

RETROFITTING A CONVENTIONAL LATHE TO A DIGITAL INTELLIGENCE SYSTEM

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Abstract

The development of modern technologies in computer software, hardware, and firmware as well as the integration of these technologies in the industrial lines have proved better and more efficient productions can be machined. In this project, an attempt has been made to equip the conventional lathe machine with Digital Intelligence system (DIS) in order to get more accurate dimensions and precise shape of high end products. The retrofitting process of the conventional lathe machines into semi automatic control lathe machine, demands two key elements, namely, mechanical and electronics parts. In the mechanical part, a design is made to feed the stepper motor to the lead screw. On the other hand, in the electronics part, an electronic circuit containing the motor driver circuit is designed in order to control the motor movement.

Keywords –*Lathe CNC Machine, Retrofitting, Intelligence System*

1. Introduction

Lathe is a machine tool for producing cylindrical, conical and flat surfaces. It can be used for drilling and boring holes which may be cylindrical or conical in shape. The basic engine lathe, one of the most widely used machine tools is very versatile when used by a skilled machinist. However, it is not particularly efficient when many identical parts must be machined as rapidly as possible. Numerical control is based on the use of numerical data for controlling the position of the operative units of a machine tool during machining operation. Today, a more popular adaptation of the basic process of NC is called Computer Numerical Control or CNC [1]. The main benefit of CNC machine it allows great accuracy as well as efficiency on improving currently developed in "lean manufacturing" [2]. To address the environmental issues in the manufacturing industry, it may offer more benefit about the safety and the productivity from the other of equipment. By using CNC machine, the operator would be placing less in human interaction and risk is decreased significantly. The first direct mechanical controlled lathe to cut the lathe machine screws and cut back to about 1483.

Machines can run the process manually or fully remote controlled. The conventional manual machines are very time consuming and tedious, has the manufacturer to think and implement new methods to automate machines, by developing devices with digital control system after World War II. These machines use digital control perforated tape or punch cards to control the movement. In 1960, computers were added to the machines that gave flexibility in process control, naming these machines later using computer numerical control or CNC. Machines can be controlled using a digital computer or accurately to replicate a series of operations over and over again, and can produce the most complex pieces of the most skilled professionals [3]. It does not take a long time until he was able to change the machines automatically cut the tool used. It can, for example, the slot machine that includes a set of blades to produce holes of different holes diameters. Previously, the operator of the device is either to change the cutting tool automatically be transferred or encumbered to another machine to do the work. The next logical step for the integration of several different machines was to run the machines, all under the control of the computer. The operational status of these devices which is the modus operandi of these products was changed. In addition, mechanical improvements developed through the use of engine lathe for the

production of component parts of the new machines. Dramatic development of lathes in the early 1960s where the application of numerical control produced high degree of accuracy and precision, and the automation of the basic lathe became possible. However there are still some developments applied in order to develop the performance of the lathe machine as it contributes a big part in industry lines.

CNC turning center in the early 1960s were developed to cut the shaft of the device of the type that is usually held at chuck at one end, and with the support of the center for tailstock at the other end. The development of these machines was done by improving the productivity and precision lathe type machines through computer control. During the time of the era of the industrial revolution John Wilkinson invented a cannon-boring machine (lathe) in England [4]. He immediately adapted this machine for boring the cylinders for Bolton & Watt's steam engines. This boring process was the only one of its kind to produce the smooth, tightly tolerance bores required of the cylinder of a steam engine.

Today's modern machinery of CNC milling machines and lathes employ microprocessors to reads the G-codes program that the user creates and performs the programmed operations [5, 6]. Personal Computers are used to design the parts and are also used to write programs by either manual typing of G-codes or using CAM (Computer Aided Manufacturing) software that outputs G-codes from the users input of cutters and tool path.

2. Aims and Objectives

The aim of the research project is to convert the conventional lathe machine into the semi-automatic CNC lathe machine. Thus eventually will improve the flexibility of a traditional lathe machine where previously depends on the skill of experience operators. Therefore the research project has two objectives, first to introduce the necessary amendments to the traditional lathes to be controlled by computer, through the feed lead screw movement which is controlled by the computer by a step motor, and the separation of the mechanical system that feed the first place to make the lead screw moving by a step motor, which can be controlled by computer. Second to design and analyze the step motor for CNC lathe machine, the relative components and the working principle of components of machine under consideration.

3. Essential Factors in Retrofitting Conventional Lathe

There are two important considerations when retrofitting a conventional lathe machine to a CNC machine. They are as follows:

- (i) Design and program an engineering model to change the traditional lathe machine into semi CNC machine using computers hardware and software's.
- (ii) Reducing the costs by converting the available old lathe machines into more efficient machines in order to help the small workshops owners in developing and rearranging their workshops with minimized cost and maximized possible flexibility to return to the traditional way.

4. Electronic Design – Power Supply

The power supply circuit, the main power source (240V AC @ 50HZ) is stepped down to 25V AC and also 9V AC. The 25V AC caters for the motor voltage supply need while the 9V AC powers the logic circuit. These two AC voltage supply are then rectified via full-wave rectifiers separately; after rectification, the 25V AC become 35V DC while the other voltage is regulated by 7805 IC regulator to 5V DC. The 7805 component will be discussed later. Since the 35DC almost the absolute maximum rating of the A3977SED, it is reduced about 1V by passing through the power diodes. There is a 15000uF capacitor serves as charge reservoir for the high voltage side. Every time the circuit is switched off, the

high voltage supply is grounded to discharge the chargers of the capacitor since it is dangerous. This can be done by simply wiring a resistor from V+ to the Ground of the power supply circuit.

Before the main AC supply is fed into the transformer and capacitor, a 2A fuse is bridged across to protect the circuit from anything higher than 240V AC and 2A. Then, as for further protection, another 5A fuse is bridged after the diode array and before into the motor circuit. As seen from the power supply, the 25V AC 5.0A transformer is a toroidal transformer. This is chosen because of the higher efficiency in transforming a voltage to another. This is due to the primary winding of the toroidal transformer is wound as such that the magnetic flux is mostly constraint within the secondary winding. This introduces less loss as compared to ordinary type of transformer like the one used for 9V AC supply. Figure 1 shows the power supply design used in this research project.

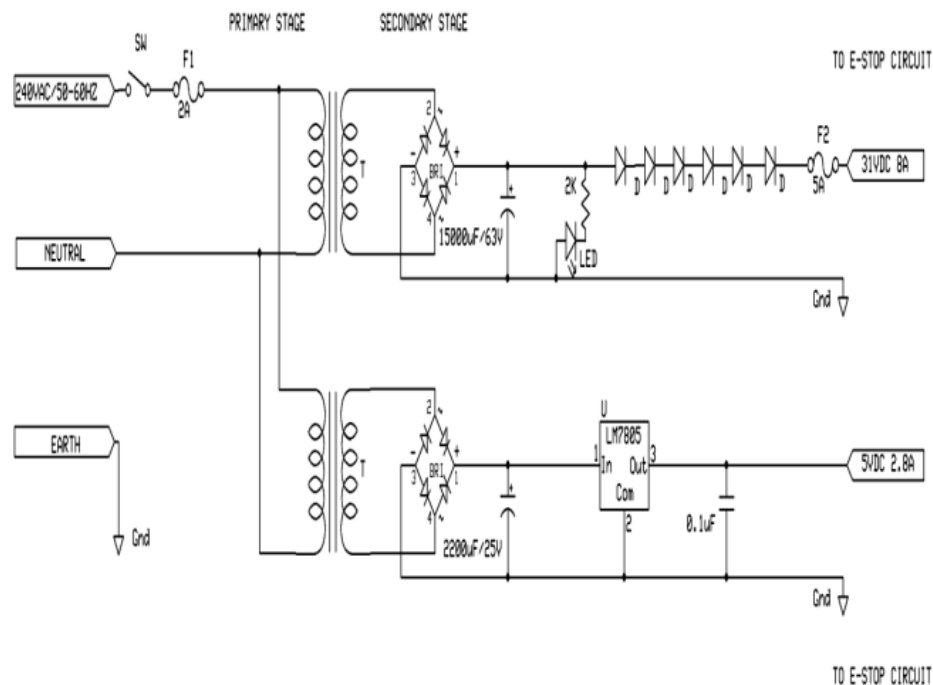


Figure 1: Power Supply Design

5. Software - CAD/CAM

In the early stage of design, researchers concerned about the limitations of a machine such as cutting speed, power, flexibility of spindle, cutter and materials before a design is actually carried out. In addition, users are likely to deal with CAM which makes the machine moves according to the design needs.

In this project, CAD designs are expected to be converted into CAM language. Then, these so-called programs are fed into CAM software that will interpret the human readable codes into machine signals. The CAM software used here is a freeware available from TurboCNC which offers control for quite a number of common CNC machines in the market. In TurboCNC, G- and M-codes are read and processed. Then, a sequence output signals are sent out via parallel port to the monitor circuit system.

In order to use this software accordingly, a number of setups is needed before running. This includes the parallel port location address, step revolution, parallel port pin-outs designation and limit switches feedback signals as depicted in Figure 2.

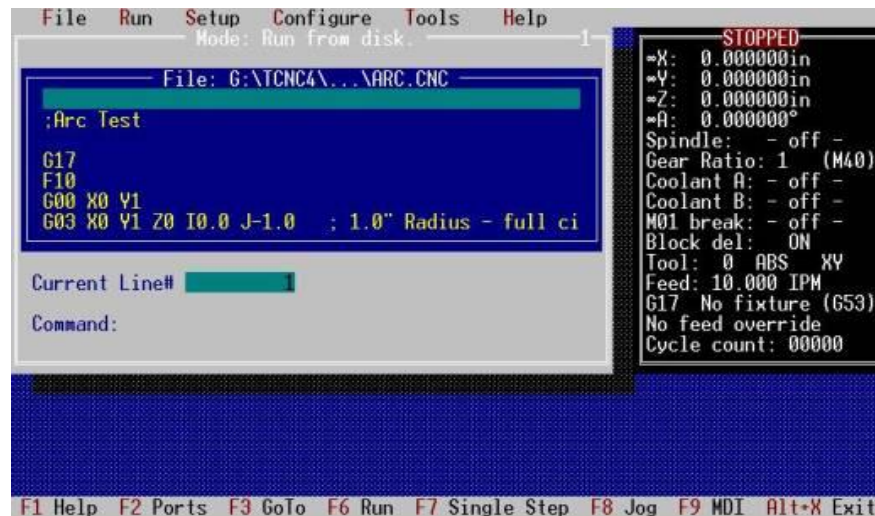


Figure 2: Turbo CNC CAD/CAM Software

6. Experimental Procedure

The program operation initialize when the user starts the software program. The program will send instructions to reset the exact coordinates and its limits. Next the user has to load the input file which carries the design. The program will then read the file and convert it to native XZ code output. The output command will be executed sequentially after performing simulation for the overall code. The limit switches will be monitored and provide a feedback to the user. The user then will be able to use the software tools to control the motor speed and the direction of the lead screw. In case of any error encountered, the program will loop back to the beginning of the code route. Figure 3 shows the flow chart of the program operation that will be implemented in this project.

An experiment is conducted for this project where the mechanical and electronic prototypes are tested independently. After both prototypes system are tested and measured, both systems were integrated to produce the final device. Furthermore, the result of using the mechanical and electronic design is discussed in this chapter. Moreover, the problems faced in both mechanical and electronic part will also discuss with possible solutions. By using mechanical engineering design principles, intuition, experiments and computer analysis, every component of this lathe is carefully analyzed and optimized pre-production to ensure a smooth manufacturing process and successful operation. In addition, the lathe is designed so that the effect of environmental and operational disturbances would be minimized.

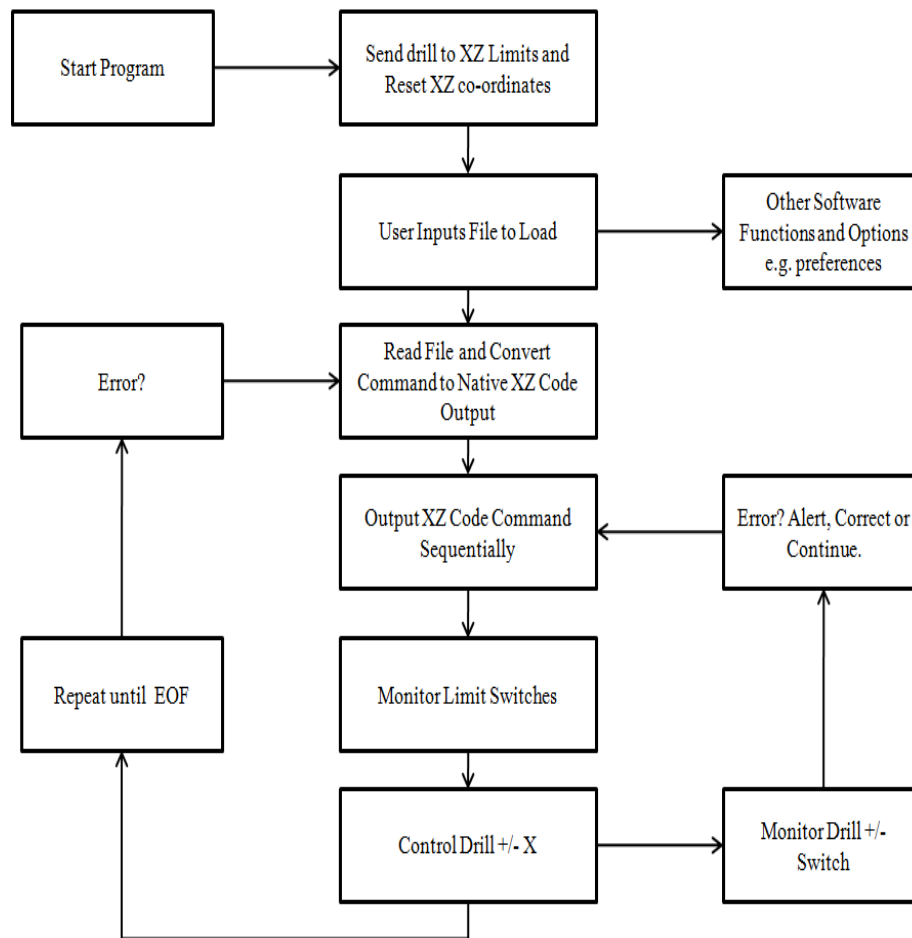


Figure 3: Data Flow Chart

7.1. Testing Tools

Several tools are used to test and measure the output results of this project included project board, oscilloscope, digital multi-meter, power generator, temperature gun meter, and tachometer.

7.2. Testing Hardware

In this section the hardware results and problems will be discussed, also the way of testing the circuit will be demonstrated, whereby before connecting the hardware parts in the PCB, the hardware must be tested and make sure it works correctly as illustrated in Figure 4.

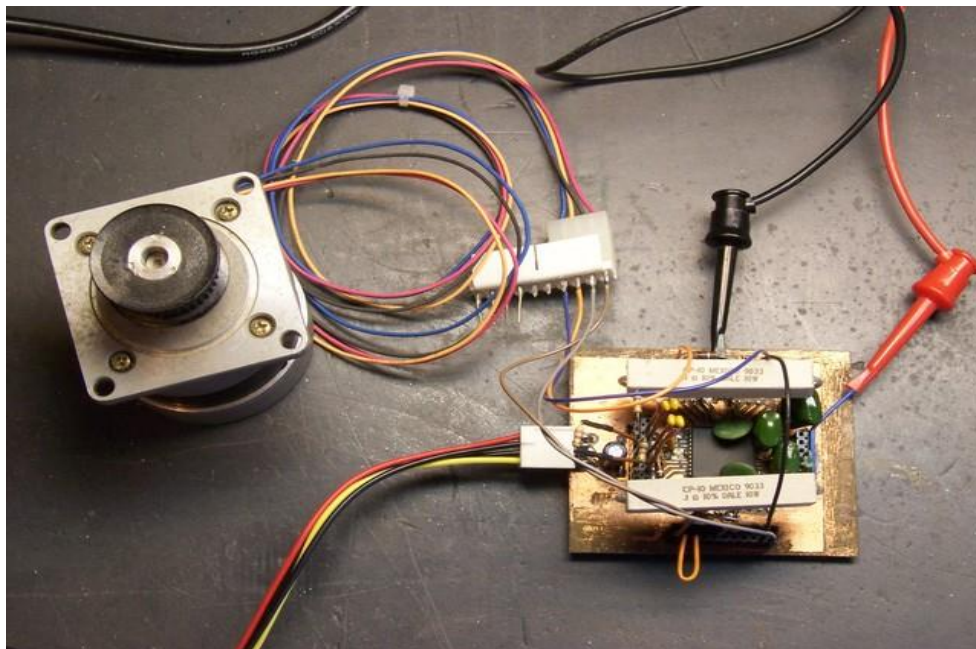


Figure 4: Testing Component

The mechanical prototype can be tested separately before connecting the motors, what required was to do some measurements and cuttings to locate the areas where the motor should be placed, it' was recommended to do some sketching manually or using CAD software to develop the correct and precise measurements before doing any wrong process that might complicate and damage the whole structure.



Figure 5: Final Design

7.3. *Assembling and Testing of the Final Device*

In this section, the mechanical conversion from the conventional lathe machine to the CNC lathe machine will be shown. The conversion steps on how the motors were embedded to the conventional structure were discussed. They are also involving electronic assembly.

The step motor and flexible couplers for the X and Z axes are mounted directly to existing hardware without any modification to the lathe. What needed to be done was mounting the motors to the mounts and slides it onto the end of the shaft on the lathe and tightens down. The power supply will power both of these motors. Figure 5 shows the final structure of the lathe machine after both of the motors were mounted at the X and Z axis.

7.4. *Troubleshooting*

Without the 3977 soldered on and IC1 not installed do the following:

- a) Power up the board and with a DC Voltmeter with the negative lead connected to board ground, measure 5vdc at IC1 (74HC14) Pins 14, 13, 1 and 5. U1 (3977) pin 16
- b) Measure the V+ (power supply) at U1 pins 43 and 25.
- c) Power down; install IC1, power back up.
- d) Run the 74hc14 (IC1) through hi (Greater Than 4vdc) and low (Less Than .7vdc) states by:
 - i. IC1 pins 13, 5, and 1 should be hi, IC1 pins 2, 3, 6, 9, 12 and 11 should be low, and IC1 pins 10, 4 and 8 should be hi (GT 4vdc). Also 3977 pins 41 and 31 should be high.
 - ii. Leaving power on, jumper pad ENABLE to ground, 3977 pin 41 should now be low.
 - iii. Move the jumper pad Step to ground, 3977 pin 31 should go low when the step pad is grounded and should go hi when you remove the jumper. Now you may install U1 the 3977. (Make sure you've disconnected the board from the power source.

7. **Conclusions**

This project considered successful since the objectives are met and the expenses are not too high. The stepper motors used are of top quality and they performed very well and accurately. As for the circuitry, A3977SED features very stable and good micro stepping features with such a high current driving capability. Moreover, at 31VDC, the motors are forced to response fast as compared to only 10-20VDC power supply. In order to gain more torque and speed, the linear bearing system used currently is recommended to be upgraded to a more industrial type such as THK, Nook Industries and so on. These linear bearing systems are very efficient and could withstand heavy loads. This kind of low-friction linear bearing increases the output torque and thus increases the rate as well. Besides, as opposed to lead screw, a ball screw will also be recommended since there is a range of ball screw that is so economical that home DIY users could afford.

The following recommendations should be considered to increase the accuracy and precision, flexibility and speed.

- (i) Use more powerful stepper motor that produces higher speed and torque produced
- (ii) Use more powerful header and cutting materials to accept any type of heavy duty tasks.
- (iii) Develop the control software in C++ or higher level language to enhance and optimize interfacing procedures.
- (iv) Utilize custom stepper motor driver and control chips to simplify interfacing complications, combining parts and to reduce component count.

- (v) Improve on the safety aspects of the lathe machine such as designing a good cover
- (vi) Introduce safety circuit with using advanced microcontroller and sensors such as Infrared and various approximate sensors.

8. References

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