Design and Fabrication of 3 Axis CNC PCB Milling and Drilling Machine

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Abstract: The scope of this project was to design and fabrication of milling and drilling machine which focus on the main operation i.e. milling and drilling. The project began with the collection of information and data on user lifestyle and current process by which they perform their job. The Concepts was developed with reference of different types of milling machine and their different operating processes. The project was developed considering the safety factor user operating environment and maintenance. Considering the users need and buying capacity, this prototype was fabricated. The machine consists of Lead Screw, Motor Driver, Stepper Motor, Arduino, Spindle Motor and Aluminum Extrusion Frame. In this project, the position of the drill hole and milling operation is taken by the developed software. Then it calculates the previous and current co-ordinate and sends the coordinate information Micro-controller unit over USB cable. Stepper motors move on the basis of co-ordinate information to accomplish the drilling and milling of the PCB.

***Index Terms* - PCB fabrication, Milling, Drilling, Composite material.**

I. INTRODUCTION

PCB stands for Printed Circuit Boards which helps in connecting the electronics components with pads, line, tracks incorporated on a laminated copper sheet. Which can be considered as an insulating material which can b e developed using epoxy on which copper layer is laminated. Different software's are used for design of PCB. Before the inception of PCB professional used laboratories method of point to point wiring to connect the electronics components. This method was costly and complicated in design. To reduce the time and to make design simple this method was introduced. This was the revolution in the electronics industry with the lots of productivity and innovative ideas. PCBs are commonly composed of composite material, composite epoxy, and fibre glasses. In the electronics devices these are the most common components used which makes the design compact and sophisticated. PCBs are provided with different layers and multiple design. In some of the electronics device's PCBs are composed of single layer. Some of the most common hardware such as motherboard and graphic card multilayer PCBs are used. PCBs are widely used advanced electronic devices such as cameras, led, etc. as they are not associated with computers only. To increase the production rate with greater percent This can be the new invention in the electronics industries. Once you set all the parameter required, the machine will start working without any human interfere so we can call it as automation. Arduino based 3 axis PCB milling and drilling machine is inspired form today's technology   revolutionary change in the world of electronics and microcontrollers. On basis of PCB drilling machine, the stepper motors are interfaced to the Arduino controller. The stepper motors are used to move plate of PCB in X, Y and Z direction.
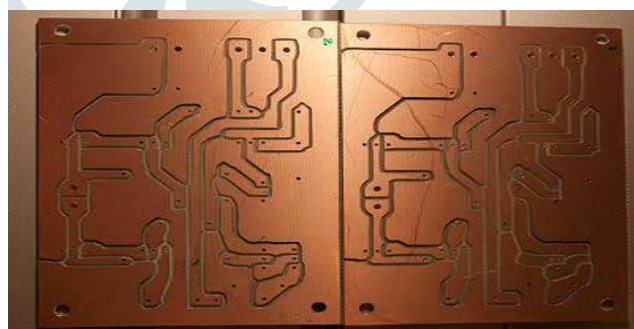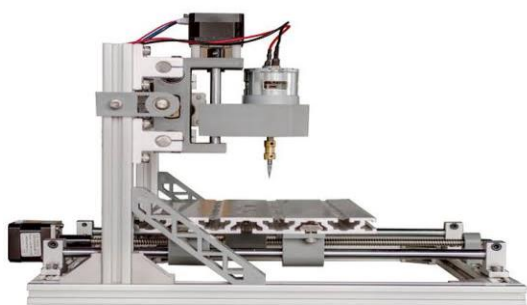
II. NEED OF PCB

In all the electronics devices printed circuit boards is very important either it is used for domestic purpose or for industrial purpose. PCB design service are used to design electronic circuit. Apart from electrically connecting it also gives mechanical support to the electrical components. The design of PCB can be created both manually or automatically. With the help of CAD drafting manual layout are created and the automatic router helps in creation of design automatically. Since they can implement their own ideas and technique the designer usually prefers the manual way.

III. CONCEPT
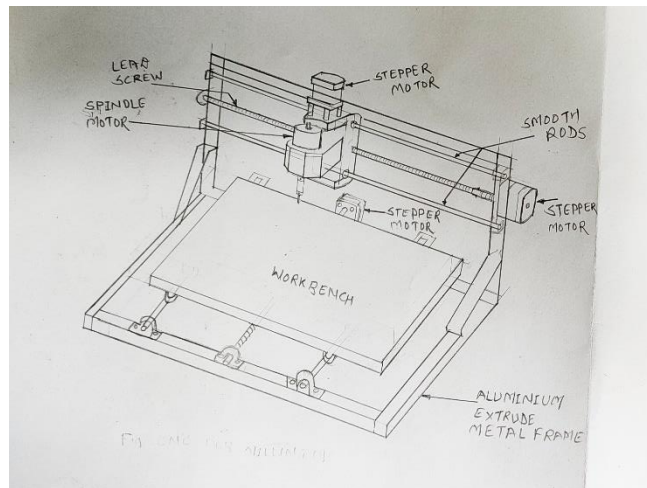
Mechanical Description

The main tools used in the mechanical design consist of work board which is of aluminium extrusion, smooth rods lead screw, angle joints, stepper motor, ball bearing, support stands, anti-backlash nuts. The PCB is placed in the system then it is drilled automatically through path planning. By the PCB design software, it generates the coordinate in x, y, z direction. A high amount of current is passed in order to drive the motor exactly. There is another method which uses microcontroller c programming. To control the drill the system is consist of 3 stepper motor. The path planning method is not used in this project. The automatic PCB drilling machine uses a path planning algorithm, which locate the exact traversing path for the drill bit to move. In this project, the position of the drill hole is taken by the developed software. Then it calculates the previous and current co-ordinate and sends the coordinate information Micro-controller unit over USB cable. Stepper motors move on the basis of co-ordinate information to accomplish the drilling of the PCB.

IV. LITERATURE REVIEW

- Manish Patil, Prof. Hredeya Mishra published a paper under a title **(Literature review for designing a portable CNC machine)** in journal **International Journal for Innovative Research in Science & Technology** they discussed literature review of different authors who were tried to make CNC machine. They said that CNC machines are main reasons in the contribution of good quality products in industries.
- R.Ginting, S. Hadiyoso and S.Aulia published a paper under a title **(Implementation 3Axis CNC router for small scale industry)** in journal **International Journal of Applied Engineering Research** in which they have realize the complex of 3 axis CNC machine which is based on microcontroller which is combined with spindle drill which can be used for cutting , engraving. Which can give more carving accuracy and more engraving accuracy.
- Rajesh Kannan Megalingam, Shree Rajesh Raagul Vadivel, Sreekumar S, Swathi Sekhar, Thejus R Nair, Midhun RR published a paper under a title **(Design and implementation of CNC milling bot for milled circuit board fabrication)** in journal **International Journal of Engineering &Technology** in this paper they purpose a computer control milling machine which would be used for fabrication of double layer PCBs which are called as MCBs where the user can test the circuit without the need waiting of conventional PCB fabrication.
- Kulkarni Bharat P, Mali Priyadarshani S, Mali Shriprasad S, Sutar Raghavendra R published a paper under a title **(Arduino based 3 axis PCB drilling machine)** in journal **International Journal of Emerging Technologies in Engineering Research** in this paper the PCB drilling machine is implemented using the Arduino controller. The whole operation is controlled by the open source software to reduce the man power and time.
- Prabhanjay Gadhe, Vikas Jangir , Mayur Yede , Wasim-Ul-Haq published a paper under a title **(Design and implementation of PCB using CNC)** in journal **International Research Journal of Engineering and Technology** in which they said that for making PCBs we required more time for various operation so to reduce the time this project is designed which will focus on the design and implementation of automatic PCB milling and drilling machine using Arduino.

V. RESEARCH METHODOLOGY

- Collecting the information of the necessity of milling and drilling machine.
- Gathering the data from literature review.
- Study of existing machine and focus on various modification.
- Identifying the proper mechanism and their role.
- Verify the design of PCB milling and drilling machine.

VI. CONSTRUCTION
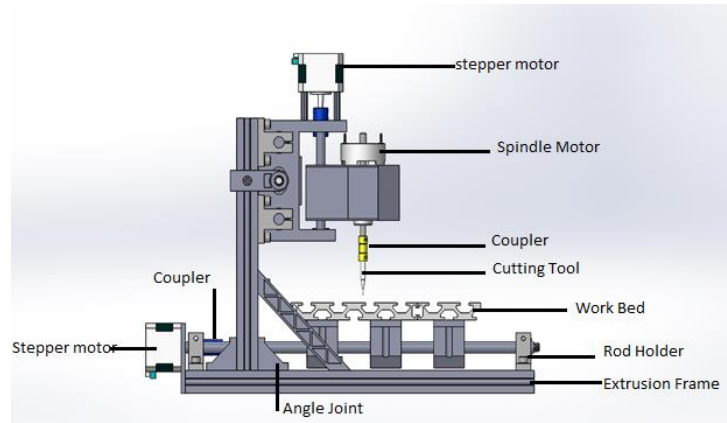
The principle tools used in the mechanical design consist of work board which is of aluminium extrusion, smooth rods, lead screw, angle joints, stepper motor, ball bearing, support stands, anti-backlash nuts. The PCB is placed in the system then it is drilled automatically through path planning. By the PCB design software, it generates the coordinate in x, y, z direction. To control the drill the system is consist of 3 stepper motor. The automatic PCB drilling machine uses a path planning algorithm, which locate the exact travelling path for the tool to move. In this project, the position of the drill hole and milling operation is taken by the developed software. Then it calculates the previous and current co-ordinate and sends the coordinate information Micro-controller unit over USB cable. Stepper motors move on the basis of co-ordinate information to accomplish the drilling and milling of the PCB.

VII. DESIGN PARAMETER
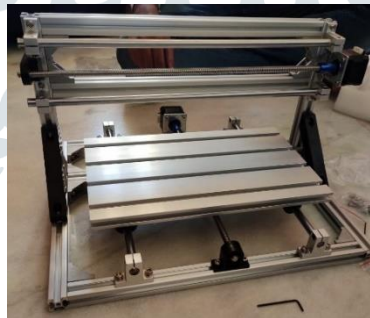
Aluminum Extrusion Frame

We used Aluminium Extrusions Aluminium Profiles Frame for milling and drilling Machine. Which reduces the cost and have good durability.

Lead Screw

Leadscrews are commonly used in linear actuators, machine slides (such as in machine tools). Leadscrews are a key component in electric linear actuators. A lead screw turns rotary motion into linear motion combining a screw and a nut where the screw thread is in direct contact with the nut thread.
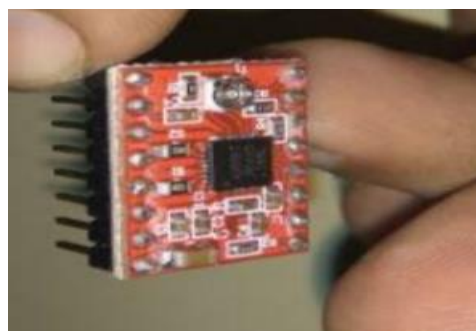

Motor Driver

The motor driver is a module for motors that allows you to control the working speed and direction of two motors simultaneously. This motor driver is designed and developed based on L293D IC. L293D is a 16-pin motor driver IC. This is designed to provide bidirectional drive currents at voltages from 5v to 36v.


Stepper Motor

NEMA 23 is a stepper motor with a 2.3×2.3-inch (58.4×58.5 mm) faceplate and 1.8° step angle (200 steps/revolution). Each phase draws 2.8 A at 3.2 V, allowing for a holding torque of 19 kg-cm. NEMA 23 Stepper motor is generally used in Printers, CNC machine, Linear actuators and hard drives.
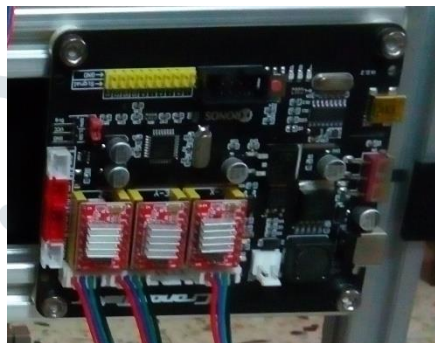

Arduino

Arduino Uno is a microcontroller board dependent on ATmega328. Its working voltage is +5V. it comprises of 14 advanced I/o pins. It can withstand input voltage from 7-20 V. The DC Current per pin 40ma. It has 32kb of glimmer memory. It working default clock recurrence is 16MHz.
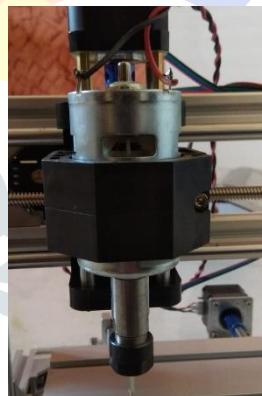
Spindle Motor

The CNC spindle is the heart of any mill. It consists of a rotating assembly with a taper where tool holders may be installed. A spindle motor with optional transmission of some kind rotates the CNC spindle. The transmission matches the highest power rpm range of the CNC spindle motor to the spindle rpms that are ideal for the particular speeds and feeds of the material being cut.

VIII. WORKING PRINCIPLE
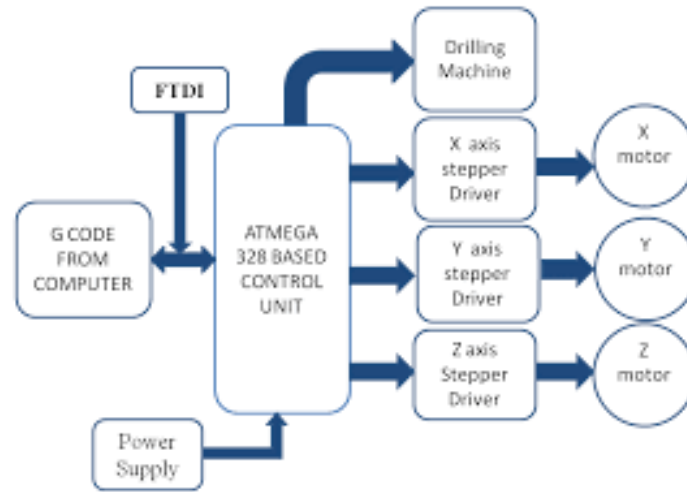
Block diagram of 3-Axis PCB Milling and Drilling Machine

The machine designed based on co-ordinate measurement machine, therefore the machines have designed with three coordinate, X, Y and Z. The PCB is moved along the X and Y axis and Z co-ordinate are used to move the tool up and down. We are using EAGLE software which is an open source software to provide design to PCB. Then the file is transferred to the candle software which is basically G-code converter. It converts design of PCB in G codes. Pc is connected to Arduino uno with usb cable. It is connected to the GRBL controller which control the motion of machines. Which gives the motion to stepper motor which are connected in 3 different axes. As per the command received from the software 3 motors work in 3 axes individually or with each other. According to the motor our whole assembly works as workbench moves along Y-axis, spindle motor moves along Z-axis, and the motor assembly moves along X-axis.

IX. DESIGN CALCULATION

Design of PCB drilling and machine require to calculate cutting force and power required for it. To calculate this, we need to fix the range of diameter we can drill / mill on machine. In this paper we have calculate all the value for the diameter of 0.1 mm, but it can be calculated upto as per the required diameter for that we are going to produce machine.

- Spindle speed (N)= (Vc * 1000)/3.14*d
  where d = drill bit / mill bit diameter (mm), Vc is cutting speed.
- Cutting Speed (Vc)=(3.14*d*N)/1000
- Degree of Freedom=4

Cutting Speed (Vc)=(3.14*d*N)/1000
- Feed=Feed/Revolution*N
- Feed/Tooth=Feed/N*no. of teeth
- Cutting Feed=F/T*no. of teeth
- Metal Removal Rate
  $$= (3.14*d^2*Fr*L*n)/4L*1000$$
  $$= (3.14*d^2*Fr*n)/4*1000$$
  Where d is Drill Diameter, Fr is drill feed, N is and L is length of hole.
- Drilling Time (T)= (Hd*No. of holes)/Speed *Fr

Where Hd = Hole Depth, and Fr = feed

Calculations for 0.1mm

Spindle Speed @5000rpm   …. Considering maximum speed of spindle motor
Cutting Speed (Vc) = (3.14*0.1*5000)/1000
                  =1.57 mm/min

Feed of Spindle
Feed/rev = 0.1 @5000rpm
Feed = 0.1*5000
      =500 mm/rev

Feed/Tooth= (500)/5000*4
           =0.025 mm/rev

Cutting Feed=0.025*4
          =0.1 mm/rev

Metal Removal Rate= (3.14*0.1*0.1*500)/4*1000
                 = $3.92*10^{-3}$ mm³/min

Accuracy: While features as small as 0.1mm are possible, the average CNC user can expect a trace width of 0.3mm with a clearance of 0.3mm.

Stepper motor provides 1.8-degree step angle, stepper drivers provide 1/16 micro stepping.

1.8*(1/16) = 0.112

thus 0.112-degree accurate movement is obtained.

Effectiveness: As comparing with chemical etching process CNC machine gives more efficiency than the etching process.

Durability: The durability of the drill before the set up and motion is 48/100. The drill bit durability, therefore, 48 is divided by 100, minus the change in length of the drill bit; for example, if the change in length is 1 inch, the final durability is 48 divided by 99, which is 2.0625

Sustainability: Sustainability means that a process or state can be maintained at a certain level for as long as is wanted. While performing experiment we seen that the engraving tool can be used for 5-6 PCBs.

Accessibility: Accessibility is the degree to which a product, device, service, or environment is available to as many people as possible. Accessibility often describes hardware and software designed to help those who experience disabilities. This machine can be operated by any person.

X. CONCLUSION

The following important points are drawn from our project work are as follows

- The developed model is simple, efficient, requires less time and cost effective when compared to the existing available model.
- Importance is given towards user friendly in operation and mainly towards safety.
- The assembly was checked for its sturdiness and was found to be reliable.
- The overall performance of milling and drilling machine was satisfactory by considering the quantity produced with respect to time.

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