

DESIGN AND FABRICATION OF A MINI CNC PLOTTER MACHINE

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Abstract- Today there is a rapid increase in technological development and the use of CNC machine. CNC plotter machine is a 2D plotter machine powered by 3D that uses a pen to draw text or image or any solid surface. This project's aim is to model the plotter and develop open source software for machine control. Essentially, this plotter machine's system is designed to operate with three axes stepper motors (like X, Y and Z axes) using solid work technology, these three stepper motors are operated by CNC shields for motion (X, Y and Z axes). Travel length means the linear motion of stepper motors which control point-to-point X, Y and Z axes. The left and right movement is controlled by the stepper motor of the X axis, front-back movement is controlled by the stepper motor of the Y axis and the pen is up-down controlled by the stepper motor of the Z axis. This is low-cost CNC machine production and reduced cost and complexity. Also G-codes are used for commands or instructions on this computer. To control the pen, the computer uses this G-code.

Keywords: Computer Numerical Control (CNC), Arduino Microcontroller, G-Code, Plotter

1.INTRODUCTION

CNC machining is a process used in the manufacturing sector involving the use of machine tools by computers. A computer program is designed for an object and the machines are programmed with CNC machining language (called G-code) which controls essentially all features such as feed frequency, coordination, position and speed. The computer can control the exact positioning and speed with CNC machining. CNC machining is used in both metal and plastic parts manufacturing. The work includes the design and development of the CNC machine tool controller unit prototype modeling. In modern CNC systems, end-to-end component development is highly automated using computer programs to construct a file that is interpreted to extract the commands necessary to operate programs for assisted design (CAD) and software assisted manufacturing (CAM) [1]. A low-cost, 3-axis vertical CNC plotting machine will be developed in this project. Arduino's open source microcontroller platform will be used to control the motors, and open source software will be used to execute G code and machine applications.

Mini CNC plotter machine is defined as being based on controller Arduino and shield CNC. CNC is a numerical control system for the processor. G codes are feature of

planning. G codes are pre-defined Function Associated motion. Also G codes are used in direction of moving the pen in X, Y, Z directions [2]. Other writing materials such as pencil, sketch, pens, etc. can change pen. The goal of over is to create a mini CNC plotter machine capable of drawing difficult design on paper or writing surface. In Cartesian coordinates X, Y, Z directions, we used 3 stepper motors with lead screw to work with great precision. Stepper motor converts the electronic pulse into rotations of the lead screw [3]. Stepper drivers are used to give the device power. The main goal is to make a mini CNC plotter machine to use G codes to draw an image. I have focused on reducing project costs and improving performance and versatility. The cost of setting up mini CNC plotter machine has been reduced. CNC machine is very expensive now for a few days, but we will be able to use CNC plotter machine in a very cost-effective way by using this technology [4]. This will also help many people who have many occasions to write different things. The plotting can be achieved without any physical work by using this tool. To make a mini CNC plotter with three stepper motors to draw an object with G-codes. This device reduces the machine's price and increases the efficiency.

1.1 METHODOLOGY

The current is supplied with external power supply to Arduino. A cable for transferring data to Arduino board from a computer. Two stepper motors in X and Y axis will be used for precise movement and one stepper motor will be used to raise the pen in Z direction. L293D IC to supply the stepper motor with the G codes in sequence. Arduino transforms the G code command into electronic pulse and sends it to the stepper motor via L293D IC. The stepper motor moves left and right in X direction. In the direction of Y, the stepper motor will travel forward and backward, and the stepper motor will move up and down in the direction of Z. We can use this machine to draw a lot of difficult designs. This machine's accuracy results in very high results. In industry, therefore, we can use it to reduce design printing costs and maintain the level of accuracy. The G code is interfaced by the FTDI module with the ATMEGA 328 CNC-based controller which transforms the code into convenient machine code, i.e. serial to USB converter. It therefore acts as a PC-to-Controller interface module. Furthermore, this code is passed to the stepper motor by easy drivers converting the code and moving the stepper motor according to instructions. We need three X, Y, Z axes that act as follows X stepper motor move left and right stepper motor move forward and backward and Z stepper motor up and down as these axes move forward according to the specified dimensions.

1.2 BLOCK DIAGRAM

Mini CNC plotter machine works on input as design G-codes and converts it to Arduino, L293d IC, stepper motor via the use of software. Figure 3.1 shows the basic block diagram of the CNC plotter machine, which indicates that it will be converted into G-code after giving the input (drawing or plotting) and transferred to the Arduino. The CNC shield will convert the Stepper motor command of G codes to digital pulse.

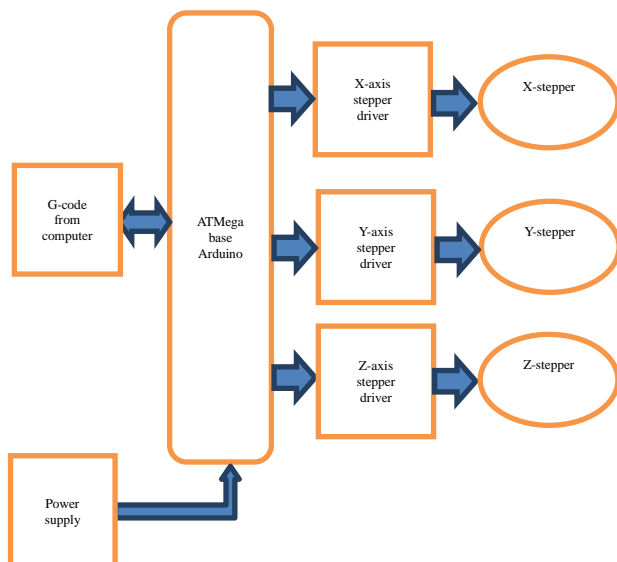
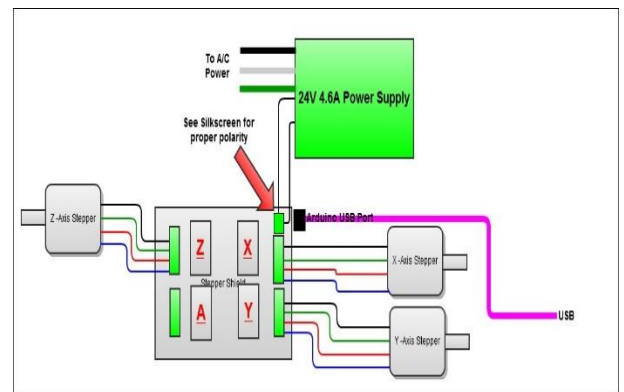


Fig. 1: Block diagram

In X direction, the stepper motor will travel left and right, the stepper motor in the Y direction will move forward and backwards, the stepper motor in the Z direction will move up and down. Lowest possible cost will be



maintained throughout my project. simple construction will be maintained on this project. This is easier way to use stepper motor with lead screw, stepper drivers, Arduino board etc. The setup of machine is flexible that's why it will be easily transported and maintenance time is short.

2. SCHEMATIC ARRANGEMENT

The Fig. 2 shows schematic circuit diagram of CNC plotter

Fig. 2: Schematic circuit diagram of CNC plotter

2.1 SOFTWARE AND CODING

Three software is used to complete the task of the entire project

- Arduino IDE
- Inkscape
- Processing

A. Arduino IDE

Arduino Software (IDE) is an open source that makes it easy to write code and upload it to the board. Language-based programming functions with a rich set of library functions can be simplified with C / C++. The program can be written by C language after downloading and installing on pc and the port connection between the computer and Arduino must be selected via USB from the tools and port. After this step, the program can be verified by checking the error and the message will be compiled when it has been completed and no error.

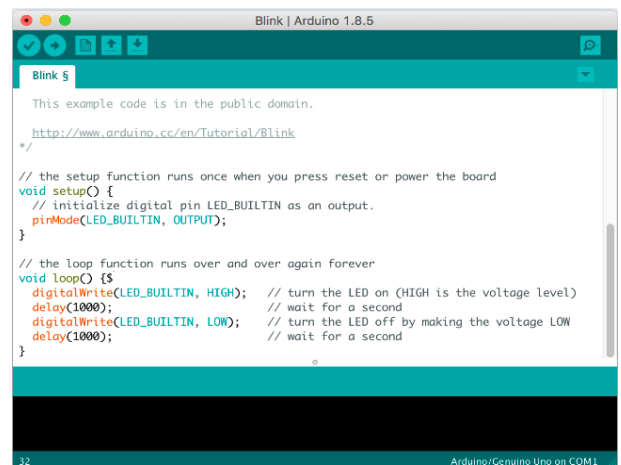


Fig. 3: Arduino Software (IDE)

B. Inkscape 0.48.5

Inkscape is used to design the diagram or text that is plotted. In this project, the G-code file of a selected image or text is created using this software. G-code is a frequently used programming language for numerical control that includes X, Y, Z coordinates.

Use Inkscape to build G-code file

Our project's CNC plotter will operate within $6 \times 6 \text{ cm}^2$ area.

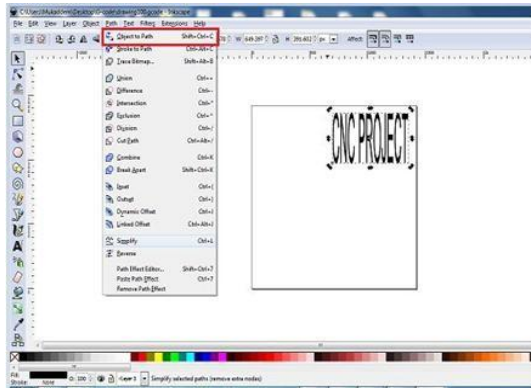


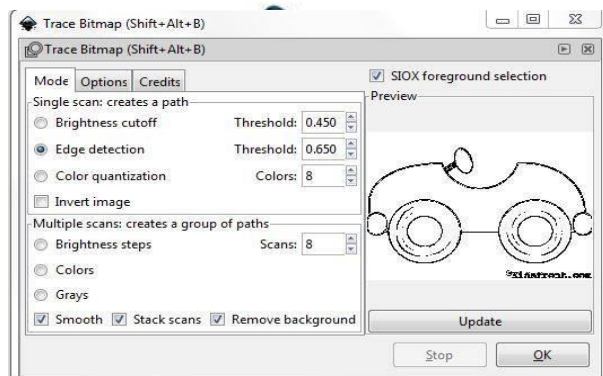
Fig. 4: Conversion of text to G-code

So we pick the file properties of the Inkscape $40 \text{ cm} \times 40 \text{ cm}$, which is four times the plotter's working area, since the plotter can draw only in the first quadrant.

And we initially kept the axes at the nearest end of the engines, which is considered to be the origin to change the model easily.

In the figure. 3 The CNC plotter work area is shown with the text written in the predefined area. Using cursor, the text is selected and then "object to route" is selected from the drop-down window to save the selected text's G-code type.

The file must have a transparent background to create an image's G-code. To create a transparent image, drag the image into the selected area and select "trace bitmap" from the drop-down window. Scans are selected as 8 and to create a black & white image, "Edge detection" is selected. After adding this transparent image in the predefined area, we've used the command "object to path" to create the selected image's G-code file by following the steps described above.



(a)

(b)

Fig. 4 Creating transparent image (a) original image (b) transparent image.

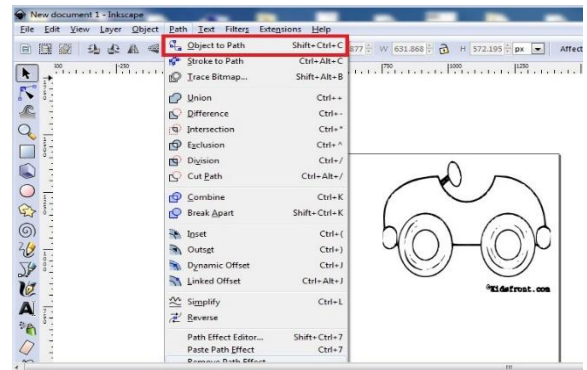


Fig. 5 Conversion of transparent image to G-code

C. Processing

Processing is the code for open source programming language used for digital drawings. Processing program GTCRL is used to send G-code file to the CNC plotter from the user interface. The fig. 6 Displays the 2.2.1 processing software user interface after running the GTCRL program.

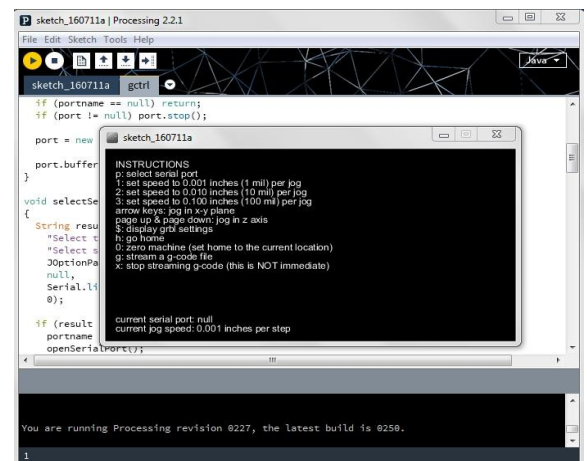
Arduino Uno's port is selected by pressing the 'P' button on the keyboard, thus using the 'G' button to upload our G-code file. CNC machine will immediately begin the sketching of the selected G-code file. Sketching can be stopped by pressing 'X' button.

Fig. 6 Uploading G-code file

d. Coding

The CNC plotter uses the Bresenham's Line Algorithm to plot. Below is a part of this algorithm

```
void line(int x0, int y0, int x1, int y1) {
    int dx = abs(x1-x0), sx = x0<x1 ? 1 : -1;
    int dy = abs(y1-y0), sy = y0<y1 ? 1 : -1;
```



```
int err = (dx>dy ? dx : -dy)/2, e2;
for(;;){
    setPixel(x0,y0);
    if (x0==x1 && y0==y1) break;
    e2 = err;
    if (e2 > -dx) { err -= dy; x0 += sx; }
```

```

    if (e2 < dy) { err += dx; y0 += sy; }
  }
}

```

The test code of Y axis stepper motor is shown below-

```

#include <Stepper.h>
const int stepsPerRevolution = 20;
// Connection pins:
Stepper myStepperY(stepsPerRevolution, 2,3,4,5);
void setup() {
  // Set speed:
  myStepperY.setSpeed(100);
  // max 250 steps for dvd/cd stepper motor
  myStepperY.step(160);
  delay(100);
}
void loop() {
}

```

The stepper motor code for the X and Z axis is the same with the exception of the pin numbers. The full CNC code is uploaded from the processing software to the arduino, then the arduino will wait for the G-code file. When the arduino command is sent by the processing software, it will start plotting the G-code.

E. G-code

First of all, the files need to be translated to G-Code to draw a text file or model a circuit layout by the CNC plotter. G-Code is a set of instructions that includes X, Y, Z, file-dependent coordinates. G-Code instructs the machine's X axis to travel with a specific speed from X1 to X2 points, and the same applies to the Y axis, but the coordinates are fixed for the Z axis because only up and down movements are involved vertically.

3. HARDWARE IMPLEMENTATION

All the physical parts or components of a system is called hardware. Two types of component is needed for this set up. They are mechanical and Electrical components.

- Mechanical components

(a) STEPPER MOTOR

Stepper can be transformed to a pen motion in the direction of axis X, Y, Z. A stepper motor is a brushless motor that divides a full rotation into a number of equivalent phases. By its function, the stepper motor is known to translate a number of impulses into a given shaft position increase. Each vibration, through a fixed angle, pushes the shaft. We've used 3 lead-screw stepper motors. The motor output will be in the form of a lead screw rotation in relation to the X, Y, Z Axis [5]. The output voltage provided by SMPS is 12 volts.



Fig. 7: Stepper Motor

(b) LEAD SCREW

A leadscrew, also known as a power screw or translation screw, is a screw used in a machine as a connection to translate movement into linear movement. Due to the wide area of sliding contact between their male and female members, screw threads have a greater loss of frictional energy compared to other connections. For low-power actuators and positioner mechanisms, they are not usually used to carry high power, but more for occasional use[6]. Common applications are linear actuators, machine slides, vises, presses, and jacks.



Fig. 8: Lead Screw

- Electrical components

(a) ARDUINO UNO R3

Arduino is an open-source platform for electronics based on hardware and software that is easy to use. Arduino boards can read inputs light on a sensor, finger on a key, send a message and turn it into an output switch on a generator, turn on an LED, and publish something online. By sending a set of instructions to the microcontroller on the board we could ask the board what to do. Arduino UNO is a board of microcontrollers, it contains all the necessary to support the plotter [7]. Hereby, using a script, controls the location of the motors.

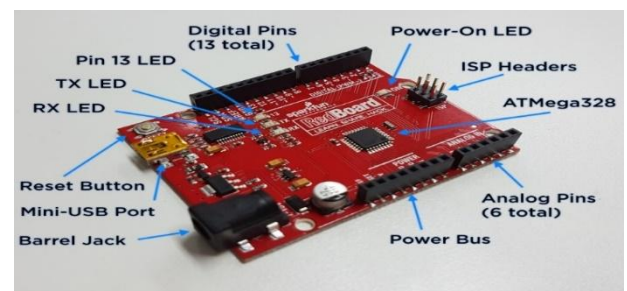


Fig. 9: Arduino

(b) CNC SHIELD

The Arduino CNC shield makes it easy in a couple of hours to get CNC project up and running. Using open source firmware, three stepper motors are controlled by three pieces of stepper driver; s breakout board, with this shield and Arduino We can build a mini CNC plotter machine that is easy to control and flexible to operate. Using SMPS (switched mode power supply), the current

supplied to the CNC shield is 12 volt. CNC shield monitors each engine's current distribution. Stepper Motor will be operated on in this $6 \times 6 \text{ cm}^2$ bed size criteria [8]. If we increase the size or length of the lead screw, we will use this machine to create a large design.



Fig. 10: CNC Shield

(c) STEPPER MOTOR DRIVER

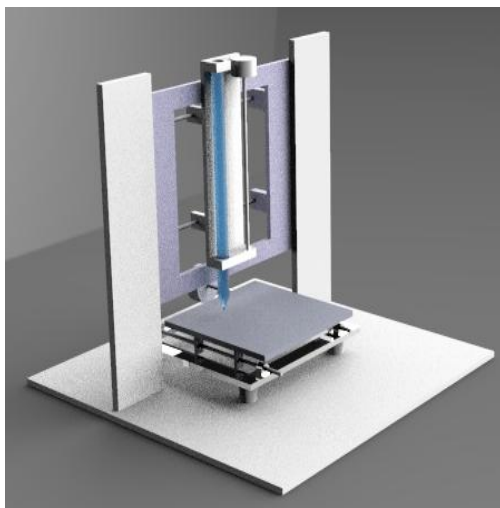
We used three stepper drivers to control stepper motor movement along the axis X, Y, and Z. Stepper driver mounted on Arduino. We provided 5 volt input current via USB cable. Stepper drivers are mounted on a CNC shield, the supply of stepper motor current will be controlled [9]. The motor will result in a rotation of the lead screw. The lead screw controls the movement.



Fig. 11: A4988 stepper motor driver

4. SOLIDWORKS DESIGN

Here two stepper motor with lead screw is used for X and Y axis movement. The third stepper motor is used for Z axis movement of the pen which will write on paper. The X and Y stepper motor will be mounted on hard wood board and the Z axis stepper motor will be mounted on the shaft of X axis stepper motor. There is a board mounted on Y axis stepper motor which will be used as the table for writing on which the paper will be attached.



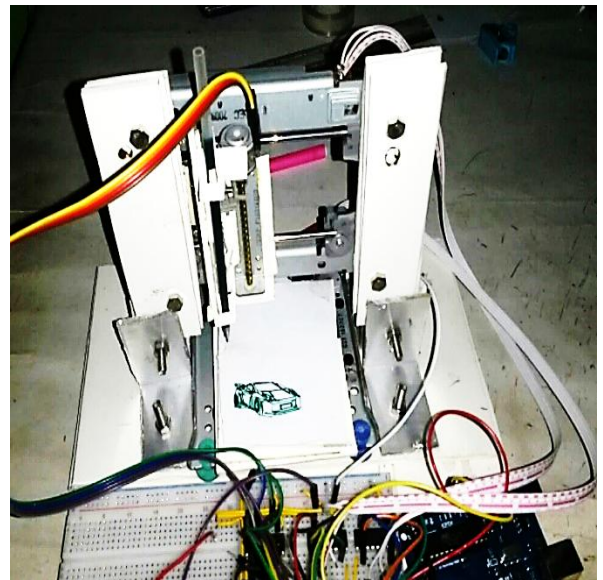
Design of Solidworks

Fig. 12:

4.1 FABRICATION OF MINI CNC PLOTTER MACHINE

We used three DVD writers from which we got together the stepper motors and the mechanism of the lead screw. Then set them up with proper orientation on the plastic wood board. We set the third stepper motor on the first stepper motor on the X axis (upper side). Then we set the pen on the third stepper motor already mounted on the stepper shaft of the X axis. On the Y axis stepper motors shaft, which works as a table for writing or complex drawing, is attached a $6 \times 6 \text{ cm}^2$ plastic wood board.

Fig. 13: Final assembled CNC plotter machine

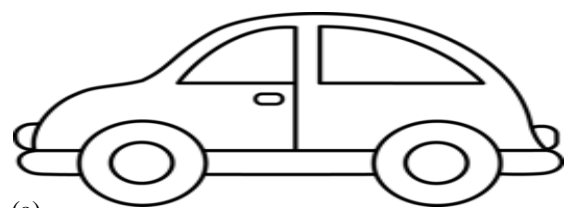


4.2 FULL PROCEDURE OF CNC PLOTTER MACHINE

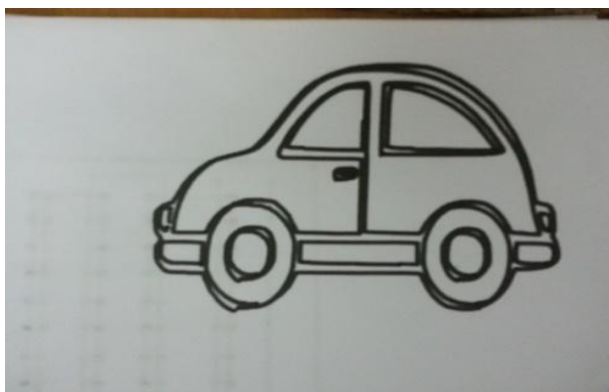
The procedure of CNC plotting machine starts with Inkscape software. we have to upload the JPG file of any image which we will need to be drawn by the machine or we can type anything on the document section which needs to be plotted by the machine. Inkscape software will convert the picture or writing into G-code. Then another software name processing should open on the computer and execute the code for transferring the G-code to the Arduino step by step. Here, Arduino always should be connected with the computer during the operation. The Arduino will receive the G-code, convert it into electronic signal pulse and send them to the motor controller IC.

5. RESULTS

The Fig. 14a shows a black and white image file which has been plotted by the plotter shown in Fig.14b.



(a)



(b)

Fig. 14 Comparison of image file (a) original black & white image (b) plotted image

6. CONCLUSION

The concept of a low-cost three-axis mini CNC plotter was presented in this paper. The new CNC machines are expensive, hard to maintain, and require highly skilled operators. These problems are solved by our CNC plotter. It is low cost and easy to manage, and highly qualified operators are not required. On a path that is not feasible in existing ones, it can be used for long hours. Extending this work for future development is planned.

6.1 FUTURE SCOPE

- This machine can be used as a laser cutter by replacing the pen with laser light.
- This machine can be converted into a PCB printer by replacing the pen with copper printer and a drill.
- This machine can be converted into a CNC drilling machine by removing the pen and installing a drill.

7. REFERENCES

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