2 Axis CNC Plasma Cutter

CNC

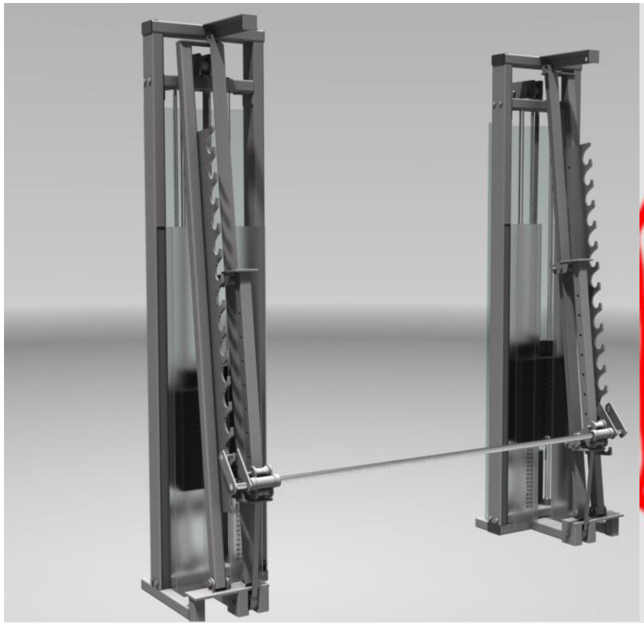
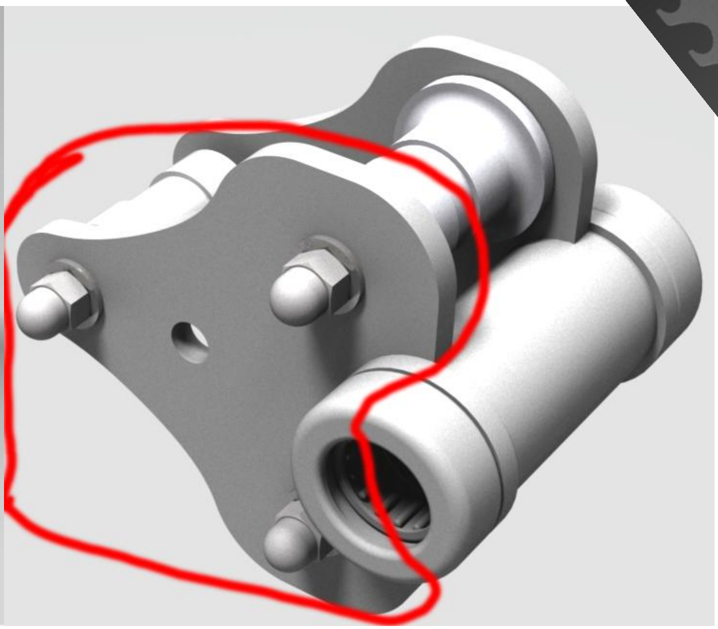
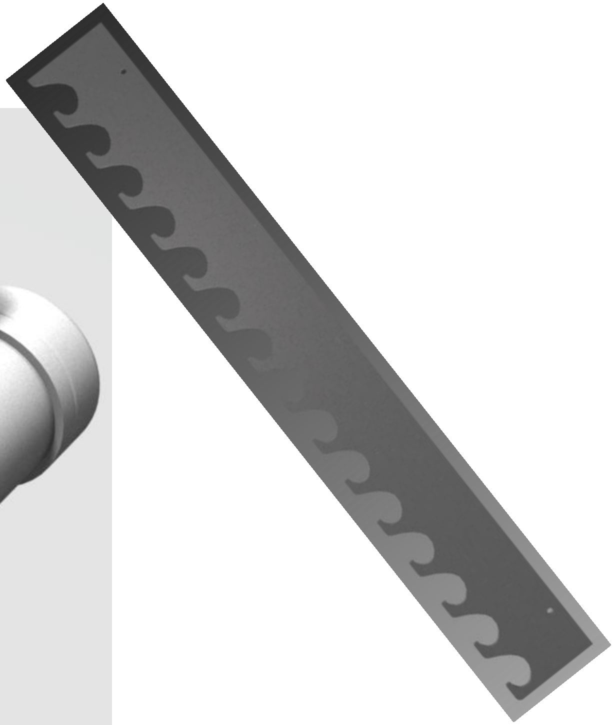
- CNC or computer numerical control is a way to control machine tools via a computer
- In this project I will be making a CNC 2 Axis platform for a plasma cutter
- CNC makes it possible to cut more complex shapes
- Accuracy is better than with manual use of a plasma torch
- Speed of operation is better than manual cutting

Why a CNC Plasma cutter ?

- This project is designed to be able to guide a plasma cutting torch by using a CAD drawing of the part to be cut
- Having a CNC plasma cutter simplifies the development and production of metal parts
- Eliminates expensive outsourcing of metal parts cutting
- Quicker product development by being able to produce prototype parts on site

Example uses

- I am currently developing for production a weightlifiting machine which has a few parts that are cut with a CNC

Requirements

- To be usefull the machine must fulfill the following requirements
- Move smoothly through it´s entire range of motion
- Follow the programmed path precisely, errors of more than 1 mm would be unacceptable in many cases
- Be able to move at various speeds for cutting different thicknesses and kinds of materials at different power levels
- Interface smoothly with the control computer
- Be able to support the weight of 20 mm steel plate without significant deflection

Commercial CNC Machines

- Many versions of commercially available CNC plasma cutters are available
- The main benefit of my system is the low cost of the design
- I used as simple a design as I thought was possible while still reaching the design specs
- My machine is made in a modualar format which means it is transportable with 2 people and a small van

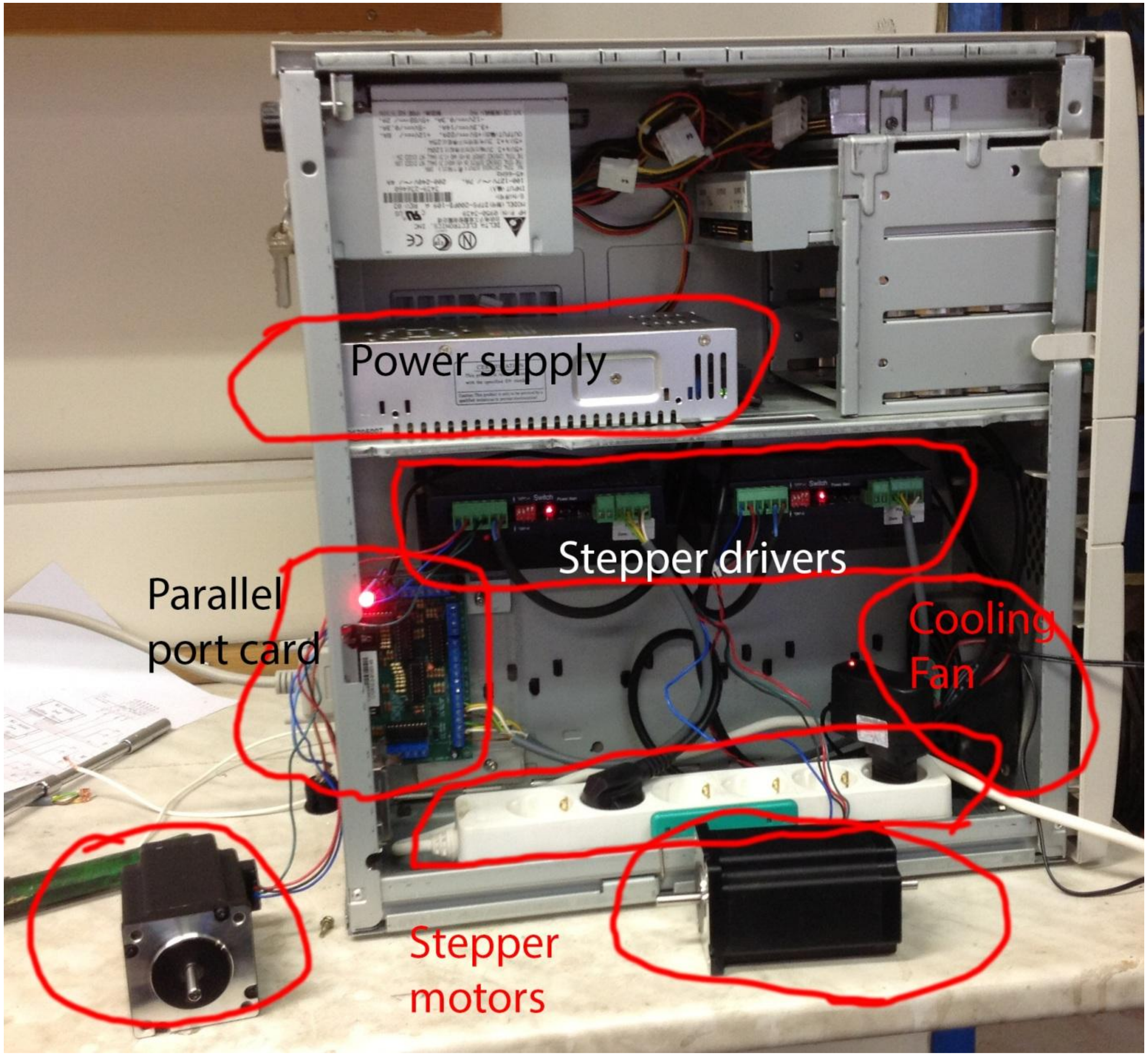
Technology used

- To move the two axis which are perpendicular to each other I needed motors and something to transfer their power into linear motion
- For the motors two options were available: Stepper or Servo motors
- I chose to use stepper motors because of their much lower cost

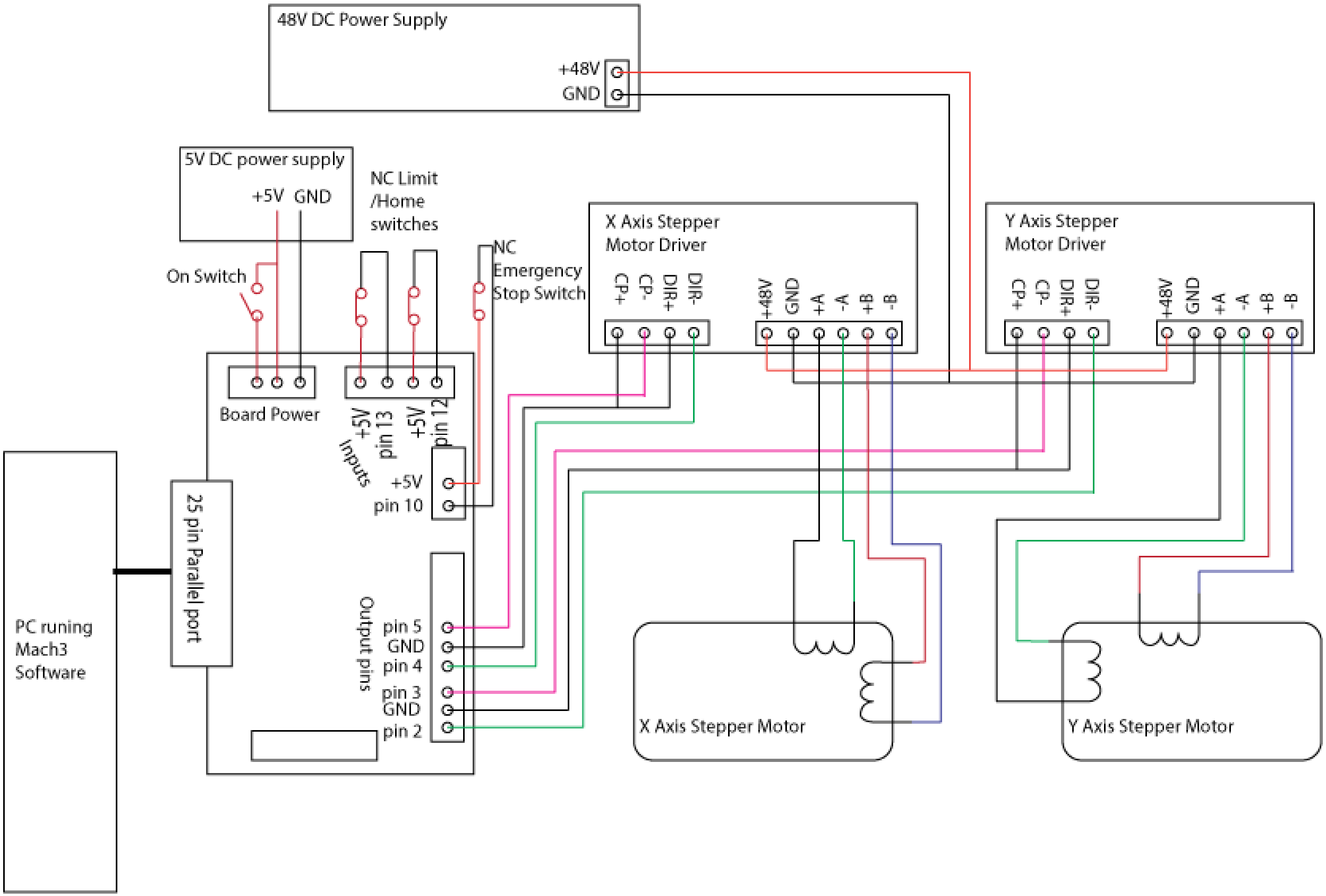
Stepper motors

- Stepper motors work by rotating the output shaft by a known amount when it recieves a pulse from the driver electronics
- My chosen Steppers move 1.8° for each „step“ or 200 steps per revolution
- To operate the steppers I use amplifier electronics known as stepper motor drivers to amplify the signal from the PC to be able to power the motors
- The motors I used have a stall torque of 4 Nm
- To connect the PC that runs the control program (Mach3) to the electronics I use an interface card that connects to the parallel port

Mounting of electronics



Electronics schematic



Actuation - Ballscrews

- To move the axis of the machine I use two 1750 mm long ballscrews with a lead of l=10mm per revolution giving a resolution of 0.05 mm
- Ballscrews use ball bearings that move along the thread to transfer force much more efficiently. Their efficiency is between $\vartheta = .9 \ and \ \vartheta = .95$
- Less motor power is required by using ballscrews and little to no backlash should be present
- The stalling force of my machine is given by $F = \frac{2\pi\vartheta T}{l} = \frac{2*\pi*0.9*4Nm}{10\ mm}$=2.26 kN
- This number is a theoretical upper limit, stepper motor torque drops with increasing speed

Ballscrews cont.

I ordered my ballscrews online from china and have had trouble with the seller, they have not arrived which is the reason I did not finish the machine yet

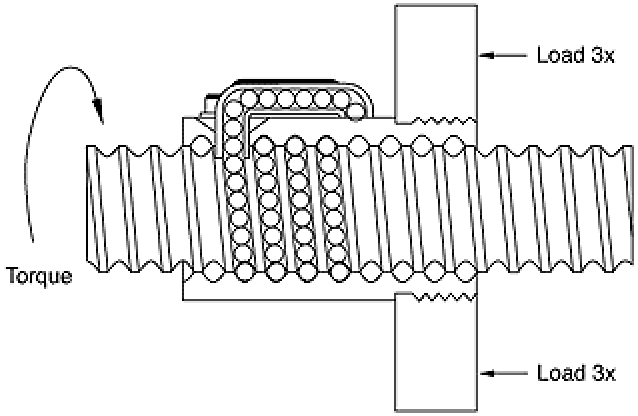


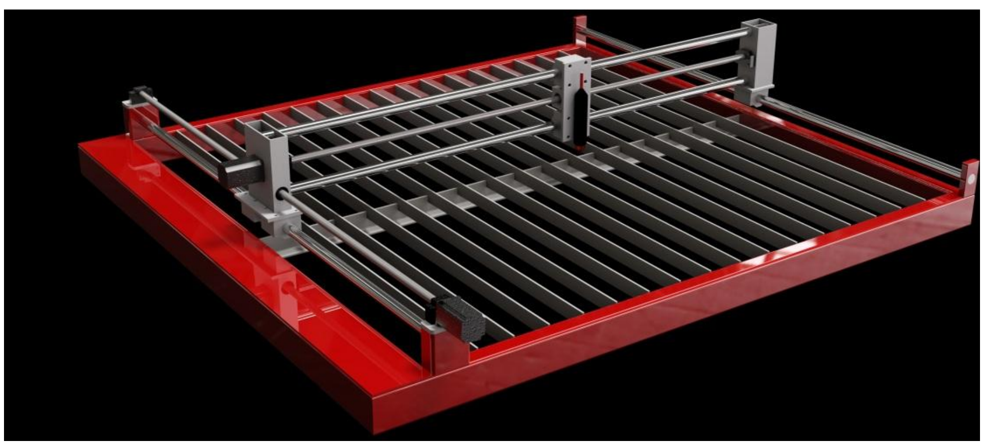
Illustration of Ballnut and Ballscrew [1]

The photo above shows the inner workings of the ballnut and ballscrew system

[1]:Roton Products, Inc. *Ballscrews and Ballnuts* [Online]. Available: http://www.roton.com/page.aspx?id=28

Mechanics

- My goal for the mahine was to be able to cut parts from a standard size of steel plate
- 1.5 m wide plates are very common so I chose that as my working width
- To minimize cost I decided to use only one motor and drive screw for each of the two axis
- At first I planed on driving the X axis asymmetrically from one side
- This might have resulted in a moment that would have introduced errors or even prevent the machine from running



Initial asymmetric design

Mechanics cont.

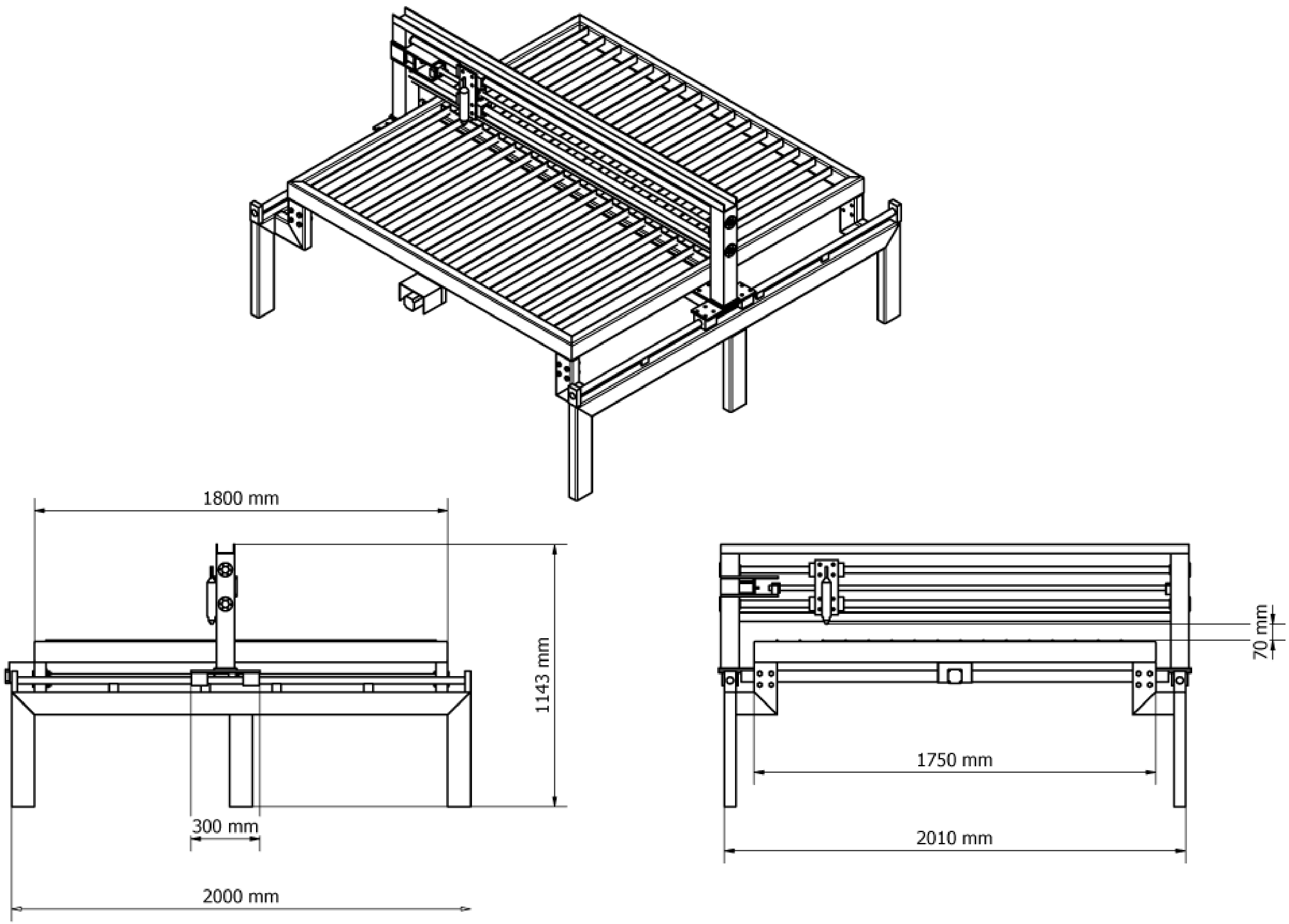
- I then decided to try to drive the X axis from it´s center
- This required me to drop the drive screw below the table
- The linear bearings and axles were dropped below the working table as well to keep them in line with the force being applied
- To minimize deflection and vibration of the X axis bearing axles I will support them along their length with thin steel plate

Mechanics cont.

- Since my machine uses bearings to constrain it´s motion I considered Saint-Venant´s Principle [2]
- For both my X and Y axis I used two linear ball bearings for each axle
- Since the distance between the two X axles was large I mounted the bearing blocks with a space between them to gain a larger resistance to moments

[2]: A.H.Slocum. *Fundamentals of Design*. MIT, Cambridge, Massachusetts 2007

Dimensions



System control

- To control the system I use an old 1.6 GHz computer running only Mach3 and Windows XP
- The computer interfaces with the system via a 25 pin parallel port at 25 kHz
- To function, the software must have unhindered control of the PC which required quite a bit of troubleshooting
- All unnecesary programs and services were uninstalled or deactivated
- Windows was configured to run in Standard PC mode instead of the default ACPI mode
- After setup the motors run smoothly

Configuration

- Stepper motors use steps and the steps can be divided into „microsteps“
- For my system I used half stepping so 2 pulses are required to go one step or 1.8°
- Using the thread pitch of my ballscrews I calculated the number of pulses per mm
- $\frac{2\frac{pulses}{step} * 200\frac{steps}{rev}}{10\frac{mm}{rev}} = 40\,\frac{pulses}{mm}$
- When my ballscrews arrive I will tune the acceleration and maximum velocity of my axles in the software
- I am aiming for a maximum travel rate of between 8000 and 9000 mm/min

Software

- Original drawings can be made in most CAD programs or vector drawing programs that can output a .dxf file
- The .dxf file is imported to a program called SheetCam that places the piercing points and adjusts for the thickness of the cut known as „kerf“ SheetCam then exports the file as G-Code
- The G-Code is then read by Mach3 which controls the motors and machine via the parallel port

Current status – Requirements met

- Since the Ballscrews/Ballnuts and ballscrew-mounts did not arrive on time I have not been able to complete the project
- The linear bearing system slides very smoothly and shows no deflection when moved around rapidly
- The Motors, Electronic interface and Software all function well
- The table and legs have been fabricated as well as motor mounting plates and the ballscrew mounts
- The table is transportable via a small van
- The table is very solid and will be set up with tensioning wire so it easily supports the required weight

Current state of CNC

Future development

- As soon as the ballscrews arrive I will complete the assembly of the machine
- When the machine is assembled I can do the tuning of the motors to set the acceleration and velocity
- For future improvement I am considering adding a Torch Height Control System
- THC systems aid in getting a cleaner pierce and improves the quality of the cut as well as extending the life of the plasma cutting tips
- The bottom of the table will be closed with sheet metal
- Rubber bellows will cover the bearing axles