Sudan University of Science and Technology

College of Engineering

Electrical Engineering

Wall Painting Robot

روبوت الطلاء الآلي

A Project Submitted in Partial Fulfillment for the Requirements of the Degree of B.Sc. (Honor) In Electrical Engineering (control)

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October 2017

الآية

قال تعالى:

(اللهُ لاَ إِلَـهَ إِلاَّ هُوَ الْحَيُّ الْقَيُّومُ لاَ تَأْخُذُهُ سِنَةٌ وَلاَ نَوْمٌ لَّهُ مَا فِي السَّمَاوَاتِ وَمَا فِي الأَرْضِ مَن ذَا الَّذِي يَشْفَعُ عِنْدَهُ إِلاَّ بِإِذْنِهِ يَعْلَمُ مَا بَيْنَ أَيْدِيهِمْ وَمَا خَلْفَهُمْ وَلاَ يُحِيطُونَ بِشَيْءٍ مِّنْ عِلْمِهِ إِلاَّ بِمَا شَاء وَسِعَ كُرْسِيُّهُ السَّمَاوَاتِ وَالأَرْضَ وَلاَ يَؤُودُهُ حِفْظُهُمَا وَهُوَ الْعَلِيُّ الْعَظِيمُ) .

[البقرة :255]

DEDICATION

Every challenging work needs self-efforts as well as guidance of elders especially those who were very close to our hearts. Our humble effort is dedicated to our sweet and loving parents, our brothers, our sisters and our friends whose affection, love, encouragement and prays in days and nights make us able to get such success and honor. Without their love and support this project would have never been made possible.

ACKNOWLEDGMENT

First and above all, we praise God, the almighty for providing us this opportunity, and granting us the capability to proceed successfully. Grateful for this opportunity, we would like to give our sincere thanks to our supervisor**; Dr. Awadalla Taifour Ali** for his valuable guidance continues encouragement, suggestions, constructive ideas and advice in assisting us to complete this work.

ABSTRACT

The painting process has many problems which all about manual labor that suffered from workers whom do the job of painting. So an automatic system was created to exchange the manual labor. The wall painting robot is an autonomous robot for painting the interior walls of buildings and backgrounds. The robot consists of a painting arm with an end effector roller that scans the walls vertically and a movable chassis is moving horizontally to paint the whole area of the wall. The painting arm has a planar two-links mechanism with two joints. An ultrasonic sensor is attached to the movable chassis and used to maintain a certain distance from the facing wall and to avoid collision with side walls. When settled on adjusted distance from the wall, the controller starts the painting process automatically. Simplicity, relatively low weight and short painting time were considered in our design. This project has shown successfulness of wall painting robot in its intended tasks.

مستخلص

عملية الطلاء بصورة عامة تعاني من مشكلة العمالة اليدوية و التي تتعلق بالعامل الذي يقوم بعملية الطلاء. لذلك تم ابتكار نظام آلي ليقوم بعملية الطلاء بدلا عن العمالة اليدوية. روبوت الطلاء الآلي يقوم بطلاء الجدران الداخلية و الواجهات بدون الحوجة إلى يد العامل. يتكون هذا الروبوت من منظومة الذراع و مثبت على طرفه فرشاة متدحرجة التي تتحرك رأسيا على امتداد الحائط لتقوم بعملية الطلاء و هذه المنظومة مثبتة على هيكل متحرك يتحرك أفقيا على نطاق عرض الحائط. تتكون منظومة الذراع من ذراعين و مفصلين أعلى و أسفل الذراع السفلي. تم استخدام حساس ليقيس المسافة بين نهاية الهيكل المتحرك و الحائط لتفادي الاصطدام مع الحوائط الجانبية. يتميز هذا التصميم بالبساطة و الموثوقية و خفة الوزن و سرعة في أداء العمل. أثبت روبوت الطلاء الآلي نجاحه و كفاءته في أداء العمل من خلال هذا المشروع.

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LIST OF ABBREVIATIONS

WPR	Wall Painting Robot
MEMS	Micro-Electro-Mechanical System
DOF	Degree-Of-Freedom
PUMA	Programmable Universal Machine for Assembly
CPU	Central Processing Unit
RAM	Random Access Memory
ROM	Read Only Memory
EEPROM	Electrical Erasable Programmable Read Only Memory
EPROM	Erasable Programmable Read Only Memory
PROM	Programmable Read Only Memory
CD	Compact Disk
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
ADC	Analog to Digital Converter
DAC	Digital to Analog Converter
PC	Personal Computer
TV	Television
USB	Universal Serial Bus
TX	Torque Transmitter
RX	Torque Receiver
RTD	Resistance Temperature Device
Tr	Transmitter
Re	Receiver
DC	Direct Current
AC	Alternating Current
IDE	Integrated Development Environment
AVR	Automatic Voltage Regulator

LABVIEW	Laboratory Virtual Instrument Engineering Workbench
RPM	Revolution Per Minute
ATX	Advanced Technology eXtended
NC	Normal Close
NO	Normal Open
COM	Common
PWM	Pulse Width Modulation
GND	Ground

LIST OF SYMBOLS

RL	Load resistance, Ω
Rp	Potentiometer resistance, Ω
Vr	Reference voltage, V
Vo	Output voltage, V
χ	Wiper position, m
χ_p	Maximum position, m
d	Distance, m
c	Velocity, m/sec
t	Time, sec
x	Distance from the center of the upper servo to the top of the wall, Cm
y	distance from the center of the movable chassis to the wall, Cm
T	Torque, gm.cm
f	Force, gm
r	The length of force arm, Cm
ϕ	The angle between the force at any point and the force arm, degree

CHAPTER ONE

INTRODUCTION

1.1 General Concepts

Now a century behave with robots is one of dependences of civilization according to their accuracy and speed of doing works. In this project the study was specified for type of robots which painting walls and backgrounds. Wall Painting Robot (WPR) is capable of painting walls and backgrounds with high accuracy and reliability performance. It can be controlled by a person and it was created for helping people and doing tasks quickly without making any risks for the worker. This idea can be applied for painting internal or external walls of buildings and public places like advertising boards.

1.2 Problem Statement

The problems were classified as medical problem and it is in rejecting paint material by the worker may that cause breathing risks for him. Also the economic problem which in paying a large amount of money to the workers for doing the job of painting. At last the handing workers problem which appears in need to do the job of painting when they are not available at that time.

1.3 Objectives

The main objectives of this study are to:

- Design of the WPR
- Implementation of the WPR
- Testing of the WPR

1.4 Methodology

- Study all of previous studies.
- The system was fabricated using appropriate materials.
- Use of Arduino as system controller.
- The code is written using Arduino.C

1.5 Project Layout

This project consists of five chapters: Chapter One gives an introduction to the project, motivation and objectives. Chapter Two discusses the theoretical background of control systems, microcontroller system, robots and electrical sensors. Chapter Three describes the system fabrication, system control circuit, software and hardware. Chapter Four handles the system implementation and the experimental results. Finally, Chapter Five provides the conclusions and recommendations.

CHAPTER TWO

THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 Introduction

Building and construction is one of the major industries around the world. In this fast moving life construction industry is also growing rapidly. But the labors in the construction industry are not sufficient. This insufficient labors in the construction industry is because of the difficulty in the work. In construction industry, during the work in tall buildings or in the sites where there is more risky situation like interior area in the city. There are some other reasons for the insufficient labor which may be because of the improvement the education level which cause the people to think that these types of work is not as prestigious as the other jobs. The construction industry is labor-intensive and conducted in dangerous situations, therefore the importance of construction robotics has been realized and is grown rapidly. Applications and activities of robotics and automation in this construction industry started in the early 90's aiming to optimize equipment operations, improve safety, enhance perception of workspace and furthermore ensure quality environment for building occupant. After this, the advances in the robotics and automation in the construction industry has grown rapidly [1]. Despite the advances in the robotics and its wide spreading applications, painting is also considered to be the difficult process as it also has to paint the whole building. To make this work easier and safer and also to reduce the number of labors automation in painting was introduced. The automation for painting the exterior wall in buildings has been proposed. Above all these the interior wall painting has shared little in research activities. The painting chemicals can cause hazards to the painters such as eye and respiratory system problems. Also the nature of painting procedure that requires repeated work and hand rising makes it boring, time and effort consuming. These factors motivate the development of an automated robotic painting system. This project aims to develop the interior wall painting robot. The development of service robots became popular recently due to the fact that the society needs robots to relax humans from tedious and dangerous jobs. The increasing population in developing countries stimulates the construction-related activities such as interior finishing and painting. Painting is classically done by humans and generally requires exhaustive physical efforts and involves exposure to dangerous chemicals. Chemicals can seriously impair the vision, respiratory system and general health of the human painter. These factors make painting an ideal candidate process for automation [2].

2.1.1 Paint

Paint is a pigmented liquid or paste used to apply color to a surface. Paint is any liquid or mastic composition that, after application to a substrate in a thin layer, converts to a solid film. It is most commonly used to protect, color, or provide texture to objects. Paint can be made or purchased in many colors and in many different types, such as watercolor, synthetic, etc. Paint is typically stored, sold, and applied as liquid [3].

2.1.2 Paint roller

A paint roller is a paint application tool used for painting large flat surfaces rapidly and efficiently. The paint roller typically consists of two parts: a "roller frame" and a "roller cover". The roller cover absorbs the paint and transfers it to the painted surface, the roller frame attaches to the roller cover. The roller frame is reusable. It is possible to clean and reuse a roller cover, but it is also typically disposed of after use [3].

2.2 Control System

One of the most commonly asked questions by a novice on a control system is: What is a control system? To answer the question, where in our daily lives there are numerous "objectives" that need to be accomplished. For instance, in the domestic domain, the temperature and humidity of homes and buildings for comfortable living are needed to regulate. For transportation, the automobile and airplane are controlled to go from one point to another accurately and safely. Industrially, manufacturing processes contain numerous objectives for products that will satisfy the precision and cost effectiveness requirements.

In recent years, control systems have assumed an increasingly important role in the development and advancement of modern civilization and technology. Practically every aspect of our day-to-day activities is affected by some type of control system.

Control systems are found in abundance in all sectors of industry, such as quality control of manufactured products, automatic assembly lines, machine-tool control, space technology and weapon systems, computer control, transportation systems, power systems, robotics, Micro-Electro-Mechanical Systems (MEMS), nanotechnology, and many others. Even the control of inventory and social and economic systems may be approached from the theory of automatic control [4].

Since advances in the theory and practice of automatic control provide the means for attaining optimal performance of dynamic systems, improving productivity, relieving the drudgery of many routine repetitive manual operations, and more, most engineers and scientists must now have a good understanding of this field [5].

2.2.1 Control system definition

A control system consists of subsystems and processes (or plants) assembled for the purpose of obtaining a desired output with desired performance, given a specified input. Figure 2.1 shows a control system in its simplest form, where the input represents a desired output [5].

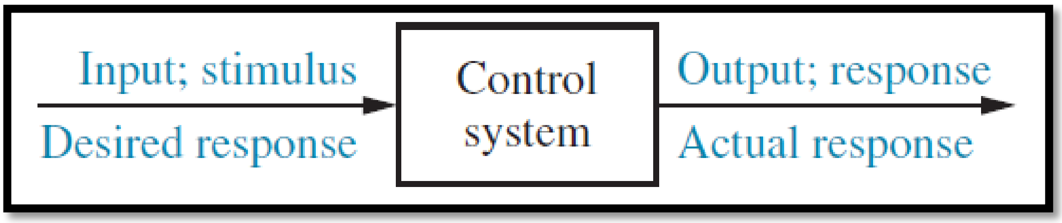


Figure 2.1: Simplified description of control system

2.2.2 Advantages of control system

With control systems we can move large equipment with precision that would otherwise be impossible. Huge antennas can be pointed toward the farthest reaches of the universe to pick up faint radio signal controlling these antennas by hand would be impossible. Because of control systems, elevators carry us quickly to our destination, automatically stopping at the right floor. The power could not require for the load and the speed, motors provide the power and control systems regulate the position and speed [5]. Control systems were built for four primary reasons:

i. Power amplification
ii. Remote control
iii. Convenience of input form
iv. Compensation for disturbances

2.2.3 Historical review

The first significant work in automatic control was James Watt's centrifugal governor for the speed control of a steam engine in the eighteenth century. Other significant works in the early stages of development of control theory were due to Minor sky, Hazen and Nyquist among many others. In 1922, Minor sky worked on automatic controllers for steering ships and showed how stability could be determined from the differential equations describing the system. In 1932, Nyquist developed a relatively simple procedure for determining the stability of closed-loop systems on the basis of open-loop response to steady-state sinusoidal inputs.

A significant date in the history of automatic feedback control systems is 1934, when Hazen's paper ''Theory of Servomechanisms'' was published in the Journal of the Franklin Institute, marking the beginning of the very intense interest in this new field. It was in this paper that the word servomechanism originated, from the words servant (or slave) and mechanism. Black's important paper on feedback amplifiers appeared in the same year. After World War II, control theory was studied intensively and applications have proliferated many books and thousands of articles and technical papers have been written, and the application of control systems in the industrial and military fields has been extensive. This rapid growth of feedback control systems was accelerated by the equally rapid development and widespread use of computers.

During the decade of the 1940s frequency response methods (especially the Bode diagram methods due to Bode) made it possible for engineers to design linear closed loop control systems that satisfied performance requirements. From the end of the 1940s to the early 1950s the root-locus method due to Evans was fully developed. The frequency-response and root-locus methods, which are the core of classical control theory, lead to systems that are stable and satisfy a set of more or less arbitrary performance requirements. Such systems are, in general, acceptable but not optimal in any meaningful sense.

Classical control theory, which deals only with single input single output systems, becomes powerless for multiple input multiple output systems. Since about 1960, because the availability of digital computers made possible time domain analysis of complex systems, modern control theory, based on time domain analysis and synthesis using state variables, has been developed to cope with the increased complexity of modern plants and the stringent requirements on accuracy, weight, cost in military, space and industrial applications [5].

2.2.4 Open loop control system

Those systems in which the output has no effect on the control action are called open-loop control systems. In other words, in an open-loop control system the output is neither measured nor fed back for comparison with the input. One practical example is a washing machine. Soaking, washing, and rinsing in the washer operate on a time basis. The machine does not measure the output signal, that is, the cleanliness of the clothes.

As shown in Figure 2.2, in any open-loop control system the output is not compared with the reference input. Thus, to each reference input there corresponds a fixed operating condition; as a result, the accuracy of the system depends on calibration. In the presence of disturbances, an open-loop control system will not perform the desired task. Open-loop control can be used, in practice, only if the relationship between the input and output is known and if there are neither internal nor external disturbances. Clearly, such systems are not feedback control systems. Note that any control system that operates on a time basis is open loop. For instance, traffic control by means of signals operated on a time basis is another [4].

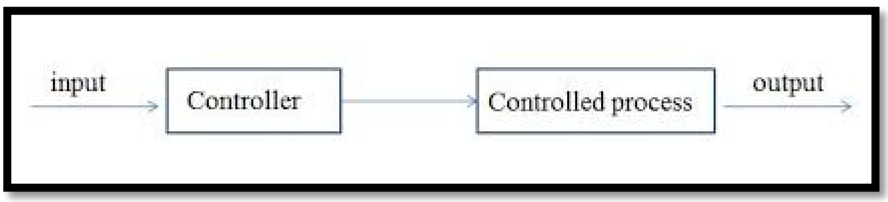


Figure 2.2: Description of open loop system

2.2.5 Closed-loop control systems

A system that maintains a prescribed relationship between the output and the reference input by comparing them and using the difference as a means of control is called a closed-loop control system. An example would be a room temperature control system. By measuring the actual room temperature and comparing it with the reference temperature, the thermostat turns the heating or cooling equipment ON or OFF in such a way as to ensure that the room temperature remains at a comfortable level regardless of outside conditions. As shown in Figure 2.3, in a closed-loop control system the actuating error signal, which is the difference between the input signal and the feedback signal (which may be the output signal itself or a function of the output signal and its derivatives and/or integrals), is feedback to the controller so as to reduce the error and bring the output of the system to a desired value. The term closed-loop control always implies the use of feedback control action in order to reduce system error [4].

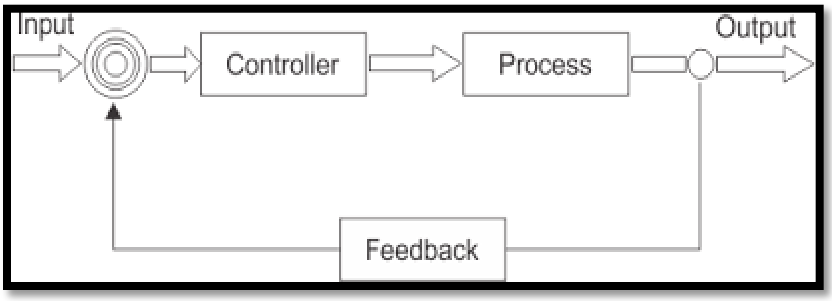


Figure 2.3: Description of closed-loop system

2.2.6 Nonlinear systems

A system is nonlinear if the principle of superposition does not apply. Thus, for a nonlinear system the response to two inputs cannot be calculated by treating one input at a time and adding the results. Although many physical relationships are often represented by linear equations, in most cases actual relationships are not quite linear. In fact, a careful study of physical systems reveals that even so-called "linear systems" are really linear only in limited operating ranges. In practice, many electromechanical systems, hydraulic systems, pneumatic systems, and so on, involve nonlinear relationships among the variables. For example, the output of a component may saturate for large input signals. There may be a dead space that affects small signals. (The dead space of a component is a small range of input variations to which the component is insensitive). Square-law nonlinearity may occur in some components. For instance, dampers used in physical systems may be linear for low-velocity operations but may become nonlinear at high velocities, and the damping force may become proportional to the square of the operating velocity. In control engineering a normal operation of the system may be around an equilibrium point, and the signals may be considered small signals around the equilibrium. (It should be pointed out that there are many exceptions to such a case). However, if the system operates around an equilibrium point and if the signals involved are small signals, then it is possible to approximate the nonlinear system by a linear system. Such a linear system is equivalent to the nonlinear system considered within a limited operating range. Such a linearized model (Linear Time-Invariant model) is very important in control engineering. The linearization procedure to be presented in the following is based on the expansion of nonlinear function into a Taylor series about the operating point and the retention of only the linear term. Because of neglecting higher-order terms of Taylor series expansion, these neglected terms must be small enough; that is, the variables deviate only slightly from the operating condition [4,5].

2.3 Robots

The robots are electromechanical device with multiple Degrees-Of-Freedom (DOF) that is programmable to accomplish a variety of tasks. Also they are group of programmable units constructed to work, these units may be sensors or another linked hardware devices. They are reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks [6].

2.3.1 Uses of robots

- Jobs those are dangerous for humans.
- Repetitive jobs those are boring, stressful or labor-intensive for humans.
- Menial tasks that human don't want to do.

2.3.2 Laws of robotics

Asimov proposed three “Laws of Robotics” and later added the “zeroth law” and these laws are [7]:

- Law 0: A robot may not injure humanity or through inaction, allow humanity to come to harm.
- Law 1: A robot may not injure a human being or through inaction, allow a human being to come to harm, unless this would violate a higher order law.
- Law 2: A robot must obey orders given to it by human beings, except where such orders would conflict with a higher order law.
- Law 3: A robot must protect its own existence as long as such protection does not conflict with a higher order law.

2.3.3 History of robotics

- 1954: The first programmable robot is designed by "George Devol", who coins the term Universal Automation. He later shortens this to Unimation, which becomes the name of the first robot company (1962).
- 1978: The Puma (Programmable Universal Machine for Assembly) robot is developed by Unimation with a General Motors design support.

- 1980s: The robot industry enters a phase of rapid growth. Many institutions introduce programs and courses in robotics. Robotics courses are spread across mechanical engineering, electrical engineering, and computer science departments.
- 1995-present: Emerging applications in small robotics and mobile robots drive a second growth of start-up companies and research [6].

2.3.4 Knowledgebase for robotics

Typical knowledgebase for the design and operation of robotics systems are [7]:

• Dynamic system modeling and analysis.

• Feedback control.

• Sensors and signal conditioning.

• Actuators (muscles) and power electronics.

• Hardware/computer interfacing.

• Computer programming.

2.3.5 Robot applications in our lives

Robots have many kinds of applications:

i. Welding

Considered as a dangerous task for a human because of toxic gases emissions. The welding job is quite difficult for a person who is required to weld two pipes from different sides and angles and to sit in a difficult position for a long time. It can be hard on ones physic and can cause health problems for the worker. The difficulty for a human is to see all the sides of welded devices when he needs to weld around a pipe as he can only see one side of the pipe [6].

ii. Painting:

It has similar problems to welding due to the use of toxic chemical products [6].

iii. Assembly operation

When we assemble a chip we need to be very precise because of very fine wires which require very precise and accurate tasks which a human cannot handle but, on the other hand, is easy for a robot [6].

iv. Medical robot to make surgery

Patient gets fast recovery. The operation is more precise with fewer mistakes. Robot can open small incisions in the body and carry out major operations with minimal damage to the patient .Therefore recovery time is decreased. Equipment is more hygienic and safety [6].

v. Robotics aircrafts and boats

Without pilot which are guided from a station on the ground, which are used by army or rescue mission [6].

2.4 Microcontroller

It is a highly integrated chip that contains all the components comprising a controller. Typically this includes a CPU, RAM, ROM and I/O ports. Unlike a general-purpose computer, which also includes all of these components, a microcontroller as shown in Figure 2.4, is designed for a very specific task to control a particular system. As a result, the parts can be simplified and reduced, which cuts down on production cost [8].

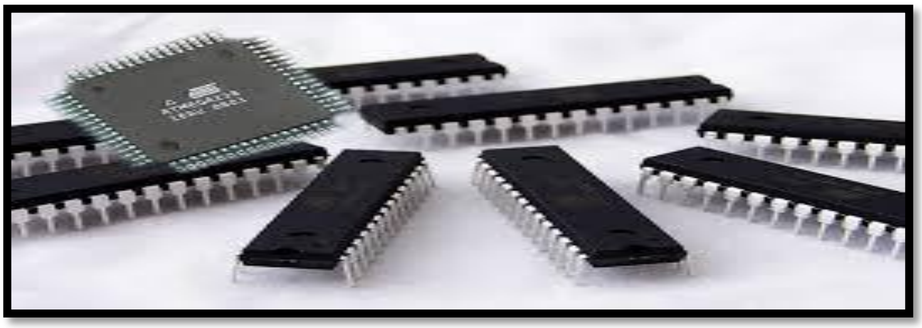


Figure 2.4: Microcontrollers

2.4.1 History of microcontroller

The first computer system on a chip optimized for control applications was the Intel 8048 microcontroller with both RAM and ROM on the same chip. Most microcontrollers at that time had two variants; one had an erasable EEPROM program memory, which was significantly more expensive than the PROM variant which was only programmable once.

The introduction of EEPROM memory allowed microcontrollers (beginning with the Microchip PIC16x84) to be electrically erased quickly without an expensive package as required for EPROM. The same year, Atmel introduced the first microcontroller using Flash memory. Other companies rapidly followed suit, with both memory types. Nowadays microcontrollers are low cost and readily available for hobbyists, with large online communities around certain processors.

A microcontroller is a single-chip computer .Micro suggests that the device is small, and controller suggests that it is used in control applications. Another term for microcontroller is embedded controller, since most of the microcontrollers are built into (or embedded in) the devices that controlling.

Microcontrollers have traditionally been programmed using the assembly language of the target device. Although the assembly language is fast, it has several disadvantages. An assembly program consists of mnemonics, which makes learning and maintaining a program written using the assembly language difficult. Also, microcontrollers manufactured by different firms have different assembly languages, so the user must learn a new language with every new microcontroller he or she uses.

Microcontrollers can also be programmed using a high-level language, such as BASIC, PASCAL, or C. High-level languages are much easier to learn than assembly languages and also facilitate the development of large and complex programs [8].

2.4.2 Microcontroller components

A microcontroller basically contains one or more following components

- **Central processing unit**

Central Processing Unit (CPU) as shown in Figure 2.5 is the brain of a microcontroller. CPU is responsible for fetching the instruction, decodes it, and then finally executed. CPU connects every part of a microcontroller into a single system. The primary function of CPU is fetching and decoding instructions. Instruction fetched from program memory must be decoded by the CPU.

Figure 2.5: CPU

- **Memory**

Memory in a microcontroller is same as microprocessor. It is used to store data and program. A microcontroller usually has a certain amount of RAM and ROM (EEPROM, EPROM, etc.) or flash memories for storing program source codes. Table 2.1 shows different types of memories.

Table 2.1: Types of memories

Type	Access	Access speed	Data lost if power loss?
ROM	Read only	Fast	No
RAM	Read/Write	Very fast	Yes
EEPROM	Read/Write	Slow	No
Flash	Read/Write	Slow	No
Hard disk	Read/Write	Very slow	No
Floppy	Read/Write	Very slow	No
CD	Read/Write	Very slow	No
Tape	Read/Write	Very slow	No

- **Parallel input/output ports**

Parallel input/output ports are mainly used to drive/interface various devices such as LCD’S, LED’S, printers, memories, etc. to a microcontroller.

- **Serial interfacing ports**

Serial ports provide various serial interfaces between microcontroller and other peripherals like parallel ports.

- **Timers and counters**

This is the one of the useful function of a microcontroller. A microcontroller may have more than one timer and counters as shown in Figure 2.6. The timers and counters provide all timing and counting functions inside the microcontroller. The major operations of this section are performing clock functions, modulations, pulse generations, frequency measuring, making oscillations, etc. This also can be used for counting external pulses.

Figure 2.6: Timers and counters

- **Analog to digital converter**

Analog to Digital Converter (ADC) shown in Figure 2.7, are used for converting the analog signal to digital form. The input signal in this converter should be in analog form (e.g. sensor output) and the output from this unit is in digital form. The digital output can be used for various digital applications (e.g. measurement devices).

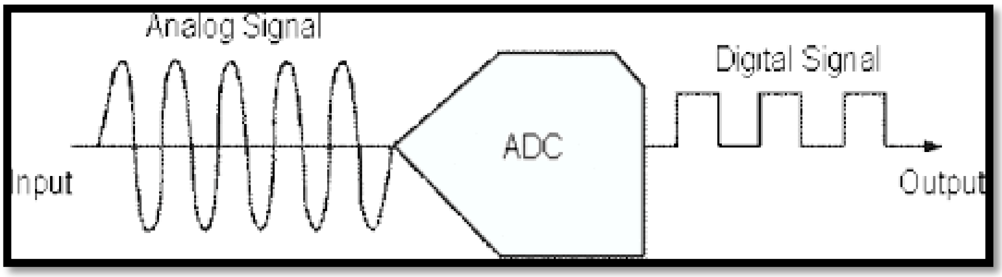


Figure 2.7: Analog to digital converter

- **Digital to analog converter**

Digital to Analog Converter (DAC) shown in Figure 2.8, perform reversal operation of ADC conversion. DAC convert the digital signal into analog format. It usually used for controlling analog devices like DC motors, various drives, etc.

Figure 2.8: Digital to analog converter

- **Interrupt control**

The interrupt control used for providing interrupt (delay) for a working program. The interrupt may be external (activated by using interrupt pin) or internal (by using interrupt instruction during programming).

- **Special functioning block**

Some microcontrollers used only for some special applications (e.g. space systems and robotics) these controllers containing additional ports to perform such special operations. This considered as special functioning block [8].

2.4.3 Microcontroller applications

Microcontrollers are widely used in modern electronic equipment. Some basic applications of microcontroller are given below:

- Used in biomedical instruments.
- Widely used in communication systems.
- Used as peripheral controller in Personal Computer (PC).
- Used in robotics.
- Used in automobile fields.

Microcontroller applications found in many lives filed, for example in Cell phone, watch, recorder, calculators, mouse, keyboard, modem, fax card, sound card, battery charger, door lock, alarm clock, thermostat, air conditioner, TV Remotes, in Industrial equipment like Temperature and pressure controllers, counters and timers [8].

2.4.4 Arduino microcontroller

Arduino is a small microcontroller board with a USB plug to connect to the computer and a number of connection sockets that can be wired up to external electronics, such as motors, relays, light sensors, laser diodes, loudspeakers, microphones, etc. Arduino can either be powered through the USB connection from the computer or from a 9V battery. Arduino can be controlled from the computer or programmed by the computer and then disconnected and allowed to work independently [9].

- **Arduino board**

It is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments in simple terms, the Arduino is a tiny computer system that can be programmed with instructions to interact with various forms of input and output. The current Arduino board model, the Uno, is quite small in size compared to the average human hand.

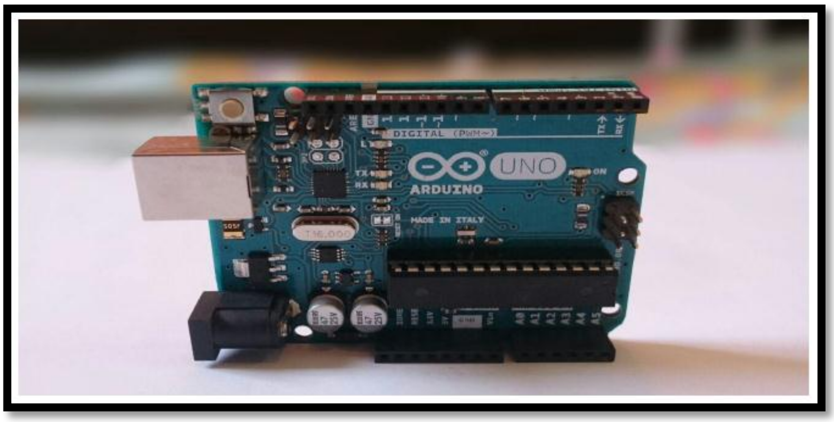


Figure 2.9: Arduino microcontroller board

Although it might not look like much to the new observer, the Arduino system allows creating devices that can interact with the world. By using an almost unlimited range of input and output devices, sensors, indicators, displays, motors, and more, the exact interactions required to create a functional device can be programmed. For example, artists have created installations with patterns of blinking lights that respond to the movements of passers-by, high school students have built autonomous robots that can detect an open flame and extinguish it, and geographers have designed systems that monitor temperature and humidity and transmit this data back to their offices via text message. In fact, there are infinite numbers of examples with a quick search on the Internet. By taking a quick tour of the Uno Starting at the left side of the board there are two connectors, as shown in Figure 2.10.

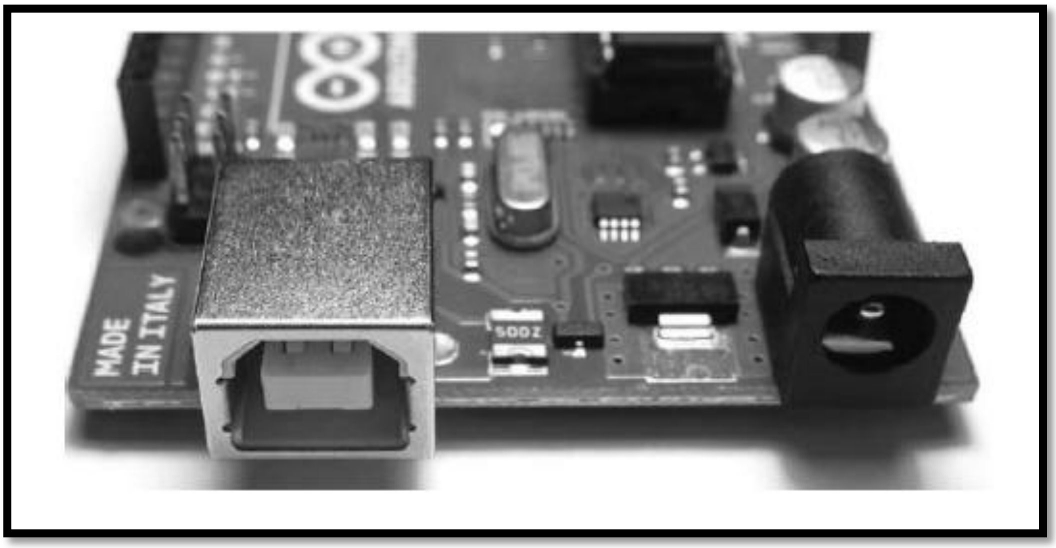


Figure 2.10: The USB and power connectors

On the far left is the Universal Serial Bus (USB) connector. This connects the board to the computer for three reasons; to supply power to the board, to upload the instructions to the Arduino, and to send and receive from a computer. On the right is the power connector, this connector can power the Arduino with a standard mains power adapter.

At the lower middle is the heart of the board: the microcontroller, as shown in Figure 2.11.

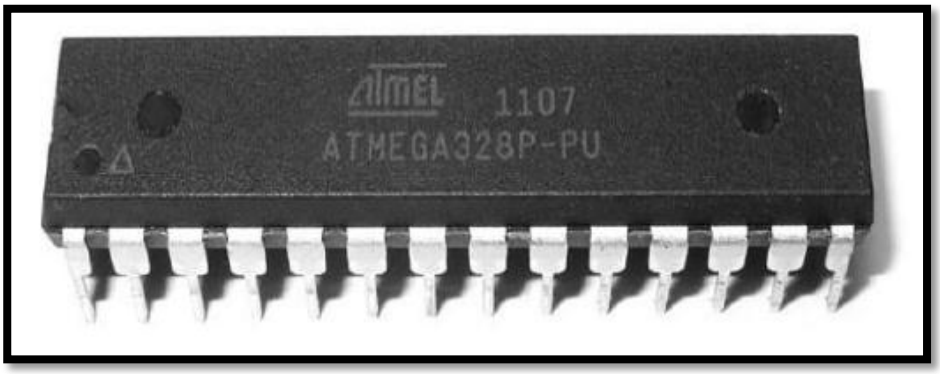


Figure 2.11: The microcontroller

The microcontrollers represent the “brains” of the Arduino. It is a tiny computer that contains a processor to execute instructions, includes various types of memory to hold data and instructions from the sketches, and provides various avenues of sending and receiving data. Just below the microcontroller are two rows of small sockets, as shown in Figure 2.12.

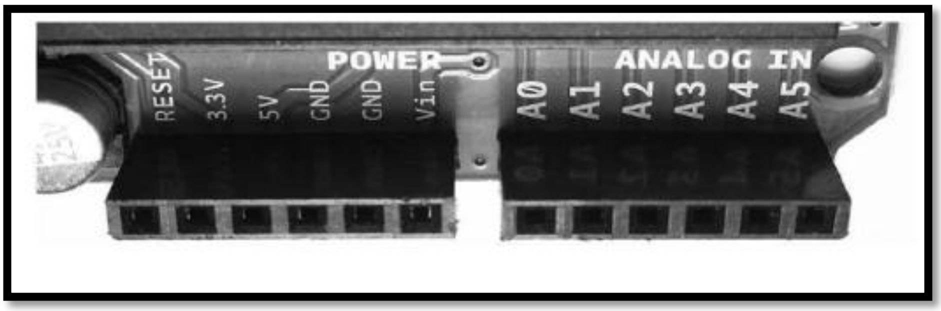


Figure 2.12: The power and analog sockets

The first row offers power connections and the ability to use an external RESET button. The second row offers six analog inputs that are used to measure electrical signals that vary in voltage. Furthermore, pins A4 and A5 can also be used for sending data to and receiving it from other devices. Along the top of the board are two more rows of sockets, as shown in Figure 2.13.

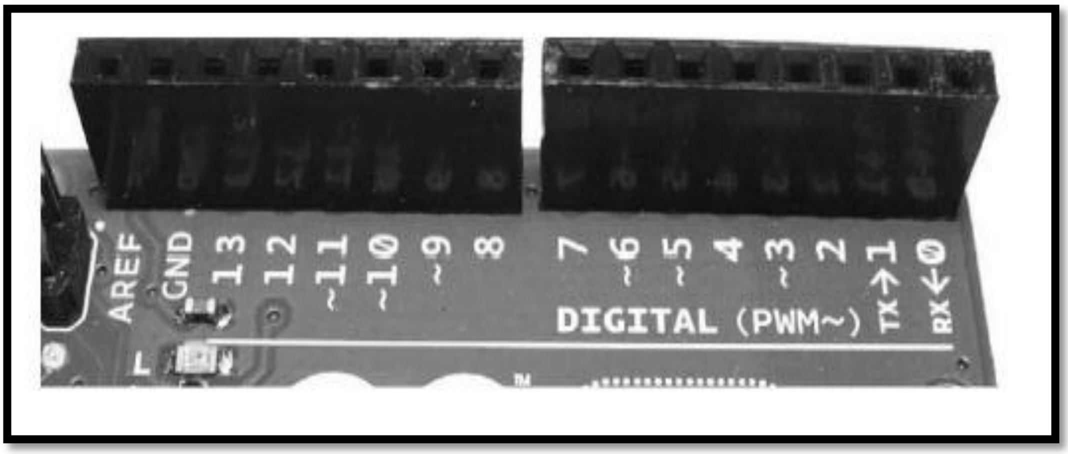


Figure 2.13: The digital input/output pins

Sockets (or pins) numbered 0 to 13 are digital input/output (I/O) pins. They can either detect whether or not an electrical signal is present or generate a signal on command. Pins 0 and 1 are also known as the serial port, which is used to send and receive data to other devices, such as a computer via the USB Connector circuit. The pins labeled with a tilde (~) can also generate a varying electrical signal, which can be useful for such things as creating lighting effects or controlling electric motors. Next are some very useful devices called light-emitting diodes (LEDs); these very tiny devices light up when a current passes through them. The Arduino board has four LEDs: one on the far right labeled ON, which indicates when the board has power, and three in another group, as shown in Figure 2.14. The LEDs labeled TX and RX light up when data is being transmitted or received between the Arduino and attached devices via the serial port and USB. The L-LED connected to the digital I/O pin number 13. The little black square part to the left of the LEDs is a tiny microcontroller that controls the USB interface that allows Arduino to send data to and receive it from a computer [9].

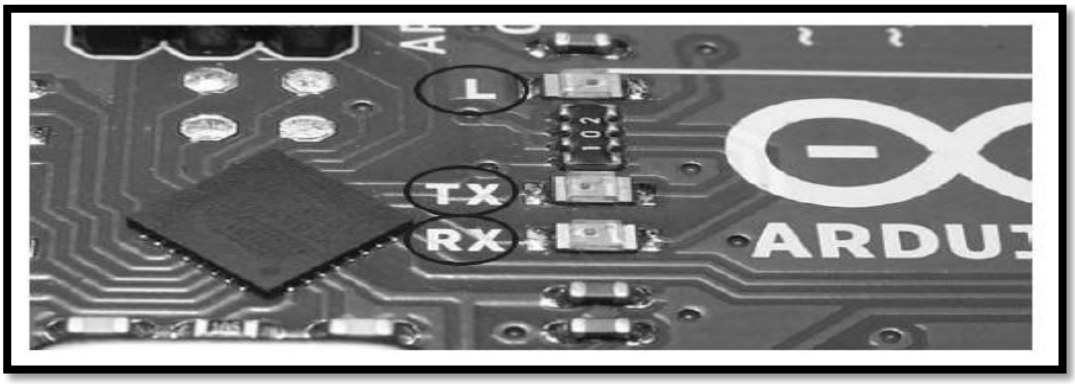


Figure 2.14: The onboard LEDs

And, finally, the RESET button is shown in Figure 2.15 [9].

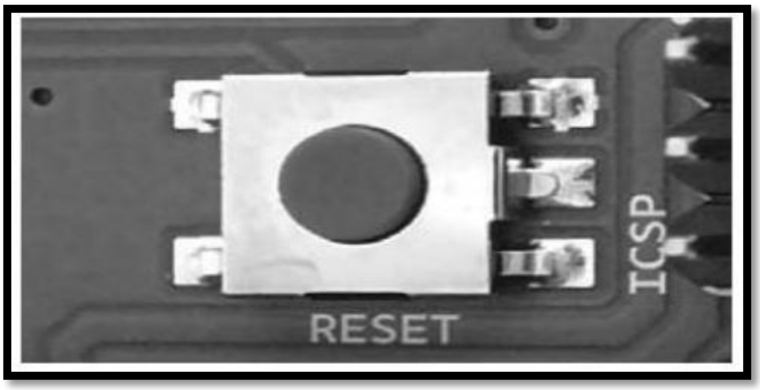


Figure 2.15: The RESET button

2.5 Sensors

Sensor and control system have explosively expanded beyond their traditional production base in to far ranging commercial ventures and they will play important role in survival of innovative industries and solve the problems of manufacturing. Sensor used for measurement of the physical parameters and it is a device that converting the physical variable input into signal variable output that can be used or understood [10]. In other term sensors are devices that respond to any change in physical phenomena or environmental variable such as heat, pressure, force, flow and speed. Signal variables have property that they can be manipulated in a transmission system, such as an electrical or mechanical circuit. Because of this property, the signal variable can be transmitted to an output or recording device that can be remote from the sensor. In electrical circuits, voltage is a common signal variable. In mechanical systems, displacement or force are commonly used as signal variables.

If the signal output from the sensor is small, it is sometimes necessary to amplify the output. The amplified output can then be transmitted to the display device or recorded, depending on the particular measurement application. In many cases it is necessary for the instrument to provide a digital signal output so that it can interface with a computer-based data acquisition or communications system. If the sensor does not inherently provide a digital output, then the analog output of the sensor is converted by an analog to digital converter (ADC). The digital signal is typically sent to a computer processor that can display, store, or transmit the data as output to some other system, which will use the measurement [11].

2.5.1 Sensor benefits

Sensors have many benefits like productivity, quantity, production reliability, greater utilization and lead time [10].

2.5.2 Characteristics of sensor

A good sensor should have the following characteristic:

- **High sensitivity**

Sensitivity indicates how much output of device change with unit change input.

- **Linearity**

The output should be change linearly with the input.

- **High resolution**

Resolution is smallest change in variable that device can be detect.

- **High accuracy**

Accuracy is difference between the indicated values an actual value.

- **Less power consumption**

2.5.3 Classifications of sensor

- At based on the power requirement sensor can be classified to:

1. **Active sensor:**

That which do not require external power source for their functioning but may remove energy in their operation, one example of a passive sensor is a thermocouple, which converts a physical temperature into a voltage signal. In this case, the temperature gradient in the environment generates thermoelectric voltage that becomes the signal variable.

2. **Passive sensor:**

Those which require power source for their functioning Such as resistive, inductive and capacitive sensor.

- Depend on output nature:

1. **Analog sensor:**

Sensor covert the physical quantity being measured to analog form or sensor provide continuous output signal that directly proportional to the input signal such as thermocouple, RTD and strain gauge.

2. **Digital sensor**

It is providing signal data that direct digital representation of the measured and basically binary ("ON" or "OFF") device Encoder for example of digital sensor.

- Classification sensor based of the quantity being measured:

1. **Pressure sensor :**

There are many groups of sensors that measure the pressure such as Manometer, Diaphragms, capsules and Bourdon tube.

2. **Flow Rate sensor**

Differential pressure flow meter is most common used to measure flow rate.

3. **Temperature sensor**

There is more group sensor measure the temperature such as Thermocouple, Resistance temperature device RTD, Thermostat and Semiconductor.

4. **Light sensor**

Photocells are used for the detection and conversion of light intensity into electrical signal. Photocells can be classified to Photovoltaic, photo conductive and photo emissive. Photovoltaic cells develop EMF in presence of light; copper oxide and selenium are example of photovoltaic material. Photo conductive device change their resistance with light intensity. Examples of these materials are selenium and aluminum oxide. Photo emissive device is liberating electronics in the presence of light. Photo emissive material such as mixture of rare earth element like cesium oxide. Other sensor light is photoelectric sensors that use the light to detect the presence or absence of an object. It consists of a source a detector. The source light emitting diode LED that emits power full beam of light either in the infrared or visible light spectrum and the detector is typically photodiode to sense the presence or absence of light. The source and detector may be separated or mounted in the same. There are three mode of detection are used by photoelectric sensor is through beam detection, reflex detection and proximity detection.

5. Displacement sensor :

There are many groups of sensors that measure the displacement such as Resistive, Inductive, Capacitive displacement sensor, Synchro and ultrasonic displacement sensor.

i. Resistive Displacement Sensor

They are commonly termed potentiometers or "pots." A pot is an electromechanical device containing an electrically conductive wiper that slides against a fixed resistive element according to the position or angle of an external shaft. Electrically, the resistive element is "divided" at the point of wiper contact. To measure displacement, a pot is typically wired in a "voltage divider" configuration, as shown in Figure 2.16.

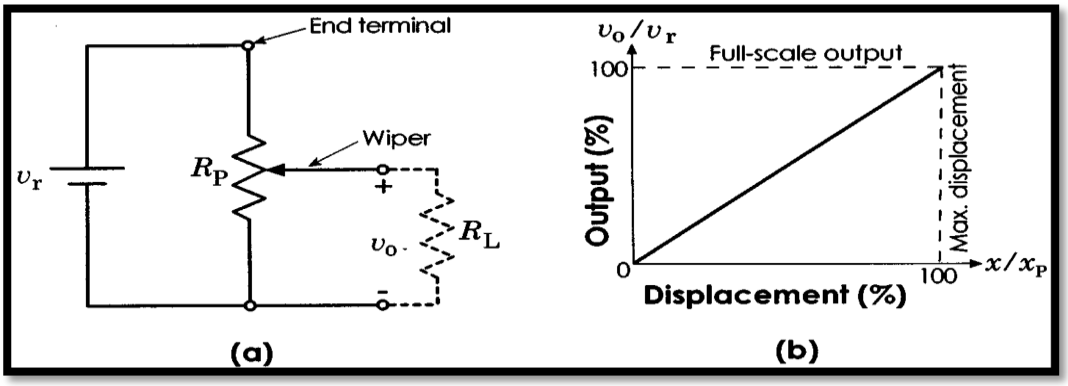


Figure 2.16: Schematic diagram of resistive displacement sensor

Figure (*a*) explains the Schematic diagrams depict a potentiometer as a resistor with an arrow representing the wiper. This schematic shows a pot used as a variable voltage divider the preferred configuration for precision measurement. ***R*P** is the total resistance of the pot, ***R*L** is the load resistance, ***vr*** is the reference or supply voltage, and ***vo*** is the output voltage. Figure (*b*) shows an ideal linear output function where ***x*** represents the wiper position, and ***x*P** is its maximum position [11].

ii. Ultrasonic sensor

Ultrasound is an acoustic wave with a frequency higher than the audible range of the human ear, which is 20 kHz. Ultrasound can be within the audible range for some animals, like dogs, bats, or dolphins. The basic principle for the use of ultrasound as a measurement tool is the time-of-flight technique. The pulse-echo method is one example. In the pulse-echo method, a pulse of ultrasound is transmitted in a medium. When the pulse reaches another medium, it is totally or partially reflected, and the elapsed time from emission to detection of the reflected pulse is measured. This time depends on the distance and the velocity of the sound. When sound travels with a known velocity *(c)*, the time *(t)* elapsed between the outgoing signal and its incoming echo is a measure of the distance *(d)* to the object causing the echo.

$$\boldsymbol{d} = \frac{\mathbf{c * t}}{\mathbf{2}} \tag{2.1}$$

Figure 2.17 shows a simple pulse-echo system. The transmitter and the receiver could be the same device, but they are separated for clarity in this figure. The oscillator generates an electric signal with a typical frequency of 40 kHz. This electric signal is transformed into mechanical vibrations of the same frequency in the transmitter. These vibrations generate sound waves that are reflected by the object. The reflected sound echo causes an electric signal in the receiver. For precise measurements, the speed of sound is a crucial parameter [11].

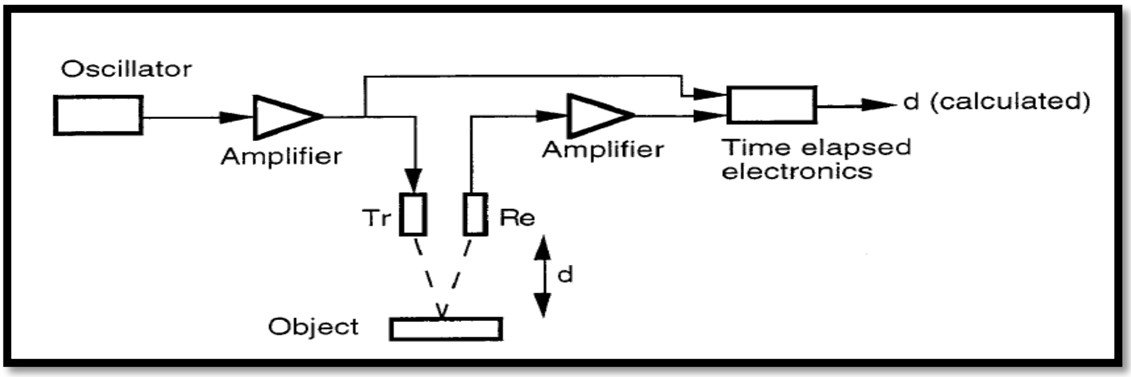


Figure 2.17: Principle of a pulse-echo ultrasound system

CHAPTER THREE

SYSTEM HARDWARE AND SOFTWARE CONSIDERATIONS

3.1 System Fabrication

The system fabrication discusses the mechanism of connecting the arms together and specifies the suitable length for the two arms. According to the overall dimensions of the arm system, the wall height has been estimated. From the calculation of torque for the system, the required specifications of the two DC servo motors have been determined.

3.1.1 Dimension calculation

As shown in Figure 3.1, the dimensions had been selected, so the height of the movable chassis from the ground is 6 Cm, the height of the two DC servo motors are 4 Cm, the height form center of the first DC servo motor for the lower arm is 29 Cm and the height of the upper arm with the roller is 30 Cm.

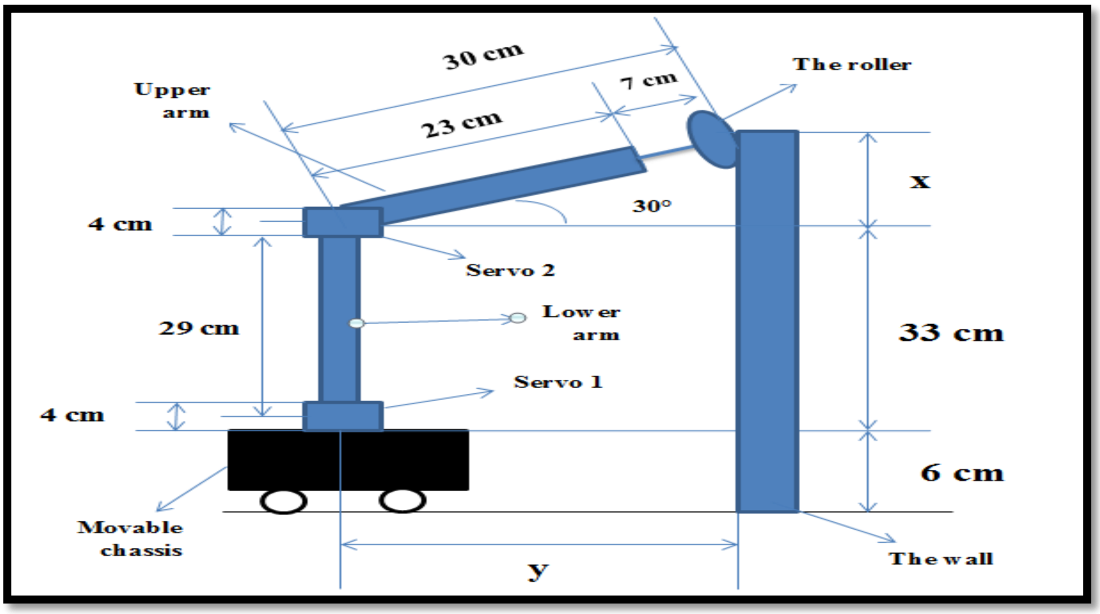


Figure 3.1: The dimensions of the WPR

To estimate the distance from the center of the upper servo to the top of the wall (x) can be calculated as below:

x = 30*sin (30) = 15 Cm (3.1)

To estimate the distance from the center of the movable chassis to the wall (y) can be calculated as below:

$$y = \sqrt{(30)^2 - (15)^2} = 26 \text{ Cm} \quad (3.2)$$

So the total height of the wall that can be painted is:

x + 33 + 5 = 15 + 33 + 6 = 54 Cm (3.3)

3.1.2 Torque equation

The weight of the arm system had been measured as follow:

- Servo's weight is 55 gm.
- The lower arm's weight is 35.9 gm.
- The upper arm's weight is 28.8 gm.
- The roller's weight is 85 gm.
- Rated torque of each servo motor is 9.4 Kg.cm

As shown in Figure 3.2, the torque around the rotation axis point can be calculated from the equation below:

$$T = f * r * \sin(\phi) \quad (3.4)$$

Where

T: torque in gm.

f: force in gm.

r: the length of force arm in Cm

ϕ: the angle between the force at any point and the force arm in degree

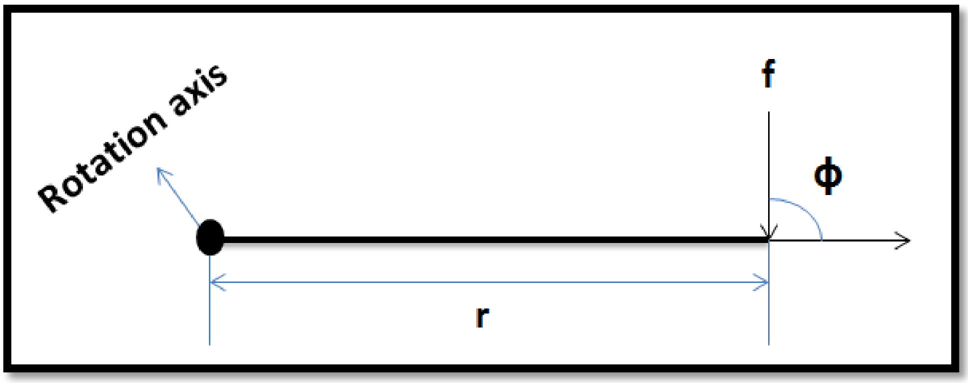


Figure 3.2: Torque diagram

The peak torque was obtained at angle ϕ=90°.

As shown in Figure 3.3, the torque has been estimated from the concentrate distributed force theory. When the force is distributed on a beam, it must be concentrated in the center the beam.

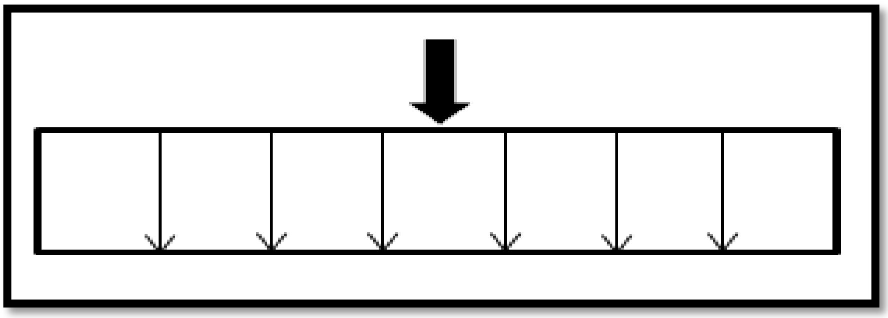


Figure 3.3: Concentrate distributed force

- **The upper servo torque's calculation :**

From the Figure 3.4, the torque has been calculated as follow:

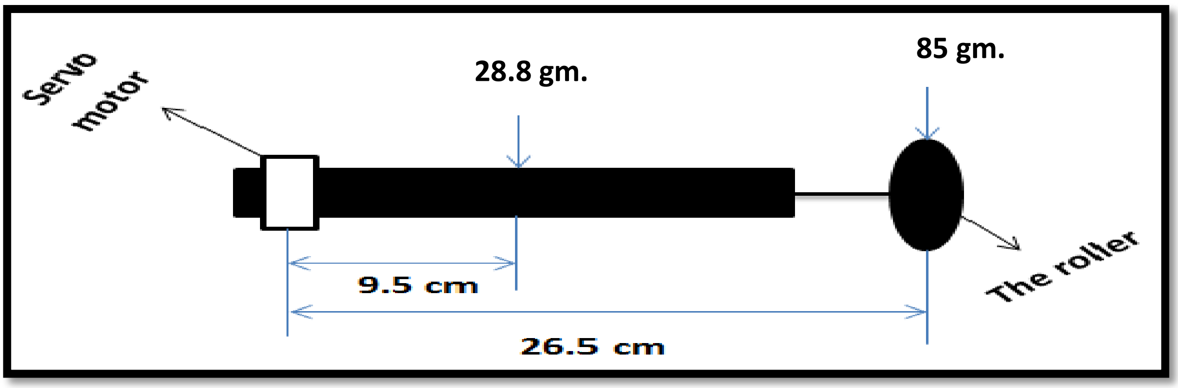


Figure 3.4: The upper arm with the roller

T = (9.5*28.8) + (85*26.5) (3.5)

= 2526.1 gm.Cm

= 2.526 Kg.Cm

- **The lower servo torque's calculation :**

From the Figure 3.5, the torque has been calculated as follow:

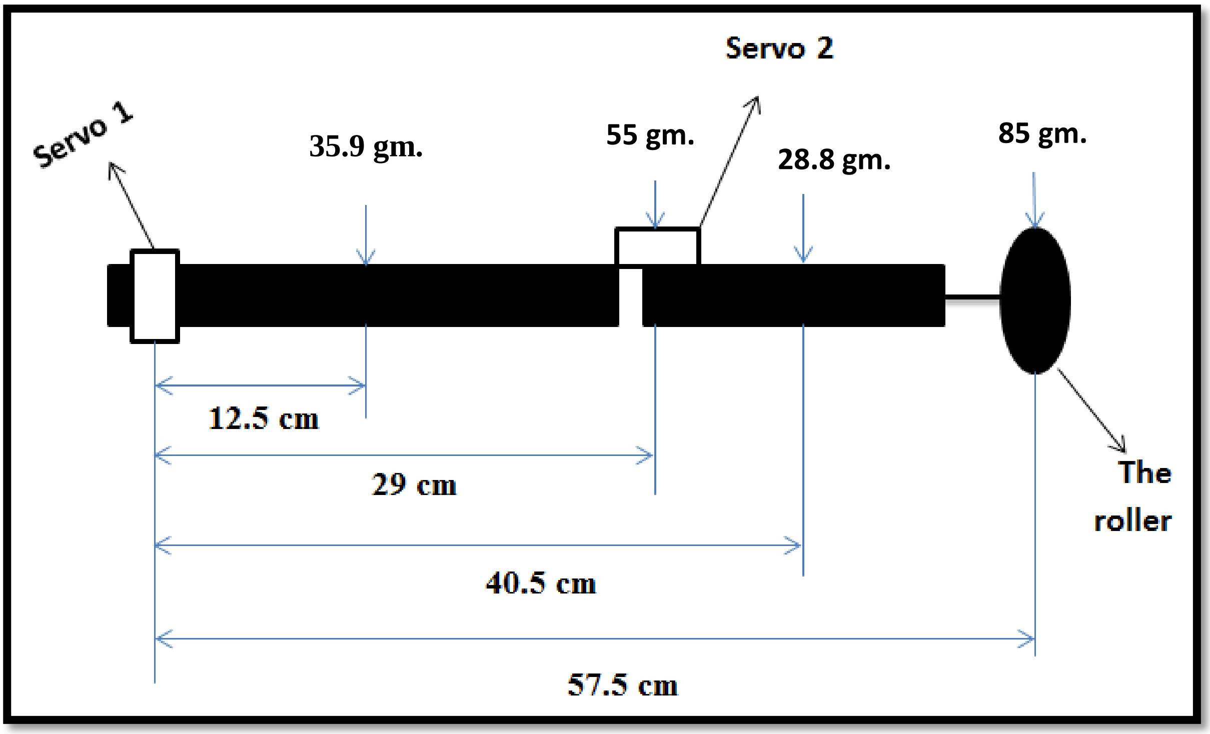


Figure 3.5: The two arms with the roller

T = (35.9*12.5) + (55*29) + (28.8*40.5) + (85*57.5) (3.6)

= 8097 gm.Cm

= 8.097 Kg.Cm

3.2 System Control Circuit

System control circuit can be described by using block and wiring diagram which declare the hardware consideration.

3.2.1 Block diagram

The two DC servo motors offer the required movements (left, right, up and down) for the arms of the wall painting robot. The moving base is controlled with stepper motor using signals that produced by the computer to the Arduino. Arduino sends commands to these motor drivers, servo motors, ultrasonic sensor and relay as shown in Figure 3.6.

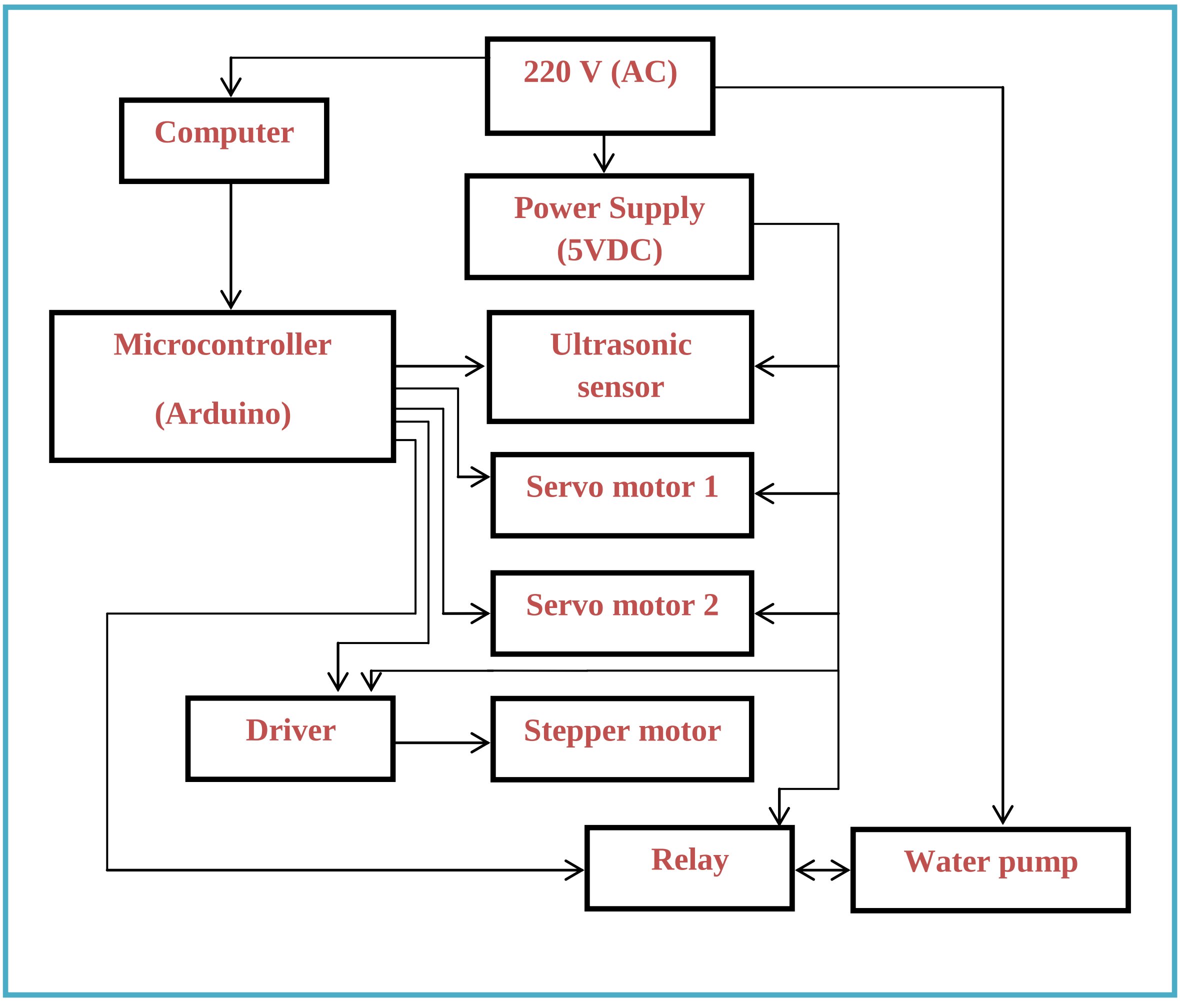


Figure 3.6: System block diagram

3.2.2 Wiring diagram

Wiring diagram is network of wires showing how to connect the circuit components, it explains the signals requirement for the movability and the ON-OFF control, also it declare the power feeding lines for the circuit. The wiring diagram describes how all wires were connected between the system circuit components. Arduino pins were used for sending the signal to the ultrasonic, servo motors, relay and the driver. The driver receives power from power supply with two wires, one is the (+5V) DC and the other is ground. The two DC servo motors were received signal from the pins of the Arduino and also supplied from the DC power supply. Ultrasonic sensor sends signal from the trigger pin and receives by the echo pin and also supplied from the DC power supply. The relay controls the operation of the water pump. Arduino receives the control and power signals from the PC with one wire. The wiring diagram is shown in Figure 3.7.

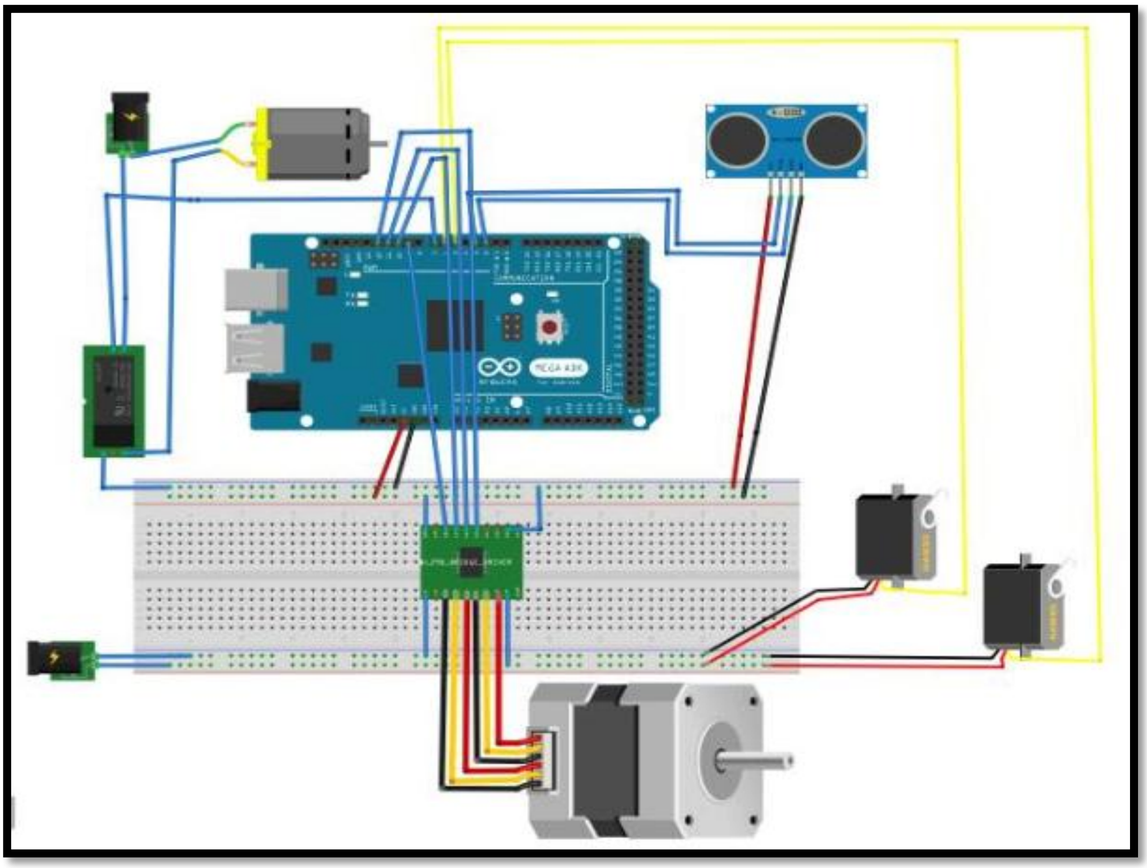


Figure 3.7: System wiring diagram

3.3 Hardware Considerations

Wall painting robot consists of many electrical components such as Arduino controller, stepper motor, drivers, DC servo motors, ultrasonic, relay, water pump and power supply.

3.3.1 Microcontroller (Arduino)

Arduino is a small microcontroller board with a USB plug to connect to your computer and a number of connection sockets that can be wired up to external electronics, such as motors, relays, light sensors, laser diodes, loudspeakers, microphones, etc. Arduino can either be powered through the USB connection from the computer or from a 9V battery, Figure 3.8 describe all Arduino pins. Arduino can be controlled from the computer or programmed by the computer and then disconnected and allowed to work independently.

The hardware consists of an open source hardware board that is designed around the Atmel AVR Microcontroller. The intention of Arduino was to make the application of interactive components or environments more accessible. Arduino is programmed via an Integrated Development Environment (IDE) and run on any platform that supports Java like LABVIEW. An Arduino program is written in either C or C++ and is programmed using its own IDE.

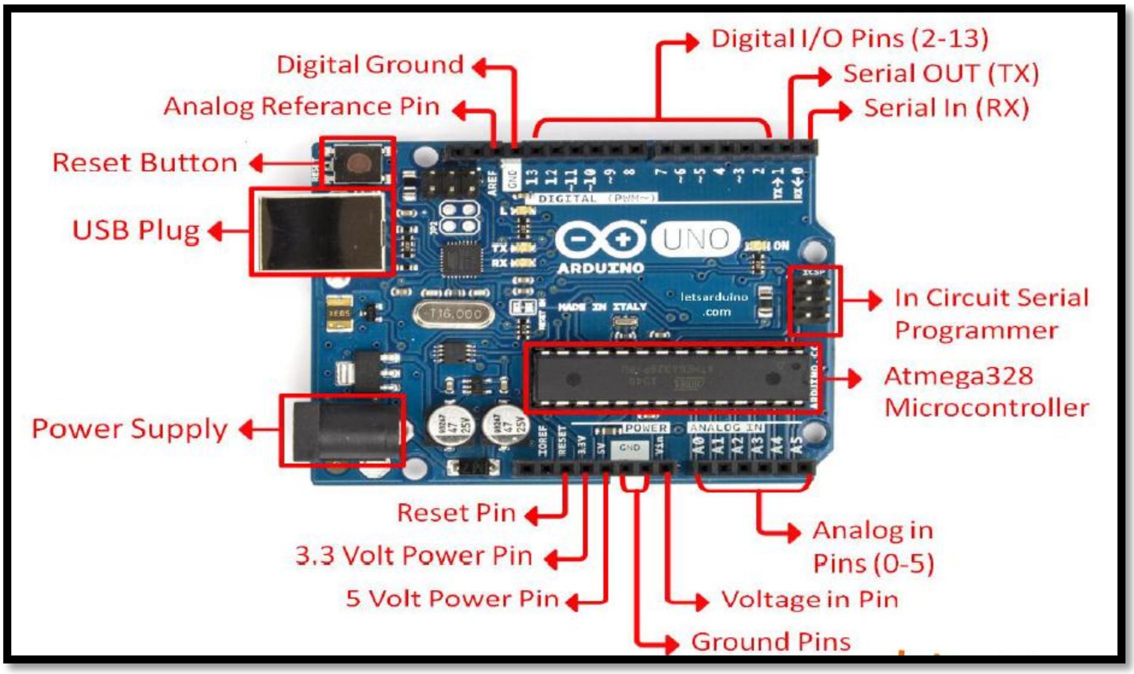


Figure 3.8: Arduino microcontroller

3.3.2 Servo motors

Servo motor is a type of motor who's the output shaft can be moved to specific angular position by sending coded signal. The servo mechanism that use position feedback to control of motion and final position. The measured position of output by sensor is compared to the command signal and be input to the controller. If the output position differ from required, an error signal is generated which then causes the motor rotate to bring the output shaft to appropriate position. The servo motor which is DC or AC motor depends on the power supplied to it. The DC servo motor consists of separately excited DC motor or permanent magnet DC motor and the armature is designed to have large resistance so that torque-speed characteristics are linear and have a large negative slope [12].

i. **Servo motor operation**

A servo consists of a motor (DC or AC), a potentiometer, gear assembly and a controlling circuit. First of all we use gear assembly to reduce RPM and to increase torque of motor. Say at initial position of servo motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. Now an electrical signal is given to another input terminal of the error detector amplifier.

Now difference between these two signals, one comes from potentiometer and another comes from other source, will be processed in feedback mechanism and output will be provided in term of error signal. This error signal acts as the input for motor and motor starts rotating. Now motor shaft is connected with potentiometer and as motor rotates so the potentiometer and it will generate a signal. So as the potentiometer's angular position changes, its output feedback signal changes. After sometime the position of potentiometer reaches at a position that the output of potentiometer is same as external signal provided. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer, and in this situation motor stop rotating [13].

ii. DC servo motor (MG 996R)

Direct Current servo motor (MG 996R) as shown in Figure 3.9, is a heavy-duty metal gear, digital servo with 180°wide angle, high torque power, improved stability and durability. The servo is able to work with 6V and deliver a strong torque power of over 9.4Kg. This (MG 996R) servo demonstrates a maximum torque of 11Kg without much vibration or heat.

Figure 3.9: (MG 996R) Servo motor

Specification:

- Weight: 55g
- Dimension: 40.7×19.7×42.9mm
- Stall torque: 9.4kg/cm (4.8v); 11kg/cm (6.0v)
- Operating speed: 0.19sec/60degree (4.8v); 0.15sec/60degree (6.0v)
- Operating voltage: 4.8~ 6.6v
- Gear Type: Metal gear
- Temperature range: 0- 55℃
- Dead band width: 1us
- Servo wire length: 32cm

3.3.3 Stepper motor

Stepper motor also called stepping motor because these motors rotate through the fixed angular step in response to each input current pulse received by the controller and it ideally suited for situations where either precise positioning or precise speed control or both are required in automation systems. The angle through which the motor shaft rotates for each command pulse is called step angle. There are three basic categories of stepper motor and they are variable reluctance, permanent magnet and hybrid stepper motor [12].

i. Application of stepper motor

The stepper motor used for many applications like operation control in computer peripherals ,textile industry, robotics and applications requiring incremental motion like typewriters, line printers, tape drives and floppy disk drives [12] .

ii. (28BYJ-48) Stepper motor

The (28BYJ-48) as shown in Figure 3.10 is a small, cheap, 5 volt geared stepping motors. These stepping motors are apparently widely used to control things like automated blinds, A/C units and are mass produced. Due to the gear reduction ratio of approximately (64:1), it offers decent torque for its size at speeds of about 15 rotations per minute (RPM). With some software “trickery” to accelerate gradually and a higher voltage power source (tested with 12 volts DC) it’s able to get about (+25 RPM). The low cost and small size makes the (28BYJ-48) an ideal option for small robotic applications and an excellent introduction to stepper motor control with Arduino.

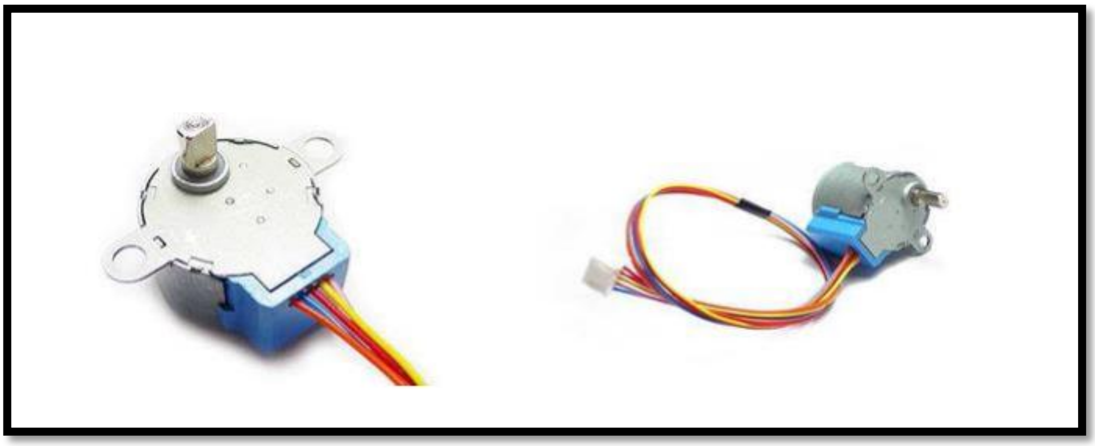


Figure 3.10: (28BYJ-48) Stepper motor

The specification of the stepper motor is shown in Table 3.1.

Table 3.1: Specifications of (28BYJ-48) stepper motor

Weight	30g
Motor Type	Unipolar stepper motor
Rated voltage	5VDC
Number of Phase	4
Speed Variation Ratio	1/64
Stride Angle	5.625° /64
Frequency	100Hz
DC resistance	50Ω±7%(25°C)
Idle In-traction Frequency	> 600Hz
Idle Out-traction Frequency	> 1000Hz
In-traction Torque	>34.3mN.m(120Hz)
Self-positioning Torque	>34.3mN.m
Friction torque	600-1200 gf.cm
Pull in torque	300 gf.cm
Insulated resistance	>10MΩ(500V)
Insulated electricity power	600VAC/1mA/1s
Insulation grade	A
Rise in Temperature	<40K(120Hz)
Noise	<35dB(120Hz,No load,10cm)
Model	28BYJ-48 – 5V

3.3.4 Power supply

A power supply is an electronic device that supplies electric energy to an electrical load. The primary function of a power supply is to convert one form of electrical energy to another and, as a result, power supplies are sometimes referred to as electric power converters. Some power supplies are discrete, stand-alone devices, whereas others are built into larger devices along with their loads. All power supplies have a power input, which receives energy from the energy source, and a power output that delivers energy to the load. Figure 3.11 shows some information about Advanced Technology eXtended ATX computer power supply which used as power supply for feeding the circuit. The ATX is the most common supply out there and is in use in most desktop computers today.

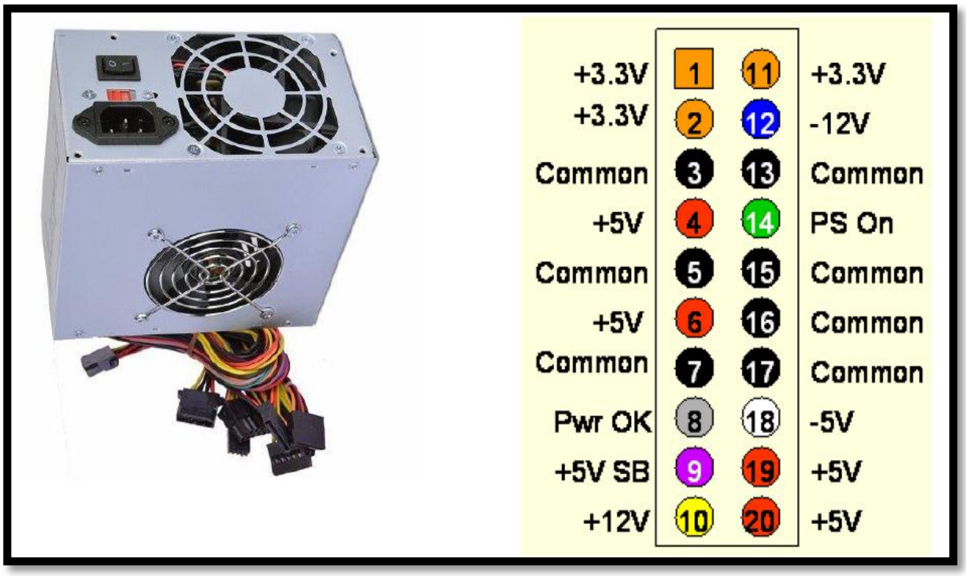


Figure 3.11: Power supply and wire color code

3.3.5 Ultrasonic sensor

Ultrasonic sensor (HC-SR04) as shown in Figure 3.12 is integrated with (MSP430). This sensor can be treated as one of the major components in the robot. This is used for sensing the obstacle, measuring the distance, giving input to the controller so that the controller can act accordingly and make other components integrated to it function accordingly.

What the sensor does it is calculating the distance from an object by sending bursts of ultrasound towards it and measuring the time it takes to the sound waves to get back:

(Distance = Velocity * Time) (3.7)

Figure 3.12: Ultrasonic sensor

3.3.6 Breadboard

These boards as shown in Figure 3.13 are used to easily create prototype circuits without having to solder. This is good in the event that you have not fully developed your soldering skills or want to quickly put together prototypes and test ideas without having to solder a new circuit each time.

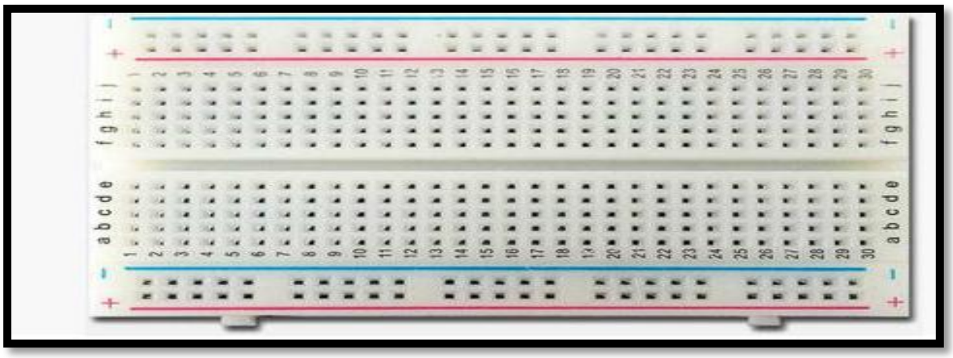


Figure 3.13: Breadboard

3.3.7 (ULN2003) Stepper motor driver

The driver convert the controller command signal into the power necessary to energize the motor winding or the phases in a timely sequence to make the motor turn. The (ULN2003) stepper motor driver board as shown in

Figure 3.14, allows easily controlling the (28BYJ-48) stepper motor from the arduino. One side of the board has a five wire socket where the cable from the stepper motor hooks up and 4 LEDs to indicate which coil is currently powered. The motor cable only goes in one way, which always helps. On the side you have a motor ON/OFF jumper (keep it ON to enable power to the stepper). The two Pins below the four resistors, is where you provide power to the stepper. Note that powering the stepper from (5V) rail of the arduino is not recommended. A separate (5-12V and 1 amp) power supply and battery pack should be used, as the motor may drain more current than the arduino can handle and could potentially damage it. In the middle of the board we have the (ULN2003) chip. At the bottom we have four control inputs that should be connected to four arduino digital pins.

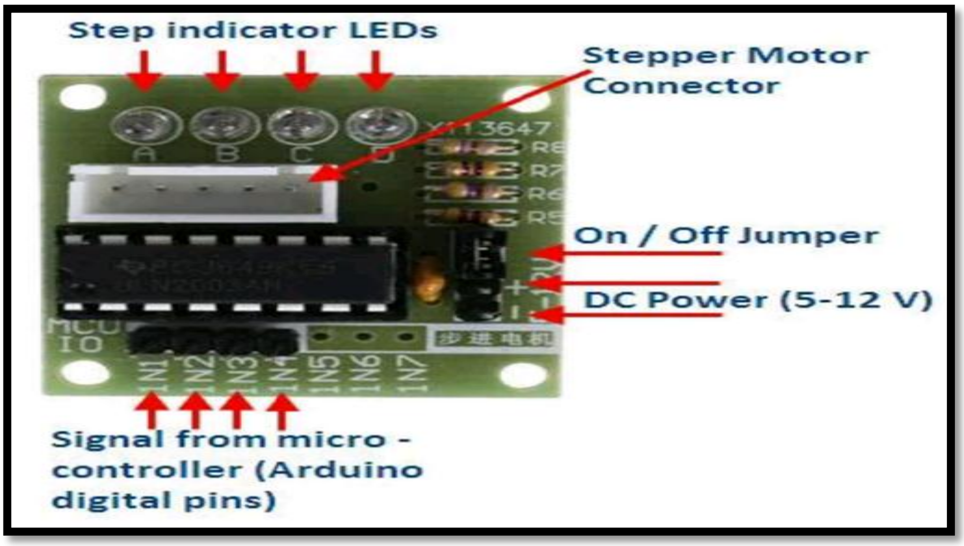


Figure 3.14: The (ULN2003) driver

3.3.8 AC Water pump

The AC water pump as shown in Figure 3.15, construct of single phase motor and turbine. The AC water pump was used for pumping the liquid from the paint bowl to the roller; here the valve was used for controlling of liquid flow.

Figure 3.15: AC water pump

3.3.9 Relay

The basic electromechanical components and its function of the Relay are:

i. **Frame :**

The frame of the relay is very light; it was used to cover, protect the relay and to support the relay.

ii. **coil wires:**

Were wounded around the relay coil to produce the magnetic field.

iii. **relay armature :**

It’s the movement part of the relay, the armature moves to open or close contact according to the input signal.

iv. **contacts:**

Contacts of the relay connecting or disconnecting the armature of the relay.
In fact relay consist of two circuits, first one for magnetizing the relay coil according to the input current flowing it called magnetizing circuit and also there is contact circuit which makes the armature moving. The relay operates depend on the magnetizing current flowing the magnetizing circuit to close or open the contacts, so when the armature in the close position NC, it will move to open the output circuit and if it in open position NO, it will close the output

circuit. The connection of the relay with the arduino through three single wires NO, NC and COM all of it on the high voltage side. The COM was connected to the line of the AC power supply and NO and NC was used to control of the output circuit on the low voltage side which connected with arduino as shown in Figure 3.16.

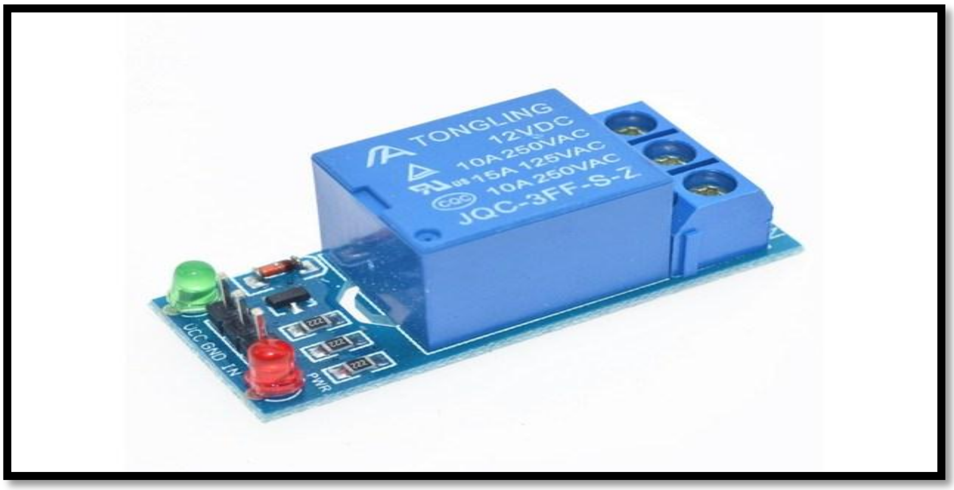


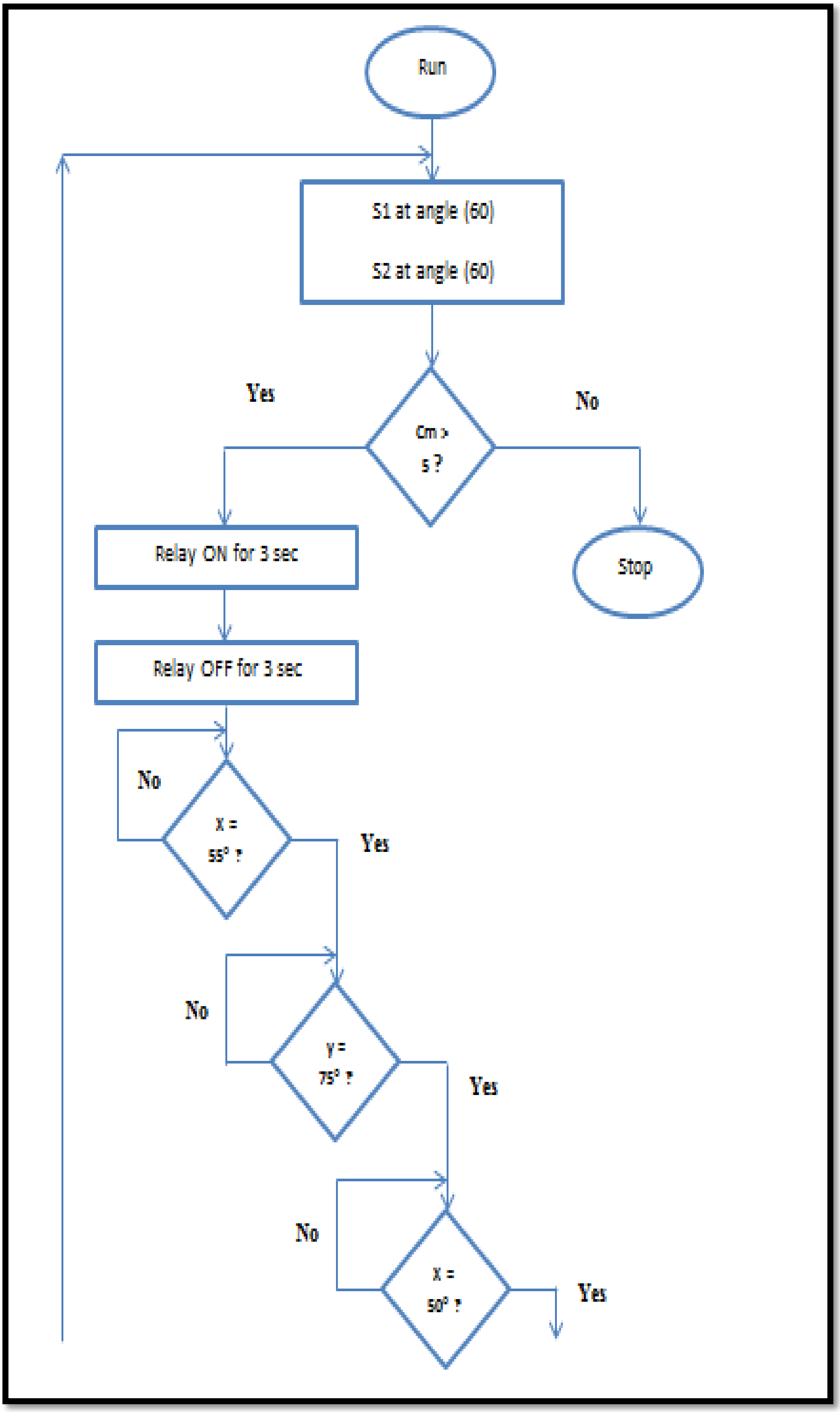
Figure 3.16: (5 VDC) Relay

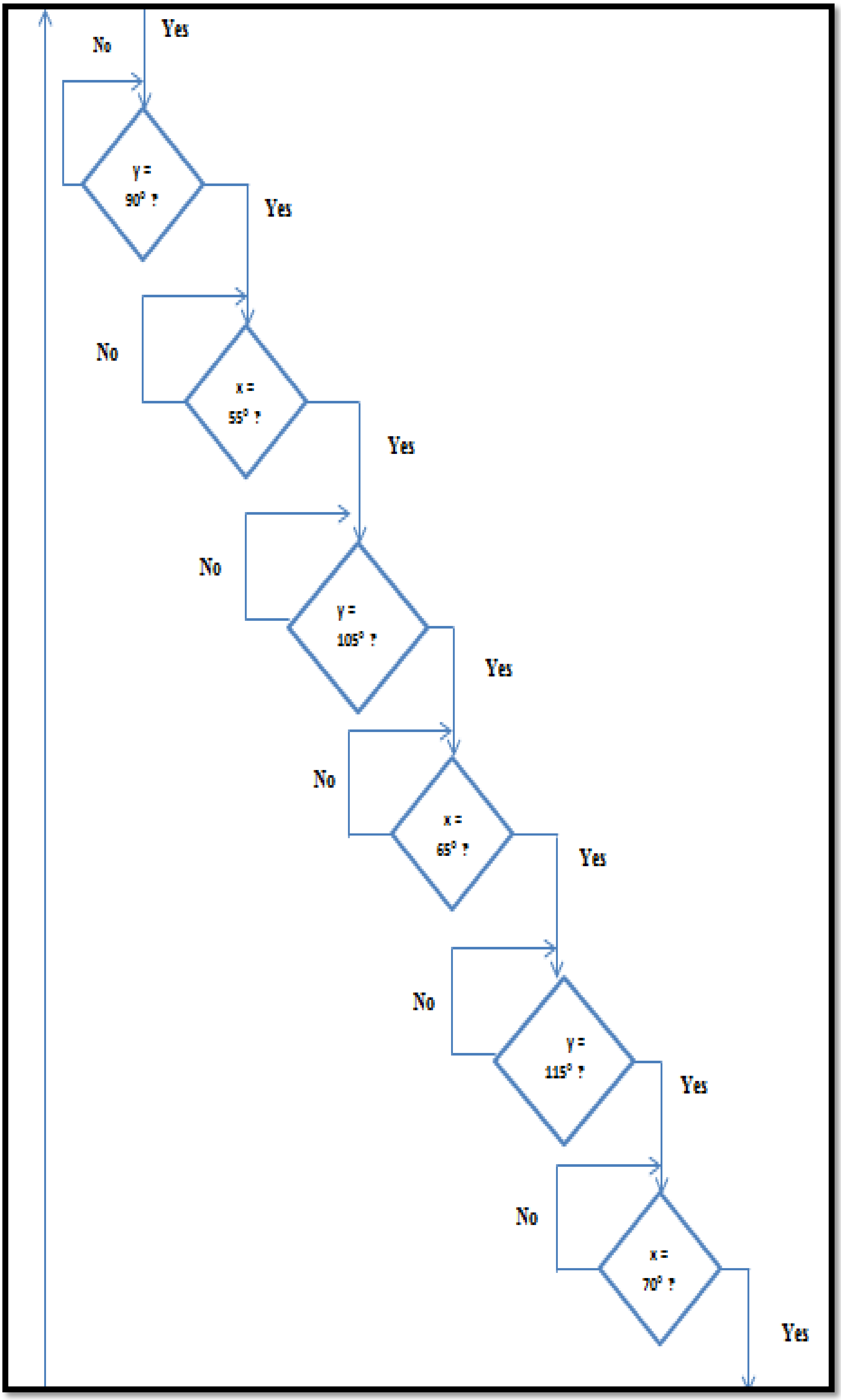
3.4 System Software

(Arduino.C) is the software used for programming the microcontroller of the Arduino. Servo motors and stepper motor are both controlled with the same principle PWM. Therefore, Servo library and stepper library were used. Servo and stepper function creates the objects to be controlled. Three objects were created since two dc servo motors and one stepper motor were used in this project.

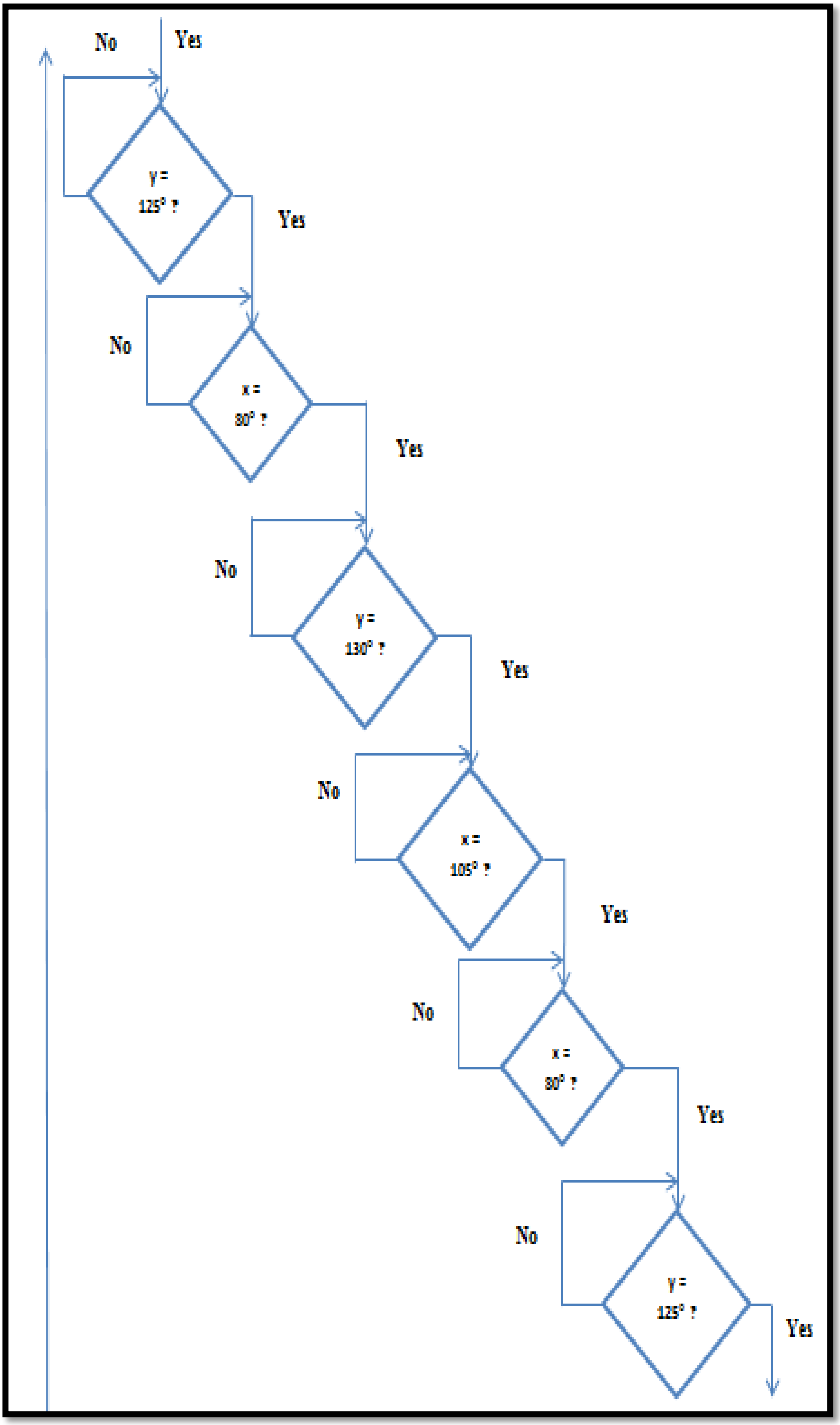
3.4.1 System flow chart

The system sequence of the operation is illustrated in flow chart of Figure 3.17.

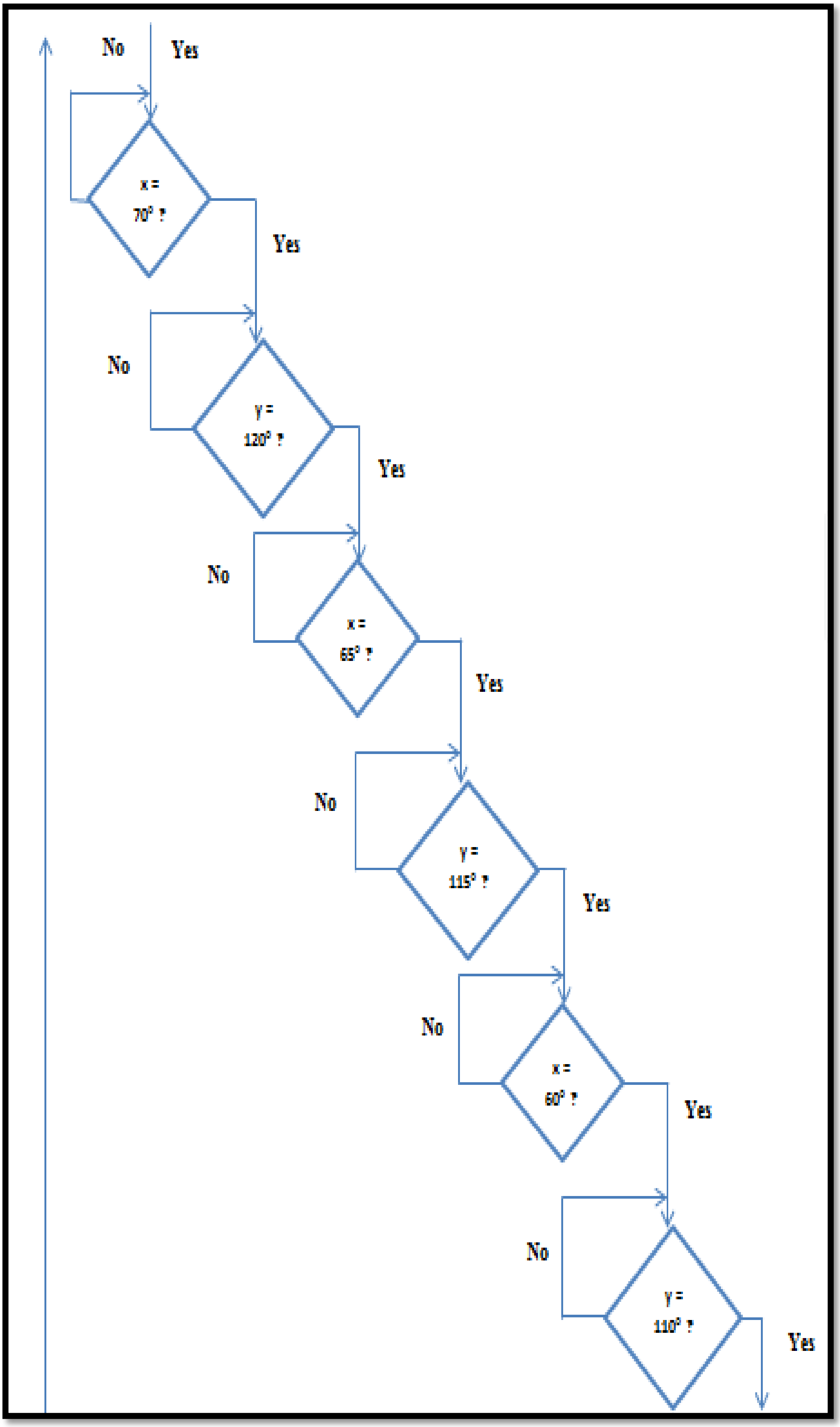

Run
S1 at angle (60)
S2 at angle (60)
Yes
No
Cm >
5 ?
Relay ON for 3 sec
Stop
Relay OFF for 3 sec
No
X =
55° ?
Yes
No
Y =
75° ?
Yes
No
X =
50° ?
Yes



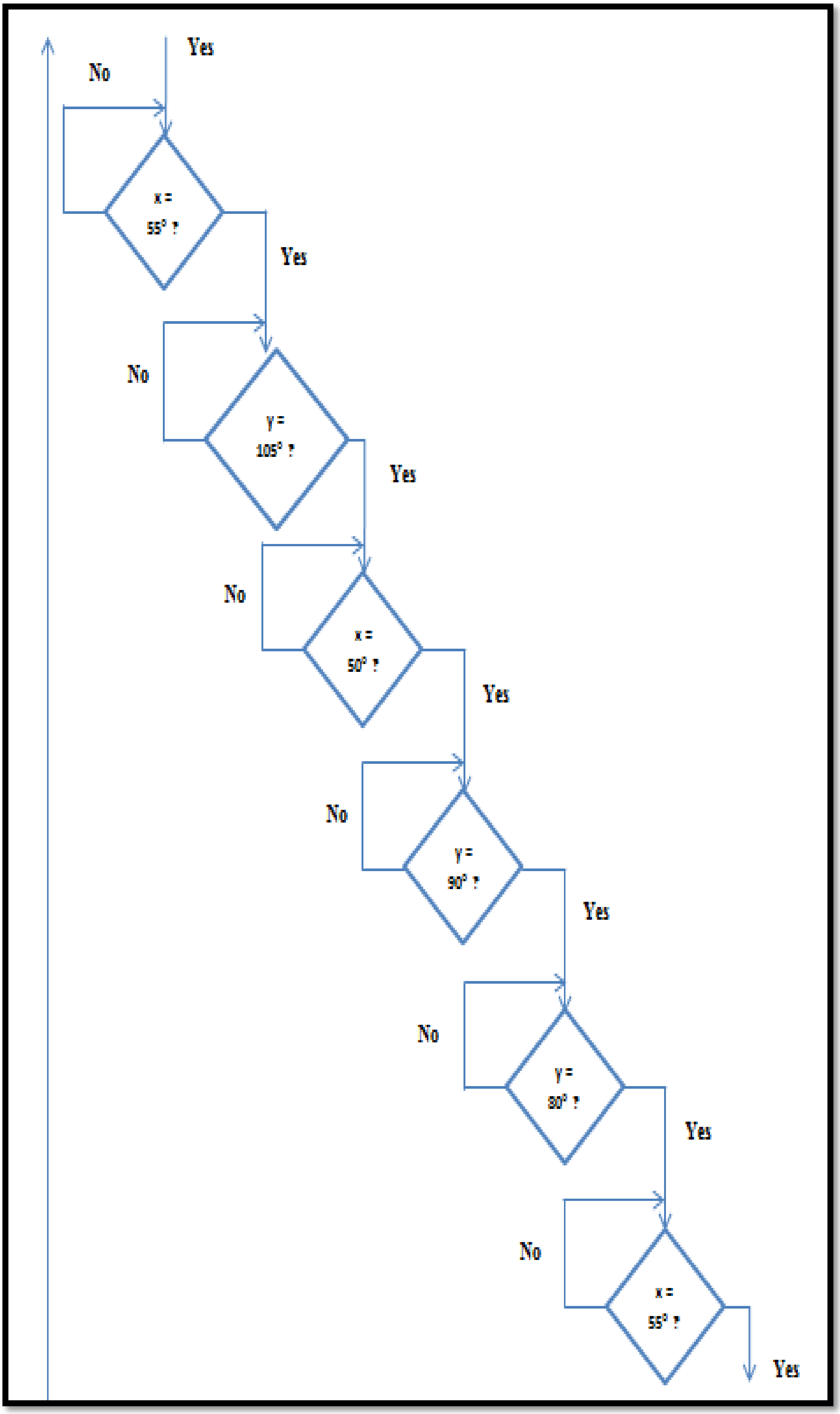
Yes
No
y = 90° ?
Yes
No
x = 55° ?
Yes
No
y = 105° ?
Yes
No
x = 65° ?
Yes
No
y = 115° ?
Yes
No
x = 70° ?
Yes



No
Yes
y = 125° ?
Yes
No
x = 80° ?
Yes
No
y = 130° ?
Yes
No
x = 105° ?
Yes
No
x = 80° ?
Yes
No
y = 125° ?
Yes



No
Yes
x = 70° ?
Yes
No
y = 120° ?
Yes
No
x = 65° ?
Yes
No
y = 115° ?
Yes
No
x = 60° ?
Yes
No
y = 110° ?
Yes


Yes
No
x = 55° ?
Yes
No
y = 105° ?
Yes
No
x = 50° ?
Yes
No
y = 90° ?
Yes
No
y = 80° ?
Yes
No
x = 55° ?
Yes

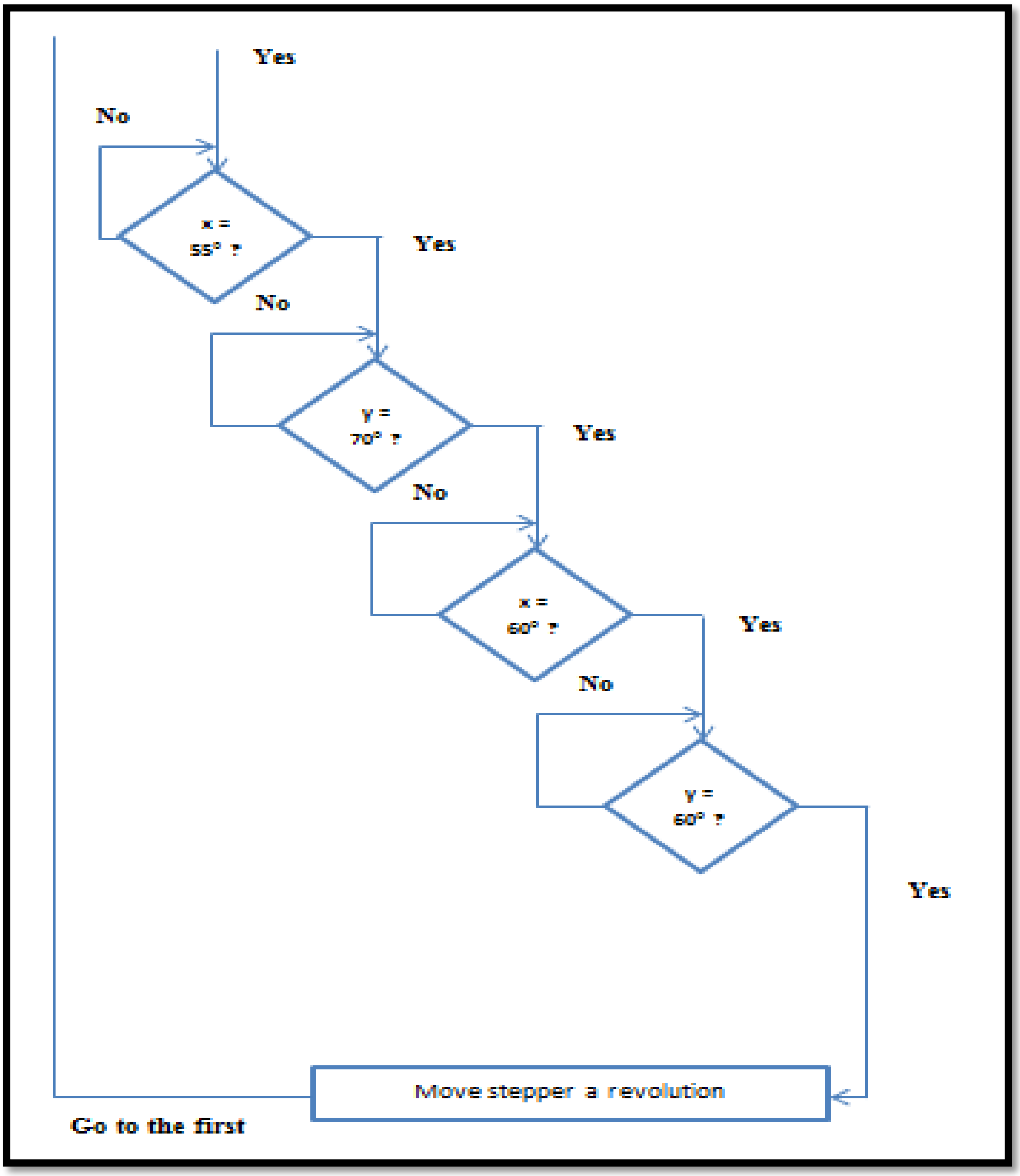


Figure 3.17: System flow chart

Where:

Cm: Distance from the side wall.

x: Position of the lower servo.

y: Position of the upper servo.

CHAPTER FOUR

SYSTEM IMPLEMENTATION AND RESULTS

4.1 System Implementation

Wall painting robot is consist of a stepper motor with its driver, two DC servo motors, AC water pump, ultrasonic and relay which were collected together and installed as described steps below:

4.1.1 Mechanical design

The mechanical design of the WPR system is designed as shown in Figure 4.1.

Figure 4.1: Mechanical design of the WPR

According to the design which made as shown in Figure 4.1, the following steps had been done to get the best design of the WPR.

- The two wooden arms of the WPR were designed to be with length (29 Cm) and (23 Cm) for the long arm and short arm respectively as shown in Figure 4.2.

Figure 4.2: Two wooden arms

- The lower end of the long arm was connected with the first DC servo motor and the upper end of it was connected with the second DC servo motor which was connected with the lower end of the other arm and the upper end of this arm was connected with a painting roller as shown in Figure 4.3 .

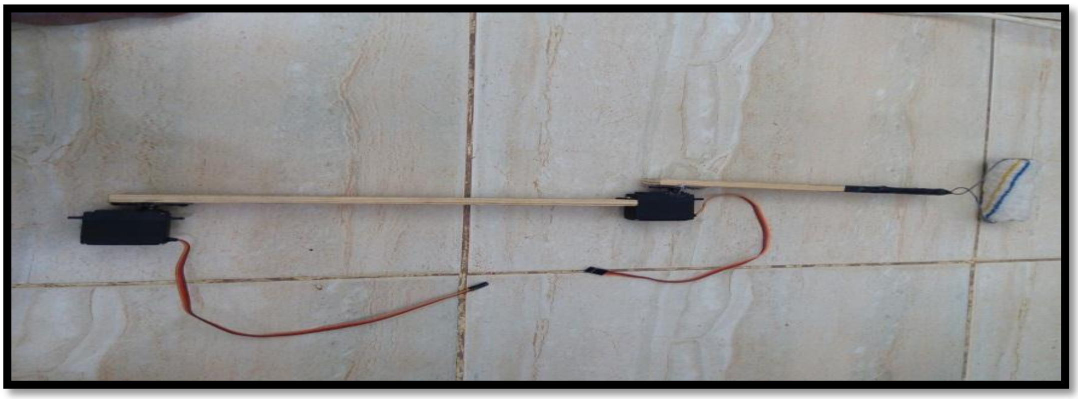


Figure 4.3: Arm system

- The internal motor of the movable chassis was exchanged with DC stepper motor to make the motion of it in form of stepping motion as shown in Figure 4.4.

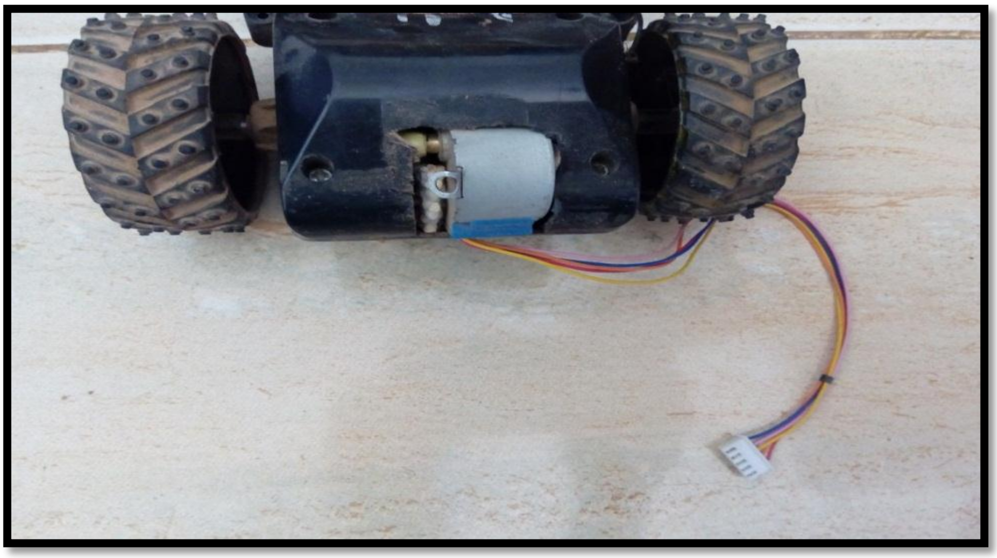


Figure 4.4: Stepper motor attached with movable chassis

- The arm system as shown in Figure 4.3 was attached with the wooden board which was glued on the top of the movable chassis as shown in Figure 4.5.

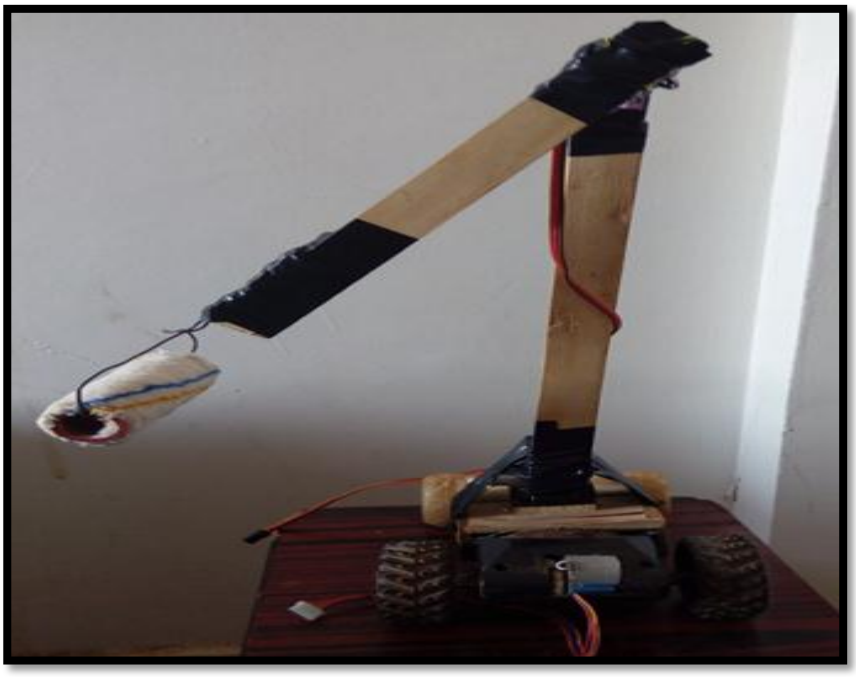


Figure 4.5: Arm system with the movable chassis

- The paint was pumped by a nozzle to the painting roller by using AC water pump as shown in Figure 4.6

Figure 4.6: pump with nozzle

- The wooden surface had been chosen to be with length 60 Cm and width of 50 Cm. Also the wooden wall that attached to the wooden surface had been chosen to be with height 57 Cm and width of 50 Cm as shown in Figure 4.7.

Figure 4.7: Wooden wall

4.1.2 System control circuit implementation

Each of two DC servo motors consist of three interfaces wires (red, black and yellow). The red wires were connected to the positive section of the breadboard and the black wires were connected to the negative section of the breadboard. For the lower servo, the yellow wire was connected to (Pin 5) of the Arduino. Also for the upper servo, the yellow wire was connected to (Pin 6) of the Arduino as shown in Figure 4.8.

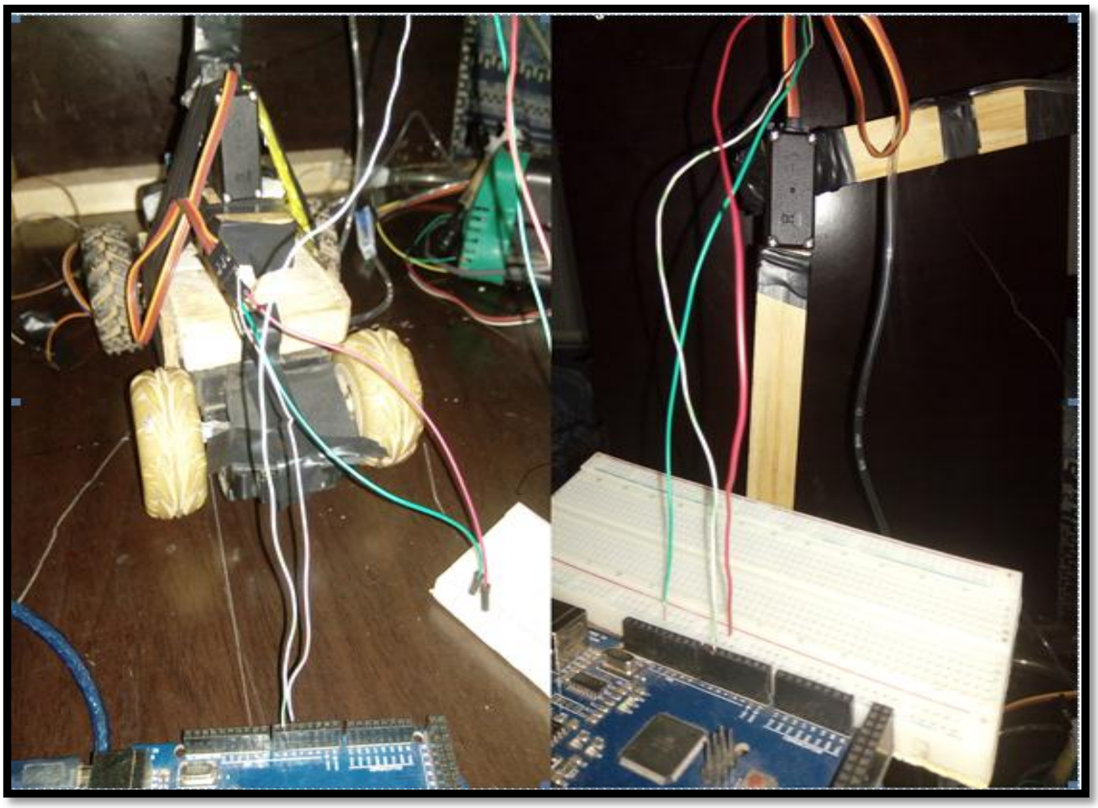


Figure 4.8: Connection of two DC servo motors with Arduino

The relay consists of two parts, the first part stand with high power (220 VAC) and the second part stand with low power (5 VDC). The first part has three interfaces (common, normal close and normal open). The common was connected to (220 VAC) source and the normal open NO was connected to the red wire of the water pump. The second part has three interfaces (Vcc, GND and IN). The Vcc was connected to the positive section of the breadboard, the GND was connected to the negative section of the breadboard and the IN was connected to (Pin 7) of the arduino. Also the blue wire of the water pump was connected to the neutral of the (220 VAC) source and the red wire of it were connected to the NO of the relay as shown in Figure 4.9.

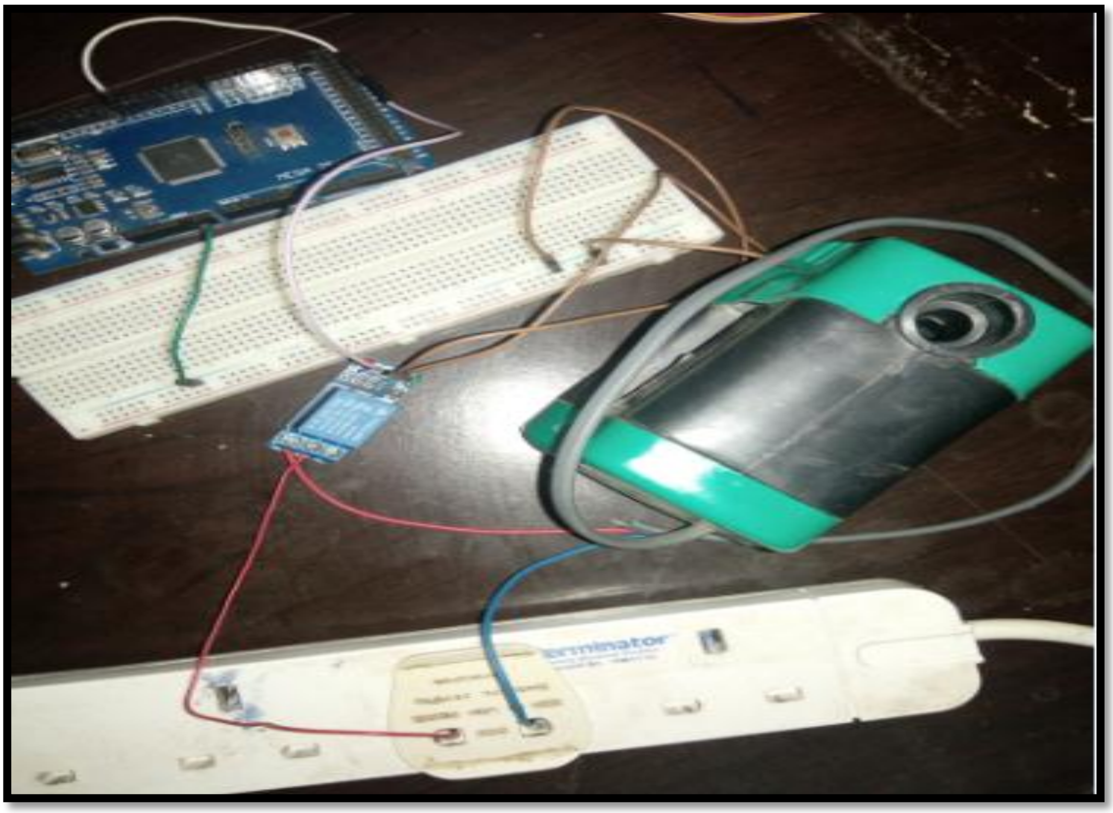


Figure 4.9: Connection of the relay and pump with the Arduino

The ultrasonic sensor on the movable chassis has four Pins (Vcc, GND, trigger and echo). The Vcc and GND were connected to the positive and negative section of the breadboard respectively, the trigger Pin was connected with (Pin 3) of the Arduino and the echo Pin was connected with (Pin 2) of the Arduino as shown in Figure 4.10.

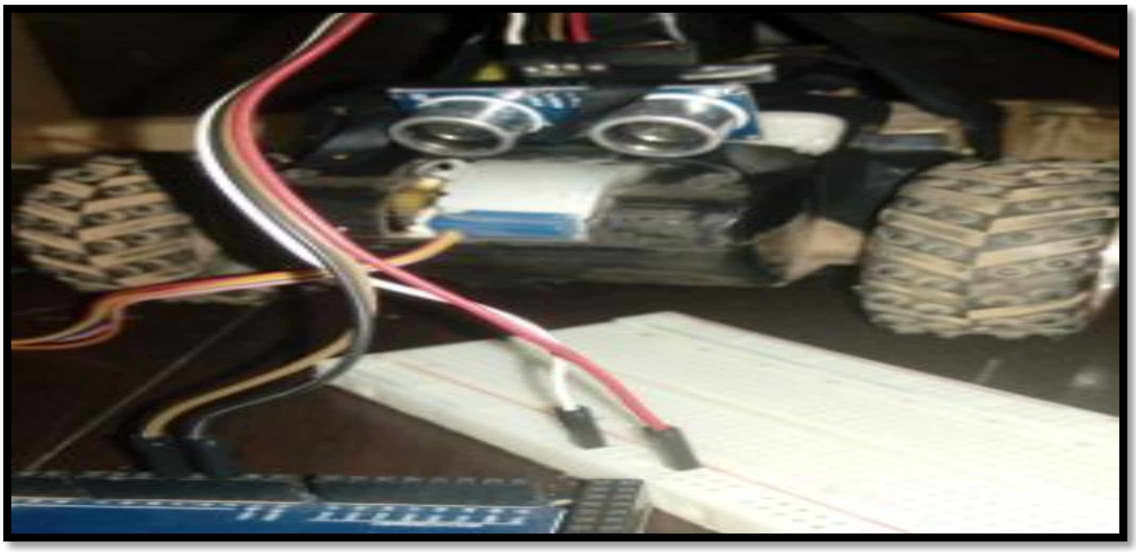


Figure 4.10: Connection of the ultrasonic sensor with the Arduino

The stepper motor was connected with its driver which controls of it. This driver has six Pins, four Pins were connected to (Pin 8,9,10 and 11) of the Arduino and the others were connected to the positive and negative section of the breadboard as shown in Figure 4.11.

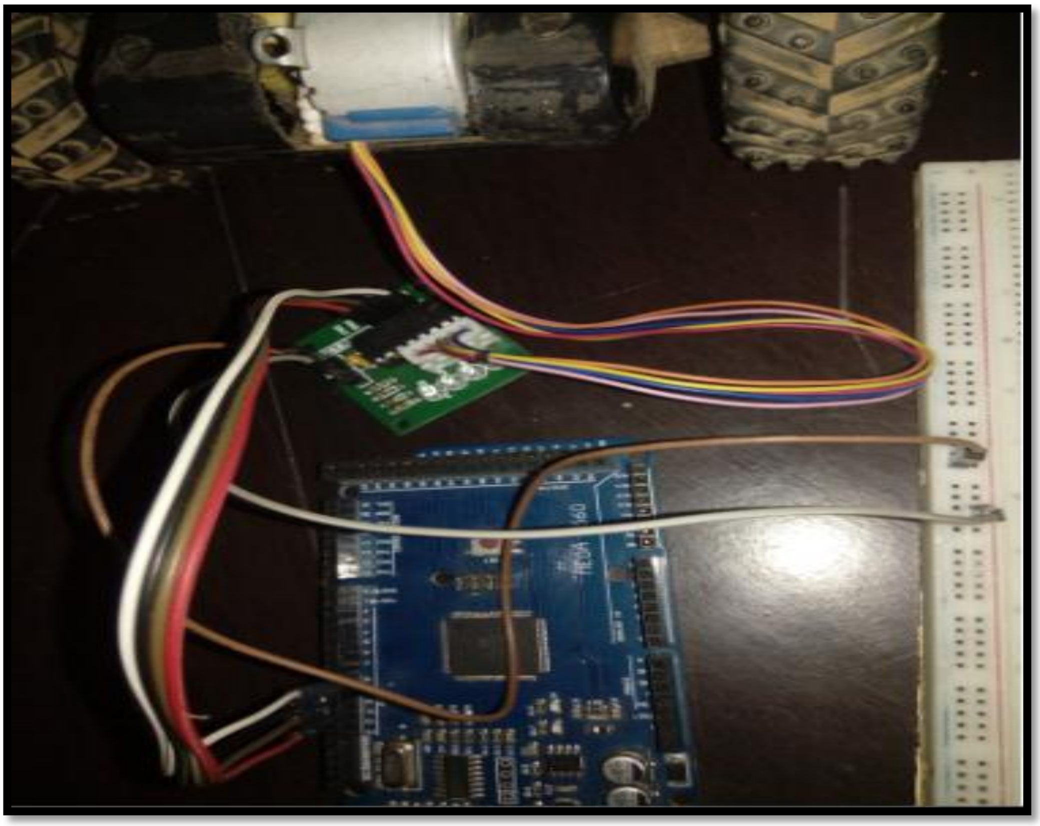


Figure 4.11: Connection of the stepper motor with the Arduino

The DC power supply was supplied from a (220 VAC) source to give a (5 VDC) to supply the all wires of the electrical part of the system which connected to the breadboard. So the overall control circuit of the system is shown in Figure 4.12.

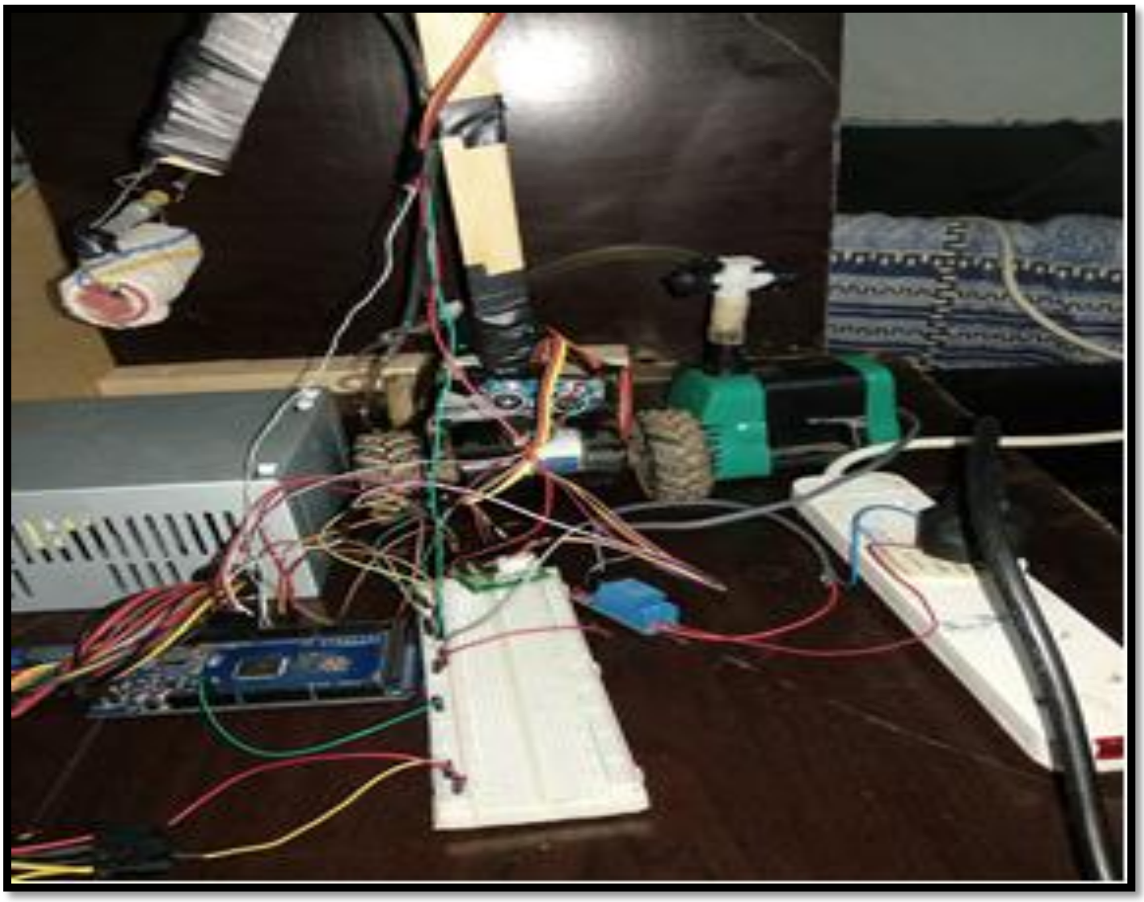


Figure 4.12: System control circuit

4.2 Discussion

- The WPR was used for painting wall at the desired distance. The accuracy depended on strength of coupled mechanical part of the robot (arm system).
- The quantity of the paint material was determined by the cross section area of nozzle which pumps the liquid and the torque of the pump depended on the power rated of the pump.
- The rated torques of the motors was affected by the length and weight of the arm system.
- The quantity of the paint material and the flow rate of the paint to the roller were effected the rated torque of the motors.

- The movement of the movable chassis depends on the roller length, so when the roller was short that increases the rate of motion and also if the roller was long the rate of motion will decrease.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The main aims of this project are to design a WPR and controlling of it by using Arduino controller. The project is chosen due to difficulties for manual labors in the job of painting such as higher cost and low accuracy of work. To solve this problem WPR was created. This robot is simple and portable. They have a very small weight to power output ratio and predictable performance i.e. losses are minimum due to less number of moving parts and so gives expected performance. Due to elegant and simple control systems it can control noise vibration and does silent operation and no vibration is produced. It has longer life, flexibility and it is efficient and dependable, and the installation is simple and the maintenance is also easy.

5.2 Recommendations

During this project, some problems appeared. Most of them were solved, but not all of them. Therefore the project has a lot of space for further improvements

- Use a hydraulic pump to get higher torque.
- Increase the toque and the length of servo arm system to get maximum length of the wall can be painted.
- The width of the roller should be equal to the movable chassis to paint all area of the wall widely.
- Use full direction movable chassis and more sensors to paint in four directions.

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Appendix

Arduino microcontroller code for the wall painting robot

```
#include <Servo.h>

#include  <NewPing.h>

#include <Stepper.h>

Const int servo1 = 5;

Const int servo2 = 6;

Const int Relay1 =7;

Const int stepsPerRevolution = 300;

Const int triggerpin=3;

Const int echopin=2;

Stepper myStepper(stepsPerRevolution, 8, 9, 10, 11);

Servo myServo1;

Servo myServo2;

NewPing sonar(triggerpin, echopin, 100);

int stroke = 0;

void setup() {

  // put your setup code here, to run once:

myServo1.attach(servo1);

myServo2.attach(servo2);
```

```
pinMode(Relay1,OUTPUT);
myStepper.setSpeed(60);
myServo1.write(60);
myServo2.write(60);
Serial.begin(9600);
}
void loop() {
  // put your main code here, to run repeatedly:
int cm=sonar.ping_cm();
Serial.println(cm);
delay(250);
while (cm>5)
{
digitalWrite(Relay1,LOW);
delay(3000);
digitalWrite(Relay1,HIGH);
delay(3000);
myServo1.write(60);
delay(500);
myServo2.write(60);
delay(500);
```

```
  for(int i = 60;i>=55;i--){
   myServo1.write(i);
   delay(50);}
for(int i = 60;i <= 75;i++){
   myServo2.write(i);
   delay(50);}
for(int i=55;i<=50;i--){
myServo1.write(i);
delay(50);}
for(int i = 75;i <= 90;i++){
   myServo2.write(i);
   delay(50);}
for(int i = 50;i <= 55;i++){
   myServo1.write(i);
   delay(50);}
for(int i = 90;i <= 105;i++){
   myServo2.write(i);
   delay(50);
}
for(int i = 55;i <= 65;i++){
   myServo1.write(i);
```

```
    delay(50);}
for(int i = 105;i <= 115;i++){
    myServo2.write(i);
    delay(50);
}
for(int i = 65;i <= 70;i++){
    myServo1.write(i);
    delay(50);}
for(int i = 115;i <= 125;i++){
    myServo2.write(i);
    delay(50);
}
for(int i = 70;i <= 80;i++){
    myServo1.write(i);
    delay(50);}
for(int i = 125;i <= 130;i++){
    myServo2.write(i);
    delay(50);
}
for(int i = 80;i <= 105;i++){
    myServo1.write(i);
```

```
  delay(50);}
  for(int i = 105;i>=80;i--){
  myServo1.write(i);
  delay(50);}
 for(int i = 130;i>=125;i--){
  myServo2.write(i);
  delay(50);}
for(int i = 80;i>=70;i--){
  myServo1.write(i);
  delay(50);}
 for(int i = 125;i>=120;i--){
  myServo2.write(i);
  delay(50);}
for(int i = 70;i>=65;i--){
  myServo1.write(i);
  delay(50);}
 for(int i = 120;i>=115;i--){
  myServo2.write(i);
  delay(50);}
   for(int i = 65;i>=60;i--){
  myServo1.write(i);
```

```
  delay(50);}
for(int i = 115;i>=110;i--){
  myServo2.write(i);
  delay(50);}
   for(int i = 60;i>=55;i--){
  myServo1.write(i);
  delay(50);}
for(int i = 110;i>=105;i--){
  myServo2.write(i);
  delay(50);}
   for(int i = 55;i>=50;i--){
  myServo1.write(i);
  delay(50);}
for(int i = 105;i>=90;i--){
  myServo2.write(i);
  delay(50);}
for(int i = 90;i>=80;i--){
  myServo2.write(i);
  delay(50);}
   for(int i = 50;i<=55;i++){
  myServo1.write(i);
```

```
    delay(50);}
    for(int i = 80;i>=70;i--){
    myServo2.write(i);
    delay(50);}
    for(int i = 55;i<=60;i++){
    myServo1.write(i);
    delay(50);}
    for(int i = 70;i>=60;i--){
    myServo2.write(i);
    delay(50);}
for (stroke=0;stroke<=3;stroke++) {
Serial.println("clockwise");
myStepper.step(stepsPerRevolution);
  delay(500);
}
   break;
}
}
```