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Title

Study and conception of a mini CNC machine

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Dedication

I dedicate this work to

My dear parents for their sacrifices and their

encouragement throughout my studies

My brothers and all my Family

My friends and all my classmates

Those who will be happy for me.

Dhequir Ali Kouider

Dedication

To my very dear mother

I dedicate this work to you as a testimony of my deep love.

May Almighty God preserve you and grant you health،

Long life and happiness.

To my very dear father

This modest work is the fruit of so many

Sacrifices made for our education.

To my brother and my sisters Who I know my success is

very important to you. May God pay you For all

your benefits.

Benaicha mohamed mosbah

Dedication

I dedicate this work to

My brothers and sisters who have always been for me examples of perseverance, courage and generosity.

My teachers who must see in this work the pride of knowledge well acquired

To all who are dear to me

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Abstract

This project is a study and implementation of a CNC machine. where , in the first ,we mentioned a generalities concerning the CNC machine .Next , the components of the CNC machine which contains an electrical and a mechanical part are described ,then, we represented the software used to control the CNC system based on Arduino Uno .Finally we implemented and an assembly of the CNC machine prototype.

Keywords: CNC, Arduino Uno**,** G-code, GRBL

Rrésumé

Ce projet est une étude et la mise en œuvre d'une machine CNC. où, dans un premier temps, nous avons mentionné les généralités concernant la machine CNC. Ensuite, les composants de la machine qui contient une partie électrique et une partie mécanique sont décrits, puis, nous avons représenté le logiciel utilisé pour contrôler le système CNC basé sur ArduinoUno. Enfin, nous avons mis en œuvre et un montage du prototype de la machine CNC.

Mots clés: CNC, Arduino Uno**,** G-code, GRBL

ملخص

يهدف هذا المشروع الى دراسة وتنفيذ آلة CNC. حيث ذكرنا في الأول عموميات تتعلق بآلة CNC ، وبعد ذلك تم ذكر اهم المكونات الكهربائية والميكانيكية للآلة ، ثم قمنا عرض البرنامج المستخدم للتحكم في نظام CNC على أساس لوح Arduino Uno و أخيرًا قمنا بتنفيذ وتجميع النموذج لآلة CNC .

الكلمات المفتاحية: CNC ، Arduino Uno ، G-code ، GRBL

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List of Abbreviations:

CNC : Computer Numerical Control

CAD : Computer Aided Design

CAM :Computer Aided Manufacturing

G-code :Geometric Code

PWM :Pulse Width Modulation

ICSP : In Circuit Serial Programming

VRM : Variable Reluctance Motor

PMSM : Permanent Magnet Stepper Motor

HSM : Hybrid Stepper Motor

UGS: Universal G-code Sender

General Introduction

Computer numerical control (CNC) machines have become highly in-demand technology in practically every modern manufacturing sector setup, in contrast to the past, when these machines were only used in the car and aviation industries.

The term "CNC" refers to the process of using a computer and a set of instructions to send pulses for controlling a stepper motor, power a spindle, heat an extruder, or pulse a laser ,depend of the type of CNC machine[18].

The main goal of this research is to implement a CNC router that can engrave complex sketches on wood using the available components local markets and at the lowest cost .

Our theses is organized into three chapters:

In chapter 1, we introduce an overview on CNC machine and their principle of operation with cited of their different types . Next, in chapter 2, the components used to construct a CNC machine, from the hardware side and the software side are introduced . Then, in the chapter3 there the design and realization of a three dimensional CNC machine based on arduino uno is presented. Detailed descriptions of different modules along with technical details of their implementations have been given. Finally, we will end this thesis with a general conclusion and perspectives.

Chapter I
Overview of CNC machine

I.1 Introduction

Recent years the industry world witness a huge development, Due the significant science and technology of robotics, Computer Numerical Control is one of them, Which allow the manufacturers to control of various machines by computer. It has become easy to add new functions to modern CNC machines, As well as it is easy to change and develop control algorithms .

In this chapter, Firstly ,The History of CNC machine is presented . Next ,Working principle of CNC machine are described .Finally, The famous Types of CNC used to represent the advantages and disadvantages there are introduced .

I.2 History

Numerical control was first introduced in 1947. It all started when John C. Parsons of the Parsons Corporation, A helicopter rotor blade maker in Traverse City, Michigan, couldn't build his templates quickly enough. As a result, He devised a method of connecting computer equipment to a jig borer. Mr. Parsons operated his digit Ron system with punched cards.

Another "Urgent requirement" occurred in 1949. The Air Material Command of the United States understood that parts for its planes and missiles were growing increasingly complicated. Changes in the sketch were also done often as the designs were continuously refined. As a result, The Air Force gave the Parsons Corporation a research contract in their hunt for speedier manufacturing methods. The Massachusetts Institute of Technology's servo mechanisms laboratory was the subcontractor.

In 1951, The Massachusetts Institute of Technology took over the complete job, And in 1952, The prototype of today's NC machine, A modified Cincinnati HydrotelMilling Machine, Was successfully demonstrated. The term numerical control was originated at Massachusetts Institute of Technology [1].

I.3 Working principle of CNC machine

The activities of running digital control machines are organized through letters, Symbols, And numbers all constructed to be called the driver has been designated CNC because it contains the computer and machine, As well as the switching mechanism between the two. The definition of digital control machines is the connection of a computer to a machine, With a translation device between them to understand them , As we say, Interface of course the machine does not understand the computer's language, Which is why we place this device[2].

COMPUTER NUMERICAL CONTROL

C N C

The CNC consists of three parts:

- Machine (which is the operation).
- Control (which is responsible for controlling machine engines).
- Computer (and the function of the computer we write on it the program dedicated to the machine and save the programs on its allocated memory).

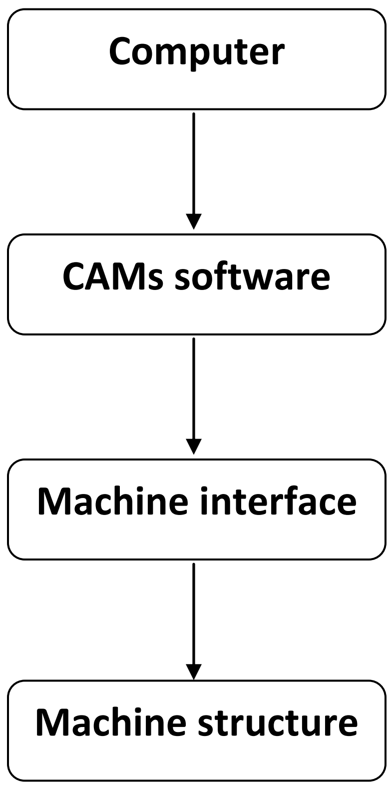


Figure.I.1cnc system

I.4 Stages of CNC work

When the computer is present, Data is transferred at the input and output and compared in memory or on the device, The sensors are read and returned to the computer to compare the input and sensor readings until we reach the lowest possible error rate for the highest accuracy and quality of CNC jobs[3].

- CAD
- CAM

- Machine control and operation Conclusion

I.4.1 Computer-Aided Design (CAD)

Computer design systems are closely related to the development of computer graphics concepts. However, The concepts of computer design go beyond many computer graphics in terms of analysis and modeling. However, Interactive Computer Graphics (ICG) is a necessary technical foundation for computer design systems. It is a software that allows us to draw the geometrical part to be made in all dimensions and then convert the 2D shape to 3D if necessary. It also allows us to model motion-related geometric parts, distribute stresses, And also allows to plot force and moment curves that affect the technical parts to be produced. Then we save the file in a suitable format to get to know the most famous CAM software of these programs[4]:

- Autodesk Inventor
- SolidWorks
- CA TIA

The next figure it explains how to process CAD software: The sketch is beginning from start and adjust settings. If we need draw the 2 dimensions, We choice the 2D icon or if we need draw 3 dimensions, We choice the 3D icon. And we can transfer design 2D to 3D by option in software. After finish the design we export the design to program languages for reading the design by CAM [4].

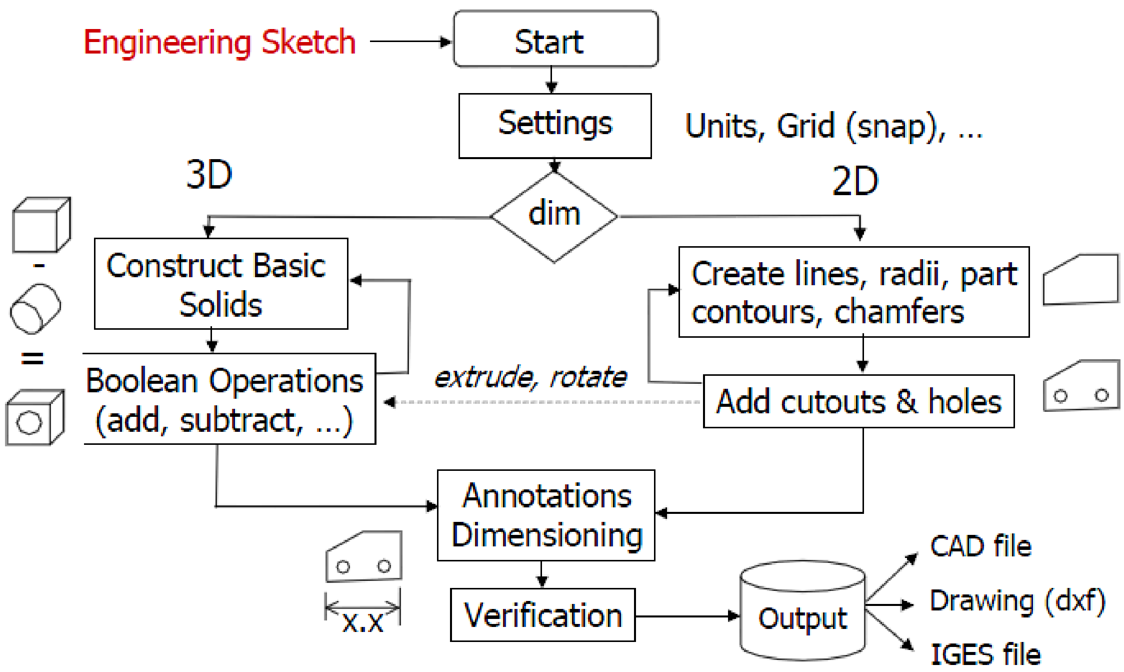


Figure.I.2 generic CAD process

I.4.2 Computer-Aided Manufacturing (CAM)

Computer Aided Manufacturing (CAM) is the use of computer systems to plan, Organize, And control manufacturing processes via direct or indirect computer contact with industrial production sites. A piece of engineering designed using CAD software is converted to GCODE by CAM software, Allowing the CNC machine to interpret the design. This GCODE is communicated directly from the program to the CNC machine through a network cable or indirectly via Flash memory, And the CNC machine's settings are then determined for the start of the manufacturing stage.[5]

The most famous of these programs:

- Surfcam
- PowerMill
- Hsm
- Solidcam

The figure 3 shows and summarized the typical workflow of a CAM system. The order of the definition can be different in different CAM systems, But the definition of the listed data is required every case for appropriate work. The most important application of the CAM systems is the milling technology, So hereafter I focus to this application.

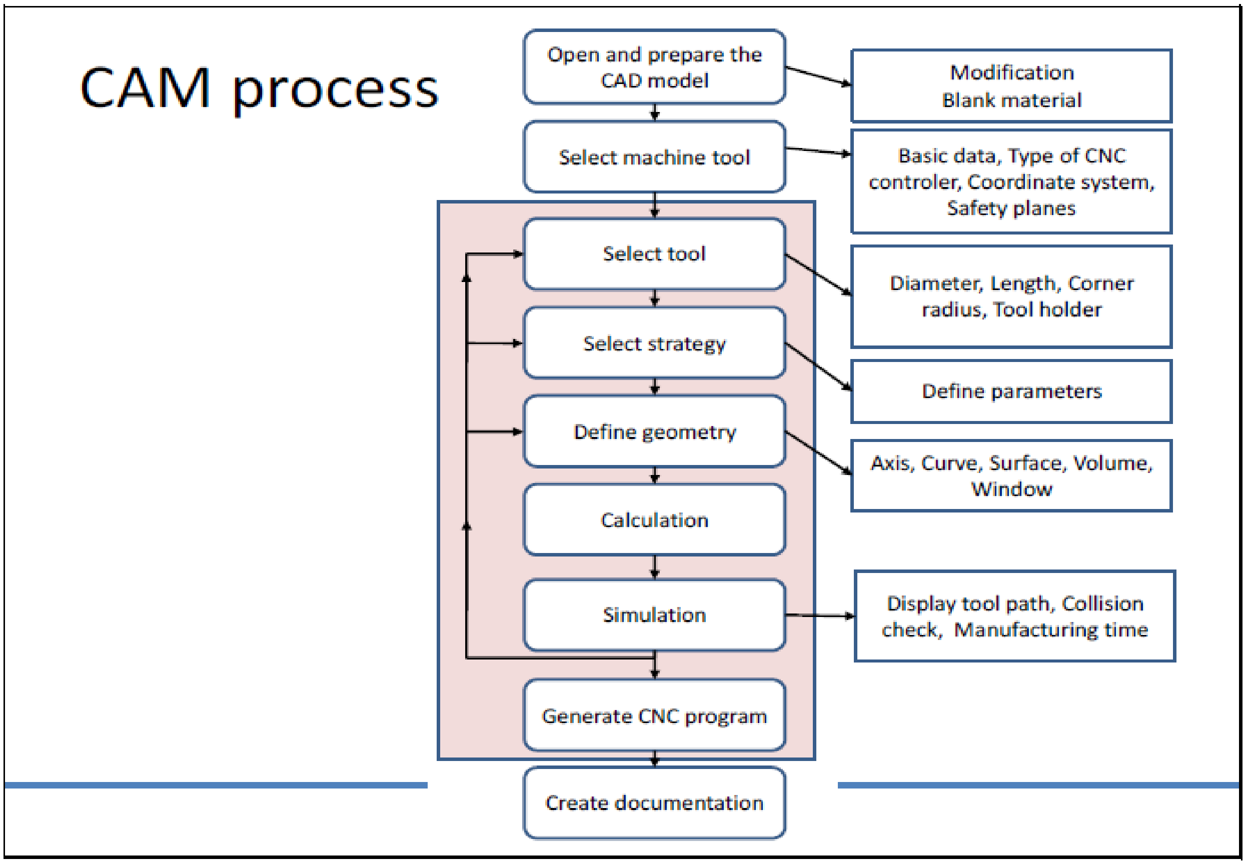


Figure.I.3 workflow of a CAM system

I.5 Types of CNC machines

CNC machines' strength rests in its ability to process a variety of materials with exceptional precision. CNC machines, Unlike other machines, Have demonstrated their effectiveness in handling thick materials and can readily pierce them. Fine details, Such as carving the letter V, Are also possible with CNC equipment. Other machines may struggle to perform this type of precision job, But CNC makes this type of cutting simple. CNC machines offer a lot of benefits and can work with a variety of materials like wood and other materials, Which is why there are so many different types of CNC machines[3].

II.5.1 CNC routers

A CNC router can cut and engrave wood, Metal, Or plastic and is a very common type of CNC machine. The user does not manipulate the router, Only enters information into the computer. Such as milling machines, Lathes machine and grinders [19].

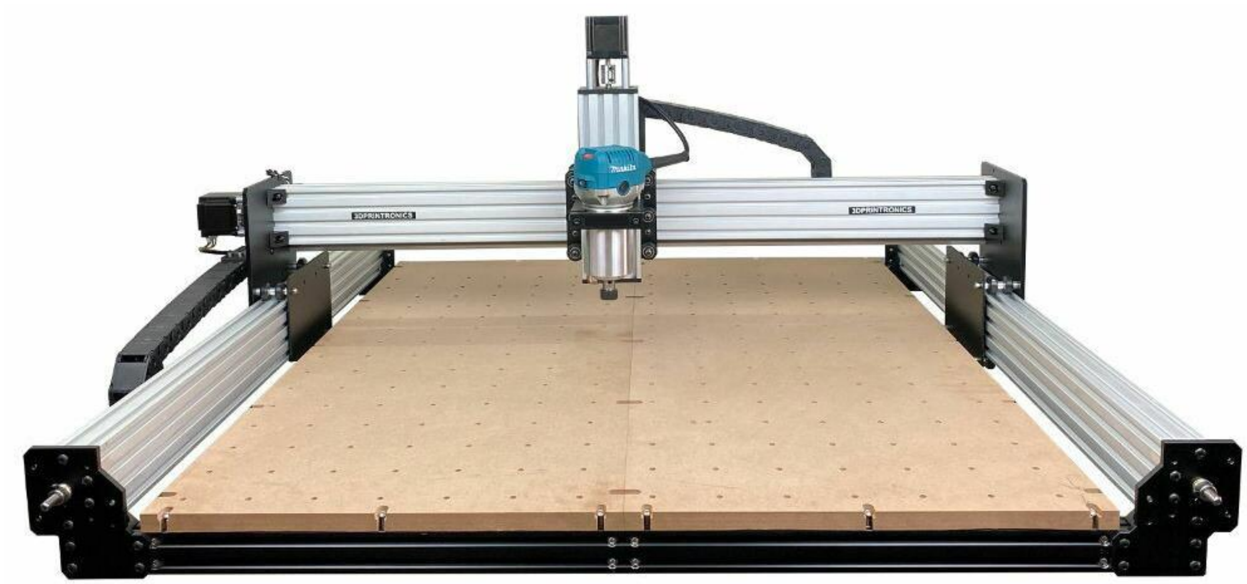


Figure.I.4 CNC routers

II.5.2 Water Jet Cutting

A CNC water jet cutting machine has all of the properties and characteristics associated with water jet cutting. The machines used for CNC water jet cutting are normally flatbed machines with CNC programming connected to the machine’s components. CNC water jet cutting machines are flexible and versatile enough to be customized to fit any production need. [20].

Figure.I.5 Water Jet Cutting

II.5.3 3D printers

Three-dimensional printing is a manufacturing of solid objects by the deposition of layers of material (such as plastic) in accordance with specifications that are stored and displayed in electronic form as a digital model [21].

Figure.I.63D printers

II.5.4 Lathes Lath

One of the types of CNC machines that are used in the filling and manufacture of metals by rotating the artifacts to be formed, Giving them the desired shape[22].

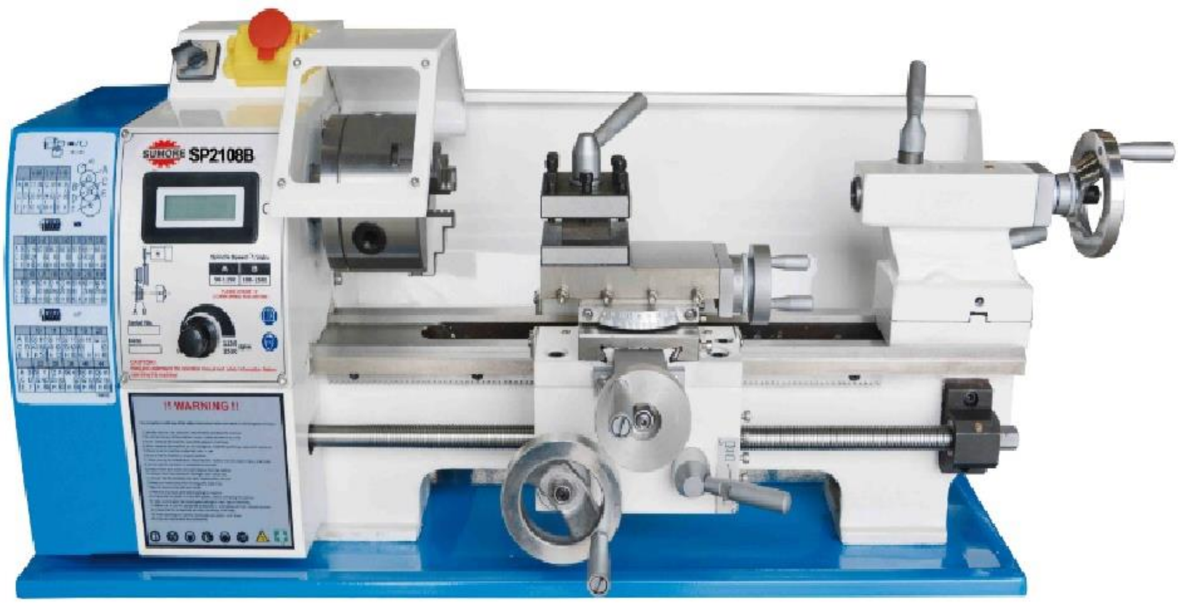


Figure.I.7 Lathes Lath

II.5.5 Milling Machine

It is a machine which is used to remove metals from the work piece with the help of a revolving cutter called milling cutter. It is used to machined the flat, rough and irregular surfaces and this is done by feeding the work piece against a rotating milling cutter [23].

Figure.I.8 Milling Machine

II.5.6 Plasma Cutters

Plasma cutting is a non-conventional manufacturing process used for the processing of a variety of electrical conducting materials (such as carbon steel, stainless-steel, Aluminum, cast iron and non-ferrous metals) [24].

Figure.I.9 Plasma Cutters

I.6 Advantage

- CNC machines can be used continuously 24 hours a day, 365 days a year and only need to be switched off for occasional maintenance.
- CNC machines are programmed with a design which can then be manufactured hundreds or even thousands of times. Each manufactured product will be exactly the same.
- Less skilled/trained people can operate CNCs unlike manual lathes / milling machines etc.. Which need skilled engineers.
- CNC machines can be updated by improving the software used to drive the machines
- Training in the use of CNCs is available through the use of 'virtual software'. This is software that allows the operator to practice using the CNC machine on the screen of a computer. The software is similar to a computer game.
- CNC machines can be programmed by advanced design software such as Pro/DESKTOP®, Enabling the manufacture of products that cannot be made by manual machines, Even those used by skilled designers / engineers.
- Modern design software allows the designer to simulate the manufacture of his idea. There is no need to make a prototype or a model. This saves time and money.

- One person can supervise many CNC machines as once they are programmed they can usually be left to work by themselves. Sometimes only the cutting tools need replacing occasionally.
- A skilled engineer can make the same component many times. However, If each component is carefully studied, Each one will vary slightly. A CNC machine will manufacture each component as an exact match[6].

I.7 Disadvantage

- CNC machines are more expensive than manually operated machines, Although costs are slowly coming down.
- The CNC machine operator only needs basic training and skills, Enough to supervise several machines. In years gone by, Engineers needed years of training to operate centre lathes, Milling machines and other manually operated machines. This means many of the old skills are been lost.
- Less workers are required to operate CNC machines compared to manually operated machines. Investment in CNC machines can lead to unemployment.
- Many countries no longer teach pupils / students how to use manually operated lathes / milling machines etc... students no longer develop the detailed skills required by engineers of the past. These include mathematical and engineering skills[6].

I.8 Conclusion

This chapter is overview of the CNC machine ,Where we have divided it into two mainly parts: The first concerns the history and working principle of CNC machine, The second part introduces the famous types used with the advantages and disadvantages of their.

Chapter II

Hardware and Software

II.1 Introduction:

Due to the complexity and the high prices of most CNC equipment in the markets, The idea came to make a prototype with simpler and cheaper components. To do that, We can divide the work into three main parts.

- Program of instructions.
- Electrical and electronic
- Mechanical (Machine tool).

This is what we will introduce in this chapter.

II.2 Program of instructions

In this section, We will review the software related to operating the machine and adjusting its basic parameters to get the best results. We will also review the software on computer, Which will send the G-code to print the design.

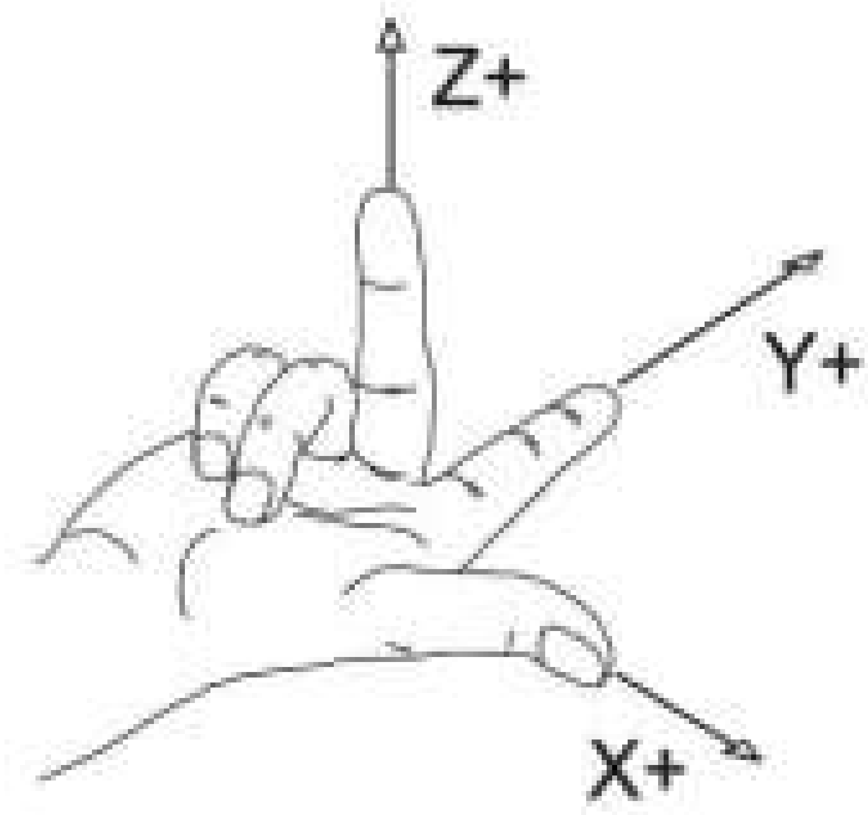
II.2.1GRBL

GRBL is free, High performance, Open source software written in C language, That control moving machine, Run on Arduino. Created by SimenSvaleSkogsrud in 2009. Due to the simplicity GRBL, It's used in many diy projects such open source CNC, 3D printer, Laser cutter and plotter[7].

II.2.2 G-code:

G-Code is a special programming language that is interpreted by Computer Numerical Control (CNC) machines to create motion and other tasks. It is a language that can be quite complex at times and can vary from machine to machine. The basics, However, Are much simpler than it first appears and for the most part follows an industry adopted standard.

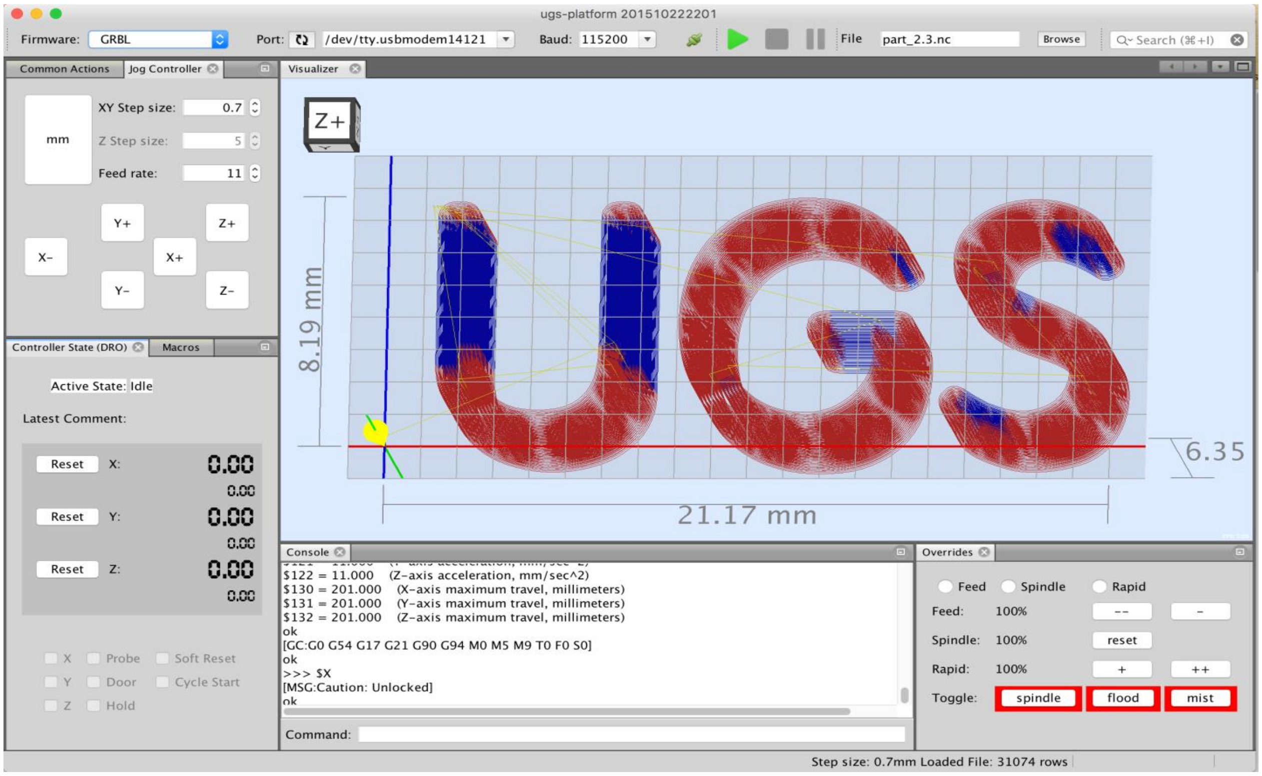
In describing motion of a machine it will always be described as tool movement relative to the work piece. In many machines the work piece will move in more axes than the tool; However the program will always define tool movement around the work piece. Axes directions follow the right hand rule, See figure below[5].



FigureII.1Dimensions of control for G-code

II.2.3 Universal G-code Sender:

A full featured G-code platform used for interfacing with advanced CNC controllers like GRBL , TinyG, g2core and Smoothieware. Universal G-code Sender is a self-contained Java application which includes all external dependencies and can be used on most computers running Windows, MacOSX or Linux.[8]



FigureII.2 Platform of software Universal G-code Sender

II.2.3.1Features

- Cross platform, Tested on Windows, OSX, Linux, and Raspberry Pi.
- 3D G-code Visualizer with color coded line segments and real time tool position feedback.
- Duration estimates.
- Support for Gamepads and Joysticks
- Web pendant interface
- Over 3000 lines of unit test code, And another 1000 lines of comments documenting the tests.
- Configurable G-code optimization:
    - Remove comments
    - Truncate decimal precision to configurable amount
    - Convert arcs (G2/G3) to line segments
    - Remove whitespace[8]

II.3 Electrical and electronic:

This section includes all the electronic parts required for the project, Which represent the main pillar of the project. The electronic circuit that includes the controller (Arduino) will represent the link between the mechanical body and the computer, Where the computer sends commands to move the motors as well as make accessories to the electronic circuit, Which in turn converts it into commands to move the motors, In this section, We will review The electronic characteristics of the project and the practical features in order to have a clear perception of the elements used and why these items were chosen over others.

We will first review these pieces and then move on to explain them in detail, the main pieces are:

- Electronic circuit
- Stepper motors
- Additional accessories

II.3.1 Electronic circuit

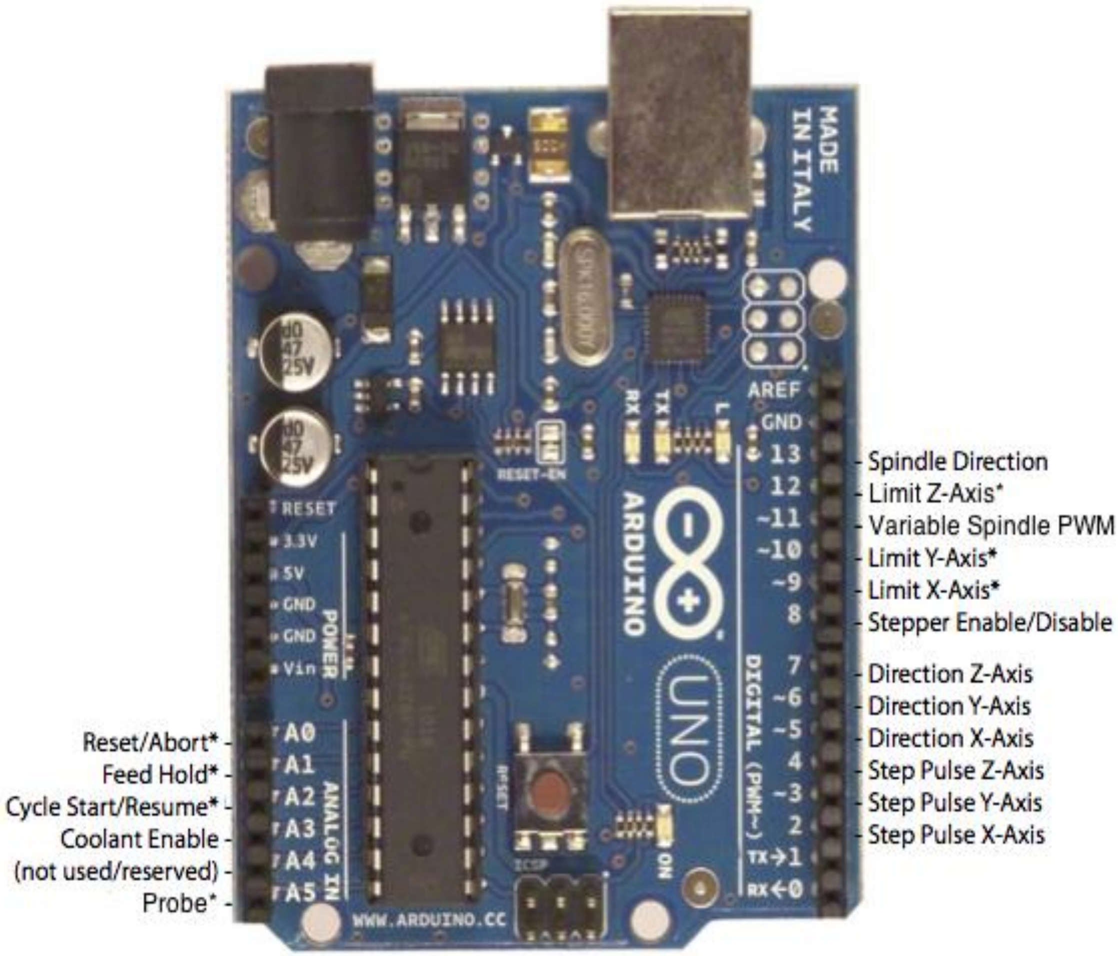
The microcontroller is the cornerstone of the electronic circuit, Which contain GRBL library that lead the CNC machine, And we choose in our project Arduino Uno board for ease of programming and handling.

II.3.1.1What is Arduino Uno:

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, A 16 MHz quartz crystal, A USB connection, A power jack, An ICSP header and a reset button.[9]

II.3.1.2How to connect its pins:

As shown in the figure below the GRBL library has specific way to connect the Arduino Uno with rest of component.



FigureII.3 Indicates input pins held high with internal pull-up resistors

II.3.2Stepper motors:

A stepper motor is an electromechanical device. The shaft or spindle of a stepper motor rotates in discrete step increments when electrical command pulses are applied to it in the proper sequence. The motors rotation has several direct relationships to these applied input pulses. The sequence of the applied pulses is directly related to the direction of motor shafts rotation. The speed of the motor shafts rotation is directly related to the frequency of the input pulses and the length of rotation is directly related to the number of input pulses applied[10].

II.3.2.1Why we use stepper motors:

Due to precise control, stepper motors are commonly used in medical, satellites, robotic and control applications. There are several features common to all stepper motors that make them ideally suited for these types of applications. They are as under

- High accuracy: Operate under open loop
- Reliability: Stepper motors are brushless.
- Load independent: Stepper motors rotate at a set speed under differentload provided the rated torque is maintained.
- Holding torque: For each and every step, The motor holds its position without brakes.

II.3.2.2 Types of stepper motors:

It can be classified into several types according to machine structureand principle of operation . Basically there are three types

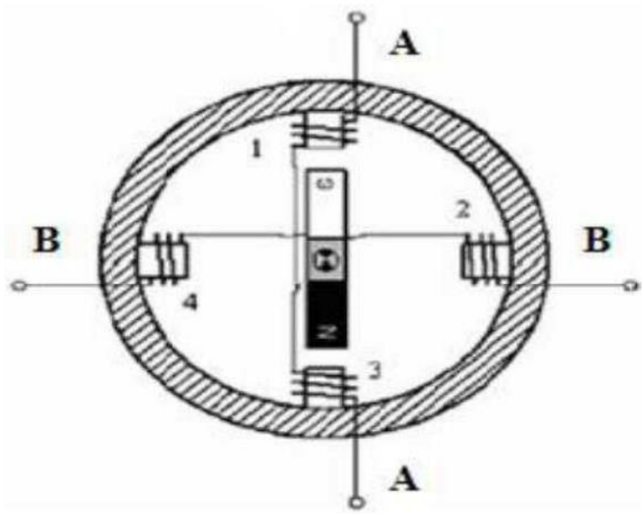
- Variable Reluctance Motor (VRM)
- Permanent Magnet Stepper Motor (PMSM)
- Hybrid Stepper Motor (HSM)

We chose Hybrid Stepper Motor due to our needs and its characteristics which we will be shown next.

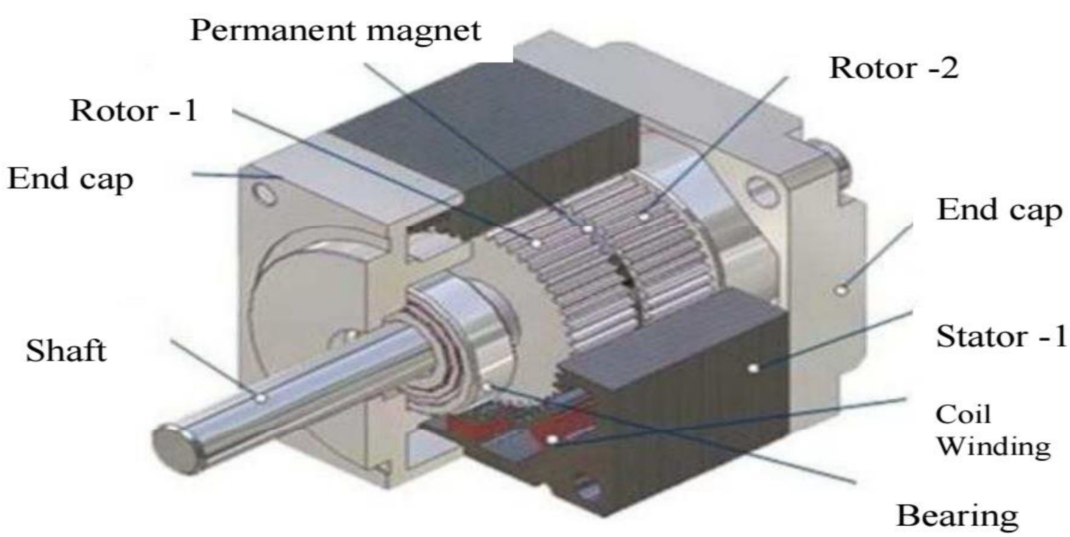
II.3.2.2.1 Hybrid Stepper Motor:

The term 'hybrid' is derived from the fact that motor is operated with the combined principles of the permanent magnet and variable reluctance motors in order to achieve small step length and high torque in spite of motor size.

Standard HSM have 50 rotor teeth and rotate at 1.8 degree per step. Figures below show a cross section and cut view of two phase HSM. The windings are placed on the stator poles and a PM is mounted on the rotor. The important feature of the HSM is its rotor structure. A cylindrical or disk-shaped magnet lies in the rotor core. Stator and rotor end-caps are toothed. The coil in pole 1 and pole 3 is connected in series consisting of phase A and poles 2 and 4 are for phase B. If stator phase A is excited pole 1 acquires north polarity while pole 2 acquires south polarity. Pole 1attracts the rotor's south pole while pole 3 aligns with the rotor's north pole [11] .



FigureII.4 Cross-section of HSM



FigureII.5 Cut view of HSM

When the excitation is shifted from phase A to phase B, In which case the stator pole 2 becomes north pole and stator pole 4 becomes south pole, It would cause the rotor to turn 90° in the clockwise direction. Again phase A is excited with pole 1 as south pole and pole 3 as north pole causing the rotor to move 90° in the clockwise direction.

If excitation is removed from phase A and phase B is excited, Then pole 2 produces south pole and pole 4 produces north pole resulting in rotor movement of 90°in the clockwise direction. A complete cycle of excitation for the HSM consists of four states and produces four steps of rotor movement. The excitation state is the same before and after these four steps and hence the alignment of stator/rotor teeth occurs under the same stator poles .The step length for a HSM and angle through which the rotor moves for each step pulse is known as step angle and is calculated by Step length = 90o/Nr

Step angle is calculated using the formulaWhere

θ - Step angle in degrees

Ns - Number of stator teeth

Nr - Number of rotor teeth

m - Number of phases

Mechanical angle represents the step angle of the step. In the full step mode of a 1.8° motor, the mechanical angle is 1.8°. In the 10 micro step mode of a 1.8° motor, the mechanical angle is 0.18º. An electrical angle is defined as 360° divided by the number of mechanical phases and the number of micro step. In the full step mode of a 1.8° motor, The electrical angle is 90°. In the 10 micro step excitation of a 1.8° motor, the electrical angle is 9º.

HSM material properties for each part and standard step angle of

HSM are tabulated in Table 1 and Table 2 respectively[11].

Table II.1: Material properties of HSM

S.No	Motor Part	Material
1	Shaft	Non-Magnatic material
2	Magnet	Neodymium Iron Boron (NdFe) / Samarium Cobalt ($SMCO_5$)
3	Rotor core	Steel sheet
4	Stator core	Steel sheet
5	Coil	Copper

Table II.2: Standard step angle of HSM

Step angle	Steps per revolution
0.9°	400
1.8°	200
3.6°	100
7.2°	50
15°	24

II.3.2.2.2Advantages of Stepper Motor

1. Step angle error is very small and non-cumulative.

2. Rapid response to starting, Stopping and reversing.

3. Brushless design for reliability and simplicity.

4. High torque per package size.

5. Holding torque at standstill.

6. Can be stalled repeatedly and indefinitely without damage.

7. No extra feedback components required (encoders)[12].

II.3.2.2.3Disadvantages

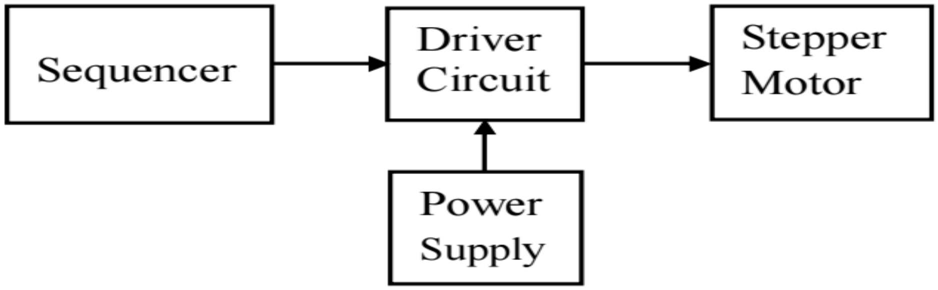
1. Resonance

2. Vibration

3. Torque ripple [12].

II.3.2.3 system of stepper motor

Stepper motor requires sequencers and driver to operate. Sequencer generates sequence for switching which determines the direction of rotation and mode of operation. Driver is required to change the flux direction in the phase windings. The block diagram of stepper motor system is shown in Figure below[12].



FigureII.6diagram of stepper motor system

II.4 Mechanical (Machine tool)

In this section we will represent the mechanical tools that convert the rotation of stepper motors to linear move

II.4.1 Ball screw

A ball screw (or ballscrew) is a mechanical linear actuator that translates rotational motion to linear motion with little friction. A threaded shaft provides a helical raceway for ball bearings which act as a precision screw. As well as being able to apply or withstand high thrust loads, they can do so with minimum internal friction. They are made to close tolerances and are therefore suitable for use in situations in which high precision is necessary. The ball assembly acts as the nut while the threaded shaft is the screw. In contrast to conventional lead screws, ball screws tend to be rather bulky, Due to the need to have a mechanism to recirculate the balls [13] .

FigureII.7 ball screw

II.4.2 Lead screw

A lead screw is a kind of mechanical linear actuator that converts rotational motion into linear motion. Its operation relies on the sliding of the screw shaft and the nut threads with no ball bearings between them. The screw shaft and the nut are directly moving against each other on a large contact area, So higher energy losses due to friction are produced. However, The designs of lead screw threads have evolved to minimize friction[14].

FigureII.8Lead screw

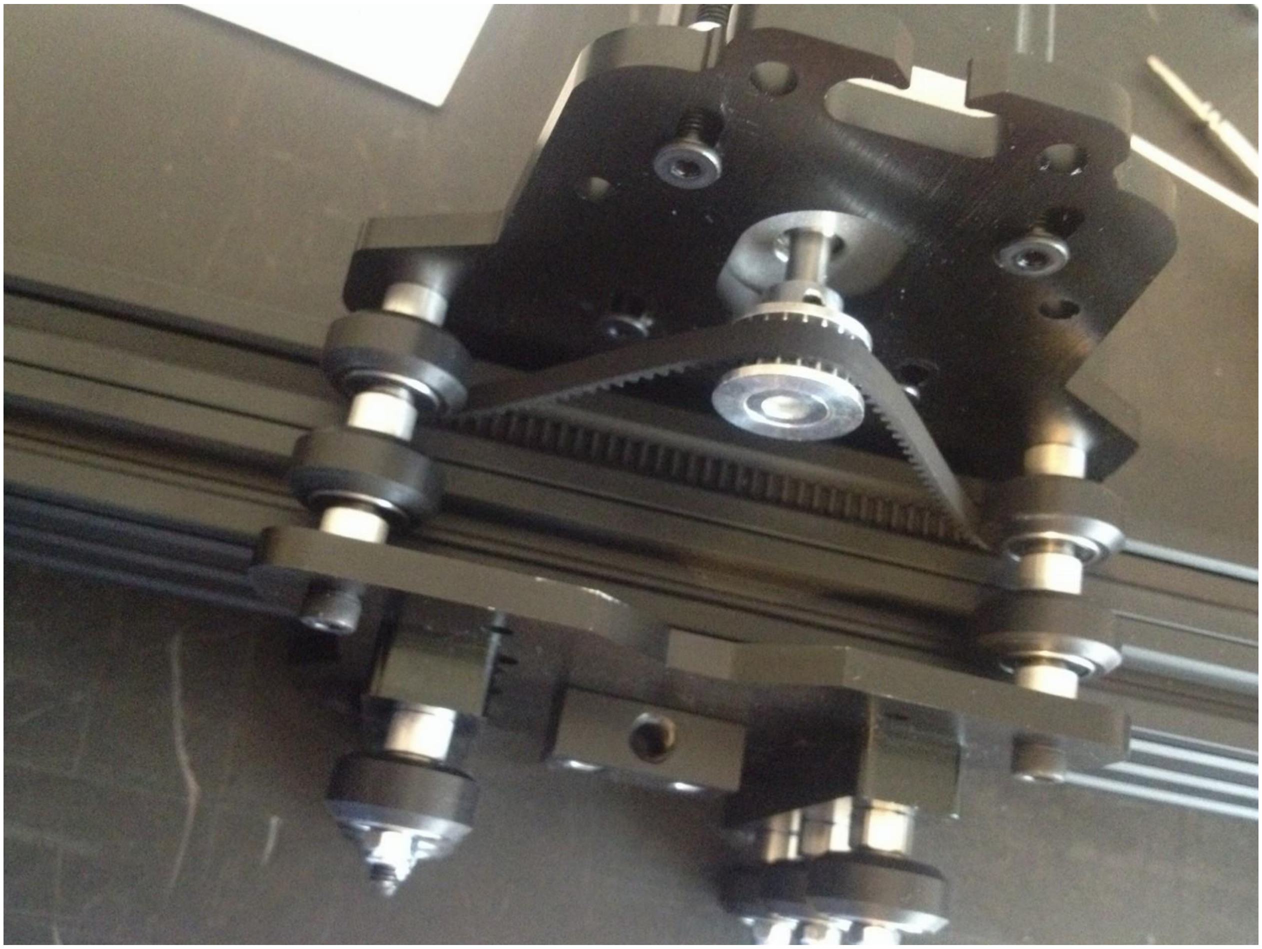
II.4.3 Rack and pinion

Gear racks are utilized to convert rotating movement into linear motion. A gear rack has straight teeth cut into one surface of a square or round section of rod and operates with a pinion, Which is a small cylindrical gear meshing with the gear rack. Generally, Gear rack and pinion are collectively called “rack and pinion”[15].

FigureII.9Rack and pinion

II.4.4 Belt drive

A belt drive is a frictional drive that transmits power between two or more shafts using pulleys and an elastic belt. In most cases, It is powered by friction but it may also be a positive drive. It can operate at wide ranges of speed and power requirements. It is also highly efficient[16].



FigureII.10Belt drive

II.5 Conclusion:

In this chapter, The main components of CNC machine has been represented to make a prototype with the available components local markets. It can to work with the same efficiency compared to what is in the market and at the lowest cost, Which will be implemented in the next chapter.

Chapter III

Prototype implementation

III.1 Introduction

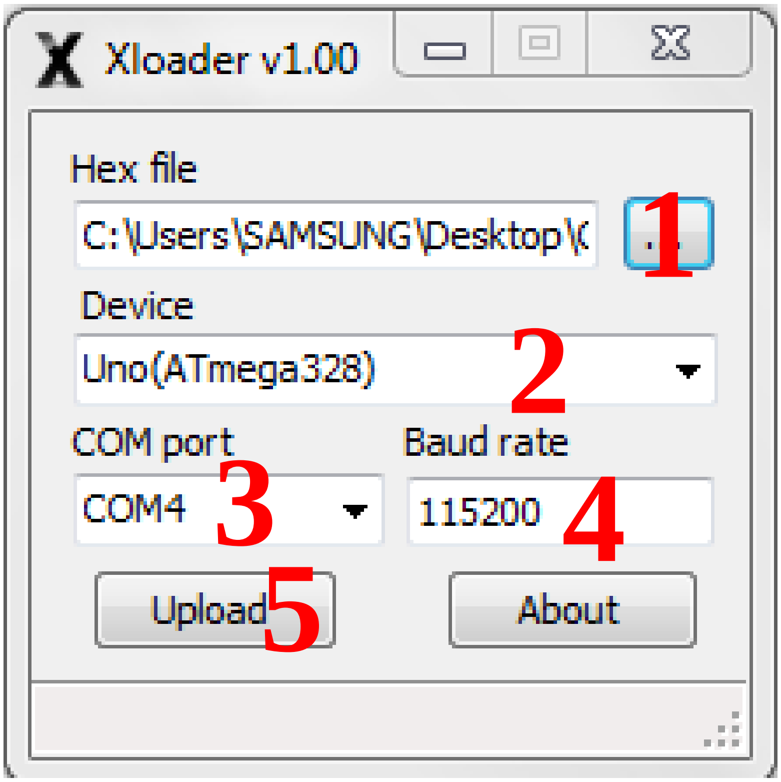
In this chapter, We will try to make a CNC machine with a three dimensional computerized numerical control (CNC) router machine based on the arduino Uno microcontroller. The CNC machine that implemented , Will be controlled with a regular PC where a graphical user interface application was programmed to send a G-code file to the machine.

III.2Arduino Uno

As we explained in Chapter 2, the Arduino Uno is an electronic open-source prototyping platform. It has a significant advantage: it is simple to use (allowing for time savings), which is why we chose it for our project.

The board can be powered by an external power supply ranging from 6 to 20 volts. The 5V pin may only give five volts if the supplied voltage is less than 7V, leading the board to become unstable. The voltage regulator may become overheated and destroyed if the input voltage exceeds 12V. As a result, the voltage range recommended is 7 to 12 volts [9].

Arduino Uno represents the interface of our machine, so we upload GRBL1.1h using Xloader to prevent any problem during the process, as showing in Figure III.1 [7].



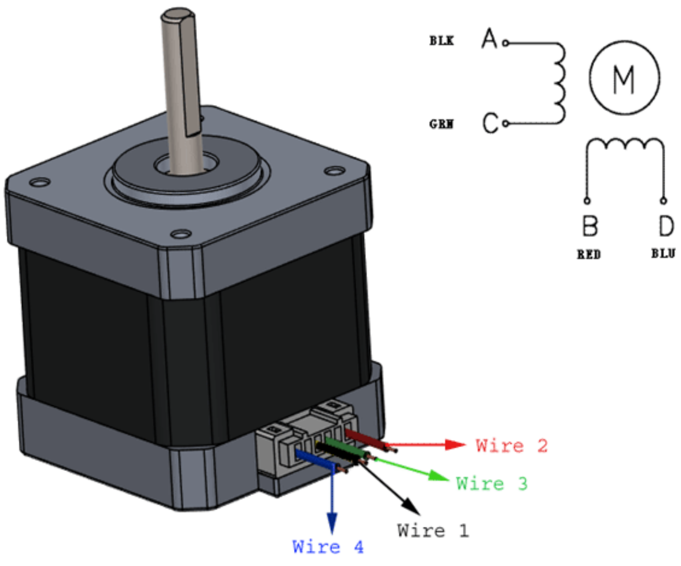
FigureIII.1 Xloader interface

1. File location.
2. Device type.
3. Port number.
4. Data transfer speed bits per second.
5. Upload to device.

III.3Stepper motors:

In our project,we use the Nema 23 stepper motor which is a hybrid stepping motor can be used as an unipolar or bipolar stepper motor and has a 1.8° step angle (200 steps/revolution),each phase draws 2.8 A at 3.2 V, allowing for a holding torque of 19 kg-cm.

FigureIII.2 Stepper motors"Nema 23"

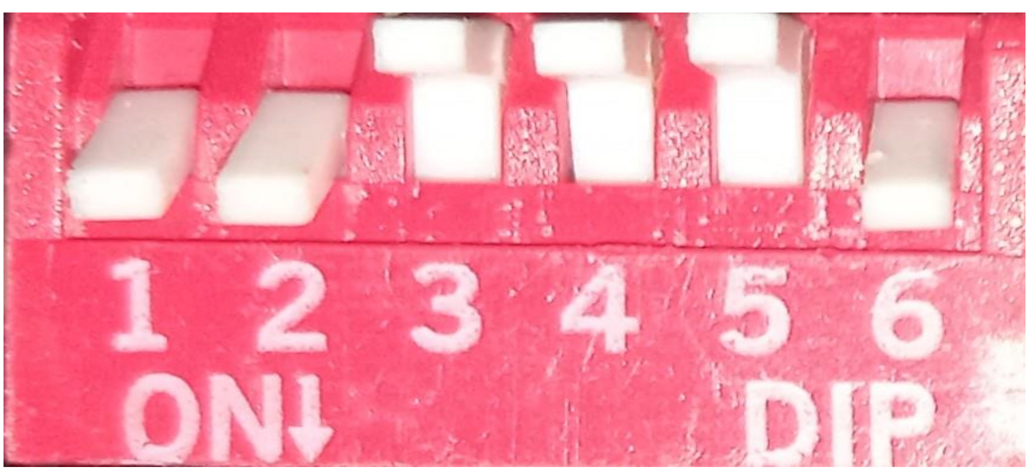


FigureIII.3 stepper motor wire

III.4Drivers:

TB6600 Stepper motor driver is a cheap and effective device which provides microstepping ability to a stepper motor. It is suitable for driving 2 phase and 4 phase hybrid stepper motors. The motor driver compatible with any microcontroller providing a 5V signal. We configure our drivers based on the characteristic of the motors, current 2.8 A, 200 steps/revolution.

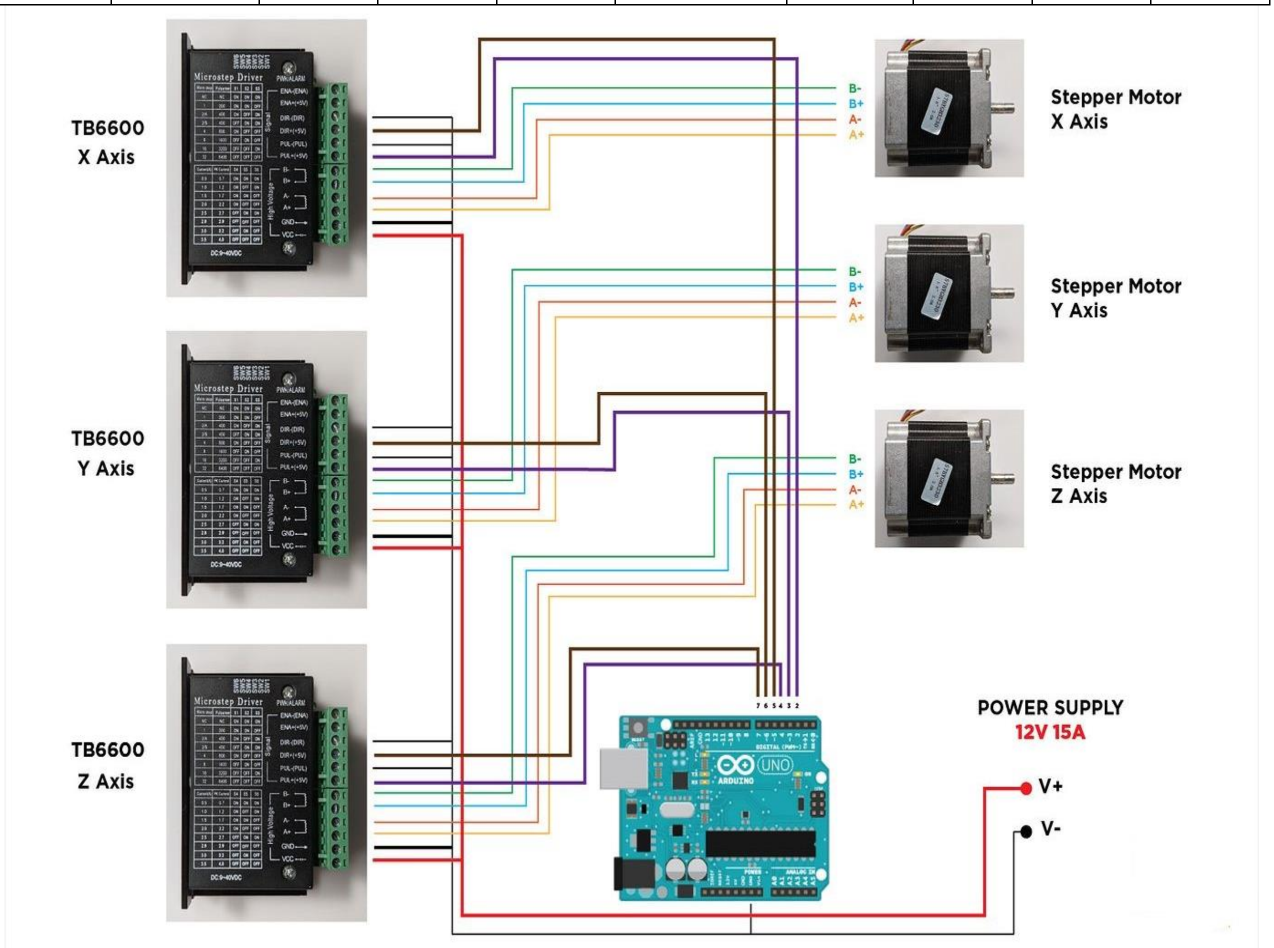
FigureIII.4 Driver's input and output



FigureIII.5 Dip switch configuration

TableIII.1 Tb6600 table of configuration

Micro step	Pulse/rev	S1	S2	S3	Currant(A)	Pk currant	S4	S5	S6
NC	NC	On	On	On	0.5	0.7	On	On	On
1	200	On	On	Off	1.0	1.2	On	Off	On
2/A	400	On	Off	On	1.5	1.7	On	On	Off
2/B	400	Off	On	On	2.0	2.2	On	Off	Off
4	800	On	Off	Off	2.5	2.7	Off	On	On
8	1600	Off	On	Off	2.8	2.9	Off	Off	Off
16	3200	Off	Off	On	3.0	3.2	Off	On	Off
32	6400	Off	Off	Off	3.5	4.0	Off	Off	Off



FigureIII.6 Stepper motors and drivers wiring diagram

III.5 Power Supply

For our project ,we have used a power supply with (24 V Dc, 10 amp) for feeding the motors and drivers, and another power supply to feed the spindle(220VAC).

Figure III.7the used Power Supply

III.6 Spindle

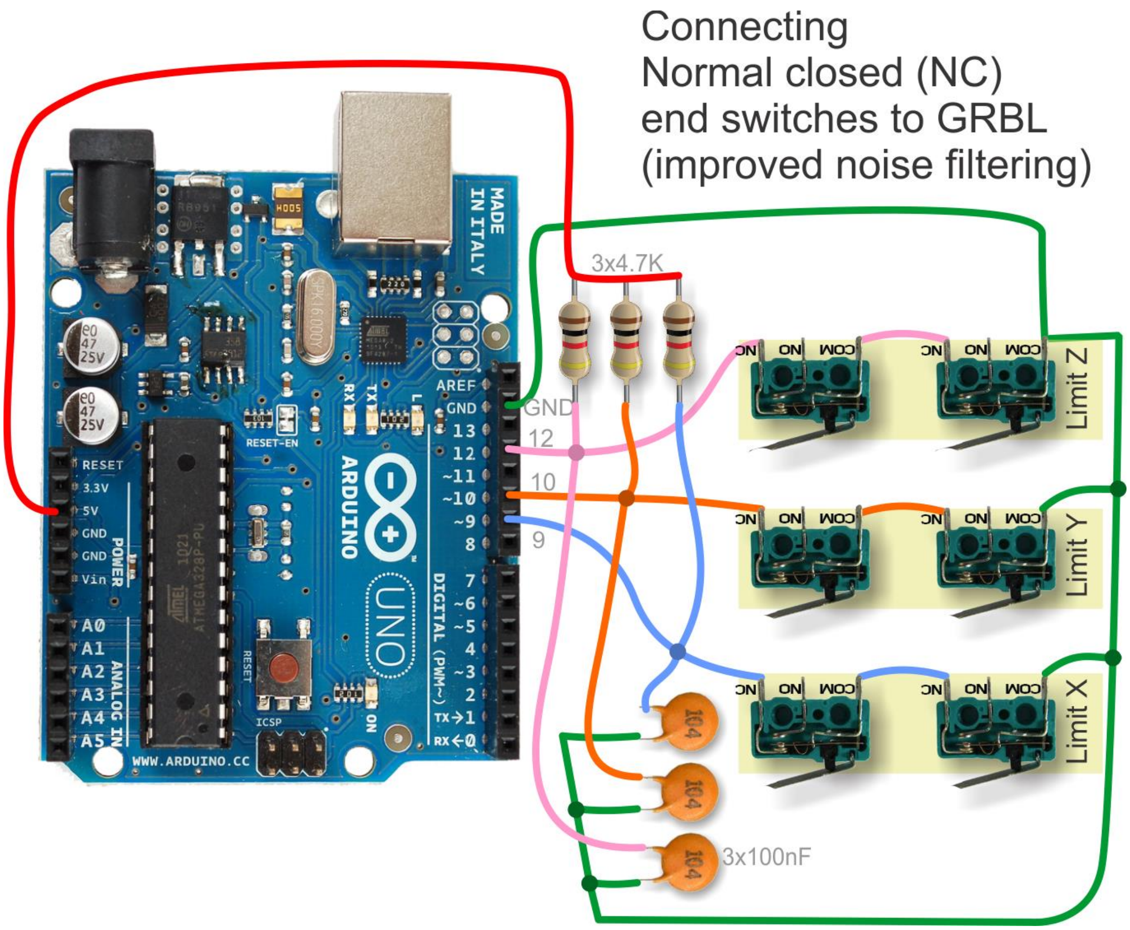
We used"orca paumelleuse"(220 V AC ,500W) spindles for our project because of its low price and good working.

FigureIII.8 spindle

III.7Limit Switch

A limit switch is a switch operated by the motion of a machine part or the presence of an object. A limit switch can be used for controlling machinery as part of a control system, as a safety interlock, or as a counter enumerating objects passing a point.

FigureIII.9 Limit switch



FigureIII.10 Limit switch wiring diagram

III.8 Model relay

To switch the spindle on with the Arduino we need a simple relay module with operating Voltage 5V . We will Connect power and then switch the relay on by applying a low signal to the "IN" pin. The module has three screw terminal connections connected to the relay that include common, normally open (N.O.), and normally closed (N.C.).

Figure.III.11 Relay model

III.8 Aspire

Aspire is software used to design the plotted diagram or text. using it a G-code file of a selected image or text is created. the G-code is a commonly used numerical control programming language which includes X, Y, Z coordinates[17].

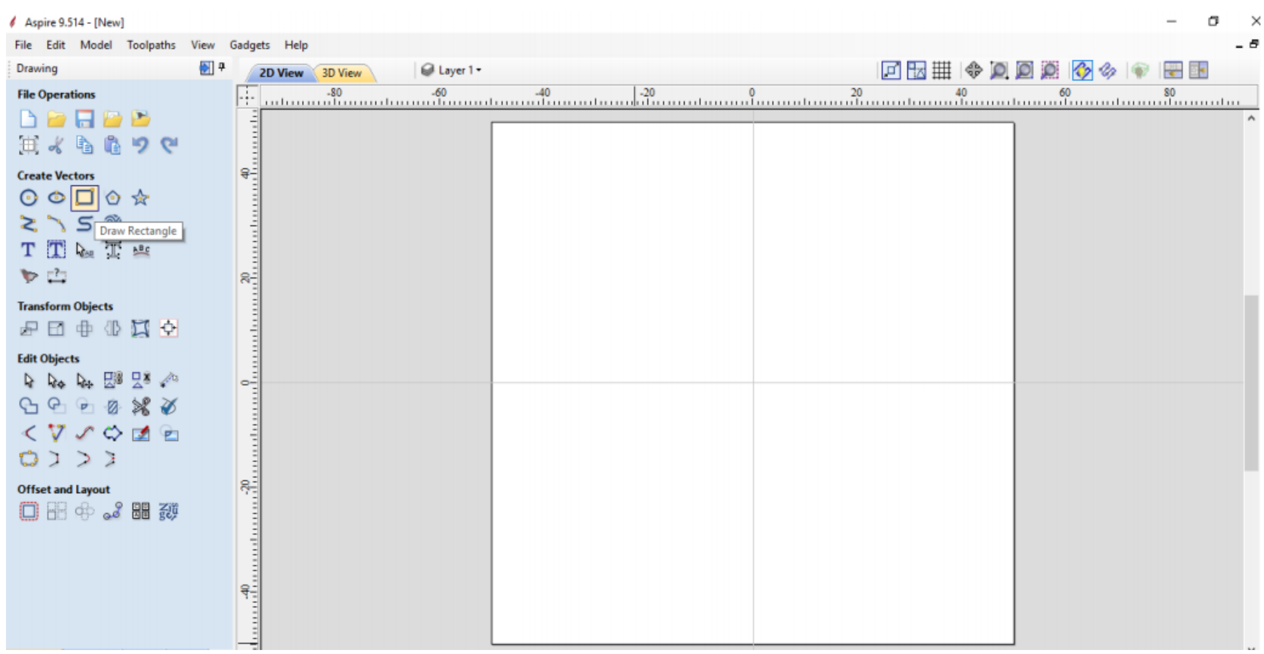


Figure III.12 Aspire Interface

III.8.1 Creating G-Code File Using Aspire

The CNC plotter of our project will work within 95cm/75cm area, So we choose the document properties of the Aspire 95cm/75cm. So we have initially kept the axes at the nearest end of the motors which is considered as origin to easily modify the design. To create G-code of an image, the file must have a transparent background. After we create a new file we draw a rectangle with the a properties of our work space and we draw a picture or text to the middle of it, and then we use the tool paths tab. The tool paths allow us to configure the deep of the engraving and choose the right tool for it. After we finish we save the project as a G-code file to be ready for upload to the GRBL [17].

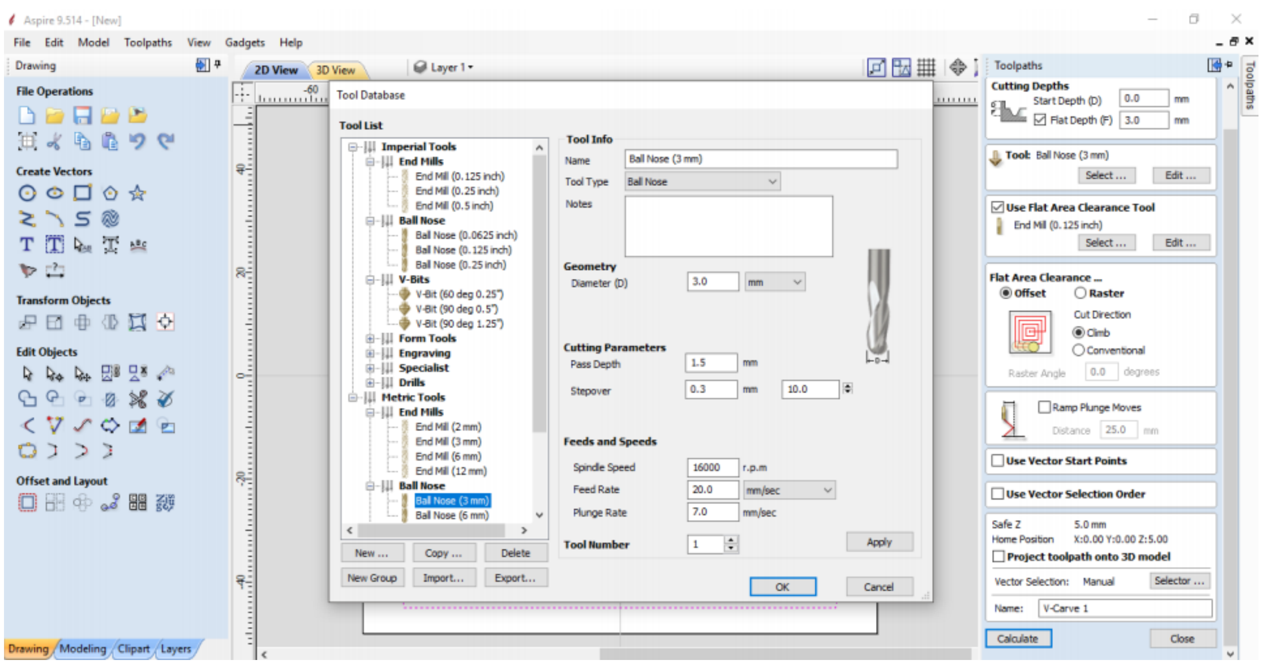


Figure III.13 Aspire toolpaths Tab

III.9 Universal Gcode Sender (UGS)

Universal Gcode Sender, more commonly known as UGS, is free CNC controller software. The “Universal” comes from it being compatible with several different firmware options like GRBL, TinyG, Smoothieware, and G2core. Control software is the communication between your CNC machine and computer [18].

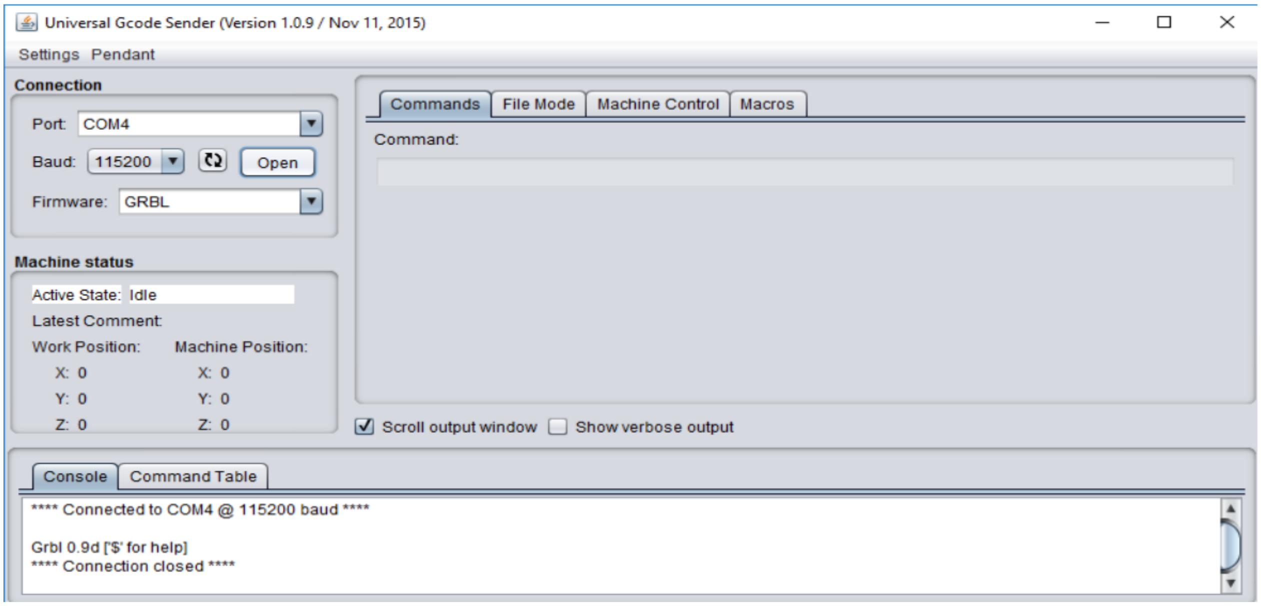


Figure III.14 Universal Gcode Sender

III.9.1 control modes

There are two modes used in this program either manual mode or automatic mode to control the CNC machine. The program provides special buttons in the basic interface which controls each motor separately, which operates these buttons after choosing manual mode.

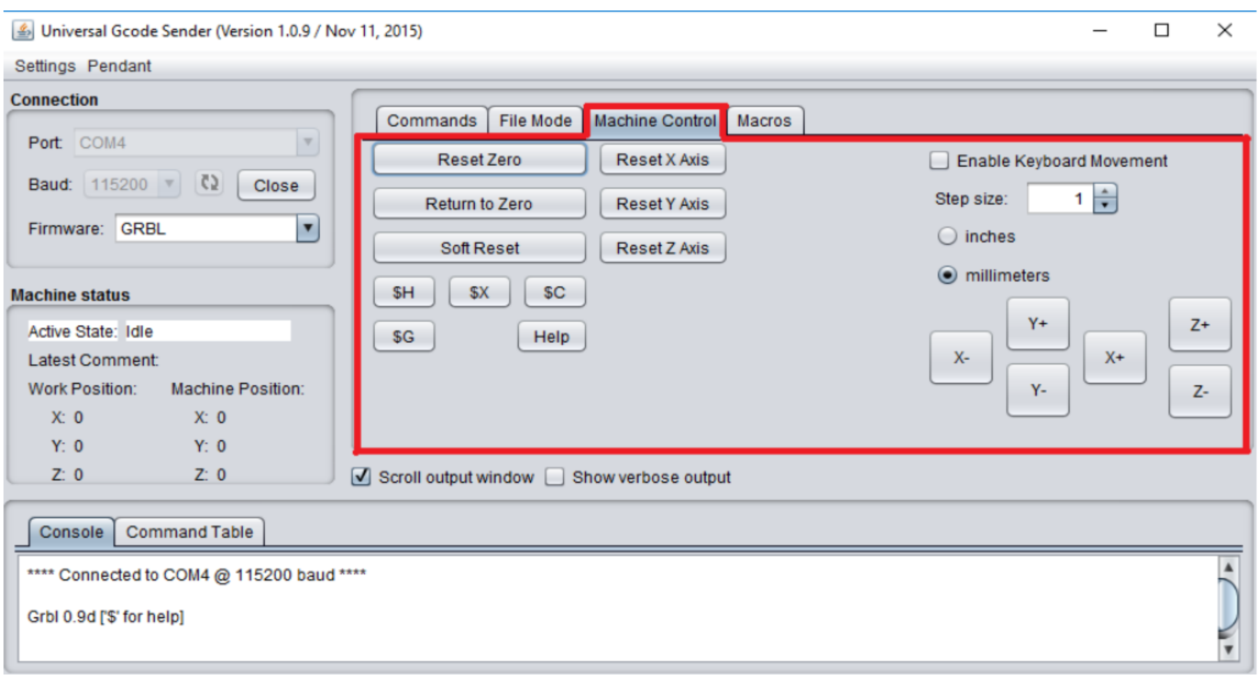


Figure III.15 the interface of "g code sender" in manual mode

For graphic use: automatic mode, Load our G-code file: in the "file mode" tab, do "browse" and select G-code file (.ngc) previously created. By doing "visualize" we can check our layout and the path taken by the tool: in red the work areas (Z<0); in blue the displacements (Z>0)

Figure III.16 the interface of “G-code sender” choose the G-code file.

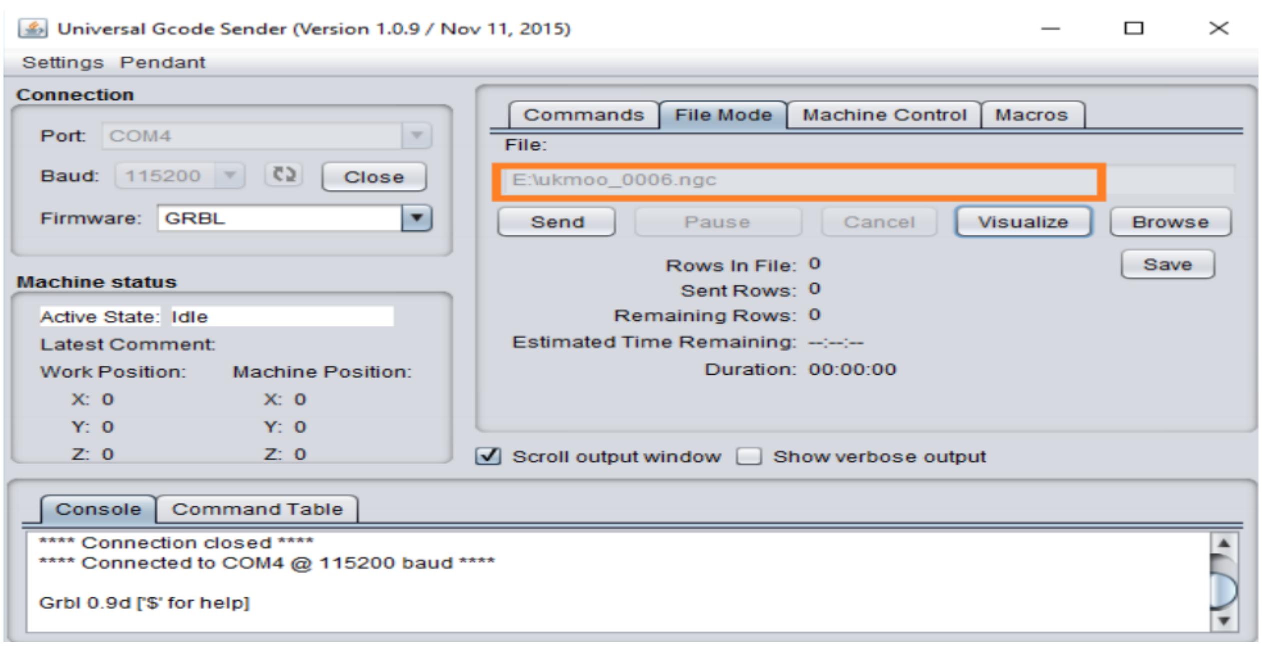


Figure III.17 l'interface de “g code sender” on mode automatique.

Make the zero (the "home"): in the "machine control" tab move the tool with the X, Y and Z buttons. We can modify the displacement step by modifying the "step size". Once the tool position where you want to establish the zero (in contact with our support) click on "reset zero". To start the job: return to the file mode tab and click on "Send".

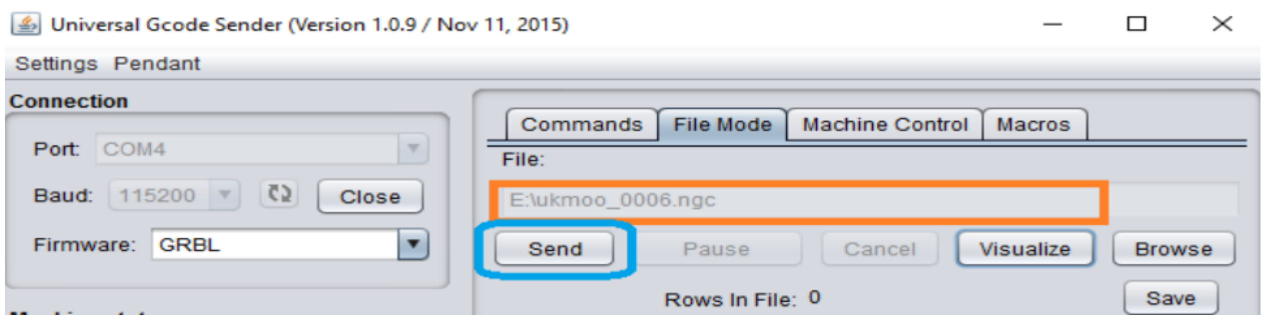


Figure III.18 sent file G code

III.10 Mechanical Design

The Figure III.19 represents the mechanical design of our machine with an explaining its dimensions.

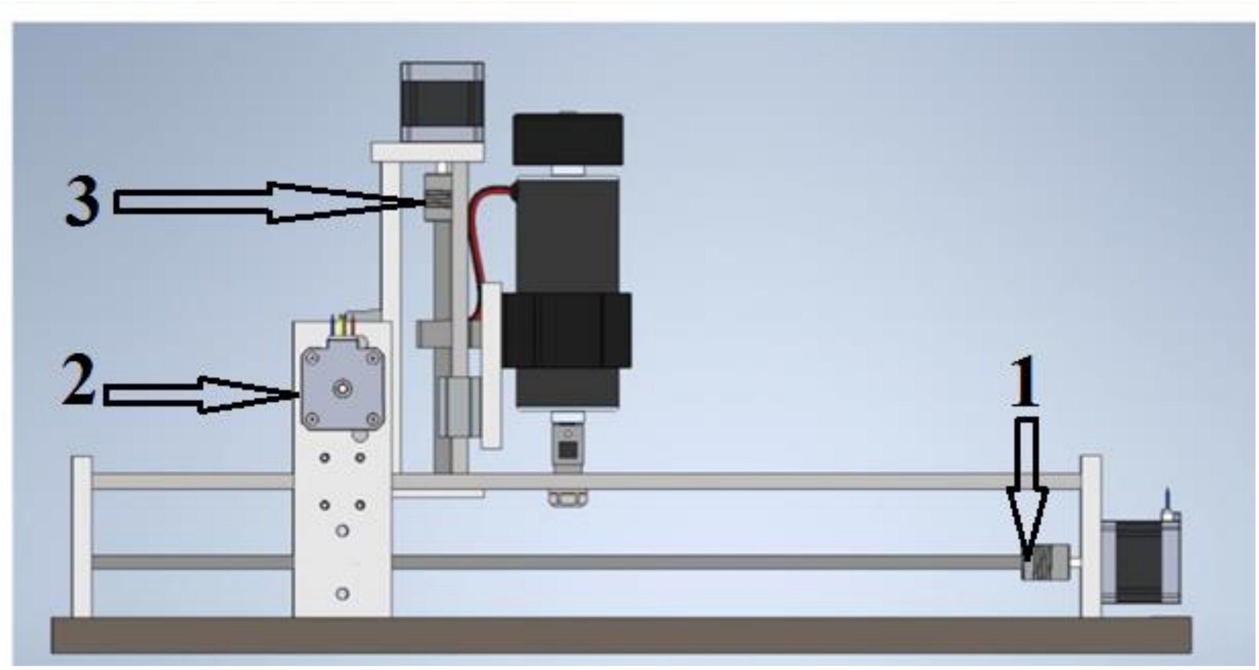


Figure III.19 CNC-machine design side view.

1: X axis 95 cm

2: Y axis 75 cm

3: Z axis 25 cm

III.11 The X axis

This axis aims to convert the rotational motion to a horizontal linear motion, we will helical connection to the axis of the stepper motor by a screw, and this screw is perpendicular to the Y axis and connected to the stator of the machine.

FigureIII.20 The X axis

III.12 Prototype of the CNC-machine

when the stepper motor rotates, the rotation is transmitted to the screw, the Y axis is equipped with a nut, the rotation of the bolt through the nut helps the Y axis to move, the movement of the axis will be very easy due to the presence of the bearings on both sides of the axis.

FigureIII.21 front view of machine

1: stepper motor

2: screws

3: nut

4: bearings

The principle for the X axis is the same as that of the Y axis.

Z axis is the same principle of the Y axis except that the bearings on both sides are replaced by a linear guide.

FigureIII.22 top view of machine

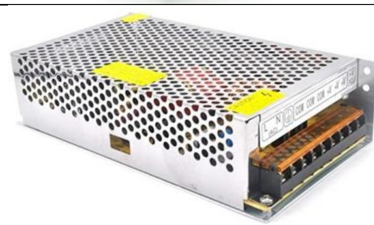
1: stepper motor

2: screws

3: nut

III.13 Cost of Project:

Table III.2 Cost electrical and mechanical parts

Electrical parts			
Stepper motor		**3**	**12000.00 DA**
Arduino uno		**1**	**1200.00 DA**
Driver		**3**	**13500.00 DA**
Power Supply		**1**	**2500.00**
Limit switch		**6**	**300.00 DA**
Model relay		**1**	**200.00 DA**
spindle		**1**	**3000.00 DA**

Mechanical parts			
Lead screw		**3**	**3000.00 DA**
ball bearing		**30**	**4200.00 DA**
Linear Shaft		**2**	**800.00 DA**
Total amount			**40500.00 DA**

III.14 Conclusion

The final result of this project is the completion of the manufacture of the CNC machine with a medium workspace (95 cm in Y-axis, 75 cm in X-axis and 25 cm in Z-axis). The machine was successfully run and tested in several operation tests.

General Conclusion

In this work, we have known one of the famous industrial technology which is Computer Numerical Control (CNC) . After a hard work to create the CNC prototype, we have learned many skills, in electronics and designing .

In electrical part, we have studied the stepper motor NEMA23 mechanism, and its control theory, we used TB6600 the stepper motor driver. These motors were very helpful in our project

This work allows us to explore the practical side of automatic field, the real problems of realization and programming, also expand our knowledge in the field of automatic control. On the other hand, this work allows us to have an idea about CNCs design and applications.

Also, in this work, we have learned using Aspire and Universal Gcode Sender software to control the CNC machine based on Arduino Uno microcontroller.

At the end, The results obtained by our CNC are acceptable after such a hard work, As further work, We are looking forward to develop this prototype to perform more complicated and more precise operations.

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