3 AXIS CNC MACHINE USING MICROCONTROLLER

BS Computer Science (Session 2019-23)

Submitted by

Muhammad Arbaz Khan (Roll No 1961115)
Abu Bakar (Roll No 1961105)

Supervised by

Mr. Ahmad Hussain

Department of Computer Science
Govt. Post Graduate Jahanzeb College Saidu Sharif Swat
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3 AXIS CNC MACHINE USING MICROCONTROLLER

By

Muhammad Arbaz Khan (Roll No 1961115)
Abu Bakar (Roll No 1961105)

Submitted to

Department of Computer Science
Govt. Post Graduate Jahanzeb College Saidu Sharif Swat

Date of Submission (17 August 2023)

Abstract

In modern industries, Computer Numerical Control (CNC) machines have revolutionized repetitive tasks, yet their high cost poses challenges for small businesses and individuals. This project centers on developing an affordable Arduino-based CNC machine that focuses on drawing tasks with user-defined scales, while also emphasizing low power consumption and portability.

Industries have noticed that using CNC machines is really helpful because they can do repetitive tasks very well. These machines have taken over jobs that used to be done by people. But, there's a problem. These machines are usually very expensive, and that makes it hard for small businesses and regular people to use them. So, the main goal of our project is to solve this problem and make CNC machines more affordable and accessible to more people.

By adopting Arduino technology, we aim to create a CNC machine optimized for different purposes. This endeavor not only ensures affordability but also emphasizes low power consumption and portability. This thesis outlines the journey undertaken to realize this multifaceted goal.

After introducing the significance of CNC machines and their limitations, we explore the rationale for developing a cost-effective and energy-efficient CNC solution. The core concept of this project revolves around the Arduino platform, renowned for its affordability and adaptability, resulting in a machine that's accessible to small businesses and families. The methods employed to design the machine's hardware, the required software, and its operational workflow are comprehensively discussed.

The output of this effort includes the creation of 3-axis CNC machine, a key factor in making the CNC machine both cost-effective and portable. We tested the machine with values and shapes and analyze the result to check its accuracy.

Considering the future, the thesis offers recommendations for enhancements. These include IOT integration, safety measures and auto tool picking.

To sum up, this thesis tells the story of creating a CNC drawing machine using Arduino that's affordable, easy to move around, and uses very little power. This project makes CNC technology available to more people, showing how we can make things accurately and efficiently without spending too much money.

Declaration

I hereby declare that this project with title **3 AXIS CNC MACHINE USING MICROCONTROLLER** neither as a whole nor as a part thereof has been copied from any source. Further, I declare that I have written reports entirely on the basis of my personal efforts, made under the sincere guidance of my supervisor. No portion of this work presented in this report has been submitted in support of an application for another degree or qualification of this or any other university or institution learning. If any part of this work is proved to be copied or found to be a report of some other, I will stand by the consequences.

Muhammad Arbaz Khan ________________________

Abu Bakar ________________________

Acknowledgement

In the name of Allah, The Creator and The Provider, we are very thankful to Him for blessing me with the power of knowledge and guide me to complete this project/thesis.

This project would not have been possible without the continuous support and help of Asst Prof. Ahmad Hussain Sir, who believed in us and supported us in every possible way. This project/thesis would not have been possible without their dedicated support and precious time to guide me all the way.

We would also pay huge respect to our parents and all the family members who have supported us. The endless patience displayed by them and support in our studies and plans throughout our journey has made it possible to achieve our goals.
May Allah bless this work of us with success and make it beneficial for mankind. (Ameen).

- Muhammad Arbaz Khan
- Abu Bakar

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Chapter 1

Introduction

1.1 Introduction

The use of Computer Numerical Control (CNC) machines has become increasingly popular in recent years due to their ability to automate the manufacturing process and produce highly precise parts. CNC machines are capable of controlling the movement of cutting tools along three or more axes, enabling them to create complex geometries with a high degree of accuracy and consistency.

1.2 History of CNC machine

The development of computer numerical control (CNC) technology is continuing the history of numerical control (NC), which began with the automation of machine tools and the introduction of concepts of abstractly programmable logic.[1]

The earliest NC machines were created in the 1940s and 1950s using modified tools that had motors attached to move the controls in order to track points fed into the system on punched tape. Analog and digital computers were quickly added to these primitive servomechanisms to produce the contemporary CNC machine tools that have revolutionized manufacturing techniques.

1.3 Motivation for the Project

The main motivation behind this project is to design and build a 3-axis CNC machine using a microcontroller. The use of a microcontroller allows for greater control over the machine's movements, making it easier to program and operate. Additionally, a microcontroller-based system can be more cost-effective, portable, and efficient than traditional CNC machines that rely on expensive and complex hardware.

The need for such a machine arises from the growing demand for precision manufacturing in industries such as aerospace, automotive, and medical devices. A 3-axis CNC machine can be used to create complex parts and components with a high degree of accuracy, which is essential in these industries.

Furthermore, the project aims to develop a machine that is user-friendly and can be easily operated by individuals with little to no experience in CNC machining. This is particularly important for small businesses and hobbyists who may not have access to expensive and sophisticated CNC machines but still require precise and accurate parts.

In summary, the main objective of this project is to design and build a 3-axis CNC machine using a microcontroller that is cost-effective, efficient, portable, and user-friendly. The machine will be capable of producing precise and accurate parts for a wide range of applications, making it a valuable tool for small businesses, hobbyists, and industries that require precision manufacturing.

1.4 Problem Statement

The problem statement for this project is to design and build a cost-effective and efficient 3-axis CNC machine using a microcontroller, while maintaining a high level of precision and accuracy in the manufactured parts. Traditional CNC machines can be expensive and complex, making them inaccessible for small businesses and individuals who require precise machining capabilities. Additionally, the process of programming and operating traditional CNC machines can be difficult, requiring specialized knowledge and training, also due to the large size of traditional CNC machines it is difficult to move the machine from one place to another.

1.5 Objective of the Project

The main objective of the project is to address the problems of high power consumption, high cost, huge size, and expertise required for operating the machine. So the project seeks to develop a machine that is user-friendly, and easy to operate, allowing individuals with little to no experience in CNC machining to create precise and accurate parts. Also, our developed CNC machine will be portable and easy to handle. By utilizing a microcontroller, the machine's movements can be precisely controlled and programmed, reducing the need for complex hardware and specialized knowledge.

1.6 Scope and Limitations of the Project

The machine will be capable of precise and accurate machining of a wide range of materials, including wood, plastic, and metals. The project will involve selecting appropriate hardware components, designing and programming the microcontroller-based system, and assembling and testing the machine.

However, there are certain limitations to the project. Firstly, the machine's machining capabilities will be limited by the power and speed of the cutting tools used and the rigidity of the machine's structure.

Another limitation of the project is the accuracy and precision of the machine. While the project aims to achieve a high level of precision and accuracy, it is unlikely to match the level of accuracy achieved by high-end, commercial CNC machines. This is because the project will be using cost-effective and readily available components, which may have limitations in terms of their precision and accuracy.

Finally, the project will be limited by the resources available, including time and budget constraints. The project will be conducted over a finite period of time and with a limited budget, which may restrict the scope and complexity of the machine.
Overall, the project will aim to create a cost-effective and efficient 3-axis CNC machine using a microcontroller that is suitable for a range of machining applications. While there are limitations to the project, it has the potential to contribute to the development of more accessible and user-friendly CNC machines.

1.7 Significance of the Project

The aim of this project is to create a 3-axis CNC machine that utilizes microcontroller technology. Although the primary objective is to fulfill academic requirements, the ultimate goal is to make the CNC machine available for purchase by small businesses. The machine's main advantage is its ability to provide precise and accurate results with minimal human intervention, which is particularly beneficial for small businesses seeking to improve their productivity and accuracy without incurring high labor costs or investing in costly manufacturing equipment.

Moreover, the CNC machine's utilization of microcontroller technology makes it straightforward to operate and program. This feature makes the CNC machine accessible to a broader range of small businesses, even those with little to no experience with CNC technology. This ease of use will allow small businesses to take advantage of the machine's benefits and enhance their productivity, leading to increased profitability and competitiveness.

1.8 Overview of the thesis structure

This thesis presents a comprehensive exploration of the development and evaluation of a portable and cost-effective 3-axis CNC drawing machine.

- **Chapter 1:** Introduction
  This chapter provides a foundational introduction to the project, its motivations, and the goals that were set.

- **Chapter 2:** Literature Review
  A comprehensive review of existing literature in the field of CNC technology is presented in this chapter.

- **Chapter 3:** Hardware Components Overview
  This chapter is representing the selection process of hardware components that are required for the building of CNC machine.

- **Chapter 4:** Software Overview
  This chapter is representing the software tools utilized, the communication between software and machine, and the conversion process from design files to machine-executable G-code.

- **Chapter 5:** Design and Frame Construction
  This chapter covers the 3D and mechanical structure, the layout considerations, and the integration of components to create a functional machine.

- **Chapter 6:** Testing and Results
  The testing phase is discussed in this chapter, including the methodologies employed to evaluate the CNC drawing machine's performance. Results and

data collected during testing provide insights into the machine's accuracy, precision, and efficiency.

- **Chapter 7:** Comparison with Commercial CNC Machine
  A comparative analysis is undertaken in this chapter, where the developed CNC drawing machine is evaluated against commercially available CNC machines. This analysis sheds light on the project's contributions and areas for further improvement.

- **Chapter 8:** Conclusion and Recommendations
  The final chapter offers a conclusive summary of the project's achievements. It addresses the project's limitations and identifies avenues for future work and enhancements in the field of portable and cost-effective CNC technology.

Chapter 2

Literature Review

2.1 Overview of CNC Technology and its Applications

Computer Numerical Control (CNC) technology has revolutionized the manufacturing industry by enabling the precision machining of complex geometries with high accuracy and consistency. CNC machines can be programmed to control the movement of cutting tools along multiple axes, allowing for the creation of intricate shapes and parts that would be difficult or impossible to produce using manual machining methods.

CNC technology has a wide range of applications in various industries, including aerospace, automotive, medical devices, and electronics. In aerospace, CNC machines are used to create complex parts for aircraft and spacecraft, such as turbine blades and structural components. In the automotive industry, CNC machines are used to manufacture engine components and chassis parts with high precision and accuracy. In the medical device industry, CNC machines are used to produce implants and other precision medical components.

CNC technology has also found applications in the production of consumer goods, such as furniture, jewelry, and electronic devices. In the furniture industry, CNC machines are used to create intricate designs and shapes in wood and other materials. In the jewelry industry, CNC machines are used to create intricate and detailed designs in precious metals and stones. In the electronics industry, CNC machines are used to manufacture printed circuit boards (PCBs) and other precision components.

Advances in CNC technology have led to the development of more advanced and sophisticated machines that are capable of performing complex machining operations with high precision and accuracy. For example, 5-axis CNC machines are capable of machining complex geometries with multiple angles and curves, making them suitable for creating parts with complex shapes and contours. Additionally, advances in software and programming tools have made it easier for individuals with little to no experience in CNC machining to create complex programs and operate CNC machines.

2.2 Review of relevant literature and research related to CNC machines

CNC machines have been extensively studied and researched in the field of manufacturing and mechanical engineering. Numerous studies have been conducted on various aspects of CNC machines, including their design, control systems, programming languages, cutting tools, and machining processes. In this section, we will review the relevant literature and research related to CNC machines.

One of the key areas of research in CNC machines is their design and construction. Several studies have focused on designing and building CNC machines[2] that are cost-effective, efficient, and capable of performing complex machining operations with high precision and accuracy. For example, researchers have proposed using modular design principles to build CNC machines that can be easily modified or upgraded for different applications. Other studies have focused on developing novel mechanical designs for CNC machines, such as using parallel kinematic structures or linear motors to improve accuracy and speed.

Another important area of research in CNC machines is their control systems. CNC machines use various control systems to control the movement of the cutting tools along multiple axes. Studies have focused on developing advanced control systems that can improve the accuracy and speed of CNC machines. For example, researchers have proposed using fuzzy logic[3] and neural networks to optimize the control of CNC machines and reduce machining errors. Other studies have focused on developing real-time monitoring and feedback systems to improve the performance and reliability of CNC machines.

In addition, to design and control systems, research has also focused on programming languages and software tools for CNC machines[4]. CNC machines use a variety of programming languages, such as G-code, to control the movement of the cutting tools. Studies have focused on developing new programming languages and software tools that are more user-friendly and easier to learn. For example, researchers have proposed using graphical programming languages and simulation software to simplify the programming of CNC machines and reduce errors.

Cutting tools and machining processes are also important areas of research in CNC machines. Studies have focused on developing new cutting tools and machining processes that can improve the efficiency and accuracy of CNC machines. For example, researchers have developed new cutting tools that can reduce machining time and improve surface finish. Other studies have focused on developing new machining processes, such as high-speed machining and ultrasonic machining, that can improve the performance of CNC machines.

In conclusion, CNC machines have been extensively studied and researched in various areas of mechanical engineering and manufacturing. Research has focused on various aspects of CNC machines, including their design, control systems, programming languages, cutting tools, and machining processes. Advances in these areas have led to the development of more advanced and sophisticated CNC machines that are capable of performing complex machining operations with high precision and accuracy.

2.3 Types of Existing CNC Machines

CNC machines are widely used in the manufacturing industry for their ability to perform complex machining operations with high precision and accuracy. In this section, we will provide an in-depth analysis of the existing CNC machine types and limitations. CNC machines can be categorized on the basis of different parameters like the number of axes, range of motion, and cutting tool.

I. **The number of axes:** CNC machines can have three, four, five, or more axes, depending on the complexity of the machining operations they are intended for. More axes generally lead to greater flexibility in machining operations, but also require more complex control systems and programming.

II. **Type of cutting tool:** Different types of cutting tools are used in CNC machines, such as end mills, drills, lasers, and lathes. The choice of cutting tool depends on the type of material being machined and the required surface finish.

III. **Range of motion:** The range of motion of a CNC machine determines the maximum size of the workpiece that can be machined. Large machines with a greater range of motion can accommodate larger workpieces, but may also require more space and energy.

2.3.1 2-axis CNC Machine

A 2D CNC machine, also known as a 2-axis CNC machine, is a computer-controlled machine tool that operates in two dimensions, typically the X and Y axes. Unlike 3D CNC machines that can move in three directions, 2D CNC machines are primarily used for cutting or engraving flat materials, such as wood, plastic, metal sheets, and composites. These machines utilize various cutting tools, including router bits, drills, and lasers, to accurately shape and manipulate materials based on pre-programmed instructions.

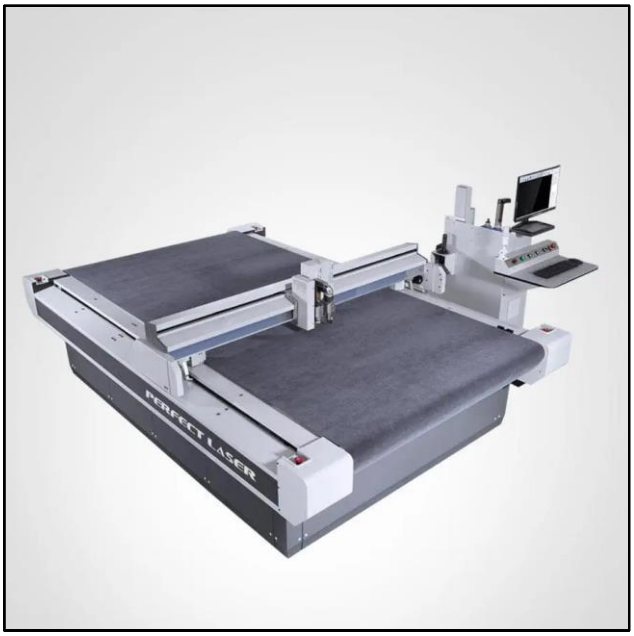


Figure 2.1: 2-axis CNC Machine

2.3.2 3-axis CNC Machine

A 3D CNC machine, also known as a 3-axis CNC machine, operates in three dimensions: the X, Y, and Z axes. Unlike 2D CNC machines that primarily work on flat materials, 3D CNC machines can shape and manipulate materials in three-dimensional space. These machines are widely used in various industries for tasks such as cutting, milling, drilling, carving, and additive manufacturing processes like 3D printing.

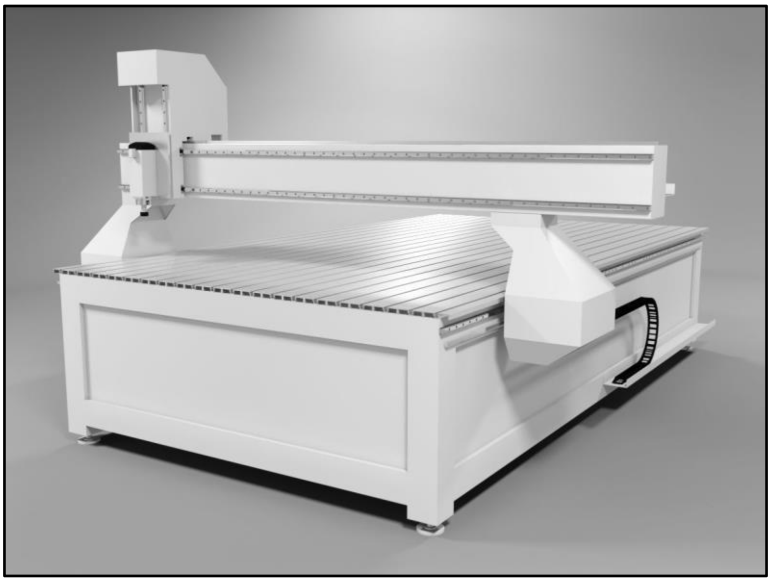


Figure 2.2: 3-axis CNC Machine

2.3.3 4-axis CNC Machine

4-axis CNC machine is not commonly used in the manufacturing industry. While there are CNC machines that can perform multi-axis movements and even simultaneous multi-axis machining, the concept of a "4D CNC machine" is not widely recognized or standardized.

However, the term "4-axis CNC machine" may refer to a machine that combines traditional three-axis movement with an additional axis of movement related to time or a rotational axis.

Figure 2.1: 4-axis CNC Machine

2.3.4 5-axis CNC Machine

A 5-axis CNC machine is a computer-controlled machine tool that can move and operate in five axes: the X, Y, and Z axes, as well as two additional rotational axes known as the A and B axes. This additional flexibility allows the machine to perform complex machining operations from multiple angles and orientations, enabling the production of highly intricate and precise parts.

Figure 2.2: 5-axis CNC Machine

2.4 Control System Analysis

The control system of a CNC machine is responsible for translating the machining program into movement commands for the cutting tool. The control system consists of hardware components, such as motors and sensors, and software components, such as programming languages and control algorithms. Some of the important parameters that are analyzed in this section include the following:

2.4.1 Open-loop and closed-loop control systems

CNC machines can use either open-loop or closed-loop control systems. Open-loop control systems rely on pre-programmed movement commands and do not provide feedback on the actual position of the cutting tool. Closed-loop control systems use feedback sensors to continuously monitor the position of the cutting tool and adjust the movement commands accordingly. Closed-loop control systems generally provide greater accuracy and precision.

2.4.2 Programming languages

Different programming languages are used in CNC machines, such as G-code. Some programming languages are more user-friendly and easier to learn than others.

2.4.3 Control algorithms

The control algorithms used in CNC machines determine how the movement commands are translated into motion. Different control algorithms can have different levels of accuracy and precision, depending on the complexity of the machining operation.

2.4.4 Efficiency and Effectiveness Analysis

The efficiency and effectiveness of a CNC machine depend on a variety of factors, such as the quality of the cutting tool, the rigidity of the machine structure, and the accuracy of the control system. Some of the factors that are analyzed in this section include:

a. Cutting tool quality

The quality of the cutting tool affects the surface finish and dimensional accuracy of the machined part. High-quality cutting tools can lead to better machining results and longer tool life.

b. Machine rigidity

The rigidity of the machine structure affects the stability of the cutting tool and the accuracy of the machining process. Machines with a more rigid structure can withstand higher cutting forces and vibrations, leading to more accurate and precise machining.

c. Control system accuracy

The accuracy of the control system determines how closely the machine can follow the programmed tool path. More accurate control systems can result in more precise machining and better surface finish.

2.5 Hardware Components Analysis

The CNC machine control system is responsible for controlling the movements and actions of the machine. It consists of several key components [11], including:

2.5.1 Control Software

This is the program that runs on the control board and interprets the G-code instructions. It converts the instructions into signals that are sent to the machine's motors, directing their movements.

2.5.2 Control board

This is the hardware that connects the computer running the control software to the machine's motors and other components. It typically includes a microcontroller, stepper motor drivers, and input/output connections.

2.5.3 Motors

CNC machines use several types of motors, including stepper motors, servo motors, and linear motors, to control movement in different axes.

2.5.4 Sensors

The machine may use sensors to monitor position, speed, temperature, and other parameters to ensure safe and accurate operation.

2.5.5 Power supply

The machine needs a reliable power supply to ensure consistent and stable operation.

2.5.6 User interface

CNC machines often have a user interface that allows the operator to input commands, adjust settings, and monitor the machine's performance.

All of these components work together to enable precise and repeatable movement of the cutting tool, allowing for complex and intricate shapes to be created with high accuracy and speed.

2.6 Challenges and Limitations

While CNC machines offer many advantages in terms of precision and efficiency, there are also challenges and limitations associated with their use. Some of the key challenges and limitations include:

2.6.1 Cost

CNC machines can be expensive to purchase and maintain, making them less accessible to smaller manufacturing operations.

2.6.2 Complexity

The complexity of CNC machines means that they require skilled operators to program and operate them, which can be a challenge for some manufacturers.

2.6.3 Safety

CNC machines can be dangerous if not operated correctly, so proper safety procedures and training are necessary to minimize the risk of injury.

2.6.4 Maintenance

CNC machines require regular maintenance to ensure that they continue to operate effectively. This can include regular cleaning and lubrication, as well as more significant repairs or part replacements.

2.6.5 Environmental impact

CNC machines can consume a significant amount of energy and generate waste, which can have environmental impacts if not managed properly.

Despite these challenges and limitations, CNC machines continue to be a critical component of modern manufacturing processes, and ongoing project is focused on improving their capabilities and reducing their costs.

2.7 Discussion of current trends and future directions in CNC Technology

In recent years, CNC technology has advanced significantly, and there are several current trends and future directions that are worth discussing. These trends and directions have the potential to significantly impact the field of manufacturing and the use of CNC machines. Some of the current trends and future directions are discussed below:

1. **Integration of additive manufacturing:** Additive manufacturing, also known as 3D printing, is a rapidly growing field that has the potential to revolutionize manufacturing. One trend in CNC technology is the integration of additive manufacturing into CNC machines, allowing for the creation of complex parts with a high degree of accuracy.

2. **IoT Integration:** Another trend in CNC technology is the integration of Internet of Things (IoT) technology. This allows for the monitoring and control of CNC machines remotely, as well as the collection of data that can be used to optimize the machining process.
3. **Hybrid machining:** Hybrid machining combines multiple machining processes, such as milling and turning, into a single system. This allows for the creation of complex parts with greater efficiency and precision.
4. **Collaborative robots:** Collaborative robots, or cobots, are robots designed to work alongside human operators. In CNC technology, cobots can assist with tasks such as loading and unloading parts, freeing up human operators to focus on other tasks.
5. **Use of advanced materials:** As new materials are developed for use in manufacturing, CNC machines must adapt to accommodate these materials. This includes the use of new cutting tools and machining strategies.
6. **Use of artificial intelligence:** The integration of artificial intelligence (AI) into CNC machines has the potential to significantly improve the efficiency and accuracy of the machining process. AI can be used to optimize tool paths, predict tool wear, and detect defects in machined parts.
7. **Sustainability:** As environmental concerns become more pressing, there is a growing trend towards sustainable manufacturing practices. This includes the use of CNC machines that are designed to minimize waste and energy consumption.

Overall, the future of CNC technology is likely to involve the integration of multiple technologies, including additive manufacturing, IoT, and AI. This will allow for greater efficiency, precision, and flexibility in the machining process, making CNC machines an even more valuable tool for manufacturers.

Chapter 3

Hardware Components Overview

3.1 Introduction

The successful design and construction of the CNC machine require careful consideration and selection of various hardware components. This chapter provides an overview of the key hardware components used in the CNC machine.

3.2 Stepper Motors

Stepper motors are essential for precise control of the machine's movements along the X, Y, and Z axes. These motors provide accurate positioning and enable the CNC machine to move with high precision.

We will be using NEMA 17 Stepper Motor[5]. The NEMA 17 stepper motor is a widely used and popular choice for CNC machines, robotics, 3D printers, and other precision motion control applications. It is named after the National Electrical Manufacturers Association (NEMA) standard, which defines the motor's physical dimensions and mounting specifications.

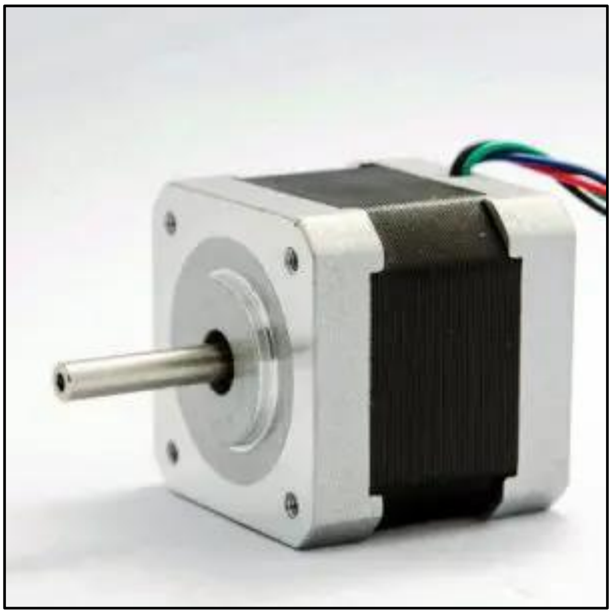


Figure 3.1: NEMA 17 Stepper Motor

3.3 Linear Guides

Linear guides are used to ensure smooth and controlled motion along the X, Y, and Z axes. These guides provide stability and reduce friction, enabling precise movements of the machine's gantry system. We will be using an 8mm Linear Guide.

Figure 3.2: Linear Guide

3.4 Spindle or Laser Module

Depending on the intended application, the CNC machine may be equipped with a spindle for cutting and milling operations or a laser module for engraving and etching tasks. The spindle or laser module is responsible for the actual material removal or modification.

Figure 3.3: Spindle

3.5 Microcontroller

The brain of the CNC machine's control system is the microcontroller. It serves as the central processing unit, responsible for interpreting instructions, generating signals for the stepper motors, and coordinating the overall operation of the machine. We will be using an Arduino Uno R3 microcontroller [6].

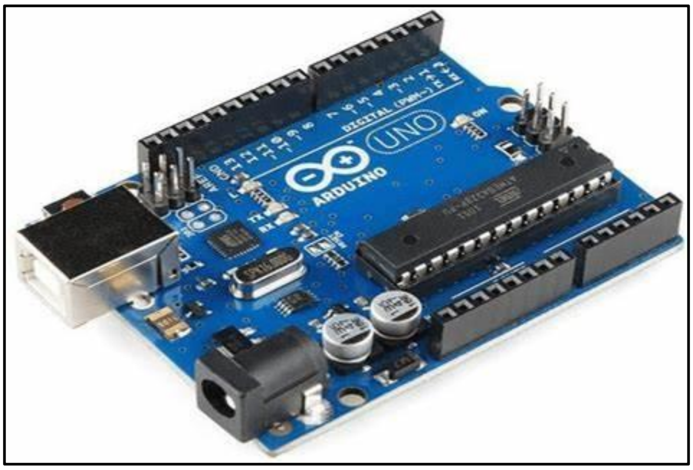


Figure 3.4: Arduino Uno R3 microcontroller

Arduino Uno is a popular microcontroller board based on the ATmega328P microcontroller. It is part of the Arduino family of open-source hardware and software platforms designed for easy prototyping and development of electronic projects. The Arduino Uno board provides a user-friendly interface and a range of input/output (I/O) pins, making it suitable for beginners and experienced users alike.

3.5.1 Key features of the Arduino Uno

The key features of the Arduino Uno are mentioned below.

a. **Processor:** The Arduino Uno is powered by the ATmega328P microcontroller, which runs at 16 MHz and has 32KB of flash memory for program storage, 2KB of SRAM for data storage, and 1KB of EEPROM for non-volatile storage.

b. **I/O Pins:** The board has a total of 14 digital input/output pins, with 6 of them capable of providing pulse-width modulation (PWM) output. Additionally, there are 6 analog input pins, allowing for the connection of various sensors, actuators, and other devices.

c. **USB Interface:** The Arduino Uno has a built-in USB interface, enabling easy connection to a computer for programming and communication. It can be programmed using the Arduino Integrated Development Environment (IDE) and supports USB serial communication for data transfer.

d. **Power Supply:** The board can be powered through a USB connection or an external power source, such as a battery or AC-to-DC adapter. It also has a built-in voltage regulator, allowing it to operate at a voltage range of 7V to 20V.

e. **Integrated Development Environment (IDE):** Arduino provides a user-friendly IDE that simplifies the programming process. It includes a code editor, a compiler, and a bootloader that allows users to easily upload their programs to the Arduino Uno board.

f. **Shields and Expansion:** The Arduino Uno is compatible with a wide range of shields, which are add-on boards that provide additional functionality such as wireless communication, motor control, and display capabilities. The availability of shields allows for easy expansion and customization of the Arduino Uno's capabilities.

3.6 CNC Shield

The CNC Shield is an expansion board designed for Arduino Uno or compatible boards, enabling the control of stepper motors in CNC machines. It features four stepper motor driver slots, endstop support, and compatibility with the GRBL firmware. The shield allows for precise control of stepper motors along the X, Y, and Z axes. We will be using CNC Shield V3[7].

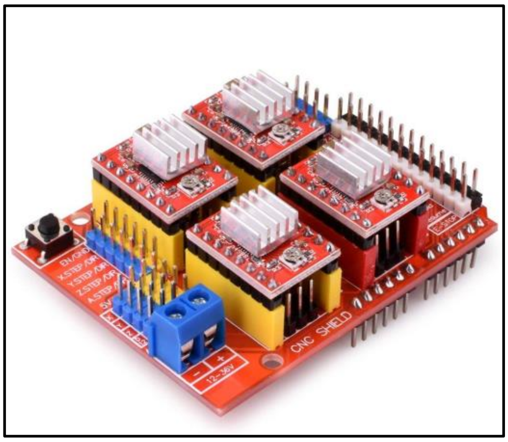


Figure 3.5: CNC Shield V3

3.7 Driver Boards

Driver boards are used to control the power and signals sent to the stepper motors. These boards receive commands from the microcontroller and convert them into precise motor movements, ensuring accurate positioning and motion control. We will be using A4988 Driver Board[8].

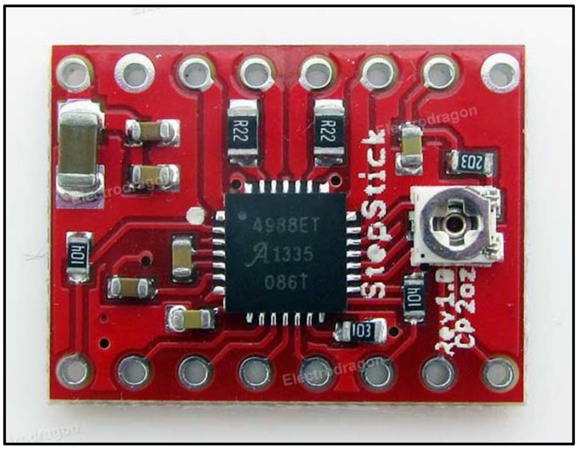


Figure 3.6: A4988 Driver Board

3.8 Power Supply

A reliable power supply is crucial for the CNC machine's operation. It provides the necessary electrical power to drive the various components, including the microcontroller, stepper motors, and driver boards. We will be using a 12V 2A power supply.

Figure 3.7: 12V 2A Power Supply

3.9 Circuit Diagram

Our circuit diagram illustrates the complex pathways that power our CNC machines and how all the electronic components will be connected together, as shown in the figure.

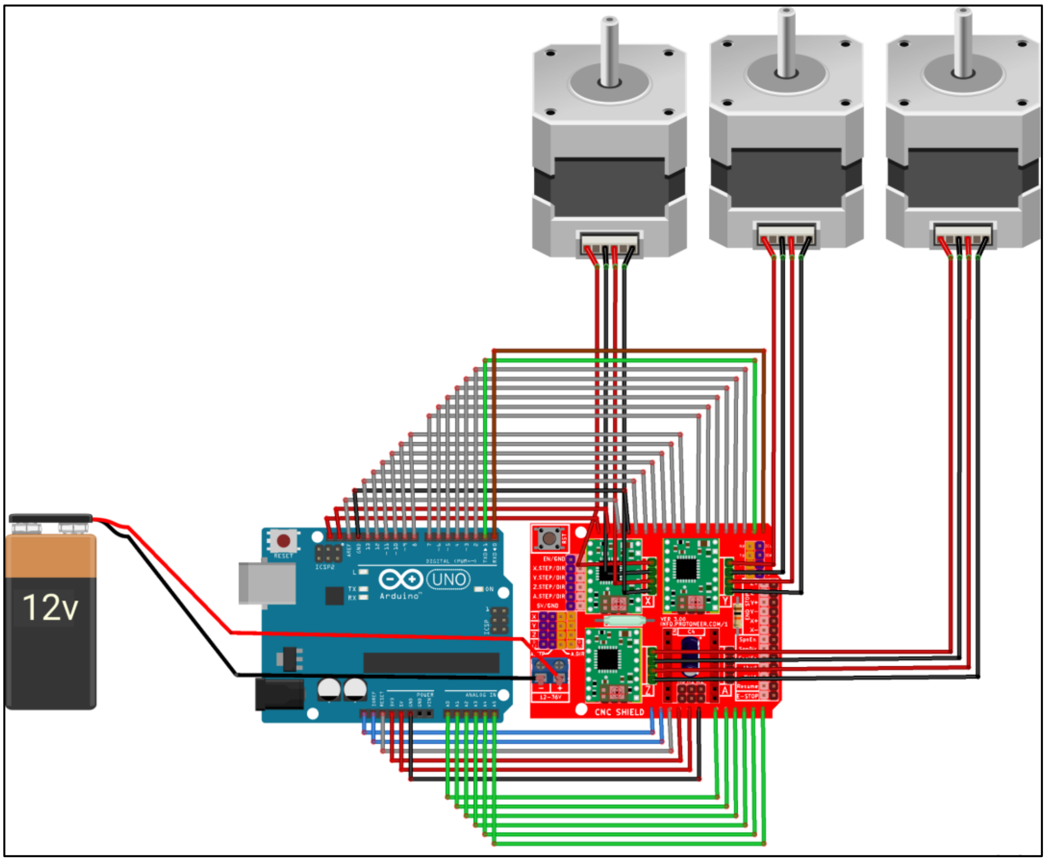


Figure 3.8: Circuit Diagram

Chapter 4

Software Overview

4.1 Introduction

The software used in the CNC machine consists of several components which do the following tasks.

I. The firmware flashing software for microcontroller (Arduino IDE).
II. The software used to generate the G-code instructions (Vetric Aspire).
III. The software used to send the G-code instructions to Microcontroller (Universal G-Code Sender).
IV. The firmware, as previously mentioned (GRBL).

The universal G-code sender software used to control the CNC machine is a custom software application. The software provides a user-friendly interface for controlling the CNC machine's movements and operations, allowing the user to specify the cutting parameters, move the machine along the X, Y, and Z axes, and monitor the machine's status. The software communicates with the microcontroller over a USB connection, sending the G-code instructions and receiving status updates.

4.2 Setup of Arduino IDE

Arduino IDE (Integrated Development Environment) is an open-source software application that is used to program and develop software for Arduino boards. Arduino boards are microcontroller-based boards that are designed for DIY projects, prototyping, and education.

The Arduino IDE provides a simple and user-friendly interface for writing and uploading code to Arduino boards. It is compatible with Windows, Mac OS X, and Linux operating systems. The IDE is based on the Java programming language and supports C and C++ programming languages.

The Arduino IDE includes several features to make programming easier, such as a text editor, a code debugger, a serial monitor, and a library manager. It also includes a set of built-in libraries for common tasks, such as reading and writing to pins, controlling servo motors, and communicating over various protocols.

In addition to the built-in libraries, the Arduino IDE supports third-party libraries that can be downloaded and installed through the Library Manager. These libraries provide additional functionality, such as controlling LCD displays, GPS modules, and other sensors.

Overall, the Arduino IDE is an essential tool for anyone working with Arduino boards. Its simplicity, ease of use, and compatibility with a wide range of operating systems make it a popular choice among hobbyists, students, and professionals alike.

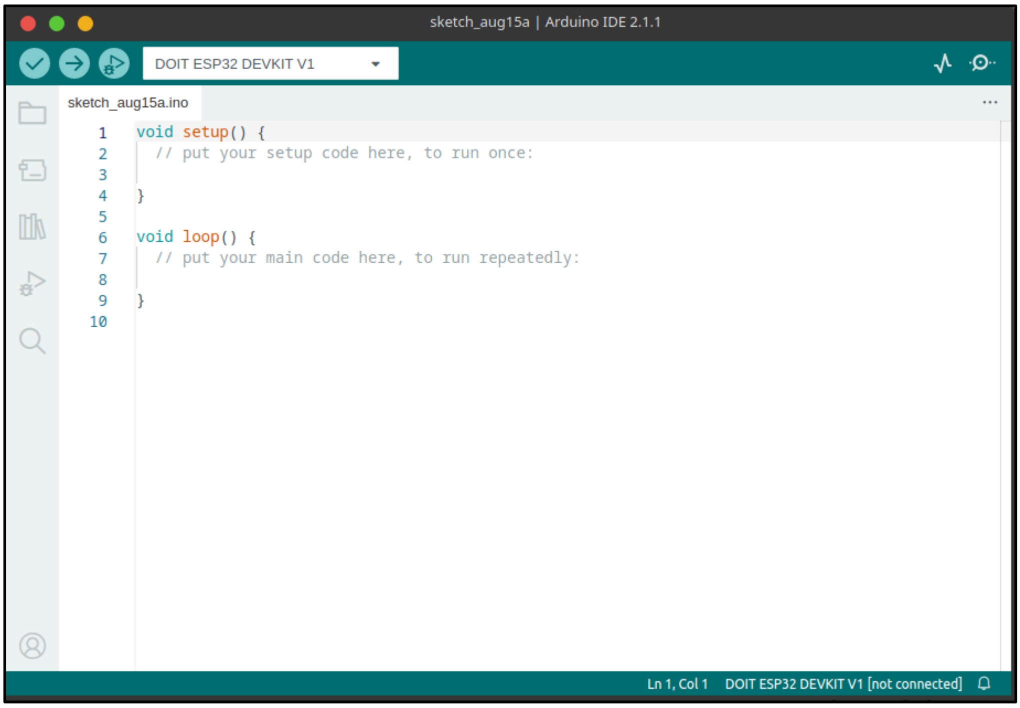


Figure 4.1: Arduino IDE

4.2.1 Steps to install Arduino IDE

Here are the steps to download and install Arduino IDE:

1. Go to the official Arduino website at https://www.arduino.cc/en/software.
2. Scroll down to the "Download the Arduino IDE" section and choose the appropriate version for your operating system.
3. Once the download is complete, open the installer and follow the on-screen instructions.

4. Select the components you want to install. By default, all components are selected.
5. Choose the installation location, or leave it as default.
6. Click the "Install" button to start the installation process.
7. After installation is complete, launch the Arduino IDE from your desktop or start menu.
8. Connect your Arduino board to your computer using a USB cable.
9. In the Arduino IDE, go to "Tools" -> "Board" and select the appropriate board type.
10. In the same menu, select the port to which the Arduino board is connected.
11. You are now ready to write, compile, and upload code to your Arduino board using the Arduino IDE.

4.3 Flashing GRBL Firmware Using Arduino IDE

GRBL (pronounced "garble") is a free, open-source firmware that is used to control CNC machines. It runs on Arduino boards and is specifically designed for CNC milling machines. GRBL provides a G-code interpreter, which enables users to send G-code files to the machine to control its movements.

4.3.1 Steps to Flash GRBL Firmware to an Arduino Microcontroller

Here are the steps to flash GRBL firmware to an Arduino microcontroller:

1. Download the latest stable version of the GRBL firmware from the official GitHub page https://github.com/grbl/grbl.
2. Download and install the Arduino IDE on your computer.
3. Connect your Arduino board to your computer using a USB cable.
4. Open the Arduino IDE and select the correct board and port under the "Tools" menu.
5. Open the GRBL firmware file in the Arduino IDE by selecting "File" and then "Open".
6. Verify that the settings in the "config.h" file are correct for your machine.
7. Upload the firmware to the Arduino board by selecting "Sketch" and then "Upload".

8. After the firmware has been successfully uploaded, connect to the Arduino board using a G-code sender such as Universal G-code Sender to verify that the machine is working correctly.

Note: It is important to follow the instructions carefully and make sure that the correct board and port are selected in the Arduino IDE to avoid any errors during the flashing process.

4.4 Universal G-code Sender

Universal G-Code Sender (UGS) is a free, open-source software program that allows you to send G-Code commands to a CNC machine. It is a cross-platform program, meaning it can be used on Windows, Mac, and Linux operating systems. UGS allows you to connect to your CNC machine via a USB or serial port, and it provides a simple interface to send G-Code commands, view the status of the machine, and monitor the progress of your job.

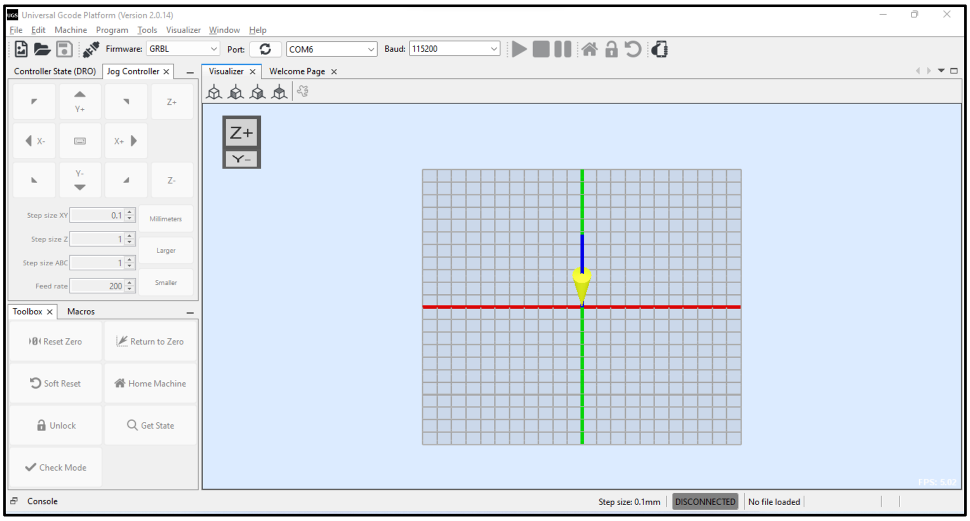


Figure 3.2: Universal G-Code Sender

4.4.1 Steps to install Universal G-code Sender

To use UGS, follow these steps:

1. Download and install UGS from the official website (https://winder.github.io/ugs_website/download/).
2. Connect your CNC machine to your computer via a USB or serial port.

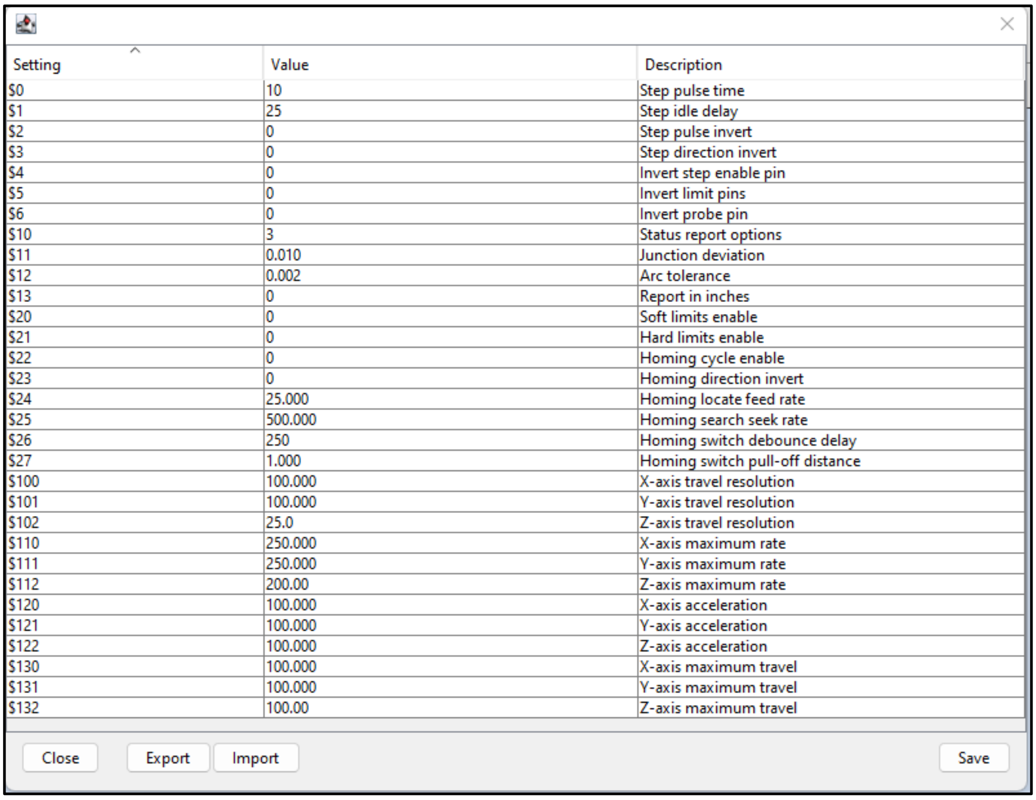
3. Open UGS and select the correct serial port in the "Port" drop-down menu.
4. In the "Machine Control" tab, you can manually jog the machine using the arrow keys and home the machine using the home button.
5. To load a G-Code file, click on the "File Mode" tab and select "Open." Navigate to the file you want to send and select it.
6. In the "Control" tab, click on the "Send" button to send the G-Code commands to the machine.
7. You can monitor the progress of the job in the "Console" tab, which displays the G-Code commands being sent to the machine and any error messages that may occur.

UGS also has advanced features such as the ability to set work coordinates, set tool offsets, and run macros. Overall, UGS is a powerful and versatile tool for sending G-Code commands to a CNC machine.

4.4.2 Configuring Machine Setting using Universal G-code Sender

To configure the machine settings using Universal Gcode Sender, follow these steps:

1. Open Universal Gcode Sender on your computer.
2. Connect your CNC machine to your computer using a USB cable.
3. Click on the "Connect" button in the top left corner of the screen to establish a connection between your computer and the CNC machine.
4. Click on the "Machine" button in the top menu bar and select "Settings" from the dropdown menu.
5. In the "Settings" window, you can configure various settings such as the machine's maximum travel speed, maximum acceleration, and steps per millimeter for each axis.
6. Once you have configured the settings to your liking, click on the "Save Settings" button at the bottom of the window to apply the changes.
7. You can now use Universal G-code Sender to send G-code files to your CNC machine and control its movements.



Setting	Value	Description
$0	10	Step pulse time
$1	25	Step idle delay
$2	0	Step pulse invert
$3	0	Step direction invert
$4	0	Invert step enable pin
$5	0	Invert limit pins
$6	0	Invert probe pin
$10	3	Status report options
$11	0.010	Junction deviation
$12	0.002	Arc tolerance
$13	0	Report in inches
$20	0	Soft limits enable
$21	0	Hard limits enable
$22	0	Homing cycle enable
$23	0	Homing direction invert
$24	25.000	Homing locate feed rate
$25	500.000	Homing search seek rate
$26	250	Homing switch debounce delay
$27	1.000	Homing switch pull-off distance
$100	100.000	X-axis travel resolution
$101	100.000	Y-axis travel resolution
$102	25.0	Z-axis travel resolution
$110	250.000	X-axis maximum rate
$111	250.000	Y-axis maximum rate
$112	200.00	Z-axis maximum rate
$120	100.000	X-axis acceleration
$121	100.000	Y-axis acceleration
$122	100.000	Z-axis acceleration
$130	100.000	X-axis maximum travel
$131	100.000	Y-axis maximum travel
$132	100.00	Z-axis maximum travel

Figure 43: Universal G-Code Sender Configuration

4.5 Setup of Vetric Aspire

Vectric Aspire is a powerful software package for 2D and 3D modeling, design, and machining. It is commonly used by CNC machinists, woodworkers, and sign makers to create complex designs and produce precision parts with their CNC machines.

Aspire offers a user-friendly interface that allows users to import 2D and 3D models, create and edit vectors, and generate toolpaths for CNC machining. The software supports a wide range of file formats, including DXF, DWG, EPS, AI, STL, and 3D clipart files.

One of the key features of Aspire is its ability to create 3D models from 2D drawings. This is accomplished through a process called "relief modeling," which allows users to add depth and texture to their designs. Aspire also includes a wide range of 3D clipart models that can be customized and integrated into designs.

Aspire's toolpath generation capabilities allow users to create efficient and precise cutting paths for their CNC machines. The software supports a wide range of tool types, including end mills, ball nose cutters, and V-bits. It also includes a simulation mode that allows users to preview their toolpaths and detect any potential issues before machining.

Overall, Vectric Aspire is a versatile and powerful software package that provides users with the tools they need to create complex designs and produce high-quality machined parts. Its user-friendly interface, advanced modeling capabilities, and efficient toolpath generation make it a popular choice among CNC machinists and designers.

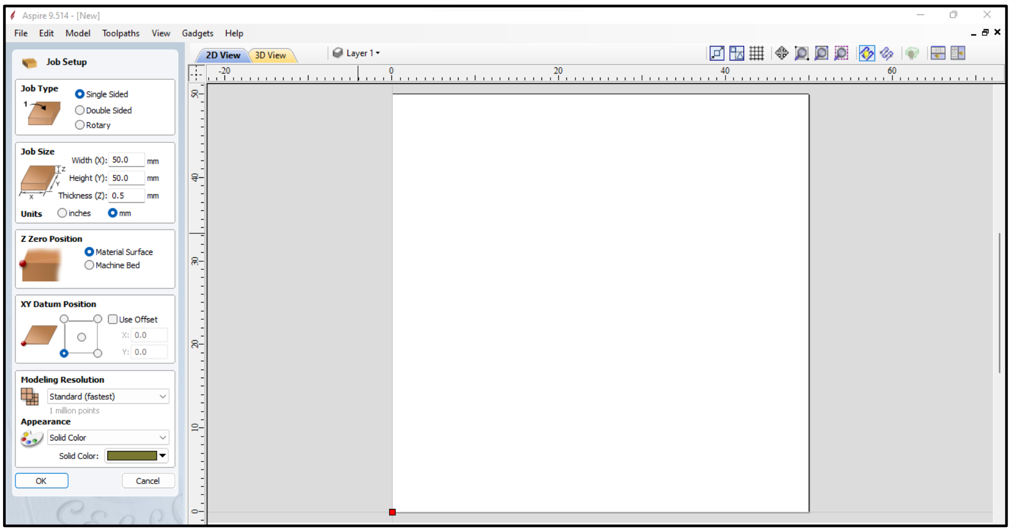


Figure 4.4: Aspire Interface

4.5.1 Steps to install Vetric Aspire

Here are the steps to download and install Vectric Aspire version 9.5:

1. Go to the official Vectric website at https://www.vectric.com/.
2. Click on the "Products" tab at the top of the page, and select "Aspire" from the dropdown menu.
3. Click on the "Download Aspire Trial" button on the Aspire page.
4. Fill out the required information to register for the trial version and click "Submit".
5. Check your email for a message from Vectric with a download link for the trial version of Aspire.

6. Click on the download link and save the Aspire installation file to your computer.
7. Double-click on the Aspire installation file to begin the installation process.
8. Follow the on-screen instructions to complete the installation.
9. Once the installation is complete, open Vectric Aspire and enter your license information if you have purchased a license. Otherwise, you can use the trial version for the specified period.

Note that these steps are for version 9.5 of Vectric Aspire and the process may differ for newer versions.

4.5.2 How to Create Document in Vetric Aspire

To create a new document in Vectric Aspire according to a user's required size, you can follow these steps:

1. Open Vectric Aspire on your computer.
2. Click on the "File" menu located in the top left corner of the software.
3. Select "New" from the drop-down menu to create a new document.
4. In the "Create a new file" window that appears, select "Job Setup" on the left side.
5. In the "Job Size" section, enter the required width and height dimensions for your design in the corresponding boxes.
6. Choose the units of measurement you prefer (inches, millimeters, or other).
7. Select any other relevant options for your design, such as the material thickness or the origin position.
8. Click "OK" to create the new document with the specified dimensions.

Once the new document is created, you can start designing your project using the various tools and features provided in Vectric Aspire.

4.5.3 How to Create object in Vetric Aspire

To draw an object in Vectric Aspire 9.5, follow these steps:

1. Open a new document in Vectric Aspire.
2. Click on the "Draw Rectangle" tool on the left-hand side of the screen, or press "R" on your keyboard.
3. Click and drag your mouse to create a rectangle of the desired size.
4. To edit the rectangle, click on it to select it, and then use the editing tools on the left-hand side of the screen to adjust its size, shape, or other properties.
5. To draw other objects, use the various drawing tools in the toolbar, such as the line tool, circle tool, or polygon tool. Click on the tool you want to use, and then click and drag your mouse to create the object.
6. Use the editing tools to adjust the properties of each object as needed.
7. Save your document when you're finished by clicking on "File" in the top-left corner of the screen, and then selecting "Save As". Choose a name and location for your file, and then click "Save".

4.5.4 Creating toolpath for a specific object using Vetric Aspire

To select a cutting toolpath for an object in Aspire, you can follow these steps:

1. Open your project file in Aspire.
2. Select the 3D model or component that you want to create a toolpath for.
3. Click on the "Toolpaths" tab at the top of the screen.
4. Choose the type of toolpath that you want to use from the list of available options, such as "Profile Cut" or "Pocket Cut".
5. Set the cutting parameters for the toolpath, such as the cutting depth, cutting speed, and tool size.
6. Preview the toolpath by clicking on the "Preview" button, and adjust the parameters as needed.
7. Once you are satisfied with the toolpath, click on the "Save Toolpath" button to generate the G-code for the toolpath.

Note that the specific steps and options available may vary depending on the version of Aspire you are using.

4.5.5 Generating G-code for an object using Vetric Aspire

To generate G-code for an object in Vectric Aspire 9.5, follow these steps:

1. Open the design file for the object you want to generate G-code for.
2. Make sure that your toolpaths are set up correctly. This includes selecting the correct tool, specifying the cutting depth, and setting the feed rate.
3. Click on the Toolpaths menu and select Save Toolpath.
4. In the Save Toolpath dialog box, select the appropriate file type for your CNC machine. This could be a G-code file.
5. Choose a location to save the file and give it a name.
6. Click Save to generate the G-code file for your object.

Once the G-code file is generated, you can transfer it to your CNC machine and use it to cut your object.

Chapter 5

3D Design and Frame Construction

5.1 Introduction

In this chapter we will focus on the design and construction of frame for CNC machine. First we will be designing 3D model of the CNC machine and then followed by the physical design and construction of the actual machine by assembling its components discussed in chapters 3.

5.2 3D Design

The design of the 3-axis CNC machine was developed using Sketchup, a 3D modeling software that allows for the creation of detailed and accurate 3D models. The 3D model was used to visualize the machine's design and to identify any potential design flaws before construction began.

The 3D model was created by first identifying the necessary components of the CNC machine, including the base, the gantry, the spindle, and the motor. These components were then designed and modeled in Sketchup, with careful attention paid to the dimensions and placement of each component.

Once the individual components had been designed, they were assembled to create the final 3D model of the CNC machine. The model was then reviewed and refined to ensure that all components fit together properly and that there were no design flaws.

The final 3D model provided a detailed visual representation of the CNC machine's design and construction, allowing for a greater understanding of the machine's functionality and potential areas for improvement. Additionally, the 3D model served as a useful tool during the construction phase, allowing for the precise positioning and alignment of each component.

Overall, the use of 3D modeling software was a critical component of the CNC machine design process, allowing for the creation of a detailed and accurate model that was used to guide the construction of the machine. The use of 3D modeling software is a common practice in modern manufacturing and construction industries, and it is likely to continue to play a key role in the design and construction of advanced automation technologies like CNC machines.

5.2.1 Bed Design

When designing the base for a CNC machine, it is essential to strike a balance between strength, stability, accessibility, and customization. By carefully considering these factors, you can create a solid and reliable base that provides a stable platform for precise machining operations.
The size of the bed is 12 inches width and 14 inches length.

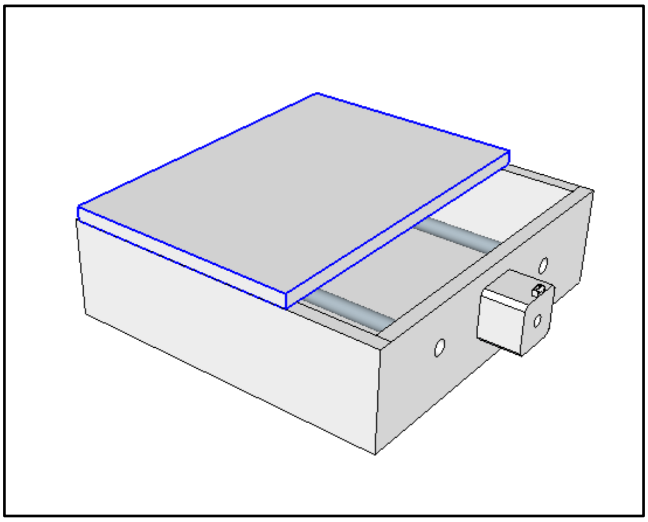


Figure 5.1: Bed Design View One

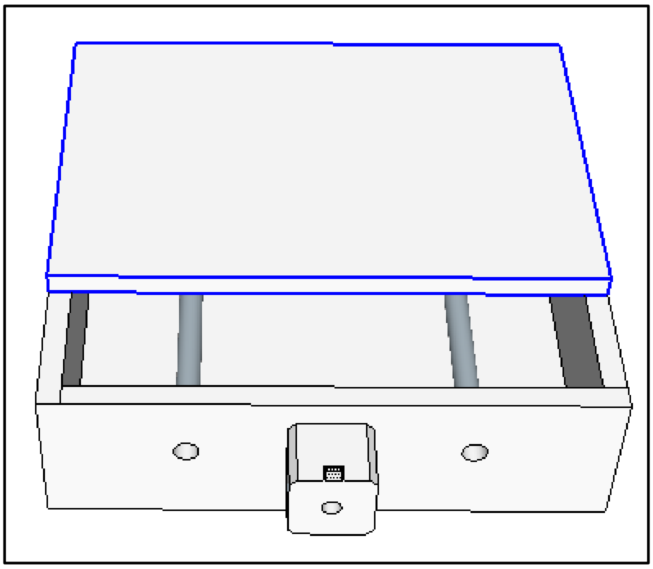


Figure 5.2: Bed Design View Two

5.2.2 Spindle Mount Design

The spindle should have proper mounting provisions to securely attach it to the machine. Design the spindle mounting interface to ensure accurate alignment with the machine's axes, allowing for precise and repeatable machining operations.
The size of the single mount is 10 inches.

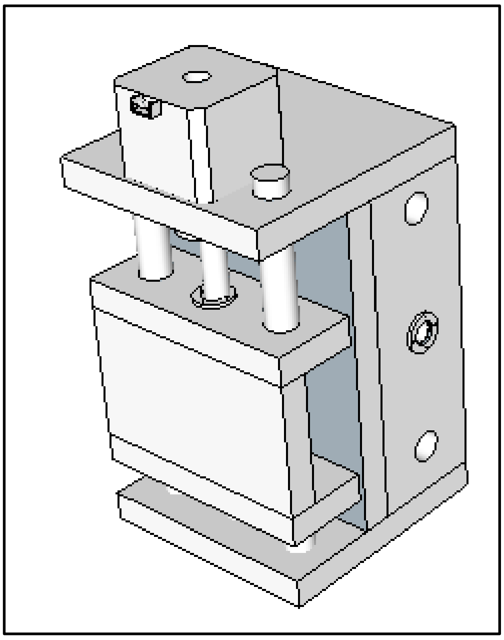


Figure 5.3: Spindle Mount Design A

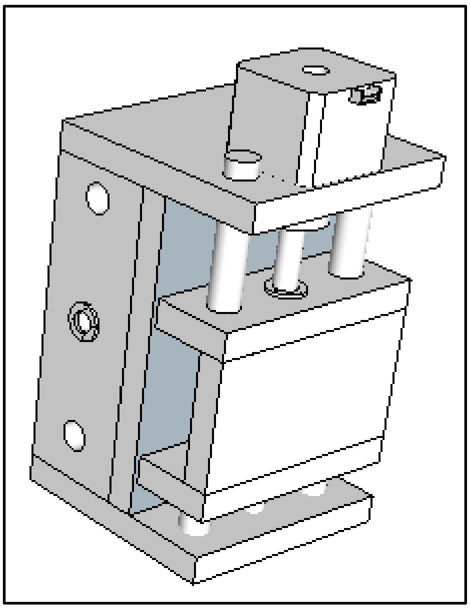


Figure 5.4: Spindle Mount Design B

5.2.3 Gantry Mount Design

The gantry mount should be designed to provide structural integrity and stability. Consider incorporating reinforcements such as ribs, gussets, or trusses to enhance the rigidity and overall strength of the gantry mount. This helps to minimize vibrations and ensure precise movement of the cutting tool.

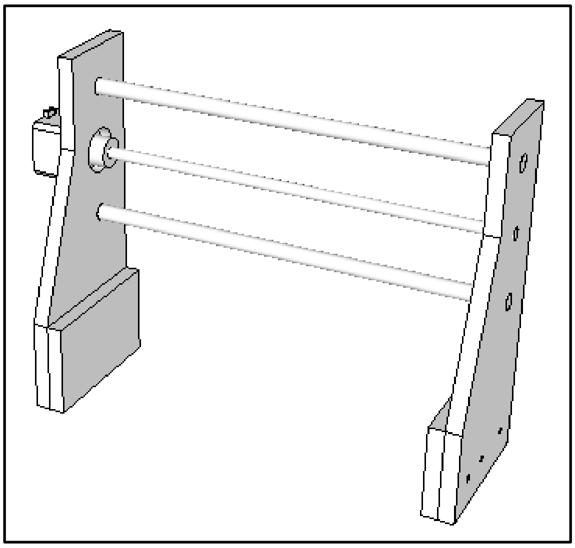


Figure 5.5: Gantry Mount Design A

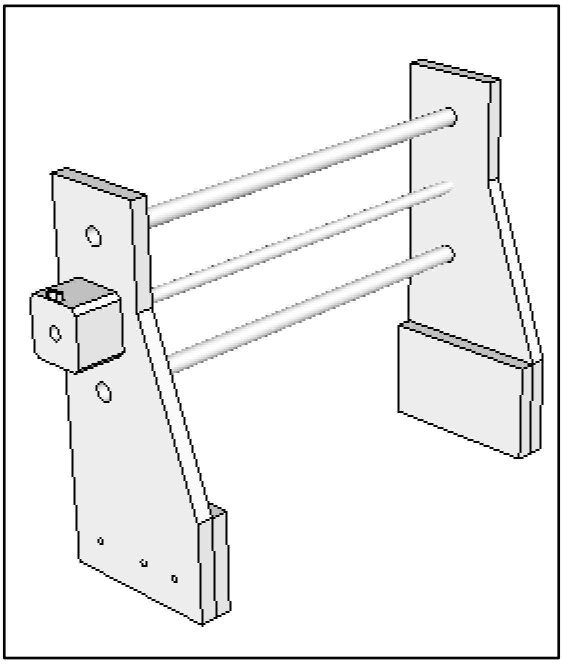


Figure 5.6: Gantry Mount Design B

5.2.4 Integrated Components Design

Integrating all the components in the design of a CNC machine requires careful planning, attention to detail, and adherence to best practices. By ensuring compatibility, proper assembly, and functional connections, you can create a well-integrated CNC machine that operates reliably and delivers accurate machining results.

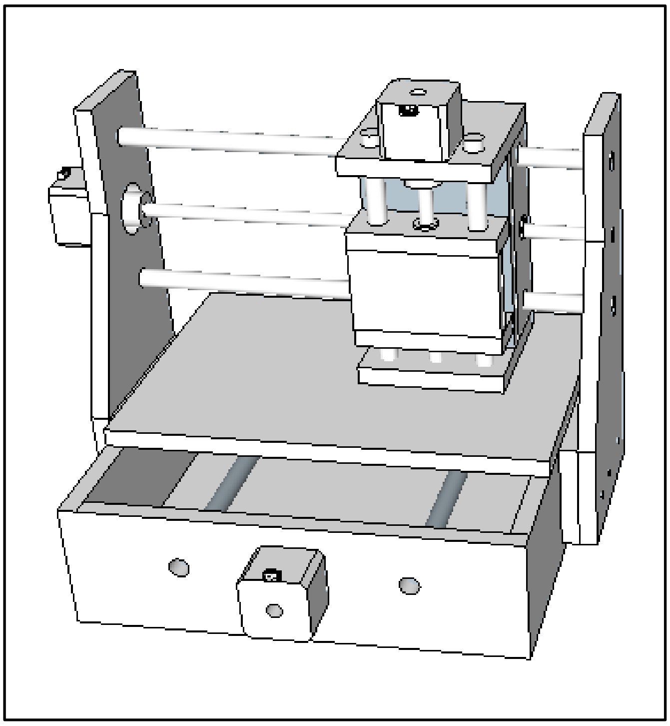


Figure 5.7: Integrated Components Design A

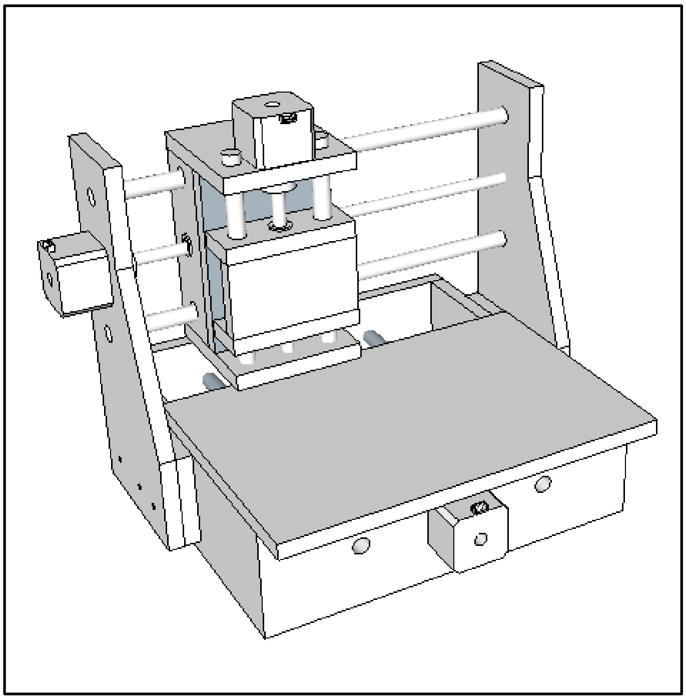


Figure 5.8: Integrated Components Design B

5.3 Material Selection

When constructing the frame for a CNC machine, the choice of materials plays a crucial role in determining its strength, stability, and overall performance. One common material used for frame construction is Medium Density Fiberboard (MDF) lasani.

MDF lasani is a type of engineered wood product made from wood fibers and resin. It offers several advantages for frame construction, including its affordability, availability, and ease of machining. MDF lasani provides a smooth and flat surface, which is ideal for mounting components and ensuring precise alignment. MDF is also a cost-effective and practical solution for smaller to medium-sized CNC machines.

5.4 Frame construction

The frame was constructed in components and then combined together to make the working piece. Here are the components built according to the 3D design as mentioned before.

5.3.1 Bed Construction

In constructing the bed for the CNC machine, one approach involves constructing the bed first and then mounting the stepper motor and sliding channels onto it. This method offers several advantages in terms of flexibility, ease of assembly, and potential for future modifications.

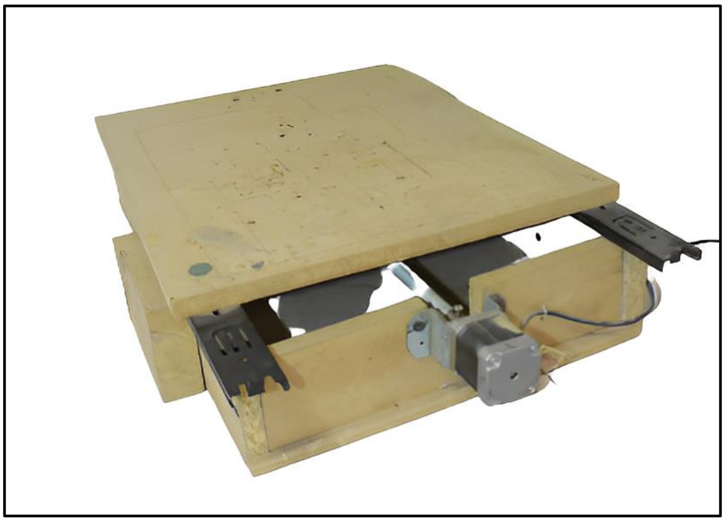


Figure 5.9: Bed Construction A

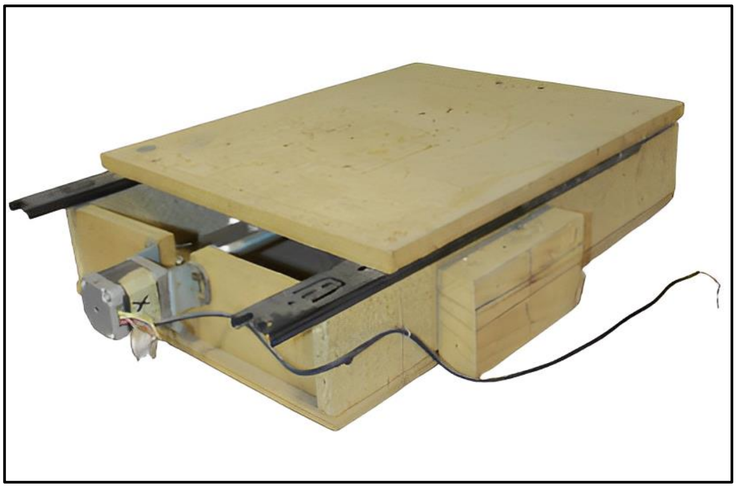


Figure 5.10: Bed Construction B

5.3.2 Spindle Mount Construction

The spindle mount construction involves attaching the spindle motor to a mounting channel or bracket, which is then secured to the CNC machine's bed or gantry system.

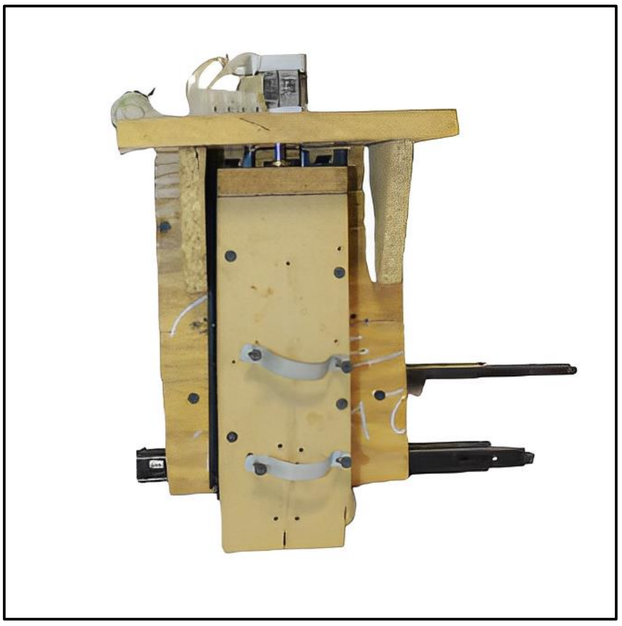


Figure 5.11: Spindle Mount A

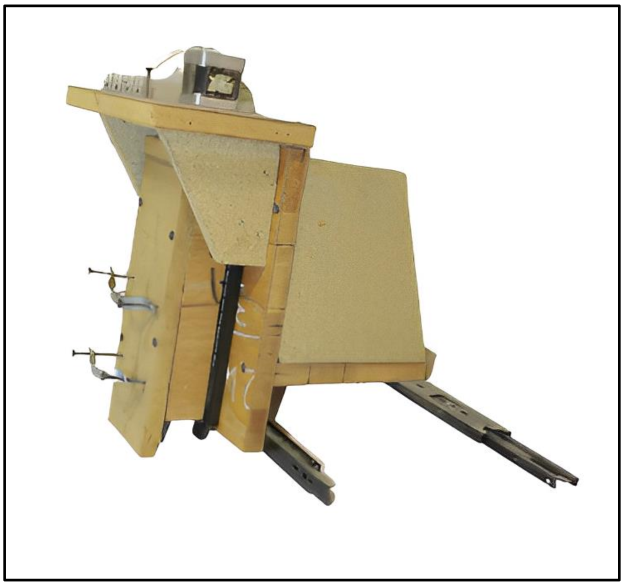


Figure 5.12: Spindle Mount B

5.3.3 Gantry Mount Construction

The gantry mount serves as the framework for supporting the motion system, such as the linear guides and stepper motors, allowing for precise movement of the cutting tool or spindle. Here's a summary of the gantry mount construction process.

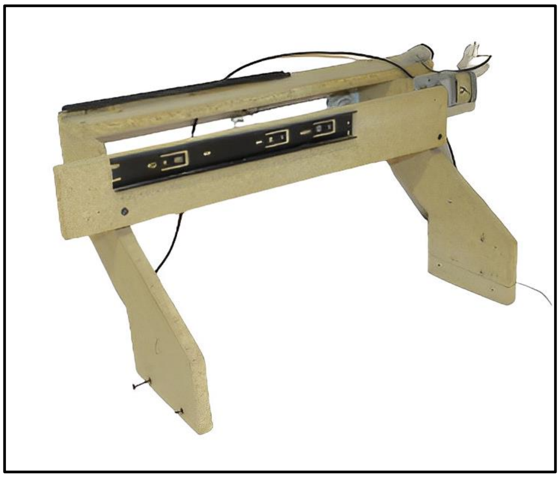


Figure 5.13: Gantry Mount A

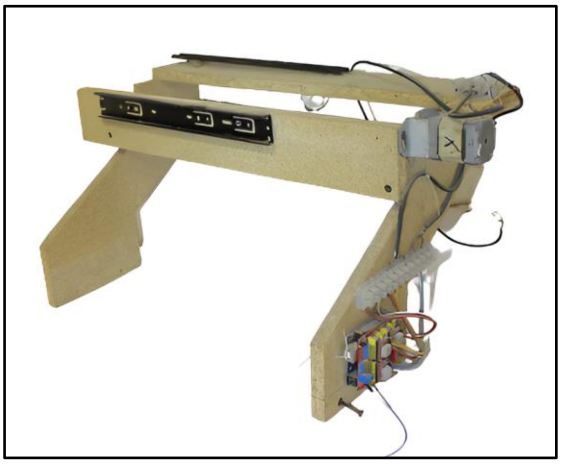


Figure 5.14: Gantry Mount B

5.3.4 Integrating All Components

Integrating all the components of a CNC machine is a critical step in the construction process. It involves bringing together the frame, gantry system, spindle, control system, and wiring to create a cohesive and functional system. Careful assembly, alignment, and connection of these components ensure smooth motion, accurate control, and reliable operation. The integration process also includes software configuration, testing, and fine-tuning to optimize the machine's performance for efficient and precise machining tasks.

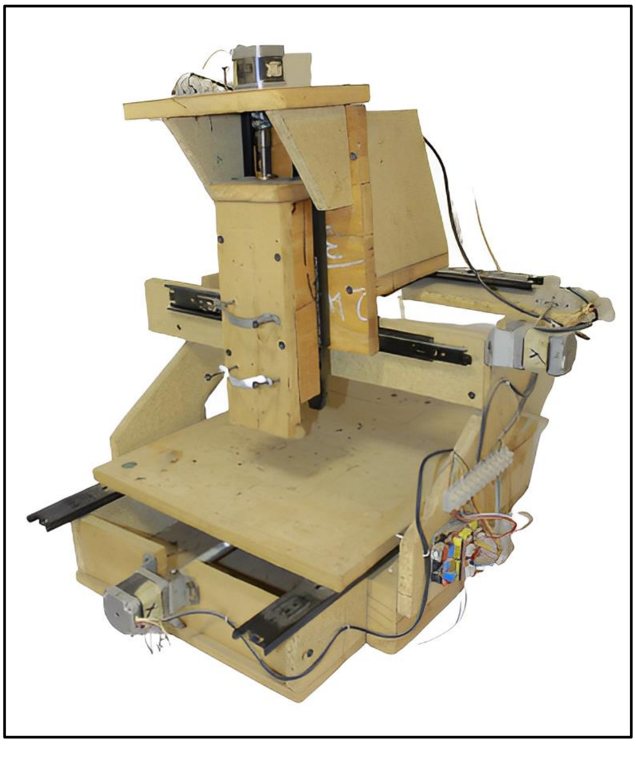


Figure 5.15: Final CNC Machine A

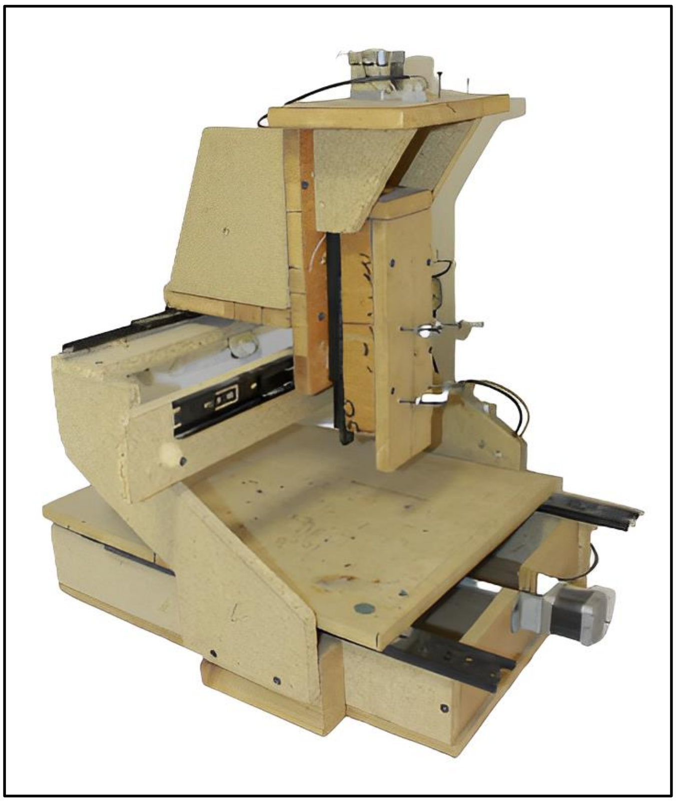


Figure 5.16: Final CNC Machine B

Chapter 6

Testing and Results

6.1 Details of the testing and validation process

After building the machine, it was tested a lot to make sure it worked right and did what it was supposed to do. This included checking how well the machine moved accurately. When making a 3-axis CNC machine, it's really important to test and check the design to make sure it matches what it's supposed to do. This part explains in detail how the testing and checking process was done, including the methods used to test the CNC machine, what the tests showed, and what we learned from them. By carefully looking at how the CNC machine worked, like how it followed instructions and placed tools correctly, the tests confirmed that it met the requirements we had set.

6.2 Testing Process

We tested the 3-axis CNC machine, by using different parameters, and below is the process and result of our testing.

6.2.1 Initial setup and calibration

Before performing any experiments, we ensured that the machine was properly calibrated and configured. This involved checking the alignment of the axes, setting the stepper motor current limits, and configuring the software settings.

6.2.2 Testing of the linear motion

To evaluate the accuracy of the machine's linear motion, we conducted several tests using a ruler. We measured the displacement of the spindle as it moved along each axis, and compared the results to the expected values. We also tested the repeatability of the machine's linear motion by performing multiple runs and comparing the results.

Figure 6.1: Linear Motion Testing

6.2.3 Testing of the rotational motion

To evaluate the accuracy of the spindle's rotational motion, we used a pen and paper to measure the displacement of the spindle as it rotated. We compared the results to the expected values and tested the repeatability of the spindle's rotational motion by performing multiple runs.

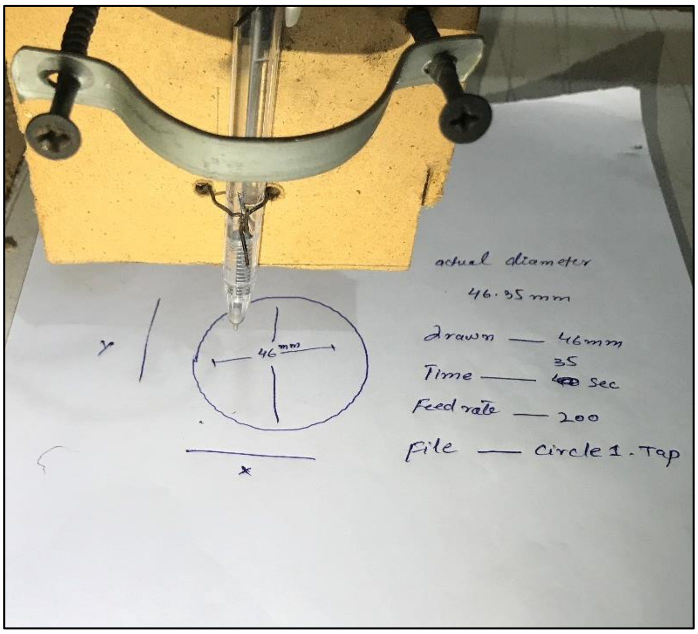


Figure 6.2: Rotational Motion

6.2.4 Testing of the irregular motion

To evaluate the accuracy of the spindle's irregular motion, we used a pen and paper to measure the displacement of the spindle as it moves. We compared the results to the expected values.

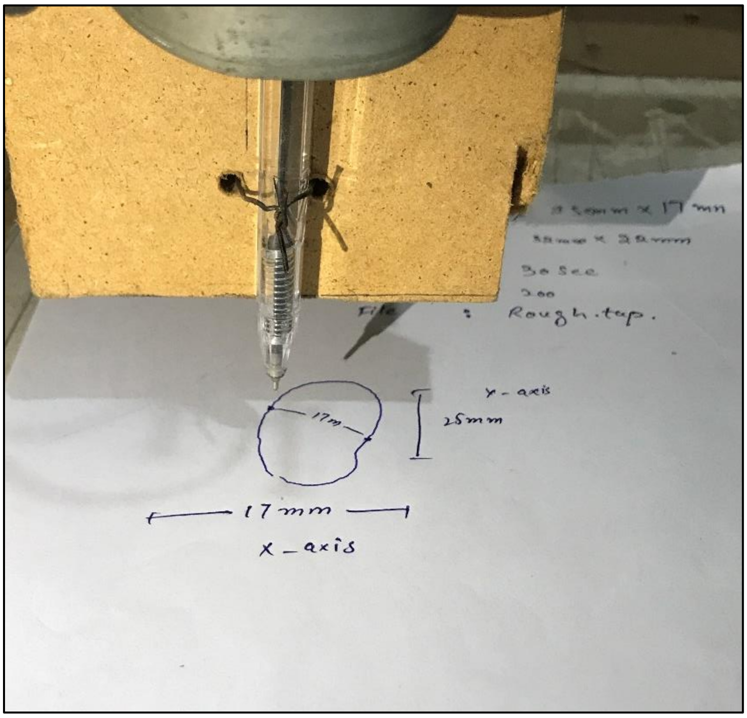


Figure 6.3: Irregular Motion

6.2.5 Testing of the square motion

To evaluate the accuracy of machine we draw square shape to check whether it gives the expected result or not.

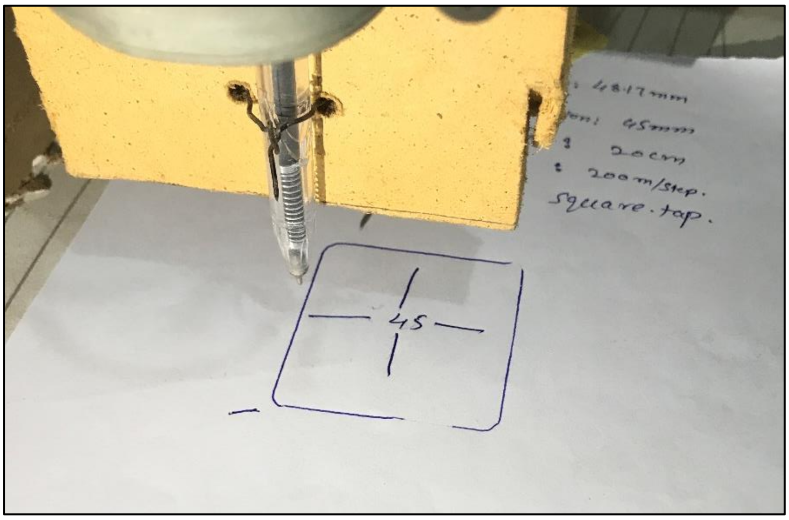


Figure 6.4: Square Motion

6.3 Results

The below table shows the results of our machine and its accuracy by using feed rate 100 mm/minute.

Table 6.1: Testing results

Shape	**Expected Result (mm)**	**Given Result (mm)**	**Time (seconds)**
Linear	40	40	2
Circle	46.35 diameter	46.35 diameter	35
Irregular	25 x 17	25 x 17	30
Square	45	45	40

6.4 Conclusions

In conclusion, the testing and validation process showed that the 3-axis CNC machine was a robust and reliable system that met the design requirements and specifications. The accuracy and repeatability of the machine's linear and rotational motion were well within the expected values. Overall, the testing and validation process provided strong evidence that the 3-axis CNC machine was a high-performance and cost-effective solution for small-scale manufacturing and prototyping applications.

Chapter 7

Comparison With Commercial CNC Machines

7.1 Introduction

This chapter presents a comparison of the results obtained from the testing and validation of the 3-axis CNC machine with the existing literature and research on CNC machines. The comparison includes an analysis of the similarities and differences between the findings of the present study and those of previous studies, as well as a discussion of the implications of the comparison for the design and operation of CNC machines.

7.2 Introduction to Commercial CNC Machines

Commercial machines are larger in size which are used by large business to do complex tasks on daily basis. They have been around for a while and come in various sizes and types, each with their own special abilities. These machines are known for being powerful and capable of handling complex tasks. Due to its style and nature for large businesses, small business can not afford this and also it consume a lot of power for running and also difficult to move from one place to another due to its huge size.
Commercial machines are larger in size and are used by large businesses to do complex tasks on a daily basis. They have been around for a while and come in various sizes and types, each with its own special abilities. These machines are known for being powerful and capable of handling complex tasks. Due to their size and nature, they are not suitable for small businesses. They consume a lot of power and are difficult to move from one place to another.

Commercial machines are typically very expensive to purchase and maintain. They also require specialized training to operate. As a result, they are only suitable for businesses that have the need and the resources to use them.

Small businesses may be able to get by with smaller, less powerful machines. These machines are typically less expensive and easier to maintain. They may also be more portable, making them easier to move from one location to another. However, they may not be able to handle the same level of workload as commercial machines.

7.3 Key Features of Our CNC Machine

Our 3-Axis CNC machine is a cost-effective, portable, and low-power machine that can be used for a variety of applications. It is perfect for small businesses and hobbyists who need a reliable and affordable CNC machine. The machine is easy to use, it is also very portable and can be easily moved from one location to another. The machine is also very energy-efficient and consumes very little power.

While comparing our CNC machine with commercial machines, we are comparing it by the following features:

- **Cost:** Our CNC machine is more affordable than commercial machines. This is because we use less expensive materials and components in our manufacturing process.
- **Portability:** Our CNC machine is more portable than commercial machines. This is because it is smaller and lighter. It can be easily transported from one location to another.
- **Power consumption:** Our CNC machine consumes less power than commercial machines. This is because it uses more efficient motors and drives.

In addition to these features, our CNC machine also offers the following advantages:

- It is easy to use.
- It is versatile.

We believe that our CNC machine is a great value for the price. It offers all of the features and advantages of a commercial machine, but at a fraction of the cost.

7.4 Comparison

The below table shows a visual comparison of our machine with the commercial.

Table 7.1: Comparison Table

Name	Manufacturer	Weight (kg)	Length (mm)	Width (mm)	Voltage	Power (Watt)	Cost (USD)
3-axis CNC milling machine B130A [9]	Alòs Industrials	400	2,550	1,300	220	1500	18,857
SUDA cnc 6060 6090 [10]	SUDA	1500	2500	1300	220	3000	3800
CNC Router 1325S-ATC [11]	ROCTECH	1800	2500	1300	220	4500	9000
Our CNC Machine	-	12	500	350	12	40	150

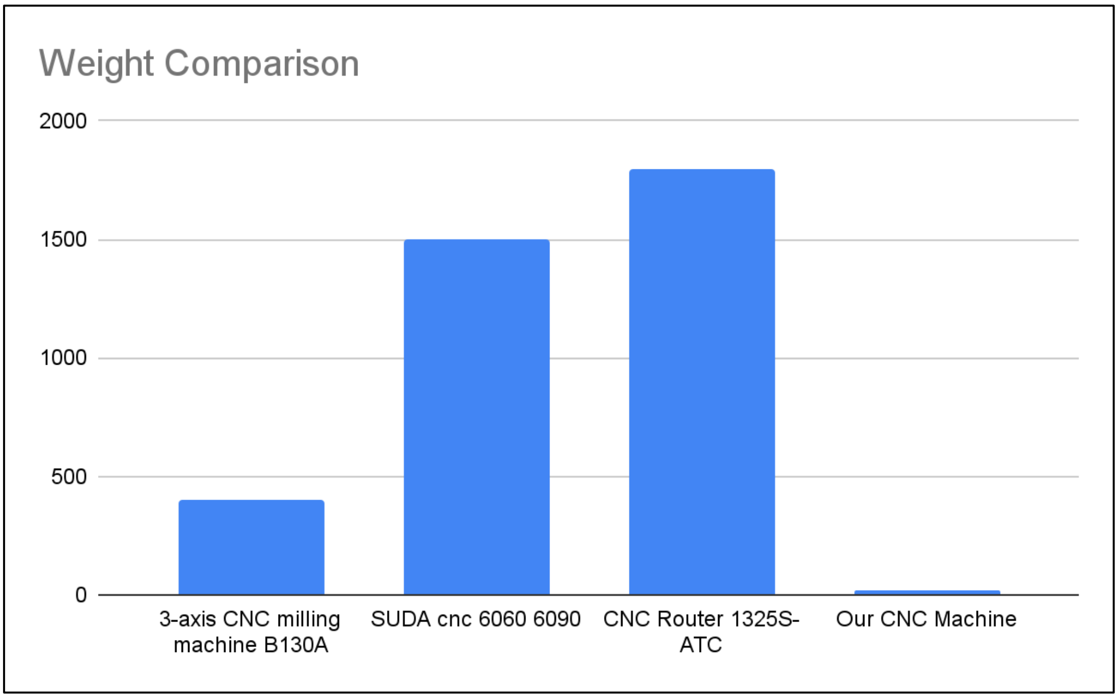


Figure 7.1: Weight Comparison

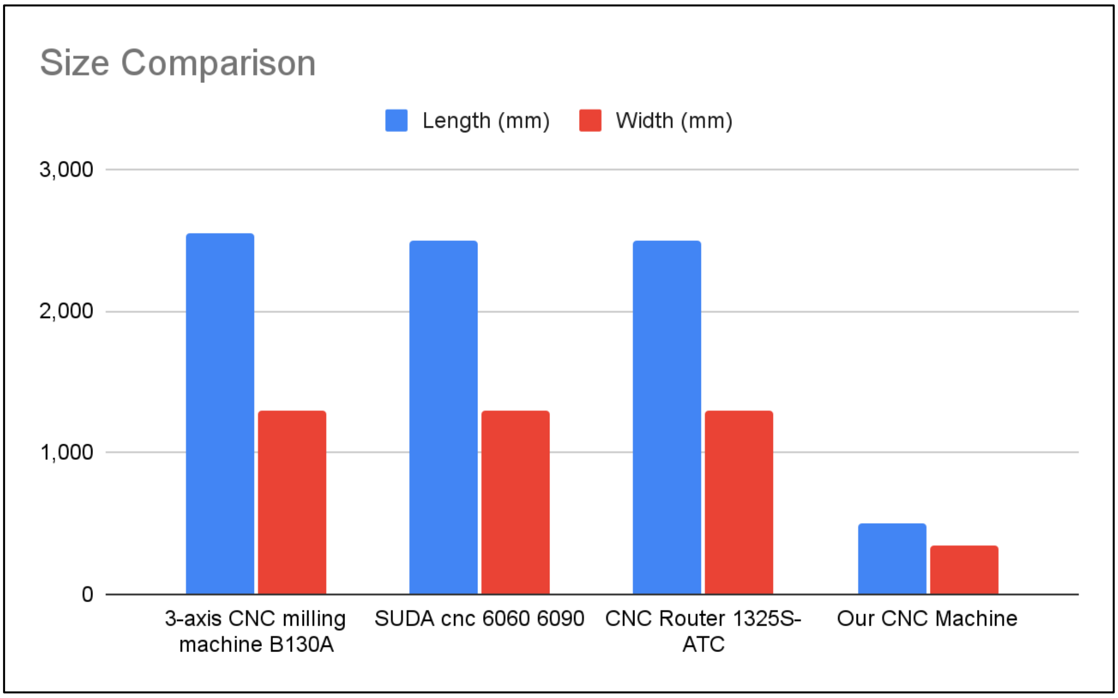


Figure 7.2: Size Comparison

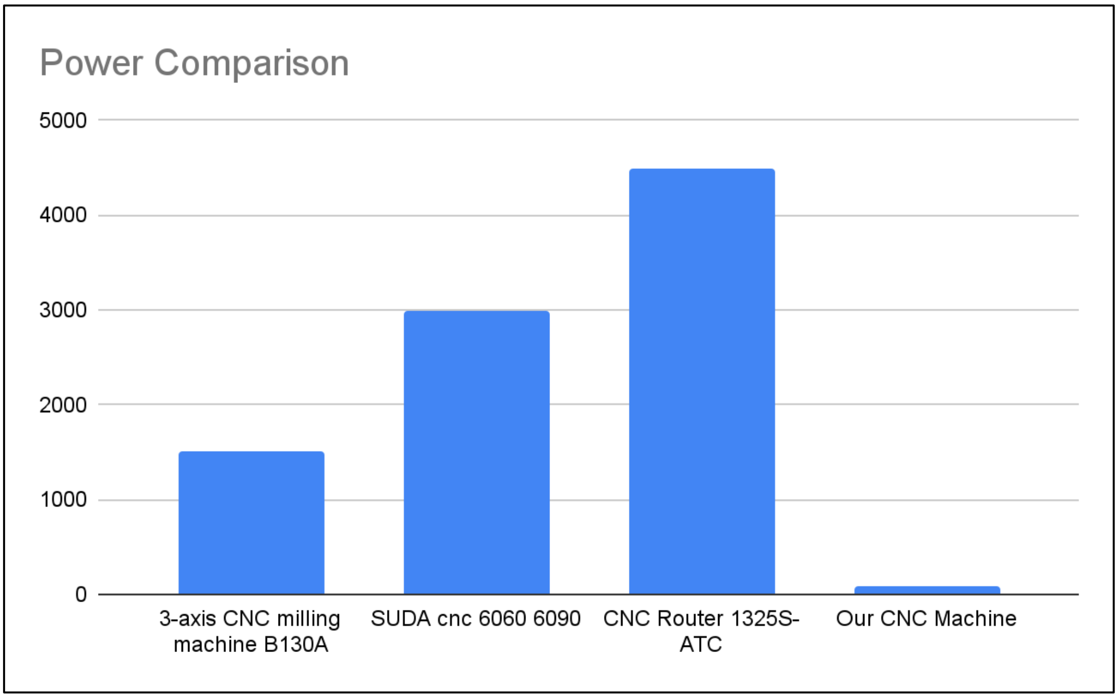


Figure 7.3: Power Comparison

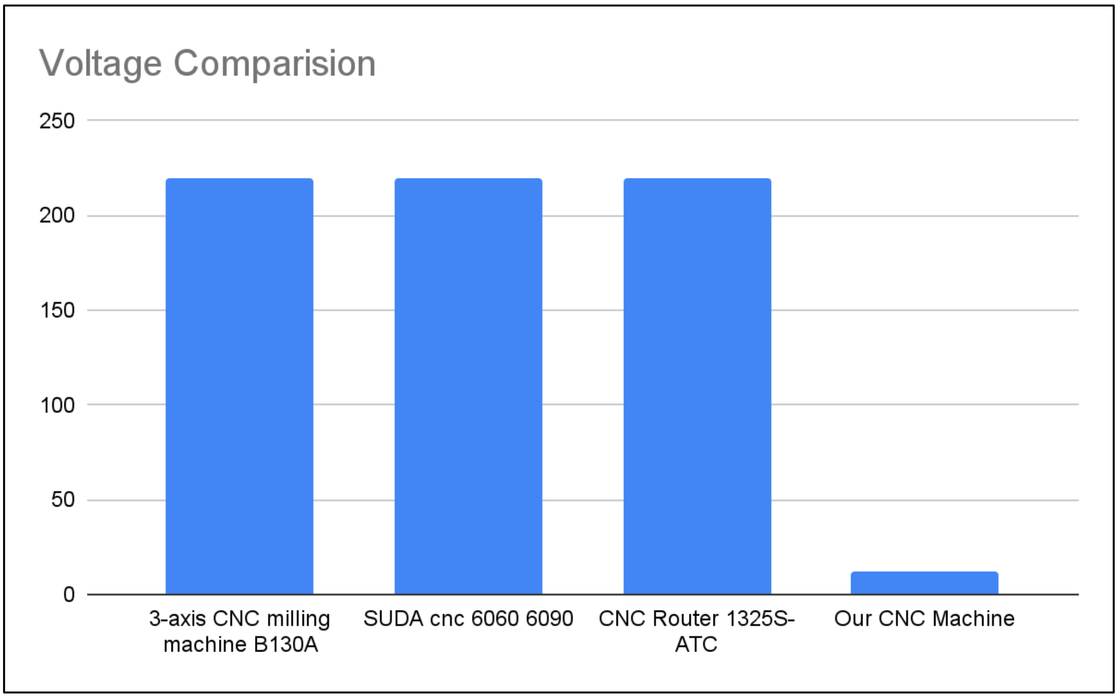


Figure 7.4: Voltage Comparison

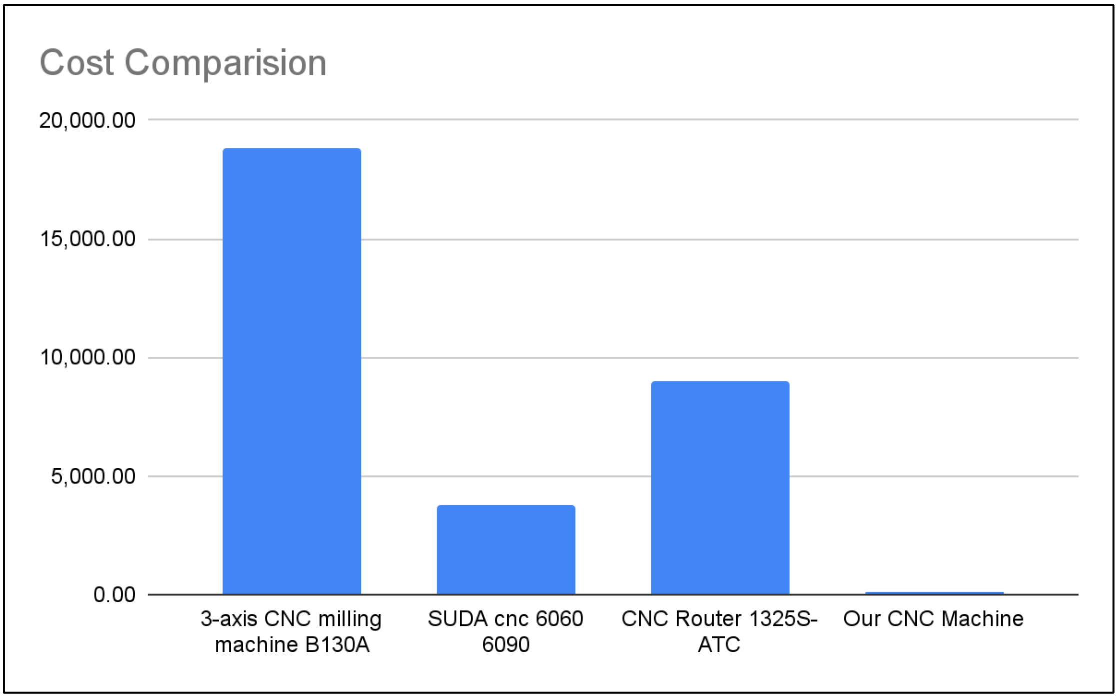


Figure 7.5: Cost Comparison

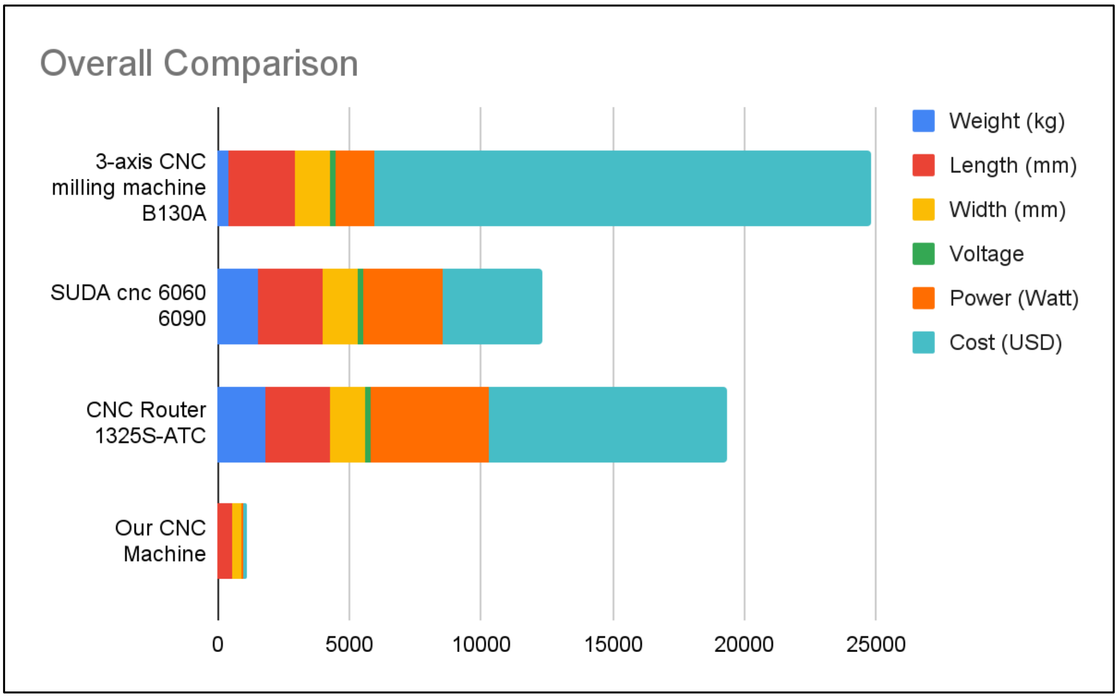


Figure 7.6: Overall Comparison

7.5 Conclusion

In wrapping things up, our CNC machine has successfully reached the goal we set out for it. This conclusion is based on a thorough comparison we made between our machine and others. The results of this comparison clearly demonstrate that our machine stands out in terms of its performance and efficiency. The evidence we gathered during this comparison emphasizes that our CNC machine is not only capable but also excels in being portable, cost-effective, and low in power consumption. This achievement validates the effort and innovation we put into developing a machine that addresses these important factors and showcases its practical advantages over other alternatives.

Chapter 8

Conclusion and Recommendations

8.1 Summary of the project and its main contributions

The aim of this project was to design and construct a 3-axis CNC machine using a microcontroller, and to evaluate its performance in terms of accuracy, speed, and efficiency. The project has been successfully completed, and several key contributions have been made.

Firstly, a CNC machine design was developed that is both compact and versatile, making it suitable for use in a wide range of applications. The design incorporates a number of innovative features, including a high-precision linear motion system and a user-friendly control interface.

Finally, a comprehensive testing and validation process was conducted to evaluate the performance of the CNC machine under different operating conditions. The results of these tests demonstrated that the machine is capable of achieving high levels of precision, speed, and efficiency, and that it is suitable for use in a variety of industrial and manufacturing applications.

5.2 Discussion of limitations and future work

While this project has successfully achieved its main objectives and brought valuable contributions to the CNC technology field, it's important to recognize certain limitations that exist. One key limitation is the current design's constrained range of motion, potentially making it less suitable for applications demanding more extensive movement capabilities. Furthermore, the precision and accuracy of the machine could be impacted by external factors like temperature and humidity, necessitating consideration in future iterations.

Moreover, the project could delve into the integration of the CNC machine with the Internet of Things (IoT) technologies. This would enable remote access and control over the network, opening the door to remote operation and monitoring – a valuable feature in today's connected world.

In terms of safety, the inclusion of limit switches is a crucial consideration. Incorporating these switches would establish a safeguard against the machine overstepping its defined limits, enhancing both user and machine safety during operation.

Furthermore, exploring potential collaborations with other automation technologies like sensors and robotics could lead to the creation of a fully automated manufacturing system. This would not only streamline production processes but also offer opportunities for innovation in the broader realm of automation and manufacturing.

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