A Micro-Controller Controlled 3 Axis CNC Machine for Engraving and Designing

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Under the Supervision of

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DECLARATION

We, hereby declare that this thesis is based on the results found by ourselves. Materials of work found by other researcher are mentioned by reference. This Thesis, neither in whole or in part, has been previously submitted for any degree.

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List of Abbreviations

2-D- 2 Dimensional

BED- Big easy Driver

CNC – Computer Numerical Control

CAD- Computer Aided Design

EMC- Enhanced Machine Controller

G-Code- G-code is the generic name for a control language for CNC

GRBL- G-code Interpreter

SVG- Scalable Vector Graphics

Abstract

The expansion in the fast development of innovation altogether expanded the use and usage of CNC machines yet is costly. This paper examines the outline viewpoints and machinability investigation of low cost CNC machine cum engraver which is fit for 3-axis synchronous operation with less complexity. The additional Bluetooth highlight makes the machine more easy to use to work utilizing a cell phone separated from USB.The lower cost is accomplished by interfacing standard PC with micro controller based CNC framework in an Arduino based embedded system. After the completion of machining, experimental trials to define machining parameters were held. The purpose of the Self-Guided CNC project is to construct a functional CNC type machine capable of tracking lines on and object to guide the armature in cutting the piece correctly. The device would be capable of functioning independent of off-board computers for both operation and determining cutting paths. The goal is not only high-precision cuts but also design and plot.

CHAPTER 01

Introduction

First of all we have to know what CNC is. CNC is an acronym for Computer Numeric Control where less human interaction with high precision plotting jobs can be done. With the help of CAD (computer aided design) or CAM (computer aided manufacturing) programs, a 2-D or 3-D version of any image can be implemented on a plain surface[17]. This image is later translated to extricate the orders required to work a specific machine by means of a post processor, and at that point stacked into the CNC machines for creation. Despite the fact that idea of CNC based machines was created in mid-twentieth century and has experienced numerous improvements, the cost is an imperative factor that stays unchanged[12]. Because of the high cost of these machines many are not ready to possess one despite the fact that they have to do some valuable machining operations.

1.1 Motivation

Low cost CNC machines are perfect for offering preparing students especially in the field of Engineering on the grounds that the cost and upkeep of the machine is low. As the utilization of cell phone is expanding step by step, interfacing the machine with cell phones utilizing bluetooth network makes it easier to understand[5]. The littler size make it compact, portable and the segments can effortlessly be dismantled or gather. The size, space and vitality required for the machine is additionally lessened. It presently requires just less material and parts to make the machine, consequently cutting down the cost extraordinarily.

1.2 Contribution Summary

The main purpose of doing this project is, this project will enable companies and engineering students to make 2-D model of their project at ease[6]. For a CNC machine an end mill attached to the machine as spindle which cuts the material. The machine spindle can be replaced with a laser engraver, plasma cutter, drill machine, water jet cutter drag knife or hot wire for a variety of applications making it more versatile. Also the probing feature helps the machine to set the zero for z axis automatically with a touch plate. Also there have been many researches in this sentiment analysis field but none have been done in context of business.

1.3 Thesis Outline

Over all in this paper, Chapter 2 provides the Background study in details including the algorithms and techniques used in the system, Chapter 3 discusses the proposed model including the algorithms and techniques, Chapter 4 presents the results and analysis and lastly Chapter 5 gives the conclusion and future work.

CHAPTER 02

Components

This proposal outlines the planned construction of a three-axis Computer Numeric Control (CNC) machine, for the purpose of rendering two dimensional vector graphics by using Inkscape. The CNC machine and control software will take vector image input in the form of Scalable Vector Graphics (SVG) files, and render the image onto a medium[4]. The medium will be a flat surface, such as conventional paper, white board, or light reactive surface. The machine will be able to move on three axes and will be capable of drawing with multiple instruments, i.e. pencil, laser, etc. in an addition the machine will also be able to cut and plot on flat surface. The machine should meet the goals of balancing high precision and speed, use-limited resources and as many recycled parts as possible. Stepper motors or servo motors are used for precise motion. The working requirement of a router is larger which means requirement of longer ball screws. A good alternative can be to use belt for X and Y axes as they are cheap and requires less maintenance. A microcontroller reads the program file, interprets it and later sends it to the machine. ArduinoUNO is best suited to be used as a microcontroller since it is open source, cheap and readily available in the market[2]. A Shield is inserted to the ArduinoUNO to connect thestepper drivers, limit switches and Emergency stop. Limit switches restrict the machine movement beyond the safe limit and an emergency stop is used to stop the machine in case of emergency

Work flow diagram

1. UNDERSTANDING THE FUNDAMENTAL

2. DESIGN THE MACHINE

3. WIRING CONNECTION

4. MACHINE DEVELOPMENT

2.1 Hardware

2.1.1 Microcontroller

Arduino Uno: Arduino/Genuino Uno is a microcontroller board based on the ATmega328P (datasheet). 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. It contains everything needed to support the microcontroller; simply by connecting it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started[2].

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

To get communication between the two Arduinos, it is possible to chain them together in such a way as. For many projects, it will be useful to have Arduino-Arduino communication. For example: having one Arduino to run motors and having another sense the surroundings and then relay commands to the other Arduino[2].

Schematic: A schematic is given to show how to connect the two Arduinos together (here two Unos used). However, if a Mega is used, it can be connected to any of the Serial ports on the Mega as long as that is accounted for in the code. Below Figure1 shows detail connection of two Arduino.

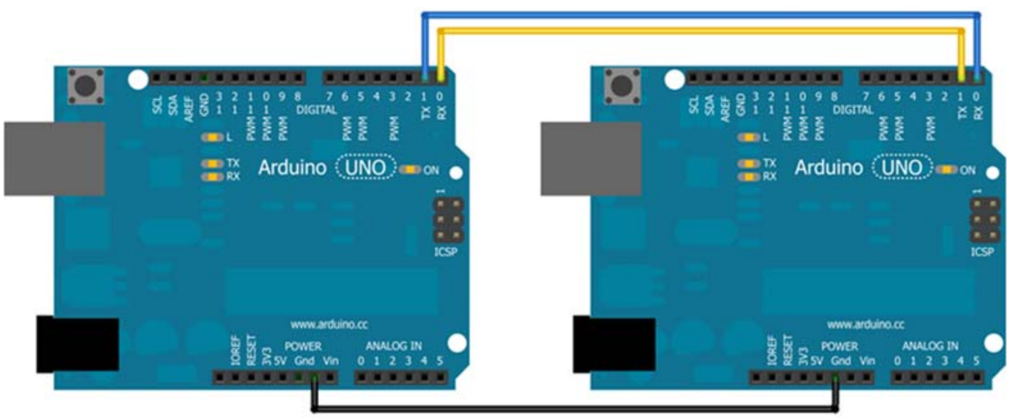


Figure 1- Connection of two Arduino

It will not function properly if there is no common ground between the two. Moreover, TX goes to RX and RX goes to TX.

Memory: The ATmega328 has 32 KB (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

ATmega328: The ATmega328 is a single-chip microcontroller created by Atmel in the megaAVR family.

AVR:AVR is a family of microcontrollers developed by Atmel beginning in 1996. These are modified Harvard architecture 8-bit RISC single-chip microcontrollers.

2.1.2 Analog Circuit

Electrical design of the CNC system.

- Arduino Mega2560
- Arduino/Genuino Uno
- Nema 17 Stepper Motor
- Stepper Motor Driver
- End Switches
- Bluetooth Module
- Bluetooth Relay
- TIP120 Transistor
- 1N4001 Diode
- Resistors
- Capacitors
- Android phone
- LCD display
- Keypad and Laptop

As proposed the design consists of two Arduinos working together to control the stepper motors which moves the individual axis accordingly through separate Stepper Motor Drivers. This was done because the Grbl library uses up approximately 70 percent of the memory and requires a lot processing power of the Arduino leaving very little to be used for other functions. Also it is not ideal for the Grbl Arduino to miss any step while calculating the coordinates from gcode therefore we designed a separate arduino to control all the other features and the Grbl Arduino itself using the interrupt pin[8]. But in Arduino there is only one interrupt pin and our design required three interrupt pin for the individual axis. To overcome this problem a combination of two Arduino was inevitable.

2.1.3 Stepper Motor

Stepper motors are used for their high working ability and precision level such as the one we are building for our CNC machines project. Unlike DC motors, the stepper motors are brushless, synchronous electric motors that can divide a full in both directions. It has a capability of holding torque at zero speed, and precise digital control without any feedback system depending on the overall size of the project and application. The stepper motors are constant power devices. As speed increases the torque decreases, so we'll have to try to find a happy medium for the need to drive our CNC machine. Stepper motors come in different types and multiple coil winding. Unipolar stepper motors are such types of motors which are easy to drive and having comparatively low torque and speed, on the other hand bipolar motors are hard to drive but have high torque and high speed. We are looking for a motor with high speed and high precision capabilities and could carry a reasonably sized object-so the bipolar would be a convenient choice. Since we have an available transformer that allows 24V, we'll look for that with our motors. We will be using a 2A driver board so the motor should only take 2 amps of current per phase. Micro stepping with 1.8 degrees and 200 steps per revolution would be great for speed and also the precision that we wanted[15].

Stepper motors are the most adequate for tasks like precise cutting, plotting, measurement and motion controlling. This is why we used NEMA 17 stepper motor in our machine. Stepper motors are brushless and synchronous. Stepper motors can partition a full turn into a large number of steps. This allows for precise control without any feedback system depending on the size of the project and application. The stepper motors are constant power devices. As speed increases the torque decreases, so we'll have to try to find a happy medium for the need to drive our CNC machine. Stepper motors come in different types, unipolar which are easy to drive but have low torque and speed, and bipolar which are hard to drive but have high torque and high speed.

As we have used NEMA 17 stepper motor which is high in speed and precision capabilities. The load capacity of this motor 5.6lbs or 2.5kgs approximately. Our available transformer is of 24V and we have used 2A driver board so that our motor only takes 2 amps of current per phase. Here are the specifications.

2.1.4 CNC Shield

A CNC shield is inserted to the Arduino microcontroller. Stop and connection of stepper drivers easy. It is compatible with the G-Code interpreter firmware called GRBL. It supports maximum of four stepper drivers to run four stepper motors. It can support a maximum of 36 volts and setting the micro stepping is easy with a shield.

2.1.5 Motor Driver

Definition of Big Easy Driver

The Big Easy Driver is a stepper motor driver board for bi-polar stepper motors up to 2A/phase. It is based on the Allegro A4983 or A4988 stepper driver chip, which is the next version of the Easy Driver board. This design is robust enough to handle most medium-sized stepper motors[19]. A reference board can be seen below in Figure 2.

Figure 2: The Big Easy Driver board

Setting up the BED to drive a 6-wire stepper motor

By cycling power between the four half-coils in sequence to rotate the magnet in the motor, the BED controls stepper motors. Because of the need for a 6-wire unipolar stepper motor to have its center tap wires connected to the positive voltage source, this connection is made slightly more complicated. Moreover, because of the low resistance windings used in stepper motors, care must be taken to make sure that the current delivered to the board does not exceed 2A. The basic wiring diagram is shown below in Figure 3.

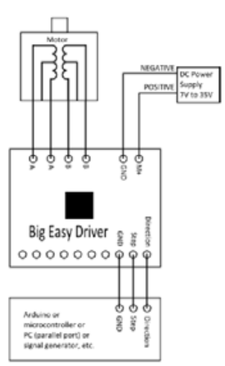


Figure 3: Diagram for Minimal Wiring Configuration

The Coils of the stepper motor are labeled A and B respectively. These connections are made as shown to the board. To step the magnet inside of the stepper motor, these connections are what are used. At in the upper right hand corner of the board, the positive and negative power connections to the board can be seen. This takes a 7V to 35V power supply (ideally between 8V and 30V) at up to 2A. We see connections to a microcontroller or signal generator at the bottom. These connections are what control the motions of the motor. For each rising-edge pulse received by the step pin the controller cycles the A and B connections to make a step of the motor. This step must be greater than 3Vpp and must have a frequency that is compatible with the stepper motor attached to the board. Figure 4 shows driver connection with stepper motor.

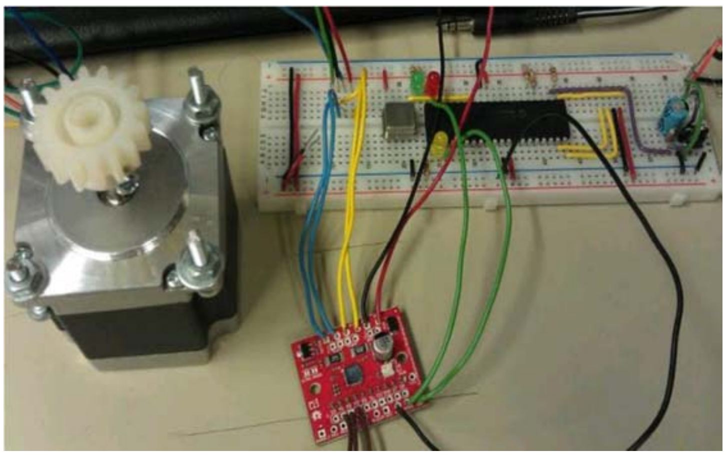


Figure 4: Driver Connection with Stepper Motor

2.2 Software

2.2.1 SVG

Scalable Vector Graphics (SVG) is a World Wide Web Consortium (W3C) standard for portraying two dimensional vector picture records. Vector pictures comprise of shapes, line vectors and style data rather than the varieties of pixels accessible in raster pictures like JPEG or PNG. SVG records are ASCII content reports in XML arrange, and can be controlled with a drawing project, (for example, the open source editorial manager Inkscape) or with a content manager as plain content. The open standard and XML arrange permits the documents to be scanned in as content and afterward parsed into a usable information structure by our image conversion software.

2.2.2 G-code

G-code is an industry standard for a machine control guideline set, specified in a few international standards including RS274D and ISO 6983. G-code documents are ASCII content records, comprising of an arrangement of charge codes. Each order code is, as a rule, a solitary in sequential order character took after by numeric parameters.

G Code Example

The program, given below, will draw a 1" diameter circle about the origin.

G17 G20 G90 G94

G54

G0 Z0.25

X-0.5 Y0.

Z0.1

G01 Z0. F5.

G02 X0. Y0.5 I0.5

J0. F2.5

X0.5 Y0. I0. J-0.5

X0. Y-0.5 I-0.5 J0.

X-0.5 Y0. I0. J0.5

G01 Z0.1 F5.

G00 X0. Y0. Z0.25

Important to remember that all gCode programs a simple text files save with a ".nc" extension.

First Step

Steps to run the program:

1. Loading a marker into the spindle(while it is off). Markers work better than pens because the tip is softer and is more forgiving. Then, setup a piece of paper or other material on which to draw near the center of the machine's work envelop.
2. Power on the machine.
3. Connecting to the machine with Universal gCode Sender

Setting the Zero Position

4. Jogging (move) the spindle to the center of the machine table

- Under the "Machine Control" Tab enter ".1" into the "Step Size" box & press enter.
- Selecting - "inches".
- To move the machine close to the center of the work table The X+,X-,Y+ and Y- buttons are used.
- To tell the machine to remember this position as the X zero location, Press the "Reset X Axis" button.
- To tell the machine to remember this position as the Y zero location, Press the "Reset Y Axis" button.
- Now we need to slowly use the "Z-" button to lower the marker tip. Then, stop when the marker tip gets close to the paper.
- Adjusting the "Step Size" to .01. After entering the value, Press enter.
- Until it touches the paper by tapping the "Z-" button, let's continue lowering the marker.
- To tell the machine to remember this position as the Z zero location, Press the "Reset Z Axis" button.
- Retracting the marker from the paper using the "Z+" button. Let's go at least .1" above the paper. This is equal to 10 clicks of the "Z+" button when the step size is set to .01

Loading the CNC Program

5. Going to the "File Mode" tab.
6. Selecting "Browse" and search for the "circle.nc" file.
7. Clicking "Open".
8. The next button press will send the "circle.nc" G-code program to the machine and it will start to move.
9. This is for all the marbles. Let's click the "Send" button.
10. The machine will start moving.

- First, it will move the Z axis to .25"
- Next, the machine will move to X = -0.5 and Y = 0.0.
  Important to remember that the marker should not be touching the paper yet.
- Now the machine will lower to Z = 0.0. Also, marker should touch the paper.

- The machine will slowly draw a clockwise circle.
- When the circle is complete, the machine will move the Z axis up to .1”
- Now that machine will return to the X & Y zero position.
- Finally the z axis will move back up to the original .25” starting position.

Figure 5 below shows universal G-code simulation.

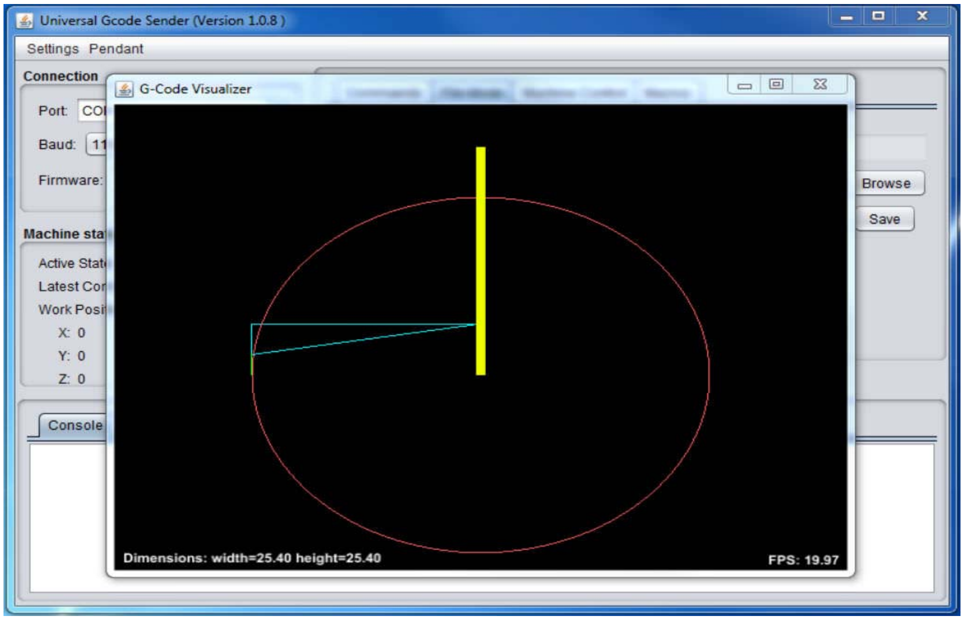


Figure 5: Universal Gcode Sender

2.2.3 GRBL Controller

Introduction

Many people use GRBL in DIY CNC Controller. The software runs the machine very smoothly with excellent acceleration & deceleration control. GRBL looks for lines of G-code passed over USB and also manages all of the timing necessary which allows for the machine controller to be computer agnostic.

Definition

An open source, embedded, high performance g-code-parser and CNC milling controller written in optimized C that will run on a straight Arduino.

Reason to choose Arduino

Now-a-days, Arduino is one of the most available platform, which is familiar by people with the hardware and IDE. Moreover, its low cost minimizes the barrier to entry for CNC motion control. Furthermore, the proliferation of Arduino allows for widespread adoption of GRBL. Using the Arduino platform aligns with the larger maker movement of democratizing fabrication.

Features

Some important features of GRBL are:

- It enables communication over USB.
- GRBL has many advanced parameters that many beginners will not need. However, these functions allow the user to grow into using the full capabilities of their machine.

Limitation of GRBL

- Backlash compensation: In any machine there is "slop" which is a technical term. Due to the mechanical components of the system, Backlash is lost motion. Backlash compensation is a way to tell the software how much lost motion the machine has in the x, y & z-axis. The machine controller will use these values each time the machine changes direction to improve the precision of the motion.
- Grbl supports 3-axis of motion (x, y, z). But it does not support rotation axes.
- Tuning GRBL can be somewhat intimidating.

Additional Items for GRBL:

To create a NC controller using GRBL software, we need a few additional items mentioned below.

- Arduino: To host the GRBL software.
- Stepper Motors: These provide the motion to move your machine
- Stepper Motor Drivers: the Bridge between the Arduino and stepper motors that move the machine.
- Power supply: connect to the stepper motor drivers and provides the power to the drivers & stepper motors.
- Computer: To have a USB connection between a computer and the Arduino.

- G-Code Parser (Software): To upload a gCode file. This software sends the file one line at time to the GRBL software.

Figure 6 shows a overview of CNC controller

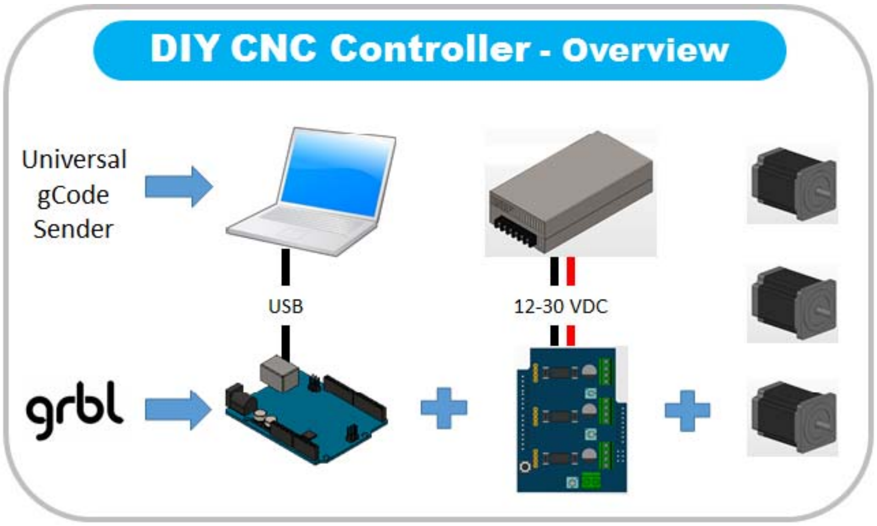


Figure 6: GRBL Overview

GRBL Settings

First Step

Figure 7 below shows installation of Universal Gcode Sender and GRBL.

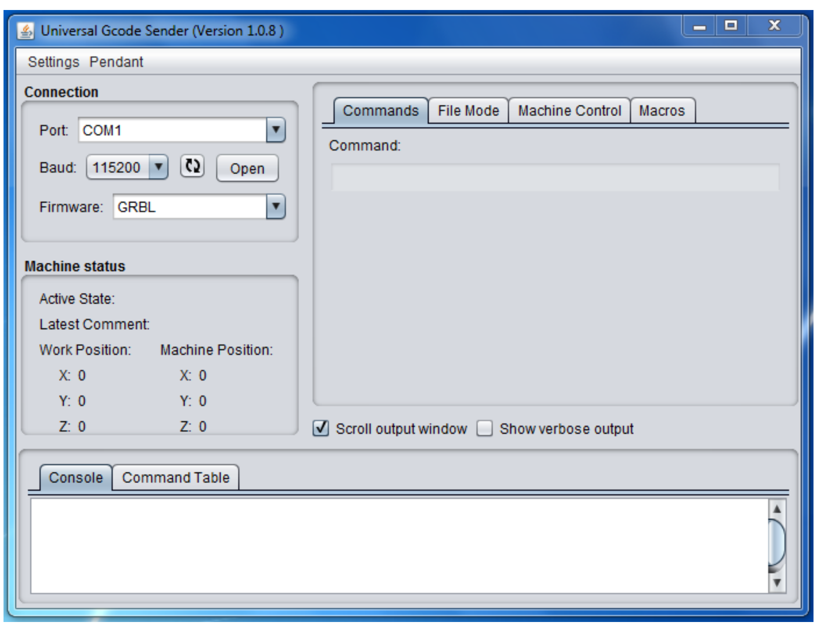


Figure 7: Universal Gcode Sender Main Screen

Display Current GRBL Settings

To get our CNC machines to do exactly what we want, there are quite a few GRBL settings that we can adjust. While setting up the machine as opposed to going back and searching the GRBL wiki page, it's easier to refer back to a single sheet.

By Typing "$$", we can see the current settings. It displays the available user defined settings in the console window.

Here, we are interested in the "Steps/mm" settings.

$100=314.961 (x, step/mm)

$101=314.961 (y, step/mm)

$102=78.740 (z, step/mm)

Important thing to remember that these were not the default settings on the system. To get 314.961:

Lead Screw Pitch = .200 inches (inches per revolution)

Stepper Motor # of Steps per Revolution = 200 (steps/revolution)

Micro Stepping Setting = 8X

For example, let's use a .200 inch pitch lead screws, stepper motors of 200 steps per revolution and the stepper motor controller is set to 8X micro stepping for the x & y axis.

Calculating the "step/mm" Value

Let's break it down one step at a time.

Step 1

Divide the # of steps per revolution by the lead screw pitch

$$\frac{\#of\ steps\ per\ rev}{lead\ screw\ pitch} = \frac{200\left(\frac{steps}{\cancel{rev}}\right)}{.200\left(\frac{inches}{\cancel{rev}}\right)} = 1000\left(\frac{steps}{inch}\right)$$

Step 2

Divide the # of steps per inch by 25.4 to convert to steps per mm

$$\frac{\#of\ steps}{inch} \times \frac{1\ inch}{25.4\ mm} = \frac{1000\ steps}{\cancel{inch}} \times \frac{1\ \cancel{inch}}{25.4\ mm} = 39.37\left(\frac{steps}{mm}\right)$$

Step 3

Multiply the steps per mm by the micro stepping setting

$$\frac{\#of\ steps}{mm} \times \text{micro stepping} = 39.37\left(\frac{steps}{mm}\right) \times 8 = 314.961\left(\frac{steps}{mm}\right)$$

Example calculations demonstrating how to find the step/mm value

After a few quick calculations we have the values we need. Let's update the GRBL settings by typing the following into the command line.

$100 = 314.961

This will set the X axis steps per mm. Let's repeat the process for the Y and Z axis using $101 and $102 respectively.

Important thing to remember that the Z axis setting is different because of running a lower micro stepping count of 2x to get a little more power to lift the head of the mill.

2.3 Mechanical

At first a rough layout of the machine was made using Free Cad software. The dimension of the machine was designed to be 8m x 8m x 8m giving a working print bed of 4m x 4m.The design consists of three individual beds as three axis placed on linear rails to restrict motion in only one axis[6]. Also a 8mm threaded rod run across each bed which screws in and out two wing nuts attached to the bed causing the bed to move along the axis as the stepper motor rotates. The structure is designed in such a way that the base consists of X and Y bed with the Z plane suspended perpendicular to the base with the help of two aluminum bars on both sides. The X axis sits on the base and the Y axis is placed on top of X axis but is perpendicular to it. Leveling of the beds is crucial. The beds must not wobble or vibrate while operating therefore while designing we placed adjustable bearings to hold the beds firmly on the linear rails while allowing the bed to move freely along its axis. Similar technique is used to hold the drill in place[7].

2.3.1 Co-ordinate System

The spindle of the machine is representing by the cylinders in each drawing. From the drawing shown above in Fig01, horizontal mills are turned around considerably. Also, as shown above in Fig05, lathes can get a lot more complicated than the simple 2-axis version. CNC machine has its own specific axis orientation. Here are some common types:

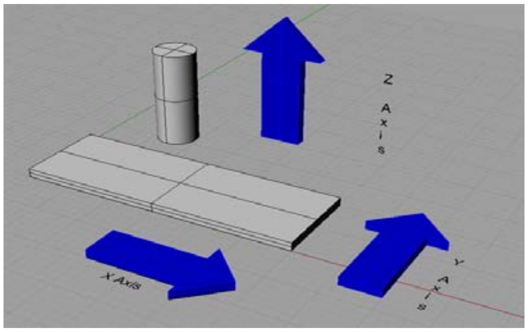


Figure 8: Mill Axes for a Typical Vertical Machining Center

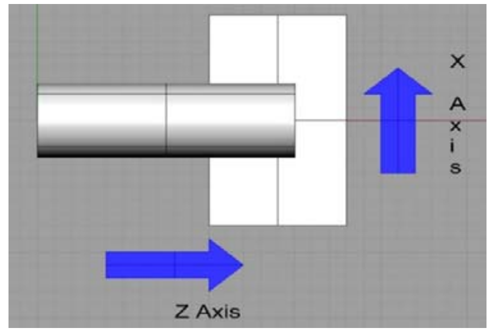


Figure 9: Lathe Axes for a Typical 2-Axis Lathe

Here, arrows show table motion in positive g-code direction. Handedness is spindle motion and reversed!

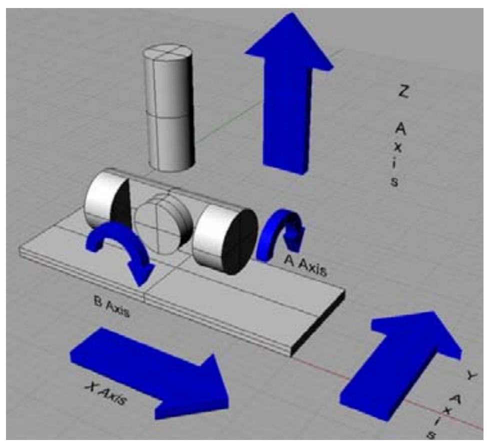


Figure 10: 5-Axis Mill With Trunion Table

Expressing Coordinates in G-Code

After knowing the coordinate systems, we express coordinates in G-Code simply by taking the axis letter and adding the value. Besides that, spaces between the letter and its value are optional.

For example, a position that is 1 inch from 0 along X, 2 inches along Y, and 3 inches along Z is written as:

X1Y2Z3

It can also be formatted with spaces to make them more readable:

X1 Y2 Z3

Or

X 1 Y 2 Z 3

X1

Y1

X-1

Y-1

Planes

A plane is a flat 2 dimensional space defined by two axes. The default plane on most mills is XY. An arc will be drawn on the XY plane if it is drawn without specifying a change in the plane. There is a plane for each combination of the linear axes XYZ:

XY

YZ

XZ

The G17, G18, and G19 G-Codes select which plane is active.

2.3.2 Nuts and Bolts

Tooling is made up of two parts:

1. **The Cutting Tool**
2. **The Tool Holder**

1. **The Cutting Tool:**

Examples: End mills, Drill bits, Center drills, Chamfer tools, Slitting saws etc.

Figure 11:Solid Carbide End Mills

Type

- **Straight** – Leaves a square corner and flat bottom used for many different types of cuts. A good place to start.
- **Ball** – Leaves a radius corner not ideal for creating a flat bottom. Will create 3D surfaces using many passes.
- **Chamfer** – Leaves a beveled edge often 45°.
- **Rougher (Corncob)** – Leaves a square corner and flat bottom used to rapidly remove material sacrificing surface finish.
- **Bull Nose** – leaves a slight corner radius with a flat bottom.

Coating

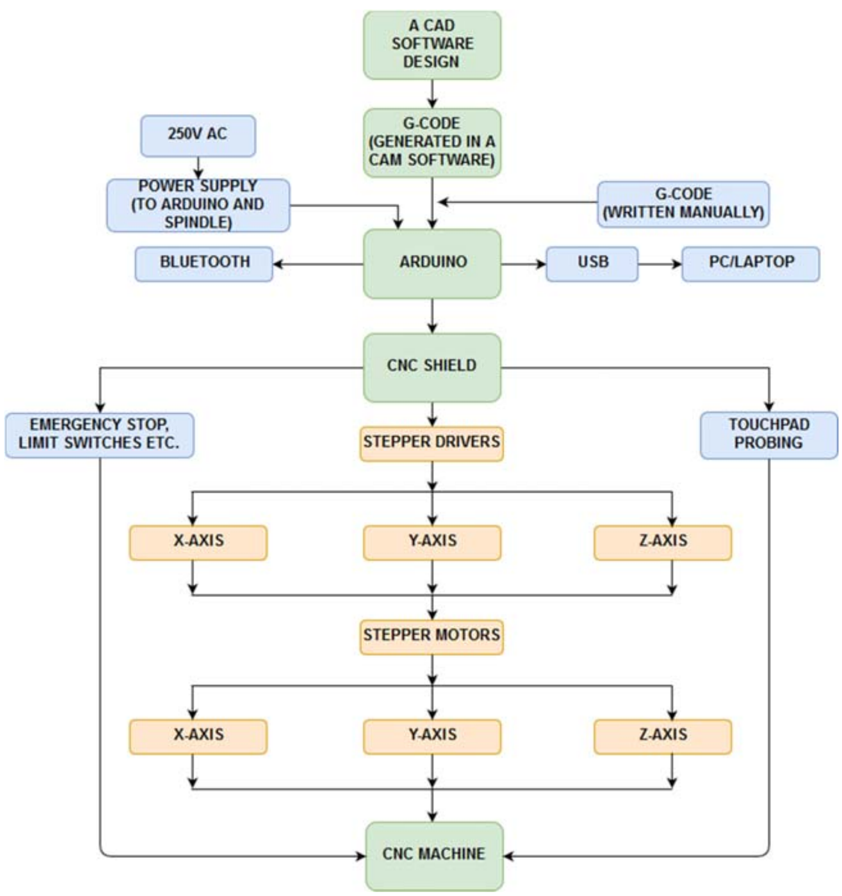
- **Titanium Nitirde (TiN)** – best suited for cutting ferrous metals typically applied to HHS cutters.
- **Zirconium Nitride (ZrN)** – high lubricity for cutting non-ferrous metals typically applied to carbide cutters.

CHAPTER 03

Proposed Model

This proposition diagrams the arranged development of a three-axis Computer Numeric Control (CNC) machine, with the end goal of rendering two dimensional vector designs. The CNC machine and control programming will take vector picture contribution to the type of Scalable Vector Graphics (SVG) records, and render the picture onto a medium. The medium will be a level surface, for example, traditional paper, white board, or light receptive surface. The machine will have the capacity to proceed onward three tomahawks and will (if configuration time licenses) be equipped for drawing with different instruments, i.e. pencil, laser, and so on. The machine ought to meet the objectives of adjusting high exactness and speed, utilize constrained assets and however many reused parts as would be prudent.

Here is the basic work flow chart.

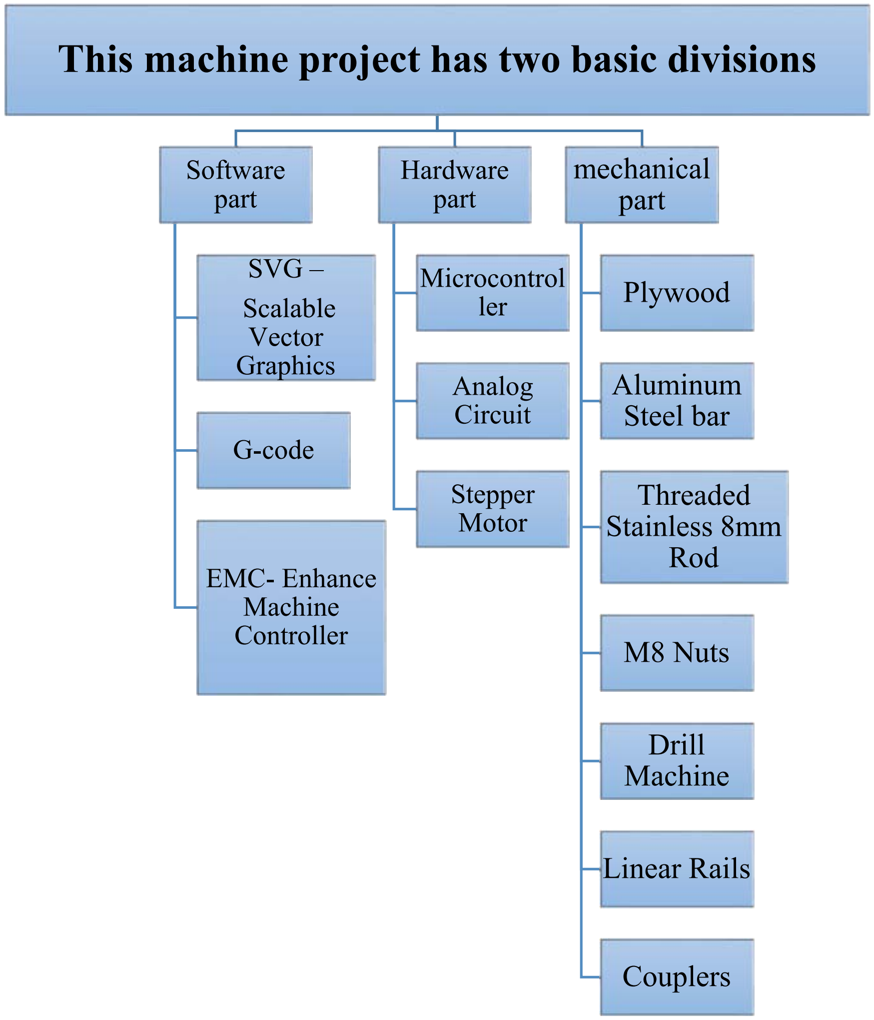


3.1 Process

The image conversion software will take SVG image file on standard input and output G-code on standard input. The Python programming language has been chosen to write the software, due to ease of use, ubiquity, and integration as a scripting language in third party applications such as Inkscape and EMC. Our algorithm for conversion will consist of several conversion stages, each stage providing a transformation towards G-code. The first step will be to de-sugar the SVG file. SVG is a complex format, allowing advanced constructs like embedded bitmap images, text and font effects, and stroke and fill styles. To make the renderingfeasible, all the extraneous elements will be removed or simplified to basic paths. Some of these simplifications, such as text to path conversion of text or polygon to path conversion, may be performed as scripted actions inside the Inkscape editor. This step may consist of several independent reductions. Once the SVG file has been simplified, the resulting XML will be parsed into a data structure consisting of a set of paths.

A series of object classes will be defined to provide a convenient storage medium for the variety of paths descriptions used (e.g. Bezier curves, simple Cartesian lines).Next, the paths will be ordered into a render priority queue. One simple algorithm would be to define a starting location for the write head, locate the path closest in distance to this location, and add it to the renderqueue. Calculate the location of the write head at the end of this path, and add the next nearest path from that location. Repeat this process until there are no line segments. This greedy algorithm should provide good performance by limiting movement between paths. Drawing closely located elements would also provide an aesthetically pleasing rendering process, as the write head will not simply scan down the page, but instead render the drawing in a more varied way.

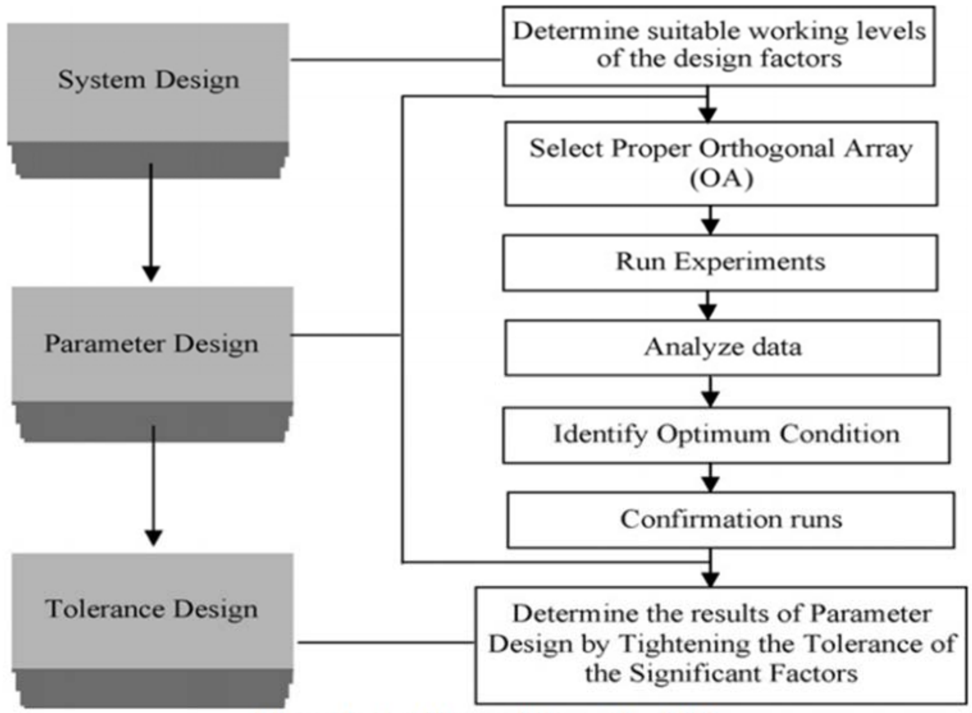
Finally, the priority queue will be used to generate the actual G-code paths. Each path will generate a pen down command and a sequence of movement instructions, followed by a pen up command a move instruction to the starting location of the next path. G-code supports a variety of control codes, and will be better understood once we have written a series of test G-code scripts. The completed G-code instruction file will be output on standard input.



Our work procedure had various steps including cutting, drilling, grinding and most of all measuring.as we have used ply-woods for our machine, the wood chunks were cut to the required dimensions and had good enough square shaped hole for stepper motor mountain. We used rail and wheels to support our X and Y axis movement.

3.2 Motor Housing

The motor housing will be very basic design with a plate that has holes for mounting a stepper motor to the plate. There will be a hole that will hold the stepper motor to poke through to the other side and move freely. Beside the stepper motor, there will be a gear mounted to a screw on one side and a shaft on the other side. The shaft will be inserted into a hole in the plate next to the stepper motor shaft which we will also mount a gear onto. We have also welded a 8mm SS rod with the shaft of our motor.There are also some intermediary gears between the stepper motor and the screw gear if necessary to reduce torque by gearing down to the screw gear, or gearing up to the screw gear to increase the speed at which the screw rotates. We will base our gearing around the abilities of our stepper motor. Each axis (X, Y,Z) will have a motor housing unit.



Flow chart of Taguchi's method [4]

Figure 12: Work Flow of a CNC Machine

3.3 Frame and Screw

Our CNC machine is created in such a way which can draw or drill or engrave in a canvas or a given flat surface. Our primarily tested canvas is 12 inch by 12 inch. It is set in a way on purpose so that the machine can travel and exceed 12 inch on both sides. Hence our machine has the ability to travel 15 inch, therefore it has an edge to travel 1.5 inch extra in both sides. The figure below illustrated base of our machine.

Figure 13: Machine Base

The wooden plate that is shown in this figure is the lower part or base part of our machine. The size of this plate is 24X24 inch. The whole machine is held by this part. The X axis and Y axis stays on this part. We have installed a rail so that the X axis can move freely. The X axis plate also has two pair of wheels so that it stays in base plate rail and does not wobble. The rails are also 24 inch long made of aluminum. We have tried to make the movement along X axis and Y axis as smooth as possible. Though our plate is made of wood and a bit heavy, our prime concern has always been to make our motor movement precise and plates to be strong. So that it can take any load and drill any object. Also to keep in mind, as our machine X and Y axis is heavy; our motors will need high torque to move the plates forward and backward. The figure below shows X-axis of our machine. Figure 14 shows X-axis of our machine.

Figure 14: X-axis of our Machine

On the upper part of our X-axis, we have installed Y- axis. The figure below shows our Y-axis. This axis plate will also work as our engraving canvas. This is in brief full picture of our machine.

Figure 15: CNC machine with X and Y axis

3.4 Fabrication Steps

1. Our Y- axis can also move along X-axis through sliding rail. Our Y-axis is 12X12inch in size. For the Y axis two rails are kept at a distance of 11inch having a length of 12 inch each.As the X axis two rails are bolted with our base plate and Y-axis plate forms a bridge between the y axis rails.

2. The Z axis is assembled next with stepper motor on top, another 8mm ss lead screw coupled to the motor shaft, ball nut passed over through it and an end bearing keeps it aligned straight which is stationed with a hooker. The spindle mount plate is fixed to the ball nut. The linear slides are fixed at the ends for smooth up and down motion. Limit switch is fixed at the top and Grooved bearings are fixed at the back of the plate.

3. Next step is to mount the X axis stepper motor with 8mm SS steel attached. We have made a square hole plate to mount our motor at the base plate. This 5inch square shaped hole is made of ply wood. It has the ability to hold a motor strongly. We have designed it in such a way so that the motor stays fixed and later on we can get rid of the part. The motor shaft has a coupler which helped us to make connection a 8mm ss steel rod. We have made the rod connection with lower part of X-axis plate with a screw nut. Hence when the motor starts

revolving clockwise or counter clockwise, the screw nut goes forward or backward as directed so that the X-axis goes forward or backward.Idler bearings to the X axis plate (back plate). The X axis plate has wheels underneath, at the corner. The wheels will be stationed with base plate rails are later joined together with a distance equal to the width of the X axis rail. The Limit switches are fixed at the bottom ends of one of the X axis plate.

4. Next step is to lay the rail over the Y axis rails such that the top grooved bearings lay exactly over it and move the machine back and forth for alignment. If so the bottom grooved bearings are installed at the bottom of the Y axis plates for tightening.

5. Next step is to move all the axis of the machine for checking the alignment. If it is free to move belts are installed for X and Y axis.

6. All the electronics are kept in a box. Emergency breaker is also fixed with another switch.

CHAPTER 04

Machine Setup

The machine works with the help of the mechanical system, electronics system and the program file creation is using CAD/CAM software. First step is to create a program file using a CAD/CAM software. There is also another option of manually writing the program file. The Bluetooth module is connected to the microcontroller to interface with smartphone and the USB connection can be used to connect with PC or laptop. The shield is inserted on top of the arduino and above it stepper drivers are mounted which amplifies the signal from the microcontroller and gives it to the stepper motors for each axis. The connections for the touch plate and limit switches for each axis goes to the arduino. The flow chart given in Fig.8 explains the whole process.

4.1 Mechanical System

Machine structure is the "spine" of the machine apparatus since it coordinates all machine segments into a finished framework. The development for the X and Y axis can be made by either the table of the machine holding the moving activity or by making the device for cutting move with the table settled called gantry sort. The gantry sort uses less material, thus is more affordable to construct. As our purpose is to make lesser and cheaper CNC machine which will also be portable, therefore we have used gantry sort. The SS steel rod driven movement for the X and Y axis influences the machine to move speedier. Though from our observation we have found that from time to time the machine might be needed to be oiled up. Hence our full project involves screw, bolts and nuts. On the other hand the machine can never be moved by pushing along X and Y axis which is impossible for ballscrews. Backlash is a typical wonder that occurs for a leadscrew driven system. For the Z axis the backlash is diminished by stacking the delrin nut with springs that presses it towards the leadscrew. All the screws and steels and rail rods are dipped into grease oil to reduce erosion.

4.2 Electronic System

Electronic system is the main functional key of our project. This part includes GRBL, Arduino , CNC shield and Driver assembly. GRBL takes data from G-code and interprets the data and sends it to Arduino. Then Arduino passes these pulses to stepper driver and stepper driver amplifies those pulses, hence the motor runs. CNC Shield is inserted to Arduino. Stepper drivers are inserted to the shield

4.2.1 GRBL

In C programming language, for the Arduino platform GRBL is a G-Code interpreter written. By keeping 20 upcoming motions, it is intelligent to manage the acceleration. This is why, to make smooth cutting or drilling, GRBL controls the velocity and avoids the jerk; or else it can damage tools. For 0.9j version, 115200 is the Baud rate for the serial port. With the output of several CAM tools, the G-code has been tested without any problems. It also supports arcs, circles, helical motion and other basic functional g-code commands. UniversalGcodeSender is used to configure the firmware. Here, we set the travel for each axis, velocity, acceleration required, steps per mm and setting the hard and soft limits.

4.2.2 Arduino, CNC Shield and Driver Assembly

Here the connection of ArduinoUNO, CNC shield and stepper drivers are shown. Here, ArduinoUNO is at the bottom. Also, the CNC shield is inserted above it. Finally, the stepper drivers are inserted into the shield at the top.

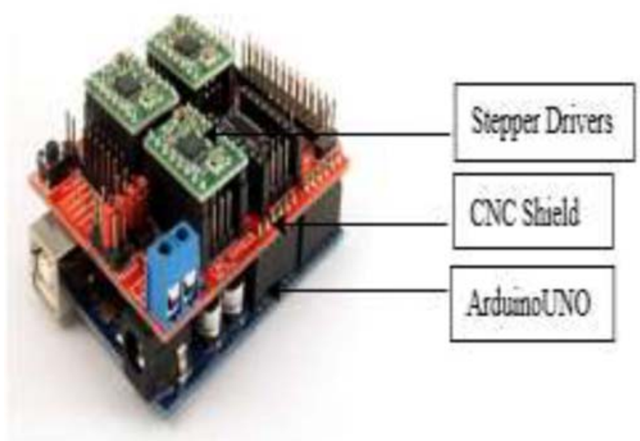


Figure 16: Electronics Assembly

Limit switches, stepper motors, emergency stop etc. are inserted to the shield on the pins provided. By shortening M0 and M1 pins on the shield, a micro-stepping of 1/8 is set to reduce the vibration of stepper motors.

CHAPTER 05

Conclusion & Future Work

5.1 Conclusion

The machine was fabricated successfully and during testing it worked well with the Bluetooth as well as with the USB connection. Most of the commonly available CAD/CAM softwares were supported and the machine proved to do 2-D. The Fabrication of this CNC Router with Bluetooth connectivity was cheaper than many commercially available CNC routers. The machining parameters were optimized using Grey relational analysis and the optimum feed rate was 100 mm/min at 0.1 mm depth of cut at spindle speed 30000 rpm. A confirmatory test was conducted to validate the calculated results.

5.2 Future Work

CNC machines are extremely versatile this day for having the capability of a wide range of functions including cutting, drilling, routing and milling.

- **Versatile Uses**

Not very long ago, CNC machines were used only in the manufacturing industries and large-scale projects. However, now the scenario changes and even small to medium size businesses and small hobby shops to handymen are using CNC machines.

- **Increment of Usage**

CNC machines are becoming more and more powerful with technological advances and software developments. Moreover, they are also becoming easier to operate and handle to new users with these advances.

- **Mobile CNC Machines**

CNC machines were larger for being used in large scale projects and industries that required large machines. However, it is totally shifting to the mobile devices that are easily portable and can be carried and used at worksites.

- **Manufacturing Development**

Manufacturing companies are able to use these machines to produce more precise products and in turn paving the way for more technological advancements such as nanotechnology, as the CNC machines are turning more advanced.

Businesses are looking at huge cost savings as CNC machining equipment becomes more precise, versatile, and affordable. The variety of CNC applications is allowing businesses greater versatility and flexibility.

- **3D Printing**

3D printing using resins, plastics, and even metal alloys is emerging from small shops around the world. These technologies are paving the way to new businesses and changing industries while it’s still in its infancy. Today’s early stages of this with on-demand 3D printing is, ordinary people can have objects created for them simply be sending a company a computer file. Moreover, nylon printing can create articles of clothing; and with this we can imagine that we may able to print the clothes we wear, after ten years from now.

- **Laser-cut plywood**

A geometric pattern can be created that can be etched into a sheet of plywood using a CNC laser cutter. The wood retains its solidity and durability once it is milled with good flexibility. While it can use the end product as wall art, there are a number of practical purposes too! The machined wood can be molded to form a bowl or place mat. Moreover, it is well-suited to curved surfaces and walls.

Of course, the future of CNC machines and CNC technology is exciting! The global economy as well as the global trends will surely be changed by the evolution of CNC technology as well as applications. Lastly, CNC technology is going to change the face of machining.

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