3-D Plasma CNC Machine

Mechanical Engineering / Electrical & Computer Engineering

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Abstract

- The 3-D Plasma CNC Machine is a joint effort between Mechanical Engineering and Computer Engineering students. The project was created to provide the Mechanical Engineering department with a low-cost CNC machine for use by the department.
- The Mechanical Engineering team was responsible for creating a robust platform to support the weight of stock materials and components. The system converted rotary motion to linear smoothly and accurately, utilizing rack and pinion gears for the horizontal axis and screw gears for the vertical axis. Safety features included were an emergency shutoff button to protect the user and a water table to extinguish burning debris.
- The Computer Engineering team was responsible for taking a CAD file, extracting the Cartesian coordinates, and passing the coordinates to a microcontroller that controlled the three stepper motors. An ac to dc power supply with full-bridge drivers was also created to power the microcontroller and stepper motors.

Mechanical Components

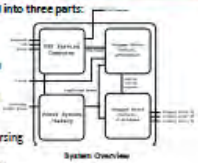
Computer Engineering Overview

The Computer/Electrical System was divided into three parts:

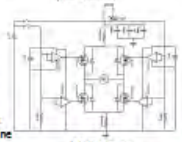
Computer Interface System
- Full featured laptop running GNU/ Linux OS (Xubuntu 18.04)
- Preconfigured with DXF manipulation software (QCAD, SheetCam)
- CNC Control Program interfaces with Stepper Motor Controller via USB

Stepper Motor Controller
- Receives cutting information from parsing computer
- Transmits digital signals to H-bridge to drive and control stepper motors
- Interprets parsed information to determine type of cut

Power System and Safety Circuit
- 120 V_{RMS} AC stepped down to 12 V DC
- DC voltage converted to drive stepper motors and microcontroller
- E-Stop on separate circuit to implement safety mechanism of Plasma CNC Machine



System Overview



H-Bridge Design

Power System

- A power supply was purchased to convert the electricity from 120 V_{RMS} AC to 12 V DC
- The 12 V DC was used to power the Gate Drivers of the H-Bridge.
- Six 12 V to 5 V DC Buck Converters were made to power the three H-Bridges used to drive the three stepper motors
- One 12 V to 9 V DC Buck Converter was made to power the Nucleo-F767ZI microcontroller
- One Emergency-Stop with double pole Normally Closed contacts was installed to allow the operator to remove power in emergency situations

120 V to 12 V AC to DC Power Supply

12 V to 5 V DC Buck Converter

LMZ-23605NDW 5-A Buck Converter

LMZ-2575 1-A Buck Converter

12 V to 9 V DC Buck Converter

Mechanical Engineering Overview

The Mechanical portion was broken into four parts.

- **Table**
  - Stable base gives a solid surface and absorbs vibrations
  - Will Support substantial raw material weights
  - Water table arrests burning material and cools cutting surface
- **X-Axis (Railing)**
  - Provides for gantry movement
  - Single motor function
- **Y-Axis and tool shuttle (Gantry)**
  - Spans the table to allow smooth tool movement
  - Houses the tool shuttle
- **Z-Axis**
  - Allows for vertical tool movement
  - Houses tool holder to accommodate multiple tool variations

Table Concept

Gantry/Tool Shuttle

- The tool shuttle traverses the Y-Axis along the gantry via rack and pinion gear
- A NEMA23 570oz/in Stepper Motor drive the tool shuttle
  - Tangential force in this component is the greatest
    - $F_T = M * g * \mu + M * a + F$
  - Force calculations show a maximum force of 570 oz-in
  - This torque will overcome a maximum tangential force of 71 lbs.
- The Z-axis is mounted to the tool shuttle
- Movement is generated through a Stepper motor and a ball screw.
- Linear railing provides smooth stable movement
- Simple adjustable tool holder allows the use of various sized and shaped tool heads

Z-Axis Tool Shuttle

Computer Interface System

Computer System Description
- Computer system is general purpose; supports internet, USB drives, industry standard software
- Uses industry software to convert drawing file (.DXF) to G-code file (.NGC)
- Uses custom software to control CNC machine
- Communicates over USB with stepper motor controller

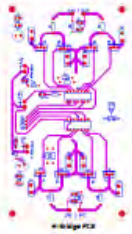
CNC Control Program
- Accepts and parses a relevant subset of valid G-code files
- Has graphical user interface that displays the cut
- Displays cut progress and errors that occur

Preliminary GUI design. The image displayed is the design to be cut.

Interface flowchart

PCB Designs

H-Bridge Motor Driver:
- Designed for low voltage, high current motors
- Design included decoupling capacitors and gate drivers and identified dead-band for H-bridge and motor combination



H-Bridge PCB

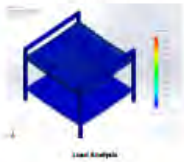
H-Bridge Power Supply:
- 12 Volt in → 5 Volt, 5 Amp out

12 V to 5 V, 5 A Buck Converter PCB

PCB Designs:
- High current requires more copper, 2 oz/ft²
- More traces made where trace width couldn't be increased

Table

- A36 Steel was chosen as the construction material for the table and components
- Low cost
- High strength
- High density
  - Keeps the table stable and absorbs vibration
- Ease of accessibility



Load Analysis

- 2x2 tubing provides strength and stability in the outer frame and railing
- 12 gauge tables offer even weight distribution
- FEA indicates a 500 lb. workpiece is well within the safety requirements.

Railing

- Unique single motor design
- Relies on the stiffness of the gantry for uniform movement

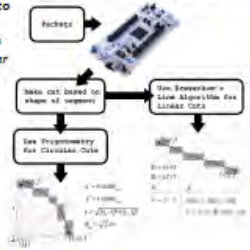
Driven Rail

- Direct drive system saves cost and production time.
- The gantry weight is supported by two separate systems two stud ball transfers
  - Two stud ball transfers support the weight on the driven side
  - A roller and rail system supports the non driven side.

Trailing Rail

Stepper Motor Control

- STMicroelectronics Nucleo F767ZI Microcontroller
- Receives packetized cutting information from parsing computer
- Cutting path broken into segments
- Segments cut based on shape: *Linear or Circular*
- STM32 HAL Software Using STM32CubeMX and Keil uVision5



Sponsors

- California State University, Fresno
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- Iron Panther Trailers
  - Material donations
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