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3-Axis CNC Router Modifiable to 3D Printer

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ABSTRACT: Numerical control is such a useful thing that can control a machine with numeric values and codes. That is what we call CNC^[1,5] machine, used in machining or any other automation. The commercial CNCs are bulky and so much expensive and not possible to afford by normal people in home. So the machine with computer ability and in less size mini CNCs came in. CNCs are much complex in its function. It works with the simultaneous interpretation of software and hardware. The three axis motion is controlled by Arduino Uno board with Atmega^[9] 328p microcontroller. The Arduino works here as an open source burner which burns the microcontroller with given hex codes. The CNC shield along with stepper motor drivers^[6,7] basically receives the signals from the Arduino board and delivers the power to the stepper motors. Here GRBL^[3] software is used to convert G-codes^[3] of a specific design to the Arduino compatible code. In this paper we tried to build a very affordable CNC with more up gradation. Here we fabricated a 3 axis CNC router with completely automatic functions and tried to make it conversable to 3D printer^[4].

KEYWORDS: CNC Router^[2,8], Arduino Uno, Atmega Microcontroller, Stepper Motor, Stepper motor driver board, GRBL

I. INTRODUCTION

In the ease of development in machining, numeric controlled machines came first to increase the production rate and accuracy. That numerical control is then advanced into computer programming and CNC machine stepped on to the flow of production. Now a day more or less every production lines work in CNC technology for its very high precision and production rate. Nevertheless CNC machines are very expensive and bulky in size.

In modern CNCs production of a product is fully controlled automatically by the help of CAD and CAM. The product is designed first with accurate dimensions and then programmed in CNC compatible universal language (with G code and M code). Required code is generated by manually or automatically by CAM software and forms a file which is loaded into CNC. The machines electronic system reads the dimensions and drives the motors and movement created. The complexity of the CNC is the accurate movement of the different axis simultaneously.

A numerous development has done in machining after CNC technology and day by its getting more easy operation and compact design. These CNC routers are so like 3D printer except the operation. They are so similar in axis control but the a CNC milling router cuts the material to form its shape and a 3D printer starts from null and extrudes molten material in dimensions to make the perfect shape. So a CNC can be modified to 3D printer if its Cutter is replaced with Extruder.

Mini CNCs are much smaller in size and affordable. With much smaller space CNCs can be used by normal people for domestic issues. Here it is tried to develop CNC technology to make it more portable and up gradable to 3D Printer for smaller issues with much less power.

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II. BACKGROUND WORK

The birth of CNC was given in America 1959, for the first time NC system get a universal code and processed by microprocessor. That flow of building CNC gave a huge change in industries. Mini CNC are the small version of the industrial CNCs and are being improvised day by day. Many of the people have researched on this type of router cnc and helped to make a reference. On their work It has been tried to make it more lower in cost and compact. With addition here in this paper 3D printing concept is taken to use it as a 3D printer also.

III. OBJECTIVE

This paper is based on the fabrication of a mini CNC router which is compatible to extrude as 3D printer. So our motto is to make this CNC machine very less expensive and affordable, compact in size and less power consuming and user friendly interface to operate very smoothly.

IV. HARDWARE

Mechanical setup

▪ Design:

A mini CNC could be designed various ways. One of them are fixed router with movable bed type and another type of design is with 3axia router movement what we have used here. A computer aided design was created first to analyze to design.

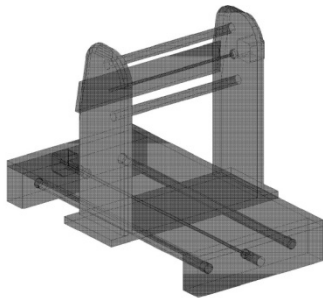


Fig.1: Basic structure for X and Y axis without router head head



Fig.2: Actual CNC structure with

The structure is made by wood and ply for the simplicity and complex machinability of the parts and less expensive too.

The structure of the machine is the prime priority here because the whole system will depend on its design and stability. In the working time of the router a huge vibration forms which can raise errors in its work and can damage the structure. To eliminate these problems the machine is designed in such a way to maximize its stability in dynamic movements. The arms are shortened as much possible and the bed is made with heavy woods. The little change in the design is done here that the router holder rack is tilted backwards with 5 degrees so that the router could be more stable when in Z movement. That inclination divides the weight of the extruder in two directions by which a horizontal support can be generated so that motor takes less power to move the extruder or cutter in Z axis.

▪ Linear Actuator:

Linear actuator changes the rotational movement to linear movement with less friction. It is possible to convert this motion in different methods, some of them are Rack pinion, Ball screw thread or by threaded rod. In general most of the CNCs use ball threaded rod for perfection and smooth motion in linear direction. For the simplicity and making it less expensive we used threaded rod and nuts for the movement.

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▪ Bearings:

Bearings are most essential thing for a machine to reduce its frictional resistance in rotational motion or in linear motion. Here we have used both types of bearings accordingly. For the junction of the wooden arm of the machine and rotating shafts, we used simple ball bearings and for liner friction reduction through the pipe supports, linear nylon bearing is used.

▪ Supports:

The accurate movement of the router in all axes is very crucial in operation. It should be smooth and perfect according to the dimension given in command. This router movement is given by threaded rod and nut but the support given here with nicked hollow pipe with 20mm diameter. This larger diameter pipes reduces the weight of the machine and supports well for the larger contact area as well.

▪ Structure:

The structure of the machine is quite simple and compact is its size. The main base is a wooden hard ply base supports with blocks at the end. Blocks are aligned with two nicked pipe which acts as the main support of the next frame above the base. X axis frame consists of two arms aligned with two similar pipes which hold the router. The movement of the Z and Y axis could be possible up to this setup. Z axis movement is set up by a platform which can traverse up or down through the nicked pipes along with the cutter or extruder.

Electrical and Electronic parts:

▪ Microcontroller:

The motion control of the machine is not possible without microcontroller. Here we have used Arduino Uno board with Atmega 328p microcontroller. Atmega 328p is a 32 bit, 24 pin microcontroller programmable with Arduino codes. The Arduino works here as an open source burner which burns the microcontroller with given .hex codes.

▪ CNC shield:

CNC shield is a stepper motor driver board which basically receives the signals from the Arduino digital pins and delivers the power to the stepper motors along with the external power. This shield receives an external power source of 24V-4A to run all three stepper motors in 3axis. The shield is attachable to the Arduino and has 4X8 pin slots for the motor driver.

▪ Motor drivers:

There are a lot of motor drivers are available to run a stepper motor. The most cheap and simple drivers are H-bridge drivers. But In case of CNC, H-bridge drivers are not compatible due to its less micro stepping capability. For that reason the software does not support these drivers. That is the reason we have used Pololu drivers with A4988 IC. This is affordable and fully compatible with software as well.

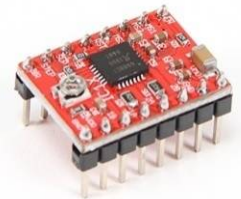


Fig.3: Stepper driver module with A4988 IC

▪ Stepper motors:

Stepper motors are DC motors that move in discrete steps. They have multiple coils that are organized in groups called "phases". By energizing each phase in sequence, the motor will rotate one step at a time. Bipolar stepper motors are more preferable for their higher torque capacity. Here NEMA 17 batch motors have been used. Those are not too expensive but very effective in their position.

Technical Details:

- 200 steps per revolution, 1.8 degrees
- Bipolar stepper
- 4-wire, 8 inch leads
- 42mm/1.65" square body
- 31mm/1.22" square mounting holes, 3mm metric screws (M3)
- 5mm diameter drive shaft, 24mm long, with a machined flat
- 12V rated voltage (you can drive it at a lower voltage, but the torque will drop) at 1-1.5 A are generally recommended, as these motors will perform near their peak torque with a current-limiting stepper controller (such as a Pololu A4988).
- 28 oz.*in, 20 N*cm, 2 Kg*cm holding torque per phase
- 35 ohms per winding

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▪ **Power source:**

The torque of the stepper motors is mainly depending upon the power is given to the shield. So for three individual stepper and their drivers we have used a power supply of 18V 2.5A rating. The supply is transformed by a 20 V 4A transformer and regulate by some ICs so that a filtered output can be adopted.

V. SOFTWARE INTERFACE

Controlling a stepper motor by a microcontroller required programming and to burn it on microcontroller. But in case of a CNC, all the 3 axis stepper motors are in simultaneous movement and the step values are changing simultaneously according to the dimensions given in G code as well. So for this we had to use interpreting software which acts as a transducer and convert G code to Arduino compatible code and sends spontaneously.

“GRBL” is the software which works all these to convert G codes to hex codes and helps to read the Arduino by universal CNC compatible codes with given dimensions.

VI. OPERATIONAL SETUP

The whole system is separated by some segments in portions of mechanical and electrical and electronics and with some software interference. So here it is figured out with the help for flow chart.

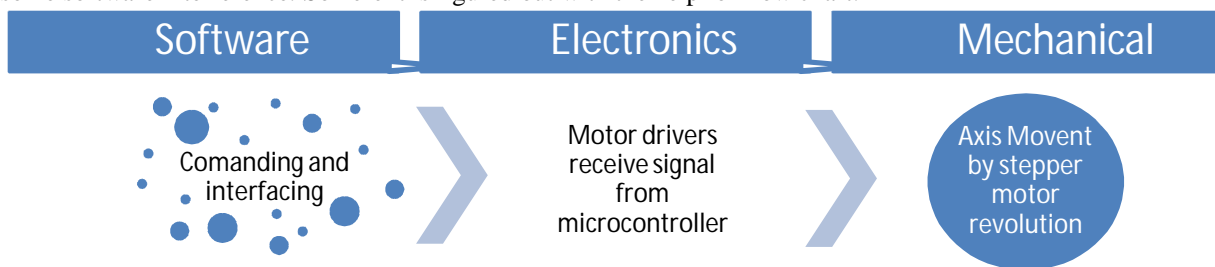


Fig.4: Operational setup

A CNC is a conjunction of Computer software and electronics and mechanical structures. It starts with programming on GRBL software and interpretation on microcontroller then stepper driver and ends in axis movement.

So first of all the GRBL software has to be identified by Arduino firmware which is done by adding the GRBL to Arduino library. After this step, controller software like ‘Universal G-code sender’, ‘GRBL controller’, etc. are eligible to be operated.

Up next, every motor driver boards have to be attached with shield and the steppers have to be connected to defined axis on the shield.

Basically the setup is ready up to this, next is the procedure to operate the machine with software.

GRBL software accepts a file written in G-codes with .NC or .NCP format. So the way to generate the file is a bit simple with CAD and computer aided manufacturing software.

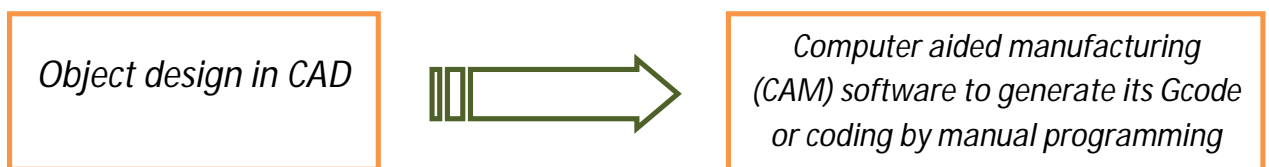


Fig.5: Block Diagram of CAD to G code conversion.

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Block Diagram of the complete operation:

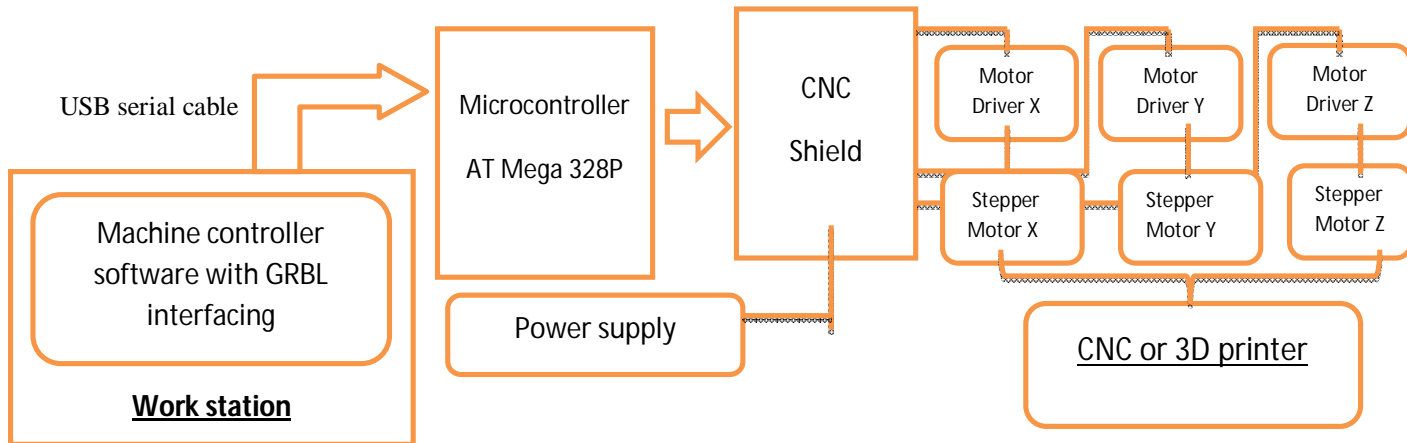


Fig.6: Block Diagram of the all over system

Programming procedure:

Programming in CNC compatible G Code follows some methods to and steps to apply. There are lots of G Code and Machine Code (M code) are introduced for different systems. The basic procedure with primary codes can be described by a flowchart, given below:

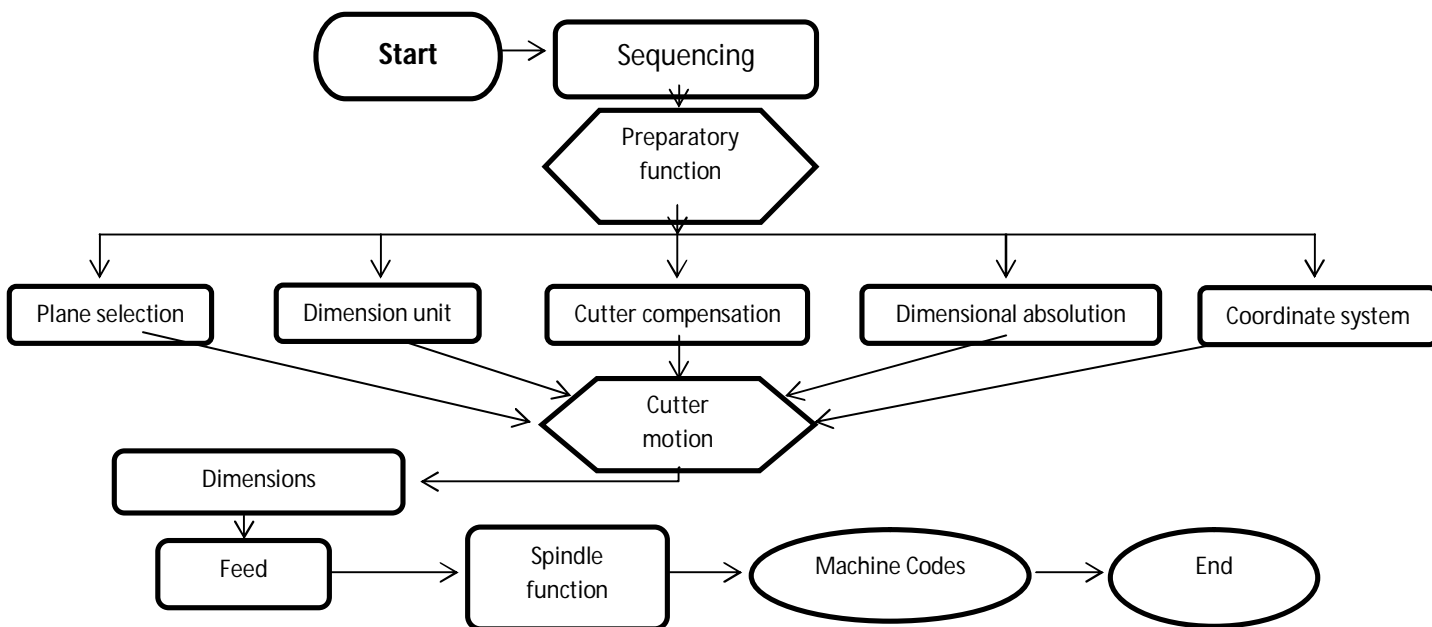


Fig.7: Flowchart on CNC compatible G code programming.

CNC Controller software:

Grbl is a free, open source, high performance software for controlling the motion of machines that move, that make things, or that make things move, and will run on a straight Arduino. Most open source 3D printers have Grbl in their hearts. It has been adapted for use in hundreds of projects including laser cutters, automatic hand writers, hole drillers, graffiti painters and oddball drawing machines.

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Grbl Controller is a piece of software which is used to send GCode to CNC Machines. The software has been optimized to send GCode to a Grbl Arduino Shield, which is the standard and default controller type. Grbl Controller is written to work on Windows, Mac, and Linux. It has been written as a superior replacement for some other popular softwares like 'GcodeSender' and 'UniversalGcodeSender'.

Grbl Controller setup:

i. Preparing:

- Power up Arduino and shield
- With motor off, manually position milling bit over origin (0,0) on the work piece. The origin is the intersection of X and Y on your CAD drawing.
- Start Grbl Controller
- Select COM port and open

ii. Adjusting:

- Choose appropriate step size (start with 1)
- Press the Z down button, the milling bit should move down towards the work piece 1 mm. The Z jog speed can be adjusted in menu Tools -> Options
- Repeat until the bit is almost touching
- Turn on motor.
- Press Grbl Controller's Reset button to zero the Arduino Grbl code.

iii. Sending G-code:

- Choose Send GCode radio button
- Open desired file, usually .nc
- Press Begin. If for some reason there is a long, slow traverse, the controller may time out. Increase timeout value in Tools -> Options.

iv. Finish:

- Turn off motor when milling is complete.

v. Emergency:

- Press the Reset, Stop or Close button on Grbl Controller - the steppers should stop within a second or two. If not, power off your shield

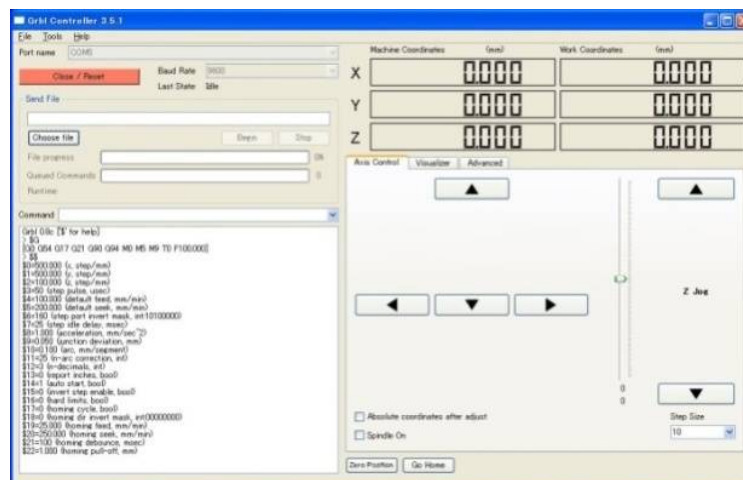


Fig.8: GRBL controller v.3.5.1

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Test and results:

A job was taken to the machine to test and cut out the defined places by milling operation. The job was quite simple which was programmed by us and then ran by the CNC. A milling cutter was mounted on the CNC and 6mm milling bit was installed to mill the job. Job material was wooden block, fitted in the CNC bed and machined.



Fig.9: Machined job



Fig.10: CNC Router

Program for the job shown in Fig. 11:

```
G17 G21 G54 G90
G00 X00 Y00 Z00 F100
G01 Z06 F200
G01 X20 Y00
G01 X00 Y 05
G01 X10 Y12.5
G01 X20 Y20
G01 X20 Y25
G01 X00 Y25
G01 X00 Y 12.5
G01 X10 Y12.5
G01 X00 Y12.5
G01 X00 Y00
G00 Z00 X25 Y00 F 200
G01 Z06 X00 Y25
G01 X00 Y00 Z00
G00 X56 Y00
G01 Z06 F200
G01 X36 Y00
G01 X00 Y12.5
G01 X56 Y12.5
G01 X36 Y12.5
G01 X36 Y25
G01 X56 Y20
G01 Z00
G01 X60 Y25
Z06
G01 X80 Y25
G01 X70 Y25
G01 X70 Y00
G01 Z00 X00 Y00
M30
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Fig.11: Project work

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VIII. CONCLUSION

With the rising demand of small parts and operations, number of small scale automated machines like CNCs and 3D printers came into the top fabricating work for the industries. The priorities are being given to fabricate those machines in affordable price and size. Here in this paper it has been designed and tried to build a CNC with compatible to 3D printer which is very simple and affordable.

IX. FUTURE WORK

It has been planned to develop the machine to very useful 3D printer with more modification on the structure, framework and speed of printing and with some other parameters. It is also taken in account to make it much limited in budget and easily workable. The required power should be minimized somehow.

XI. ACKNOWLEDGE

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