DESIGN OF A LOW-COST PRINTED CIRCUIT BOARD DEVELOPMENT SYSTEM

[1]Ene P. C., [2]Eneh I. I., [3*]Egoigwe S. V., [4]Chike K. C.

[1]mosfetjipower@yahoo.com, [2]doceneiee@yahoo.com, [3]sochima.egoigwe@unn.edu.ng, [4]kennethshari34@gmail.com

[1,2]Electrical and Electronic Engineering Department, Enugu State University of Science and Technology (ESUT), Enugu State, Nigeria.

[3]Electronic Engineering Department, University of Nigeria Nsukka (UNN), Enugu State, Nigeria.

[4]Electrical Engineering Department, University of Nigeria Nsukka (UNN), Enugu State, Nigeria.

*Corresponding author

ABSTRACT

Mass production of electronic appliances by electronic engineers in underdeveloped and developing countries has been challenged by the high cost of sophisticated printed circuit board (PCB) production machines. Based on this technological challenge, the design of a low-cost PCB production system was proposed in this work to enable the reproduction of the circuit board of an electronic circuit design. The system prints the layout of the conducting parts of the circuit on a conducting side of a metallic copper board through a rectangular mesh that has the electronic circuit layout inscribed on it. The paint used for the printing was a Polyvinyl Chloride (PVC) type that has a plastic component, which cannot be attacked by etching solvents such as iron (Ferric Chloride), cupric chloride (Cupric Chloride) etc. The transfer of the PVC paint unto the copper board through the circuit layout mesh was done by the proposed automated system which has a slide mechanism that squeezes the PVC paint through the tiny holes of the mesh. In this paper, the block diagram of the system was designed, the operation flowchart of the proposed PCB production system was developed, the algorithm for the system controller was written using C^{++} programming language, and the electronic control of the system was designed to implement the operational sequence described in the flowchart. The mechanical structure of the system was designed and simulated using SolidWorks software to observe the movement of the various parts of the system before the prototype of the system was implemented.

1.0 Introduction

One could imagine the hectic procedure manufacturers of electronic circuits go through in order for the production of the Printed Circuit Board (PCB). Accuracy and precision are some of the skills one must possess in order to achieve high-quality PCB. In addition, it is worth noting that the time elapsed to drill a PCB could have an effect on overall efficiency **[1].** Advances in technology have brought to spotlight the automated PCB. The automated Printed Circuit Board (PCB) printing machine is used in the manufacturing sector for the production of electronics devices and equipment. PCB production consists of many processes which include cutting, printing inner layer, routing, etching, automatic optical inspection (AOI), lay-up, lamination, drilling, solder masking, bare board test (BBT), quality control and packing **[2]**.

Manual printing of PCB also known as a traditional method of printing PCB using mesh was the main problem the authors wish to address. The pitfalls like limited production and accuracy of the output component can be minimized by automated PCB screen-printing machine. This will ensure efficiency and achieve a higher level of accuracy to be. Also, cutting down on wastage in the manual printing process reduced the cost of production. An impressive measure of productivity was maximized, hence automated PCB screen-printing machine using mesh, addresses the challenges manufacturers face in the mass production of the PCBs. The scope of this project was bordered with the design and construction of an automated Printed Circuit Board (PCB) printing machine. It covers the theory and technique needed for the machine to automatically printing on a copper board with the aid of a microcontroller, motors, motor drivers and sensors to control its printing process. Hence the designing of the intended circuit, which will be printed on the copper board by the machine, is beyond the scope of this work. This study would be of benefit to electronic designers and manufacturers because the quality assurance of products would be achieved.

2. 0 Literature Review

An automatic mini CNC machine for PCB drawing and drilling was presented in **[3]**. The machine was designed to incorporate PC features with a microcontroller (ATMEGA 328) in an Arduino, and a G code to control the movement and speed of the machine was a fabrication of low-cost CNC machines to reduce cost and complexity of the machine. The idea behind the CNC machine was to draw images or a picture that was done using motors as a linear actuator. The miniature nature of the design limits the work to certain production **[4]** the design and fabrication of an automatic pneumatic screen-printing machine. The technique of printing on different materials, both textile and no textile was shown in their work. Their screen-printing machine described a method of automated screen printing using gear motor for the movement (to and fro) of the squeegee during printing and the microcontroller with other sensors to control and detect when the work was done. The technique of their automatic pneumatic screen-printing machine was able to improve the quality of prints and reduce production time and cost. This idea could be tapped and harnessed in the design of Automatic PCB machines. The authors in **[5]** presented the solder paste printing process, critical parameters defects scenarios, specifications, and cost reduction. The investigation was conducted on the printing performance of different solder paste materials, PCB pad designs, stencil aperture designs and printing process parameters aid the design of various circuit of the block diagram in the research, It suggests through detailed experiments and investigation correlation between the results of SPL analysis and post reflow defective scenarios, that SPIs with specifications and modifications, minimize the total cost of poor quality. This investigation complements the research aim of designing a PCB screen-printing machine with a higher level of accuracy in production and cost. Effects of temperature on the wave soldering of printed circuit boards. While all focus was centered on the development of automated PCBs with improved efficiency and draws attention to the effects of temperature on the soldering of printed circuit boards. This study uses three-dimensional finite volume analyses to explore the effects of temperature on PCBs. PLC-HMI Base automatic screen-printing system.

The authors in **[6]** conducted a study on design a fully automated screen-printing machine, controlled and operated with PLC-HMI as an alternative to manual printing system using microprocessors to ensure the efficiency and nonlinearity in printing. The study employed the use of a mechanical setup for controlling the printing operation and automating the screen-printing set up. The set up encompasses the control system, motion system and visualization. This design aimed at increased productivity, reduction of human and material power with a simplified performance. In this same study provides a frame ware for the on-going research mechanism and programmable logic controller. However, the modus operandi share a slight difference while the design was PLC – HMI automated screen-printing system. The on-going study on building an automated screen-printing machine will adopt the use of microcontroller (ATMEGA 328), gear motors, motor drivers and sensors rather than a continuous print by the screen-printing machine.

3.0 Materials and Methodology

The design of the proposed PCB printing machine involves serials of steps, which include the development of the block diagram that guides the implementation of the system. This section describes the procedure adopted in implementing the automated Screen Printing Machine for PCB production. In order to do that, the block diagram, flowchart and algorithm of the system were developed. The necessary mathematical expression and a brief description of each module were also discussed.

3.1 Block Diagram of the System

The design and construction of a PCB printing machine involve a number of planned steps that would be needed to achieve a good and reliable printing mechanism. The microcontroller was programmed using C++ programming language and this would help control the actions of the action of the machine using the microcontroller (ATMEGA328 IC). After the microcontroller receives a signal from the sensors, it sends a signal to the motor driver; the motor driver drives the motors according to the instruction from the microcontroller. The best way to summarize this process was through a block diagram. The block diagram for the system is shown in Figure 1

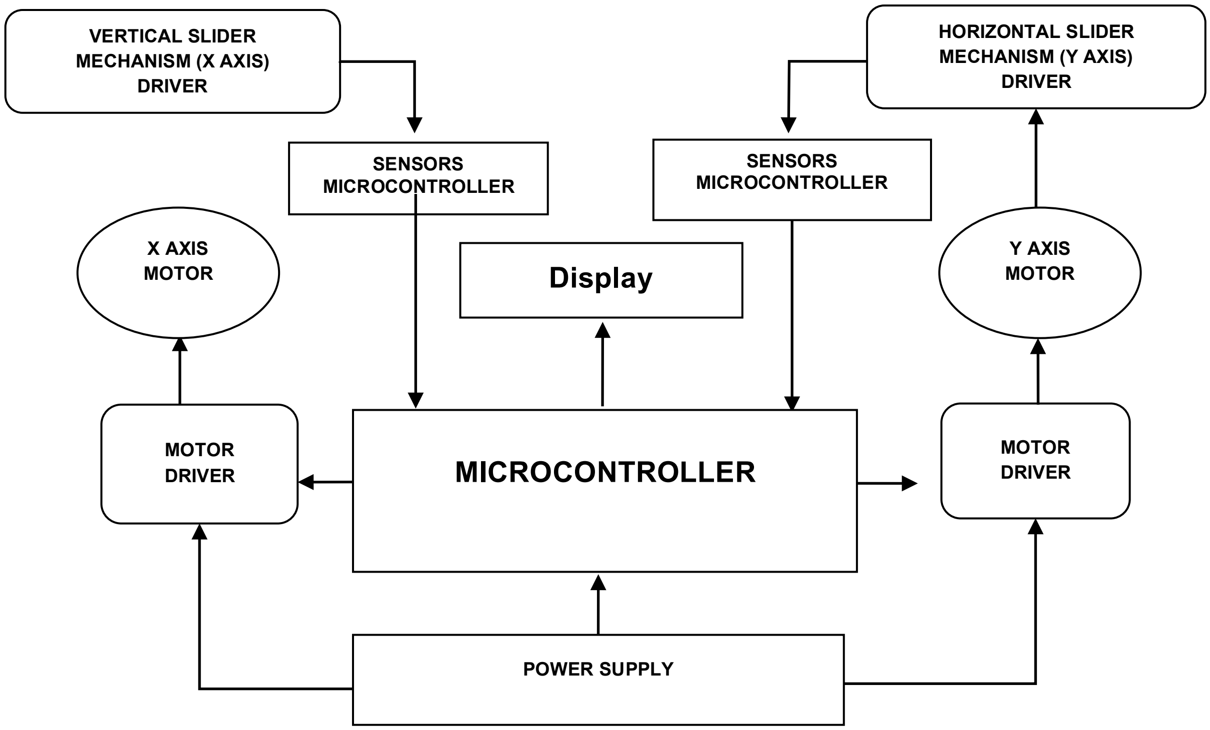

Fig. 1: Proposed PCB Screen Printing Machine block diagram

3.1.1 Description of the Block Diagram:

The Power Supply:

The power supply was a 220v input power supply with multiple outputs, which enables it to distribute different voltages to the various modules of the system with the help of voltage regulators according to their voltage rating. The microcontroller needs 5 volts power input to work, the geared motors use 15 volts power rating to move. Hence the power supply was designed to satisfy the various needs of these different modules. This makes the power supply most suitable for the system.

The Microcontroller:

From the block diagram shown in figure 3.1, the microcontroller is the control unit. The motor drivers, sensors, input button, and display are all connected to the microcontroller through the interfacing pins. ATMEGA 328P microcontroller IC was used in the system to receive and execute the sets of instructions during the operation of the machine. It monitors the input signal from the sensors and sends output to the motor driver and display unit (LCD). When the logic level from the sensor moves from 1 to 0, it stops and terminates the movement of the slider mechanism by stopping the motor through the motor driver and executes the next instruction. The flow chart describes the workflow of the system.

The Sensors

Sensors were used to detect when the vertical and horizontal mechanisms have attained their various maximum distances. These sensors communicate with each other through a line of sight. This was achieved using an infrared transmitter and receiver. Whenever the transmitter is no longer receiving infrared rays from the IR transmitter it means that the carriage has gotten to the extreme of the frame and as such the logic level of the IR signals to the MCU to changes from 1 to 0.

The Display

The LCD gives a visual output of the printing status. The Display consists of a 16 X 2 LCD and an LED. The LCD displays when the job is in progress and if there is interruption or malfunction it displays the error code. The LED only indicates when the device is either on or off and when the job is done.

The Motor Driver

The motor driver is a set of relays triggered by NPN transistors, which drives the motors in either CW (Clock-Wise) or CCW (Counter Clock-Wise) movements according to the set of instructions sent from the microcontroller.

The Motors

The motors are DC high torque geared motors, with 15 volts power rating, which transmits rotary kinetic energy to the slider that is controlled by the motor driver.

The Slider Mechanism

The slider mechanisms are sets of mechanisms that convert rotary motion to transverse motion. These mechanisms are needed to achieve the PCB printing of a to and fro movement. The DC motor can only give a rotary motion; therefore a slider mechanism was employed to get the transverse movement part of the system.

3.2.1 Algorithm of the system (flowchart)

Step 1: Start

Step 2: Put the copper board in the PCB printing machine

Step 3: On the machine to initializing the Port (MCU)

Step 4: Move the y-axis motor (vertical) to lift the copper board for printing

Step 5: Stop the y-axis motor once it gets to the sensor

Step 6: Start the x-axis motor (horizontal clockwise movement) to print the PCB

Step7: Stop the x-axis motor once it gets to the sensor (i.e. after the printing)

Step8: Start the y-axis motor to bring down the PCB (anticlockwise horizontal movement)

Step9: Display "work done" on the LCD

Step 10: End

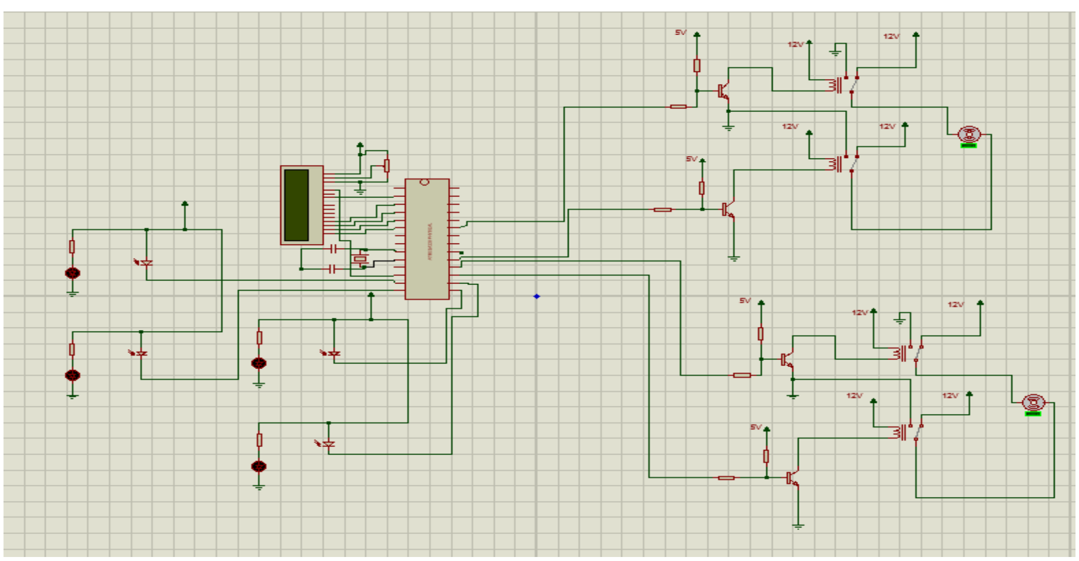

Fig. 2: Complete circuit diagram of the printing machine

From Fig. 2, the microcontroller contains sets of instructions embedded into it as a frame ware connected to the LCD. The 4 digital pins of the LCD are connected to pins 2 to 6 of the microcontroller. Information was sent to the microcontroller by sending 4 bits of data per cycle. The E pin of the LCD was set low whenever new information is being sent to the LCD while the RS pin is clocked per bit of instruction writing to the LCD. The configuration of the D4 and D1 is an obstacle detector. Absence of obstacle allows current to flow from V_{cc} through the D1 which is an infrared receiver to pin 14 of the MCU while the presence of obstacle blocks the line infrared rays from the D4 and as such, the diode blocks the flow of current, which means the presence of positive current and no obstacle while negative current means that there is an obstacle. The Q1, Q2, Q3, and Q4 are PNP transistors. Therefore sending logic 1 to the base of the transistor, which will cause it to saturate and allow current to flow from collector to emitter of the transistor. R1, R2, R3 and R4 are current limiting resistors of the transistors Q1, Q2, Q3, and Q4. Whenever the microcontroller wants to turn on the motor through pin 17, 18, 19, and 23 of the MCU goes high and low simultaneously according to the logic arrangements in the firmware. Logic 1 enables the transistors to trigger the relays. Where RL1, RL2, RL3 and RL4 are relays, which has C, NC and NO terminals as a switch. By manipulating the positions of the C, NC and NO the polarity of the motors can change to give CW and CCW rotation moments. TR1 is a step-down transformer that steps down 220VAC to 12VAC. 6A10 is a set of junction diode arranged in a rectification manner, which rectifies 12VAC to 12VDC. The C1 is a capacitor, which serves as a filter to the rectified current. U1 is a voltage regulator that regulates 12VDC to 5VDC where C2 serves as an output filter to stabilize the output of the regulator.

3.3 Mechanical Structure of the System

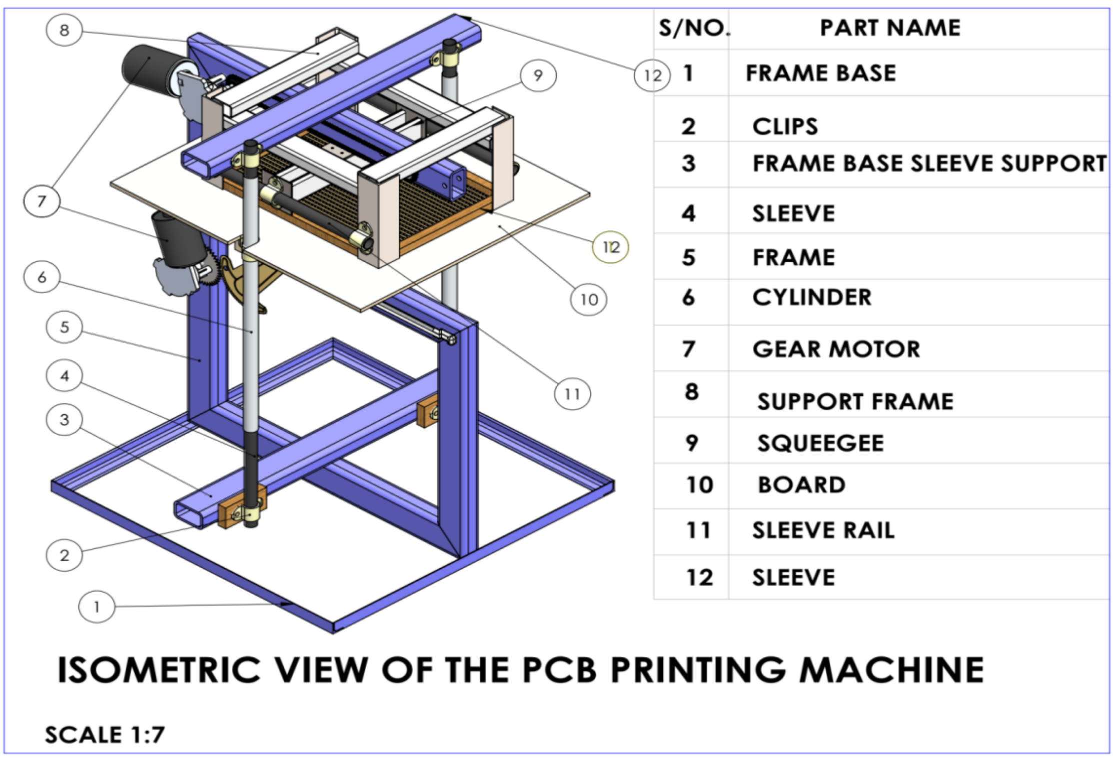

Fig. 3: Automated PCB Screen Printing Machine

Fig. 3 shows the mechanical design of the PCB machine drawn using Solidworks.

4.0 Results and Discussion

On startup, the LCD displayed a welcome message screen, which includes the project title and the name of our institution. After the welcome screen message the screen cleared and printed "PRESS START BUTTON TO START PRINTING" On placing the unprinted copper board and pressing the start button, the first motor was activated which caused the vertical slider mechanism to move upwards and on-getting to the maximum height (touching the sensor), the motor stopped. The stopping of the first motor activated the second motor's movement which caused the horizontal slider mechanism to slide rightwards and on getting to the extreme it slides back to its initial position, then the first motor spanned anti-clockwise movement to move the carriage back to its original position. The LCD displays work done; hence the printing of the copper board was achieved.

References

1. M. S. Abdul Aziz, M. Z Abdullah and C. Y. Khor, Effects of Solder Temperature on Pin Through-Hole during Wave Soldering: Thermal-Fluid Structure Interaction Analysis", The Scientific World Journal, Vol. 12, 2014 pp. 1-13., 2014.
2. E. H. Yuk, S. H. Park, P. Cheong-Sool, B. Jun-Geol "Feature-Learning-Based Printed Circuit Board Inspection via Speeded-Up Robust Features and Random Forest", Applied Sciences, Vol. 8, 2018, pp. 1-14.
3. K. J. Madekar, K.R. Nanaware, Phadtare, P. R., & Mane, V. S. “Automatic mini CNC machine for PCB drawing and drilling”. *International Research Journal of Engineering and Technology (IRJET)*, *3*(02), 1107-1108, 2016.
4. C. R. Sachin, K. Surenders, K. Sumita, A. Irshad, S. V Satish, "Design and Fabrication of Automatic Pneumatic Screen Printing Machine", International Journal of Science and Research (IJSR), 2017, pp. 168-172.
5. H. Chien-Yi, Yueh-Hsun and Y. Kuo-Chong, "The solder paste printing process: Critical parameters, defect scenarios, specifications and cost reduction", Soldering & Surface Mount Technology, Vol. 23, No. 4, 2011, pp. 211-223
6. A. S. Priyadharson and P. K. Surarapu "PLC-HMI Based Automatic Screen Printing System", International Journal of Mechanical Engineering and Technology (IJMET), Vol. 8, Iss. 10, 2017, pp. 101-107.