

10W Laser CNC Machine

The design described below is constantly evolving as I learn new things and feel my way through the world of laser cutting. The document was last updated on 03 JULY 2019.

Materials

Below is a list of materials for the laser machine, and their price:

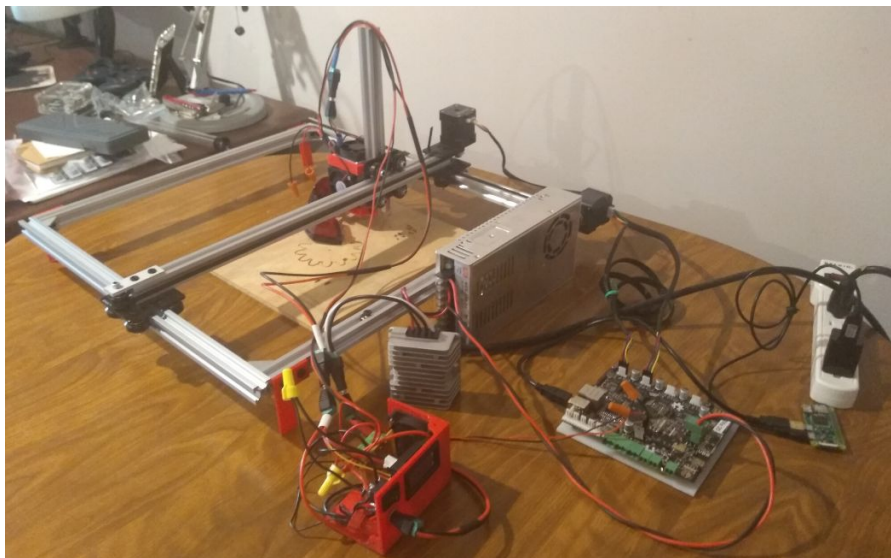
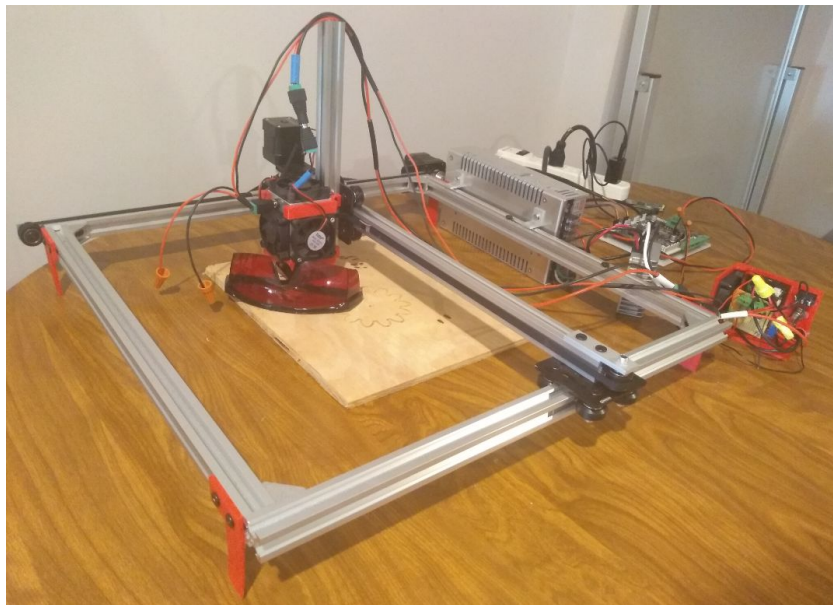
	Product Name	Quantity	Unit Price	Notes
X/Y Axis Motion				
	NEMA 17 Stepper Motor	2	\$17.99	
	Smooth Idler Pulley Kit	2	\$5.99	
	GT2-2M Timing Belt	8	\$2.49	
	GT2-2M Timing Pulley - 30 Tooth	2	\$6.99	
	Belt Clamp Crimp Style	4	\$0.53	
	Timing Belt Tension Torsion Spring	2	\$0.71	
Frame & Gantry				
	V-Slot Gantry Set - 20mm	3	\$23.99	
	V-Slot® 20x20 Linear Rail Length: 500mm	5	\$4.94	X/Y/Frame
	V-Slot® 20x20 Linear Rail Length: 250mm	1	\$3.29	Z-axis
Fasteners & Spacers				
	Aluminum Spacers (10 Pack) Size: 3mm	1	\$2.24	Idler Mounts
	Low Profile Screws M5 (10 Pack) Length: 6mm	5	\$1.16	
	Low Profile Screws M5 (10 Pack) Length: 8mm	1	\$1.25	Frame Fasteners
	Socket Head Cap Screw M4	4	\$0.08	Power Adapter Mount
	Button Head Screws M3 (10 Pack) Length: 8mm	1	\$0.89	Motor Mount
	Tee Nuts - M5 (10 Pack)	3	\$2.69	
	Double Tee Nut	10	\$0.62	
Plates & Brackets				
	3 Hole Joining Strip Plate	2	\$1.49	Idler Mounts
	Cast Corner Bracket	4	\$1.49	Frame Brackets
	L Bracket Size: Single	4	\$1.16	Power Adapter Mount
	Motor Mount Plate - NEMA 17 Stepper Motor	2	\$5.24	Motor Mount
Electronics				
	Smoothieboard	1	\$100.00	Motion & Laser Control
	Raspberry Pi Zero	1	\$10.00	Wireless interface w/ Octopi
	10W Endurance Laser Diode Kit	1	\$454.36	
	Mean Well NES-350-24 24V 350 Watt UL Switching Power Supply 120 Volt	1	\$50.00	24V Power Supply
	Nextrox DC/DC Converter Regulator 24V Step Down To 12V 20A 240W	1	\$18.00	24V to 12V Converter
	HiLetgo W1209 12V DC Digital Temperature Controller	1	\$8.00	
	Mc19cM Digital Voltmeter Ammeter Dual Display	1	\$8.00	

Equipment

Allen wrenches and pliers were needed for assembling the frame and gantry. A soldering iron and multimeter were used for electronics. A 3d printer was used to design and build custom parts, especially for the laser mount and feet for the frame.

Machine

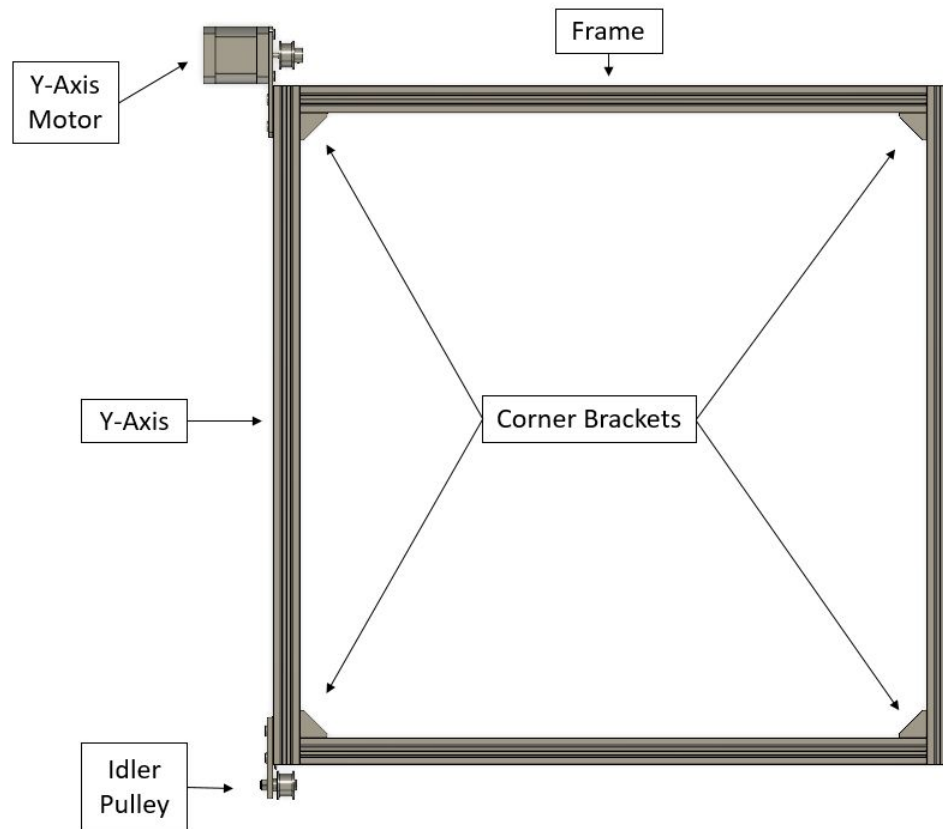
The machine was designed using [Autodesk Fusion 360](#), using parts from [OpenBuilds Parts Store](#). Emphasis was put on simplicity and cost.



Frame & Gantry

The frame is built using 20mm extruded aluminum with an OpenBuild's V-Slot profile. The profile of the V-Slot is made to work as a track for OpenBuild's V-Wheels and allows for it to double as both a track for the gantry carts and as part of the frame. The frame is held together by four corner brackets to keep the sides orthogonal. Mounted on the left side of the machine are the Y-axis motor and idler pulley. The feet of the frame were 3D printed and attached to the corners.

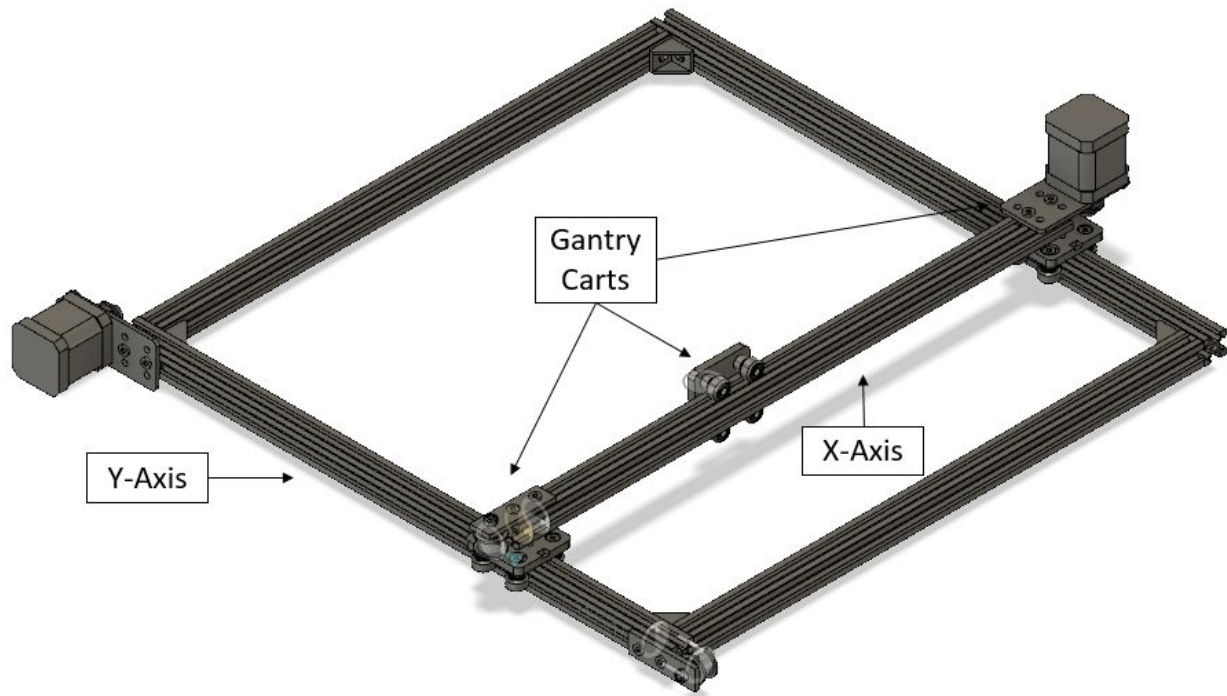
¹ The total cutting area of the laser CNC machine is approximately 360mm by 360mm.



The Y-Axis and frame.

The gantry is the part of the machine that will carry the laser. The frame acts as the gantry's Y-axis and the gantry is the X-axis. The gantry's X-axis track also utilizes the V-Slot extruded aluminum, and rests on two gantry carts that slide along the frame's Y-axis. A third gantry cart is used for movement along the X-axis, to which the laser diode will be attached.

¹ This is a work in progress. The frame's feet design is likely to change as the design is improved.

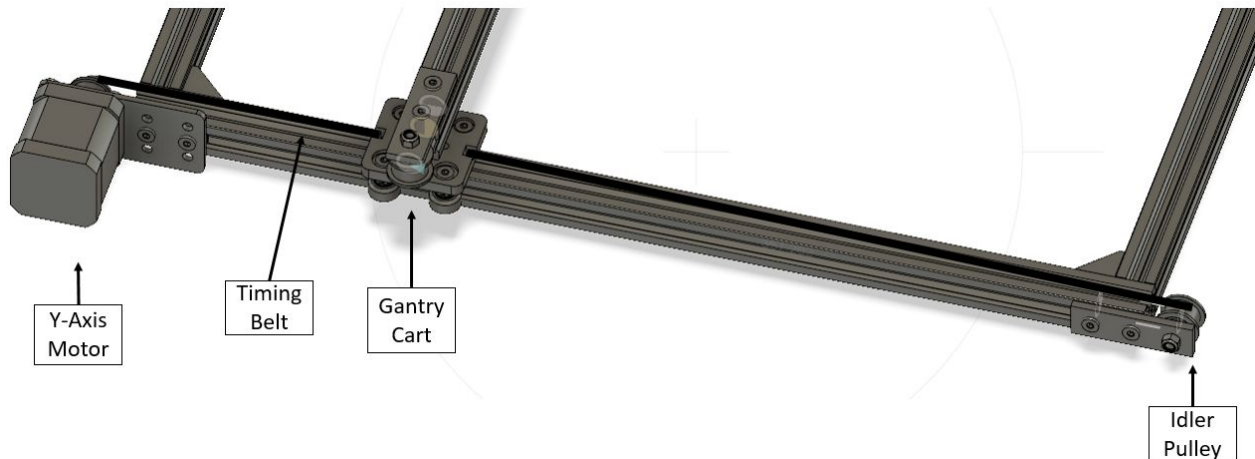


X and Y axis assembly. The gantry rests on two carts that slide along the Y-axis. A third gantry cart is used along the X-axis.

A Z-axis has not been designed yet, but I plan on designing a manually controlled height adjustment, primarily used for focusing the laser for different material thicknesses and lense focal lengths.

Motion

The gantry is controlled by two NEMA-17 stepper motors, one for each axis. The motors turn $1.8^\circ/\text{step}$ and drive a 30-tooth 2mm pitch timing pulley. The pulleys are connected to a gantry carts via timing belts running along the V-Slot channel and is looped to the underside of the channel using an idler pulley. Springs were added to the belts to keep the tension constant.



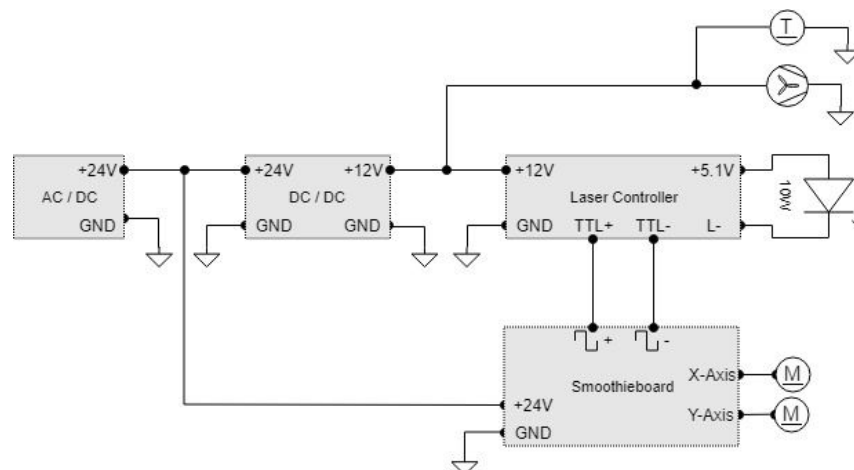
Stepper motors turn the timing belt that is connected to the gantry cart and returned via an idler pulley.

The parameters for the stepper motors and timing pulley, combined with 1/16th micro-stepping (from the Smoothieboard), produce 200 steps per mm, giving a theoretical resolution of 18.75 microns. This is given by the equation:

$$\begin{aligned} \text{steps per mm} &= ((360 / \text{degrees per step}) * \text{microstepping}) / (\text{pitch} * \#\text{teeth}) \\ &= ((360/1.8) * 16)/(2 * 30) = 53.3 \text{ steps per mm} \end{aligned}$$

Electronics

The electronics for the CNC machine consist of a Smoothieboard for motion and laser control, a Raspberry Pi Zero for a wireless interface to the Smoothieboard, NEMA-17 stepper motors, an Endurance Laser 10W kit, and various power converters for all of the electronic components.



General wiring diagram for the entire machine.

Power

The main power source is a 24V 350W AC/DC converter. 24V was chosen since the NEMA-17 steppers are rated for 24V and it is generally considered best to run them at their maximum voltage rating. This worked out well since the Smoothieboard can also run off of 24V.

The laser kit requires 12V to power the laser, thermometer, and fans for cooling, so a 24V-to-12V, 240W DC converter is used to power the laser and its peripherals.

Smoothieboard

The [Smoothieboard](#) was chosen as the primary controller for the machine. It is well suited for controlling both the motion and power levels for the laser.

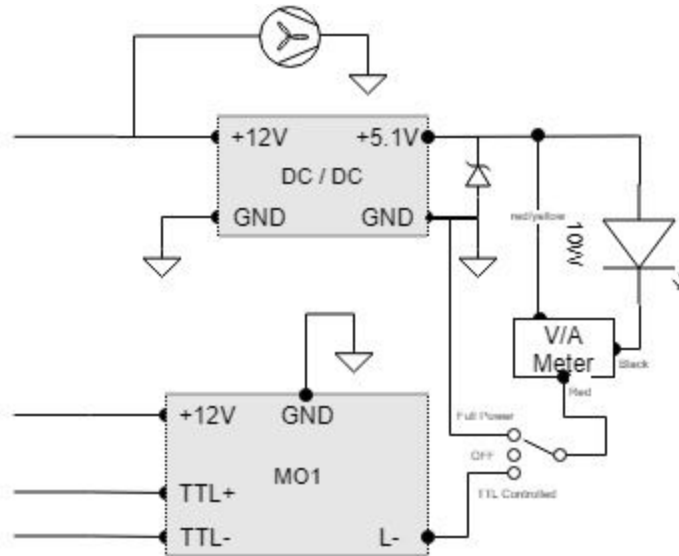
Motion Control

Motion control is very simple. The Smoothieboard is equipped with several A5984 stepper drivers with output pins that match the NEMA-17 motors. This machine only requires two motors for each axis.

Laser Control

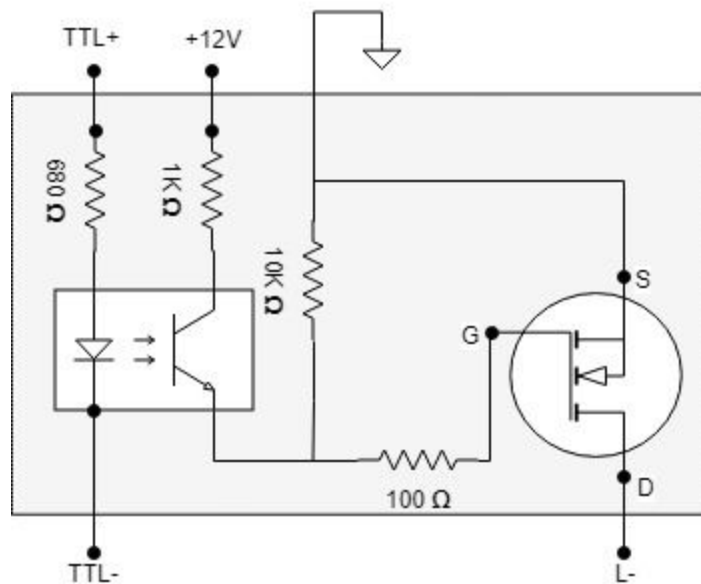
Endurance lasers are controlled through the MO1 board's Transistor-Transistor-Logic (TTL) that needs to be controlled through a Pulse-Width-Modulation (PWM) signal. On the Smoothieboard, there are many PWM pins that are capable of controlling the TTL on the MO1 board. Simply modify the laser-module settings within Smoothieboard's config file to the appropriate pin (See the Smoothieboard Settings section in the Appendix).

The Endurance Laser 10W kit came with all the necessary components to control the laser via a 12V power and a TTL signal. The 12V is converted to 5.1V (with high amperage) to power the laser through a DC to DC buck converter. A zener diode is attached to the 5.1V output to protect the laser diode. Also shown is how to wire the Volt/Amp meter that will measure the voltage and current running through the laser. There is also a switch that can toggle between TTL-control and full-power for the laser.



More detail on the Laser Controller.

The MO1 board enables transistor-transistor logic (TTL) for controlling the laser's power. The TTL signals are attached to the Smoothieboard's PWM output which is optically isolated from the high-current power of the mosfet - which protects the logic circuits of the Smoothieboard.



Wiring diagram for the MO1 board.

Raspberry Pi

The Raspberry Pi Zero W is used as a wireless interface to the Smoothieboard, used to give commands to the laser and upload files for cutting and engraving. The Pi uses a typical 5V

phone charger for power, and a micro USB-B to USB-B cord to interface with the Smoothieboard's serial interface.

User Interface

The Raspberry Pi is flashed with an image called [OctoPi](#). OctoPi contains a web server called OctoPrint that is primarily used for 3D printers but can easily be used to control a milling machine or laser. OctoPrint already has the required software to interface with the Smoothieboard's serial interface. Among other capabilities, OctoPrint can jog the machine, load and cut files, and even accept manual g-code commands. It made for an easy, (almost) plug-and-play user interface for the laser.

Future Improvements

The machine is still a work in progress and I have many improvements planned.

- Include a manual Z-axis adjustment for coarse & fine focusing of the laser
- Add an air-assist system.
- Possibly add a slave motor to the other Y-axis rail. This will depend on more testing of the laser to make sure it doesn't suffer from hysteresis due to the motor "dragging" the second Y-axis.
- Upgrading the MO1 board to the MO2 board (when it is released) for the added protection it provides.
- Move the 5.1V buck converter to the laser mount to reduce voltage drop
- Create a cutting bed for the laser
- Add a camera to the Pi Zero. OctoPrint has a webcam interface that would allow me to view the laser cutting.
- Add end-stops. For now they are not necessary as I will never leave the laser unattended. The Smoothieboard is already designed to use them, so integrating them will not be difficult.

Appendix

Smoothieboard Settings

The Smoothieboard's config file is really where all the magic happens. Here I will post the relevant settings for both motor control and laser control.

```
→ ##Stepper module configuration
→ Alpha_steps_per_mm      53.33 # Steps per mm for alpha ( X ) stepper
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→ Beta_steps_per_mm      53.33 # Steps per mm for beta ( Y ) stepper
→ Acceleration           300    # Acceleration in mm/second/second.
→ Alpha_step_pin         2.0    # Pin for alpha stepper step signal
→ Alpha_dir_pin          0.5!   # Pin for alpha stepper direction
→ Alpha_en_pin           0.4    # Pin for alpha enable pin
→ Alpha_current           1.68   # X stepper motor current
→ Alpha_max_rate         3000.0 # Maximum rate in mm/min

→ Beta_step_pin          2.1    # Pin for beta stepper step signal
→ Beta_dir_pin           0.11   # Pin for beta stepper direction, add '!'
to reverse direction
→ Beta_en_pin            0.10   # Pin for beta enable
→ Beta_current           1.68   # Y stepper motor current
→ Beta_max_rate         3000.0 # Maximum rate in mm/min

→ ## Laser module configuration
→ # See http://smoothieware.org/laser
→ Laser_module_enable    true   # Whether to activate the laser
module at all
→ Laser_module_pwm_pin   2.5    # This pin will be PWMed to control
the laser.
→ # Only pins 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 1.18, 1.20, 1.21, 1.23, 1.24,
1.26, 3.25 and 3.26
→ # can be used since laser requires hardware PWM, see
http://smoothieware.org/pinout
→ Laser_module_maximum_power 0.5 # This is the maximum duty cycle that
will be applied to the laser
→ laser_module_pwm_period 166   # This sets the pwm frequency as the period
in microseconds [6kHz via Endurance Lasers]

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