Mini CNC Drawing Machine for PCB Printing

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Abstract - *The usage of CNC machines in industries has increased due to rapid development in technology. The machine fabricated helps in reduction of cost and the complexity in design. This project deals with the design of mini CNC 2D plotter machine that can help in PCB fabrication. The idea behind the project is to design a low-cost CNC system, the lower cost is achieved by incorporating features of PC with ATMEGA 328 controller in an Arduino and CNC shield V3. The image is processed by Benbox software and given to the Arduino board. The stepper motors are used for X-axis and Y-axis movement. The image can be made accurate by properly designing the motion of X-axis and Y-axis. The threaded shaft, plain shaft and sliders are used to convert the rotational motion of stepper motor into linear motion of X and Y axis. The stepper motor signals are produced by CNC shield V3, that produces the motor signals based on G-codes catalysed by the GRBL 0.9 compatible. The movement of pen is controlled by servo motors, that in turn are controlled by the servo signals produced by the CNC shield.*

Keywords— CNC shield V3, ATMEGA 328, Stepper motor, Servo motor, Benbox software, Arduino Uno

1. INTRODUCTION

Since the industrial revolution, modern life has depended on advanced machinery to manufacture everything from textiles to steel. The advent of computer numerical control (CNC) machines revolutionized the manufacturing industry by allowing for a programmable design of virtually limitless types of shapes. Tracing the history of computer numerical control demonstrates not only its importance but also the accelerating pace of change in manufacturing in the span of a generation, CNC machining advanced to such a degree that it made possible the widespread automation of virtually any machined part of wood, stone, or metal. This has reduced time and labour costs and allowed goods to spread across the globe for a fraction of what a hand-made equivalent would cost. The project was initiated in order to provide economical and durable solution for PCB printing. Manufacturing of this machine takes very less time when compared to other CNC machines. This machine is a low-cost machine for drawing in two dimensions. It is mainly used for PCB layout drawing. PCB's boards are used in almost all the electronic applications and by many universities and students in their projects.

2. METHODOLOGY

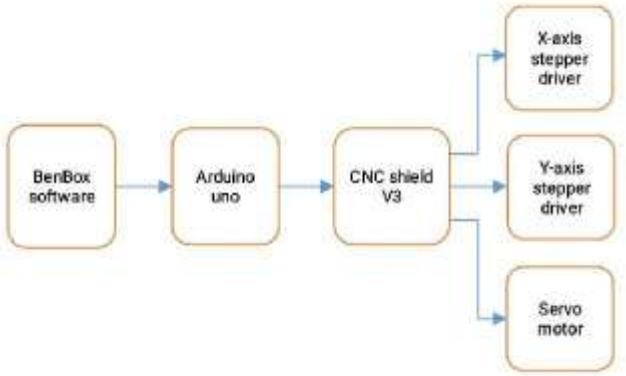

Fig 1: Block diagram

Mini CNC Drawing Machine takes input command or image from the computer using benbox software and the image is plotted via use of Arduino, Stepper Drivers, CNC Shield, Stepper Motor, servo motor and various hardware part used to convert rotational motion of stepper into linear motion for printing. The image is processed by benbox software and the input is given to the Arduino Uno board via USB cable. Arduino processes the signals are given to the CNC shield V3.

2.1 Benbox software

This software is used to interface the image to be printed with the CNC shield. In the software initially the COM port and the firmware file required is selected. There are various parameters that need to set in the software. These parameters are to specify the servo motor position, speed and angle, and also the stepper motor position, step size and speed. The image is directly given to the benbox software.

Fig 2: Benbox software

2.2 Arduino Uno board

Arduino Uno is microcontroller based on ATmega328P Atmel AVR family microcontroller (MCU). It is an open source software and hardware design and manufacture a single of microcontroller. It has 14 digital Input/output pins and 6 Analogue input can be sampled using on-chip ADC. By using open source can be programming Arduino Uno. It also has 6 PWM outputs multiplexed on to the digital IO pins. The dimensions of Arduino Uno measured are [68.6 mm x 53.4mm].The image or the command is processed by the benbox software. And the processed signal is given to the Arduino Uno board using a cable. The Arduino Uno board is directly connected to the CNC shield V3. The supply required for the servo motor is given by the Arduino board.

Fig 3: Arduino Uno board

2.3 CNC shield V3

The Arduino CNC Shield makes it easy to get the CNC projects up and running in a few hours. It uses open source computer code on Arduino to control 4 stepper motors using 4 pieces of A4988 Stepper Motor driver breakout board, with this CNC shield and Arduino Uno, can be build project including CNC routers. The purpose of this CNC shield to control on the three axes (X, Y and Z axes) of CNC plotter machine, meaning control on the stepper motors. The Arduino CNC shield is powered by 5V, 2A power supply. This power drives the two stepper motors in X and Y axis. The required voltage is supplied by setting the pot on driver module

Fig 4: CNC shield V3

- GRBL 0.9 compatible. (Open source firmware that runs on an Arduino UNO that turns G-code commands into stepper signals)
- PWM Spindle and direction pins
- 4-Axis support (X, Y, Z, A-Can duplicate X, Y, Z or do a full 4th axis with custom firmware using pins D12 and D13)
- 2 x End stops for each axis (6 in total)
- Coolant enabled
- Uses removable A4988 or DRV8825 compatible stepper drivers
- Jumpers to set the Micro-Stepping for the stepper drivers. (Some drivers like the DRV8825 can do up to 1/32 micro-stepping)
- Compact design.
- Stepper Motors can be connected with 4 pin connectors or soldered in place

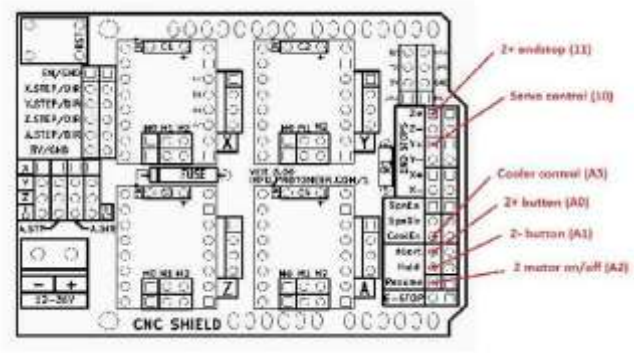

Fig 5: Layout of CNC shield V3

2.4 Stepper motor

The stepper motor used in the project is NEMA 17 2 phase 4 wire 1.8 degree step size with torque of 4.2kg/cm.The digital pulse stepper can be converted into the movement of the pen with respect to the X, Y, Z axes directions. The stepper motor is a brushless motor that distributes full rotation in several equal steps. Stepper motors are used to convert rotational motion into linear motion. They are kept in X axis and Y axis. They are kept exactly at an angle 90 degree. They are mounted in horizontal direction, one which moves forward and back, and the other which moves left and right. This machine has used two stepper motors with threaded shaft and slider. The output of the motor will be in the form of the rotation of the shaft with respect to the X and Y axis. The power supply is given from the 5V, 2A adopter given to the CNC shield.

Fig 6:Stepper motor

2.5 Servo motor

MG90s micro servo motor having a torque of 2kg/cm and a reaction speed of 0.11seconds/degree is used. This is fixed in the vertical direction for the moment of Z axis. The servo motor moves the pen up and down. The supply to the servo motor is given from the Arduino Uno board.

Fig 7: Servo motor

3.DESIGN

Designing of the model includes X-axis, Y-axis and pen stand that are required to convert rotational motion of stepper motor to linear motion for printing. The figure included houses all the components with their connections. Processing and operation of Benbox software is explained very briefly.

3.1 X-axis

X-axis design comprises of components such as stepper motor, 5mm to 8mm coupler, threaded shaft, plain shaft, bearings, slider and wooden piece. Stepper motor is used to drive the shafts along the axis. Coupler is used to couple the stepper motor shaft and threaded shaft. Bearings provide the purpose of holding the shafts at place and to reduce the friction for more accuracy. Sliders are provided on both threaded and plain shafts to serve the purpose of joining them and to act as a basement for Y-axis

Fig 8: X-axis and Y-axis design

3.2 Y-axis

The Y-axis basement design is exactly the same as X-axis design. The only difference is Y-axis is mounted on the slider (that couples the threaded shaft and plain rod). The Y-axis houses the pen holder on the slider.

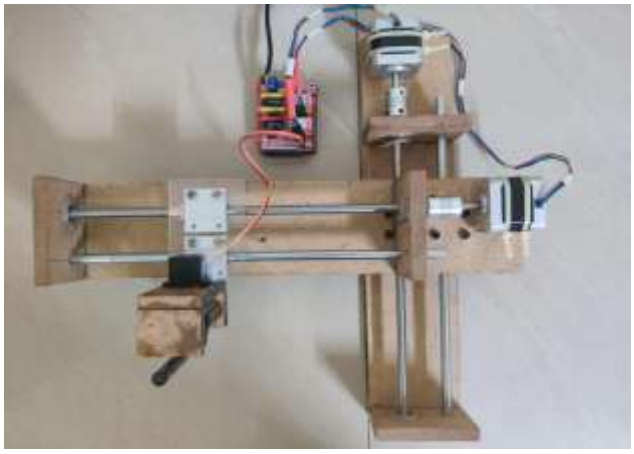

Fig 9: Mounting of Y-axis on X-axis design

3.3 Pen holder

A pen holder is built by using a 80mm nail enclosed by a refill and screw equally. This nail is joined between two wooden pieces of 4mm thickness. The part of the nail enclosed by refill performs the motion of the pen that is cemented on a wooden piece. The servo motor controls the movement of the pen.

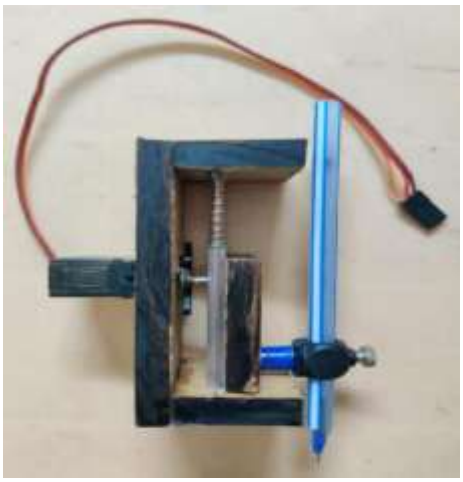

Fig 10: Pen holder

3.4 Benbox processing section

Plug in USB cable to Arduino UNO and 12V power supply to the CNC shield V3.

Leave the 12V power OFF initially.

The 12v runs the stepper motor.

Once ready, double click the BenBox icon on the desktop.

Set the LANGUAGE by clicking on the tiny flag in upper left corner and select EN (or appropriate)

It is required to install firmware into the Arduino Uno.

1. Be sure that CNC shield is plugged in to power and USB. Leave the 12V power button OFF.

2. Select the "lighting bolt" icon to upload HEX ROM.

3. Select the COM port (probably the bottom one on the dropdown list)

4. Select UNO device

5. Click Choose Firmware and navigate to the Benbox directory and select the firmware. Hex file and click the OK button (blue check mark box)

6. The position of servo motor for Pen Up and Pen Down are given according to the requirement.

7. Check the motion of X-axis and Y-axis by giving input through the software. The image that is drawn on the screen will be drawn by the CNC drawing machine.

4. HARDWARE

4.1 Wooden pieces

Wooden pieces serve many purposes. They are used as the basement for housing the entire machine. They are used as a support for both the threaded shaft and the supporting rod. The wooden pieces also serve the purpose of housing the stepper motor.

Fig 11: Wooden pieces

4.2 Coupler

5-8mm coupler is used in order to couple the 8mm threaded shaft and 5mm shaft of the stepper motor.

Fig 12: Couplers

4.3 Plain rod

The purpose of the plain rod is to provide balance to the threaded shaft during its linear motion. 30mm two chrome plated rods were used in this project

4.4 Threaded shaft

Threaded shaft is threaded along the complete length of the rod. They are designed to be used in tension. 8mm diameter, 30mm length two threaded shafts were used in the construction of this project

Fig 13: Threaded shaft

4.5 Bearing

The bearing constraints relative movement to the desired motion and reduces friction between moving parts. 8mm four bearings were used for construction.

Fig 14: Bearing

4.6 Slider

The slider has closed type aluminium alloy housing that ensures reduced noise and low coefficient of friction. 8 mm four sliders were used in this project

Fig 15: Slider

4.7 Acrylic sheet

An acrylic sheet of 3mm is used in order to join the two sliders present on the plain rod and threaded rod respectively.

4.8 Zip tag

Zip tag is used to hold the stepper motor at its position and not to allow any movement of the stepper motor that results in inaccurate output. 200mm four zip tags are used for this purpose.

5. RESULT

In this project, the concept of low-cost mini CNC drawing machine, that is easily controllable with computer like stop and pause action by click on computer. By using the machine, the difficult and complex design is printed on paper. This is a small machine that is easily transportable and assembled wherever required. Bed size of this machine is 25X25mm. Stepper motor run based on the criteria of bed size. No codes are used for giving command. Benbox software is used to give the command to the machine to move right, left or up and down. On the successful work of this machine some changes are performed on it in order to make it suitable for commercial use like milling, drilling etc. This low cost CNC drawing machine is used mainly for PCB printing, that itself is used in almost all manufacturing industries throughout the world. The accuracy of this machine is what makes it unique as the cost of this machine is way less than the actual machine cost as specified.

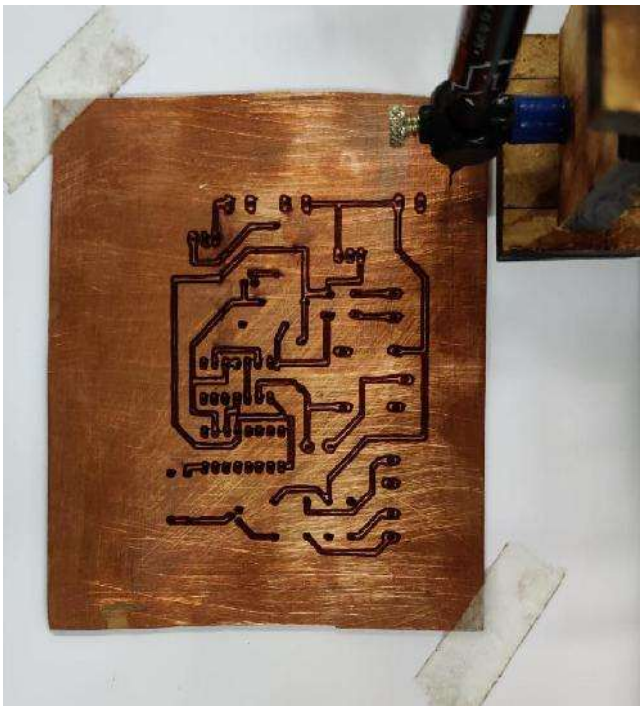

Fig 16: Printed layout on copper cladding

6. FUTURE SCOPE

The machine can be used to print on photographic sheets. It is planned to scale up the prototype of CNC machine in terms of size, use more powerful motors, strengthen the frame and work table using materials like Aluminium or cast iron. The pen can be changed by a laser to make it work like a laser engraving machine. That machine is used for sketching on wood. The pen can also be replaced with a drill, so it can be used for both milling and drilling work. The servo motor can be replaced with a steeper motor and the pen with a 3D pen to build a 3D printer that prints with object within measurement.

Fig 17: Text printed on photographic sheet

7. CONCLUSION

The model designed is controlled by the Benbox software. The image gets converted to G-codes that provides signals that controls the movement of the machine. The hardware design and G-codes generated ensures better accuracy reduces the workload. The Benbox software controls the model, therefore provides reliability and the G-codes generated ensure smooth working of the motors. Making a small machine brings flexibility to do work. The machine designed is a low force machining that yields less heat and reduces pen deflection. The machine is easily transportable.

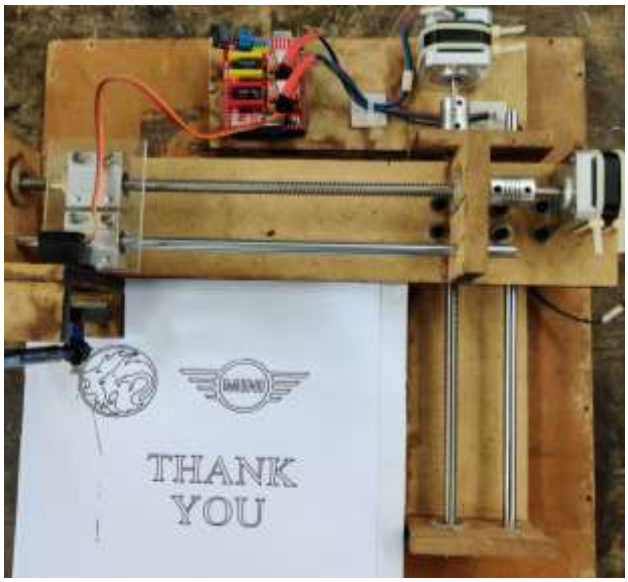

Fig 18: Mini CNC machine model

8. REFERENCES

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