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Implementation of Low Cost Cnc Plotter Using Arduino

Prof. Neha Chourasia[1], Rohit Tembhurne[2], Pradeep Wasnik[3], Shivam Londhe[4], Roshani Sahare[5], Vaibhav Mundafale[6]
[1, 2, 3, 4, 5, 6,] *Department of Electronics & Telecommunication, RTMNU University, Nagpur, Maharashtra, India*

Abstract: ***With the advancement of technology, demand for Computer Numerical Control (CNC) plotter machines in Educational Institutions and Laboratories is rapidly rising. Low cost manufacture of Printed Circuit Board (PCB) has become a basic need in electronics laboratories, for electronics engineering students and for electronics hobbyists. This paper will present an affordable model of a CNC plotter machine which is able to draw a circuit layout on PCB or any other solid surface using simple algorithm and available components. At first the user needs to convert any image file or text file into G code using Ink space software and then feed it to the machine using Processing software. Arduino uno with an ATmega328P micro-controller is used as the control device for this project. The micro-controller converts G-code into a set of machine language instruction to be sent to the motor driver of the CNC plotter.***

Keywords: Computer Numerical Control (CNC), Printed Circuit Board (PCB), G-code, Micro-controller Unit (MCU), Plotter, arduino board.

I. INTRODUCTION

A Plotter is a special type of printer that uses a pen to draw images on solid surfaces. In Computer Numeric Control (CNC), microprocessor is used which is capable of processing logical instructions interfaced with a computer. The logical instructions are provided by using a computer in the form of code or text or image which is then transformed into a machine language by microprocessor to be executed by the machine. A CNC plotter machine is a 3D controlled 2D plotting machines which uses a pen to draw text or image on any given solid surface. It can be used for the purposes such as PCB Design, logo design, etc. This project is based on CNC plotter machine With the increasing demand for the use of CNC plotters in universities and laboratories, a cheap and less complex design is an absolute need. The parts used for the plotter in our project are easily available at a very low price and spare part sare also used. The construction is very simple and robust.

II. OBJECTIVES

The objectives of this project is to design and implement a CNC plotter machine (Drawing surface area 20cm x 20cm) which will be able to draw a PCB layout (or any image) on a solid surface.

III.METHODOLOGY

A CNC plotter is able to draw complex line drawings. The coordinates are uploaded to the machine controller by a separate program. The image file is transformed into a G-code via Software. Then the code is transferred to the microcontroller by which the motor mechanism is instructed to draw the image. In this project, we are going to present a simple design for a CNC plotter. Our idea is an arduino based design using ATMEGA 328P microcontroller. The machine will have three motors to implement the X, Y, and Z axis. A servo motor will be used along the Z axis for positioning the pen which will go up for logic 0 and down for logic 1[1]. Drawing will be done on the X-Y plane where the positioning will be controlled by stepper motors.

Mini CNC Plotter Machine is worked on input as a G codes of Design and Converting it via use of arduino, Stepper Drivers, CNC Shield, Stepper Motor in to a Rotation of Lead screw. We have work on to maintain lowest cost of our project. We have design a simple construction of our project. This is easier way to use stepper motor with lead screw, CNC shield, Stepper drivers, Arduino based atmega328 Board, etc. The Setup of machine is flexible that's why it will be easily Transported and Maintenance time is short.

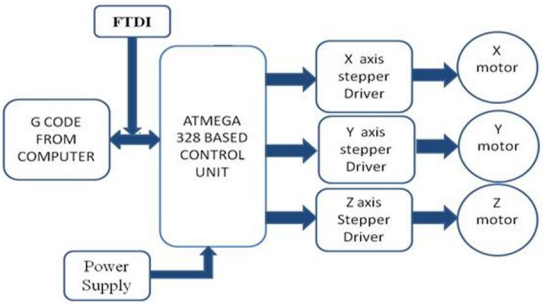


Fig1. Block Diagram Mini CNC Plotter Machine

IV. SCHEMATIC ARRANGEMENT

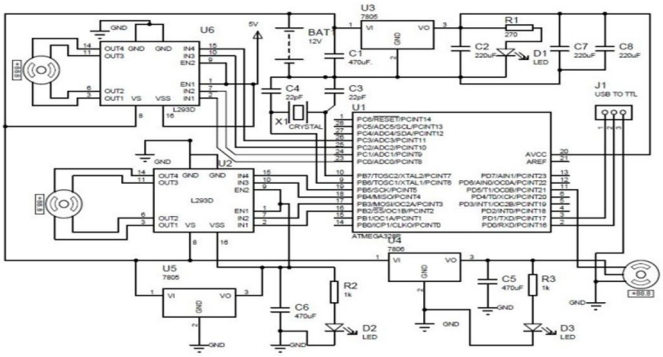


Fig2. Schematic Diagram

V. PCB CIRCUIT LAYOUT

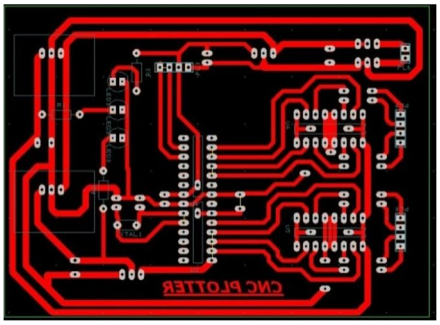


Fig3.Pcb Circuit Layout

VI. WORKING OF PROJECT

Main blocks of this system consists of power supply, FTDI module, ATMEGA328, 3 Easy drivers each connected to stepper motors X, Y, Z. From power supply we get two voltages i.e. +5volt and +12 volt. 5volt which is required to ATMEGA328, Easy drivers whereas +12volt supply is required to stepper motors. RESET is connected to5v supply through 10k ohms resistors to pull up the voltage thus it act as a pull up resistors. We have used here16MHz crystal oscillator connected to ATMEGA with two capacitors of 22pF. The GRBL code from computer is interface with controller using FTDI 232 module i.e. serial to USB converter. The output of FTDI is given to pin no.2 and 3 i.e. RXD and TXD pins of ATMEGA328. The output of ATMEGA328 is given to three Easy Drivers. Easy Driver consists of 16 pins from which we are using in our project only 9 pins. Four pins are used for two stepper motor coil i.e. coil A and coil B. Two pins for input 5volt supply i.e. VCC and GND. Three pins are used for STEP, DIR; GND. STEP is used for micro stepping. DIR is direction input pin which will move stepper motor according to the given dimensions. Third pin is directly grounded. Spindle motor is connected to pin no. 16 of ATMEGA328. It is used for drilling purpose. According to the given dimensions Easy drivers or drilling machine will move. When working of motors is completed the dimensions on pc will roll of to again its initial value i.e. zero.

VII. SOFTWARE AND CODING

A. To Complete The Task Of Entire Project Three Software Is Used-

1) Inkscape
2) Fritzing.
3) Processing
4) G- Code

B. Inkscape 0.47

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

Creating G-Code File Using Inkscape

The CNC plotter of our project will work within 80 mm×80 mm area.

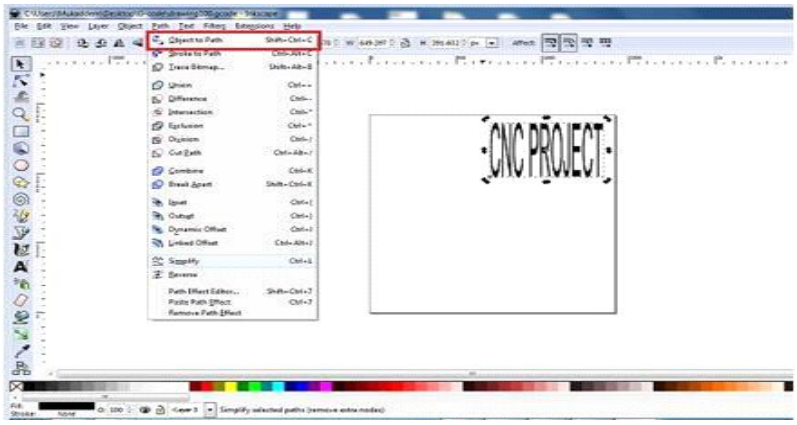


Fig. 4 Conversion Of Text To G-Code

So we choose the document properties of the Inkscape 40cmx40cm (Width × Height) which is four times the working area of the plotter because the plotter can draw only in the first quadrant. So we have initially kept the axes at the nearest end of the motors which is considered as origin to easily modify the design. In Fig. 3 the working area of CNC plotter is shown with the text written in the pre-defined area. The text is selected using cursor and then select “object to path” from the drop down window to save the G-code form of the selected text. To create G-code of an image, the file must have a transparent background. The image should be dragged into the selected area then select “trace bitmap” from drop down window to create a transparent image. Scans are selected as 8 and “Edge detection” is selected to create black & white image. After adding this transparent image in the predefined area we“ve used “object to path” command to create the G-code file of the selected image by following the steps described earlier.

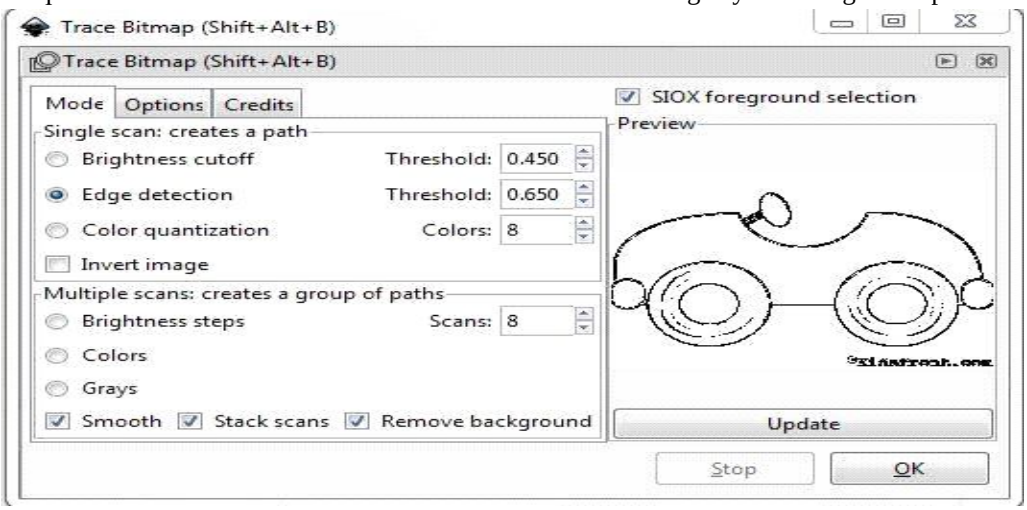


Fig. 5 Creating Transparent Image (A)Original Image (B) Transparent Image.

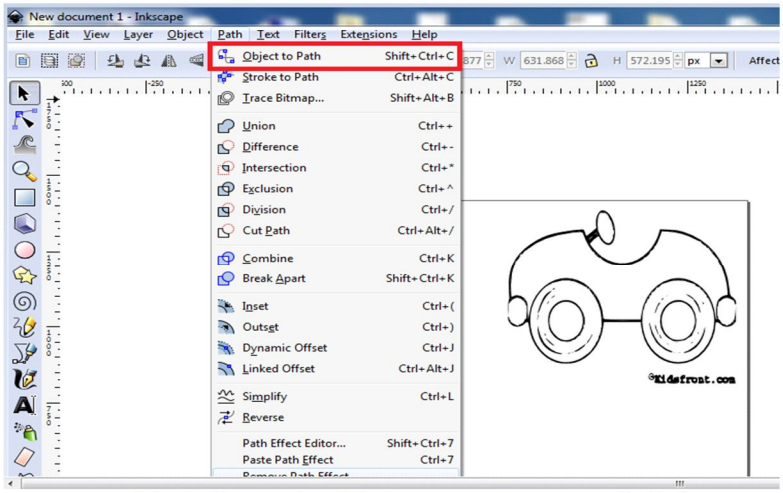


Fig. 6 Conversion Of Transparent Image To G-Code

C. *Fritzing*

It is friendly open source circuit simulator software which is mainly used for PCB design. Creating PCB Layout Using Fritzing Using „Breadboard" option any circuit can be built easily by simply dragging and dropping down different components. Schematic circuit diagram and PCB layout will be generated automatically. In PCB layout we need to choose positions of the components, their layers and establish connections. Then "Export for PCB" option is selected and choose "Etchable SVG" (Scalable Vector Graphics). From the saved folder the top layer mirror file is loaded. The file is automatically loaded in Inscape software and from there G-code will be generated as described earlier.

D. *Processing*

Processing is open source programming language software which is used for electronic drawings. GTCRL processing program is used to send G-code file from user interface to CNC plotter. The Fig. 6 shows the user interface of processing 2.2.1 software after running GTCRL program. The port of Arduino Uno is selected by pressing „P" button on keyboard hence „G" button is used to upload our desired G-code file. Immediately CNC machine will start sketching selected G-code file. Sketching can be stopped by pressing „X" button.

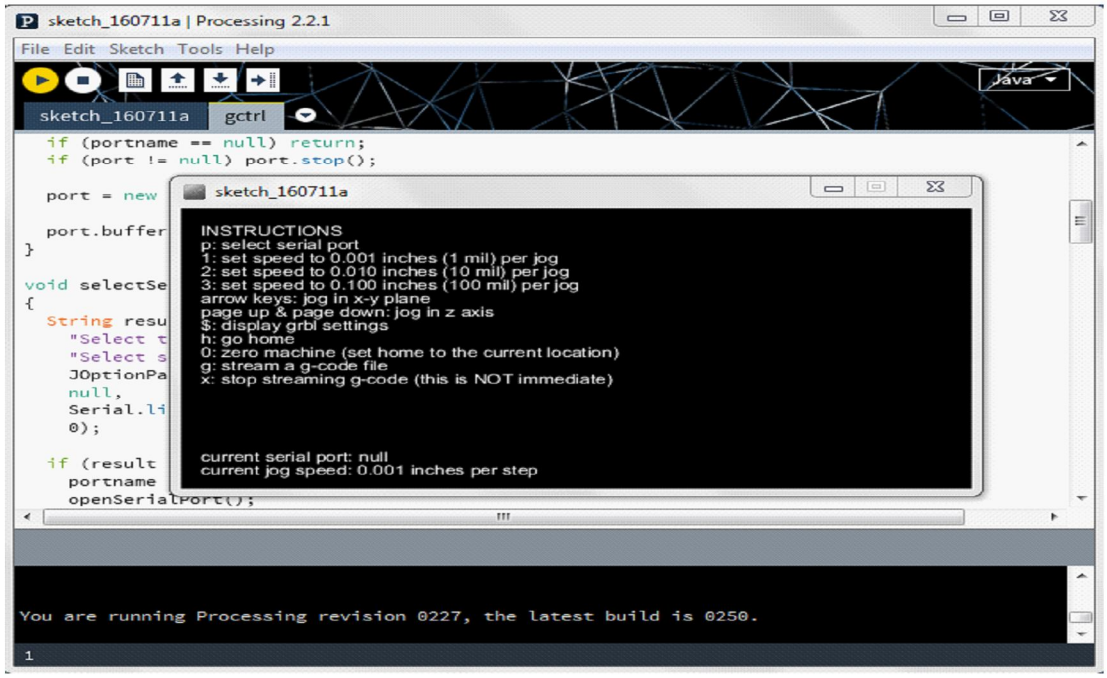


Fig. 7 Uploading G-Code File

E. G-code

To draw a text file or design a circuit layout by the CNC plotter firstly the files need to be converted into G-Code. G-Code is a set of instruction that contains number of X, Y, Z, coordinates depending on the file. G-Code instructs X axis of the machine to travel from X1 to X2 points with a specific speed and same is true for Y axis, but for Z axis the coordinates are fixed because only vertically up & down movements are involved.

VIII. HARDWARE IMPLEMENTATION

A. Mechanical Design

Mechanical Design of CNC Plotter Machine the two dimensional mechanical design of the body of CNC plotter is shown in Fig. 7

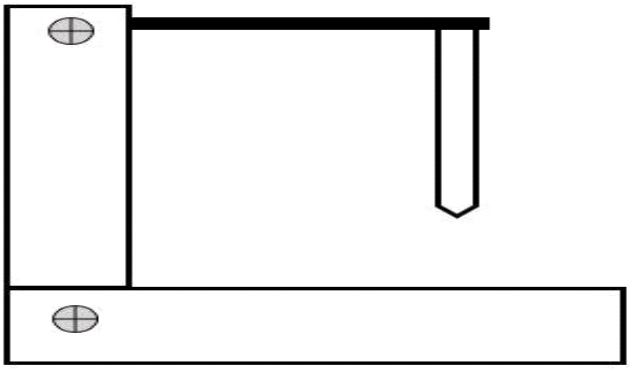


Fig. 8 Mechanical Design Of CNC Plotter

B. Components Required

To erect the CNC plotter machine, the required components are listed below:

1) Stepper motor (2 pieces)
2) Motor driver module (2 pieces)
3) Servo motor
4) Power supply
5) Arduino uno
6) Gears
7) Pen
8) PCB
9) Connectors and Cables
10) Diodes

C. Mechanical Body Description

1) Motor Mount: We took DVD slider have been disassembled and their sliding mechanism units have been collected. One of which will act as X axis and the other as Y axis.

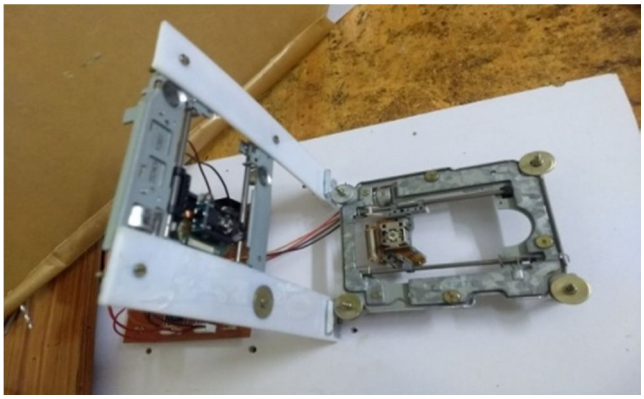


Fig. 9 Sliding Mechanism

For the X and Y axes we will use two stepper motors and rails from dvd/cd drives and for the Z axis we will use a small servo motor that moves the pen up and down. For the mounting base we will use a small piece of plexiglass. You can easily attach a pen (or pencil) - irrespective of its thickness - on it. I tried to use an extension of cutting tool (e.g. Dremel) to engrave materials with no success. So this mini cnc can only be used as a small plotter and not as an engraver machine. The Arduino-based circuit is using the ATmega328 microcontroller, two L293 motor driver ICs and an usb to serial module. You can easily make it with the Arduino uno board and an breadboard. You can also use an Bluetooth module (e.g. HC-06) to print your texts (or images) wirelessly through your computer Bluetooth connection! Pretty cool huh?

2) Axis Mount: Y-axis: Place the other stepper motor on two plexiglass pieces and mark them with a pen in order to open the (4) holes for the screws. Again, make sure that the motor is perfectly align (use a triangle ruler).

Place the two pieces of plexiglass on the X axis (big plexiglass piece) and mark them with a pen in order to open the (4) holes required to fit on the mounting angles.

X-axis: Place one stepper motor (with rails) on a big plexiglass piece and mark it with a pen in order to open the (4) holes for the screws. Make sure that is perfectly align! (use a triangle ruler). Open the holes and mount the motor with nut screws. Place on one side of it the four mounting angles and then mark it with a pen in order to open the (8) holes required for the screws. Make sure that the distance between them is 5mm (thickness of plexiglass). The second image above will help you to understand more.

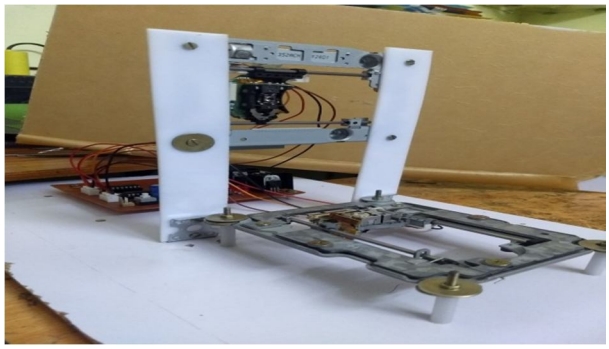


Fig. 10 Mounted X Axis On Y Axis

Z-Axis: That's the most difficult part of our construction. You will need something to attach it on Y axis, a flat surface. On that surface you will attach the servo motor (Z axis) and the pen base. Pen (or pencil) must be able to move up and down with the help of servo motor. Watch the above image to understand what you need to do to build Z axis.

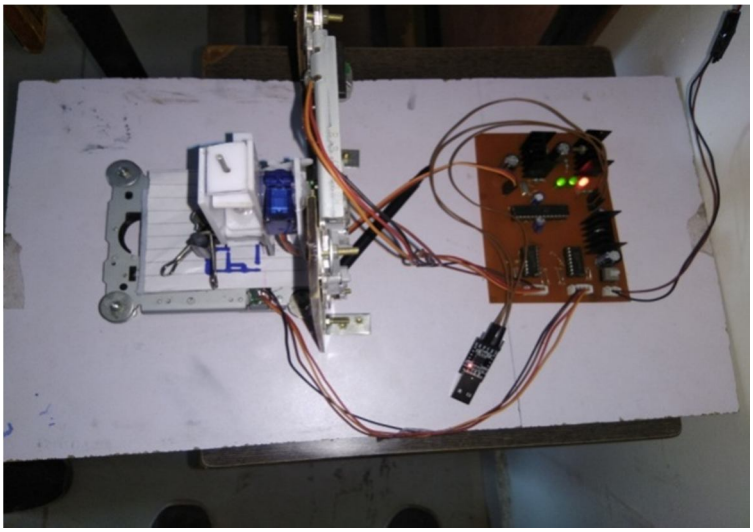


Fig. 11 Mounted Z Axis With X Axis

D. Complete CNC Plotter

After all those mounting of motors with the sliding mechanism unit and axis with each other also with basement implementation become completed. The Fig. 12 shows complete CNC plotter.

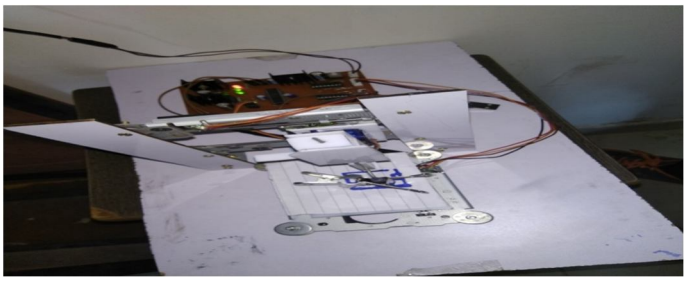


Fig. 12 A Complete Cnc Plotter

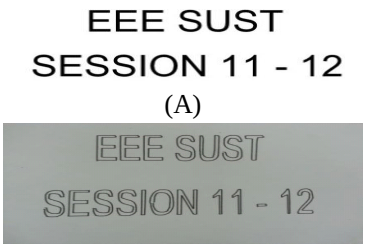
E. Calibration

After finishing the complete build-up of the machine, it is necessary to calibrate the movement of the axes. Test code for stepper motor mentioned in the section IV (D) is used where stepper motor's steps per revolution was 20 and 160 steps were allowed for the motor to travel. On running the code, it is found that the motor has travelled 26.5 mm which indicates that the motor takes 6 steps to cover 1mm. this is how calibration is done for both X and Y axes.

IX. EXPERIMENTAL RESULTS

A. Text File

A text file has been designed and sent to the CNC plotter for drawing the text. The original file and the plotted files are shown in the Fig. 13.



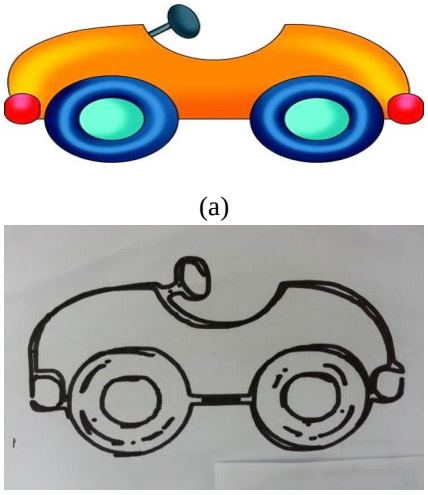
(A)

(B)

Fig. 13 Comparison Of Text File (A) Original Text (B) Plotted Text

B. Colorful Image

Fig. 14a shows a colourful image file that has been converted into a sketch through bitmapping and edge detection and then plotted via cnc plotter machine shown in Fig. 14b.



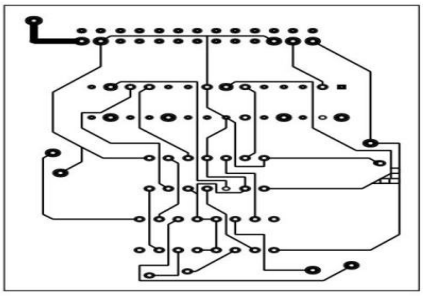
(a)

(b)

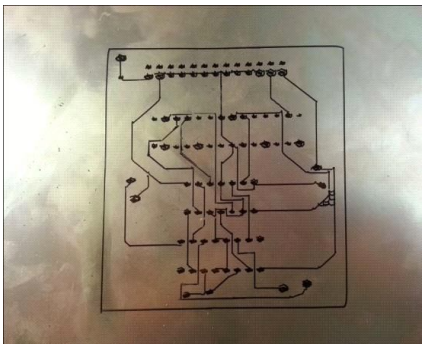
Fig. 14 Comparison Of Image File (A) Original Image (B) Plotted Image.

C. PCB Layout

The Fig. 15a shows PCB layout that has been drawn on PC and Fig. 15b shows the one which is plotted by the plotter. We can see that the layout is accurately drawn by the plotter with only slight error by a few mm in two places.



(a)



(b)

Fig. 15 PCB Layout By (A) Inscape (B) Plotter On Copper Clad.

X. FEATURE

This project is about building a mechanical prototype of a CNC plotter machine which is able to draw a PCB layout of 20cm by 20cm (or any image/text) on a given solid surface.

It consumes low power and works with high accuracy due to precise controlling of stepper motors.

This is a low cost project as compared to other CNC product. It is made with easily available components and spare parts.

It is designed for private manufacturing and small scale applications in educational institutes. The machine is designed with a very simple construction scheme and can be carried anywhere without much effort. The algorithm used is simple.

The pen can be replaced with a pinhead or laser head or any other tool for different purpose of use. Software that has been used is open source and user-friendly.

The existing CNC machines are of high cost, difficult to maintain and requires highly skilled operators. Our CNC plotter overcomes these problems.

It is of low cost and easy to control and there is no need of highly skilled operators. It can be used for long hours at a stretch which is not possible in existing ones. It is hoped to extend this work for future development.

XI. APPLICATION

Metal Removal Industries the proposed CNC 2D sketcher can also be modified to use in metal removing industries so as to remove the unwanted metals from the raw materials to get the desired small size automotive parts and industrial components.

Metal Fabricating Industries In fabrication industry, the machining operations can be performed on metal bars / plates with the help of CNC lathe or milling machine. Similar application like CNC milling in manufacturing of turbine blades are widely employed in recent times.

Electrical Discharge Machining (EDM) Industry The proposed CNC 2D sketcher can also be modified as an electrical discharge machine which removes the metal by burning of metal and as a electron beam melting machine.

Other Industries There are other industries which use CNC machines widely. Industries like the wood working which includes various operations like routing, drilling, lettering and engraving operations.

XII. FUTURE SCOPE

The pen of the machine can be replaced by a laser to make it work like a laser engraving or cutting machine. Engraving machine can be used on wood.

The pen can also be replaced with a powerful drill so that it can be used for both milling and drilling purposes.

The servo can be replaced with a stepper motor and the pen with a 3-D pen to make it a 3-D printer which can print objects with dimensions. By extrapolation of the axes, the working area of the machine can be extended keeping the algorithm unaltered.

XIII. CONCLUSION

This project is about building a mechanical prototype of a CNC plotter machine which is able to draw a PCB layout of 20cm by 20cm (or any image/text) on a given solid surface. It consume slow power and works with high accuracy due to precise controlling of stepper motors. This is a low cost project as compared to other CNC product. It is made with easily available components and spare parts. It is designed for private manufacturing and small scale applications in educational institutes. The machine is designed with a very simple construction scheme and can be carried anywhere without much effort. The algorithm used is simple. The pen can be replaced with a pinhead or laser head or any other tool for different purpose of use. Software that has been used is open source and user- friendly.

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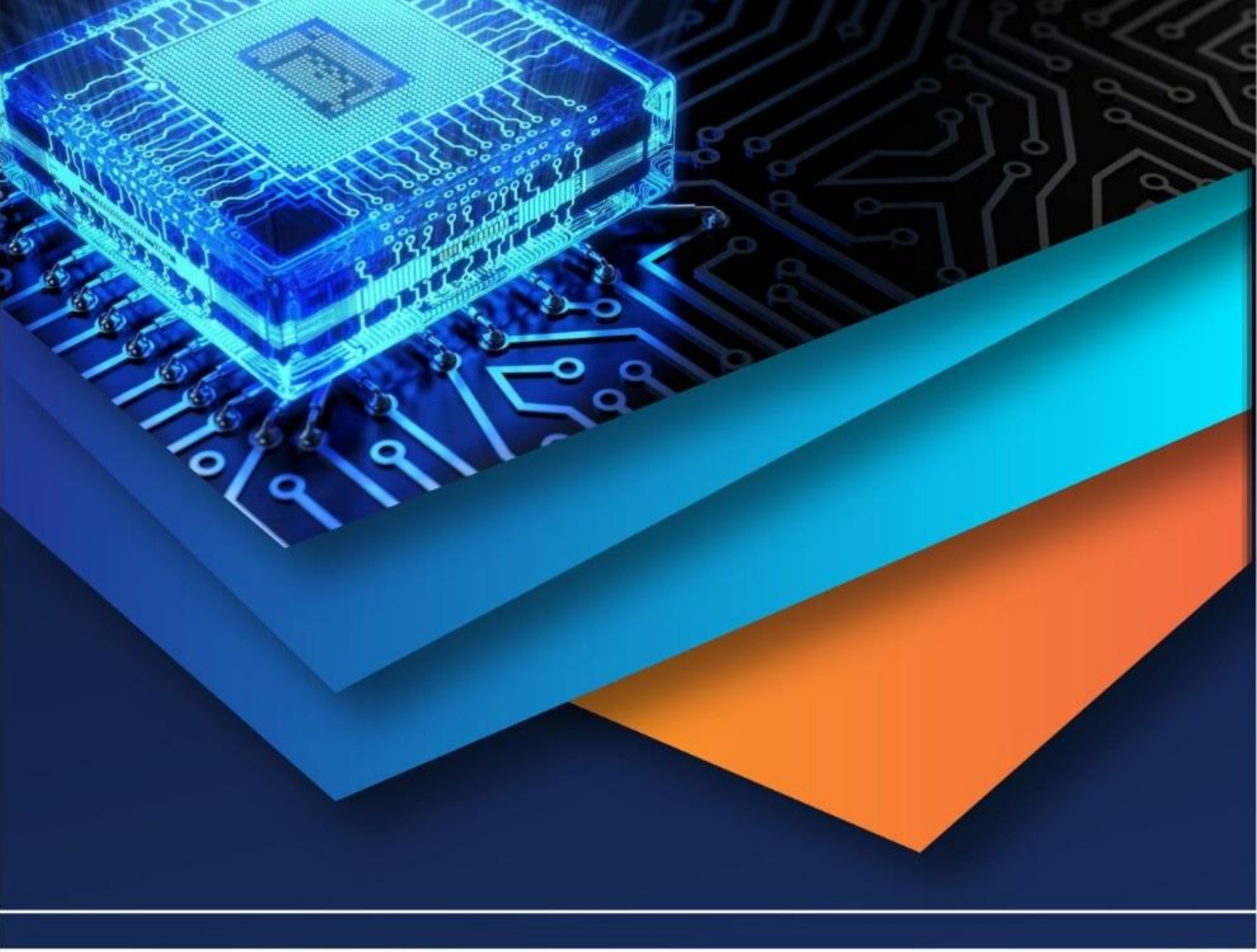

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