POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022
Volume 2, Issue 4, 2024
Received: 13 October 2024
Accepted: 9 November 2024
Published: 20 November 2024

DESIGN AND FABRICATION OF ARDUINO BASED 3D CNC ENGRAVING ROUTER MACHINE

Shahbaz Khan

Research Scholar at University of Engineering and Technology (UET), Peshawar

khanengrshahbaz@gmail.com

ABSTRACT

The present study discusses the design and assembly of an economical three-axis medium size portable CNC machine utilizing an ARDUINO UNO microcontroller, stepper motors, and a GRBL shield. For accurate task manufacturing, the system must exhibit excellent dimensional accuracy and surface polish. In applications such as drilling, punching, marking, boring, and tapping, the work piece is initially positioned, after which the cutting tool executes its function while the motion axis remain motionless. In the conventional method for such applications, the manufacturer employs a costly CNC machine for programming and performing the task cycle. Large-scale manufacturers can invest in expensive machinery; nevertheless, the small-scale mechanical job manufacturing sector must consider cost-effective solutions that yield superior results.

This project aims to present a low-cost design that provides capabilities comparable to that of high-cost CNC machines. Utilizing this equipment in the industry can achieve multi-generational efficiency quickly. CNC machines are employed in the industry for operations necessitating continuous cutting along a specified curve, as opposed to conventional equipment. The installation of a CNC machine necessitates a substantial financial commitment and experienced labor to execute various operations on the machine. Additionally, the maintenance costs of such machines are likewise elevated. In small-scale companies where operations are conducted on minor job pieces, the implementation of high-cost CNC machines is challenging; thus, this project involves the creation of a low-cost CNC cutting machine utilizing Arduino technology. This CNC cutting machine will be highly beneficial for small-scale enterprises with limited project sizes. The machine does not need highly specialized labor for operation.

INTRODUCTION

1.1 Introduction

A Computer Numerical Control (CNC) machine is a traditional machine in which an operator determines and modifies different parameters, such as feed and depth of cut, according to the specific task and manually controls the slide motions. It is a specialized and adaptable kind of Soft Automation, with applications spanning several domains, although it was originally designed to regulate the motion and functioning of machine tools. A CNC machine receives code from a computer and transforms them into electrical impulses using software. The computer's signals are then utilized to regulate motors. The motors' capability to rotate in minute increments enable the machine to execute very accurate motions repeatedly. The 3-axis CNC machine currently has a variety of sizes available in the open market. Over the decades, industrial technology has revolutionized several facets of everyday life.

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

Numerous research has been conducted to build a CNC machine that is smaller, thinner, lighter, and cost-effective. The primary concept underlying this CNC development effort is derived from pertinent publications and studies. The technology of CNC machines is distinguished by affordability and accessibility, enabling anyone to develop and manufacture CNC-controlled machines. The advanced capabilities and precision control of CNC tools, in comparison to conventional machines, have significantly impacted the creation of functional components, frame bodies, stepper motors, and control circuits. Development and assessment of an economical table CNC milling apparatus Utilizing a low-cost milling cutter for the main spindle, owing to a reduced voltage supply of the primary cutting forces, enables the use of dimension tools to process materials such as wood, aluminum, and plastics. Design and Implementation of a Three-Dimensional CNC Machine, focusing on the development of an economical three-dimensional CNC system. The primary function is a microcontroller-based CNC machine that facilitates communication between a personal computer (PC) and the CNC machine through a software subsystem, which receives a set of commands and transmits them to the mechanical subsystem to operate the three axis. A software subsystem that is a personal computer with a user-friendly interface for programming commands in a language compatible with microcontrollers.

The employment of CNC machines in industrial industries is rapidly rising due to enhanced productivity, superior product quality (regarding dimensional tolerances), reduced production costs, and user-friendliness. Nonetheless, the expense related to this equipment restricts their complete use, leaving tiny artisans bereft of their advantages. The analysis indicates significant potential for various CNC machines in the manufacturing industry. The government of Pakistan has initiated several awareness and skill development initiatives to enhance worker quality, provide sophisticated machine knowledge, and foster self-employment in diverse industrial industries. To achieve the objectives, many subsidies and loan approval mechanisms have been established for micro, small, and medium companies (MSMEs). The deployment of CNC machines in rural regions can be enhanced by lowering equipment costs and offering enough training to the workforce. Pinero et al. developed a small CNC plotter with the Arduino microcontroller, which is cost-effective and user-friendly. Moreover, researchers have documented the utilization of the Arduino microcontroller in many CNC-based machines owing to its accessibility, affordability, and programming simplicity. The current project was initiated with consideration of the aforementioned requirements for the cost-effectiveness and precision of CNC machines. The project started with a market survey, and a feasibility assessment was conducted. A significant demand exists for an affordable, lightweight, portable, small-scale CNC machine suitable for effortless production. The application of Arduino-based microcontrollers is adaptable and ideal for interdisciplinary applications.

The design of low-cost CNC machines started and was completed with design software (CATIA), informed by market research and needs. The machine frame was constructed from medium-density fireproof wood and connected to a computer using Arduino Uno and GRBL Shield. This device is a portable mini-CNC machine suitable for prototype manufacturing in small-scale enterprises and for educational applications. Small to medium companies (SMEs) in Pakistan are encountering significant challenges, including heightened local and global rivalry, shortages of working capital, a lack of qualified workers, inefficiencies in supply chains, shifts in marketing techniques, and an unstable market environment. Designing and producing an ergonomic, cost-effective, and accurate CNC machine. May provide substantial assistance to small firms. Small enterprises, artists, and woodworkers might significantly reduce expenses by utilizing more economical options while improving production speeds.

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

1.2 Objective

The concept of developing a low-cost CNC milling machine is to meet the need for CNC machines across both small and large-scale sectors while minimizing expenses. A significant advancement in computer technology is the accessibility of affordable open-source hardware, exemplified by the Arduino microcontroller. An advantage of open-source hardware is the extensive availability of ready-to-use software online, which significantly reduces prototyping and development timeframes. Additionally, a diverse array of affordable interfaces and peripherals, like Arduino shields, is readily accessible. Nevertheless, for the advancement of economical CNC machine models, such instruments may be sufficiently effective regarding machine control.

This project presents the creation of a prototype 3-axis CNC milling machine utilizing an Arduino-based control system, along with the following specifications.

1. Inexpensive
2. User-friendly
3. Intuitive UI
4. Adaptable
5. Minimal energy usage

1.3 Research Methodology

The initial phase in the functioning of the CNC machine involved calibrating the tool to ascertain if the stepper motor and other systems functioned in accordance with the configured software. Commenced by establishing the initial position of the spindle drill on the CNC machine with Universal G-code Sender software, both by automated means and manual rotation. The spindle drill speed may be adjusted to a maximum of 12,000 rpm (revolutions per minute). Upon calibration of the CNC machine, the design in G-code format was transferred to the Arduino Uno using a Universal G-code Sender utilizing a serial connection. The microcontroller will interpret the data as a command and supply logic to the A4988 motor driver. The information the motor driver received input to operate three Nema 17 stepper motors on the X, Y, and Z axis, therefore creating a pattern on the object.

1.4 Block Diagram of Assembly Specification

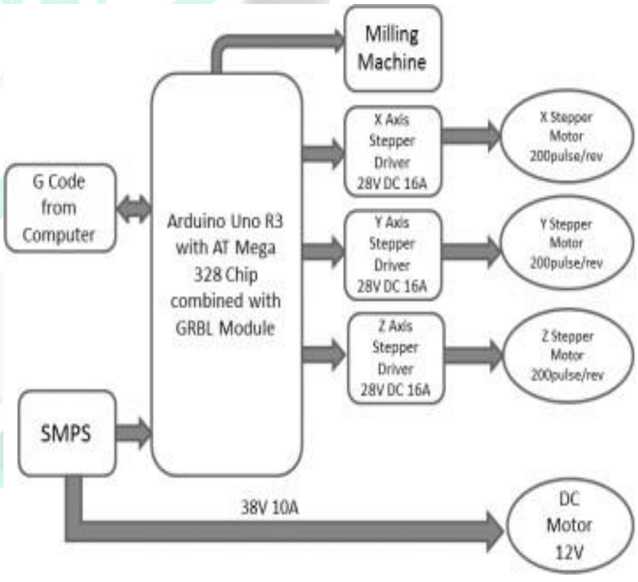


Figure 1.1 Block Diagram of Assembly Specification

LITERATURE REVIEW

2.1 Literature Review

According to Correa J. et al. (2016), a software design that emphasizes a component-based approach in which each part has A paradigm for a freelancing finite state machine (FSM). A multiprocessor distributed controller with varying process levels and adaptability to various hardware specifications might be the hardware architecture in question. As part of the technique, a description of the fundamental management algorithms is included, along with examples of their application to the open-source Arduino platform. Various outcomes include the first system check for a two-axis CNC and, therefore, the Simulink control loop mathematical model. According to this article, architecture can transform CNC into open supply physics from a tool-oriented system to one in which users will create their controllers for machines with specific uses. Open management design, which enables open design controllers for CNC systems, has the potential to revolutionize open supply physics.

This research focuses on suggesting a design for open supply physics that is compatible with CNC engraving machines to engrave the tire mildew's aspect walls. Three axis make up the proposed engraving machine: the A, Y, and Z axis, also known as the rotating axis. Sharath, D. O., et al. (2017) The author's primary goal is to lower the cost and labor requirements for the machinery used in businesses and educational institutions. To create 2D graphics, he used a laser module to manufacture a CNC engraver. It will be used to engrave leather, plastic, and wood. He makes use of computer numerical control or CNC. CNC enables us to control machine tools, such as grinding, until we can use the CNC to operate any tools. We must utilize specialized software that generates G code to regulate and provide certain directives, such as feed rate and speed. G code is just the language used for CNC machining. He uses a microcontroller and a stepper motor in addition to a CNC to create the engraving machine. The microcontroller is called Arduino. It is a two-axis machine that uses a stepper motor for linear motion on the x and y axis. The two stepper motors must be synchronized for correct movement. He employs aluminum profiles and wood to make the machine lighter and more compact. He utilized the A3967 stepper driver to control the stepper motor in his build. A stepper motor drives and regulates the stepper motor. It can do this by providing voltage. For the etching procedure, he employs a laser diode. These days, Arduino is a popular and affordable microcontroller for project creation. It is simple to use and free.

Arduino must first be fed the g code routines. After that, it will regulate anything that is electrically linked to it. The g code allows us to accomplish the motions we want. In 2020, Jaya Prasad V.C. et al. The author of this article provides a thorough explanation of laser operations as well as the design and

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

construction of a laser engraver that uses a CNC. All a laser engraver does is use a laser beam to etch the surface to be engraved. The etched portion differs from the rest of the surface. Laser engaging is not the same as laser cutting. Laser cutting allows us to accurately cut any material into a variety of forms by passing the beam through the material. Cutting may be accomplished by allowing the laser beam to penetrate the material for a certain amount of time before cutting it. Various materials have varying holding times. Machines that are used for quick prototyping include laser engraving and final cutting. Any models may be quickly fabricated with rapid prototyping. The entire definition of a laser, which was created in 1960, is light amplification by simulated radiation emission. A typical laser beam differs from other types of light beams.

2.2 CNC machines

The industrial sectors make extensive use of computer numerical control (CNC) devices. In recent years, they have become quite popular. A computer-controlled machine system, or CNC machine, allows producers to automate several industrial processes that would otherwise need to be completed by hand. Therefore, the adoption of CNC-powered equipment reduces waste, boosts productivity, and even eliminates the possibility of human mistakes. Actuators, motors, and software enable CNC machines to manufacture a variety of goods.

2.3 CNC Machine Types

The kinds of CNC machines are as follows:

1. CNC lathe
2. CNC milling machine
3. CNC drilling machine
4. A CNC grinding machine
5. CNC machine for laser cutting
6. A CNC plasma cutting machine
7. CNC machine with electric discharge
8. CNC router machine
9. A CNC machine that changes its tools automatically
10. A 3D printer
11. CNC machine with five axis
12. A machine that picks and places

2.3.1 CNC lathe machine

The capacity of lathe CNC machines to rotate materials while in use is what distinguishes them. They are shorter and more compact than CNC milling machines because they have fewer axis.

The core component of CNC lathe machines is a lathe that programmatically controls and transmits materials to the computer. It is now commonly employed as a lathe because of its quick and precise operation.

A semi-skilled person may use it with ease after the basic setup is complete. Mass manufacture of items like capstans and turrets is another use for this kind of lathe. However, the supplied system is not programmed.

Figure 2.3.1 Lathe CNC Machine

ISSN (E): 3006-7030 (P) 3006-7022

2.3.2 CNC Milling Machine

It is a prevalent type of CNC machine equipped with integrated tools for drilling and cutting. The materials are situated within a milling CNC machine, after which the computer directs the tools to drill or cut them. The majority of CNC milling machines are offered in configurations ranging from 3 to 6 axis. This machine is utilized to produce gears, such as spur gears, drilling the work piece bore, and creating slots by inputting a component program into the system. A semi-skilled laborer can use it with ease. It is furthermore utilized for mass manufacture, including capstans and turrets. However, an established feeding system is needed. The components produced by this machine exhibit exceptional dimensional accuracy.

Figure 2.3.2 CNC Milling Machine

2.3.3 CNC Drilling Machine

The CNC drilling machine is often used for large-scale manufacturing. Drilling machines usually possess a multifunctional machining center that is sometimes intermingled and, at times, distorted. The primary source of downtime in CNC drilling is attributed to tool changes; thus, to enhance efficiency, the fluctuation in overall diameter must be minimized.

The most efficient drilling machine has many spindles in the turret, each equipped with pre-mounted drills of varying sizes. This CNC machine is capable of reaming, counter boring, and tapping holes.

Figure 2.3.3 CNC Drilling Machine

2.3.4 CNC Grinding Machine

It is an accurate device that uses a rotating wheel to eliminate metal substances. CNC grinding machines are frequently utilized for camshafts, ball bearings, gearbox shafts and other components requiring accurate finishing.

A variety of components manufactured with a CNC grinding machine are cylindrical. A grinding machine is utilized to produce several types of workpieces. In CNC grinding

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

machines, "CNC" stands for computerized numerical control.

Figure 2.3.4 CNC Grinding Machine

2.3.5 CNC Laser Cutting Machine

Laser-cutting CNC machines are engineered to cut rigid materials using a laser instead of a plasma flame. Lasers offer considerable precision; yet they are inferior to plasma torches in effectiveness.

Laser-cutting CNC machines often utilize one of three laser types: CO2, neodymium (Nd), or yttrium-aluminum-garnet (Nd: YAG).

Figure 2.3.5 CNC Laser Cutting Machine

2.3.6 CNC Plasma Cutting Machine

Plasma-cutting CNC machines, which are similar to machining CNC machines, are also employed to cut materials. However, they distinguish themselves from their milling counterparts by employing a plasma flame to perform this operation.

An accelerated stream of heated plasma is used to cut electrically conductive materials, which is the definition of a plasma cutting machine. These CNC machines are equipped with a powerful torch that is capable of cutting through tough materials, such as metal.

Figure 2.3.6 CNC Plasma Cutting Machine

2.3.7 Electrical Discharge Machine using CNC Technology

Another name for this is a spark. One kind of CNC machine manipulates materials into the required form by using electric sparks. Because electrical discharge has a temporary impact, the materials it comes from may deteriorate. The electric discharge CNC machines use this to their advantage by creating controlled sparks that can change the form of materials.

The materials are situated between the electrode's top and bottom, and the computer then determines how much electrical discharge the electrodes generate.

Figure 2.3.7 CNC Electrical Discharge Machine

2.3.8. CNC Router Machine

The CNC router operates similarly to other CNC machines, such as lathes or mills. The primary distinction is that all carpentry tasks are performed manually, including interior work, door carving, external ornamentation, wood paneling, signboards, wood framing, molding, musical instruments, furniture, and more items.

Based on the drawing, you may design and, if feasible, implement it inside the system before executing it on a CNC router machine. This yields an improved surface polish. The machine would excel in door design and other features.

Figure 2.3.8 CNC Router Machine

2.3.9 CNC Machine Featuring Automatic Tool Changes

Automated tool Changers the CNC machine is used to enhance the tool's load-bearing capability and the machine's output rate. Additionally, it was used to enhance the machine's ability to operate with many tools. This sort of CNC machine rapidly and effortlessly exchanges tools, accommodating the replacement of old or damaged implements.

The primary advantage of this CNC machine is its ability to minimize non-productive time. The Automatic Tool Changer CNC machine represents a significant advancement in achieving full automation.

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

Figure 2.3.9 Automatic Tool Changes

2.3.10 Three-Dimensional Printer

It is a CNC machine that fabricates components in a layer-by-layer manner. The design and drawing are generated using the CAD and CAM processes, subsequently, realized by the 3D printer to manifest that design. The 3D printer CNC apparatus used for the construction of edifices and facilities.

Figure 2.3.10 3-D Printer

2.3.11 5-Axis CNC Milling Machine

The 5-Axis CNC machine has five axis in total. Initially, it had three axis (X, Y, and Z), allowing cutting operations in three dimensions; however, the inclusion of two more axis (A, B) resulted in a total of five axis. This apparatus is used for the fabrication of sculptures.

Figure 2.3.11 5-Axis CNC Milling Machine

2.4 What constitutes CNC engraving?

Engraving is a cutting method that involves carving a pattern into a hard surface to adorn or identify items produced from various materials, traditionally using manual engraving equipment. However, CNC engraving is now also accessible. CNC engraving employs computer-controlled machinery that utilizes milling routes produced by CAD-CAM software according to the design blueprint. CNC engraving machines, in contrast to manual engraving machines, minimize mistakes and enhance speed, enabling a range of intricate precision engraving for both practical and artistic applications.

2.5 CNC Engraving Machinery and Tools

CNC engraving, like CNC milling, necessitates a Computer Numerical Control apparatus and CAD and CAM software. Which engraving machine should you select? Let us examine the many categories of CNC engraving machines.

1. Laser Engraving Apparatus

A laser engraving apparatus typically comprises a laser, a controller, and a substrate. The laser serves as a precision instrument for cutting or marking materials, with the control system regulating the direction, intensity, movement speed, and dispersion of the laser beam directed at the surface. The surface will correspond with the kind of material selected for engraving. Laser engravers operate more straightforwardly than spinning cutting tools, eliminating the need for a clamping mechanism. Prevalent laser types include laser diodes, CO2 lasers, fiber lasers, and crystal lasers. Laser engraving equipment is capable of processing wood, leather, plastic, and metal materials.

2. CNC Milling and Engraving Machine

A CNC milling machine may function further as a CNC engraving machine. CNC engraving necessitates a certain spindle speed for the mill since the small-sized engraving tools and soft materials demand an elevated spindle speed. CNC milling engraving may be executed on stainless steel, mild steel, aluminum, brass, wood, plastics, and several other materials.

3. CNC Router Engraving Apparatus

CNC routers are also great options for engraving work. A CNC router is a computer-controlled cutting apparatus that generally affixes a hand-held router as a spindle for the purpose of cutting various materials.

4. CNC Engraving Instruments

Common engraving cutting tools include v-bits, tiny ball nose end mills, and drag engravers.

2.6 Engraving Techniques

Laser engraving: The predominant engraving technique in contemporary civilization is using a heated laser beam to vaporize superfluous material in designated areas. The laser head oscillates to provide precise cuts and intricate engravings. The direction, velocity, depth, and other parameters may be regulated.

Electric engraving: Entails electrical discharge machining and welding techniques. A metallic pin serves as the anode, while the substance is designated for cutting functions as the cathode. The current traversing between the cathode and anode incinerates the material at the designated engraving point. This engraving method is only appropriate for conductive materials.

Hand engraving: The traditional engraving technique uses hand tools, such as a curved instrument with a sharp blade. This engraving technique is used for refining lettering on gravestones and similar applications and is suitable for intricate craftsmanship.

CNC rotary engraving typically uses a rotary tool to eliminate material, making it suitable for indoor and outdoor signatures, nameplates, 3D effects on wood, and further applications.

Computer-controlled instruments can inscribe a variety of forms and designs.

METHODOLOGY

3.1 Methodology

The methodology for developing an engraving involves framing first, followed by the electrical system, and concluding with computers. Utilizing CAD software, we can create and analyze our models. The author employs three stepper motors for linear motion, using guide rods, bearings, and control signals to facilitate the movement of the stepper motors along the frame. He used Arduino Uno as a microcontroller for the electrical system. Initially, we must input G-code into the microcontroller board. Utilizing a CNC shield and stepper motor drive enables the generation of signals. It converts the signal into a voltage signal. It needs specialized software known as Grbl. It produces G-code for the microcontroller. The quality of the product is enhanced by CNC use. We can really create a cost-effective engraving with great accuracy with CNC technology. It will also automatically improve the output pace.

3. 2 Circuit Diagram

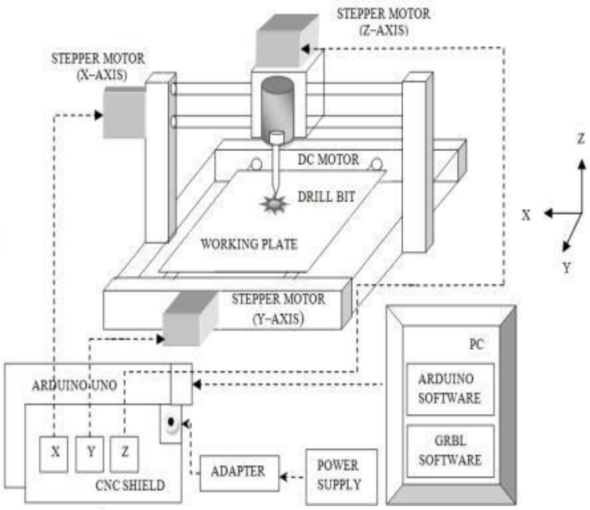


Figure 3.1 Circuit Diagram

3.3 Software's

G Code

CNC machines are operated via instructions known as CNC G Codes. While various manufacturers of machine tools may implement specific G Codes, a fundamental set exists that is universally applicable across all machine tools. These standards are applied to CNC lathes, milling machines, routers, and, more recently, to 3D printers in a rudimentary version. It is used when the cutter or tool is not eliminating material, hence minimizing the machining time for the component. The machine's specifications determine the maximum speed and may only be adjusted by the operator via fast override control.

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

Exercise caution about any clamps, vices, and components that may obstruct your trajectory while executing a quick man oeuvre. If uncertain, it may be prudent to adjust the X and Y axis first, followed by a further adjustment along the Z axis. It will extend your machining time by one or two seconds, but it will prevent a 3 Axis crash.

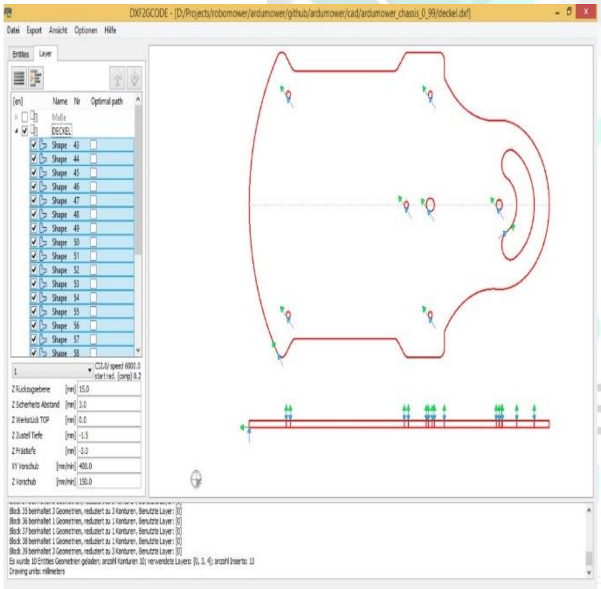


Figure 3.2 Software's G code

Arduino Integrated Development Environment (IDE)

Arduino (IDE) is a cross-platform program for Windows, macOS, and Linux, developed in C and C++ languages. Arduino provides a library from the IDE wiring project that offers many general information and development methodologies. The Arduino open-source programming environment (IDE) facilitates the creation and manipulation of code, irrespective of its appearance. It operates on Windows, Mac OS, and Linux. The code is developed in Java and relies on preparation and another open-source programming language. This device is compatible with any Arduino board.

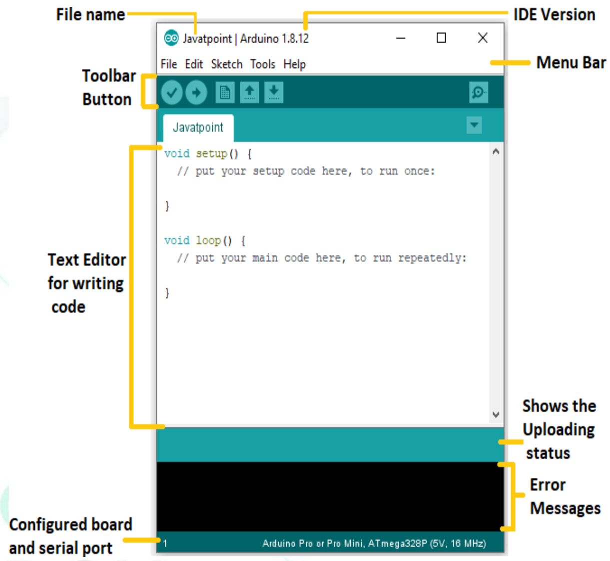


Figure 3.3 Arduino IDE

3.4 Hardware Specifications

Arduino Uno
Stepper Motors
Stepper Motor Driver
CNC Griddle Motor
Aluminum Framework

3.4.1 Arduino Uno

The Arduino Uno is a microcontroller board based on the ATmega328, with "Uno" being the Italian word for one. The Arduino Uno is named to signify the impending launch of the microcontroller board known as Arduino Uno Board 1.0. This board has 14 digital I/O pins, a power connector, 6 analogue inputs, a 16 MHz ceramic resonator, a USB connection, an RST button, and an ICSP header. This board

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

may facilitate the microcontroller's subsequent operations by connecting it to the computer. The power source for this board may be achieved via an AC-to-DC converter, a USB cable, or a battery. This article examines the Arduino Uno microcontroller, its pin arrangement, specs, and uses.

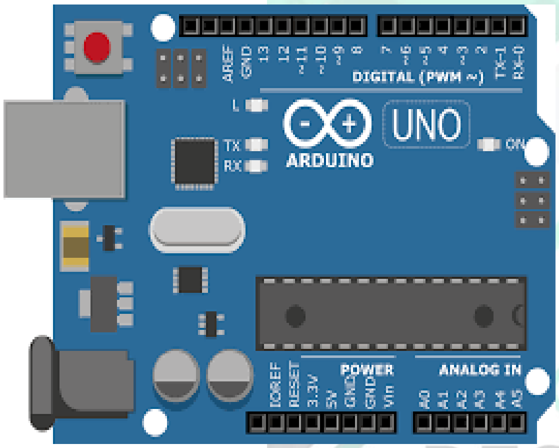


Figure 3.4 Arduino Uno

What is the ATmega328 Arduino Uno? Atmel created the ATmega328, a single-chip microcontroller that is a member of the megaAVR family. The Arduino Uno has an 8-bit RISC processor core with a customized Harvard architecture. The Arduino Pro Mini, Arduino Nano, Arduino Due, Arduino Mega, and Arduino Leonardo are other Arduino boards.

The Arduino Uno Board's attributes The following are some of the Arduino Uno ATmega328's features.

- Operating voltage: 5V;
- Suggested input voltage range: 7V to 12V;
- Input voltage range: 6V to 20V;
- Digital input/output pins: 14;
- Analogue input pins: 6;
- DC per input/output pin: 40 mA;
- DC for 3.3V pin: 50 mA;
- 32 KB of flash memory;
- 2 KB of SRAM;
- 1 KB of EEPROM;
- clock speed: 16 MHz;
- pin diagram for an Arduino Uno.

A reset button, a power LED, digital pins, a test LED (pin 13), TX/RX pins, an ATmega328 microprocessor, an ICSP header, analogue and power pins, a USB interface, and an external power supply are all included in the Arduino Uno board. Below is a description of the Arduino UNO board.

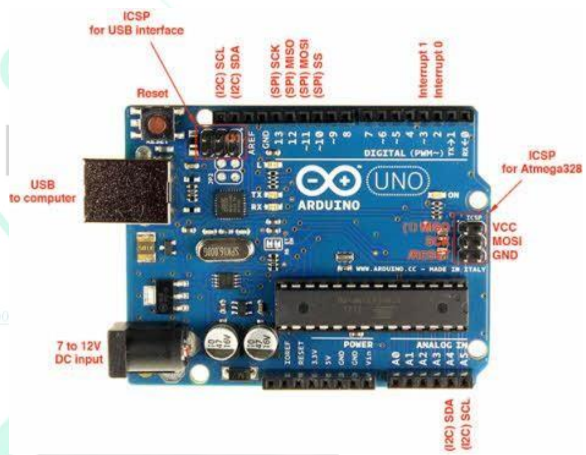


Figure 3.5 Features of Arduino Uno Board

Power Supply

The Arduino Uno can be powered by either an external power supply or a USB cable. The external power supplies primarily consist of an AC to DC adapter, or a battery. By connecting the adapter to the Arduino Uno, the power port of the Arduino board can be utilized. In the same way, the battery leads can be connected to the Vin pin and the GND pin of the POWER connector. The voltage range that is recommended is 7 to 12 volts.

Input and Output

Arduino Uno's 14 digital ports can be utilized as input and output by using the functions pin Mode (), digital Write (), and Digital Read ().

Pin1 (TX) and Pin0 (RX) (Serial):

The ATmega8U2 USB to TTL Serial chip equivalent terminals is connected to Pin1 (TX) and Pin0 (RX) (Serial), which are utilized for the transmission and reception of TTL serial data.

Pin 2 and Pin 3 (External Interrupts): External pins can be connected to activate an interruption in response to a low value or change in value.

Pins 3, 5, 6, 9, 10, and 11 (PWM): The analog Write () function provides 8-bit PWM o/p through this pin.

SPI Pins (Pin-10 (SS), Pin-11 (MOSI), Pin-12 (MISO), Pin-13 (SCK)): These pins are currently not included in the Arduino language, even though they are available in the fundamental hardware. They are used to maintain SPI communication.

Pin-13 (LED): The integrated LED can be connected to pin-13 (digital pin). The light emitting diode is activated whenever the pin is LOW, as it is the HIGH-value pin.

Pin-4 (SDA) and Pin-5 (SCL) (I2C): The Wire library facilitates TWI communication.

AREF (Reference Voltage): The reference voltage is for the analog i/ps with analogReference().

Reset Pin: This pin is utilized to reset the microcontroller (RST).

Memory:

The Atmega328 Arduino microcontroller contains 32 KB of flash memory for code storage, 2 KB of SRAM, and 1 KB of EEPROM.

Communication

The Arduino Uno ATmega328 provides UART TTL-serial communication, which is accessible via digital terminals such as TX (1) and RX (0). Arduino's software employs a serial monitor to facilitate data acquisition. The board contains two LEDs, RX and TX, which will flash whenever data is transmitted via the USB.The ATmega328P supports TWI (I2C) and SPI communication, and a Software Serial library enables serial communication on Arduino Uno digital interfaces. A wired library is included in the Arduino software to facilitate the utilization of the I2C interface.

How to Operate an Arduino Uno?

The Arduino Uno can detect its environment based on the input. In this case, the input consists of a diverse array of sensors, which can influence the environment by regulating

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

motors, lighting, and other actuators. The Arduino programming language and the IDE can be used to program the ATmega328 microcontroller on the Arduino board. (Integrated Development Environment). While operating on a personal computer, Arduino creations can communicate through software.

Programming with Arduino Attach the Arduino board to the computer using a USB cable after the Arduino IDE utility has been installed on the PC. Open the Arduino IDE and select the appropriate board by selecting Tools–>Board..>Arduino Uno. Then, select the appropriate port by selecting Tools–>Port. This board can be programmed using the Arduino programming language, which is contingent upon the wiring. To activate the Arduino board and illuminate the LED on the board, delete the program code by selecting Files–> Examples–> Basics–>illuminate. After the programming codes have been loaded into the IDE, select the "upload" icon in the upper bar. After this procedure is finished, verify that the LED flashes on the board. Arduino Uno ATmega328 Applications

The following are examples of Arduino Uno's applications.

1. Arduino Uno is employed for the prototyping of Do-it-yourself initiatives.

2. When creating initiatives that are governed by code-based control

3. Automation System Development

4. Development of fundamental circuit designs.

Consequently, this is the entirety of the Arduino Uno datasheet. Ultimately, the aforementioned information enables us to determine that this is an 8-bit ATmega328P microcontroller. The microcontroller is supported by a voltage regulator, a crystal oscillator, and various components, including serial communication. This board is equipped with a USB connection, 14 digital I/O pins, 6 analog I/P pins, a power-barrel port, a reset button, and an ICSP interface.

3.4.2 Stepper motors

A stepper motor is an electromechanical device that transforms electrical energy into mechanical energy. Additionally, it is a brushless, synchronous electric motor that has the capacity to divide a complete rotation into a vast number of stages. The motor's position can be as long as the motor is appropriately proportioned for the application, it can be precisely controlled without the use of a feedback mechanism. Switched reluctance motors are analogous to stepper motors. The stepper motor employs the theory of operation for magnets to ensure that the motor shaft rotates at a precise distance in response to an electrical discharge. The rotor has six poles, while the stator has eight. In order to complete a full revolution, the rotor will necessitate 24 pulses of electricity to move the 24 steps. An

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

alternative expression for this is that the rotor will rotate precisely 15° for each pulse of electricity that the motor receives. Principles of Construction and Operation. The construction of a stepper motor is somewhat comparable to that of a DC motor. It is equipped with a persistent magnet, similar to a rotor, that is situated in the center and will rotate when a force is applied to it. A magnetic coil is wound around the rotor, which is enclosed by a number of stators. Stators are positioned in close proximity to the rotor to regulate the rotor's motion through magnetic fields within the stators. The stepper motor can be managed by individually energizing each stator. Therefore, the stator will magnetize and function as an electromagnetic pole that propels the rotor forward by utilizing repulsive energy. The stator's alternative magnetizing and demagnetizing will progressively adjust the rotor, enabling it to rotate with great control. The electro-magnetism principle underpins the operation of the stepper motor. The stator is composed of electromagnets, while the rotor is constructed with a permanent magnet. The magnetic field within the stator will be generated upon the supply being applied to the stator's winding. The rotor in the motor will now commence to rotate in conjunction with the stator's rotating magnetic field. Therefore, this is the fundamental operating principle of this motor.

Through the electromagnetic stators, a malleable iron is contained within this motor. The type of stepper does not affect the poles of the stator or the rotor. The rotor will rotate to align itself with the stator once the stators of this motor are energized. Otherwise, it will turn to minimize the distance between the stator and the rotor. In this manner, the stepper motor is rotated by activating the stators in a series.

Figure 3.6 Stepper Motor

Figure 3.7 Stepper Motor winding

Driving Techniques

Stepper motor driving approaches are feasible with specialized circuits owing to their intricate construction. This motor may be driven using many ways, which are outlined below with reference to a four-phase stepper motor.

Unipolar Excitation Mode

The fundamental technique for operating a stepper motor is via a single excitation mode. This is an antiquated strategy that is hardly used nowadays, although it is essential to be informed about this procedure. This approach involves sequentially triggering each phase or stator alternately using a specialized circuit. This will magnetize and demagnetize the stator to advance the rotor.

Complete Step Drive

This approach involves activating two stators simultaneously rather than one, within a much-reduced time frame. This approach produces substantial torque and enables the motor to handle significant loads.

Half-Step Drive

This approach is closely associated with the Full step drive, since the two stators are positioned next to one another, allowing for the initial activation of one, followed by the subsequent activation of the third. This cycle involves first switching two stators, followed by the activation of the third stator to drive the motor. This strategy will enhance the resolution of the stepper motor while reducing the torque.

Micro stepping

This approach is mostly used because of its precision. The variable step current will be supplied by the stepper motor driver circuit to the stator coils in the form of a sinusoidal waveform. The precision of each step may be improved by this little current adjustment. This approach is widely used because to its great accuracy and significant reduction in operational noise.

Stepper Motor Circuit and Its Functionality

Stepper motors function distinctively compared to DC brush motors, which revolve with the application of voltage to their terminals. Stepper motors consist of many toothed electromagnets positioned around a central gear-shaped iron component. The electromagnets are activated by an external control circuit, such as a microprocessor. To initiate the rotation of the motor shaft, an electromagnet is powered, resulting in the magnetic attraction of the gear's teeth to those of the electromagnet. When the gear's teeth align with the first electromagnet, they are slightly misaligned with the subsequent electromagnet. When the subsequent electromagnet is activated and the first is deactivated, the gear spins slightly to align with the next one, and the process is repeated. Each minor rotation is referred to as a step, with an integer quantity of steps constituting a complete rotation.

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

In this manner, the motor may be actuated with precision. Stepper motors do not spin continuously; they revolve in discrete stages. Four coils are affixed to the stator, each positioned at a 90-degree angle relative to one another. The connections of the stepper motor are dictated by the configuration of the coil interconnections. In a stepper motor, the coils remain unconnected. The motor has a 90-degree rotational step, with the coils activated in a sequential manner, dictating the direction of the shaft's revolution.

The operation of this motor is shown by activating the switch. The coils are engaged sequentially at one-second intervals. The shaft spins 90 degrees with each activation of the subsequent coil. The low-speed torque will be precisely proportional to the current.

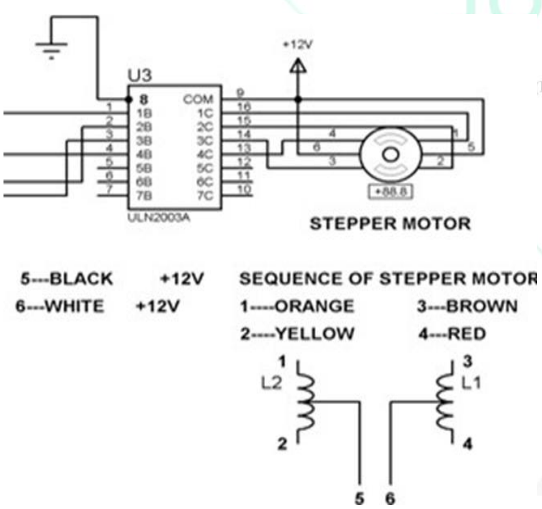


Figure 3.8 Stepper Motor Circuit

Categories of Stepper Motors

There are three primary categories of stepper motors:

- Permanent magnet stepper motor
- Hybrid synchronous stepper motor
- Variable reluctance stepper motor

Benefits

The benefits of a stepper motor include the following.

- Durability
- Uncomplicated design
- Operable in an open-loop control system
- Minimal maintenance required
- Functional in diverse conditions
- High reliability
- The motor's rotation angle is directly proportional to the input pulse.
- The motor exhibits full torque at rest.
- Accurate placement and consistent movement, since high-quality stepper motors exhibit an accuracy of 3 – 5% every step, with this inaccuracy being noncumulative over successive steps.
- Outstanding responsiveness to initiation, cessation, and reversal.
- Highly dependable due to the absence of contact brushes in the motor. Consequently, the lifespan of the motor is solely contingent

upon the lifespan of the bearing. The motor's reaction to digital input pulses facilitates open-loop control, making the motor simpler and more economical to manage.

• Very low-speed synchronous rotation may be attained with a load directly linked to the shaft.

• A broad spectrum of rotational speeds can be achieved, since speed is proportional to the frequency of the input pulses.

Utilizations

The applications of stepper motors include the following.

1. Industrial Machines - Stepper motors are used in automobile gauges and automated manufacturing equipment for machine tooling.

2. Security - innovative surveillance solutions for the security sector.

3. Medical - Stepper motors are used in medical scanners, samplers, digital dentistry photography, fluid pumps, respirators, and blood analysis equipment.

4. Consumer Electronics - Stepper motors used in cameras for automated digital focus and zoom functionalities.

The Arduino is open-source electronics prototyping platform that utilizes adaptable, user-friendly hardware and software. Engraving is executed by the CNC machine module, which only comprehends G-code language. G-code denotes Gerberic code. It is the programming language that comprises a collection of commands used by CNC machines. The command provides the path, location, and orientation for engraving the specified picture. The image may comprise a logo, nameplates, shapes, and letters. This document discusses the generation of G-codes using the program "LX Easy Tool code." The program allows for the insertion of a picture for engraving code based on user specifications. Engraving refers to the technique of incising a design onto a specified item using a cutting tool.

Instruction issued via G-code.

The Atmega328 controller receives G-code from the laptop. We are using two stepper motors to manage three axis, necessitating three stepper drivers for their operation. One corresponds to the X axis, the second to the Y axis, and the third to the Z axis. The cutting module is maintained at a consistent position along the Y axis.

Procedure for Design Development

1. Import the picture selected for engraving into the program.

2. Software produces G-code for the corresponding picture. Subsequently, it is sent to the microcontroller - Atmega328.

3. The Arduino may be programmed using the Arduino Integrated Development Environment (IDE).

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

4. Stepper motor drivers and engraving drivers will operate in accordance with the specified signals, initiating the engraving process on the item.

3.4.3 Stepper Motor Driver and Controller
A Motor Driver is a crucial apparatus that supplies the necessary voltage and current to a stepper motor, ensuring its smooth functioning. This is a stepper DC motor. Designing a stepper motor driver requires the careful selection of an appropriate power supply, microprocessor, and motor driver. Microcontrollers can regulate motor rotation; however, while building the driver, attention must be given to voltage and current considerations. A solitary motor driver board is capable of managing the currents and voltages required for a motor. A stepper motor operates precisely using a controller that synchronizes pulse pulses via a driver. This motor driver converts pulse signals from a microcontroller into the motion of the stepper motor.

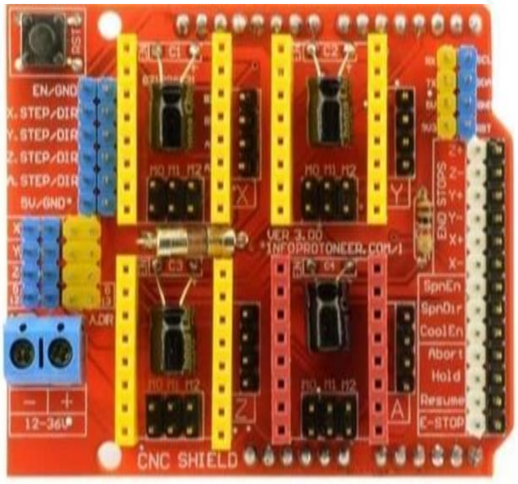


Figure 3.9 Stepper Motor Driver and Controller

What is a stepper motor driver?

A stepper motor driver is defined as a motor driver designed to enable continuous rotation of a stepper motor by precisely regulating its position without the use of a feedback system. The motor drivers primarily provide variable current regulation and several step resolutions. They include fixed translators to facilitate motor control via straightforward step and direction inputs.

These drivers include many types of integrated circuits that function at supply voltages below 20 V. Low-voltage and low-saturation voltage integrated circuits are optimal for a two-phase stepper motor driver used in various portable devices such as cameras and printers. These drivers are offered in various ratings for both voltage and current. The selection of this might be depending on the motor's requirements. Most of these drivers are available in a dimension of 0.6”×0.8”.

Stepper Motor Driver Operating Principle. This driver circuit operates by regulating a stepper motor's function by the transmission of electricity in pulsed phases directed towards the motor. The designers never used the wave driving approach because to its limited torque output and inefficiency, since only one phase of the motor is utilized at a time.

The fundamental components used to operate a stepper motor include controllers such as a microprocessor or microcontroller, a

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

driver integrated circuit, and a power supply unit, along with other elements like switches, potentiometers, heat sinks, and connecting cables.
Regulator

Controller

The first step is to choose the microcontroller for driver design. The microcontroller must possess at least four output pins for the stepper motor. Furthermore, it encompasses ADC, timers, and a serial port, contingent upon the driver's application.

Motor Driver

The motor driver integrated circuits are economically priced and provide straightforward implementation, hence reducing the overall circuit design duration. The selection of drivers might be dependent on motor ratings such as voltage and current. The ULN2003, a widely used motor driver, is employed in non-H-Bridge applications. It is appropriate for operating the stepper motor. This driver has a Darlington pair capable of managing a maximum current of 500mA and a maximum voltage of 50VDC. The circuit for the stepper motor driver is seen below. The CNC Shield was created to capitalize on the need for an economical controller solution for DIY CNC machines. It was engineered for complete compatibility with Grbl, the open-source G-Code translator, and is meant to be compatible with the widely-used Arduino Uno. The CNC Shield is capable of controlling several kinds of CNC equipment, such as CNC milling machines, laser engraving and cutting machines, drawing machines, 3D printers, or any project requiring precise stepper motor control. It employs Pololu and comparable stepper drivers, either the A4988 or the higher current DRV8825. The three essential components required to operate the CNC Shield are:

1) CNC Shield

2) Stepper Drivers

3) Arduino UNO.

This extension board serves as a driver expansion board for engraving machines and 3D printers. The device comprises four slots and is capable of driving four A4988 or DRV8825 stepper motor drivers, enabling 4-axis control. Arduino CNC Shield Version 3. Each road stepper motors only need two 10 ports. In summary, three stepper motors can effectively control six 10 ports. Extremely user-friendly.

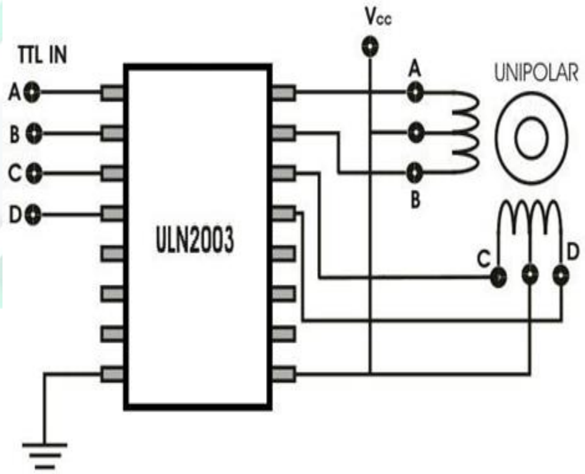


Figure 3.10 Motor Driver Circuit

Specifications:

1. Latest Arduino CNC Shield Version 3.10
2. Compatible with GRBL 0.9. Open-source firmware operating on an Arduino UNO that converts G-code instructions into stepper motor impulses.
3. PWM spindle and directional pins
4. 4-Axis functionality (X, Y, Z, A - may replicate XY, Z or do a complete fourth axis with customized firmware using pins D12 and D13)
5. 2 x end stops for each axis, totaling six.

Characteristics

• Coolant facilitates

•Employs replaceable Pololu A4988-compatible stepper drivers. A4988, DRV8825, and similar models (Not Included)

• Jumpers to configure the Micro-Stepping for the stepper drives. Certain drivers, such as the DRV8825, are capable of achieving up to 1/32 micro-stepping.
• Concise architecture.

Stepper motors may be linked using 4-pin Molex connectors or soldered directly.

• Operates on 12-36V DC. Currently, only the Pololu DRV8825 drivers can accommodate voltages up to 36V; thus, please take the operating voltage into account while supplying power to the board.
• The color of jumpers may fluctuate according on supply availability.

Benefits

The benefits and drawbacks of the stepper motor driver include the following.
• Battery-operated

• Secure design

• Spark protection

• Thermal protection

• Compact mounting space

• This motor driver is used for driving unipolar stepper motors. This enables us to circumvent costly driver boards.

Utilizations

The applications include of

• Industrial

• Brush DC/Stepper motors

3.4.4 CNC Griddle Motor

This brushed spindle DC motor has a pure copper coil, exhibiting exceptional strength and temperature resistance. The 400W electric motor has a rated speed of 12000 RPM for efficient operation. This brushed DC motor has a durable metal casing that is resistant to corrosion and friction, safeguarding the internal circuitry. This brushed motor has a mounting bracket that facilitates installation. This compact electric motor is equipped with a PWM speed controller that has a soft-start feature to mitigate excessive current, so protecting the motor and power supply from harm (default soft start duration is 0 seconds, configurable

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

from 0 to 5 seconds). This electric DC motor has a power supply of 115V/230V±10% AC input, 50/60Hz, and 48V DC output, offering significant benefits such as high operational frequency, simple installation, and composite expansion. This brushed spindle motor significantly enhances model execution stability and is an excellent solution for equipment requiring high control precision and rotational velocity. It is appropriate for art technology, engraving machinery, and precise instruments or equipment.

Figure 3.11 CNC Griddle Motor

Technical Specifications

The item pertains to a 48V 400W brushed spindle DC motor with an ER11 collet, accompanied by a Mach3 PWM speed controller, mounting bracket, and power supply. This motor has a rated speed of 12,000 RPM, ensuring superior performance and sufficient durability to serve as an ideal replacement for your damaged or obsolete motor.

- Brushed Spindle Direct Current Motor
- Operating Voltage: 48V DC
- Rotational Speed: 12000 r/min
- Power Output: 400W
- Torque: 230 mN·m
- Insulation Resistance: >2 MΩ
- Dielectric Strength: 400V
- Diameter: 2.05 inches / 52 millimeters
- Motor Length: 6.89 inches / 175 millimeters
- ER11 Collet Chuck
- Diameter of Axis Collet Chuck: 0.63 inches / 16 mm
- Length of Axis Collet: 1.89 inches / 48 mm
- Repeat Accuracy: 0.0007-0.0019 inches / 0.02-0.05 mm
- PWN Speed Controller
- Operating Voltage: DC 12V-48V
- Power Supply
- Input: AC 115/230V±10%, 50/60Hz
- Output: DC 48V, 8.3A
- Adapter Power: 300W

3.4.5 Power Supply

The power supply has an integrated fan control circuit that activates the fan automatically based on the operating temperature. The switch may be used to choose between 115V and 230V AC input.

Figure 3.12 Power Supply

3.5 Design Parameters

Total area:	360,000 sq. mm
Work space area:	250,000 sq. mm
Cutting tool:	Cobalt (3mm)
Tool cutting speed:	12000 rpm
Motors:	Stepper (3 qty)
Step angle:	1.8(200 steps / rev)
Microcontroller:	Arduino UNO
Linear rails:	600 mm (4 qty)
Bearings:	Linear (10 mm)
Couplers:	10mm (3 qty)

Table 3.1 Design Parameters

RESULT AND DISCUSSION

4.1 Results

The results of our project indicates that we may complete the aluminum frame process, following which we can acquire our project hardware components, including a microcontroller, Nema 17 stepper motor, CNC griddle motor, and CNC controller. Upon completing the whole frame assembly, attach the hardware components, including the Nema 17 motors for the X, Y, and Z axis. The procedure for finalizing hardware components involves connecting the Arduino Uno to the CNC controller and Nema 17 motors to provide motor access. The EASEL controller facilitates the connection of a PC to CNC machines for the transmission of G-code. It is user-friendly and an open-source application compatible with Arduino, enabling virtual commands to control machine movements via a simple driver, with the EASEL software interface linked to Arduino. To compile Easel for Arduino, it is unnecessary to download source code to be put to the Arduino library folder by following the instructions on the Easel website. After configuring the easel library in the Arduino IDE, the next step is to transfer the CNC .hex file firmware to the Arduino using the Xloader program. This requires downloading and opening Xloader, selecting the COM port attached to the Arduino, and setting the right baud rate for the Arduino Uno, which is 115200, to upload the hex file. As shown in the image below:

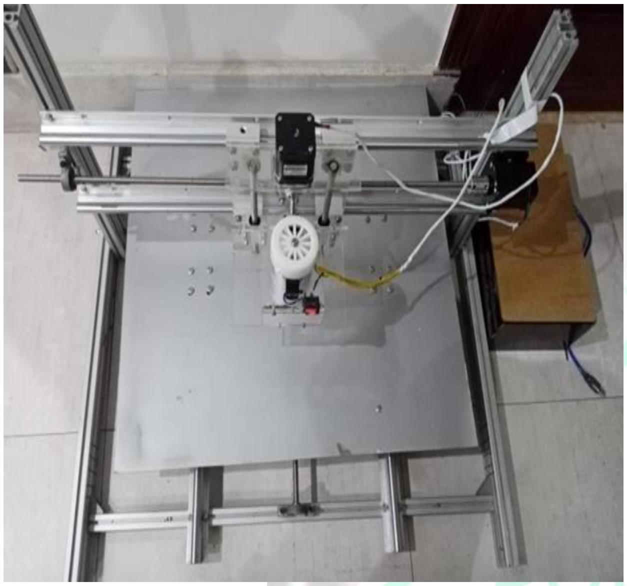
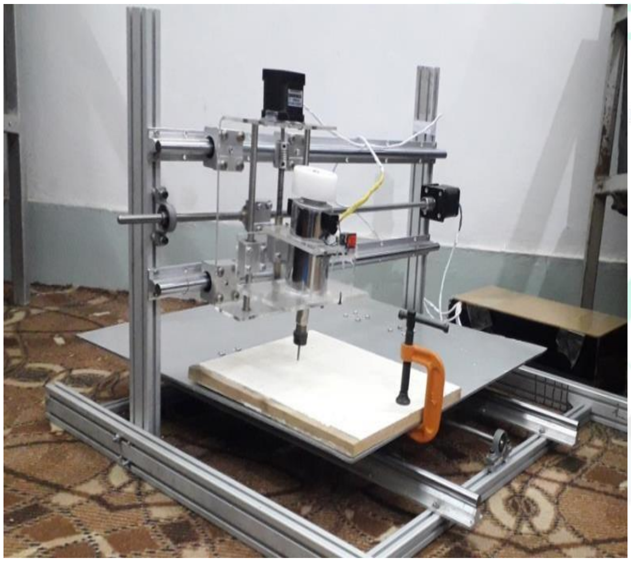


Figure 4.1 Top view of CNC Engraving Machine



4.2 Side view of CNC Engraving Machine

4.2: Discussions

The main parameter for every CNC machine is the accurate movement of the axis and the calibration of the motion of either the tool or the workpiece. The axis motions may be calibrated by measuring a reference test specimen. This test was conducted to get data and to verify the functionality of the stepper motors and system in accordance with the preset program. The last stage included establishing the reference location of the spindle on the workpiece via Universal G Code sender software. The tool was secured in the spindle, which was linked to a DC motor and operated at a constant speed of 1200 RPM (rotations per minute). The velocity was verified via a tachometer. Subsequent to calibration and establishing the reference position, the following step was uploading the G-code file in extension format to the Arduino Uno R3 using a Universal G-code Sender over the USB serial connection connector. The microcontroller's role was to interpret the instruction and direct the Nema stepper motor driver to operate along the X, Y, and Z axis, therefore facilitating the engagement of the tool and workpiece to execute a profile cut.

4.3 Results of Machine Testing

Accuracy and repeatability are the two primary attributes of every computer numerical control equipment. Various experiments were conducted to examine these factors. This section presents the output findings of several tests that demonstrated the dependability of the manufactured CNC machine.

4.4 Coordinate Marking System Examination
This test assesses the accuracy of tool movement facilitated by axis stepper motors, directly correlating with precision in manufacturing activities. To conduct this test, a G-Code programmer was configured to maneuver the tool from the edge of the workpiece to the specified sites, thereafter measuring the coordinates of those designated spots using a Coordinate Measuring Machine (CMM). Initially, a programmer designated four coordinates on the workpiece, with one corner 'O' as the origin at (0,0) and the points A (3,3), B (3,6), C (6,6), and D (6,3) established. The last stage is creating a command to calibrate the machine to the initial place, using the origin established inside the machine. The tool drills into the coordinates specified in the software, and these drilled spots were measured using a CMM.

4.5 Machine Fabrication

The last step encompasses all electrical connections established to control and run the CNC machine with accuracy and precision. The Machine Control Unit operates and regulates the machine, serving as its central processing unit. The Control Unit consists of an Arduino Uno (Data Processing Unit) and a GRBL shield (Control Loop Unit). The constructed mini-CNC machine is seen in the image above, and the comprehensive technical specifications of the machine are presented in the table.

Length	24in
Breadth	24 in
Height	20 in
X Axis	20 in
Y Axis	20 in
Z Axis	12 in
Bit size	0.12 in

Table 4.1 Machine Specifications

4.6 Engraving System Examination

Engraving experiments were conducted on 18 mm thick wood and acrylic sheets, using a 3 mm drill bit at a spindle speed of 12,000 rpm. The engraving depth was established at 4 mm, and the results of the engraving experiments are shown in the figure. The findings indicate a high accuracy of 99.2% in engraving depth, as assessed by CMM throughout the sample.

4.7 Accuracy Assessment

The tests were performed to assess the accuracy level of the CNC machine in producing a certain shape. The test used a profile "CNC" of 30 mm in width and 60 mm in length, to be executed on a wood sample with a depth of 5 mm. The experiment was conducted with a 3 mm vbit600 drill bit at a spindle speed of 12,000 rpm.

4.8 Drilling System Examination

The drilling test was conducted on wood and MDF with a thickness of 14 mm, using a 3 mm v60 drill bit at a spindle speed of 12,000 rpm. The drilling depth was set at 4 mm, resulting in drilled holes. The findings indicated that depth was machined with an average accuracy of 98.85%, length with an average accuracy of 99.91%, and width with an average accuracy of 99.81%. The tool's operations were precise in coordinate placement; nevertheless, depth variations were influenced by variables such as insufficient DC motor torque and operational vibrations.

4.9 CNC Structure Assembly

Following the collection of all necessary components and accessories for construction, the sequential technique for constructing the CNC is outlined below.

1. Commence with the lowest deck, which serves as the foundational table.

2. Install four rubber bush levers.
3. Assemble the top deck, which serves as the Y-axis basis.
4. Joining of 40x40 aluminum extrusion rod
5. Assemble the frame using the aluminum stand.
6. Finalization of the Framework.
7. Assemble the gantry, which serves as the support for the X-axis.
8. Connecting C-channel
9. Inserting the sliding wheel into the C-channel.
10. Assemble the Cutting-Head Slider, which serves as a tool mount.

4.10 Components

Stepper Motor and Accessories: It is a system including a stepper motor drive linked to a pillow bearing with a lead screw, which serves as a mechanical linear bar, and linear bearings that convert rotational motion into linear motion with little friction. The stepper motor shown in Fig. 5 has a step angle of 1/30, and its speed is directly proportional to the pulse frequency; hence, a greater output voltage from the driver results in increased torque levels.
Microcontroller Board: Uno The Arduino Board has been designated as the control unit for this project, serving as the motion control board. The Arduino Uno is a microcontroller-based board. The device has 14 digital input/output pins (6 of which are capable of PWM output), 6 analog inputs, a 16 MHz ceramic resonator, a USB interface, a power connector, an ICSP header, and a reset button. It encompasses all necessary components to facilitate the microcontroller; only connect it to a computer via a USB connection or provide power using an AC-to-DC converter or battery to commence operation.

Figure 4.3 Chromium Rod and lead screw

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

Figure 4.4 Arduino Uno

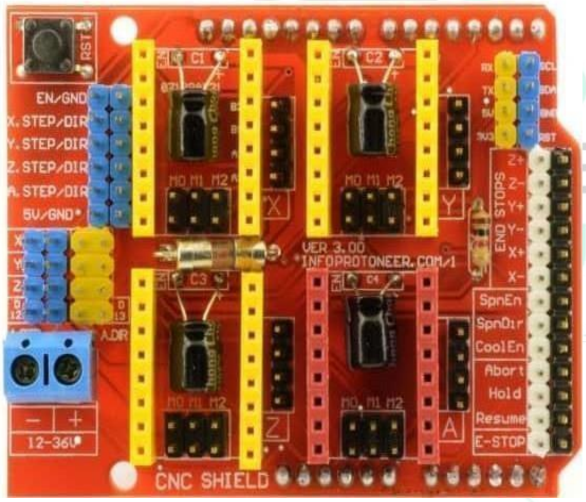


Figure 4.5 Motor driver and controller

CONCLUSION AND FUTURE WORK

5.1 Conclusion

This project imparted knowledge on the principles of CNC machinery. We acquired a deeper comprehension of the operational modes of CNC machines. Various types of current CNC machines are used in business. The automatic production of various preparatory (G codes) and miscellaneous function (M codes) is used in CNC part programming to ensure the effective execution of a CNC program. The CNC milling machine operates using computer numerical control, which interprets G-code instructions to manipulate the machine tool for component fabrication with an appropriate material removal rate. G-codes are directives for CNC machines, enabling autonomous operation without human intervention. The zero setup is a crucial step for achieving an exact geometry of the work piece. The design and construction of a 3-axis milling machine. A computer numerically-controlled (CNC) machine using an Arduino microcontroller to provide pulse-width modulation (PWM) outputs for operating the stepper motors used in this project. A 3-axis CNC milling machine is specifically designed for the exact surfacing of wood, plastic sheets, and thin metal alloys utilizing a revolving drill bit, which offers much lower precision compared to a finer cutting approach. This machine tool is portable and is operated by a computer (PC). Design and fabrication of a CNC system using precision stepper motors interfaced with a lead screw mechanism along three axis. The Mini CNC engraving machine was effectively constructed with an Arduino Uno R3 with an AT Mega 328 processor, GRBL Shield, SMPS, and stepper motors. The synchronization of three stepper motor drivers along the X, Y, and Z axis was achieved with GRBL Driver and Universal G Code Sender Software in conjunction with X Loader. The machine executed many operations including drilling, engraving, cutting, and marking on wood and acrylic to create 2D or 3D profiles with a depth accuracy of 98.85% and an average dimensional accuracy of 99.86%. This project provides newcomers with a virtual understanding of CNC machine operation.

5.2 Future Plan

5.2.1 Evolution of the CNC Technology Structural System

Intellectualization represents the future trajectory of numerical control technology. Intelligence may be included across all components of a CNC system. An adaptive control system may be implemented in a CNC system. The system may autonomously identify and modify pertinent data to maintain optimal system performance. It can also implement an artificial intelligence system to execute CNC machining, establish an artificial intelligence framework to regulate production and processing according to machining protocols, and develop an intelligent fault diagnosis and monitoring system to more swiftly and effectively oversee, diagnose, and rectify faults in CNC machine tools.

5.2.2 The tendency in the structural growth of networks and the integration of CNC Technology

The integration and networking of numerical control technology is the primary method to respond to the market's changing product demands. It is essential to transition numerical control technology from a point and line framework to a surface and solid framework. Simultaneously, it is essential to consider the practicality and cost-effectiveness of numerical control technology.

5.2.3 Evolution of CNC Technology Functionality

The graphical interface function of CNC technology and the graphical user interface represent a developmental trend in numerical control technology. The connection between the user and the CNC system is facilitated by the user interface, making its development crucial. The user interface is graphical, catering to diverse user demands, facilitating operation, and enhancing clarity. The visualization function of scientific computing enhances the efficiency of CNC processing and interpretation by employing graphics, animation, and various means of information exchange, transcending the limitations of textual representation. This approach can decrease product design time, lower costs, and improve product quality.
Multimedia technology enables complete processing of many forms of text, audio, video, and other information by computers. The use of multimedia technologies in

Numerical control technology enhances information processing by making it comprehensive and intelligent, facilitates real-time monitoring of the manufacturing process, and elevates the standard of numerical control technology.

5.2.4 Evolutionary Trajectory of CNC Technology in Product Performance

The superior performance of goods is a future trend in the development of CNC technology. The performance of CNC machine tools is characterized by high speed and high efficiency, which may reduce cutting time and enhance production efficiency.

CNC technology must exhibit high precision performance, transitioning from high precision machining to ultra precision machining, hence enhancing product accuracy and advancing CNC machining technology. CNC machines are required to operate inside a somewhat intricate environment. CNC machining items must exhibit superior stability and dependability, enhanced performance compared to standard products, and include early warning and protective measures.

CNC technology has emerged as the cornerstone of manufacturing technology, serving as the basis for future automation, networking, adaptability, and integration.

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

Appendices 1:

```
#define STEPPING_PORT            PORTD
#define X_STEP_BIT           2 // Uno Digital Pin 2 #define
Y_STEP_BIT               3 // Uno Digital Pin 3 #define
Z_STEP_BIT               4 // Uno Digital Pin 4 #define
X_DIRECTION_BIT          5 // Uno Digital Pin 5 #define
Y_DIRECTION_BIT          6 // Uno Digital Pin 6 #define
Z_DIRECTION_BIT          7 // Uno Digital Pin 7
#define STEP_MASK ((1<<X_STEP_BIT)|(1<<Y_STEP_BIT)|(1<<Z_STEP_BIT))
// All step bits
#define                                        DIRECTION_MASK
((1<<X_DIRECTION_BIT)|(1<<Y_DIRECTION_BIT)|(1<<Z_DIRECTION_BIT))
// All direction bits
#define STEPPING_MASK (STEP_MASK | DIRECTION_MASK) // All stepping-related bits
(step/direction)
#define STEPPERS_DISABLE_DDR          DDRB
#define STEPPERS_DISABLE_PORT  PORTB
#define STEPPERS_DISABLE_BIT          0 // Uno Digital Pin 8
#define STEPPERS_DISABLE_MASK (1<<STEPPERS_DISABLE_BIT)
// NOTE: All limit bit pins must be on the same port#define
LIMIT_DDR                DDRB
#define LIMIT_PIN            PINB
#define LIMIT_PORT           PORTB
#define X_LIMIT_BIT          1 // Uno Digital Pin 9 #define
Y_LIMIT_BIT              2 // Uno Digital Pin 10#define
Z_LIMIT_BIT              3 // Uno Digital Pin 11
#define LIMIT_INT            PCIE0 // Pin change interrupt enable pin#define
LIMIT_INT_vect  PCINT0_vect
#define LIMIT_PCMSK          PCMSK0 // Pin change interrupt register#define
LIMIT_MASK
((1<<X_LIMIT_BIT)|(1<<Y_LIMIT_BIT)|(1<<Z_LIMIT_BIT)) // All limit bits
#define    SPINDLE_ENABLE_DDR    DDRB    #define
SPINDLE_ENABLE_PORT  PORTB
#define SPINDLE_ENABLE_BIT  4  // Uno Digital Pin 12
#define    SPINDLE_DIRECTION_DDR    DDRB    #define
SPINDLE_DIRECTION_PORT  PORTB
#define SPINDLE_DIRECTION_BIT  5  // Uno Digital Pin 13 (NOTE: D13 can't bepulled-high input
due to LED.)
#define    COOLANT_FLOOD_DDR    DDRC    #define
COOLANT_FLOOD_PORT  PORTC
#define COOLANT_FLOOD_BIT  3  // Uno Analog Pin 3
// NOTE: Uno analog pins 4 and 5 are reserved for an i2c interface, and may beinstalled at
// a later date if flash and memory space allow.
// #define ENABLE_M7  // Mist coolant disabled by default. Uncomment to enable. #ifdef
ENABLE_M7
#define    COOLANT_MIST_DDR    DDRC    #define
COOLANT_MIST_PORT  PORTC
#define COOLANT_MIST_BIT 4 // Uno Analog Pin 4#endif
```

```
// NOTE: All pinouts' pins must be on the same port#define
PINOUT_DDR                  DDRC
#define PINOUT_PIN              PINC   #define
PINOUT_PORT                 PORTC
#define PIN_RESET               0  //  Uno  Analog  Pin  0  #define
PIN_FEED_HOLD               1  //  Uno  Analog  Pin  1  #define
PIN_CYCLE_START  2  // Uno Analog Pin 2
#define PINOUT_INT              PCIE1  // Pin change interrupt enable pin#define
PINOUT_INT_vect  PCINT1_vect
#define PINOUT_PCMSK            PCMSK1 // Pin change interrupt register
#define PINOUT_MASK ((1<<PIN_RESET)|(1<<PIN_FEED_HOLD)|(1<<PIN_CYCLE_START))
// Define runtime command special characters. These characters are 'picked-off'directly from the
// serial read data stream and are not passed to the grbl line execution parser. Selectcharacters
// that do not and must not exist in the streamed g-code program. ASCII controlcharacters may be
// used, if they are available per user setup. Also, extended ASCII codes (>127),which are never
in
// g-code programs, maybe selected for interface programs.
// NOTE: If changed, manually update help message in report.c.
#define CMD_STATUS_REPORT '?'
#define     CMD_FEED_HOLD     '!'     #define
CMD_CYCLE_START          '~'         #define
CMD_RESET 0x18 // ctrl-x
// The temporal resolution of the acceleration management subsystem. Higher numbergive smoother
// acceleration but may impact performance.
// NOTE: Increasing this parameter will help any resolution related issues, especiallywith machines
// requiring very high accelerations and/or very fast feedrates. In general, this willreduce the
// error between how the planner plans the motions and how the stepper programactually performs
them.
// However, at some point, the resolution can be high enough, where the errors relatedto numerical
// round-off can be great enough to cause problems and/or it's too fast for the Arduino.The correct
// value for this parameter is machine dependent, so it's advised to set this only as highas needed.
//  Approximate  successful  values  can  range  from  30L  to  100L  or  more. #define
ACCELERATION_TICKS_PER_SECOND 50
// Minimum planner junction speed. Sets the default minimum speed the planner plansfor at the end
// of the buffer and all stops. This should not be much greater than zero and shouldonly be changed
// if unwanted behavior is observed on a user's machine when running at very slowspeeds.
#define MINIMUM_PLANNER_SPEED 0.0 // (mm/min)
// Minimum stepper rate. Sets the absolute minimum stepper rate in the stepperprogram and never runs
// slower than this value, except when sleeping. This parameter overrides theminimum planner speed.
// This is primarily used to guarantee that the end of a movement is always reachedand not stop to
// never reach its target. This parameter should always be greater than zero.
#define MINIMUM_STEPS_PER_MINUTE 800 // (steps/min) - Integer value only
// Time delay increments performed during a dwell. The default value is set at 50ms,which provides
// a maximum time delay of roughly 55 minutes, more than enough for most anyapplication.
Increasing
// this delay will increase the maximum dwell time linearly, but also reduces theresponsiveness of
// run-time command executions, like status reports, since these are performedbetween each dwell
// time step. Also, keep in mind that the Arduino delay timer is not very accurate forlong delays.
#define DWELL_TIME_STEP 50 // Integer (1-255) (milliseconds)
```

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

```
// If homing is enabled, homing in it lock sets Grbl into an alarm state upon power up.These forces
// the user to perform the homing cycle (or override the locks) before doing anythingelse. This is
// mainly a safety feature to remind the user to home, since position is unknown toGrbl.
#define HOMING_INIT_LOCK // Comment to disable
// The homing cycle seek and feed rates will adjust so all axis independently move atthe homing
// seek and feed rates regardless of how many axis are in motion simultaneously. Ifdisabled, rates
// are point-to-point rates, as done in normal operation. For example in an XYdiagonal motion, the
// diagonal motion moves at the intended rate, but the individual axis move at 70%speed. This option
// just moves them all at 100% speed.
#define HOMING_RATE_ADJUST // Comment to disable
// Define the homing cycle search patterns with bitmasks. The homing cycle firstperforms a search
// to engage the limit switches. HOMING_SEARCH_CYCLE_x are executed in orderstarting with suffix 0
// and searches the enabled axis in the bitmask. This allows for users with non-standard cartesian
// machines, such as a lathe (x then z), to configure the homing cycle behavior to theirneeds.
// Search cycle 0 is required, but cycles 1 and 2 are both optional and may becommented to
disable.
// After the search cycle, homing then performs a series of locating about the limitswitches to hone
// in on machine zero, followed by a pull-off maneuver.
HOMING_LOCATE_CYCLE governs these final moves,
// and this mask must contain all axis in the search.
// NOTE: Later versions may have this installed in settings.
#define HOMING_SEARCH_CYCLE_0 (1<<Z_AXIS)                    // First move Z toclear
workspace.
#define HOMING_SEARCH_CYCLE_1 ((1<<X_AXIS)|(1<<Y_AXIS))  // Then
move X, Y at the same time.
// #define HOMING_SEARCH_CYCLE_2                    // Uncomment and add axis
mask to enable
#define HOMING_LOCATE_CYCLE ((1<<X_AXIS)|(1<<Y_AXIS)|(1<<Z_AXIS)) // Must contain
ALL search axis
// Number of homing cycles performed after when the machine initially jogs to limitswitches.
// This help in preventing overshoot and should improve repeatability. This valueshould be one or
// greater.
#define N_HOMING_LOCATE_CYCLE 2 // Integer (1-128)
// Number of blocks Grbl executes upon startup. These blocks are stored in EEPROM,where the size
// and addresses are defined in settings.h. With the current settings, up to 5 startupblocks may
// be stored and executed in order. These startup blocks would typically be used to setthe g-code
// parser state depending on user preferences. #define
N_STARTUP_LINE 2 // Integer (1-5)

// FOR ADVANCED USERS ONLY:
// The number of linear motions in the planner buffer to be planned at any given time.The vast
// majority of RAM that Grbl uses is based on this buffer size. Only increase if there isextra
// available RAM, like when re-compiling for a Teensy or Sanguino. Or decrease ifthe Arduino
// begins to crash due to the lack of available RAM or if the CPU is having troublekeeping
// up with planning new incoming motions as they are executed.
// #define BLOCK_BUFFER_SIZE 18  // Uncomment to override default inplanner.h.
// Line buffer size from the serial input stream to be executed. Also, governs the sizeof
// each of the startup blocks, as they are each stored as a string of this size. Make sure
// to account for the available EEPROM at the defined memory address in settings.hand for
```

```
// the number of desired startup blocks.
// NOTE: 50 characters is not a problem except for extreme cases, but the line buffersize
// can be too small and g-code blocks can get truncated. Officially, the g-codestandards
// support up to 256 characters. In future versions, this default will be increased, when
// we know how much extra memory space we can re-invest into this.
// #define LINE_BUFFER_SIZE 50  // Uncomment to override default in protocol.h
// Serial send and receive buffer size. The receive buffer is often used as anotherstreaming
// buffer to store incoming blocks to be processed by Grbl when its ready. Moststreaming
// interfaces will character count and track each block send to each block response. So,
// increase the receive buffer if a deeper receive buffer is needed for streaming andavailable
// memory allows. The send buffer primarily handles messages in Grbl. Only increaseif large
// messages are sent and Grbl begins to stall, waiting to send the rest of the message.
// #define RX_BUFFER_SIZE 128 // Uncomment to override defaults in serial.h
// #define TX_BUFFER_SIZE 64
// Toggles XON/XOFF software flow control for serial communications. Notofficially supported
// due to problems involving the Atmega8U2 USB-to-serial chips on currentArduinos. The
firmware
// on these chips do not support XON/XOFF flow control characters and theintermediate buffer
// in the chips cause latency and overflow problems with standard terminal programs.However,
// using specifically-programmed UI's to manage this latency problem has beenconfirmed to work.
// As well as, older FTDI FT232RL-based Arduinos (Duemilanove) are known to workwith standard
// terminal programs since their firmware correctly manage these XON/XOFFcharacters. In any
// case, please report any successes to grbl administrators!
// #define ENABLE_XONXOFF // Default disabled. Uncomment to enable.
// Creates a delay between the direction pin setting and corresponding step pulse bycreating
// another interrupt (Timer2 compare) to manage it. The main Grbl interrupt (Timer1compare)
// sets the direction pins, and does not immediately set the stepper pins, as it would in
// normal operation. The Timer2 compare fires next to set the stepper pins after thestep
// pulse delay time, and Timer2 overflow will complete the step pulse, except nowdelayed
// by the step pulse time plus the step pulse delay. (Thanks langwadt for the idea!)
//  This is an experimental feature that should only be used if your setup requires alonger
// delay between direction and step pin settings (some opto coupler-based drivers), asit may
// adversely effect Grbl's high-end performance (>10kHz). Please notify Grbladministrators
// of your successes or difficulties, as we will monitor this and possibly integrate thisas a
// standard feature for future releases. However, we suggest to first try our directiondelay
// hack/solution posted in the Wiki involving inverting the stepper pin mask.
// NOTE: Uncomment to enable. The recommended delay must be > 3us and the totalstep pulse
// time, which includes the Grbl settings pulse microseconds, must not exceed 127us.Reported
// successful values for certain setups have ranged from 10 to 20us.
// #define STEP_PULSE_DELAY 10 // Step pulse delay in microseconds. Defaultdisabled.
// TODO: Install compile-time option to send numeric status codes rather than strings.#endif
```

Appendices 2:

```
#define MODAL_GROUP_NONE 0
#define MODAL_GROUP_0 1 // [G4,G10,G28,G30,G53,G92,G92.1] Non-modal
#define MODAL_GROUP_1 2 // [G0,G1,G2,G3,G80] Motion
#define MODAL_GROUP_2 3 // [G17,G18,G19] Plane selection
#define MODAL_GROUP_3 4 // [G90,G91] Distance mode
#define MODAL_GROUP_4 5 // [M0,M1,M2,M30] Stopping
```

POLICY RESEARCH JOURNAL
ISSN (E): 3006-7030 (P) 3006-7022

```
#define MODAL_GROUP_5 6 // [G93,G94] Feed rate mode
#define MODAL_GROUP_6 7 // [G20,G21] Units
#define MODAL_GROUP_7 8 // [M3,M4,M5] Spindle turning
#define MODAL_GROUP_12 9 // [G54,G55,G56,G57,G58,G59] Coordinate systemselection
// Define command actions for within execution-type modal groups (motion, stopping,non-modal). Used
// internally by the parser to know which command to execute. #define
MOTION_MODE_SEEK 0 // G0
#define MOTION_MODE_LINEAR 1 // G1 #define
MOTION_MODE_CW_ARC 2 // G2 #define
MOTION_MODE_CCW_ARC 3 // G3 #define
MOTION_MODE_CANCEL 4 // G80 #define
PROGRAM_FLOW_RUNNING 0
#define PROGRAM_FLOW_PAUSED 1 // M0, M1
#define PROGRAM_FLOW_COMPLETED 2 // M2, M30
#define NON_MODAL_NONE 0
#define NON_MODAL_DWELL 1 // G4
#define NON_MODAL_SET_COORDINATE_DATA 2 // G10
#define NON_MODAL_GO_HOME_0 3 // G28
#define NON_MODAL_SET_HOME_0 4 // G28.1
#define NON_MODAL_GO_HOME_1 5 // G30
#define NON_MODAL_SET_HOME_1 6 // G30.1
#define NON_MODAL_SET_COORDINATE_OFFSET 7 // G92
#define NON_MODAL_RESET_COORDINATE_OFFSET 8 //G92.1
typedef struct {
uint8_t status_code;                // Parser status for current block
uint8_t motion_mode;                    // {G0, G1, G2, G3, G80}
uint8_t inverse_feed_rate_mode;  // {G93, G94}
uint8_t inches_mode;                    // 0 = millimeter mode, 1 = inches mode {G20, G21}
uint8_t absolute_mode;                  // 0 = relative motion, 1 = absolute motion {G90,G91}
uint8_t program_flow;                   // {M0, M1, M2, M30}
int8_t spindle_direction;               // 1 = CW, -1 = CCW, 0 = Stop {M3, M4, M5}
uint8_t coolant_mode;                   // 0 = Disable, 1 = Flood Enable {M8, M9}
float feed_rate;                    // Millimeters/min
//  float seek_rate;                  //  Millimeters/min.  Will  be  used  in  v0.9  when  axis
independence is installed
float position[3];                  // Where the interpreter considers the tool to be at thispoint in
the code
uint8_t tool;
//  uint16_t spindle_speed;              //        RPM/100
uint8_t plane_axis_0,
plane_axis_1,
plane_axis_2;                       // The axis of the selected plane
uint8_t coord_select;                  // Active work coordinate system number. Default:0=G54.
float coord_system[N_AXIS];                // Current work coordinate system (G54+). Stores offset
from absolute machine
// position in mm. Loaded from EEPROM when called.
float coord_offset[N_AXIS];                //  Retains  the  G92  coordinate  offset  (work
coordinates) relative to
// machine zero in mm. Non-persistent. Cleared upon reset and
```

```
boot.
} parser_state_t;
extern parser_state_t gc;
// Initialize the parservoid gc_init();
// Execute one block of rs275/ngc/g-code uint8_t
gc_execute_line(char *line);
// Set g-code parser position. Input in steps.
void gc_set_current_position(int32_t x, int32_t y, int32_t z);
#endif
```

References

Correa J, Toombs N, Ferreira PM. Implementation of an open-architecture control for CNC systems based on open- source electronics. Proceedings of the ASME 2016 IMECE 2016.

Mr. D. O. Shirsath et.al "CNC Machine based on LASER Engraver using Arduino UNO" IJSTE - International Journal of Science Technology & Engineering | Volume 3 | Issue 09 | March 2017 ISSN (online): 2349-784X.

Jayaprasad V C et.al "Design and Development of CNC Based Laser Engraver" International Journal of Scientific & Engineering Research Volume 11, Issue 6, June-2020 ISSN 2229-5518.

P. Jamaleswara Kumar, M. Gowtham "Design and fabrication of portable laser cutting and engraving machine" International Journal of Engineering & Technology, 7 (1.1) (2018) 570-573.

Kamal Prasath Balaji et.al "A Build-Your-Own Open-Source CNC Laser Engraver Machine" Version 2.0, December 2016

Yusri Yusof, et.al "New Interpretation Module for Open Architecture Control based CNC Systems" 12th global conference on sustainable manufacturing, Pocedia CIRP 26 (2015) 729-734."

Ginna Vaishnavi et.al "Design and Fabrication of Laser Engraver" International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 p-ISSN: 2395-0072 Volume: 07 Issue: 05 | May 2020.

S. Cuenca, et.al" Hardware approach to tool path computation for STEP-NC enabled CNC: A case study of turning operations". Computers in Industry 62 (2011) 509–518.

P. Thamma Rao et.al "Design and fabrication of portable laser cutting and engraving machine" International Journal of Engineering & Technology, 7 (1.1) (2018) 570-573.

T. Douillard et.al "Microstructure and Hydrothermal Ageing of Alumina-zirconia Composites Modified by Laser Engraving" Journal of the European Ceramic Society Volume 40, Issue 5, May 2020, page 2077-2089.

Prof. Ameya Jadhav et.al "Mini CNC Plotter and Laser Engraver" International Journal of Trend in Scientific Research and Development (IJTSRD) Volume 4 Issue 5, August 2020 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470.

S.Guler and H. Karagulle "Finite Element Analysis of Structures with Extruded Aluminum Profiles" Latin American Journal of Solids and Structures 13 (2016) 1499-1514.

G. Costa Rodrigues "Laser cutting with direct diode laser" Physics Procedia 41 (2013) 558 – 565.

Barra Jabbar et.al "Design and Analysis Mini CNC Plotter Machine" Department of Mechanical Engineering, University of Al-Qadisiyah.

Noreen L. Thomas "Cellular PVC-U: Current Technology and Future Challenges" Institute of Polymer Technology & Materials Engineering, Loughborough University, Loughborough, Leicestershire, LE11 3TU.