A PROJECT REPORT ON

IOT-Integrated CNC Machine

SUBMITTED BY

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Chaitanya Nijai

UNDER THE GUIDANCE OF

Prof. Sagar Joshi:

Department of Robotics and Mechatronics

INSTITUTE FOR DESIGN OF ELECTRICAL MEASURING INSTRUMENTS
SWANTANTRYAVEER TATYA TOPE MARG, CHUNABHATTI, SION, MUMBAI-400022
2023-2024.

CERTIFICATE

This is to certify that

Suyash Mestry
Harsh Chavan
Sherviin Manickam
Hadeen Khan
Advait More
Chinmay Dalvi
Chaitanya Nijai

have undertaken the project **"IOT-Integrated CNC Machine"** under our guidance as prescribed by the IDEMI, as the curriculum for the Diploma in Robotics & Mechatronics for the academic year 2023-2024.

Project Guide
Prof. Sagar Joshi

H.O.D.
Diploma in Robotics & Mechatronics

Examiner

Date-________________

DECLARATION

We declare that this written submission represents our ideas in our own words and where others ideas or words have been included. We have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when required**.**

Hadeen Khan

Suyash Mestry **Advait More**

Sherviin Manickam

Harsh Chavan **Chaitanya Nijai**

Chinmay Dalvi

ACKNOWLEDGEMENT

It is our privilege to express our sincerest regards to our project Guide **Prof. SAGAR JOSHI** who gave us the golden opportunity to do this wonderful project on the topic **IOT-Integrated CNC Machine** for his valuable inputs, guidance, encouragement, whole-hearted cooperation and constructive criticism throughout the duration of our project. We deeply express our sincere thanks to our HOD of Diploma in Robotics and mechatronics for encouraging and allowing our department premises for the partial fulfilment of the requirements.We also extend our deepest gratitude to all the esteemed faculty members, and dedicated workers who contributed their invaluable expertise and support to this project. Last but not the least we express our sincere thanks to all our friends and our parents who have patiently extended all sorts of help for accomplishing this undertaking.

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Project Details

Project Name : **IOT-Integrated CNC Machine**

Group Members:

Sr.no.	Name	Enrollment No.
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2.	Harsh Chavan	2111004
3.	Sherviin Manickam	2111005
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Branch: **Diploma in Robotics & Mechatronics.**

Year: **3rd (Final).**

Semester: **5th & 6th**

College Name: **Institute of Design and Electrical Measuring Instruments.**

Assigned Faculties: **Prof. Sagar Joshi.**

Project Time: **September 2023- June 2024.**

Aim of the Project

Our project's primary goal was to advance our technical and engineering capabilities while contributing to societal welfare. Transparently acknowledging our use of an existing open-source CNC model, we aimed to explore and learn, incorporating modifications such as adjustments to the work volume and the redesign of key components. The emphasis was on expanding our knowledge and skills in mechanical, electronic, and software engineering aspects.

Initiation Of Idea

We chose to embark on the journey of creating a tabletop CNC as our project, combining all the skills we've acquired during our college education. This project draws on our knowledge in CNC programming, analog and digital electronics, C programming, microcontrollers, AutoCAD, mechatronic systems, control systems, machine drawing, and basics of electronics and electrical engineering. Additionally, we incorporated external knowledge from the internet, focusing on IoT systems. The decision to pursue this project stems from the belief that it encapsulates the essence of all the skills we've gathered, making it the optimal choice given our educational background and additional insights gained from external sources.

Understanding Concept Of CNC

During our research, we explored CNC, or Computer Numerical Control, a revolutionary technology reshaping the manufacturing landscape. CNC involves controlling machine tools and 3D printers through computerized systems, fundamentally altering production methodologies.

CNC machines operate with numerical data input, often derived from a Computer-Aided Design (CAD) file. This data guides precise movements, resulting in a highly accurate and efficient manufacturing process. We delved into CNC's role across diverse industries, such as metalworking, woodworking, and plastic fabrication. The versatility of CNC machines enables the creation of intricate shapes with incredible precision, surpassing the consistency of traditional manual methods.

Our exploration also revealed that CNC technology significantly minimizes human error in manufacturing processes. The automated nature of CNC machines ensures consistency, leading to heightened output quality and increased efficiency. The quick programmability of CNC machines is a key advantage, allowing adaptability to changing production requirements, particularly valuable in industries prioritizing customization and rapid prototyping.

Key Factors Of Considerations

We began by understanding the different types of CNC machines, such as milling machines, lathes, routers, and plasma cutters. Each type has its specific applications and capabilities.

Machine Configurations:

We delved into the various configurations, such as 3-axis, 4-axis, and 5-axis machines, considering how these setups affect our machine's capabilities and the complexity of the work we can handle.

Accuracy and Precision:

We examined the accuracy and precision of our CNC machine, taking into account factors like repeatability, tolerance levels, and the impact of thermal effects on precision.

Control System:

We looked into our CNC control system, understanding the type of control (open-loop or closed-loop), the control algorithms, and the user-friendly features of our control panel.

Programming:

We explored the programming capabilities of our CNC machine, understanding the programming languages it supports (G-code, M-code) and the ease of programming using CAM software.

Tooling and Workholding:

We investigated the compatibility with different types of tooling and workholding devices, considering aspects like tool changes, tool life monitoring, and adaptability to various workpiece geometries.

Speed and Feed Rates:

We assessed our machine's speed and feed rates, considering their impact on productivity and our ability to handle different materials and cutting conditions.

Materials Compatibility:

We looked into our machine's compatibility with various materials, such as metals, plastics, and composites, considering factors like spindle power and cutting capabilities.

Automation and Integration:

We explored the level of automation and integration capabilities, considering compatibility with robotic systems, pallet changers, and other automation features.

Maintenance and Serviceability:

We assessed the ease of maintenance and the availability of service and support, considering factors like machine uptime, preventive maintenance requirements, and spare parts availability.

Cost and ROI:

We analyzed the initial cost of our CNC machine, factoring in additional costs like tooling, software, and training. We also considered the potential return on investment (ROI) based on our machine's capabilities and productivity.

Safety Features:

We investigated the safety features incorporated into our CNC machine, looking at emergency stops, interlocks, and protective enclosures. It was crucial to ensure compliance with safety standards and regulations.

Reviews and References:

We sought reviews and testimonials from users with experience using our specific CNC machine model. Consulting industry experts and seeking references from manufacturers was valuable in making an informed decision.

Future Upgradability:

We assessed future upgrade potential and scalability for our machine, crucial for long-term planning and adaptability to evolving technology.

Process Of Making

- **Conceptualization and Design:**
  We begin by brainstorming and conceptualizing the design of the tabletop CNC machine. We identify the key features, dimensions, and the type of materials we'll be using. The design phase involves creating detailed drawings, considering factors like stability, precision, and ease of use.

- **Material Selection:**
  Once the design is finalized, we gather the necessary materials. This includes high-quality aluminum or steel for the frame, precision ball screws or leadscrews, stepper motors, bearings, and a durable work surface. The choice of materials is crucial for the machine's stability and accuracy.

- **Mechanical Components Assembly:**
  With the frame in place, we move on to assembling the mechanical components. This involves installing the ball screws or leadscrews, attaching the stepper motors, and integrating the bearings and guides. Attention to detail is key here to ensure smooth movement and minimal backlash.

- **Electronics Integration:**
  We install the electronics, including the controller, power supply, and wiring for the stepper motors. Precision is essential to prevent interference or signal disruptions that could affect the machine's performance.

- **Programming and Calibration:**
  With the mechanical and electronic components in place, we move on to programming the CNC machine. This includes writing the code for the controller, setting up the work coordinates, and fine-tuning the parameters for optimal performance. Calibration is crucial to achieve accurate and repeatable results.

- **Testing and Troubleshooting:**
  We conduct thorough testing to ensure all components are functioning as intended. This involves running test programs, checking for any vibrations or irregularities, and troubleshooting any issues that may arise. We pay close attention to the machine's precision and accuracy
- **Final Touches:**
  Once we are satisfied with the performance, we add any final touches such as safety features, dust collection systems, and user-friendly interfaces. We also make sure the machine is aesthetically pleasing and easy to operate.

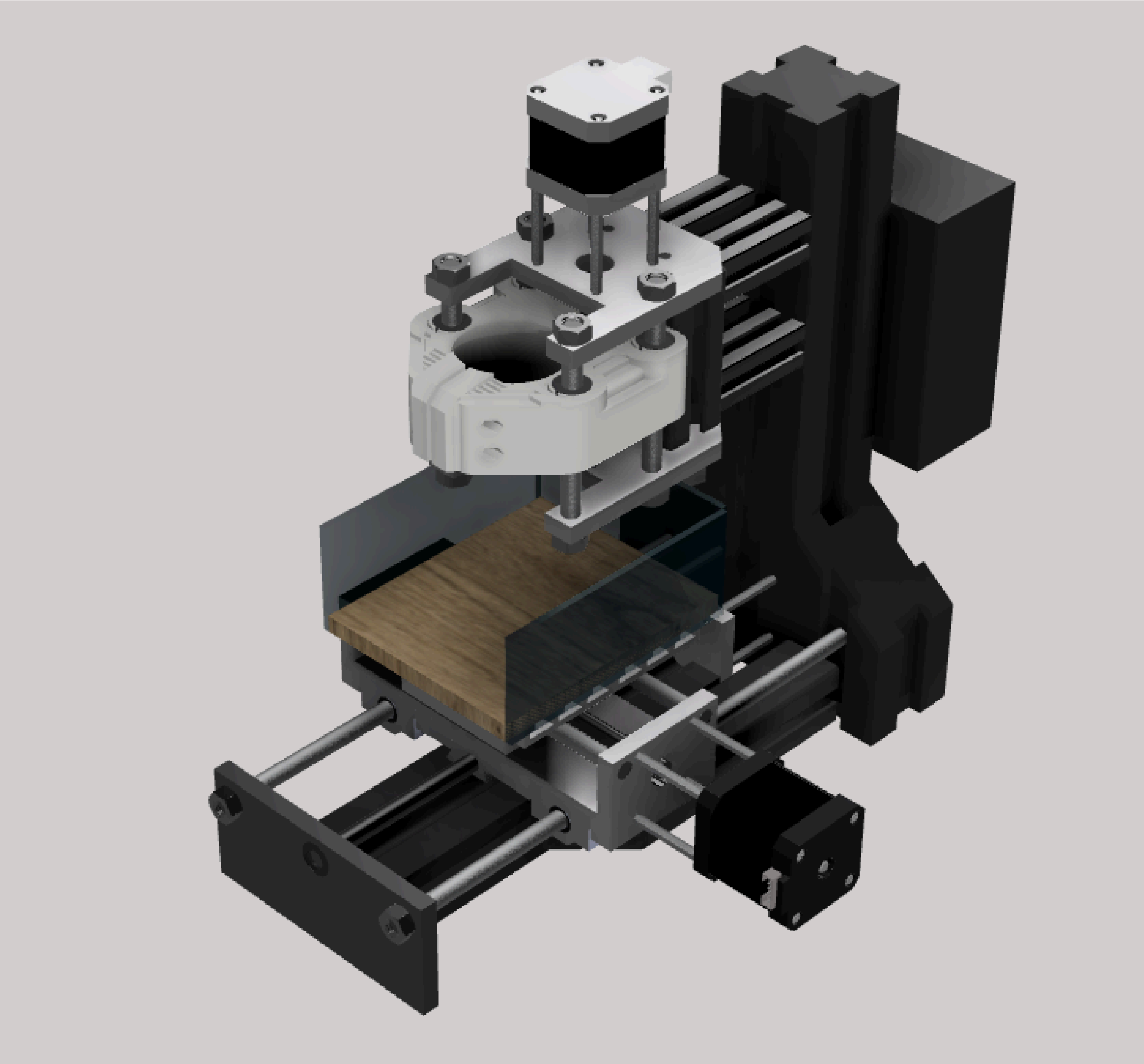
- **Quality Control:**

Before releasing the tabletop CNC machine to the market, we perform rigorous quality control checks. This involves running various cutting and milling tests to ensure the machine meets the specified standards for precision and reliability.

- **Documentation and User Manuals:**
  We document the entire process, from design to assembly, creating comprehensive user manuals and guides. This documentation ensures that users can operate and maintain the CNC machine effectively

Conceptualization and Design:

Three - Dimensional Rendering :



Key Features

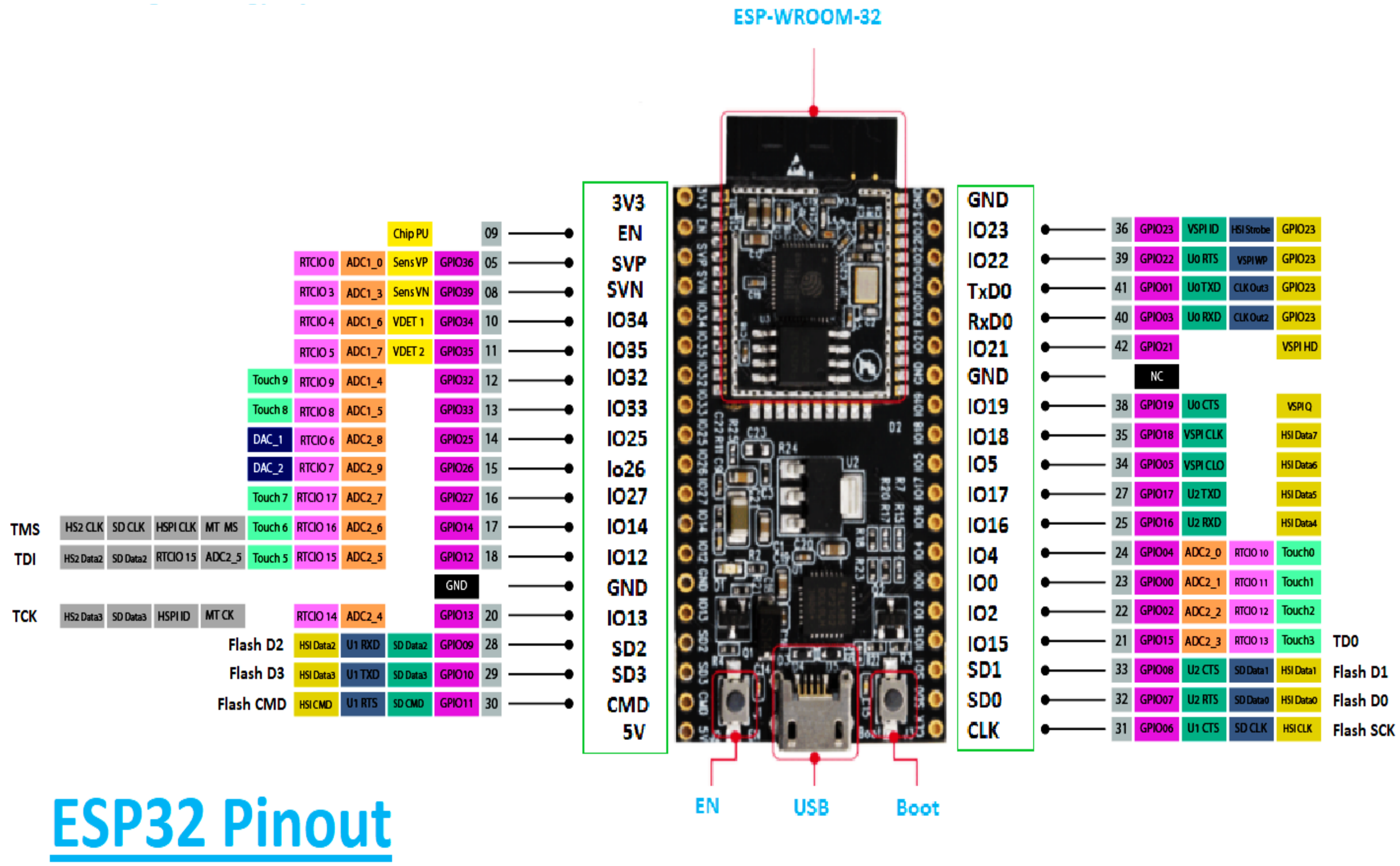
- **Fluid NC Firmware Integration :** Utilization of the Fluid NC firmware for controlling and managing the CNC machine.
- **Offline Programming :** Capability to program and simulate CNC jobs offline using the Fluid NC firmware.
- **Wireless Connectivity:** Integration of wireless connectivity (Wi-Fi or Bluetooth) for ease of control and monitoring.
- **CAM Software Compatibility:** Integration with Computer-Aided Manufacturing (CAM) software for generating toolpaths and optimizing machining strategies.
- **Toolpath Visualization**: Visualization of toolpaths within the Fluid NC firmware interface for better understanding and verification.
- **Customizable Machining Profiles :** Ability to save and recall machining profiles for different materials or job requirements.
- **Basic Security Features**: Basic security measures within the Fluid NC firmware to ensure authorized access.
- **Emergency Stop Functionality:** Integration of an emergency stop function for safety during machining operations.
- **Workholding Adaptability :** Support for customizable workholding solutions to secure various workpiece sizes and shapes.
- **Compact Design :** A tabletop CNC machine with a compact design suitable for small workspaces.

- **Compatibility with Standard G-Code:** Support for standard G-code commands for CNC programming.
- **Basic Error Handling :** Error handling features within the Fluid NC firmware to manage unexpected situations during machining.
    - **Automation Support:** Basic automation features within the Fluid NC firmware to streamline CNC machining processes.
    - **Toolpath Optimization:** Basic optimization capabilities for toolpaths to improve machining efficiency.
    - **Open Source Community Support:** Potential support from the open-source community for updates, enhancements, or issue resolutions related to the Fluid NC firmware.It's important to note that the specific features available may depend on the version of the Fluid NC.

Electronics Components:

ESP32-WROOM-32U Module

ESP32-WROOM-32U is a powerful, generic Wi-Fi + Bluetooth + Bluetooth LE MCU module that can be used the controller for all the cnc machine's operations.**ESP32-WROOM-32U integrates a connector to connect an external antenna.**When the ESP32 is set as a Wi-Fi station, it can connect to other networks (like your router). In this scenario, the router assigns a unique address to your ESP board. You can communicate with the ESP using other devices (stations) that are also connected to the same network by referring to the ESP's unique IP address.



1. **Processor:**

   The ESP32 WROOM U Board is driven by a single or dual-core Tensilica Xtensa 32-bit LX6 processor, offering a balance of computational power and efficiency.

2. **Operating Voltage (V):**

   Operating within the range of 2.3 to 3.6 volts, the board exhibits flexibility in voltage requirements, accommodating various power supply configurations.

3. **Operating Current (mAmp without limitation)**

   an operating current of 80 mA, the board maintains an efficient power profile, contributing to its suitability for battery-powered applications.

4. **Clock Frequency (MHz):**

   Operating within the broad range of 80 to 240 MHz, the ESP32 WROOM U Board allows for dynamic adjustment of clock frequencies, offering versatility in performance optimization.

5. **Flash Memory (MB):**

   The board is equipped with 4 MB of Flash memory, providing ample space for storing firmware, configurations, and other essential data.

6. **Rate (Mbps):Data**

Capable of achieving data rates of up to 54 Mbps, the ESP32 WROOM U Board ensures swift and reliable communication over Wi-Fi networks.

7. **SRAM Memory (KB):**

   Featuring 512 KB of SRAM memory, the board provides sufficient high-speed volatile memory for data manipulation and storage during runtime.

8. **Dimensions and Weight:**

   The board's compact dimensions of 49.5 mm (length), 26.5 mm (width), and 11.5 mm (height), coupled with a weight of 10 grams, contribute to its suitability for diverse form factors and applications.

Features:

Integrated 520 KB SRAM:

The ESP32 WROOM U Board features integrated 520 KB SRAM, facilitating efficient multitasking and data storage for complex applications.

Hybrid Wi-Fi & Bluetooth:

Seamlessly integrating Wi-Fi (802.11b/g/n, with speeds up to 150 Mbps) and Bluetooth functionalities, the board provides a versatile platform for IoT projects.

High Level of Integration:

This board achieves a high level of integration, consolidating multiple functions into a compact form factor, enhancing ease of use and optimizing space.

Ultra-Low-Power Management:

With ultra-low-power management capabilities, the ESP32 WROOM U Board ensures energy-efficient operation, making it suitable for extended battery life applications.

4 MB Flash:

Equipped with 4 MB of Flash memory, the board offers ample storage for program code and data, enabling the implementation of complex applications.

On-board PCB Antenna:

Featuring an on-board PCB antenna, the design is simplified, eliminating the need for external antenna components, and enhancing integration into various projects.

Clock Frequency Adjustment:

The board supports clock frequency adjustment in the range of 80 MHz to 240 MHz, offering flexibility in performance optimization. It also supports Real-Time Operating System (RTOS).

High-Precision ADC:

Built-in 2-channel 12-bit high-precision ADC with support for up to 18 channels, providing accurate analog-to-digital conversion for sensor interfacing.

Versatile Interface Support:

The ESP32 WROOM U Board supports UART, GPIO, ADC, DAC, SDIO, SD card, PWM, I2C, and I2S interfaces, offering flexibility for diverse connectivity requirements.

Multiple Sleep Modes:

The board supports multiple sleep modes, with the ESP32 chip exhibiting a sleep current of less than 5 µA, contributing to energy-efficient operation.

Embedded LwIP Protocol Stack:

Incorporating an embedded LwIP protocol stack, the board ensures reliable communication in networking applications.

Operation Modes:

Supports STA (Station), AP (Access Point), and STA + AP operation modes, enhancing flexibility in networking configurations.

Remote Firmware Upgrade (FOTA):

The board supports remote firmware upgrades (FOTA), enabling seamless updates and maintenance of deployed devices.

General AT Commands:

General AT commands can be used for quick configuration and communication with the board.

Support for Secondary Development:

The ESP32 WROOM U Board facilitates secondary development, offering an integrated development environment compatible with both Windows and Linux.

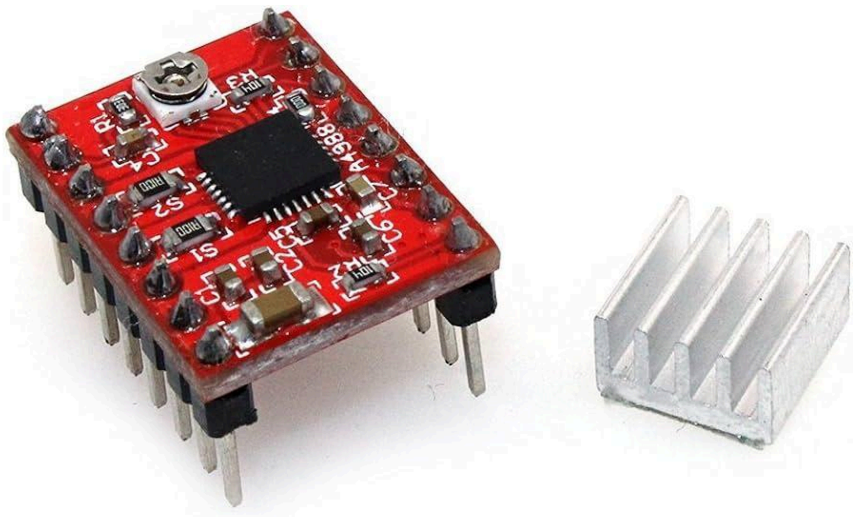
No.	Pin	GPIO	Description
1	3.3V	-	Module power supply pin
2	EN	-	Chip Enabled Pin, Active High
3	SVP	36	GPIO36, ADC1_CH0, RTC_GPIO0
4	SVN	39	GPIO39, ADC1_CH3, RTC_GPIO3
5	P34	34	GPIO34, ADC1_CH6, RTC_GPIO4
6	P35	35	GPIO35, ADC1_CH7, RTC_GPIO5
7	P32	32	GPIO32, XTAL_32K_P, ADC1_CH4, TOUCH9, RTC_GPIO9
8	P33	33	GPIO33, XTAL_32K_N, ADC1_CH5, TOUCH8, RTC_GPIO8
9	P25	25	GPIO25, DAC_1, ADC2_CH8, RTC_GPIO6, EMAC_RXD0
10	P26	26	GPIO26, DAC_2, ADC2_CH9, RTC_GPIO7, EMAC_RX_DV

11	P27	27	GPIO27, ADC2_CH7, TOUCH7, RTC_GPIO17, EMAC_RX_DV
12	P14	14	GPIO14, ADC2_CH6, TOUCH6, RTC_GPIO16, MTMS, HSPICLK, HS2_CLK, SD_CLK, EMAC_TXD2
13	P12	12	GPIO12, ADC2_CH5, TOUCH5, RTC_GPIO15, MTDI, HSPIQ, HS2_DATA2, SD_DATA2, EMAC_TXD3
14	GND	-	Ground
15	P13	13	GPIO13, ADC2_CH4, TOUCH4, RTC_GPIO14, MTCK, HSPID, HS2_DATA3, SD_DATA3, EMAC_RX_ER
16	SD2	9	GPIO9, SD_DATA2, SPIHD, HS1_DATA2, U1RXD
17	SD3	10	GPIO10, SD_DATA3, SPIWP, HS1_DATA3, U1TXD
18	CMD	11	GPIO11, SD_CMD, SPICS0, HS1_CMD, U1RTS
19	5V	-	Module power supply pin
20	CLK	6	GPIO6, SD_CLK, SPICLK, HS1_CLK, U1CTS

21	SD0	7	GPIO7, SD_DATA0, SPIQ, HS1_DATA0, U2RTS
22	SD1	8	GPIO8, SD_DATA1, SPID, HS1_DATA1, U2CTS
23	P15	15	GPIO15, ADC2_CH3, TOUCH3, MTDO, HSPICS0, RTC_GPIO13, HS2_CMD, SD_CMD, EMAC_RXD3
24	P2	2	GPIO2, ADC2_CH2, TOUCH2, RTC_GPIO12, HSPIWP, HS2_DATA0, SD_DATA0
25	P0	0	GPIO0, ADC2_CH1, TOUCH1, CLK_OUT1, RTC_GPIO11, EMAC_TX_CLK (Download mode: external pull low; Running mode: floating or external pull high)
26	P4	4	GPIO4, ADC2_CH0, TOUCH0, RTC_GPIO10, HSPIHD, HS2_DATA1, SD_DATA1, EMAC_TX_ER
27	P16	16	GPIO16, HS1_DATA4, U2RXD, EMAC_CLK_OUT
28	P17	17	GPIO17, HS1_DATA5, U2TXD, EMAC_CLK_OUT_180
29	P5	5	GPIO5, VSPICS0, HS1_DATA6, EMAC_RX_CLK
30	P18	18	GPIO18, VSPICLK, HS1_DATA7

31	P19	19	GPIO19, VSPIQ, U0CTS, EMAC_TXD0
32	GND	-	Ground
33	P21	21	))11
34	RX	3	GPIO3, U0RXD, CLK_OUT2
35	TX	1	GPIO1, U0TXD, CLK_OUT3, EMAC_RXD2
36	P22	22	GPIO22, VSPIWP, U0RTS, EMAC_TXD1
37	P23	23	GPIO23, VSPID, HS1_STROBE
38	GND	-	Ground

A4998 Stepper Motor Driver



The A4988 driver Stepper Motor Driver is a complete micro-stepping motor driver with a built-in converter, **It operates from 8 V to 35 V and can deliver up to approximately 1 A per phase without a heat sink or forced air flow (it is rated for 2 A per coil with sufficient additional cooling).**

A4988 driver Stepper Motor Driver includes a fixed off-time current regulator, the regulator can be in slow or mixed decay mode. The converter is the key to the easy implementation of the A4988.

Provide internal synchronous rectification control circuitry, in order to improve the pulse width modulation (PWM) power consumption during operation.

Internal circuit protection includes thermal shutdown with hysteresis, under-voltage lockout (UVLO) and crossover current protection.

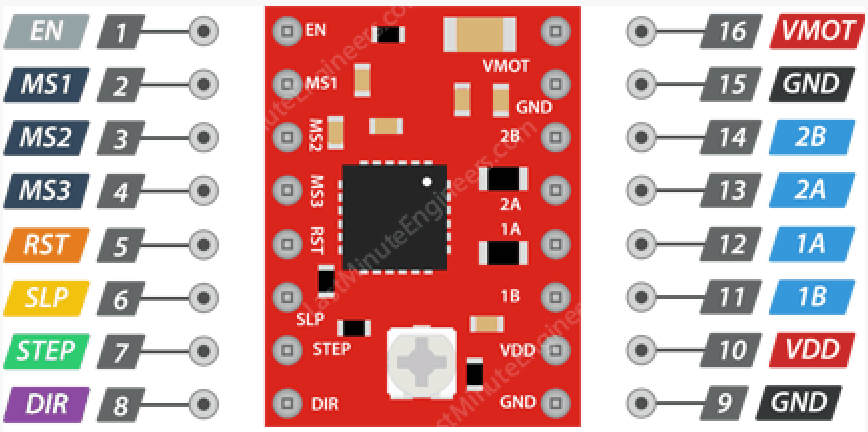
Features :

1. Max. Operating Voltage: 35V
2. Min. Operating Voltage: 8V
3. Max. Current Per Phase: 2A
4. Microstep resolution: Full step, ½ step, ¼ step, 1/8 and 1/16 step
5. Reverse voltage protection: No
6. Dimensions: 15.5 × 20.5 mm (0.6" × 0.8")
7. Short-to-ground and shorted-load protection
8. Low RDS(ON) outputs
9. Thermal shutdown circuitry
10. Automatic current decay mode detection/choice.
11. Mixed with slow current decay mode.
12. The low power dissipation of synchronous rectifier.
13. Internal UVLO(ultra voltage lockout).
14. Crossover current protection.
15. Thermal shutdown circuit.
16. Ground fault protection.
17. Loading and short circuit protection.
18. The optional five-step mode: full, 1/2, 1/4, 1/8 and 1/16

Pin Configuration

Pin Name	Description
VDD & GND	Connected to 5V and GND of Controller
VMOT & GND	Used to power the motor
1A, 1B, 2A, 2B	Connected to the 4 coils of motor
DIRECTION	Motor Direction Control pin
STEP	Steps Control Pin
MS1, MS2, MS3	Microstep Selection Pins
SLEEP	

	Pins For Controlling Power States
RESET	
ENABLE	



The current supplied by the driver to the motor can be limited by setting its reference voltage .

This is done by using the following formula:

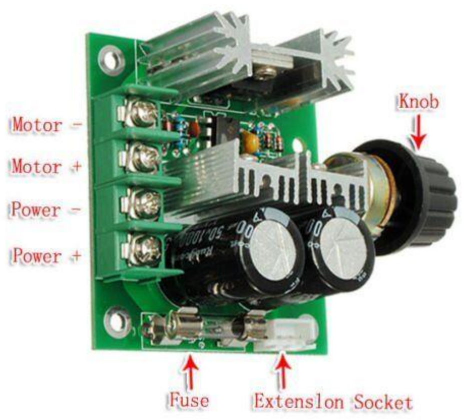
Vref = Imot x 8 x Rsen

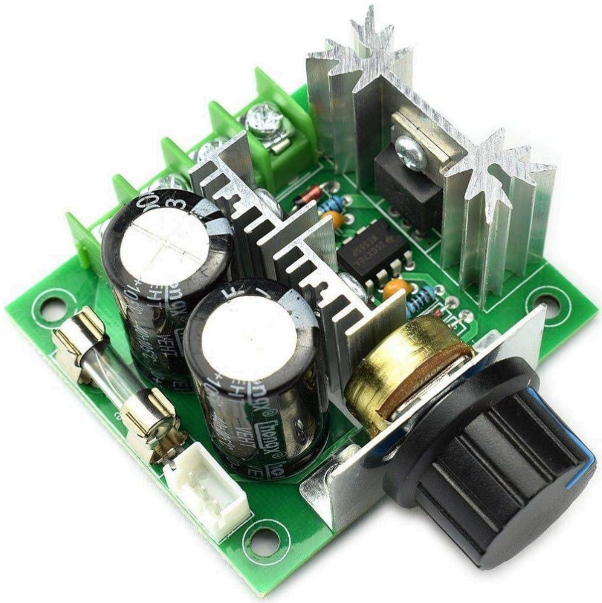
The reference voltage is equal to the maximum motor current, multiplied by 8, and then by the current sensing resistance.

The maximum motor current can be found on the motor datasheet, ours is A. The current sensing resistance can be found on your driver's datasheet but is most commonly 0.068 ohms for newer drivers.

Using this formula, we calculate that our reference voltage should be set to volts. Turning the potentiometer provided at the top of the driver anticlockwise decreases the voltage and clockwise increases the voltage. Turning it slightly will set the reference voltage to volts, which will limit the motor current from not going higher than A per phase.

10A DC Motor PWM Speed Controller



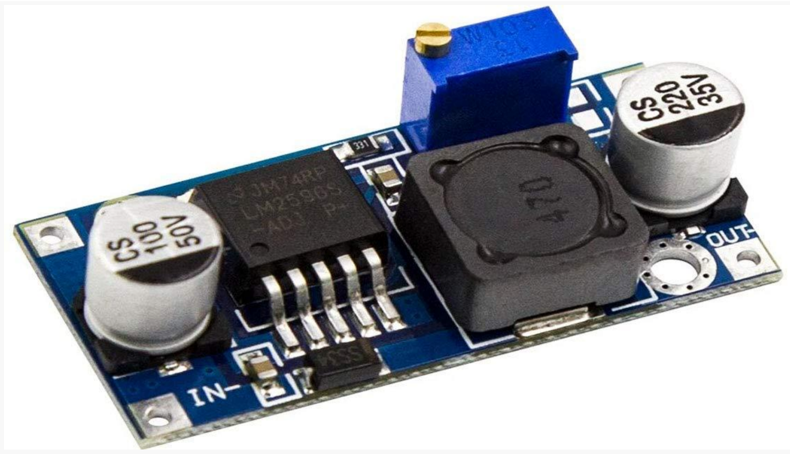


The DC Motor Speed Controller allows controlling direction of a DC motor using a Pulse-Width-Modulated (PWM) DC voltage with a Duty Cycle fully adjustable from 10%-100%. The motor speed controller can provide a continuous current of 8A to your DC motor or other DC load. The circuit also includes a 10A fuse, with the reverse connection of power supply and control voltage over-voltage protection function.

Features:

1. Control the speed of a DC motor with this controller.
2. High efficiency, high torque, low heat generating.
3. With reverse polarity protection, high current protection.
4. Control voltage over-voltage protection function
5. The overload and short circuit protecting current is 10A
6. Working Voltage: DC 12V – DC 40V.
7. Control Power:0.01 – 400W.
8. Static Current:0.02 A (Standby).
9. PWM Duty Cycle:10% -100%.

LM2596 DC-DC Buck Converter



DC-DC Buck Converter Step Down Module LM2596 Power Supply is a step-down(buck) switching regulator, capable of driving a 3-A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3 V, 5 V, 12 V, and an adjustable output version.

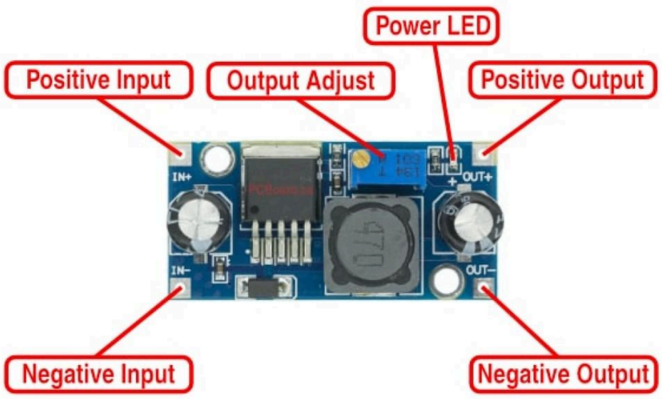
The LM2596 series operates at a switching frequency of 150kHz

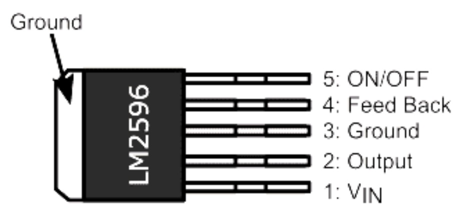
The input operating voltage is 3-40 Volts

the output operating voltage is 1.5V-35V (Adjustable)

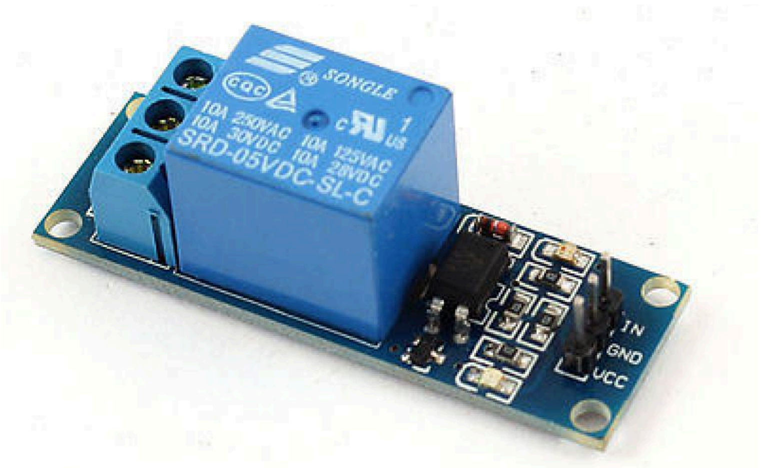
Rectification: non-synchronous rectification

Short circuit protection: current limiting,





Relay Module



This is a 5V single Channel Relay Board Module For Arduino PIC AVR DSP ARM. A wide range of microcontrollers such as Arduino,Espressif, and so on can control it. The module is triggered, high trigger current less than 5mA, part of the 51 single-chip IO port output capability is weak, pull or increase the drive capability of the circuit. it Can be used for microcontroller development board module or home appliance control.

Specification and Features :-

1. 1 channel relay board
2. Operating Voltage 5V
3. Max Current : 20mA
4. Relay Contact Current Capacity at AC250V: 10A
5. Relay Contact Current Capacity at DC5V: 10A
6. One normally closed contact and one normally open contact
7. Triode drive, increasing relay coil
8. High impedance controller pin
9. Pull-down circuit for avoidance of malfunction
10. Power supply indicator lamp
11. Control indicator lamp
12. Indicator for Relay output status
13. Can Be controlled various appliances & other Equipment With Large current.
14. Standard TTL Level logic controlled (AVR, Arduino, 8051, PIC, ARM)
15. The module is compliant with international safety standards, control and load areas isolation trenches

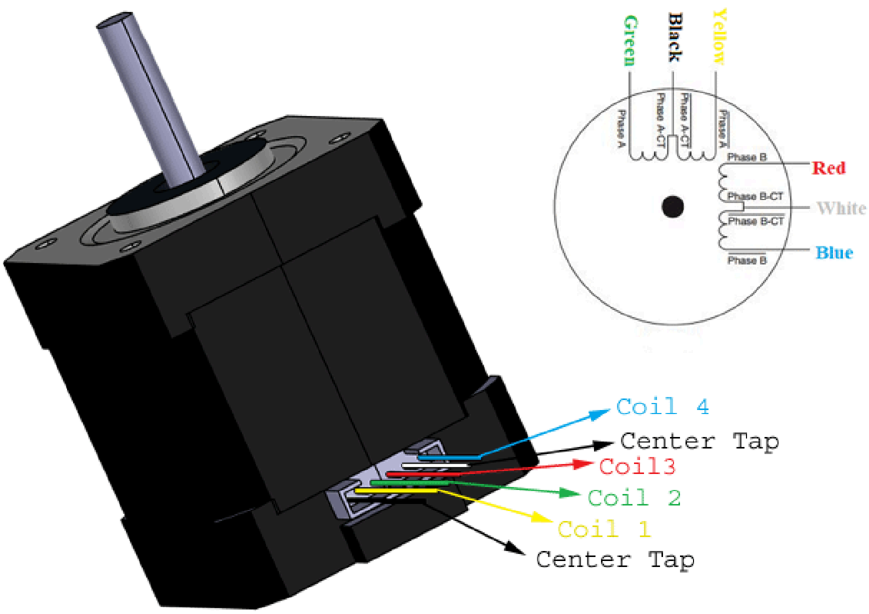
NEMA17 Stepper Motors

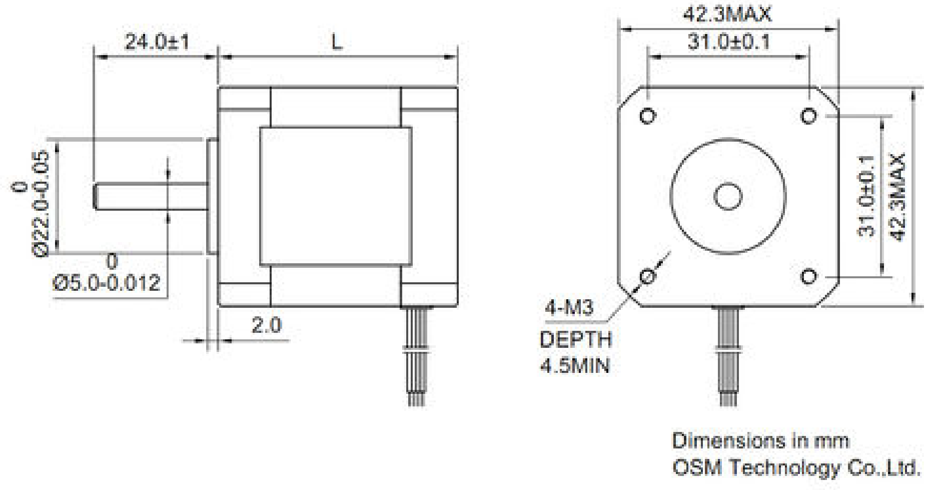
A **NEMA 17 stepper motor** is a stepper motor with a 1.7 x 1.7 inch (43.18 x 43.18 mm) faceplate.

NEMA 17 stepper motors are the cornerstone of precision control systems and excel at providing detailed angle management.

Its notable feature is the 1.8° step angle, which helps the motor shaft rotate accurately with each

step. A complete 360° rotation requires 200 steps. This complex stepping has proven to help improve positioning accuracy, making the motor an excellent choice for 3D printers, CNC machines and robots where accuracy is critical.



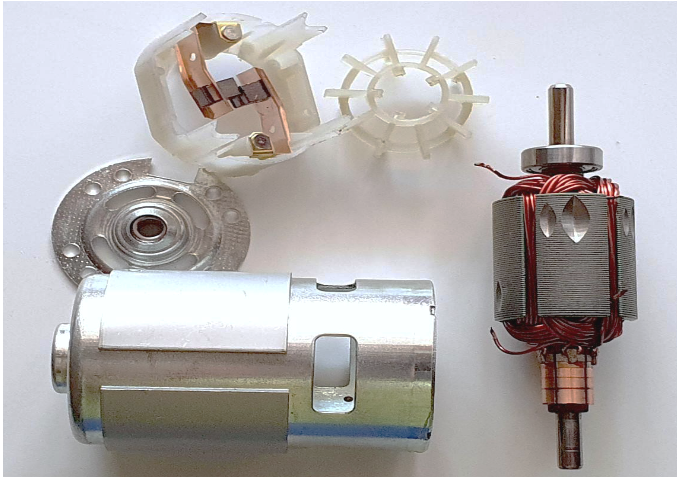

24.0±1
L
0
Ø22.0-0.05
0
Ø5.0-0.012
2.0
42.3MAX
31.0±0.1
31.0±0.1
42.3MAX
4-M3
DEPTH
4.5MIN
Dimensions in mm
OSM Technology Co.,Ltd.

specifications

Model No.	JK42HS40-1204AF-02
Operating Voltage (VDC)	12~24
Rated current(A)	1.5A/Phase
Step Angle	1.8⁰
Inductance(mH/Phase)	3.7*(1±20%)mH
Resistance (Ω)	/phase, 2.4*(1±15%)
Number of Phase	2
Frame Size(mm)	42*42*38
Step Angle(degree)	1.8
Width (mm)	42
Height (mm)	38
Shaft Type	D type
Shaft Length (mm)	21
Shaft Diameter (mm)	5
Insulation Resistance (MΩ)	(DC 500V), ≥100

	Model No.	SL42STH48-168A4
	Holding-Torque	4.8 kg-cm
	Step Angle (degree)	1.8
	Operating Voltage(VDC)	24
	Supply Current(A)	1.68
	No. of leads	4
	Inductance(mH/Phase)	3.2
	Resistance (Ohms)	1.65
	Rotor inertia(gm-cm2)	54
	Frame size(mm)	42*42*48
	Shaft Length (mm)	21

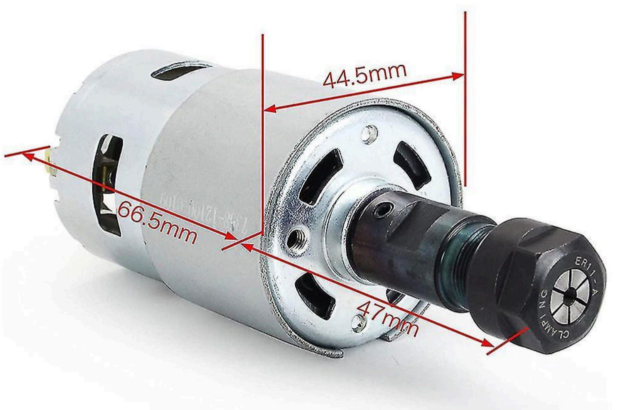
775 DC-Spindle Motor with ER11 Chuck



The D Shaft 775 24V DC Motor is a powerhouse engineered for high-speed and high-torque performance. With a staggering 8000 RPM, this motor is designed for robust applications.It has an in-built cooling fan for high-heat tolerance.This motor will be used as a Spindle motor in the cnc machine. With an end mill bit coupled with its shaft using the er11-collet. The high-speed rotations of the endmill will be able to carve out wooden chips easily.

Specifications :

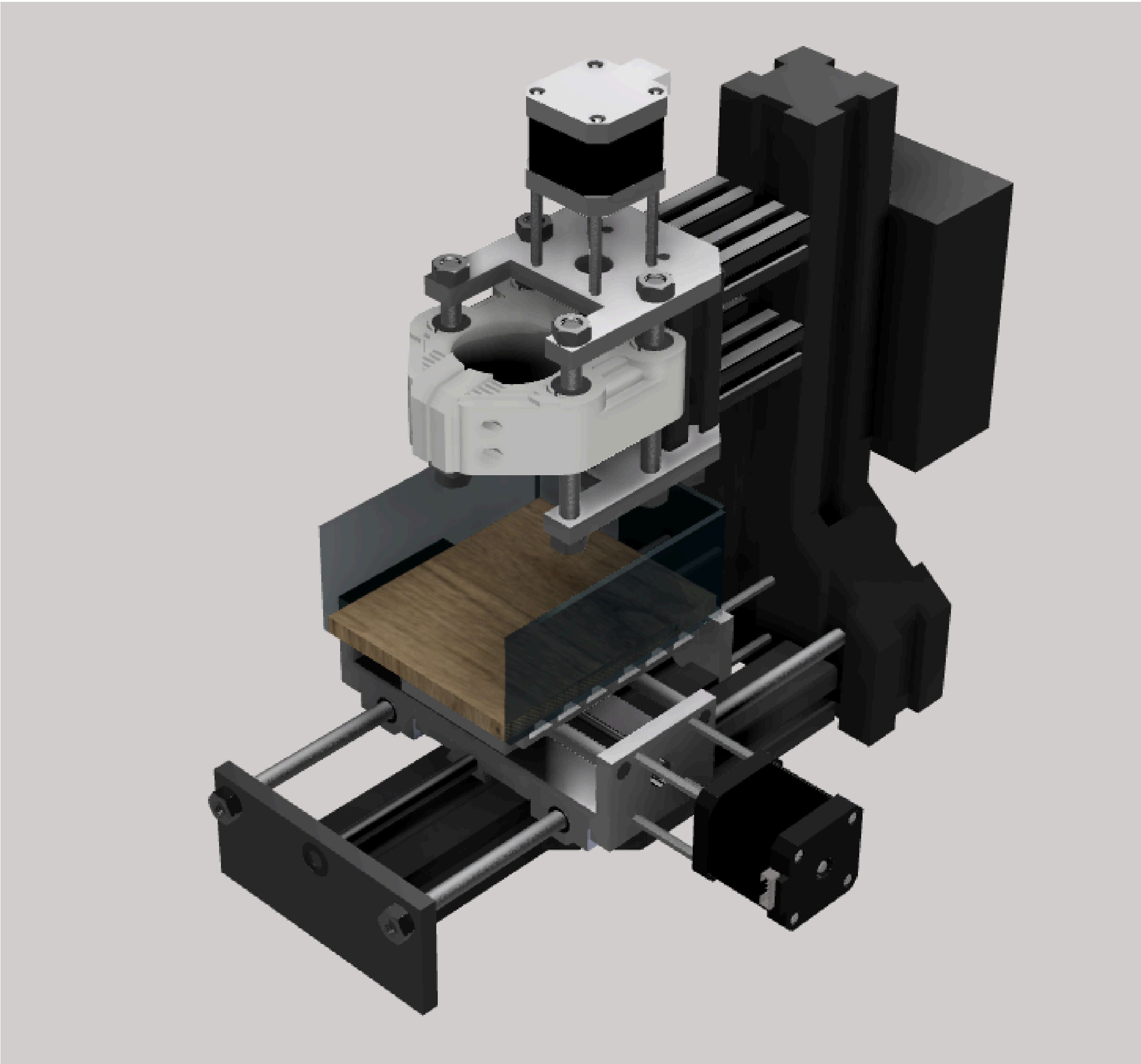
- Model ; 775
- Operating voltage: 24 V
- Power:300W
- Speed: 8000 RPM
- Insulation resistance:>2 Mega ohm
- Dielectric strength:400V
- Motor Length : 122 mm
- Diameter : 45 mm

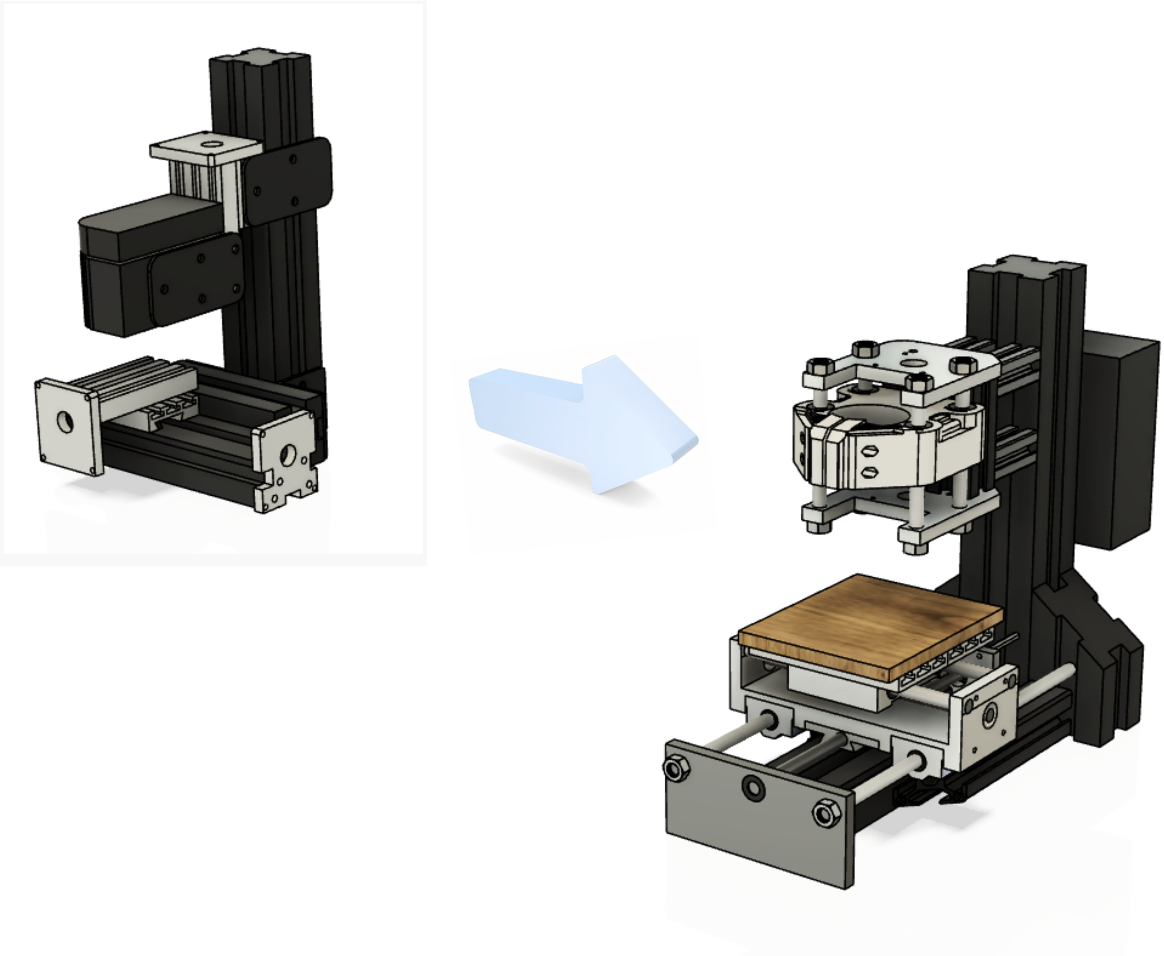


- Axis collet Length: 48mm
- Diameter of Axis collect holder : 18 mm
- ER11 chuck : 1/8 inch

limit switches

Mechanical Structure





To accommodate larger workpieces for wood carving, a comprehensive redesign of the CNC machine frame was undertaken. This resulted in a significant increase in work area while enabling customization to meet specific project requirements. The redesign included the incorporation of new, more rigid metal components to enhance machine stability. Additionally, the linear guide system was overhauled, transitioning from dovetail slides to linear bearings and smooth shafts. This optimized design minimized friction and ensured smoother movement, better suited to the stepper motors employed. Essentially, a complete machine rebuild was performed, replacing all components with a custom design, resulting in a functionally new CNC machine.

Machine Assembly

We undertook a complete disassembly of the CNC machine and subsequently reassembled the components to create a machine tailored to our specific needs.

In accordance with our design specifications, all necessary components were manufactured in the college workshop to precise dimensions.

3D Printed Parts

To accommodate the spindle motor's intricate geometry, we employed additive manufacturing (3D printing) to fabricate a lightweight holder from polylactic acid (PLA). This approach significantly reduced the mass of the Z-axis assembly, minimizing the workload of the stepper motor during vertical movements.

X-axis Assembly

Y-Axis Assembly

Z-Axis Assembly

Assembled Structure

Final Product

Test and Analysis

9. Smooth Shaft

SLy

SLx

SLz

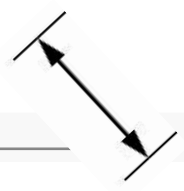
SLy= 0.8cm(M8) +41.6cm +0.8cm(M8) = 43.2 cm *2PCs

SLx= 0.8cm(M8) +31.6cm +0.8cm(M8) = 33.2 cm *2PCs

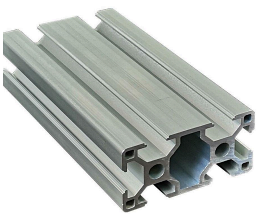
SLz= 11 cm +0.8cm(M8) = 11.8 cm *2PCs

10. Extrusion 40cm

2PCs

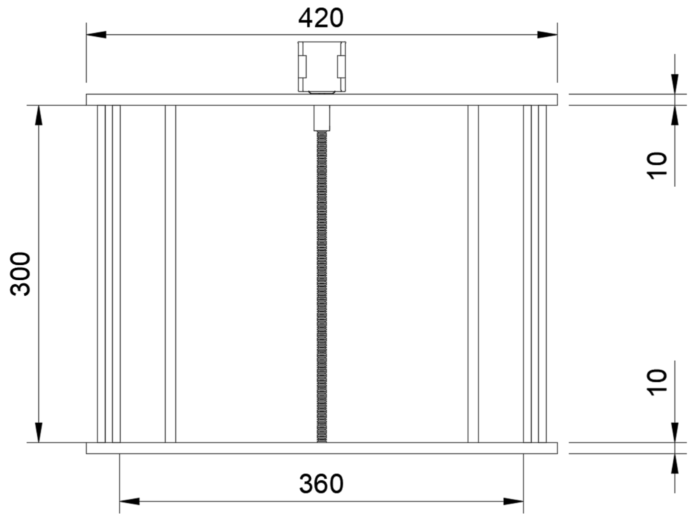


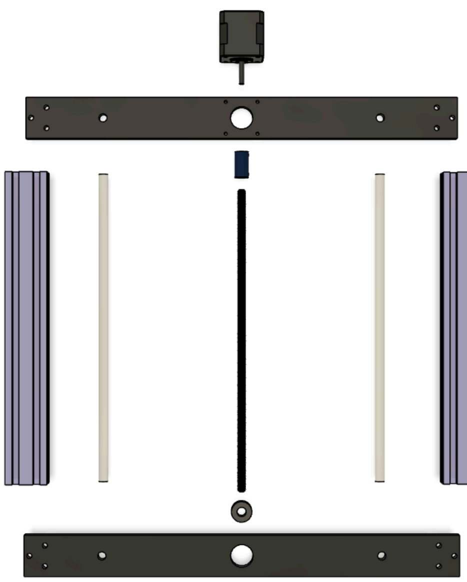
30cm



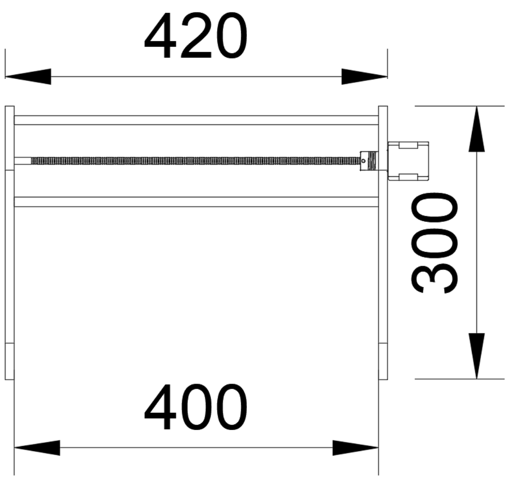
Mechanical Assembly

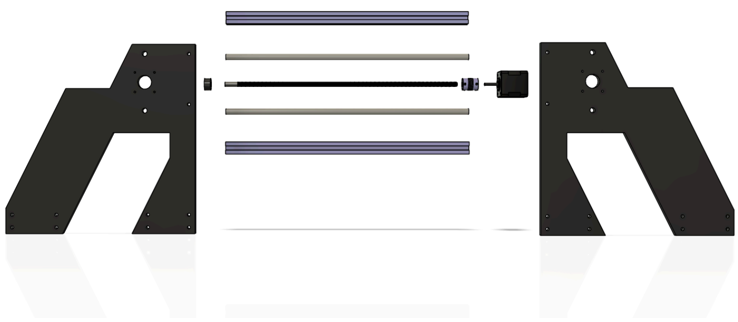
Y axis Assembly



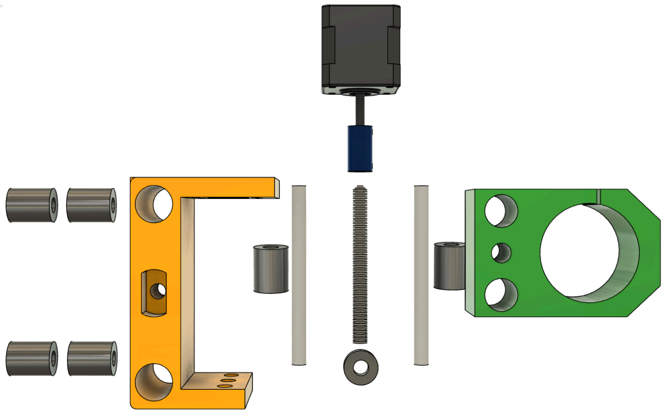


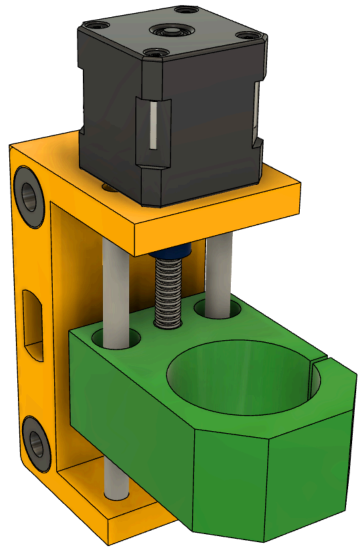
X Axis Assembly

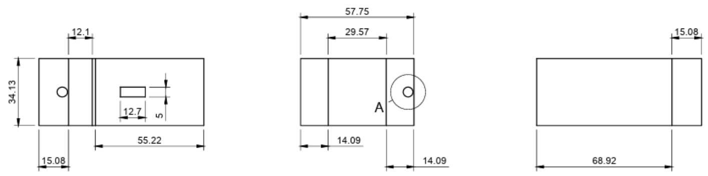


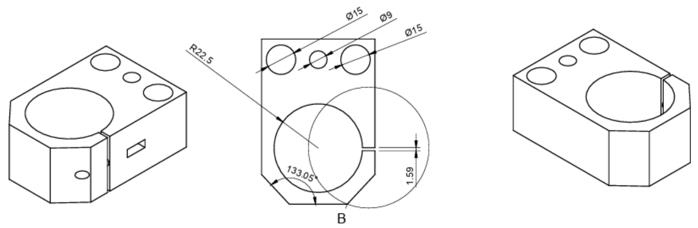


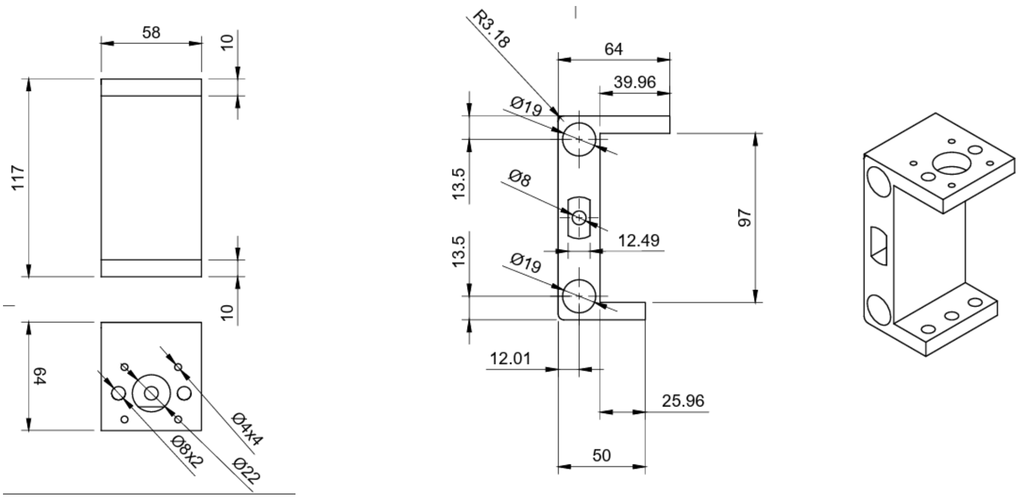
Z Axis Assembly



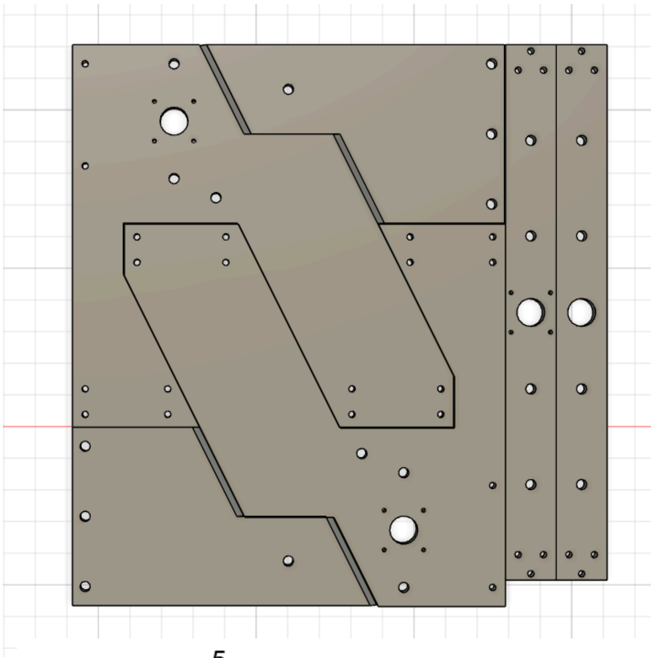


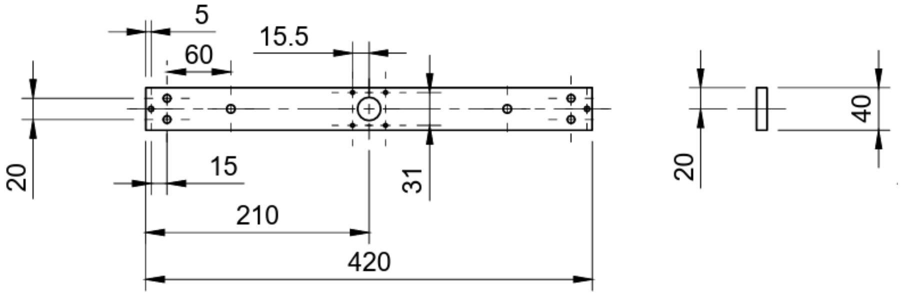


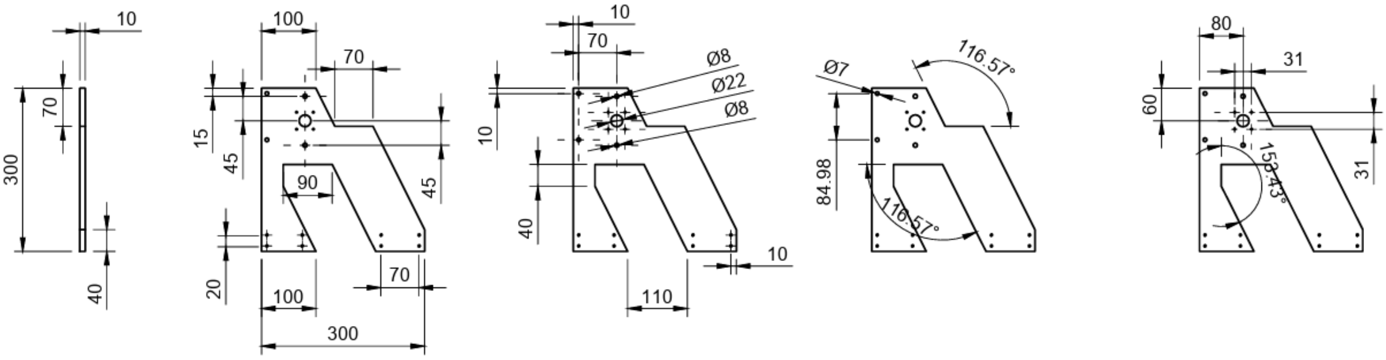


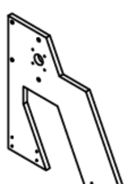


CNC Mechanical Frame Assembly :









Material Selection

Bill Of Material

SR.NO	COMPONENTS	QUANTITY	PRICE(₹)
01	RS-775 DC Motor	01	200.00
02	NEMA 17	03	550.00
03	Stepper Motor Coupler	03	68.00
04	X axis lead screw (450 mm, 2mm pitch)	01	332.00
05	Y axis lead screw (350mm, 2mm pitch)	01	239.00
06	Z axis lead screw (150mm, 2mm pitch)	01	195.00
07	X axis smooth shaft - D 8mm (450- 470 mm)	02	150.00
08	Y axis smooth shaft - D 8mm (350 - 370 mm)	02	192.00
09	Z axis smooth shaft - D 8mm (150-170mm)	02	155.00
10	Linear Bearing - Inner D 8mm	10	670.00
11	Ball Bearing- Inner D 8mm	03	85.00
12	T8 Nut Pitch 2mm Lead 8mm Brass T 8x8mm		350.00

13	Manual Handle		
14	2020 T Slot (2 Meter) Aluminum Extrusion	01	200.00
15	4040 T Slot (2 Meter) Aluminum Extrusion	01	800.00
16	Aluminum sheet (600×600×10)	01	390.00/kg
17	Nuts and Bolts M3	25	60.00
17	Nuts and Bolts M5	50	120.00
18	Jumper Wire & Cables	40	40.00
19	Slider	4	123.00/pic
20	Clamps		
21	Chuck	1	360.00
22	Drill bits		
23	Wooden Sheets	1	
24	Limit Switches	2	11.00
25	Sensors		
26	Cables and Adapters		
27	Cable Chains		
28	Acrylic enclosure		

29	Touch probe		
30			
31			

Firmware Selection and Features :

About Firmware:

Introduction

FluidNC is a CNC firmware optimized for the ESP32 controller. It is the next generation of firmware from the creators of Grbl_ESP32. It includes a web based UI and the flexibility to operate to a wide variety of machine types. This includes the ability to control machines with multiple tool types such as laser+spindle or a tool changer.

Firmware Architecture

The firmware architecture adopted for our IoT-based tabletop CNC system is grounded in an Object-Oriented Hierarchical Design. This design philosophy serves as the backbone for the efficient functioning of the CNC system and is tailored to meet the specific requirements of our project.

Object-Oriented Hierarchical Design:

Our firmware architecture is structured around an Object-Oriented paradigm, facilitating a modular and organized approach to system development. This design allows us to represent key elements such as spindles, motors, and stepper drivers as objects with distinct properties and behaviors. This modularity enhances code readability, maintainability, and scalability, providing a solid foundation for the CNC system's functionality.

Hardware Abstraction for Machine Features:

The firmware incorporates a robust hardware abstraction layer specifically tailored for machine features, including spindles, motors, and stepper drivers. This abstraction layer allows for the seamless integration of these hardware components into the overall system. By abstracting the hardware details, the firmware becomes more adaptable, allowing for straightforward integration of different hardware configurations without compromising the core functionalities of the CNC system.

Grbl Compatibility:

- Our firmware choice is fully compatible with Grbl, a popular open-source CNC control system. This compatibility ensures that our CNC system can interpret standard G-code commands, enabling precise control of the machining operations.

Commands and Settings:

- The firmware provides a comprehensive set of commands and settings, allowing for fine-tuning and customization. This flexibility is essential for adapting the CNC system to different machining requirements and scenarios.

Wifi and Bluetooth Connectivity:

- A key feature of the firmware is its compatibility with Wifi and Bluetooth connectivity. This allows for wireless communication, enabling remote monitoring and control of the CNC system. The inclusion of these communication options aligns with the IoT aspect of our project.

WebUI (Web User Interface):

- The firmware includes a WebUI, providing a user-friendly interface accessible through a web browser. This feature enhances the user experience by allowing operators to interact with the CNC system intuitively.

Local File System (FLASH):

- With a built-in local file system stored in FLASH memory, the firmware supports the storage and retrieval of CNC programs. This feature enhances the autonomy of the CNC system by allowing it to execute machining tasks locally without the need for continuous external input.

Speed and Feed Over rides:

- The firmware offers speed and feed override functionalities, enabling real-time adjustments during machining. This feature enhances flexibility and control over the machining process, allowing for on-the-fly optimization.

Emergency Stop (E-Stop):

- An Emergency Stop feature is integrated into the firmware, providing a rapid and effective means to halt the CNC system in case of emergencies. Safety is paramount, and this feature ensures swift response to unexpected situations.

Parking Feature:

- The firmware includes a parking feature, allowing the CNC system to park the tool or spindle safely during pauses or tool changes. This contributes to efficient machining operations and reduces the risk of damage.

Spindle Speed Maps (Linearization):

- Spindle speed maps, or linearization, is a feature that ensures consistent and accurate spindle speeds across different operating conditions. This contributes to achieving desired machining results with precision.

Supported G Codes:

- The firmware supports a wide range of GCodes, providing compatibility with standard CNC programming. This versatility ensures that the CNC system can interpret a variety of commands for diverse machining tasks.

Jogging and Serial Terminal:

- The firmware supports jogging functionality, allowing for manual control of the CNC system's movements. Additionally, a Serial Terminal feature provides a direct communication interface for advanced users, facilitating direct command inputs.

Easy Compatibility with ESP32 WROOM and Simple Configuration Process:

- Our chosen firmware seamlessly integrates with the ESP32 WROOM, offering a straightforward configuration process. This compatibility streamlines the setup and configuration of the CNC system, making it accessible to users with varying levels of technical expertise.

Basic Grbl Compatibility

The intent is to maintain as much Grbl compatibility as possible. It is 100% compatible with the day to day operations of running GCode with a sender, so there is no change to the Grbl GCode send/response protocol.

Support for All Grbl GCodes:

Our firmware fully supports all Grbl GCodes, providing users with a comprehensive set of commands for controlling and instructing the CNC machine. This compatibility ensures that users can leverage the extensive library of Grbl GCodes for diverse machining tasks.

Configurable Parameters in the Config File:

Users can conveniently adjust machine parameters directly in the configuration file, using human-readable items instead of numerical codes. This adaptability promotes ease of customization and allows users to tailor the CNC system to their unique needs.

WebUI

FluidNC includes a built-in brower-based Web UI (ESP3D-WebUI) so you control the machine from a PC, phone, or tablet on the same Wifi network. Below are key aspects of the WebUI integration within FluidNC:

Cross-Device Accessibility:

- The WebUI enables users to control the CNC machine using a PC, phone, or tablet, offering flexibility and convenience in choosing the device that best suits their preferences or is readily available.

Optimized Tablet Mode:

- FluidNC's WebUI includes an optimized tablet mode designed for use on tablet computers. This mode enhances the user experience on tablets, providing an interface tailored for touch interactions. Notably, it features a GCode visualizer, allowing users to visualize and comprehend the toolpath directly on their tablet.
- The FluidNC team maintains a separate fork of the ESP3D-WebUI with enhancements and additional features. Notable among these is an alternative tablet mode optimized for tablet computers. This mode is designed to maximize usability and take advantage of the unique capabilities of tablet devices.

GCode Visualizer:

- One of the prominent features of the tablet mode is the integrated GCode visualizer. This tool allows users to visualize the GCode toolpath directly within the WebUI, providing a real-time representation of the machining process. This visual feedback enhances user understanding and control over the CNC operations.

Installation and Connectivity:

- To utilize the WebUI, users need to install the wifi version of FluidNC and configure it to connect to their local Wifi network. Once configured, they can simply browse to fluidnc.local from their web browser to access and control the CNC machine through the WebUI.

FluidNC-Specific Integration:

- The FluidNC-specific features integrated into the WebUI enhance the overall functionality and compatibility with the FluidNC CNC system. These features are tailored to complement FluidNC's capabilities, providing a seamless and integrated user experience.

In essence, the inclusion of the ESP3D-WebUI in FluidNC not only ensures accessibility from various devices but also introduces tailored enhancements, particularly in tablet mode, to optimize the user interface for touch-enabled devices. The availability of the source code fosters transparency and collaboration within the CNC community, allowing users to contribute to and benefit from ongoing improvements in the WebUI.

Configuration Process :

The configuration process for our IoT-based tabletop CNC system prioritizes simplicity and flexibility, allowing users to easily set up and customize the machine without the need for firmware compilation. The process involves utilizing an installation script to upload the latest firmware release and creating a configuration file to describe the machine's parameters. Below are additional details on this streamlined configuration approach:

Installation:

To initiate the configuration process, users will employ a user-friendly installation script. This script automates the firmware upload, eliminating the need for manual compilation. Users can execute the script to seamlessly deploy the latest release of the CNC firmware onto the ESP32 microcontroller.

Config File Creation:

After uploading the firmware, users will create a configuration file in the form of a text document, typically in YAML format. This file serves as a comprehensive description of the machine, encompassing critical parameters such as motor specifications, spindle details, and other relevant configurations.

Upload to FLASH Memory:

The configuration file is then uploaded directly to the FLASH memory on the ESP32. This can be achieved through either the USB/Serial port or Wifi connectivity, providing users with flexibility in choosing their preferred method of communication. This upload process ensures that the machine is equipped with the specific configuration settings required for optimal performance.

Multiple Config Files Support:

The configuration system supports the use of multiple config files on the ESP32. While the default configuration file is named config.yaml, users have the freedom to create and store alternative config files to address different machine setups or operating conditions. This flexibility allows for swift adaptation to varying machining requirements.

Custom Config File Naming:

Users can easily specify a custom configuration file name using the $Config/Filename directive. This feature enables the machine to reference and utilize a specific configuration file, allowing for convenient switching between different setups without manual intervention.

User-Friendly Interaction:

The configuration process emphasizes a user-friendly interaction, where operators can effortlessly manage firmware updates and tailor the machine's settings. This approach minimizes the learning curve for users and encourages accessibility, making CNC machine configuration an intuitive and straightforward task.

Remote Configuration via Wifi:

Leveraging Wifi connectivity, users can remotely configure the CNC machine. This feature is particularly advantageous in scenarios where physical access to the machine is limited, enabling users to modify settings conveniently over the network.

Adaptable Machine Setup:

The configuration process is designed to cater to the unique specifications of the CNC machine. Users can adapt the machine setup by modifying the configuration file, ensuring that the CNC system aligns with specific project requirements and machining tasks.

By adopting this configuration approach, our IoT-based tabletop CNC system promotes accessibility, ease of use, and adaptability, empowering users to efficiently set up and customize the machine to suit their specific needs.

Installation:

Visit the FluidNC GitHub Page:

- We initiated the process by navigating to the FluidNC GitHub repository at https://github.com/FluidCNC/FluidNC to access the latest firmware and resources.

Check for Latest Releases:

- Checking the latest releases section on the GitHub page, we identified the most stable version of the FluidNC firmware.

Download and Unzip Firmware:

- After identifying the latest release, we downloaded the firmware as a zip file and proceeded to unzip the contents to obtain the necessary firmware files.

Connect ESP32-Compatible Board:

- Connecting our ESP32-compatible board to the computer using a USB cable, we ensured a stable connection.

Install Required Drivers:

- To ensure smooth communication with the ESP32 board, we verified that the required drivers were installed on our computer.

Run install-wifi.bat:

- In the firmware folder, we ran the install-wifi.bat script, initiating the upload process of the firmware to the ESP32 board.

Access Point Creation:

- Following a successful installation, an access point was automatically created, secured with the default password '12345678'.

Connect to the Access Point:

- We connected our device to the newly created access point and were automatically redirected to a webpage.

Upload the index.html.gz :

- On the redirected webpage, we followed the instructions to upload the index file located in the firmware's wifi folder, an essential step for setting up the web interface.

Access ESP3D Web Interface :

- Upon successful index file upload, the ESP3D web interface was accessible, providing a platform for further configuration.

Configuring YAML File:

Download FluidNC Main File:

- We downloaded the main FluidNC file from the repository and extracted its contents.

Copy Example Config File:

- Copying the example config file provided with FluidNC, it served as a template for configuring our YAML file.

Edit YAML File:

- Opening the YAML file in a text editor, we made necessary adjustments according to our CNC machine setup, modifying settings such as motor pins and limit switches.

Upload YAML File to ESP32:

- Using the FluidNC dashboard, we uploaded the edited YAML file to the ESP32, choosing either Wi-Fi or Fluid Term for the upload process.

Config File

```yaml
board: IOT CNC
name: IOT CNC Milling XYZ
meta: 2024 3rd Year IDEMI
stepping:
  engine: RMT
  idle_ms: 255
  pulse_us: 4
  dir_delay_us: 1
  disable_delay_us: 0
```

```
  segments: 12

axes:
  shared_stepper_disable_pin: NO_PIN
  x:
    steps_per_mm: 100.000
    max_rate_mm_per_min: 5000.000
    acceleration_mm_per_sec2: 50.000
    max_travel_mm: 300.000
    soft_limits: false
    homing:
      cycle: 2
      positive_direction: false
      mpos_mm: 0.000
      feed_mm_per_min: 100.000
      seek_mm_per_min: 200.000
      settle_ms: 500
      seek_scaler: 1.100
      feed_scaler: 1.100

    motor0:
      limit_neg_pin: gpio.33
      limit_pos_pin: NO_PIN
      limit_all_pin: NO_PIN
      hard_limits: false
      pulloff_mm: 1.000
      stepstick:
        ms3_pin: NO_PIN
```

```
      step_pin: I2SO.2
      direction_pin: I2SO.1
      disable_pin: I2SO.0

  y:
    steps_per_mm: 100.000
    max_rate_mm_per_min: 5000.000
    acceleration_mm_per_sec2: 50.000
    max_travel_mm: 300.000
    soft_limits: false
    homing:
      cycle: 2
      positive_direction: false
      mpos_mm: 0.000
      feed_mm_per_min: 100.000
      seek_mm_per_min: 200.000
      settle_ms: 500
      seek_scaler: 1.100
      feed_scaler: 1.100

    motor0:
      limit_neg_pin: gpio.32
      limit_pos_pin: NO_PIN
      limit_all_pin: NO_PIN
      hard_limits: false
      pulloff_mm: 1.000
      stepstick:
        ms3_pin: NO_PIN
```

```
    step_pin: I2SO.5
    direction_pin: I2SO.4
    disable_pin: I2SO.7

z:
  steps_per_mm: 100.000
  max_rate_mm_per_min: 5000.000
  acceleration_mm_per_sec2: 50.000
  max_travel_mm: 300.000
  soft_limits: false
  homing:
    cycle: 2
    positive_direction: true
    mpos_mm: 0.000
    feed_mm_per_min: 100.000
    seek_mm_per_min: 200.000
    settle_ms: 500
    seek_scaler: 1.100
    feed_scaler: 1.100

  motor0:
    limit_neg_pin: NO_PIN
    limit_pos_pin: gpio.35
    limit_all_pin: NO_PIN
    hard_limits: false
    pulloff_mm: 1.000
    standard_stepper:
      step_pin: NO_PIN
```

direction_pin: I2SO.9

disable_pin: I2SO.8

probe:

pin: gpio.34

check_mode_start: true

i2so:

bck_pin: gpio.22

data_pin: gpio.21

ws_pin: gpio.17

spi:

miso_pin: gpio.19

mosi_pin: gpio.23

sck_pin: gpio.18

sd card:

cs_pin: gpio.5

card_detect_pin: NO_PIN

start:

must_home: false

relay:

output_pin: gpio.26

enable_pin: NO_PIN

direction_pin: NO_PIN

```
  disable_with_s0: false
  s0_with_disable: true
  spinup_ms: 0
  spindown_ms: 0
  tool_num: 100
  speed_map: 0=0.000% 0=100.000% 1=100%
arc_tolerance_mm: 0.002
junction_deviation_mm: 0.010
verbose_errors: false
report_inches: false
enable_parking_override_control: false
use_line_numbers: false
planner_blocks: 16
```


Uploaded Edited YAML File:

Through the FluidNC dashboard, we uploaded the edited YAML file, ensuring the correct file name (e.g., "IOT CNC.yaml") was used.

Restart FluidNC :

After uploading the YAML file, we restarted FluidNC to apply the configuration changes.

By following these steps, we successfully installed FluidNC, configured the YAML file to match our CNC machine setup, connected to Wi-Fi, and managed files through the FluidNC dashboard.

Testing and Troubleshooting:

e.

Final Touches:

Quality Control:

Documentation and User Manuals:

Results and Achievements:

Applications:

The IoT-based tabletop CNC (Computer Numerical Control) system has versatile applications across various industries, offering enhanced functionality and connectivity. Here are detailed applications of the IoT-based tabletop CNC:

Precision Manufacturing:

- The CNC system ensures precise and accurate machining of materials, making it suitable for manufacturing intricate and detailed components.

- The integration of IoT allows for real-time monitoring and adjustment, ensuring optimal precision throughout the manufacturing process.

Prototyping and Small-Scale Production:

- The tabletop CNC is ideal for prototyping and small-scale production, enabling rapid and cost-effective manufacturing of custom parts or prototypes.
- IoT connectivity facilitates remote monitoring and control, making it suitable for agile manufacturing environments.

Educational Purposes:

- The system serves as an excellent educational tool for students learning about CNC programming, mechatronics, and control systems.
- IoT features provide students with hands-on experience in integrating smart technologies into manufacturing processes.

Research and Development:

- The tabletop CNC is valuable in research and development activities, allowing researchers to experiment with different materials and machining techniques.
- IoT capabilities enable data collection and analysis, aiding in the improvement of manufacturing processes and efficiency.

Artistic and Design Applications:

- Artists and designers can leverage the CNC system for creating intricate and detailed artistic pieces or customized designs.
- The precision and versatility of the system, coupled with IoT connectivity, offer new possibilities in artistic expression.

Remote Monitoring and Control:

- The IoT integration allows users to monitor and control the CNC machine remotely. This feature is particularly beneficial for troubleshooting, adjustments, and overseeing the manufacturing process from a distance.

Energy Efficiency and Sustainability:

- Smart features enabled by IoT contribute to energy-efficient operation. The system can optimize energy usage based on real-time data and user-defined parameters.
- Sustainable practices can be implemented through precise material utilization and reduced wastage in the manufacturing process.

Customization in Production:

- The CNC system, when connected to IoT, facilitates customization of production runs based on real-time demand and specific requirements.
- This adaptability is particularly valuable in industries where product variations are frequent.

Quality Control:

- IoT sensors can be incorporated for real-time quality monitoring during the machining process. Any deviations from specifications can be detected and addressed promptly, ensuring high-quality output.

Integration with Industry 4.0:

- The tabletop CNC, with IoT capabilities, aligns with the principles of Industry 4.0 by providing connectivity, data exchange, and smart automation in the manufacturing environment.
- It contributes to the evolution of smart factories, where machines communicate and collaborate seamlessly for efficient and intelligent production.

In summary, the IoT-based tabletop CNC system finds applications in precision manufacturing, education, research, artistic endeavors, and contributes to advancements in smart manufacturing practices. Its adaptability and connectivity make it a valuable tool across diverse industries.

Future Scope:

With an extended budget, the IoT-based tabletop CNC system can be further enhanced and expanded to unlock additional capabilities and features. Here are some future scope considerations with an extended budget:

Advanced Materials and Machining Capabilities:

- Invest in high-quality and specialized machining tools to broaden the range of materials the CNC system can work with.
- Explore additional machining processes such as multi-axis milling or laser cutting for increased versatility.

Smart Sensors and Quality Assurance:

- Integrate advanced sensors for in-process monitoring to enhance real-time quality control.
- Implement machine vision systems for automated inspection and quality assurance, ensuring precise and error-free manufacturing.

Machine Learning and Adaptive Control:

- Incorporate machine learning algorithms to enable the CNC system to adapt and optimize machining parameters based on historical data and real-time feedback.
- Develop adaptive control mechanisms to automatically adjust settings for improved efficiency and quality.

Collaborative Robotics (Cobots):

- Explore the integration of collaborative robotic systems that work alongside the CNC machine, automating tasks like material handling, tool changes, and part loading/unloading.
- This can enhance overall productivity and efficiency.

Augmented Reality (AR) Assistance:

- Integrate AR technologies to provide real-time guidance and assistance to operators during setup, maintenance, and troubleshooting.
- AR overlays can assist in visualizing machining paths and identifying potential issues.

Cloud Connectivity and Data Analytics:

- Implement cloud connectivity to store and analyze machining data for performance optimization and predictive maintenance.
- Utilize data analytics tools to gain insights into production trends, machine utilization, and areas for improvement.

Energy-Efficient Systems:

- Invest in energy-efficient components and systems to reduce the environmental impact of the CNC machine.
- Explore renewable energy sources or energy recovery systems to further enhance sustainability.

Enhanced User Interface and Human-Machine Interaction:

- Develop a user-friendly and intuitive interface for seamless interaction with the CNC system.
- Implement touch-screen controls, voice commands, or gesture-based controls for enhanced user experience.

Expandable Work Envelope and Modular Design:

- Design the CNC system with a modular approach, allowing for easy expansion of the work envelope or integration of additional modules for diverse applications.
- Consider a larger work area to accommodate larger workpieces.

Cybersecurity Measures:

- Implement robust cybersecurity measures to protect the CNC system from potential cyber threats.
- Secure data transmission and storage to ensure the integrity and confidentiality of sensitive information.

By allocating resources to these advanced features and technologies, the extended-budget IoT-based tabletop CNC system can evolve into a cutting-edge and future-ready solution, catering to the growing demands of precision manufacturing and smart production environments.

Conclusion :

In the mechanical domain, our endeavors included creating 3D components, integrating modules, and simulating the CNC using Fusion 360's machine builder. We delved into auto tool path generation, property settings, rendering images, and acquired basic drafting skills. On the electronic front, we gained insights into component datasheets, understood the workings of motors, explored limit switches, and grasped concepts like series/parallel connections and voltage regulation. Software-wise, we successfully configured open-source firmware, understanding its documentation and integrating a web UI. Real-world experiences involved market surveys, highlighting price variations. The culmination of our efforts was the practical simulation of a fully functional CNC, reinforcing our theoretical and practical engineering skills for the betterment of society.

Reference :

http://wiki.fluidnc.com