

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ



PALESTINE POLYTECHNIC UNIVERSITY

College of Engineering & Technology

Department of Electrical

Automatic wall painting machine

Submitted to the College of Engineering

In partial fulfillment of the requirements for the

Bachelor degree in industrial automation Engineering

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Dec 2019

إهداء

إلى المعلم الاول ... الحبيب المصطفى صلى الله عليه وسلم ... إلى القلب
الحنون التي كانت بجانبى بكل المراحل التي مضت ... من تلذذت بالمعاناة
وكانت شمعة تحترق لتنير دربي ... إلى أمهاتنا الحبيبات.. إلى من علمني أن
اقف وكيف ابدأ الالف ميل بخطوة .. إلى يدي اليمنى .. إلى من علمني
الصعود وعيناه ترقباني ... إلى آبائنا الأجلاء .. إلى من رووني من ينابيع
الفضيلة .. إلى الذين أخذو بيدي إلى منهل المعرفة وأظلونني بشجرة الإيمان
... إلى أهلنا الأعزاء.. إلى من أمسك بيدي وعلمي حرفا .. إلى من كانوا
سندا لي ..

الى من لهم الفضل بإرشادي إلى طريق العلم والمعرفة ..

إلى الدكتور الفاضل نسيم اقطيط.

إلى كل محبي المعرفة.

إلى من ضاقت السطور عن ذكرهم فوسعهم قلبي ... إلى أصدقائنا الأوفياء

.

إلى من ضحوا بحرياتهم من أجل حرية غيرهم ... إلى أسرانا البواسل.

إلى من هم أكرم منا ... إلى شهدائنا الأبرار.

ولن أنسى هذا المكان الذي جمعني بمقاعده وأبوابه حتى فنائه .. إلى كل

جزء .. إلى جامعة بوليتكنك فلسطين. إلى من احتضنتني طوال هذه

الأعوام ... إلى فلسطين الحبيبة ..

نهدي علمنا هذا ..

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Abstract:

Automatic wall painting machine:

The primary aim of the project is to design, develop and implement automatic Wall Painting Machine which helps to achieve low cost painting equipment and safety. The advantages of using this machine are for saving in man power, raw material and cycle time. The painting wall machine will help to save labor cost up to 85%, increase productivity by 2-5 times, get professional quality finishing in less time and reduce project cost.

Keyword: wall painting machine, transferring, quality, automated.

الملخص:

آلة الطلاء الذاتي للجدران:

ان الهدف الرئيسي من المشروع هو تصميم وتطوير وانشاء اله الطلاء الذاتي للجدران و التي تساعد في تحقيق عمل الطلاء بأقل التكاليف واكثر أمنأ وسلاماً، ومن ميزات هذه الآلة أنها تقلل من الأيدي البشرية العاملة كما وانها تقوم بحفظ الوقت والجهد، وتساعد ايضا في تخفيض التكاليف التشغيلية بنسبه ٨٥% وتزيد من الإنتاجية حتى ٢-٥ اضعاف، كما ان كفاءتها الإنتاجية عالية .

1

Chapter 1: Introduction

1.1. Introduction

1.2. Objective of project

1.3. Methodology

1.4. LITERATURE REVIEW

Chapter 1: Introduction

1.1 Introduction:

Building and construction is one of the major basics of life around the world. In this fast-moving life construction industry is also growing rapidly. But the works in the construction industry are not sufficient. This is because of the difficulty in the work.

The construction process needs a lot of workers, and many of these actions are dangerous to these people, so there is a need to find machines that help them to accomplish these works more safely. Attempts began to build machines capable of compensating the human being in the early 1990s, with the aim of improving performance and completing work in a short time and at a lower cost.

The internal finishing's of buildings and constructions are many and multiple. One of the most important things is the painting process.

Painting can be defined as the final layer covered the walls and for this purpose have several goals we mentioned:

- 1 - Cosmetic process and aesthetic character and decorative walls
- 2- The paint is used for insulation process for moisture
- 3 - Facilitate the cleaning of buildings and walls of dust and dirt.

- **Types of paint:**

1. **Policed:** It is usually used indoors and is not suitable for outside due to its low resistance to weather conditions.
2. **Super Krill:** Used indoor and outdoor and is used for ceilings and walls the same degree.

- **Traditional painting :** This process needs a group of workers who use the roller and brush for paint work disadvantages:

- a) The traditional process is very expensive.
- b) Long time need: The work needs more time to produce the work well.
- c) May result in this process paint is not homogeneous: may be a defect in the roller or that the worker is not qualified for this process.

- d) Is somewhat clean: lead paint from the walls or falling from the roller and brush to dirt floors and furniture located in the work area.
- e) Unhealthy where inhalation of odors resulting from the substance of paint causes damage to the human and therefore, they are exhausted and very tired especially at the hands of the worker.



FIGURE 1.1 PAINTING WORK

Wall painting is a repetitive, exhausting and hazardous process which makes it an ideal case for automation. There are different ways for painting such arm and brush painting. In this project we are going to design an automatic as well as manually working wall painting machine which is consisting of a flat spray gun that scans the walls vertically and is fitted on a mobile machine base to give the feed motion to cover the painting area.

Above all these the interior wall painting machine are able to perform repetitive tasks more quickly, cheaply and accurately than humans. So, we have designed this machine for painting application. Because of this task becomes simpler and there is no possibility of any mistakes due to the fact that the society needs it to relax humans from tedious and dangerous jobs.

The primary aim of the project is to design, develop and implement automatic Wall Painting Machine which helps to achieve low cost painting equipment and safety. This machine is used for

transferring paint by conveyor belt to the board that make the surface finish good and same color. The advantages of using this machine are for saving in man power, raw material and cycle time. Additionally, Painting is widely used as a finishing technology for both interior and exterior walls made from bricks. The painting wall machine will help to save labor cost up to 85%, increase productivity by 3-5 times, get professional quality finishing in less time, reduce project cost, manufacture painting wall machine in low cos.

We control the forward and backward motion of the machine by using DC motor. A plastic box contains color which placed on the machine body. A compressor is use to pump paint. A screw mechanism is use to move to cover the displacement, by screw mechanism we move gun of color spray at upside and down side, IR sensor is used to stop the spraying process if anything is approached to the flat gun, flat gun is used to spray the paint. Last but not least all of the above are controlled by Arduino.

We will design the machine to operate in two different mode. The first one is the traditional or manual and the other is the automatic. Traditional control systems are pre-designed of overload switches and cutters and sensors through static graphics.

This system multiplies its parts in a way that leads to difficulty in tracking the defect in addition to the lack of time to remember any defect. But it is easy for the owner of this system to add any modification without returning to the master designer.

The traditional system is designed for calibrations, maintenance and some applications that can be done manually.

Automatic system is designed primarily from a processing unit that contains many switches that are interconnected by logical operations.

The processing unit comes with input from mechanical devices: thermal, motion, moisture, etc., or electrical appliances such as circuits or circuit breakers. It processes them through logical equations and outputs them in the form of "do or do not work" electrical commands. This system can get a chronological history of its events. It also reduces the number of devices in the circuit, but if you want to modify the logical processors, it must go back to the factory to be reprogrammed.

1.2. Objective of project

The actual targets of this research were set as follows:

1. Design and implementation of a control system for the automatic wall painting machine.
2. Make machine structure simple to enable easy mounting as well as for safety.
3. Perform painting in a multi colors.
4. To Avoid Hazard Effect of Paint on Human Body.
5. Design a prototype for machine.
6. Introducing industrial automation to the building and construction.

1.3. Methodology

- Start
- Study of all preview related works.
- Find the definition of project
- Selecting a suitable control.
- Survey of field construction & gather information
- Design of components
- Testing & Modification

1.4 LITERATURE REVIEW:

DESIGN AND FABRICATION OF WALL PAINTING ROBOT (March 2015):
In [1] the researchers have made a robot which comprises of a set of heavy load capacity wheels moving along a railing and a pulley mechanism. Their design involves using a spray gun painting mechanism that moves vertically with the help of a lead screw from a platform mounted on a horizontal railing. The method proposed here applies only for buildings with flat wall surf.



FIGURE 1.2 : WALL PAINTING ROBOT

Development of Roller-Based Interior Wall Painting Robot (2011): In [2] the authors have described the development of robot for painting the interior walls of buildings. The robot consists of a painting arm with an end effector roller. It is obvious that there is a large error in arm that is beyond allowable, wasting the time and so dirty.

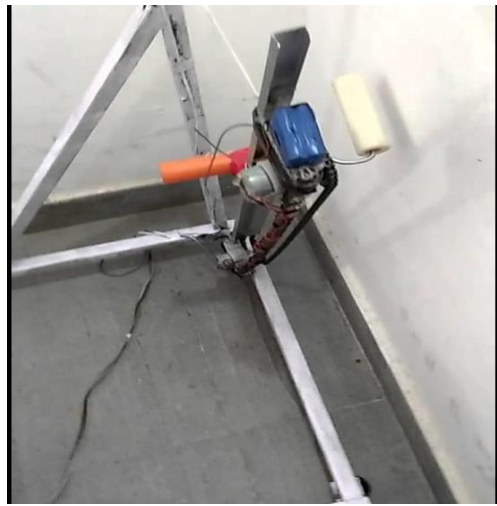


FIGURE 1.3 : ROLLER-BASED INTERIOR WALL PAINTING ROBOT

Automatic Wall Painting Robot (2013): In this paper [3] the students aim to design Automatic Wall Painting Robot which helps to achieve low cost painting equipment. Automatically paint the wall of given dimension has been designed and implemented.



FIGURE 1.4 : AUTOMATIC WALL PAINTING ROBOT (2013)

2

Chapter 2: Conceptual Design

2.1. Project procedure.

2.2. Mechanical Components

Chapter 2: Conceptual Design

In this chapter we will suggest a mechanical design of the project, this design will match the following procedures:

2.1. Project procedure.

1. In the beginning, the area of the work is specified and the starting point and end are defined by the encoder.
2. The paint tank shall be equipped with the appropriate color to be used for painting the walls.
3. limit switch must be pressed so that the machine returns to the initial and pre-set point to start the painting process
4. The process takes place during the control cycle, where the process is done as follows:
 - a) Painting process starts when the gun turned on during first work path.
 - b) The machine starts moving right until reach right limit switch, after that it will move in the reverse direction until reach left limit switch.
 - c) Then the actuator goes down one step.
 - d) The previous two steps are repeated until the selected workspace is finished.
5. SENSOR is used to mark the walls of others so as to avoid coating the furniture, glass or spray empty places.

To match the procedures, the conceptual design shown in Figure2.1.a, and the mechanical design shown in Figure2.1. b

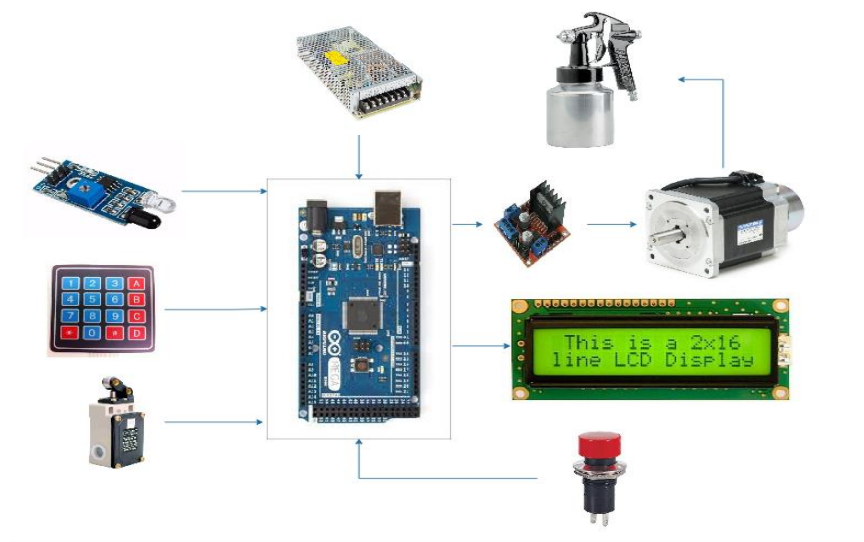


FIGURE2.1.A: CONCEPTUAL DESIGN

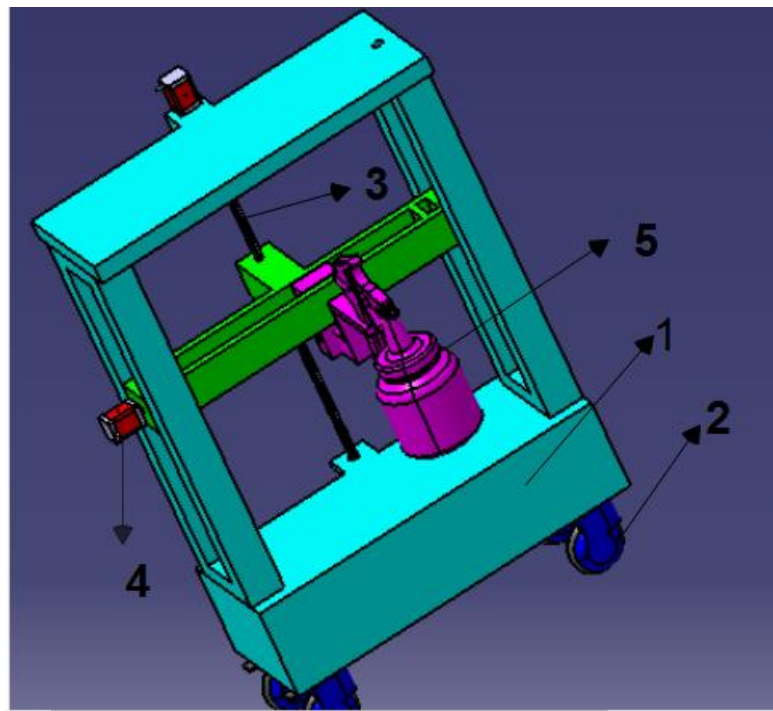


FIGURE2.1.B: MECHANICAL DESIGN

The construction of the automatic wall painting machine consists of two main parts. They are:

A. Mobile platform

1. Frame stand
2. Wheels
3. Lead screw rod.
4. DC motor
5. Battery

B. Control unit

1. Spray gun mount
2. Sensor
3. Flow control
4. Pressure control valve.
5. Spry gun valve

2.2 Mechanical Components

This design contains the following parts as appears in Figure2.1.b

2.2.1) Frame:

Material: aluminum

The frame stand is the steel welded in such a way that it can carry the whole equipment. The steels are welded strongly in welding to carry the entire machine equipment with the control unit, battery and DC motor, the IR sensor, solenoid valve and spray gun.

Frame design:

❖ Note: The overall design was done using Catia VR5.

a) Base design:

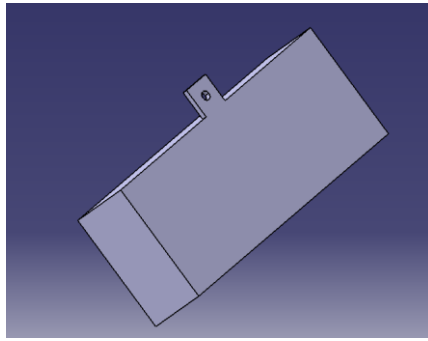


FIGURE2.2.A BASE DESIGN

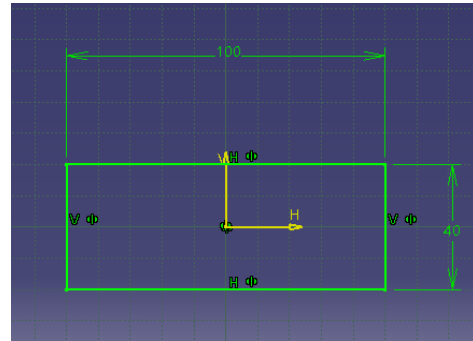


FIGURE2.2.B: BASE SKETCH

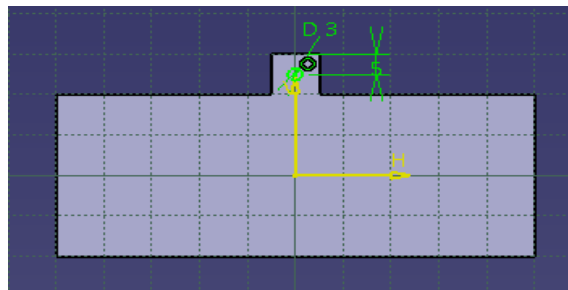


FIGURE2.2.C: BASE HOLE

b) Sides design:

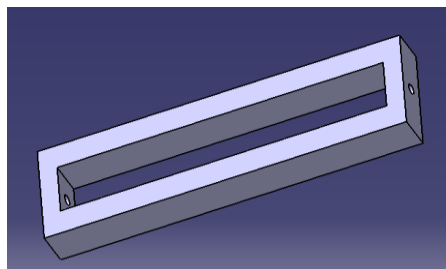


FIGURE2.3.A:SIDES DESIGN

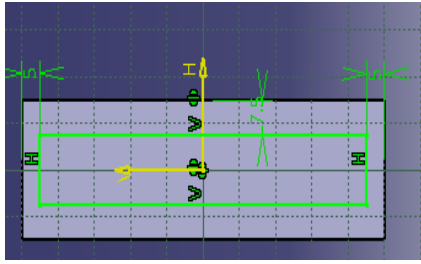


FIGURE2.3.C INNER SKETCH

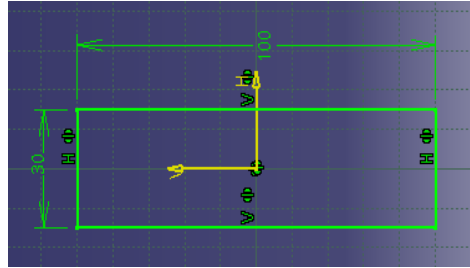


FIGURE2.3.B: SIDES SKETCH

c) Top design:

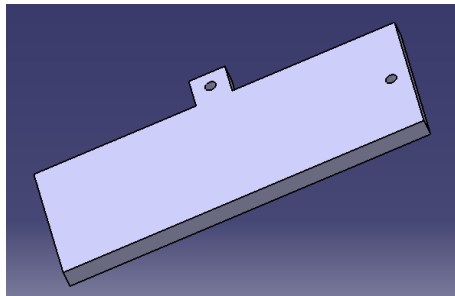


FIGURE2.4.A: TOP DESIGN

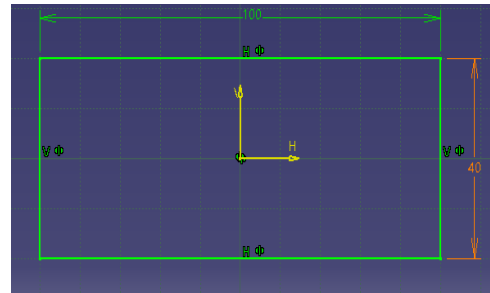


FIGURE2.4.B: TOP SKETCH

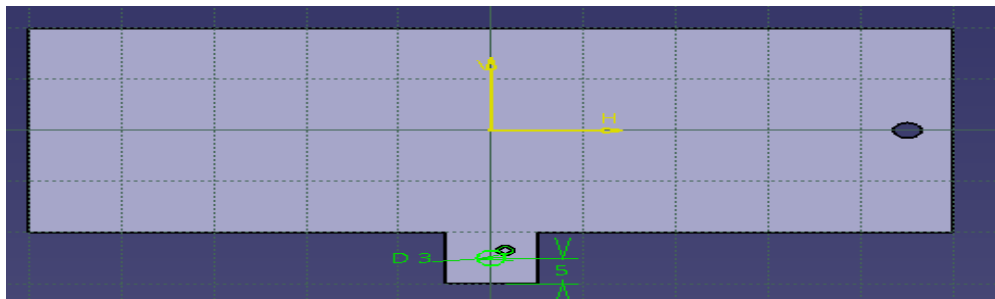


FIGURE2.4.C: TOP HOLES

2.2.2) Wheels:

Four wheels are attached to the frame stand in order to move the machine in the direction specified. The movement of these wheels are controlled by the DC motor rotation which is controlled by the controller.



FIGURE2.5 WHEELS

2.2.3) Lead screw rod:

A threaded rod is a metal rod with threads welded on or rolled out. It is used as a linkage in a machine, to translate turning motion into linear motion

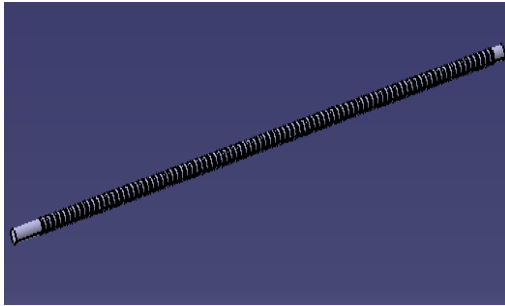


FIGURE2.6.B: LEAD SCREW ROD

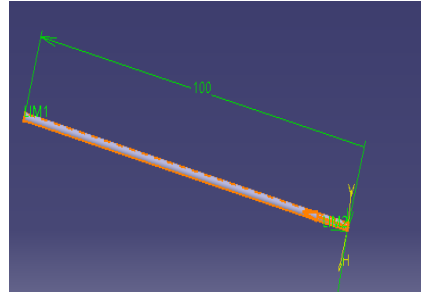


FIGURE2.6.A: LEAD SCREW ROD

2.2.4) Spray gun:

Spray painting is a painting technique where a device sprays a coating (paint, ink, varnish, etc.) through the air onto a surface. The most common types employ compressed gas—usually air—to atomize and direct the paint particles.

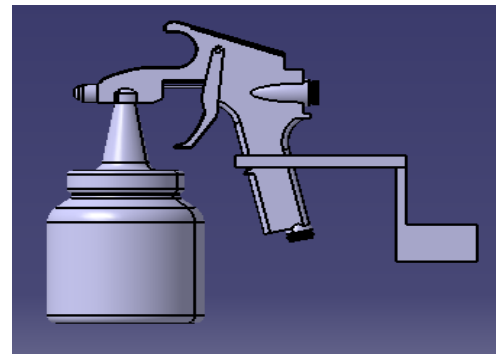


FIGURE2.7.A: SPRAY GUN

Spray guns evolved from airbrushes, and the two are usually distinguished by their size and the size of the spray pattern they produce. Airbrushes are hand-held and used instead of a brush for detailed work such as photo retouching, painting nails or fine art. Air gun spraying uses equipment that is generally larger. It is typically used for covering large surfaces with an even coating of liquid. Spray guns can be either automated or hand-

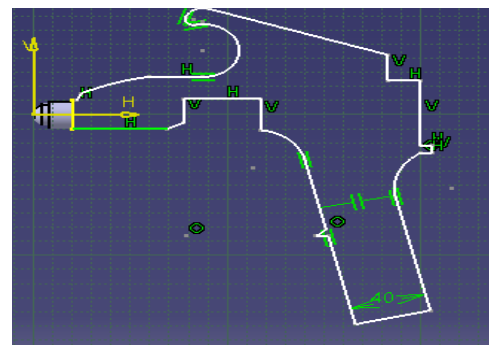


FIGURE2.7.B: SPRAY GUN SKETCH

held and have interchangeable heads to allow for different spray patterns. Single color aerosol paint cans are portable and easy to store [4]

3

Chapter 3: Electrical System

- 3.1. Electrical Components.**
- 3.2. stepper motor**
- 3.3. DC Motor Driver (H-Bridge)**
- 3.4. IR.**
- 3.5. Dc power supplies**
- 3.6. Electrical switches**
- 3.7. Encoder**
- 3.8. Pneumatic system**

Chapter 3: Electrical System

In this chapter we will review the electrical system of the project; the electrical elements are connected together as shown in Figure 5.2. Automatic wall painting machine mainly consists of an Arduino Mega, DC stepper motor, driver, infrared sensor, HMI display, battery, power supply, push button switches, limit switches, selector switch and encoder.

3.1. Electrical Components:

In the following, we will browse the components of the electrical design:

a) Arduino Mega 2560:

The Arduino Mega is a microcontroller board based on the ATmega1280. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack. [5] An ICSP header, and a reset button. As shown in Figure 3.1



FIGURE 3.1: ARDUINO MEGA 2560 R3

b) Keypad 3X4:

Keypads allow users to input data while a program is running. This tutorial shows you how to connect a twelve-button keypad to an Arduino and how to use the library. A keypad is often needed to provide input to an Arduino system, and membrane-type keypads are an economical solution for many applications. They are quite thin and can easily be mounted wherever they are needed. In this project, we demonstrate how to use a 12-button numeric keypad, similar to what you might find on a telephone. A 12-button keypad has three columns and four rows as show in Figure3.2 Pressing a button will short one of the row outputs to one of the column outputs. From this information, the Arduino can determine which button was pressed. For example, when key 1 is pressed, column 1 and row 1 are shorted. The Arduino will detect that and input a 1 to the program.

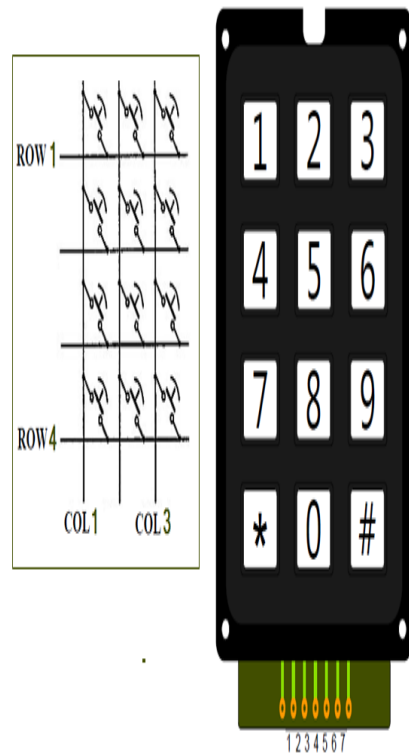


FIGURE3.2: KEYPAD

LCD Display 16x2:

Interfacing a character LCD to an Arduino adds a nice element of readability to your project. Many of the best Arduino projects around the world sport LCD displays as show in Figure 3.3. These LCDs can be used to display information from the Arduino or any sensor connected to it. For example, you can create a temperature monitoring system which displays the temperature on your Arduino. You can make your own speedometer that displays your speed on the LCD! Depending on

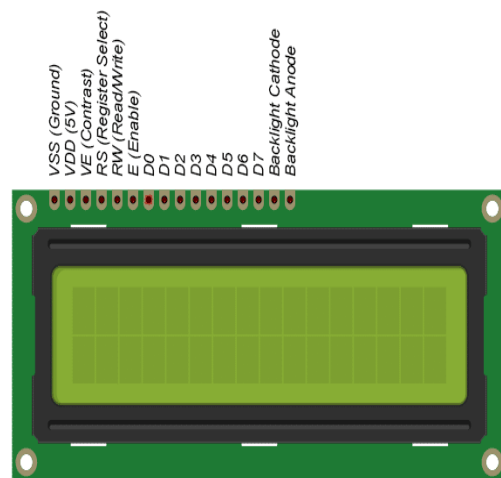


FIGURE3.3: LCD 16x2

what you want to build, an LCD is a highly useful output device for your Arduino. [6]

3.2 stepper motor:

Stepper motors is a DC motors that move in discrete steps. They have multiple coils that are organized in groups called "phases". By energizing each phase in sequence, the motor will rotate, one step at a time. With a computer controlled stepping you can achieve very precise positioning and/or speed control. For this reason, stepper motors are the motor of choice for many precision motion control [7]



applications.

FIGURE3.4: STEPPER MOTOR

What are stepper motors good for?

1. Positioning: Since steppers move in precise repeatable steps, they excel in applications requiring precise positioning such as 3D printers, CNC, Camera platforms and X, Y Plotters. Some disk drives also use stepper motors to position the read/write head.
2. Speed Control: Precise increments of movement also allow for excellent control of rotational speed for process automation and robotics.
3. Low Speed Torque: Normal DC motors don't have very much torque at low speeds. A Stepper motor has maximum torque at low speeds, so they are a good choice for applications requiring low speed with high precision.

What are their limitations?

1. **Low Efficiency:** Unlike DC motors, stepper motor current consumption is independent of load. They draw the most current when they are doing no work at all. Because of this, they tend to run hot.
2. **Limited High-Speed Torque:** In general, stepper motors have less torque at high speeds than at low speeds. Some steppers are optimized for better high-speed performance, but they need to be paired with an appropriate driver to achieve that performance.
3. **No Feedback:** Unlike servo motors, most steppers do not have integral feedback for position. Although great precision can be achieved running 'open loop'. Limit switches or 'home' detectors are typically required for safety and/or to establish a reference position.

| | |
|---------------|--------|
| Input voltage | 24VDC |
| speed | 60 rpm |

TABLE 3.1 STEPPER MOTOR SPECIFICATION

Acceleration and deceleration profile of separately DC motor:

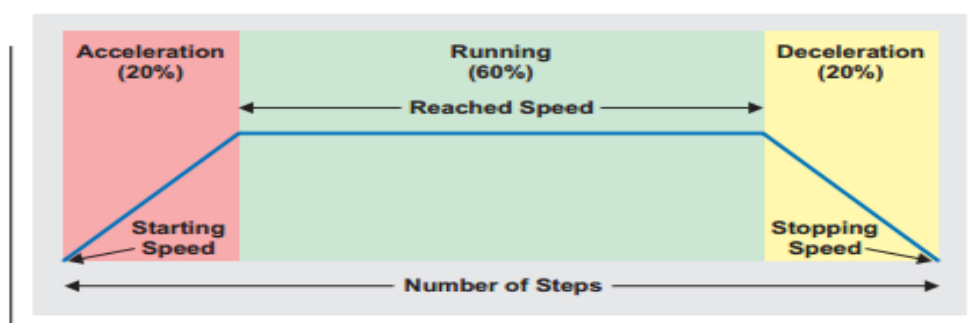


FIGURE3.5: MOTOR TRAPEZOIDAL MOVEMENT

3.3 DC Motor Driver (H-Bridge):

The suitable drivers to control a DC Motor is H-Bridge which is an electronic circuit that enables a voltage to be applied across a load in opposite direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards or backwards

The term H Bridge is derived from the typical graphical representation of such a circuit. An H- bridge is built with four switches (solid-state or mechanical). When the transistors S1 and S4

according to (Figure 3.3.a) are closed and transistors S2 and S3 are open a positive voltage will be applied across the motor. By opening S1 and S4 transistors and closing S2 and S3 transistors, this voltage is reversed, allowing reverse operation of the motor.

We will use Dual H-Bridge motor driver for DC / Steppers - L293D as shown in (Figure 33.b) which can run four solenoids, two DC motors or one bi-polar or unit-polar stepper with up to 600mA per channel using the 600 mA [8].

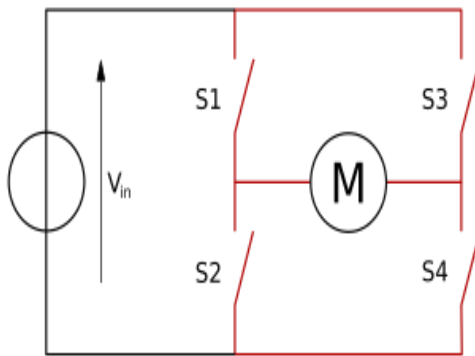


FIGURE3.6.A: H-BRIDGE ELECTRICAL CIRCUIT

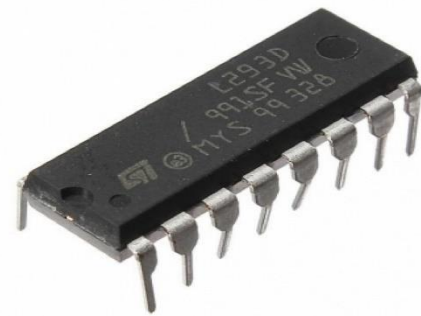


FIGURE3.6.B: H-BRIDGE

3.4 IR:

Infrared sensors as show in Figure 3.7 can be passive or active. Passive infrared sensors are basically infrared detectors. Passive infrared sensors do not use any infrared source and detects energy emitted by obstacles in the field of view. They are of two types: quantum and thermal. Thermal infrared sensors use infrared energy as the source of heat and are independent of wavelength. Thermocouples, pyro electric Figure 3.4.a detectors and bolometers are the common type of thermal infrared detectors.



FIGURE3.7.A: IR SENSOR

IR Transmitter

Infrared Transmitter is a light emitting diode (LED) which emits infrared radiations. Hence, they are

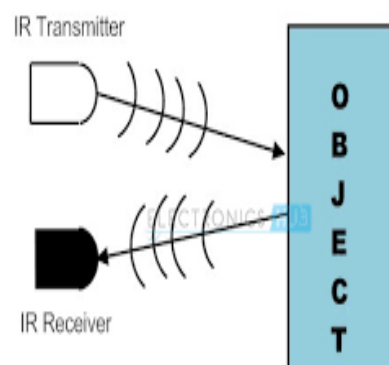


FIGURE3.7.B: IR SENSOR WORK PRINCIPLE

called IR LED's. Even though an IR LED looks like a normal LED, the radiation emitted by it is invisible to the human eye.

✚ IR Receiver

Infrared receivers are also called as infrared sensors as they detect the radiation from an IR transmitter. IR receivers come in the form of photodiodes and phototransistors. Infrared Photodiodes are different from normal photo diodes as they detect only infrared radiation

3.5. DC Power Supplies :

Which is a device that is responsible for converting the 220 V AC to DC with any required volt as shown in Figure 3. 8 . (5V power supply circuit, 2017



FIGURE3.8.A: AC TO DC RECTIFIER

TABLE 3.2: POWER SUPPLY SPECIFICATIONS

| | |
|--------|--------|
| input | 220 AC |
| output | 24 DC |

Power supply as shown in Figure 3.8.b consists of:

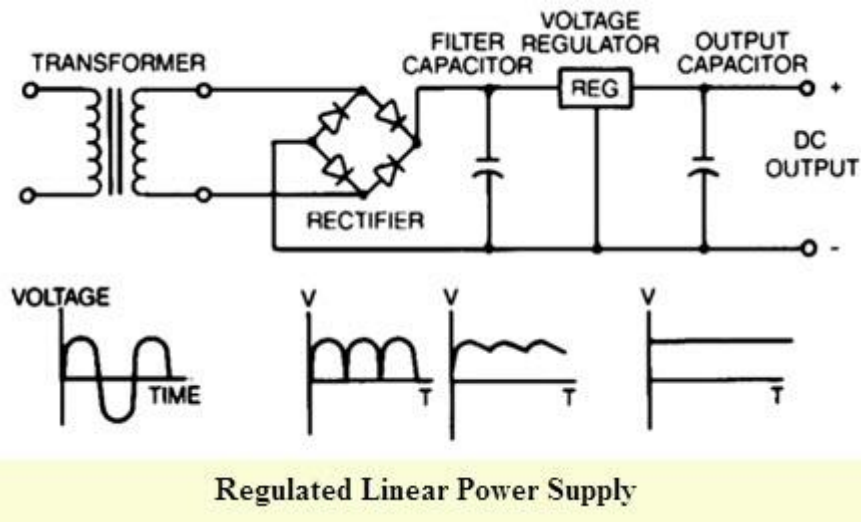


FIGURE 3.8.B: ELECTRICAL CIRCUIT OF RECTIFIER

1. Transformer

The transformer is a static device that transfers electrical energy from the primary winding to the secondary winding without affecting the frequency. It is used to step up or step-down the ac voltage level and isolates the remainder of the electronic system from the ac power.

2. Rectifier

The rectifier is a device used to change the ac power into pulsating dc. The basic rectifier is the diode. This diode is a unidirectional device that operates as rectifier in the forward direction. The three basic rectifier circuits using diodes are the half-wave, full-wave center-tapped and full-wave bridge type.

3. Filter

The filter of the power supply is used to keep the ripple component from appearing in the output. It is designed to convert pulsating DC from rectifier circuits into a suitably smooth dc level.

The two basic types of power supply filters are the capacitance filter (C-filter) and RC-filter. The C-filter is the simplest and most economical filter available. On the other hand, RC-filter is used to reduce the amount of ripple voltage across a capacitor filter. Its primary function is to pass most of the dc component while attenuating the ac component of the signal.

4. Voltage Regulators

A voltage regulator is designed to provide a very steady or well-regulated dc output. It is always ideal to have a steady output voltage so that the load will operate properly. The output level is maintained regardless of the variation of the input voltage. The commonly used transistor voltage regulators are the series voltage regulator and the shunt voltage regulator.

3.6. Electrical Switches:



FIGURE3.9: SWITCHES

Are electromechanical devices that are used in electrical circuits to control power, detect when systems are outside their operating ranges, signal controllers of the whereabouts of machine members and work pieces, provide a means for manual control of machine and process functions, control lighting, and so on. Switches come in a variety of styles and are actuated.

By hand, foot, or through the detection of pressure, level, or objects. Switches can be simple on-off types or can have multiple positions that, for instance, can control the speed of a multi-speed fan. Switch operators can be found in various shapes and sizes as shown in Figure 3.7 such as toggles or buttons, and can be furnished in a variety of colors [9].

a) pushbutton switches:

Are momentary contact switches, where contacts change from their default state only when the button is pressed and held down .The two types of momentary contact switches are:

- Normally open (NO): In a normally open switch, the default state of the contacts is open. When you push the button, the contacts are closed. When you release the button, the contacts open again. Thus, current flows only when you press and hold the button.
- Normally closed (NC): In a normally Closed switch, the default state of the Contacts are closed. Thus, current flows until you press the button. When you press the button contacts are opened and current does not flow. When you release the button the contacts close again and current resumes.

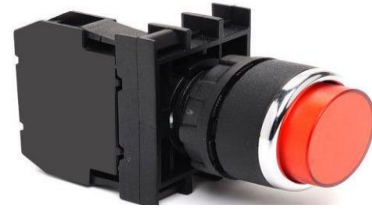


FIGURE3.10.A: PUSHBUTTON

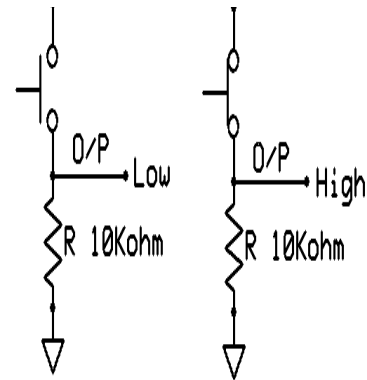


FIGURE3.10.B: PUSHBUTTON CIRCUIT

A pushbutton switch is a switch that has a knob that you push to open or close the contacts.

In some pushbutton switches, you push the switch once to open the contacts and then push again to close the contacts. As shown in Figure 3.10.a and 3.10.b In other words, each time you push the switch, the contacts alternate between opened and closed [10].

b) Limit switch:

Limit switches are a type of sensor that detect presence and absence. Specifically, mechanical limit switches are switches that are mechanically activated, meaning that they have some sort of arm, lever, knob, plunger, etc., which is physically—or mechanically—activated by making contact with another object. As the object makes contact with the actuator of the switch,



FIGURE3.11.B: LIMIT SWITCH

it eventually moves the actuator to its “limit” where the contacts change state. Other varieties of sensors/switches exist, including proximity sensors, light sensors, electric switches, among others. In its simplest form, a limit switch is a “switch” that can be mounted into remote locations so that it is actuated by an object other than a human operator.

Some basic functions of limit switches are:

- ✚ Detecting presence/absence
- ✚ Counting
- ✚ Detecting range of movement
- ✚ Detecting positioning & travel limit
- ✚ Breaking a live circuit when unsafe conditions arise
- ✚ Detecting speed

c) Selector switch:

Selector Switch works on a general principle; they contain a simple selector switch on the front of the panel, and a broad range of potential contact combinations on the inside of the enclosure. The major difference between the selector switch and the pushbutton is that, while a pushbutton has a plate that pushes down both contact plungers at the same time, a selector switch has a rotating cam with ridges and flats, allowing to actuate the plungers independently.



FIGURE3.12: SELECTOR SWITCH

Selector switches are available in 2, 3, 4 or more-position versions, and are often used when more than one control option is needed. In general, the center position of the selector switch is the starting cam position. Left position presses the left plunger in the selector switch. Turning the selector switch to the right presses down the right plunger.

How Selector Switches Work:

Selector switches use cams in combination with contact blocks to provide a wide range of circuit openings and/or closings. In the following diagram, "X" designates a closed circuit (energized or "on") for a particular selector switch position, and "O" to designate an open circuit (not energized or "off") In the table (3.3). A 3-position selector switch is used to open or close two circuits, "manual", "off" and "auto", for painting machine. It works in the following manner

| | |
|----------|---------------------|
| Select 0 | Machine off |
| Select 1 | Manual operation |
| Select 2 | Automatic operation |

TABLE 3.3 PRINCIPLE OF SELECTOR SWITCH

3.7. Encoder:

The encoder is an electromechanical device that can measure displacement. Encoders are normally digital displacement transducers, consisting of a mechanical element and a sensing head, typically of optical type. The mechanical element can be a disc (for rotary type encoders) or a ruler (for linear type encoders) with deposited or carved patterns. The sensing head includes a light source (LED) and a light sensor (photo detector) to read the generated code (the encoder output).

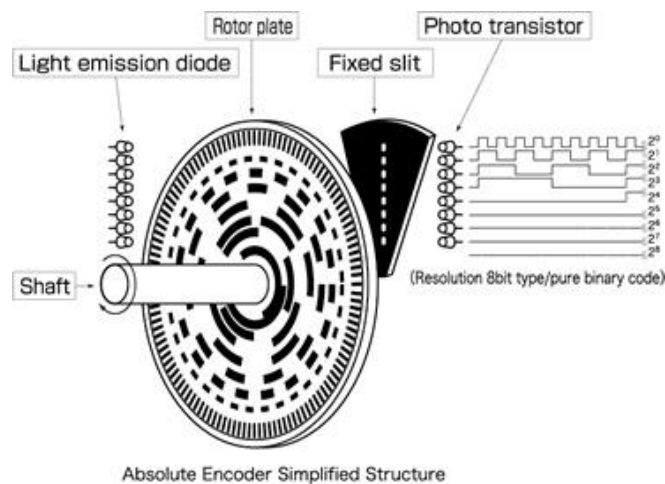


FIGURE 3.12.A: ENCODER

How can the disc angle rotation be measured?

With this encoder, the displacement is obtained by counting the number of times that transitions occur between logical values "0" and "1". This allows the transformation of physical quantities by converting the angular displacement variations into electrical type signal output that is translated into logical values by suitable electronics. The counting of the number of transitions that occur in the (reflective / opaque and no reflective / transparent) disc sectors is related to the

concept of resolution. The resolution may be defined as the smallest change in a quantity under measurement that causes a noticeable change in the corresponding outcome. In this case, the resolution of the disc corresponds to its minimum angular variation that causes a transition at the logical output level.

Resolution of encoder (α) = $360/n$ Where n is the number of holes

How can we detect the direction of disc rotation?

This solution with only a sensing head is not able to identify the direction of disc rotation. To solve this problem another optical sensing head is used, with its output signal offset from the first by 90°; in other words, the optical sensing head signals are in quadrature. This layout produces two square waves in quadrature, corresponding each to one sensing head (channels A and B), as shown in Figure 3.12.b.

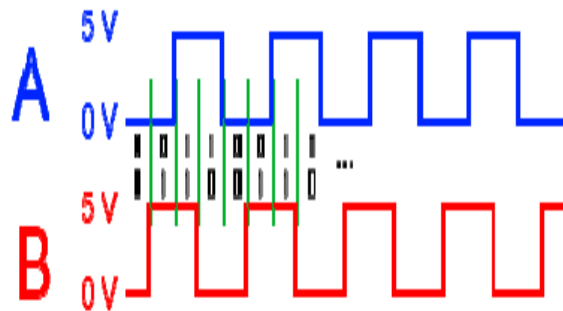


FIGURE3.12.B: ENCODER WAVE FORM

3.8. Pneumatic system.

A pneumatic system is a system that uses compressed air to transmit and control energy.

The advantages of pneumatic systems:

Pneumatic control systems are widely used in our society, especially in the industrial sectors for the driving of automatic machines. Pneumatic systems have a lot of advantages:

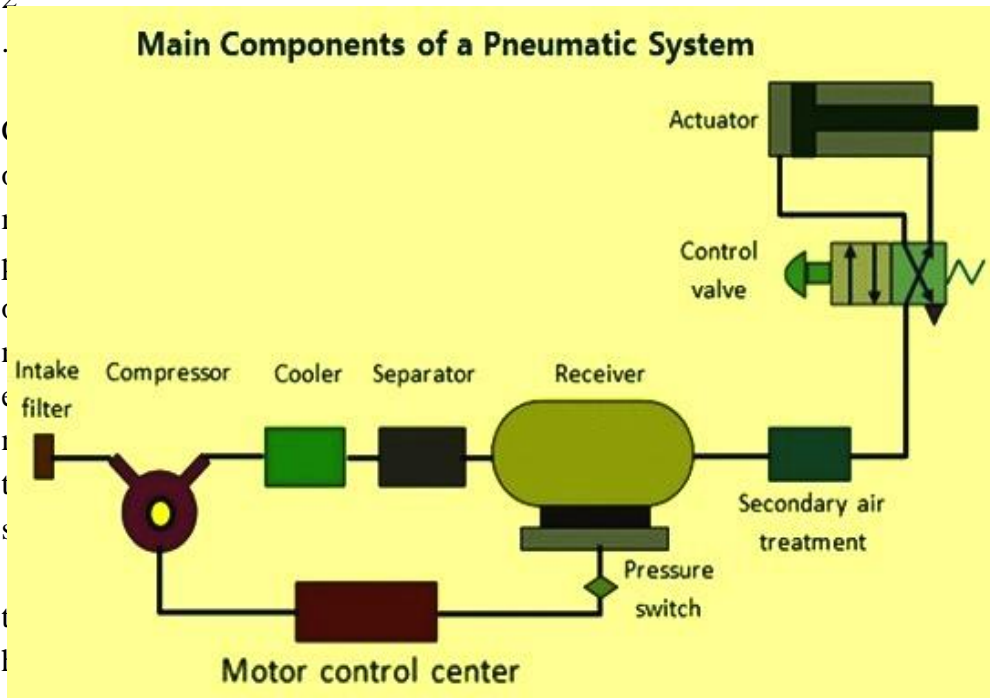
- a) High efficiency
- b) Simple design
- c) Safety
- d) Easy selection of speed and pressure

- **Main pneumatic components**

Pneumatic components can be divided into two categories:

1. Components that produce and transport compressed air.

2.



t consume compressed air.

FIGURE3.12.A: PNEUMATIC SYSTEM

All main pneumatic components can be represented by simple pneumatic symbols. Each symbol shows only the function of the component it represents, but not its structure. Pneumatic symbols can be combined to form pneumatic diagrams. A pneumatic diagram describes the relations between each pneumatic component, that is, the design of the system.

- ❖ **Compressor:** A compressor can compress air to the required pressures. It can convert the mechanical energy from motors and engines into the potential energy in compressed air (Fig3.12b).



FIGURE3.12.B: COMPRESSOR

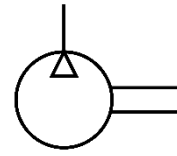


FIGURE3.12.C: COMPRESSOR SYMBOL

- ❖ **Pressure regulating component:** Pressure regulating components are formed by various components, each of which has its own pneumatic symbol(fig.3.14)
 - Filter: can remove impurities from compressed air before it is fed to the pneumatic component
 - Pressure regulator: to stabilize the pressure and regulate the operation of pneumatic components
 - Lubricator: To provide lubrication for pneumatic components

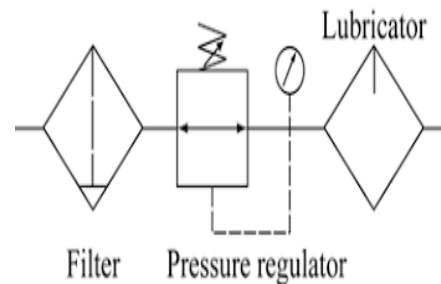


FIGURE3.14: PRESSURE REGULATOR

- ❖ **Directional control valve:** Directional control valves ensure the flow of air between air ports by opening, closing and switching their internal connections. Their classification is determined by the number of ports, the number of switching positions, the normal position of the valve and its method of operation. Common types of directional control valves include 2/2, 3/2, 5/2, etc. The first number represents the number of ports; the second number represents the number of positions(fig.3.15).

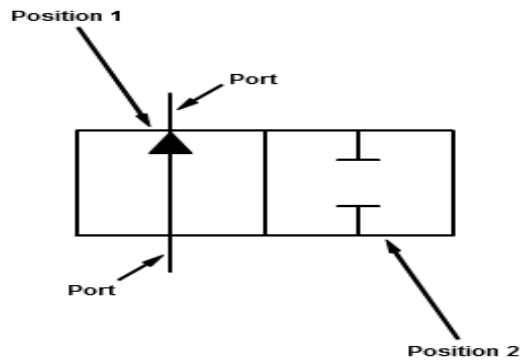


FIGURE 3.15 DIRECTIONAL CONTROL VALVE

- 3/2 Directional control valve: A 3/2 directional control valve can be used to control a single acting cylinder (Fig. 5). The open valves in the middle will close until 'P' and 'A' are connected together. Then another valve will open the sealed base between 'A' and 'R' (exhaust). The valves can be driven manually, mechanically, electrically or pneumatically. 3/2 directional control valves can further be divided into two classes: Normally open type (N.O.) and normally closed type (N.C.) (Fig. 3.15)

❖ **Flow control valve:** Flow Control Valves are used to reduce the rate of flow

In a section of a pneumatic circuit, resulting in a slower actuator speed. Unlike a Needle Valve, a Flow Control Valve regulates air flow in only one direction, allowing free flow in the opposite direction (fig.3.16)

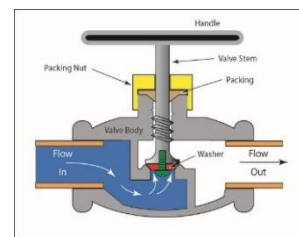


FIGURE3.16: FLOW CONTROL VALVE

4

Chapter 4: Project calculations

4.1. Mechanical design and motor sizing.

Chapter 4: Project calculations

The design of the automatic wall painting machine includes a motor, screw, paint box and frame. Each part of the system will be designed and select the appropriate dimension and materials according to specific length and width of the system also according to the paint weight and dimension of screw. The standard dimension of the system will be:

4.1 Mechanical design and motor sizing [11].

TABLE 4.1: MACHINERY SELECTION

| | |
|---------------------------------------|---------------|
| Load Mass M | 20kg |
| Ball Screw Pitch P | 3mm |
| Ball Screw Diameter D | 10mm |
| Ball Screw Mass MB | 3kg |
| Ball Screw Friction Coefficient | 0.2 |
| Since no decelerator | $G=1, \eta=1$ |

Machine distance:

TABLE 4.2: MACHINE DISTANCE

| | |
|----------------|--------|
| Maximum length | 1000mm |
| Maximum width | 500mm |
| Maximum height | 1000mm |

Stepper motor and screw specification:

TABLE 4.3: STEPPER MOTOR AND SCREW SPECIFICATION

| | |
|---------------------------------|----------------|
| Motor type | 2 phase 4 wire |
| Driving voltage(v) | 20_30-volt DC |
| Driving current(i) | 3_5 A |
| Efficiency of motor(η_m) | 0.90 |
| Screw length(l) | 1000mm |
| Screw diameter(D) | 10mm |
| Effective stroke(le) | 990mm |
| Screw pitch(p) | 10mm |
| Efficiency of screw(η_s) | 0.80 |
| Step angle | 1.8 degree |
| Stage size | 120*60mm |

Maximum load weight:

TABLE 4.4: MAXIMUM LOAD WIGHT

| | |
|------------------|-------|
| Paint weight | 10kg. |
| Spray gun | 2kg. |
| Horizontal stand | 8kg. |
| Total weight | 20kg. |

Determining Operating Pattern

- One Speed Change
- Velocity for a Load Travel $V = 300$ [mm/s]
- Strokes $L = 1000$ [mm]
- Stroke Travel Time $T_S = 3.5$ [s]
- Acceleration/Deceleration Time
 $T_A = 0.2$ [s].
- Positioning Accuracy $AP = 0.01$ [mm]

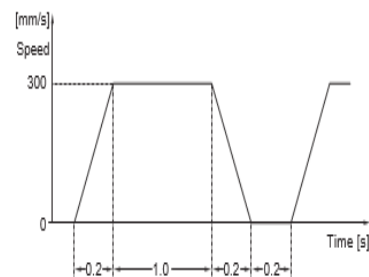


FIGURE4.1: MOTOR ACCELERATION AND DECLARATION

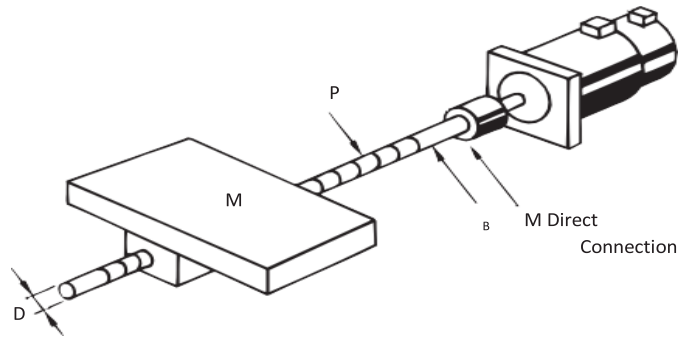


FIGURE4.2: SCREW WITH MOTOR

Calculation of Motor Shaft Conversion Load Inertia:

Ball screw Inertia JB:

$$\begin{aligned}
 JB &= \frac{MB \cdot D^2}{8} * 10^{-6} & (6.1) \\
 &= \frac{3 * 10^2}{8} * 10^{-6} = 3.75 * 10^{-5} kg.m^2
 \end{aligned}$$

Where: D is the diameter of ball screw.

MB is the mass of ball screw.

Load Inertia JW:

$$\begin{aligned}
 JW &= M \left(\frac{P}{2\pi} \right)^2 * 10^{-6} + JB & (6.2) \\
 &= 20 \left(\frac{10}{2\pi} \right)^2 * 10^{-6} + 3.75 * 10^{-5} = 2.4 * 10^{-4} kg.m^2
 \end{aligned}$$

Where: M is the total mass of load.

LL=JW since we don't have decelerator.

$$JL = 2.4 * 10^{-4} kg.m^2$$

Load Torque Calculation:

Torque against Friction Torque TW:

$$TW = \mu M g \frac{P}{2\pi} * 10^{-3} \quad (6.3)$$

$$= 0.1 * 20 * 9.82 * \frac{10}{2\pi} * 10^{-3} = 31.27 * 10^{-3} Nm$$

Where: μ is the Ball Screw Friction Coefficient.

M: the mass of the load.

G: gravity acceleration = $9.82 m/s^2$

Motor Shaft Conversion Load Torque TL:

$$TL = \frac{G}{\eta} * TW = 31.27 * 10^{-3} Nm \quad (6.4)$$

Where: G: gear ratio = 1

η : efficiency of gear = 1 since we don't have gear.

Rotation Speed Calculation:

$$N = \frac{60 * V}{p * G} = \frac{60 * 300}{10} = 1800 [r/min] \quad (6.5)$$

Where: N is the rotation speed of motor

V: velocity for load travel.

Motor Temporary Selection:

Motor inertia:

$$JM \geq S * JL = 0.30 * 2.4 * 10^{-4} = 7.2 * 10^{-5} kg.m^2 \quad (6.6)$$

Motor torque:

$$TM \geq \frac{TL}{0.80} = \frac{31.27 * 10^{-3}}{0.80} = 39.08 * 10^{-3} Nm \quad (6.7)$$

Where S: safety factor = 0.30

Acceleration/ Deceleration Torque T_A :

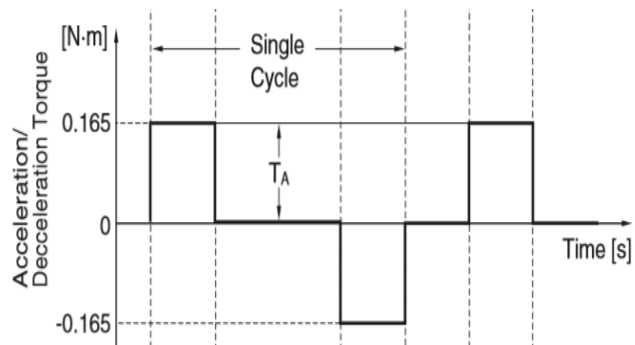


FIGURE 4.3: ACCELERATION AND DECELERATION TORQUE

$$T_A = \frac{2\pi * N}{60t_A} \left(JM + \frac{JL}{\omega} \right) = 0.294 Nm$$

(6.8)

5

Chapter 5: Project Control

5.1. Arduino

5.2. Connection Circuit

5.3. System Flowchart

Chapter 5: Project Control

This chapter presents control design of the moving parts in the automatic wall painting machine in order to obtain the desired output in high accuracy. On the other hand, the software and programming detail that will be used in this project will be introduced using flowchart. In addition, explanation of the machine procedure operation will be given.

5.1 Arduino:

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 as shown in Figure 5. 1 It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button as show in Table 5. 1. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or

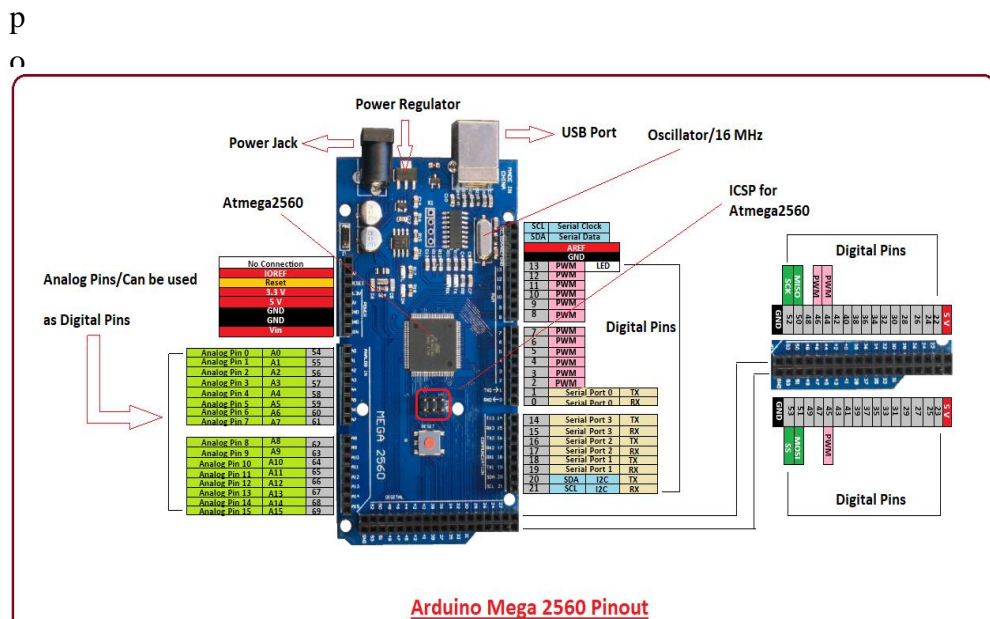


FIGURE 5.1: ARDUINO MEGA 2560 PIN OUT

AC-to-DC adapter or battery to get started.

The Mega 2560 can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the GND and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may become unstable. If using

more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

VIN: The input voltage to the board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.

5V: This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board. We don't advise it.

3V3: A 3.3-volt supply generated by the on-board regulator. Maximum current draw is 50 mA.

- **GND:** Ground pins.

IOREF: This pin on the board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source or enable voltage translators on the outputs for working with the 5V or 3.3V.

- **Memory:** The Arduino mega2560 has 256 KB of flash memory for storing code, 8 KB of SRAM and 4 KB of EEPROM [5]

TABLE5.1 ARDUINO MEGA SPECIFICATIONS

| | |
|-----------------------------|---|
| Microcontroller | ATmega2560 |
| Operating Voltage | 5V |
| Input Voltage (recommended) | 7-12V |
| Input Voltage (limits) | 6-20V |
| Digital I/O Pins | 54 (of which 15 provide PWM output) |
| Analog Input Pins | 16 |
| DC Current per I/O Pin | 40 mA |
| DC Current for 3.3V Pin | 50 mA |
| Flash Memory | 256 KB of which 8 KB used by bootloader |
| SRAM | 8 KB |
| EEPROM | 4 KB |
| Clock Speed | 16 MHz |

Microcontroller ATmega2560 Operating Voltage 5V Input Voltage (recommended) 7-12V Input Voltage (limits) 6-20V Digital I/O Pins 54 (of which 14 provide PWM output) Analog Input Pins 16 DC Current per I/O Pin 40 mA DC Current for 3.3V Pin 50 mA Flash Memory 256 KB of which 8 KB used by bootloader SRAM 8 KB EEPROM 4 KB Clock Speed 16 MHz.

5.2. Connection Circuit: Computer simulations have become a useful part of mathematical modeling of many natural systems to observe their behavior. It allows the engineer to test the design before it is built in the real situation; the simulations for this system were performed in PROTEUS program shown in Figure 5. 2. These software applications

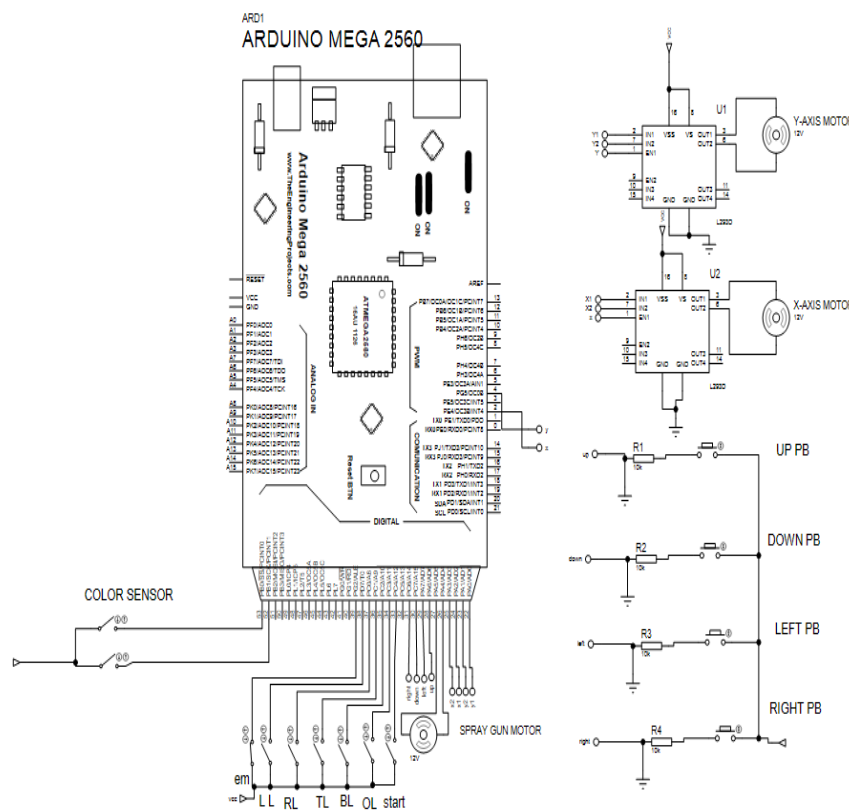


FIGURE 5.2: CONNECTION CIRCUIT

are widely used in control engineering for both simulation and design.

TABLE 5.2: SYSTEM INPUT AND OUTPUT

| System Input | System output |
|-------------------------------------|---------------|
| Toggle Switch on/off | X-axis motor |
| Push Button start(manual/automatic) | |
| Selector Switch | Y-axis motor |
| Push Button-up | |
| Push Button-down | LCD display |
| Push Button-Right | |
| Push Button-Left | |
| Limit switch-up | Spray Gun |
| Limit switch-down | |
| Limit switch-Right | |
| Limit switch-Left | |
| Keypad | |
| IR Sensor | |

5.2.1 Working principle of circuit:

The control circuit contains keypad that user will press the room's number through it, if the code is right the room will be ready for parking when the car reaches the gate IR sensor active and the gate is open, user park the car and exit parking area, then the gate will be closed when he presses.

In Returning car case the system will operate in the same principle, if the driver was in the parking are and the gate closed after one hundred second, he will press second push button to open it and leaves.

5.3. System Flowchart:

A flowchart is a type of diagram that represents an algorithm, workflow or process, showing the steps as boxes of various kinds, and their order by connecting them with arrows. This diagrammatic representation illustrates a solution model to a given problem. Flowcharts are used in analyzing, designing, documenting or managing a process or program in various fields.

The flowchart illustrates the principle of system as shown in Figure5.3

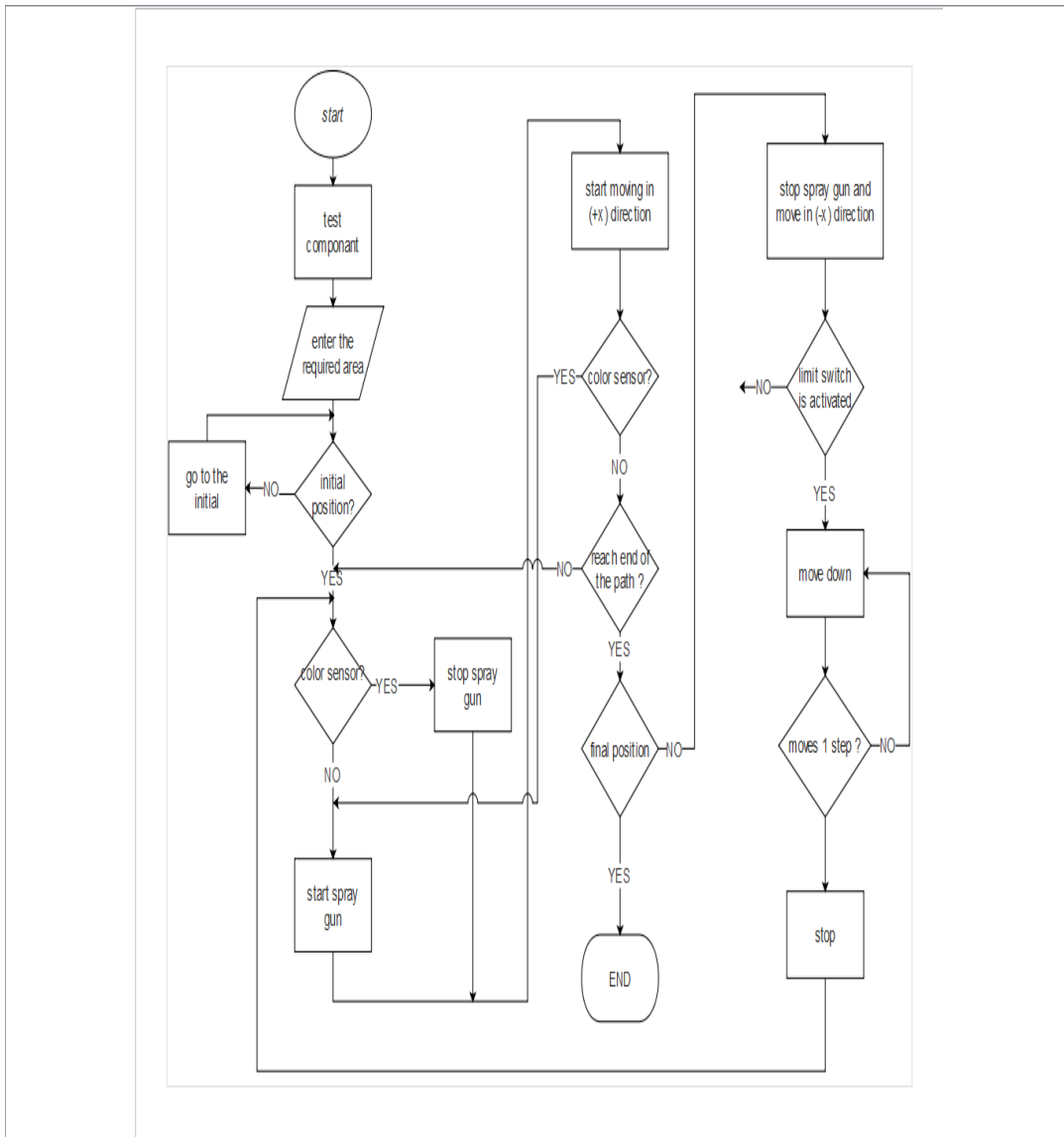


FIGURE5.3: SYSTEM FLOWCHART

6

Chapter 6: System Implementation and Testing

- 6.1. Electrical Circuit Implementation.**
- 6.2. Mechanical Structure Implementation.**
- 6.3. System Testing.**
- 6.4. Work Plan.**
- 6.5. Budget and costs.**
- 6.6. Conclusion.**

Chapter 6: System Implementation and Testing

This chapter will introduce the implementation process is done and how components connected with each other step by step.

6.1 Electrical Circuit Implementation

For the implementation of the control circuit correctly we follow the following steps:

- **Step one:**

Connect Arduino with the PC and start Programming of Arduino mega 2560 as shown in Figure 6.1.

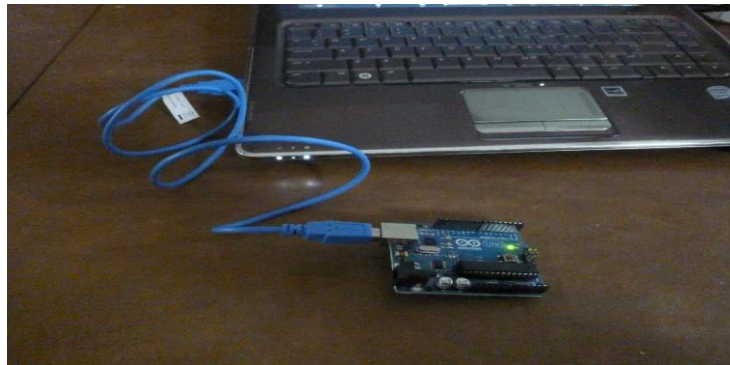


FIGURE 6.1 CONNECTION OF THE ARDUINO WITH PC

- **Step two:**

Preparing relays with Arduino, stepper motor and drivers and as shown in Figure 6.2

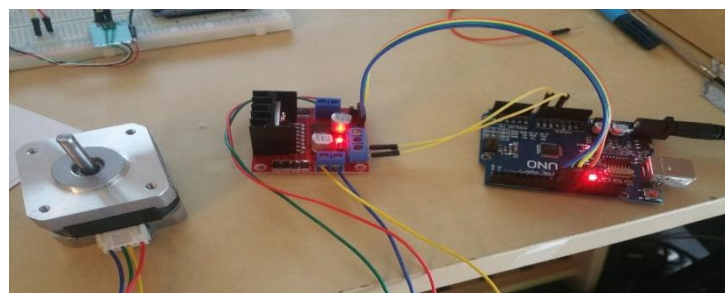


FIGURE 6.2 CONNECT STEPPER MOTOR WITH ARDUINO

6.2 Mechanical Structure Implementation.

For the implementation of the mechanical structure correctly we follow the following steps:

- **Step one.**

Prepare and paint the frame which will hold the whole system components as shown in Figure 6.3



FIGURE 6.3 OUTER FRAME

- **Step two.**

Prepare the inside frame which will hold motors shown in figure 6.4



FIGURE 6.4 INNER FRAME

- **Step three.**

Prepare motors and Install them to the inside frame as shown in figure 6.5



FIGURE 6.5 PREPARING MOTORS

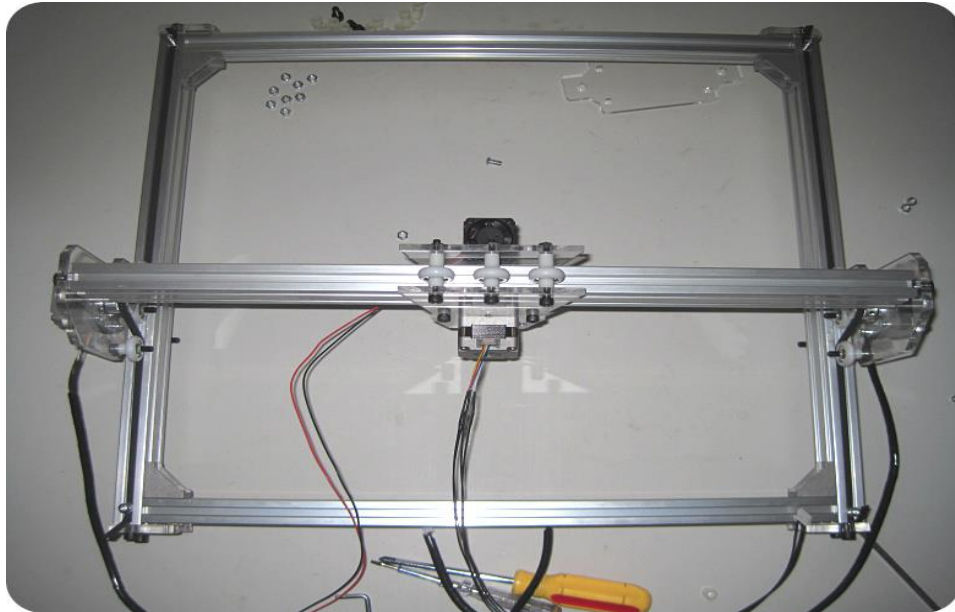


FIGURE 6.6 INSTALLING MOTORS IN FRAME

- **Step four.**

Install the inside frame to the body of project to form the final appearance of the project as shown in figure 6.8.



FIGURE 6.7 FINAL FORM OF THE PROJECT

6.3 System Testing.

After the electrical circuit is completed, it has been installed on the model to simulate the painting machine and to test the electrical circuit and assure its efficiency then apply the possible conditions to ensure that the system responds.

After that Prepare the spray gun and connect the system to the air compressor in order to start the examination of the project and make sure it works correctly.

After the installation of the equipment, the system is checked in the automatic mode and the manual is as follows:

Manual mode: at the first selector switch was pressed at the manual mode then a set of pushbutton switches was used to control the motion of the motors in the system at all directions and a key was used for the spray

automatic mode: the selection key was switched to automatic mode then the system returned to the initial position and then started the process of painting and move in the direction required according to the code.

6.4 Work plan.

In order to achieve the main objective of this project, it is necessary to divide the work into several tasks and the distribution of the tasks along the first and second semester 2018/2019 as shown in Table 6.1.

TABLE 6.1 WORK PLAN

| Task | Duration | Introduction | Graduation project |
|---|----------|--------------|--------------------|
| 1. Getting information | 2 weeks | X | |
| 2. Summarize the project idea | 2 weeks | X | |
| 3. Software design | 6 weeks | X | |
| 4. machine Control | 3 weeks | X | |
| 5. Simulation | 2 weeks | X | |
| 6. Obtaining at mechanical and electrical tools | 2 weeks | | X |
| 7. prepare the mechanical structure | 5 weeks | | X |
| 8. prepare the electrical system | 5 weeks | | X |
| 9. Run the project | 2 weeks | | X |
| 10. Conclusion | 1 week | | X |

6.4 Budget and Costs

The approximate cost of the required components is shown in Table 6.2. The total cost of the automatic painting machine project is estimated below:

TABLE 6.2 : PROJECT BUDGET

| | |
|--|----------------|
| Programmers (Arduino mega, Sensor, key pad) | 70 JD |
| Material | 200 JD |
| Tools (Motor, Rods, Spray gun, compressor, valves, switches, Beam rods, earing, frame) | 1000 JD |
| manufactory | 200 JD |
| Total | 1470 JD |

6.5 Conclusion

Designing and manufacturing of an automatic wall painting machine is one of the responsibilities towards our country as this type of machine will help to avoid the risk of painting building. The machine is specially designed for painting the exterior Flat wall of the structure.

The machine is cost effective, reduces work force for human workers, reduce time consumption.

In the future the painting machine can be enhanced by using image processing in order to scan the objects and obstacles that are present in the wall so that those objects can be automatically omitted while painting.

The painter machine system has achieved optimum benefits with regard to reliability, safety appearance, and ease of use. All the objectives set up for this system have been achieved successfully.

This prototype including the mechanical structure will moved using suitable electrical actuators which will be drive and controlled by microcontroller system "Arduino Mega"

Appendix A

```

//defines pins numbers

const int SY = 0; //STEP OF X MOTOR

const int DY = 1; //DIRECTION OF X MOTOR

const int SX = 2; //STEP OF X MOTOR

const int DX = 3; //DIRECTION OF X MOTOR

const int start_m = 4; //

const int automatic = 5; //

const int manu = 6; //

const int ru = 7;

const int ld = 12;

const int fn=13;

const int lsxl=8;const int lsxr=9;const int lsyl=10;const int lsyr=11;int x=0;

void L();void R(); void U();void D(); void check();

int STATE=0;int c=1200; int x1=0;

int x2 =0;

int z=0;

int o=0;

void setup() {

// Sets the two pins as Outputs

pinMode(SX,OUTPUT);

pinMode(DX,OUTPUT);

pinMode(SY,OUTPUT);

pinMode(DY,OUTPUT);

// pinMode(start_m,INPUT);

//pinMode(start_p,INPUT);

// pinMode(select,INPUT);

//pinMode(right,INPUT);

```

```

//pinMode(down,INPUT);

//pinMode(left,INPUT);

//pinMode(up,INPUT);

pinMode(lsxl,INPUT); pinMode(lsxr,INPUT); pinMode(lsyl,INPUT); pinMode(lsyrr,INPUT);

STATE=0;

}

void loop() {

if (digitalRead(automatic)==1) {

if (digitalRead(start_m)) STATE=1;

switch (STATE)

{

case 1: while (x1==0) {L();check();} STATE=2; break;

case 2: while (x2==0){U();check(); } STATE=3;break;

case 3: while (z==0){R();check();} if (digitalRead(lsyrr)==1 &&digitalRead(lsxr)==1){STATE=7;} else STATE=4;break;

case 4: while(o==0&&c!=0){ D(); c--;check();}if (digitalRead(lsyrr)==1 &&digitalRead(lsxr)==1){STATE=7;} else STATE=5; break;

case 5: while (x1==0){L();check();}if (digitalRead(lsyrr)==1 &&digitalRead(lsxr)==1){STATE=7;} else {c=1200;STATE=6;} break;

case 6: while(o==0&&c!=0){ D(); c--;check();}if (digitalRead(lsyrr)==1 &&digitalRead(lsxr)==1){STATE=7;} else {c=1200; STATE=3;} break;

case 7: break;

}}

else if (digitalRead(manu)) {

if ((digitalRead(fn)==1) && digitalRead(ru)==1) U();

else if ((digitalRead(fn)==1) && digitalRead(ld)==1) D();

else if ((digitalRead(fn)==0) && digitalRead(ru)==1) R();

else if ((digitalRead(fn)==0) && digitalRead(ld)==1) L();

```

```
}
```

```
}
```

```
void U(){ digitalWrite(DX,HIGH); digitalWrite(SX,HIGH); delayMicroseconds(50);  
digitalWrite(SX,LOW);delayMicroseconds(500);}
```

```
void D(){ digitalWrite(DX,LOW); digitalWrite(SX,HIGH); delayMicroseconds(50);  
digitalWrite(SX,LOW);delayMicroseconds(500);}
```

```
void R(){digitalWrite(DY,HIGH); digitalWrite(SY,HIGH); delayMicroseconds(50);  
digitalWrite(SY,LOW);delayMicroseconds(500);}
```

```
void L(){digitalWrite(DY,LOW); digitalWrite(SY,HIGH); delayMicroseconds(50);  
digitalWrite(SY,LOW);delayMicroseconds(500);}
```

```
void check(){if (digitalRead(lsxl)==1) x1=1; else x1=0 ;
```

```
if (digitalRead(lsy)==1){ x2=1;} else {x2=0 ;}
```

```
if (digitalRead(lsxr)==1) z=1; else z=0 ;
```

```
if (digitalRead(lsy)==1) o=1; else o=0 ;}
```

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