PCB MANUFACTURING MACHINE USING HYBRID DNC MACHINE

RAJARANATHNAM D.R.P.[1] ,R.T.AJAYKARTHIK[2],ARUNKUMAR.G[3], GOWSIC RAJ.T[4]

Associate professor, Mechatronics Department, Paavai Engineering College, Tamilnadu, India

Associate professor, Mechatronics Department, Paavai Engineering College, Tamilnadu, India
Student, Mechatronics Department, Pavaai Engineering College, Tamilnadu, India
Student, Mechatronics Department, Pavaai Engineering College, Tamilnadu, India

ABSTRACT

Normally, for making PCB, we required more time for designing, printing etching also drilling. Hence to reduce time and more effort we are design this project. In this paper, the design of PCB milling and drilling machine, where the drill holes and circuit path are automatically find out the layout in EAGLE software. This paper focuses on the design and fabrication of automatic PCB milling and drilling machine for large production. This is the microcontroller based machine that uses path planning through the numerical codes for the circuit layout. In this project, multiple spindle or fixtures are controlled by single control unit, which is used to make the system more stable and accurate for high productivity.

Keyword: *Hybrid DNC, PCB Milling, Multiple Spindles, Common drive system.*

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1. INTRODUCTION

The goal of this project is to design and implement a computer controlled PCB drilling machine. All the mechanical and electronics design are done from scratch to realize the project. There is also a computer program which communicates with the machine Electronics. Next chapter reveals the main blocks of the designed project. It gives introductory information about the whole system. Following chapters explain the main blocks of the system seperately in detail. The conclusions chapter includes the results of the project and future decisions. References are also added at the end of the project report. Finally, appendices list the source codes and circuit diagrams that are used in this project.

2.SYSTEM OVERVIEW

In electronics industry, Printed Circuit Boards (PCB) are designed using Computer Aided Design (CAD) progra ms. These programs generate a standardized file which is known as Excellon Drill File . Excellon files define t he position of hole locations on the designed PCB. This information is used in Computer Numerical Control (CNC) machines to drill the necessary holes on the PCB. In this project, the developed software takes the Excellon drill file of the PCB. Than it calculates the necessary parameters and sends the coordinate information to PIC16F877 m icrocontrollerunit(MCU)overs232 line. When MCU takes the necessary information, it immediately indexes th e stepper motor drivers. Stepper motor drivers turn the stepper motors according to the index pulses applie d to them. Stepper motors move the mechanism to accomplish the drilling of the PCBs

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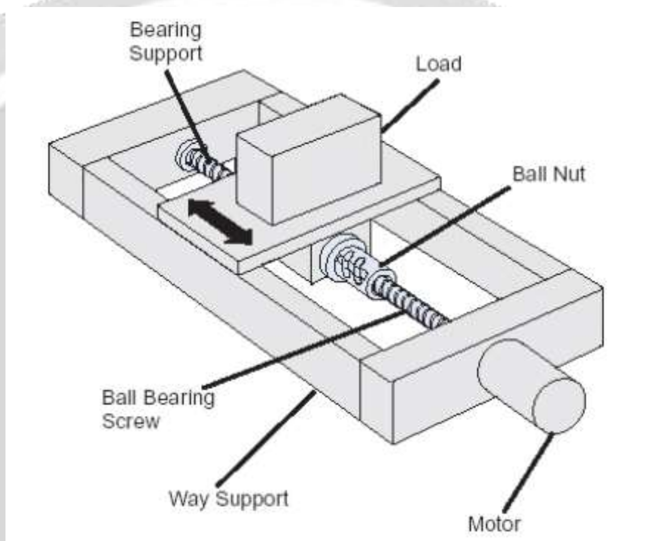
3.MECHANICS

Mechanical system is the realization of 3-dimensional motion control. Motion Control, in electronic terms, means to accurately control the movement of an object based on speed, distance, load, inertia or a combination of all these factors. There are numerous types of motion control systems, including; stepper motor, linear stepper motor, DC brush, brushless DC, servo, brushless servo and more. The stepper motors are chosen in this study, for the following reasons that they are generally preferred to use with computer controls because they are essentially digital devices and ideal for low cost, open loop control schemes where high torque and rotation speed values are not required. In theory, a Stepper motor is a marvel in simplicity. A stepper motor-lead screw combination is used on all three axis to make axis movements. The shaft of the motors are coupled to lead screws. The screws are beared at two ends by ball bearings. With this mechanism the rotational movement of the stepper motors are converted to linear movements to drive the axises.



A 3-D solid model of the mechanical system is designed with AutoCAD 2000 before making the mechanical parts. The design is investigated for various working parameters. These parameters include lightness in weight, low friction, low mechanical cost and low inertia. The system idesigned to be driven with NEMA 23 sized stepper motors.

By considering these parameters, the mechanical system is constructed as follows:

- 3 axis stepper motor – lead screw linear motion mechanism
- 12mm diameter Inox stainless steel lead screws
- 12mm Inox Nuts
- Kestamid and Polietheleyn nut holders
- 12mm mercury steel shafts for axis support
- 12mm delrin parts for shaft sliders
- Polietheleyn parts for main body
- Kestamid couplings
- Aluminium motor holders

All parts are done in mechanical workshops by using lathes and milling machines.

4.STEPPER MOTOR BASICS

4.1 Technical Description

Stepper motors are electromechanical equipment converting electrical energy into rotation movement. Pulses of electricity drive rotor and connected shaft. They are connected to stepper motor drivers which have high switching capability. This driver gets pulses from a digital controller and each pulse drives the shaft of the motor for a determined angle. This little angle is called step angle and fixed for each motor. The speed and direction of the movement depends on pulse sequence and pulse frequency. The rotation has not only a direct relation to the number of input pulses, but its speed is also related to the frequency of the pulses. Stepper motors vary in the amount of rotation that the shaft turns each time when a winding is energized. The amount of rotation is called step angle as mentioned before and vary from 0.9° degrees (1.8° degrees is more common) to 90° degrees. Step angle determines the number of steps per revolution. A stepper with a 1.8° degrees step angle must be pulsed 200 times (1.8° x 200 = 360°) for the shaft to turn one complete revolution. Sensitivity of a stepper motor increases with the number of steps in one revolution like its cost. Obviously, a smaller step angle increase the accuracy of a motor. But stepper motors have an upper limit to the number of pulses they can accept per second. Heavy-duty steppers usually have a maximum pulse rate (or step rate) of 200 or 300 steps per second, so they have an effective high speed of one to three revolution per second (60 to 180 rpm). Some smaller steppers can accept a thousand or more pulses per second, but they don't provide very torque and are not suitable as driving or steering motors.

The stepper motor coils are typically rated for a particular voltage. The coils act as inductors when voltage is supplied to them. As such they don't instantly draw their full current and in fact may never reach full current at high stepping frequencies. The electromagnetic field produced by the coils is directly related to the amount of current they draw. The larger the electromagnetic field the more torque the motors have the potential of producing. The solution to increasing the torque is to ensure that the coils reach full current draw during each step. Stepper motors can be viewed as electric motors without commutators. Typically, all windings in the motor are part of the stator, and the rotor is either a permanent magnet or, in the case of variable reluctance motors, a toothed block of some magnetically soft material. All of the commutation must be handled externally by the motor controller, and typically, the motors and controllers are designed so that the motor may be held in any fixed position as well as being rotated one way or the other. It should be noted that stepper motors couldn't be motivated to run at their top speeds immediately from a dead stop. Applying too many pulses right off the bat simply causes the motor to freeze up. To achieve top speeds, the motor must be gradually accelerated. The acceleration can be quite swift in human terms. The speed can be 1/3 for the first few milliseconds, 2/3 for the next 50 or 75 milliseconds, then full blast after that. Actuation of one of the windings in a stepper motor advances the shaft. Continue to apply the current to the winding and the motor wont turn any more. In fact, the shaft will be locked, as if brakes are applied. As a result of this interesting locking effect, you never need to add a braking circuit to a stepper motor, because it has its own brakes built in. The amount of breaking power of a stepper motor is expressed as holding torque.

5.Stepper Motor Types

5.1.1 Variable Reluctance (VR)

VR motors are characterized as having a soft iron multiple rotor and a wound stator. They generally operate with step angles from 5 degrees to 15 degrees at relatively high step rates, and have no detent torque (detent torque is the the holding torque when no current is flowing in the motor).

In Figure 5.2, when phase A is energized, four rotor teeth line up with the four stator teeth of phase A by magnetic attraction. The next step is taken when A is turned off and phase B is energized, rotating the rotor clockwise 15 degrees; Continuing the sequence, C is turned on next and then A again. Counter clockwise rotation is achieved when the phase order is Reversed.

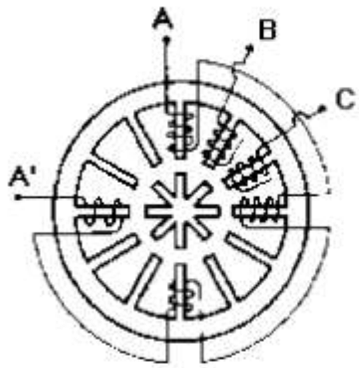


Figure5.2 Variable Reluctance Motor

5.1.2 Permanent Magnet (PM)

PM motors differ from VR's by having permanent magnet rotors with no teeth, and are magnetized perpendicular to the axis. In energizing the four phases in sequence, the rotor rotates as it is attracted to the magnetic poles. The motor shown in Figure 5.3 will take 90 degree steps as the windings are energized in sequence ABCD. PM's generally have step angles of 45 or 90 degrees and step at relatively low rates, but they exhibit high torque and good damping characteristics.

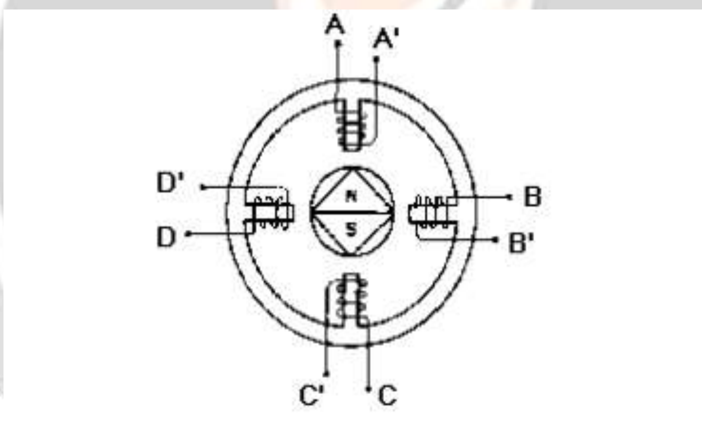


Figure5.3 Permanent Magnet Motor

5.1.3 Hybrid (HB)

Combining the qualities of the VR and the PM, the hybrid motor has some of the desirable features of each. They have high detent torque and excellent holding and dynamic torque, and they can operate at high stepping speeds. Normally, they exhibit step angles of 0.9 to 5 degrees. Bi-filar windings are generally supplied (as depicted in Figure 5.4), so that a single-source power supply can be used. If the phases are energized one at a time, in the order indicated, the rotor would rotate in increments of 1.8 degrees. This motor can also be driven two phases at a time to yield more torque, or alternately one then two then one phase, to produce half steps or 0.9 degree increments.

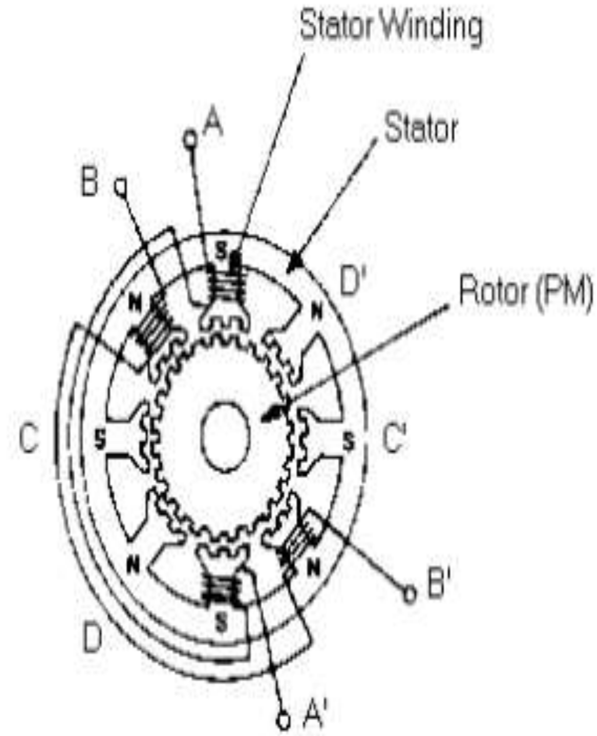


Figure5.4 Hybrid Motor

6.STEPPER MOTOR DRIVING

6.1 Winding Resistance and Inductance

Resistance and inductance are two inherent physical properties of a winding, or any coil. These two basic factors also limit the possible performance of the motor. The resistance of the windings is responsible for the major share of the power loss and heat up of the motor. Size and thermal characteristics of the winding and the motor limit the maximum allowable power dissipated in the winding. The power loss is given by:
Pr = R* Im2 where R is the winding resistance and Im is the winding current.It is important to note that a motor should be used at its maximum power dissipation to be efficient. If a motor is running below its power dissipation limit, it means that it could be replaced by a smaller size motor, which most probably is less expensive. Inductance makes the motor winding oppose current changes, and therefore limits high speed operation. Figure 5.1 shows the electrical characteristics of an inductive-resistive circuit. When a voltage is connected to the winding the current rises according to the equation

$$I(t) = (V / R) * (1 - e - t \cdot R/L)$$

x

8.CONTROL BOARD

8.1 Microcontrollers

Microcontroller is basically a small computer which has in-built central processing unit (CPU), read only memory (ROM), random access memory (RAM) and peripheral input/output (I/O) ports. With the advance in VLSI technology, todays microcontrollers also can have A/D (Analog/Digital) - D/A (Digital/Analog) convertors, USART

(Universal Synchronous Asynchronous Receiver Transmitter) and I2C (Inter Integrated Circuit) interfaces, comparators, timers, PWM (Pulse Width Modulation) modules packaged in a standard IC socket.

8.2 Microcontroller Selection

In this project, main tasks of the microcontroller are:
1. Communication with PC at reliable speeds
2. Generation of control signals for 3 stepper motor drivers
3. Limit switch inputs for axis overrange protection
4. Spindle speed control (As a future work)

9.PC SOFTWARE

Main parts of the developed software are:
- A Graphical User Interface (GUI) to interact with the user
- Excellon Drill File Import
- Conversion of string hole coordinates to proper variables
- Jog movement to set offset coordinates
- Drill routine to drill all holes from the imported file
- Machine settings to change machine resolution, axis speeds, driving modes, etc.
- Com port settings to change RS-232 transmission parameters
- Tool index to show different tool diameters
- An emergency stop button to immediately stop machine movements

9.1 Jog Movements

When user clicks Jog button on PC, the following steps are executed:
1. PC sends an OPENJOGMODE byte to PIC.
2. PIC responds with a JOGMODEON byte.
3. Jog form is opened on PC.
4. When user presses on an axis movement button, a 4-bytes long “Jog Data Packet” is constructed and sent to PIC according to the user parameters.
5. Upon completion of the movement PIC responds with a JOGMODEDONE byte.
6. PIC starts waiting for new Jog Data Packets.
7. If user closes Jog form, 4-bytes long 0’s (zeros) are sent to PIC to close Jog mode.
8. PIC responds with a JOGMODEOFF byte and goes to mode selection.

10.ARDUINO UNO

Arduino Uno is a microcontroller board based on the ATmega 328P(datasheet). It has 14 digital input/output pins of which 6 can be used as PWM outputs, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack an ICSP header and a reset button.

10.1 ATmega 328P-PU

ATmega 328P is a single chip microcontroller created by ATMEL in the mega AUR family. A common alternative to the ATmega 328P is the “Pico power” ATmega 328P. The most common implementation of this is on the popular Arduino development platform, namely the Arduino UNO or Arduino Nano models.

10.2 ATmega 328P pin diagram

Atmega 328P is a 28 pin microcontroller. It has 14 digital I/O pins, of which 6 can be used as PWM outputs and 6 analog input pins. These I/O pins account for 20 of the pins.

HYBRID DNC MACHINE

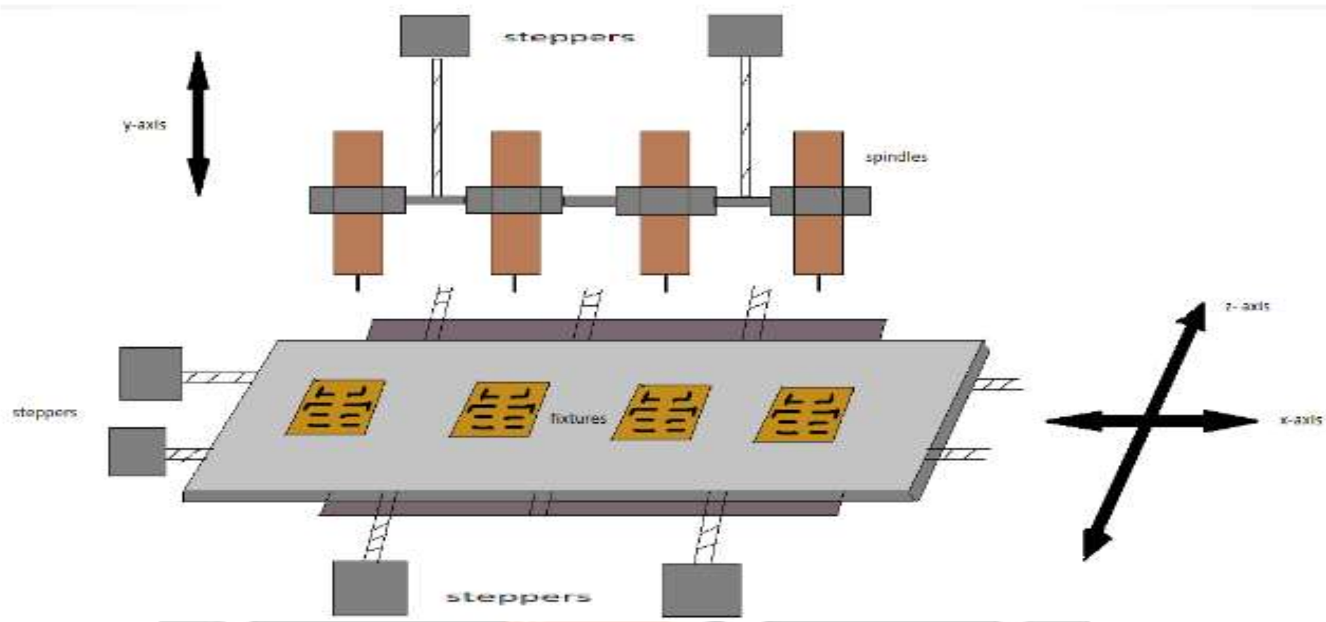


Figure 11.1 Block Diagram of DNC

12.RESULTS AND CONCLUSION

Errors that might occur in manual drilling are totally eliminated with the 3-axis precise control of the drill head movements. So, drill bit positioning on a pad or breaking of tools is no more a problem. In addition, PCBs can be drilled with this machine before the etching process. This provides smooth drill faces causing better solder ability on the final PCBs. Also with the help of a chemical process, this system can be used to produce two sided and through hole plated printed circuit boards.

In the future,

- Current system can be improved to reach higher axis speeds;
- Variable spindle speed control mechanism can be easily incorporated to the system;
- The developed system can be built up for milling PCBs.

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