

# Review on Building a Cost Efficient Pen Plotter

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**Abstract** - Pen plotter works in the principle of Computer Numerical Control. It is more efficient and productive for plotting 2D data provided in the form of vector graphic files on a rectangular sheet. The robot plots the information transferred through PC and controlled by a microcontroller. It fundamentally uses two stepper motors for two axes control and a servo motor to raise and place the pen. These motors are controlled and driven by CNC shield or L293 motor drivers. For programming G code converting software like Inkscape is utilized. The main objective for reviewing this topic is, in this era the technology based on the CNC machine is to reduce cost and complexity for producing machines with maximum efficiency and low cost. On this review paper a conclusion about choosing microcontroller, motor driver and other components for the productive machine with maximum efficiency will be discussed. The uses are it reduces the human effort for sketching, writing in different styles, long sheets and also reduces the chances of error, especially in business graphics. It also allows you to plot in cardboard and other materials in a rectangular shape with providing exceptional quality resolution.

**Key Words:** Computer Numerical Control, L293 driver, G code, Inkscape

## 1. INTRODUCTION

Robotics is more focussed on industries, where machines can be demonstrated automatically. This whole process which is made and works with the human mind, no need for any human effort for further production is known as Automation. Similarly in this machine, after uploading the code it performs plotting by itself. The main reason for reviewing is to evaluate existing methodologies and its efficiency to make a pen plotter of reduced cost under fewer circumstances. After reading this paper there will be a clear understanding and help to guide to build a pen plotter. The working principle is Computerized Numerical Control(CNC), where the activities are self-regulated based on the G-codes entered and the working of a plotter, components used are explained in further topics. Since there must be given equal importance for mechanical design, hardware and software implementation the topics are also framed based on it.

## 2. WORKING

With the block diagram (Fig 1) as a reference, the overall technique is when we upload the converted G-code file into

the software in a computer, the signals are passed through the controller and from there to motor shield or driver based on selection and then to the stepper motor X-1 and stepper motor Y-1 for moving in two cartesian coordinates and for Z-axis it uses a servo motor. Writing pen is attached with servo motor which moves up and down for plotting. This way all types of pen plotter works.

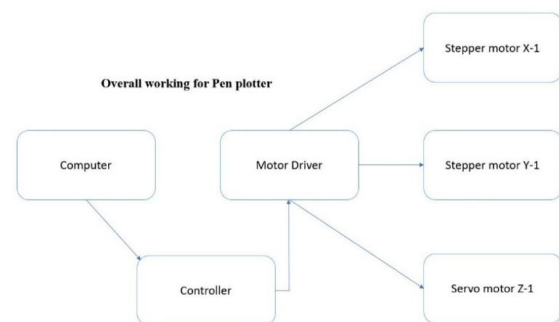


Fig -1: Working of Pen Plotter

## 3. METHODOLOGY

The main difficulty in the production a pen plotter is choosing the perfect design and proper electrical components. Upon discussing on mechanical design, it is based on the place where it should plot. The main factors that judge the design are an area of plotting, driving mechanism and also the placement of components. As simple as plotter can be made using two DVD/CD drives and can be used. But the outcome is of small area and it can also become a prototype for further tasks. Here it focusses for plotting area of 400mm\*400mm. This is the first step because all works have some purpose of output. After these upcoming topics, the selection of components and the uses of them will be clear.

## 4. MECHANICAL DESIGN

For any machine, mechanical design is the basic or essential need only after that any electrical elements can be covered upon it. Since this topic also includes actions like manufacturing, assembling and fixing up. It focusses on the available materials. As mentioned before using DVD drives can also be used. But for the area of 400mm\*400mm, the design will be like as shown in figures Fig 2, 3.

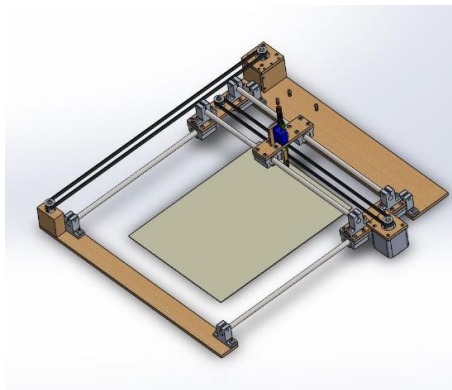


Fig -2: Plotter with fixed Paper

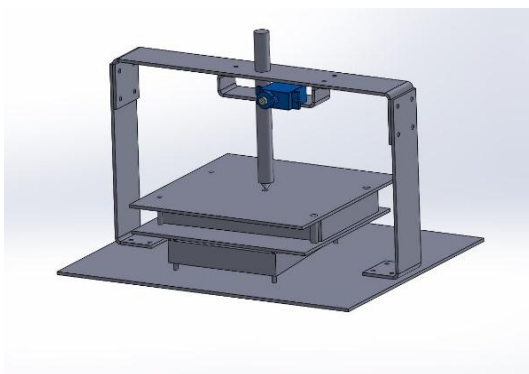


Fig -3: Plotter with moving Paper

From these diagrams, a conclusion about all types of plotter will be cleared. Figures 2 have an output paper base fixed and while in Fig 3, the base plate where the sheet is to be attached will move accordingly instead of moving the pen frame. Another difference is the type of mechanism used. For moving along the axis belt-driven mechanism using a pulley or lead screw mechanism is used. The difference between both is while using a belt, it is easier to use for changing the positions and cheaper than the lead screw. But for highly precise control and heavy load application, the lead screw is the best choice. The outer frame can be built using wood or acrylic plastic or aluminium from shop or online. For low cost and high efficiency, it's better to use accessible material for the outer frame. After fixing the outer frame as per design, based on the mechanism of movement, inner parts like rods and attachments can be purchased. While choosing these maintenance and drafting parts should be focussed little advanced. Side rods are linked to keeping the pen frame from interruptions due to vibration or any rotation while sliding. Plotting frame or pen frame should be fixed with spring for free movement. For reducing the noise produced, fixing of motors and wiring should be convenient for movement. These are the divisions of mechanical design and also high performance can be achieved through this. But also choosing the right pen for plotting also matters. Mostly 0.5mm ballpoint pen is used for testing, based on the need it can be varied.

## 5. HARDWARE DESIGN

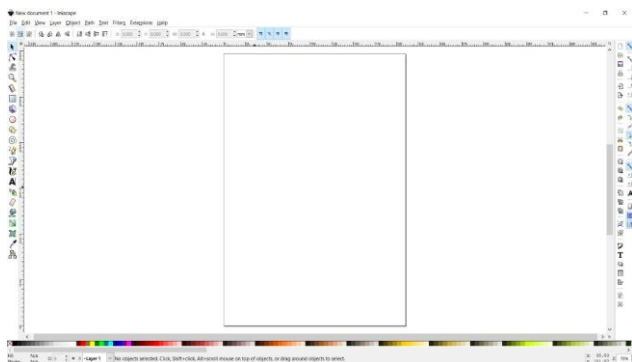
The electrical components are chosen by starting with motors and then the type of driver followed with a controller. The technique for the selection of motors is based on mechanical design. After getting the weight of design that each motor should carry, the choice of motors based on torque required to rotate, the motors are chosen. For most of the conditions, Nema 17 hybrid stepper motor with 1.8-degree step angle of holding torque 4.2 kg-cm can be used for both axis control. Only at 12 volts, this motor provides high torque. For different axis using different torque stepper motor based on the weight it carries, will be good but both should be of the same step angle. Next is to select a motor for holding, placing up and down the pen at correct positions. This can be accomplished by SG-90 servo motor which has 2.5kgcm torque and 180-degree rotation. Since the usage of motors and the selection of it is finished. Based on the working and controlling of the motor, the driver can be chosen. By that way for PWM signal control, Arduino CNC shield V3.0 with A4988 stepper drivers is the best pair for any CNC application. Although running stepper motor using TB6600, L293D is possible but this shield could be faster and compact. Now for the selection of controller, Arduino UNO is excellent for this application. CNC shield also fixes on Arduino perfectly. Raspberry Pi can also be used instead of Arduino, but the requirements are satisfied with Arduino and if any additional process like scanning and storing data are done, then Raspberry Pi 3 can be used. Replacement of Raspberry in the place of Arduino can be also done. There are also other controllers named MSP430 and Mach 3 which is of high cost and mainly focussed on robust applications. It has its own separated interface for programming and motor driver can be used the same. MSP430 needs RS232 cable for communication and operates at a low voltage of 3.5 volts.



Fig -4: Hardware Components

## 6. SOFTWARE DESIGN

Basically for running this CNC machine, G-code is the language for communicating with it. This type of communication between computer and hardware is not possible without these serial ports, USB ports, parallel ports, ethernet cables. Coming is nothing but a type of function used to control the position of tools. There are also other types of codes namely M-code, T-codes used for other CNC machines. These G-code files have vector graphics in terms of x, y and z coordinates which orders the position of machine to move. All these works can be made by just drag and drop the required image or document into the respective software. For most of the conditions, Inkscape software is used as a G-code converter. The steps for converting are opening the software and do some changes in settings like changing the area of the sheet, scale to millimetres and especially adding libraries. Then place the word or image file and rescale accordingly. After that just save the file as in the form of example.gcode and upload to IDE based on the controller attached. For Arduino UNO, download the library GRBL and run the file. Use GRBL software for the final steps, here the converted file is uploaded and the vector file will be plotted. Figure Fig 5 is about how the software Inkscape looks and its logo.

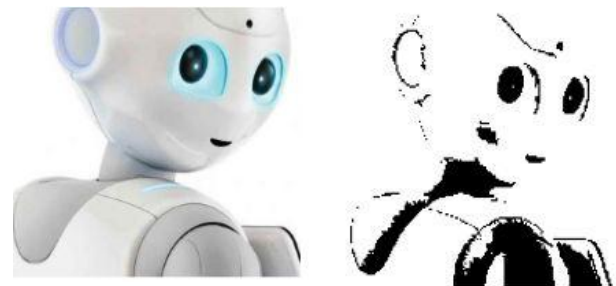


**Fig -5:** Software Outlook

Other software can also be used are Coral Draw for converting .dxf file, Lazy CAM for .gcode and Mach 3 for loading the G-code in case the controller is Mach 3. This requires a special package named Parallel port driver and session profile named Mach 3 Mill. After installing any software, drawing simple figures like square, the circle is a must and measuring the size of the plotted image because it varies with the given input. This can only be rectified by trial and error method through adjusting the steps per revolution of stepper motors. Few plotted diagrams are shown in figures Fig 6, 7.



**Fig -6:** Plotting of Animation



**Fig -7:** Plotting of Robot

## 7. CONCLUSION

By referring to the discussed topics, building a pen plotter will be effortless and time-consuming for new individuals. As discussed, converting G-code of input files and uploading into the controller will make the pen plotter to work accurately. Since this paper mainly focuses on the construction of pen plotter, its methodologies and reducing the cost by selecting components, it did not target about using this machine in other ways like laser cutting, PCB designing. These functions can also be accomplished.

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