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Microcontroller – Based Plotter Machine

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Abstract

The main idea behind this paper is to design and implement a cheap, smaller size, easily operable, easy interface and flexible 3-axis Computer Numerical Control (CNC) plotter machine. The lower cost is achieved by using 2 CD drives from old PC's with their stepper motors as the main structure for the hardware. The two stepper motors already found in the CD drives used to control the pen movements onto X and Y axis and one servo motor on the Z axis. An Arduino Uno microcontroller is used to controls the proper synchronization of these three motors during printing/drawing process. The Arduino Uno is programmed with G-Code parser from PC that is connected to the Arduino via a USB cable to control the motors movement and synchronization. The plotter machine is implemented and tested by printed different images and texts on papers (8cm × 8cm) using a pen, the small size of the papers because of the small plotter size. The motors winding voltages were displayed on the oscilloscope during the printing process to investigate the synchronization between the three motors. The design of the circuit is simple, inexpensive and can be accomplished using commercially available components.

Keywords: Plotter machine, CNC Plotter, Arduino microcontroller, CNC Programming

1 Introduction

CNC Machining is a process uses computers to control machine tools such as plotters, lathes, mills, machines ... etc for the manufacturing process. Nowadays, CNC machine expand its application to other tasks like in cutting, welding and assembling robots which are used in cars manufacturing factories. Due to the great developments in the personal computers (PC), it becomes easy to add new features to the modern CNC machines such as new sensors and actuators and it becomes easy to change and develop the control algorithms these facilities are not previously observed in the design phase of the older CNC machines [1]. The CNC stands for Computer Numerical Control inspiring from this CNC technology and revolutionary change in the world of digital electronics & microcontroller. Because of the high relative cost and versatility of the conventional CNC machine it remains as a staple of industry and this makes difficult for the companies to manufacture large quantities of these CNC machines especially when a high-quality goods one are required [2]. The MIT Servomechanisms laboratory invent the first numerical control programming language in the late 1950s, they used G-code in the implementation. G-code (a.k.a. RS-274) is the most widely used language in the numerical control programming to control CNC machine tools. G programming language is a language that's make the programmer control the speed and directions of the cutting tool in the CNC machine and makes the motors follow the path that is predefined in the program. The same concept included for the other machines that's used drawing, burnishing, forming and 3D printing tools.

However, many different projects were implemented for small low cost CNC machines such as in [3] where Aneeta Pinhiero et al implemented three axis Mini CNC Plotter using stepper motor, microcontroller and motor control software. The microcontroller is connected to the PC through serial communication port DB9, no information about the software is mentioned. Sundar Pandian and S. Raj Pandian presented the results of development of a low-cost three-axis vertical CNC mill suitable for adoption in undergraduate mechanical engineering laboratory setting, the total cost of their developed system is just about 1/20th of the existing commercial CNC machine used currently in the laboratory [4]. Kajal J. Madekar et al showed that the used of G-code programming to control the motors for small CNC machines gives better accuracy such as in large CNC machines and reduces the work load, their moving motor are directly seen on computer hence can start or stop the machine whenever are needed and hence making a small machine brings an flexibility to do work [2].

The main idea in this paper is to implement a small low cost CNC plotter machine which can draw images or pictures on a small paper; it uses two stepper motors as linear actuators on each axis X, Y and servo motor on axis Z. The Arduino Uno microcontroller controls the proper

synchronization of these three axes during printing / drawing.

2 CNC Plotter Design

Figure (1) shows the circuit block diagram of the designed plotter machine. There are three axes namely X, Y and Z which we have to control. X and Y axes controls the motion of worktable while Z axis controls the motion of pen upward or downward. The PC program converts the text into G-code and sending it sequentially to the microcontroller. The Arduino start to controls the three motors according to the received G-code locations with a proper synchronization of these three axes motors during printing. CNC plotter machine schematic diagram is presented in Figure (2) below.

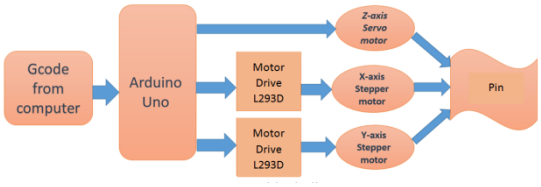

Figure 1: System block diagram.

The two stepper motors taken from an old two DVD/CD drive represent X and Y axes controls the motion of worktable and one servo motor represent Z axis for controls the motion of pen up and down. The movement control for these three motors is done through microcontroller, the Arduino microcontroller is used in this work to control motors rotation. The Arduino microcontroller is an open source microcontroller, easy to use, has a good number of input/output ports with suitable memory size and can easily interact with computer physical computing platform for creating interactive objects that stand alone or collaborate with software on the computer. It has gained considerable attraction in the professional market [5].

The microcontroller used in the hardware implementation is Arduino Uno microcontroller. The microcontroller connected with a PC through USB serial port in order to receive the G-code from the PC. The Ardunio here acts as the brain that controls the speed and directions of the stepper and servo motors. In the PC a C language program is programmed to generate the control signals in the G-code and transmit these codes to the Arduino microcontroller through G-code interpreter via USB port. These command signals directly controls the motion and speed of the three motors in order to controls the drawing tool.

The stepper motors can rotate clockwise or counterclockwise direction with discrete steps. The appropriate voltages sequence that energizing the motor coils is responsible about motor direction of rotation. The Arduino microcontroller generates these voltages sequence and drives the stepper motors with it through drive circuit. The drive circuits receive voltage signals from Arduino ports and these signals controls the speed and direction of motors rotations. The stepper motors consider the heart of CNC plotter because the size and type of motor speed and accuracy depend on it [6]. Servo motor tiny and light weight DC motor, it can rotate 90 degrees in each direction, in order to rotate the servo motor 90 degree a 1.5 ms (about 5V) pulse is applied to its control pin from a total period of 20 ms [8]. The servo motor is used to left the pen up or down on the paper, because that the current from the servo motor is too small and the Arduino port can hold this small current there is no need for a drive circuit. This motor has three legs (VCC, GND, and Control) the microcontroller sends an ON/OFF switch signal to the control pin of the servo motor in order to start or stop motor rotation. The GND (-) pin has brown color and the VCC (+) has red color [8].

The computer (PC) is connected to the Arduino-based circuit via the USB serial port. Two L293 motor drive ICs [7] connect the two stepper motors to Arduino at pins 2,3,4,5,8,9,10,11. because the current limitation of the Arduino output port pin to about 40 mA while the stepper motor draw more than 150 mA. The drawing current of the stepper motor varied around this typical value when the motor rotate at low or high step speed. The control pin (orange color) of the servo motor received the pulse signal from pin 6 (PWM) of the Arduino Uno microcontroller.

3 Software Description

At first the user use Inkscape program to convert the word that to be printed by CNC plotter into G-code format, the word is saved to G-code format via Inkscape program which can be used to create or edit vector graphics such as illustrations, diagrams and text. Figure (3) shows the Inkscape program window and how to save the file into G-code format. After save the text as G-code the Inkscape program is closed and the hardware is connected to the pc through USB, then another program called the G-code Sender program is opened to read the converted word and send it line-by-line to the Arduino microcontroller. Figure (4) shows the G-code Sender program window. The Arduino controls the speed and direction of rotation of the three motors according to the G-code. Figure (5) shows the flowchart of the program, Inkscape is an editor for vector fees is subject to the General Public License (GNU) it is a free software, it stated aim to become a powerful graphics tool while maintaining full compatibility with standards XML ,SVG and CSS. G-code is a

special programming language and it's varying from machine to machine because it depends on the machine job and capabilities. This language become easier than when it is first invented and it follows an industry adopted standard [9].

If the word (Aman) is written on the Inkscape program, the following steps show the G-code and microcontroller procedure for the letter (A):

1) The coordinates (x=0, y=0, and z=0) are set as a starting point for the pen.
2) The microcontroller moves the pen down, waiting for simple delay and lifts it up. The following three steps are to calibrate the height of the pen.
3) The servo motor associated with the pen is switched off.
4) The stepper motors moved according to the coordinates of the beginning point of writing, the pen is down, wait for simple delay.
5) Start typing the letter by proper movement of the two stepper motors.
6) After finishing from letter typing, the pen is lifted up, wait for a simple delay and return to the initial point.

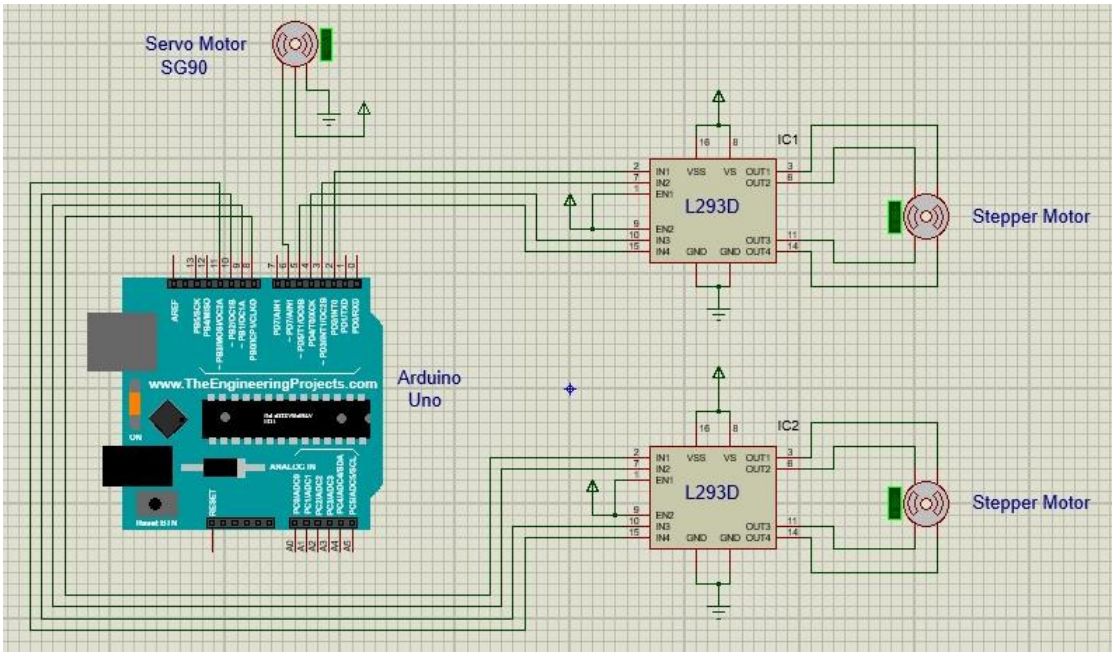

Figure 2: Circuit Schematic Diagram.

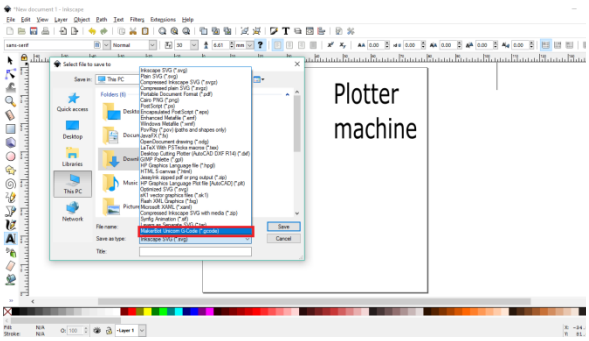

Figure 3: Inkscape window showing how to save the text as a G-code.

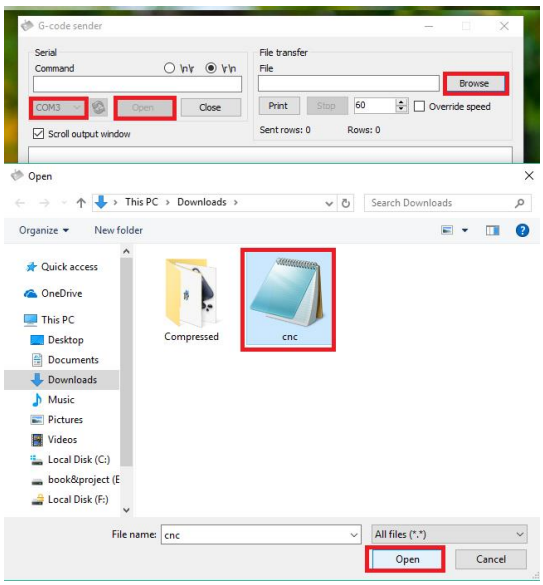

Figure 4: G-code Sender program window and the process of transferring codes into the microcontroller.

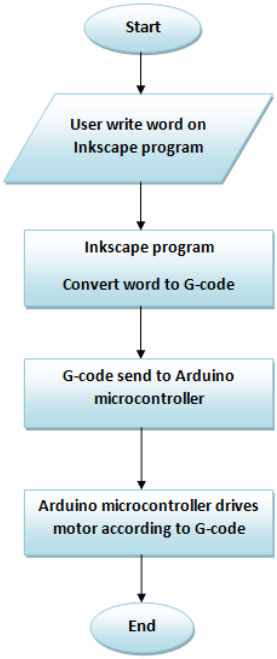

Figure 5: Program flowchart.

4 Experimental Results

The circuit shown in Figure (2) was connected and tested in the laboratory. Figure (6) shows the input voltage waveform of the servo motor taken from pin 6 of the Arduino. The voltage waveform is measured during the printing condition and it is clear from the figure the ON/OFF switching (1.5 ms ON pulse in 20 ms period) of the motor with a constant delay. The winding voltages of the stepper motor were measured also during a printing operation as shown in Figures (7) and (8). In Figure (7) the first and the second winding voltages of the stepper motor were measured from pins 3 and 6 respectively of the first L293D drive IC. While in Fig. (8) the first and the third winding voltages are measured from pins 3 and 11 respectively, the voltages sequence of the stepper motor winding are important for motor rotation.

When the stepper motors switch ON it draws high starting currents because of the motor coils which cause a drawn reactive power and this significant sudden current cause a voltage drops in the supply voltage. While when the motors switch OFF the reactive power drops and the supply voltage rises. The rises and drops in the supply voltage cause the voltage fluctuations that is noticed in the figures and these fluctuations are repetitive or random variations due to sudden changes in the real and reactive power drawn by a load.

From the previous figure it is noticed that the output voltages from microcontroller port has no significant fluctuations in comparison to those seen in motor winding voltages. Figure (9) shows the discrete components needed for the hardware implementation of the proposed plotter, while Figure (10) shows the complete experimental layout of the plotter machine. Figure (11) shows some printed examples using the implemented plotter machine. As mentioned earlier that the size of each printed paper was (8cm × 8cm), this small size paper is because of the small size implemented plotter.

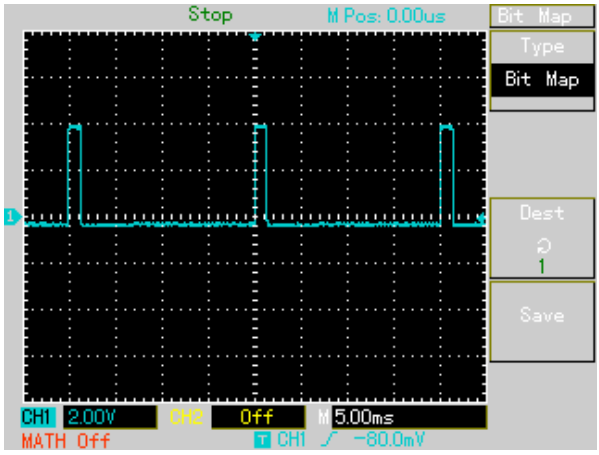

Figure 6: Input voltage of the servo motor (y: 2V/div, x: 5ms/div).

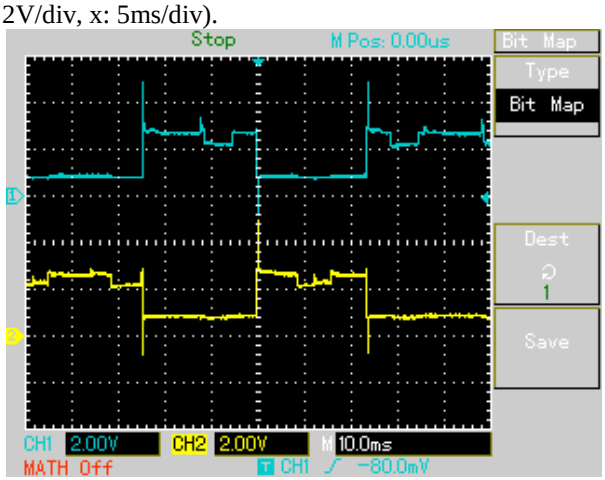

Figure 7: First and second winding voltages of the stepper (y: 2V/div, x: 10ms/div) motor.

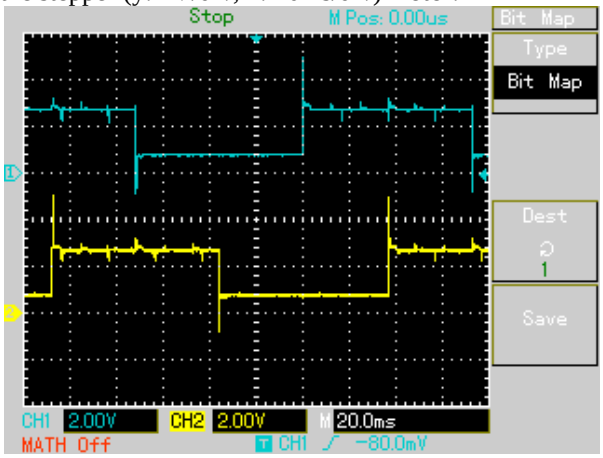

Figure 8: First and third winding voltages of the stepper motor (y: 2V/div, x: 20ms/div).

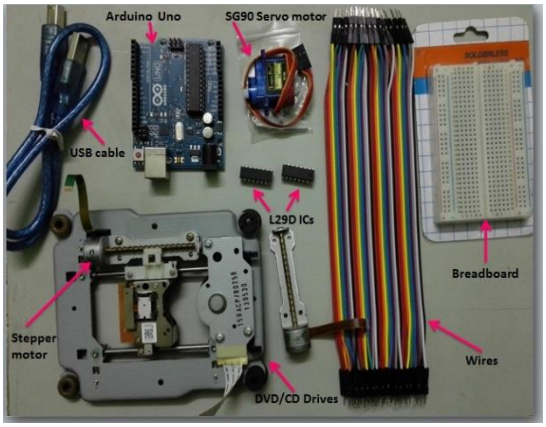

Figure 9: Parts of the plotter machine.

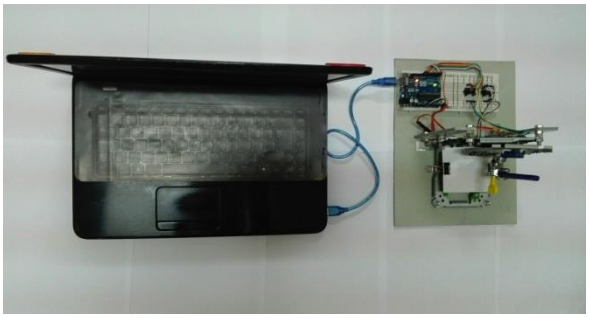

Figure 10: Experimental layout of the system.

Figure 11: Different printed examples using the implemented plotter. Experimental layout of the system.

5 Conclusions:

In this paper, we discuss the three-axis mini CNC plotter. The existing CNC plotter machines are of high cost, difficult to maintain and requires highly skilled operators. Our CNC plotter overcomes these problems. It is of low cost and easy to control and there is no need of highly skilled operators. It describes the structure of the machine suitable for domestic modeling. Investigation static rigidity, positioning accuracy and repeatability, further, the control of the machine is presented. The device needs to be very stable during printing process because any simple vibration can cause errors in printing. The motors need lubrication and run from time to time to work properly. The synchronization between the motors is very important for correct operation and any simple delay during printing process must be noticed and solved in the beginning.

6 References

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الخلاصة

التطور السريع للتكنولوجيا وزيادة استخدام نظم التصنيع باستخدام الحاسوب بشكل خاص في الصناعات التي تتضمن استخدام الحاسوب في السيطرة على آلآت CNC وبشكل عام هذه الآلات تتطلب تكلفه باهضه الثمن، من هنا جائت فكرة تنفيذ وتصميم آله راسمه منخفضة التكلفه والتعقيد، تمتاز بصغر حجمها ومرونتها ودقتها بالعملوقابليتها للتشغيل بسهولة. يناقش هذا المشروع تطوير آلة الراسمة القادرة على التحكم بثلاث محاور في وقت واحد ليتم تحقيق اقل تكلفة عن طريق استخدام (2 CD drives) الذي يحوي كل واحد منهما على محرك خطوه واحد واخذ قاعده (CD drive from old PC) ليتم تثبيت محرك السيرفوعليه. كما يتميز النظام بتحليل-G codeوبعدها يتم تفسيره عن طريق دخوله الى الاردوينو من وصلة USB. يتم استخدام اجراءات محسنة في النظام للحد من النفقات العامه الحاسوبيه في السيطره على محاور آلة التصنيع باستخدام الحاسوب، معتجنب اي خساره في اداء النظام بشكل عام، تم استخدام اثنين من محركات الخطوه للسيطره على حركات محور X وحركات محور Y، في حين تم استخدام محرك سيرفو نوع (Sg90) للسيطره على محور Z.النتائج العملية الرئيسية التي تم اخذها هي قياس الفولتيات على الملفات الاربعه لمحركي الخطوه وكذلك على ملف محرك السيرفو اثناء عملية الطباعة. تصميم الدائرة بسيطة وغير مكلفة باستخدام مكونات متاحه وغير مكلفه تجاريا.