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Design and Fabrication of an Automatic PC-Based Drilling Machine

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Abstract

The abbreviation CNC stands for "Computer Numerical Control" and refers specifically to a computer "controller" that functions depending up on the program prepared to run a machine efficiently. These machines are capable of performing multiple operations simultaneously and due to this many manufacturing industries are adopting these CNC machines to increase their production. In this regard, this project work is taken up, which is aimed to design and develop one CNC machine that can be used for drilling the PCB (printed circuit board). The program is prepared in 'C' language and a step by step approach is implemented to control four motors independently. Three heavy duty stepper motors are used to control the machine in three axes and one small AC motor of 3600 RPM is used for drilling purpose. Since it is a prototype module,

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the machine is designed to drill the PCB of not larger than $12x20$ cm approximately. In drilling, the head will be moved to the referred position before each drilling. After the drilling is finished to the fed data, the drilling head will move back to the referred position. As per the data fed to the machine, it can drill as many holes as in specific area. After completing the task, the computer displays on its monitor that the job is completed. To avoid friction, the mechanical transmission part of each axis is designed with ball bearing type of sliding channels.

Keywords

Design and Fabrication, Automatic PC-Based Drilling Machine.

Introduction

Current development in industry has been towards computer controlled manufacturing to increase quality and quantity of products. Manual manufacturing of such items as the circuit board will have a big faulty case and uneven quality. Then have developed an automatic print circuit board drilling machine, which is controlled by computer. The main aim of the project lies in interfacing or in simple words, is to make a mechanical system work, making use of a personal computer of basic configuration, this project is carried on keeping in mind the needs of a small scale industry, which need small sized components in a few number, which by other processes would cost them more. This project makes use of a printed circuit board that interfaces a drilling machine with a personal computer through a buffer. This system is mainly aimed at small scale production of printed circuit boards in small scale industries The system has an advantage of simplicity in operation, moreover the cost of production comes down for a small scale sector. Though the system involves many small electronic parts it is easy to study the working, and in operation, as use the simple user-friendly language in programming the software.

Basic Design Concept

The goal here is to design and build a very low-cost, very simple, desktop drilling machine, which is used for drilling the PCB's (printed circuit boards). Drilling the PCB's manually consumes lot of time and due to errors by drilling at wrong points, causes wasting many PCB's. All these problems can be avoided

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by implementing CNC concept, there by this project work is taken up and a prototype module is constructed for the live demonstration. Since it is a prototype module, size of the work or drilling size of the PCB is minimized. Due to the restriction, the machine cannot drill PCB of more than $12x20$ cm.The platform which moves in X, Y directions is made out of clear see through type of Acrylic sheet of 5 mm thick is used, the idea of using this sheet is to have a clear visibility of the other mechanism, which is below the plat form. A thermo coal sheet of same size can be arranged over the plat form and the job (the PCB which is supposed to be drilled) can be kept over the thermo coal with some fixing arrangement. The mechanical transmission section to drive the X, Y table is designed with Sliding channels with ball bearings, the whole mechanism of X, Y table is designed with two stepper motors, four sliding channels, two screw rods of 12 mm, end plates to hold screw rods, 12 mm nuts loaded with MS (mild steel) plates, etc. When the motor rotates, screw rod also rotates and moves the MS plate, which is loaded with 12 mm nut. Depending up on the motor speed, MS plate travels along with screw rod at certain speed. And depending up on the motor shaft rotation direction (clockwise or anti clockwise) 12 mm nut along with plate moves in both the directions, i.e., forward or reverse. Likewise with the help of two stepper motors, the X, Y table moves in X, Y directions. Another sliding channel is used and it is arranged in vertical direction for drill machine, which moves in 'Z' direction. In general the mechanical construction slightly differs with this machine, the detailed description is as follows. A computer-controlled drilling machine requires a device that guarantees that the drill lands repeatable at the specified point. This device should be firmly fixed to the machine and in any case designed to make precise alignment easy.

Introduction to Concept

The system uses three pivots, two for moving the X, Y table for positioning the job (the circuit board) at specified coordinate and one for the drilling mechanism. This allows any desired point on the circuit board to be brought into range on the turntable. This system has the big advantage over a linear construction that only two bearing points are needed whose exact separation is the only quantity that needs to be known. This requires no expensive specialist components: the bearings simply have to remain vertical and free of play. [Refer figure 1]

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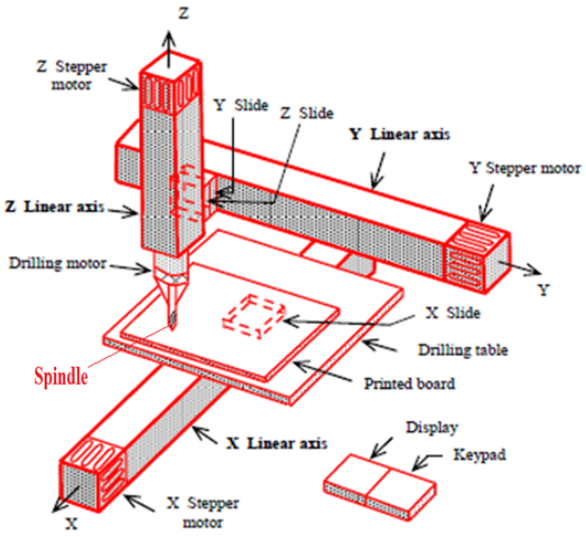

Figure 1: *Automatic PC-Based Drilling Machine*

Polar Coordinates

Here a point on a surface has its position defined not by X- and Y coordinates as in the Cartesian system, but by a length (distance from a fixed point) and an angle. Polar and Cartesian coordinates can be inter converted without loss of information. In the PCB layout, draw a circular pad with diameter exactly 3 mm in an unused area; alternatively, use a mounting hole. In the circuit board itself, before exposure, drill a hole with diameter 3.1 mm, in the corresponding place to the pad on the layout.

Transmission System

Here a point on a surface has its position defined not by X- and Y coordinates as in the Cartesian system, but by a length (distance from a fixed point) and an angle. Polar and Cartesian coordinates can be inter converted without loss of information. In the PCB layout, draw a circular pad with diameter exactly 3 mm in an unused area; alternatively, use a mounting hole. In the circuit board itself, before exposure, drill a hole with diameter 3.1 mm, in the corresponding place to the pad on the layout.

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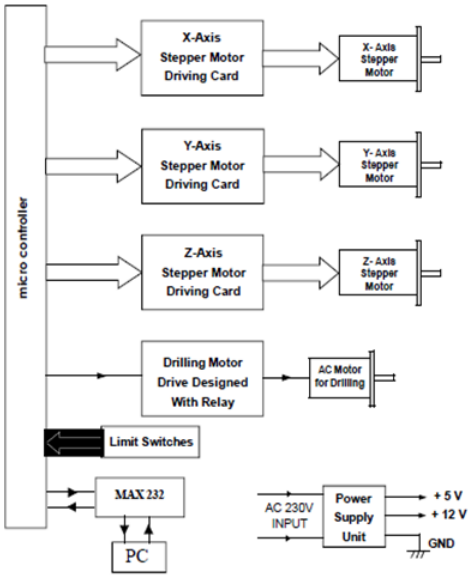

Figure 2: *Micro-controller Controlled Drilling Machine*

The Stepper Motor Drives by Computer

Stepper motors are very different from a regular DC motors. Instead of spinning like DC motors do stepper motor steps at a specific resolution for each pulse. The motor that are using needs 200 steps / pulses just to complete a single revolution which should be enough to tell about its precision. Another advantage of stepper motors is the fact that their speed of rotation can be achieved almost instantly even if you change the spinning direction. Stepper motor consists of a `rotor` - the permanent magnet that rotates inside, and `stator` - four coils (north, east, south, and west) that are part of the case, and which `don't move`. Rotor can be moved by sequentially applying a pulsed DC voltage to one or two coils at a time. In order to move the rotor it requires a driver. Driver is a circuit that applies a voltage to any of the four-stator coils. To drive the stepper motor in both the directions (clockwise or anti-clockwise) the system is programmed to produce the pulses in a sequence at four different outputs (9, 5, 6, A). These sequential programmed outputs energize the motor windings one after another in a sequence.

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Numerical Control Machine Drives

The complete circuit diagram of the project work is provided at the end of this chapter, the following is the brief description about the circuit design.

Stepper Motor Driver Circuit

This is an easy to build stepper motor driver that will precisely control a uni-polar stepper motor through the micro controller. In order to move the rotor driving circuit is required. Driver is a circuit that applies a voltage to any of the four-stator coils. Driver can be built with four Darlington transistors or four power MOSFETS. Here the circuit is designed with power MOSFETS and its pre-driver. The pre-driver is used to switch the power MOSFET effectively. It has the following objectives:

1. To develop core technology of PC based CNC control system,
2. To explore new concept of integration of CNC control with adaptive feedback control for intelligent material processing,
3. To develop a prototype of open architecture PC-based CNC control system.

Brief Description about Micro-controllers

Introduction

A Micro controller consists of a powerful CPU tightly coupled with memory, various I/O interfaces such as serial port, parallel port timer or counter, interrupt controller, data acquisition interfaces-A/D converter, D/A converter, integrated on to a single silicon chip. If a system is developed with a microprocessor, the designer has to go for external memory such as RAM, ROM, EPROM and peripherals. But controller is provided all these facilities on a single chip. Development of a Micro controller reduces PCB size and cost of design. One of the major differences between a Microprocessor and a Micro controller is that a controller often deals with bits not bytes as in the real world application.

Features of 8051 Architecture

1. Optimized 8 bit CPU for control applications and extensive Boolean processing capabilities.

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2. 64K Program Memory address space.
3. 64K Data Memory address space.
4. 128 bytes of on chip Data Memory.
5. 32 Bi-directional and individually addressable I/O lines.
6. Two 16 bit timer/counters.
7. Full Duplex UART.
8. 6-source / 5-vector interrupt structure with priority levels.
9. On chip clock oscillator.

8051 Micro-controller Architecture

The 8051 architecture consists of these specific features:

1. EightBit CPU with registers A (the accumulator) and B
2. Sixteen-bit program counter (PC) and data pointer (DPTR)
3. Eight- bit stack pointer (PSW)
4. Eight-bit stack pointer (Sp)
5. Internal ROM or EPROM (8751) of 0(8031) to 4K (8051)
6. Internal RAM of 128 bytes: (1)Four register banks, each containing eight registers, (2)Sixteen bytes, which maybe addressed at the bit level, (3)Eighty bytes of general- purpose data memory.
7. Thirty two input/output pins arranged as four 8-bit ports: P0-P3
8. Two 16-bit timer/counters: T0 and T1
9. Full duplex serial data receiver/transmitter: SBUF
10. Control registers: TCON, TMOD, SCON, PCON, IP, and IE
11. Two external and three internal interrupts sources.
12. Oscillator and clock circuits.

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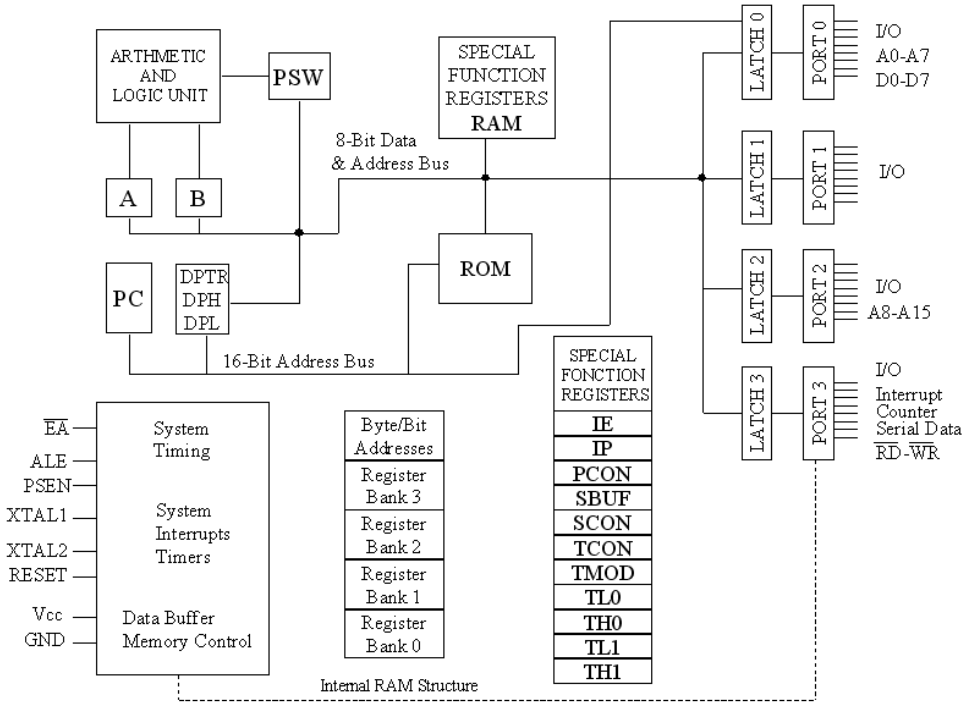

Figure 3: *Functional Block Diagram of Micro-controller*

Functional Block Diagram of Micro-controller

Port Pin Alternate Function:

- P3.0- RxD (serial input port)
- P3.1 -TxD (serial output port)
- P3.2 -INT0 (external interrupt 0)
- P3.3 -INT1 (external interrupt 1)
- P3.4 -T0 (timer 0 external input)
- P3.5 -T1 (timer 1 external input)
- P3.6 -WR (external data memory write strobe)
- P3.7 -RD (external data memory read strobe)
- VCC: -Supply voltage

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- VSS: -Circuit ground potential

Brief Description about Max 232

Introduction

In order to connect micro-controller to a modem or a PC to modem a serial port is used. Serial is a very common protocol for device communication that is standard on almost every PC. Most computers include two RS-232 based serial ports. Serial is also a common communication protocol that is used by many devices for instrumentation numerous GPIB-compatible devices also come with an RS-232 port. Furthermore, serial communication is used for data acquisition in conjunction with a remote sampling device. The concept of serial communication is simple. The serial port sends and receives bytes of information one bit at a time. Although this is slower than parallel communication, which allows the transmission of an entire byte at once, it is simpler and can be used over long distances.

About RS-232

RS-232(ANSI/EIA-232 Standard) is serial connection found on IBM-compatible PC's.It is used for many purposes, such as connecting a mouse, printer, or modem, as well as industrial instrumentation. Because of improvements in line drivers and cables, applications often increase the performance of RS-232 beyond the distance and speed listed in the standard. RS-232 is limited to point-to-point connections between PC serial ports and devices. RS-232 hardware can be used for serial communication up to distance of 50 feet.

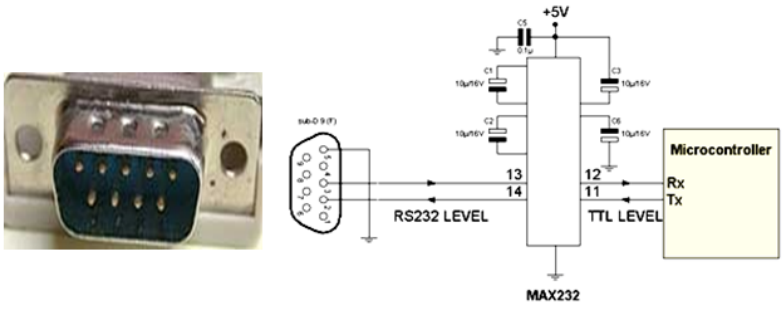

Figure 4: *RS 232 DB-9 Pin Connector*

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Pin Description of RS-232 DB-9 Pin Connector

Pin	Functions
Data	TxD on pin-3, RxD on pin-2
Handshake	RTS on pin-7, CTS on pin-8, DSR on pin-6, CD on pin-1, DTR on pin-4.
Common	Ground on pin-5
Other	RI on pin-9

Table 1: *Pin Description of RS-232 DB-9 Pin Connector*

MAX 232 Full-Duplex

The circuit below use MAX232 which is the Maxim's devices. This circuit is very stable and use for professional design. This device is inexpensive and it can provide 2 channel for RS232. The MAX232 line drivers/receivers are designed for RS-232 and V.28 communications in harsh environments. Each transmitter output and receiver input is protected against 15 kV electrostatic discharge (ESD) shocks, without latch up. It can operate from a Single +5V Power Supply. [Refer figure 5]

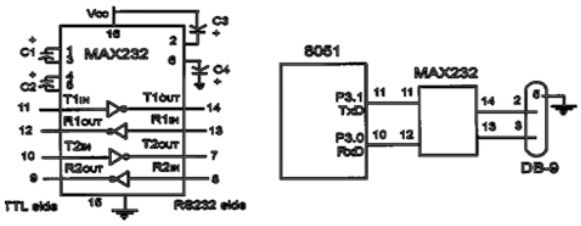

Figure 5: *Max 232 and its connection to 8051*

Description about RS 232

This article is intended to help the designer's sort through the various features available in RS-232 interface products. The main features described are the

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regulated charge pump, Auto shutdown, RS-232 compatible versus compliant operation, ESD protection, and data rates including Mega baud operation.

Hardware Details

1. Atmel 89C51 Micro-controller chip
2. MAX 232
3. 7805 Voltage Regulator
4. BC547 NPN Transistors
5. Z44 Por MOSFET

Figure 6: *Hardware*

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Programming Display

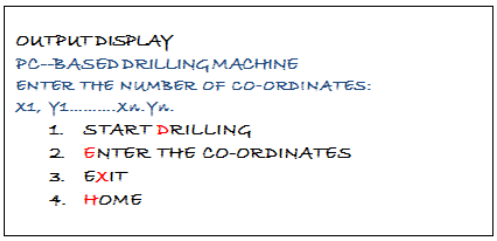

Figure 7: *Programming Display*

X, Y, Z	Three linear axes
U, V, W	Three rotational axes
NC	Numerical Control
CNC	Computer Numerical Control
MCU	Machine control unit
DPU	Data Processing unit
CLU	Control loops unit
PCB	Printed circuit boards
ALU	Arithmetic and Logic Unit
CPU	Central Processing Unit
CU	Control Unit
I/O	Input/ Output
IC	Integrated Circuit
ROM	Read only Memory
RAM	Random access Memory
MC	Microcontroller
CW	Clockwise
CCW	Counter clockwise

Table 2: *Nomenclature*

Conclusion

This project revealed that building a relatively low cost, high precision CNC machine is possible. Also the benefits of CNC systems are seen with this project., which is the main process of rapid prototyping. It was proved that having such

a tool saves both time and money. In the future more process level outputs, constraints, cost estimation, and a CNC program editor with syntax check will be added into the current one and finally the results will be benchmarked with industrial tests. A set of the recommended values of speed, feed, and depth of cut for certain tools and materials will also be added. Visual aid to support the lectures and lab, Easy to learn, easy to use, easy to modify system, No need to look up tables and calculations, Constraints will be added into calculated results.

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