

## DEVELOPMENT OF A PROTOTYPE CNC ROUTER

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### ABSTRACT

A CNC router is an automated router whose tool paths can be controlled via Computer Numerical Control. It is a technology which aims to generate, parse and execute sequential actions that describe the behavior of the end effectors. This paper reports the development of small sized prototype CNC router, based on a modular system to achieve the required accuracy and reliability for complex shapes. It also reports the development of the basic electronic devices to run the router with the capability of communication between computer and the router through USB port. The system uses C# as a programming language and Microsoft Visual Studio platform for graphical user interface (GUI).

**KEYWORDS:** CNC Router, Modular System, C#, Microsoft Visual Studio, GUI

### INTRODUCTION

Nowadays, CNC machines are widely used in almost all manufacturing systems due to its flexibility in the programming and faster machining process with high accuracy and reliability. The main component of factory automation is the CNC machines which provide a set of functionalities for the managements of the machine tools.

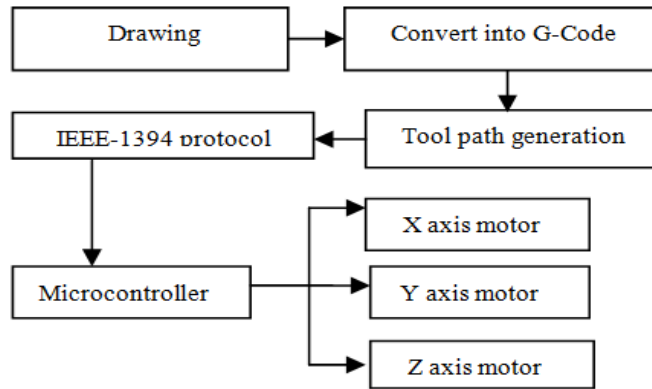
The adoption of a CNC for controlling machine tools (MTs), instead of using classical PLC's (programmable logic controllers), provides support for implementing complex strategies and thus for building complex MT's such as Milling machines, Lathe machines, etc. [1,2,3,4].

A CNC router is a computer-controlled machine for cutting various hard materials, such as wood, composite material, aluminum, steel, plastics, and foams. CNC routers come in many configurations: from small home-style "desktop" CNC routers to large "gantry" CNC routers used in boat-making facilities [5, 6, 7].

Although there are many configurations, most CNC routers have a few specific parts like: a dedicated CNC controller, one or more spindle motors, AC inverters, and a work table. CNC routers are generally available in 3-axis and 5-axis CNC formats. The setting of axis coordinates are adjusted and uploaded into the machine controller from a separate program. CNC router owners often have two software applications: one program to make designs (CAD) and another to translate those designs into a program of instructions for the machine (CAM process).

In this research, prototype of a CNC router has been developed. The architecture of the entire system is divided into 3 subsystems namely i) Mechanical, ii) Electronics and iii) Software subsystem. Mechanical subsystem gets necessary control signals from electronics subsystem which ultimately results in desired actuation of motors.

Electronics subsystem gets command or a set of commands from software subsystem. Software subsystem which is usually a computer provides easy to use interface for users and generates controls for mechanical subsystem. The Overall working principle of the router is shown in Figure 1 with a simplified block diagram.



**Figure 1: A Simplified Block Diagram for the CNC Router**

## SUBSYSTEMS

### Mechanical Subsystem

In this research, a prototype CNC router has developed, with three Cartesian axes X, Y and, Z having a maximum travel of  $15'' \times 15'' \times 6.5''$ . In this project, three stepper motors are used as mechanical drive with holding torque of 1.17N - m, 1.80 step angles, 1.4 amp of current per phase and positional precision more than 95%. As an end effector, a RIPO die grinder is used with nominal power of 130W and nominal speed of 30,000RPM. Three Leadscrews are used to convert the rotational motion into linear motion in three axes direction respectively with 5mm of pitch and precision higher than 90%. The machine's general characteristics are listed on Table 1. It is assumed that in no occasion the machine will be used to machine a material that requests mechanical power higher than the available power in the plant.

**Table 1: Machine Characteristics**

Travel on axis X and Y	381mm
Travel on axis Z	165mm
Maximum Torque on Axis	1.4Nm(unipolar)
Motor Parameters	$L=10\text{mH}$ , $R=3.6\Omega$
Driving Mode	Full stepping
End effector	RIPO Die Grinder, 130W, 30000rpm. Variable speed

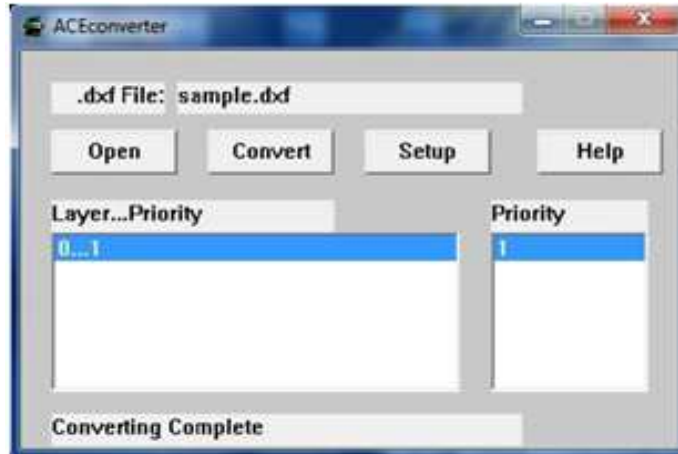
### Electronics Subsystem

The electronic circuit is developed in a modular fashion, where there is a master which is responsible for the interface with the computer, and the slaves that are connected to the master and are responsible for the control of each axis. The master device is based on a PIC18F2550 micro controller [8], which features the necessary hardware to communicate through Universal Serial Bus (USB) [9]. The USB communication runs at full speed upto 12 Mbps. This data transmission rate allows enough data to be transferred and exchanged between the machine and the computer in real time. The USB implementation utilizes the communication device class as define in [9]. The slave devices are based on a PIC16F872 micro controller [10] and its main function is to control the stepper motor.

### Software Subsystem

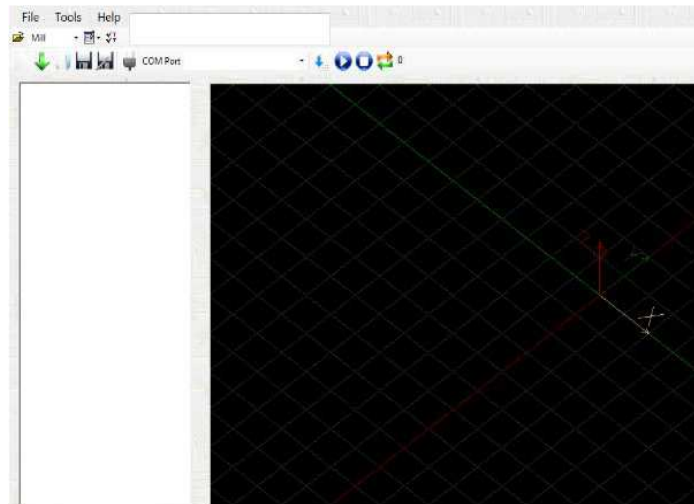
This subsystem focuses on developing the user friendly environment by providing ease to use graphical user interface. The commands can be sent in automatic way. The computer program is able to communicate with peripherals connected to the computer. A protocol has developed in such a way that the computer always has the knowledge about the

present task being executed by the machine. At first, the users have to create a dxf file by drawing the cutting profile on AutoCAD and then converted it into G code. Figure 2 shows the interface of the dxf2gcode conversion software. It consists of a browser for browsing file, a conversion button for converting drawing file from dxf to G code, It will display “Conversion success” after converting the file.



**Figure 2: The Conversion Software**

Once the conversion has been completed, user can load that file on simulation software. Figure 3 shows the user interface of the simulation software where converted G-code and the required cutting profile have displayed. This program sends the commands to the machine.



**Figure 3: User Interface of Simulation Software**

For designing simulation software, an object-oriented language C# (C sharp) is used and Microsoft Visual Studio frame work is used on windows XP based system.

## **EXPERIMENTAL RESULTS**

After the definition of all the mechanical parameters of the plant, an initial 3D model was developed using the software Solid Works. The model is of great relevance for the physical implementation of the machine, allowing the individual design of each component, reducing the possibility of errors. The assembly of the machine is shown in Figure 4.



Figure 4: Partial Assembly of the Router

Figure 5 shows the input profile (as a cutting job) drawn with AutoCAD which has to be cut by the router. Figure 6 shows the GUI system which includes the G-code and generated path which is created through a complex generation process in the simulation system. For analyzing the performance of the CNC router, such kind of several profiles were selected as test case. Figure 7 shows the final profile obtained by the cutting tool of the CNC routing machine when the input task is like Figure 5. At present, the machining can be performed on wood, thin metallic sheet due to limitations.

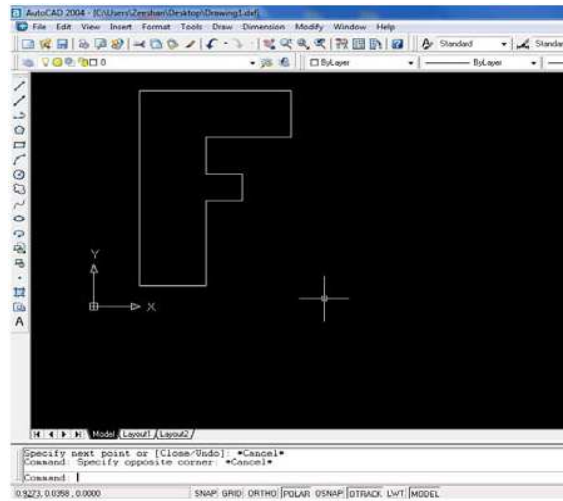


Figure 5: Input Drawing

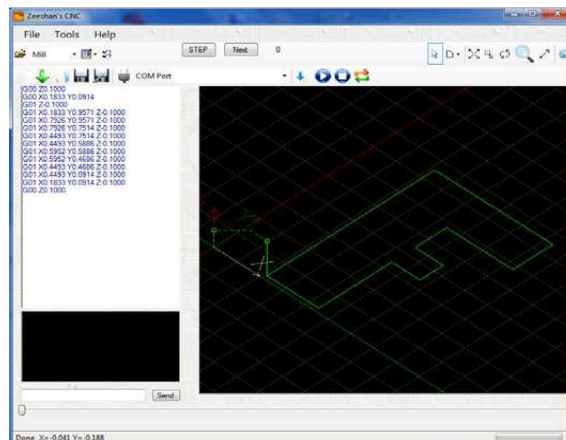


Figure 6: Output of the Desired Profile Having G Code on the Left Side of the Window



**Figure 7: Final Output on Wood**

## CONCLUSIONS

Although all the electronic parts are already built and fully functional, the proposed prototype CNC router is still under consideration for further modification. Therefore, the final output (as shown in Fig.7) is slightly distorted from the input drawing (shape 'F'). There are some time slag and sleep between the leadscrew and work table movement. But, the user interface is functioning satisfactorily. In particular, the G-Code translation functions are proved to be useful and allowed programs to be generated for the system using standard CAD/CAM software. For future works, it is intended to develop educational modules with a process efficiency analysis system to show the inner working of each piece of the machine with an advanced prediction tools based on Artificial Intelligence (AI) to infer results from measurements like vibration and end effector's position, etc.

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