(RESEARCH ARTICLE)

CNC machine for image and PCB layout drawing

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Abstract

Increment in the number of accidents in the workshops and due to the problems caused by the production of the complex part by traditional machining such as lack of quality and the need of plenty time for the production process and with the advancement of technology, all these demands for Computer Numerical Control machines in industries is rapidly rising. Computer Numerical Control machining is a process used in the manufacturing sector that involves the use of computers to control machine tools without direct human assistance. Computer Numerical Control is a very broad term that encompasses a variety of types of machines all with different sizes, shapes, and functions. Computer Numerical Control has found its applications mainly in lathes, drills, milling machines etc. In this paper, a two-dimensional Computer Numerical Control machine designed and implemented in efficient and low-cost hardware architecture, it is able to draw images/texts. In addition, the idea behind our project is to design and draw Printed Circuit Board layouts based on a low-cost Computer Numerical Control system. The control mechanism of the designed machine is based on using Arduino UNO, Inkscape and the Geode-sender software. The outcome of the paper is to help researchers and designers in the area of Computer Numerical Control machines.

Keywords: CNC Machine; Arduino; G Code Sender; Image Drawing; PCB Layout Drawing

1. Introduction

The first numerical control (NC) milling machine was conceived by Mr. John T. around 1940s-1950s. This machine worked to attach servomotors to the x and y axes of a manual operated machine tool to control them with a computer that reads punch cards to give it positioning instructions [1].
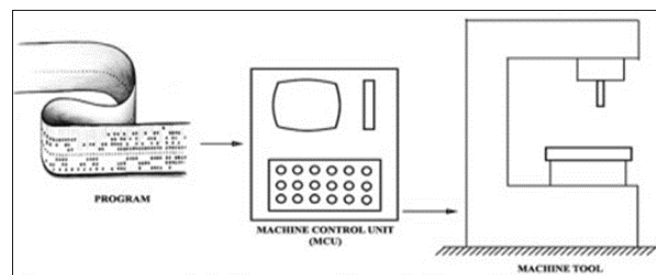

Figure 1 Basic Components of NC System

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Computer numerical control (CNC) machines play an important role in the manufacturing industry. The technique of CNC has been widely used in the field of automatic control of the functions and motions of a machine tool. In early times, Canon boring machine or Lathe invented to do operations like shaping, cutting etc. However, it was very time consuming because it does only one work at a time. CNC machines invented to scale down the workload and it includes advantages like high efficiency, flexibility and production rate. CNC machines are more precise than manual machining; it repeatedly used in the same manner many times [2]. The most common usage of CNC, and the one relevant to us, is the name given to devices that under computer control are able to cut, etch, mill, engrave, build, turn and otherwise perform manufacturing operations on various materials. By controlling a NC machine through a PC it is possible for the user to design a product on-screen, convert it to CNC readable code and then send that data to the CNC machine to produce a physical copy of the item designed [3]. A microprocessor in each machine reads the G-Code program that the user creates and performs the programmed operations. Personal computers are used to design the parts and are used to write programs by either manual typing of G-Code or using Computer Aided Design (CAD) and using Computer Aided Manufacturing (CAM) software that outputs G-Code from the users input of cutters and tool path [1].

Printed Circuit Board (PCB) is board layout used in modern electronics devices boards to connect the components together, PCB layouts can be designed by Computer, there are a lot of software programs to design a PCB layout, one of these called proteus program which use to simulate and design PCB boards. After PCB is designed, the PCB is taken as picture and the CNC machine draw it on the real electronic board as any other picture.

2. The System Overview

The system of this project is a combination of many hardware and software components. The drawing procedure require special pen that moves on three directions of motion (x- axes, y-axes, and pen up/down), which require also three types of servomechanisms. These mechanism should be automated by a single control element which will programed by a single computer device. Figure 2 shows the logical arrangement and the main ones of these components.
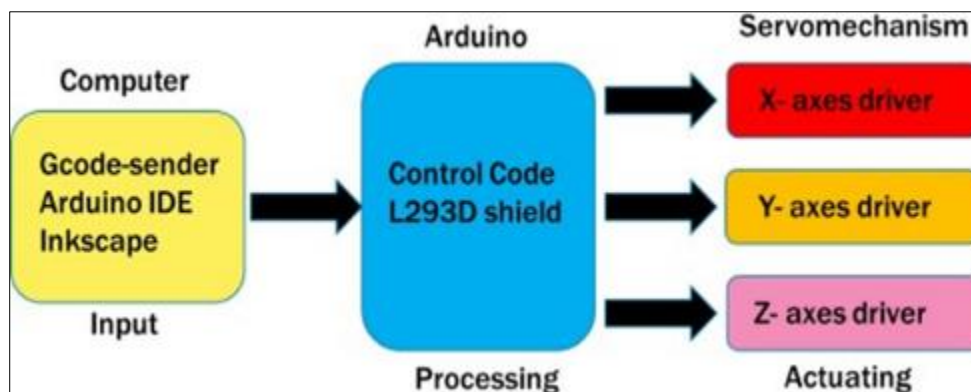

Figure 2 The main components of the system

The processing unit consists of Arduino UNO microcontroller board and its shield interface, the servomechanism part involves three distinguish mechanical units which represent the actuating unit.

3. System Design and Implementation

According to the desired machine requirements; a low cost, high accuracy and simplicity elements will be selected to design the proposed machine. Fig 3 shows the first designing body of the machine prototype. The design procedure will be concerned in the following parts.

- The system frame.
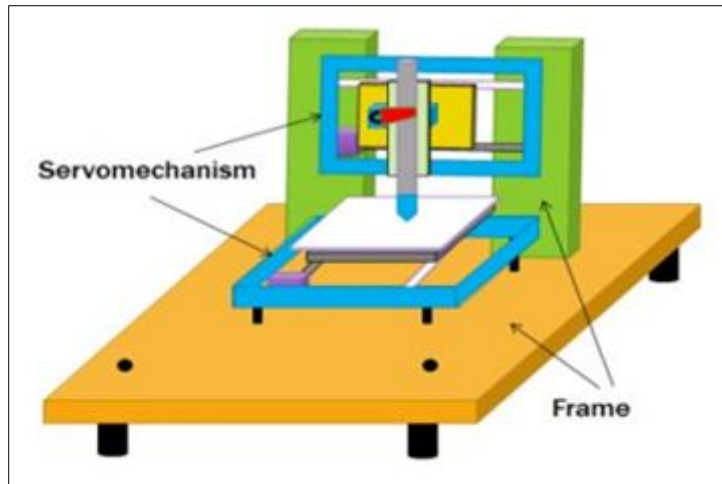- The system servomechanism.
- The system control and interfacing.

Figure 3 The machine body

3.1. The system frame

The frame of the machine is made from PVC material and consist of two parts as shown in Figure 4.
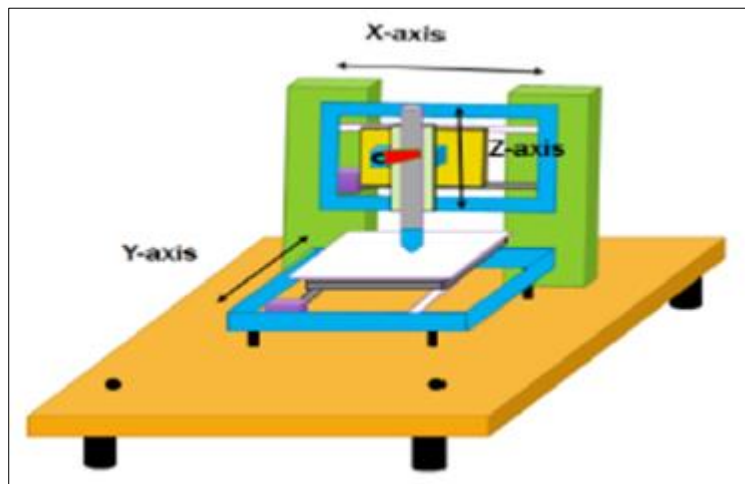
- Vertical base
- Horizontal base

Figure 4 The machine frame

The dimension of the frame parts will be chosen with respect to the suggested system servomechanism.

3.2. The system servomechanism

The servomechanism of the system is consist of three axes drivers systems as shown in Figure 5.

- X-axes (left/right pen driver movement).
- Y-axes (towards /upward plate driver movement).
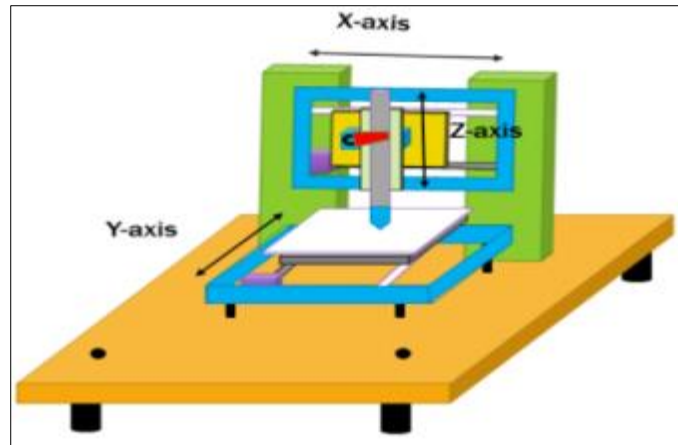- Z-axes (up /down pen driver movement).

Figure 5 The system servomechanism direction

The X-axes and Y-axes servomechanism drivers are constructed from the DVD driver module that consist of stepper motor with screwed shaft (Rotary to linear movement Shaft Converter) as shown in Figure 6.

Figure 6 DVD driver servomechanism

Z-axis servomechanism differ from XY-axes. Z-axis uses 180º Servomotor that moves the pen up and down, a spring used to hold the pen down to sketch and move smoothly as shown in Figure 7.

Figure 7 Pen up/down servomechanism

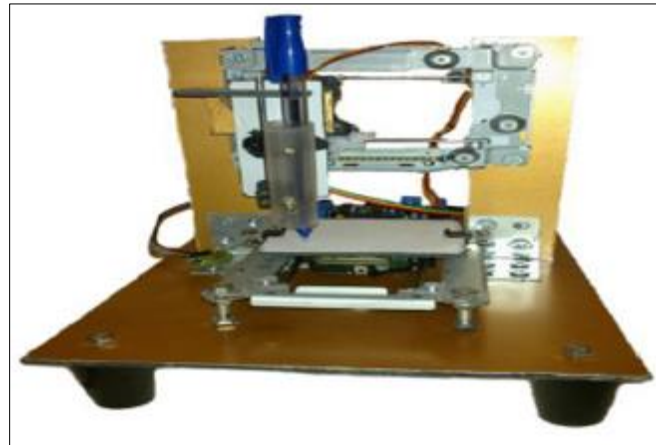The complete structure of the proposed machine (body frame and its servomechanism) is shown in the Figure 8.

Figure 8 The complete system body

3.3. System control and interfacing

The control system of the proposed machine is consist of two parts, which are:

Hardware modules

- Arduino Uno
- L293D Shield motor drivers
- Computer
- 12V Power supply

Software program

- Inkscape or any other (Gcode Creator)
- Gcode-sender
- Arduino IDE & "AF Motor" library

The Arduino microcontroller board
The Arduino Uno in Figure 9 is a microcontroller board based on the ATmega328. It has 14 digital Input /Output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16MHz ceramic resonator, USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

Figure 9 The Arduino UNO board

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 programmed as a USB-to-serial converter.

Table 1 Microcontroller ATmega 328 specifications

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6Pins
DC Current per I/O Pin	40mA
DC Current for 3.3V Pin	50 Ma
Flash Memory	32 KB (ATmega328)
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

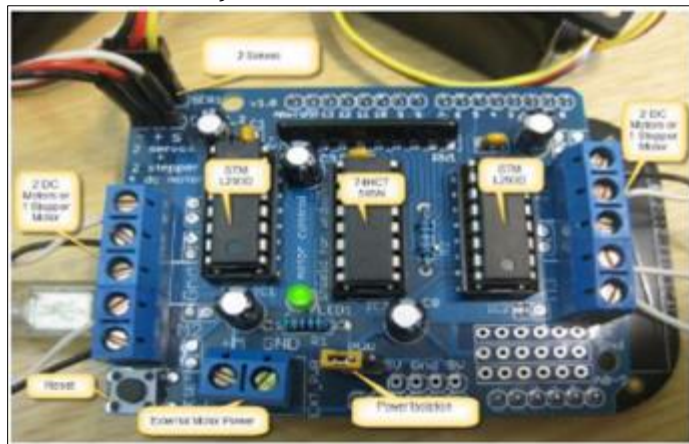Adafruit Motor Shield (motors control interface)
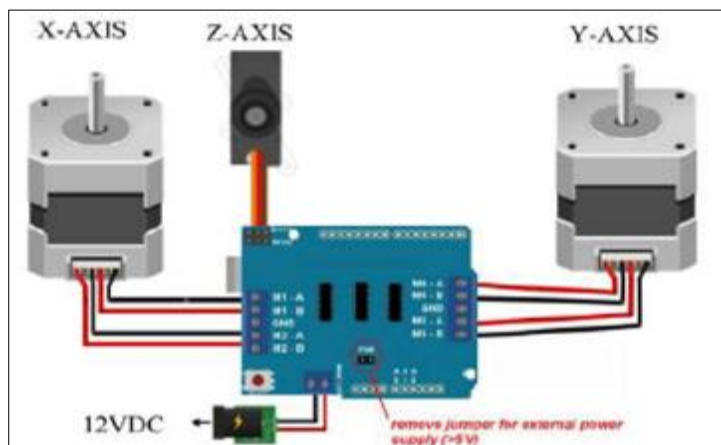

Figure 10 Adafruit Motor Shield

Figure 11 The interfacing-wiring diagram

Adafruit designed a very useful shield (in 2008), called "Adafruit Motor Shield". The shield contains two L293D motor drivers and one 74HC595 shift register. The shift register expands 4 pins of the Arduino to 8 pins to control the direction for the motor drivers. The output enable of the L293D directly connected to PWM outputs of the Arduino. Figure 10 shows this board.

The simplified wiring diagram of the motors with the interface board is showing in Figure 11. The figure shows also the terminals of the 12V power supply unit.

Inkscape Program v0.48.5
Inkscape is a powerful, open source desktop application for creating two-dimensional scalable vector graphics. Although it is primarily an illustration tool, Inkscape is used for a wide range of computer graphic task. Figure 12 shows the front picture of the Inkscape program.

Figure 12 The Inkscape program

The variety of what can be done with Inkscape is vast and sometimes surprising. It used to make diagrams, logos, web graphics, and even for paper scrapbooking. People also draw game sprites, produce banners, posters. Others use Inkscape to draft web design mockups, detail layouts for printed circuit boards, or produce outline files to send to laser cutting equipment [1]. In this Project, the Inkscape is used to produce the outline of the images as shown in Figure 13, and then convert it to a Gcode file. On other hand, the Inkscape represent the CAD/CAM (computer Aided Design/Computer Aided Manufacturing) program.

Figure 13 The image in Inkscape program

Gcode and Gcode sender
G-Code or Geometric Code is the generic name for a control language for CNC machines. It is a way to tell the machine to move to various points at a desired speed, turn on and off various coolants, and all sorts of other things. It is standard, and is a useful tool. Since Gcodes are preparatory codes [2]. Gcode files it is nothing but a text file fills of commands in plane text and it has ".Gcode" as file extension as shown in Figure 14.

```
3885
3886   (end of print job)
3887   M300 S50.00 (pen up)
3888   G4 P150 (wait 150ms)
3889   M300 S255 (turn off servo)
3890   G1 X0 Y0 F3000.00
3891   G1 Z0.00 F150.00 (go up to finished level)
3892   G1 X0.00 Y0.00 F3000.00 (go home)
3893   M18 (drives off)
```

Figure 14 The common G code instructions

The Gcode sender is a chrome application capable of sending Gcode commands to a USB Gcode interpreter; it is an open source application.

Arduino IDE Program and "AFMotor" library
In this paper, Arduino is a USB Gcode interpreter and post-processer. While Gcode sender sends Gcode commands line by line, Arduino interpret each command and analyze it, and sends an equivalent signals to the interface to moves the actuators. The following block steps illustrate the sequence of the image drawing procedure related with the previous control components.
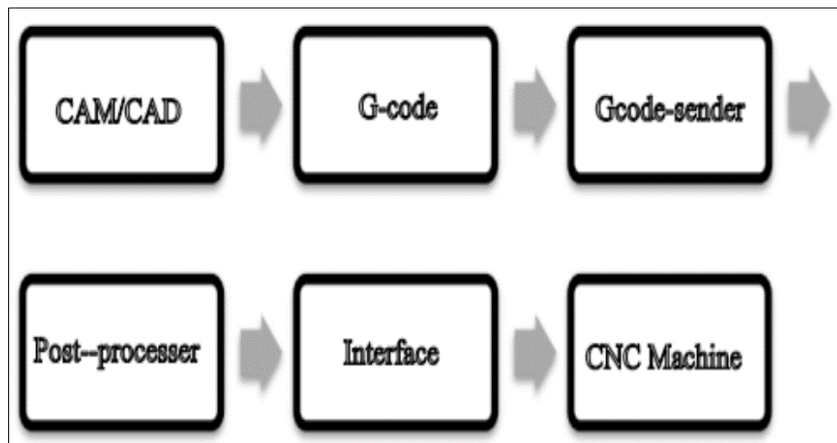

Figure 15 Image drawing procedure

4. The System Results

The following picture is in Figure 16 used to examine the designed CNC machine, after taking the sequence of drawing procedure; the resulting drawing is shown in Figure 17.

Figure 16 The tested picture

Figure 17 The resulting drawing

Also -as the same manner – the PCB layout can be drawing in the real electronic board by using the following steps:

Connect the Circuit on Proteus Program as shown in Figure 18.

Figure 18 Circuit Schematic Designed by Proteus

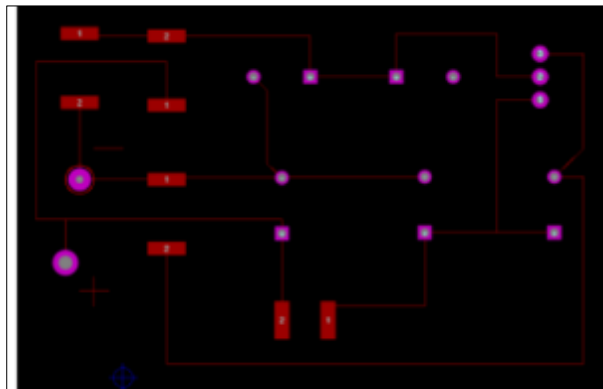Convert the circuit to PCB layout by using the same program as shown in Figure 19

Figure 19 PCB Designed by Proteus

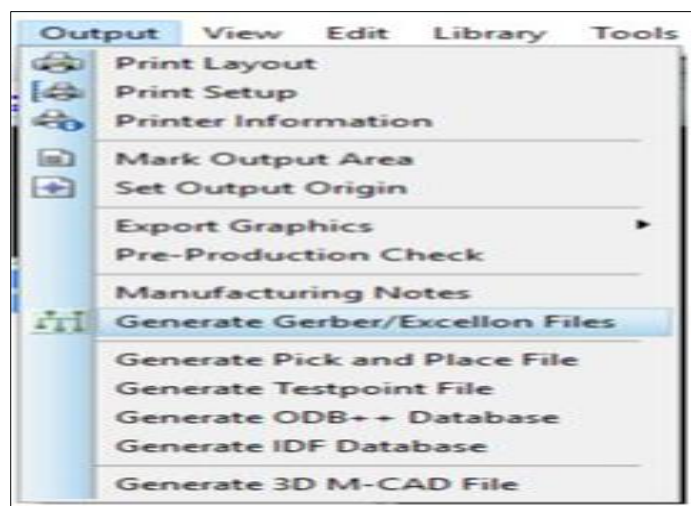Convert the PCB layout to Gerber files from Output Manu in proteus program as appeared in Figure 20

Figure 20 Generate Gerber Files

Convert grabber files to Gcode file Using Flat CAM 8.5 Program as shown in Figure 21
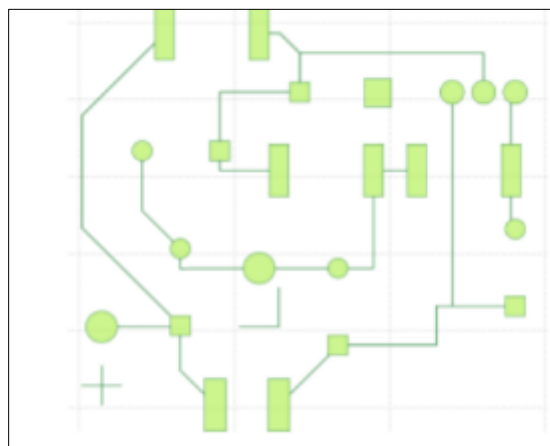

Figure 21 Convert grabber files to Gcode

Send the Gcode file to the machine and draw the PCB layout with permanent waterproof pen on the real electronic copper board as shown in Figure 22
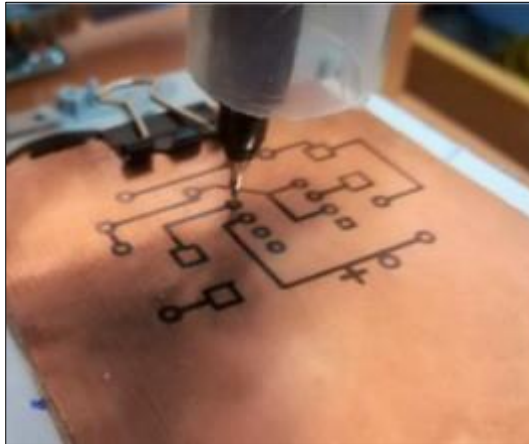

Figure 22 Sketching PCB layout

Put the board in Ferric Chloride (FeCl3) for about 10 minutes

Figure 23 Remove the Copper with FeCl3

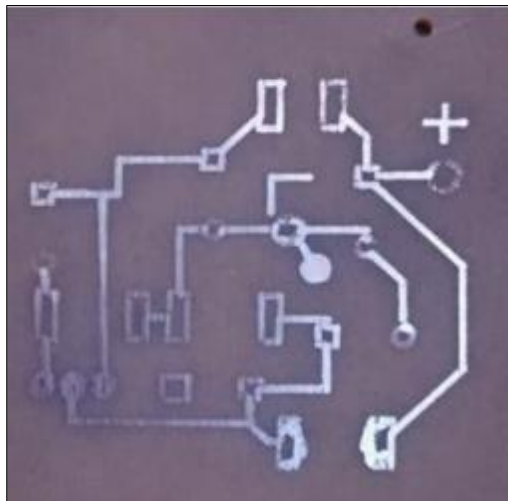Clear the path from the ink using alcohol

Figure 24 Using alcohol to remove the ink off the path

5. Conclusion

The CNC plotter successfully designed, implemented and during testing it worked well. It is ready for drawing image/text and PCB layout. The machine is designed with a very simple construction scheme and can be carried anywhere without much effort. Making a small machine brings a flexibility and efficiency with high accuracy to do work. The CNC must have a computer or some sort of Gcode sender device to send the Gcode to the machine. The Adafruit motor driver shield and its library of code save a lot of time code writing and save the Arduino from short-circuit and over- voltage. In addition, it avoids using test board and all wiring mess. Stepper motor is the best motor for CNC machines due to their high torque, accuracy, and the robustness motor for control application. This face comes out from the way of control technique that called "pulse with modulation". The PWM gives the stepper motor very accurate movement and high resolution at medium driving speed, since stepper motors could lose some micro-steps at high speed that effects the real position.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no conflict of interest.

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