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ABSTRACT

To demonstrate in this project how to use an Arduino Uno to create a mini CNC PCB plotter. This project walk you through building a CNC plotter so it will be inexpensively design and print PCBs at home. It uses stepper motors and rails from DVDs and CD ROMs to create a small CNC PCB plotter for the X, Y, and Z axes. The maximum printing area for our example project will be 4*4 cm. The project works on serial communication.

The need for computer numeric control (CNC) plotter machines is quite strong these days due to technological advancements. Low-cost printed circuit boards (PCBs) are in high demand as purchasing PCBs from businesses or the internet may be expensive.

With the use of a small CNC PCB plotter, anybody may now affordably print their own PCBs at home. They can effectively and cheaply print and design their own PCBs, and they can innovate without worrying about incurring large costs. Numerous industries, including education, hobbies, new technologies, and engineering students, will use this initiative. This article shows off a reasonably priced little CNC PCB plotter model. Additionally, you may use this gadget to sketch paintings, tattoos, wood carvings, and laser printing as needed. As said, this system will be completely functional and include some multitasking functions.

With the help of accessible components and sets of algorithms, this project will be able to sketch and sculpt a circuit on a PCB. Initially, the user must use any program, such as "inks space," to convert the picture file into G code before feeding it to the computer via processing software. In this project, the controlling device is an Arduino Uno. In a CNC plotter, it converts G-code into machine instructions that are supplied to the motor driver.

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CHAPTER 1 : INTRODUCTION

1.1 INTRODUCTION

A CNC plotter machine focus on making a 2d image or engraving a image as per needs on a plane surface. The Arduino based mini CNC PCB plotter is a computer controlled system. It uses a Microcontroller and CNC shield with motor drivers to control moments of the X,Y&Z axis. Stepper motor with rails extracted from Cd drivers a CNC shield, motor drivers, Arduino Uno a 12v DC motor are components used for the project. The project works on serial communication. The image is turned into a G code through "ink space" software this G-code is convert to machine code that controls the movements of the X,Y& Z axis. 12v Dc motor, pen, laser or any other engraving mechanical tool can be used in mechanism. It will have a 4*4cm printing area. The purpose is to make it a PCB printer but can also used for multiple purpose like wood carving, sketching, laser printing. This CNC plotter can print difficult designs that take times to do it manual it saves time, cost and manual work. This project is a low cost project, has great reliability & efficiency. It can design our own PCB at low cost and innovate new things for future, students can innovate new things by designing and printing their own PCB's. This project will be used in many sectors like educational use, hobbyist, industries, new innovations, engineering students. This paper demonstrate the building of mini CNC PCB plotter for X,Y,Z axis using stepper motors and rails from DVD's, CD ROM's. For this demo project printing area will be maximum 4*4 cm This project works on serial communication. Due to advancement in technology now a days, demand for computer numeric control (CNC) plotter machine is very high. Printing (PCB) printed circuit board from companies or online is costly so low cost PCB's are on high demand. Now anybody can print their own PCB at home in low cost by use of mini CNC PCB plotter. They can print and design their own PCB's at low cost and efficiently and innovate new thing without any fear of high costing .

This mini CNC PCB plotter, designed with affordability and functionality in mind, caters not only to cost-sensitive environments but also to those seeking hands-on educational tools. The integration of commonly available components like stepper motors from DVD or CD ROM drives and the utilization of a straightforward Arduino Uno and CNC shield setup underscores the project's approachability and ease of assembly. The software side is equally user-friendly; converting designs into G-code via the open-source "Inkscape" software, which then interprets these designs for precise machine operation, allows even beginners to start producing their own PCBs or other small-scale engravings with minimal learning curve. The versatility of the device extends beyond PCB fabrication. Its capability to adapt various tools, such as pens for sketching or lasers for engraving, makes it a multi-purpose machine suitable for a wide array of applications—from educational projects in schools to crafty undertakings in home workshops. The small footprint of the machine does not limit its potential; rather, it provides a compact solution that fits well in limited spaces while still offering substantial functionality. This CNC plotter also opens up avenues for experimentation and innovation, particularly in academic settings where engineering students can explore the realms of mechanical and electronic design. By enabling the rapid prototyping of PCBs and other materials, it encourages iterative design processes, critical thinking, and creativity, all of which are essential skills in the modern engineering landscape. Moreover, the DIY aspect of building the plotter from scratch using recycled components is in line with sustainable practices, adding an element of environmental consciousness to the project. It demonstrates that high-tech innovation doesn't necessarily require expensive resources and can be achieved with a blend of simple yet effective technology and a creative reuse of materials. This aspect is particularly appealing to hobbyists and educators who advocate for sustainable engineering solutions. In summary, the development of this mini CNC PCB plotter not only addresses the demand for low-cost PCB production but also fosters a broader engagement with technology, from individual tinkerers to institutional educators, thereby contributing to a culture of innovation and self-reliance in various sectors.

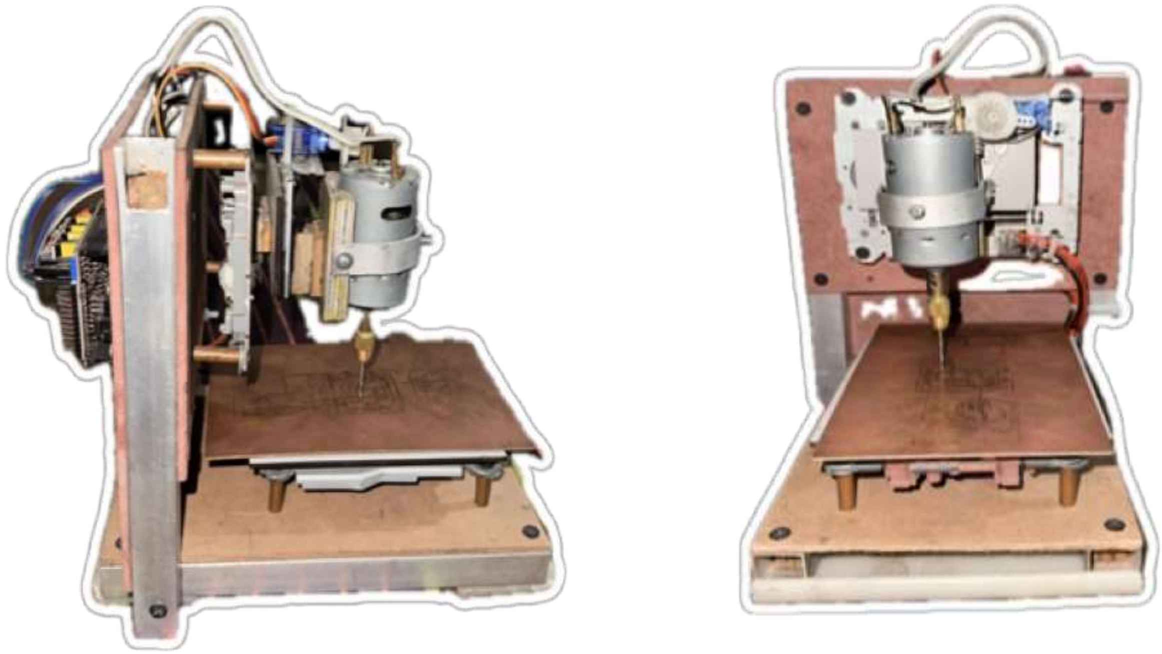


Figure 1.1: Mini CNC PCB plotter

1.2 MOTIVATION

- Making Mini CNC PCB plotter facilitates your creative process.
- Customizing the size, design, and layout of a PCB to meet our unique requirements and preferences is possible.
- Plotters sold in stores cost a lot of money. It can be save a lot of money by making plotter, which can accomplish even better outcomes than the costly ones.
- Abilities in a variety of industries, including software, mechanical, and electronics, can be enhanced by using this little CNC plotter.
- The project will encounter several issues at every stage of this project, which will help you become more adapt at addressing problems.
- To begin with a modest production line that is interested in becoming an entrepreneur. Can present a fantastic opportunity for foundation and innovation.

1.3 PROBLEM STATEMENT

Create a low-cost, portable, and small CNC PCB (Printed Circuit Board) plotter that can be used to precisely engrave circuit designs on copper-clad boards or any other surface, such as paper, wood, or other materials. Plotters should be simple to use and intuitive so that they can efficiently layout PCBs at a low cost, free of labor, service, or shipping fees that come with expensive offline or online purchases. The goal is to simply and affordably plan and print our own PCBs at home in accordance with user requirements. Allowing small-scale producers, amateurs, and electronics enthusiasts to quickly prototype their products."

1.4 OBJECTIVE

- To use a microcontroller and printing mechanism to make 2D and 3D images on a plane surface.
- To simply and inexpensively design and print our own printed circuit boards (PCBs) at home as opposed to purchasing heavy priced PCBs from businesses or online.
- This project will cut down on production time without including any additional costs, such

as those associated with internet shopping or designing. Because of its mobility, assembling PCBs to specifications is possible at any time and from any location.

- The primary goal is to produce an affordable, user-friendly, automated PCB plotter that may save time and money while offering the customer flexibility and dependability.

CHAPTER 2 : LITERATURE SURVEY

2.1 INTRODUCTION

An image can be created in two dimensions or engraved on a flat surface using a CNC plotter machine. The tiny CNC PCB plotter with an Arduino foundation is a computer-controlled device. To control moments of the X, Y, and Z axes, it makes use of a microcontroller, a CNC shield, and motor drivers. For this project, use of stepper motor with rails taken from CD drivers, an Arduino Uno, motor drivers, a CNC shield, and a 12 volt DC motor. The initiative focuses on communication in serial form. Using "ink space" software, the picture is converted to a G code, this G-code controls movements of X,Y&Z axises. The system may be used with any other mechanical engraving instrument, such as a pen, laser, or 12v Dc motor. Its printing area will be 4 by 4 cm. Our goal is to create a PCB printer, but it may also be used for other things, such as laser printing, wood carving, and drawing.

2.2 LITERATURE SURVEY

This research study provided insight into the X-Y-Z coordinate system used by a CNC plotter. Y. M. Hasan, L. F. Shakir, and H. H. Naji [11] (2018) Production and Application of an Arduino and CNC Shield-Based Three-Axis Plotter. This research paper's goal is to build a plotter and create open-source software to run the apparatus. This study provided information on how to build an open-source hardware and software Arduino plotter machine using XYZ coordinates at a reasonable price.

Antariksh V 2020 [4], Rahul Somalwar, Namesh A. Kale, Ashish J. Nandeshwar[] and A brief report on CNC PCB milling equipment. The study paper's objectives are to lower the price of CNC machines and satisfy the expanding demands of major companies in small applications. This study provided guidance on the design, evaluation, and implementation of a low-cost CNC-based PCB milling machine suitable for small businesses.

Nazim TN, Aneeta Pinhiero, Beljo Jose, and Tinsemon Chacko In 2016 [6] Wireless Plotter for CNC The development of a compact three-axis CNC plotter machine is the aim of this research work.This study clarified the idea behind a cordless CNC plotter that may be utilized for drilling and PCB designing.

M. Bhavani, V. Jerome, P. Lenin Raja, B. Vengesh, and D. Vengesh (2019) [12] CNC Router Design and Implementation. This article's goal is to design and construct a router machine for wood engraving that is based on a CNC plotter machine. An idea for the construction and design of a small CNC plotter machine suitable for engraving was provided by this research.

A knowledge-centric process management framework with process and knowledge integration is presented by Linyan Liu et al. (2017) [7] for CNC machine tool design and development (D&D). The primary basis for generating requirements for the framework is the machine tool design practice. Modules for knowledge objects management, process execution, process simulation, and process integration model make up the suggested framework. Each of these modules has been developed to enhance the management of the knowledge-centric machine tool development process. The author also presents the evolution of the prototype. The study's findings speed up development cycle time and cost, improve machine tool development capabilities, and guarantee top-notch machine tool development by facilitating knowledge integration in CNC machine tool D&D. Ultimately, the study has presented a framework that encourages designers to work effectively and conveniently on machine tool development for the mutual benefit of the organization and each person.

CHAPTER 3 : HARDWARE REQUIRMENTS

3.1 INTRODUCTION

The intended use, specifications, and kind of software to be built are all described in a software requirements specification document. It also covers the software's cost and yield. A project's, software's, or application's requirements are outlined in a software requirements specification (SRS). SRS, to put it simply, is a project handbook that is produced before the project or application is started. A software document is often created for an application, software, or project.

3.1.1 Assumptions and Dependencies

1. Material Assumptions:

   PCB Material, Tool Compatibility.

2. Mechanical Assumptions:

   Frame Rigidity, Accuracy of Components.

3. Electrical Assumptions:

   Power Requirement, Motor Calibration, Controller Compatibility.

4. Software Assumptions:

   Arduino Software, Driver Software, G-code Compatibility.

5. Operational Assumptions:

   Environmental Factor, Operator Skill Level

6. Cost and Budget:

   Cost Estimates

7. Maintenance and Upkeep:

   Regular Maintenance

3.2 FUNCTIONAL REQUIREMENTS

1. Power Efficiency
2. Safety Features
3. PCB Size Compatibility
4. Automatic Tool Change
5. Software Compatibility
6. G-code Interpretation:
7. Motion Control
8. Speed and Feed Control
9. Emergency Stop Functionality
10. User Interface
11. Dust Collection System
12. Compatibility with Various Operating Systems
13. Precision and Accuracy
14. Motion Control
15. Speed and Feed Control
16. Emergency Stop Functionality

3.2.1 Hardware Interfaces

1. The hardware have following specification :
2. Microcontroller/Processor
3. Stepper Motor Drivers
4. Power Supply Connections
5. Limit Switch Inputs
6. Encoder Interfaces
7. Emergency Stop Input

8. User Interface Connections
9. Communication Interfaces
10. USB/Serial Ports
11. Stepper Motor Connectors
12. Power Distribution
13. Power Distribution Board/Connectors
14. Data Storage Connectors
15. Connectors for External Devices
16. Motor Cable Connectors
17. Motor Cable Interfaces

3.3 NONFUNCTIONAL REQUIREMENTS

3.3.1 Performance Requirements

The CNC plotter's minimum step size and precision needed to guarantee exact motions. For the creation of complex PCB designs, this is essential. Accurate repetition of the same actions should be possible with the CNC plotter. This is crucial for processes involving several passes. Provide a simple user interface that makes it easy to set up and operate the CNC plotter. Provide users with feedback tools, including status indications, to keep them updated on the plotter's functionality. To guarantee the CNC plotter works dependably for a long time, aim for a high accuracy. Indicate how long vital parts like bearings and motors should last. Quick response to input commands from the control system is necessary to guarantee real-time control over the CNC plotter. Make sure it works with popular CAD/CAM software to expedite the production and design processes. Give precise instructions on the voltage and current needed for the CNC plotter to function properly. Give the CNC plotter a maximum speed limit that it can travel between points. Increased traversal speeds can boost productivity in general. As certain the ideal cutting speed for the various PCB materials. To get precise and clean cuts, this is essential.

3.3.2 Security Requirements

Control access to the CNC plotter's control system by implementing user authentication. Users should be given varying levels of access according to their positions and responsibilities. To secure sensitive data during transmission, encrypt communication between the CNC plotter and any linked devices or systems. Protect the firmware of the CNC plotter to avoid tampering or unauthorized alterations. To confirm the firmware's integrity and make sure that only approved upgrades are implemented, use digital signatures. Put in place physical security measures, particularly in shared or public areas, to prevent illegal access to the CNC plotter. To limit physical access, think about using access control systems or lockable enclosures. Audit logs on a regular basis to look for and look into any questionable activity. Make sure that the CAD/CAM software and the CNC plotter are able to communicate securely and without being intercepted or manipulated. Create a safe and impenetrable emergency stop system to bring the CNC plotter to a stop in an emergency. Incorporate safety measures to stop the CNC plotter from working in hazardous situations.

3.3.3 Software Quality Attributes

Design files should be precisely interpreted by the CNC control software, which will then translate them into exact tool motions on the PCB. To prevent system failures and elegantly manage unforeseen circumstances, provide strong error handling methods. Optimize the program to execute toolpaths as efficiently as possible to reduce processing time. Make sure the program can react instantly to user inputs and system events to offer a seamless user experience.

3.4 HARDWARE REQUIREMENT

3.4.1 Arduino

[11] This is an open-source hardware and software form, project, and user group that creates and produces microcontroller kits and single-board microcontrollers for use in the construction of digital devices. An assortment of microprocessors and controllers are used in Arduino board designs. Sets of digital and analog input/output (I/O) pins on the boards allow them to be interfaced with other expansion boards (also known as "shields"), breadboards (used for prototyping), and other circuits. Some types of the boards have Universal Serial Bus (USB) connections for serial communications, which are also utilized for software loading.

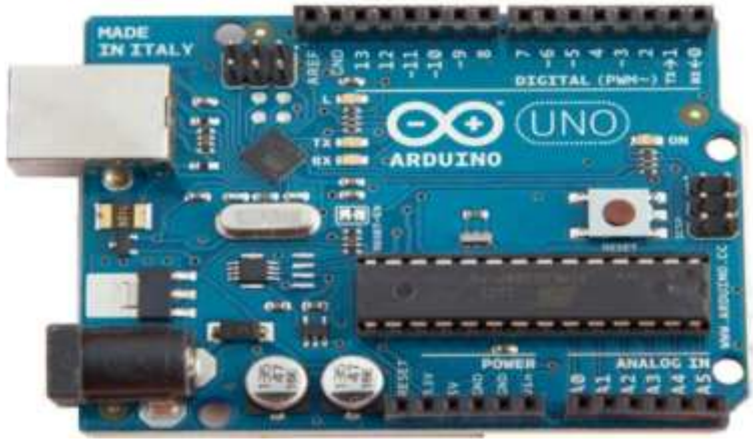


Figure 3.1: Arduino

Specification:

- Microcontroller: ATmega328P
- Operating Voltage: 5V
- Input Voltage (recommended): 7-12V
- Input Voltage (limit): 6-20V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- PWM Digital I/O Pins: 6
- Analog Input Pins: 6
- DC Current per I/O Pin: 20 mA
- Flash Memory: 32 KB (ATmega328P) of which 0.5 KB used by bootloader
- SRAM: 2 KB (ATmega328P)
- EEPROM: 1 KB (ATmega328P)
- Clock Speed: 16 MHz

3.4.2 CNC SHIELD:

A CNC shield's main purpose is to provide the Arduino precise control over stepper motors. It decodes instructions from CNC software (often G-code) and transforms them into signals that power the stepper motors that move the axes of the CNC machine. The shield controls how power is distributed to the motors and decodes limit switch signals to stop over-travel and guarantees the CNC system operates without hiccups. The CNC shield functions as an overall interface that acts as a convenient and effective means of controlling the mobility and functionality of the CNC machine between the Arduino and its numerous components.

Figure 3.2 : CNC Shield

CNC Shield Specifications:

- Runs on 12-36VDC.
- GRBL 0.9 compatible.
- 4-Axis support.
- Compact design.
- 2x End stops for each axis (6 in total)

3.4.3 A4988 Stepper Motor Driver:

This device creates the signals required to operate a stepper motor that is linked by interpreting step and direction inputs from a control system, such as a microcontroller. These input signals are transformed into the exact sequences needed to operate the motor in discrete stages. The motor windings' current flow is regulated by the driver, which also determines the rotational direction and speed. By including safety measures like thermal shutdown and over current prevention, it also guarantees that the motors function within safe parameters.

Figure 3.3 : A4988 Stepper Motor Driver

Specifications:

- Minimum operating voltage: 8 V
- Maximum current per phase: 2 A3
- Minimum logic voltage: 3 V
- Maximum logic voltage: 5.5 V
- Microstep resolutions:full, 1/2, 1/4, 1/8, and 1/16

3.4.4 Stepper Motor:

Stepper motors are a kind of electric motor that are utilized in many different applications that call for precise and regulated rotating motion. [8] It moves in exact angular steps, or increments, by converting electrical pulses into mechanical rotation. Stepper motors function by sequentially turning on and off coils to produce magnetic fields that interact with the motor's rotor to produce distinct steps in its movement. Electrical pulses are sent to the motor windings in order to regulate the motor's spin. The motor moves according to the number of steps each rotation and the order in which the coils are activated. Complete, half, or even smaller microsteps can be used in these steps, enabling smooth, precise control over motion.

Figure 3.4 : Stepper Motor

Specification:

- Voltage 5V
- Current 170mA
- Steps per Revolution 20
- Revolutions Full Travel 11

3.4.5 DC Motor:

DC motors work by using the interplay of magnetic fields to transform electrical energy into mechanical energy. The rotor turns as electricity flows through the coils, interacting with the motor's magnetic field to produce a magnetic field.

Figure 3.5 : DC Motor

Specifications :

- Model Name: dc 775
- Speed: 12000 RPM
- Voltage: 12 Volts (DC)
- Rated Voltage: 12V-24V
- Rated Speed: 6000-12000 ± 10% RPM
- No-load current: about 0.5A

3.4.6 Servo Motor :

A servomotor, also known as a servo motor or simply servo, is an actuator capable of precise control over angular or linear position, velocity, and acceleration within a mechanical system. It is a crucial component of a servomechanism and typically comprises a motor linked to a sensor for position feedback. Utilizing a relatively advanced controller, often a specialized module tailored for servomotors, is essential. Although servomotors don't belong to a distinct motor category, the term "servomotor" commonly denotes a motor suitable for integration into a closed-loop control system. These motors find widespread applications in areas like robotics, CNC machinery, and automated manufacturing.

Figure 3.6 : Servo Motor

Specifications :

- Stall Torque: 9.4kg/cm (4.8v); 11kg/cm (6v)
- Op. speed: 0.20sec/60degree (4.8v); 0.16sec/60degree (6.0v)
- Operating voltage: 4.8~ 6.6v.
- Gear Type: Metal gear.
- Temperature range: 0- 55deg.

3.4.7 Jumper Wires :

Jumper wires are essential components in electronics, used primarily for making connections between different points in a circuit without the need for soldering. These wires are commonly used in prototyping, testing, and building electronic projects, especially on breadboards.

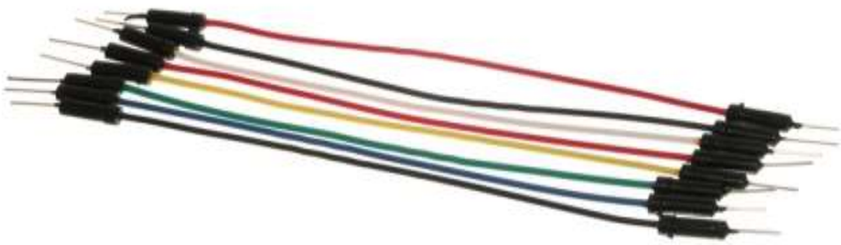


Figure 3.7 : Jumper Wires

CHAPTER 4: SOFTWARE REQUIRMENTS

4.1 SOFTWARE REQUIREMENT

4.1.1 Arduino IDE :

The Arduino Integrated Development Environment (IDE) functions as the primary software for Arduino projects. [10] It includes essential components like a text editor, message area, console, toolbar, and menus. This IDE facilitates the connection between the software and Arduino hardware, enabling program uploads and communication with the devices. The Arduino IDE serves as the main software platform for Arduino projects. It encompasses key elements such as a text editor, message display area, console, toolbar, and menus. This IDE streamlines the interaction between software and Arduino hardware, allowing for program uploads and communication with the devices.

The Arduino platform has gained significant popularity among beginners in electronics due to its affordability, user-friendly interface, and extensive support network.

4.1.2 Inkscape :

Inkscape, a freely available vector graphics editor compatible with Windows, macOS, and GNU/Linux, serves various purposes in computer graphics, from artistic illustrations to technical diagrams. [12] Its applications span across creating cartoons, clip art, logos, typography, flowcharts, web graphics, and paper scrapbooking. In functionality, Inkscape rivals commercial software such as Adobe Illustrator and Deneba Canvas. The project website offers tutorials, guides, and forums for user support.

[3] Inkscape offers the ability to create basic vector shapes like rectangles, ellipses, polygons, arcs, spirals, stars, and 3D boxes, as well as text. These shapes can be filled with various colors, patterns, or gradients, and their borders can be customized with adjustable transparency. Additionally, Inkscape supports embedding and optional tracing of raster graphics, allowing users to convert photos and other raster images into vector graphics. Users can further manipulate shapes with transformations such as moving, rotating, scaling, and skewing.

4.1.3 G-Code Reference Block Library (GRBL) Controller :

GRBL, initially developed by Simen Svale Skogsrud and later maintained by Sungeun(Sonny) K. Jeon since 2009 [2], is exclusive to Arduino-based controllers.
It serves as open-source software/firmware facilitating motion control for CNC machines. By installing GRBL firmware onto an Arduino, users gain access to an affordable yet high-performance CNC controller. Utilizing G-code as input, GRBL directs motion control through the Arduino. Its versatility across various CNC machines and efficient motion control capabilities make it a preferred choice for tasks like milling, laser cutting, and metal engraving.

4.2 SOFTWARE IMPLIMENTATION :

4.2.1 Arduino IDE :

The Arduino Integrated Development Environment (IDE) is a software application used for programming and developing code for Arduino microcontroller boards. It provides a user-friendly interface that simplifies the process of writing, compiling, and uploading code to Arduino boards.

Steps To Include GRBL Library :

- Open a web browser and go to the GRBL GitHub repository (https://github.com/gnea/grbl).
- Click on the green "Code" button, and then choose "Download ZIP."
- Extract the downloaded ZIP file to a location on your computer.
- Inside the extracted folder, you should find the "grbl" folder. This folder contains the GRBL library.
- Navigate to the Arduino libraries folder on your computer. This folder is usually located in the "libraries" subdirectory of your Arduino IDE installation directory.

- Copy the entire "grbl" folder from the extracted ZIP file and paste it into the "libraries" folder.
- Close and reopen the Arduino IDE to ensure that it recognizes the newly added library.

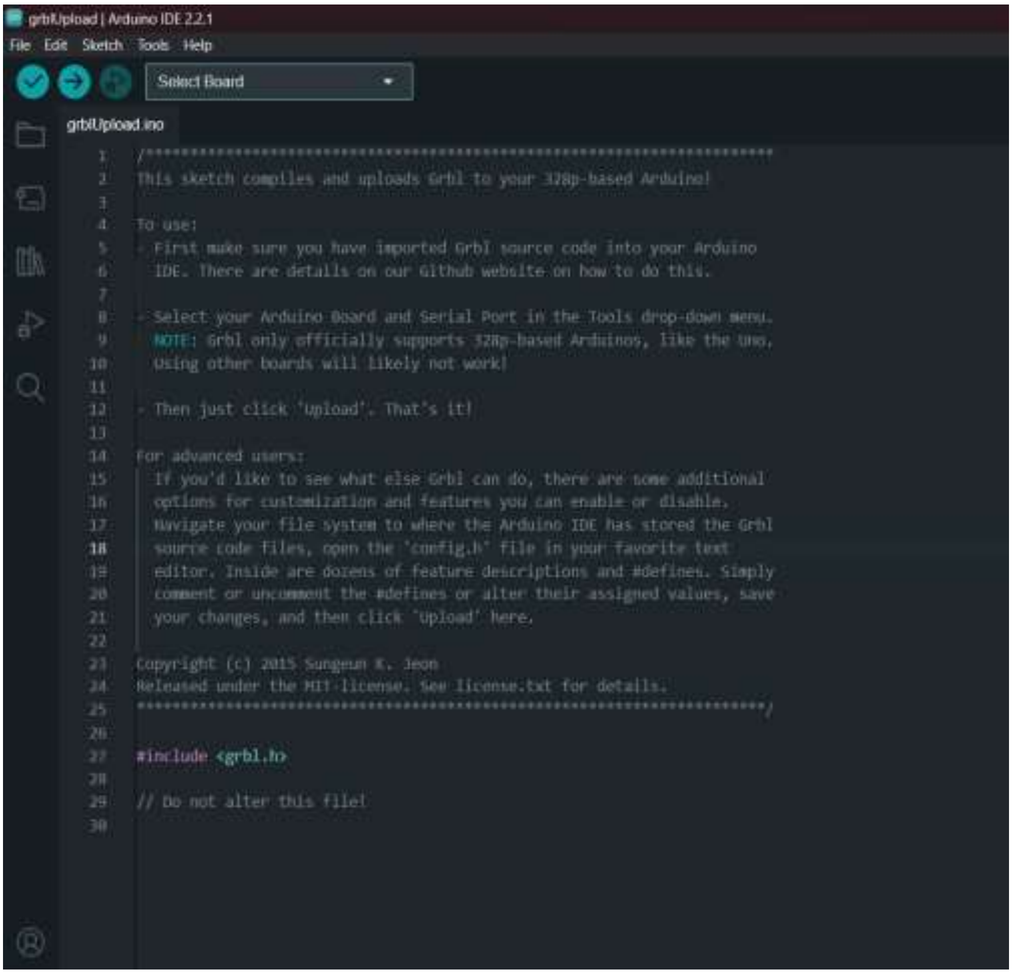


Figure 4.1 : Arduino IDE

4.2.2 Easy EDA :

The Easy EDA app simplifies the process of Exploratory Data Analysis (EDA) by providing intuitive tools and features for data exploration and visualization. With a user-friendly interface, Easy EDA allows users to effortlessly import datasets, analyze key statistics, and generate insightful visualizations to uncover patterns, trends, and relationships within their data.

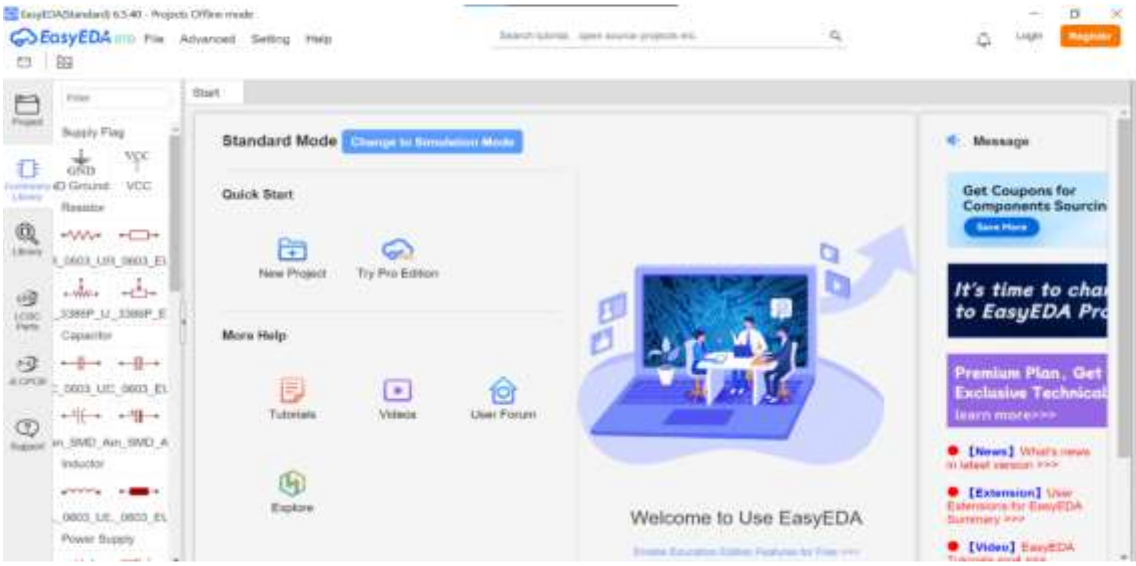


Figure 4.2 : Easy EDA

Step1: Open the easy eda application go to files, create new project, and save the file.

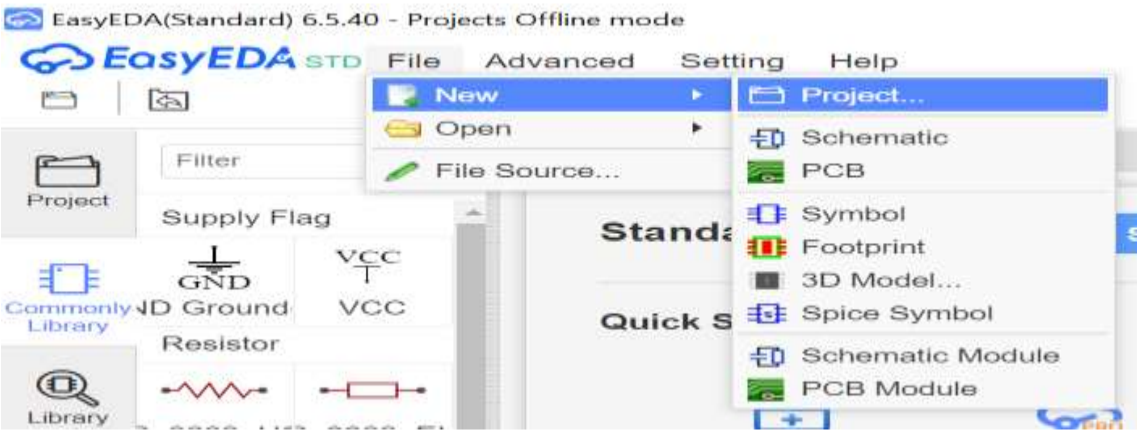


Figure 4.3 : Creating new Project in Easy EDA

Step2: start creating a PCB design as per requirement using common library and library search.

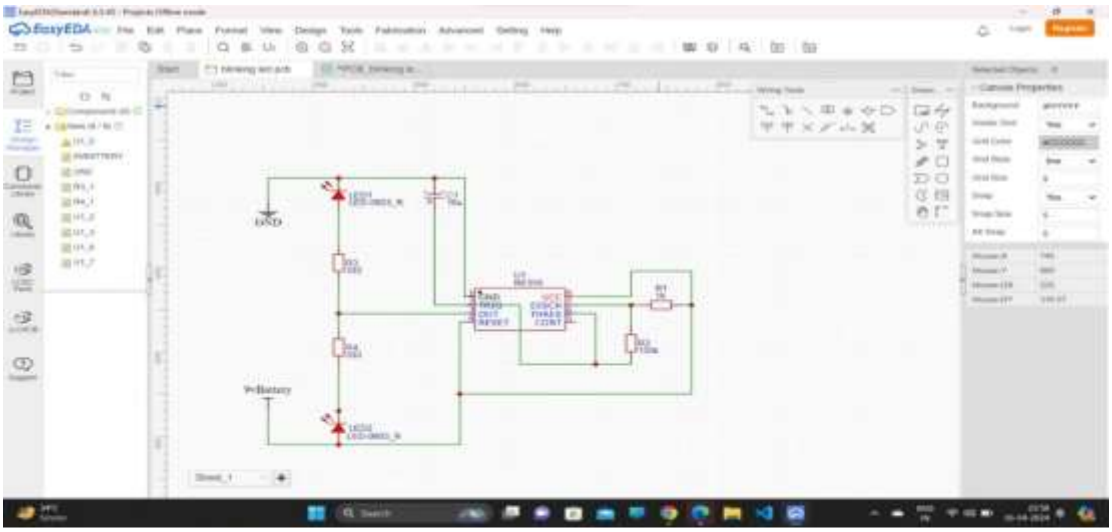


Figure 4.4 : Creating PCB Design

Step3: after completing the design, click on "Design" select "Convert schematic to PCB".

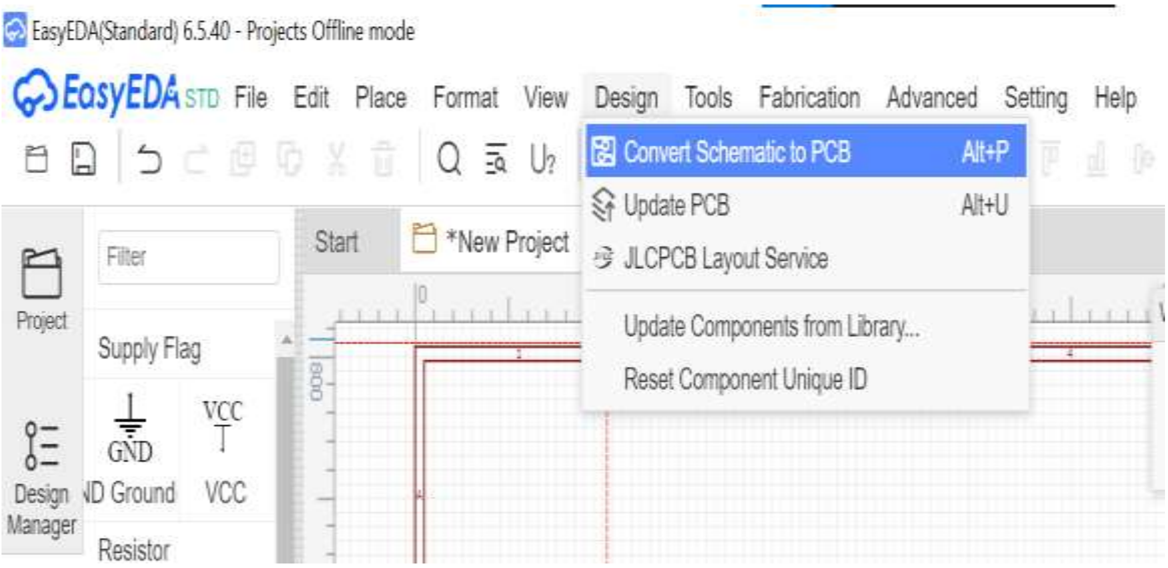


Figure 4.5 : Convert Schematic to PCB

Step4: Assemble the components and connects properly.

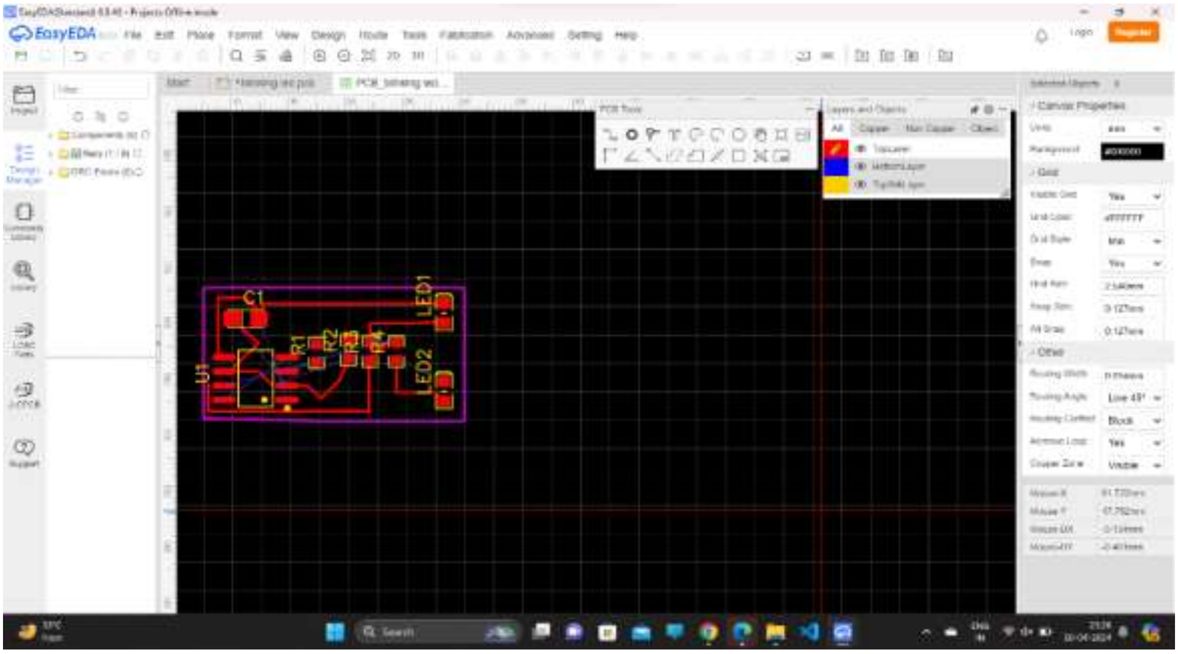


Figure 4.6 : Component Connections

Step5: For the final steps after the assembly is done go to files select the option “Export” can save the file in “PDF” or “PNG” as required.

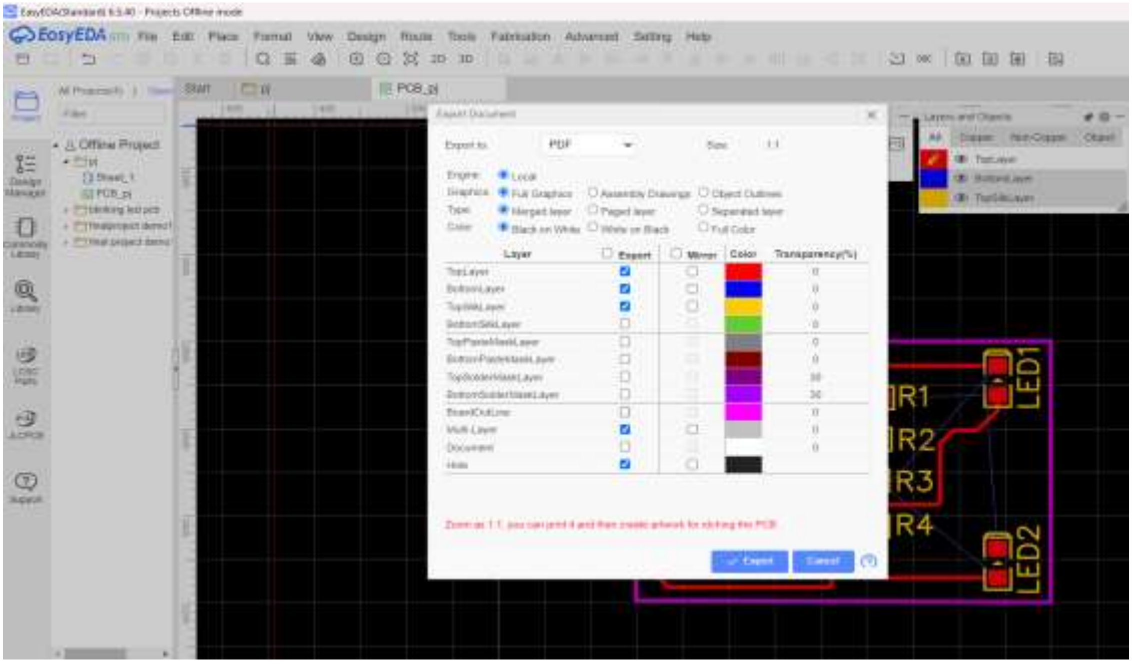


Figure 4.7 : Saving PCB Design

Step6: Select “black and white” color in color option and export the file, save the file.

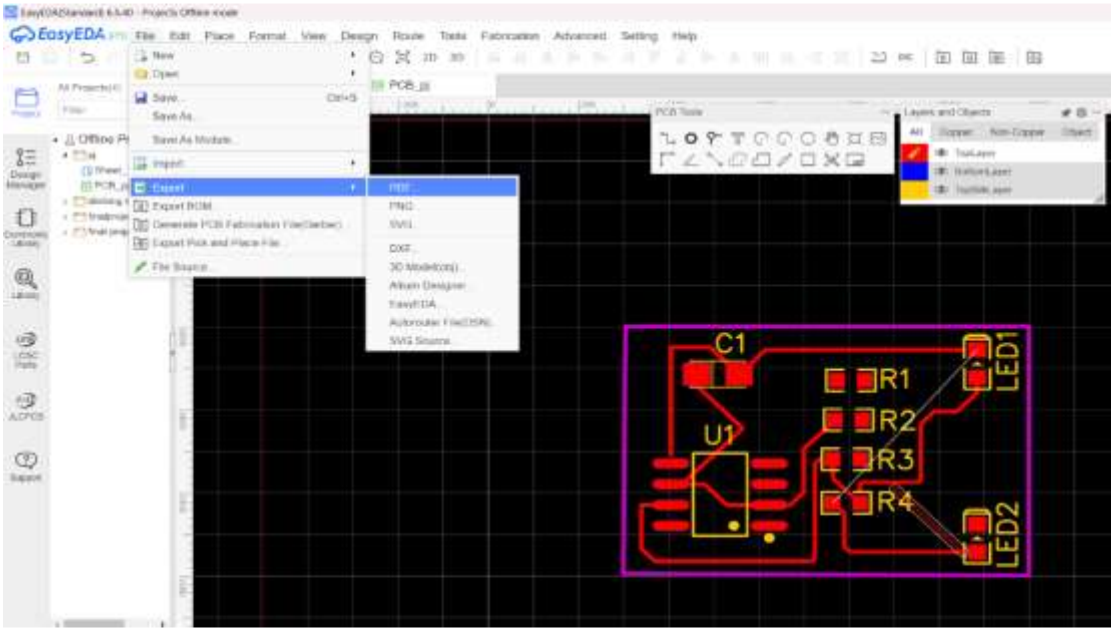


Figure 4.8 : Select “Black and white” colour

Step7: The saved pdf or png.

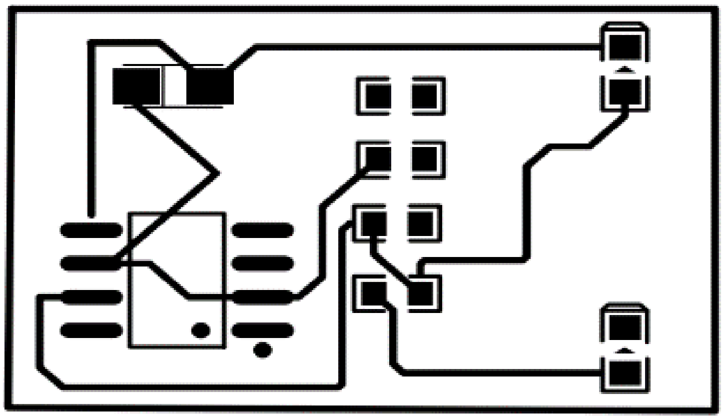


Figure 4.9 : PCB Design

4.2.3 InkScape :

[4] InkScape is a free and open-source vector graphics editor that allows users to create and manipulate scalable vector graphics (SVG) images. It provides a wide range of tools and features for graphic design, illustration, and vector-based artwork. Inkscape supports various file formats, including SVG, AI, EPS, PDF, and others, making it versatile for both web and print design.

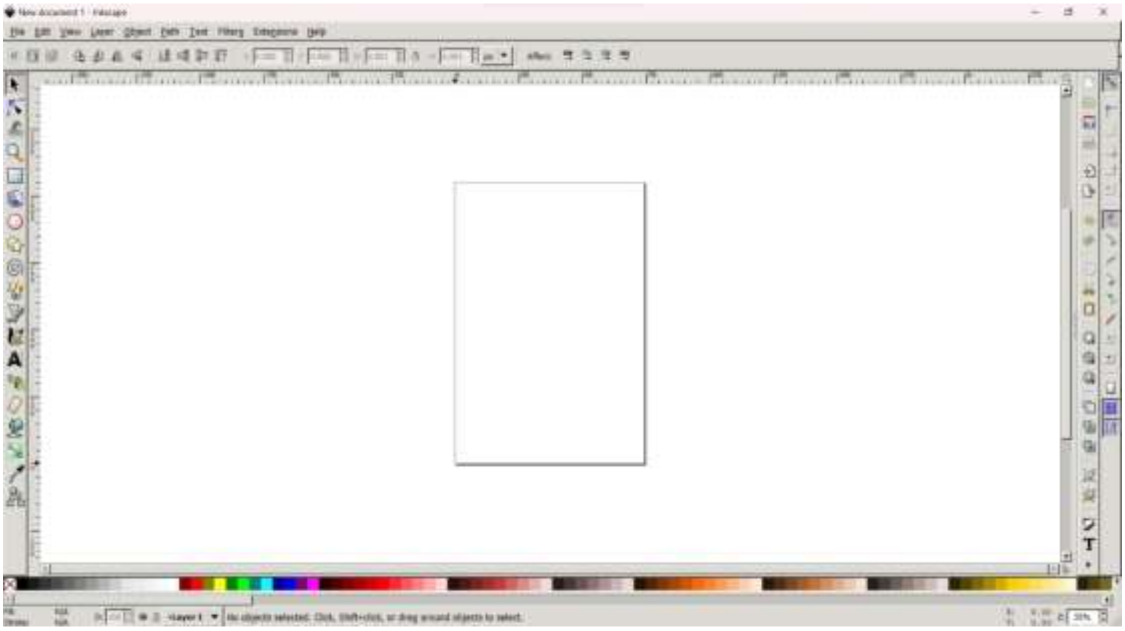


Figure 4.10 : Inkscape

Process To Make G-code In InkScape :

Step 1 : open “inkscape” software , go to files and select “documents properties” to set the document size as per requirnment.

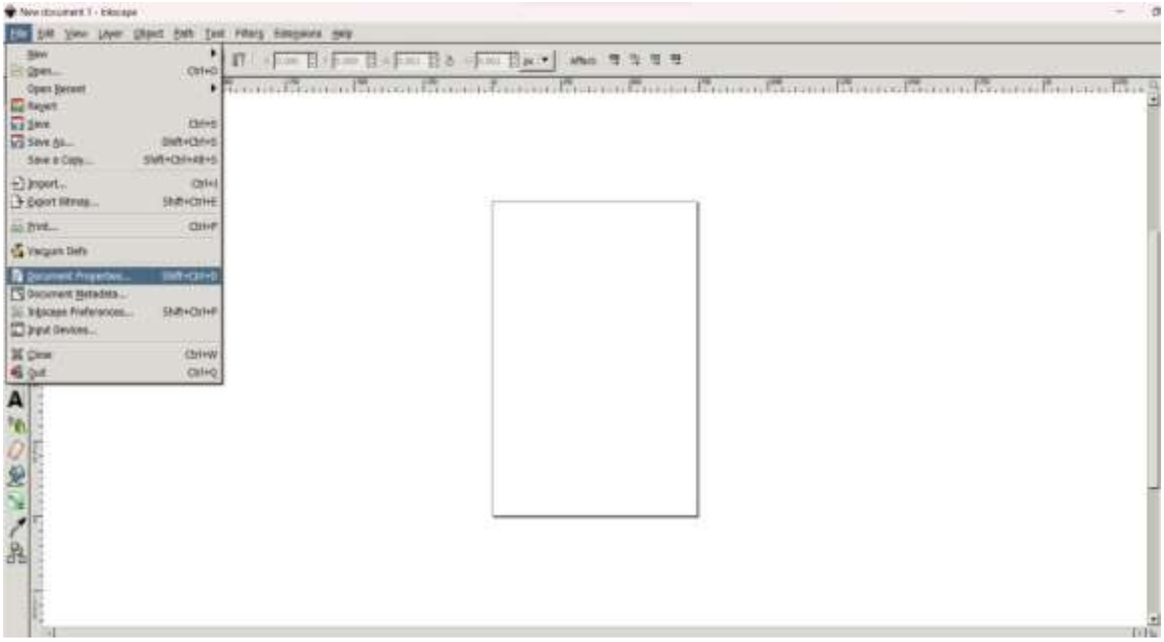


Figure 4.11: Document Selection in Inkscape

Step 2 : Set size of the block as per requirnments in cm, mm as the printing area of the cnc plotter.

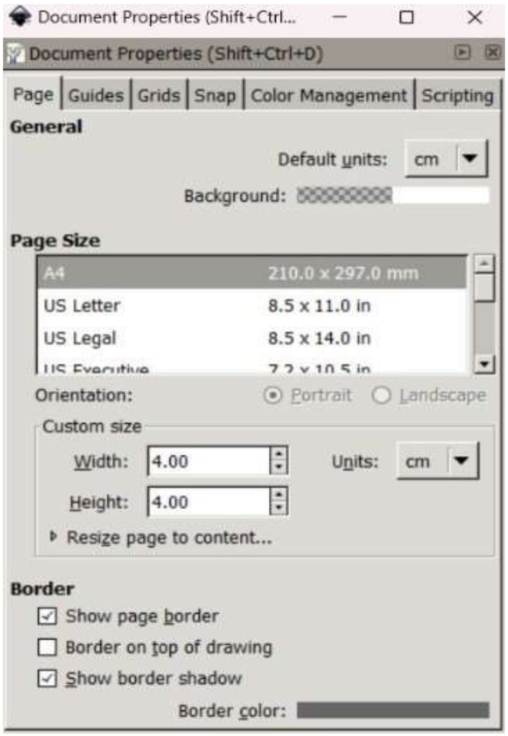


Figure 4..12: Set Size of Document

Step 3 : As the size of the document is set as required import image to be printed on the plotter. Go to “files” and select “import” option

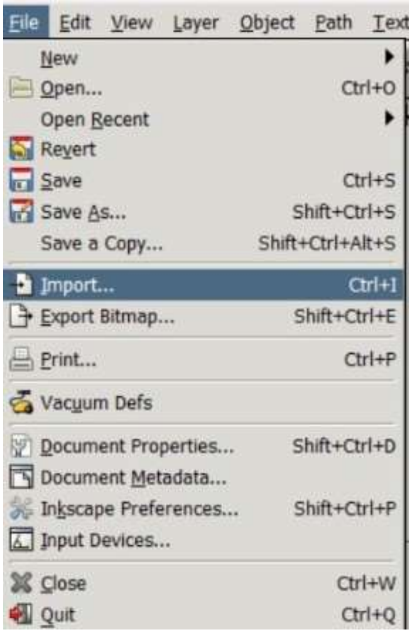


Figure 4.13: Import File

Step 4 : Select “image file” to be imported from folder. And “open” the file.

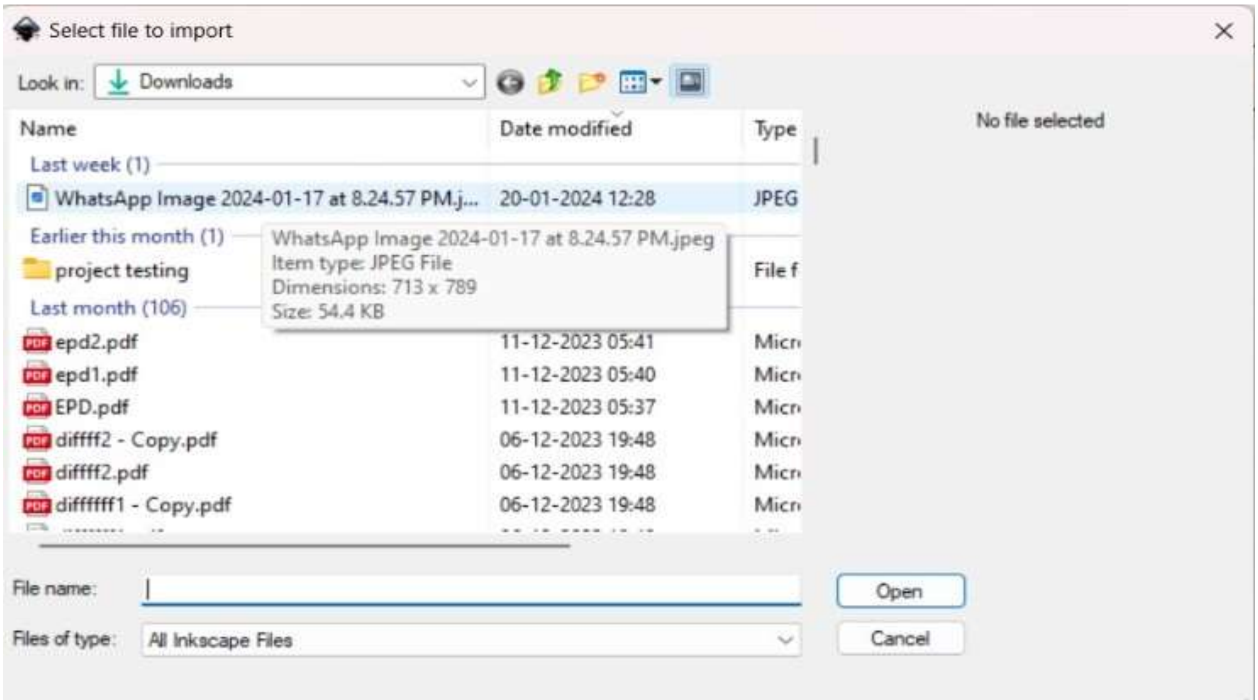


Figure 4.14: Select File

Step 5 : Adjust the selected image in the square block, go to “path” option select “trace bitmap” option.

Figure 4.15: Trace Bitmap

Step 6 : A small window of trace bitmap opens up, select the “edge detection” option and click on “update”. An outline of the image is updated for printing. Click on “ok”.

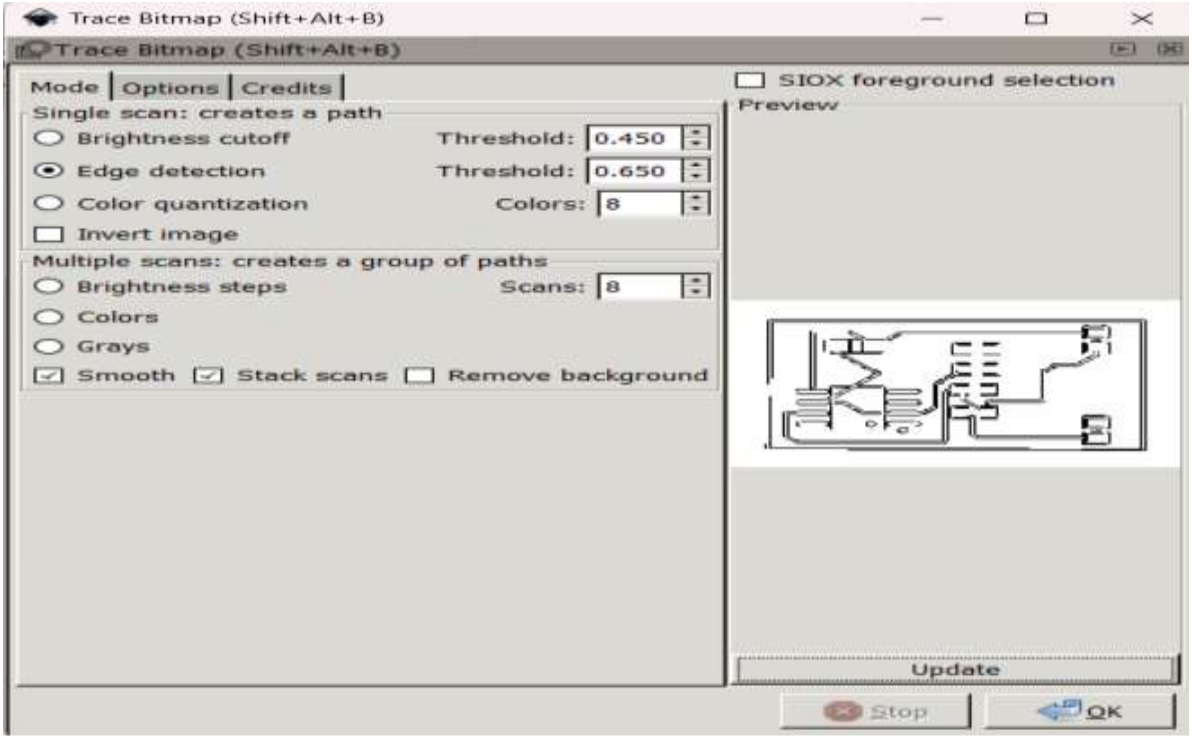


Figure 4.16: Edge Detection

Step 7 : An edged image of the original image is created deleted the original image and place the after image in the square block.

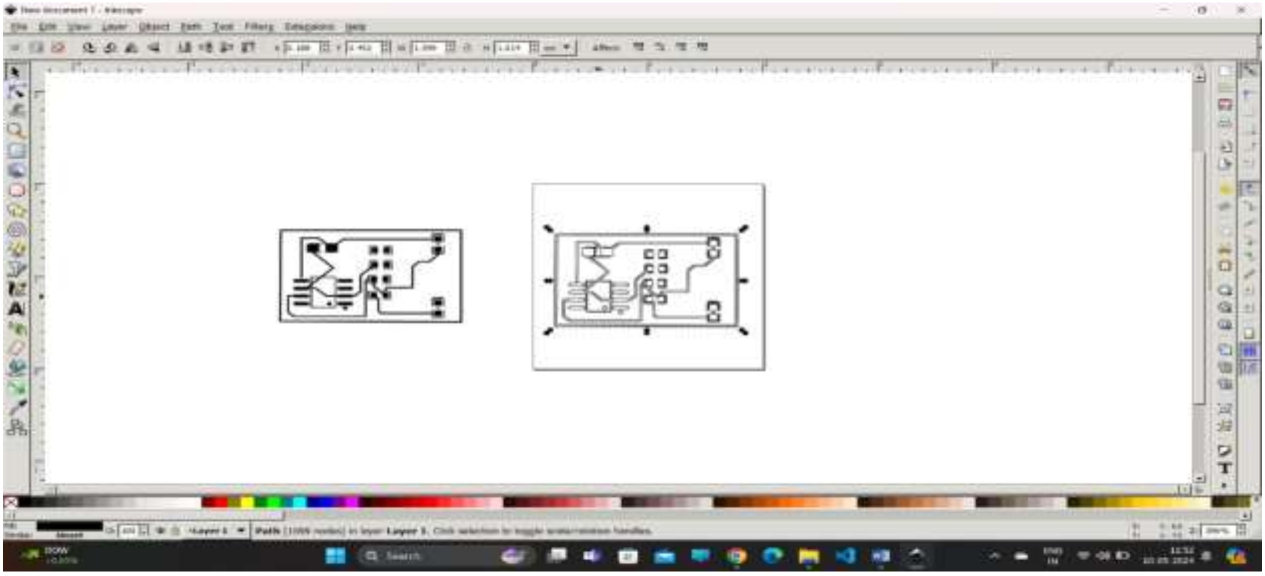


Figure 4.17: Edge Detected img

Step 8 : Press "ctrl A" select the updated image, go to the "path" option select "object to path".

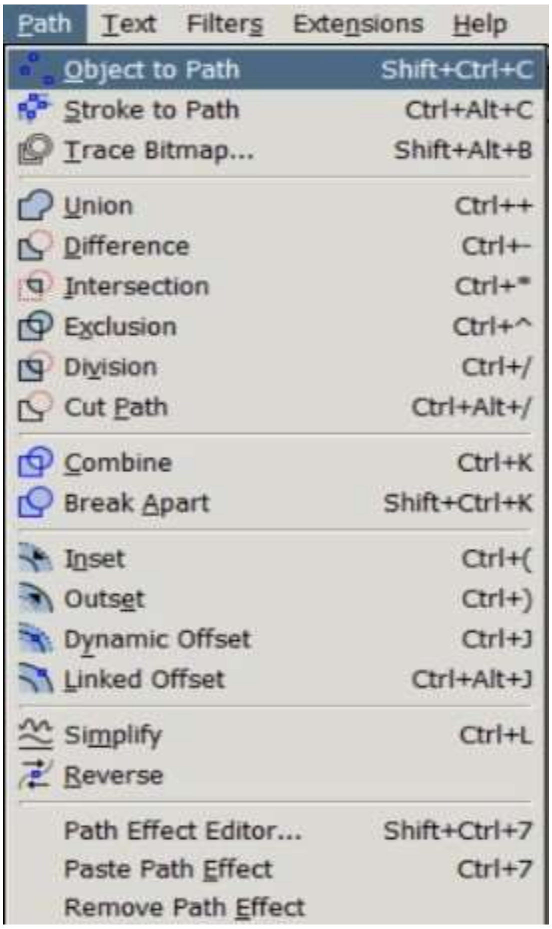


Figure 4.18: Object to Path

Step 9 : Go to the "Extensions" option, select the "MI GRBL SERVO CONTROLLER" option to save the file.

Figure 4.19 : Save File of Inkscape

Step 10 : A small window will pop up here, set the X,Y axis speed as required and servo angle as per required and save the image in "G-Code" file.

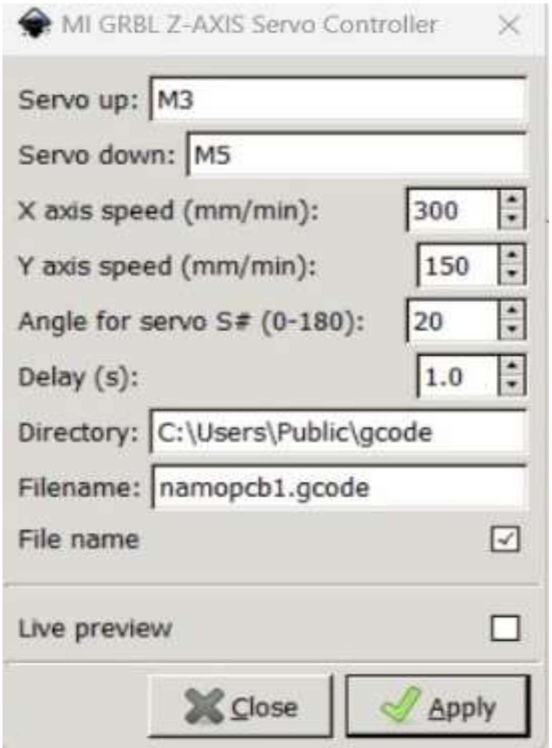


Figure 4.20: Select Axis

4.2.4 GRBL Controller :

GRBL (pronounced "grubble") is a free, open-source, high-performance CNC (Computer Numerical Control) milling controller that runs on Arduino-compatible hardware. It's designed to interpret G-code, the standard programming language for CNC machines, and translate those instructions into precise movements of stepper motors.

Step 1: open the GRBL controller

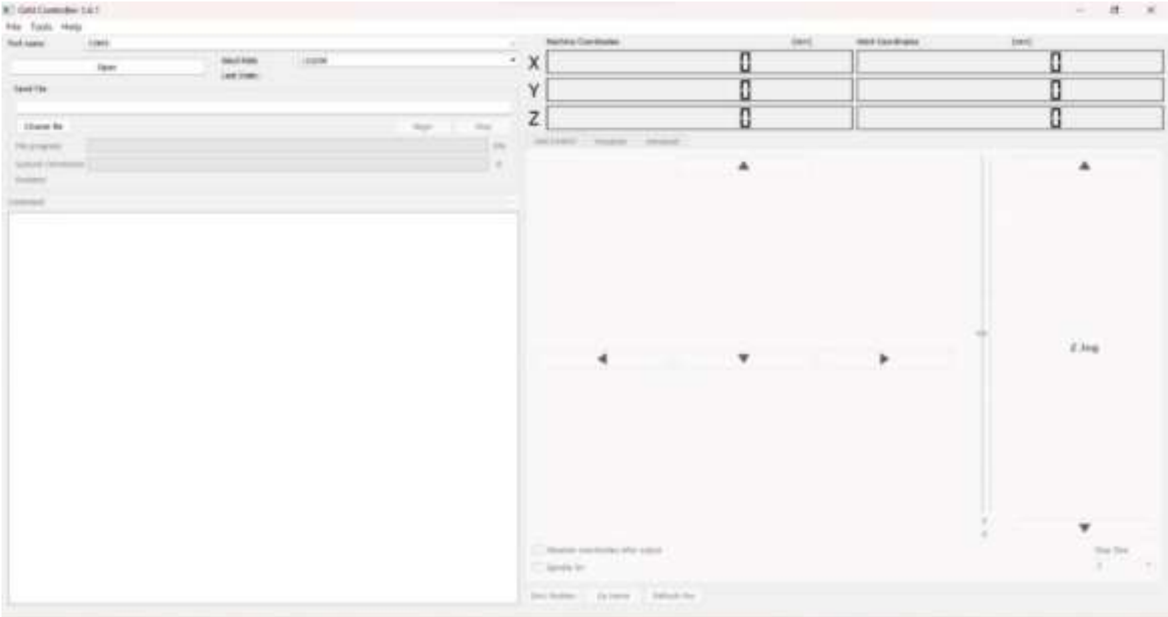


Figure 4.21: GRBL Controller

Step 2: Select Com port as per Arduino and set the baud rate to “115200”.

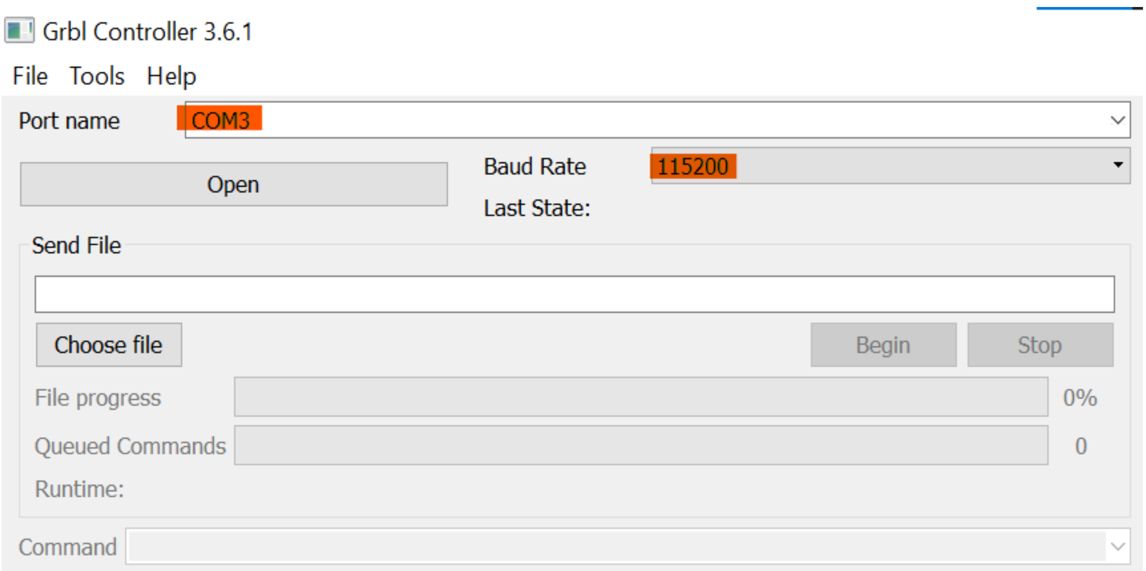


Figure 4.22: Select Com Port & Baud rate

Step3: Connect the Arduino to the laptop or pc then press the "open" button

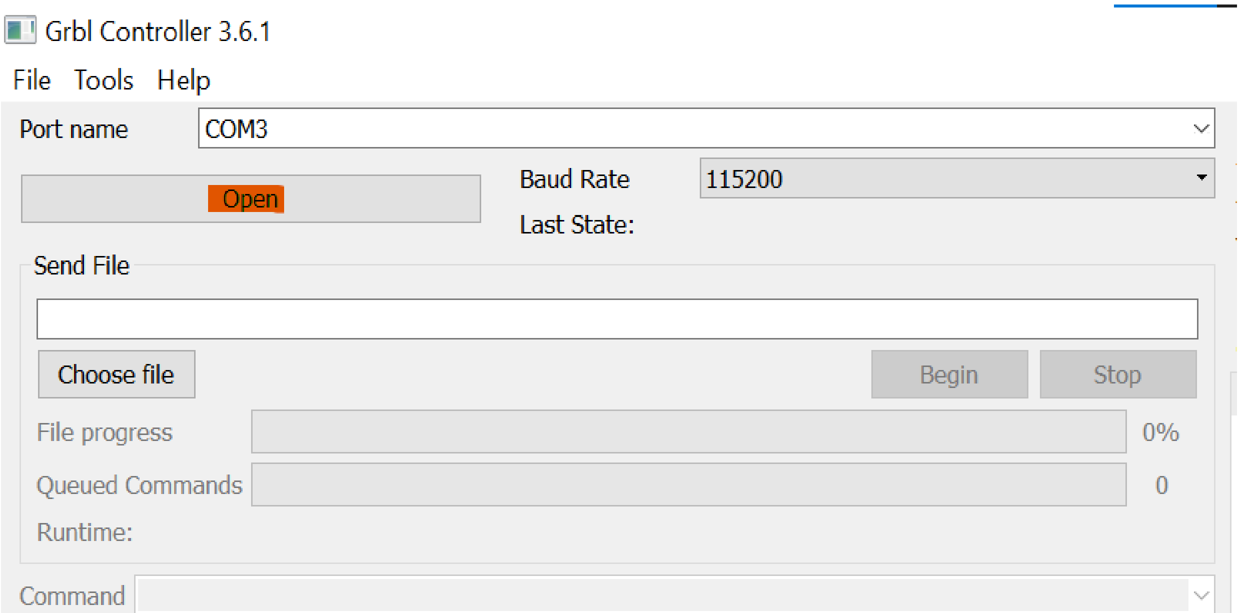


Figure 4..23: Connect Arduino

Step4: After the open button is red, Now to choose the g-code file to be uploaded on the plotter for printing.

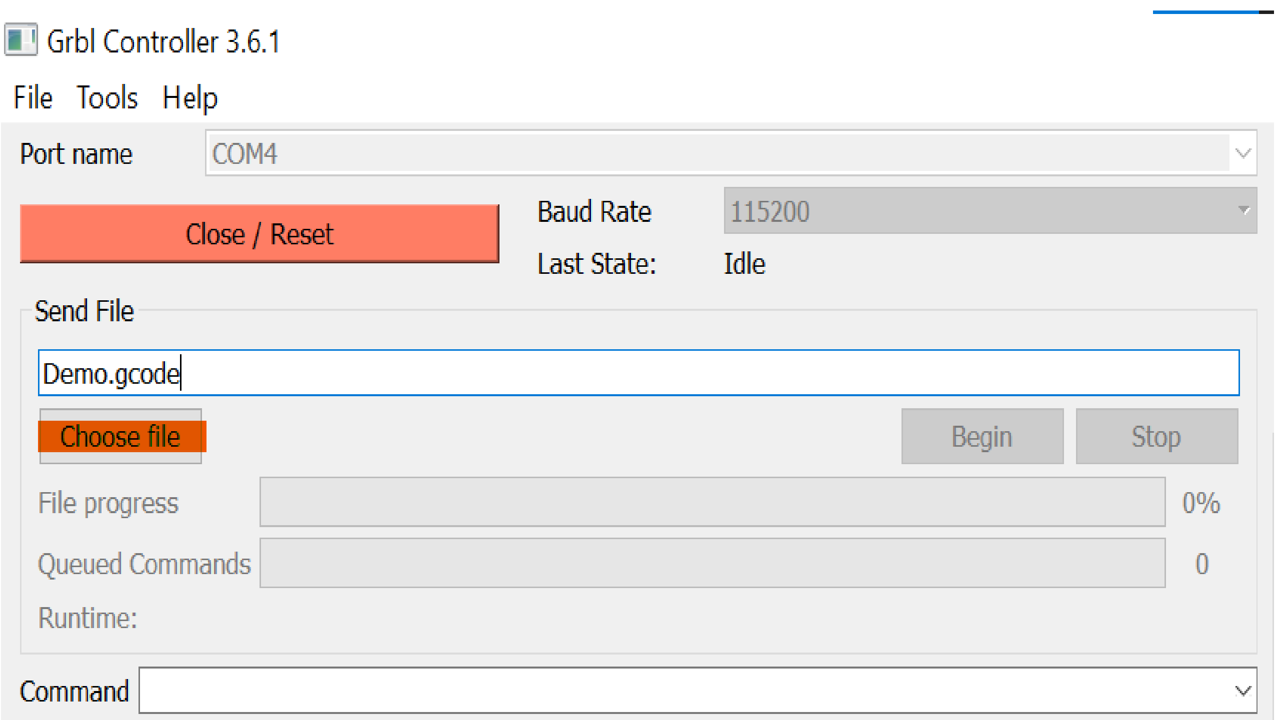


Figure 4.24:Choose g-code file

Step5: After selecting the file, To start or stop the printing use the “begin” and “stop” button.

Figure 4.

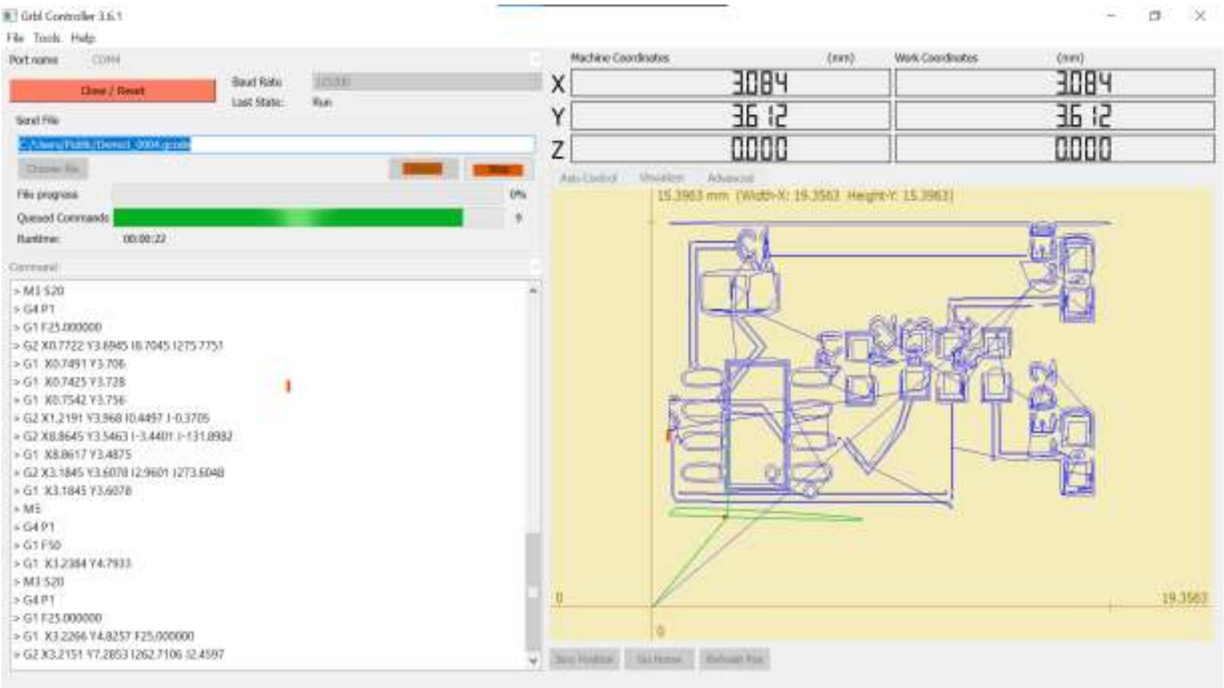


Figure 4.25:Start the Printing PCB

The printing begins, live tracking and axis movement can be tracked on this GRBL Controller. This application controls the moments of the X,Y axis and the servo motor.

CHAPTER 5 : SYSTEM DESIGN

System design consist of system architecture and data flow diagram :

5.1 SYSTEM ARCHITECTURE

A small CNC PCB plotter's system architecture consists of a number of hardware parts and some software for implementation. The little CNC PCB plotter's architecture is shaped by how its parts interact with one another. The CAM program transforms the picture data into G-code, and the CAD software creates the PCB designs.

Figure 5.1: System Architecture

5.2 DATA FLOW (DFD) DIAGRAMS

5.2.1 DFD Level 1 Diagram

The data flow diagram (DFD) is one of the most important modeling tools. It is used to model the system components.

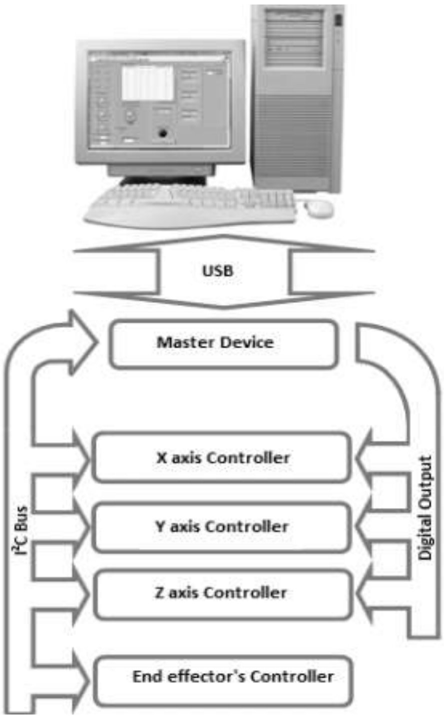


Figure 5.2: DFD Multi Level Diagram

A tiny CNC PCB plotter requires a multi-level Data Flow Diagram (DFD), which is created by abstracting the system at several levels. Processes, data storage, data flow, and external entities are usually included in a DFD. Via a USB cable, the computer is linked to the master devices, which is the Arduino. Through the i2c bus wires, which link the controller to the motors in the same way as the three axes (X, Y, and Z), manage the axis's motions the laptop or PC uploads the g-codes to the Arduino in digital forms, which then translate the code into machine language and regulate the motor motions correspondingly. It subsequently prints patterns according to given commands.

5.3 UML DIAGRAMS

5.3.1 Activity diagram

Activity diagrams are graphical representations of work flows of step wise activities and actions with support for choice, iteration and concurrency. In the Unified Modeling Language, activity diagrams are intended to model both computational and organizational processes (i.e. work flows).

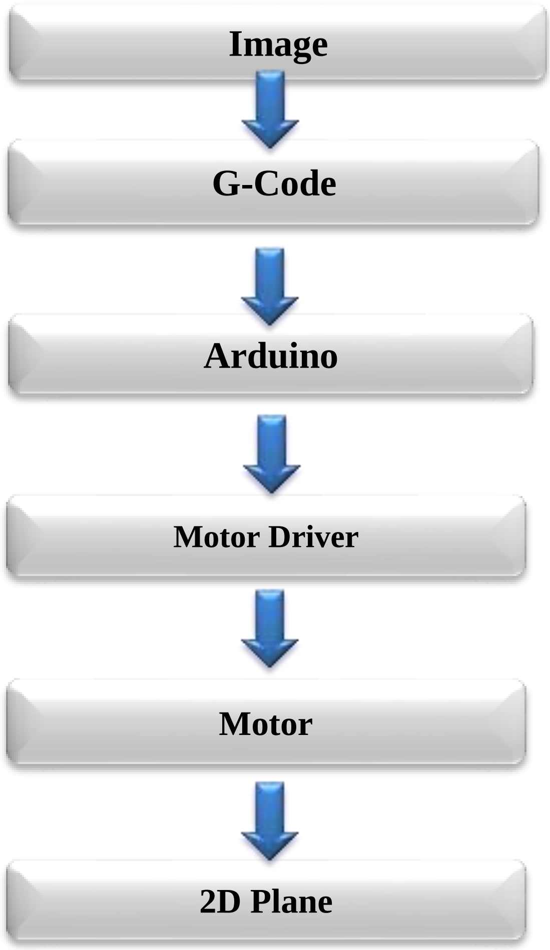


Figure 5.3: Activity Diagram

5.3.2 Use case Diagram

A small CNC PCB plotter's use case specification describes the precise operations and interactions that users may carry out with the machine. Every use case depicts a specific objective or operation that the small CNC PCB plotter may accomplish for a user or an external system.

Figure 5.4 : Use case Diagram

5.3.3 Class Diagram

The class diagram is a static diagram. It represents the static view of an application. Class diagram is not only used for visualizing, describing and documenting different aspects of a system but also for constructing executable code of the software application. The class diagram describes the attributes and operations of a class and also the constraints imposed on the system

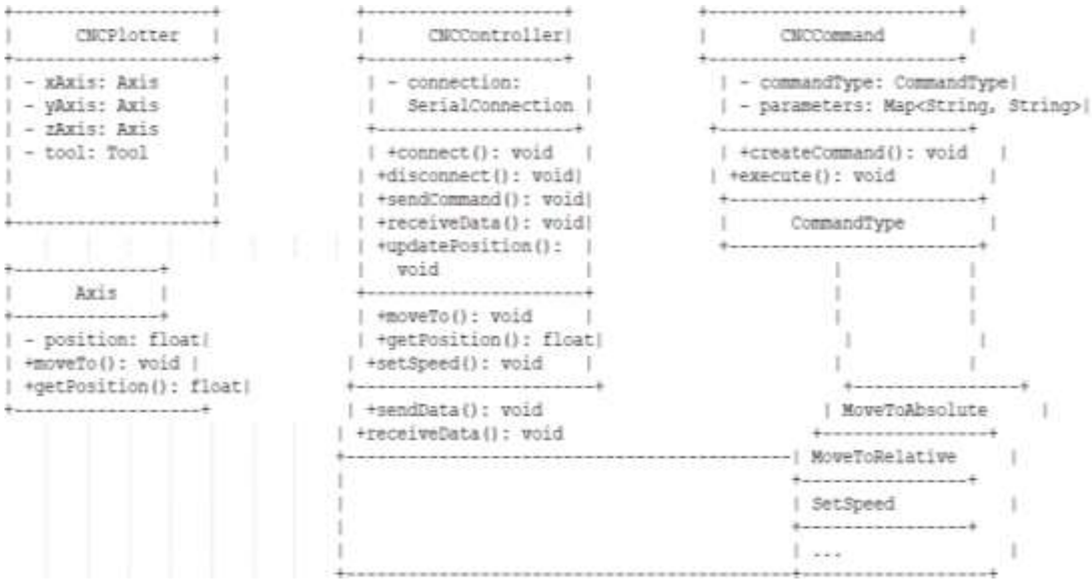


Figure 5.5: Class Diagram

5.4 ALGORITHM TO IMPLEMEMT CNC PCB PLOTTER

1. Initialize CNC Plotter:

   - Initialize the CNC plotter system, including axes, tool, and controller.

   - Establish communication with the CNC controller.

2. Load PCB Design:

   - Load the PCB design file (e.g., Gerber file) into the CNC plotter software.

   - Parse the file to extract relevant information such as traces, pads, and dimensions.

3. Convert Design to Tool Movements:

- Iterate through the design elements (traces, pads, etc.).

- Convert each design element into a series of tool movements.

- Determine the toolpath based on the desired cuts and traces.

4. Generate CNC Commands:

- For each tool movement, generate the corresponding CNC command.

- Commands may include moving to a specific position, adjusting the tool, and performing cuts.

5. Send Commands to CNC Controller:

- Send the generated CNC commands to the CNC controller for execution.

- Ensure proper synchronization and timing for accurate tool movements.

6. Execute Tool Movements:

- Execute the tool movements as per the generated commands.

- Monitor feedback from the CNC controller, adjusting for any discrepancies.

7. Post-Processing:

- Perform any necessary post-processing steps, such as cleaning, inspection, or additional tool changes.

8. Shutdown CNC Plotter:

- Safely shutdown the CNC plotter system.

- Close communication with the CNC controller.

9. End Algorithm

CHAPTER 6 : ADVANTAGES, LIMITATIONS & APPLICATIONS

6.1 ADVANTAGES

- This machine is portable
- It has a compact size
- It is easy to use
- It is Low cost
- More Reliable
- Has a Low power consumption
- We can customize as per our needs
- It can be used in Educational purpose
- The machine is versatile
- We can change printing devices as per our needs.

6.2 LIMITATIONS

- Limited cutting depth
- Limited material compatibility
- Limited speed
- Limited automation
- Limited accuracy

6.3 APPLICATIONS :

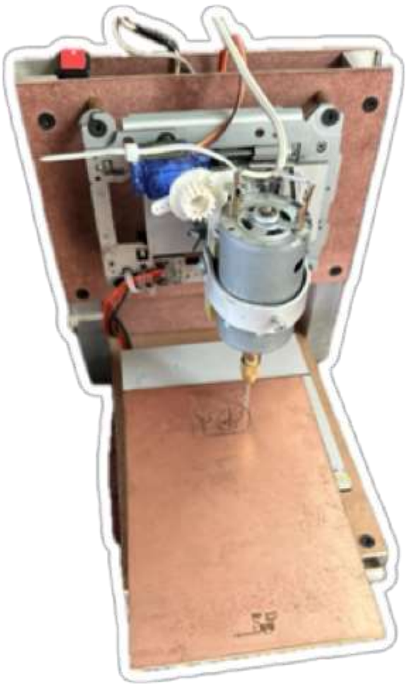
- To quickly and easily prototype your circuit designs.
- We can use a mini CNC PCB plotter to create stencils for solder paste application,
- We can use a mini CNC PCB plotter to engrave text, logos, and other designs onto front panels for electronic devices.

- we can use a mini CNC PCB plotter to create artwork, signs, and other decorative items.
- Mini CNC PCB plotter machines are a great way to teach students about electronics, design, and manufacturing

CHAPTER 7 : RESULT

7.1 RESULT

In this project the development of an Arduino-Uno-based, portable, dependable, three-axis tiny CNC PCB plotter is described. The CNC machines now on the market come at a heavy cost. Maintaining it takes a highly experienced operator and is rather challenging. The CNC machine solves this issue since it is affordable, dependable, portable, and it does not require a highly skilled person to run the apparatus. The equipments are very simple to maintain and reasonably priced. Compared to other machines on the market the working hours of this machine is extended. As the machine can be alter to suit the demands, it becomes more flexible. More features can be added to the CNC PCB plotter. A precise and accurate PCB with fine traces and distinct features should be able to be produced using a well-designed and calibrated small CNC PCB plotter. The productivity of the CNC plotter, which includes traverse and cutting speeds, will affect how long it takes to finish a PCB. Productivity may be increased by using faster and more effective processes. The CNC plotter's resolution, ascertained Achievable detail will depend on variables like lead screw pitch and stepper motor accuracy during PCB design.



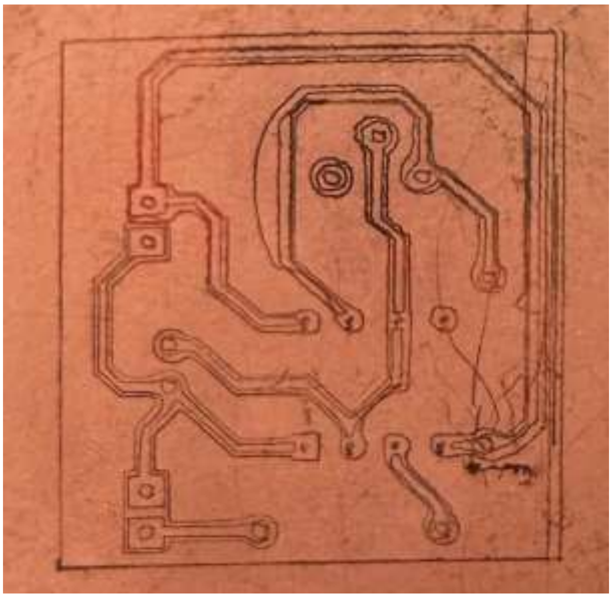


Figure 7.1: Mini CNC PCB Plotter With Output

This project introduces a compact and affordable CNC PCB plotter based on Arduino Uno. Unlike many expensive CNC machines available, this plotter is designed to be easy to use, maintain, and transport. You don't need specialized skills to operate it, and maintenance is straightforward and inexpensive. Plus, it offers extended working hours compared to other machines. Being adaptable to various demands, it's highly flexible, allowing additional features to be incorporated. With precise calibration, it can produce intricate PCBs with fine traces and clear features. The speed at which it operates, both in traversal and cutting, affects productivity, which can be enhanced with faster processes. The level of detail achievable depends on factors like the precision of stepper motors and lead screw pitch during PCB design.

CHAPTER 8 : CONCLUSION & FUTURE SCOPE

8.1 CONCLUSION

A mini CNC PCB plotter represents a significant advancement for hobbyists, educators, and small-scale developers in the field of electronics manufacturing. Compact, precise, and highly adaptable, these plotters transform the process of PCB creation from a cumbersome, chemically intensive procedure to a streamlined, digital fabrication process. By allowing users to rapidly prototype PCBs with high accuracy directly from their digital designs, mini CNC plotters not only save time but also reduce waste and costs associated with traditional methods. The integration of such technology into workshops and educational settings promotes a deeper understanding of both design and manufacturing processes, empowering users to experiment more freely and innovate. Moreover, the ability to iterate designs quickly enhances troubleshooting and optimization of electronic circuits, accelerating the development cycle and leading to better outcomes in projects.

In conclusion, mini CNC PCB plotters stand out as transformative tools in electronics fabrication. They encapsulate the merging of digital precision with physical production, offering a gateway to sophisticated electronics manufacturing that is accessible even in a non-industrial setting. This technology is not just about creating more efficiently; it's about inspiring a new generation of inventors and engineers who can bring their ideas to life with unprecedented ease and speed.

8.2 FUTURE SCOPE

By adding a 3D pen or heatend, this machine may be improved to become a 3D printer. Devices like pens, lasers, drilling machines, engraving machines, and so on, can have removable slots added to them. It is possible to include a camera sensor that will automatically translate an image or object into G-code for printing when it is detected. The bluetooth component or wifi module has wireless printing capabilities. It is possible to create a cloud-based printing project goal at any time and from anywhere. For this project, an android or web application that can automatically convert images to G-code and upload them to the machine may also be made. An auto sholdering device and an automated PCB component planter might improve this project. Workspace of the The machine can be scaled up without changing the algorithm. The method may be improved by using premium elements. The PCB printing time can also be lessen and make the printing more faster.

Imagine upgrading a regular machine to a 3D printer by adding a special pen or a heating tool. You could also make slots for other tools like lasers or drills. Plus, you can add a camera that turns pictures into instructions for printing. With Bluetooth or Wi-Fi, you could print wirelessly, even from far away using a cloud-based system. You could even make an app that turns images into printing instructions and sends them to the machine. Adding devices for soldering and planting PCB components could make it even better. And you could make the workspace bigger without changing how it works. Using better materials could make it work even smoother and faster, especially when printing PCBs.

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ATmega328/P

DATASHEET SUMMARY

Introduction

The Atmel® picoPower® ATmega328/P is a low-power CMOS 8-bit microcontroller based on the AVR® enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega328/P achieves throughputs close to 1MIPS per MHz. This empowers system designer to optimize the device for power consumption versus processing speed.

Feature

- High Performance, Low Power Atmel® AVR® 8-Bit Microcontroller Family
- Advanced RISC Architecture
  - 131 Powerful Instructions
  - Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 20 MIPS Throughput at 20MHz
  - On-chip 2-cycle Multiplier
- High Endurance Non-volatile Memory Segments
  - 32KBytes of In-System Self-Programmable Flash program Memory
  - 1KBytes EEPROM
  - 2KBytes Internal SRAM
  - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
  - Data Retention: 20 years at 85°C/100 years at 25°C[1]

- Optional Boot Code Section with Independent Lock Bits
    - In-System Programming by On-chip Boot Program
    - True Read-While-Write Operation
    - Programming Lock for Software Security
- Atmel® QTouch® Library Support
    - Capacitive Touch Buttons, Sliders and Wheels
    - QTouch and QMatrix® Acquisition
    - Up to 64 sense channels

- Peripheral Features
    - Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
    - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
    - Real Time Counter with Separate Oscillator
    - Six PWM Channels
    - 8-channel 10-bit ADC in TQFP and QFN/MLF package

- Temperature Measurement
    - 6-channel 10-bit ADC in PDIP Package
    - Temperature Measurement
    - Two Master/Slave SPI Serial Interface
    - One Programmable Serial USART
    - One Byte-oriented 2-wire Serial Interface (Philips I^2C compatible)
    - Programmable Watchdog Timer with Separate On-chip Oscillator
    - One On-chip Analog Comparator
    - Interrupt and Wake-up on Pin Change
- Special Microcontroller Features
    - Power-on Reset and Programmable Brown-out Detection
    - Internal Calibrated Oscillator
    - External and Internal Interrupt Sources
    - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby
- I/O and Packages
    - 23 Programmable I/O Lines
    - 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF
- Operating Voltage:
    - 1.8 - 5.5V
- Temperature Range:
    - -40°C to 105°C
- Speed Grade:
    - 0 - 4MHz @ 1.8 - 5.5V
    - 0 - 10MHz @ 2.7 - 5.5V
    - 0 - 20MHz @ 4.5 - 5.5V
- Power Consumption at 1MHz, 1.8V, 25°C

- Active Mode: 0.2mA
- Power-down Mode: 0.1µA
- Power-save Mode: 0.75µA (Including 32kHz RTC)

Description

The Atmel AVR® core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in a single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

The ATmega328/P provides the following features: 32Kbytes of In-System Programmable Flash with Read-While-Write capabilities, 1Kbytes EEPROM, 2Kbytes SRAM, 23 general purpose I/O lines, 32 general purpose working registers, Real Time Counter (RTC), three flexible Timer/Counters with compare modes and PWM, 1 serial programmable USARTs , 1 byte-oriented 2-wire Serial Interface (I2C), a 6channel 10-bit ADC (8 channels in TQFP and QFN/MLF packages) , a programmable Watchdog Timer with internal Oscillator, an SPI serial port, and six software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next interrupt or hardware reset. In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer and ADC to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low power consumption. In Extended Standby mode, both the main oscillator and the asynchronous timer continue to run.

Atmel offers the QTouch® library for embedding capacitive touch buttons, sliders and wheels functionality into AVR microcontrollers. The patented charge-transfer signal acquisition offers robust sensing and includes fully debounced reporting of touch keys and includes Adjacent Key Suppression® (AKS™) technology for unambiguous detection of key events. The easy-to-use QTouch Suite toolchain allows you to explore, develop and debug your own touch applications.

The device is manufactured using Atmel’s high density non-volatile memory technology. The On-chip ISP Flash allows the program memory to be reprogrammed In-System through an SPI serial interface, by a conventional nonvolatile memory programmer, or by an On-chip Boot program running on the AVR core. The Boot program can use any interface to download the application program in the Application Flash memory. Software in the Boot Flash section will continue to run while the Application Flash section is updated, providing true Read-While-Write operation. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega328/P is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications.

The ATmega328/P is supported with a full suite of program and system development tools including: C Compilers, Macro Assemblers, Program Debugger/Simulators, In-Circuit Emulators, and Evaluation kits.

Configuration Summary

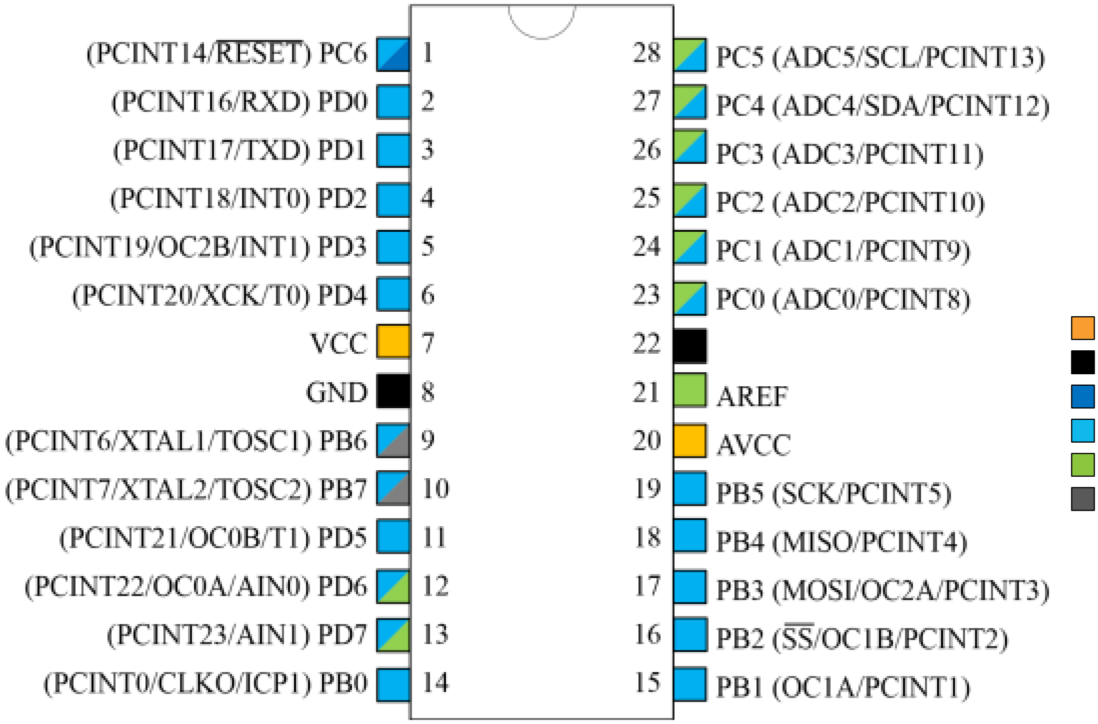
Features	ATmega328/P
Pin Count	28/32
Flash (Bytes)	32K
SRAM (Bytes)	2K
EEPROM (Bytes)	1K
Interrupt Vector Size (instruction word/vector)	1/1/2
General Purpose I/O Lines	23
SPI	2
TWI (I^2C)	1
USART	1
ADC	10-bit 15kSPS
ADC Channels	8
8-bit Timer/Counters	2
16-bit Timer/Counters	1

and support a real Read-While-Write Self-Programming mechanism. There is a separate Boot Loader Section, and the SPM instruction can only execute from there. In , there is no Read-While-Write support and no separate Boot Loader Section. The SPM instruction can execute from the entire Flash.

1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
2. Pb-free packaging, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green

Pin Configurations

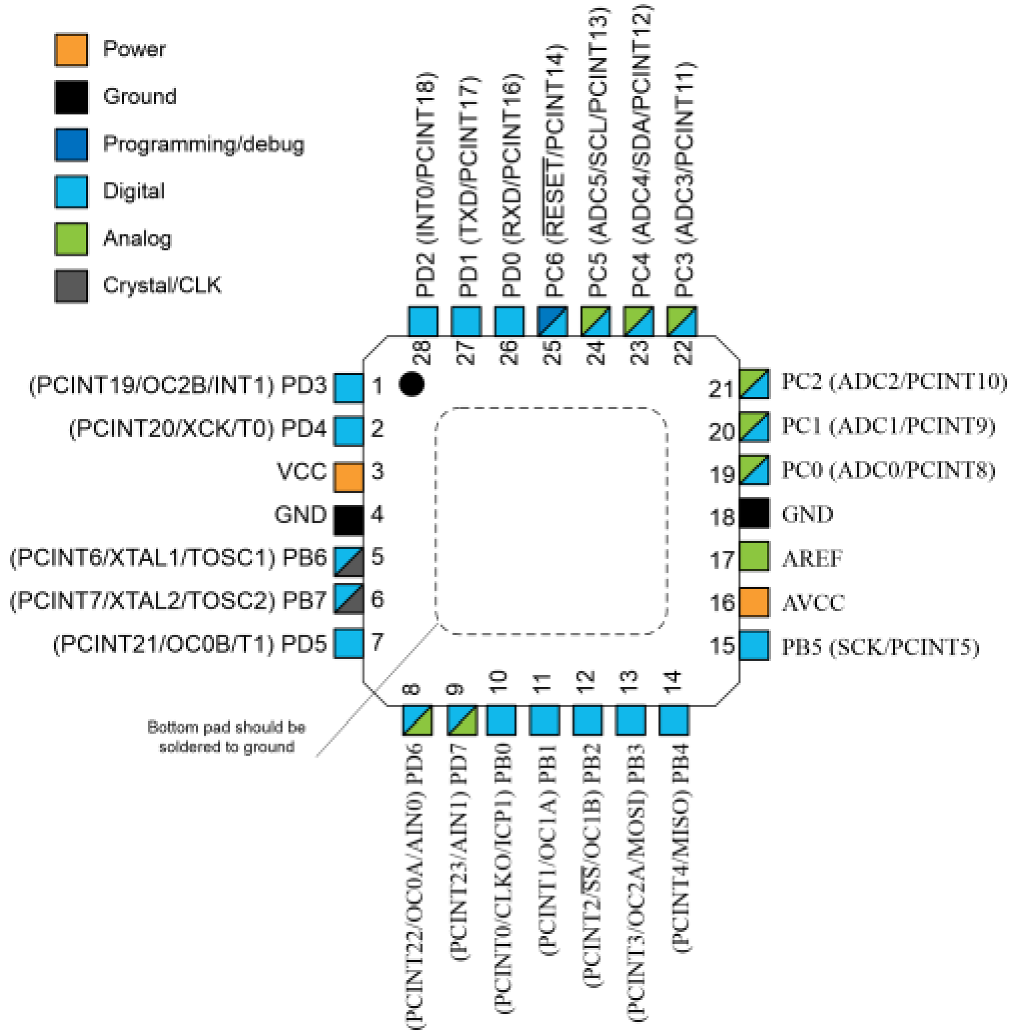
Pin-out



28-pin PDIP

GND

28-pin MLF Top View



Pin Descriptions

VCC

Digital supply voltage.

GND

Ground.

Port B (PB[7:0]) XTAL1/XTAL2/TOSC1/TOSC2

Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Depending on the clock selection fuse settings, PB6 can be used as input to the inverting Oscillator amplifier and input to the internal clock operating circuit.

Depending on the clock selection fuse settings, PB7 can be used as output from the inverting Oscillator amplifier.

If the Internal Calibrated RC Oscillator is used as chip clock source, PB[7:6] is used as TOSC[2:1] input for the Asynchronous Timer/Counter2 if the AS2 bit in ASSR is set.

Port C (PC[5:0])

Port C is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The PC[5:0] output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running.

PC6/RESET

If the RSTDISBL Fuse is programmed, PC6 is used as an I/O pin. Note that the electrical characteristics of PC6 differ from those of the other pins of Port C.

If the RSTDISBL Fuse is unprogrammed, PC6 is used as a Reset input. A low level on this pin for longer than the minimum pulse length will generate a Reset, even if the clock is not running. Shorter pulses are not guaranteed to generate a Reset.

The various special features of Port C are elaborated in the *Alternate Functions of Port C* section.

Port D (PD[7:0])

Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.

AV_{CC}

AV_{CC} is the supply voltage pin for the A/D Converter, PC[3:0], and PE[3:2]. It should be externally connected to V_{CC}, even if the ADC is not used. If the ADC is used, it should be connected to V_{CC} through a low-pass filter. Note that PC[6:4] use digital supply voltage, V_{CC}.

AREF

AREF is the analog reference pin for the A/D Converter.

ADC[7:6] (TQFP and VFQFN Package Only)

In the TQFP and VFQFN package, ADC[7:6] serve as analog inputs to the A/D converter. These pins are powered from the analog supply and serve as 10-bit ADC channels.

3-Axis CNC/Stepper Motor Shield for

The Arduino CNC Shield makes it easy to get your CNC projects up and running in a few hours. It uses opensource firmware on Arduino to control 4 stepper motors using 4 pieces of A4988 Stepper Motor driver breakout board, with this shield and ArduinoUno/Mega, you can build all kinds of robotics, linear motion project or projects including CNC routers, laser cutters and even pick&place machines.

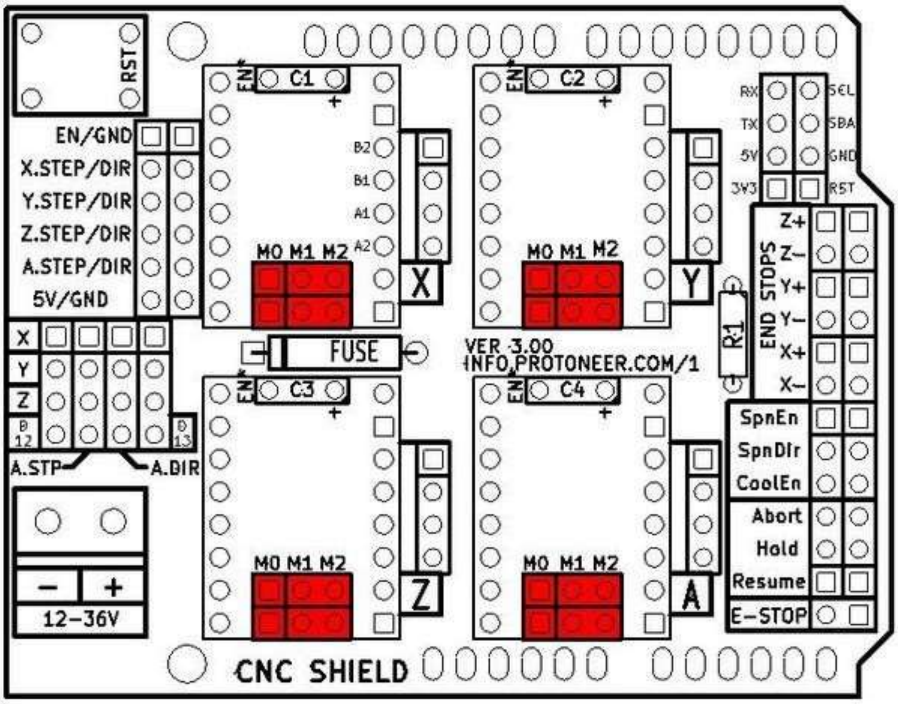
SKU: **DRV1001**

Brief Data:

- GRBL 0.9 compatible. (Open source firmware that runs on an Arduino UNO that turns G-codecommands into stepper signals)
- 4-Axis support (X, Y, Z , A-Can duplicate X,Y,Z or do a full 4th axis with custom firmware usingpins D12 and D13)
- 2 x End stops for each axis (6 in total)
- Coolant enable
- Uses removable A4988 compatible stepper drivers. (A4988, DRV8825 and others)(Not Included)
- Jumpers to set the Micro-Stepping for the stepper drivers. (Some drivers like the DRV8825 can doup to 1/32 micro-stepping)
- Compact design.
- Stepper Motors can be connected with 4-pin Molex connectors or soldered in place.
- Runs on 12-36VDC. (At the moment only the DRV8825 drivers can handle up to 36V so pleaseconsider the operation voltage when powering the board.)

1. Configuring Micro Stepping for Each Axis

Each axis has 3 jumpers that can be set to configure the micro stepping for the A4988 plug-in driver board.



Micro-stepping jumper location, before inserting A4988.

In the tables below „High" indicates that a jumper is insert and „Low" indicates that no jumper is inserted.

MS0	MS1	MS2	Microstep Resolution
Low	Low	Low	Full Step
High	Low	Low	½ Step
Low	High	Low	¼ Step
High	High	Low	$^{1}/_{8}$ Step
High	High	High	$^{1}/_{16}$ Step

After setting the microstep jumper, you can plug-in A4988 driver boards as shown in the photo below. The photo also shown this CNC sit nicely on top of Arduino Uno board, without any external jumper wires.

!!! Beware of the orientation of the A4988 driver boards! You will destroy the A4988driver board if plug-in with wrong orientation.

2. GRBL Control Software/Firmware for Arduino

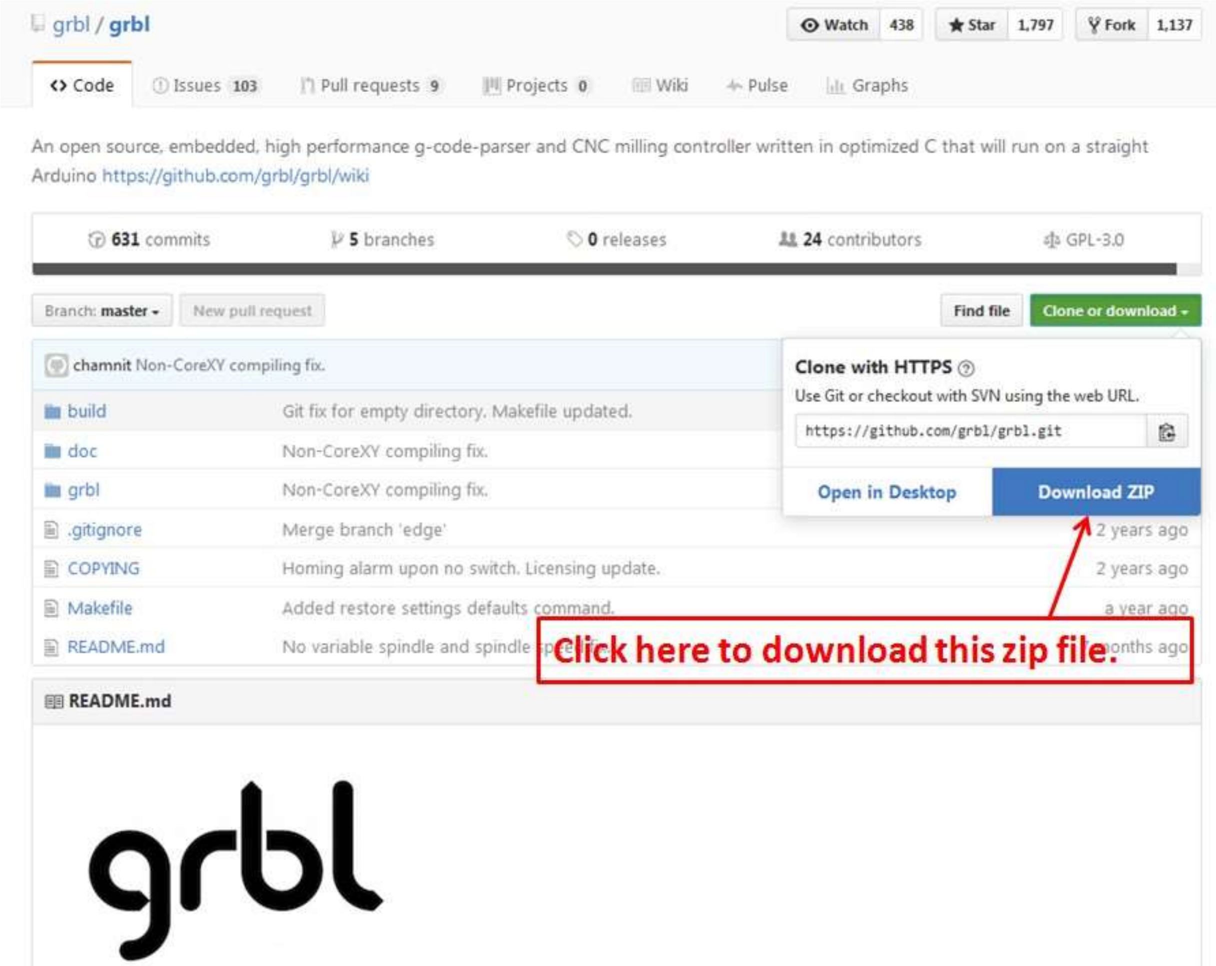
Before you can use this CNC shield with Arduino, a control firmware need to be downloaded into Arduino board. We are going to use „GRBL" to accomplish our job. GRBL is open-source software that runs on an Arduino Uno that takes G-Code commands via Serial and turns the commands into motor signals. Grbl is a no-compromise, high performance, low cost alternative to parallel-port-based motion control for CNC machine. It accepts standards-compliant g-code and has been tested with the output of several CAM tools with no problems. Arcs, circles and helical motion are fully supported, as well as, all other primary g-code commands. Macro functions, variables, and most canned cycles are not supported, but we think GUIs can doa much better job at translating them into straight g-code anyhow.

A copy of this open-source firmware can be downloaded from

the below link: Following the below steps to prepare this CNC

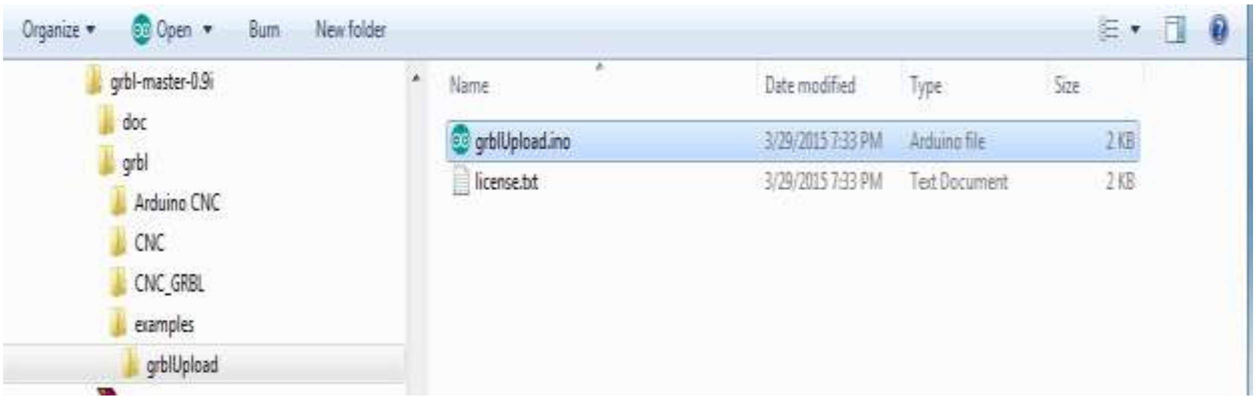
Shield board to function properly:

1. Download a copy of GRBL from: https://github.com/grbl/grbl

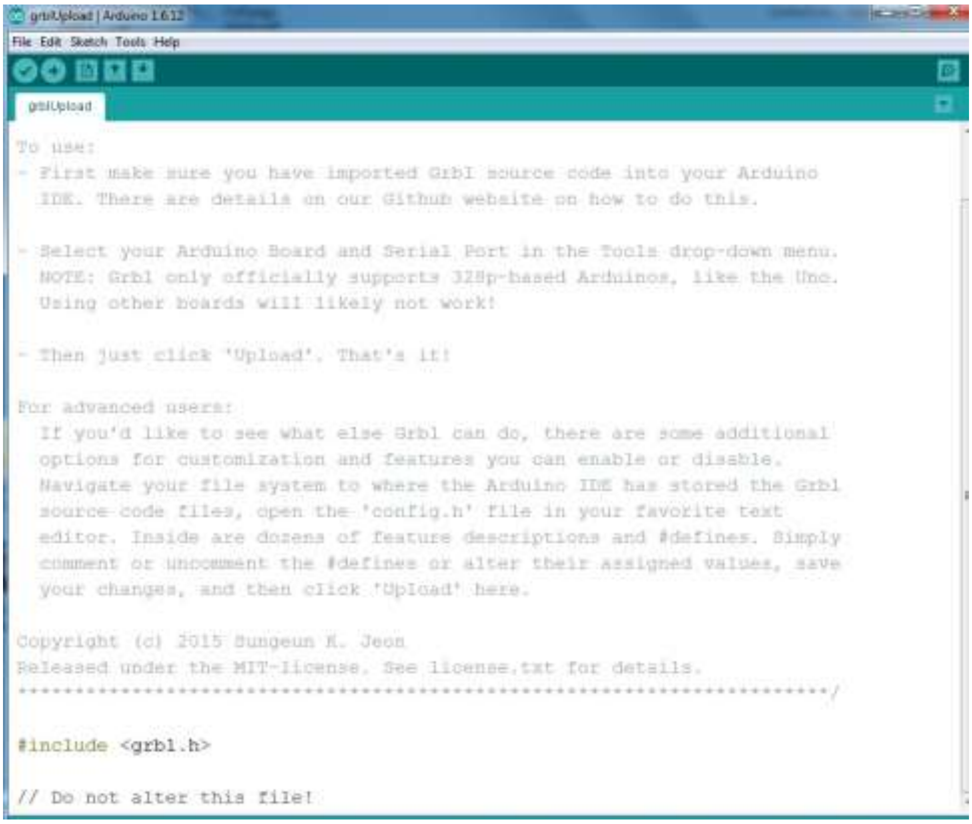


Unzip this file into your local hardisk location, you may want to create a special new folder for this purpose for easy locating of all files needed in your project. Locate an Arduino sketch „***grblUpload.ino***" in this folderwhere you have unzip the files.

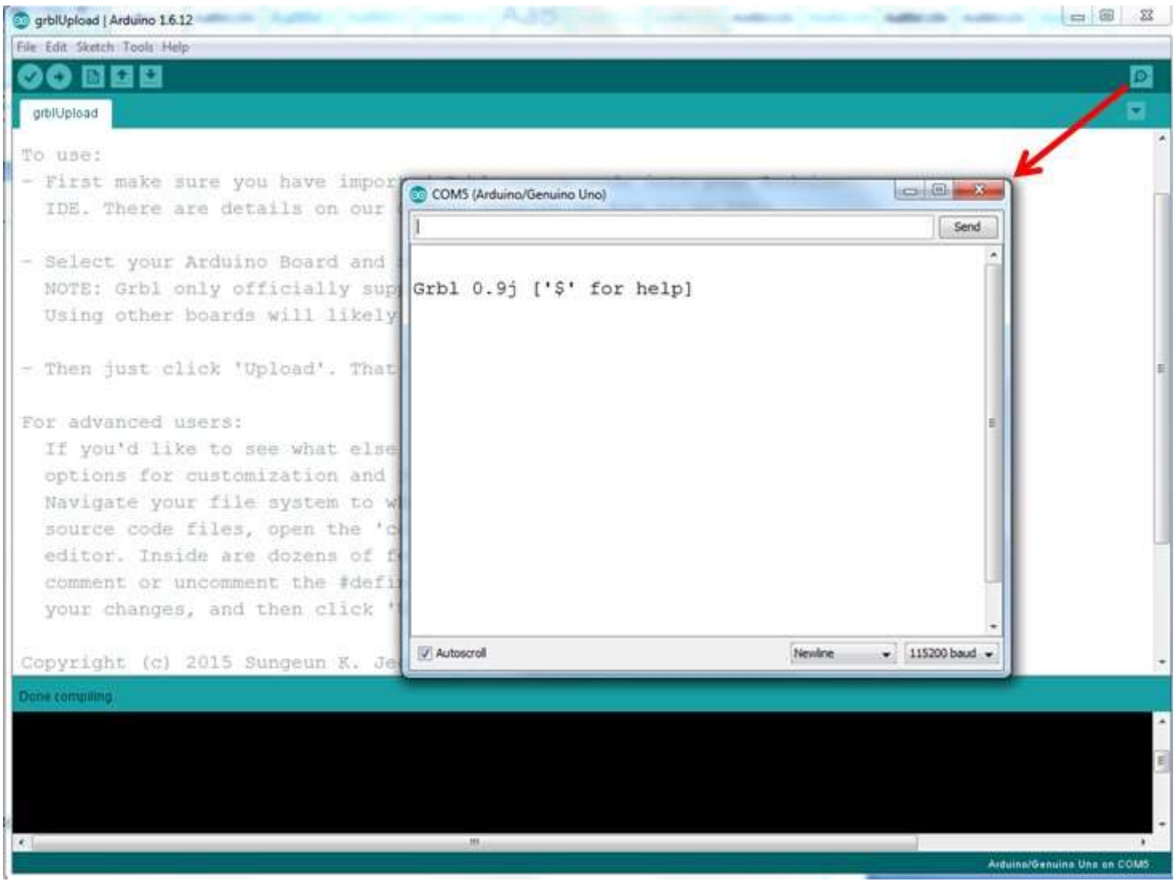
Below is the files structures located in my local hardisk:



Open up this sketch „***grblUpload.ino***" and you should see the screen as below:



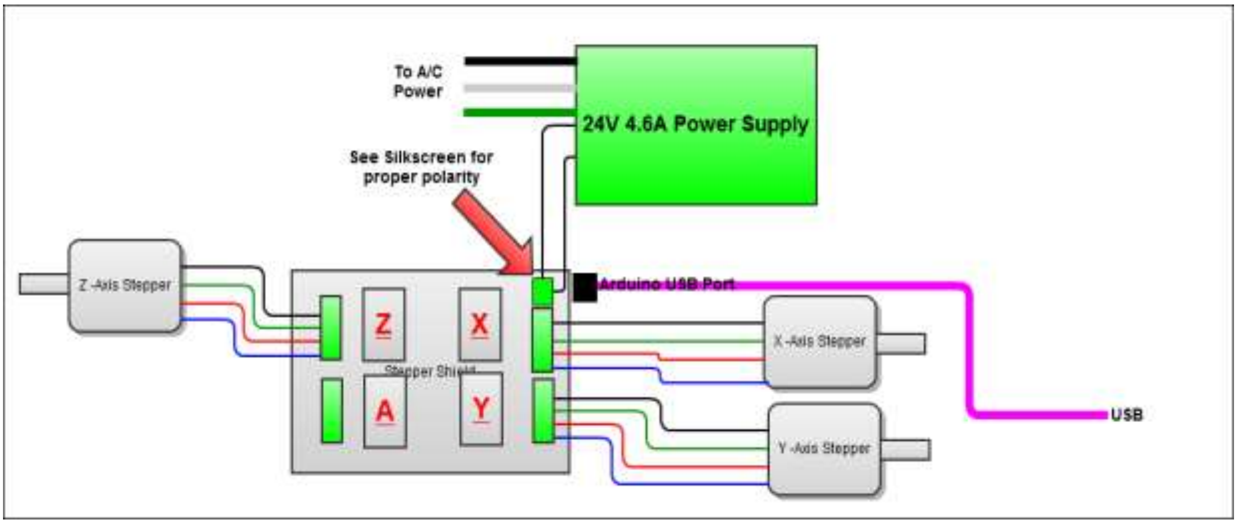
Click the upload icon as usual to „compile/upload" as you normally upload Arduino sketch. When you see
„done uploading", click the „Serial Monitor" on Arduino IDE as shown below:

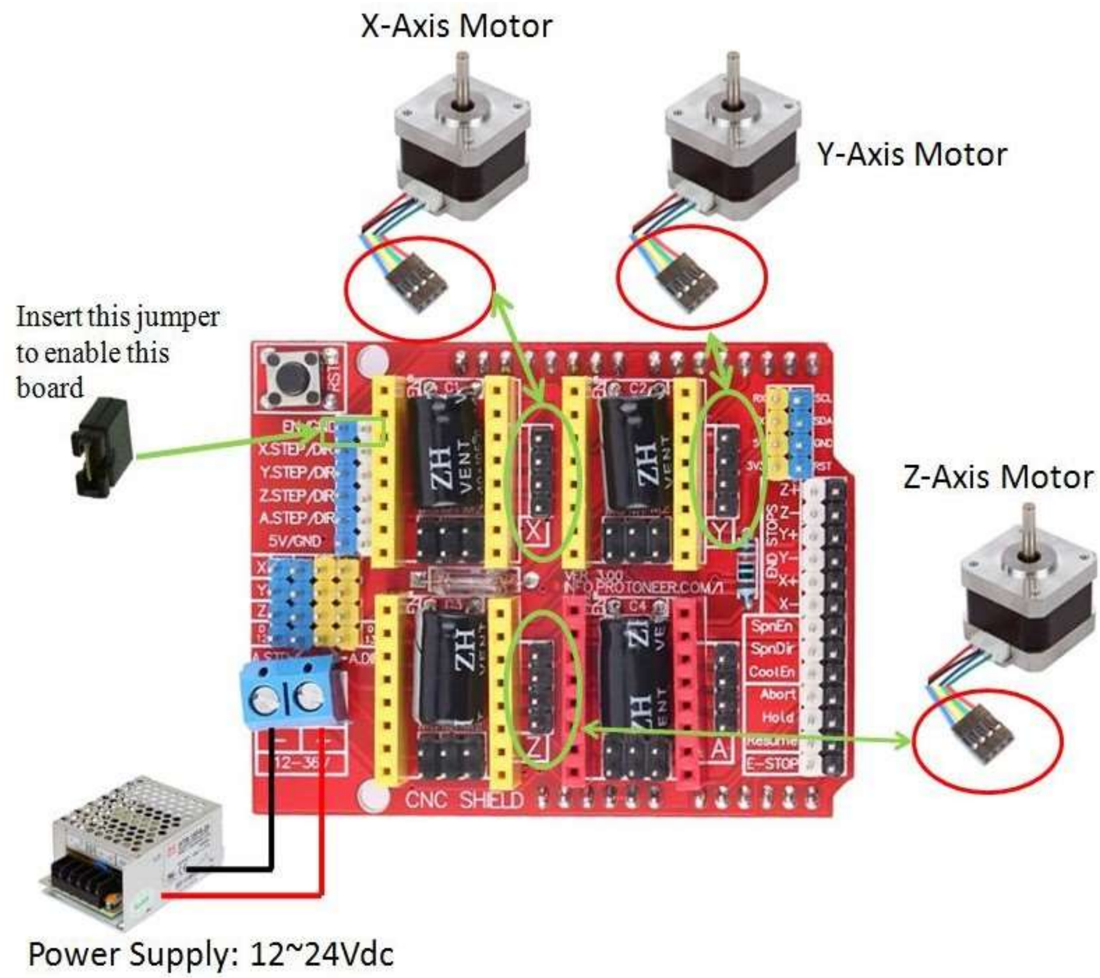


If you can receive response message " ***Grbl 0.9j ['$' for help]*** " from your Serial Monitor, congratulation!You have successful uploaded the „GRBL" firmware into your Arduino board.

3. Hooking Up the Stepper Motor to CNC Shield

Connect steppers motor to CNC Shield board as the below block diagram. of the CNC Shield connected to 3-steppermotor:





Your CNC Shield board is now ready to go for a test run, let's try to turn the motor as to our instruction !!

4. G-Code Sender

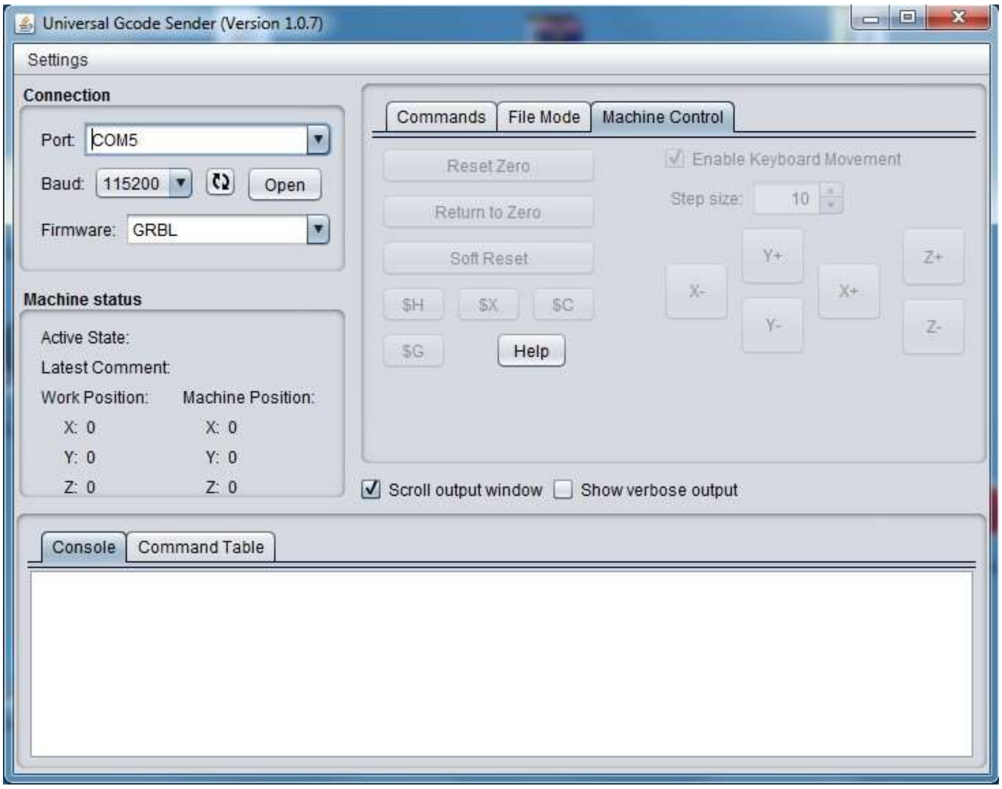
To send commands to your CNC/3-axis stepper motor driver board you need a g-code sender to send command andinstruction.

[Download the Universal-G-Code-Sender.]

Universal GcodeSender is a Java based GRBL compatible cross platform G-Code sender. Use this program to run a GRBL controlled CNC machine. Once downloaded, connect the UNO board USB to your computer and take note of the COM port it is connected to.

Run the *start-windows.bat* or the

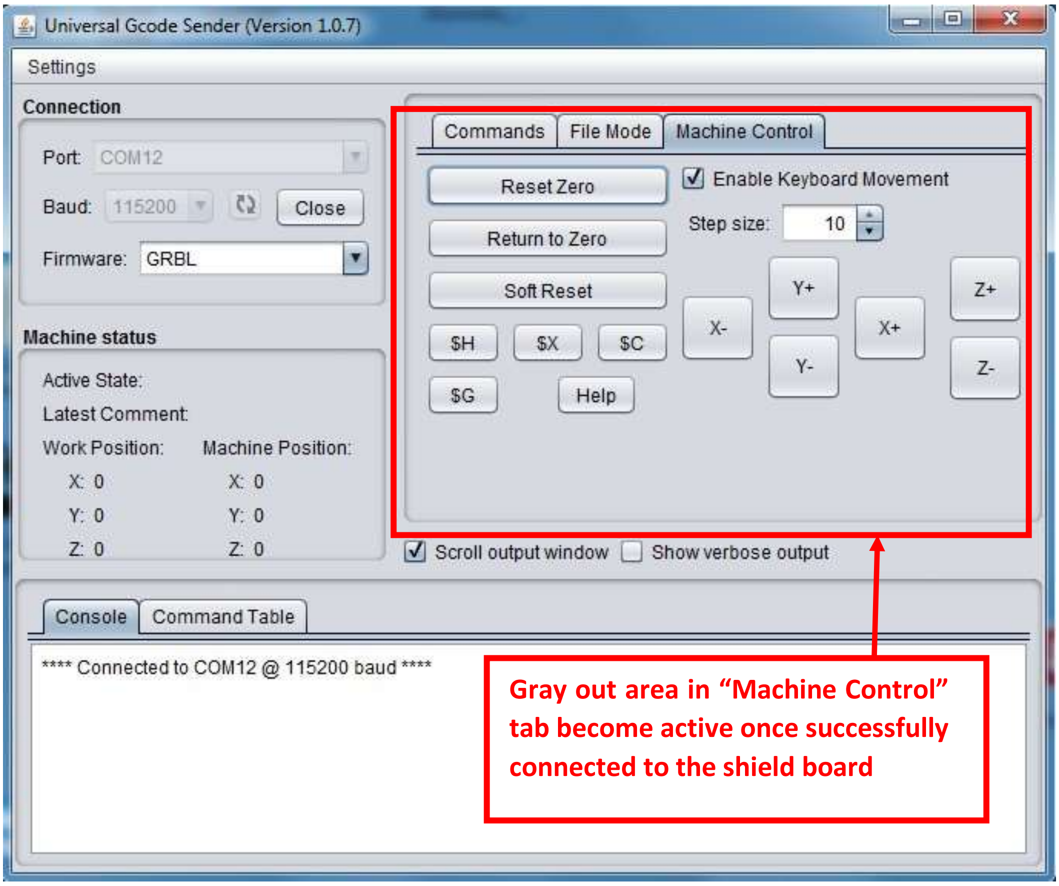
JAR file directly.You will be



presented with the following

screen:

Click the "Machine Control" tab. Select the "Port" number which your Arduino board is attached to. Select 115200 asthe Baud rate as this is the speed configured in "GRBL" firmware. Click "Open" button to start the communication for controlling this shield board.



Now, you are ready to control the XYZ stepper motor connected to shield board. Click X+ or X- for example, thestepper motor attached to X terminal will turn in forward or reverse direction.

This will complete our initial setup for driving 3-axis stepper motor connected to this shield board with "GRBL" loaded to Arduino controller board using "Universal G-Code Sender" user interface.

555 Low Voltage DC Motor

Low Voltage DC motor with built-in cooling fan. High torque with wide operating voltage 6~20Vdc. Suitable for motor tools application and DIY projects.

SKU: FAM1033

Specifications:

- Motor Type: 555.
- Dimensions: Ø35.8 X 57.0 mm
- Shaft Diameter: Ø3.175 mm
- Input Voltage: 6~20 VDC.
- No Load Speed: 7400RPM @ 12V.
- Stall Torque: 334mNm.
- Maximum Output Power: 46W.
- Operation Temperature: -10 to 50 °C
- Electrical Connection: Terminal.
- Weight: 225g.

Application:

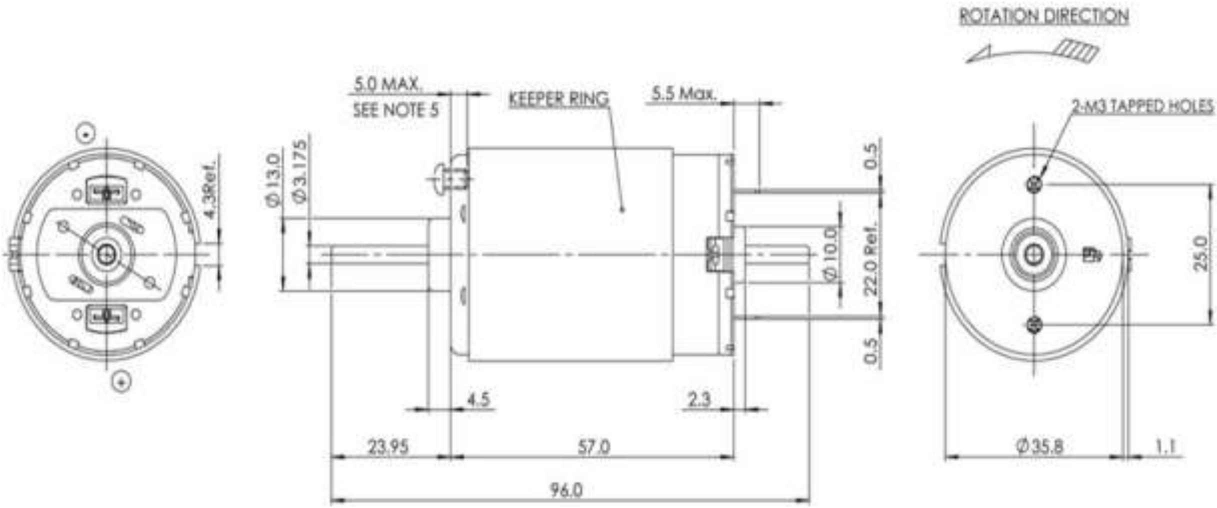
- CNC Machine
- Robotics
- Linear Motion

Features:

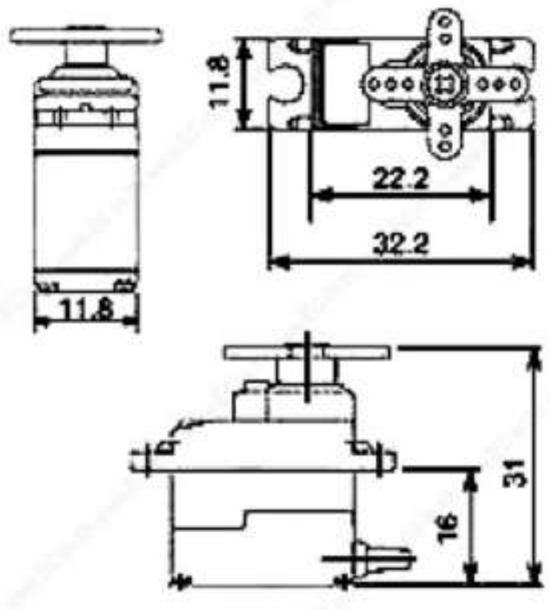
- 12VDC Supply Voltage
- Sintered bronze bearings
- Spur gear head
- All ratios with 4mm output shaft RE280, RE280/1 and RE280/5 motors available
- Maximum 2° no load backlash

Mechanical Dimension:

Unit: mm



SG90 9 g Micro Servo

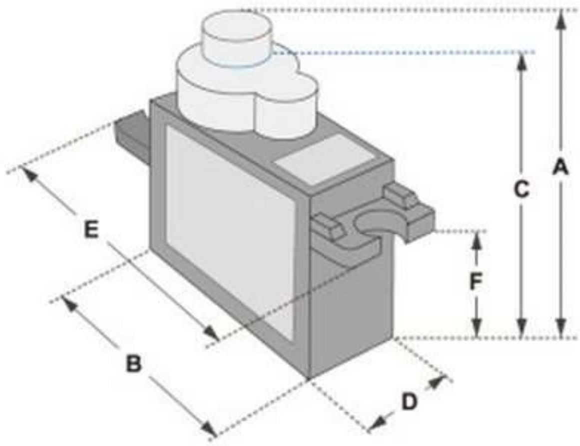


Tiny and lightweight with high output power. Servo can rotate approximately180 degrees (90 in each direction), and works just like the standard kinds but*smaller*. You can use any servo code, hardware or library to control these servos. Good for beginners who want to make stuff move without building a motor controller with feedback & gear box, especially since it will fit in small places. It comes with a 3 horns (arms) and hardware.

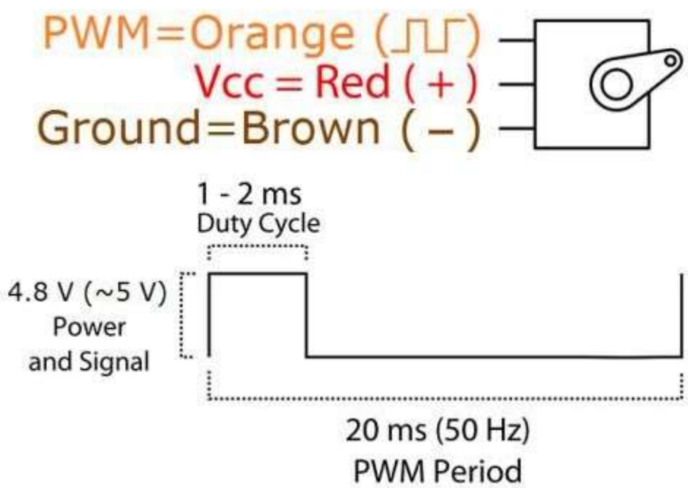
Applications :

- Robotics
- Machine tools
- Printing presses
- Conveyer and handling systems
- Food and beverage
- Subsea and oil and gas

Position "0" (1.5 ms pulse) is middle, "90" (~2ms pulse) is all the way to the left.ms pulse) is all the way to the right, ""-90" (~1ms pulse) is all the way to the left.



Dimensions & Specifications
A (mm) : 32
B (mm) : 23
C (mm) : 28.5
D (mm) : 12
E (mm) : 32
F (mm) : 19.5
Speed (sec) : 0.1
Torque (kg-cm) : 2.5
Weight (g) : 14.7
Voltage : 4.8 - 6



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A Mini CNC PCB Plotter Using Arduino - UNO

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ABSTRACT: This project demonstrates how to use an Arduino Uno to create a mini CNC PCB plotter. This project walk you through building a CNC plotter so it will be inexpensively design and print PCBs at home. It uses stepper motors and rails from DVDs and CD ROMs to create a small CNC PCB plotter for the X, Y, and Z axes. The maximum printing area for our example project will be 4*4 cm. The project works on serial communication. The need for computer numeric control (CNC) plotter machines is quite strong these days due to technological advancements. Low-cost printed circuit boards (PCBs) are in high demand as purchasing PCBs from businesses or the internet may be expensive. With the use of a small CNC PCB plotter, anybody may now affordably print their own PCBs at home. They can effectively and cheaply print and design their own PCBs, and they can innovate without worrying about incurring large costs. Numerous industries, including education, hobbies, new technologies, and engineering students, will use this initiative. This article shows off a reasonably priced little CNC PCB plotter model. Additionally, you may use this gadget to sketch paintings, tattoos, wood carvings, and laser printing as needed. As said, this system will be completely functional and include some multitasking functions. With the help of accessible components and sets of algorithms, this project will be able to sketch and sculpt a circuit on a PCB. Initially, the user must use any program, such as "inks space," to convert the picture file into G code before feeding it to the computer via processing software. In this project, the controlling device is an Arduino Uno. In a CNC plotter, it converts G-code into machine instructions that are supplied to the motor driver.

KEYWORDS: Arduino-uno, CNC Shield, Driver, Servo Motor, Stepper Motor, Dc Motor.

I. INTRODUCTION

A CNC plotter machine focus on making a 2d image or engraving a image as per needs on a plane surface. The Arduino based mini CNC PCB plotter is a computer controlled system. It uses a Microcontroller and CNC shield with motor drivers to control moments of the X,Y&Z axis. Stepper motor with rails extracted from Cd drivers a CNC shield, motor drivers, Arduino Uno a 12v DC motor are components used for the project. The project works on serial communication. The image is turned into a G code through "ink space" software this G-code is convert to machine code that controls the movements of the X,Y& Z axis. 12v Dc motor, pen, laser or any other engraving mechanical tool can be used in mechanism. It will have a 4*4cm printing area. The purpose is to make it a PCB printer but can also used for multiple purpose like wood carving, sketching, laser printing. This CNC plotter can print difficult designs that take times to do it manual it saves time, cost and manual work. This project is a low cost project, has great reliability & efficiency. It can design our own PCB at low cost and innovate new things for future, students can innovate new things by designing and printing their own PCB's. This project will be used in many sectors like educational use, hobbyist, industries, new innovations, engineering students. This paper demonstrate the building of mini CNC PCB plotter for X,Y,Z axis using stepper motors and rails from DVD's, CD ROM's. For this demo project printing area will be maximum 4*4 cm This project works on serial communication. Due to advancement in technology now a days, demand for computer numeric control (CNC) plotter machine is very high. Printing (PCB) printed circuit board from companies or online is costly so low cost PCB's are on high demand. Now anybody can print their own PCB at home in low cost by use of mini CNC PCB plotter. They can print and design their own PCB's at low cost and efficiently and innovate new thing without any fear of high costing .

This mini CNC PCB plotter, designed with affordability and functionality in mind, caters not only to cost-sensitive environments but also to those seeking hands-on educational tools. The integration of commonly available components like stepper motors from DVD or CD ROM drives and the utilization of a straightforward Arduino Uno and CNC shield setup underscores the project's approachability and ease of assembly. The software side is equally user-friendly; converting designs into G-code via the open-source "Inkscape" software, which then interprets these designs for precise machine operation, allows even beginners to start producing their own PCBs or other small-scale engravings with minimal learning curve. The versatility of the device extends beyond PCB fabrication. Its capability to adapt various tools, such as pens for sketching or lasers for engraving, makes it a multi-purpose machine suitable for a wide array of applications—from educational projects in schools to crafty undertakings in home workshops. The small footprint of the machine does not limit its potential; rather, it provides a compact solution that fits well in limited spaces while still offering substantial functionality. This CNC plotter also opens up avenues for experimentation and innovation, particularly in academic settings where engineering students can explore the realms of

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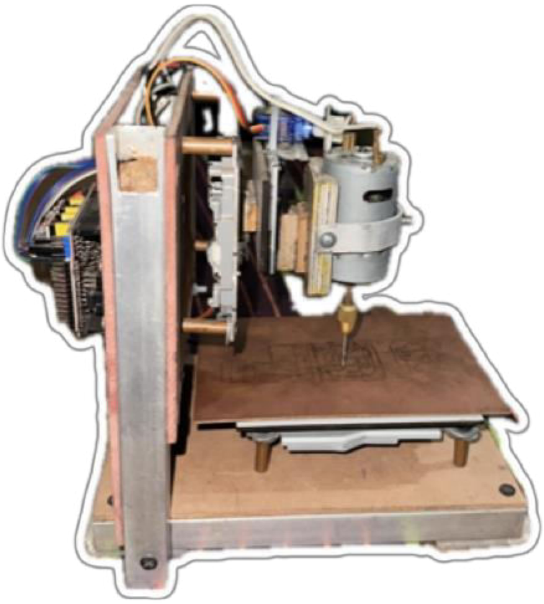
mechanical and electronic design. By enabling the rapid prototyping of PCBs and other materials, it encourages iterative design processes, critical thinking, and creativity, all of which are essential skills in the modern engineering landscape. Moreover, the DIY aspect of building the plotter from scratch using recycled components is in line with sustainable practices, adding an element of environmental consciousness to the project. It demonstrates that high-tech innovation doesn't necessarily require expensive resources and can be achieved with a blend of simple yet effective technology and a creative reuse of materials. This aspect is particularly appealing to hobbyists and educators who advocate for sustainable engineering solutions. In summary, the development of this mini CNC PCB plotter not only addresses the demand for low-cost PCB production but also fosters a broader engagement with technology, from individual tinkerers to institutional educators, thereby contributing to a culture of innovation and self-reliance in various sectors.

Mini CNC PCB Plotter



II. RELATED WORK

The field of mini CNC PCB plotters has seen considerable development, spurred by advancements in digital fabrication and the increasing accessibility of CNC technology. Several related works have contributed to this progress. Notably, various DIY and open-source projects have democratized the technology, with platforms like Instructables and GitHub hosting numerous designs and modifications that enhance the functionality and user-friendliness of these devices. Academic research has also played a pivotal role, focusing on improving the precision and efficiency of CNC machines specifically tailored for PCB milling. Studies often explore the optimization of parameters such as spindle speed, feed rate, and cutting depth to minimize errors like overcutting and ensure the integrity of the delicate traces and pads on PCBs. Commercially, companies have developed compact and more affordable CNC machines that are suitable for desktop use in small workshops or educational environments. These units frequently incorporate software improvements, such as integrated CAM (Computer-Aided Manufacturing) tools, which simplify the process of going from PCB design to physical board. Furthermore, enhancements in hardware, like the incorporation of more robust and precise stepper motors and the use of durable milling bits, have significantly increased the reliability and lifespan of these plotters. Additionally, the expansion of supportive ecosystems around these tools, including forums, online tutorials, and dedicated software, reflects a comprehensive approach to not just developing a product but fostering a community that can use and improve upon it. This holistic development in the realm of mini CNC PCB plotters illustrates a trend not only towards technical innovation but also towards creating more inclusive and accessible technology platforms.

The surge in innovation and accessibility in the mini CNC PCB plotter domain is further complemented by the integration of advanced sensing technologies, which provide real-time feedback and adjustments during the milling process. This incorporation enhances precision by dynamically compensating for any potential inaccuracies or material inconsistencies, which is crucial for achieving the high tolerances required for modern PCB designs. Additionally, the emergence of hybrid models that combine traditional milling with additive manufacturing techniques, such as ink deposition or solder paste application, represents a significant step towards more versatile desktop fabrication tools. This convergence of technologies not only broadens the scope of applications for these plotters but also offers users the ability to execute multiple fabrication steps with a single machine, streamlining the PCB production process. Environmental considerations are also becoming increasingly important. Developers are focusing on reducing the noise and dust generated by these machines, making them more suitable for indoor use without requiring extensive safety or ventilation systems. Furthermore, the use of recycled or biodegradable materials for machine components and consumables is beginning to be explored, reflecting a growing commitment to sustainability within the industry. The educational impact of these tools cannot be overstated. By providing students and hobbyists access to affordable, yet powerful, fabrication tools, mini CNC PCB plotters serve as practical learning platforms for engineering, robotics, and electronics. Educational institutions are increasingly incorporating these tools into their curricula, thereby nurturing a new generation of engineers and designers who are well-versed in the intricacies of digital fabrication technologies. Thus, the evolution of mini CNC PCB plotters not only reflects technological advancements but also a broader cultural shift towards more sustainable, accessible, and integrated approaches to engineering and design. This shift is likely to continue driving innovation in the field, as users and developers together push the boundaries of what these compact yet powerful machines can achieve.

III.METHODOLOGY

The methodology for operating a mini CNC PCB plotter typically involves several key steps, starting with the design and setup, followed by the actual plotting process, and concluding with post-processing. Initially, users design their printed circuit board (PCB) layouts using specialized software, such as Eagle CAD or KiCad. This design software enables the creation of the schematic and board layout, which are essential for defining the electrical connections and physical dimensions of the PCB. Once the design is finalized, it is converted into a standard Gerber file format, which serves as a blueprint for the CNC plotter. The next phase involves setting up the mini CNC plotter. This includes securely mounting a blank copper-clad board onto the machine's work area and ensuring that the plotter's tools, typically a sharp, fine-pointed V-bit or an engraving bit, are properly installed and calibrated for precise depth control. The machine's software then imports the Gerber files and translates them into commands that guide the CNC plotter's movements. During the plotting process, the CNC machine meticulously mills the copper layer of the PCB, removing unwanted copper to leave behind only the traces that form the circuit layout. This is done with high precision to avoid any errors that could cause short circuits or breaks in the traces.

The control software also plays a critical role in monitoring and adjusting the spindle speed and feed rate according to the board's material density and the complexity of the circuit patterns. These adjustments are essential to prevent damage to the thin copper traces during milling and to achieve the cleanest cuts possible. In addition to this, the software can utilize probe sensors to map the surface of the copper-clad board. This surface mapping allows the CNC plotter to adjust the cutting depth dynamically, compensating for any irregularities in the board's surface, which is crucial for maintaining uniform trace depths across the entire PCB. After the milling is complete, the mini CNC plotter often performs a second pass to clean up any residual copper particles that might have been left behind, ensuring the traces are clearly defined and isolated. This step enhances the reliability of the PCB by minimizing the risk of electrical faults. Post-processing includes carefully removing the milled PCB from the plotter and cleaning it to remove any copper shavings or debris. Users then typically inspect the board for any errors or imperfections, using magnification tools if necessary. Final steps may involve drilling holes for through-hole components and applying a protective coating to prevent oxidation of the copper traces. This coating also helps to improve the solderability of the PCB during component assembly. This comprehensive approach not only ensures the production of high-quality PCBs but also enhances the user's ability to consistently produce complex electronic circuits with precision and efficiency using a mini CNC PCB plotter.

IV.EXPERIMENTAL RESULTS

In this project the development of an Arduino-Uno-based, portable, dependable, three-axis tiny CNC PCB plotter is described. The CNC machines now on the market come at a heavy cost. Maintaining it takes a highly experienced operator and is rather challenging. The CNC machine solves this issue since it is affordable, dependable, portable, and it does not require a highly skilled person to run the apparatus. The equipments are very simple to maintain and reasonably priced. Compared to other machines on the market the working hours of this machine is extended. As the machine can be alter to suit the demands, it becomes more flexible. More features can be added to the CNC PCB plotter. A precise and accurate PCB with fine traces and

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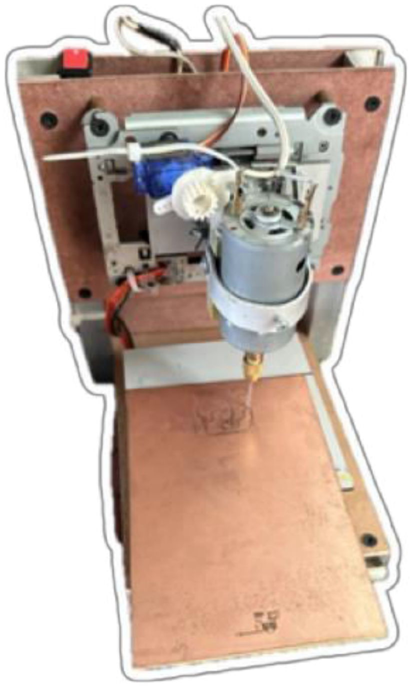
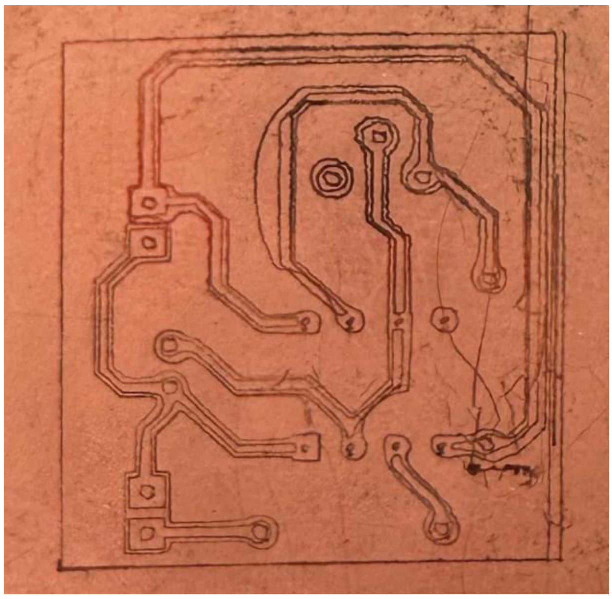
distinct features should be able to be produced using a well-designed and calibrated small CNC PCB plotter. The productivity of the CNC plotter, which includes traverse and cutting speeds, will affect how long it takes to finish a PCB. Productivity may be increased by using faster and more effective processes. The CNC plotter's resolution, ascertained Achievable detail will depend on variables like lead screw pitch and stepper motor accuracy during PCB design.

This project introduces a compact and affordable CNC PCB plotter based on Arduino Uno. Unlike many expensive CNC machines available, this plotter is designed to be easy to use, maintain, and transport. You don't need specialized skills to operate it, and maintenance is straightforward and inexpensive. Plus, it offers extended working hours compared to other machines. Being adaptable to various demands, it's highly flexible, allowing additional features to be incorporated. With precise calibration, it can produce intricate PCBs with fine traces and clear features. The speed at which it operates, both in traversal and cutting, affects productivity, which can be enhanced with faster processes. The level of detail achievable depends on factors like the precision of stepper motors and lead screw pitch during PCB design.

V. CONCLUSION

A mini CNC PCB plotter represents a significant advancement for hobbyists, educators, and small-scale developers in the field of electronics manufacturing. Compact, precise, and highly adaptable, these plotters transform the process of PCB creation from a cumbersome, chemically intensive procedure to a streamlined, digital fabrication process. By allowing users to rapidly prototype PCBs with high accuracy directly from their digital designs, mini CNC plotters not only save time but also reduce waste and costs associated with traditional methods. The integration of such technology into workshops and educational settings promotes a deeper understanding of both design and manufacturing processes, empowering users to experiment more freely and





innovate. Moreover, the ability to iterate designs quickly enhances troubleshooting and optimization of electronic circuits, accelerating the development cycle and leading to better outcomes in projects. In conclusion, mini CNC PCB plotters stand out as transformative tools in electronics fabrication. They encapsulate the merging of digital precision with physical production, offering a gateway to sophisticated electronics manufacturing that is accessible even in a non-industrial setting. This technology is not just about creating more efficiently; it's about inspiring a new generation of inventors and engineers who can bring their ideas to life with unprecedented ease and speed.

This shift towards using mini CNC PCB plotters is revolutionizing how electronics are made, especially for those who work in small-scale settings or educational environments. These machines allow for quick and precise production of PCBs right from digital files, eliminating many of the traditional steps that were both time-consuming and hazardous due to the chemicals involved. This makes the process cleaner, faster, and much less wasteful, which is not only good for the environment but also lowers costs. With these plotters, students and hobbyists can see their projects come to life much faster, making it easier to test ideas and make improvements on the fly. This rapid iteration is invaluable for troubleshooting and perfecting electronic devices, significantly speeding up the learning and development process. Ultimately, mini CNC PCB plotters are more than just tools for

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cutting circuit boards—they are enablers of innovation and creativity. They democratize access to advanced manufacturing techniques, making it possible for anyone with an idea to explore complex electronics projects. This is not only empowering but also encourages a whole new generation of tech enthusiasts to translate their visions into tangible, working prototypes without the barriers of traditional PCB fabrication techniques. This way, mini CNC PCB plotters are paving the way for future innovations in electronics by making sophisticated manufacturing accessible to all.

VI. FUTURE SCOPE

By adding a 3D pen or heatend, this machine may be improved to become a 3D printer. Devices like pens, lasers, drilling machines, engraving machines, and so on, can have removable slots added to them. It is possible to include a camera sensor that will automatically translate an image or object into G-code for printing when it is detected. The bluetooth component or wifi module has wireless printing capabilities. It is possible to create a cloud-based printing project goal at any time and from anywhere. For this project, an android or web application that can automatically convert images to G-code and upload them to the machine may also be made. An auto sholdering device and an automated PCB component planter might improve this project. Workspace of the The machine can be scaled up without changing the algorithm. The method may be improved by using premium elements. The PCB printing time can also be lessen and make the printing more faster. Imagine upgrading a regular machine to a 3D printer by adding a special pen or a heating tool. You could also make slots for other tools like lasers or drills. Plus, you can add a camera that turns pictures into instructions for printing. With Bluetooth or Wi-Fi, you could print wirelessly, even from far away using a cloud-based system. You could even make an app that turns images into printing instructions and sends them to the machine. Adding devices for soldering and planting PCB components could make it even better. And you could make the workspace bigger without changing how it works. Using better materials could make it work even smoother and faster, especially when printing PCBs.

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