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Realization of a Mini CNC machine with control system based on LINUXCNC

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Acknowledgment

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We would like to thank very warmly and our deep gratitude, in advance to the members of the jury who will do the honor to assess this end of studies work.

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Finally, we express our gratitude to our whole family, to all our friends, comrades, and to all who have contributed closely or by far at the culmination of this work, in particular those that we did not quote, they will always remain in our hearts.

Dedication

I dedicate this modest work:

To my parents, to my brothers and sisters for their support

To all my friends who I am love and respect a lot.

To the entire 2021 promotion.

To everyone I love.

HAMZA, AYOUB

Abstract

Our project is a study and realization of a mini CNC machine and its control and digital manufacturing. This project contains two parts: the first one is destined to the literature review on the mini CNC machine, which includes the Fundamental Knowledge about the CNC Machines and their control, and the second part is focused on a modeling of Mini CNC machine and 3D geometric modeling using SOLIDWORKS 2016 software. Finally, an experiment and result of work are presented and discussed.

Keywords: NC machine, LinuxCNC, Arduino Mega, Mini lathe.

ملخص

مشروعنا هو دراسة وتحقيق آلة CNC صغيرة والتحكم فيها والتصنيع الرقمي. يحتوي هذا المشروع على جزأين: الأول هو مراجعة الأدبيات حول آلة CNC المصغرة، والتي تتضمن المعرفة الأساسية حول آلات CNC والتحكم فيها، والثاني يركز على نمذجة آلة CNC الصغيرة والنمذجة الهندسية ثلاثية الأبعاد باستخدام برنامج SOLIDWORKS 2016. أخيرًا، تم عرض ومناقشة تجربة ونتيجة العمل.

الكلمات الدالة: NC machine, LinuxCNC, Arduino Mega, Mini lathe

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Notations and Abbreviations

NC	Numerical control.
CNC	Computer Numerical control.
CAD	Computer-Aided Design.
FAO	Computer-Aided Manufacturing.

General Introduction

Computer Numerical Control (CNC) machines allow automatic many tasks in various fields of activity: engraving and drilling circuits printed the production of small mechanical parts, the tracing and cutting of various components of the scale models, and much more.

An ever-growing number of model makers, electronics engineers, and other enthusiasts use digitally controlled machine tools.

These small machines, most often milling machines, make it possible to obtain an almost professional quality result. However, these machines being often of a very high purchase price, many users design them and do them themselves.

Most CNC machines have three axes, but there are four or even five-axis models.

The industrial revolution, which began with the creation of the tools of industry traditional and others, and then these tools, were developed into semi-automatic machines then in automatic machines, which functioned with the help of computer and programs by transferring the instructions from the control part to the operational part of the machine.

The existence of programmable electronic boards like the Arduino, DSP, and FPGA ... etc. allows to commanding and controlling any system or machine such as CNC.

Our project is based on the study and realization of the Lathe CNC machine with three axes. To achieve this objective, we have structured this thesis as follows:

In the first chapter, we will present the overview about CNC machine, by starting with the different stages of development of NC, and generalities on CNC machines and their classifications and families of CNC machines, than the main components of CNC as Coordinate Systems and CNC Lathe coordinate are presented.

In the second chapter, the fundamental knowledge of Numerical Control and the CNC machine tools are presented and discussed, then, an overview of NC technology, citing the classification, architecture, and programming of NCs for different orders and Coordinate Systems.

Finally, thirty chapter is destined where going to realization of Mini CNC machine.

Chapter I: Fundamental Knowledge of CNC Machines

Chapter I: Fundamental Knowledge of CNC Machines

I.1. Introduction

In recent years, the control of electrical machines has shown great progress, due to the technological developments that humans have achieved in the mechanical industry and this through the different phases and eras began with the industrial revolution that began with the creation of tools for traditional industry and others.

This chapter deals with the fundamental knowledge of Numerical Control and the CNC machine tools and it gives an overview of NC technology, citing the classification, architecture, and programming of NCs for different orders and Coordinate Systems.

I.1. Definition of CNC

It is a fully or partially automatic machine to which orders are communicated thanks to codes, which are carried on a material medium (diskette, USB ...). The machine tool is equipped with a numerical control capable of carrying out the calculations of the coordinates of the points defining a trajectory (interpolation).

The primary role of a CNC (Computerized Numerical Control) machine is to generate movements. It will receive values of position, speed, and acceleration and will generate, following processing, digital output instructions. It has large computing power and greater flexibility of use than a PLC programmable [1].

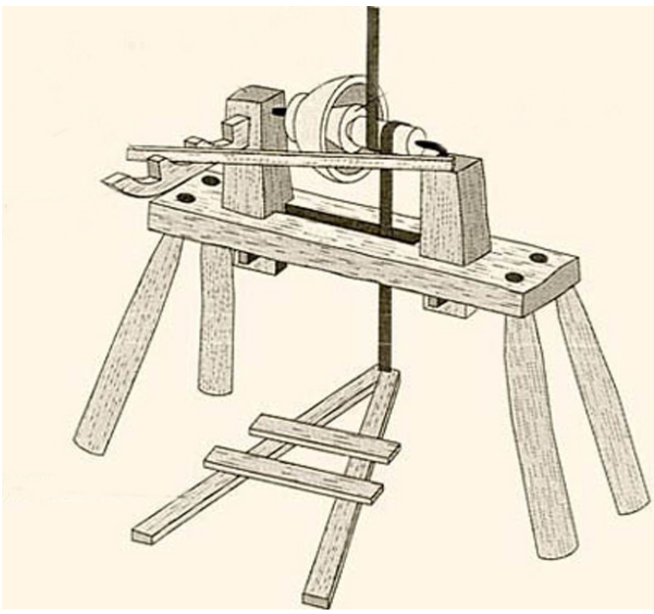


Figure I.1: The pedal lathe. [1]

I.2. CNC System

There is a large exodus in the industry from the popular PLC (Programmable Logic Controller) (hardwired or software) to a PC-based controller. PC-based control offers great advantages like faster design cycles, lower downtime using diagnostics and simulation tools, increased productivity, and decreased maintenance costs.

There are many PC-based machine tool controllers for CNC available in the market today, but they are proprietary and the customer needs to depend on the software vendor for maintenance and support.

I.3. Operation principle of the NC

The machine tool is equipped with a numerical control capable of carrying out calculations of coordinates of the points defining a trajectory (interpolation), we say that it is a calculator. It is called CNC (Computer Numerical Control). Most Machine numerical controllers CNCs [1].

The numerically controlled machine tool forms an assembly comprising a part control and an operative part, as shown in figure I.3.

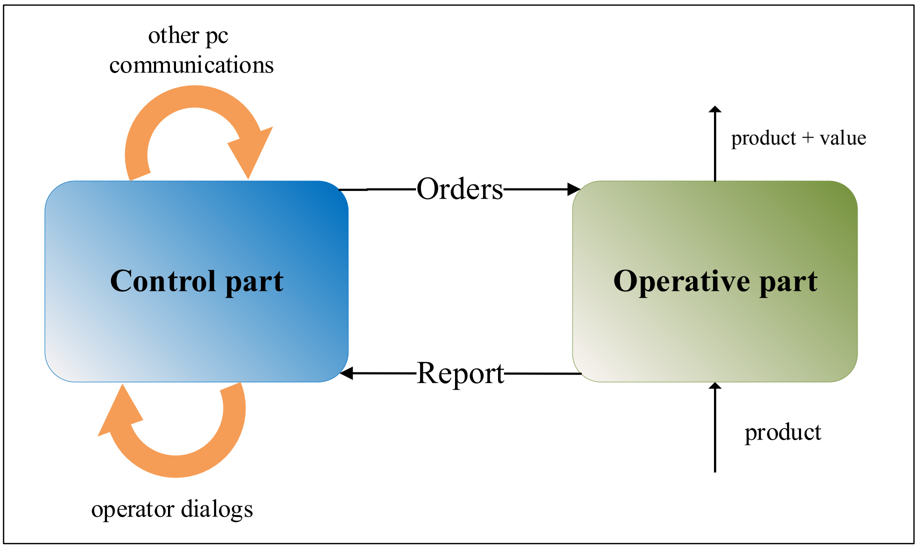


Figure I.2: architecture of a CNC machine tool.

I.3.1. Operative part

The operative part of automation is the sub-assembly that performs the actions physical (displacement, machining, lubrication, etc.), measurement of physical quantities (acceleration, speed ...) and reports to the control part, it is generally composed of actuators, sensors, effectors and a frame. Hence, the operative part receives the orders from the control part and executes them [3].

The movements are controlled by motors almost comparable to a machine tool classic, and it includes:

- ✓ Bed, ensuring the independence of the machine on the ground.
- ✓ Frame, the wide slides of which are in treated steel.
- ✓ Cover and Safety window, secure the machine and the human.
- ✓ The tool support or Tool turret (spindle, torch, laser, water jet, etc.).
- ✓ Main Spindle,
- ✓ A workpiece support table, mobile along 2 or 3 axes, equipped with a control system screw and ball nut.
- ✓ Motors responsible for driving the table.
- ✓ A measuring element or position sensor providing information at any time on the position mobile on each axis. [4].

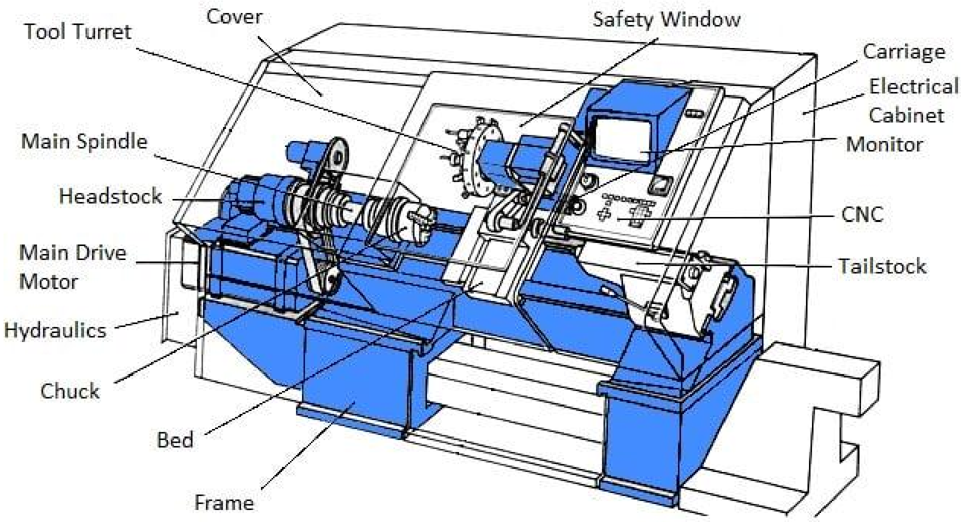


Figure I.3: The elements of the operative part.[9]

I.3.2. Control part

The function of the command part is to transform the coded information of the programming in order to the servomechanisms of the operating part, in order to obtain the movements of moving parts, see Figure I.4 [2].

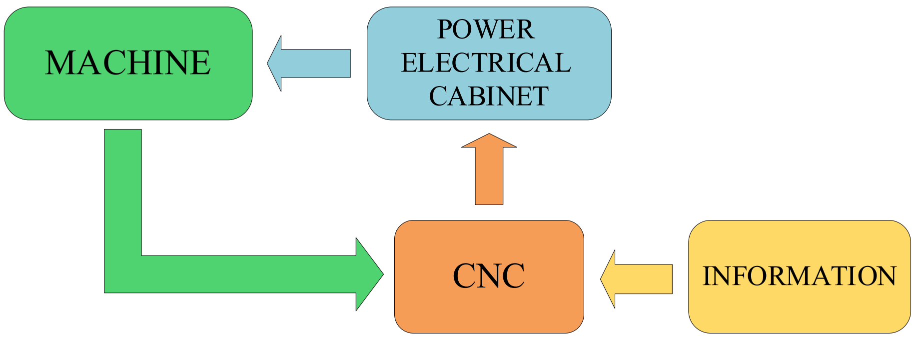


Figure I.4: Original function of a Control part.

Different from a conventional machine and consisting of a cabinet in which we find:

➢ The console allowing you to enter commands using a keyboard.

➢ The data reader (this reader can be an option when purchasing the machine).

➢ The RS 232 output for links with external peripherals.

➢ The display screen for all the recorded data.

➢ The calculator.

➢ electronic boards (axis controls, memory, etc.) [2].

I.4. Families of NC machine

We can split the family of numerical controls into four sub-families of machines:

➢ Milling numerically Controlled.

➢ Turning numerically controlled.

➢ Rectification numerically controlled.

➢ electro-erosion numerically controlled.

In each family, the assembly and working methods are totally different, but they agree on the principle of programming, the vast majority of machines using an ISO language.

To this can be added so-called conversational interfaces or by learning which simplifies the use of the machine.

The concept of numerical control also extends to the field of boiler making: plasma cutting, press brake [2].

(a) CNC milling machine (b) CNC grinding machine (c) CNC machining center

Figure I.5: Examples of CNC machines. [7]

There are several types of machines:

➢ Coux removal machines: drills, lathes, centers of turning, milling machines, machining centers, grinding machines… etc.

➢ electro-erosion: die-sinking machines, wire machines.

➢ cutting machines: flame cutting, laser, water jet ...

➢ presses: metal, plastic injection.

➢ special machines: panel, multi-head, packaging (for the food industry) ...

I.5. The Components of the CNC system

CNC systems include the following six major elements listed below and shown in Figure I.6

- **Input Device:** E-stop, Limit switch…
- **Machine Control Unit:** PC-Based system, PLC…
- **Machine Tool:** structure of a machine, the operative part of a machine
- **Driving System:** Motor driver, Stepper driver…
- **Feedback Devices:** closed-loop Feedback
- **Display Unit:** GUI

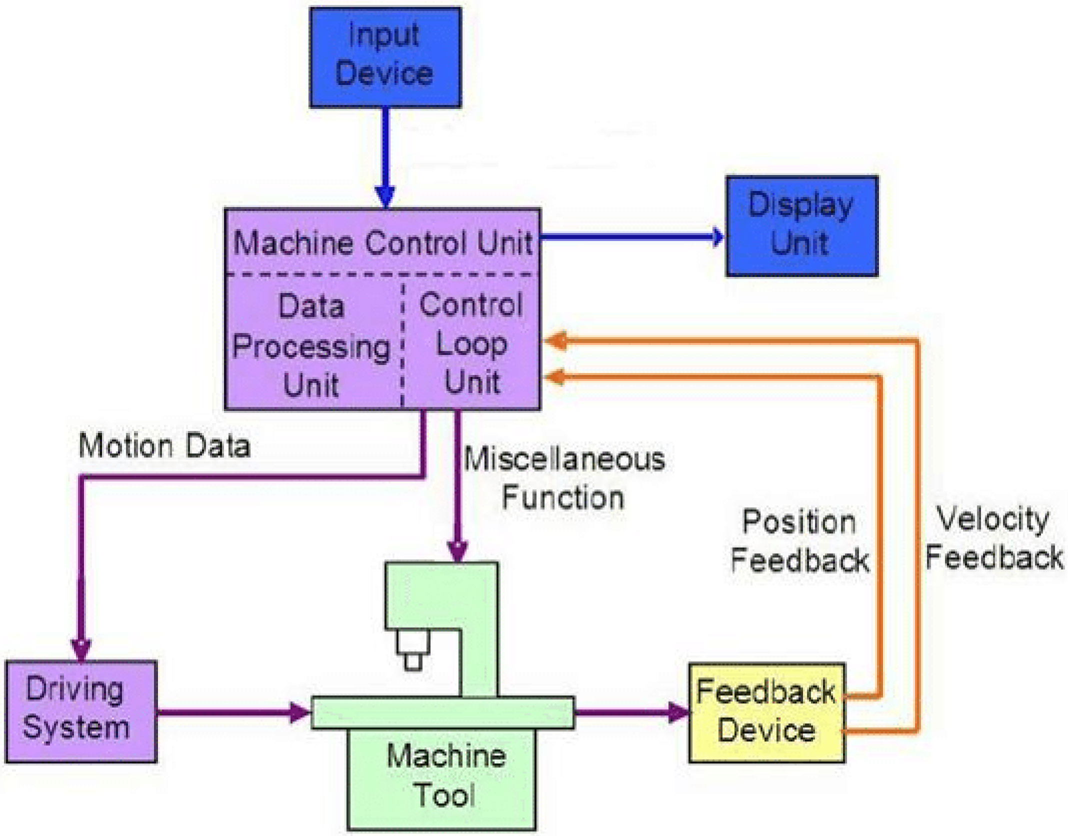


Figure I.6 : Components of CNC-System [7]

I.6. Coordinate Systems

In order to shape metal by machine tools, the cutting tool should move in contact with the workpiece at certain specific points, while the workpiece or cutting tool is rotating.

- A coordinated system is required to define the movement on the machine.
- Basically, there are two common coordinate systems:
    - Cartesian coordinate system.
    - Polar Coordinate system.

I.7. CNC Lathe (turning) Machines' coordinate system:

To ensure that the control system of the machine will read the specified coordinates correctly to indicate the position of the workpiece; the machine tool has its own "coordinate system".

The following points are part of this system.

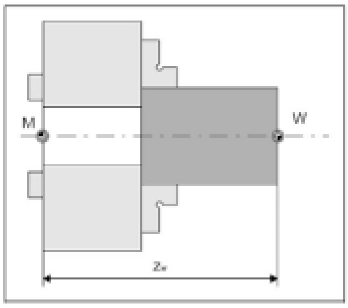


Figure I.7: Machine zero point and Workpiece zero point. [20]

I.7.1. Machine Zero Point (M):

The origin of the coordinate system. It is defined by the manufacturer and cannot be changed. In general, the machine zero point M is located in the center of the work spindle nose for the CNC lathe.

Figure I.8 (a) show (M) machine zero point for lathe machine and its symbol.

(a) (b)

Figure I.8: (a) Left: "M" Machine zero point symbol. (b) Right: "W" Workpiece zero point symbol. [20]

I.7.2. Workpiece Zero Point (W):

The workpiece zero point (W) is the origin of the work part-based coordinate system. Its location is specified by the programmer. The ideal location of the work part zero point allows the dimensions to be directly taken from the drawing. In the case of turning the workpiece, zero point is generally in the center of the left or right side of the completed part. Figure I.8 (b) show (W) workpiece zero point and its symbol.

I.7.3. Turning Machine axes:

CNC Turning machine has at least 2 controllable feed axes, marked as X and Z;

- When the cutting tool moves toward and backward the machine spindle, this is called

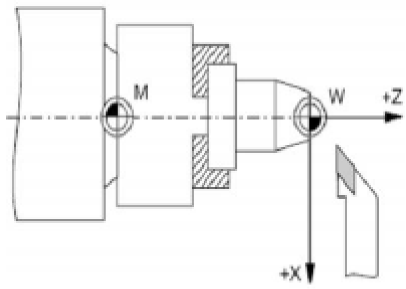


Figure I.9: Axes on turning machine. [20]

movement along Z-axis.

- When the cutting tool moves in a cross direction to the longitudinal axis of the workpiece, this is called movement along X-axis.
- Positive Z direction is when the tool moves away from the workpiece in Z-axis.
- Positive X direction is when the tool moves away from the work part in X-axis.

I.8. Advantages and disadvantages of CNC [10]

I.8.1. Advantages of CNC

- The CNC Machine provides a workpiece with better precision and accuracy.
- Fewer workers are required which helps to saves the labor cost.
- CNC Machine can produce complex designs with high accuracy in the minimum possible time.
- The conversion of the unit can easily be done by this machine (SI to British or from British to SI).
- It also helps with safety reasons.
- Low Maintenance required
- Reduce setup change over time.

- The CNC Machine has Higher Production and capability.
- It can run for 24 hours a day.
- Reliable.

I.8.2. Disadvantages of CNC

- The installation cost is high.
- Even do the parts of the CNC machine are high.
- When any failure occurs in the machine, a high skilled professional requires to solve the issue.
- Computer knowledge is required.
- Program knowledge is required

I.9. Computer-aided design (CAD)

CAD (Computer-Aided Design) is a set of tools and computer programs to assist the engineer in the design and development of a product. A CAD system makes it possible to represent and study the functioning of an object without having actually manufactured it, that is to say in virtual [11].

CAD provides global visibility into the behavior of an object before it exists, both in the level of its appearance as of its structure and functioning. Objects can be represented in two or three dimensions (2D or 3D). Their appearance can be wireframe, solid, surface, it can also simulate texture.

A large number of CAD software are available in open-source, for example:

- ➢ Solidworks
- ➢ Blender
- ➢ FreeCAD
- ➢ ImplicitCAD
- ➢ QCAD
- ➢ OpenCASCADE
- ➢ Art of Illusion
- ➢ Fusion36

I.10. Computer-Assisted Manufacturing (CAM)

Computer-Aided Manufacturing or CAM is to write the file containing the program for controlling a numerically controlled machine tool. This file will describe precisely the movements that the machine tool must perform to produce the part requested. This type of file is also called: ISO program or ISO blocks.

CAM software uses models and assemblies created in CAD software to generate machining paths on which the machines convert designs into physical parts [12].

The tools of the CAM are modelers, we quote:

- Catia
- RhinosCAM.
- SolidCAM.
- Power MILL.
- Hyper MILL.
- CAMWorks.
- Fusion360.
- ArtCAM.

I.11. Conclusion

In this chapter, we have presented an overview of the numerical control and the CNC machine and its history, then we discussed in general the CNC machine in terms of principle, use and structure, and we talked about the families of CNC machines, coordinate system and therefore after having we will deal with a study control system software of CNC machine.

Chapter II: Analyze of LinuxCNC

Chapter II: Analyze of LinuxCNC

II.1. Introduction:

In the literature survey it is found that under the open source category, there is an open system for CNC as LinuxCNC. It is developed in open source software under GNU public license for Numerical Control (NC) of machines.

II.2. Control System Software

In the last two decades, many efforts have been made in the development of open control systems for machine tools. They were recognized as a solution to machine tool and control manufacturer's endeavors to elaborate common concepts, develop basic technologies, and produce basic components together, in order to fulfill continuous demands for higher machine tool functionality and flexibility, product quality, and costs reduction [12].

According to the IEEE, "an open system provides capabilities that enabled properly implemented applications to run on a variety of platforms from multiple vendors, interoperate with other system applications and present a consistent style of interaction with the user " (IEEE 1003.0).

This means that, Open Architecture Controller (OAC) has to be flexible in hardware and software, for all control levels the first OAC solution was proposed by National Institute of Standards and Technology (NIST). This project has evolved over time and is currently focused on the development of an open-architecture control system named Enhanced Motion Controller (EMC) [recent cell LinuxCNC]

There is much software for the control system of CNC machine tools, so we are choosing one of them to discuss it and give a better look at it and how it works, for who to a choice we look at which operating system that support, how many axes can control, capabilities of development and so on...

Some of the control system software:

- Mach3/Mach4.
- LinuxCNC.
- Grbl.

II.3. LinuxCNC overview

LinuxCNC uses the real-time kernel of the Linux system and can send signals without overloading the operating system. It supports both servo and stepper motors. Currently, many motion control card and drive manufacture developed drivers for LinuxCNC. Since LinuxCNC uses a hardware abstraction layer, it is possible to mix and match various control boards. LinuxCNC communicates to the motion controller using various ports like parallel port, serial ports, PCI, and PCI-express bus. It can control up to 9 axes in a CNC machine.

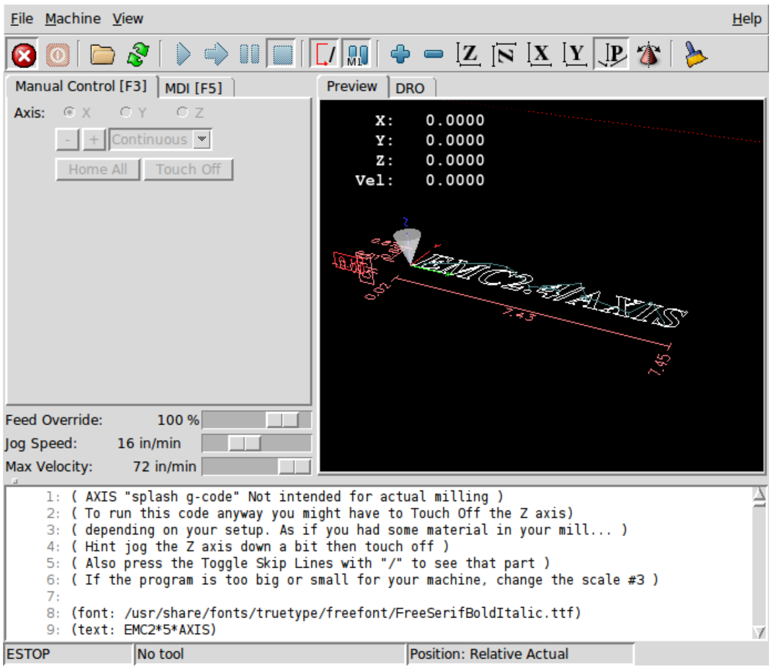


Figure II.1: LinuxCNC Axis GUI [16]

II.4. Architecture of EMC

There are four components contained in the LinuxCNC Architecture: a motion controller (EMCMOT), a discrete IO controller (EMCIO), a task executor (EMCTASK) which coordinates them, and several text-mode and graphical User Interfaces.

The motion control card receives commands from userspace modules via a shared memory buffer and executes those commands in real-time. The status of the controller is made available to the user space modules through the same shared memory area. The motion controller interacts with the motors and other hardware using the HAL [13]. Figure II.2 shows the architecture of LinuxCNC.

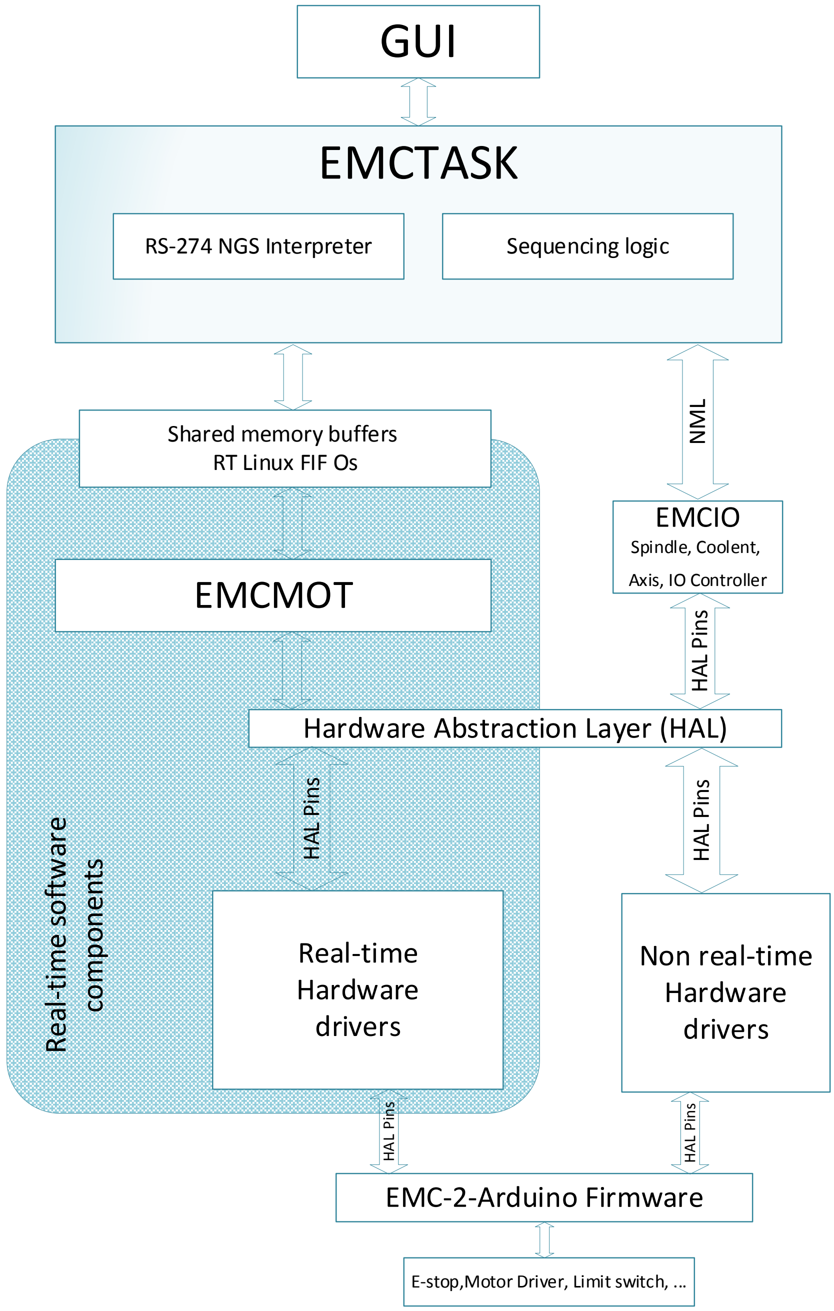


Figure II.2: the architecture of LinuxCNC.

II.5. EMC Motion Controller (EMCMOT):

EMCMOT executes the executable modules in a loop to perform real-time operations and performs trajectory planning, direct and inverse kinematic calculations, and computation of a desired output to the motor control subsystem. This process includes sensing of controlled axis positions, computation of the next trajectory point, and interpolation between these trajectory points. It supports both hardware limits and programmable software limits. The hardware limits will be sensed by the axes limit and home switches [13].

Supported modes of operation are individual axis jogging (continuous, incremental, absolute), queued blended moves for linear and generalized circular motion, as well as programmable forward and inverse kinematics.

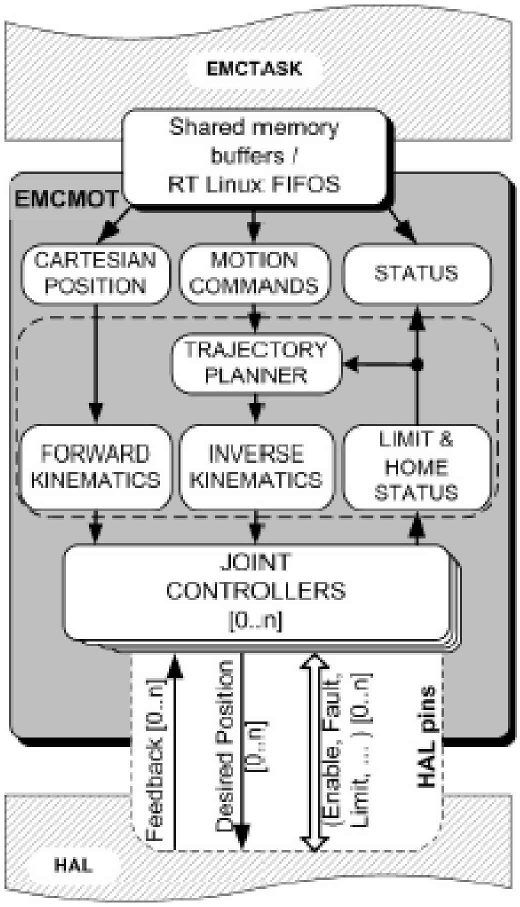


Figure II.3: EMCMOT Structure

II.6. Discrete I/O Controller (EMCIO)

The EMCIO module handles all I/O functions, which are not directly related to the actual motion of the machine axis. It is implemented as an I/O controller consisting of a hierarchy of subordinate controllers for the main spindle, automatic tool change, the coolant, auxiliary functions (E-STOP chain, lubrication, etc.), and other user-defined subsystems [13].

II.7. Task Executer (EMCTASK)

EMCTASK is having two modules the G-code interpreter and sequencing logic. It monitors the status of subordinate modules (EMCMOT and EMCIO) and coordinates them. It also receives and analyses the commands, either from the operator through GUI or from another process as in auto mode (data may be provided from a file for sequencing), interprets them into Neutral Messaging

Language (NML) messages, and dispatches them to EMCMOT, EMCIO or EMCTASK itself at appropriate times.

II.8. User Interfaces

A user interface is the part of the LinuxCNC that the machine tool operator interacts with. The LinuxCNC comes with several types of user interfaces: AXIS is the standard GUI interface. Touchy is a touch screen GUI. Keystick is a character-based screen graphics program suitable for minimal installations [14].

II.9. EMC-2-Arduino firmware

EMC 2 Arduino is a small collection of files intended to allow a person with an Arduino Mega2560 (or UNO), an old USB enabled computer and a free copy of LinuxCNC to begin building their very own CNC machine cheaply and quickly with a variety of components, ranging from low-end inexpensive (even salvaged) components such as old steppers and computer parts to high-end linear servos [15]. Shown in Figure II.4

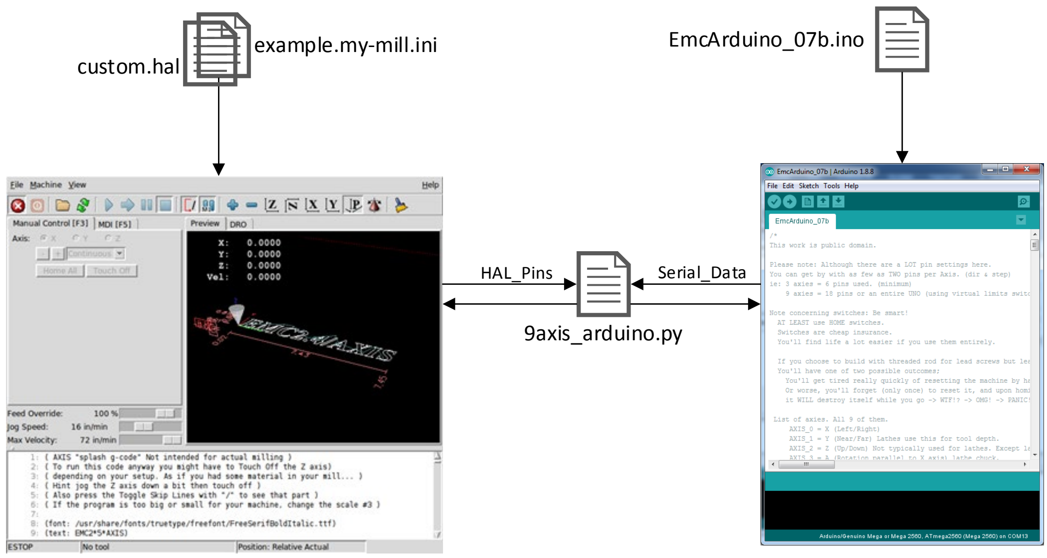


Figure II.4: EMC-2-Arduino configuration.

II.10. System Configuration of LinuxCNC

A test setup has been prepared for the testing of LinuxCNC using the selected cards, drives, and motors. LinuxCNC is installed on Linux PC or laptop (Linux mint 20). The drivers for the cards are also installed by downloading them from the manufactures web portal. The additional plugins for parameter setting and simulation are also installed. Now the system is ready for the basic machining testing. Figure II.5 shows the system configuration for Linux

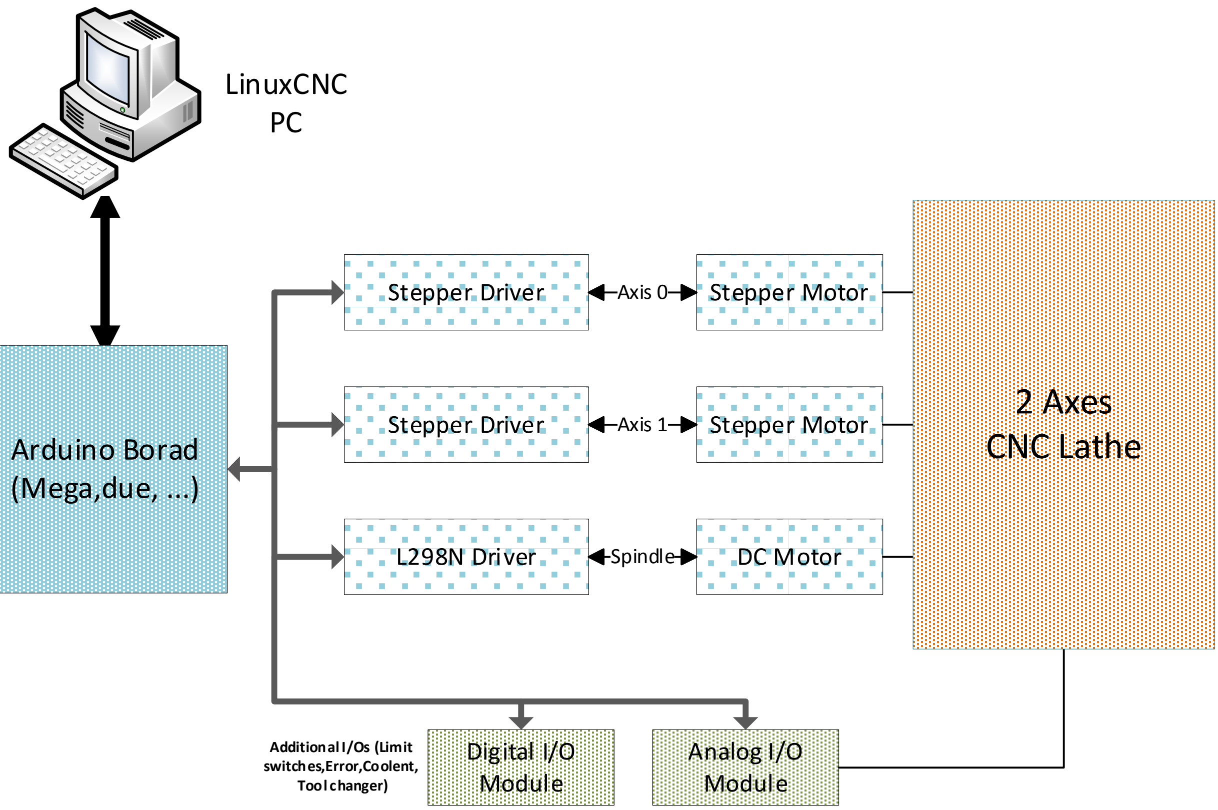


Figure II.5: System configuration of Linux CNC

II.11. Conclusion

In this chapter, we conclude the LinuxCNC satisfies the educational and light operations level machining operations, due to the robust open-source real-time OS, LinuxCNC promotes expansion possibilities, scalability, interoperability, and configurability of open architecture.

As the system operation is tested with a two axes machine, the performance evaluation should be extended with multi axes platform.

In the next part, we going to realization this control system to real Mini CNC machine.

Chapter III: Realization of Mini CNC machine

Chapter III: Realization of Mini CNC machine

III.1. Introduction

In this chapter, a design and realization of the mini CNC machine is presented, and we relied on our project and shown the different parts and the relation between it, follow that with explanation of some basic parts and the steps of configuration the software to operate the machine, as well the result of project has been discussed.

III.2. System overview

III.2.1. Conception the mini CNC

We use SolidWorks 2016 to design the mini CNC machine type lathe machining that has two linear axes call it X-axis, Z-axis. In addition, one rotary axis perpendicular to Z-axis continent dc motor and chuck to fix and turn workpiece, show Figure III.1.

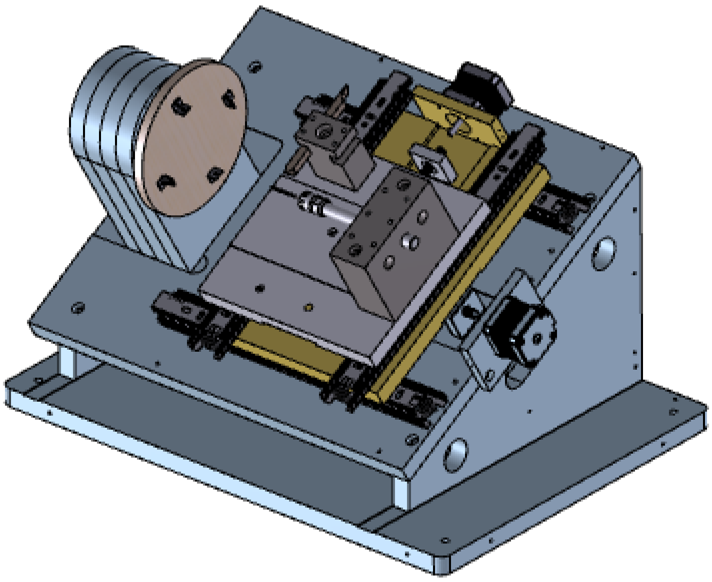


Figure III.1 Design of the Mini lathe CNC machine

III.2.2. Parts of CNC Machine

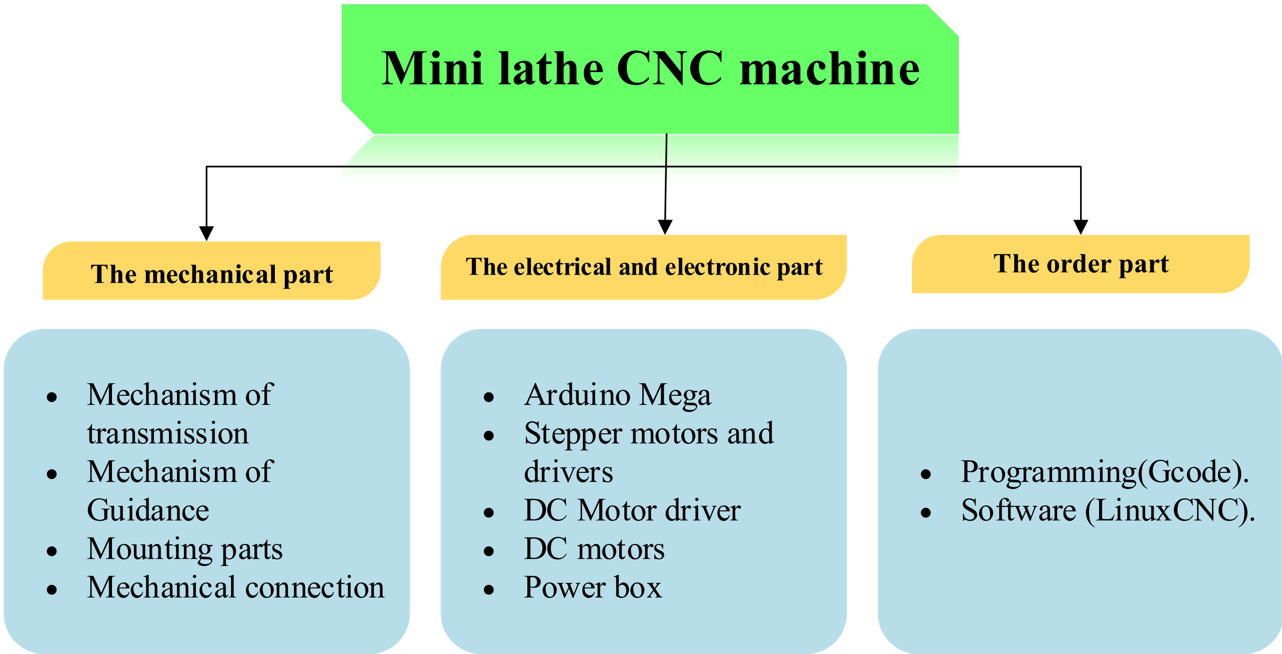


Figure III.2: Part graph of the Mini lathe Machine CNC.

III.2.3. FAST diagramme

FAST (technical function analysis system) is a type of diagram that presents a way of thinking, acting, or speaking. The FAST diagram is constructed from left to right, in the following logic: from "why" to "how". Thanks to its technical culture and scientist, the engineer develops the service functions of the product into technical functions.

He chooses solutions to ultimately build the product. The FAST diagram constitutes then a set of essential data allowing to have a good knowledge of a complex product and thus to be able to improve the proposed solution.

Standard NF EN 12973 (value management) describes the FAST diagram as one of the usual methods of functional analysis [17].

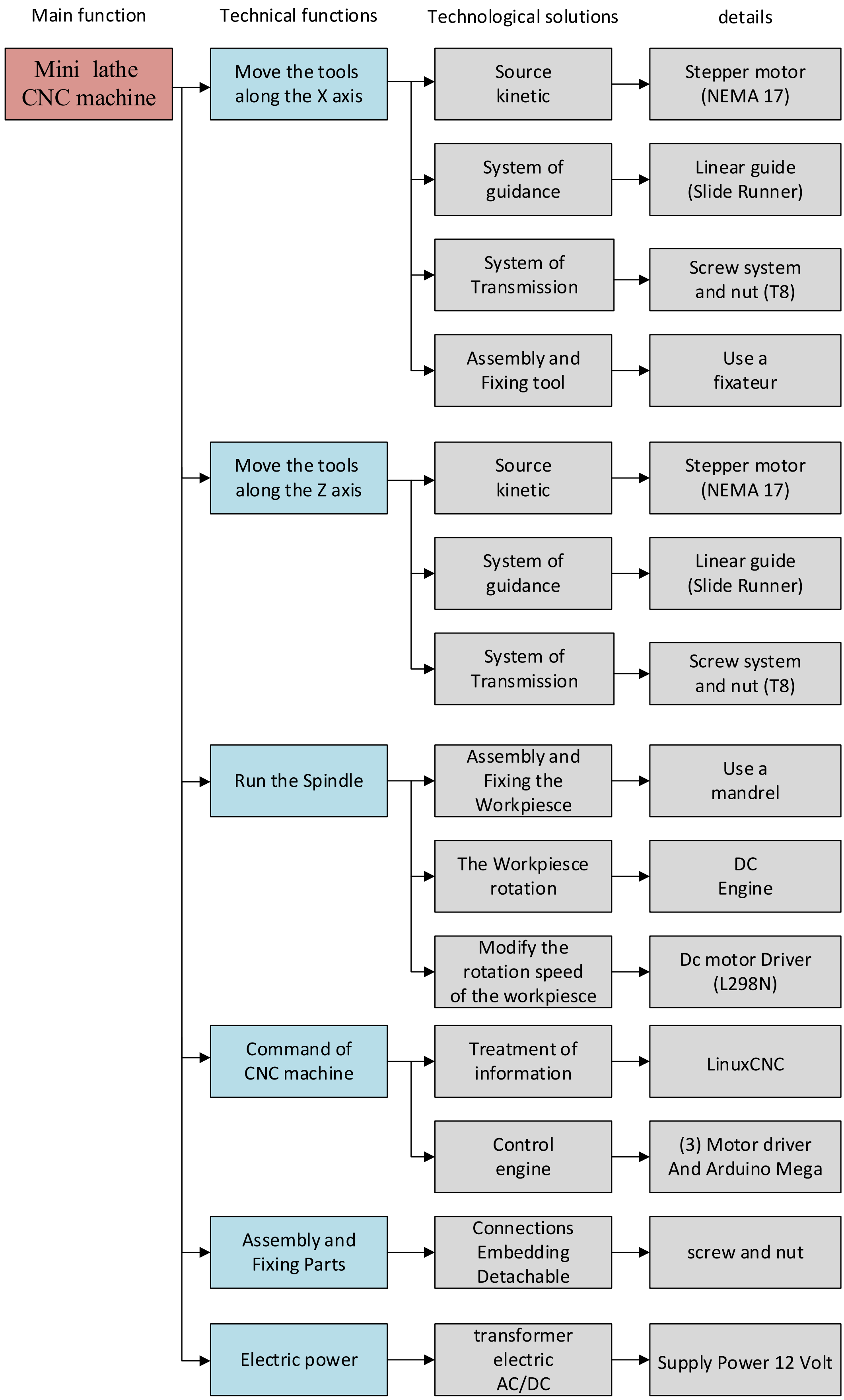


Figure III.3: FAST diagram of the main function.

III.3. The Mechanical Parts

III.3.1. Slide runner

We use slide runner as a linear guide because it smooth and has a low cost. Show Figure III.4.

Figure III.4: Slide Runner 300mm

III.3.2. Lead screw & Nut

for linear transmission we T8 with 8mm diameter, show Figure III.5

Figure III.5: T8 lead screw with nut

III.3.3. Coupling

A flexible coupling is mainly used as the machine component that connects a servo motor shaft with a ball screw. When a ball screw and servo motor are joined, the center of their shafts should be identical. However, in practice, this is very difficult. For this reason, a coupling should be designed to be insensitive to misaligned rotation centers. The flexible coupling shown in Figure III.6

Figure III.6: Coupler 8-5 mm

III.4. The electrical and electronic part

III.4.1. Arduino mega

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC to DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

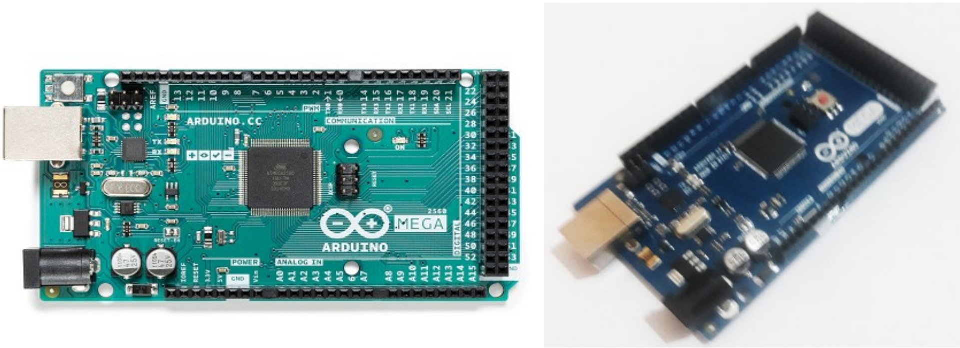


Figure III.7: ARDUINO MEGA 2560 REV3

III.4.1. Stepper Motors [20]

Stepper motors have attracted the public because of their direct control of them by PC or microcontrollers. Their special feature is that the rotational movement of the axis is made through discrete angular intervals, or otherwise steps, each time one is taken pulse. In this way, the supply

Figure III.8: NEMA17 JK42HS40 1704 13A of several pulses to the motor will result in its rotation at a known angle. This fact makes them ideal for open-loop position control.

The stepper motor uses the theory of operation for magnets to make the motor shaft turn a precise distance when a pulse of electricity is provided. The stator has eight poles, and the rotor has six poles. The rotor will require 24 pulses of electricity to move the 24 steps to make one complete revolution. Another way to say this is that the rotor will move precisely 15° for each pulse of electricity that the motor receives [18].

It can be classified into several types according to machine structure and principle of operation as explained by Kenjo (1984). Basically, there are three types: [19]

1. Variable Reluctance Motor (VRM)
2. Permanent Magnet Stepper Motor (PMSM)
3. Hybrid Stepper Motor (HSM)

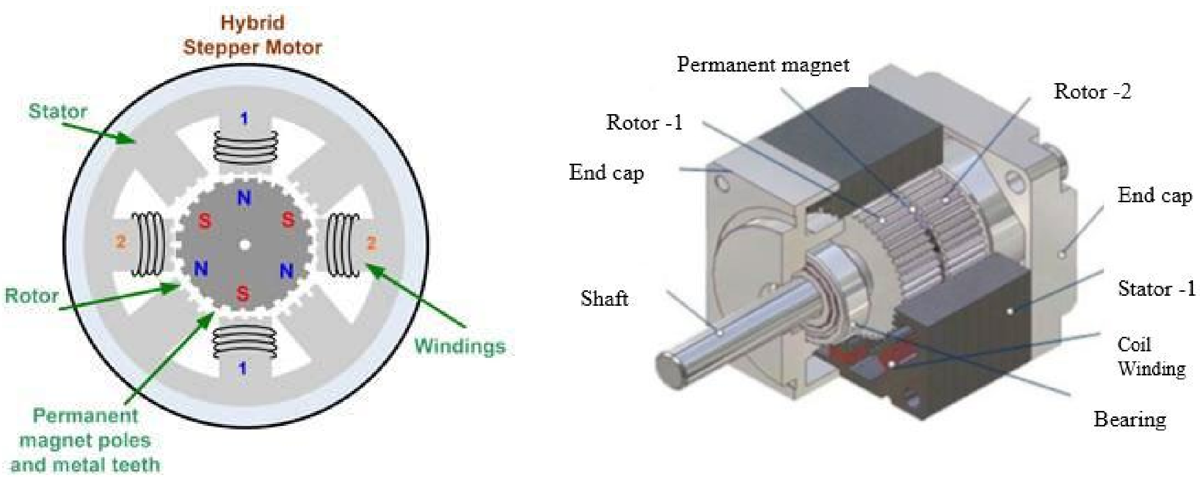


Figure III.9: Cross-section & Cut view of HSM.

III.4.1. Motor DC

Figure III.10 shows the dc motor we use it in our machine.

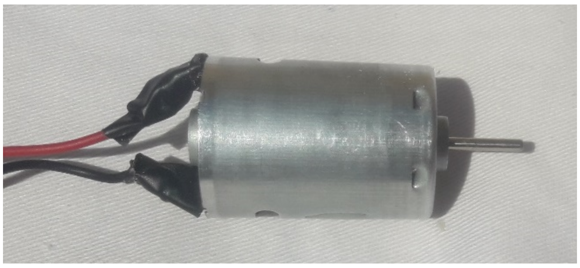


Figure III.10: DC Motor 12V

Some specification:

- No-load speed at 12 VDC is 5,200 RPM
- Operates on 12 VDC nominal
- Operating voltage range: 2VDC to 24VDC
- Shaft dimensions: 13.8mm long x 2.3mm diameter
- Full load (maximum efficiency @ 12VDC) performance characteristics:
    - Speed: 4,248 RPM
    - Current: 3.83 A
    - Power output: 46 Watts

III.4.2. TB6600 Driver:

A. Introduction:

This is a professional two-phase stepper motor driver. It supports speed and direction control. You can set its micro-step and output current with a 6 DIP switch. There are 7 kinds of micro-steps (1, 2 / A, 2 / B, 4, 8, 16, 32) and 8 kinds of current control (0.5A, 1A, 1.5A, 2A, 2.5A, 2.8A, 3.0A,

Figure III.11: TB6600 Driver

3.5A) in all. And all signal terminals adopt high-speed optocoupler isolation, enhancing its anti-high-frequency interference ability.

B. Features:

- Support 8 kinds of current control
- Support 7 kinds of micro-steps adjustable
- The interfaces adopt high-speed optocoupler isolation
- Automatic semi-flow to reduce heat
- Large area heat sink
- Anti-high-frequency interference ability
- Input anti-reverse protection
- Overheat, over current and short circuit protection

C. Electrical Specification

Table 1: Electrical Specification

Input Current	0 ~ 5.0A
Output Current	0.5 ~ 4.0A
Power (MAX)	160W
Micro Step	1, 2/A, 2/B, 4, 8, 16, 32
Temperature	-10 ~ 45℃
Humidity	No Condensation
Weight	0.2 kg
Dimension	96×56×33 mm

D. INPUT & OUTPUT:

- **Signal Input:**

PUL+ Pulse +

PUL- Pulse -

DIR+ Direction +

DIR- Direction -

EN+ Off-line Control Enable +

EN- Off-line Control Enable -

- **Motor Machine Winding:**

A+ Stepper motor A+

A- Stepper motor A-

B+ Stepper motor B+

B- Stepper motor B-

- **Power Supply:**

VCC V_{CC} (DC9-42V)

GND GND

E. DIP Switch

Micro Step Setting

The following tablet shows the driver Micro step. You can set the motor micro-step via the first three DIP switches.

Step Angle = Motor Step Angle / Micro Step

E.g. An stepper motor with a 1.8° step angle, the finial step angle under "Micro step 4" will be 1.8°/4=0.45°

Table 2: Micro Step Setting

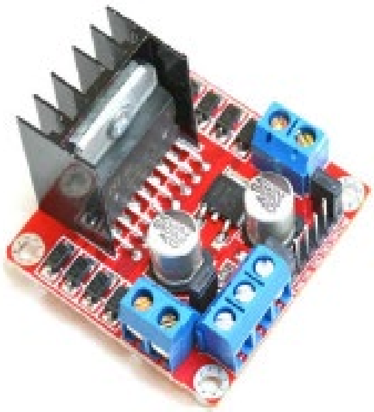
Micro Step	Pulse/Rev	S1	S2	S3
NC	NC	ON	ON	ON
1	200	ON	ON	OFF
2/A	400	ON	OFF	ON
2/B	400	OFF	ON	ON
4	800	ON	OFF	OFF
8	1200	OFF	ON	OFF
16	3200	OFF	OFF	ON
32	6400	OFF	OFF	OFF

Table 3: Current Control Setting

Current A	S4	S5	S6
0.5	ON	ON	ON
1	ON	OFF	ON
1.5	ON	ON	OFF
2	ON	OFF	OFF
2.5	OFF	ON	ON
2.8	OFF	OFF	ON
3	OFF	ON	OFF
3.5	OFF	OFF	OFF

III.4.3. L298n Motor driver:

This dual bidirectional motor driver is based on the very popular L298 Dual H-Bridge Motor Driver Integrated Circuit. The circuit will allow you to easily and independently control two motors of up to 2A each in both directions. It is ideal for robotic applications and well suited for connection to a microcontroller requiring just a couple of control lines per motor. It can also be interfaced with simple manual switches, TTL logic gates, relays, etc. This board is equipped with power LED indicators, an onboard +5V regulator, and protection diodes.



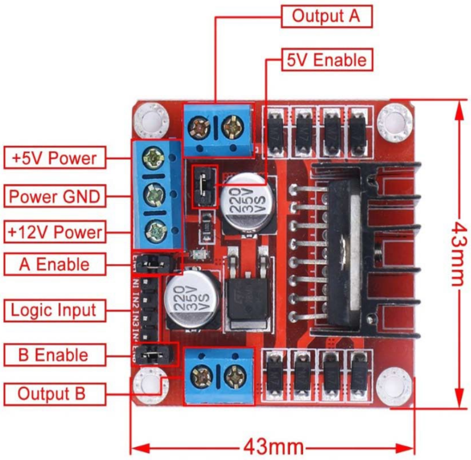


Figure III.12: L298n Driver

- **Input Voltage:** 3.2V~40Vdc.
- **Driver:** L298N Dual H Bridge DC Motor Driver
- **Power Supply:** DC 5 V - 35 V
- **Peak current:** 2 Amp
- **Operating current range:** 0 ~ 36mA
- **Control signal input voltage range :**
  - Low: -0.3V ≤ Vin ≤ 1.5V.
  - High: 2.3V ≤ Vin ≤ Vss.
- **Enable signal input voltage range :**
  - Low: -0.3 ≤ Vin ≤ 1.5V (control signal is invalid).
  - High: 2.3V ≤ Vin ≤ Vss (control signal active).
- **Maximum power consumption:** 20W (when the temperature T = 75 ℃).
- **Storage temperature:** -25 ℃ ~ +130 ℃.
- On-board +5V regulated Output supply (supply to controller board i.e. Arduino).
- **Size:** 4.3cm x 4.3cm x 2.7cm

III.4.4. Limit switch

The limit switches will be used to limit the travel of the steppe, as shown in Figure III.13

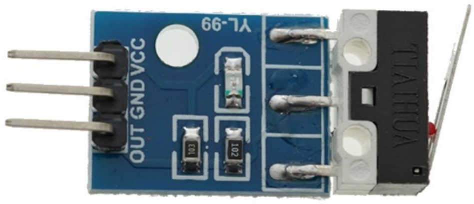


Figure III.13: Limit Switch

Figure III.14 show where limit switch use and how to limit the travel of motor

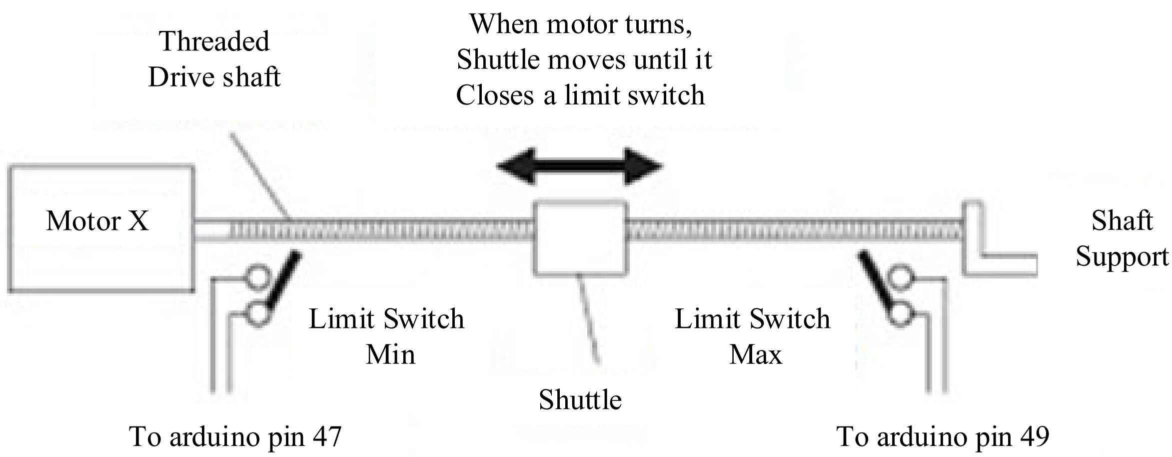


Figure III.14: Limit the Travel with Limit Switch

III.4.1. Power Supply

The power supply is a converter from Ac 220 v to 12v, 5v, and 3.3v with 185W, as shown in Figure III.15

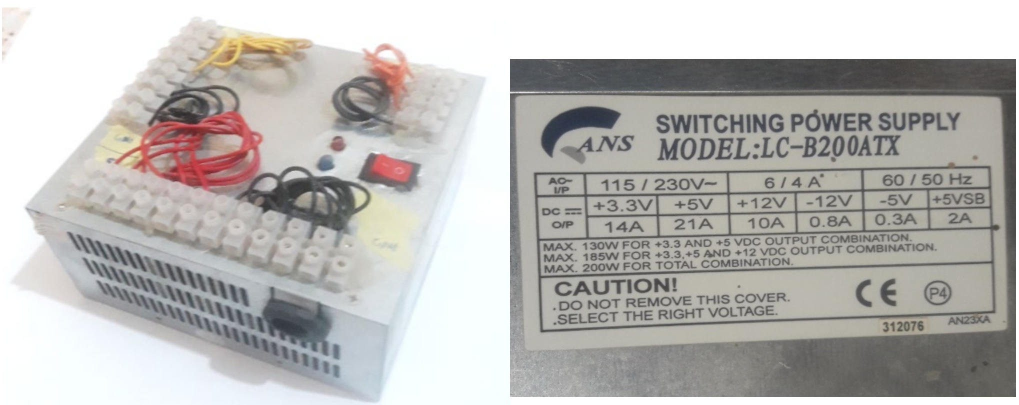


Figure III.15: Power Supply 185kw

III.5. Assembly the Mini CNC Machine

III.5.1. Base

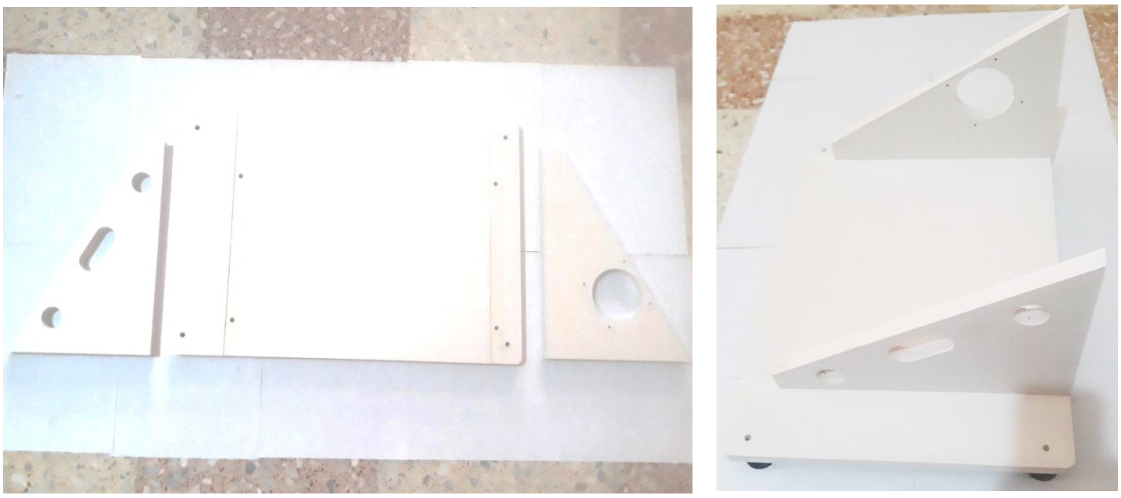
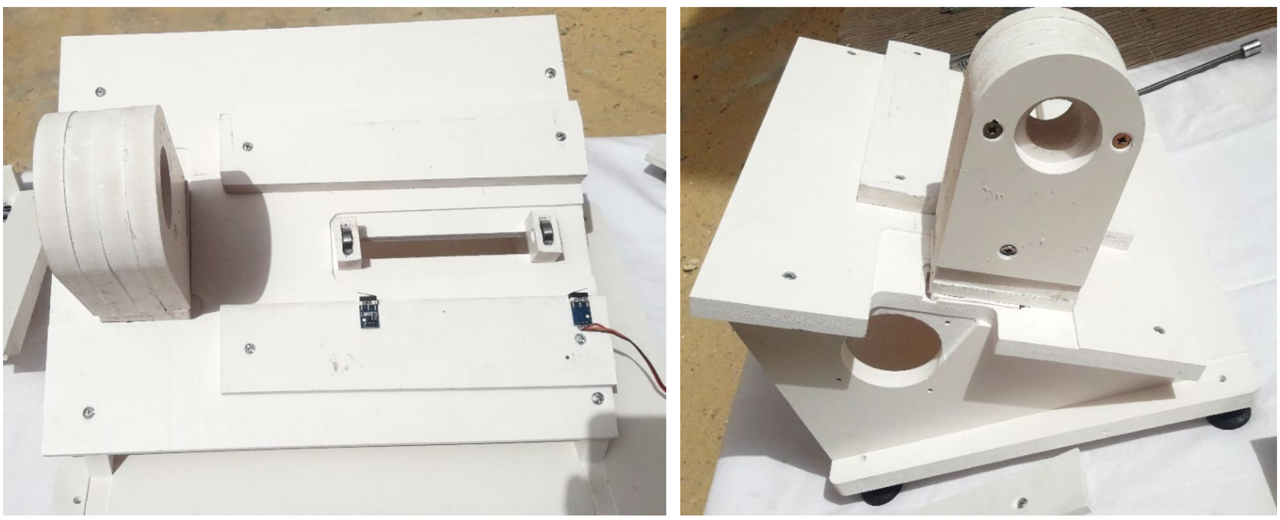


Figure III.17 The bottom of the base

Figure III.16 the Top of the base



Top Side

Figure III.18 The final look of the base

III.5.2. Mechanism The movement of the Z-axis

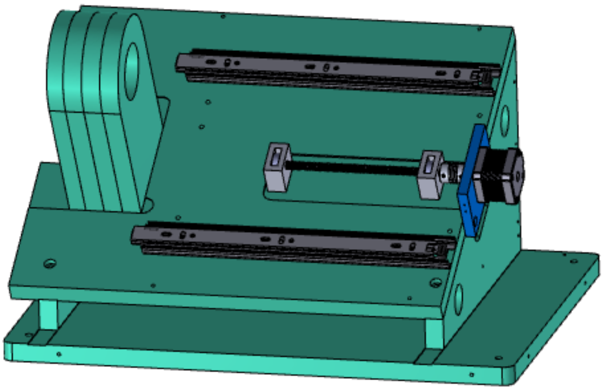


Figure III.19: the design of bottom Z-axis.

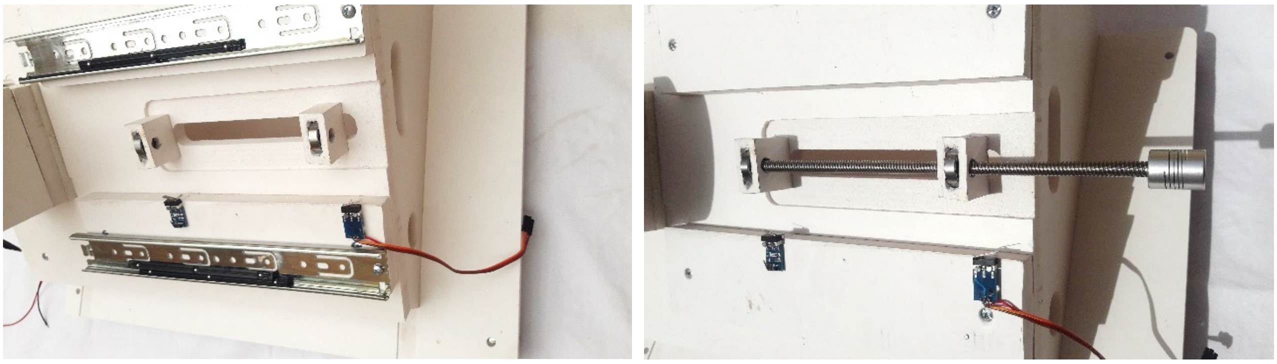


Figure III.21: the real of bottom Z-axis.

Figure III.20: the top of Z-axis

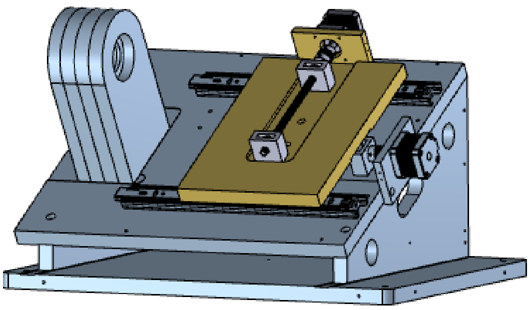


Figure III.22: The design of final look Z- axis.

III.5.1. Mechanism The movement of the X-axis

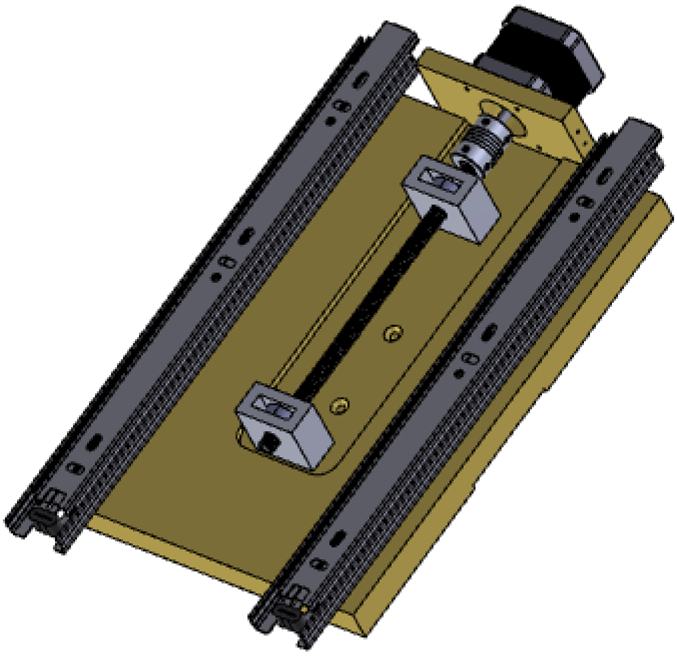


Figure III.23: the design of bottom X-axis.

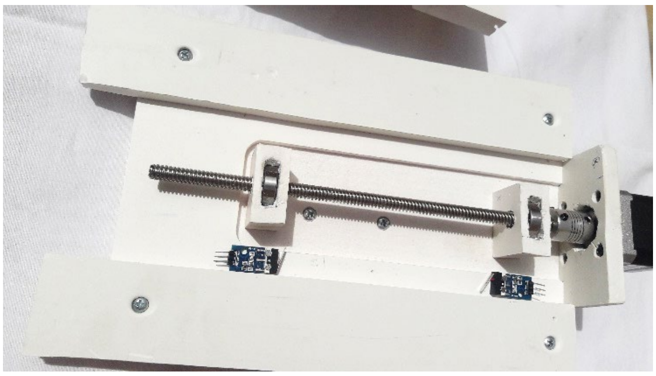
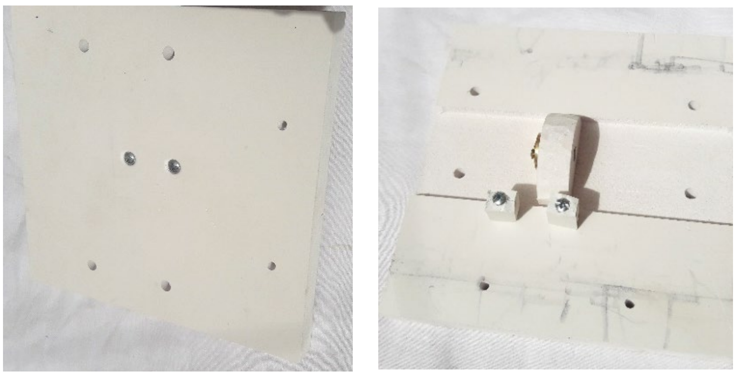


Figure III.24: the real of bottom X-axis.



Top Bottom

Figure III.25: the Top of X-axis

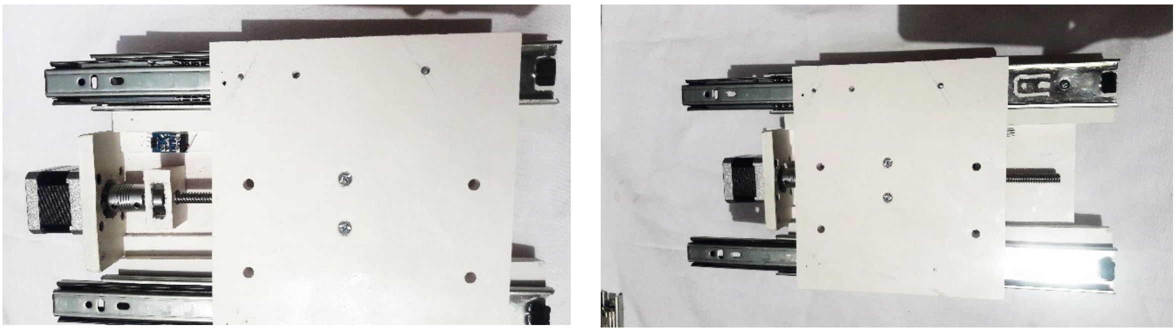


Figure III.26 The final look of the X axis

III.5.2. Mini Lathe CNC machine

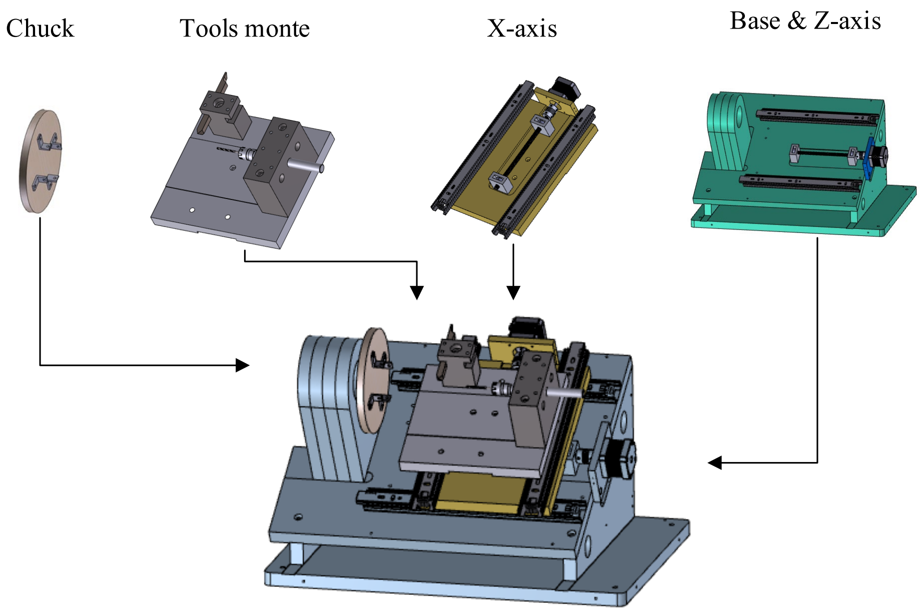


Figure III.27 The Mini Lathe CNC Machine.

III.6. Electrical diagram

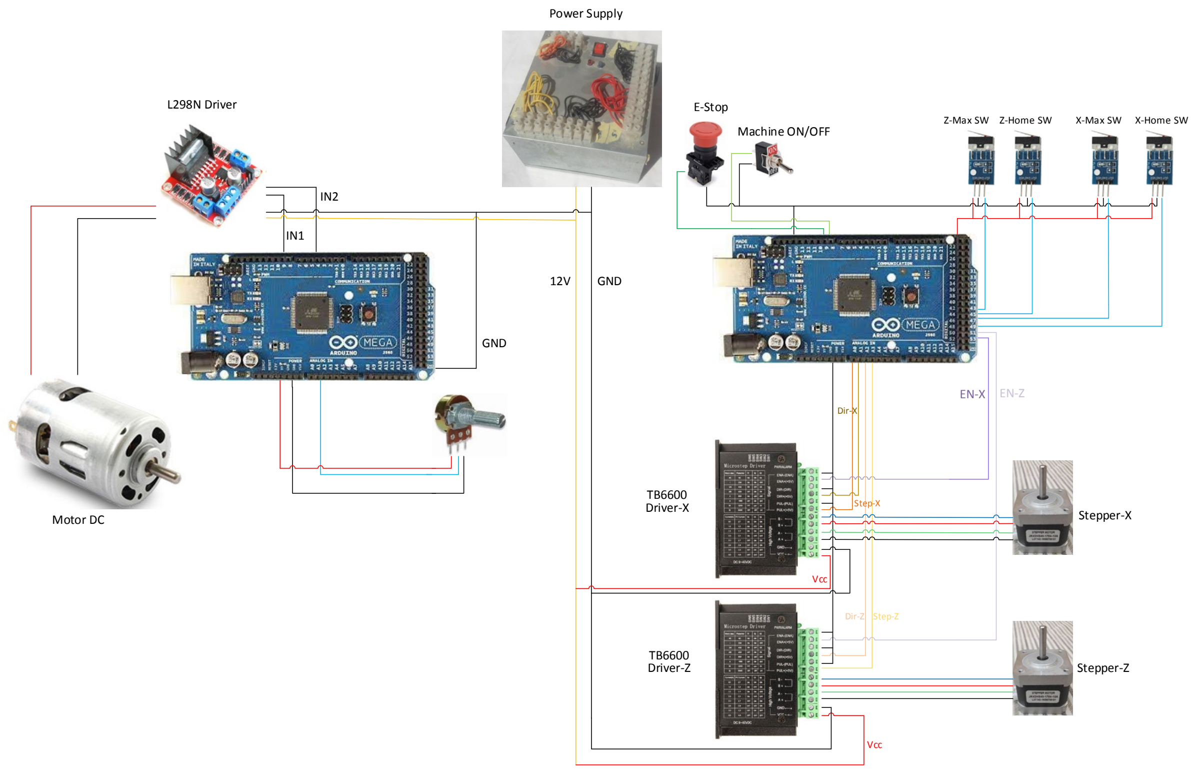


Figure III.29 Electrical diagram of our machine.

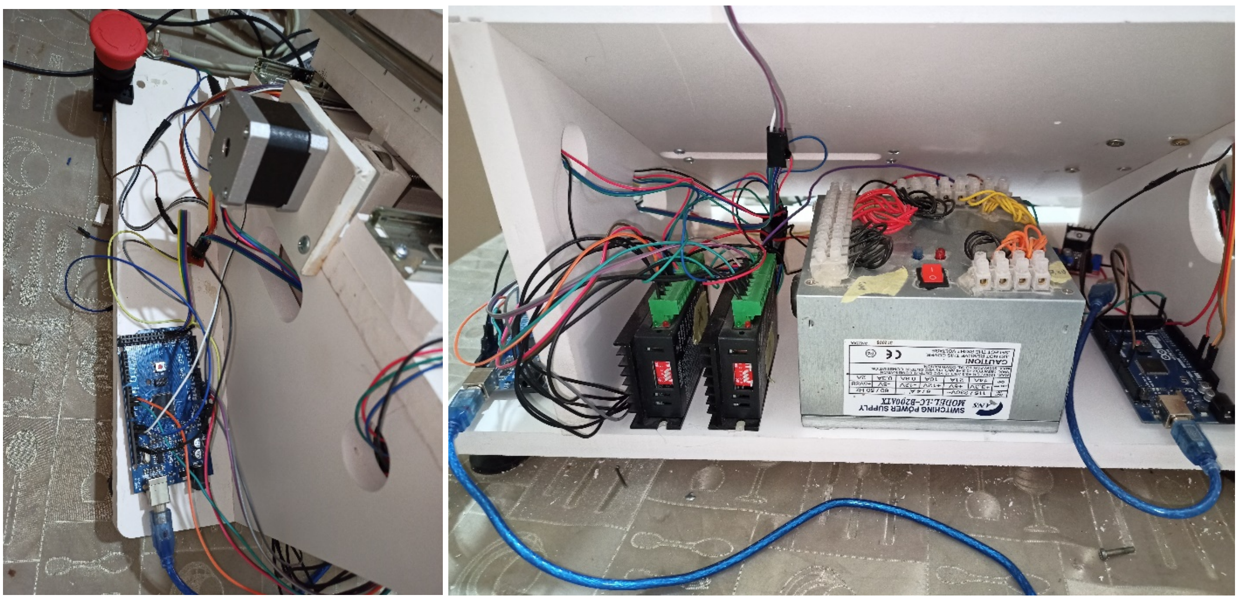


Figure III.28: Electrical on Real.

III.7. Configuration of the Software

III.7.1. LinuxCNC

To install LinuxCNC on the Linux distributions there is a serveral method, all explained on the wiki website:

http://linuxcnc.org/docs/2.7/html/getting-started/getting-linuxcnc.html#_installing_linuxcnc

Steps for configuration a new machine:

- **Step 1:** open Stepconf Wizard

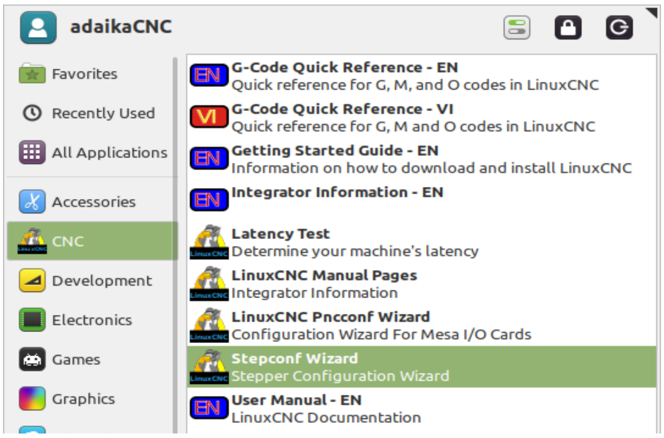


Figure III.30: Open Stepconf Wizard

- **Step 2:** the window shows up

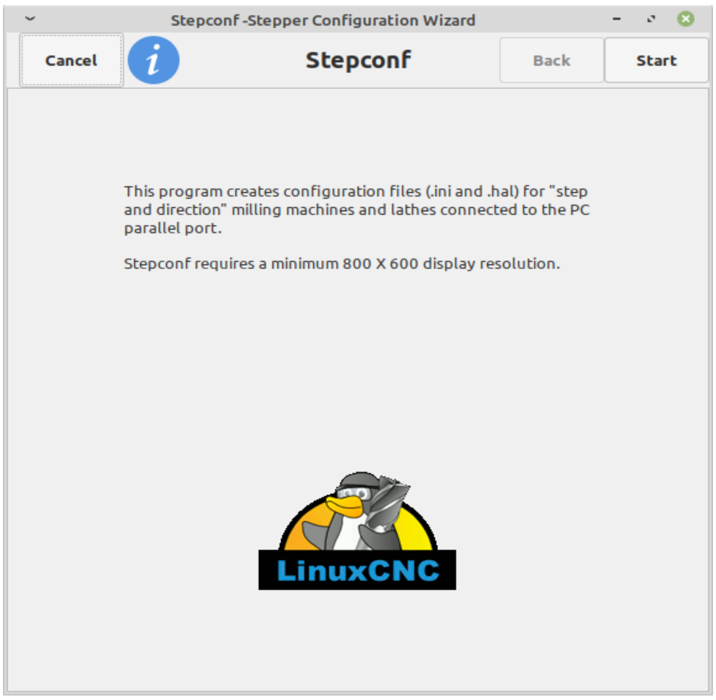


Figure III.31 The Stepconf Window

- **Step 3:** create a new configuration

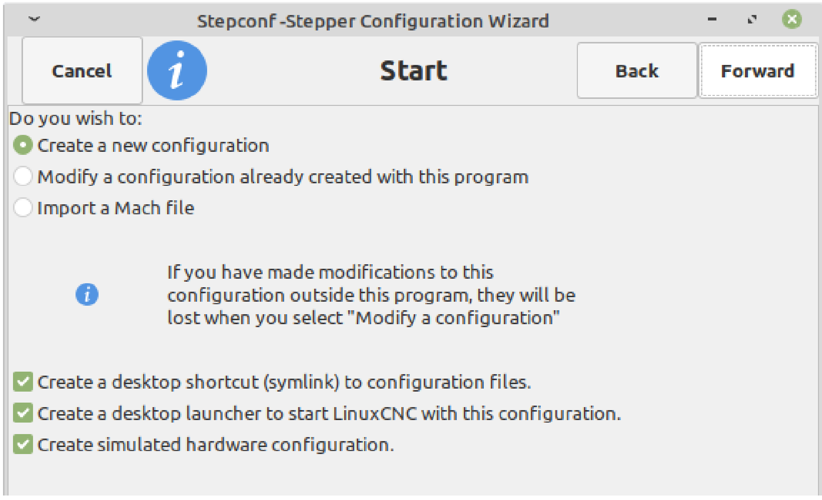


Figure III.32: The start configruation

- **Step 4:** selection parameter

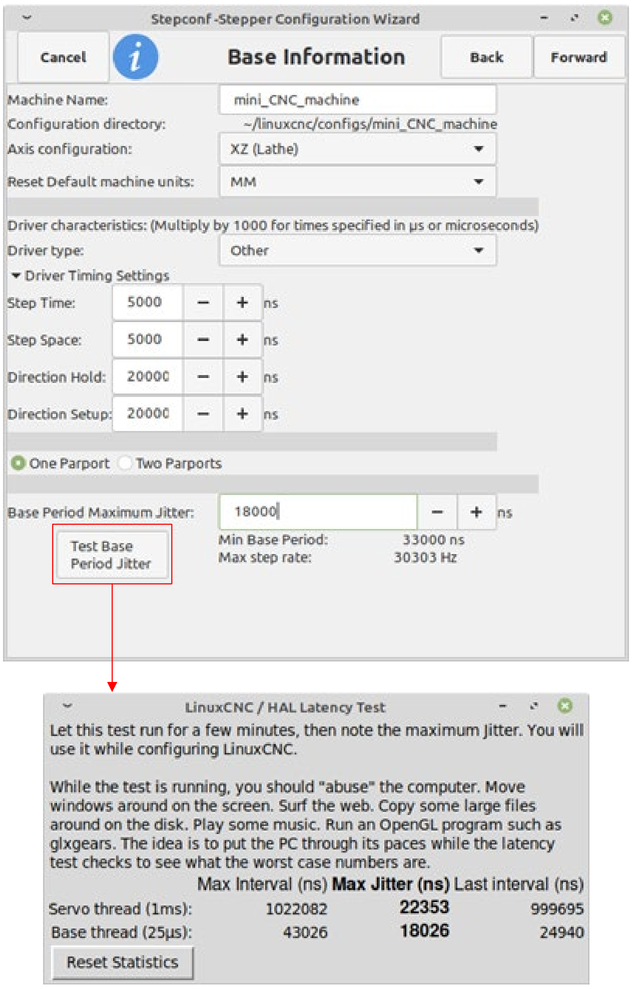


Figure III.33: The Base information

- **Step 5:** Parallel Port & Other options

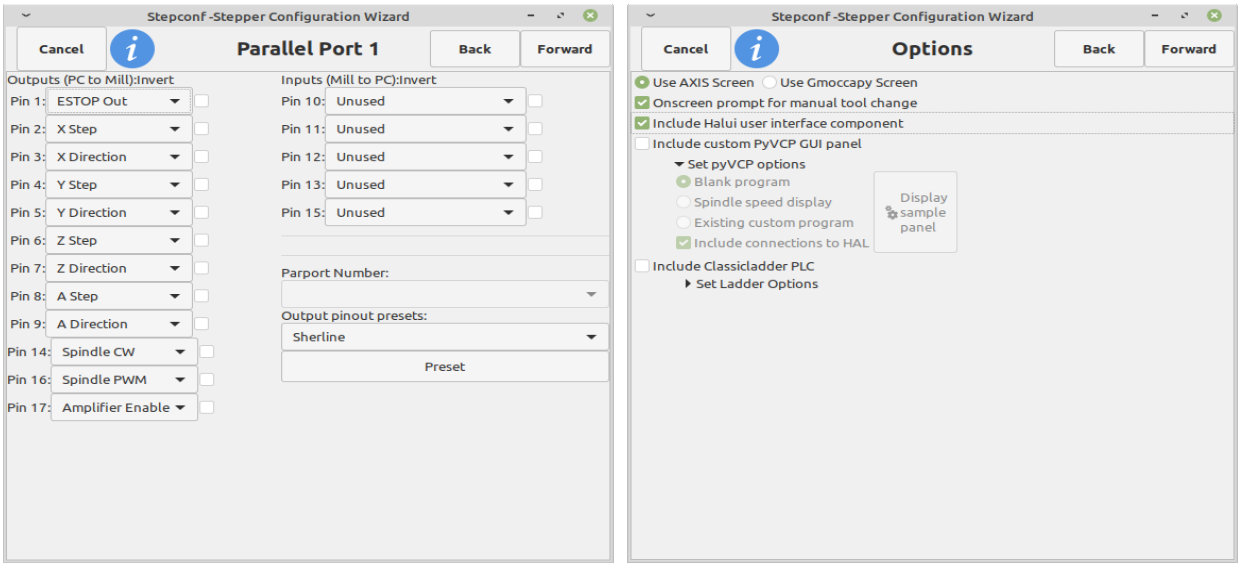


Figure III.34: Other options configrautíon.

- **Step7:** HALUI Command

Here we can add a specification command to our control panel, we keep it with no changes.

Figure III.35 HALUI Command.

- **Step 8:** Axis Configuration

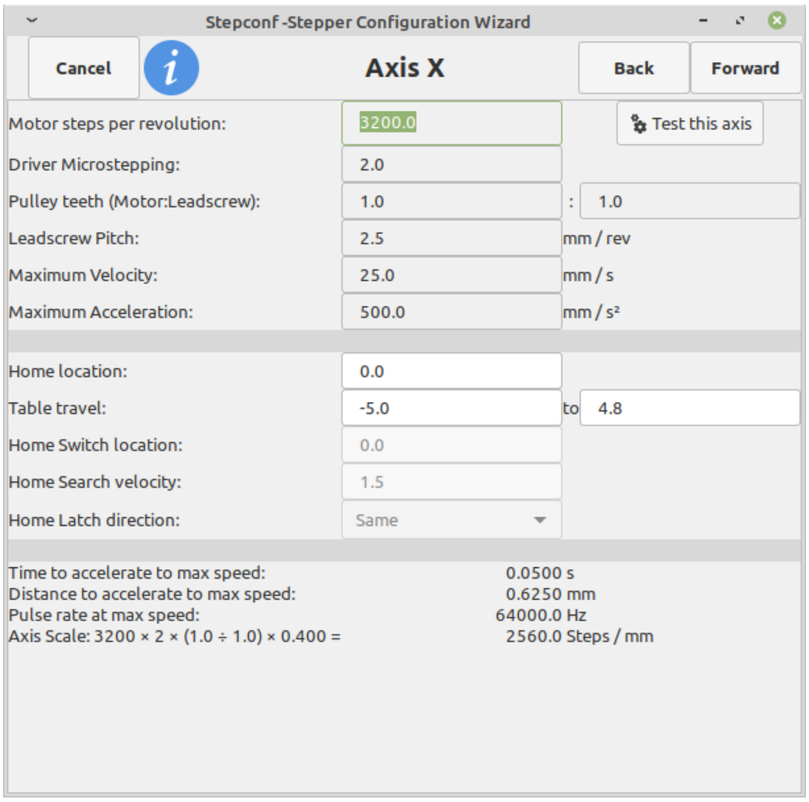


Figure III.36: The Axis-X configuration.

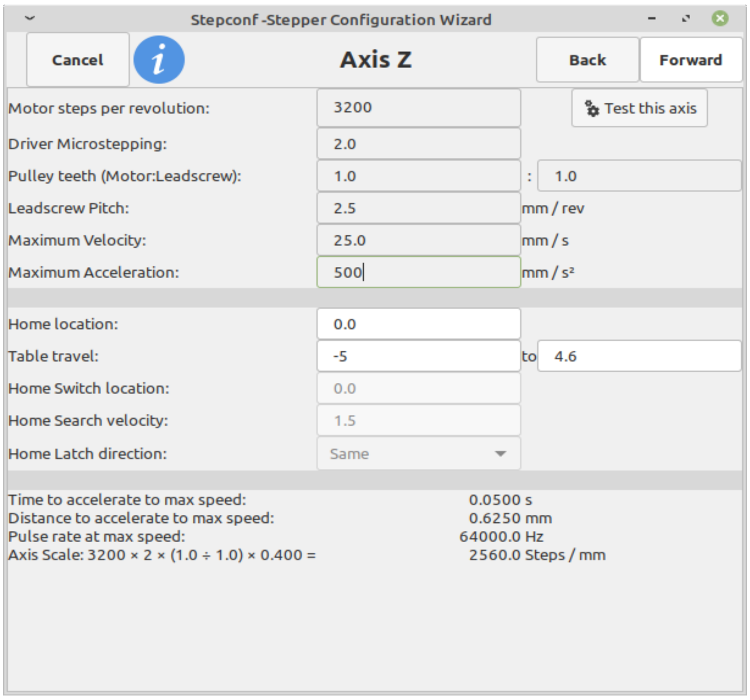


Figure III.37: The Axis-Z configuration.

- **Step 9:** the spindle configuration

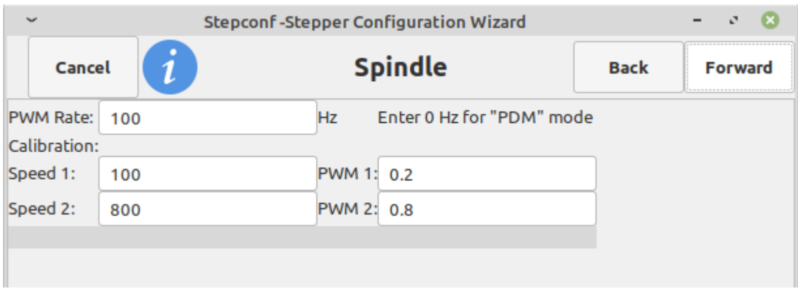


Figure III.38: Spindle configuration

- **Step 10:** finally step

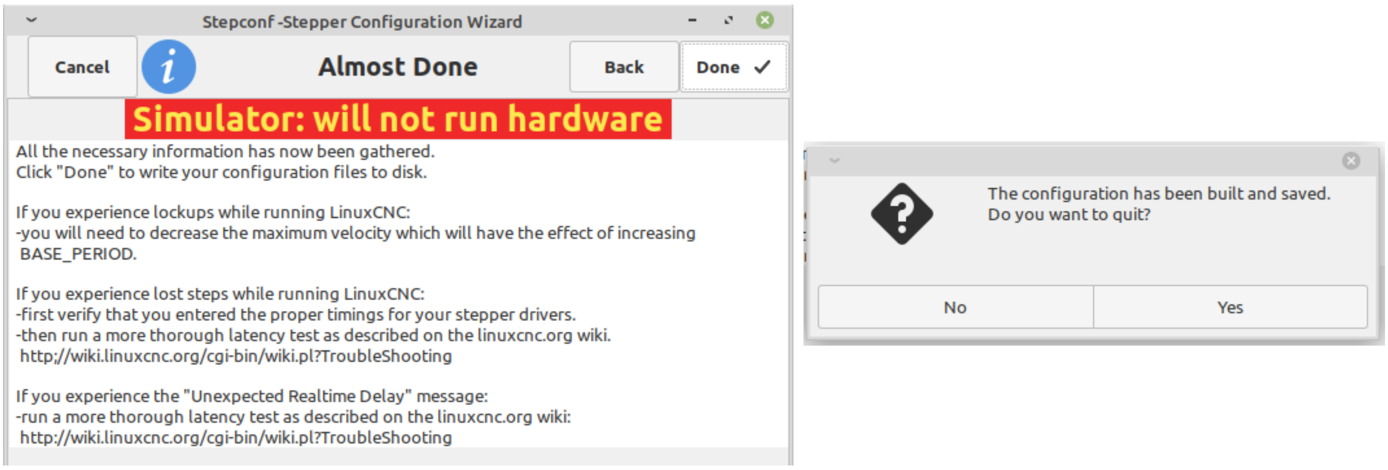


Figure III.39: the end of configuration

Result show up on Desktop

Figure III.40: The configuration Result of our machine.

Add this code to custom.hal file

```
#First load the Python user module named /user/bin/9axis_arduino with the name 'arduino'
loadusr -Wn arduino /usr/bin/9axis_arduino

# X-axis (axis.0) ###
unlinkp joint.0.home-sw-in
unlinkp joint.0.neg-lim-sw-in
net home-X <= arduino.xHome
net home-X => joint.0.home-sw-in
net home-X => joint.0.neg-lim-sw-in
unlinkp joint.0.pos-lim-sw-in
net max-X <= arduino.xMaxLmt
net max-X => joint.0.pos-lim-sw-in
unlinkp joint.0.motor-pos-cmd
net xpos-cmd joint.0.motor-pos-cmd => arduino.axis0-cmd

# Z-axis (axis.1) ###
unlinkp joint.1.home-sw-in
unlinkp joint.1.neg-lim-sw-in
net home-Z <= arduino.yHome
net home-Z => joint.1.home-sw-in
net home-Z => joint.1.neg-lim-sw-in
unlinkp joint.1.pos-lim-sw-in
net max-Z <= arduino.yMaxLmt
net max-Z => joint.1.pos-lim-sw-in
unlinkp joint.1.motor-pos-cmd
net zpos-cmd joint.1.motor-pos-cmd => arduino.axis1-cmd

# Control panel switches
    # E-Stop
unlinkp iocontrol.0.user-enable-out
unlinkp iocontrol.0.emc-enable-in
net eStop iocontrol.0.user-enable-out => arduino.eStop
net eStop iocontrol.0.emc-enable-in <= arduino.eStop
```

Power

unlinkp halui.machine.on

unlinkp halui.machine.off

net turnoff halui.machine.off <= arduino.switch-off

net turnon halui.machine.on <= arduino.switch-on

Table 4: Parameter of our configruation

Name of machine	Mini_CNC_machine
Axis configuration	XZ (lathe)
Units	mm
Max Jitter	18000 ns
Axis Steps par revolution	3200
Leadscrew Pitch	8
X table travel	-5 to 4.8
Z table travel	-5 to 4.6

III.7.2. Arduino

Download firmware and change parameter EMC2Arduino…

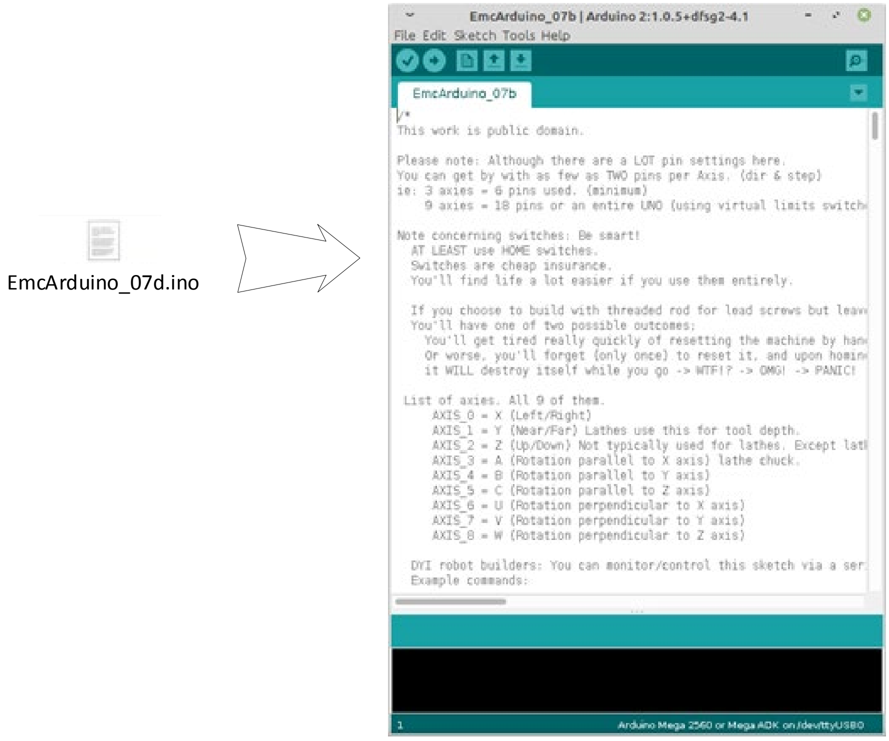


Figure III.41: Open EmcArduino file

Table 5: Change of EmcArduino file.

stepsPerInchX	3200
stepsPerInchY	3200
stepPin0	54
stepPin1	56
dirPin0	55
dirPin1	57
xEnablePin	3
yEnablePin	4
useEstopSwitch	true
usePowerSwitch	true
useRealHomeX	true
useRealHomeY	true
useRealMaxX	true
useRealMaxY	true
xHomePin	49
yHomePin	51
xMaxPin	47
yMaxPin	53
powerPin	10
eStopPin	9
xHomePinInverted	true
yHomePinInverted	true
xMaxPinInverted	true
yMaxPinInverted	true

III.8. Execution of the experiment

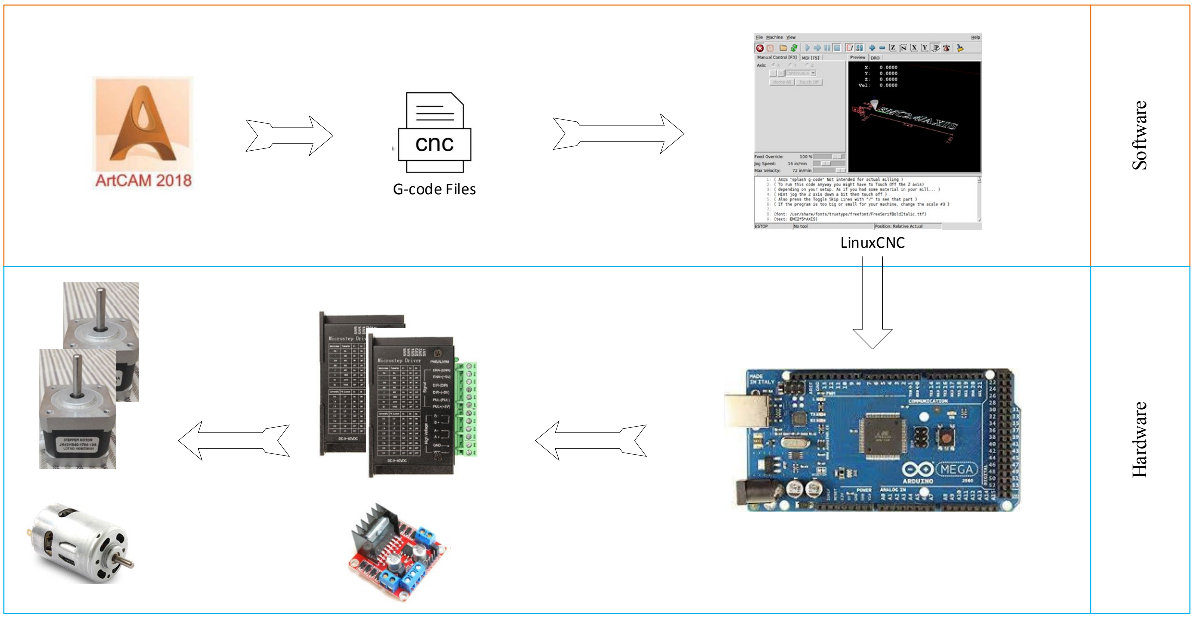


Figure III.42 Steps to experiment with the realization of the model.

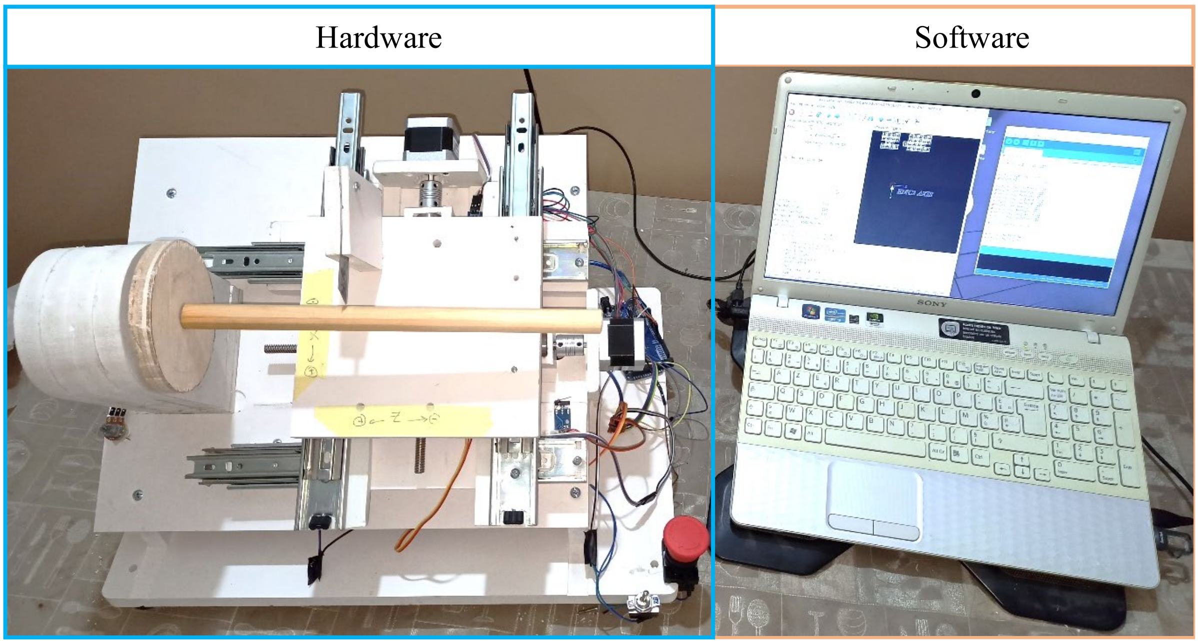


Figure III.43: Model on Real.

III.9. Suggestions for improving the machine

The machine needs many improvements that we could not make due to lack of time and money. We mention them:

- The use of a structure a do absorb vibrations
- The use of course fine to avoid the problem of collision
- The use of force detector to detect collusion and other problem
- The change of slides with another type more precise
- The change of driver with another type more powerful...

III.10. Cost of Project

Table 6: Materials cost

The electrical and electronic part	
Raspberry Pi 4 (as computer)	18500DA
Arduino Mega	2900DA*2
NEMA 17	3200DA*2
TB6660 driver	4500DA*2
DC motor 12V	3400DA
L298N driver	1300DA
Limit Switch	400DA*4
Power Supply 12v	2500DA
The Mechanical parts	
T8 Screw & nut 500mm	4000DA
Roulement 8mm	30DA*4
Slide runner 300mm	100DA*4
Coupler 5-8mm	500DA*2
Structure of machine (Forex) 18mm	6000DA
Chuck (80-100mm)	15000DA
Other hardware	5000DA

III.11. Conclusion

In this chapter, we have provided a lot of detailed and important information about a mini lathe CNC machine. Where we made the machine based on the study results of Chapter II, then we discussed and verification of the results.

Finally, we presented a real machine and the results were very satisfying.

General Conclusion

Our end of study project consists in the practical realization of a CNC machine based on LinuxCNC and employs academic and professional experience know-how in the control field.

First, and before tackling this study, we started with the presentation the fundamental knowledge of our project, such as the CNC machine numerical control, the operation of a CNC machine tool, then cited the different families and classifications of machines numerically controlled as well as their field of use, subsequently by reviewing its advantages and disadvantages. At the end of this part we proposed the machine to three-axis digital control as our project's choice with the design and computer aided manufacturing (CAD).

Then, and before directly realizing the machine, we presented a general study of the LinuxCNC as controller software, first mentioned all the components of the control system, and study the method of programming the machine.

The last part is devoted the design and realization of a numerically controlled lathe machine as part of the development of our project that is consists of the practical realization of a CNC machine based on LinuxCNC and employs academic and professional experience knowledge in the control field.

As a future perspective, we propose:

- The control of other axes (3D printer).
- The application of the command with a smart model.
- The use of wireless communication between the acquisition system and the PC.

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