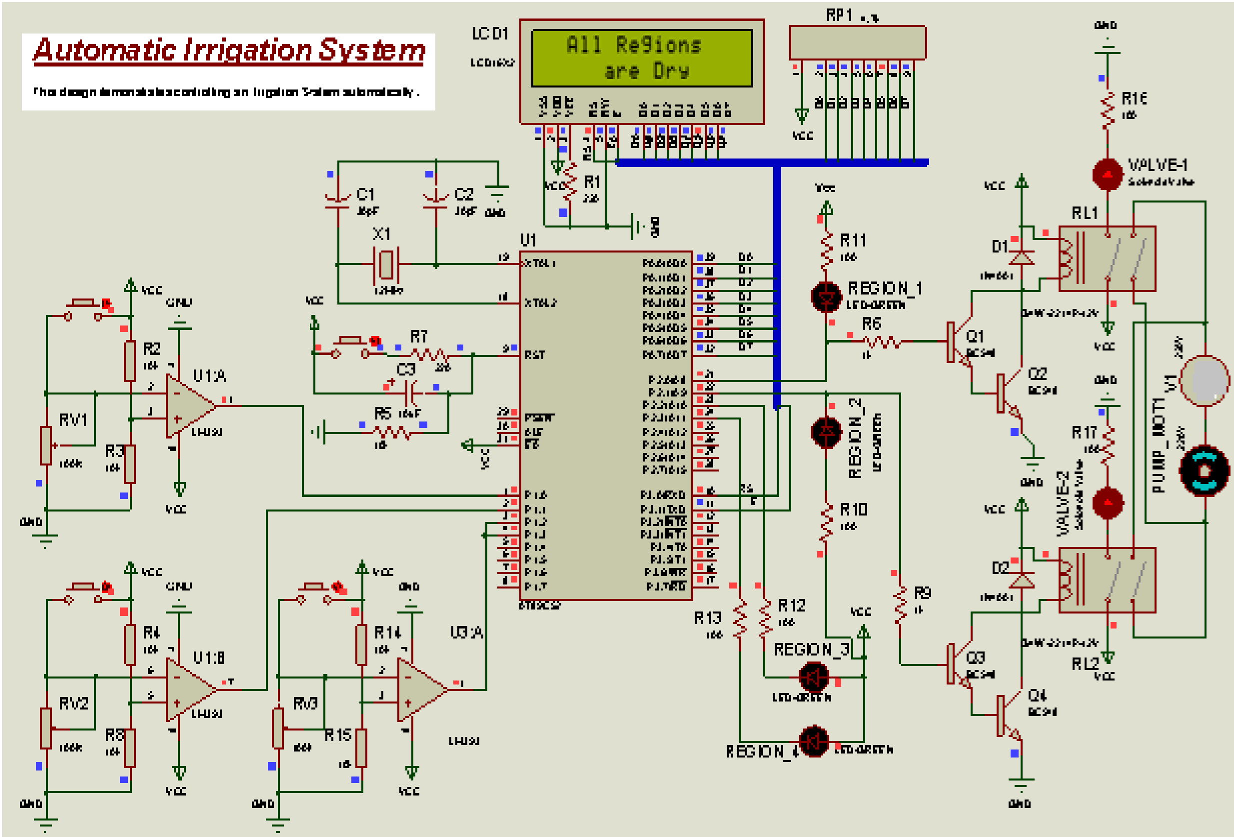
4.2. Software Subsystem Implementation

The entire software driving the irrigation system control is implemented Using C- language coding. The source code was developed inkeilC51 version 9.05and compiled using keil µvision 4 to generate Hex file. The Hex file was then burnt into the flash memory of the AT89C52 microcontroller with the aid of a device called a "Unipro" programmer. The entire Source code is given in appendix A.

4.2.1. Simulation of the Project

After compilation the program written on keilC51 version 9.05 µvisions 4 a hex file is generated. by browsing this file to the Proteus ISIS window all instructions are loaded to AT89C52 Microcontroller unit. After loading instruction to MCU memory we are ready to run the simulation.

Case 1.When all sensors send a dry state message, microcontroller decides to irrigate all regions. All regions are dry statement is display on LCD screen and region indicator LEDs are not lit. As a result of these all solenoid valves and motor are activated to watering regions, as shown in figure 4.10 below.



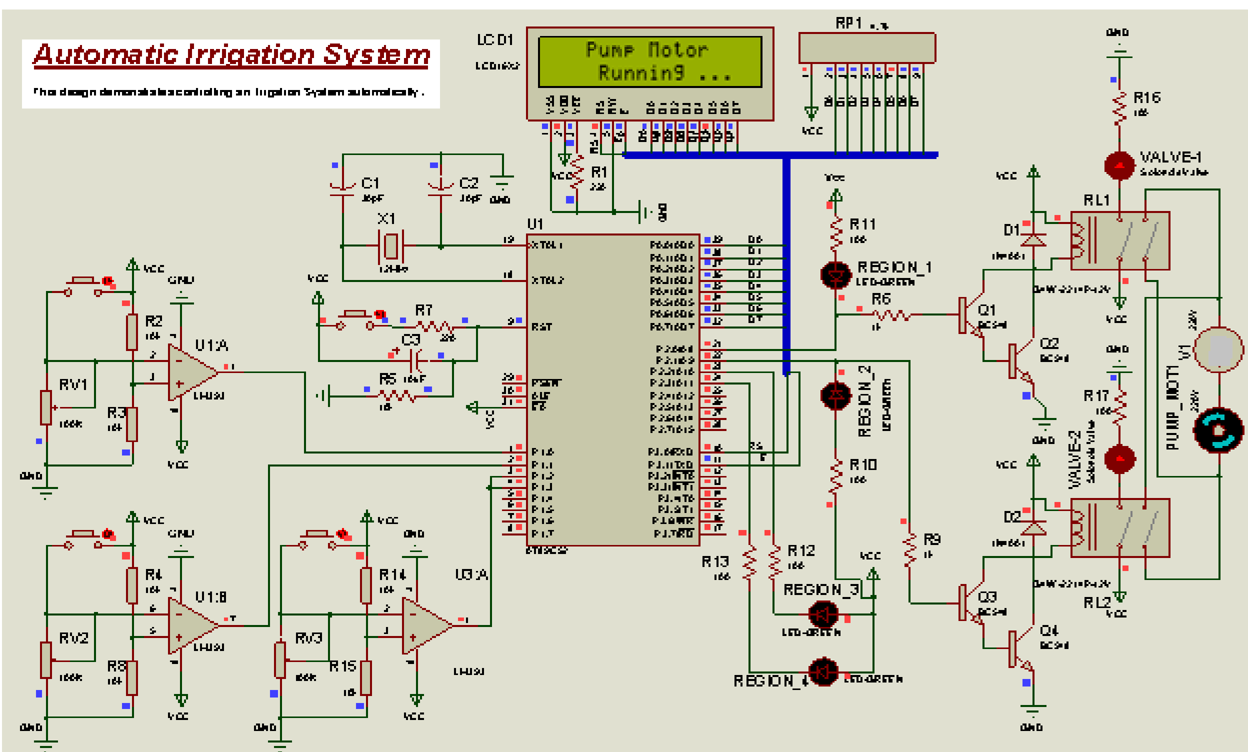


Figure 4.10 for all region dry state

Case 2.when region one sensor only send wet message, microcontroller decides to irrigate all regions except region one. One region is wet statement is display on LCD screen and region indicator LED for region one only gives light, as shown in figure 4.11 below.

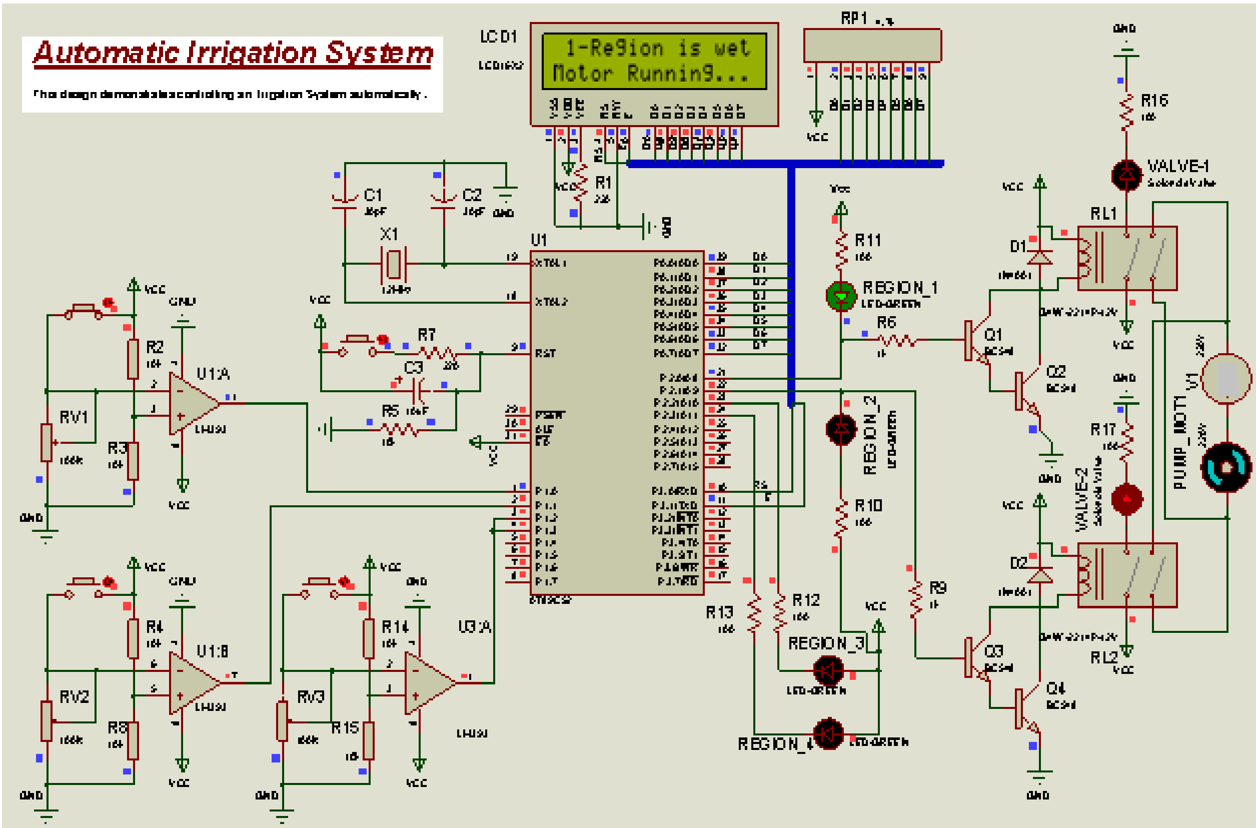
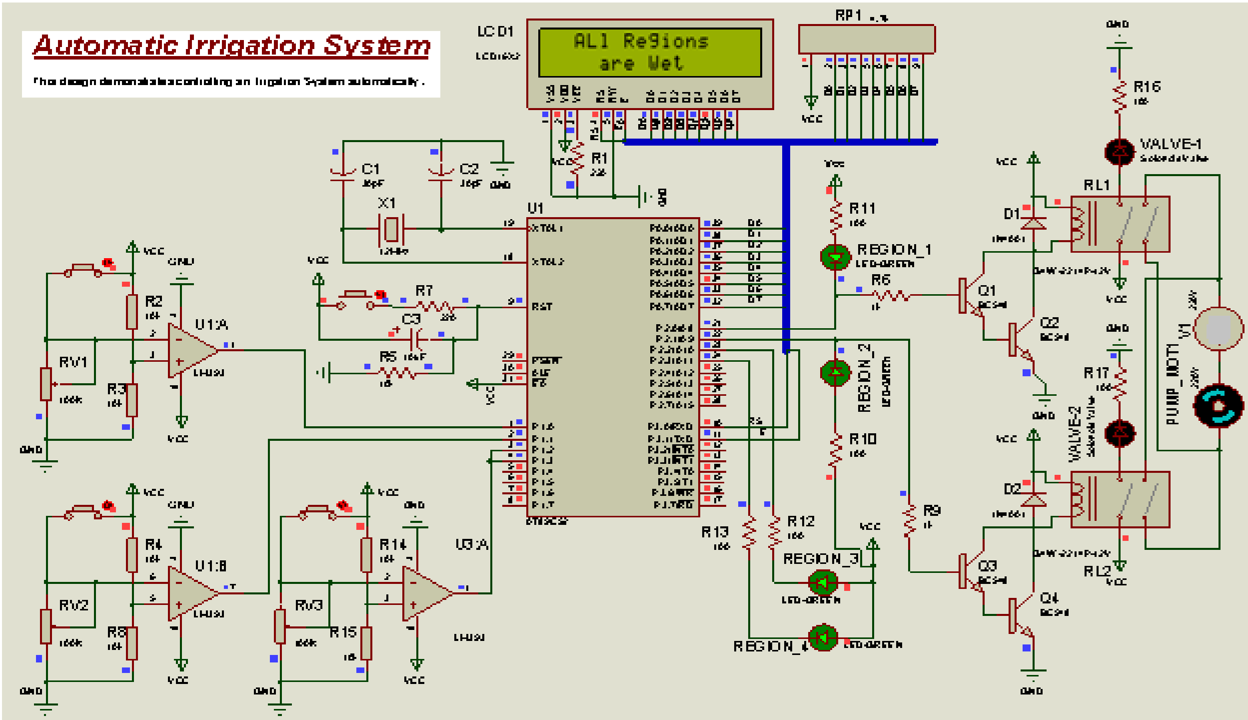


Figure 4.11 for region one wet state

Case 3. When all sensors send a wet state message, microcontroller decides to stop watering all regions. All regions are wet statement is display on LCD screen and region indicator LEDs are all lit. As a result of these all solenoid valves and motor are de-activated to watering regions as shown in figure 4.12 below.



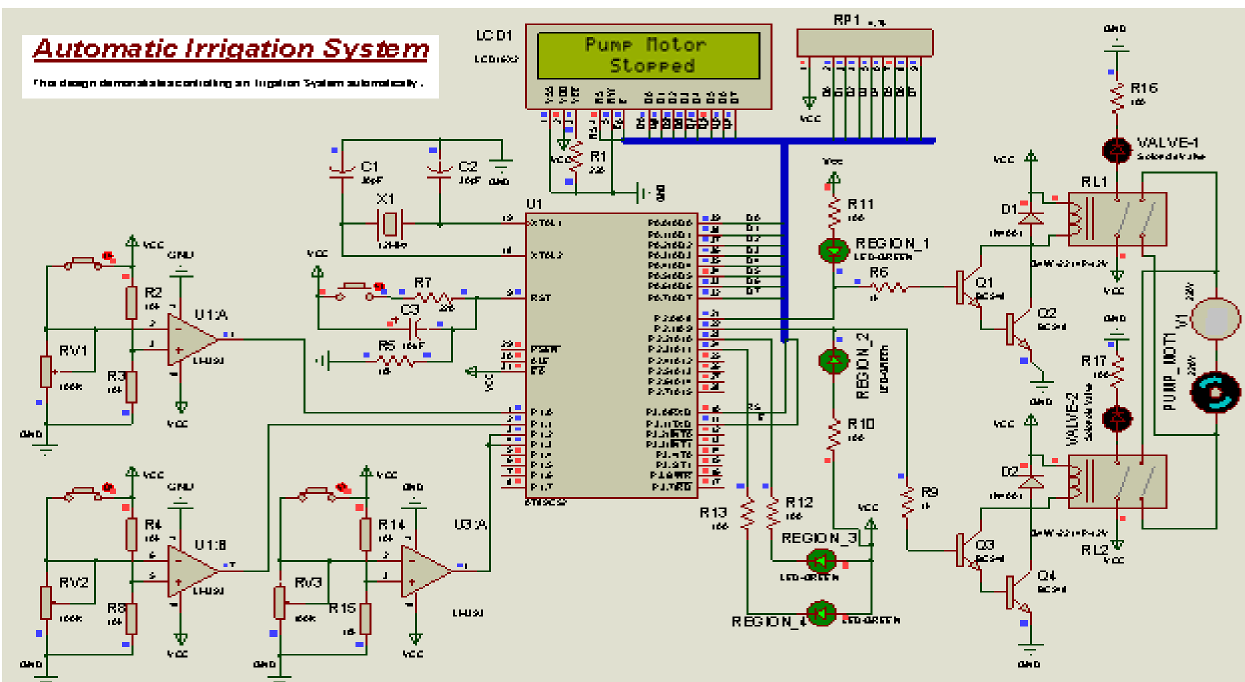


Figure 4.12 for all regions wet state

CHAPTER FIVE

RESULTS AND DISCUSSIONS

5.1. Results

The VWC (Volumetric Water Content) of sand soil, red soil and black soils were calculated. The raw data collected from the soil moisture sensor was recorded as shown in table 5.1. The soil was measured in equal amount of 250 gram. Water was added in the soils in steps and the sensor values recorded. The data obtained from the sensor reading is recorded in table 5.1.

Table 5-1 Sensor Reading values

Soil water content (cm^3)	Sensor Reading		
	Loam soil	Sand soil	Red soil
0	1021	1022	1020
50	580	546	781
75	360	234	568
100	237	243	295
125	203	184	274
150	191	180	235
175	180	170	220

5.2. Discussion

The data obtained from the sensor reading and recorded in table 5.1 was used to plot a graph, graph 5.1, of soil water content against sensor reading.

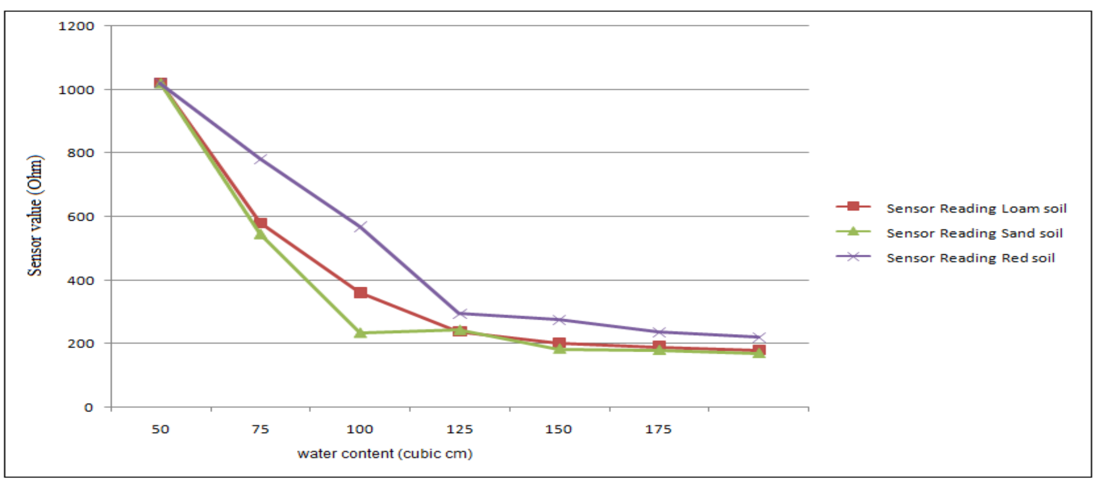


Figure 5.1 Soil water content against sensor reading.

The SMS used is a resistance sensor type. Its output is the resistance in the soil between the two SMS probes. The obtained graph is an exponential one. The value of the soil resistance decreases with increase in water content to a certain point. To come up with the results the three soils were dried using a frying pan until all the moisture content was lost. 250 grams was measured for the red soil, black soil and the sand soil. Water was added in steps of 25cm cube and sensor value recorded. The value of soil sensor at dry soil was almost equal for the three soils at 1021, 1022, 1020 for black soil, sand soil and red soil respectively. On adding 50cm cube the resistance value reduced drastically to the range of 500. On adding more water the resistance value kept reducing. At around 100cm cube of water the reduction on the soil resistance stated reducing at a much lower rate. This is because at this point the soil is now becoming saturated with water and thus adding more water has a small effect on the soil resistance.

The sensor was calibrated and states defined. The states are moist and dry. When the dry state was achieved the control unit (micro controller) switched the water pump on via a relay circuit. The states were indicated using different LEDs and an LCD. The LCD also indicated when the pump was running. The control circuit and the sensor circuit were powered using a5V dc regulated from 220V ac line.

5.3. Problems

In the course of development this prototype, the real challenging problems encountered were the interfacing sensors with MCU and the design of control algorithm. However these problems were combated by careful analysis and design except that we are not able to find RF transceiver compatible to the system and double pole single throw relay switch, so in the project prototype we are obliged to use a car door remote control and single pole single throw relay switch for demonstration purpose.

5.4. Conclusion

A system to monitor moisture levels in the soil was designed. The system was used to switch on/off the solenoid valves and watering system/pump according to set soil moisture levels. The control unit prototype was implemented using a microcontroller. The communication channel between the control unit and moisture sensor is based on radio frequency transceiver.

The LEDs and LCD were used to display the soil states i.e. moist soil and the dry soil states. The output of the controller unit is given to the solenoid valves and pump motor through switching relay circuit.

5.4. RECOMMENDATIONS

To improve on the effectiveness and efficiency of the system the following recommendations can be put into considerations:

- Integrating GSM technology can be used, such that whenever the water pump switches. ON/OFF, an SMS is sent to the concerned person regarding the status of the pump.
- The pump should also be controlled via SMS.
- The system can be integrated with temperature and humidity sensors to monitor the weather conditions in the farm.
- In case of system fail, it’s possible to use some techniques to inform on time for the concern body.

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APPENDIXE A

Microcontroller code

```
//Automatic Irrigation System main code
#include<reg52.h>
#include<lcd.h>
voidlcd();
void scan();
sbit sen1=P1^0;         //assign single bit p1.0 for sensor-1
sbit sen2=P1^1;         //assign single bit p1.1 for sensor-2
sbit sen3=P1^2;         //assign single bit p1.2 for sensor-3
sbit sen4=P1^3;         //assign single bit p1.3 for sensor-4
sbit rel1=P2^0;         //assign single bit p2.0 for relay-1
sbit rel2=P2^1;         //assign single bit p2.0 for relay-2
sbit rel3=P2^2;         //assign single bit p3.0 for relay-3
sbit rel4=P2^3;         //assign single bit p4.0 for relay-4
intval=0;
void main()
{
  sen1=sen2=sen3=sen4=0x01;          //Initialize all sensors with high state
 rel1=rel2=rel3=rel4=0x00;          //Initialize all relays with low state
lcd();
for(;;)
   {
val=0;
scan()
if(sen1==0x01){rel1=0x01;}          // If sensor-1 is high, turn on relay- 1
else{rel1=0x00;}                   // otherwise turn off relay-1
if(sen2==0x01){rel2=0x01;}          // If sensor-2 is high, turn on relay- 2
else{rel2=0x00;}                   // otherwise turn off relay-2
if(sen3==0x01){rel3=0x01;}          // If sensor-3 is high, turn on relay- 3
else{rel3=0x00;}                   // otherwise turn off relay-3
```

```
if(sen4==0x01){rel4=0x01;}                  // If sensor-4 is high, turn on relay- 4
else{rel4=0x00;}                            // otherwise turn off relay-4
if(val==0)
{
command(0x01);                                                              //clear command
command(0x80);display("  All Regions   ");          //first line fist location display "All regions"
command(0xc0);display("    are Dry    ");          //second line fist location display "Irrigation
                                                                       system"
lcddeley();                                                 //delay command
command(0x01);                                              //clear command
command(0x80);display("   Pump Motor   ");          //first line fist location display "Pump motor"
command(0xc0);display("    Running ... ");          //second line fist location display "running"
lcddeley();                                                 //delay
}
if(val==1)
{
command(0x01);
command(0x80);display(" 1-Region is wet");
command(0xc0);display("Motor Running...");
lcddeley();
 }
if(val==2)
{
command(0x01);
command(0x80);display(" 2-Regions wet  ");
command(0xc0);display("Motor Running...");
lcddeley();
}
if(val==3)
{
```

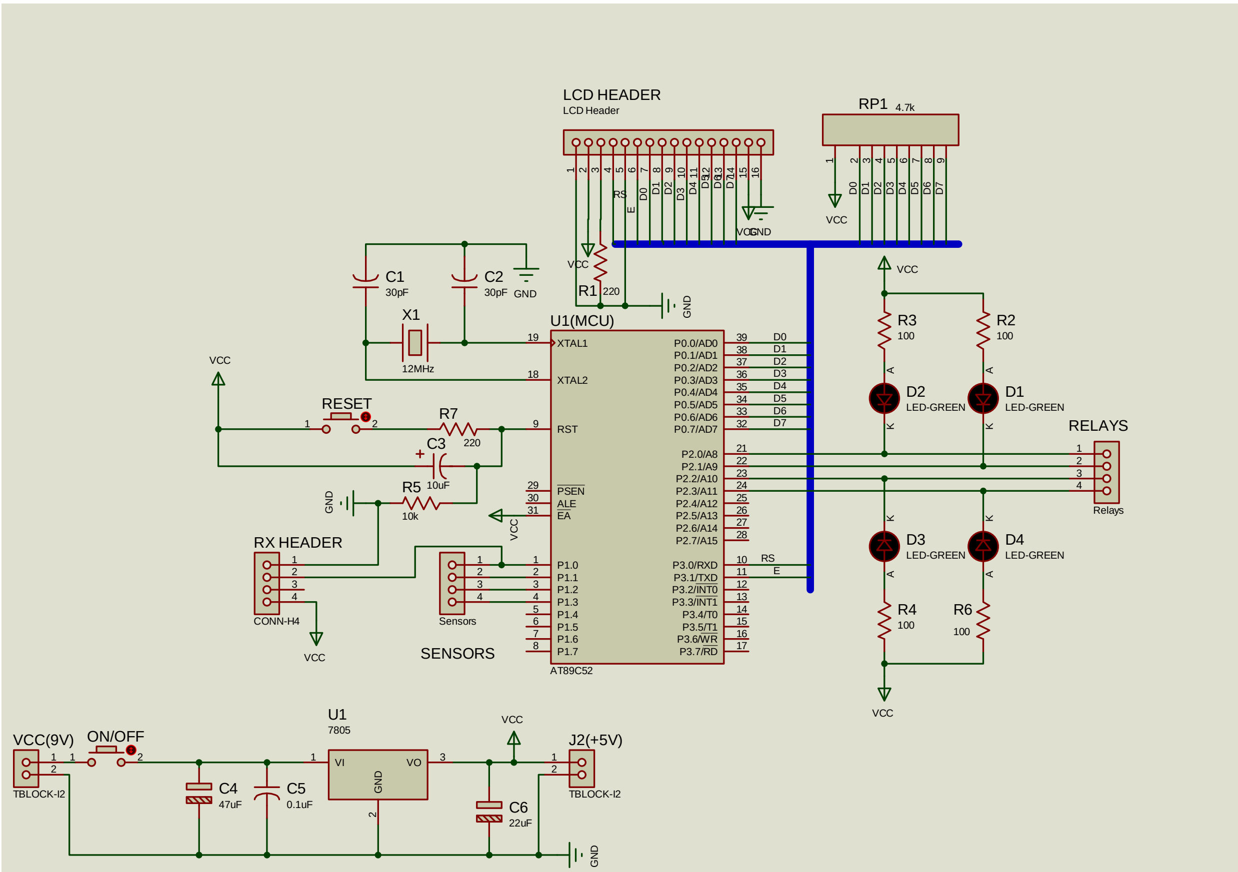
```
command(0x01);
command(0x80);display(" 3-Regions wet  ");
command(0xc0);display("Motor Running...");
lcddeley();
 }
if(val==4)
{
command(0x01);
command(0x80);display("  ALl Regions ");
command(0xc0);display("    are Wet   ");
lcddeley();
command(0x01);
command(0x80);display("   Pump Motor   ");
command(0xc0);display("     Stopped   ");
lcddeley();
}
}
}
void scan()
{
if(sen1==0x00){val++;}
if(sen2==0x00){val++;}
if(sen3==0x00){val++;}
if(sen4==0x00){val++;}
}
voidlcd()
{
init_lcd();
command(0x80);display("     Welcome    ");                 //first line fist location display "welcome"
```

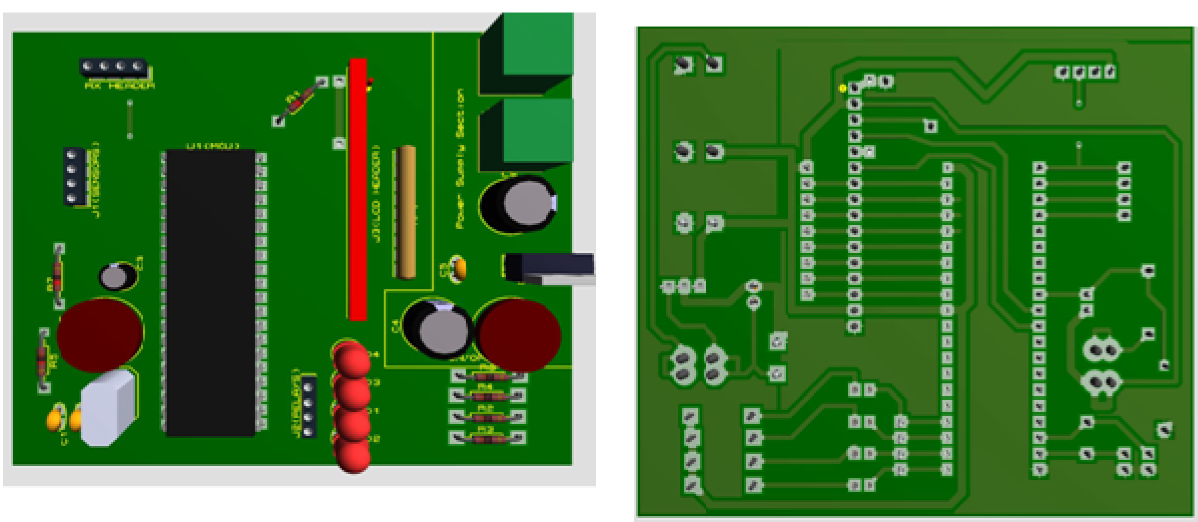
lcddeley();command(0x01); //delay and clear commandcommand(0x80);display(" Automatic ") //first line fist location display "Automatic"command(0xc0);display(" Irrigation Sys "); //second line fist location display "Irrigation system"

lcddeley();lcddeley();ndisplay(1);command(0x01); //delay and clear command

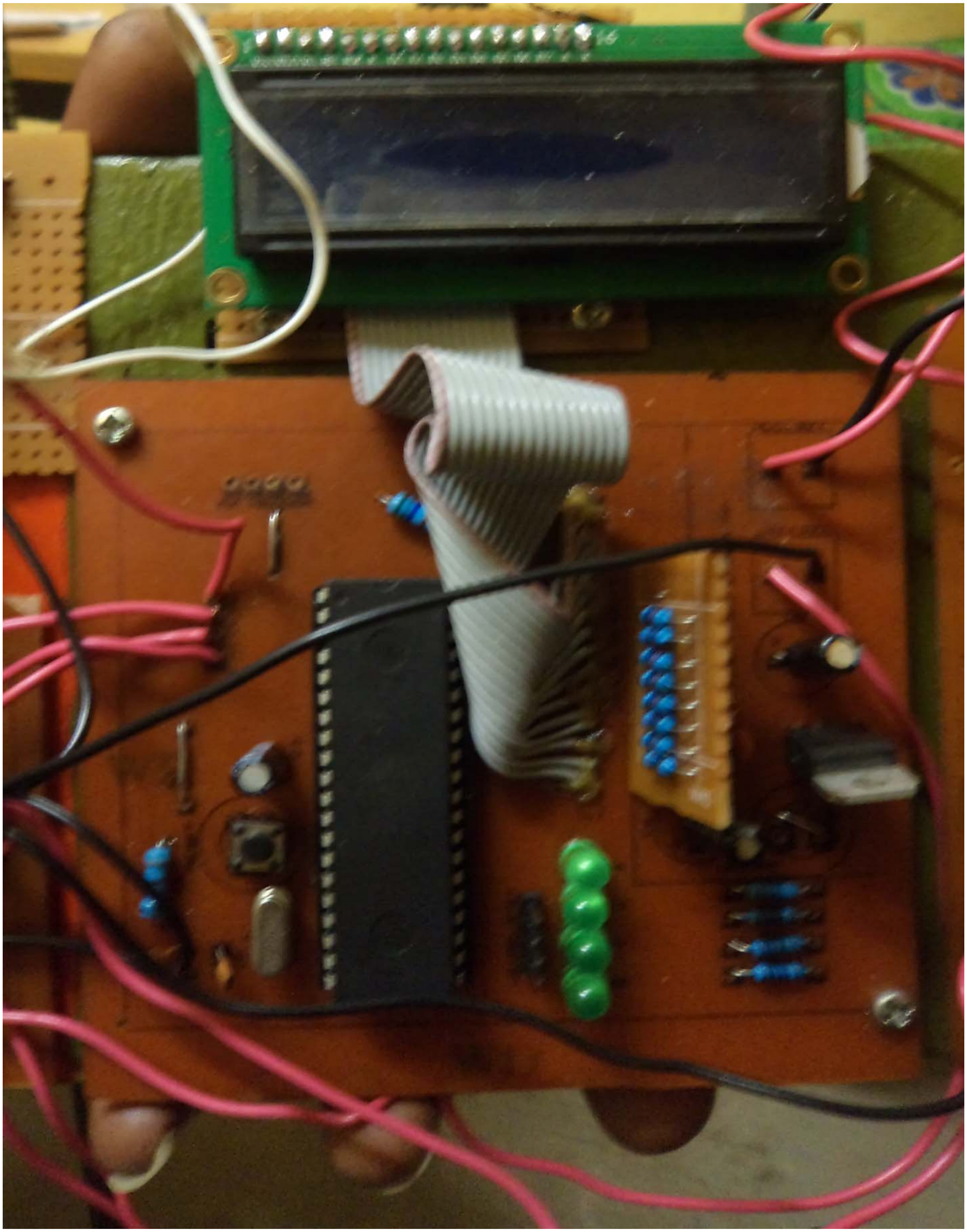
}

APPENDIXE B

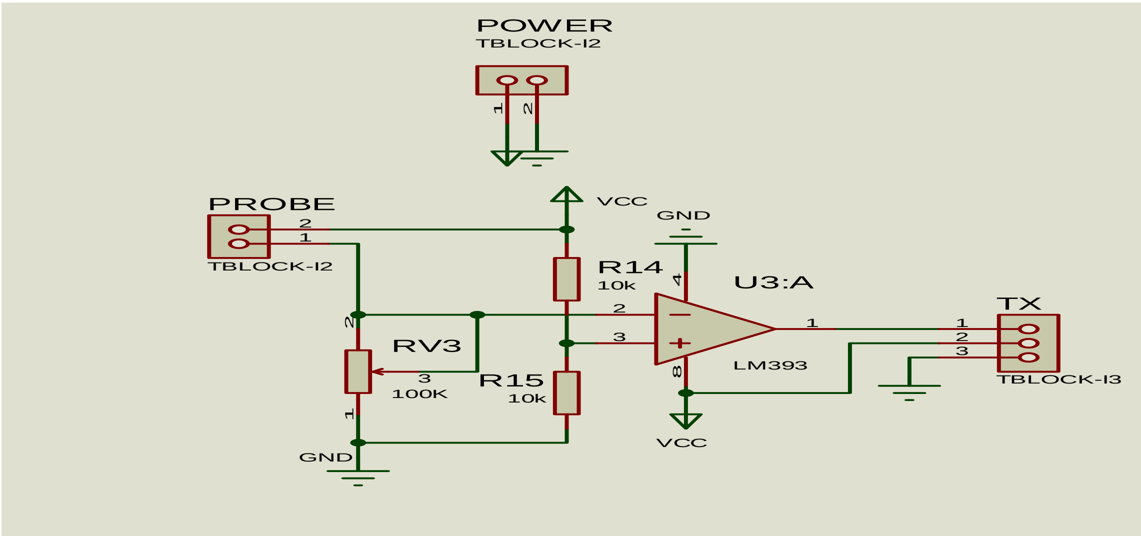


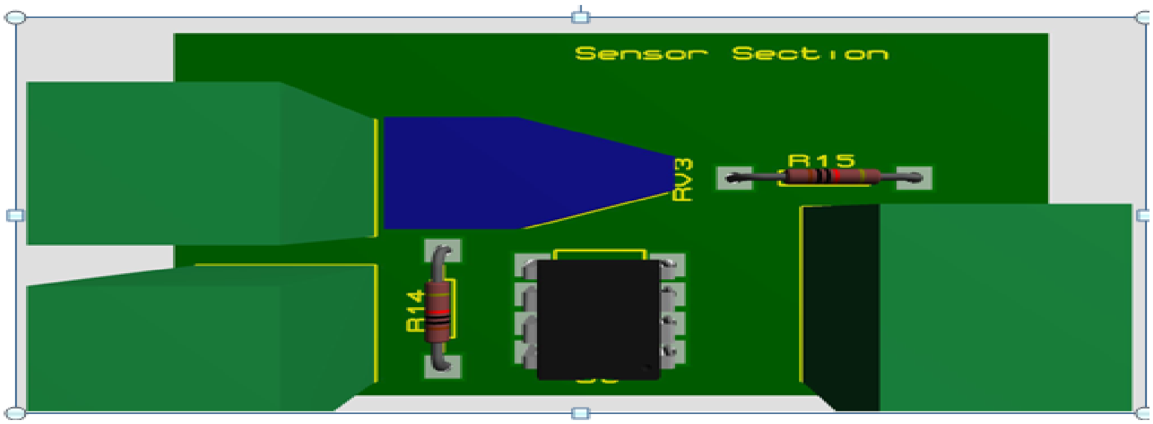


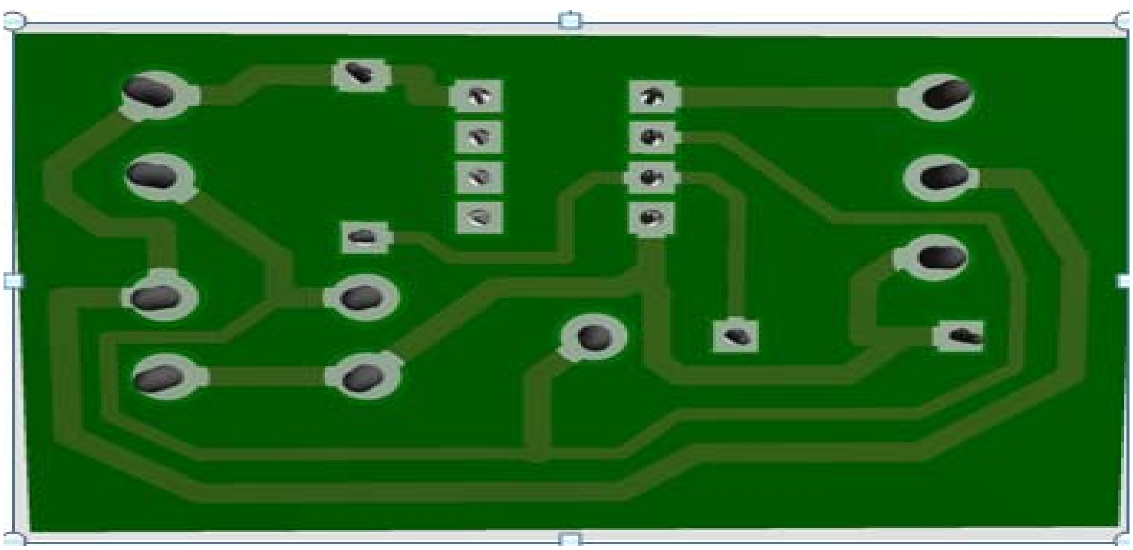
PCB layout and 3D Visualization for MCU



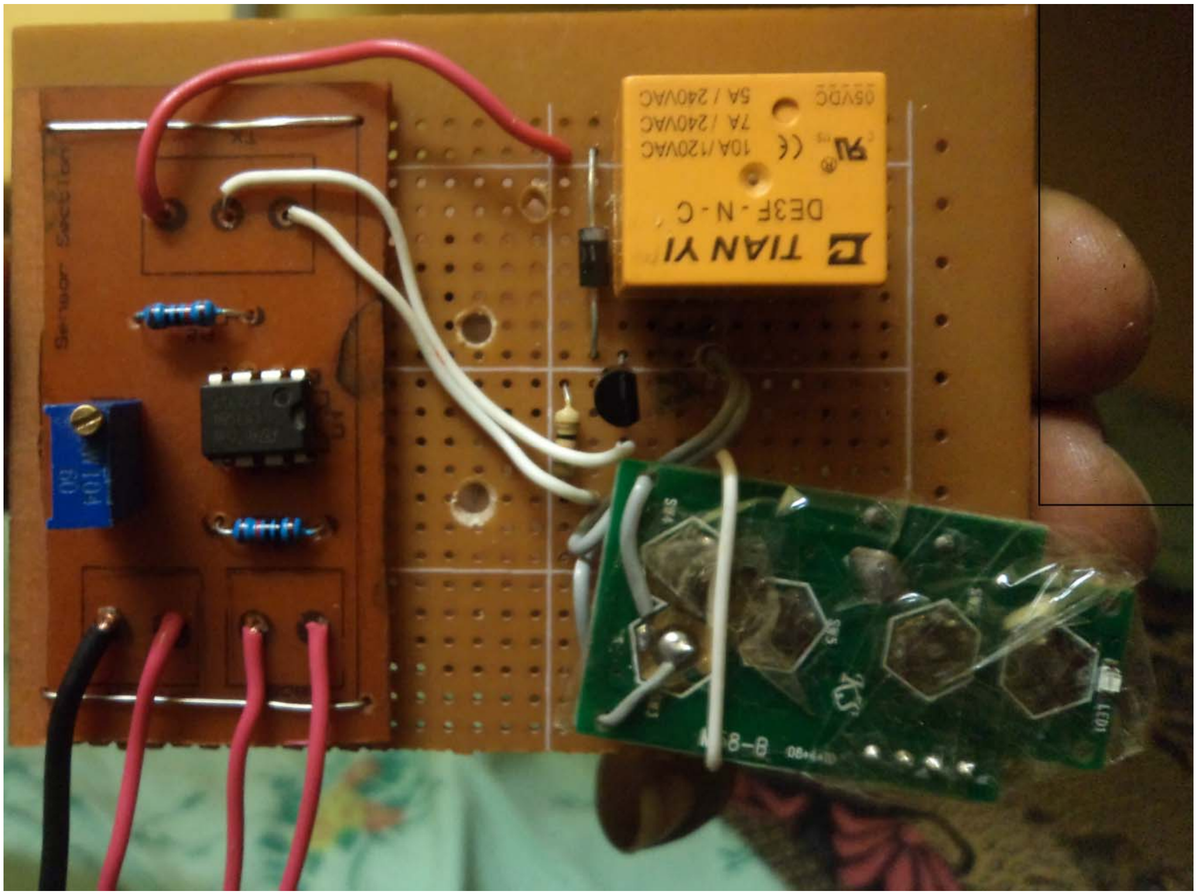
Proto type of MCU section



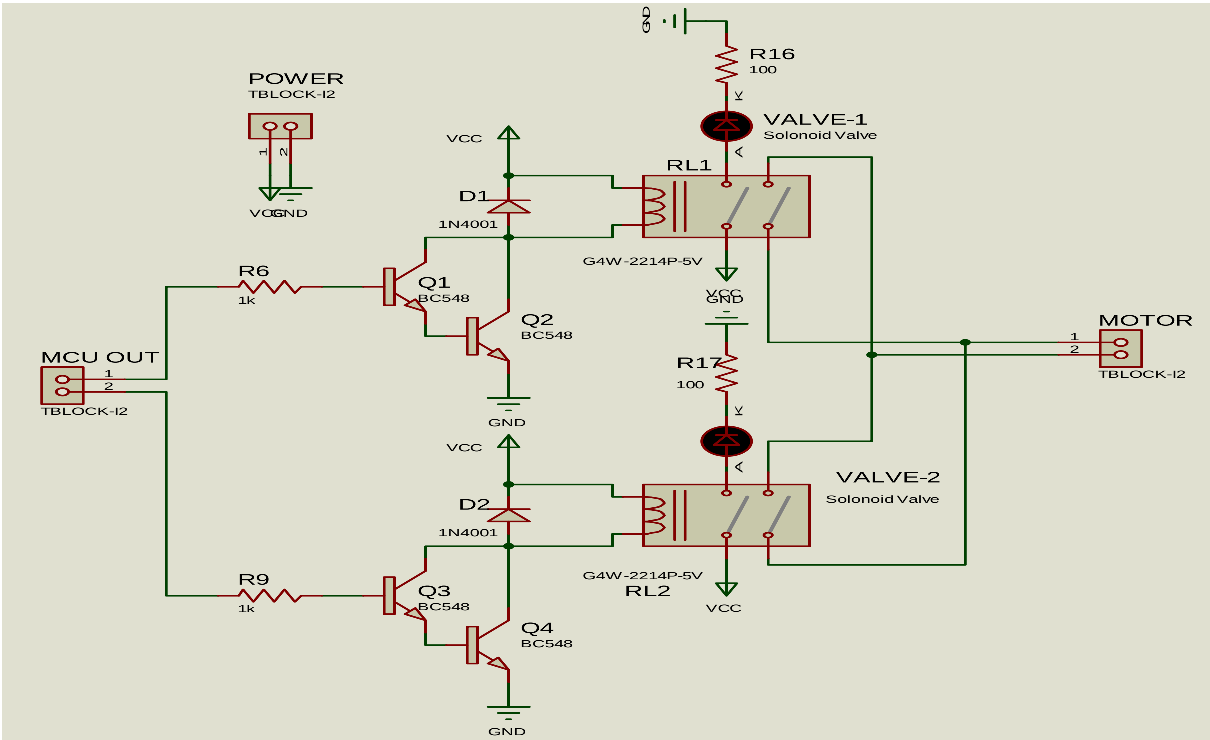


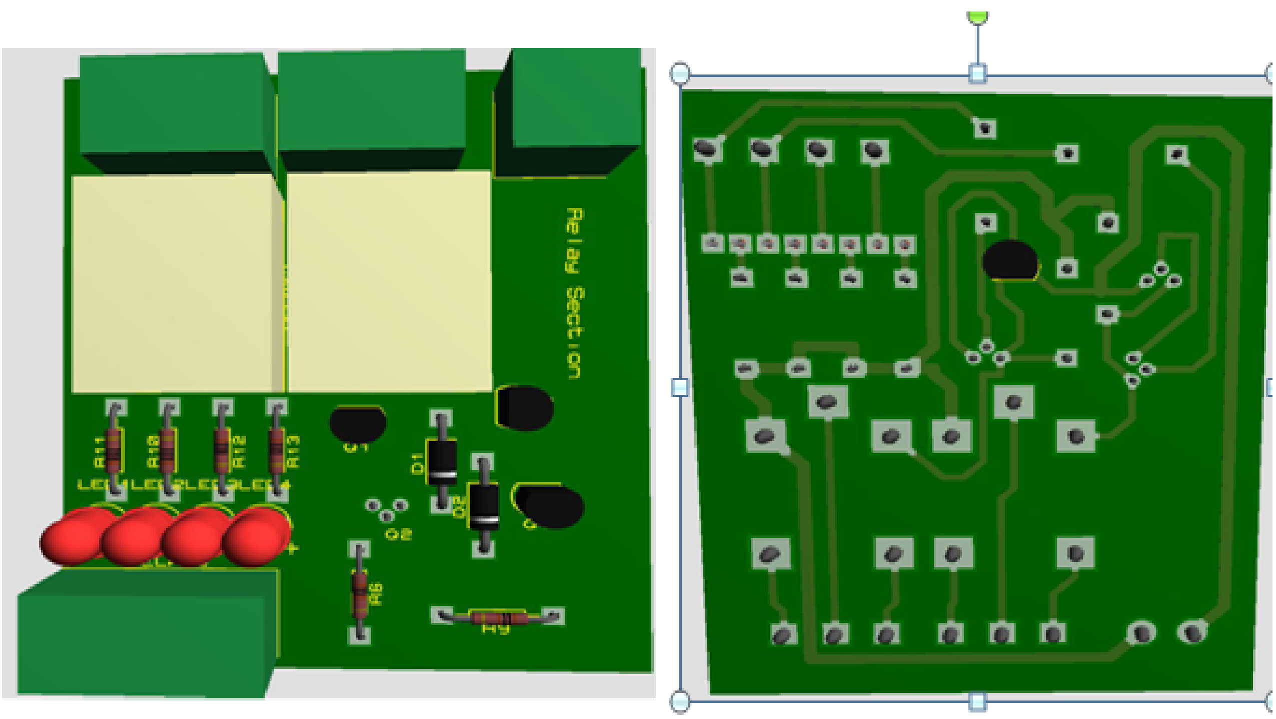


PCB layout and 3D Visualization for sensor section

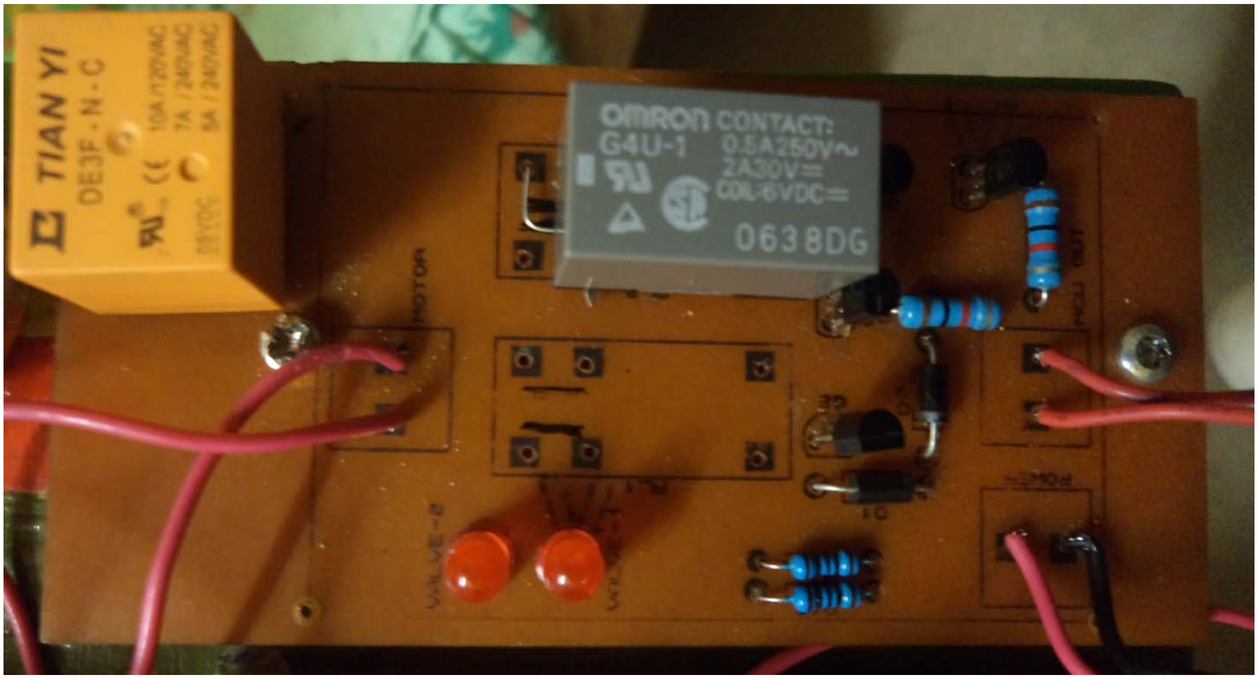


Prototype of sensor section with RF transmitter





PCB layout and 3D visualizations for relay section



Prototype of relay section

APPENDIXE C

G2R

PCB Power Relay

The Best Seller G2R

- 1General purpose power Relays of single-pole10 A and double-pole 5 A.
- Safety-oriented design with dielectric strength of 5,000 V between coil and contacts, and surge resistance of 10,000 V.
- AC and DC types are both available for operational coils.

RoHS Compliant

■Ratings

● Coil

Classification / Item	Rated voltage	Rated current (mA) 50 Hz	Rated current (mA) 60 Hz	Coil resistance (Ω)	Must operate voltage (V) (% of rated voltage)	Must release voltage (V) (% of rated voltage)	Max. voltage (V) (% of rated voltage)	Power consumption (VA, W)
• General-purpose • Quick-connect • Fully sealed • High-capacity	12 VAC	93	75	65	80% max.	30% min.	140% (at 23°C)	Approx. 0.9 (60 Hz)
	24 VAC	46.5	37.5	260				
	100/(110) VAC	11	9/(10.6)	4,600				
	200/(220) VAC	5.5	4.5/(5.3)	20,200				
• General-purpose • High-capacity • Bifurcated contact • Quick-connect • Fully sealed	5 VDC	106		47	70% max.	15% min.	170% (at 23°C)	Approx. 0.53
	6 VDC	88.2		68				
	12 VDC	43.6		275				
	24 VDC	21.8		1,100				
	48 VDC	11.5		4,170				
	100 VDC	5.3		18,860				
• High-sensitivity	5 VDC	71.4		70	70% max.	15% min.	170% (at 23°C)	Approx. 0.36
	6 VDC	60		100				
	12 VDC	30		400				
	24 VDC	15		1,600				
	48 VDC	7.5		6,400				

Note 1. The rated current and coil resistance are measured at a coil temperature of 23°C with a tolerance of+15%/-20% (AC rated current) or ±10% (DC coil resistance).
2. AC coil resistances shown above are only reference values.
3. The operating characteristics are measured at a coil temperature of 23°C.
4. The "Max. voltage" is the maximum voltage that can be applied to the relay coil.

● Contacts: Latching Models

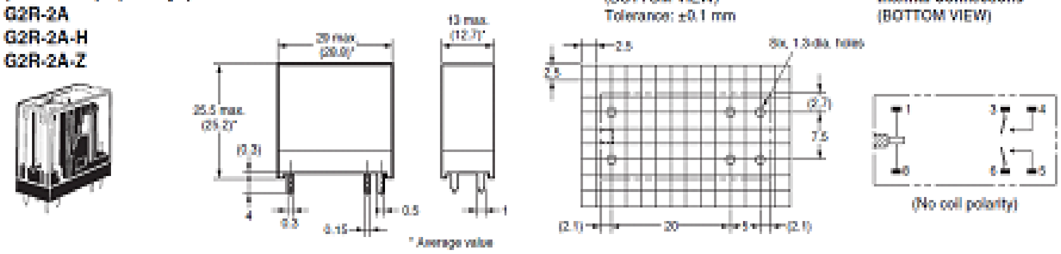
Item / Load / Number of poles	1-pole		2-pole	
	Resistive load (cosϕ = 1)	Inductive load (cosϕ = 0.4; L/R = 7 ms)	Resistive load (cosϕ = 1)	Inductive load (cosϕ = 0.4; L/R = 7 ms)
Contact type	Single		Single	
Contact material	Ag-alloy (Cd free)			
Rated load	5 A at 250 VAC 5 A at 30 VDC	3.5 A at 250 VAC 2.5 A at 30 VDC	3 A at 250 VAC 3 A at 30 VDC	1.5 A at 250 VAC 2 A at 30 VDC
Rated carry current	5 A		3 A	
Max. switching voltage	380 VAC, 125 VDC		380 VAC, 125 VDC	
Max. switching current	5 A		3 A	
Failure rate (P level) (reference value) *	100 mA at 5 VDC		10 mA at 5 VDC	

* This value was measured at a switching frequency of 120 operations/min.

Relays with PCB Terminals (DPST-NO (2a) Relays)
G2R-2A
G2R-2A-H
G2R-2A-Z

PCB Mounting Holes (BOTTOM VIEW)
Tolerance: ±0.1 mm

Terminal Arrangement/ Internal Connections (BOTTOM VIEW)



G2R

2-pole

Model	Contact form	Coil ratings	Contact ratings	Number of test operations
G2R-2A G2R-2A4 G2R-2A-H	DPST-NO (2a)	3 to 120 VDC 6 to 240 VAC	5 A, 250 VAC (General Use) at 40°C	6,000
G2R-2 G2R-24 G2R-24-H	DPDT (2c)		5 A, 30 VDC (Resistive) at 40°C	100,000
			TV-3 (N. O. only) at 40°C	25,000

Note: Consult separately for UL/CSA contact standard ratings.

OMRON Corporation
Electronic and Mechanical Components Company
Contact: www.omron.com/ecb
Cat. No. K013-E1-13
0812(0207)(O)

NPN general purpose transistors BC548

FEATURES

- Low current (max. 100 mA)
- Low voltage (max. 65 V).

APPLICATIONS

- General purpose switching and amplification.

DESCRIPTION

NPN transistor in a TO-92; SOT54 plastic package.
PNP complements: BC556, BC557 and BC558.

PINNING

PIN	DESCRIPTION
1	emitter
2	base
3	collector

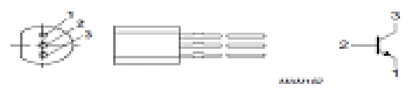


Fig.1 Simplified outline (TO-92; SOT54) and symbol.

Absolute Maximum Ratings T_a=25° C unless otherwise noted

Symbol	Parameter	Value	Units
V_{CBO}	Collector-Base Voltage	75	V
V_{CEO}	Collector-Emitter Voltage	40	V
V_{EBO}	Emitter-Base Voltage	6	V
I_C	Collector Current	600	mA
P_C	Collector Power Dissipation	625	mW
T_J	Junction Temperature	150	°C
T_{STG}	Storage Temperature	-55 ~ 150	°C

Electrical Characteristics T_a=25° C unless otherwise noted

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Units
BV_{CBO}	Collector-Base Breakdown Voltage	I_C=10× A, I_E=0	75			V
BV_{CEO}	Collector Emitter Breakdown Voltage	I_C=10mA, I_B=0	40			V
BV_{EBO}	Emitter-Base Breakdown Voltage	I_E=10× A, I_C=0	6			V
I_{CBO}	Collector Cut-off Current	V_{CB}=60V, I_E=0			0.01	× A
I_{EBO}	Emitter Cut-off Current	V_{EB}=3V, I_C=0			10	nA
h_{FE}	DC Current Gain	I_C=0.1mA, V_{CE}=10V V_{CE}=10V, I_C=1mA V_{CE}=10V, I_C=10mA V_{CE}=10V, *I_C=150mA V_{CE}=10V, *I_C=500mA	35 50 75 100 40		 300 	
V_{CE} (sat)	* Collector-Emitter Saturation Voltage	I_C=150mA, I_B=15mA I_C=500mA, I_B=50mA			0.3 1	V V
V_{BE} (sat)	* Base-Emitter Saturation Voltage	I_C=150mA, I_B=15mA I_C=500mA, I_B=50mA		0.6	1.2 2	V V
f_T	Current Gain Bandwidth Product	V_{CE}=20V, I_C=20mA f=100MHz	300			MHz
C_{ob}	Output Capacitance	V_{CB}=10V, I_E=0, f=1MHz			8	pF
t_{ON}	Turn On Time	V_{CC}=30V, I_C=150mA I_{B1}=15mA, V_{BE}(off)=0.5V			35	ns
t_{OFF}	Turn Off Time	V_{CC}=30V, I_C=150mA I_{B1}=I_{B2}=15mA			285	ns

Figure 9. Programming the Flash Memory

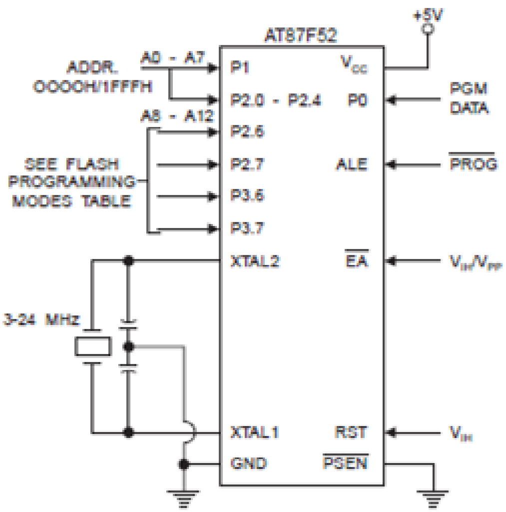
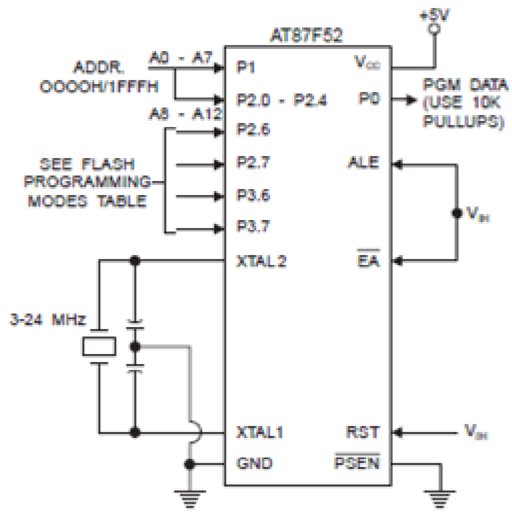


Figure 10. Verifying the Flash Memory



Flash Programming and Verification Characteristics

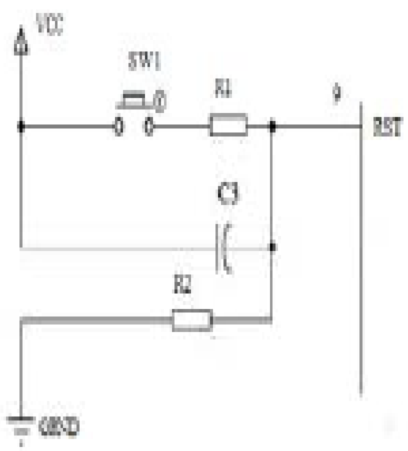
T_A = 0°C to 70°C, V_{CC} = 5.0 ±10%

Symbol	Parameter	Min	Max	Units
V_{PP}[1]	Programming Enable Voltage	11.5	12.5	V
I_{PP}[1]	Programming Enable Current		1.0	mA
$1/t_{CLCL}$	Oscillator Frequency	3	24	MHz
t_{AVGL}	Address Setup to $\overline{PROG}$ Low	$48t_{CLCL}$		
t_{GHAX}	Address Hold after $\overline{PROG}$	$48t_{CLCL}$		
t_{DVGL}	Data Setup to $\overline{PROG}$ Low	$48t_{CLCL}$		
t_{GHDX}	Data Hold After $\overline{PROG}$	$48t_{CLCL}$		
t_{EHSH}	P2.7 ($\overline{ENABLE}$) High to V_{PP}	$48t_{CLCL}$		
t_{SHGL}	V_{PP} Setup to $\overline{PROG}$ Low	10		µs
t_{GHSL}[1]	V_{PP} Hold after $\overline{PROG}$	10		µs
t_{GLGH}	$\overline{PROG}$ Width	1	110	µs
t_{AVQV}	Address to Data Valid		$48t_{CLCL}$	
t_{ELQV}	$\overline{ENABLE}$ Low to Data Valid		$48t_{CLCL}$	
t_{EHQZ}	Data Float after $\overline{ENABLE}$	0	$48t_{CLCL}$	
t_{GHBL}	$\overline{PROG}$ High to $\overline{BUSY}$ Low		1.0	µs
t_{WC}	Byte Write Cycle Time		2.0	ms

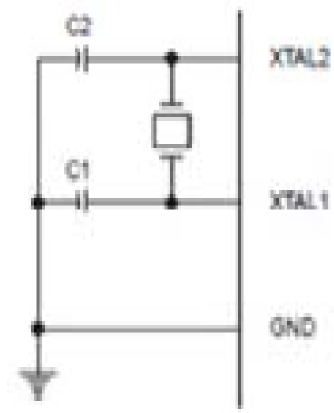
The clock circuit of AT89C52 composed of 18, 19 feet from the clock side (XTAL1 and XTAL2), and12MHz crystal X, capacitor C1 and C2, and uses on-chip oscillator mode

The reset circuit uses a simple power-on reset circuit, and constitute of resistor R1, capacitor C3, and R3 connected to the AT89C52's reset input pin.

Reset circuit connection



Oscillator connections



Note: R1=220Ω, R2= 10KΩ

C3= 10μF, VCC= +5V

Note: C1, C2=30pF±10 pF for crystals

=40pF±10 pF for ceramic resonators

Bay Linear

Inspire the Linear Power

Low Power Low Offset Voltage Dual Comparators

LM393

Description

The LM393 consists of two independent precision voltage comparators with an offset voltage specification as low as 2.0 mV max for two comparators which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage. These comparators also have a unique characteristic in that the input common-mode voltage range includes ground, even though operated from a single power supply voltage.

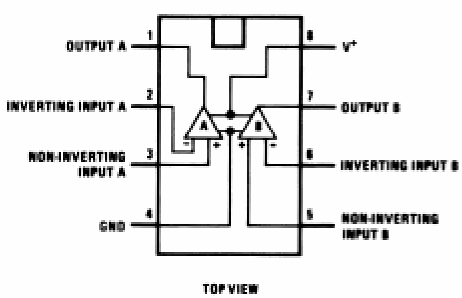
Application areas include limit comparators, simple analog to digital converters; pulse, squarewave and time delay generators; wide range VCO; MOS clock timers; multivibrators and high voltage digital logic gates. The LM393 was designed to directly interface with TTL and CMOS. When operated from both plus and minus power supplies, the LM393 will directly interface with MOS logic where their low power drain is a distinct advantage over standard comparators.

Features

- **Wide supply Voltage range: 2.0V to 36V Single or dual supplies: ± 1.0V to ± 18V**
- **Very low supply current drain (0.4 mA) independent of supply voltage**
- **Low input biasing current: 25 nA**
- **Low input offset current: ± 5 nA**
- **Maximum offset voltage: ± 3 mV**
- **Input common- mode voltage range includes ground**
- **Differential input voltage range equal to the power supply voltage**
- **Low output saturation voltage,: 250 mV at 4 mA**
- **Output voltage compatible with TTL, DTL, ECL, MOS and CMOS logic systems**

Pin Connection

Dual-In-Line/SOIC Package



Ordering Information

Devices	Package	Temp.
LM393M	SO-8	0 °C to 70 °C
LM393P	8-DIP	0 °C to 70 °C

Absolute Maximum Rating

Parameter	LM393	Unit
Supply Voltage	36	V
Differential Input Voltage	36	V
Input Voltage	-0.3 to 36	V
Input Current	50	mA
Storage Temperature	0 to 70	°C
Lead Temperature (solder 10 Second)	260	°C
ESD	250	V

Electrical Characteristics

(V_{CC} = 5V; T_J=25°C , unless otherwise specified)

PARAMETER	TEST CONDITIONS*		MIN	TYP	MAX	UNIT
V_{IO} Input offset voltage	Vcc = 5V to 30V, V_{IC} = V_{ICR} min, Vo=1.4V	25 °C		2	5	mV
		Full range			9	
I_{IO} Input offset current	Vo=1.4V	25 °C		5	50	nA
		Full range			150	
I_{IB} Input bias current	Vo=1.4V	25 °C		-25	-250	nA
		Full range			-400	
V_{ICR} Common-mode input voltage range**		25 °C	0 to Vcc-1.5			V
		Full range	0 to Vcc - 2			
A_{VD} Large-signal differential voltage amplification	Vcc = 15 V, Vo=1.4V to 11.4 V, R_L ≥ 15 kΩ to V_{CC}	25 °C	50	200		V/mV
I_{OH} High-level output current	V_{OH}=5 V, V_{ID}=1V,	25 °C		0.1	50	nA
	V_{OH}= 30V, V_{ID}=1V	Full range			1	µA
V_{OL} Low-level output voltage	I_{OL} = 4 mA, V_{ID}=-1V	25 °C		150	400	mV
		Full range			700	
I_{OL} Low-level output current	V_{OL}= 1.5V, V_{ID}=-1V	25 °C	6			mA
I_{CC} Supply current	R_L = ∞, V_{CC} = 5V	25 °C		0.8	1	mA
	R_L = ∞, V_{CC} = 30V	Full range			2.5	

* Full range (MIN to MAX), for the LM393 is O °C to 70 °C. All characteristics are measured with zero common-mode input voltage unless otherwise specified.

** The voltage at either input or common-mode should not be allowed to go negative by more than 0.3V. The upper end of the common-mode voltage range is V_{CC} -1.5V, but either or both inputs can go to 30V without damage.

switching characteristics, Vcc=5V, T_A=25 °C

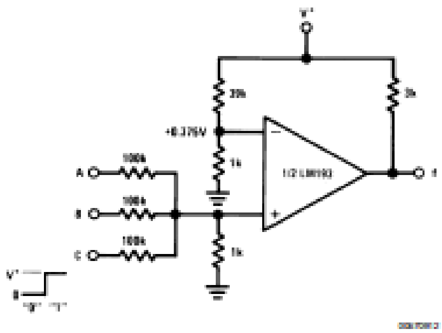
PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Response time	R_L connected to 5V through 5.1 kΩ, C_L=15pF* (See Note 1)	100-mV input step with 5-mV overdrive		1.3		µs
		TTL-level input step		0.3		

* C_L includes probe and jig capacitance.

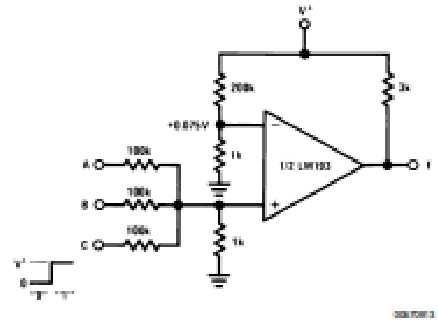
NOTE 1: The response time specified is the interval between the input step function and the instant when the output crosses 1.4V.

Typical Applications $(V^{+}=5.0\ V_{DC})$ (Continued)

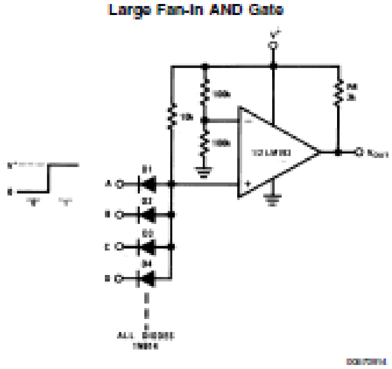
AND Gate



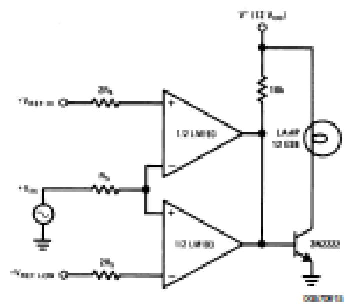
OR Gate



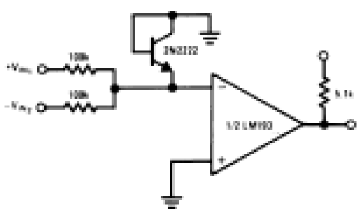
Large Fan-In AND Gate



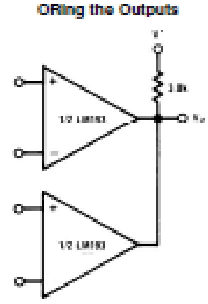
Limit Comparator

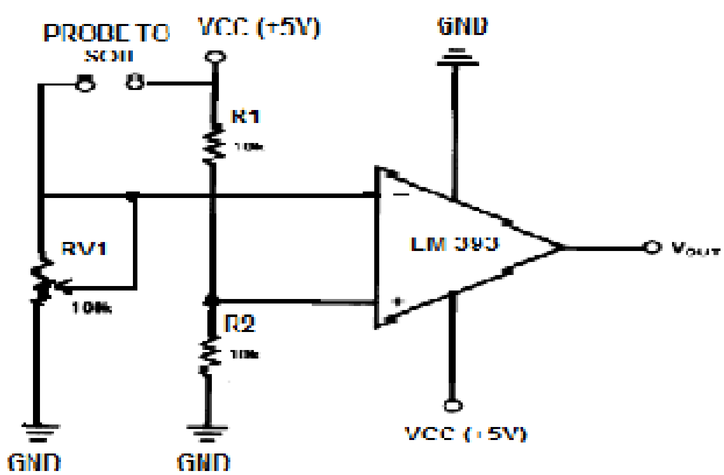


Comparing Input Voltages of Opposite Polarity



ORing the Outputs





Sensor circuit