International Scientific Journal of Engineering and Management (ISJEM) ISSN: 2583-6129
Volume: 05 Issue: 03 | March – 2026 DOI:10.55041/ISJEM05890
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

Design and Development of 2-Axis CNC Plotter Machine using Ardunio

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Abstract - The design and development of a mini CNC plotter machine using the Arduino platform presents a low-cost and compact solution for precise 2D drawing and engraving applications. CNC (Computer Numerical Control) technology is widely used in manufacturing industries for automated control of machining tools. However, conventional CNC machines are expensive and large in size, making them unsuitable for educational and small-scale applications. The objective of this project is to design and build a portable mini CNC plotter capable of accurately drawing images and text on a flat surface using simple electronic and mechanical components.

The system mainly consists of an Arduino Uno microcontroller, stepper motors, Stepper Motor Driver, guide rails, a pen holder mechanism, and a power supply unit. The stepper motors are responsible for controlling the movement of the plotter along the X and Y axes, while a servo motor controls the pen's up and down motion. The machine operates based on G-code instructions generated from design software such as Inkscape and processed using GRBL.

The Arduino microcontroller interprets the G-code commands and sends appropriate signals to the motor drivers, which in turn control the stepper motors to move the plotting mechanism with high accuracy. The developed mini CNC plotter demonstrates reliable performance in drawing complex shapes, patterns, and text with good precision. Due to its simple construction, affordability, and ease of operation, the system is highly suitable for educational purposes, prototyping, and small-scale graphic plotting tasks. This project also provides practical knowledge of CNC principles, embedded systems, and automation technology.

1. INTRODUCTION

Computer Numerical Control technology is really important in manufacturing and automation. It helps machines do repetitive tasks with very little help from people. Computer Numerical Control machines are used a lot in industries like manufacturing, electronics and product design for things like cutting, drilling, milling and engraving.

These machines work based on instructions, which are usually called G-code. The G-code controls how the machine tools move and work. However the big machines used in industries are often very expensive and hard to use which makes it tough for students, hobbyists and small projects to use them.

With open-source electronics and affordable microcontroller platforms like Arduino it is now possible to make small and cheap Computer Numerical Control machines for learning and trying out new things. The small Computer Numerical Control plotter machine is a version of a Computer Numerical Control machine.

It can draw pictures, patterns and words on surfaces using a pen or marker.It works by controlling the movement of a plotting mechanism along the X and Y axes using stepper motors. A servo motor controls the down movement of the pen.

The control system of the plotter uses the Arduino Uno, which understands G-code commands from design software like Inkscape. Special firmware like GRBL is used to interpret the commands and control the motor drivers.

The main goal of making a Computer Numerical Control plotter machine is to create a device that is cheap, small and easy to use. This device shows the working principles of Computer Numerical Control technology. This project helps students learn about automation, embedded systems, motor control and computer-aided manufacturing. It also gives them hands-on experience, in designing and building a working Computer Numerical Control system.

1.1 .Literature Review

The Arduino board can understand instructions. Move motors precisely when it uses firmware like GRBL.

1. Studies have shown that using the Arduino Uno makes it easier to control CNC machines. Researchers found that the Arduino can control stepper motors and make movements for tasks like plotting and engraving.

2. Many projects have worked on designing CNC plotters that use stepper motors and guides to move accurately. People like to use stepper motors because they can control movement without needing complicated systems. Sometimes a small servo motor is used to move the pen up and down so the plotter can lift the pen or put it down while drawing.

3. Design software is also important for CNC plotting. Software like Inkscape helps turn images and text into a format that the machine can understand, which is called G-code. This makes it easier to turn designs into instructions that the machine can follow.

4. Overall research has shown that mini CNC plotter machines that use Arduino are great for learning about CNC principles and automation. They are also cheap.

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Work well which has encouraged people to keep innovating and making new compact CNC machines, for schools and prototype testing.

2. Technical Specifications

2.1 Stepper Motor:

A stepper motor is a type of DC motor that moves in discrete steps, allowing for precise control of rotation and position. It's commonly used in applications like CNC machines, 3D printers, and robotics due to its high accuracy and good torque at low speeds. Stepper motors are relatively simple to control using pulses, making them a popular choice for various automation tasks.

Fig 1 : NEMA23 Stepper Motor

2.2 Stepper Motor Driver (TB 6600)

The TB6600 Stepper Motor Driver is a module that helps control stepper motors. It is used in things like CNC machines and robotics. The TB6600 Stepper Motor Driver works with a controller, such as an Arduino to make the stepper motor move accurately.

The TB6600 Stepper Motor Driver needs a power supply of about 9 to 42 volts. It can give the stepper motor up to 4 amps of current. This makes the TB6600 Stepper Motor Driver good for stepper motors that need a lot of power. The TB6600 Stepper Motor Driver also has a feature called micro-stepping. This helps the stepper motor run smoothly. The module has safety features to protect it from problems like much current or heat. There are switches that can be used to adjust the current and stepping settings for the stepper motor.

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Fig. 2 TB6600 Motor Driver

2.3 Servo Motor:

A servo motor is a small motor that is designed to move very precisely and hold a specific position. It is commonly used in devices like robots, CNC machines, remote-controlled cars, and automated systems. Inside a servo motor there is a DC motor, gears, a control circuit, and a position sensor, all working together to control movement. The motor receives a signal from a controller (such as Arduino) that tells it exactly how much to rotate. Because of this feedback system, servo motors can move accurately, respond quickly, and stay fixed at a required position, which makes them very useful in applications that need controlled and precise motion.

Fig. 3 : Servo Motor

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2.4 CNC Shield V3:

The CNC Shield V3 is a small control board that works with an Arduino Uno to run stepper motors in CNC and automation projects. It easily plugs onto the Arduino and helps manage the movement of motors used in machines like CNC routers, laser engravers, and small DIY devices. The shield is compatible with motor drivers such as the A4988 Stepper Motor Driver and DRV8825 Stepper Motor Driver, which drive the motors. It can control up to four motor axes: X, Y, Z, and A. The board also provides connections for limit switches and a power supply. By using firmware like GRBL, the board turns G-code instructions into signals that move the motors accurately. This makes it great for building simple CNC or robotic systems.

Fig. 4 : CNC Shild V3

2.5 Ardunio UNO:

The Arduino Uno is a microcontroller board that helps people create electronic and automation projects. It centers around the ATmega328P chip, which serves as the board's brain. Users can control various components like sensors, LEDs, motors, and displays by writing and uploading code through the Arduino IDE using a USB cable. The board features several digital and analog pins for connecting to many electronic devices. Because it is easy to program and beginner-friendly, the Arduino Uno is often used in learning electronics, robotics, and small automation projects.

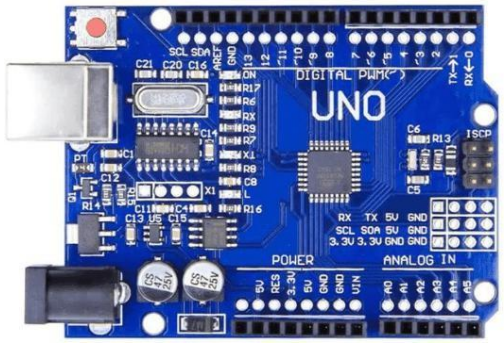

Fig. 5 : Arduino UNO

PARAMETERS	SPECIFICATIONS
Micro Controller	Atmega328p
Operating voltage	5V
Input voltage(recommended)	7-12V
Input voltage(limits)	8-20V
Digital I/O pins	14
Dc current per I/O pins	40mA
Flash memory	32kb (of which 0.5 kb is used by boot loader)
SRAM	2kb
EEPROM	1kb
Clock speed	16MHz

3. Block Diagram:

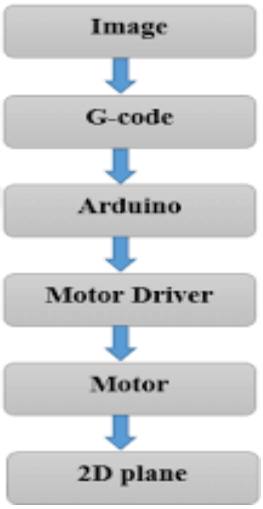

Image : To start we need to create a design for the CNC plotter using a drawing program like Inkscape. This design will be what we input into the CNC plotter system.The next step is to convert the design into G-code, which's the language that the CNC plotter understands.

G- Code: G-code has step-by-step instructions that tell the machine where to move what position to be in and what path to take to draw the image.

The CNC plotter uses G-code to draw the image.

Ardunio: The Arduino is the controller of the CNC plotter.It reads the G-code. Follows it one instruction at a time. The Arduino then sends control signals to the motors based on the instructions in the G-code.

Motor Driver: The motor driver helps the stepper motors work with the Arduino, the Arduino can't power the motors directly because it doesn't have power.

So the motor driver makes the signals from the Arduino stronger, which controls the speed and direction of the motors.

Motors: The stepper motors help move the pen or tool in steps, in the X and Y directions. This makes it possible to place the tool or pen accurately while drawing.

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2D Final Output: The final product is drawn on a surface like paper. The motors work together to move the pen and create the drawings that were defined by the G-code.

The CNC plotter uses the G-code and the motors to draw the images. The motors coordinate their movement to create the desired drawing.

4. SOFTWARE TOOLS:

4.1 Ardunio IDE:

The Arduino IDE is a program that people use to write and send code to Arduino boards. It is not hard to use. People can make their programs, which are called sketches to control things like sensors and motors and LEDs. The Arduino IDE uses a version of the C programming language. The Arduino IDE lets people send their code to boards like the Arduino using a USB cable. The Arduino IDE is great, for people who are just starting out.

The Arduino IDE is simple. It has lots of examples and libraries to help people. This makes it easier for people to build and test their electronics and automation projects using the Arduino IDE and Arduino boards.

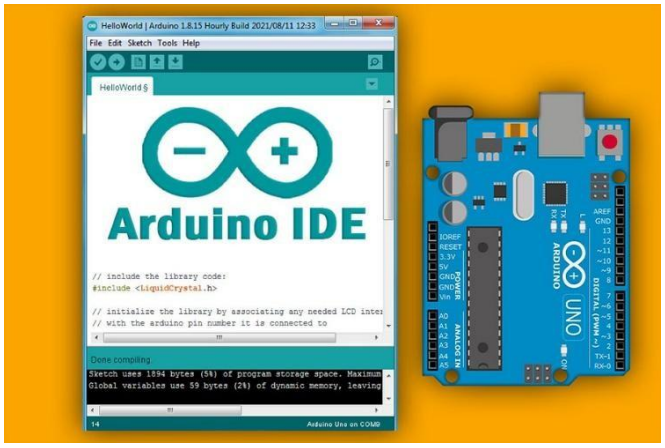

Fig. 7 : Arduino IDE Software

4.2 INKSPACE:

Inkscape is a software that helps you create and edit vector graphics.You can use it to draw designs with shapes, lines and curves.The best part is you can make these designs bigger or smaller without losing quality.People often use Inkscape to create logos, illustrations, diagrams and technical drawings.

Inkscape is great for projects like CNC plotters. You can design images. Save them in SVG format. Later you can convert these images into G-code. This way the machine can draw the designs. Inkscape is easy to use. It has many useful drawing tools. That is why both beginners and experienced users like Inkscape.

It is perfect for anyone who wants to create vector graphics. Inkscape is also source, which means it is free to use and share. The software keeps getting better with features and updates. Overall Inkscape is a choice, for creating and editing vector graphics.

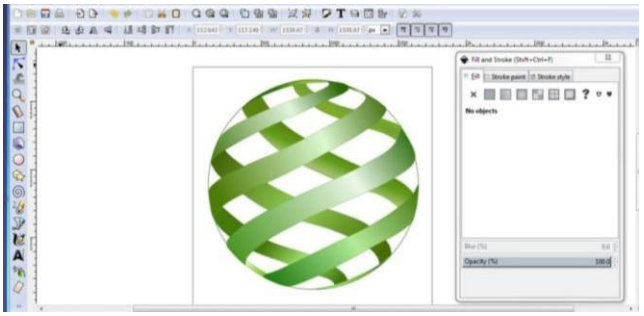

Fig. 8 : Inkspace interface

5. ADVANTAGES:-

i. Low Cost
ii. Easy to Use
iii. Good accuracy
iv. Low maintenance.

6. DISADVANTAGES:

i. Limited to X-Y Movement
ii. Cannot o 3D matching
iii. Works on limited materials.

7. APPLICATIONS:

- **Technical Drawing and Sketching:**

Used to draw accurate diagrams, graphs, and engineering drawings on paper.

- **PCB Layout Marking:**

Helps in marking PCB tracks and drilling points before actual fabrication.

- **Pen Plotting and Calligraphy:**

Used for automatic writing, signatures, and calligraphy designs.

- **Educational Purpose:**

Useful in engineering colleges and labs to demonstrate CNC and automation concepts.

8. Conclusion:

In this project we made a low-cost CNC plotter machine. You can easily control it using a computer.The machine is simple to use. It makes drawings, with very few errors. It has a design. So it is easy to transport and assemble wherever you need it. The working area of the machine is 50×50 cm. The stepper motors move according to this board size. They control the drawing process. If you make the lead screw or guide mechanism longer you can modify the machine. It can then draw designs on paper. However the machine is small. So it can only draw within a width and length. The CNC plotter machine works well for designs. It is easy to use and makes drawings.

9. Future Scope:

The CNC plotter machine developed in this project is a simple prototype built with the aim of keeping the design affordable and easy to use. Although it performs its basic functions well, there is still a lot of room for improvement in the future. The machine can be upgraded by adding one "Z-Axis " and spllinder motor for wood engraving and also by increasing its size, using more powerful motors, and strengthening the frame so that it can work with stronger materials like aluminium or cast iron. The CNC control software can also be improved to include simulation features before running the actual machine. In addition, the same hardware setup could be adapted to support 3D printing, allowing it to create basic 3D models as well as drawings.

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