SHORT PAPER ON CNC BASED PCB MILLING MACHINE CONSIDERING HUMAN SAFETY

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Abstract: Today with the enormously increasing and the advancing technologies the need of the automation has been reached to a great extent and will further increase in the future. Therefore, in this view our research work deals with the design, testing and implementation of cost-effective CNC based PCB Milling Machine which can be deployed in small scale industries and most targeted areas like academic institutions(engineering) to encourage self-designing of electronic circuits among students. Technically the control mechanism is sole work of AT Mega 328P Arduino microcontroller with auxiliary drivers which help in precise step control of stepper motors whose rotational movement appears as a controlled linear motion of x, y& z-axis each deployed with this motor. The input signal in form of design, picture is interpreted in form of G-codes through dedicated firmware which are installed in the Arduino Programming IDE to help generate the actuating signals proportional to the interpolating situations. This paper discusses about the additional feature of human safety system using IR sensors which are employed around the periphery of the working area.

Keyword: CNC, PCB Milling, Stepper Motor Control, Arduino interfacing, IR sensors, Human Safety.

1. Introduction

One of the fastest growing industries in the modern era is the semiconductor industry. With this the use of electronic product i.e. PCB is increasing day by day[1]. Due to the high cost of commercial and often imported PCB prototyping equipment, there is a severe lack of practical hands-on PCB design teaching and learning in the world. This situation can be remedied with the microcontroller and microcomputers which are having affordability and versatility, commercial off-the-shelf components like actuators, sensors as well as free, open source software, which can be integrated for the design of low-cost PCB prototyping machines for electronic industries[2-3]. People use cheap methods like chemical etching which is most famous in small scale industries to design PCB circuits, but these methods lack sufficient consistency for surface mount devices (SMDs) and the drilling of holes is very tedious as it has to be done manually[4]. Further, the environmental and health hazards risk is high in these processes. Development of safe and high-resolution milling and drilling of PCBs is enabled using routing which overcomes many difficulties involved in the traditional methods[5-6].

2. Objectives of the work

The important thing which is considered in this paper is to make the CNC machine cost efficient and to accomplish the rising demands of large-scale industry in small scale applications. This situation is possible because of open source firmware and software such as grbl, Eagle Layout Editor, Universal G-codes Sender/Inkscape. Furthermore, this paper also discusses about the human safety protection scheme using IR sensors. Thus, by using these kinds of firmware, software and IR sensor it has become much easier for a beginner to operate the CNC Machine and hence becoming more users friendly and protective. Moreover, desktop is compatible with microcontroller (Arduino UNO, Arduino MEGA etc.), microcontroller shield and motor drivers thus making CNC Milling Machine cost efficient, power saving, easy to interface and user friendly.

3. Design and Implementation

For the fulfillment of each aspect of the objective effectively, our paper will require high accuracy components and processors which will be reliable and fast. The idea of our paper is to design a 3-axis PCB Milling Machine which is cost efficient and this machine consist those essential elements which will contribute for the drilling and milling of PCB. To design the model the paper is categorized into 3 systems.

A. Mechanical B. Electrical C. Software D. Protection

A. Mechanical System

This system consists of assembly of components which are given in the following table.

| Sr. No | Components         | Specifications |
|--------|--------------------|----------------|
| 1)     | Aluminum Extrusion | 2020           |
| 2)     | Steel Shaft        | 8 mm           |
| 3)     | Ball Bearing       | LMRCU          |
| 4)     | Linear Bearing Slide Unit | SC8UU |
| 5)     | Shaft Coupler      | Flexible Type  |
| 6)     | Collet             | 0.5-3 mm       |
| 7)     | Threaded Rod       | 8 mm           |
| 8)     | Lead Screw         | Pitch -2 mm    |
| 9)     | Auxiliaries        |                |
The installation of the mechanical system begins with the assembly of aluminum extrusion for base and gantry. The grooves in extrusion provide easy assembly and disassembly of structure [7]. By using these structures becomes compact, lightweight and robust. For the smooth motion of the base in X-axis and the spindle motor in Z-axis sliding units are used. The motion of the gantry in Y-axis is carried out by linear bearing. The threaded rod and lead screw contribute to the motion in all the 3-axis. [2]

![Assembly of Mechanical Components](image1)

**Fig. 1: Assembly of Mechanical Components**

**B. Electrical System**

This system has following components and devices which are summarized in following table-

| Sr.No. | Components       | Specifications                      | Quantity |
|--------|------------------|------------------------------------|----------|
| 1.     | Stepper Motor Nema 17 | 4 kg-cm, 1.8 degree                | 2        |
| 2.     | Stepper motor Nema 17 | 5.5 kg-cm, 1.8 degree              | 1        |
| 3.     | Spindle Motor 775 | 12000 RPM, 12V, 1.2A, 79 N-cm      | 1        |
| 4.     | Arduino UNO      | ATmega328P                          | 1        |
| 5.     | Stepper Motor Driver | A4988                               | 3        |
| 6.     | Power Supply     | 12-24V                             | 1        |

**Table 2: - List of Electrical Components**

The heart of this system is Arduino UNO which controls all the operations. For precise motion control of the 3-axis the stepper motor is employed which is known for its precise movement with each input pulse. However, the input signals to the stepper motor are produced by the microcontroller Arduino Uno). The spindle motor 775 is mounted on gantry and it is powered by SMPS which varies its RPM according to operating voltage. Stepper motor driver is used as an interfacing component between the microcontroller and stepper motor which is powered by separate power.

![Control System](image2)

**Fig. 2: Control System**

**C. Software System:**

For the designing of the PCB we are using Eagle Layout Editor. This software provides platform for designing considering various aspects like thickness, type of material, and workspace. Inkspace/ Universal G-code sender is used to convert the design into G-codes. Arduino use these G-codes to provide actuating signals to the stepper motor and hence the milling is done. [4]

**D. Protection System**

This system is designed by using IR sensor and is the most prominent feature of our paper. IR sensor is device which consist of transmitter and receiver which is used to detect the presence of any object within its vicinity.

![ Principle of operation of IR sensor](image3)

**Fig. 3: Principle of operation of IR sensor**
During the engraving operation of the spindle motor if the IR sensor senses any external obstruction within the working premises of the machine it will pass these signals to the microcontroller which will result in turning on of buzzer and will lead to the termination of engraving operation. By implementing this protection method, we can eliminate the future accidents and human injuries which makes the machine safer for unskilled and beginner.

5. Conclusion

A cost-efficient PCB milling machine is designed and developed by optimizing the cost for milling of PCB with surface mount technology. The machine is fabricated with inexpensive and commercial open source software and hardware components and can be adapted and advanced for future requirement. We can add the advance features like soldering tools, human safety, fully automated PCB machine with pick and place assembly, feedback, IoT, etc. We can also make changes in stepper motors according to requirement. We can also change the processor in order to add more features to machine.

REFERENCES

[1] Shilpa, V. Jean, and S. H. Mahmood. "Design and Implementation of Three-Axis Cost Efficient CNC PCB Milling Machine." 2018 International Conference on Recent Trends in Electrical, Control and Communication (RTTECC). IEEE, 2018.

[2] Ginting, R., S. Hadyooso, and S. Aulia. "Implementation 3-axis CNC router for small scale industry." International Journal of Applied Engineering Research 12.17 (2017): 6553-6558.

[3] Berbesi, J. Marthein, K. Saumeth, and F. Pinilla. "Parallel control firmware for CNC milling machine based in Arduino." 2017 12th International Microsystems, Packaging, Assembly and Circuits Technology Conference (IMPACT). IEEE, 2017.

[4] Aciu, Razvan-Mihai, and Horia Ciocarlie. "G-code optimization algorithm and its application on printed circuit board drilling." 2014 IEEE 9th IEEE International Symposium on Applied Computational Intelligence and Informatics (SACI). IEEE, 2014.

[5] Choudhary, Rohit, et al. "CNC PCB milling and wood engraving machine." 2017 International Conference On Smart Technologies For Smart Nation (SmartTechCon). IEEE, 2017.

[6] Rizal, Muhammad, et al. "A review of sensor system and application in milling process for tool condition monitoring." Research Journal of Applied Sciences, Engineering and Technology 7.10 (2014): 2083-2097.

[7] Drumea, Andrei, and Cristina Ioana Marghescu. "Analysis of current carrying capacity of silver-based conductive pastes for PCB repair." 2015 IEEE 21st International Symposium for Design and Technology in Electronic Packaging (SITIME). IEEE, 2015.
Fig 5: Block diagram of control system