

**CZECH TECHNICAL UNIVERSITY IN PRAGUE**

**FACULTY OF MECHANICAL ENGINEERING**

**DEPARTMENT OF INSTRUMENTATION AND CONTROL ENGINEERING**



**MASTER THESIS**

**ELECTRONICS AND CONTROL SYSTEM FOR LASER CUTTER**

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Master's thesis title in English:

**Electronics and control system for Laser cutter**

Master's thesis title in Czech:

**Elektronika a řídicí systém pro laserovou řezačku**

Guidelines:

The goal is to rebuild and old printed circuit board plotter into a cnc laser cutter for plastics. Expected CO2 laser power around 40 W or more.

Tasks

- 1) Specify required electrical components and their parameters
- 2) Install and test all electrical component of the control system
- 3) Configure and program the Smoothieboard control board
- 4) Make the machine fully functional and show the functionality on few cut parts

Bibliography / sources:

- [1] Smoothieboards, online <<http://smoothieware.org/smoothieboard>>, accessed 26.10.2018  
[2] Laser Cutter 101, online <<https://github.com/Obrary/ebook-laser-cutter-101/raw/master/eBook/Laser-Cutter-101-eBook.pdf>>, accessed 26.10.2018,

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The student acknowledges that the master's thesis is an individual work. The student must produce his thesis without the assistance of others, with the exception of provided consultations. Within the master's thesis, the author must state the names of consultants and include a list of references.

26.04.2019  
Date of assignment receipt



Student's signature

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I declare that I have worked on this thesis independently assuming that the results of the thesis can also be used at the discretion of the supervisor of the thesis as its co-author.

I also agree with the potential publication of the results of the thesis or of its substantial part, provided I will be listed as the co-author.

Prague,

Signature:  11.06.2019

## **ACKNOWLEDGMENT**

For accomplishing this thesis, I am indebted to a few people who I would like to acknowledge here.

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Lastly, I would like to thank my family and friends for their constant encouragement and moral support they have given to me for finishing this thesis successfully on time.

## **ABSTRACT**

This thesis deals with the conversion of an old PCB plotter into an automated Laser Cutting machine. The main tasks involved will be to upgrade the mechanics and install and configure the electronics and control system for the machine. The movement of the axes has been done by the use of stepper motors and the control has been achieved by using a smoothieboard. Instructions to the smoothieboard will be in the form of G-code which will be generated by using a CAM software.

Keywords: Laser Cutter, Stepper motor, Smoothie board, Laser tube, Optics, CNC, G-Code.

## **ABSTRAKT**

Tato diplomová práce se zabývá přeměnou starého PCB plotru na automatizovaný laserový řezací stroj. Hlavním úkolem bude modernizace mechaniky, konfigurace, a také instalace u elektroniky a řídicího systému. Pohyb os je zajištěn krokovými motory, kde ovládání je zajištěno díky smoothie-board. Instrukce/souřadnice pro smoothie-board budou ve formě G-kódu, který bude generován za pomoci CAM softwaru.

Klíčová slova: Laserový řezač, Krokový motor, Smoothieboard, Laserová trubice, Optika, CNC, G-kód

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## SCOPE OF THESIS WORK

The Faculty of Mechanical engineering has in its laboratory an old PCB plotter that is approximately 50 years old. The main aim of my diploma thesis is to refurbish the PCB plotter and convert it into a Laser cutter/engraver with the purpose of the cutting Plexi glass into small components.

The project would be a joint work between the AIRSHIP Club and Department of Instrumentation and Control Engineering with the former taking care of the mechanical construction and the latter configuring the electronics and control system for the Laser Cutter.

Scope of my work involved in it is:

1. Perform a case study of the existing PCB plotter and identify the functioning of its key components.
2. Study the working and technologies of Laser Cutters and the components required to build one.
3. Prepare and propose a Bill of Material to purchase components required.
4. Test and see the possibility of using the existing stepper motors.
5. Install the Electronics for the machine.
6. Configure the Control System for the Laser Cutter using a Smoothie Board controller.
7. Test the working of the system and show functionality of the machine by some cut parts.
8. Prepare the necessary documentation of the Laser cutter.



## ABBREVIATIONS

ADC	Analog to Digital Converter
CO <sub>2</sub>	Carbon-Dioxide
CAM	Computer Aided Manufacturing
CNC	Computer Numerical Control
DAC	Digital to Analog Converter
PCB	Printed Circuit Board
RAM	Random Access Memory
ROM	Read Only Memory
SD-Card	Secure Digital Card
VLSI	Very Large Scale Intergrated
DC	Direct Current
CPU	Central Processing Unit
IO	Input/Output
LCD	Liquid Crystal Display

# 1 INTRODUCTION

## 1.1 Laser Cutting

Laser cutting is a technology that uses a laser to cut materials, and is typically used for industrial manufacturing applications, but recently has been started to be used by schools for research purposes, small businesses, and hobbyists. The main principle in Laser cutting is to cut materials by directing the output of a high-power laser.

The laser optics and CNC are used to direct the laser beam generated onto the material that is to be cut. A typical commercial laser cutter for cutting materials involves a motion control system to follow a G-code of the pattern to be cut. The focused laser beam is directed at the material, which then either melts, burns, vaporizes away, leaving an edge with a high-quality surface finish.

The movement of the laser beam is achieved by the use of Optical Mirrors which are mounted on an X-Y axis table. By coordinated movement of the X-axis and Y-axis, the laser beam can be directed to different parts of the work piece. The displacement of the X-Y axis is generally carried out by motors preferably Stepper Motors which are controlled by a Microcontroller.

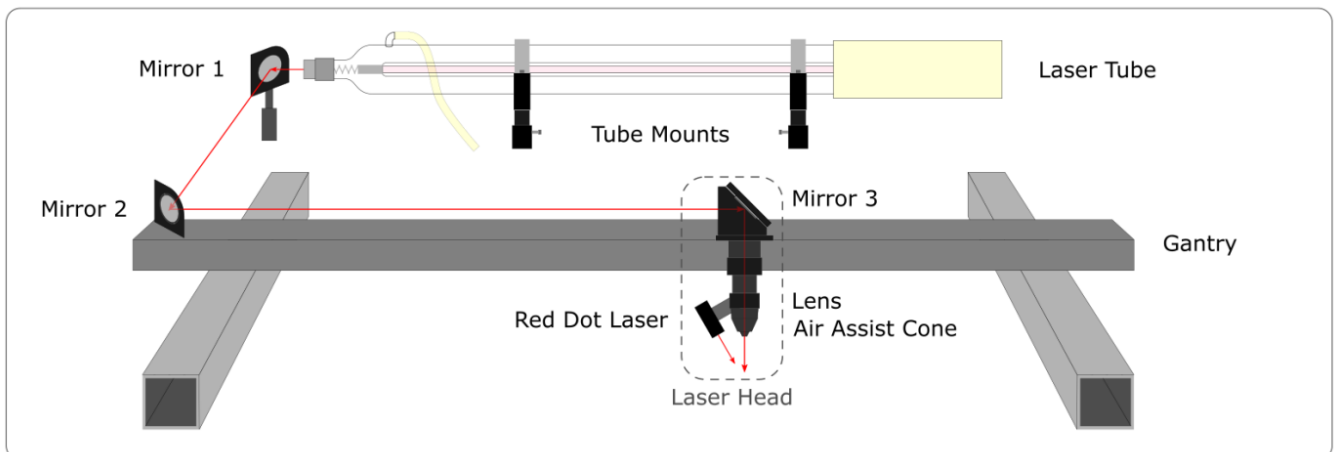


Figure 1: Proposed Model of Laser Cutting System [1]

## 1.2 Microcontroller

A microcontroller is a VLSI integrated circuit that contains Electronic Computing and Logic Unit, Memory, Input-Output ports and few other components integrated on a single chip.

### 1.2.1 Applications

Today, microcontrollers are used in any application where measuring, storing, calculating, controlling and displaying of information is required.

Microcontrollers are used in automatically controlled devices ranging from automotive applications, medical implants, industrial machines to everyday consumer electronics.

### 1.2.2 Basic Structure of Microcontroller

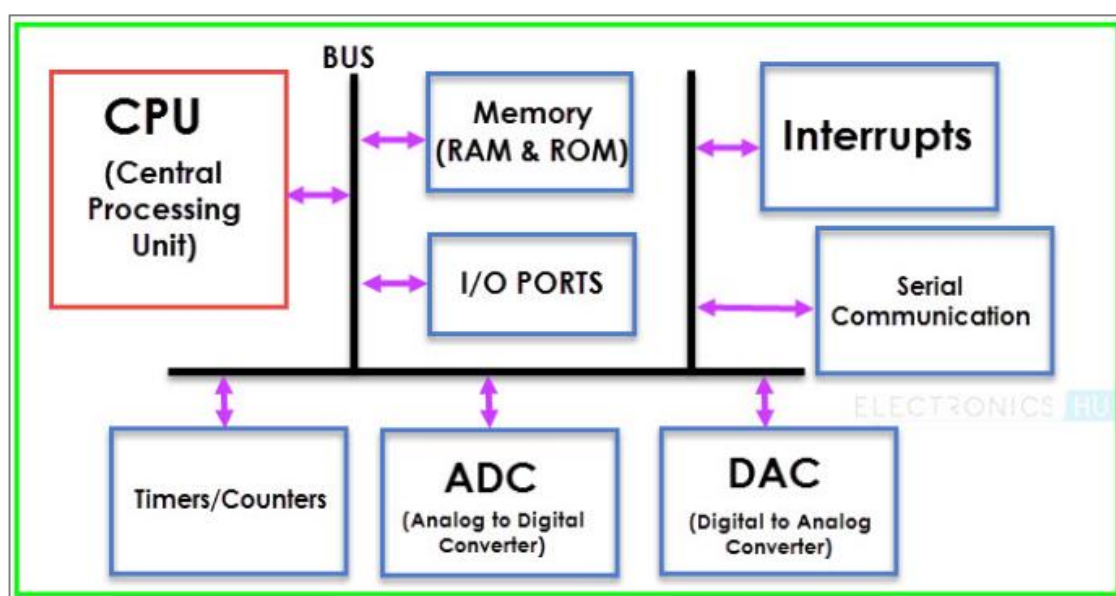


Figure 2: Microcontroller Architecture [2]

The major components of a Microcontroller are as follows:

a. **CPU**

The Central processing unit is the brain of the microcontroller. It consists of an Arithmetic Logic Unit and Control Unit. The CPU reads, interprets and executes instructions which are given to it to perform arithmetic, Logic and Data Transfer operations.

## **b. Memory**

The memory is a very important part of the microcontroller because it stores all temporary data and the instructions for the CPU. All computational systems require two types memory:

**Program Memory:** This memory contains the program or the instructions to be executed by the CPU. The program memory is usually a Read Only Memory (ROM).

**Data Memory:** It holds the temporary data while the CPU is executing the instructions. Data memory is a Random Access Memory (RAM).

## **c. I/O Ports**

The microcontroller communicates to the external world via IO ports. The CPU receives information through input devices processes them and then provides the results through output devices.

## **d. BUS**

The bus is the medium through which the CPU, memory, IO ports and other supporting components communicate. There are different buses for different purposes for example Data bus, Control bus and Instruction bus.

## **e. Timers/Counters:**

An additional important feature of Microcontroller is Timers and Counters. They provide for the Time Delay and Counting operations. It is through this component that the microcontroller carries out functions like Pulse Width Modulation and clock control.

## **f. Serial Port**

The serial Port provides for serial communication with external devices and peripherals.

## **g. Interrupts**

All control processes are subjected to events that can deviate the controller of its functions. To be able to deal with this, all microcontrollers are equipped with interrupt handling mechanism to handle these fast asynchronous events.

## **h. ADC and DAC**

ADC is the circuit that converts analog signals to digital signals so that the CPU can understand them and process it. It is the interface between external analog devices and the microcontroller. Once the CPU has processed them, It feeds the data into the DAC to convert the digital signal to analog signals so that the microcontroller can communicate with the external analog devices.

### **Advantages of Microcontroller's:**

- **Flexibility:** Since they are programmable, they can be used for a wide range of applications.
- **High Speeds:** Since microconrollers are integrated on a single integrated chip, the processing time of instructions is very fast.
- **Inexpensive:** Microccontrollers are relatively inexpensive to manufacture and use. [2]

## **1.3 Stepper Motor**

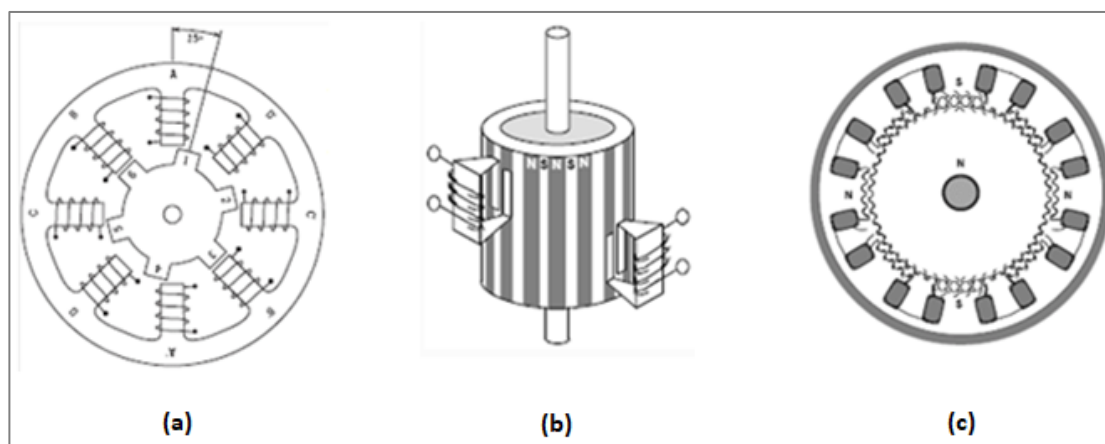
A stepper motor is an electric motor that can divide a full rotation of the shaft into smaller steps. The shaft rotates in discrete steps when electrical pulses are applied to it in a proper sequence. The motor's position can be controlled precisely without any feedback.

Stepper motors are formed by coils and magnets and include a shaft that moves when power is applied. The rotor moves by applying power to different coils in a predetermined sequence. The stepper motor can also hold their position and resist rotation.

The electromagnets of a stepper motor are energized by an external control cicuit called as a stepper motor driver. To make the shaft turn, first one of the electromagnet is given power which makes the gear's teeth magnetically attracted to the electromagnet's teeth. When the gear's teeth are alligned to the first electromagnet, they are slightly offset from the next electromagnet. Thus, when the next electromagnet is turned on and the first one is switched off, the gear rotates to align with the next and by repeating this process the motor runs.

Each of the slight rotations is called step with an integer number of steps making a full rotation. By configuring the number of steps, precise control of rotation can be acheived.

### 1.3.1 Types of Stepper Motor's



**Figure 3: Types of Stepper Motor's [3]**

#### **a. Variable Reluctance Stepper**

The simplest type of Stepper motors. Consist of soft iron multi-toothed rotor and a wound stator. When DC voltage is applied to the stator windings, the poles become magnetized. Rotation occurs when the rotor tooth are attracted to the magnetized stator poles. The motors of this type are usually small and light hence making them faster but they have small torque.

#### **b. Permanent Magnet Stepper**

Motors of this type have a permanent magnets added to their motor structure. Unlike the Variable Reluctance type, the rotor does not have teeth. Instead the rotor is magnetized with alternating north and south poles situated in a straight line parallel to the rotor shaft. These magnetized rotor poles account for an increased magnetic flux intensity and due to this this type of motor has larger torque than the variable reluctance type.

#### **c. Hybrid Synchronous Stepper**

It is a combination of both the variable reluctance and permanent magnet types. The rotor of this type is a multi-toothed like the variable reluctance stepper and it contains an axially magnetized concentric magnet around its shaft. [3]

### 1.3.2 Types of Stepper Motor Winding

Stepper motors can be divided into two classes depending on the type of winding as Unipolar steppers and Bipolar Steppers.

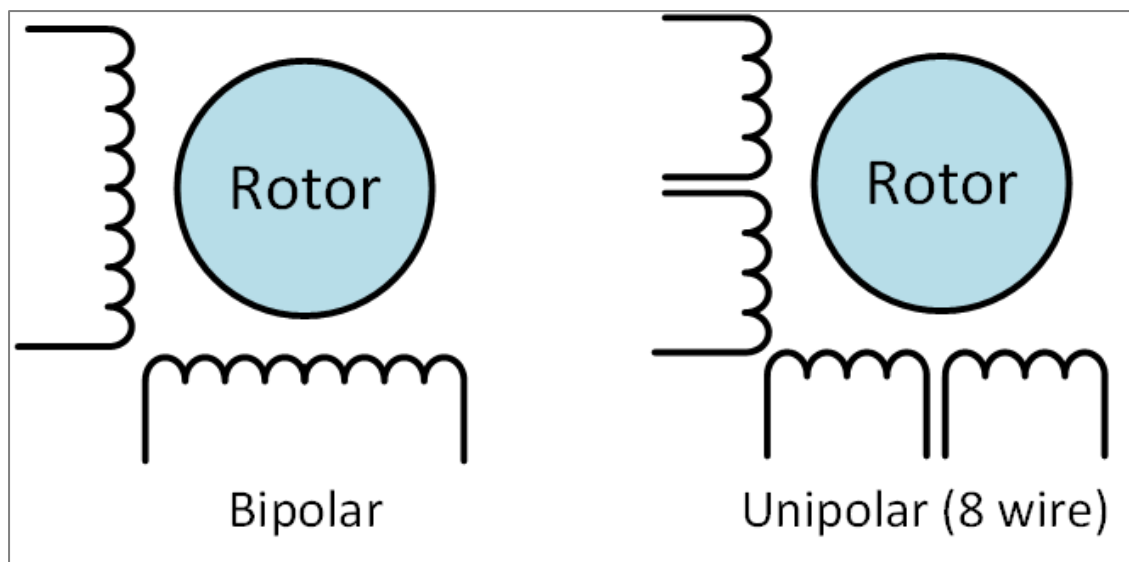


Figure 4: Types of Stepper Motor Winding [4]

#### a. Unipolar Steppers

Unipolar stepper motors have a single winding with a centre per phase. Each section of the windings is switched on for each direction of the magnetic field. Due to this arrangement, a magnetic pole can be reversed without reversing the direction of the current. The centre tap of each motor is made common resulting in six leads for a typical two phase motor.

#### b. Bipolar Steppers

Bipolar stepper motors have a single winding per phase. Unlike the unipolar stepper motor, to reverse the magnetic pole, the current in a winding needs to be reversed. To achieve this, a more complicated circuit is required. There are two leads per phase and none of them are connected in common. Hence for a typical two phase motor, there will be four leads. [4]

## Advantages of Stepper Motors:

- **Positioning:** Since stepper motors are moving in precise repeatable steps, they excel in applications requiring precise positioning such as 3D printers, CNC machines, X-Y plotters.
- **Speed Control:** The precise increments of movement also allow for excellent control of rotational speed for process automation and robotics.
- **Low Speed Torque:** Normal DC motors don't have very much torque at low speeds. A stepper motor has maximum torque at low speeds, so they are a good choice for applications requiring low speed with high precision.

## Disadvantages of Stepper Motors:

- **Low efficiency:** Unlike DC motors, stepper motor current consumption is independent of load. They draw the most current when they are doing no work at all. Because of this, they tend to run hot.
- **Limited High Speed Torque:** In general, stepper motors have less torque at high speeds than at low speeds. Some stepper can be optimized for better high speed performance but they need to be paired with an appropriate driver to achieve that performance.
- **Feedback Absent:** Unlike Servo motors, most stepper motors do not have integral feedback for position.

## 1.4 Stepper Motor Driver

A Stepper motor driver is a circuit or device that provides the necessary current and voltage to a stepper motor so that it has smooth operation.

A stepper motor rotates precisely by synchronising the pulse signals from a controller which are given through a driver. A stepper motor driver is a circuit that takes the pulse signals from a controller and converts them into a stepper motor motion.

While some basic drive units only supply power, many of the drives that are used in the industry incorporate with it controller electronics into a complete package. These electronics often include logic sequencer, switching components and a clock pulse to determine step rates.



## 1.4.1 Types of stepper motors drives

The type of the driver that is chosen to drive the motor has a large influence on the performance of the stepper motors performance especially on its torque, output power and speed.

Stepper motor drives can be distinguished mainly by three main properties:

1. Motor Winding Arrangement
2. Drive Circuitry
3. Step Mode

### 1. Motor Winding Arrangement

#### a. Unipolar Arrangement

In drives for unipolar stepper motors, instead of reversing the current in each phase, the drive simply switches current from one coil to the other in each phase. Due to its winding configuration, the switching reverses the magnetic field in the motor.

#### b. Bipolar Arrangement

In drivers for Bipolar motors, the electronics in the driver alternately reverse the current in each phase to drive the rotor. The electronics for bipolar drivers are more complex and sometimes more expensive than unipolar drivers.

### 2. Drive Circuitry

The Drive Circuitry can be configured either as Constant voltage or constant current.

#### a. Constant Voltage ( L/R Drive Circuits)

They are called constant voltage drives because a positive or negative voltage is applied to each winding to set the step position. L/R denotes the electrical relationship of inductance(L) to resistance(R) which describes the rate of change of current in L/R circuit motors. Drivers of these circuits can be configured to run both bipolar and unipolar stepper motors. The electronics are also simpler and less expensive when compared to the constant current circuit drivers.

#### b. Constant Current (Chopper Drive Circuits)

These drives generate almost a constant current in each winding. It is named chopper drive circuits because this circuit rapidly switches on and off the the output voltage to control the motor current. Compared to Constant voltage circuits, Constant Current circuits allows stepper motors to maintain greater torque and higher speeds.

### **3. Step Mode**

Step modes include full, half and microsteps. Stepmodes are a key factor to determine the stepper motor's output torque and resolution.

#### **a. Full Step**

In this mode, the motor moves in increments of the actual detent position. It has no of resolution. In full step mode, one digital pulse is equal to one step. The full step is acheived by energizing both windings while reversing the current alternativly. This mode will produce the full rated torque of the motor.

#### **b. Half Step**

In half step mode, one winding is energized and then two windings are energized alternately causing the rotor to rotate half the distance. By doing this, the angular resolution is doubled and the motor will advance to the next magnetic position when power is disconnected.

#### **c. Micro Step**

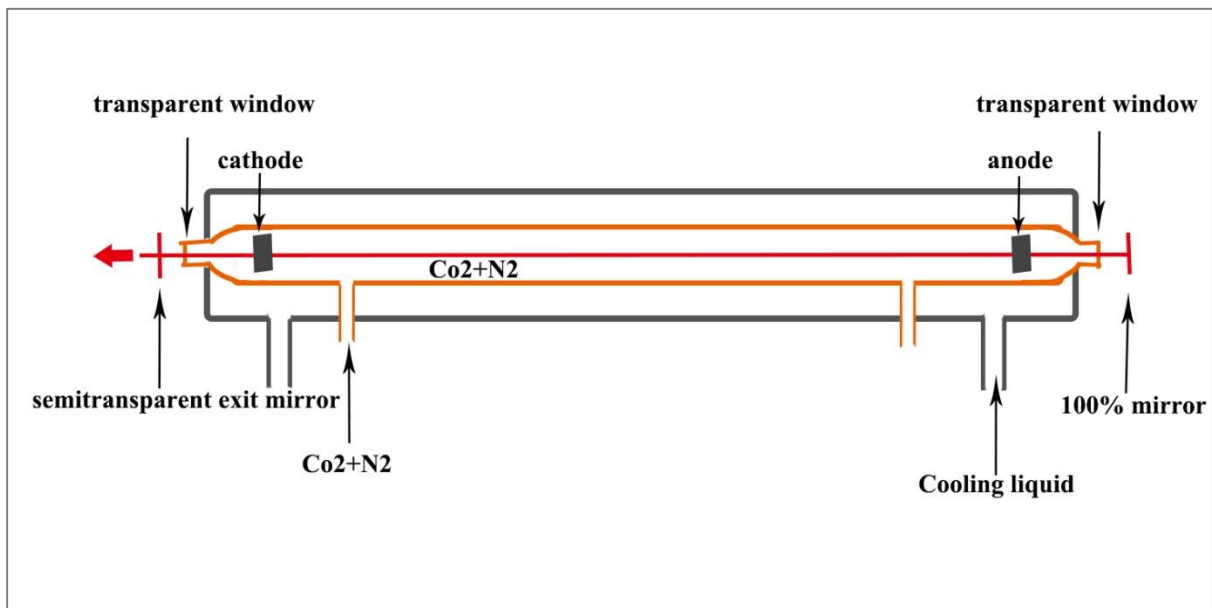
This mode electronically controls the current in the motor winding to a degree that further subdivides the number of positions in between poles which results in the full step being divided into smaller steps. Microstepping mode is used for applications that require accurate positioning and smoother motion over high range of speeds. [5]

## **1.5 Carbon-Dioxide Laser**

Lasers are now coommonly used for the cutting and welding of many materials for industrial applications. They offer high speeds, are more durable and have low levels of noise and fume generation. Two types of laser used mainly for cutting applications are:

1. Carbon Dioxide (CO<sub>2</sub>) Laser
2. Nd-YAG Laser

A CO<sub>2</sub> laser is a type of gas laser. In this device, electricity is run through a gas-filled tube, producing light. The ends of the tube are mirrors; one of which is fully reflective and the other one is semi transparent. The gas mixture is generally comprised of carbon dioxide, nitrogen, hydrogen and helium. Light produced by CO<sub>2</sub> lasers is invisible, falling in the far infrared range of the light spectrum and has a wavelength of about 10 micrometer.



**Figure 5: CO2 Laser Working Principle [7]**

A CO2 laser is a type of gas laser. In this device, electricity is run through a gas-filled tube, producing light. The ends of the tube are mirrors; one of which is fully reflective and the other which lets some light through. The gas mixture is generally comprised of carbon dioxide, nitrogen, hydrogen and helium. Light produced by CO2 lasers is invisible, falling in the far infrared range of the light spectrum.

When stimulated by electric current, nitrogen molecules in the gas mixture become excited. The high-energy vibrations of the nitrogen in turn excite the carbon dioxide molecules. At this point, the laser achieves a state called population inversion, the point at which a system has more excited particles than non-excited ones. For the laser to produce a beam of light, the nitrogen atoms must lose their excited state by releasing energy in the form of photons. This happens when the excited nitrogen atoms contact the very cold helium atoms, which causes the nitrogen to release light.

The light produced is very powerful compared to normal light and can cut many materials, including cloth, wood and paper; the most powerful CO2 lasers are used for engraving on steel and other metals. [6]

Advantages of CO2 lasers:

1. Very powerful.
2. Less noise produced.
3. Higher safety when compared to other types of lasers.
4. Produces better edge cut quality.
5. More flexibility for cutting different materials.

## 2 CASE STUDY

The existing machine in our subject is a 50 year old PCB plotter which was used to plot Printed Circuit Boards. Although the machine as a whole was not functional, some of the existing parts needed to be tested and verified if it could still be used to build the laser cutter.

### 2.1 Existing Parts

The existing machine had the following components which possibly could have been used:

1. X-Y axis Table
2. Stepper Motors
3. Limit Switches

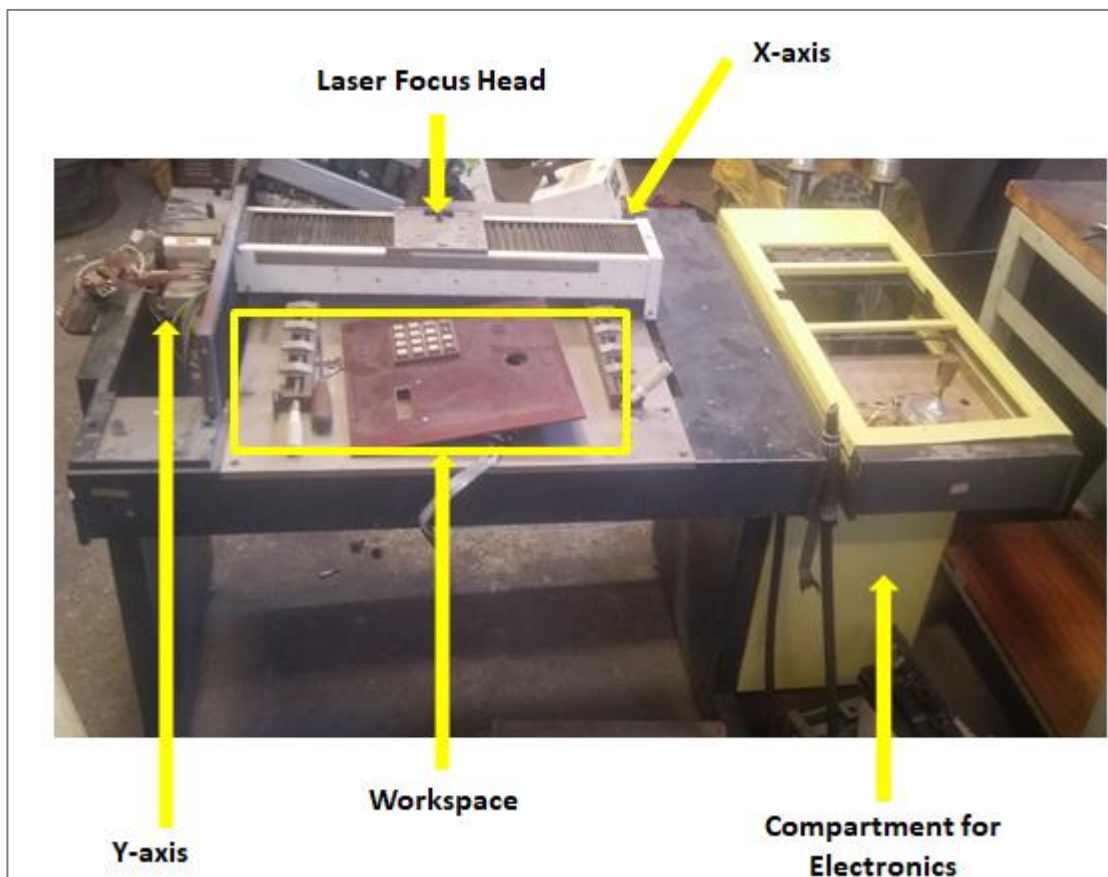


Figure 6: Original State

### 2.1.1 X-Y Axis Table

The existing machine had a very durable X-Y table which was found to be still functional without any mechanical problems or wearing such as rusting. Each of these axes was driven by 2 stepper motors and corresponding gears to combine the torque of both the motors.

The transmission system in the X-Y axis table is made of ball bearing and the ball screw pitch of both axes is 7mm. The maximum displacement length for the X-axis is 410mm and for the Y-axis is 320mm.

### 2.1.2 Stepper Motors

The stepper motors which were available are approximately 50 years old. Because of this we were unable to find any catalogues providing more information about them. Hence we had to test them step by step.

However, we know that these motors are Unipolar motor with 8 leads. The existing PCB plotter had 5 available stepper motors. Two motors for each axis and another motor to adjust the height of the drill head.



**Figure 7: Existing Stepper Motors**

#### Stepper Motors Test 1

In the first test, we tried to find which leads were paired. We did this by measuring the resistance across the leads and we were able to find which leads were paired. We then gave a supply directly to the motors and found that torque was produced in the motors. All 5 motors passed this test.

## Results of Testing

Motor 1	
Ports	Ohms
1-2	41.4
3-4	42.3
5-6	41.5
7-8	42.0

Motor 2	
Ports	Ohms
1-2	40.6
3-4	40.9
5-6	40.8
7-8	41.2

Motor 3	
Ports	Ohms
1-2	42.3
3-4	40.9
5-6	41.0
7-8	40.3

Motor 4	
Ports	Ohms
1-2	40.8
3-4	41.2
5-6	40.8
7-8	41.8

Motor 5	
Ports	Ohms
1-2	42.1
3-4	42.0
5-6	40.4
7-8	40.8

**Table 1: Stepper Motor Testing Results**

## Stepper Motors Test 2

### Conversion from Unipolar to Bipolar Stepper

1. Since unipolar motors are less used these days, it was difficult to find a proper unipolar stepper motor driver with desired specifications like current control.
2. Hence, we decided to convert the unipolar stepper motor into a Bipolar Stepper motor. I did this by parallel connection of the ports.
3. To test the working of it, I connected the motors to a driver and with the help of an Arduino controller we tested the working of the motors.

### Parallel Connection of the Ports

To convert the motors into Bipolar, we parallel connected the ports. In all the five motors, the ports which were connected in parallel are as follows:

1	5
2	6
3	7
4	8

Table 2: Paired Ports of Stepper Motor

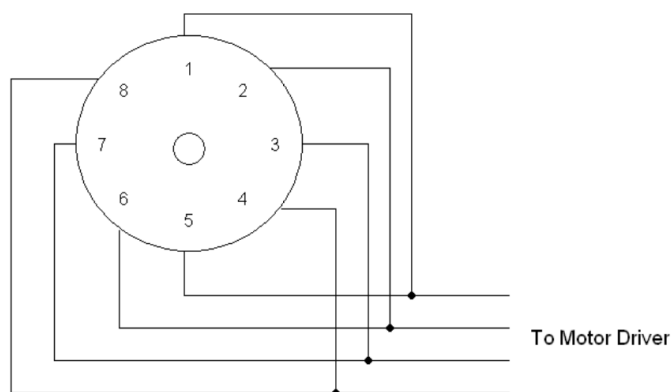


Figure 8: Schematic of Paired Ports

From the second test, we found that, only two of the five stepper motors were working and the other three were faulty. However, even though these two motors were working their torque was less and their general performance was unsatisfactory. **So, it was decided to replace these stepper motors with new and more powerful motors.**

### 2.1.3 Limit Switches

The existing machine had four limit switches. Out of this only the two limit switches for the Y-axis were working. The limit switches for the X-axis had to be replaced.

### 3 COMPONENT DESCRIPTION

#### 3.1 Bill of Material

Item	Brand/Model	Quantity	Cost (Czk)
X-Y Table	-	1	Existing
Stepper Motors	GeeTech	2	592
Stepper Motor Driver	TB6600	2	500
Smoothieboard	Opensource	1	1974
Laser Tube	Tenen	1	2902
Laser Power Supply	Tenen	1	1210
Focusing Lens	Tenen	1	230
Reflective Mirrors	Tenen	3	252
LCD Screen	RepRap	1	203
Limit Switches	Zeppy	2	22
Reflective Dot module	Tenen	1	275
Mirror Mounts	Tenen	3	362
Laser Tube Mount	Tenen	2	585
Water Pump	Tenen	1	275
<b>Total Cost</b>			9382

Table 3: Bill of Material



### 3.2 Stepper Motors



**Figure 9: Stepper Motor [8]**

The drive the stepper motors, we choose existing motors that were already present in the Robotics laboratory. The details of the stepper motors are as follows:

Make: **GEEETECH**

Model: **N42HS3418-24B22**

Quantity: **2 Pieces**

#### **Specifications:**

No of Leads	4
No of Phases	2
Step angle	1.8 degrees
Mass	0.24Kg
Rated Voltage	3.57 V
Rated Current	1.5 A
Torque	1.5 N.m

**Table 4: Stepper Motor Specifications [8]**

### 3.3 Stepper Driver



**Figure 10: Stepper Motor Driver [9]**

To drive the stepper motors, we needed suitable drivers that will do the job. It was necessary, that we needed drivers with in-built current control. After considerations, we finally chose the Industrial standard stepper motor drivers shown on the picture.

**Model : TB6600**

**Quantity : 2 Pieces**

**Features:**

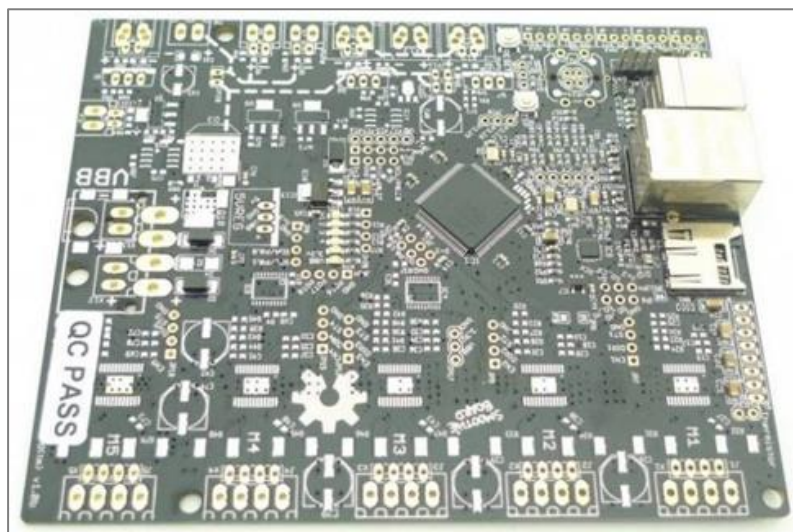
1. Supports 8 kinds of Current Control.
2. Supports 7 levels of microstepping.
3. The interfaces adopt high speed opto-coupler isolation.
4. Large area heat sink.
5. High Frequency isolation.
6. Input anti-reversal protection.
7. Overheat, over current and short circuit protection.

**Specifications:**

Input Current	0 - 5.0 Amps
Output Current	0.5 – 4.0 Amps
Max Power	160 Watts
Microstepping Levels	1, 2/A, 2/B, 4, 8,16, 32
Temperature	-10 – 45°C
Weight	0.2 Kg
Dimension	96*56*33 mm

**Table 5:Stepper Motor Driver Specifications [9]**

### 3.4 Smoothieboard



**Figure 11: Smoothieboard [10]**

The smoothieboard is an open source hardware CNC controller that is designed by a group of volunteers called as the Smoothie community. The main objective of the designing the hardware is to run the smoothieware firmware.

This smoothieware is again a free and open source high performance program that executes on the smoothieboard's microcontroller. The micro-controller receives instructions mainly in form of G-code which is usually generated by a CAM software.

The micro-controller then executes these instructions by powering the stepper motors which control the 2 axes in a coordinated fashion which will direct the laser beam onto the work material and produce desired output.

#### **Advantages of the Smoothieboard:**

1. Has powerful in-built hardware.
2. Possible to control several type of CNC machines ( 3D-printers, Laser cutters, CNC mills & routers.)
3. Easy to setup and user friendly.

There are currently three different versions of smoothieboard available in the market. The version that is used in this thesis is Smoothieboard v1.

## Features of smoothieboard v1:

### Microcontroller:

1. The board uses a Cortex-M3 LPC1769 chip.
2. Specifications of the chip are:
  - 32-bit architecture
  - 120MHz frequency
  - 512kB program memory
  - 64kB RAM
3. This chip allows for more faster and smoother movement of the stepper motors.

### Communication:

The 3 methods of communication with the smoothieboard are through:

#### 1. USB

- Connects as a mass storage and provides direct access to the SD card contents
- Connects serially to the computer to send commands (G-code) using a suitable host software.

#### 2. Ethernet

The ethernet interface allows you to connect the board to your LAN. Two protocols that can be used to communicate with the board are:

- HTTP: To use Web interfaces hosted on the board
- Telnet: To send commands via a serial interface.

#### 3. SD- Card

With the SD-Card option you can directly add G-code files into it and then play them directly from it. This comes very useful in situations where the files are so dense that streaming them to the board via the other two options becomes time consuming.

The SD- card is also used to store the:

- Configuration file that the firmware reads at boot time to setup everything.
- A boot G-code file which is executed when the board starts.
- Web interfaces for access via ethernet interface.

### End Stop Control:

Endstops are small interrupters typically limit switches that are installed at the end of the axes.

When the Laser cutter is powered on, the smoothie does not the current position of each axis. The first thing the smoothie does before it starts to print is to move the axis until it hits the end stop switches. On hitting the end-stops, the smoothie declares that this is the zero position for that axis. The smoothie does this process for both the axes.

The smoothie board is equipped with 6 end stop inputs, 2 for each axes. [10]

### 3.5 CO2 Laser Tube (50 watts)

The main purpose of our laser cutter is to cut Acrylic materials having thickness of atleast 5mm. The power of the Laser Tube choosen has an important role to play in the proper cutting of the acrylic material.

As per theory, a Laser Tube having a power of 10watts can cut 1mm of acrylic material. This is the optimal cutting power ratio for acheiving a reasonable cut of the material.

Hence to cut 5mm of plexiglass material, we will need a laser tube having a power of 50watts. This however does not mean that we cannot use a Laser tube of less power, but in doing so the process will be much slower and the quality of the cut will be improper and when it comes to cutting parts for precision purposes, this can be a huge disadvantage.

So as to have a decent cut and keeping in mind the economic factors, we decided to use a 50 watts laser tube. The laser used and its specifications are below:

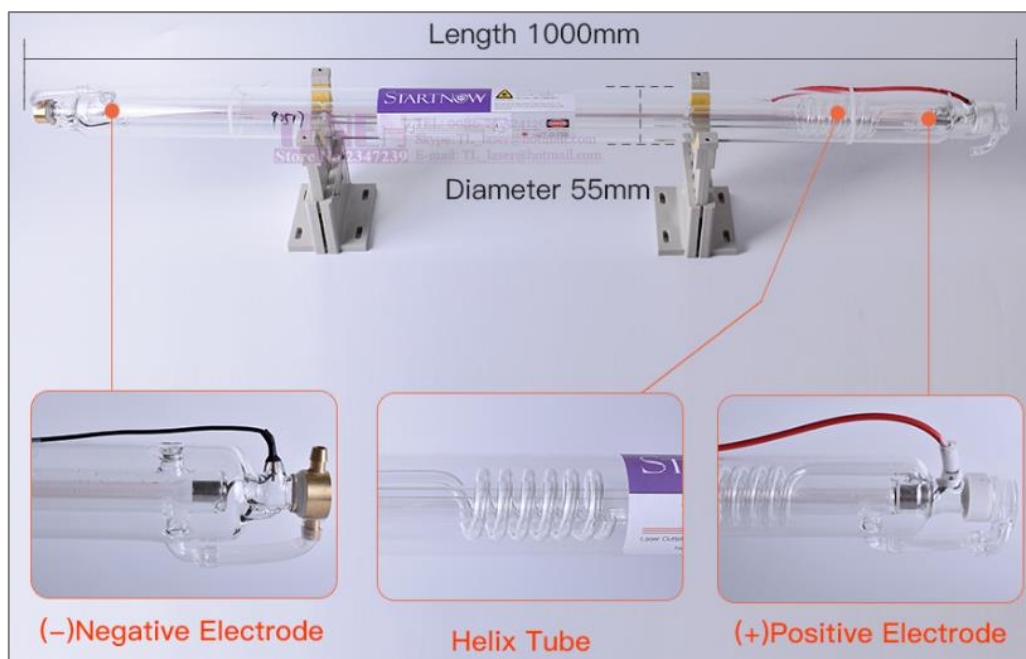


Figure 12: 50 Watts Laser Tube [11]

Make: **TENO**  
Model: **50W-1000-55**  
Quantity: **1 Piece**

**Specifications:**

Rated Power	50 W
Power Range	50 – 60 W
Length	1000mm
Diameter	55mm

**Table 6: Laser Tube Specifications [11]**

### **3.5 CO2 Laser Power Supply**

To power our Laser, we need a compatible Power supply which will provide the power need to fire the laser. Although, we can use a power supply of different power, it is best to use a Power supply with same output power needed by our Laser Tube. In our case, we will need a 50 watts power supply.

Apart from just supplying the Laser with power, it should also provide for control of the laser output. This can be done by the using an in-built TTL level to switch on and switch off the laser output based on control signals from the microcontroller.



**Figure 13: Laser Tube Power Supply [12]**

Make: **TENO**  
Model: **50W-G / MYJG-50W**  
Quantity: **1 Piece**

### Features:

1. Good Compatibility : It can be applicable to 50W laser tubes of different makes.
2. Quick response speed and effect with large cutting power.
3. Easy control : Start and stop of laser can be easily controlled by TTL level.
4. Has a button to test manually.

### Specifications:

Rated Power	50 W
AC Input	110V/220V
DC Output	25KV/18 $\mu$ A
Weight	1Kg
Size	175mm*142mm*78mm

Table 7: Laser Power Specifications [12]

### Connection Diagram:

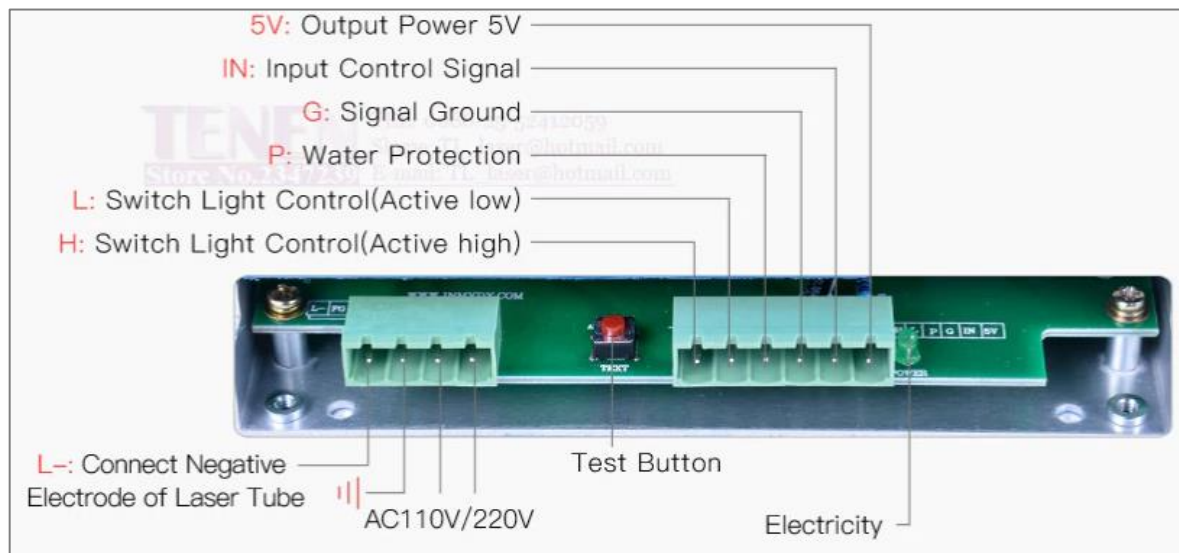


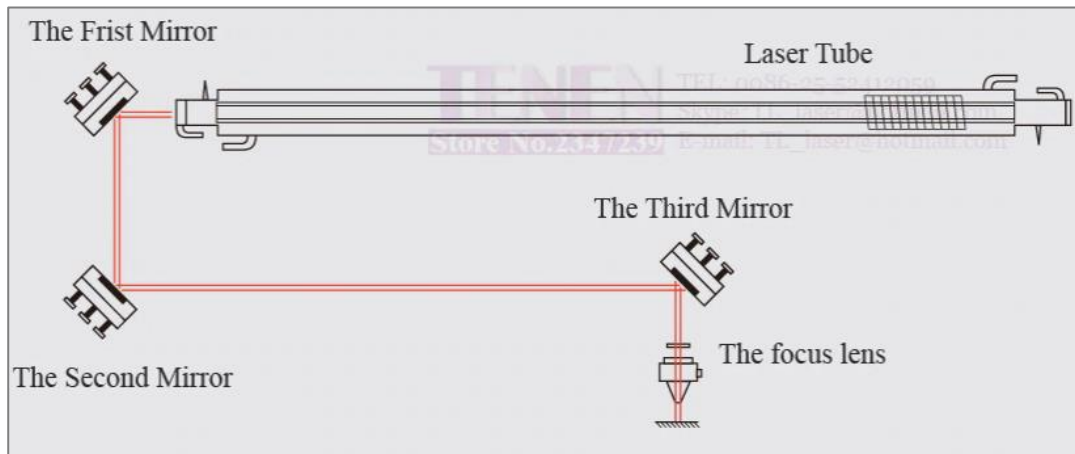
Figure 14: Connection Diagram for Laser Power Supply [12]

## 3.6 Optics

The laser tube will be fixed in a stationary position. It is required to transmit the laser beam onto the work piece to cut it. To do this we have to make use of necessary optics. The necessary optics will consist of:

1. Focusing Lens
2. Reflective Mirrors

To complete a path outside the laser tube, we will need One focusing lens and three reflective mirrors.



**Figure 15: Positioning of Mirrors and Focus Lens [13]**

### 3.6.1 Focusing Lens

Lens play an important role in the cutting of the materials. The lens have different focal lengths which affect their beam radius. It is very important to chose a fousing lens of the right focal length because the Lenses are responsible for the shape and quality of cut edges.

For materials upto 20mm (0.75 inches) in thickness, it is advisable to use a lens having focal length of 2.5 inches (63.5mm)



**Figure 16: Focusing Lens [13]**

Make: **TENEN**  
Model: **Dia 12**  
Quantity: **1 Piece**



**Specifications:**

Material	Zinc Selenide (ZnSe)
Diameter	12mm
Focal Length	63.5mm
Shape	Meniscus
Structure	Plano Convex

**Table 8: Focus Lens Specifications [13]**

**3.6.2 Reflective Mirrors**

The mirrors will propagate the laser beam from the laser tube and onto the focusing lens.



**Figure 17: Reflective Mirror [14]**

Make: **TENEN**  
Model: **Dia.20 Thk.3/5mm**  
Quantity: **3 Pieces**

**Specifications:**

Material	Molybdenum (Mo)
Diameter	12mm
Shape	Circular
Structure	Double flat

**Table 9: Reflective Lens Specifications [14]**

### 3.7 Supporting Components

To put the optics into function, we will need a few supporting components. They are:

#### 3.7.1 LCD SCREEN

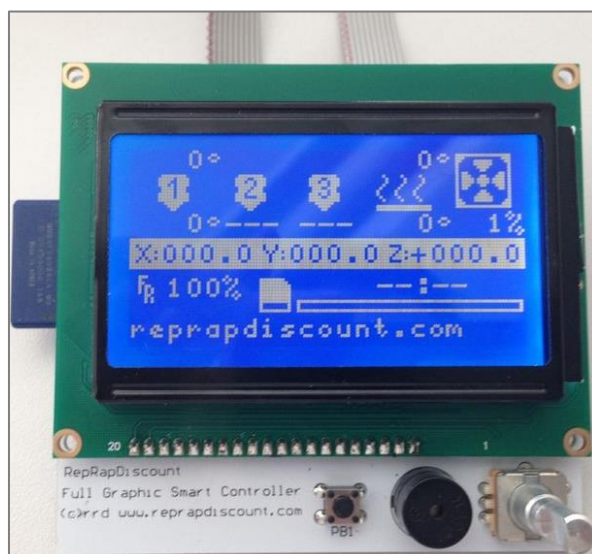


Figure 18: LCD Screen [15]

Make: **REPRAP**

Model: Full Graphic Smart Controller

Quantity: **1 Piece**

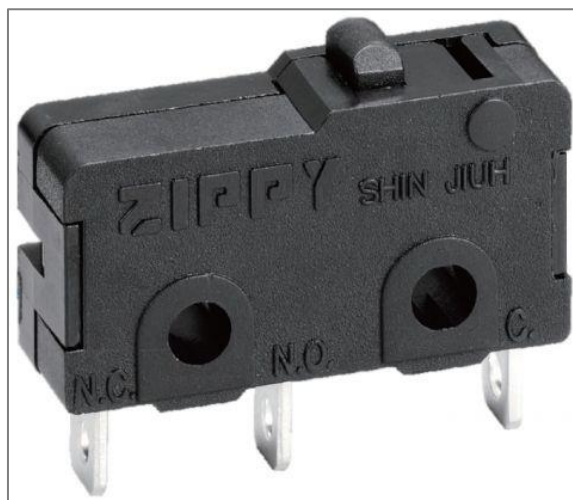
#### Specifications:

Size	128 x 64
Type	Dot Matrix LCD display

Table 10: Specifications of LCD Screen [15]

The full graphic smart controller also includes a SD-card reader from which it can directly read G-Code files stored on it. With this feature, after the LCD has been connected to the Smoothieboard, it can directly control the Laser Cutter without the use of a PC. Actions like calibration, axes movements can be achieved using the rotary encoder.

### 3.7.2 Limit Switches



**Figure 19: Limit Switches [16]**

Limit switches are needed for the homing positions so that the machine is able to recalibrate to its home positions. As each axis hits the limit switch, it sends a signal to the smoothieboard that the axis has homed and then the smoothieboard correspondingly turns off the motor.

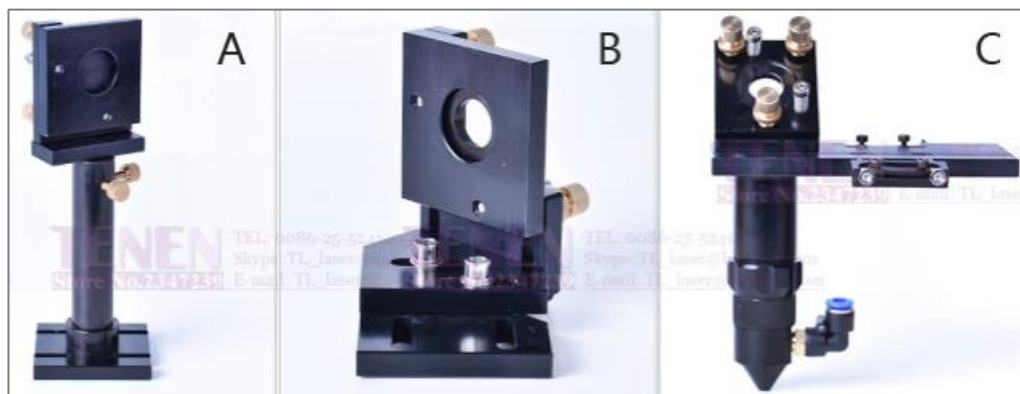
### 3.7.3 Red dot Laser Diode Module



**Figure 20: Red Dot Laser Diode [17]**

The output of the 50 watts laser tube is invisible to the human eye. To know exactly the position of the 50 watts laser, we use a red dot laser module which will clearly indicate the position of the laser.

### 3.7.4 Holders for Lens and Mirrors



**Figure 21: Mirror Mounts [18]**

To hold the mirrors and lens in position, we used the holders shown in the image above. The holder (A) will hold the mirror that is straight in front of the laser tube. The holder (B) will hold the mirror that will receive this beam and transmit it to the mirror held by holder (C). The holder (C) will hold the mirror on top and the lens below. All the holders are adjustable so that they can be adjusted to ensure that the laser beam travels in a straight line.

### 3.7.5 Adjustable Laser Tube Holders



**Figure 22: Laser Tube Holder [19]**

The holders shown above will hold the laser tube. The height of these holders can be adjusted so that the laser tube can also be mounted onto uneven surfaces.

## 4 WIRING CONNECTIONS

### 1. Stepper Motor to Stepper Motor Driver Typical

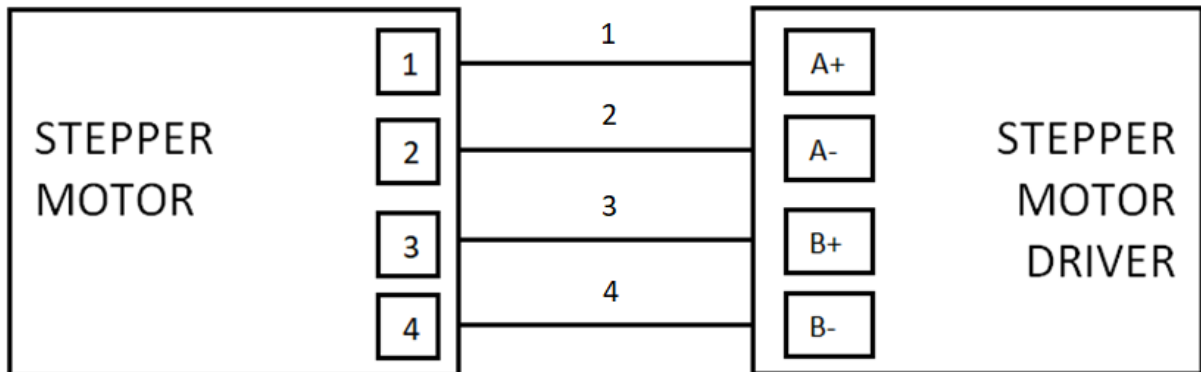


Figure 23: Wiring Diagram B/W Stepper Motor and Driver

Stepper Motor Port	Stepper Driver Pin	Wire No.	Wire Colour
1	A+	1	Blue
2	A-	2	Green
3	B+	3	White
4	B-	4	Yellow

Table 11: Connections B/W Stepper Motor & Driver

### 2. Stepper Motor Driver to Smoothieboard Typical

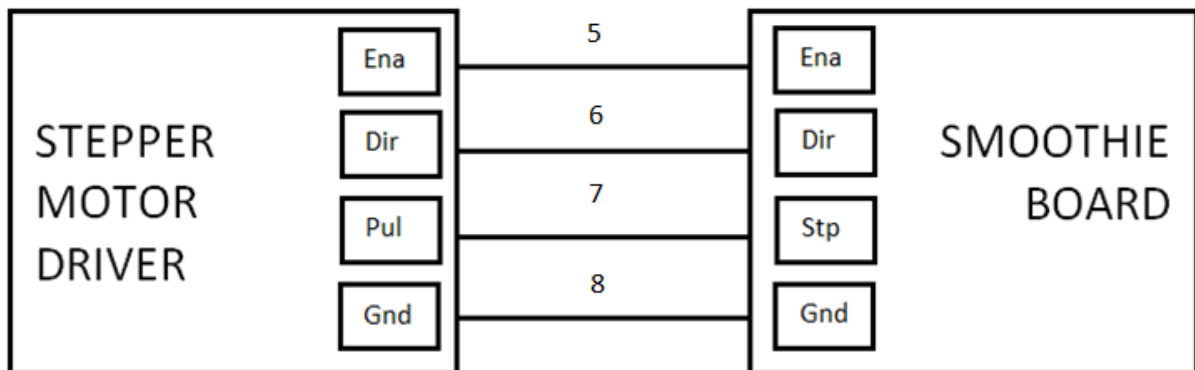


Figure 24: Wiring Diagram B/W Driver and Smoothieboard

Stepper Driver Pin	Smoothieboard Pin	Wire No.	Wire Colour
Ena (Enable)	Ena (Enable)	5	Red
Dir (Direction)	Dir (Direction)	6	Yellow
Pul (Pulse)	Stp (Step)	7	Blue
Gnd (Ground)	Gnd (Ground)	8	White

Table 12: Connections B/W Driver & Smoothieboard

### 3. Endstop Switch to Smoothieboard ( X-axis)

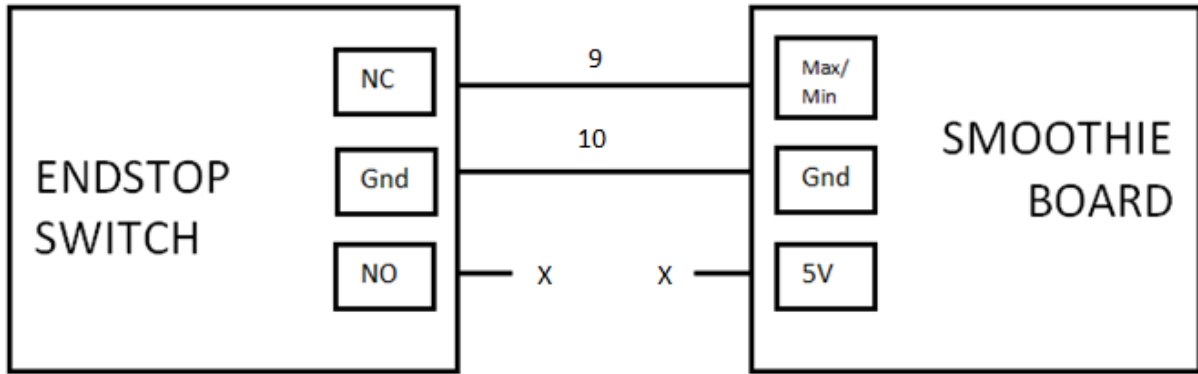


Figure 25: Wiring Diagram B/W Endstop and Smoothieboard

Endstop Switch Pin	Smoothieboard Pin	Wire No.	Wire Colour
NC (Normally Closed)	X Max/Min	9	Brown
Gnd (Ground)	Gnd (Ground)	10	Green
NO (Normally open)	5V	-	

Table 13: Connections B/W Endstop & Smoothieboard

### 4. Endstop Switch to Smoothieboard ( Y-axis)

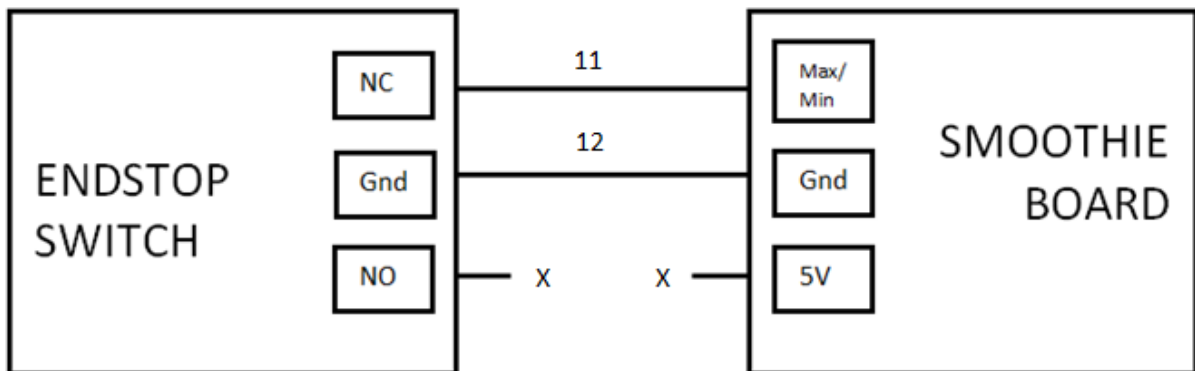


Figure 26: Wiring Diagram B/W Endstop and Smoothieboard

Endstop Switch Pin	Smoothieboard Pin	Wire No.	Wire Colour
NC (Normally Closed)	X Max/Min	9	Red
Gnd (Ground)	Gnd (Ground)	10	White
NO (Normally open)	5V	-	

Table 14: Connections B/W Endstop & Smoothieboard

## 5. Laser Power Supply to Smoothieboard

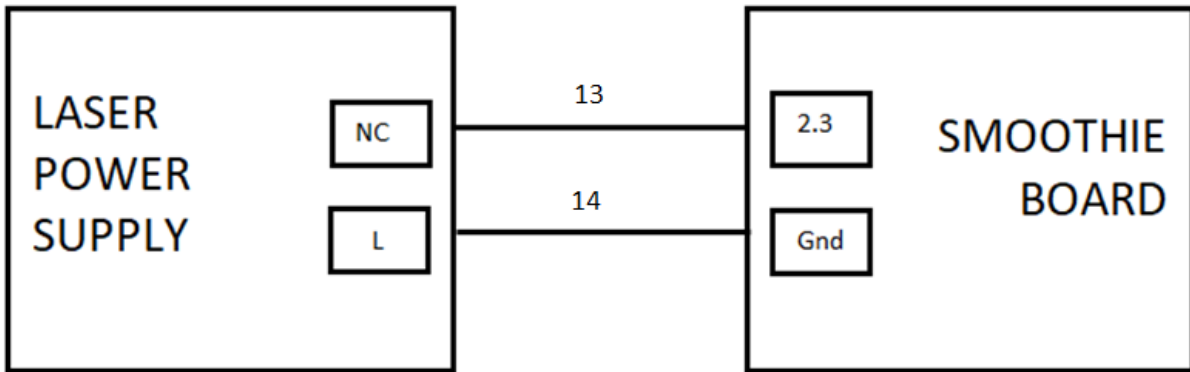


Figure 27: Wiring Diagram B/W Power Supply and Smoothieboard

Laser Power Supply	Smoothieboard Pin	Wire No.	Wire Colour
L ( Active Low)	2.3	13	Red
G (Ground)	Gnd (Ground)	14	Yellow

Table 15: Connection B/W Laser Supply & Smoothieboard

## 6. LCD Panel to Smoothieboard

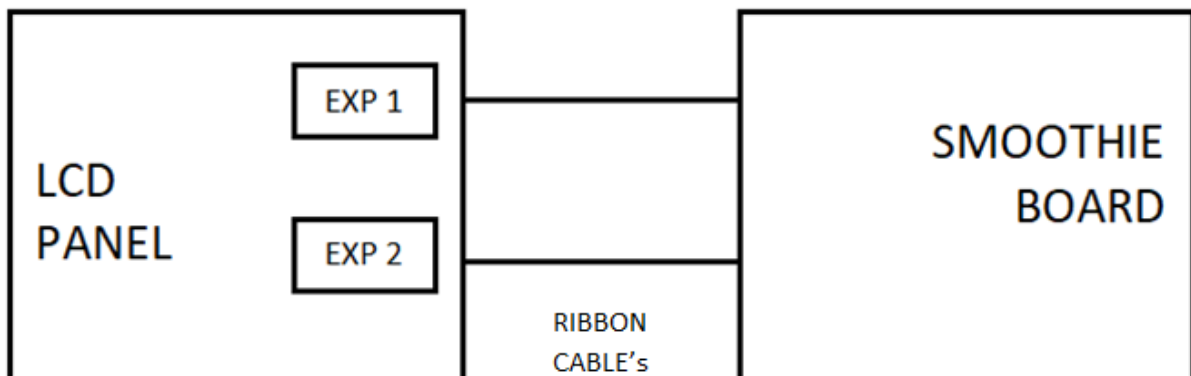


Figure 28: Wiring Diagram B/W LCD Panel & Smoothieboard

LCD Panel Pin		Smoothieboard Pin	Wire No.
EXP 1	1	1.31	Ribbon Cable 1
	2	1.30	
	3	0.18	
	4	0.16	
	5	0.15	
	9	Gnd	
	10	Vcc	
EXP 2	3	3.25	Ribbon Cable 2
	5	3.26	
	8	2.11	

Table 16: Connection between LCD Panel & Smoothieboard

## 5 SOFTWARE CONFIGURATION

The smoothieboard comes with a configuration file that can be configured for different use cases. As the smoothieboard is used for different CNC applications, we will only be enabling and configuring the parameters that are required for laser cutting.

A pin is an input or an output on the smoothieboard. The pins can be modified as per need depending on requirements using modifiers. Then modifier has to be added next to the pin number.

For example, a pin can be inverted by adding an exclamation mark next to the pin number. List of modifiers available:

Modifier	Funtion
!	Invert Pin
O	Set Pin to Open Drain
^	Set Pin to Pull Up
v	Set Pin to Pull Down
-	To set no pull up

Table 17: Smoothieboard Pin Modifiers [10]

The parameters that are configured for our application from the configuration file are as follows:

### 1. Basic Motion Configuration

```
default_feed_rate          600
# Default speed (mm/minute) for G1/G2/G3 moves
default_seek_rate          600
# Default speed (mm/minute) for G0 moves
```

In this line we have to define the speed of the movement of the X-axis and Y-axis. This has been calculated physically based on the movement of our axis.

The speed calculated experimentally was found to be 600mm/minute.



## 2. Arm Solution Configuration

<code>alpha_steps_per_mm</code>	914.286
<code># Steps per mm for alpha ( X ) stepper</code>	
<code>beta_steps_per_mm</code>	914.286
<code># Steps per mm for beta ( Y ) stepper</code>	

As we know, a stepper motor operates in steps. Since all our measurements for drawings will be in millimeters, it is essential for us to convert this steps into millimeters. The smoothieboard can do this and will convert the millimeters into steps so the stepper motor driver can understand.

This conversion depends on the type of arm solution we have used. As we have used a cartesian arm solution, all we have to do is to convert a certain number of millimetres to a certain number of steps. This is referred to as the steps per millimeter.

To calculate the steps per millimeter, the formula is given below:

$$\text{Steps per millimeter} = \frac{(\text{full steps per rotation}) \times (\text{microsteps per step})}{(\text{millimetres per rotation})}$$

Where,

- Full steps per rotation = The number of steps a stepper motor can rotate. For our motor its 200 steps per rotation.
- Microsteps per Step = The number of microsteps we have set in our driver. We have set it to 32 microsteps.
- Millimeters per rotation = This is the distance each axis moves per rotation of the stepper motor. For our stepper, it is calculated experimentally that our axis moves 7mm per rotation of the stepper motor.

Hence,

$$\text{Steps per millimeter} = \frac{200 \times 32}{7}$$

$$\text{Steps per millimeter} = 914.285$$

### 3. Cartesian Axis Speed Limits

<code>x_axis_max_speed</code>	600
<code># Maximum speed in mm/min</code>	
<code>y_axis_max_speed</code>	600
<code># Maximum speed in mm/min</code>	

The max speed has been set as the speed of the movement of the axis which is equal to 600mm/minute.

### 4. Stepper Module Configuration

<code>alpha_step_pin</code>	2.0
<code># Pin for alpha stepper step signal</code>	
<code>alpha_dir_pin</code>	0.5
<code># Pin for alpha stepper direction, add '!' to reverse direction</code>	
<code>alpha_en_pin</code>	0.4
<code># Pin for alpha enable pin</code>	
<code>alpha_current</code>	1.5
<code># X stepper motor current</code>	
<code>alpha_max_rate</code>	600
<code># Maximum rate in mm/min</code>	

In this part of the configuration, the pin numbers to which the stepper motor's step pin, direction pin and enable pin are connected are defined.

The configuration shown above is for the alpha motor. The configuration for beta motor exactly the same but with different pin numbers for the step, direction and enable pins.

### 5. Laser Module Configuration

<code>laser_module_enable</code>	true
<code># Whether to activate the laser module at all</code>	
<code>laser_module_pwm_pin</code>	2.3o!
<code># This pin will be PWMed to control the laser.</code>	

The laser module has to be enabled by setting it to true. The signal to the Laser power supply is a PWM signal and so any available PWM pin on the smoothieboard can be chosen. The Pin 2.3 has been chosen. It has been inverted and set to open drain.

## 6. Endstops Configuration

```
endstops_enable true
# The endstop module is enabled by default and can be disabled
here
#corexy_homing false
# Set to true if homing on a hbot or corexy
alpha_min_endstop 1.24^
# Pin to read min endstop, add a ! to invert if endstop is NO
connected to ground
alpha_max_endstop 1.25^
# Pin to read max endstop, uncomment this and comment the
above if using max endstops
alpha_homing_direction home_to_min
```

The endstops has to be enabled by setting to true. The pin numbers for the for the min and max limit switches for the alpha and beta motors are default. The homming direction of the axes can be set to either home\_to\_min or home\_to\_min.

## 7. Panel Configuration

```
reprap_discount_glcd #
panel.spi_channel 0
# SPI channel to use ; GLCD EXP1 Pins 3,5 (MOSI, SCLK)
panel.spi_cs_pin 0.16
# SPI chip select ; GLCD EXP1 Pin 4
panel.encoder_a_pin 3.25!^
# Encoder pin ; GLCD EXP2 Pin 3
panel.encoder_b_pin 3.26!^
# Encoder pin ; GLCD EXP2 Pin 5
panel.click_button_pin 1.30!^
# Click button ; GLCD EXP1 Pin 2
panel.buzz_pin 1.31
# Pin for buzzer ; GLCD EXP1 Pin 1
panel.back_button_pin 2.11!^
# Back button ; GLCD EXP2 Pin 8
```

The panel has to be first enabled by setting it to true. Then type of panel has to be defined, in our case we are using the “Reprap Discount GLCD.” Then the pins to which the Panel is interfaced has to be defined. A better overview of the connections can be found in the Wiring Schematics (Chapter 4).

## 8. Network Settings

```
network.enable true
# Enable the ethernet network services
network.webserver.enable true
# Enable the webserver
network.telnet.enable true
# Enable the telnet server
#network.ip_address auto
# Use dhcp to get ip address
# Uncomment the 3 below to manually setup ip address
network.ip_address 169.254.161.255
# The IP address
network.ip_mask 255.255.0.0
# The ip mask
network.ip_gateway 192.168.3.1
```

Firstly, the network has to be enabled by setting to true. Since we will be using the Web-interface, it has to be enabled aswell.

Then the IP settings of the smoothieboard has to be manually configured here. The IP address of the smoothieboard can be obtained by 2 ways:

1. **LCD Panel:** If a LCD panel is used, the IP address should be displayed there.
2. **Pronterface:** The smoothieboard should be connected through USB. Then in Pronterface, send the command @net in the command window and the IP settings of the smoothieboard should be displayed.

## 6 TESTING

This chapter deals with how the machine has been tested. As I mentioned in the beginning, the main aim of this Laser Cutter being built is to cut small components from Plexi glass.

Hence I carried out various tests on plexi glass, with different speeds of the axes, different power of the laser and different heights from the laser head to the material.

### 6.1 Testing Strategies

For testing purpose, I decided to use a heart shape to be cut. I chose this shape mainly because it was simple and had straight lines and curves which will be good when testing the flexibility of the cutting.

The Gcode for the heart shape which was used is as follows:

```
-----  
M107 S0  
  
G90  
G21  
G0 F555  
G0 X153.8623 Y105.7423 Z48  
G4 P0  
M106 S254  
G4 P11  
G0 F500.000000  
G3 X166.612 Y115.0412 I-61.6276 J97.8867  
G3 X176.7982 Y127.1557 I-29.5224 J35.1629  
G3 X179.2916 Y133.0851 I-25.4054 J14.1724  
G3 X179.94 Y139.5084 I-16.6781 J4.9277  
G3 X176.7131 Y148.2823 I-14.0788 J-0.1976  
G3 X168.842 Y153.317 I-11.7697 J-9.7301  
G3 X163.1647 Y153.7412 I-3.9989 J-15.3176  
G3 X157.711 Y152.0658 I1.5863 J-14.8774  
G3 X154.7656 Y149.6811 I4.434 J-8.4879  
G3 X152.6065 Y146.6231 I18.9344 J-15.6599  
G3 X149.8697 Y150.0629 I-70.1838 J-53.0296  
G3 X146.051 Y152.6468 I-6.4212 J-5.3761  
G3 X135.4761 Y153.2238 I-6.0406 J-13.5134  
G3 X127.233 Y146.5836 I4.5209 J-14.0485  
G3 X124.9912 Y137.1138 I12.7664 J-8.0226  
G3 X127.8282 Y127.8914 I23.8994 J2.3046  
G3 X135.4631 Y117.8627 I35.9419 J19.4422
```

G3 X145.0632 Y109.7569 I67.9867 J70.7819  
G2 X148.712 Y107.2922 I-1685.7528 J-2499.6337  
G3 X152.4647 Y105. I26.5325 J39.2187  
G3 X153.1817 Y105.3391 I-1.4597 J4.014  
G3 X153.8623 Y105.7423 I-14963.3558 J25262.8749  
G0 X153.8623 Y105.7423  
G4 P0  
M107 S0  
G0 F555  
G0 X0 Y0  
M18

-----  
The cutting quality of the material depends on the following factors:

1. **Speed of Motors:** The maximum speed of our motors is 600mm/min. During our testing, I lowered the speeds of the motor to 300mm/min and 150mm/min according the material used.
2. **Power of the Laser:** The power of the Laser is another important factor which influences the cut. For most of the testing, I set the power to maximum (100% of Power) and only adjusted the speed of the motors.
3. **Distance between Laser Head and Material:** The distance between the laser head and the material has had a significant impact on the quality of the cut.
4. **Number of Passes:** The number of times the Laser has to pass over the material to cut it.

## 6.2 Tested Materials

### Plexiglass ( Thickness: 2mm)

- **First Test**
  1. **Speed of Motors:** 600mm/minute
  2. **Power of Laser:** 100%
  3. **Distance between Laser Head and Material:** 28mm
  4. **Number of Passes:** 3 Passes

The first test was carried out with the above parameters. The material was cut but there were imperfections in the cut and also the edges of the shape were bevelled.

- **Second Test**

1. **Speed of Motors:** 200mm/minute
2. **Power of Laser:** 100%
3. **Distance between Laser Head and Material:** 28mm
4. **Number of Passes:** 1 Pass

After reducing the motor speed, the cut quality improved a significant but it still was not perfect. Also, the product remained to have a bevelled edge.

- **Third Test**

1. **Speed of Motors:** 200mm/minute
2. **Power of Laser:** 100%
3. **Distance between Laser Head and Material:** 6mm
4. **Number of Passes:** 1 Pass

In the third test, we reduced the distance between the laser head and material using the help of metal plates. The cut quality was smooth without any imperfections. Also in this cut, the edges were straight and not bevelled.

From these tests, it is concluded that using the parameters in The third test, plexiglass can be cut succesfully with precision.



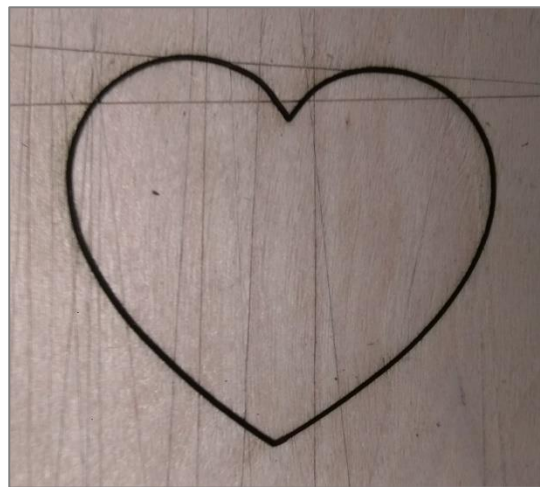
**Figure 29: Stack of Plexiglass heart parts**

Figure 29 shows a stack of hearts which were cut. From this image we can see that all the hearts are the same proving the reliability of the machine.

### Plywood ( Thickness: 5mm)

- First Test
  1. **Speed of Motors:** 600mm/minute
  2. **Power of Laser:** 100%
  3. **Distance between Laser Head and Material:** 28mm
  4. **Number of Passes:** 5 Passes

Even after the 5 passes, we measured and found the laser did not penetrate more than 2mm of the plywood.



**Figure 30: First Test with Plywood**

- Second Test
  1. **Speed of Motors:** 200mm/minute
  2. **Power of Laser:** 100%
  3. **Distance between Laser Head and Material:** 6mm
  4. **Number of Passes:** 3 Passes

In the second test, even after reducing the motor speeds and the distance between the laser head and material, the laser still only penetrated 2mm of the wood.



**Figure 31: Second Test with Plywood**



From these tests, it is concluded that the Laser Cutter cannot cut plywood of thickness 5mm. Even if it does cut a plywood of thickness 2mm, the cut quality will be really bad.

However, from the Figures, (30) & (31), we can see that the Laser cutter can be used to engrave on plywood. I tried to engrave a complex design on plywood and the result is as follows:

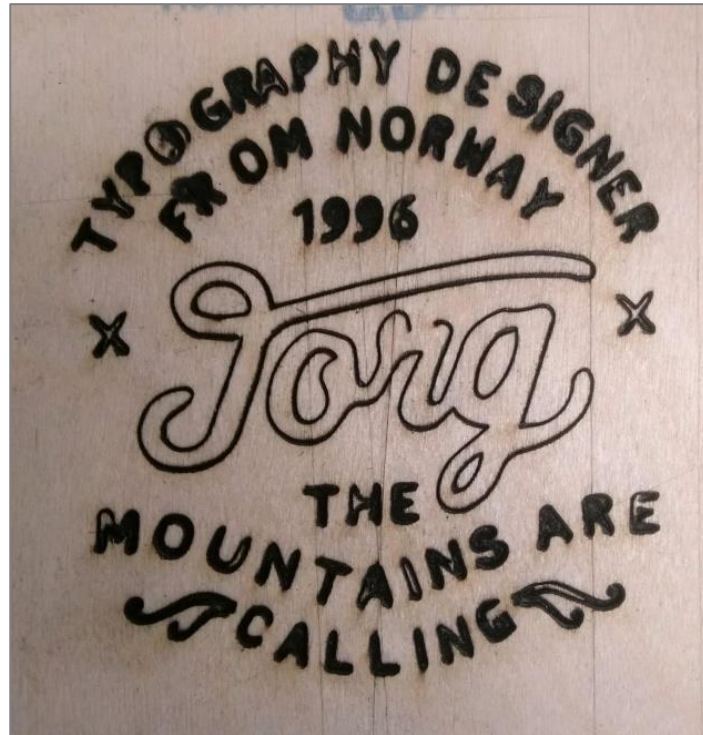


Figure 32: Engrave Test on Plywood

Apart from plexiglass and plywood, I tried cutting other materials using the the laser cutter with the following parameters:

1. **Speed of Motors:** 200mm/minute
2. **Power of Laser:** 100%
3. **Distance between Laser Head and Material:** 6mm
4. **Number of Passes:** 1 Pass

### **Foam**

This material was excellently cut with perfect edges and good precision.



**Figure 33: Test with Foam**

### **Nylon Fabric**

Nylon Fabric was also well cut without any distortions. It has to be noted that the fabric must be well tight before cutting to get the best result.



**Figure 34: Test with Nylon Fabric**

## **Rubber**

Rubber was also cut but there was a little distortions at the edges.



**Figure 35: Test with Rubber**

## **Silicon**

The Laser cutter failed to cut through Silicon. From the figure (35) we can see that engraving also did not yield good results.



**Figure 36: Test with Silicon**

## Stainless Steel

As expected the laser cutter failed to cut or even engrave on stainless steel. This is because the wavelength is not suitable for stainless steel.



**Figure 37: Test with Stainless Steel**

## **6.3 Precision Test**

To test if the machine was precise and accurate in measurements, I designed a simple rectangle having dimensions 100mm X 50mm in Autodesk Fusion 360 and cut Plexiglass using the machine. I then measured the rectangle and it was found to have an error of 1%. This error can be removed by recalibrating the “steps\_per\_millimetre” in the software configuration.



**Figure 38: Rectangle Piece**

# 7 USER MANUAL

This chapter is a step by step description of how to use the Laser Cutter, from design of Gcode to the final cut material.

## 1. Producing G-code

The smoothieboard accepts instructions in G-code. Hence before we can start cutting the design we need, it is necessary to produce the G-code of the desired design. This can be achieved using any CAM software.

There are a lot of CAM software's which can do the job, but I have used Autodesk Fusion. A simple step by step method to create the G-code of a heart shape is explained here.

- **Step 1: Create Your design**

The Autodesk Fusion Desk is like other Autodesk softwares and can be used to easily draw your design. Make sure all dimensions are in mm.

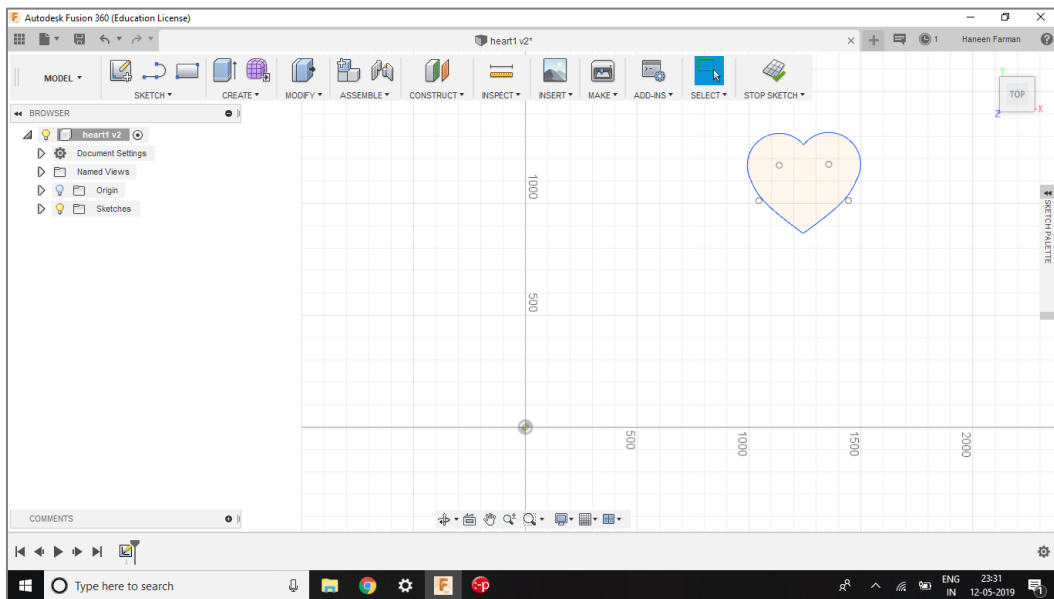
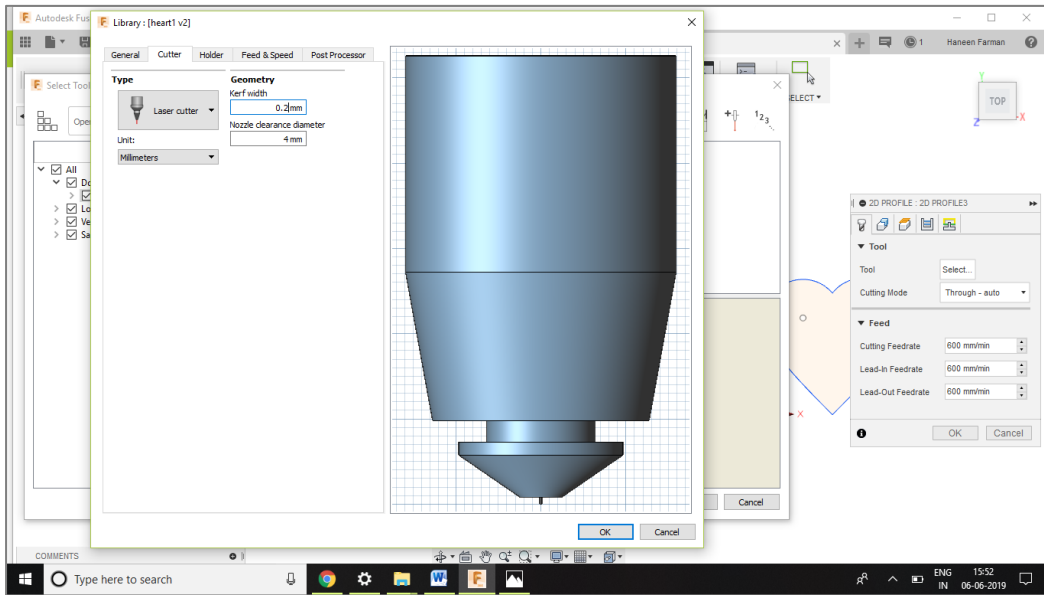


Figure 39: Fusion 360 Design Layout

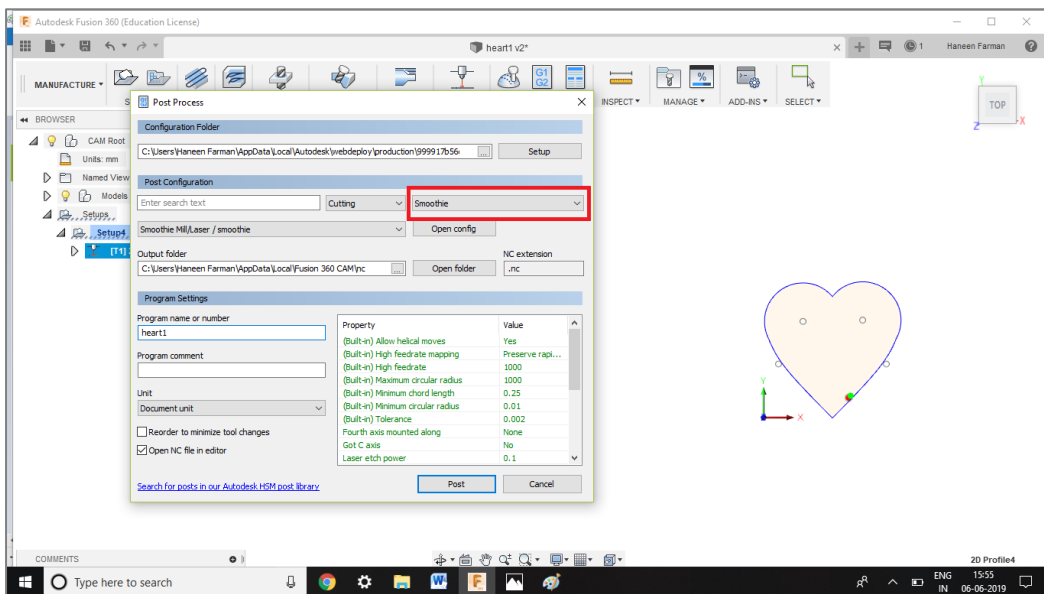
- **Step 2: Prepare the Toolpaths**



**Figure 40: Fusion 360 Tool Selection**

After the design is finalized, it is necessary to create the toolpaths. The operation has to be set as cutting and the tool as Laser. Also in this part, parameters like the starting point, direction of cut can be set.

- **Step 3: Simulation and Conversion to Gcode**



**Figure 41: Fusion 360 Post Process**

**Simulation:** Once the tool path is created, we can simulate how the cutting will take place.

**Post Process:** If you are happy with the simulation, we can convert our design into a gcode.

## 2. Connecting to the Web Interface

We can communicate with the smoothieboard over the network using ethernet connection. The network settings of the smoothieboard including has already been configured.

The IP address of the Smoothieboard is: **169.254.161.255**

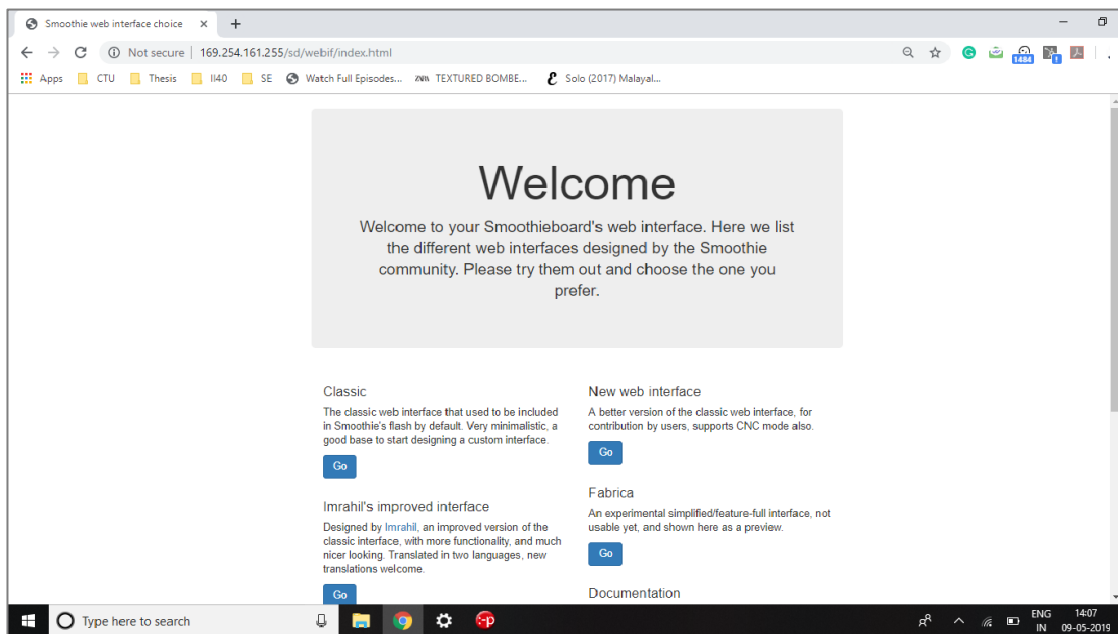
- **Step 1: To Access The Index Page**

To access the index page of the Web interface, go to the following address on your Web browser:

***http://169.254.161.255/sd/webif/index.html***

***Note: If the page does not open, delete the cache in your web browser and restart the smoothieboard and try again.***

The following Page should turn up:

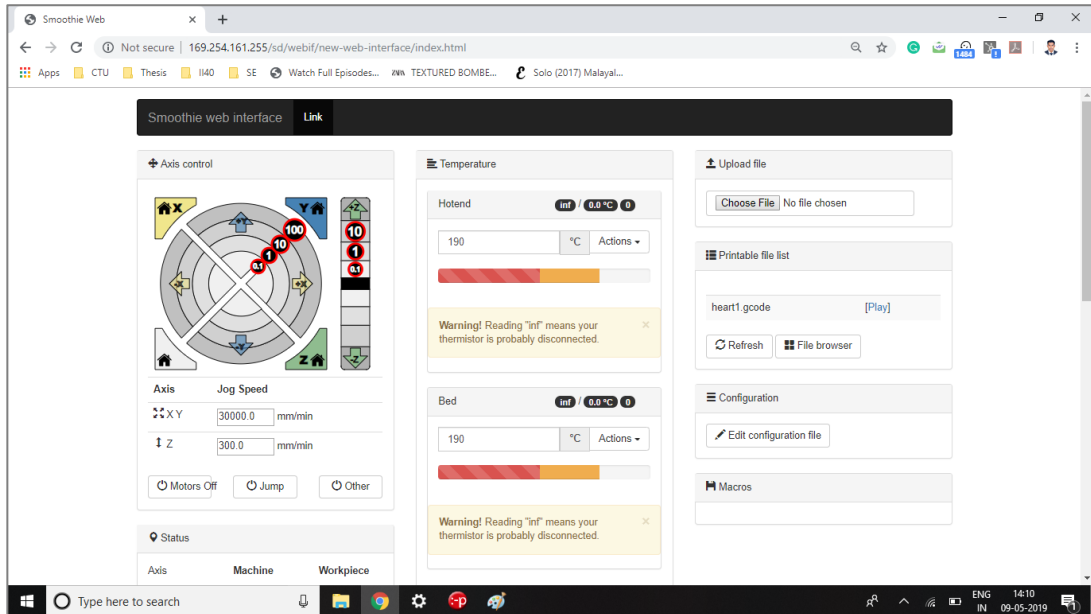


**Figure 42: Web Interface Index Page**

Figure40 shows the Index of the Web Interface. From this Index, you have a variety of interfaces from which you can choose from.

- **Step 2: Choose Your Preferred Web-Interface**

For our Laser Cutting application it is preferred to choose the“New Web Interface.“ On choosing this option the following Page opens up:



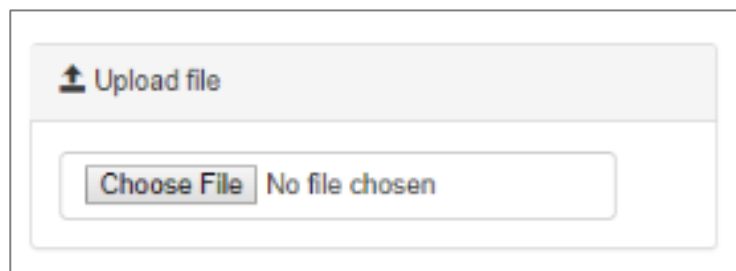
**Figure 43: New Web Interface**

From the interface, you move the axes as per your desire with the arrow buttons of the X and Y axes. The jog speed of the axes can also be set up here. Also there is a control button to turn off the motors.

### 3. Uploading the Gcode

Once you are familiarized with the interface and have already tested the jogging of both the axes and their homing, it is time to upload the G-code of the design you would like cut.

- **Step 1:** To upload the G-Code, on the top right hand side of the interface, you should find the below:



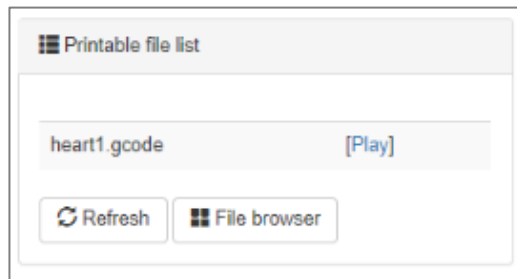
**Figure 44: Upload File Option**

- **Step 2:** Click on choose file, and select the G-code file you desire to be cut.



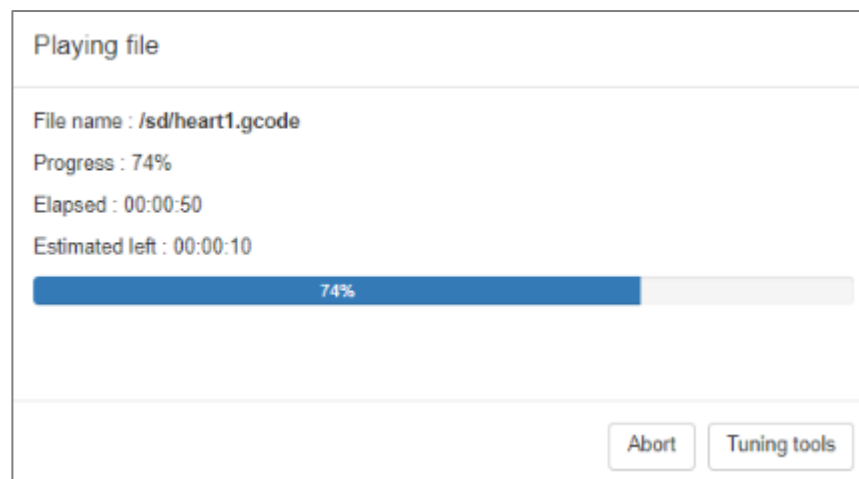
## 4. To start Cutting

- **Step 1:** Once you have selected the desired G-code and if the format is accepted, the file will be updated in the Printable File list as shown below:



**Figure 45: Updated Print List**

- **Step 2:** To start cutting, click on the [Play] button and the machine should start the cutting operation. Once the operation has started the below dialog box opens up with information of the operation.



**Figure 46: Status Bar during Cutting**

## 5. Editing the Configuration file.

From the the Web Interface, it is possible to directly access and edit the configuration file if it is required.

- **Step 1:** Chose the edit configuration option and the configuration file will open.
- **Step 2:** Make the changes you want and save it. Reset the smoothieboard and the changes will be applied.

## 8 CONCLUSION

The goal of this thesis was to convert an old PCB plotter into a Laser cutter for plastics and this has been successfully achieved.

A case study of the existing system was undertaken and the results were discussed in Chapter 2. The components required were shipped in from China and their parameters have been defined in Chapter 3. All these components were tested individually and then installed onto the setup.

The Control system for the setup was successfully configured using a smoothieboard. The configuration of the programming has been explained in Chapter 5. Finally, after the installation and wiring of all parts, the machine was tested for full functionality by producing some cut parts. The testing procedure has been elaborated in Chapter 6.

Working on this thesis was a very great learning experience for me. I have acquired in depth knowledge of Stepper motors and gained experience working with them. I was introduced to working with renowned embedded controllers, the Arduino and the Smoothieboard.

Throughout the course of working on this thesis, I encountered many difficulties and challenges. In overcoming them, I sharpened my problem solving skills and experienced engineering at a first hand. This thesis has been an excellent example of application engineering and I aspire to continue my career in it.



**Figure 47: Final State of Laser Cutter**

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## **APPENDIX ON CD**

1. Laser Cutter Configuration File
2. Sample G-code File