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COURSE NAME: Bachelor of Science in Electrical & Electronic Engineering
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REGISTRATION NUMBER: F17/2442/2008
COLLEGE: Architecture and Engineering
WORK: MICROCONTROLLER-BASED IRRIGATION SYSTEM

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DEDICATION

This project is dedicated to my late parents who taught me the value of honesty and hard work at an early age. May God rest their souls in eternal peace.

ACKNOWLEDGEMENT

First and foremost, I would like to acknowledge the Almighty God for giving me physical and spiritual strength during my studies.

Sincere thanks also goes to the Chairman-Department of Electrical and Information Engineering and all my lecturers in the University of Nairobi including the supporting staff for the impact they have had to my life and also for providing the conducive and enabling environment for learning

Special appreciation to my supervisor, Dr G. N Kamucha for the critical comments and valuable advice that guided me immensely throughout my project work and also in the lectures he undertook with me within the five year course work.

Finally, I extend my appreciation to my family and friends for the support they offered me during my study at the University.

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LIST OF ABBREVIATIONS

SMS –Soil Moisture Sensor

VWC -Volumetric Water Content

TDR -Time Domain Reflectometry

FDR -Frequency Domain Reflectometry

RDAC -Resistive Digital-To-Analog Converters

PIC -Programmable Interface Controllers

LCD   -Liquid crystal Display

ADC   -Analog to Digital Converter

DAC –Digital to Analog Converter

LED   -Light Emitting Diode

SPST -Single Pole Single Throw

SPDT - Single Pole Double Throw

DPST -Double Pole Single Throw

PCB –Printed Circuit Board

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.

The aim of this project is to use control engineering principles and concepts to provide a microcontroller based irrigation system. The system will help in saving money and water and at the same time increasing crops production. The automated irrigation system is controlled using ATmega328 micro controller based on arduino platform. 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/humidity levels are checked using soil moisture sensor. Whenever there is a change in moisture/humidity in the soil this sensor senses the change and gives an interrupt signal to the micro-controller and thus the watering system is activated or deactivated.

Contents

1. INTRODUCTION

1.1 Brief Background

The continuous increase in food demand requires a rapid improvement in food production technologies. Food insecurity is a major challenge in developing countries. In a country like Kenya where the economy is mainly agriculture based, use of technology to improve on yields is paramount.

Agriculture in Kenya is mainly rain fed. Global warming has led to climate changing thus rendering the rain fed agricultural systems unreliable. This has resulted on more land being put under irrigation to meet the food demand for the growing population.

In Kenya approximately 125,000 hectares of land is under irrigation out of the estimated potential of 1.3 million hectares. Only 30% of the 1.3 million hectares potential irrigation land has available water resources while the other 70% require water harnessing for irrigation to be realized. [10]

Irrigation is the process of artificial application of water to land to aid crops growth. It is mainly used during dry seasons or in dry areas where rainfall is scarce.

1.2 Types of irrigation

1.2.1.1 Ditch Irrigation

This is one of the earliest irrigation methods to be used. Ditches/trenches are dug out and crops are planted along the ditches in rows.

1.2.1.2 Terrace Irrigation

The land is shaped into steps. Crops are planted on the flat areas. Water flows down the steps watering each of the flat areas. This method is both time and labour intensive in building the terraces.

1.2.1.3 Drip Irrigation

This is one of the most effective and efficient method of irrigation as water is dripped at the crop root zone. The method saves water from runoff and evaporation.

1.2.1.4   Sprinkler irrigation

This method uses overhead sprinklers. Each sprinkler irrigates a given area. During installation care should be taken to avoid over or under watering some areas. If poorly installed a lot of water is wasted via runoff.

1.2.1.5   Rotary Systems

This is an improvement of sprinkler irrigation method where sprinklers are mechanically moving in a rotary/circular manner. This method is best suited for huge tracks of land. This method is more efficient than the basic sprinkler method.

This project presents a microcontroller based irrigation system which monitor and control the soil moisture content so as to optimize the application of water. Good water balance leads to maximum crop production. The system presented automates irrigation systems with the use of low cost sensor, microcontroller and the simple circuitry, thereby making it a low cost.

1.3   Problem statement

Over the last decades, empirical experience has shown that irrigation increases yield of most crops by between 100 and 400%. It is expected that, over the next 30 years, 70% of the grain production will be from irrigated land in the world. The Food and Agriculture Organization estimates that irrigated land in developing countries will increase by 27%t in the next 20 years, but the amount of water expected to be available for agricultural production will only increase by a mere 12 per cent. The available water resource for irrigation has to be put to optimal use through appropriate technology.

This project aims at automating irrigation systems using a micro-controller to improve on water management. This will increase yields, improve crop quality, and most importantly conserve water thus saving money.

1.4   Main objectives

The system is expected to monitor moisture/humidity levels in the soil and switch on/off the watering system according to set moisture levels.

1.5   Project justification

The increasing world population has lead to exponential increase in food demand. This event has necessitated the need for more land to be cultivated. Due to change of weather patterns brought about by global warming, irrigation remains as the only reliable method of crops production. With more and more land now being under irrigation there is a need for optimal use of water.[2]

Over the last few years knowledge in electronics and computation has been used to solve present day challenges. In the forefront of the electronics revolution has been the microcontroller. The microcontroller has been used together with various sensors to measure and control physical quantities like temperature, humidity, heat and light. By controlling this physical quantities using the microcontroller; automatic systems have been achieved.

Irrigation systems in crop production can and has also been automated. This solves the challenge brought about by the unreliability of climate changes thus need for water optimization. Automation of the irrigation systems is one of the most convenient, efficient and effective method of water optimization. The systems helps in saving water and thus more land can be brought under irrigation. Crops grown under controlled conditions tend to be healthier and thus give more yields. Controlled watering system results in reduction of fertilizer use and thus fertilizer costs go down.

1.6   Project scope

The scope of this project entails the design and implementation of a micro controlled irrigation system, depending on the soil moisture content. Humidly/moisture sensor will be the input of the system and an electric water pump will be the output of the microcontroller.

1.7   Project organization

This project report is organized into five chapters:
- Chapter one gives the introduction to the project, the project objectives and the scope.
- Chapter Two is the literature review which describes the system and the components used in the design.
- Chapter Three gives a complete technical aspect of the design.
- Chapter Four analyses and discusses the project.

- <u>Chapter Five</u> gives the conclusion of the whole project, if the objective and scope of the project were achieved. This chapter also includes appendices and the references used.

2 LITRATURE REVIEW

2.1 Sensors

A sensor is a device that detects and measures a physical quantity from the environment and converts it into an electronic signal. The physical quantity could be moisture, temperature, motion, light or any other physical phenomenon. Examples of sensors include: oxygen sensors, temperature sensors, infra red sensors, humidly sensors, soil moisture sensors and motion detection sensors. The output of the sensors is usually charge, current or voltage. Of interest in this paper is the soil moisture sensor. [4]

2.1.1 Soil moisture sensors

A soil moisture sensor is a device that measures the volumetric water content (VWC) of soil. Mathematically VWC, θ, is given as follows;

$$\theta = \frac{V_w}{V_T}$$

Equation 2-1: mathematical representation of VWC

Where: V_w is the water volume and V_T is the total volume (soil volume + water volume).

Soil moisture sensors are classified according to how they measure the soil moisture content.

2.1.2 Soil Moisture calculation

Two methods are used in determining the volumetric water content (VWC); direct and indirect. The direct method entails drying a known volume of soil in an oven and weighing it. [4]The direct method of measuring VWC is done using the following mathematical notation:

$$\theta = \frac{m_{\text{wet}} - m_{\text{dry}}}{\rho_w \cdot V_b}$$

Equation 2-2 Soil Moisture calculation

Where:

- M_{wet} is soil sample before drying in the oven
- M_{dry} is soil sample after drying in the oven
- ρ_w is water density
- V_b is the volume of soil sample before drying

Indirect method is based on correlating soil physical and chemical properties with water content. Three techniques are used in this method namely: chemical titrations, geophysical sensing and satellite remote sensing.

Chemical titration determines the moisture loss in sample soil after freeze drying or heating. Satellite remote sensing uses microwave radiation to check on the difference in dielectric properties of dry and wet soils. Geophysical sensing uses physical devices which are inserted in the soil to determine the soil moisture content. Techniques used in this method include: electrical resistance, electrical conductivity, soil dielectric, soil tension, TDR, FDR, soil capacitance among others.

2.1.3 Types of soil moisture sensors

2.1.3.1 Electrical resistance blocks Sensors
These sensors are made up of two electrodes made from a porous substance like sand ceramic mixture or gypsum. The two electrodes are imbedded in the soil during installation. [4] Moisture is allowed to move freely in and out of the sensors electrodes as the soil becomes moist or dries up. The resistance of the electrodes to the flow current is correlated with moisture content. To measure this resistance the electrodes are biased (energized) with a dc voltage and the current flowing through them measured. Applying Ohm's law;

R=V/I

Where: R is resistance (Unknown) (Ω)

V is biasing voltage (3.3V to 5.0V)

I is the current flowing through the electrodes (Amps)
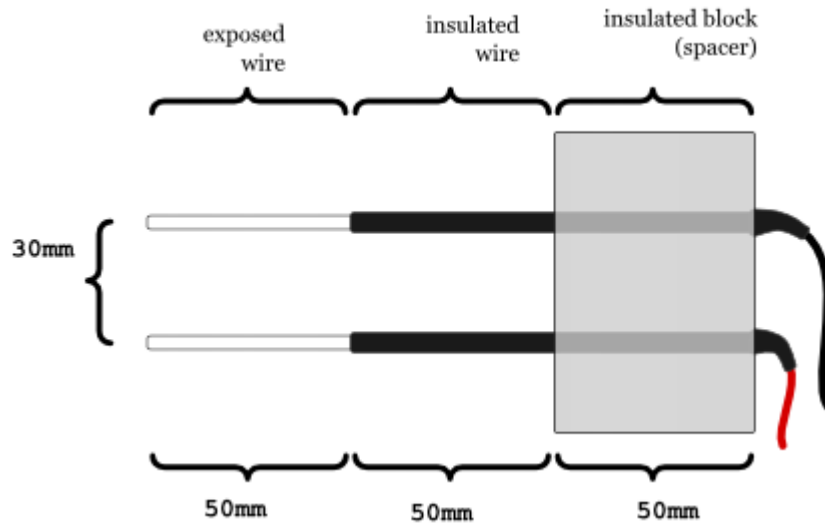
Figure 2.1.Home made soil moisture sensor

When the moisture content in the soil is high more current will be allowed to flow thus indicating low resistance. On the other hand for dry soils the sensor will indicate higher resistance portrayed by the low current reading.

This type of sensor is cheap and readily available. Electrical resistance blocks Sensors can also be readily assembled from home using two metal plates or steel nails.

Electrical resistance blocks Sensors are mostly used in small projects and gardens due to the following disadvantages;

- They are badly affected by soil PH and salinity thus requiring regular maintenance
- They have low sensitivity.

- The electrodes; especially which provides a constant source of ions; do not dry at the same rate as the soil surrounding it.

RESISTANCE METER

ELECTRODES

LEAD WIRES

GYPSUM BLOCK
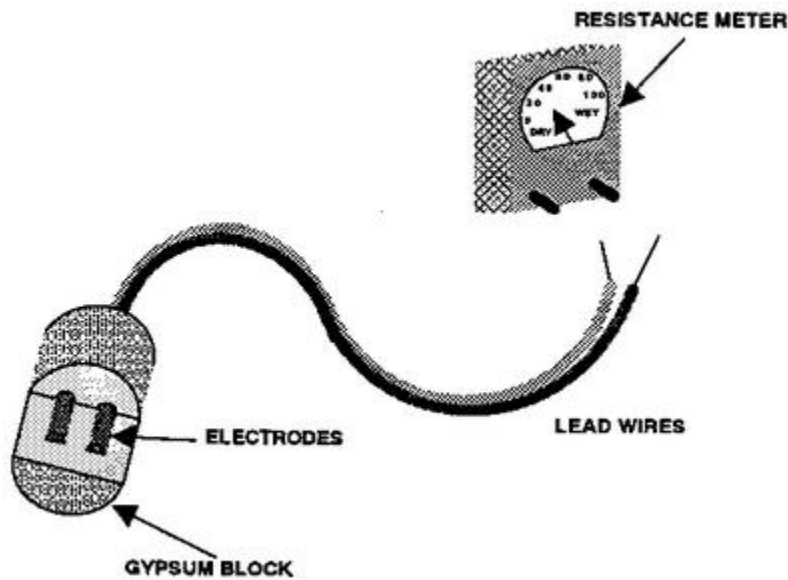
Figure 2.2. Schematic of an electrical resistance block and meter

2.1.3.2 Electrical conductivity probe sensors

Electrical conductivity probes employ the same principle as the Electrical resistance blocks Sensors. The one major difference between the two types of sensors is that Electrical conductivity probes sensors have their electrodes/probes in direct contact with the soil. [4]

By definition electricity is the flow of charges and water in its pure form cannot conduct electricity. The amount of impurities in water and mineral salts make it polar thus able to conduct electricity. A large volume of water will mean more ions and thus better electric conduction. Electrical conductivity probes sensors takes advantage of this phenomenon. [4]

The amount of current passing between the probes is directly proportional to the soil moisture content. Moist soil allow more current to flow between the probes while drier soils only allow a little current to flow between the probes. Better conductivity indicates a lower electrical resistance.

Most of the soil moisture sensors currently in the market especially for small projects are Electrical conductivity probes sensors. They have the following advantages.

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- They are cheap

- They are readily available

- Easy to calibrate and install

2.1.3.3 Dielectric sensors

Dielectric sensors measure the soil water content in the soil by measuring the dielectric permittivity of the soil. A dielectric material is substance that does not conductor electricity, but supports electrostatic field s efficiently. At some cases dielectric substance are referred to as insulators. The volume of water in the soil influences the dielectric permittivity of soil. [4]The dielectric of water which is 80.4 is greater than other soil constituents. Therefore change in the amount of water in the soil will directly lead to change in the soil dielectric permittivity.

Dielectric sensors are very complex to build thus making them very expensive. These sensors are mostly used in scientific research owing to their high accuracy and cost

Dielectric sensors are classified into two types namely: Capacitance sensors and Time Domain Reflectometry (TDR) sensors. These sensors do not measure electrical conductivity while measuring soil moisture. [7]

2.1.3.4 Capacitance sensors

Capacitance sensors use frequency domain reflectometry (FDR).Frequency domain reflectometry is the measure of signal reflections through a medium across frequency. Capacitance sensors contain two electrodes which are separated by a dielectric material.

The soil becomes the dielectric component after the electrodes are inserted into the soil; it could even be inserted into the access tube in the soil to achieve the same results. A high oscillating frequency is thereafter applied to the electrodes to induce a resonant frequency. The magnitude of the resonant frequency is dependent on the dielectric constant of the soil which in turns depends on or can change to the soil's moisture content. The change of the frequency as a result of the soil's moisture content is converted into the measurement of the soil moisture.

2.1.3.5 Time Domain Reflectometry (TDR) sensors

Time Domain Reflectometry uses the principle of waveguides. The actual content of water in the soil is measured under this technology and not the water potential.[7] The TDR device sends signals to the rods inserted in the soil. The time required for an electromagnetic signal to travel

along the wave guide is measured. The rate at which the send signal returns is used to measure the water content in the soil. The return rate is dependent on the dielectric properties of the soil. The signal takes longer time in moisture soils and shorter time in dry soil. This pulse signal is then converted into soil moisture measurement. [4] TDR sensors give accurate readings faster and require very little maintenance. The major disadvantage of TDR sensors is that they require they require different calibrations depending on different soil types.

2.1.3.6 Heat dissipation sensors

Heat dissipation sensors measure the soil moisture content by measuring the amount of heat dissipated from a medium which is of ceramic kind in most cases. The water contained in the medium spaces is directly proportional to the heat dissipated from the medium. [8]The less the water contained in the medium the less the heat dissipated and more heat is dissipated if the water contained in the medium is high. More heat dissipated leads to lower reading on the sensor and less heat dissipated leads to higher reading on the sensor.

The sensor uses the principle of capillarity. Capillary forces influence movement of water between the sensor medium and the surrounding soil.   Heat dissipation sensors are independent of soil salinity thus not affected by soil type. They require minimum or no calibration at all. On the downside this type of sensors are very expensive.

2.1.3.7 Tensiometer Sensors

Tensiometers sensors measure the soil moisture content in the soil by measuring the moisture tension/suction in the soil. Tensiometers sensors is made up of two major parts; a plastic tube which has a ceramic porous medium at its tip and a vacuum gauge on the opposite end. [7]

During installation the ceramic tip is buried in the soil at the calibrated depth which should be as near as possible to the plants root area. The vacuum gauge measures the effort the plants roots have to put to extract water from the soil.[4]This is the measure of the soil measure tension which is measured in centibars.
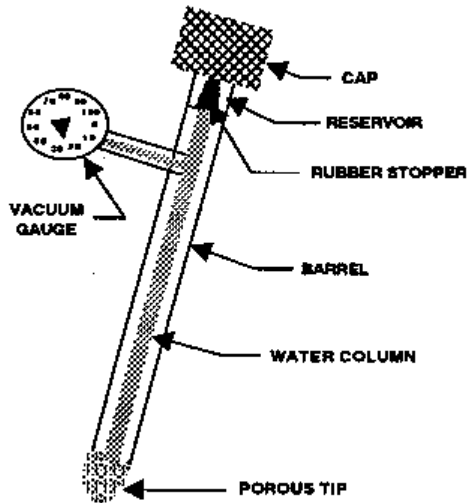
Figure 2.3 Diagram of a tensiometer

If the soil moisture content is low the roots work harder to extract water from the soil. The reading on the sensor is high. When water is more available in the soil the roots works less and thus lower reading is indicated on the sensor.[8]
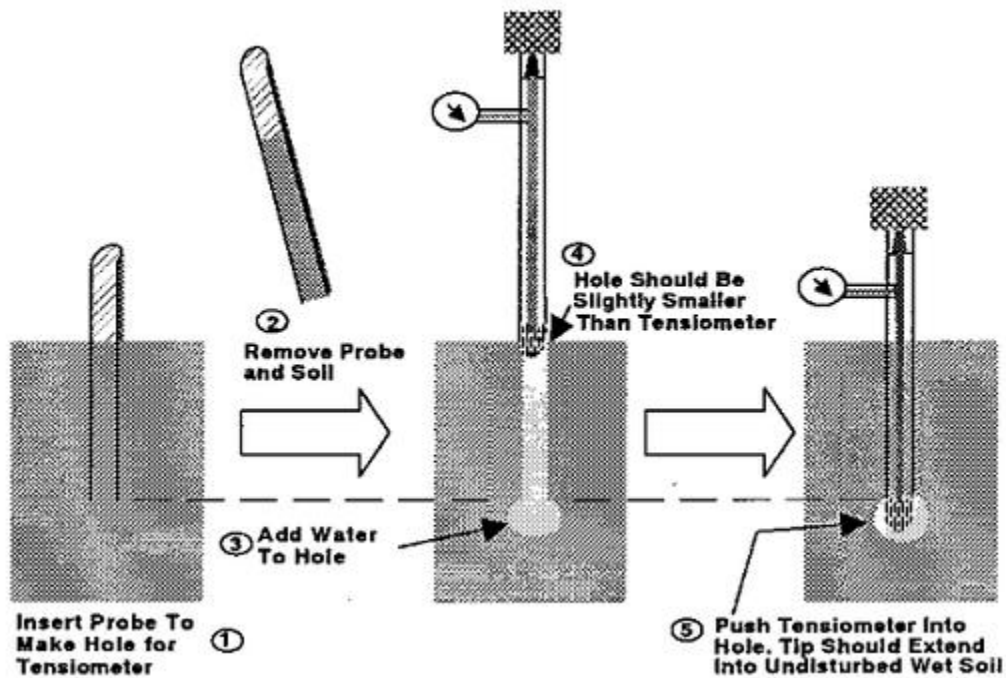

Figure 2.4 Tensiometer installation

2.1.3.8 YL-69 Moisture Sensor

This is an Electrical resistance Sensor. The sensor is made up of two electrodes. This soil moisture sensor reads the moisture content around it. A current is passed across the electrodes through the soil and the resistance to the current in the soil determines the soil moisture. If the soil has more water resistance will be low and thus more current will pass through. On the other hand when the soil moisture is low the sensor module outputs a high level of resistance. [7]This sensor has both digital and analogue outputs. Digital output is simple to use but is not as accurate as the analogue output.
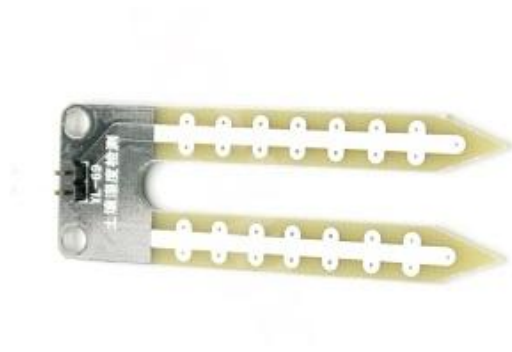
Figure 2.5 YL-69 Sensor

YL-69 soil moisture sensor has the following specifications: [7]

Vcc power supply	3.3V or 5V
Current	35mA
Signal output voltage	0-4.2V
Digital Outputs	0 or 1
Analog	Resistance (Ω)
Panel Dimension	3.0cm by 1.6cm
Probe Dimension	6.0cm by 3.0cm
GND	Connected to ground

Table 2-1 YL-69 specifications

The sensor comes with a small PCB board fitted with LM393 comparator chip and a digital potentiometer.
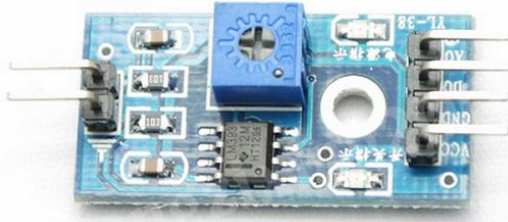
Figure 2.6 YL-69 PCB

2.1.3.8.1 Digital potentiometer

A potentiometer is basically a variable resistor. Like analog potentiometers, digital potentiometers are used to scale or adjust resistance of a circuit. [7] Digital potentiometers are also known as a digital pot or digipot. Digipots are used mostly in scaling analog signals to be used in a microcontroller.
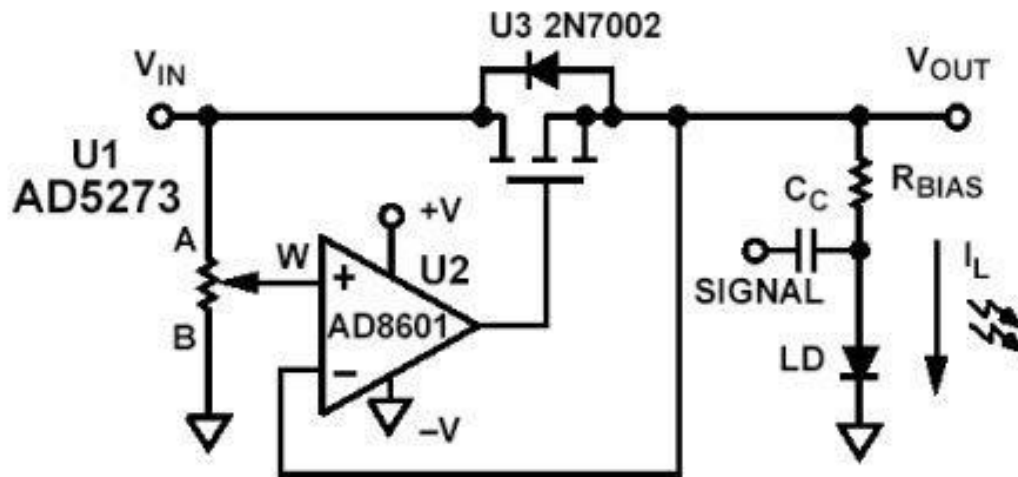
Figure 2.7 Digipot schematic

Digipot output resistance is variable based on digital inputs and thus also know as resistive digital-to-analog converters (RDACs). Some RDACs come with nonvolatile memory thus

provide wiper setting retention after a power ON to OFF cycle. Digipots are available as integrated circuits (ICs).
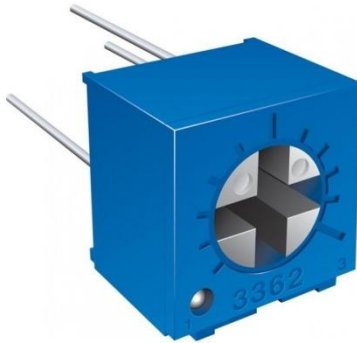
Figure 2.8 P3362 Electronic potentiometer

On the soil moisture sensor the digital potentiometer acts as a low resolution digital to analog convertor (DAC) thus adjusting it varies the sensitivity of the sensor.

2.1.3.8.2 LM393 comparator

A compactor 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 a 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.
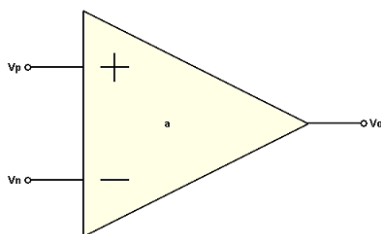
Figure 2.9 Operational amplifier

One of the most commonly used comparators is LM393. It is available as an IC.
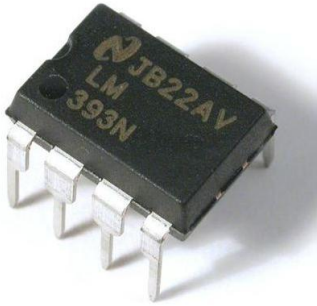
Figure 2.10 LM 393 Comparator

It is preferred due to the following characteristics: [7]

• Supply Voltage	(2.0 to 36.0) V
• Supply	Single or dual (±1.0 to ±18.0) V
• Current drain	0.4 mA
• Biasing current	25 nA
• Offset current	± 5 nA
• Saturation Voltage	± 3 mV
• Compatibility	TTL, DTL,ECL, MOS and CMOS logic systems
• Differential input voltage range	Same as power supply voltage

Table 2-2 8 LM 393 Comparator specifications
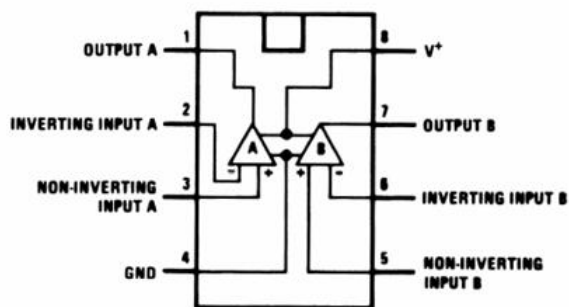
Figure 2.11 LM393 pin configuration

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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.

2.1.4 Sensor Selection

When deciding on which sensor to use the following factors should be put into consideration: [4][8]

Price: This is the most important parameter when selecting any component. The price of the sensor will ultimately affect the price of the whole system as this is one of the major system modules. Sensor with the most competitive price should be chosen.

Power: In any electrical system power efficiency is critical. Moisture sensor will low power consumption should be selected. Sensors which can be battery powered can be used in areas without electricity connection.

**Technology:** Technology used to design sensor dictate the sensitivity, cost and durability of the sensors. Most low cost sensors have poor sensitivity, rust and corrode over time. Resistive or conductive sensors which are affected by soli salinity thus have a short life.

Shape: Long and slender sensors can be used in many applications than bulky ones.

Durability: Soil moisture sensor which are not affected by soil salinity, corrode or rust should be selected. Soil moisture sensor probes that measure conductivity or resistance should be avoided, since they will wear out over time.

Accuracy and Linearity: A quality soil moisture sensor probe should give an output which is proportional to water content over the full output range. In addition, the soil moisture sensor probe should have a good output range to reduce sensitivity to noise.

Voltage Range: Choose a sensor that has a big supply voltage range. Powering a sensor with the wrong voltage will damage the sensor or give inaccurate results.

Sensor Installation

Sensors orientation and installation depends on the sensor type, size and shape (flat, node, and rod). Installation should be guided by the manufacturer's installation manual. But in general the sensor should be installed as close to the root area as possible. [4]

On new fields; the SMS should be installed prior to planting crops. The sensor should be installed at approximately 3 inches deep. For existing fields trenches are dug at uniform intervals and SMS installed.[8]

Figure 2.12.Installation of flat probe SMS

Flat sensor probes are commonly found in two types and typically use TDT technology. These are the Exposed wave guides and the Encased wave guides. Both of these sensor types are installed horizontally. [7]

Node probes type soil moisture sensors are usually installed vertically around the root area. Granular Matrix technology is typically used in this SMS type.

Figure 2.13. SMSs with node probes installation

For rod type probes SMSs; the probes are installed inclined at 45^0 to the ground to allow the probes to the read moisture content from the root zone. TDR technology is typically used in this class of sensors. SMSs should be installed away from structures, tree canopy, construction roads and plant debris.

2.1.5   Sensor Calibration

As is the case of sensors installation, sensor calibration should also be done in line with the manufacturer's specifications. Different sensors have different calibration procedures. Development stage of the plants roots also determines the SMSs calibration. [7] The soil type and crops water requirements greatly influence the sensors calibration.

Dry soil	0 ~300
Humid soil	300~700
In water(soil soggy)	700~950

Table 2-3. YL-69 sensor value description

Maintenance

The technology used to design the sensors determines the regularity of maintenance. Electric resistance and conductance sensors tend to corrode with time and thus require regular maintenance and replacement. TDT and TDR sensors are the most stable and durable thus requiring minimum maintenance.

2.2   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. [1] There are different microcontroller families including: 8051, PIC (Programmable Interface Controller) and AVR. Microcontrollers are used in digital applications as control units. [3] 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 years high level languages like C, C++ PASCAL and java have been used. [5] 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.

2.2.1 Types of Microcontrollers

2.2.1.1 8051

These are among the earlier microcontrollers to be fabricated. Due to superiority in technology in the newer versions, very few companies still fabricate 8051. Earlier types of 8051 have 12 clocks per instruction whereas the newer versions have 6 clocks per instruction. 8051 microcontroller does not have an in built memory bus and ADC. First 8051 microcontroller to be fabricated with Harvard architecture was done in 1980 by Intel. [1]

2.2.1.2 Programmable Interface Controller (PIC)

Programmable Interface Controllers are commonly referred to as PIC. PICs are slightly older than 8051 microcontrollers. PICs are preferred to 8051 because of their small low pin count devices. PICs perform better and are affordable than 8051. [3] The Microchip technology fabricated the single chip microcontroller PIC with Harvard architecture. The only major downside of PIC is its programming part is very tedious. PICs are hence not recommended for beginners.

2.2.1.3 AVR:

In 1996, Atmel fabricated this single chip microcontroller with a modified Harvard Architecture. This chip is loaded with C- compiler and a free IDE. Like PIC, AVR microcontrollers are difficult for the beginners to work with. AVR microcontroller has on-chip boot-loader thus AVR can be programmed easily without any external programmer. [3] AVR controllers has number of I/O ports, timers/counters, interrupts, A/D converters, USART, I2C interfaces, PWM channels, on-chip analog comparators.[8]

2.2.2 Arduino

Arduino is an open-source electronics design platform. The Arduino board is specially designed for programming and prototyping with Atmel microcontrollers. [5] An arduino interacts with physical world via sensors. Using arduino; electric equipments can be designed to respond to change in physical elements like temperature, humidity, heat or even light. [5] This is the automation process. For example, reading a humidity sensor and turning on and off of an automatic irrigation system. There several types of arduino boards.

The open-source Arduino environment allows one to write code and load it onto the Arduino board's memory. The development environment is written in Java and based on Processing, AVR-GCC, and other open source software. [5] The Arduino programming language is an implementation of Wiring, a similar physical computing platform, which is based on the Processing multimedia programming environment. The arduino software is published as open source tools, available for extension by experienced programmers. The language can be expanded through C++ libraries, and people wanting to understand the technical details can make the leap from Arduino to the AVR C programming language on which it's based. Similarly, AVR-C code can be added directly into the Arduino programs if one so wishes.[5]

2.2.3 Types of arduino boards

2.2.3.1 Legacy Versions

Arduino legacy versions include Arduino NG, Diecimila, and the Duemilanove. These arduinos use ATMEGA168 chips. They require manual selection of either USB or battery power.[5] For Arduino NG one is required to hold the rest button on the board for a few seconds before uploading a program on to it.

Figure 2.14 Different types of arduino

Arduino Uno

This is the most common arduino type. This arduino type uses ATmega328 AVR microcontroller.
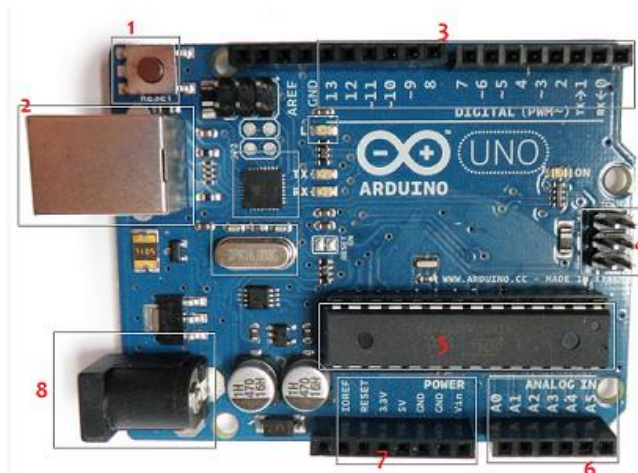
1- Reset Button
2- USB Port
3- Digital Pins
4- in circuit serial Programmer
5- ATmega328
6- Analog In
7- Power Management sockets
8- External power sockets

Figure 2.15 Parts of arduino uno

ATmega328 is more preferred due to the following features:

- Have three 8-bit bi-directional I/O ports with internal pull-up resistors.[5]
- 32K Bytes of flash memory.
- 1K Bytes EEPROM
- 2K Bytes of RAM
- 2 instruction words/vector.

- 8-channel 10-bit successive approximation ADC

- Programmable Serial USART

- 23 Programmable I/O Lines

- Operating Voltage 1.8 - 5.5Ve.t.c
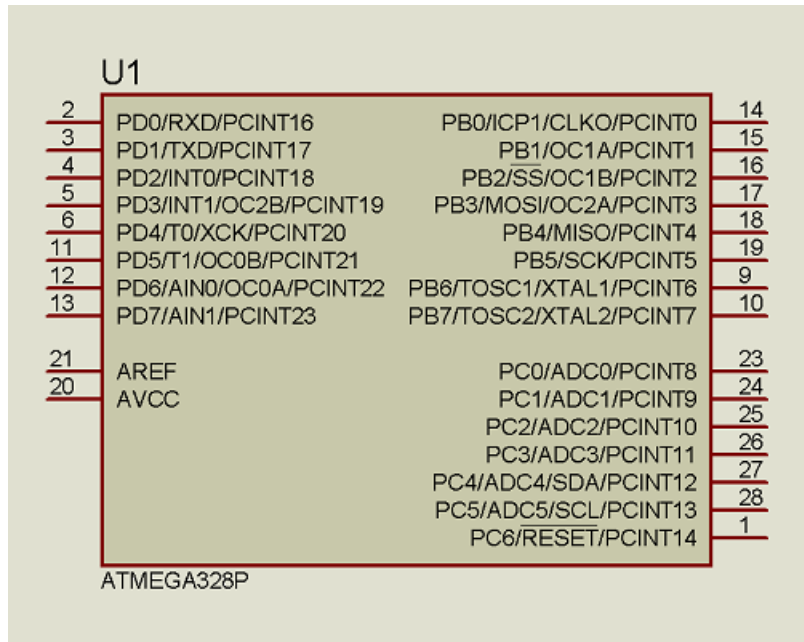
Figure 2.16 Atmega 328 microcontroller pin configuration

2.2.3.2 Arduino Mega 2560

This is regarded as an advancement of arduino uno. It has more memory than arduino uno. It has a total of 54 input pins of which 16 are analog inputs. It has a larger PCB board than arduino. Overall it is more powerful than arduino uno. This arduino board is based on ATmega2560. [5]

2.2.3.3 Arduino LilyPad

This arduino board is designed for wearable applications. It is usually sewn on fabric. This board requires the use of a special FTDI-USB TTL serial programming cable. Arduino LilyPad is used to design "smart" wearable. [5]

2.2.3.4 Arduino Mega ADK

This arduino board is specifically designed to interact with android devices.

2.3   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. LCDs are commonly preferred in display because they are cheap, easy to programme and can display a wide range of characters and animations.

A 16x2 LCD have two display lines each capable of displaying 16 characters. This LCD has Command and Data registers. The command register stores command instructions given to the LCD while the Data register stores the data to be displayed by the LCD.

Figure 2.17 LCD (16X2)
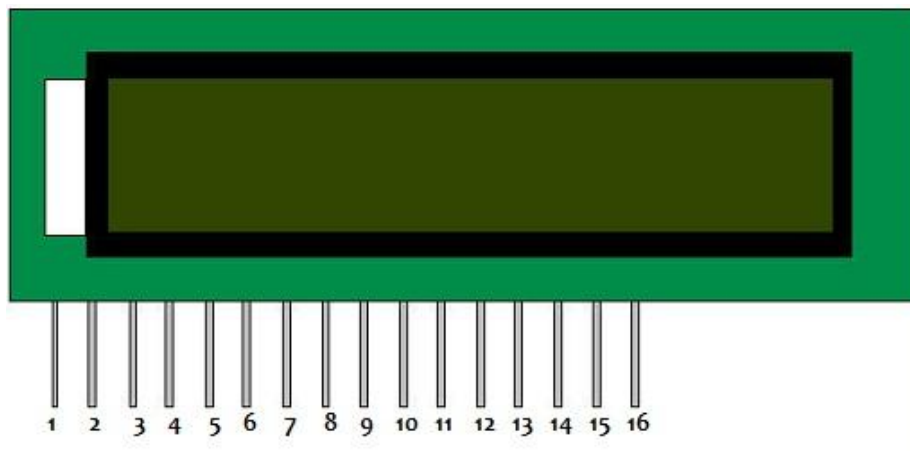
When using 8-bit configuration all 8 data pins (DB0-DB7) are used while only 4 data pins (DB4-DB7) are used in a 4-bit configuration.

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 V_{CC} (5V)	A
16	Backlight Ground (0V)	K

Table 2-4 LCD Pin configuration

2.4 Automatic switching circuits

In electronics automation many times the designer is confronted by a situation where he/she has to switch very high voltage equipment on, using a low voltage circuit. For example using a 5v dc voltage, it is possible to switch on/off a 230v ac machine. [6] Digital or discrete signals enables as opposed to analog signals are used. There are a number of components used in electronic switching today.

2.4.1 The Triac Switching circuit

Triode for Alternating Current (TRIAC) is an electronic component-of the thyristor family- that can conduct current in either direction when it is triggered. Due to this capability a TRIAC is also known as bidirectional triode thyristor or bilateral triode thyristor. TRIAC has 3-terminals. There are two Main Terminals, A1 and A2 which carry the heavy current that is being switched, and a control terminal, the Gate, G, which accepts the control signal to turn the switch on.

Figure 2.18 The TRIAC

TRIACs are closely related to silicon-controlled rectifiers (SCR) but a number of differences arise between the two.

Triac is bidirectional devices unlike SCR which is unidirectional. Triac can be activated using either negative or positive current applied to its gate unlike SCR which can only be activated using positive currents. Triac cannot be turned off using the gate once turned on.

The bi-directionality makes TRIACs very convenient switches for AC circuits, also allowing them to control very large power flows with only milliampere-scale gate currents. In addition, applying a trigger pulse at a controlled phase angle in an AC cycle allows one to control the percentage of current that flows through the TRIAC to the load (phase control), which is commonly used, for example, in controlling the speed of low-power induction motors, in dimming lamps and in controlling AC heating resistors.

2.4.2 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.[6] 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.
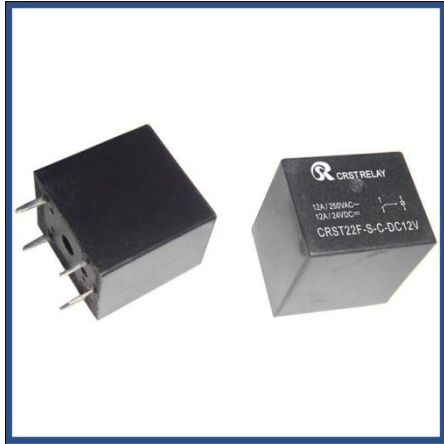
Figure 2.19 5VDC Coil Relay

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).

Just like manual switches the relay switch part is available in various configurations. Double pole, double throw (DPDT) configuration is most common configuration. DPDT means that the relay separately controls two switches that work together. Both switches have a normally NO and NC contacts. Other commonly used configurations are:

- SPST – Single Pole Single Throw. This relay configuring has four terminals. Two of the terminals are coil terminals.
- SPDT – Single Pole Double Throw. This configuring has five terminals. One of the terminals is a common terminal which connects to either of the two others.
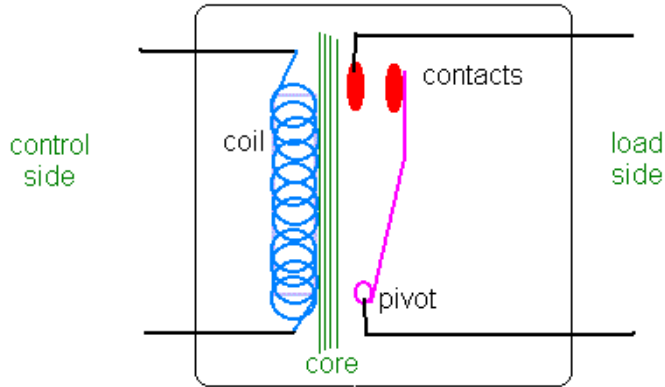
Figure 2.20 Inside a SPST relay

- 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.

A simple example of relay application is where a 9V DC circuit can be used to turn on/off a 230v AC lamp.
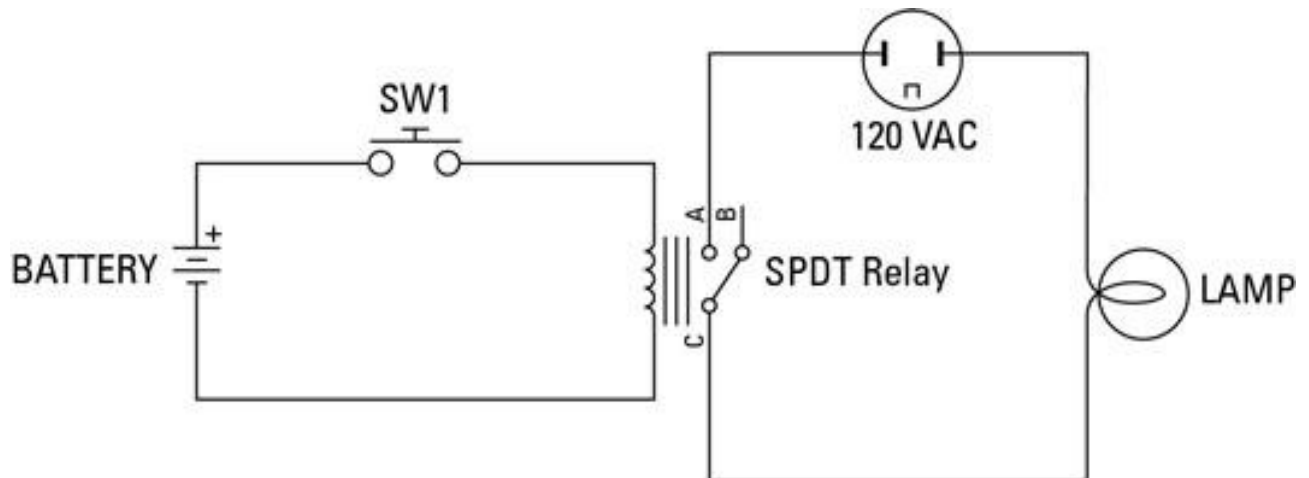

Figure 2.21Simple relay interfacing

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 DESIGN AND IMPLEMENTATION

The system has three major parts; humidity sensing part, control section and the output section. The soil humidity was detected using YL-69 soil sensor (a resistance type sensor). The control unit was achieved using ATMega328 microcontroller based on arduino platform. The output was the control unit was used to control the irrigation system by switching it on and off depending on the soil moisture contents. Two stages of design were undertaken; hardware and software.

3.1 Hardware design

3.1.1 Control Unit: ATMega328 microcontroller on arduino platform

ATMega328 microcontroller on arduino platform was selected the control unit of the microcontroller. Arduino Uno was selected from the expansive arduino family. Arduino Uno has a total of 20 inputs pins of which 14 are digital and 6 are analog inputs. [5] The digital pins can be used as either inputs or outputs and also 6 of the 14 pins can be utilized as PMW. The board has a 16 MHz ceramic resonator, a USB connection and a power jack.
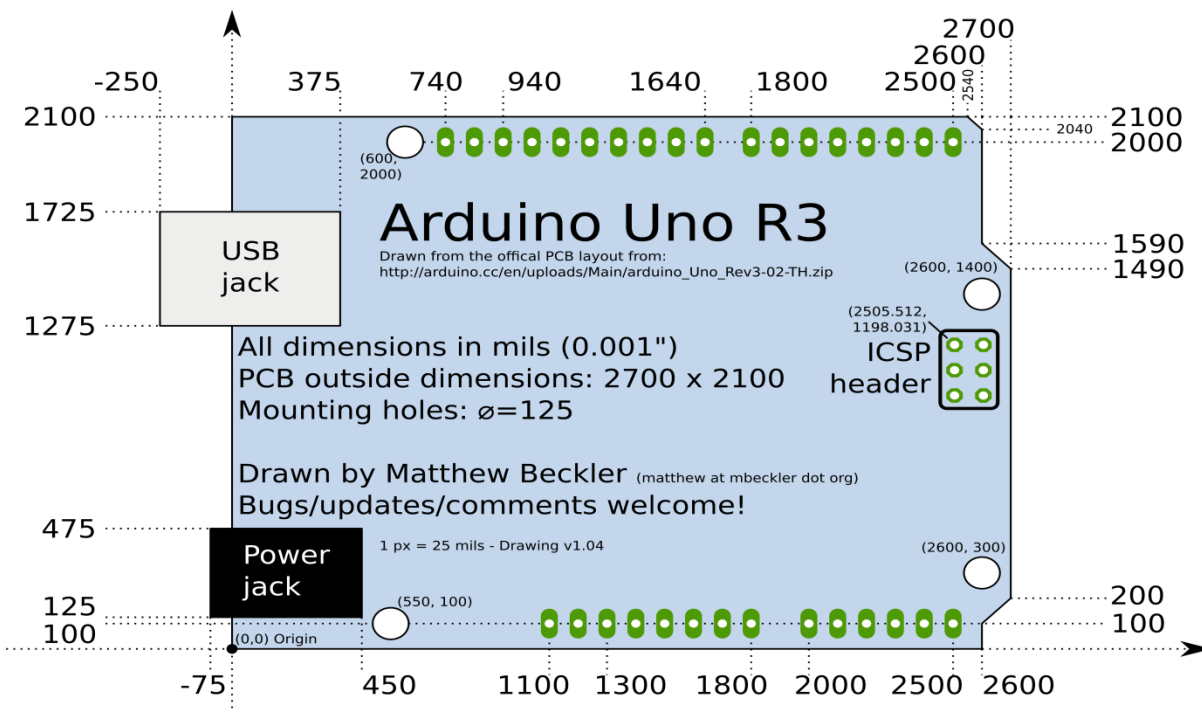

Figure 3.1 Arduino Uno

In the design of the system analog pins were selected as the arduino input and digital pin was selected as the arduino output pins.[5]

Other important pins on the arduino board are shown in the table below.

AREF	Analog Reference pin
GND(Digital side)	Digital Ground
Vin	Input voltage (external power source)
5V	Regulated power to the microcontroller
3.3V	3.3V generated by the on-board FTDI chip
GND	Ground

Table 3-1 Important pins in arduino

The pins on the arduino were selected as shown below.

Pin	Connections
• Digital pin 2	LCD D7 pin
• Digital pin 3	LCD D6 pin
• Digital pin 4	LCD D5 pin
• Digital pin 5	LCD D4 pin
• Digital pin 11	LCD Enable
• Digital pin 12	LCD RS pin
• Digital pin 7	Connection to Water Pump
• Digital pin 8	LED Pin indicating Soggy soil
• Digital pin 9	LED Pin indicating Moist soil
• Digital pin 10	LED Pin indicating Dry soil
• Analog Pin 4	Connection to Soil Moisture Sensor
• VCC	5VDC
• GND	Ground

Table 3-2 Selected pins on arduino

3.1.2 Sensing Unit:

3.1.3 YL-69 soil moisture sensor connection to arduino

YL-69 soil moisture sensor was interfaced to the arduino through a digital a PCB drive. The PCB drive has a digital potentiometer and a LM393 comparator. The LM393 comparator is used to compare the voltages across the sensor probes and the set Vcc voltage.[7] The digipot is used to alter the sensitivity of the sensor when connected in digital mode. The out of the PCB drive has four connections pins as shown in the table below.

Vcc	Connected to 5VDC
GND	Connected to ground
A0	Analog value output connector
D0	Digital value output connector（0 or 1）

Table 3-3 YL-69 PCB pins

The analogue configuration was selected as its more stable compared to the digital configuration. The PCB drive pin A0 was connected to the arduino analog pin A0.
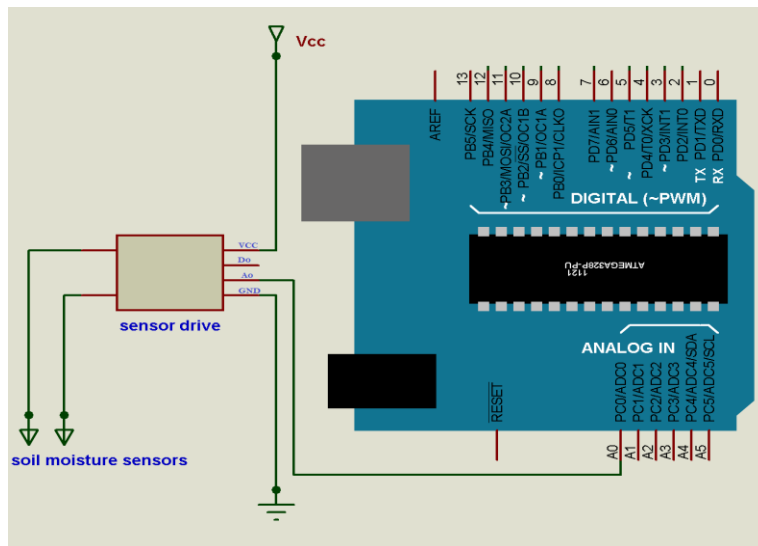

Figure 3.2 YL-69 Connection to arduino board

The output of the sensor to the arduino analog pin A0 was resistance. 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 (I_{out}) for different soils and different soil moisture levels was calculated as shown below:

I_{out} = Vcc / {Soil Resistance value (R_S)}

Equation 3-1 YL-69 Current calculation

3.1.4   Output Units

3.1.4.1 LCD interface with Arduino

To affect display a 16x2 Liquid Crystal Display (LCD) was chosen. LCD pins D4, D5, D6 and D7 were used as data lines in a 4 bit mode configuration. These pins were connected to arduino pins 5, 4, 3 and 2 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 digital pin 11 on the arduino board. Pin RS (Register Select) on the LCD was connected to arduino digital pin 12. R/W pin of the LCD was connected to GND (ground).

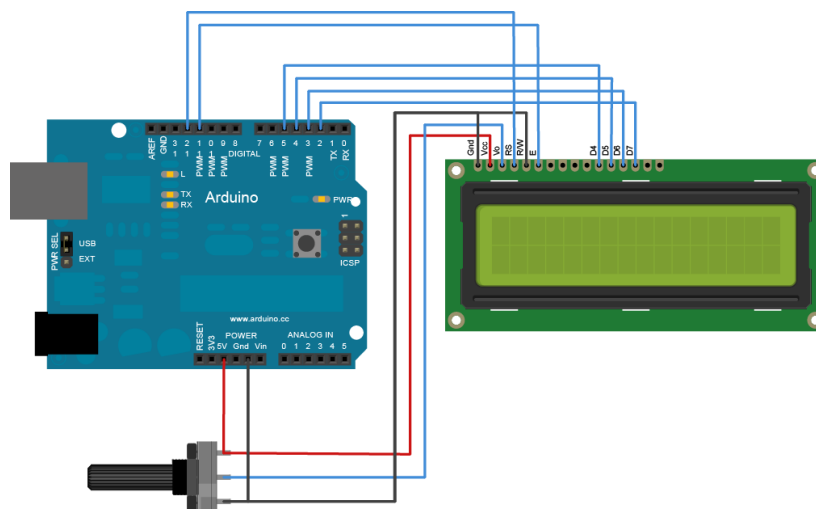The figure below shows the LCD-microcontroller interface.

Figure 3.3 LCD Connection to arduino board

3.1.4.2 LEDS

To indicate the three states of the soil three LEDs were used. The three LEDs lit up depending on the soil moisture content. When the soil was dry LED connected to arduino digital pin 13 was lit. For moist soil (required condition) LED connected to arduino digital pin 12 lit up and for soggy soil LED connected to arduino digital pin 11 lit up.

The three LEDs were connected to the microcontroller as shown below.
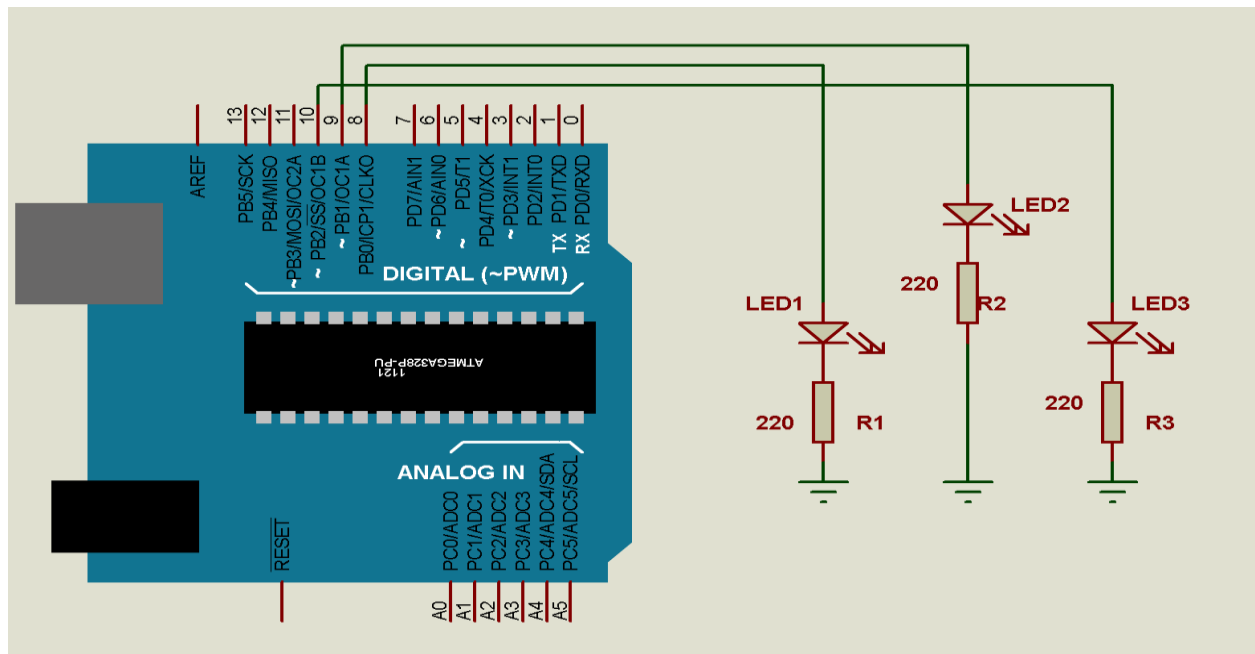

Figure 3.4 LEDs Connection to arduino board

Ohms law was utilized to determine the size (in ohms) of the protection resistor to be interfaced with the LEDs. From Ohms law

Voltage (V) = {Current (I)}*{Resistance(R)}

Where as in our case;

V= Vcc (5V) -Voltage drop across LED (selected LEDs has 2.0V)

I_{LED}= LED current (20mA)

V_{LED} = LED Voltage drop (red in colour) (2V)

R= minimum required resistance value

Therefore

R_{min} = {(5-2) V}/ {20mA} =150 Ω

To achieve current limitation a resistance value higher than the calculated R_{min} was selected. A 220Ω resistor was used and thus only 13.6mA current was allowed to pass through each of the three LEDs.

3.1.4.3 Water pump connection to the Arduino

To implement the final bit of the automated irrigation system an electric motor (240VAC) 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 (SLT73-5D-1Z) was used as the isolation unit.

The microcontroller was connected to the relay via an NPN transistor (2N4123). To protect the transistor; while turning it on, a resistor was used. The resistor limits the current flowing through the transistor. As was the case with LEDs ohms law was used as shown below.

R_{min} = (5 − 0.7) V / 40mA = 107.5Ω

A resistor of 470Ω was selected and thus the current through the transistor was limited to;

4.3V / 470Ω =9.12 mA

To protect the microcontroller from back e.m.f during switching a diode was connected across the relay. The connection was as shown below.
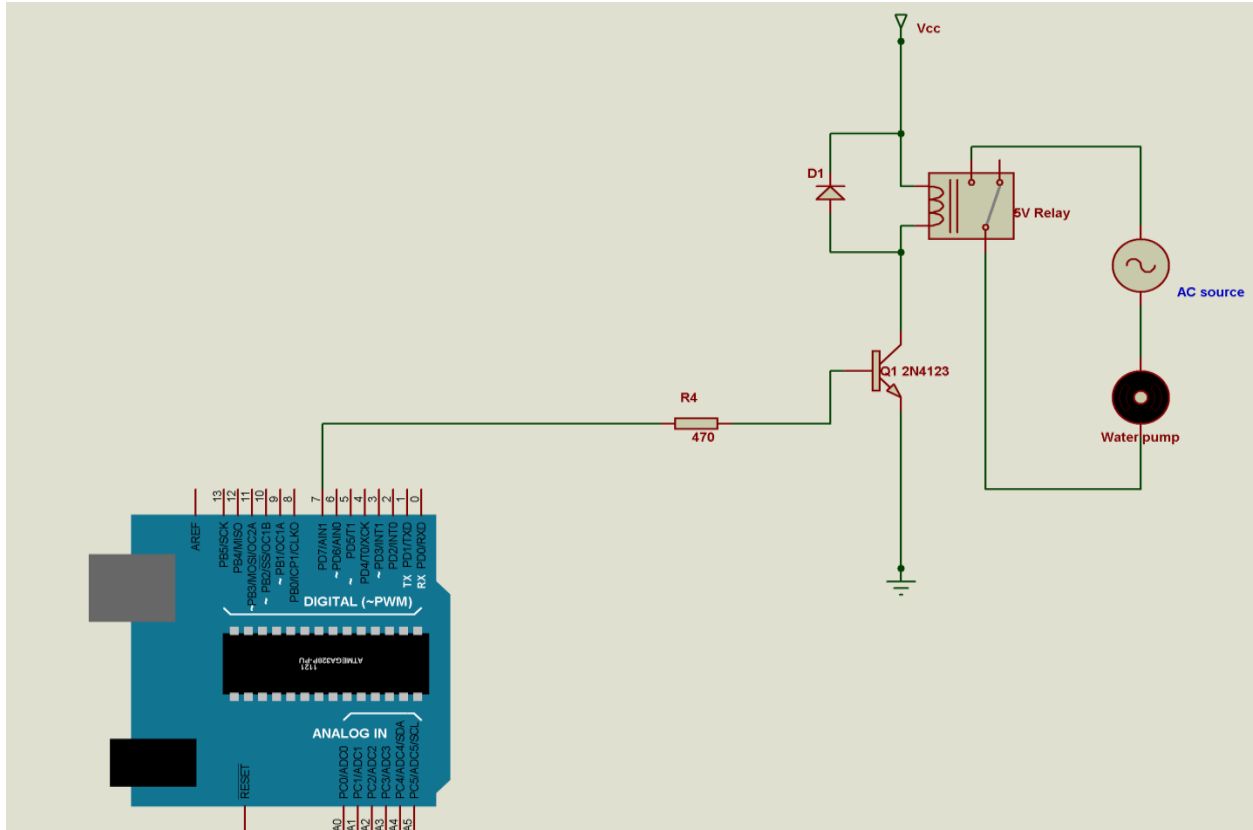
Figure 3.5 Relay interfacing of arduino to the 240VAC pump

3.1.5 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 arduino board pins were also terminated at the PCB. The following steps were followed in preparing the PCB.

1. The circuit's schematic was captured/designed using ExpressPCB software. Though not mandatory, this stage is very important in that it helps one in placing all the components correctly.

2. Using the same ExpressPCB 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.
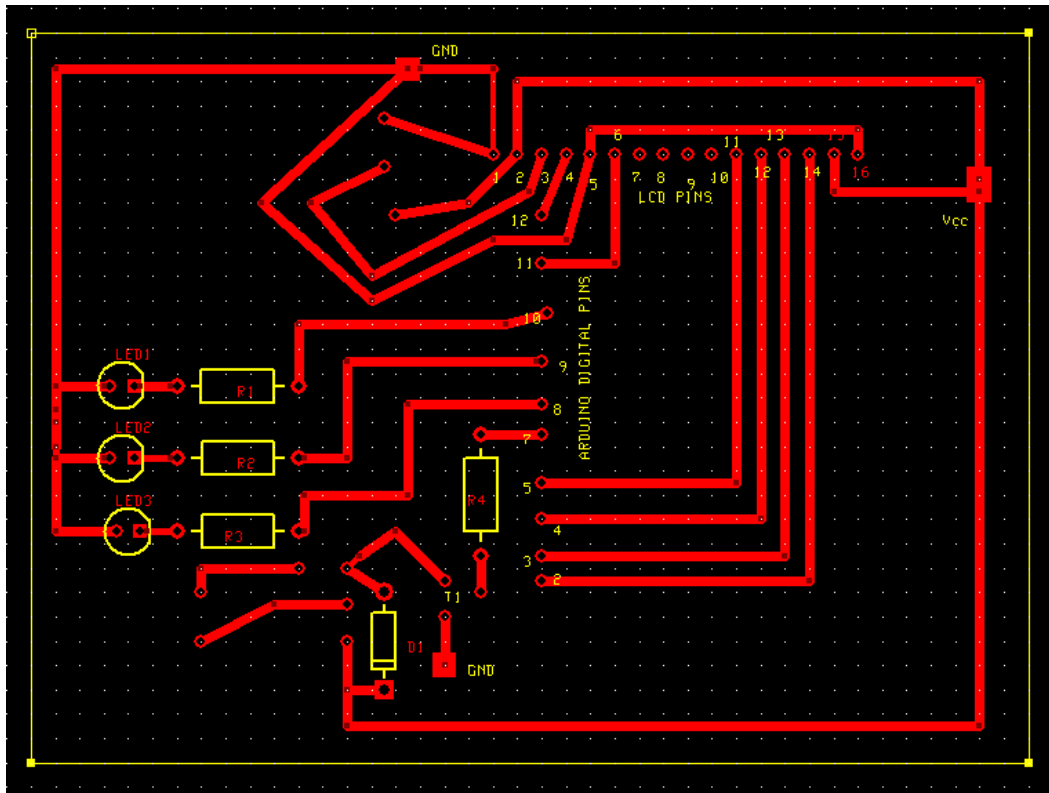
Figure 3.6 Printed Circuit Board design

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 Persulfate (Natriumpersulfat - Feinätzkristall), 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.
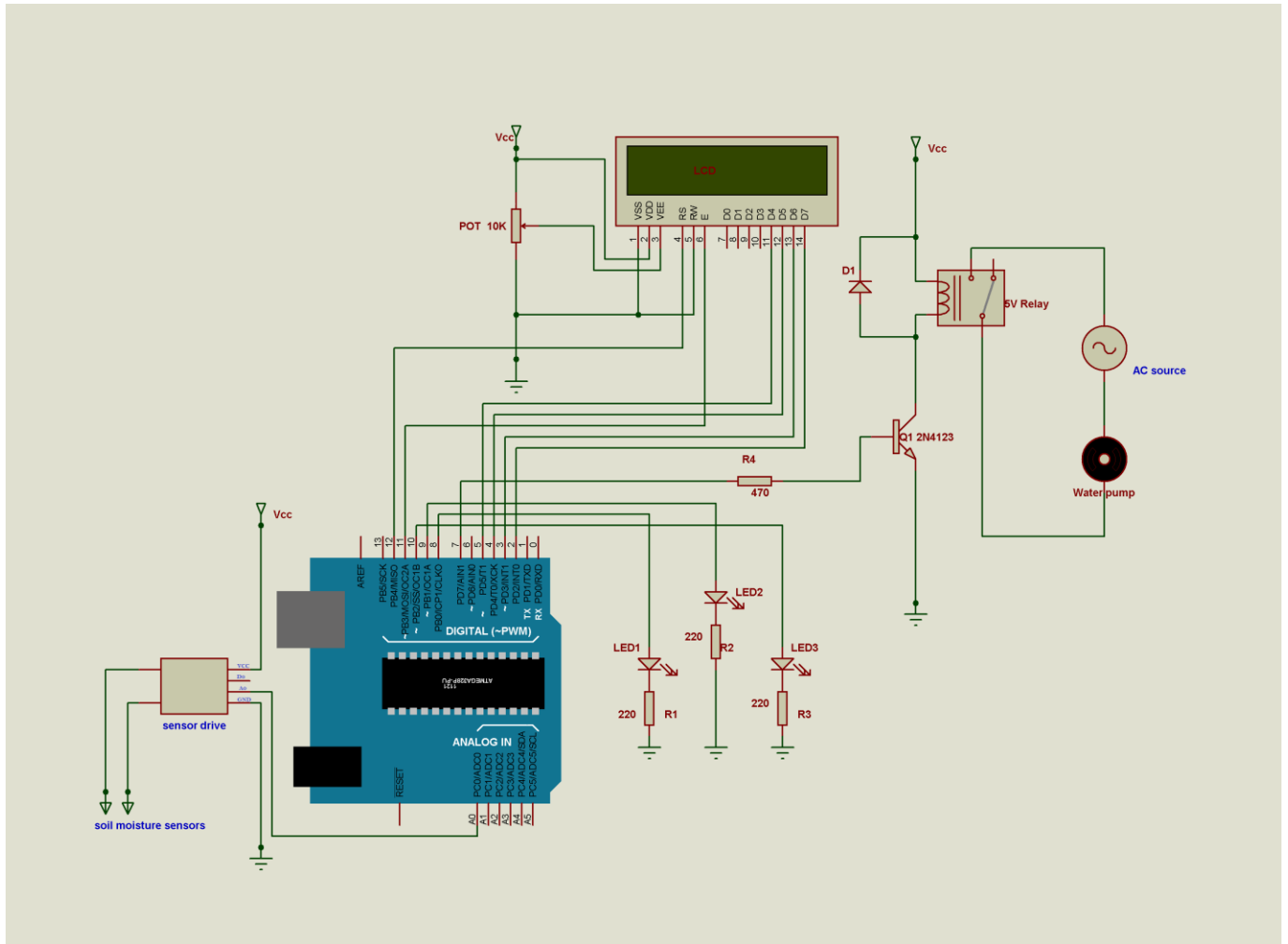
Figure 3.7 Circuit with all the components and parts

3.2 Software design

To be able to interpret the different states of the soil as prompted by the soil sensor the microcontroller was programmed. The arduino integrated development environment (IDE) was used. The idea is based on C++ and thus can be extended using C++ libraries. Arduino programs (sketches) are cross platform, Simple, clear and at the same time flexible for advanced programmers.

The project sketch is attached at the appendices page.

3.2.1 Program Pseudo code

READ sensorvalue

COMPARE sensorvalue with set threshold

IF sensorvalue > maximum set value

TURN-ON pump

DISPLAY soil condition on LCD

LIGHT dry soil LED

ELSE IF sensorvalue < maximum set value > minimum set value

TURN-OFF pump

DISPLAY soil condition on LCD

LIGHT moist soil LED

ELSE IF sensorvalue < minimum set value

TURN-OFF pump
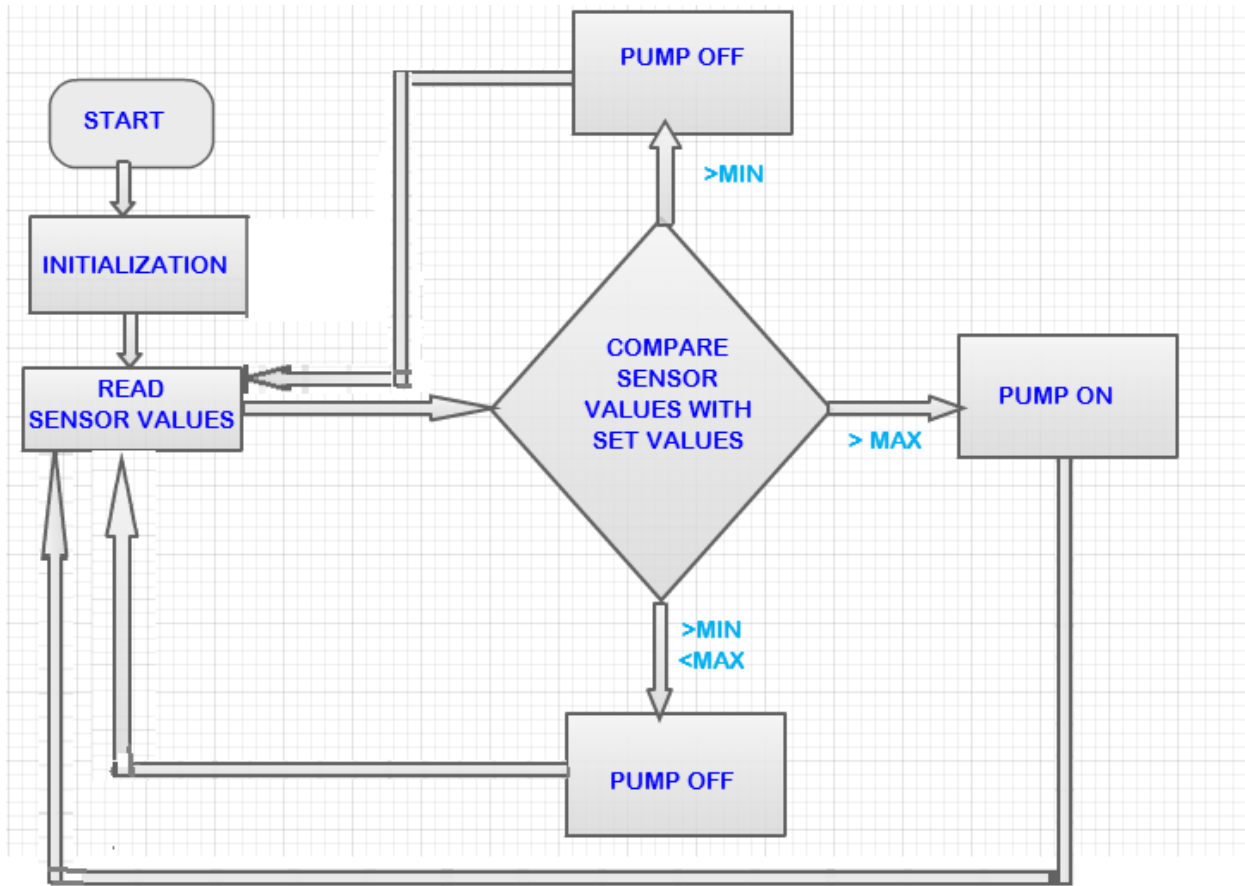
DISPLAY soil condition on LCD

LIGHT soggy soil LED

Figure 3.8 The program flow Diagram

4 RESULTS ANALYSIS AND DISCUSSIONS

4.1 Results

The VWC 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 3.1. The soil was measured in equal amount of 250gramms. Water was added in the soils in steps and the sensor values recorded.

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

Table 4-1 Sensor values

4.2 Discussion

The data obtained from the sensor reading and recorded in table 3.1 was used to plot a graph of Soil water content against sensor reading.
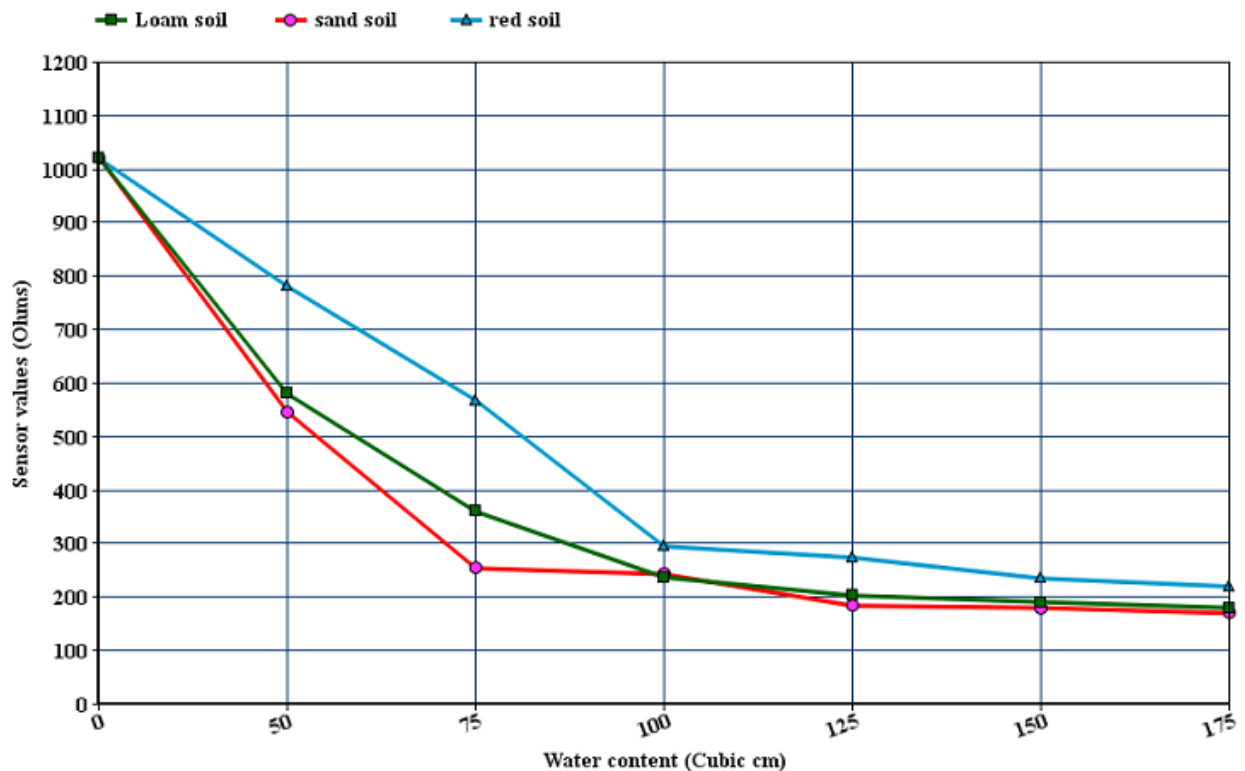
Graph 3.1

The SMS (YL-69) 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 $25cm^3$ 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 $50cm^3$ the resistance value reduced drastically to the range of 500. On adding more water the resistance value kept reducing. At around $100cm^3$ 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 three states defined. The states are soggy, moist and dry. When the dry state was achieved the control unit (micro controller) switched the water pump on via a relay circuit. The three states were indicated using three different LEDs and an LCD. The LCD also indicated when the pump was running.

The control circuit and the sensor circuit were powered using a 9V alkaline battery which was connected via a voltage regulator with an output of 5V.

5 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

A system to monitor moisture levels in the soil was designed. The system was used to switch on/off the watering system/pump according to set soil moisture levels. The control unit the prototype was implemented using a microcontroller on arduino platform while the sensing bit was implemented using a SMS YL-69.

Three LEDs and an LCD were used to implement the display of the three soil states i.e. soggy soil, moist soil and the dry soil states. To switch between the control and the irrigation systems a relay switching circuit was used.

5.2 RECOMMENDATIONS

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

- Cost effective techniques to overcome the limitation of requiring a soil specific calibration should be employed.
- 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.

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[10] http://www.vision2030.go.ke/ accessed on 12th January 2014

6 APPENDIX

6.1 Microcontroller code

```
/*

###############################################################################

#       Objectives:     Micro-controlled Irrigation System

#       Behavior:       When the soil is dry-Water pump starts running

#       Author:         Paul Kimani

###############################################################################

// include the lcd library code:

#include <LiquidCrystal.h>

// pins definition

int soggyLEDPin = 8;

int moistsoilLEDPin = 9;

int drysoilLEDPin = 10;

int PumpPin = 7;

// initialize the library with the numbers of the interface pins

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

// variables

int moistureSensorValue;   // stores the moisture sensor values

int j = 0;

void setup(){

 // serial initialization

 Serial.begin(9600);
```

```
  // Arduino pins initalization

pinMode(soggyLEDPin, OUTPUT);

pinMode(moistsoilLEDPin,OUTPUT);

pinMode(drysoilLEDPin,OUTPUT);

pinMode(PumpPin,OUTPUT);

 // set up the LCD's number of columns and rows:

lcd.begin(16, 2);

  }
void loop(){

    moistureSensorValue = analogRead(4); // reads the sensor

if(moistureSensorValue < 300){

  //Serial.println("The soil is too Soggy");    // in case of soggy soil:

  Serial.println (analogRead(4));

  //LED for Soggy lights up

  digitalWrite(drysoilLEDPin,LOW);

  digitalWrite(moistsoilLEDPin,LOW);

  digitalWrite(PumpPin,LOW);

  digitalWrite(soggyLEDPin,HIGH);

  // system messages via LCD

  lcd.clear();

  lcd.setCursor(0,0);

  lcd.print("Soil Soggy");

  }    // in case of moist soil:

  if((moistureSensorValue < 700) && (moistureSensorValue >300)){

    //Serial.println("Moisture Content is OK");

    Serial.println (analogRead(4));
```

```
   //LED for moist lights up

 digitalWrite(drysoilLEDPin,LOW);

 digitalWrite(moistsoilLEDPin,HIGH);

 digitalWrite(soggyLEDPin,LOW);

 digitalWrite(PumpPin,LOW);

 // system messages via LCD

 lcd.clear();

 lcd.setCursor(0,0);

 lcd.print("Moisture OK!");

  }    //in case of dry soil:

if(moistureSensorValue > 700){

  //Serial.println("The Soil too dry");

  Serial.println (analogRead(4));

  //LED for DRY lights up

  digitalWrite(drysoilLEDPin,HIGH);

  digitalWrite(moistsoilLEDPin,LOW);

  digitalWrite(soggyLEDPin,LOW);

  digitalWrite(PumpPin,HIGH);

   // system messages via LCD

  lcd.clear();

  lcd.setCursor(0,0);

  lcd.print("Soil Dry!");

  lcd.setCursor(1,1);

  lcd.print("Pump Running");

  }

 delay(1000); }
```

6.2 KSP2222A datasheet

General Purpose Transistor

- Collector-Emitter Voltage: V_{CEO}= 40V
- Collector Power Dissipation: P_C (max)=625mW
- Refer KSP2222 for graphs

TO-92
1. Emitter 2. Base   3. Collector
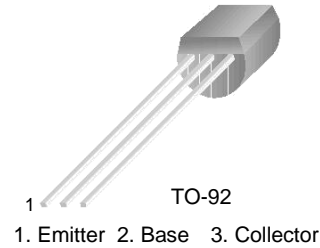
NPN Epitaxial Silicon Transistor

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

6.3   SONGLE RELAY

松乐继电器 ® SONGLE RELAY	RELAY ISO9002	SRS/SRSZ

1. MAIN FEATURES

0Subminiature Type.

0Silver or Silver Alloy Contacts withGold Plated.

0Low Dissipation.

0Sealed Type Available.

0Design conforms to foreign safety standard UL,CUL,TUV

2. APPLICATIONS

óMicroprocessor Control, Store Program Exchanger and Household Appliance.

3. ORDERING INFORMATION

SRS/SRSZ	XX VDC	S	L
Model of relay	Nominal coil voltage	Structure	Coil sensitivity
SRS/SRSZ	03ŋ05ŋ06ŋ09ŋ12ŋ24VDC	S: Sealed type	H: 0.20W
			L: 0.36W
		F: Flux free type	D: 0.45W

4. RATING

UL /CUL   FILE NUMBER: E167996   1A/120VAC 24VDC

TUV   FILE NUMBER: R50056114   3A/250VAC 30VDC

3A/120VAC 24VDC

5. DIMENSION(unit:mm)   DRILLING(unit:mm)   WIRING DIAGRAM