Automated Printed Circuit Board Manufacturing With Microcontroller Based Machine

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Abstract — Traditional PCB (Printed Circuit Board) manufacturing involves a lot of manual work, which can slow things down and lead to mistakes. Our research aims to make things better by using CNC (Computer Numerical Control) technology in the process. However, current CNC methods for PCBs are too expensive for many manufacturers. But this new method is a solution to make CNC based PCB manufacturing more affordable. It will reduce the need for manual work, make the process more accurate, and bring down the overall cost. The new method that has integrated traditional PCB manufacturing method and CNC, robotic arm, and automated machines. Most of every step in this new proposed method has less human work and less time required to manufacture PCB. The low cost CNC machines can reduce the overall cost of PCB production. By using the single board microcontrollers to control the robotic arms, CNC plotter, automated shaker in desired manner.

Keywords: PCB, PCB manufacturing with CNC, Arduino, Robotic Arm

I. INTRODUCTION

The evolution of PCB in electronics is a drastic change in the industrial world. It takes the form of a laminated sandwich structure of conductive and insulating layer. Conventional method of making PCB is huge time taking process and each step is performed manually [4]. The printing of circuit in a copper clad board is done by laser printer. It requires separate laser printer to print the circuit. The transferring of circuit board is done manually for the process of etching. Now in some large scale PCB manufacturing industries to reduce the manual process and to reduce the time for the manufacturing of PCB, the CNC integrated automated machine is used [1]. The CNC driller make desired circuit into the copper clad by clearing out the unnecessary copper from the board. But this automated machine is so costly [5], [8] and the machine is only for large PCB manufacturing industry. Our new method is also integrating CNC in the manufacturing processes but in cost effective manner. The method is to draw/print with a temporary ink. The CNC machine print/draw the circuit on the copper clad board. Then the robotic arm is used to take the clad board from the CNC machine and put it in a solution to etch out the excess copper so that the only the place marked with marker remains. To etch out the copper we use an automatic shaker to remove the copper and another robotic arm uses to take out the clad board from the solution and placed it in a drier. After that the drawn print from the first step is removed using another shaker containing rubbing alcohol. The combination of the CNC machine and the robotic arm speed up the manufacturing of PCB in a faster and reliable method. This paper propose the combination of automated machines for the manufacturing of PCB.

II. PCB MANUFACTURING PROCESS

The proposed method involve steps Circuit Design and G-Code Generation, CNC Plotting, Drying Process, Etching Process, Automated Handling with Arduino, Post-Etching Process, Advanced Prototype with Micro Drill Machine [4].

A. Circuit Design and G-Code Generation

The process begins with the meticulous design of the printed circuit board (PCB) using specialized PCB design software. This software allows engineers and designers to create a detailed layout of the circuit, specifying the placement of components and the traces that will carry electrical signals. Commonly used software includes Eagle, KiCad, and Altium, each offering a range of features for designing complex circuitry. Once the PCB design is completed, the next step involves the generation of G-Code. G-Code is a programming language used to control CNC machine movements and actions. In the context of PCB fabrication, the G-Code provides instructions for the CNC machine to precisely guide a small thickness marker across the copper-clad board. This digital-to-physical translation ensures that the designed circuit pattern is accurately replicated on the board.

B. CNC Plotting

The CNC machine [1], the main part of this process, it interprets the G-Code and moves its marker in a highly controlled manner. The precision of the CNC machine is crucial for achieving a well-defined circuit pattern [5]. The marker deposits ink onto the copper surface, outlining the traces and components according to the designer's specifications. CNC machines come in various sizes and capabilities, and the choice of a specific model depends on factors such as the complexity of the circuit and the desired level of precision [11].

C. Drying Process

After the process of the CNC plotting, the board enters a crucial drying phase. Ensuring that the marker ink adheres effectively to the copper surface is essential for the subsequent steps. Proper drying minimizes the risk of smudging or irregularities in the circuit pattern. The controlled drying process sets the stage for the subsequent chemical etching step, where the accuracy of the circuit pattern is preserved.

D. Etching Process

The etching process is a pivotal stage in PCB fabrication, and it involves immersing the plotted copper-clad board into a solution of Ferric Chloride. Ferric Chloride serves as a common and effective etchant, selectively removing the unwanted copper from the board. Automation comes into play through a shaking tub, manipulated by a robotic arm

controlled by an Arduino. This ensures an even distribution of the etchant across the board, facilitating a uniform and controlled etching process. The Arduino, programmed with precision, guides the robotic arm to handle the board methodically, optimizing the efficiency of the etching operation. The shaking tub's movement ensures that the Ferric Chloride solution reaches every part of the board, effectively etching out the copper from areas not protected by the marker.

E. Automated Handling with Microcontroller

The Arduino is used as the Microcontroller. The role of the Arduino Nano in this process is pivotal. Serving as the brain of the automated system, the Arduino controls the movements of the robotic arm. Its programming dictates the specific actions required during the PCB fabrication process. From picking up the board after drying to placing it into the Ferric Chloride solution, the Arduino ensures a seamless and precise workflow. The choice of Arduino for automation is strategic due to its cost-effectiveness, ease of programming, and a robust.

The Arduino Nano, with its compact form factor, is well-suited for applications where space is a consideration. Its versatility makes it an ideal candidate for managing the intricacies of an automated system in the PCB fabrication process.

F. Post-Etching Process

Following the completion of the etching process, the board is removed from the solution and allowed to dry. At this stage, the remaining marker ink on the PCB surface needs to be removed. This is achieved through the use of rubbing alcohol, a cost-effective solution widely available. The rubbing alcohol efficiently cleans the PCB surface, leaving behind only the copper traces that form the intricate circuitry. The post-etching process highlights the importance of meticulous cleaning to ensure the functionality and reliability of the fabricated PCB. The efficiency of this step is crucial for the subsequent stages of the project, such as soldering components onto the board and integrating it into the final electronic system.

G. Advanced Prototype with Micro Drill Machine

For an advanced prototype, considerations are made to replace the marker with a micro drill machine. This evolution aims to enhance precision in the creation of the circuit pattern. The micro drill machine employs specialized drill bits designed for intricate work on PCBs [5]. However, this advancement introduces challenges such as the cost and availability of these specialized drill bits. Moreover, the issue of vibration from the drill motor impacting precision must be addressed. To maintain the desired level of accuracy, the stepper motors in the CNC machine may need to be upgraded. This upgrade, while enhancing precision, also contributes to an increase in the production cost of the CNC system. Balancing the benefits of increased precision against the associated costs becomes a critical consideration in determining the feasibility of adopting a micro drill machine for advanced prototypes.

III. COMPONENTS OF AUTOMATED PCB MANUFACTURING MACHINE

In new proposed method has simpler steps and time efficient. The components used for this method are CNC Machine, Robotic Arm, Automated shake tub, Microcontroller.

A. CNC Machine

The input of the CNC machine is given as numerical data from a computer aided design (CAD) or computer-aided manufacturing (CAM) program. The data then converted into electrical signal to control the movement of the CNC. CNC machines are programmed using G-code [2], a set of instructions that tells the machine how to move, turn, and control the tools. Here the CNC is mainly used to print/draw the circuit into the copper clad board. The gerber/SVG file from the PCB software is converted to G-code so that the CNC machine can print the desired circuit to the clad board.

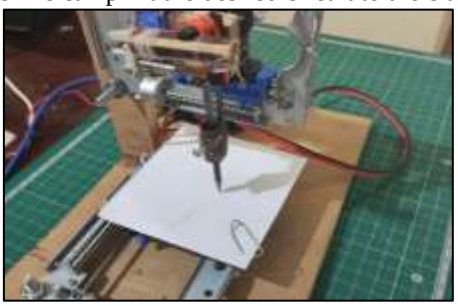

Fig. 1: CNC Plotter

1) Computer Numerical Control Machine

The microcontroller is used to interpret the G-code and send signals to the motor to control the movement of the CNC. Servo/servo motor is used for the movement of the CNC arm [2]. The required circuit is designed in the PCB designing software, then the circuit converted into SVG file and then to G-code. The microcontroller with the help of G-code controls the movement.

2) Stepper motor

The X and Y axis of CNC is controlled by stepper motor [3]. The whole system has been attached to slider mechanism and this slide function is controlled by these stepper motors [9]. The motors can be NEMA stepper motor or any other stepper motor having the enough power and torque for the movement of the plotter base. And Stepper motor drive is used for the control of the stepper motor. The Stepper motor drive get command from a Arduino module. To drive the stepper motor [9] a motor drive is used. These stepper motors cannot be controlled like a conventional DC motor or servo motor. The signals from the arduino is digital output and this must be converted to electrical signals consisting of four phases since these stepper motors are for phase five wire motors. This can be done with the help of motor drivers like L293D or L298N or ULN2003 motor drivers.

B. Robotic Arm with Servo Motor

Servo motor is used for the transferring of the copper board from one step to another. For the robotic arms a set of 9 micro servo motors are used. These servo motors are more than enough to hold the clad board. There are 3 servo motors for the X, Y and Z axes movement and an individual servo for the picking mechanism. If the weight of the copper clad board exceeds, then the servo motors can be upgraded to metal

geared servo motors of higher torque. All these servo motors are connected to preprogrammed arduino nano. Also three potentiometers and a switch is connected to the arduino to guide the servo motors to set the initial and final points in all the three axes. Once the initial and final positions are fixed then the switch can be triggered to auto mode and the servo robotic arm began to work by itself.

C. Automated PCB Shake Tub

In the process of manufacturing PCB the excess copper after the plotting of circuit must be removed from the copper clad board this step has the usage of Ferric Chloride to remove unwanted parts. Normally, you leave the PCB in the chemical for up to an hour, but you can speed up the process to 10-20 minutes by shaking the container. However, shaking it manually for that long can be annoying, so I made a machine to do it automatically. The Fig. 2 shows the prototype of automated PCB shaker. The automated PCB shaker with speed controller can be used to fast removal of copper from the clad board. This machine is made up of a plastic tray to hold the Ferric Chloride, this tray is mounted on a moving system. Geared motor is used for the movement control of the shaker. And a LM2596 DC-DC Adjustable Converter is used to drive the geared motor. For the speed control mechanism 10K Ohm Potentiometer is used.

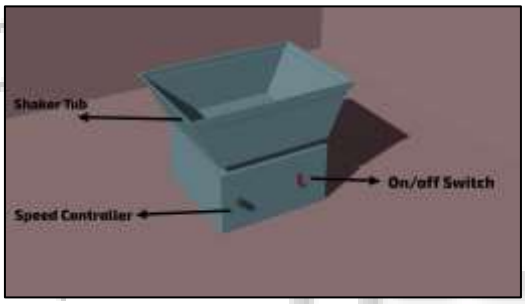

Fig. 2: Automatic PCB shake tub

D. Microcontroller

To control and coordinate the whole manufacturing processes a controller is used. The microcontroller we used is Arduino. Arduino microcontroller is used to control the motor drivers and control the X, Y, and Z axis of robotic arm. Arduino microcontrollers are well-suited for interfacing with stepper motor drivers. The simplicity of the Arduino platform allows even beginners to quickly set up and control stepper motors. Stepper motors move in discrete steps, making them suitable for applications where precise control of position is essential. Arduino can generate the necessary control signals to move the stepper motor in specific increments, achieving accurate positioning. Servo motors offer precise control over angular position, and Arduino facilitates the accurate positioning of servo arms or mechanisms. The Servo library enables users to specify the desired angle, and the Arduino takes care of generating the appropriate PWM signal to achieve that position. Arduino's real-time capabilities make it suitable for applications where immediate and accurate responses are required. This is particularly beneficial in robotic arm construction, where servo motors are often used for controlling joints and achieving precise movements. Arduino is widely used in CNC applications, particularly for controlling the movement of stepper motors and managing various aspects of CNC machines [2]. CNC machines often use stepper motors to control the movement of axes (X, Y, Z) [3]. Arduino boards, with their ability to generate precise digital pulses, are well-suited for driving stepper motors. This allows for accurate and controlled movement of the CNC machine. CNC machines operate based on G-Code, a set of instructions that dictate the movement and actions of the machine. Arduino can be programmed to interpret G-Code commands and convert them into signals that drive the stepper motors, controlling the tool's position and other machine functions. In CNC milling machines, the spindle speed is crucial for achieving desired cutting results. Arduino can be employed to control the spindle motor speed using Pulse Width Modulation (PWM) signals, allowing for variable speed control during machining.

IV. CONCLUSION

Using CNC machines, robotic arms, and automation with Arduino controllers is changing how PCBs are made. This method speeds up production, makes things more precise, cuts costs, and makes everything more consistent. It's easier for more people to use because it combines processes and lets you customize with Arduino. It also lets you monitor things in real-time and work with complex designs. This new way of making PCBs shows how combining and automating tasks can really improve how electronics are made as technology gets better.

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