

# Mini CNC Plotter

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**Abstract:** *Mini CNC Plotter is an automated 2D drawing machine designed to draw precise designs on flat surfaces using computer control. The main objective of this project is to develop a low-cost CNC plotter that can be used by students, hobbyists, and small workshops for educational and prototyping purposes. Industrial CNC machines are highly accurate but very expensive and large in size, making them unaffordable for small-scale applications. To overcome this limitation, this project presents a compact and affordable Mini CNC Plotter using open-source hardware and software.*

*The system is built using Arduino Uno as the main controller, which is programmed with GRBL firmware. GRBL is an open-source G-code interpreter specifically developed for CNC machines and 3D printers. It converts G-code commands received from computer into STEP and DIR pulses to control stepper motors. Three 28BYJ-48 Stepper motor are used to provide movement along X-axis, Y-axis, and Z-axis. UNL2003 stepper motor driver modules are used between Arduino and motors because Arduino cannot supply the high current required by stepper motors. A 12V 5A DC adapter is used as power supply and a Buck Converter is used to provide stable 5V to Arduino and driver logic.*

*For software implementation, Inkscape is used to create vector drawings. The design made in Inkscape is converted into G-code using G-code tools extension. Universal G-code Sender (UGS) software is used as the communication interface between computer and Arduino. UGS sends G-code line by line to Arduino and also provides manual jog control to move the machine and set the home position.*

*This project successfully demonstrates the integration of mechanical, electrical, and computer systems in automation. It provides hands-on learning of stepper motor control, motor driver interfacing, G-code programming, and CNC working principles. In future, this machine can be upgraded by adding a laser module for engraving or a small spindle for PCB milling.*

**Keywords:** Mini CNC Plotter, Arduino Uno, GRBL Firmware, 28BYJ-48 Stepper motor, UNL2003 Stepper motor driver, G-Code, DIR(Direction) pulses, Automation, JS-cut (JavaScript- cutting Tool) Software, Inkscape software, UGS (Universal G-code Sender) Software, Arduino Compiler IDE, PVC (Polyvinyl Chloride)Sheet.

## I. INTRODUCTION

Computer Numerical Control (CNC) technology has transformed modern manufacturing by enabling precise, automated control of machining tools through computer programs. Conventional CNC machines, though highly accurate and efficient, are costly, bulky, and require specialized infrastructure, which limits their accessibility for educational institutions, small-scale workshops, and hobbyists. To address this gap, there is a growing need for low-cost, compact, and easy-to-operate CNC systems that can demonstrate core automation principles without compromising on functional accuracy. A Mini CNC Plotter serves as an effective solution by performing 2D drawing operations with the precision and programmability of industrial CNC systems at a fraction of the cost[1-70].

The proposed Mini CNC Plotter is a 3-axis automated drawing machine developed using open-source hardware and software. The system utilizes an Arduino Uno microcontroller as the central controller, programmed with GRBL firmware to interpret G-code commands received via USB. Three UNL2003 Stepper motor driver the X, Y, and Z axes, with ULN2003 motor driver modules providing controlled current and 1/16 micro stepping for smooth motion. The Z-



axis employs a stepper motor with a lead screw mechanism for pen up/down operation, eliminating the need for servo actuators. Power management is handled by a 12V 5A SMPS and an LM2596 Buck Converter to supply stable 12V and 5V to motors and control logic respectively. A custom PCB with screw terminal connectors integrates all electronic components, reducing wiring complexity and improving reliability. The mechanical framework is fabricated using 3D printed parts, achieving a working area of 200mm x 200mm suitable for A4-sized media[71-170].

The use of free and open-source software tools such as Inkscape for vector design and Universal G-code Sender for machine control eliminates licensing barriers and promotes student engagement with CNC programming. Furthermore, the modular design with PCB-based interconnections and 3D printed parts simplifies assembly, troubleshooting, and maintenance. This project thus provides a practical platform for understanding mechatronics integration, stepper motor control, and computer-aided manufacturing concepts, making advanced automation technology accessible for learning and small-scale prototyping.

The main aim of this project is to reduce manual drawing efforts, improve operational positioning accuracy, and make computer-aided vector plotting faster, easier, and more efficient using automation and a compact, low-cost 3-axis mechanical assembly driven by open-source control software. By translating digital design paths into synchronized movements along the Cartesian axes, the system establishes an affordable, user-friendly prototyping and educational platform that demonstrates automation principles with minimal human intervention.

## II. EXISTING SYSTEM

In the existing manual drawing system, engineers, students, and artists draw technical diagrams, PCB layouts, and designs by hand using scale, compass, and pen. This method requires continuous human effort and consumes significant time, especially for complex drawings and repetitive patterns.

The current system also faces problems such as human error, inconsistent line thickness, and difficulty in achieving high accuracy. Small mistakes in measurement can spoil the entire drawing. Since drawing depends completely on manual skill, the quality and speed vary from person to person. For PCB design and engineering drawing, even 0.5mm error can make the design unusable.

Another limitation is that manual drawing cannot be repeated exactly. If the same design needs to be drawn multiple times, the output will be different each time. The existing system does not provide computer control, automation, or digital file to physical drawing conversion.

## III. PROPOSED SYSTEM

The proposed Mini CNC Plotter is developed to provide automated, accurate, and low-cost drawing solution for 2D designs. The system uses Arduino Uno, three stepper motors, ULN2003 motor drivers, and GRBL firmware for computer-controlled movement in X, Y, and Z axes.

When a user creates a design in computer using Inkscape, the design is converted to G-code using G-code tools extension. The G-code file is sent to Arduino through USB. The Arduino reads G-code commands and generates STEP and DIR signals. These signals are sent to ULN2003 motor drivers which drive X, Y, and Z stepper motors. X and Y motors move the pen left-right and front-back, while Z motor moves the pen up-down for drawing.

If the G-code command is valid, the pen moves to correct position and draws the line on paper. If the command is invalid or machine reaches limit, the movement stops automatically, preventing damage to machine or paper. The system also supports repeatable drawing. The same G-code file can be used to draw identical copies multiple times without error.

The proposed system achieves drawing accuracy of  $\pm 0.3\text{mm}$  to  $\pm 0.5\text{mm}$  using 1/16 micro stepping and rigid 3D printed frame. Due to automated control, drawing speed is 300-400 mm/min which is much faster than manual drawing. The machine can draw vector designs, text, logos, and PCB layouts directly from digital files, eliminating human error and saving time.



**BLOCK DIAGRAM**

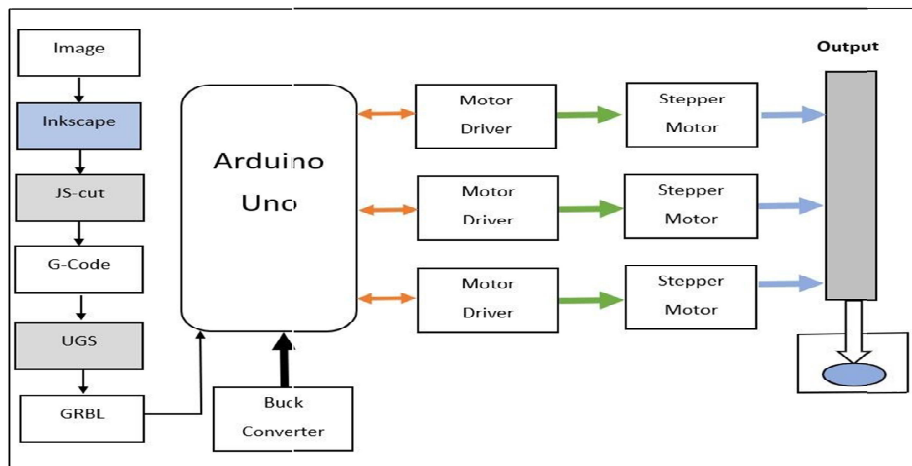


Fig.1 Block diagram of Mini CNC Plotter

**FLOWCHART**

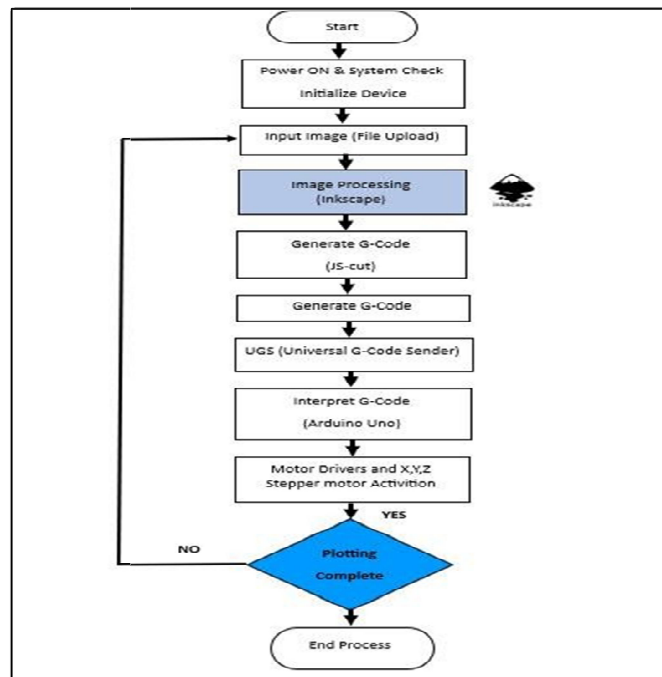


Fig.2: Flowchart of Mini CNC Plotter

**IV. WORKING**

The Mini CNC plotter converts a digital vector design into a physical drawing using computer-controlled motion. The working process starts when the user creates a 2d design, text, or PCB layout in inkscape software and saves it in .svg format. This svg file is then converted into G-code using the G-code tools extension in inkscape. G-code contains movement instructions with x, y, and z coordinates that define the tool path for drawing.



The generated g-code file is sent to the arduino uno microcontroller through a usb cable using universal g-code sender software. The arduino runs grbl firmware, which reads each G-code command and converts it into step and dir electrical pulses. These pulses are sent to three UNL2003 stepper motor drivers. Each driver controls one 28BYJ-48 stepper motor responsible for movement along the x-axis, y-axis, and z-axis.

The x-axis and y-axis motors move the pen holder left-right and front-back on the xy plane using a belt and pulley system. The z-axis motor moves the pen holder up and down. When the z-axis moves down, the pen touches the paper to draw a line. When the z-axis moves up, the pen lifts to move across the paper without drawing. The GRBL firmware ensures precise coordination between all three axes to follow the exact path defined in the G-code.

If a G-code command is valid and within the machine limits, the pen moves to the exact position and draws the design on paper with an accuracy of  $\pm 0.3\text{mm}$  to  $\pm 0.5\text{mm}$ . If the command is invalid or the machine reaches an end limit, the movement stops automatically to prevent damage. The same G-code file can be used repeatedly to produce identical copies of the design. This process eliminates human error and draws faster than manual methods.

## V. TECHNOLOGIES USED

### Hardware Components

1. Arduino Uno
2. Stepper motor
3. Motor driver
4. PCB
5. Connector
6. Wires
7. 3d printed parts
8. Buck converter step down

### Software Components

1. Arduino Compiler IDE
2. JS-cut (JavaScript- cutting Tool) Software
3. Inkscape software
4. UGS (Universal G-code Sender) Software

### FEATURES

- **3-Axis Control:** X, Y for movement (Left, Right, Front and Back), Z for automatic pen up/down
- **GRBL Firmware:** Industry-standard CNC control on Arduino Uno
- **Inkscape Integration:** Direct SVG to G-code conversion using G-code tools
- **UNL2003 Stepper motor drivers:** Smooth and accurate stepper motor control
- **Limit Switch Support:** Prevents machine damage at end positions
- **Multi-Material:** Can draw on paper, card sheet, PVC sheet, PCB

### ADVANTAGES

- **High Accuracy:** Draws with  $\pm 0.3\text{mm}$  to  $\pm 0.5\text{mm}$  precision, eliminates human error
- **Repeatability:** Same design can be drawn unlimited times with identical output
- **Low Cost:** Total cost using 3D printed parts and open-source software
- **Time Saving:** 5x faster than manual drawing, speed of 300-400 mm/min
- **Automation:** Computer-controlled via G-code, no manual skill required
- **Compact Size:** Small footprint, easy to place on desk
- **Time Complexity:** 5\*5 cm image(2 to 4 minutes) and 10\*10 cm image(12 to 14 minutes)



### **VI. FUTURE SCOPE**

The system framework can be expanded by replacing the pen tool with a high-intensity diode laser module to enable precise engraving capabilities on wood and acrylic mediums. Upgrading the mechanical drive structure with ball screws and a wider base frame will significantly increase the functional working area while improving structural precision and structural load capacity. Additionally, integrating a wireless wi-fi or bluetooth module will eliminate physical usb tethering, allowing seamless g-code transmission directly from a mobile device or pc. The system can be further automated by implementing a camera-based machine vision alignment system for complex computer-aided manufacturing tasks like PCB drilling and surface-mount device placement. Finally, developing an onboard touch screen control interface will enable users to manage file paths and run drawing operations directly from local storage, eliminating the need for a permanent computer connection.

### **VII. CONCLUSION**

The Mini CNC Plotter successfully achieves automated 2D drawing at low cost. It proves that open-source hardware like Arduino and GRBL can replace expensive industrial plotters for educational and prototyping use. The project improves accuracy, saves time, and gives hands-on experience with CNC technology. With future upgrades like laser module and wireless control, this system can be expanded for PCB manufacturing and small-scale production. Overall, the project meets all design objectives and provides a strong base for advanced CNC applications.

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