WiFi controlled farming robot using ATmega328

Main Project Report

Submitted in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

in

ELECTRONICS AND COMMUNICATION ENGINEERING

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APRIL 2018

Abstract

The world's population is growing and with that growth we must produce more food. Due to the industrial and petrochemical revolutions, the agriculture industry has kept up in food production, but only by compromising the soil, the environment, our health, and the food production system itself. Conventional agriculture methods are unsustainable and a paradigm shift is needed. The farming robot is an open source and scalable precision farming machine.Similar to today's 3D printers, the farming robot hardware employs linear guides in the X, Y, and Z directions that allow for tooling such as seed injectors, watering nozzles, and sensors to be precisely positioned and used on the plants and soil. The entire system is fully designed from the sowing of seeds to watering and monitoring. The hardware is designed to be simple, scalable, and hackable. Using an open source web based user interface, the user can design their farm to their desired specifications.

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List of Abbreviations

IC - Integrated Circuits

UTM - Universal Tool Mount

MCU- Microcontroller Unit

ESP - Electronic Stability Program

WiFi - Wireless Fidelity

SMPS - Switched Mode Power Supply

EEPROM - Electrically Erasable Programmable Read-Only Memory

SRAM - Static Random Access Memory ory

RTC - Real Time Clock

PWM - Pulse Width Modulation

USART -Universal Synchronous/Asynchronous Receiver/Transmitter

I2C - Inter Integrated Circuits

ADC - Analog to Digital Converter

TQFP - Thin Quad Flat Package

QFN - quad-flat no-leads

SPI - Serial Peripheral Interface

CPU - Central Processing Unit

I/O - Input/Output

SoC - Silicon on Chip

IoT - Internet of Things

OS - Operating System

SDK - Software Development Kit

XTOS - eXTendable Operating System

USB - Universal Serial Bus

PCB - Printed Circuit Board

Acknowledgement

First and foremost we thank God Almighty for providing us with the strength to move forward with our ideas and perceive our project with full effort.

We express our heartfelt gratitude to **Prof. Dr.V P Devassia, Principal, Govt. Model Engineering College, Thrikkakara** for providing us with the facilities we required for the completion of our project. We also extend our gratitude to **Dr.Vinu Thomas, Head of the Department, Electronics and Communication, Govt.Model Engineering College, Thrikkakara**, for all his support through the course of the project.

We are indebted to our project coordinator, **Mr.Arun C R, Assistant Professor in Electronics and Communication Engineering**, for his constructive criticisms, guidance, advice and also the struggle he has made for planning the schedule of our project. We are also immensely thankful to our project guide **Ms. Vinitha George E, Associate Professor Electronics and Communication Engineering** for spending her valuable time for guiding us to make this project possible.

This project involved a lot of mechanical work and wouldn't have been made possible without timely helps and inputs from our batchmates and teachers. We would especially like to thank **Mr.Sajeev, Staff Carpentry Workshop, Jawahar M J, Jamie Joe** and **Anurith R**, who've helped us a lot with their ideas and experience.

We would also like to extend our thanks to all those teachers who offered us valuable suggestion, guidance and support throughout the project: **Asst. Prof. Anu Thangam George, Asst. Prof. George Joseph, Asst. Prof. Ganeshnath R, Asst. Prof. Arun A V, Asst. Prof. Joseph George, Associate Prof. Pradeep M** and **Mr. Sujith M S, Demonstrator**.

Finally, we would like to thank all our family member who have been a constant pillar of support by helping us both financially and mentally.

Chapter 1

Introduction

Population explosion has turned out to be a major threat of the 21st century. This exponential growth of human population has called for a greater increase in food production and other services. There have been quite a few revolutions in the agriculture industry but these have come with a price such as deteriorated soil quality, increased used of pesticides etc. There also remains the fact that there still a greater percentage of the human population who remain deprived of food.

This project aims to create an automated farming system that can be easily installed and isn't detrimental to the environment or food in any way. This device is an open source and scalable precision farming machine and software package designed from the ground up with today's technologies. Similar to today's 3D printers the robot's hardware employs linear guides in the X, Y and Z directions that allow for tooling such as seed injectors, watering nozzles, and sensors, to be precisely positioned and used on the plants and soil. The entire system is numerically controlled and thus fully automated from the sowing of seeds to harvest. The hardware is designed to be scalable, simple, and hackable. The farmer can design their farm according to their requirements. This farming robot has several distinct advantages over today's methods and technologies such as increased precision, reduced manual labour and also a great scope for future development.

Chapter 2

Literature Survey

Farmers today spend a lot of money on machines that help them decrease labor work and increase yield of crops. There are various machines that are available for ploughing, harvesting, spraying pesticides etc., however these machines have to be manually operated to perform the required operations and moreover separate machines are used for every functions. The yield and profit returns from employing this equipment are very less as compared to the investment. Another issue is the growing demands of the world's population. The World Health Organization estimates that Earth's population will touch 9 billion in 35 years which will lead to a staggering demand in increase of growth of food crops. Automation is the ideal solution to overcome all the above mentioned shortcomings by creating machines that perform more than one operation and automating those operations to increase yield on a large scale. XUE Jinlin, XU Liming [1] published a paper on "Autonomous Agricultural Robot and its row Guidance", at the International Conference on Measuring Technology. The objectives of this paper are:

1 To enable the farmer to plough large areas of land in minimum amount of time.

2 To perform automated ploughing and simultaneous seeding process using Advanced Virtual RISC (AVR).

3 To provide manual control with the help of Bluetooth.

4 To measure and control humidity in the field using humidity sensors and water sprinkler.

2.1 Robots in Agriculture

Agriculture is humankind's oldest and still important economic activity, providing the food, feeder, fiber and fuel necessary for our survival. The current trend in agricultural robot development is to build more smart efficient machines that reduce the expense of the farmer. Robotics and automation can play a significant role in enhancing agricultural production needs. Automation can be done by man in operations such as pruning, thinning and harvesting, as well as mowing, spraying and weed removal. Once the concept of automation and agriculture is accepted, the adoption rates will become high and the costs of technology will come down. Autonomous machines will be safer, more consistent with more efficient plant agronomy.

Robotics and automation can play a significant role in enhancing agricultural production needs. Automation can be done by man in operations such as pruning thinning and harvesting, as well as mowing, spraying and weed removal. We can also implement with the advancement in sensors and control systems that allow for optimal resource and integrated disease and pest management. Alijanobi, A.A [2] published a paper titled “A set up of mobile robotic unit for Fruit harvesting” at the 2010 19th International workshop. Yan Li, chunlei Xia, Jangmyung Lee [3] published a paper titled ”Vision based pest detection and automatic spray in green house plant”, page no 920-925

2.2 Proposed system

Rory Landon Aronson [4] published a paper entitled, ”The Farmbot Whitepaper” which laid out the vision of the proposed farming robot which is a small scale robot, primarily constructed from aluminum extrusions and plates. It is driven by stepper motors using the driver IC’s and micro controller ATmega328. This robot operates in a similar mechanism of a 3D printer. The farming robot can vary in size from a planting area of acres to a small scale area depending on the user specifications and technology used.

2.3 High Level Overview

The given figure shows the mechanical structure of the farming robot with each part explained in detail below:-

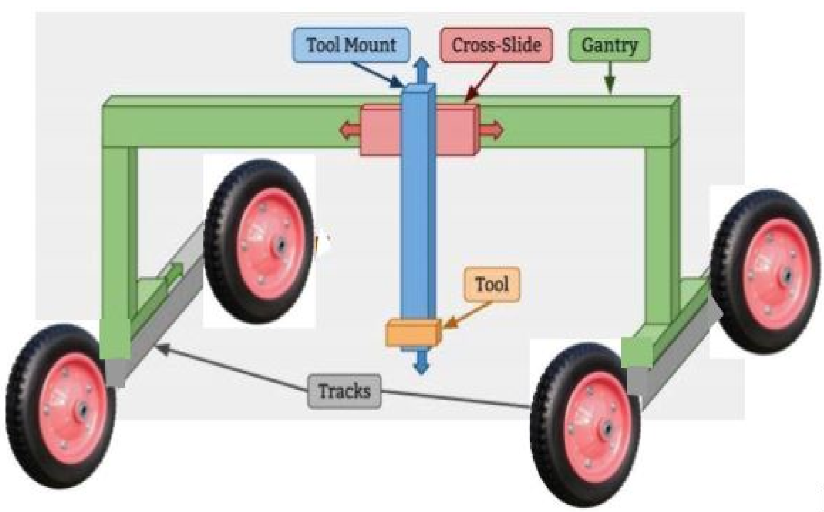

Figure 2.3.1: High Level Structure of proposed farming robot

2.3.1 Wheels

Two wheels are attached on either side to the aluminum extrusions and the motion is controlled using motors.This establishes the X-axis motion (to and fro).

2.3.2 Gantry

The Gantry is the the structural component that bridges the two tracks and moves in the X-direction via an X-Direction Drive System. Typically, it serves as a linear guide for the Cross-Slide and a base for the Y-Direction Drive System that moves the Cross-Slide across the Gantry in the Y-direction. It can also serve as a base for mounting other tools, electronics, supplies, and/or sensors.Each completed gantry wheel plate will have five wheels which are connected through a belt to the pulley in order to ensure X and Y axis movement.

2.3.3 Crossslide

The Cross-Slide moves in the Y-Direction across the Gantry. This motion provides the second major degree of freedom for the device and allows operations such as planting to be done anywhere in the XY plane. The Cross-Slide is moved using a Y-Direction Drive System and functions as the base for the Tool Mount and Z-Direction Drive System. The CrossSlide consists of wheels which run on tracks mount on the gantry driven using a motor driver IC.

2.3.4 Universal Tool Mount(UTM)

The Universal Tool Mount is a plastic component that mounts to the Z-axis aluminum extrusion. It features passageways for water, liquid amendments (eg: fertilizer), and vacuum (or compressed air), water pump to pass through from the UTM to the tool.

Chapter 3

System Overview

This chapter mainly consists of the block diagram and circuit diagram of the proposed farming robot and their explanation.

3.1 Block Diagram

The block diagram of the WiFi controlled farming robot is illustrated below.

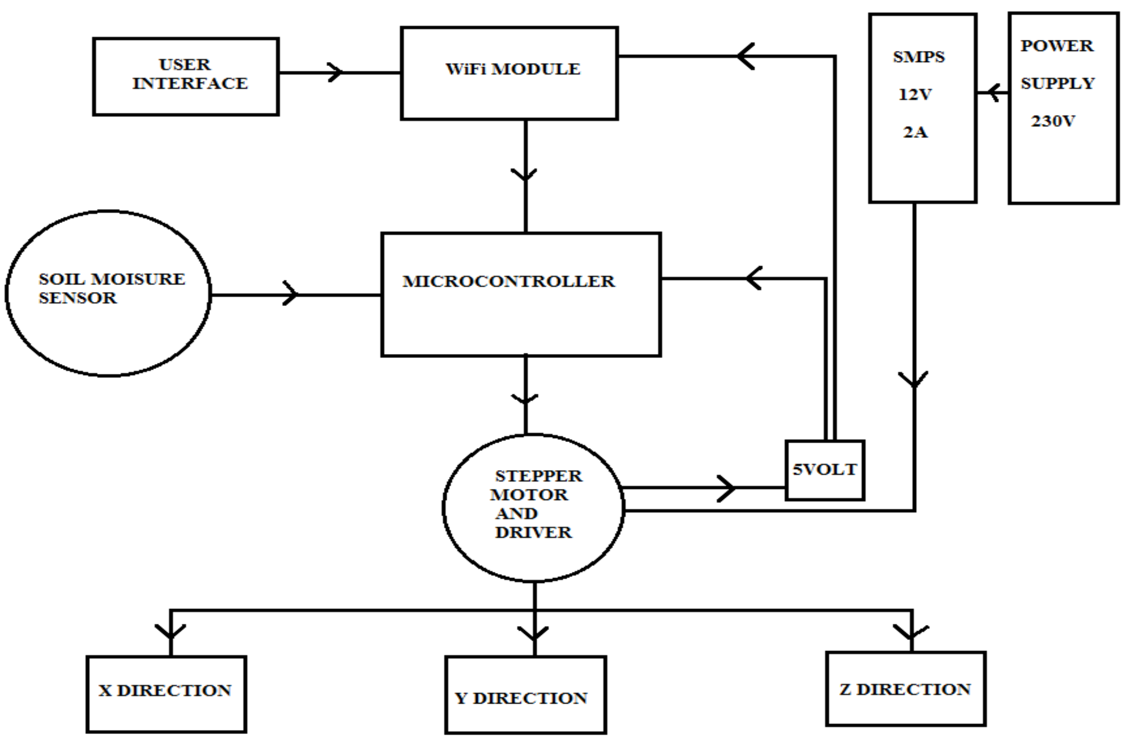

Figure 3.1.1: Block diagram of proposed farming robot

3.2 Block Diagram Description

The heart of this project is the Atmega328 microcontroller. The main parts of the block diagram include:

1. Establishing Communication using a nodeMCU ESP8266 WiFi Module
2. Seeding, watering, fertilizing and monitoring using a user interface
3. Collecting information from various sensors for monitoring the device

User inputs the necessary instructions through a user interface setup using the microcontroller, (here ATmega328) and WiFi module.Based on the given instructions, the microcontroller decides which plot it should seed, water and fertilize by sending instructions to the motor driver IC to move the tool in the X,Y and Z motion just like a 3D printer.It does the operation of seeding and watering by turning on and off the air compressor and water pump.

The entire system is monitored using sensors. Path along which the tool moves is predefined and it is reset back to the original position. The soil moisture sensor provides information regarding the humidity of the soil and thereby replenishes the soil with water if it is below a particular threshold value. Similarly we can also add various temperature and weather sensors to make the system more effective. SMPS(Switched Mode Power Supply) is used as a power supply and voltage regulation is achieved using specific voltage regulators.

3.3 Circuit Diagram

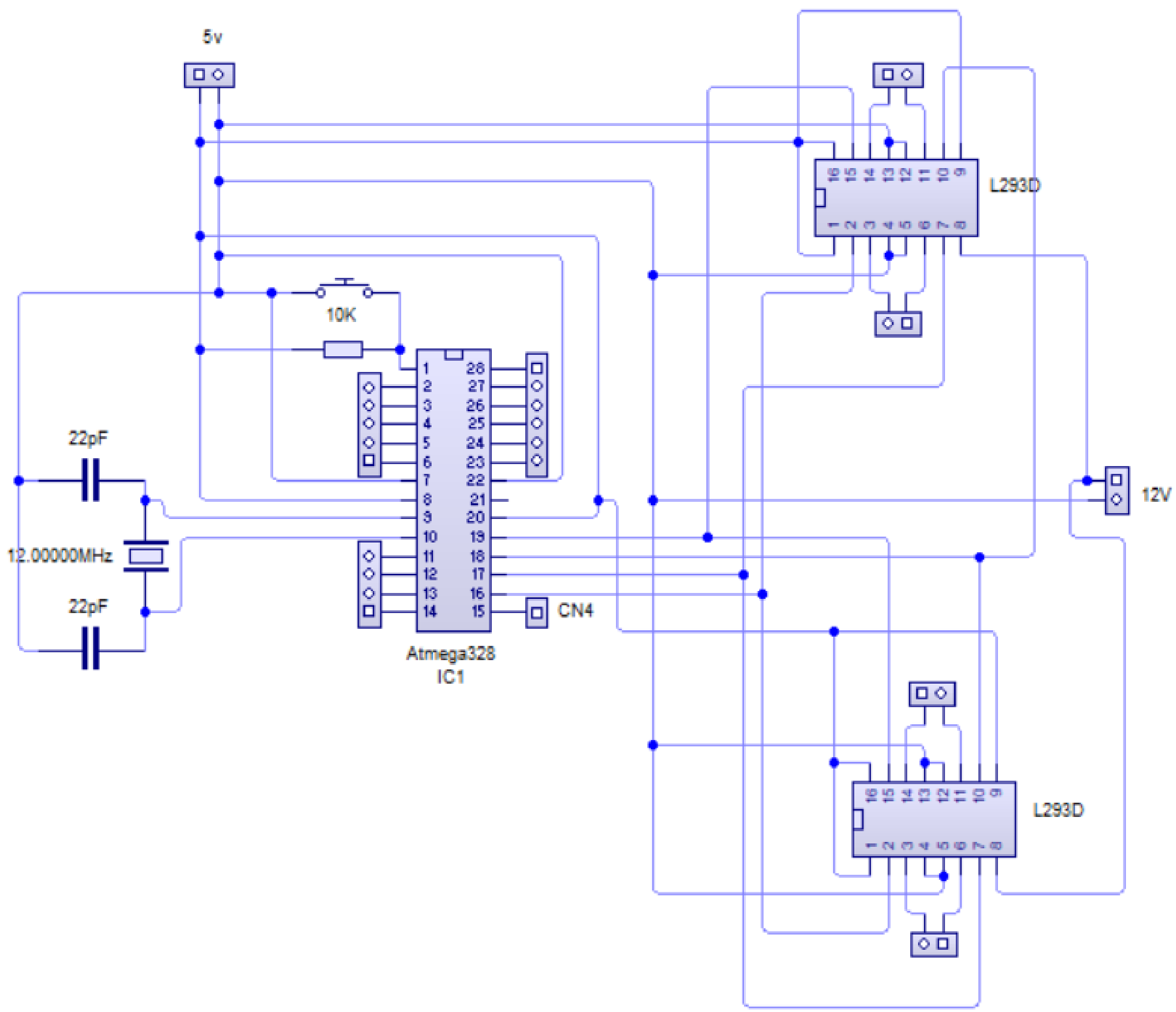

Figure 3.3.1: Circuit diagram of proposed farming robot

3.4 Circuit Diagram Explanation

The circuit diagram shows the interfacing between the various modules such as WiFi module, ICs such as ATmega328, L298H and L293D motor driver ICs, discrete components such as capacitors, resistors, crystal oscillator, reset switches, connectors and jumper wires.

Chapter 4

Hardware and Software Details

4.1 Hardware Description

The hardware details give an insight to the various components and their features, for the assembling of the farming robot. These are explained as below:-

4.1.1 ATmega328 IC

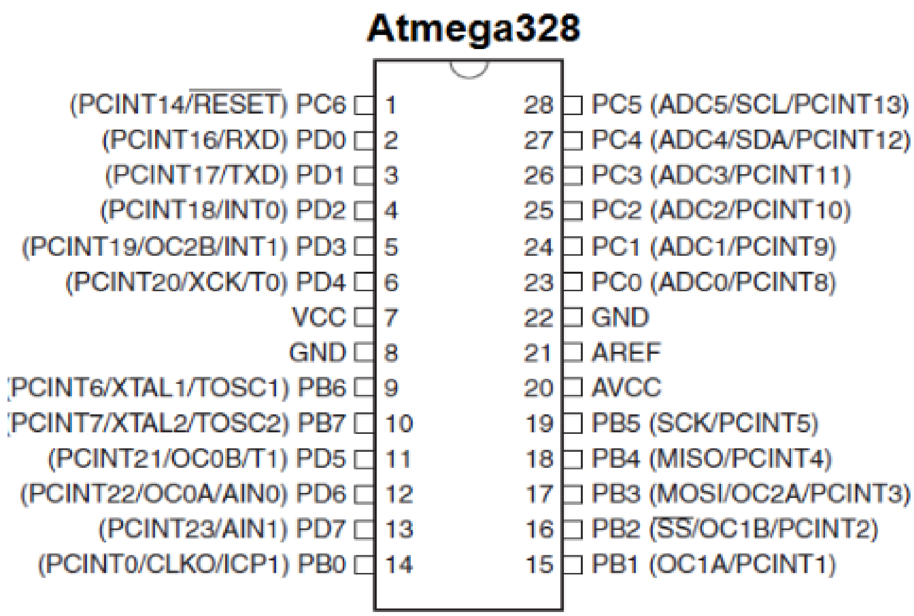

Figure 4.1.1: Pinout diagram of ATmega328 IC

General Description: The ATmega328P provides the following features: 32Kbytes of In-System Programmable Flash with Read-While-Write capabilities, 1Kbytes EEPROM, 2Kbytes SRAM, 23 general purpose I/O lines, 32 general purpose working registers, Real Time Counter (RTC), three flexible Timer/Counters with compare modes and PWM, 1 serial programmable USARTs , 1 byte-oriented 2-wire Serial Interface (I2C), a 6- channel 10-bit

ADC (8 channels in TQFP and QFN/MLF packages) , a programmable Watchdog Timer with internal Oscillator, an SPI serial port, and six software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next interrupt or hardware reset. In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer and ADC to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low power consumption. In Extended Standby mode, both the main oscillator and the asynchronous timer continue to run.

Features:-

1 2 x 8-bit Timers/Counters each with independent prescaler and compare modes

2 A single 16-bit Timer/Counter with an idependent prescaler, compare and capture modes

3 Real time counter with independent oscillator

4 10 bit, 6 channel analog to digital Converter

5 6 pulse width modulation channels

6 Internal temperature sensor

7 Serial USART (Programmable)

8 Master/Slave SPI Serial Interface

4.1.2 NodeMCU on WiFi Module

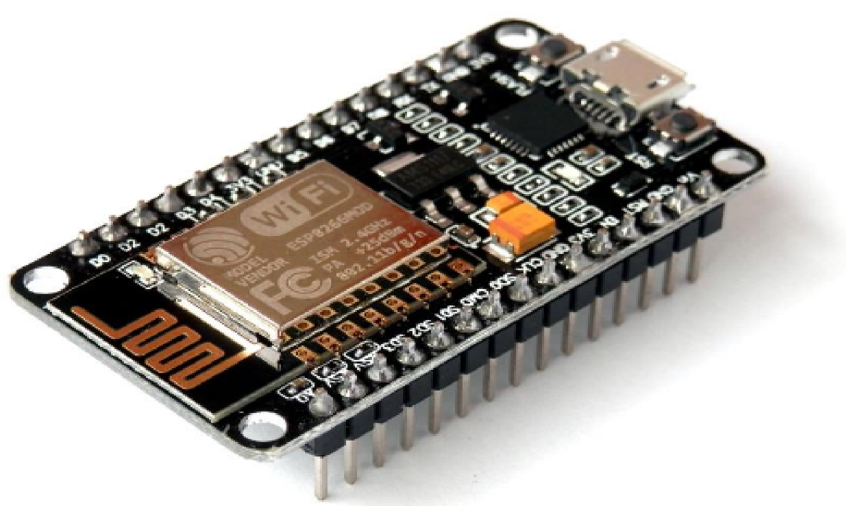

Figure 4.1.2: WiFi Module ESP8266 of the proposed farming robot

General Description: NodeMCU is an open source IoT platform.It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module.The term ”NodeMCU” by default refers to the firmware rather than the dev kits. The firmware uses the Lua scripting language. It is based on the eLua project, and built on the Espressif Non-OS SDK for ESP8266. It uses many open source projects, such as lua-cjson,and spiffs.

An Arduino Mega microcontroller, will be used to control the stepper motors, vacuum pump, servo, and future electronics and sensors. This platform was chosen for it's low cost, general availability, hackability, expandability through shields, the expansive learning resources available, the strong DIY community already using the platform, and the fact that it is opensource. In addition, Arduino programs are written in the C language and therefore very familiar to many. Expansion shields likely to be used will include wifi, a and a stepper driver.

4.1.3 Nema 17 stepper Motor

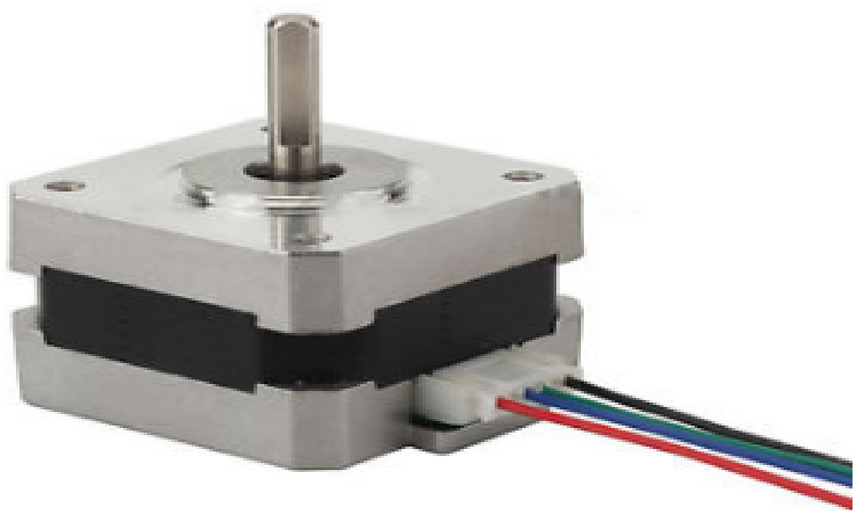

Figure 4.1.3: Nema 17 stepper Motor

General Description: The Nema 17 stepper motor shown in in figure has been chosen for it's general availability, common use in similar projects such as the 3D printer, easy setup and control, as well as it's accuracy, speed, and torque outputs. In addition, this motor interfaces with components such as pulleys and mounting plates available.It is a stepper motor with 1.7*1.7 inch faceplate.It is larger and generally heavier than for example a Nema14,but this also means that it has more room to put a higher torque.However, it's size is not an indication of it's power.

The rotation angle of the motor is proportional to the input pulse.The motor has full torque at standstill.Precise positioning and repeatability of movement since good stepper motors have an accuracy of 3 – 5% of a step and this error is non cumulative from one step to the next.Excellent response to starting, stopping and reversing.Very reliable since there are no contact brushes in the motor. Therefore the life of the motor is simply dependant on the life of the bearing.The motors response to digital input pulses provides open-loop control, making the motor simpler and less costly to control.It is possible to achieve very low speed synchronous rotation with a load that is directly coupled to the shaft.A wide range of rotational speeds can be realized as the speed is proportional to the frequency of the input pulses.

Features:-

1 Phase Number: 2

2 Operating Voltage: 12-24VDC

3 Current: 1.33A

4 Step Angle: 1.8 Degree

4.1.4 DC Geared Motor(30rpm, 12V

Figure 4.1.4: DC geared Motor

General Description: 30 RPM Side Shaft 37mm Diameter Compact DC Gear Motor is suitable for small robots / automation systems. It has sturdy construction with gear box built to handle stall torque produced by the motor. Drive shaft is supported from both sides with metal bushes. Motor runs smoothly from 4V to 12V and gives 30 RPM at 12V. Motor has 6mm diameter, 22mm length drive shaft with D shape for excellent coupling.

Featuers:-

1 RPM: 30 at 12V

2 Voltage: 4V to 12V

3 Stall torque: 28 Kg-cm at stall current of 1.3 Amp.

4 Shaft diameter: 6mm

5 Shaft length: 22mm

6 Gear assembly: Spur

7 Brush type: Carbon

8 Motor weight: 143gms

4.1.5 Switched Mode Power Supply(SMPS)

Figure 4.1.5: SMPS Module for power supply

General Description: A switched-mode power supply (switching-mode power supply, switch-mode power supply, switched power supply, SMPS, or switcher) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from a DC or AC source (often mains power) to DC loads, such as a personal computer, while converting voltage and current characteristics. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy. Ideally, a switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time.

Features:-

1 It has greater efficiency than linear regulators because the switching transistor dissipates little power when acting as a switch.

2 It has smaller size and lighter weight from the elimination of heavy line-frequency transformers, and comparable heat generation.

3 Standby power loss is often much less than transformers.

4.1.6 YL-69

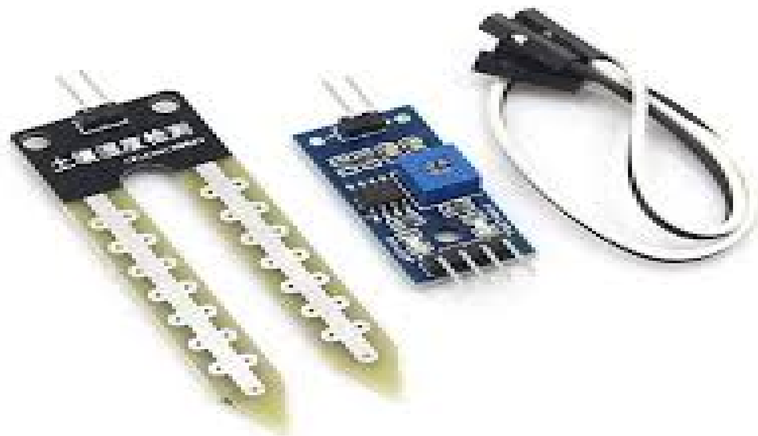

Figure 4.1.6: Soil moisture sensor-YL69

General Description: The soil moisture sensor or the hygrometer is usually used to detect the humidity of the soil. So, it is perfect to build an automatic watering system or to monitor the soil moisture of your plants. The sensor is set up by two pieces: the electronic board (at the right), and the probe with two pads, that detects the water content (at the left).The sensor has a built-in potentiometer for sensitivity adjustment of the digital output (D0), a power LED and a digital output LED. The voltage that the sensor outputs changes accordingly to the water content in the soil.

When the soil is:

Wet: the output voltage decreases

Dry: the output voltage increases

Features:-

1 Operating voltage: DC 3.3V - 5V

2 Output voltage signal: 0 4.2V

3 Current: 35mA

4 LED: Power indicator (Red) and Digital switching output indicator (Green)

Pin Definition

1 VCC external 3.3V-5V

2 GND external GND

3 DO digital output interface (0 and 1)

4 AO analog output interface (0 4.2V)

4.1.7 L298H Driver IC

General Description: It is an all-in-one H-bridge motor driver. It can control two motors, not just one. It can handle 2 amps per motor, though to get the maximum current be sure to add a heat sink. The L298 has a large cooling flange with a hole in it.The schematic below shows a basic connection diagram for controlling two motors using the L298 motor bridge IC.There are three input pins for each motor: Input1, Input2, and Enable1 controls Motor1. Input3, Input4, and Enable2 controls Motor2.The L298 uses two different supply voltages. The voltage on pin 9 powers the chip itself and should be 5 volts. The voltage on pin 4 supplies the motors, and it can be up to 46 volts.

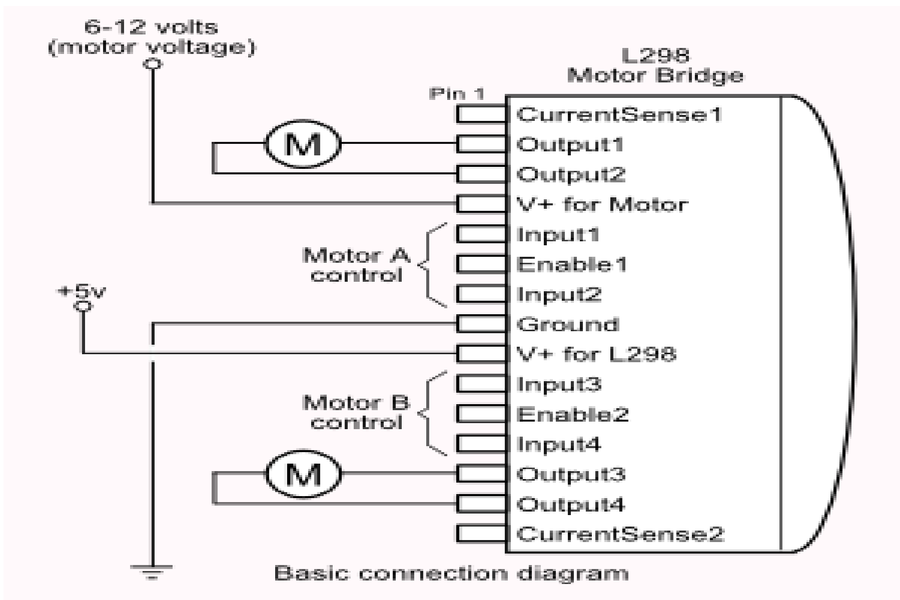

Figure 4.1.7: L298H Driver IC

4.1.8 Voltage Regulator-7805

General Description: Voltage regulator IC's are the IC's that are used to regulate voltage. IC 7805 is a 5V Voltage Regulator that restricts the voltage output to 5V and draws 5V regulated power supply. It comes with provision to add heatsink.

IC 7805 is a series of 78XX voltage regulators. It's a standard, from the name the last two digits 05 denotes the amount of voltage that it regulates. Hence a 7805 would regulate 5v and 7806 would regulate 6V and so on. The schematic given below shows how to use a 7805 IC, there are 3 pins in IC 7805, pin 1 takes the input voltage and pin 3 produces the output voltage. The GND of both input and out are given to pin 2.It is used as a

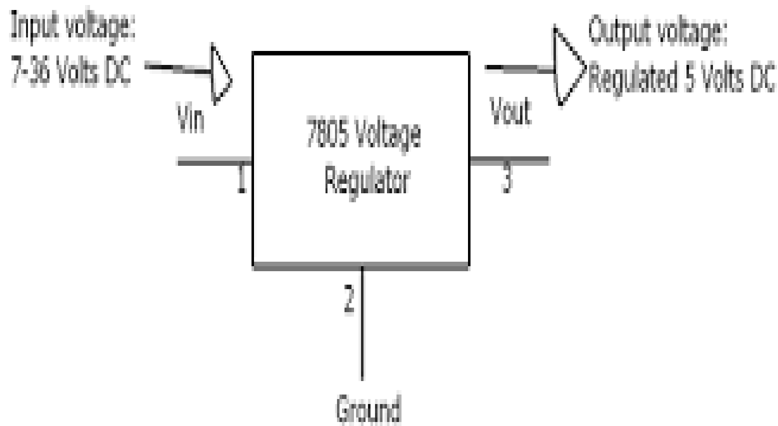

Figure 4.1.8: Pinout diagram of 7805 voltage regulator

4.1.9 Crystal Oscillator

General Description: A crystal oscillator is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a precise frequency.This frequency is often used to keep track of time, as in quartz wristwatches, to provide a stable clock signal for digital integrated circuits, and to stabilize frequencies for radio transmitters and receivers. The most common type of piezoelectric resonator used is the quartz crystal, so oscillator circuits incorporating them became known as crystal oscillators, but other piezoelectric materials including polycrystalline ceramics are used in similar circuits.

4.2 Software Descriptions

This chapter briefly describes the different types of software used to program and design the working of the proposed farming robot.

4.2.1 Arduino IDE Software

The Arduino project provides the Arduino integrated development environment (IDE), which is a cross-platform application written in the programming language Java. It originated from the IDE for the languages Processing and Wiring. It includes a code editor with features such as syntax highlighting, brace matching, and automatic indentation, and provides simple one-click mechanism to compile and load programs to an Arduino board. A program written with the IDE for Arduino is called a "sketch".

The Arduino IDE supports the languages C and C++ using special rules to organize code. It supplies a software library called Wiring from the Wiring project, which provides many common input and output procedures. A typical Arduino C/C++ sketch consist of two functions that are compiled and linked with a program stub main() into an executable cyclic executive program:
setup(): a function that runs once at the start of a program and that can initialize settings.
loop(): a function called repeatedly until the board powers off.
After compiling and linking with the GNU toolchain, also included with the IDE distribution, the Arduino IDE employs the program avrdude to convert the executable code into a text file in hexadecimal coding that is loaded into the Arduino board by a loader program in the board's firmware.

The version used in this project is 1.6.5

4.2.2 Circuit Wizard

Circuit Wizard is an electronic design program produced by New Wave Concepts which offers a range of features likely to be of particular appeal to electronics hobbyists and educational users, including schematic capture, interactive simulation and PCB design. Circuit diagrams may be rapidly created and simulated.

Chapter 5

Implementation

5.1 Project Development Stages

The development stages of the project is given below:-

5.1.1 Phase 1: Created a webserver using nodeMCU.

NodeMCU is a firmware that allows you to program the ESP8266 modules with LUA script. Programming is similar to programming in Arduino. With few lines of code WiFi connection can be established, ESP8266 GPIOs can be controlled, ESP8266 can be turned into a webserver.Thereby ESP8266 was flashed with NodeMCU.

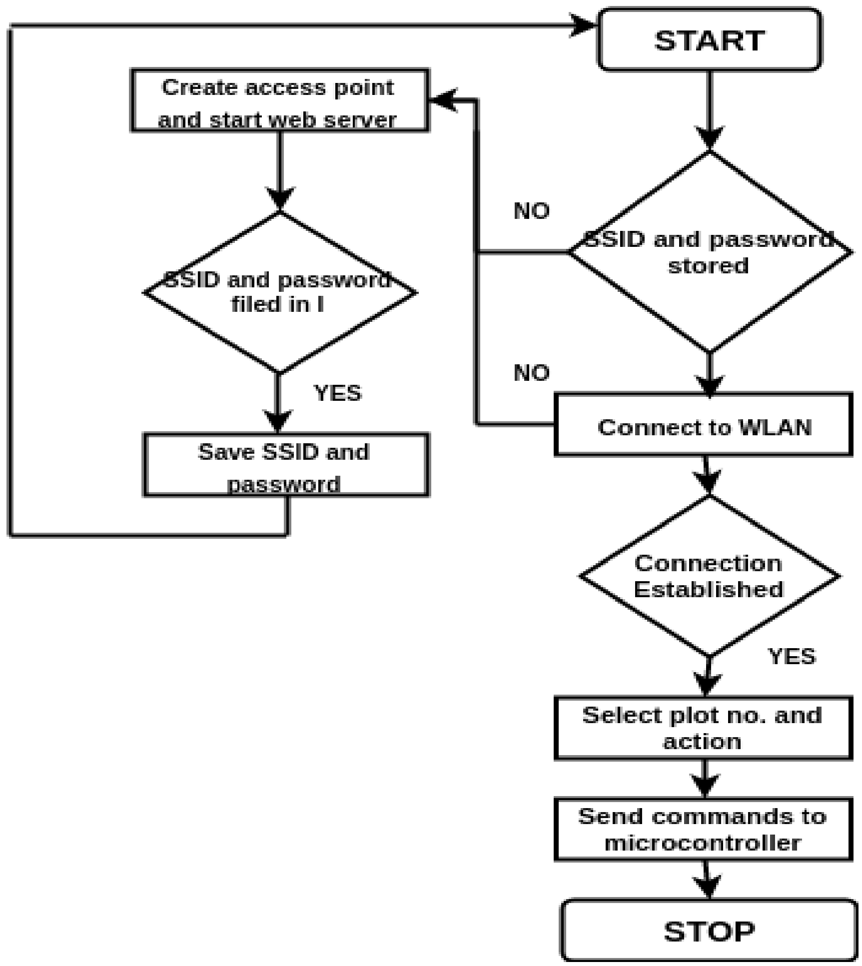

Figure 5.1.1: Flowchart of Wifi server on NodeMCU to provide user interface

5.1.2 Phase 2: Decided the area to be planted, constructed gantry, crossSlide and mounted the tool

The current area is 75*150 sq.cm which is divided into 2x3 plots with each plot having an area of 37.5x37.5 sq.cm, while accommodating a maximum plant height of about 10 cm. With additional hardware and modifications,the model can be scaled to a higher value.The gantry was constructed using aluminum extrusions using screws, connected to a DC geared motor to move along the X axis. The CrossSlide is made using ball bearings and gear to drive it to and fro along the Y axis. The Z axis is made using aluminum extrusion which moves up and down. The universal tool mount setup is used to mount the various pumps and sensors.

Figure 5.1.2: Mechanical structure of farming robot

5.1.3 Phase 3: Programmed the stepper motors, DC geared motors and the various pumps.

The pathway through which the the tool should be directed was decided. Stepper motors and DC geared motors were programmed accordingly. The vacuum and water pumps are turned ON and OFF depending on the requirements by the user. If in any case, the user wants to go to a particular plot to seed or water any plant individually, the shortest path was decided from the initial position.

5.1.4 Phase 4: The sensors were interfaced with the arduino and threshold set.

Soil moisture sensors were tested and attached to the Universal Tool Mount and the threshold for the same was assigned.

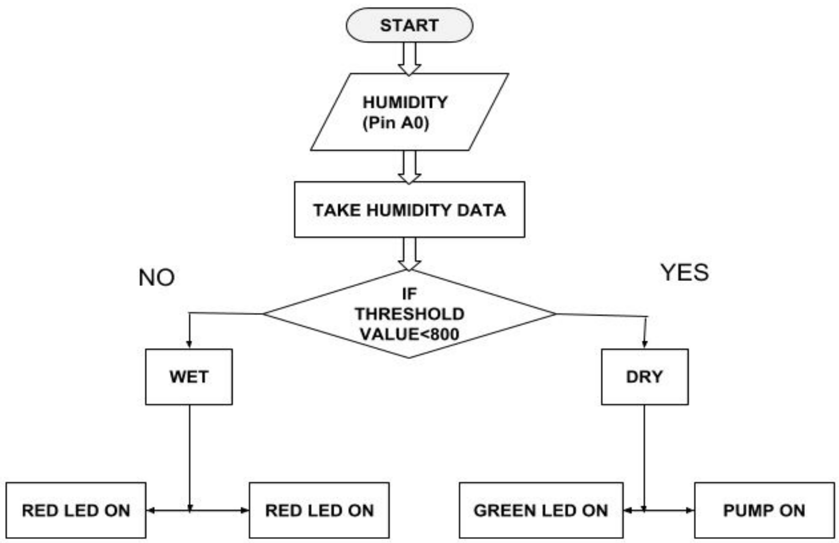

Figure 5.1.3: Flowchart of soil moisture sensor

5.1.5 Phase 5: Developed PCB board.

The circuit diagram was drawn and tested. PCB layout was designed using Circuit Wizard software. There were two different PCBs used. One for the Atmega chip and the discrete components, the other for the motor for providing ample power supply.

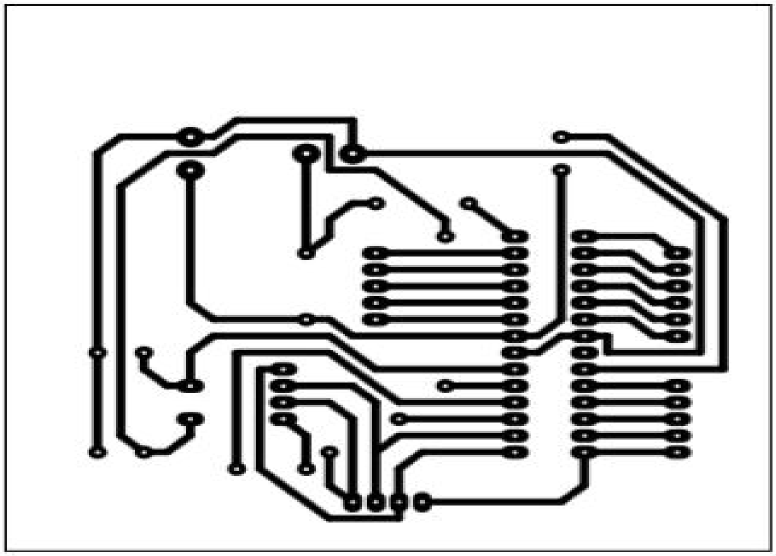

Figure 5.1.4: PCB Layout of ATmega328

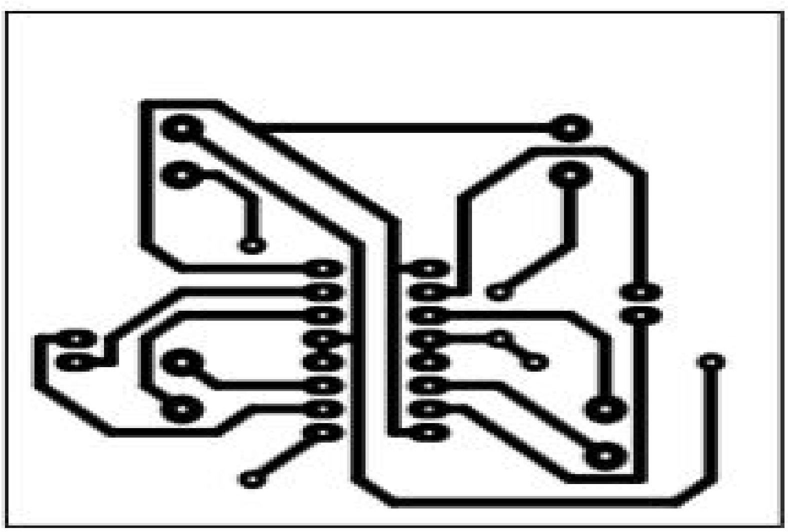

Figure 5.1.5: PCB Layout of motor interconnection

Chapter 6

PCB Fabrication and Soldering

Chapter 5 details the preparation of PCB layout and its subsequent fabrication procedures. The materials required for PCB fabrication are copper clad, ferric chloride solution, and drilling machine. The PCB fabrication includes the following steps:

6.1 Preparation of PCB Layout

First the circuit is drawn using Circuit Wizard. The image of the layout of is printed on an A4 size translucent tracing sheet or butter paper.

6.2 Transferring the layout to copper clad sheet

First the copper clad sheet of required dimension is cut by using a cutting machine. Then the sheet is cleaned by using a metal scrubber. The next step is to form an image of the layout on the copper clad sheet. The copper clad sheet is exposed to heat by ironing using an iron box till the design is printed on the board. After that, the board is washed gently in water for about 1m so that the image is copied into the board.In case the process is not successful ,the process is repeated.

6.3 Etching of the board

When the board is ready for etching, it is placed in the ferric chloride solution of required concentration. It is checked in regular intervals to prevent over etching and successive damage to the part. After etching is complete, the board is taken out of the solution and is washed in water to remove the excess ferric chloride. The D13X NC thinner is applied to remove any dew or paint material on copper tracks. Then the sheet is cleaned by using steel scrubber and washed again in water. Now the copper lines are exposed and the body is checked with the magnifying glass to see whether all the lines in the layout are clearly formed. Now the board is ready for tinning.

6.4 Tinning

For tinning, the PCB is cleaned well and flux is applied to surface. Then it is passed through the tinning machine. In tinning, the copper lines are plotted with an alloy of TIN and LEAD.

6.5 Drilling

After tinning, the next process is drilling. In this the holes of required sizes are drilled in the PCB wherever needed, using a PCB drilling machine.

6.6 Finishing

In the process after drilling the holes on the PCB, the board is taken and a light coat of air dyeing varnish insulating varnish is applied to the bottom side carefully avoiding the PAD areas. The PCB is then left till the insulating varnish dry up.

6.7 Soldering

Soldering is the process of joining two or more dissimilar metals by melting another metal having low melting points.

6.8 Soldering flux

In order to make the surface accept the solder readily, the component terminals should be free from the oxides and other obstructing films. Soldering flux cleans the oxides from the surface of the metal.

6.9 Process of soldering

Place the soldering iron in its stand and plug it on. The iron will take a few minutes to reach its operating temperature of about 673K. Dampen the sponge in the stand. Wait for a few minutes for the soldering iron to warm up. Wipe the tip of the iron on the damp sponge. Melt little solder on the tip of iron and solder the components in the corresponding locations

Chapter 7

Results and Discussion

The project "WiFi controlled farmbot using ATmega328" is successfully completed fulfilling all requirements. The farming robot provides a useful human interface to select the various plots and also provides ample amount of water at correct time intervals. Provision for selective seeding and watering is also provided. Based on the input from the user, necessary action is implemented.

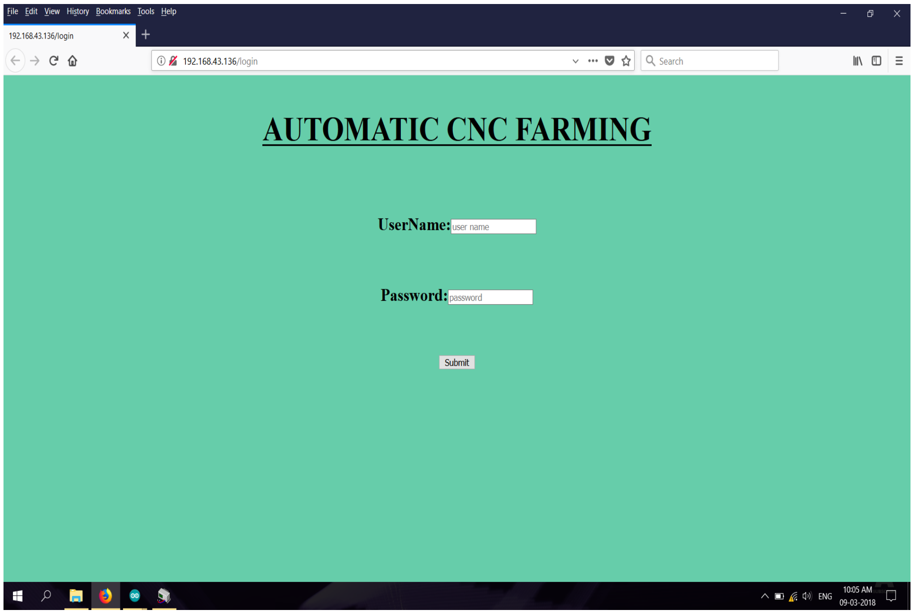

Figure 7.0.1: Login page

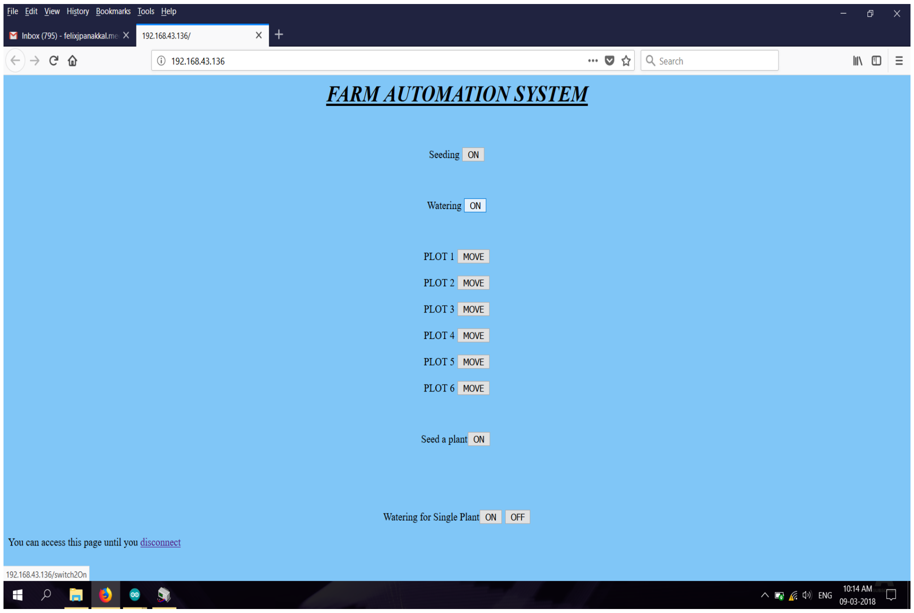

Figure 7.0.2: Crystal oscillator

Chapter 8

CONCLUSION AND FUTURE SCOPE

The proposed machine serves as a very attractive alternative when compared to conventional farming techniques and is also a very large step towards sustainable farming. Another advantage the machine brings along is it's ease to use and the preciseness of the machine which are far more superior compared to modern farm automation techniques. The machine perfectly blends in with the lifestyle of the present generation.

The farming robot enables farming with proper necessities at the right time without human intervention.Some of the future scope or relevance to the society include addition of better weather sensors to monitor atmospheric conditions more precisely, inclusion of small water harvesting systems', turning the machine into a self sustainable one and inclusion of higher grade harvesting systems or tools.

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Bill of Materials		
Components	Count Code	Amount per piece
Atmega328 and 16 MHz crystal	1 each	140 + 5
L293 Driver module and 22pF capacitors	2 each	50 + 10
L298 Driver module	3	480
Esp8266, SMPS and resistor	1 each	500 + 190 + 5
Nema 17 Stepper motor and Pulley	3 each	860 x 3 + 60
Aluminum extrusions		250
Metal plates and Belt	2m	400 + 200
Water Pump and vacuum pump	1 each	190+ 50
DC Geared motor	4	800
Tubes, Nuts and Bolts		250 + 150
Total		6310

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