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Ministry of Higher Education and Scientific research
Emirates International University
Faculty of Engineering
Department of Mechatronics

DESIGN AND IMPLEMENTATION OF HIGH ACCURACY THREE-AXES CNC PLASMA MACHINE

تصميم وتنفيذ ماكينة سي ان سي بلازما ثلاثة محاور عالية الدقة

Submitted by:

Hatem Abdulqader Saeed Al-Maqtari	**2020070007**
Ammar Yasser Ahmed Al-Aghabari	**2020070595**
Mohammed Abdulsalam Dammaj	**2017040263**
Hizam Abdullah Manna Talib	**2020071353**
Suhail Mohammed Ahmed Al-Maqtari	**2020070040**
Emran Jameel Abdulhadi Al-Saruri	**2019060665**
Musfer Mohammed Hussein Al-Maqrahi	**2020071083**

Supervised by:

Prof. Farouk Al-Fuhaidi

Eng. Ahmed Salah

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Student name	Signature	Date
Hatem Abdulqader Saeed Al-Maqtari		
Ammar Yasser Ahmed Al-Aghabari		
Mohammed Abdulsalam Dammaj		
Hizam Abdullah Manna Talib		
Suhail Mohammed Ahmed Al-Maqtari		
Emran Jameel Abdulhadi Al-Saruri		
Musfer Mohammed Hussein Al-Maqrahi		

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Supervisor Certification

I certify that the preparation of this project entitled

………………………………………………………………………………

prepared by …………………………………………………………………

…………………………………………………………………

Was mad under my supervision at ……………. department as partial fulfillment of the requirements of bachelor degree in ……………….

Supervisor Name: Farouk Al-Fuhaidi

Signature:

Date:

Examination Committee

Project Title…………………………………………………………...

Supervisor

No	Name	Position	Signature
1	Prof. Farouk Al-Fuhaidi		
2	Eng. Ahmed Salah		

Examiner Committee

No	Name	Position	Signature
1		Supervisor	
2		Supervisor	
3		Examiner	

Department Head

..……………………

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CHAPTER 1: INTRODUCTION

1.1 OVERVIEW

The modern industry has been involving its production methods. An example of this evolution is the Computer Numeric Control, best known as CNC. A CNC controls the position of a cutter by moving mechanical axes, making possible the execution of high-resolution tasks. In general, a CNC works in a tridimensional space and uses a plasma to cut sheets metals. One example of this kind of systems are the 3D printers that are very popular nowadays.

A computer sends to the CNC a several instructions that are translated in cutter’s motion to cut. However, the use of a plasma has several disadvantages such as smoke due the overheating of the cut metal, the necessity of lubes usage to avoid fraction while motion. Plasma can cut materials without direct contact as same as Laser.

1.2 PROBLEM STATEMENT

Some complicated designs of sheet metal work become necessary because of new modern decoration. The goal of this project is to solve the issue of cutting different types of work. For batch runs and one-off prototypes, 3-axis CNC plasma machines offer high-quality, precisely controlled cutting. They are a fantastic option for people or any workshop owners to do more work in less time. By avoiding multiple-turn setups, 3-axis capabilities shorten operation times, streamlines production, and the high cost of manual labor.

1.3 PROJECT OBJECTIVES

The following list might be used to outline the project's primary goals:

1. Making use of the knowledge we acquired during our four years of study in the major of Mechatronics Engineering.
2. To make an optimal design that satisfy the requirement.
3. Automating one of the most crucial industrial systems.
4. Creating an adaptable system to handle numerous product changes.
5. Lowering manufacturing costs by doing away with the need for labor.
6. Acquiring the bare minimum working space needs.

1.4 MOTIVATION

The motive behind this project comes from the needs of the labor market for this project and also for the products we work, which affects a large percentage of customers from engineers and technicians who want complex designs that meet their needs, because this project is rare in Yemen and that is why we decided to make it and we intend to complete this 3-AXIS CNC plasma machine project.

Applying principles and knowledge from mechatronics engineering to a full project is another motivation. Developing cooperation abilities can also help you create integrated engineering machines, which are extremely tough to create by yourself.

1.5 METHODOLOGY

- Implementation of the project with Mach Software Program, in order to understand the working mechanism of "CNC 3-axis" machines.
- design the structure of machine "as CAD" in the "Solid Work" program.
- deducing the mathematical equations of movement.
- correcting the parameters to reach the required values.
- making a CAM for all CAD pieces and then manufacturing them.
- assembling the pieces together.

1.6 RESEARCH ORGANIZATION

In addition to this chapter, this research is organized as follows:

- Chapter1: Introductions
- Chapter2: Literature Review
- Chapter3: Projects Methodology
- Chapter4: Mathematical and Simulation
- Chapter5: Implementation
- Chapter6: Conclusion and Future Work

CHAPTER 2: LITERATURE REVIEW

2.1 BACKGROUND

In 1949, the first CNC machine was invented. Since then, CNCs have developed rapidly in industries and manufacturing forever. Depending on your budget, time, working materials, shape and size of the product, you can choose from several types of CNC machines to make almost anything you want. A precision CNC machine tool called a 3-axis CNC machine, commonly referred to as a 3-axis machining center, removes material from a workpiece using a cutting laser. This is done by placing or cutting the element simultaneously along three separate directional axes until the desired shape is obtained.

2.1.1 **HOW CNC MACHINE WORKS**

1. First, the part program is inserted into the MCU of the CNC.
2. In MCU all the data process takes place and according to the program prepared, it prepares all the motion commands and sends it to the driving system.
3. The drive system works as the motion commands are sent by MCU. The drive system controls the motion and velocity of the machine tool.
4. The feedback system records the position and velocity measurement of the machine tool and sends a feedback signal to the MCU.
5. In MCU, the feedback signals are compared with the reference signals and if there are errors, it corrects it and sends new signals to the machine tool for the right operation to happen.
6. A display unit is used to see all the commands, programs and other important data. It acts as the eye of the machine.

2.2 APPLICATION

Almost every manufacturing industry uses CNC machines. With an increase in the competitive environment and demands, the demand for CNC usage has increased to a greater extent. The machine tools that come with the CNC are lathe, mills, shaper and cutting. The industries that are using CNC machines are the automotive industry, metal removing industries, industries of fabricating metals, electrical discharge machining industries, the wood or minerals cutting industries, etc.

2.3 TYPES OF CNC MACHINE

There are types of CNC machines:

1. CNC Lathe Machine
2. CNC Mill Machine
3. CNC drilling Machine
4. CNC Plasma Machine
5. CNC Laser Machine

2.3.1 **CNC LATHE MACHINE**

Lathe CNC machines are defined by their capability to turn materials during operation. They have a smaller number of axes than CNC milling machines, making them shorter and more compact. CNC lathe machines consist of a lathe at the center that manages and transfers material programmatically to the computer. At the present time, it is widely used as a lathe due to its fast and accurate function. Once the initial setup is done, a semi-skilled worker can operate it easily. This type of lathe is also used for mass production such as capstan and turret. But there is no programmed fed system.

Figure 2.1: CNC Lathe Machine

2.3.2 **CNC MILLING MACHINE**

It is one of the most common types of CNC machine, that have built-in tools for drilling and cutting. The materials are located inside a milling CNC machine, after which the computer will lead the tools to drill or cut them. Most of the CNC milling machines are available in 3 to 6-axis configurations. This machine is used to produce gears like spur gear and is also used to drill the workpiece bore and make slots by inserting part program into the system. A semi-skilled worker can operate it easily. It is also used for mass production such as a capstan and turret. But there is no programmed fed system. The parts made by this machine are very precise in dimensional tolerance.

Figure 2.2: CNC Milling Machine

2.3.3 **CNC DRILLING MACHINE**

The CNC drilling machine is typically applied for mass production. Drilling machines, however, often have a multi-function machining center that is occasionally mingled and sometimes twisted. The greatest sink time for CNC drilling is with tool changes, so for speed, the variation of hole diameter must be reduced. The fastest machine size for drilling holes consists of several spindles in the turret with drills of different diameters pre-mounted for drilling. This type of CNC machine can perform reaming, counterboring, and tapping holes.

Figure 2.3: CNC Drilling Machine

2.3.4 **CNC PLASMA MACHINE**

This machine similar to milling CNC machines, plasma-cutting CNC machines are also used to cut materials. But they differ from their milling counterparts by doing this operation applying a plasma torch. A plasma cutting machine is defined as it is a method that cuts by electrically conductive materials using an accelerated stream of hot plasma. These types of CNC machine feature a high-powered torch that's capable to cut through rough materials like metal.

Figure 2.4: CNC Plasma Cutting Machine

2.3.5 **CNC LASER MACHINE**

The Laser-cutting CNC machines are designed to cut through hard materials, although they use a laser to perform this task instead of a plasma torch. Lasers offer a high degree of accuracy, but they are not as effective as plasma torches. Laser-cutting CNC machines commonly use one of these three types of lasers that is CO2, neodymium (Nd), or yttrium-aluminum-garnet (Nd: YAG).

Figure 2.5: CNC Laser Cutting Machine

2.4 RELATED WORKS

In this part, previous studies were presented in a table with what the students studied in order to compare the studies.

The study	PROGRANING SOFTWARE	HARDWARE (CONTROLLER)
DIMENSIONS ACCURACY IN DIFFERENT PLASMA CUTTING SCHEMES	-The Plasma software chooses the zig-zag cutting scheme on default since this scheme ensures the shortest fast strokes and the highest process effectiveness.	-Integrated CNC Controllers: Ensures direct integration with mechanical hardware and its software to achieve complete control. -Mitsubishi Electric MELDAS: Mitsubishi Electric offers MELDAS CNC controllers that are widely used in manufacturing processes.
STUDYING THE BEHAVIOR OF CNC PLASMA CUTTING MACHINES IN THE CONTOURING REGIME	-The most common way 2D plasma cutting technology is implemented in industrial systems is the CNC (computer numerically controlled) -The motion control system uses advanced servocontrol algorithms and techniques (PID control, Cross coupling control, real-time error compensation)	-Taking into account the system, the data entered is collected via Fanuc CNC Controllers brushed servomotors
Development of a Plasma Computer Numerical Control Machine	-This document presents the development of an electronic controller system for a Plasma CNC. All system development is based on a Colinbus CBR-40 CNC, where only its mechanical structure and motors are effectively used.	-All electronic control of the motors and laser is developed on this project and efficient discrete controlling algorithms are used with a Mach microcontroller.
MY OWN PROPOSAL	-Mach3 is used to convert 3D designs into motion movements for machine motors, enabling precise and complex cuts to be achieved. -The system provides the possibility of linking digital outputs and signals to other parts of the control system.	Mach3 can be used with a wide range of control cards and different types of actuators and sensors, giving users the flexibility to choose the right hardware for their project - Mach3 is one of the popular systems and provides an easy-to-use graphical interface, which helps users understand and program machining processes easier.

Note that all previous studies were recent, and consideration was taken to review the most recent studies, so that the previous studies were taken between the years 2018-2021, and this is the table and comparison between the previous studies and what we have developed.

2.5 MAIN COMPONENTS OF CNC SYSTEM

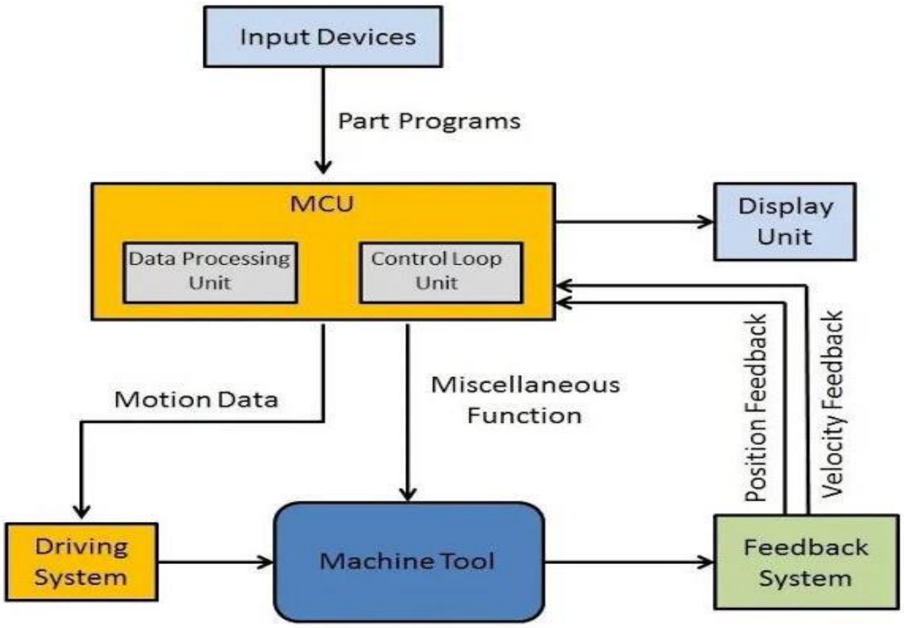


Figure 2.6: Components of CNC system

There are five main components of the numerical control or NC system. These are:

2.5.1 **PROGRAM OF INSTRUCTIONS**

A typical desktop program instructs computers to perform specific tasks. The NC machine's program of instructions is a step-by-step set of instructions that tells the machine what it needs to do. These instructions can tell the machine to turn the piece of metal to a specific diameter, drill a hole to a specific length, form a specific shape, and so on. The set of instructions is coded in numerical or symbolic form and written on a specific medium that can be interpreted by the NC machine's controller unit. Previously, punched cards, magnetic tapes, and 35mm motion picture film were commonly used for writing instructions, but now 1-inch-wide punched tape is more commonly used. The program instructions are written by an expert with both programming and machining knowledge. The individual should be familiar with the various steps of machining required to manufacture a specific product and be able to write these steps in the form of a program that can be understood by the NC machine's control unit, which will eventually direct the machine tool to perform the required machining operations.

Manual data input (MDI) is another method for manually entering instructions into the controller unit. This method is used for very simple jobs. Then there's direct numerical control (DNC), which uses a direct link to control machines without using a tape reader.

2.5.2 **CONTROLLER UNIT OR MACHINE CONTROLLER UNIT (MCU)**

The controller unit is the most important component of NC and CNC machines. The electronics components make up the controller unit. It reads and interprets the instruction program and converts it into mechanical actions of the machine tool. As a result, the controller unit serves as a vital link between the program and the machine tool. The control unit operates the machines in accordance with the instructions provided to it.

A typical control unit includes a tape reader, a date buffer, signal output channels to machine tools, machine tool feedback channels, and sequence control to coordinate the overall machining operation.

Initially, the tape reader, which is an electromechanical device, reads the set of instructions from the punched tape. The data from the tape is stored in the data buffer as logical blocks of instructions, each of which results in a specific sequence of operations. The controller sends instructions to the machine tool via signal output channels connected to the servomotors and other machine controls.

The feedback channels ensure that the machine correctly executed the instructions. The controller unit's sequence control component ensures that all operations are carried out in the correct order.

One thing to keep in mind about the controller unit is that all modern NC machines are equipped with a microcomputer that serves as the controller unit. The program is directly fed into the computer, and the computer controls the operation of the machine tool. These machines are known as Computer Controller Machines (CNC).

2.5.3 **MACH MACHINE TOOL**

The machine tool is responsible for the actual machining operations. The machine tool can be any machine, such as a lathe, drilling machine, milling machine, and so on. The machine tool is the part of the NC system that is controlled. In the case of CNC machines, the microcomputer controls the machine based on a set of instructions or a program. The control panel or control console on the NC machine contains the dials and switches that the operator uses to operate the NC machine. There are also displays to show the user information. The majority of modern NC machines are now referred to as CNC machines.

2.5.4 **DRIVING SYSTEM**

The driving system of a CNC machine consists of amplifier circuits, drive motors. The MCU feeds the signals (i.e., of position and speed) of each axis to the amplifier circuits. The control signals are than augmented (increased) to actuate the drive motors.

2.5.5 **FEEDBACK SYSTEM**

This system consists of transducers that act as sensors. It is also called a measuring system. It contains position and speed transducers that continuously monitor the position and speed of the cutting tool located at any instant. The MCU receives the signals from these transducers and it uses the difference between the reference signals and feedback signals to generate the control signals for correcting the position and speed errors.

2.5.6 **DISPLAY UNIT**

A monitor is used to display the programs, commands and other useful data of CNC machine.

CHAPTER 3: PROJECT METHODOLOGY

3.1 INTRODUCTION

The success of any engineering project relies heavily on the methodology used to guide it from concept to completion. In this chapter, we outline the structured approach followed in the development of the CNC plasma cutting machine. This methodology covers every phase of the project, from initial planning and design to testing and final implementation. By detailing the processes, techniques, and tools used.

3.2 MACHINE SPECIFICATIONS

Table 3.1: Machine Specifications

Machine Type	3-Axis CNC Plasma Cutting Machine
Function	Metal Cutting
Operating Power	3.5 to 7.1 kW
Liner axis	1500*2600*300 mm X, Y, Z
Structure Dimension	2000*3000*1250 mm X, Y, Z
Motor Type	Stepper Motor
Communication	USB

3.3 CNC DESIGN SOFTWARE

3.3.1 **DESIGN THE BASE**

We first designed the base in order to obtain durability and non-vibration, based on what we studied in the course Designing Elements of Machines and Theory of Machines, using the Solid work program as show (Fig3-1).

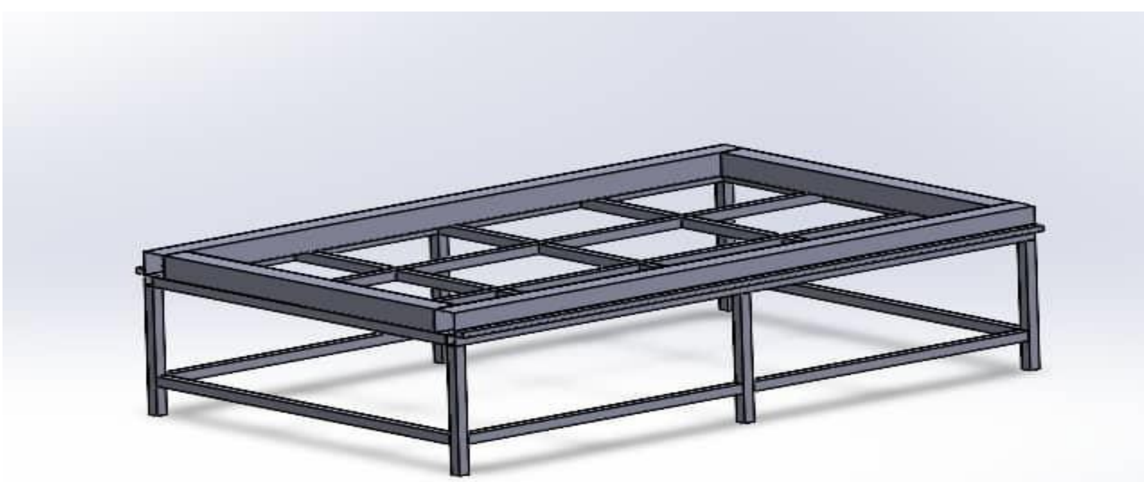


Figure 3.1: Designed the Base

3.3.2 **DESIGN THE LINER AXIS (THE BRIDGE)**

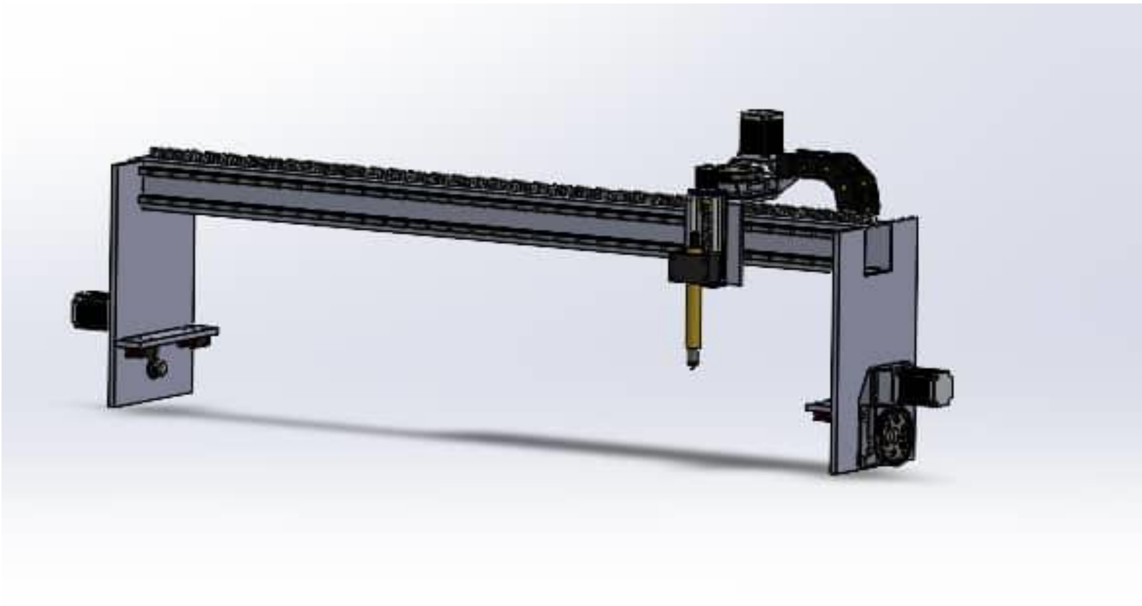


Figure 3.2: The Liner Axis

3.3.3 **FINAL DESIGN**

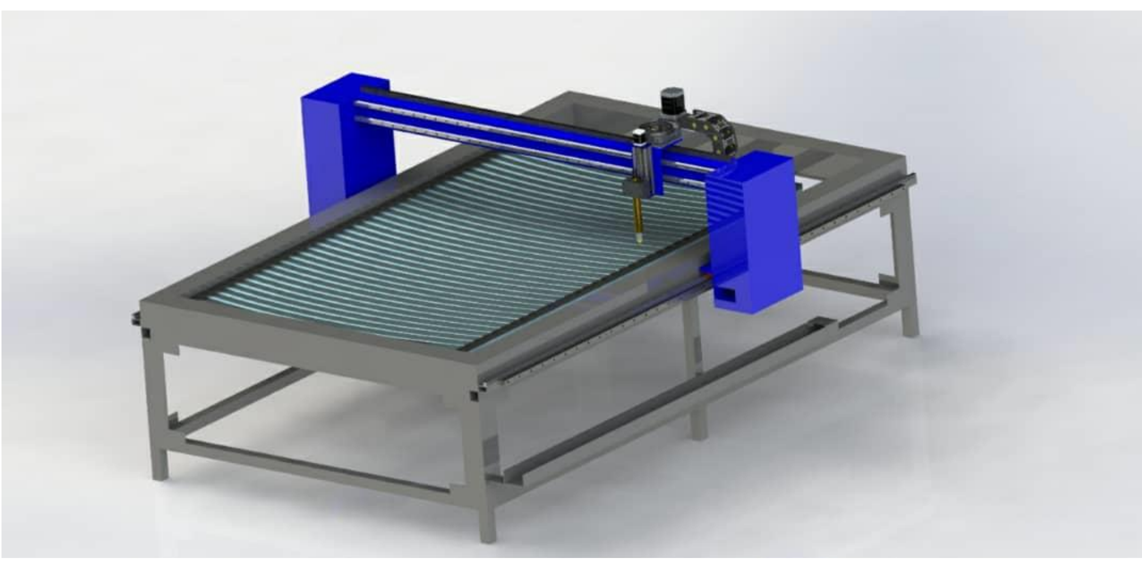


Figure 3.3: Final Design

3.4 COMPONENTS

3.4.1 **ELECTRONIC COMPONENTS**

Electronic components are the basic elements that form the basic parts of electronic circuits. Here is a general guideline on some common electronic components in CNCs.

Table 3.2: List of Electronic Components

NO.	COMPONENT	Quantity
1	4-Axis Breakout Board	1
2	Plasma Generation Unit 2.7 to 6.2KW	1
3	DMA860H Stepper Motor Driver	4
4	Stepper Motor Nema 34	4
5	Step-Down Transformer 220V to 70V	1
6	Power Supply 24V,12A	1
7	Limit Switch	3
8	Emergency Stop Switch Button	1
9	Cooling fan	1

3.4.1.1 **4-AXIS BREAKOUT BOARD**

The 4-axis breakout board is specifically designed for CNC single axis 2-phase stepper driver controllers, such as the M542, M542H, MA860H, 2M542, 2M982, DM542(A), DM860(A), and other single axis stepper driver controller series. With this 4-axis breakout board, you can directly control any 1-4 single axis stepper driver controllers via the PC using MACH3 software, providing seamless integration and control for your CNC setup, etc.

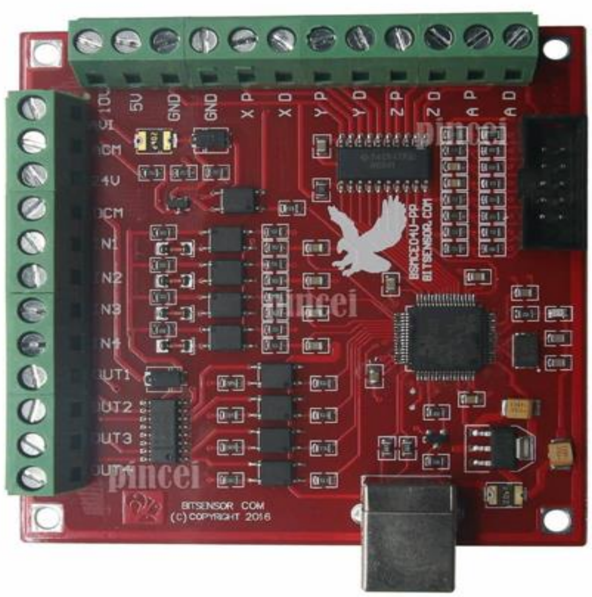


Figure 3.4: 4-Axis Breakout Board

➢ FEATURES

• Supports up to 4-axis stepper motor control for precise multi-axis operation.
• Compatible with parallel-control CNC software such as MACH3 and Linux CNC (EMC2), ensuring flexibility and versatility.
• Features isolated USB power supply and separate peripheral power to protect your computer and ensure safe operation.
• Opto-isolated signal interfaces to enhance computer protection from electrical interference.
• Multiple input interfaces to define functions such as limit switches, emergency stop, and cutter alignment, enhancing safety and operational efficiency.
• Wide input voltage range (24V) with reverse polarity protection, ensuring reliable performance and safeguarding against incorrect power connections.
• 0-10V analog voltage output for inverter control, allowing precise adjustment of cutting speed.

➢ SPECIFICATIONS

Table 3.3: Specifications Breakout Board

Electrical proportional (ambient temperature Tj =25)	
Input Power	USB Port to Directly get Power from PC
Compatible Stepper Motor Driver	Max 4-2 Phase Microstep Controllers
Driver Type	Pulse and Direction Signal controller
Net/Total Weight	Approx 27g
Dimension	90*70*20 mm

3.4.1.2 **PLASMA GENERATION UNIT**

Plasma Generation Unit of the "KeyGree CUT-70S" type. This machine is used for precise metal cutting using plasma technology, where compressed gas is passed through a narrow nozzle and an electric arc is generated, converting the gas into high-temperature plasma, enabling fast and efficient metal cutting.

Figure 3.5: Plasma Generation Unit

3.4.1.3 **DMA860H STEPPER MOTOR DRIVER**

The DM860H is a driver for stepper motors, an essential part in CNC systems and other applications where precise control of motor movement is important.

Figure 3.6: DMA860H Stepper Motor Driver

3.4.1.4 **LIMIT SWITCH OF MODEL TL-Q5MC1**

Figure 3.7: Limit Switch

3.4.1.5 **STEP-DOWN TRANSFORMER (220V to 70V)**

A step-down transformer, is an electrical device designed to convert the voltage from 220 volts to 70 volts. This type of transformer is used in applications that require lowering the voltage to operate devices or systems that run on 70 volts instead of 220 volts, ensuring safe and efficient operation.

Figure 3.8: Step-Down Transformer

3.4.1.6 **POWER SUPPLY (24V, 12A)**

This is a power supply (24V, 12A) that converts AC to DC. It's used in industrial applications, featuring a metal casing with ventilation slots and a fan for heat dissipation and stable performance.

Figure 3.9: Power Supply

3.4.1.7 **STEPPER MOTOR**

NEMA 34 is a stepper motor with a (86×86×115 mm) faceplate and 1.8° step angle (200 steps/revolution). Each phase draws 5.6 A, allowing for torque of 8.5 N.M NEMA 34 Stepper motor is generally used in Printers, CNC machine, Linear actuators and hard drives. Stepper motors are a very practical technique of moving things to a desired position since they operate in steps and you can precisely control how many steps you travel in each direction. They are therefore excellent for most CNC applications.

Figure 3.10: Stepper Motor

➢ **SPECIFICATIONS**

Table 3.4: Stepper Motor Specifications

NEMA 34 Stepper Motor Specifications	
Rating	60V
Current Rating	5.6A
Holding Torque	8.5 N.m
Step Angle	1.8 deg
Steps Per Revolution	200
No. of Phases	2
Motor Length	115mm
No. of Leads	4
Inductance Per Phase	11mH

3.4.1.8 **EMERGENCY STOP PUSH BUTTON**

Figure 3.11: Emergency Stop

3.4.2 **MECHANICAL COMPONENTS**

Mechanical components are the active parts that make up the structure and moving parts of mechanical systems. Here's an overview of some common mechanical components in CNCs.

3.4.2.1 **RAIL GUIDE 25MM &BLOCK 25MM**

Figure 3.12: Rail Guide 25mm & Block 25mm.

3.4.2.2 **HELICAL/STRAIGHT TEETH RACK 1400MM**

1.25 module 22mm x 25mm helical/straight rack 1400mm with M5 hole spacing of 100mm for CNC mounting.

Figure 3.13: Helical Teeth Rack

3.4.2.3 **R55 25MM X 57MM PLASTIC CABLE WIRE HOLDER**

Figure 3.14: Wire Holder

3.4.2.4 **CNC GEARBOX WITH 5:1 RATIO**

Gearbox with a 5:1 ratio, Helical Gear Teeth, 1.25 module, Gear Rack Reducer.

Figure 3.15: CNC Gearbox 5:1 Ratio

3.4.2.5 **C-BEAM LINEAR ACTUATOR**

The C-Beam linear actuator is a mechanical device used to convert rotational motion into linear motion using a motor and a lead screw. It consists of an aluminum C-shaped frame with a central lead screw, along which a movable platform is mounted on rails and moves back and forth based on the screw s rotation. This type of actuator is known for its strength and precision and is commonly used in applications requiring linear motion, such as CNC machines.

Figure 3.16: C-Beam Linear Actuator

3.4.2.6 **MANUAL DISTRIBUTOR**

Figure 3.17: Manual Distributor

3.4.2.7 **OIL DISPENSER**

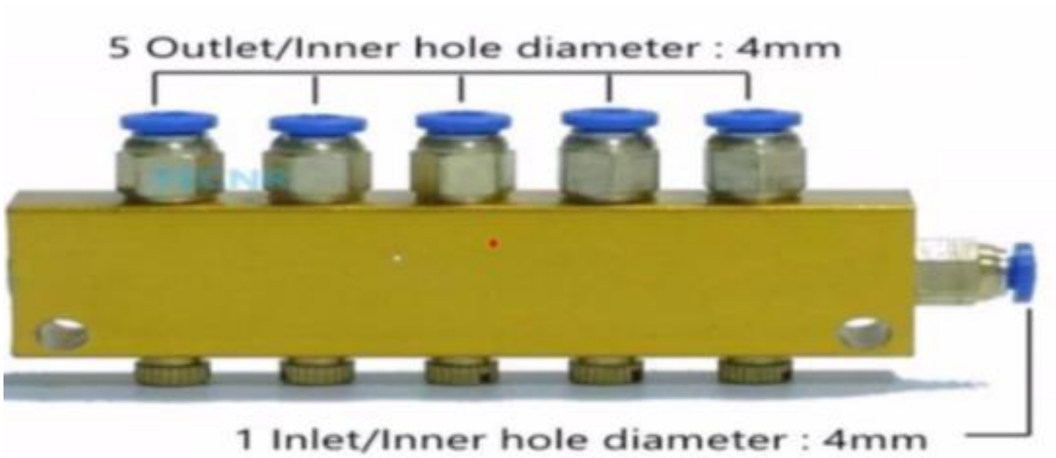


Figure 3.18: Oil Dispenser

3.4.2.8 **GALVANIZED SQUARE IRON TUBE THICKNESS 3**

Galvanized square iron tube with dimensions of 120×120 mm and a thickness of 3 mm. This type of tube is commonly used in applications that require corrosion resistance along with strength and durability, such as metal structures, and various construction works.

Figure 3.19: Galvanized Square Iron Tube

3.4.2.9 **SCREW**

Table 3.5: Types of Screw

B18.3.1M - 10 x 0.9 x 30 Hex SHCS -- 20NHX	
B18.3.1M - 8 x 0.6 x 20 Hex SHCS -- 12NHX	
B18.3.1M - 8 x 0.4 x 10 Hex SHCS -- 12NHX	

CHAPTER 4: MATHEMATICAL & SIMULATION

4.1 THE TORQUE REQUIRED TO MOVE THE X-AXIS

4.1.1 **COMMENTS:**

Bridge Mass (m): 70 kg

Total Force Acting on the Y-Axis (Fy): 687 N

Normal Force (N): Half of the total force acting on one side of the Y-axis: $N = \frac{687}{2} = 343.5$ N

the coefficient of friction is $\mu = 0.15$

Frictional Force (F_f): Calculated as $F_f = 0.15$ x $687 = 103.05$ N

Pulley Radius (R): 0.2 mm

Torque from Mass (T_m): T_m = 0.2 x 70 = 14 N·m

ΣF = $14 + 103.05 = 117.05$ N·m The Force Required to Calculate the Torque to Move It

Moment Arm (r): r = 0.015 m

Opposing Torque (T_1): T_1= 117.05 x $0.015 = 1.75575$ N·m

Small Radius (R_1): 1.35 cm

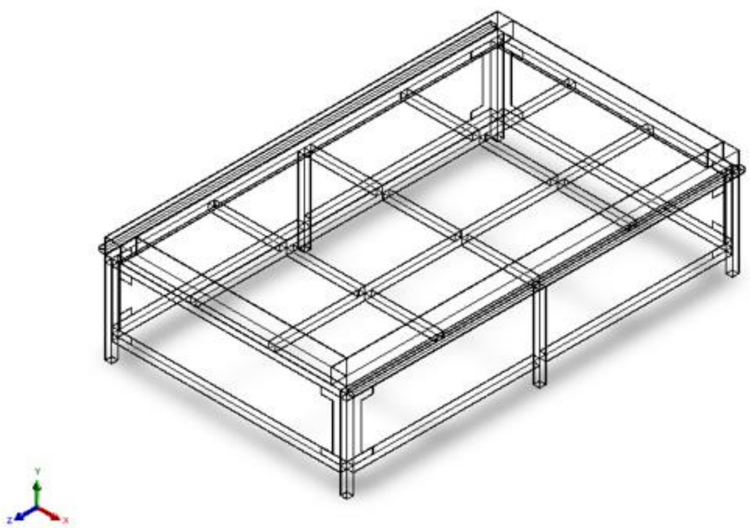
Large Radius (R_2): 7 cm

T_{Total} = 1.75575 x $\frac{1.35}{7} = 0.34$ N·m Total Torque

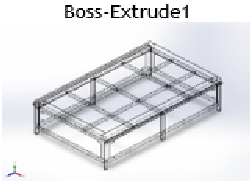
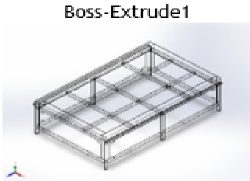
T_{Motor} = $\frac{0.354}{2} = 0.177$ N·m Torque per Motor

4.2 SIMULATION FOR A BASE WITH WATER TABLE

4.2.1 **MODULE INFORMATION**



Model name: Assem cnc last7
Current Configuration: Default

Solid Bodies			
Document Name and Reference	**Treated As**	**Volumetric Properties**	**Document Path/Date Modified**
Boss-Extrude1 	Solid Body	Mass:0.829739 kg Volume:0.000107758 m^3 Density:7,700 kg/m^3 Weight:8.13144 N	C:\Users\lenovo\Desktop\ مجلد جديد\تعديل\angal.SLDPRT
Boss-Extrude1 	Solid Body	Mass:0.829739 kg Volume:0.000107758 m^3 Density:7,700 kg/m^3 Weight:8.13144 N	C:\Users\lenovo\Desktop\ مجلد جديد\تعديل\angal.SLDPRT
Boss-Extrude1	Solid Body	Mass:0.829739 kg Volume:0.000107758 m^3 Density:7,700 kg/m^3 Weight:8.13144 N	C:\Users\lenovo\Desktop\ مجلد جديد\تعديل\angal.SLDPRT

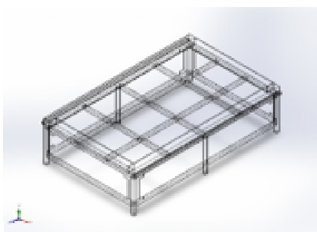
4.2.2 **STUDY PROPERTIES**

Study name	Static 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	Automatic
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (C:\Users\lenovo\Desktop\تحديل\مجلد جديد\New folder)

4.2.3 **UNITS**

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

4.2.4 **MATERIAL PROPERTIES**

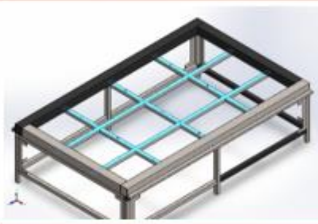
Model Reference	Properties	Components
	**Name:** Alloy Steel **Model type:** Linear Elastic Isotropic **Default failure criterion:** Max von Mises Stress **Yield strength:** 6.20422e+08 N/m^2 **Tensile strength:** 7.23826e+08 N/m^2 **Elastic modulus:** 2.1e+11 N/m^2 **Poisson's ratio:** 0.28 **Mass density:** 7,700 kg/m^3 **Shear modulus:** 7.9e+10 N/m^2 **Thermal expansion coefficient:** 1.3e-05 /Kelvin	SolidBody 1(Boss-Extrude1)(angal-1), SolidBody 1(Boss-Extrude1)(angal-2), SolidBody 1(Boss-Extrude1)(angal-3), SolidBody 1(Boss-Extrude1)(angal-4), SolidBody 1(Boss-Extrude1)(angal-5), SolidBody 1(Boss-Extrude1)(angal-6), SolidBody 1(Boss-Extrude1)(angal-7), SolidBody 1(Boss-Extrude1)(angal-8), SolidBody 1(Boss-Extrude1)(heigh120t1850-1), SolidBody 1(Boss-Extrude1)(heigh120t1850-2), SolidBody 1(Cut-Extrude1)(heigh120t3000-1), SolidBody 2(Boss-Extrude1)(heigh120t3000-1), SolidBody 1(Cut-Extrude1)(heigh120t3000-2), SolidBody 2(Boss-Extrude1)(heigh120t3000-2), SolidBody 1(Boss-Extrude1)(lengh50t1425-1), SolidBody 1(Boss-Extrude1)(lengh50t1425-2), SolidBody 1(Boss-Extrude1)(lengh50t1425-3), SolidBody 1(Boss-Extrude1)(lengh50t1425-4), SolidBody 1(Boss-Extrude1)(lengh50t1750-1), SolidBody 1(Boss-Extrude1)(lengh50t1750-2), SolidBody 1(Boss-Extrude1)(lengh50t1750-3), SolidBody 1(Boss-Extrude1)(lengh50t1750-4), SolidBody 1(Boss-Extrude1)(lengh50t2900-1), SolidBody 1(Boss-Extrude1)(lengh50t2900-2), SolidBody 1(Boss-Extrude1)(lengh50t3000-1),

4.2.5 **LOADS AND FIXTURES**

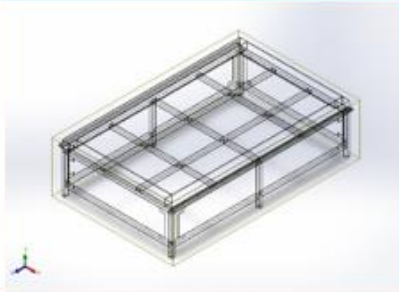
Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: 6 face(s) Type: Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-0.000823975	63,448	0.00292969	63,448
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Force-1		Entities: 11 face(s) Type: Apply normal force Value: 5,768 N

4.2.6 **INTERACTION INFORMATION**

Interaction	Interaction Image	Interaction Properties
Global Interaction		**Type:** Bonded **Components:** 1 component(s) **Options:** Independent mesh

4.2.7 **MESH INFORMATION**

Mesh type	Solid Mesh
Mesher Used:	Blended curvature-based mesh
Jacobian points for High quality mesh	16 Points
Maximum element size	98.0704 mm
Minimum element size	98.0704 mm
Mesh Quality	High
Remesh failed parts independently	Off

4.2.8 **MESH INFORMATION - DETAILS**

Total Nodes	29961
Total Elements	14481
Maximum Aspect Ratio	182.19
% of elements with Aspect Ratio < 3	0
Percentage of elements with Aspect Ratio > 10	100
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:22

4.2.9 **RESUITANT FORCES**

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0.000823975	63,448	0.00292969	63,448

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Free body forces

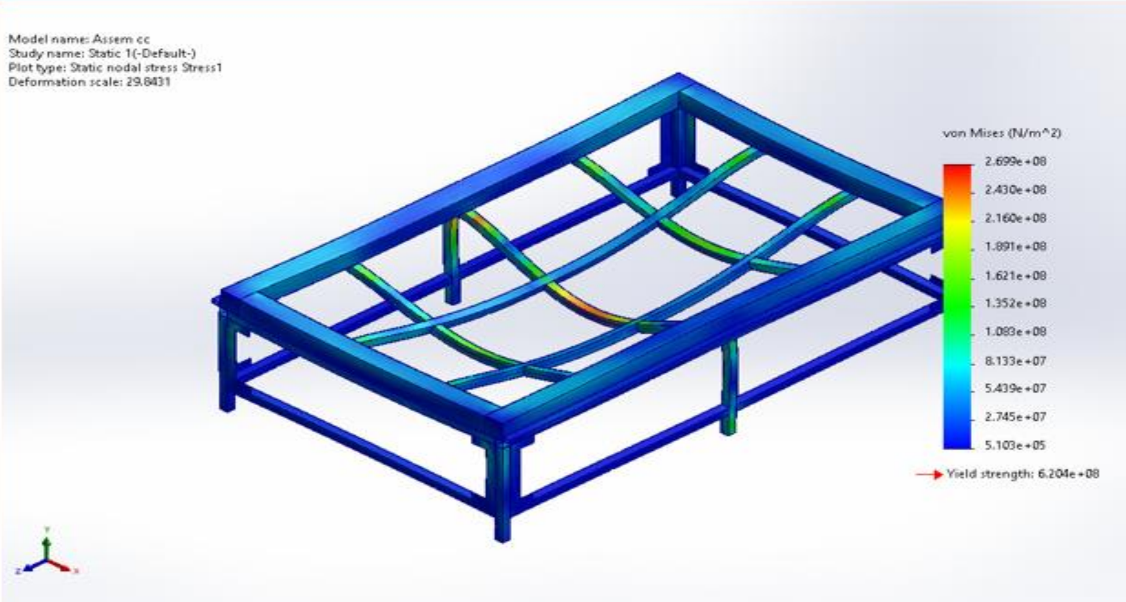
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.0332031	-0.0264282	-0.00274658	0.0425258

Free body moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33

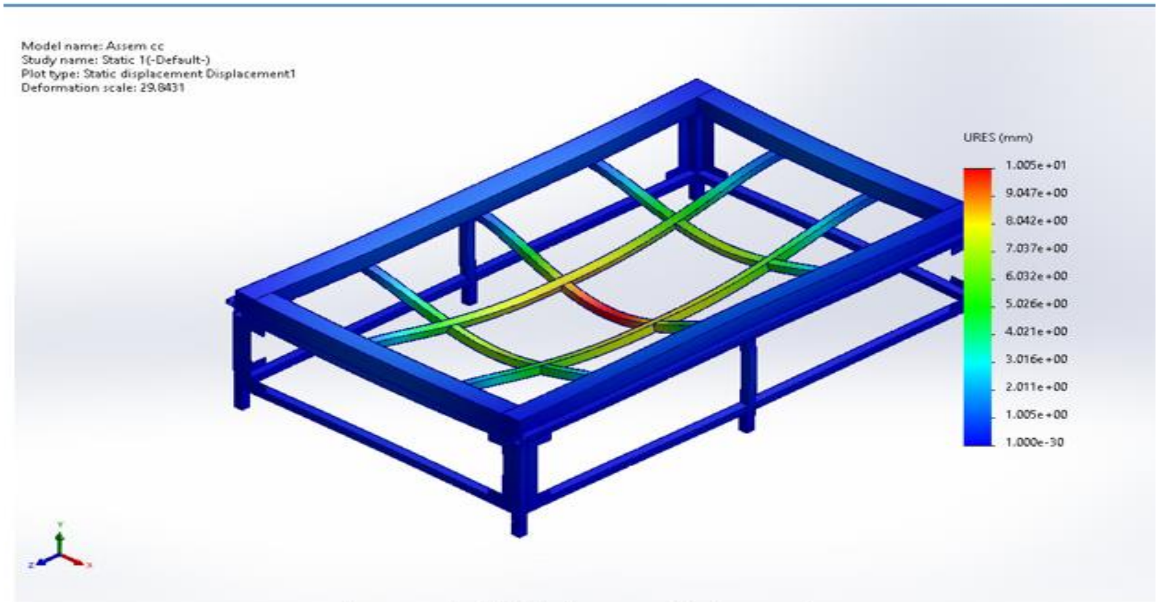
4.2.10 **STUDY RESULTS**

Name	Type	Min	Max
Stress1	VON: von Mises Stress	5.103e+05N/m^2 Node: 422	2.699e+08N/m^2 Node: 25165



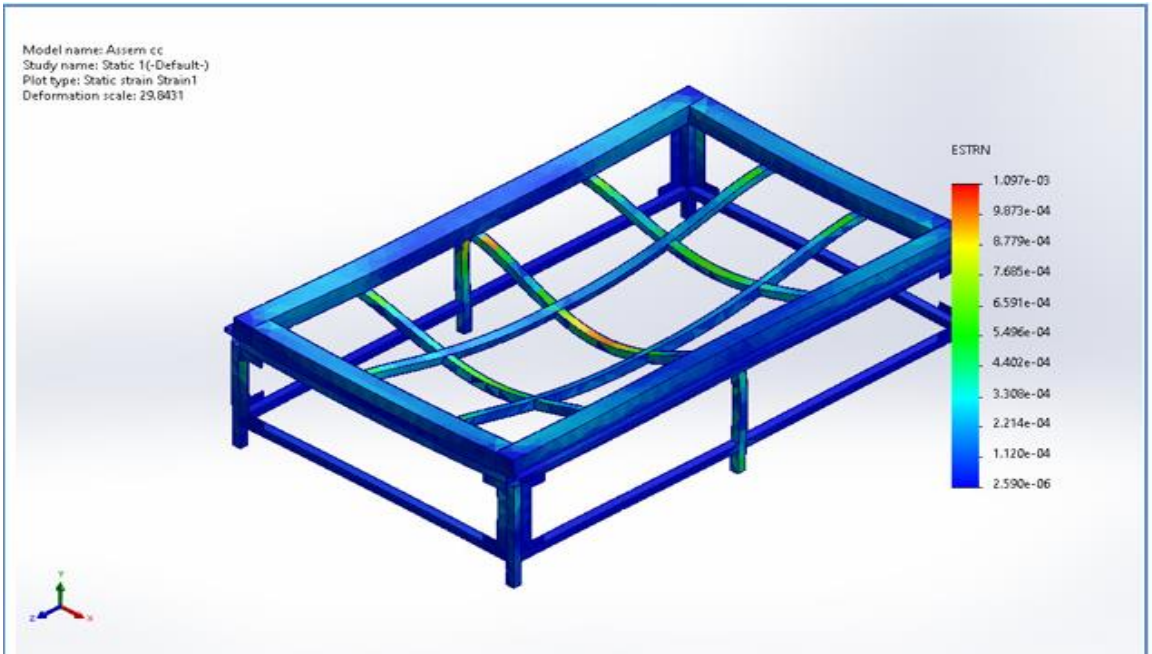
Assem cc-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 27693	1.005e+01mm Node: 25889



Assem cc-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	2.590e-06 Element: 1107	1.097e-03 Element: 12252



Assem cc-Static 1-Strain-Strain1

Name	Type	Min	Max
Factor of Safety1	Automatic	2.299e+00 Node: 25165	1.216e+03 Node: 422

4.3 SIMULATION OF THE MAXIMUM STRESSABLE POINT AT THE BASE

4.3.1 RESUITANT FORCES

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-4.24385e-05	1,471.5	-1.90735e-05	1,471.5

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Free body forces

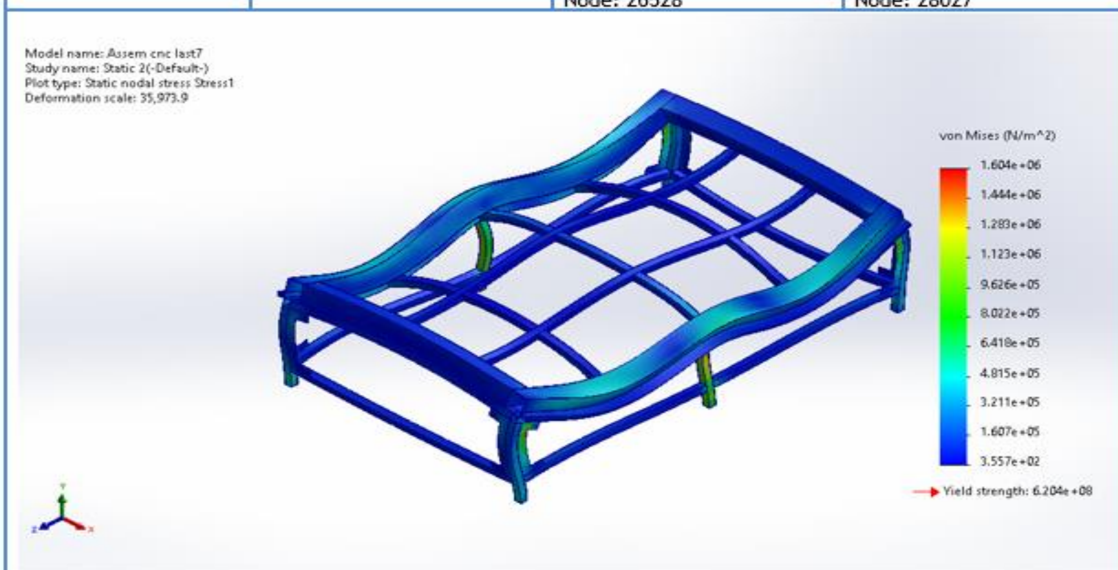
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.000396907	0.000877857	5.12302e-05	0.000964776

Free body moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33

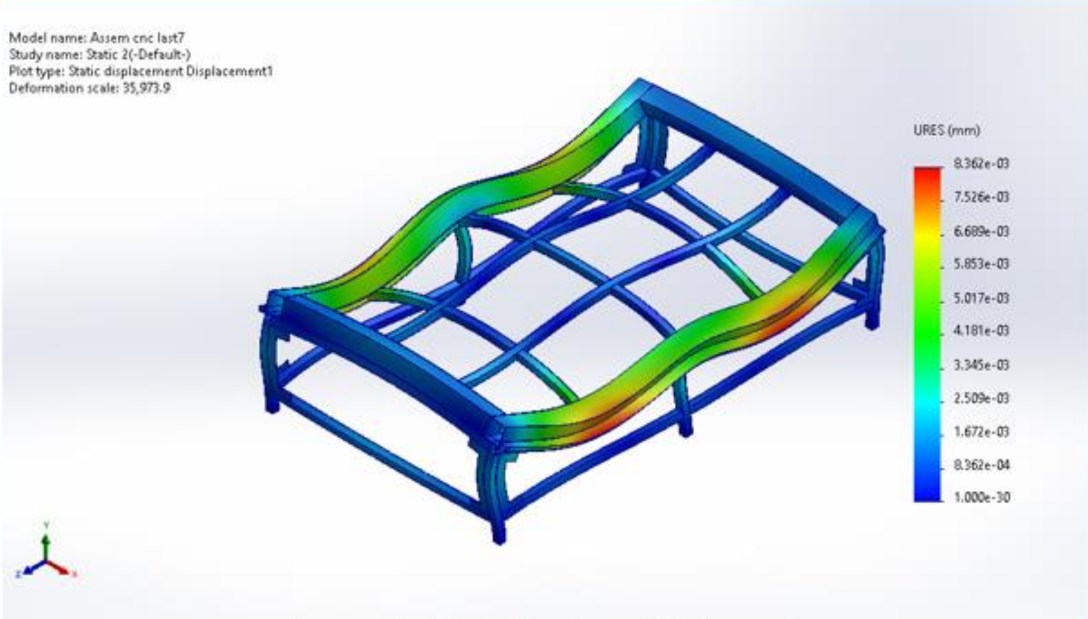
4.3.2 STUDY RESULTS

Name	Type	Min	Max
Stress1	VON: von Mises Stress	3.557e+02N/m^2 Node: 26528	1.604e+06N/m^2 Node: 28027



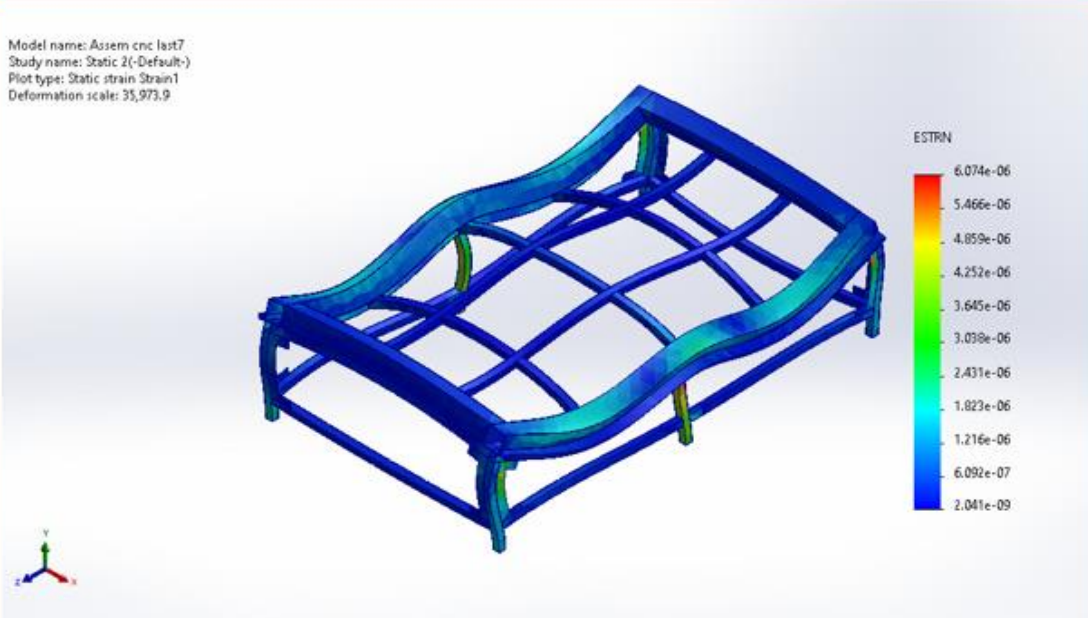
Assem cnc last7-Static 2-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 27625	8.362e-03mm Node: 3750



Assem cnc last7-Static 2-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	2.041e-09 Element: 12802	6.074e-06 Element: 13802



Assem cnc last7-Static 2-Strain-Strain1

CHAPTER 5: IMPLEMENTATION

5.1 PRODUCTION PROCESSES IN CNC PLASMA

The production processes in CNC Plasma begin by transforming ideas into tangible products. This involves carefully selecting metal materials, focusing on properties that ensure optimal performance during manufacturing.

5.1.1 **WHAT IS CNC PLASMA CUTTING?**

It is the process of cutting electrically conductive materials with an accelerated jet of hot plasma. Steel, brass, copper and aluminum are some of the materials that can be cut with a plasma torch. CNC plasma cutter finds application in automotive repair, fabrication units, salvage and scrapping operations, and industrial construction. The combination of high speed and precision cuts with low cost makes the CNC plasma cutter widely used equipment.

5.2 SEARCH FOR SYSTEMS AND SOFTWARE

First, the search for the programs necessary to operate the three-axis system, as well as the programs necessary to generate the G-code three axes, commensurate with the programs operating the system, then the Mach3 program was the operating program for the system of the machine.

5.3 DESIGN (CAD) STAGE

Designing the elements of the machine using the Solidwork program, then we assembled all the pieces.

5.3.1 **DESIGN STAGES OF OUR MACHINE**

As part of our graduation project, we designed and manufactured a CNC plasma machine, an advanced tool used for cutting and shaping iron with high precision and efficiency. This project aims to provide a technical solution that meets the needs of modern industry. Our design consists of three main stages, each playing a crucial role in achieving the final goal. Let’s review these stages:

5.3.1.1 **STAGE ONE: STRUCTURE AND WELDING**

In this stage, we begin by assembling the basic structure of the machine. Advanced welding techniques are used to ensure the strength and durability of the frame. Materials are carefully selected to ensure the machine can withstand high pressures during operation. This stage is the foundation upon which everything else is built, ensuring that the structure is strong and stable enough to support the other components.

Figure 5.1: Stage One

5.3.1.2 **STAGE TWO: WIRING AND CONNECTIONS**

After completing the structure, we move on to the second stage, which involves wiring and connecting the components to form the machine’s electrical circuit. High-quality wires and advanced electronic components are used to ensure the efficiency and safety of the electrical system. The wires are carefully connected to ensure there are no faults that could affect the machine’s performance. This stage requires high precision and advanced technical knowledge to ensure everything works correctly.

Figure 5.2: Stage Two

5.3.1.3 **STAGE THREE: MACHINE OPERATION**

In the final stage, we focus on testing and operating the machine. We ensure that everything runs smoothly and that the machine can cut and shape iron with high precision. Multiple tests are conducted to ensure performance quality and system stability. Once everything is confirmed to be working perfectly, we begin using the machine in practical applications, demonstrating its efficiency and ability to achieve the desired goals.

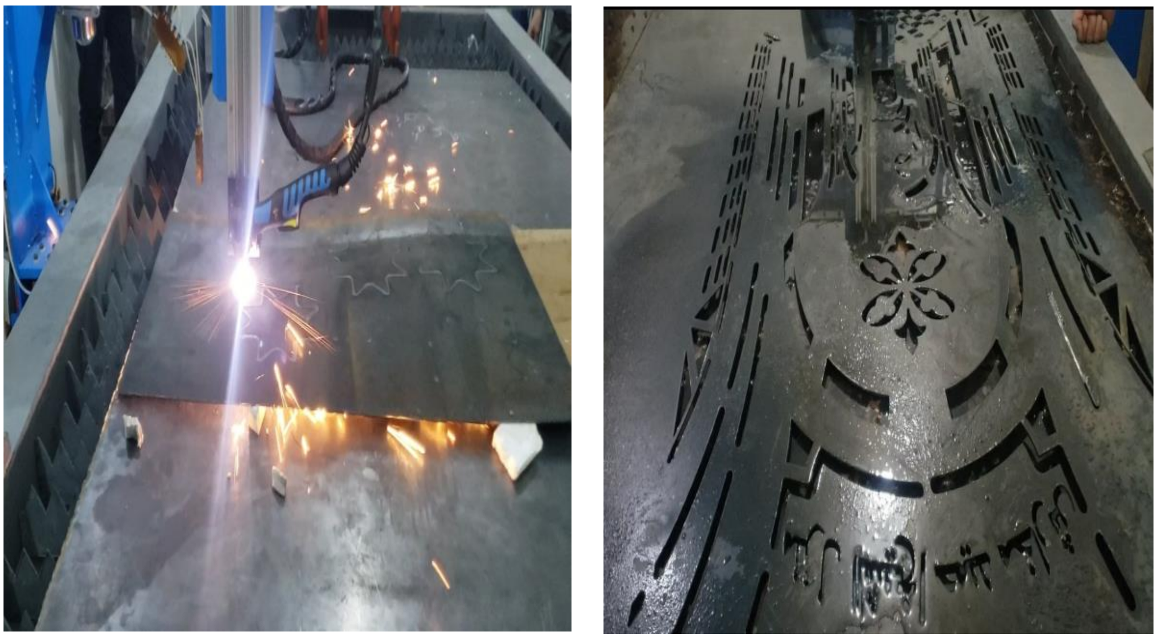


Figure 5.3: Stage Three

5.4 COMPUTER AIDED MANUFACTURING (CAM)

Computer-Aided Manufacturing (CAM) software is used to generate tool paths and cutting instructions for the CNC machine. The Art Cam program and The Sheet Cam program were used in order to create a tool path for the designed pieces that need to be manufactured by CNC machines.

5.5 CNC CONTROL SOFTWARE

5.5.1 **MACH 3**

Mach3 is a software that transforms a computer into a control unit for CNC machines. It controls the movement of the axes using stepper motors or servo motors by processing G-code commands and converting them into electrical signals that precisely guide the motors. Mach3 is known for its user-friendly interface, allowing for easy loading, monitoring of commands, and effective machine control.

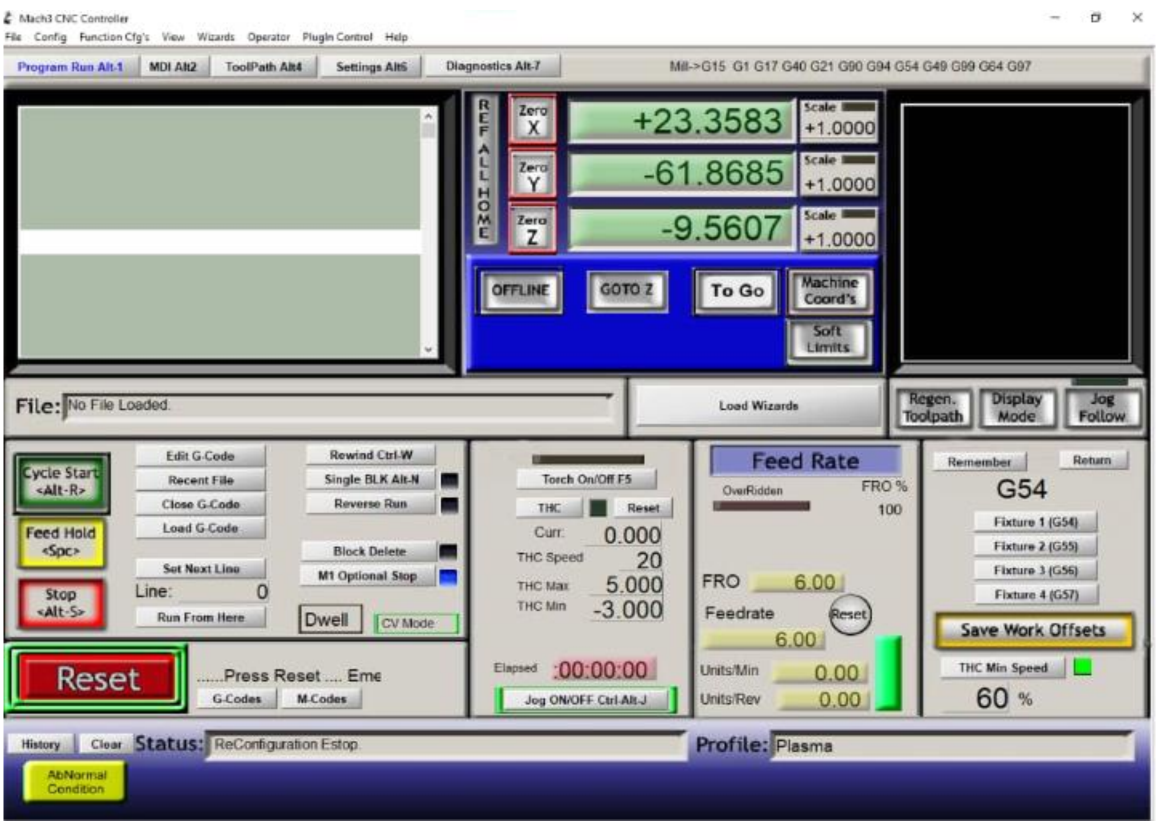


Figure 5.4: Mach3 Interface

5.5.1.1 **MACH3 SETTING**

Setup Units: Choose “MM’s” in Config->Set Default Units for Setup.

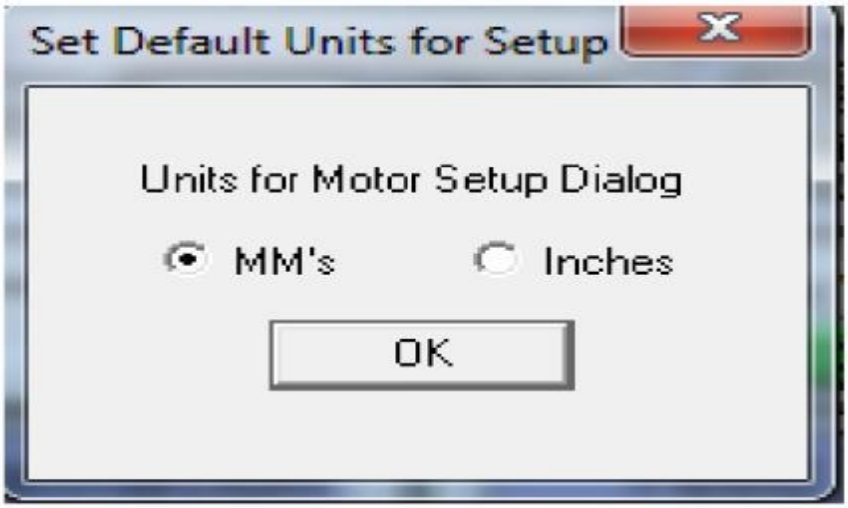


Figure 5.5: Setup Units

Click “Config”->”Ports and Pins” on Main Interface.

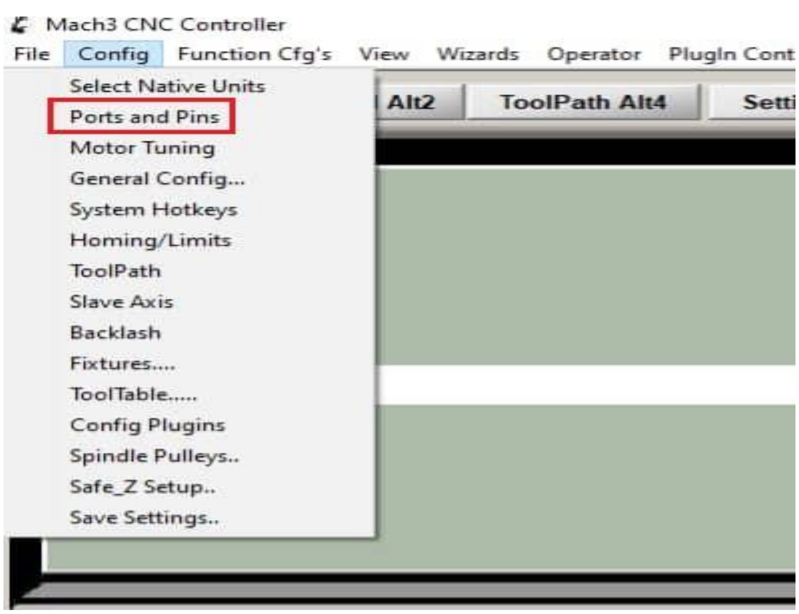


Figure 5.6: Main Interface.

Enter in “Port Setup and Axis Selection” to set “Port#1” and “Kernel Speed” shown as below.

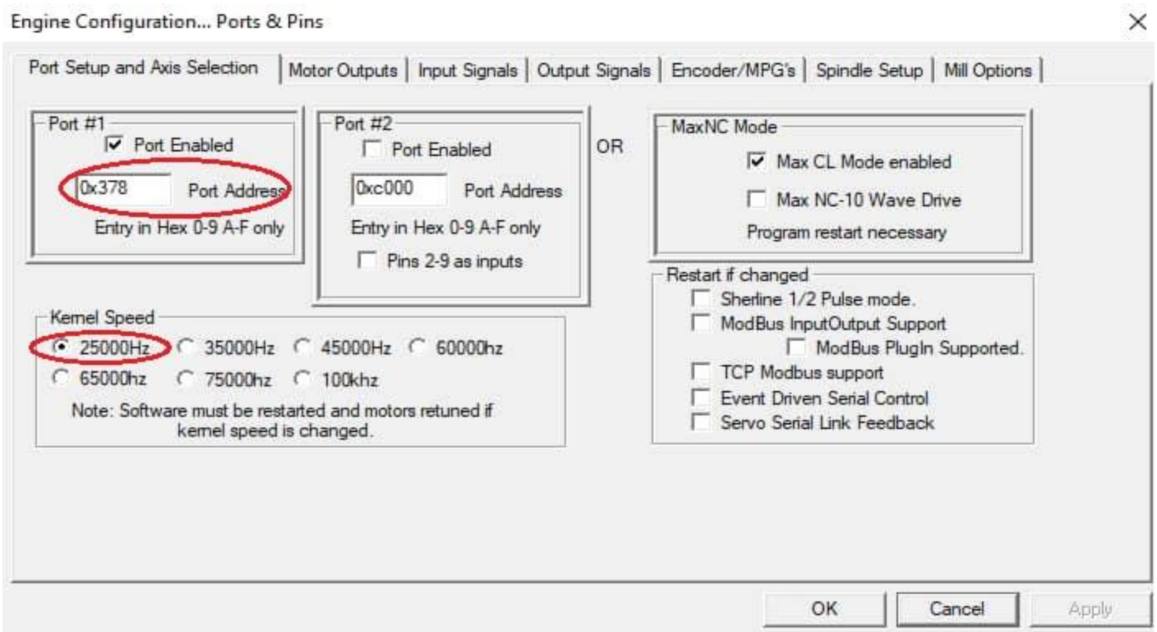


Figure 5.7: Port Setup and Axis Selection

Click “Motor Outputs” to set it shown as below.

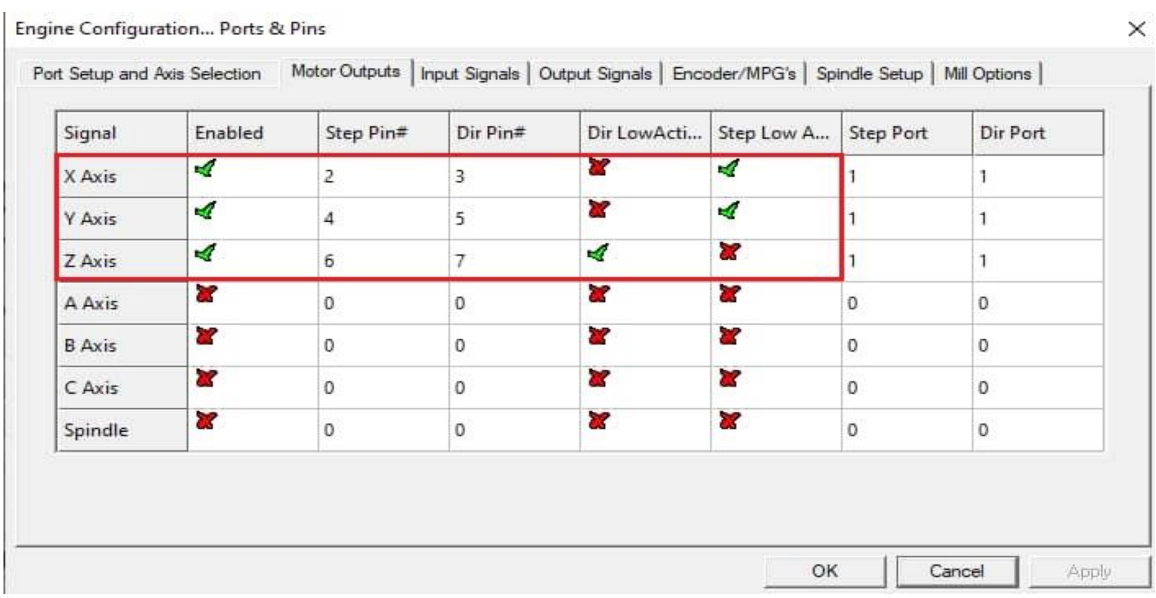


Figure 5.8: Motor Outputs

Click “Input Signals” to set it shown as below.

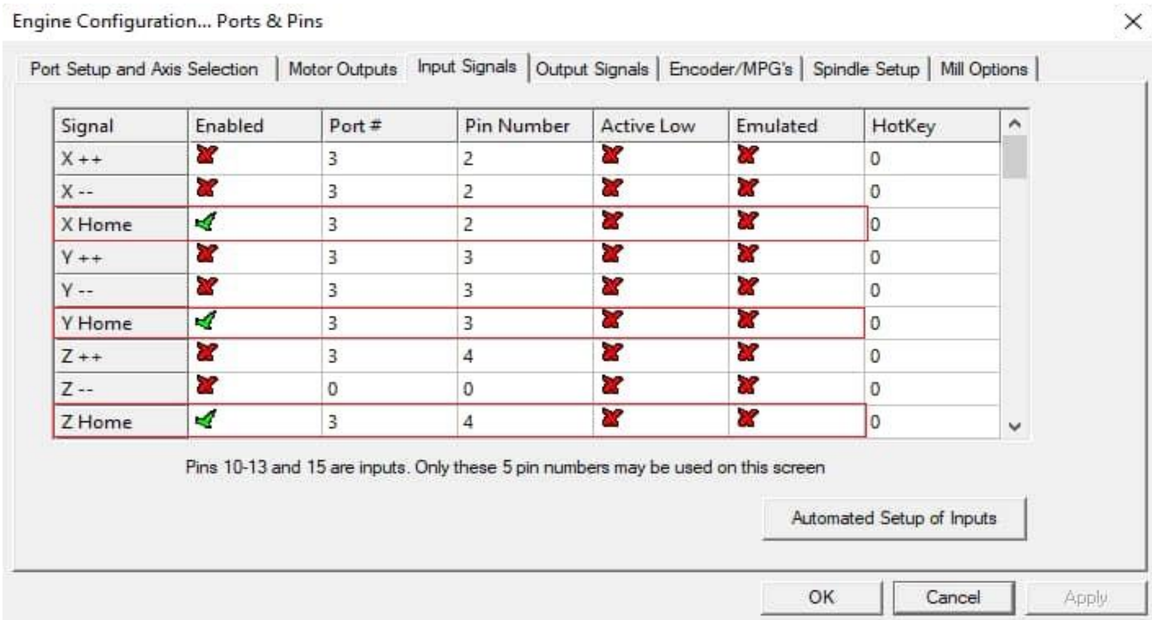


Figure 5.9: Input Signals

Click “Output Signals” to set it shown as below.

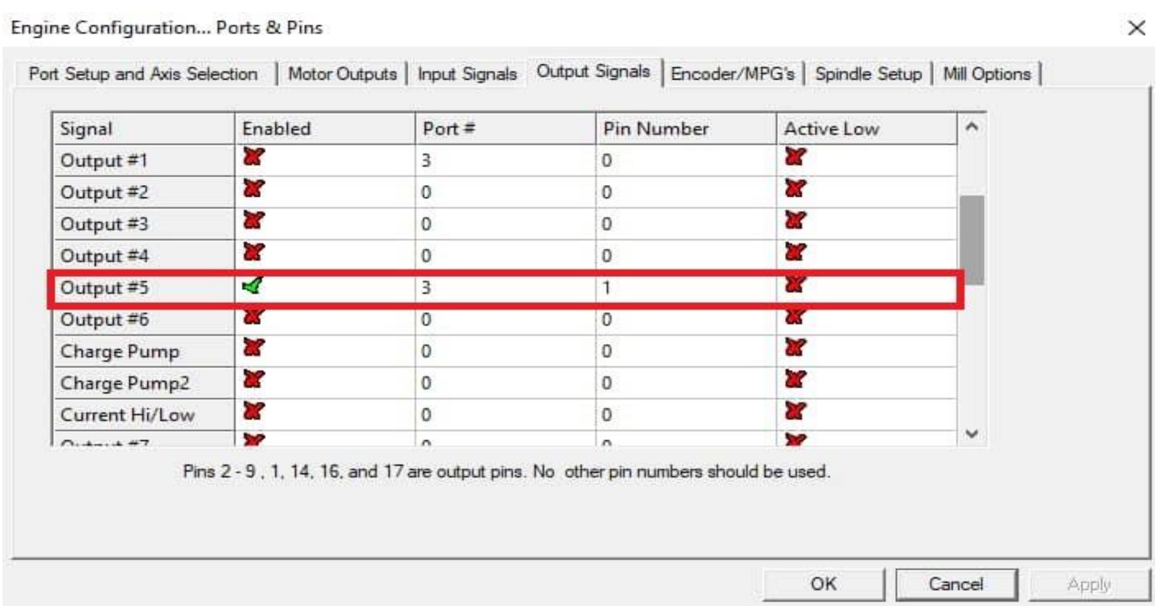


Figure 5.10: Output Signals

Click “Config”->” Motor Turning” on Main Interface.

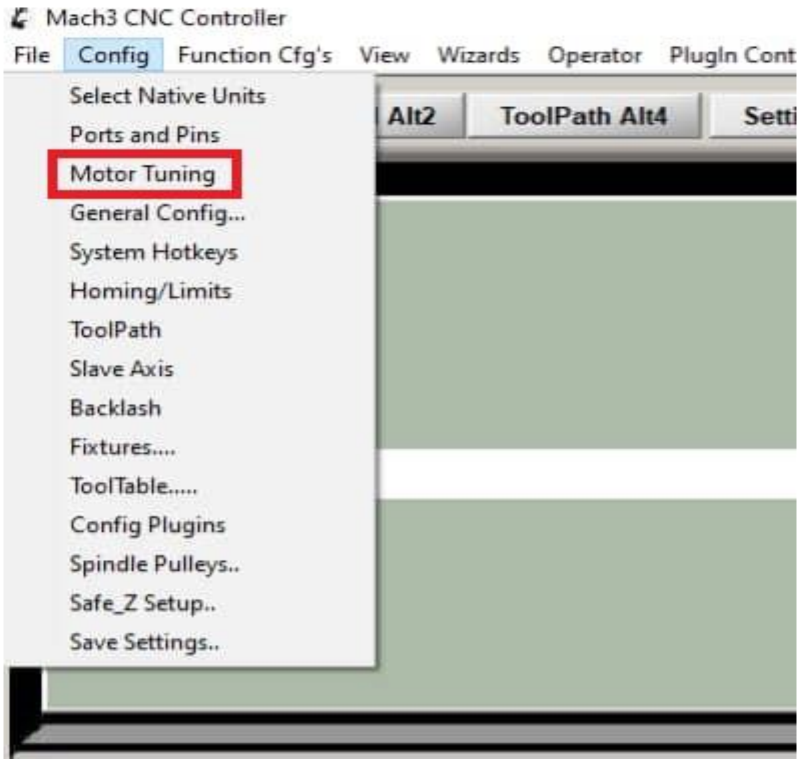


Figure 5.11: Motor Turning

Click “Motor Turning and Setup” to set it shown as below

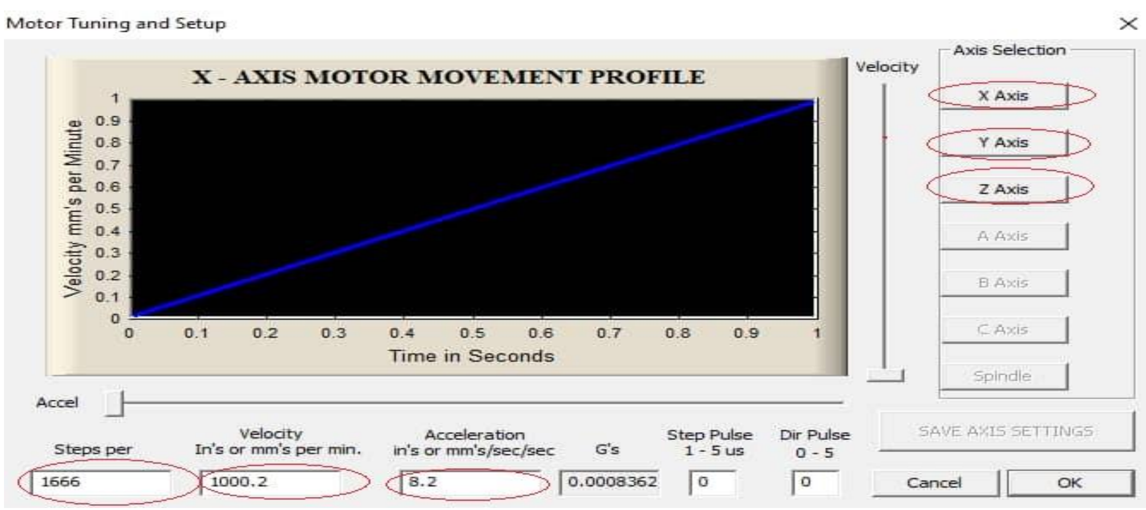


Figure 5.12: Motor Turning and Setup

CHAPTER 6: CONCLUSION AND FUTURE WORK

6.1 CONCLUSION

This thesis represents a significant step in the design and development of a three-axis CNC plasma machine. By focusing on improving the precision and efficiency of the manufacturing process, we have provided new insights into enhancing performance and effectiveness in cutting operations. This work emphasizes improvements in usability and control, allowing operators to perform complex tasks with greater effectiveness. Overall, this study contributes to advancing the applications of CNC plasma machines and opens new avenues in manufacturing technology.

6.2 FUTURE WORK

This thesis represents an important step towards developing a three-axis CNC plasma machine, with significant potential for future improvements. Future work includes integrating artificial intelligence techniques to enhance the precision and speed of the cutting process, developing a more interactive and intuitive user interface, and improving the machine's ability to cut a variety of materials while increasing its energy efficiency. Additionally, enhancing integration with advanced CAD/CAM systems can facilitate the conversion of digital designs into precise cutting operations, contributing to greater machine efficiency and expanding its applications across various industries.

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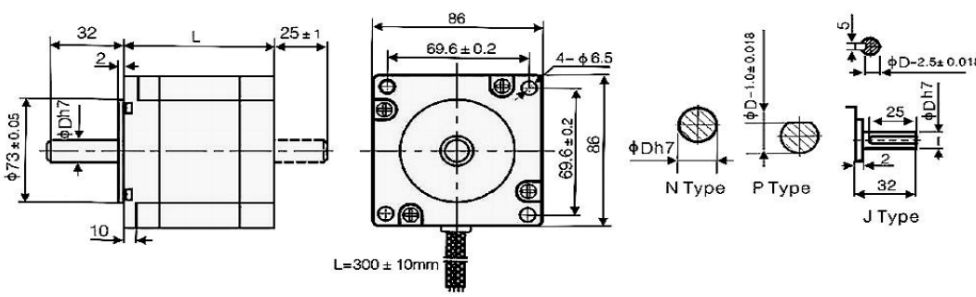
APPENDIX A: NEMA34 STEPPERMOTOR

Nema 34 Stepper Motor

Nema 34 hybrid bipolar stepper motor is a permanent magnet stepper motor with an end face size of 86mm x 86mm. Nema 34 stepper motor with high torque is used for CNC machine, 3D printer and robot arm, etc. It is simple structure, small size and easy assembly. ATO high torque stepper motor at low cost, including 2 phase open loop, 3 phase open loop and 2 phase closed loop, can be controlled by AC or DC digital stepper controllers for precise position control.

2 Phase Open Loop Stepper Motor

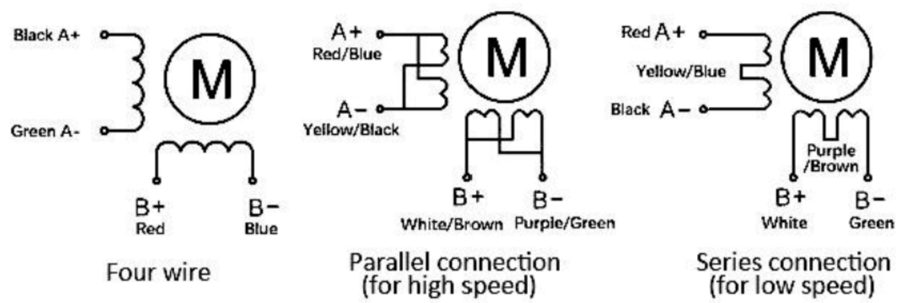
Specification



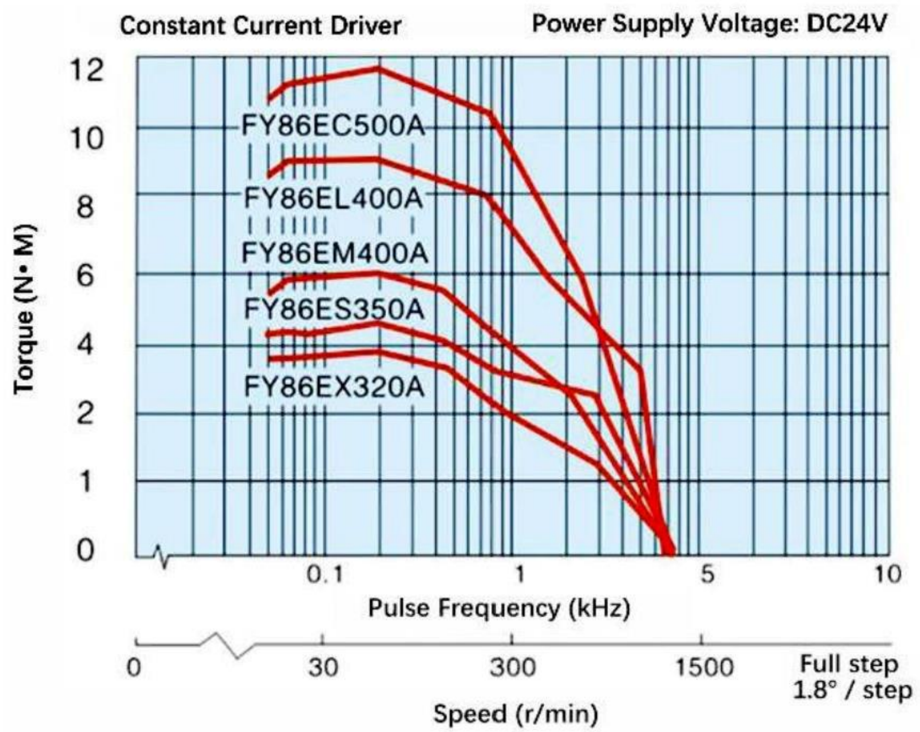
Model	Step Angle (°)	Motor Length (mm)	Rated Current (A)	Holding Torque (N.m)	Phase Resistance (Ω)	Phase Inductance (mH)	Rotor Inertia (g.cm²)	Lead Wires (NO.)	Motor Weight (Kg)
FY86ES350A	1.8	80	3.5	4.50	1.0	4.4	1500	4	2.00
FY86EM400A		94	4.0	6.00	0.8	3.5	2700	4	2.80
FY86EL400A		118	4.0	8.50	0.97	5.5	4100	4	3.80
FY86EC500A		150	5.0	12.0	1.20	6.0	6200	4	5.20

Technical Specification	
Shaft Diameter	14mm/ 12.7mm
Step Angle Accuracy	±5% (Full Step, No Load)
Resistance Accuracy	±10% (20℃)
Inductance Accuracy	±20% (1KHz)
Temperature Rise	80℃ Max. (rated current, 2 phase on)
Ambient Temperature	-20℃~+50℃
Insulation Resistance	100MΩ Min. 500VDC
Dielectric Strength	1Min. 500VAC
Shaft Radial Play	0.02Max. 450g Load
Shaft Axial Play	0.08Max. 450g Load
Radial Max. Load	75N
Axial Max. Load	15N
Warranty Period	12 months
Certificate	CE, ROHs, FCC

Wiring Diagram

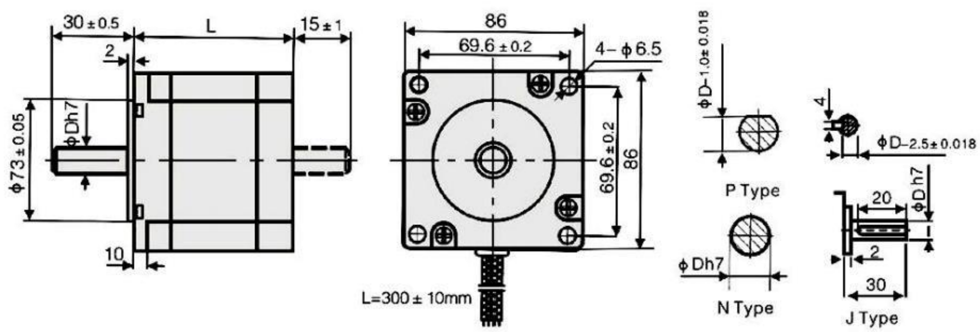


Speed-Torque Curve Diagram



3 Phase Open Loop Stepper Motor

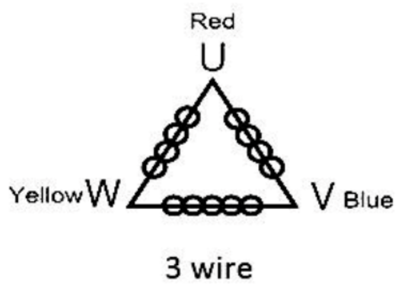
Specification



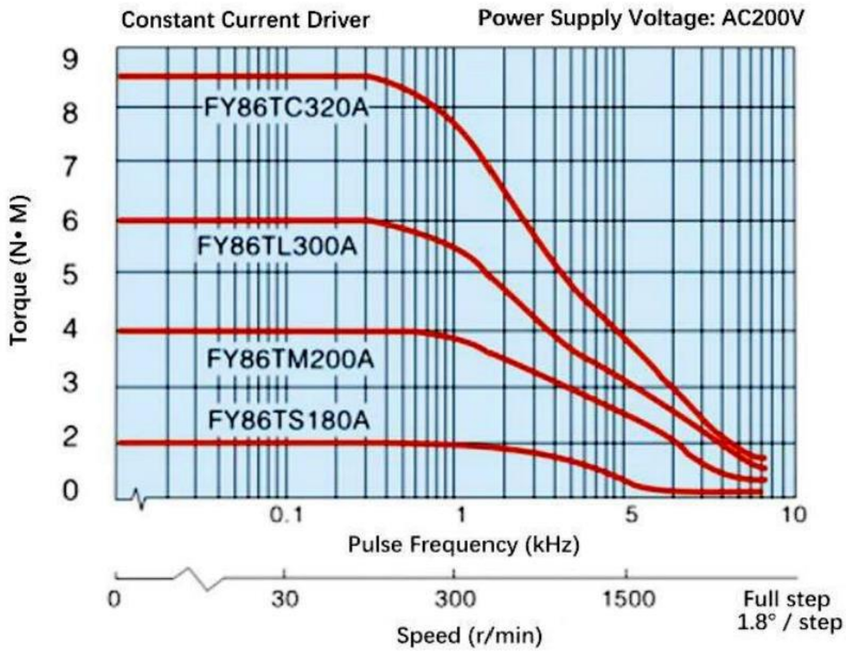
Model	Step Angle (°)	Motor Length (mm)	Rated Current (A)	Holding Torque (N.m)	Phase Resistance (Ω)	Phase Inductance (mH)	Rotor Inertia (g.cm²)	Lead Wires (NO.)	Motor Weight (Kg)
FY86TM200A	1.8	97	2.0	4.00	4.65	14.6	2400	3	2.80
FY86TC320A		145	3.2	8.50	2.60	9.57	4560	3	4.70
FY86TL300A		125	3.0	6.00	2.00	8.00	3480	3	3.80

Technical Specification	
Shaft Diameter	14mm
Step Angle Accuracy	±5% (Full Step, No Load)
Resistance Accuracy	±10% (20℃)
Inductance Accuracy	±20% (1KHz)
Temperature Rise	80℃ Max. (rated current, 2 phase on)
Ambient Temperature	-20℃~+50℃
Insulation Resistance	100MΩ Min. 500VDC
Dielectric Strength	1Min. 500VAC
Shaft Radial Play	0.02Max. 450g Load
Shaft Axial Play	0.08Max. 450g Load
Radial Max. Load	75N
Axial Max. Load	15N
Warranty Period	12 months
Certificate	CE, ROHs, FCC

Wiring Diagram

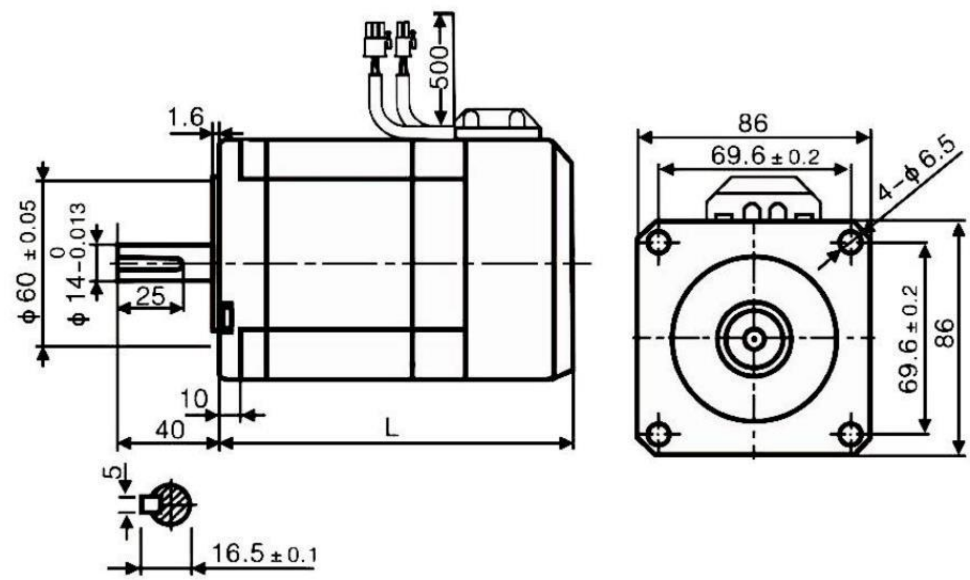


Speed-Torque Curve Diagram



2 Phase Closed Loop Stepper Motor


Specification

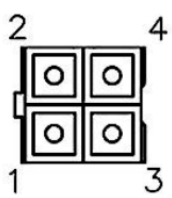


Model	Step Angle (°)	Motor Length (mm)	Rated Current (A)	Holding Torque (N.m)	Phase Resistance (Ω)	Phase Inductance (mH)	Rotor Inertia (g.cm²)	Lead Wires (NO.)	Motor Weight (Kg)
FY86EC620BC1	1.8	172	6.2	12.00	0.65	5.6	5600	4	5.00
FY86EM620BC1		102	6.2	4.50	0.34	2.5	1800	4	2.10
FY86EL620BC1		134	6.2	8.20	0.45	4.7	3600	4	3.60

Technical Specification	
Shaft Diameter	12mm
Step Angle Accuracy	±5% (Full Step, No Load)
Resistance Accuracy	±10% (20℃)
Inductance Accuracy	±20% (1KHz)
Temperature Rise	80℃ Max. (rated current, 2 phase on)
Ambient Temperature	-20℃~+50℃
Insulation Resistance	100MΩ Min. 500VDC
Dielectric Strength	1Min. 500VAC
Shaft Radial Play	0.02Max. 450g Load
Shaft Axial Play	0.08Max. 450g Load
Radial Max. Load	220N
Axial Max. Load	60N
Warranty Period	12 months
Certificate	CE, ROHs, FCC

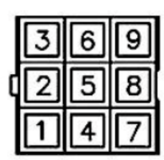
Motor & Encoder Wiring Diagram

Motor Wiring



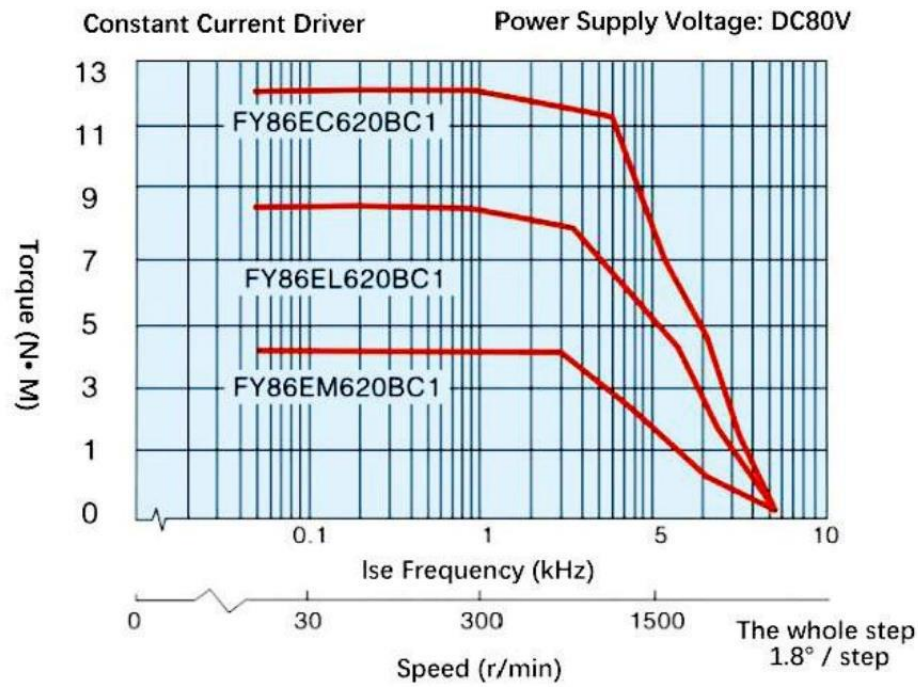
Motor End	Color	Function
1	Blue	B-
2	Red	B+
3	Green	A-
4	Black	A+

Encoder Wiring



Encoder	Color	Function
1	Blue	EA+
2	—	—
3	Blue/White	EA+
4	Orange	EB+
5	—	—
6	Orange/ White	EB-
7	Red	VCC
8	Black	GND
Encoder	Shield	

Speed-Torque Curve Diagram



APPENDIX B: USER MANUAL - DMA860H

User's Manual

For

DMA860H

Fully Digital Stepper Drive

Version 1.0

Attention: Please read this manual carefully before using the drive!

Leadshine Technology Co., Ltd.

3/F, Block 2, Nanyou Tianan Industrial Park, Nanshan Dist, Shenzhen, China

T: (86)755-26409254 F: (86)755-26402718

Web site: www.leadshine.com E-Mail: sales@leadshine.com

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1. Introduction, Features and Applications

Introduction

The DMA860H is a fully digital stepper drive developed with advanced DSP control algorithm based on the latest motion control technology. It has achieved a unique level of system smoothness, providing optimal torque and nulls mid-range instability. Its motor auto-identification and parameter auto-configuration feature offers quick setup to optimal modes with different motors. Compared with traditional analog drives, DMA860H can drive a stepper motor at much lower noise, lower heating, and smoother movement. Its unique features make DMA860H an ideal choice for high requirement applications.

Features

- Anti-Resonance provides optimal torque and nulls mid-range instability
- Motor auto-identification and parameter auto-configuration technology, offers optimal responses with different motors
- Multi-Stepping allows a low resolution step input to produce a higher microstep output, thus offers smoother motor movement
- 16 selectable microstep resolutions including 400, 800, 1600, 3200, 6400, 12800, 25600, 51200, 1000, 2000, 4000, 5000, 8000, 10000, 20000, 40000
- Soft-start with no "jump" when powered on
- Input voltage 18-80VAC or 26-113VDC
- 8 selectable peak current including 2.40A, 3.08A, 3.77A, 4.45A, 5.14A, 5.83A, 6.52A, 7.20A
- Pulse input frequency up to 200 KHz, TTL compatible and optically isolated input
- Automatic idle-current reduction
- Suitable for 2-phase and 4-phase motors
- Support PUL/DIR and CW/CCW modes
- Over-voltage, over-current protections

Applications

Suitable for a wide range of stepping motors, from NEMA size 23 to 42. It can be used in various kinds of machines, such as X-Y tables, engraving machines, labeling machines, laser cutters, pick-place devices, and so on. Particularly adapt to the applications desired with low noise, low heating, high speed and high precision.

2. Specifications

Electrical Specifications (T_j = 25℃/77℉)

Parameters	DMA860H			
	Min	Typical	Max	Unit
Output Current	1.0	-	7.2 (Peak)	A
Input Voltage	18	48	80	VAC
	26	68	113	VDC
Logic Signal Current	7	10	16	mA
Pulse input frequency	0	-	200	kHz
Pulse Width	2.5	-	-	uS

Pulse Voltage	-	5	-	VDC
Isolation resistance	500			MΩ

Operating Environment and other Specifications

Cooling	Natural Cooling or Forced cooling	
Operating Environment	Environment	Avoid dust, oil fog and corrosive gases
	Ambient Temperature	0℃ — 50℃
	Humidity	40%RH — 90%RH
	Operating Temperature	70℃ Max
	Vibration	5.9m/s² Max
Storage Temperature	-20℃ — 65℃	
Weight	Approx. 620g (21.9oz)	

Mechanical Specifications

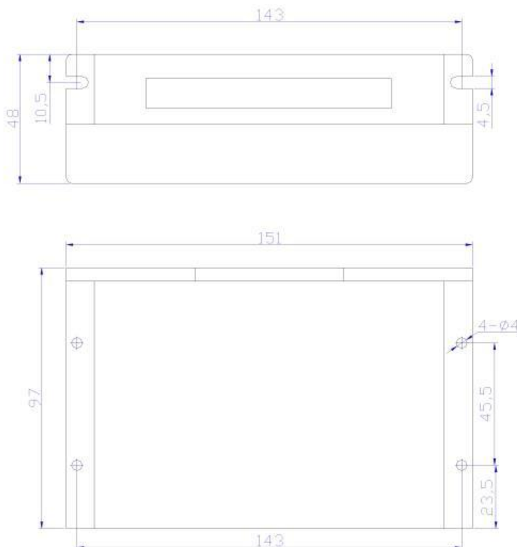


Figure 1: Mechanical specifications
***Recommend use side mounting for better heat dissipation**

Elimination of Heat

- Driver's reliable working temperature should be <70℃(158℉), and motor working temperature should be <80℃(176℉);
- It is recommended to use automatic idle-current mode, namely current automatically reduce to 50% when motor stops, so as to reduce driver heating and motor heating;
- It is recommended to mount the driver vertically to maximize heat sink area. Use forced cooling method to cool

the system if necessary.

3. Pin Assignment and Description

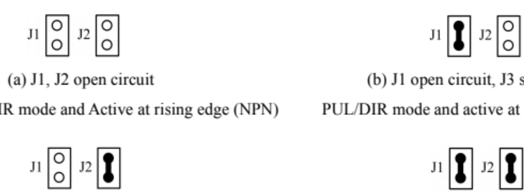
The DMA860H has two connectors, connector P1 for control signals connections, and connector P2 for power and motor connections. The following tables are brief descriptions of the two connectors. More detailed descriptions of the pins and related issues are presented in section 4, 5, 9.

Connector P1 Configurations

Pin Function	Details
PUL+	Pulse signal: In single pulse (pulse/direction) mode, this input represents pulse signal, each rising or falling edge active (set by inside jumper J1); 4.5-5V when PUL-HIGH, 0-0.5V when PUL-LOW. In CW/CCW mode (set by inside jumper J2), this input represents clockwise (CW) pulse. For reliable response, pulse width should be longer than 2.5μs.
PUL-	
DIR+	DIR signal: In single-pulse mode, this signal has low/high voltage levels, representing two directions of motor rotation; in CW/CCW mode (set by inside jumper J2), this signal is counter-clock (CCW) pulse. For reliable motion response, DIR signal should be ahead of PUL signal by 5μs at least. 4.5-5V when DIR-HIGH, 0-0.5V when DIR-LOW. Please note that rotation direction is also related to motor-driver wiring match. Exchanging the connection of two wires for a coil to the driver will reverse motion direction.
DIR-	
ENA+	Enable signal: This signal is used for enabling/disabling the driver. High level (NPN control signal, PNP and differential control signals are on the contrary, namely low level for enabling.) for enabling the driver and low level for disabling the driver. Usually left **UNCONNECTED (ENABLED)**.
ENA-	

Selecting Active Pulse Edge or Active Level and Control Signal Mode

There are two jumpers J1 and J2 inside the DMA860H specifically for selecting active pulse edge and control signal mode, as shown in figure 2. Default setting is PUL/DIR mode and upward-rising edge active. (Note: J3 inside the driver is used to reverse the default rotation direction.)



(a) J1, J2 open circuit
PUL/DIR mode and Active at rising edge (NPN)

(b) J1 open circuit, J3 shirt circuit
PUL/DIR mode and active at falling edge (NPN)

(c) J1 short circuit, J3 open circuit
CW/CCW mode and Active at rising edge (NPN)

(d) J1, J3 short circuit
CW/CCW mode and active at falling edge (NPN)

Figure 2: J1 and J2 jumper Settings

Connector P2 Configurations

Pin Function	Details
AC	Power supply, 18~80 VAC or 26-113VDC, Including voltage fluctuation and EMF voltage.
AC	
A+, A-	Motor Phase A
B+, B-	Motor Phase B

4. Control Signal Connector (P1) Interface

The DMA860H can accept differential and single-ended inputs (including open-collector and PNP output). The DMA860H has 3 optically isolated logic inputs which are located on connector P1 to accept line driver control signals. These inputs are isolated to minimize or eliminate electrical noises coupled onto the drive control signals. Recommend use line driver control signals to increase noise immunity of the driver in interference environments. In the following figures, connections to open-collector and PNP signals are illustrated.

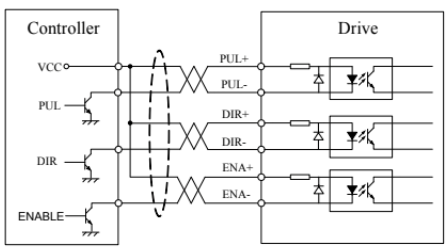


Figure 3: Connections to open-collector signal (common-anode)

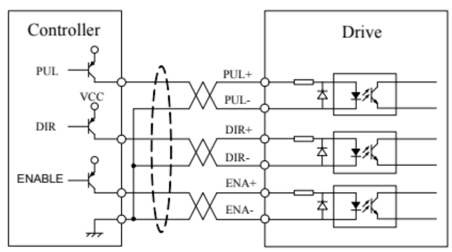


Figure 4: Connection to PNP signal (common-cathode)

5. Connecting the Motor

The DMA860H can drive any 2-pahse and 4-pahse hybrid stepping motors.

Connections to 4-lead Motors

4 lead motors are the least flexible but easiest to wire. Speed and torque will depend on winding inductance. In setting the driver output current, multiply the specified phase current by 1.4 to determine the peak output current.

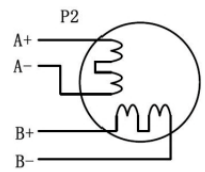


Figure 5: 4-lead Motor Connections

Connections to 6-lead Motors

Like 8 lead stepping motors, 6 lead motors have two configurations available for high speed or high torque operation. The higher speed configuration, or half coil, is so described because it uses one half of the motor's inductor windings. The higher torque configuration, or full coil, uses the full windings of the phases.

Half Coil Configurations

As previously stated, the half coil configuration uses 50% of the motor phase windings. This gives lower inductance, hence, lower torque output. Like the parallel connection of 8 lead motor, the torque output will be more stable at higher speeds. This configuration is also referred to as half chopper. In setting the driver output current multiply the specified per phase (or unipolar) current rating by 1.4 to determine the peak output current.

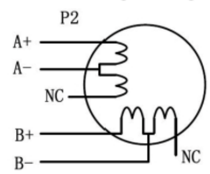


Figure 6: 6-lead motor half coil (higher speed) connections

Full Coil Configurations

The full coil configuration on a six lead motor should be used in applications where higher torque at lower speeds is desired. This configuration is also referred to as full copper. In full coil mode, the motors should be run at only 70% of their rated current to prevent over heating.

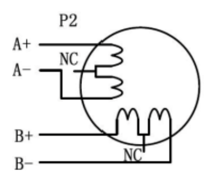


Figure 7: 6-lead motor full coil (higher torque) connections

Connections to 8-lead Motors

8 lead motors offer a high degree of flexibility to the system designer in that they may be connected in series or parallel, thus satisfying a wide range of applications.

Series Connections

A series motor configuration would typically be used in applications where a higher torque at lower speeds is required. Because this configuration has the most inductance, the performance will start to degrade at higher speeds. In series mode, the motors should also be run at only 70% of their rated current to prevent over heating.

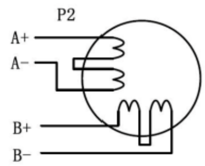


Figure 8: 8-lead motor series connections

Parallel Connections

An 8 lead motor in a parallel configuration offers a more stable, but lower torque at lower speeds. But because of the lower inductance, there will be higher torque at higher speeds. Multiply the per phase (or unipolar) current rating by 1.96, or the bipolar current rating by 1.4, to determine the peak output current.

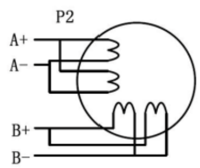


Figure 9: 8-lead motor parallel connections

6. Power Supply Selection

The DMA860H can match medium and small size stepping motors (from NEMA frame size 17 to 34) made by Leadshine or other motor manufactures around the world. To achieve good driving performances, it is important to select supply voltage and output current properly. Generally speaking, supply voltage determines the high speed performance of the motor, while output current determines the output torque of the driven motor (particularly at lower speed). Higher supply voltage will allow higher motor speed to be achieved, at the price of more noise and heating. If the motion speed requirement is low, it's better to use lower supply voltage to decrease noise, heating and improve reliability.

Regulated or Unregulated Power Supply

Both regulated and unregulated power supplies can be used to supply the driver. However, unregulated power supplies are preferred due to their ability to withstand current surge. If regulated power supplies (such as most switching supplies.) are indeed used, it is important to have large current output rating to avoid problems like current clamp, for example using 4A supply for 3A motor-driver operation. On the other hand, if unregulated supply is used, one may use a power supply of lower current rating than that of motor (typically 50%～70% of motor current). The reason is that the driver draws current from the power supply capacitor of the unregulated supply only during the ON duration of the PWM cycle, but not during the OFF duration. Therefore, the average current withdrawn from power supply is considerably less than motor current. For example, two 3A motors can be well supplied by one power supply of 4A rating.

Multiple Drivers

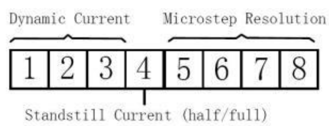
It is recommended to have multiple drivers to share one power supply to reduce cost, if the supply has enough capacity. To avoid cross interference, DO NOT daisy-chain the power supply input pins of the drivers. (Instead, please connect them to power supply separately.)

Selecting Supply Voltage

The power MOSFETS inside the DMA860H can actually operate within +24 ~ +80VDC, including power input fluctuation and back EMF voltage generated by motor coils during motor shaft deceleration. Higher supply voltage can increase motor torque at higher speeds, thus helpful for avoiding losing steps. However, higher voltage may cause bigger motor vibration at lower speed, and it may also cause over-voltage protection or even driver damage. Therefore, it is suggested to choose only sufficiently high supply voltage for intended applications, and it is suggested to use power supplies with theoretical output voltage of +20 ~ +68VDC, leaving room for power fluctuation and back-EMF.

7. Selecting Microstep Resolution and Driver Output Current

This driver uses an 8-bit DIP switch to set microstep resolution, and motor operating current, as shown below:



Microstep Resolution Selection

Microstep resolution is set by SW5, 6, 7, 8 of the DIP switch as shown in the following table:

Microstep	Steps/rev.(for 1.8°motor)	SW5	SW6	SW7	SW8
2	400	ON	ON	ON	ON
4	800	OFF	ON	ON	ON
8	1600	ON	OFF	ON	ON
16	3200	OFF	OFF	ON	ON
32	6400	ON	ON	OFF	ON
64	12800	OFF	ON	OFF	ON
128	25600	ON	OFF	OFF	ON
256	51200	OFF	OFF	OFF	ON
5	1000	ON	ON	ON	OFF
10	2000	OFF	ON	ON	OFF
20	4000	ON	OFF	ON	OFF
25	5000	OFF	OFF	ON	OFF
40	8000	ON	ON	OFF	OFF
50	10000	OFF	ON	OFF	OFF
100	20000	ON	OFF	OFF	OFF
200	40000	OFF	OFF	OFF	OFF

Current Settings

For a given motor, higher driver current will make the motor to output more torque, but at the same time causes more heating in the motor and driver. Therefore, output current is generally set to be such that the motor will not overheat for long time operation.

Since parallel and serial connections of motor coils will significantly change resulting inductance and resistance, it is therefore important to set driver output current depending on motor phase current, motor leads and connection methods. Phase current rating supplied by motor manufacturer is important in selecting driver current, however the selection also depends on leads and connections.

The first three bits (SW1, 2, 3) of the DIP switch are used to set the dynamic current. Select a setting closest to your motor's required current.

Dynamic Current Setting

REF Current	Peak Current	SW1	SW2	SW3
2.00A	2.40A	ON	ON	ON
2.57A	3.08A	OFF	ON	ON
3.14A	3.77A	ON	OFF	ON
3.71A	4.45A	OFF	OFF	ON
4.28A	5.14A	ON	ON	OFF
4.86A	5.83A	OFF	ON	OFF
5.43A	6.52A	ON	OFF	OFF
6.00A	7.20A	OFF	OFF	OFF

Notes: Due to motor inductance, the actual current in the coil may be smaller than the dynamic current setting, particularly under high speed condition.

Standstill Current Setting

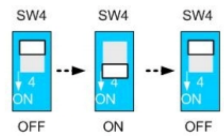
SW4 is used for this purpose. OFF meaning that the standstill current is set to be half of the selected dynamic current, and ON meaning that standstill current is set to be the same as the selected dynamic current.

The current automatically reduced to 50% of the selected dynamic current one second after the last pulse. Theoretically, this will reduce motor heating to 36% (due to $P=I^2*R$) of the original value. If the application needs a different standstill current, please contact Leadshine.

Auto Tuning by SW4

To get the optimized performance, switch SW4 two times in one second to identify the motor parameter after power-up if it is the first time installation. The motor parameter is identified and the drive's current loop parameters are calculated automatically when SW4 is activated. The motor shaft will have a little vibration during auto-configuration. If the user changes the motor or the power supply, don't forget to toggle SW4 once again.

Auto Tuning Requirement and Procedure:
1. Motor is connected to drive.
2. Power is connected to drive.
3. Turn on the power.
4. Make sure there is no pulse applied to drive.
5. Switch SW4 two times in one second. That is OFF-ON-OFF or ON-OFF-ON.



8. Wiring Notes

- In order to improve anti-interference performance of the driver, it is recommended to use twisted pair shield cable.
- To prevent noise incurred in PUL/DIR signal, pulse/direction signal wires and motor wires should not be tied up together. It is better to separate them by at least 10 cm, otherwise the disturbing signals generated by motor will easily disturb pulse direction signals, causing motor position error, system instability and other failures.
- If a power supply serves several drivers, separately connecting the drivers is recommended instead of daisy-chaining.
- It is prohibited to pull and plug connector P2 while the driver is powered ON, because there is high current flowing through motor coils (even when motor is at standstill). Pulling or plugging connector P2 with power on will cause extremely high back-EMF voltage surge, which may damage the driver.

9. Typical Connection

A complete stepping system should include stepping motor, stepping driver, power supply and controller (pulse generator). A typical connection is shown as figure 10.

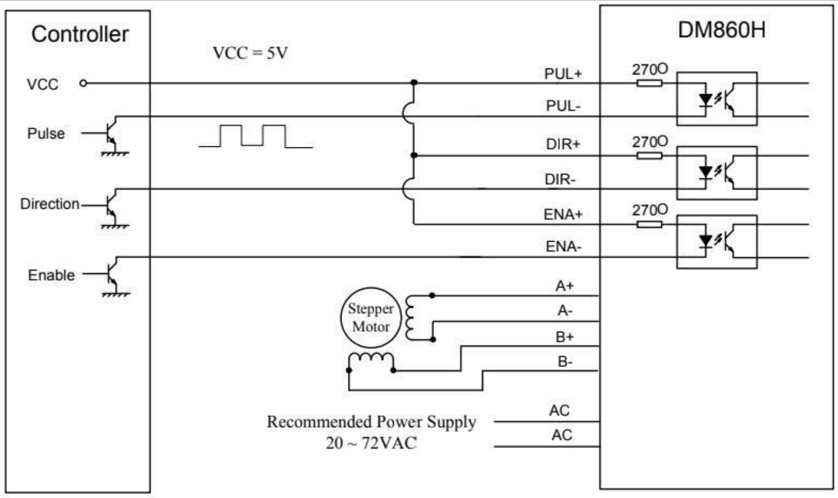


Figure 10: Typical connection

10. Sequence Chart of Control Signals

In order to avoid some fault operations and deviations, PUL, DIR and ENA should abide by some rules, shown as following diagram:

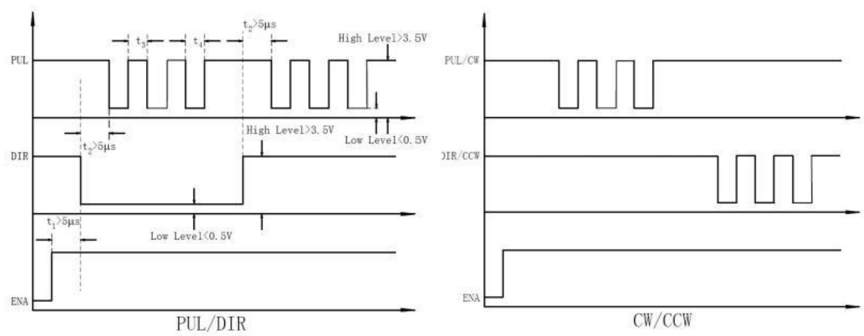


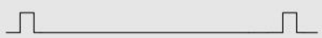
Figure 11: Sequence chart of control signals

Remark:

a) t1: ENA must be ahead of DIR by at least 5µs. Usually, ENA+ and ENA- are NC (not connected). See "Connector P1 Configurations" for more information.
b) t2: DIR must be ahead of PUL effective edge by 5µs to ensure correct direction;
c) t3: Pulse width not less than 2.5µs;
d) t4: Low level width not less than 2.5µs.

11. Protection Functions

To improve reliability, the driver incorporates some built-in protections features.

Priority	Time(s) of Blink	Sequence wave of red LED	Description
1st	1		Over-current protection activated when peak current exceeds the current limit.
2nd	2		Over-voltage protection activated when drive working voltage exceeds the voltage limit.

When above protections are active, the motor shaft will be free or the red LED blinks. Reset the driver by repowering it to make it function properly after removing above problems.

12. Frequently Asked Questions

In the event that your driver doesn't operate properly, the first step is to identify whether the problem is electrical or mechanical in nature. The next step is to isolate the system component that is causing the problem. As part of this process you may have to disconnect the individual components that make up your system and verify that they operate independently. It is important to document each step in the troubleshooting process. You may need this documentation to refer back to at a later date, and these details will greatly assist our Technical Support staff in determining the problem should you need assistance.

Many of the problems that affect motion control systems can be traced to electrical noise, controller software errors, or mistake in wiring.

Problem Symptoms and Possible Causes

Symptoms	Possible Problems
Motor is not rotating	No power
	Microstep resolution setting is wrong
	DIP switch current setting is wrong
	Fault condition exists

	The driver is disabled
Motor rotates in the wrong direction	Motor phases may be connected in reverse
The driver in fault	DIP switch current setting is wrong
	Something wrong with motor coil
Erratic motor motion	Control signal is too weak
	Control signal is interfered
	Wrong motor connection
	Something wrong with motor coil
	Current setting is too small, losing steps
Motor stalls during acceleration	Current setting is too small
	Motor is undersized for the application
	Acceleration is set too high
	Power supply voltage too low
Excessive motor and driver heating	Inadequate heat sinking / cooling
	Automatic current reduction function not being utilized
	Current is set too high

APPENDIX

Twelve Month Limited Warranty

Leadshine Technology Co., Ltd. warrants its products against defects in materials and workmanship for a period of 12 months from shipment out of factory. During the warranty period, Leadshine will either, at its option, repair or replace products which proved to be defective.

Exclusions

The above warranty does not extend to any product damaged by reasons of improper or inadequate handlings by customer, improper or inadequate customer wirings, unauthorized modification or misuse, or operation beyond the electrical specifications of the product and/or operation beyond environmental specifications for the product.

Obtaining Warranty Service

To obtain warranty service, a returned material authorization number (RMA) must be obtained from customer service at e-mail: tech@leadshine.com before returning product for service. Customer shall prepay shipping charges for products returned to Leadshine for warranty service, and Leadshine shall pay for return of products to customer.

Warranty Limitations

Leadshine makes no other warranty, either expressed or implied, with respect to the product. Leadshine specifically disclaims the implied warranties of merchantability and fitness for a particular purpose. Some jurisdictions do not allow limitations on how long and implied warranty lasts, so the above limitation or exclusion may not apply to you. However, any implied warranty of merchantability or fitness is limited to the 12-month duration of this written warranty.

Shipping Failed Product

If your product fail during the warranty period, e-mail customer service at tech@leadshine.com to obtain a returned material authorization number (RMA) before returning product for service. Please include a written description of the problem along with contact name and address. Send failed product to distributor in your area or: Leadshine Technology Co., Ltd. 3/F, Block 2, Nanyou Tianan Industrial Park, Nanshan Dist, Shenzhen, China. Also enclose information regarding the circumstances prior to product failure.

Contact Us

China Headquarters
Address: 3/F, Block 2, Nanyou Tianan Industrial Park, Nanshan District Shenzhen, China
Web: http://www.leadshine.com

Sales Hot Line:
Tel: 86-755-2643 4369 (for All)
86-755-2641-7674 (for Asia, Australia, Africa areas)
86-755-2640-9254 (for Europe, America areas)
Fax: 86-755-2640-2718
Email: sales@leadshine.com.

Technical Support:
Tel: 86 755-2641-8447 and 86-755-2647-1129
Fax: 86-755-2640-2718
Email: tech@leadshine.com.

Leadshine U.S.A
Address: 25 Mauchly, Suite 318 Irvine, California 92618
Tel: 1-949-608-7270
Fax: 1-949-608-7298
Web: http://www.leadshineUSA.com
Email: sales@leadshineUSA.com and support@leadshineUSA.com.

Leadshine Hong Kong
Address: Rm 3, 9/F, Block E, Wah Lok Industrial Center,31-41 Shan Mei St., Fo Tan, Shatin, Hong Kong
Tel: 852-2952-9114
Fax: 852-2952-9395
Email: hk_sales@leadshine.com.