Valentine Mod

By Cooper Zurad

Document to be under regular revision.

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WARNING

This is not a toy. Electrochemistry can be dangerous and even **DEADLY**. The user of this mod is making the choice to combine salt water and electricity in order to stimulate chemical reactions. There are chemicals that are *very easy* to create with this mod that will cause **RAPID ONSET CANCER**(e.g. Hexavalent Chromium, Nickel Salts). It cannot be overstated that one should take appropriate safety precautions when performing all chemical reactions. Unless you know exactly what you're doing, which most of you will not, do **NOT MACHINE ALLOYS CONTAINING CHROMIUM**(e.g. Stainless steel, 4130 steel, inconel, etc). There are simple ways to mitigate the danger posed by machining chromium containing alloys, but I have to say for your own safety to just avoid it entirely.

ECM will always produce hydrogen gas. Improper setups can produce **CHLORINE GAS**. Do NOT run without ventilation. Begin all operations with anode and cathode in close proximity. Never have an anode that cannot be machined(e.g. carbon) as this is more likely to produce chlorine gas.

Please, for the love of God, know your chemistry, wear PPE, work in a well ventilated area, and dispose of waste properly. It's not just about you, it's about your family, friends, and your community's watershed as well. This is not a joke.

Foreword

Hi there, I'm Cooper Zurad, designer of the Valentine Mod. My sincere wish and greatest ambition for this project is to help people to achieve their own goals without having to ask anyone's permission and without having to get large capital investment. In a singular phrase, I want to do my part in the ongoing global effort to "distribute the means of production".

This mod is, in effect, an extension of and a direct consequence of the RepRap project that was started by Dr. Adrian Bowyer over a decade ago. What the Valentine does is leverage off of widely available 3D printer kinematics and power supplies in order to open up CNC sheet metal fabrication to anyone. By removing most of the skill and a large part of the cost from the sheet metal cutting process, I hope to open the doors to more robust, longer lasting, and greener manufacture at home.

While Valentine is currently *capable* of cutting steel up to 6mm thick as seen on the ZURAD Youtube channel, there are major problems with speed and taper. The current iteration of Valentine is optimized for sheet metal 1mm or thinner, be it aluminum, steel, copper, brass, etc. The only metal it's not quite ready to handle is titanium, but you can expect that soon™.

I believe that information wants to be free. You are a human being, same as me, with a mind, a conscience, and a soul. You must be free to take information available to you and to make your own choices on how to use it, no matter what risks may be associated with that. I pray that you use what I've made to make something amazing and to improve the lives of people all around the world.

I trust you'll at least do your best.

-Cooper Zurad

January 13th, 2022

Bill of Materials and Tools

BoM

- 24v DC Relay - Non-affiliate amazon link: https://www.amazon.com/HiLetgo-Channel-Module-Isolation-Support/dp/B00LW2H5GC
- XT60 3-Way Connector - Non-affiliate amazon link: https://www.amazon.com/ShareGoo-Connector-Extension-Multicopter-Quadcopter/dp/B082M6QFTQ
- 24v Aquarium Pump - Non-affiliate amazon link: https://www.amazon.com/MOUNTAIN_ARK-Submersible-Aquarium-Hydroponic-Fountains/dp/B07QVNBNX9/
- Female JST Connector - Non-affiliate amazon link: https://www.amazon.com/mxuteuk-XH2-54-Connector-Female-JST-XH2-54/dp/B083HWDPSV/
- Sewing Needle ~.5mm - .7mm ∅
- 3D prints
    - Electrode Holder (SLA Optimized)
    - Relay Box (FDM or SLA)
    - Work Holders Minimum 2 (FDM or SLA)
- (2x) M4x5 Screws w/ M2.5 Allen Key Head (Retain Relay Box)
- Zip Ties
- Solder
- Alligator Clip Head
- 16ga 2 part Automotive Wire (~200mm - 250mm)
- Flexible tubing .25” or 6mm(~200mm)
- High Low Screws McMaster #97349A430
- Appropriate plastic or glass container for machining area

Tools

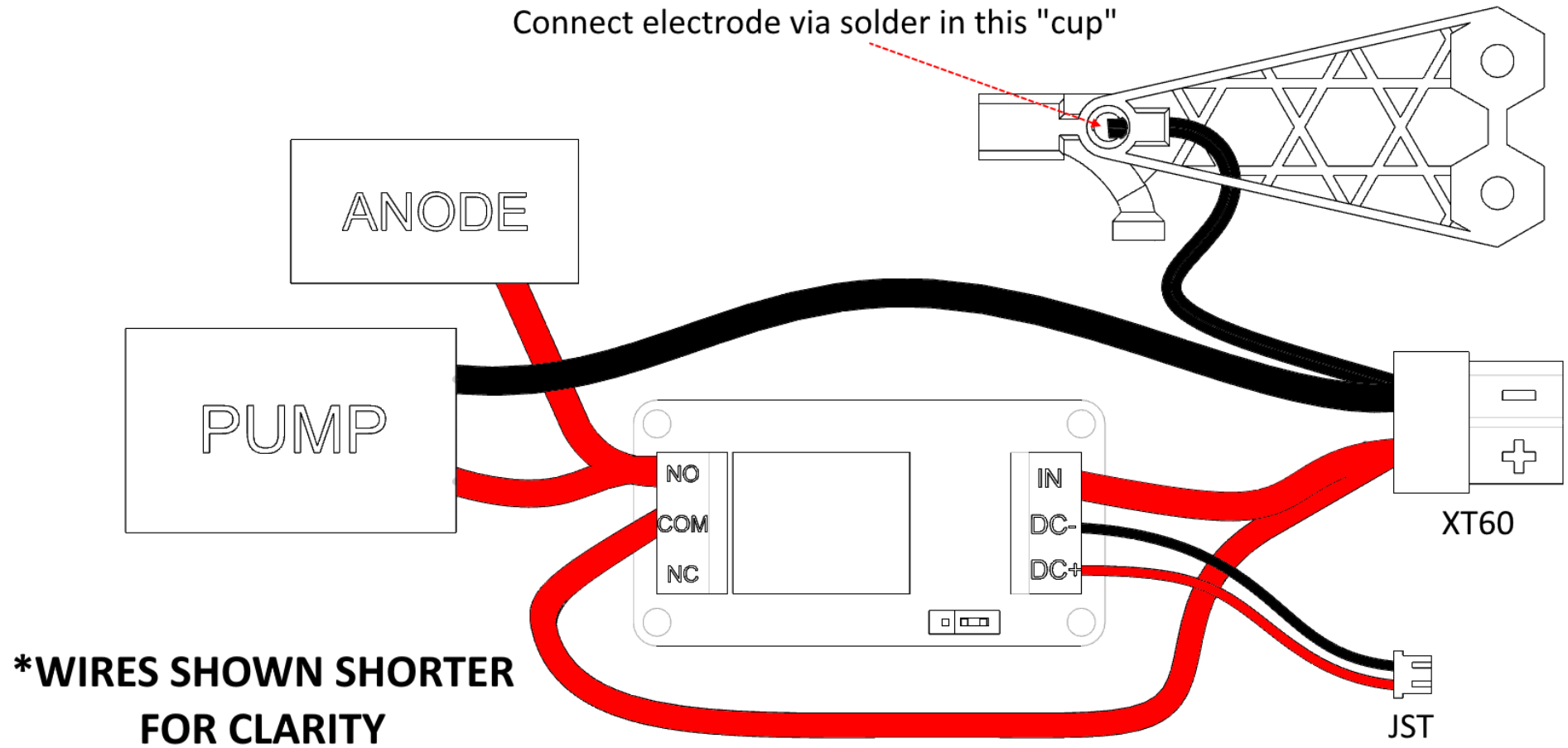
- Soldering Iron
- Allen Keys (M2 and M2.5)

Assembly

Wiring

Required Parts:

- JST Jumper
- XT60 Jumper
- 24v Relay
- 16ga Leads
- Alligator Clip(ANODE)
- Sewing Needle(CATHODE)

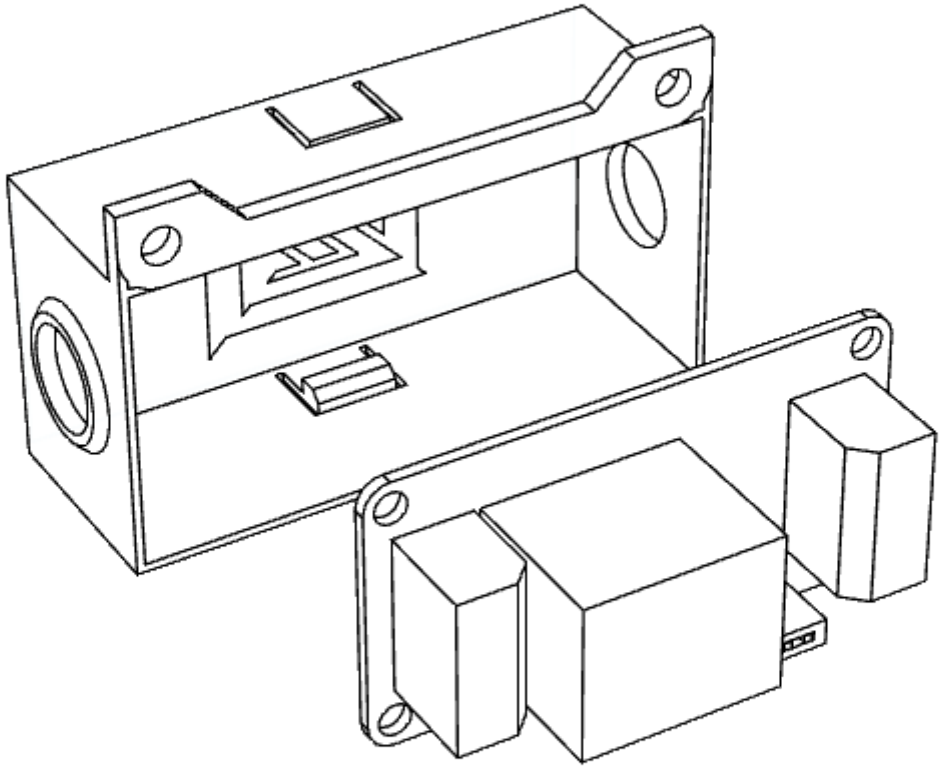


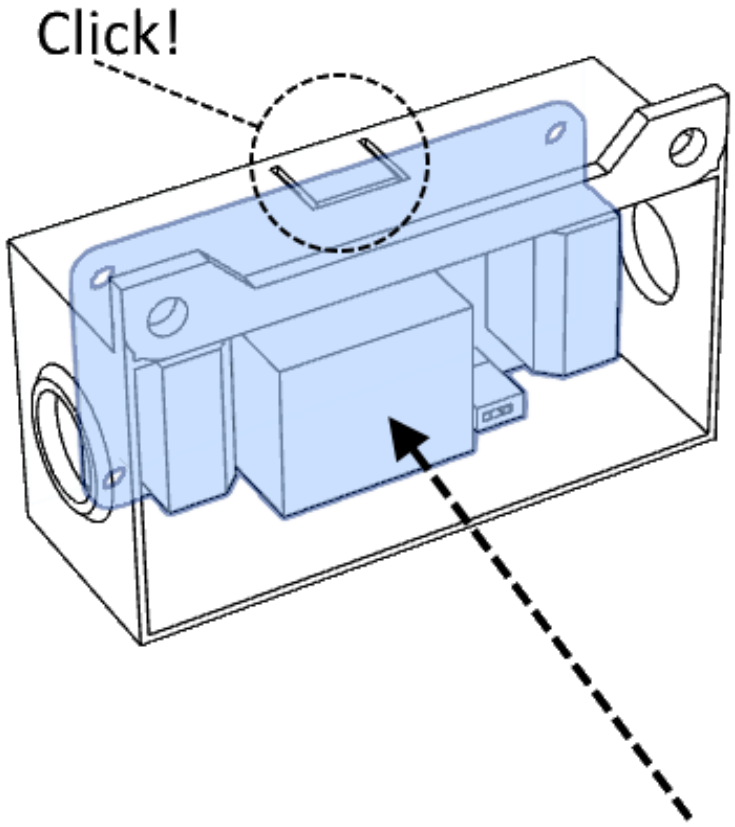
Relay Box

Required Parts:

- Printed Relay Box
- Wired Relay

Press the wired Relay into the Relay box as shown paying close attention to get orientation correct:



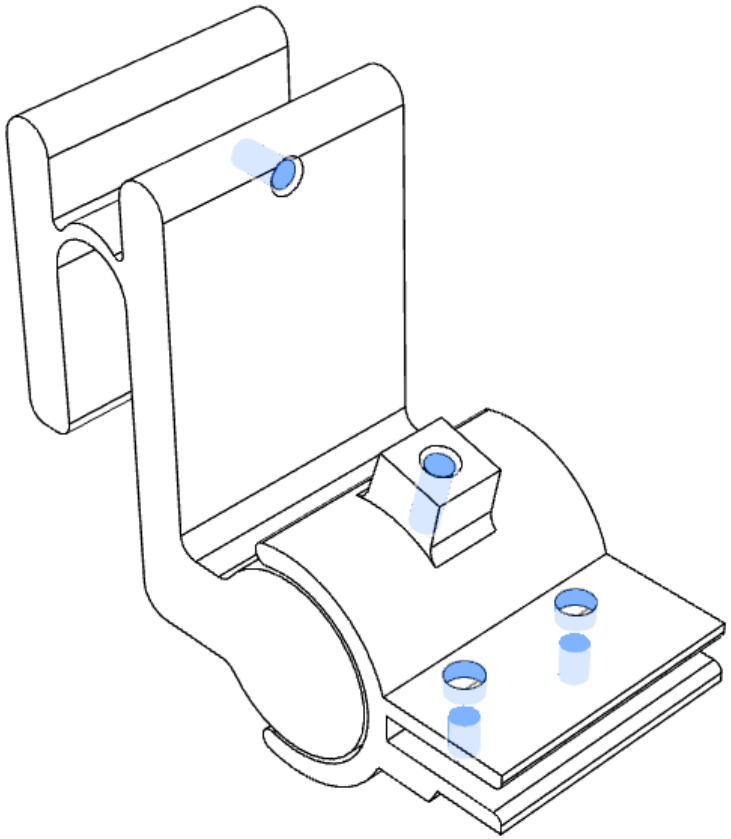


Work Holders

Required Parts:

- Work Holder Prints
- High Low Screws McMaster #97349A430

Install screws into workholder prints. Screws apply pressure to prints clamping to the basin and workpiece as well as locking workpiece orientation.



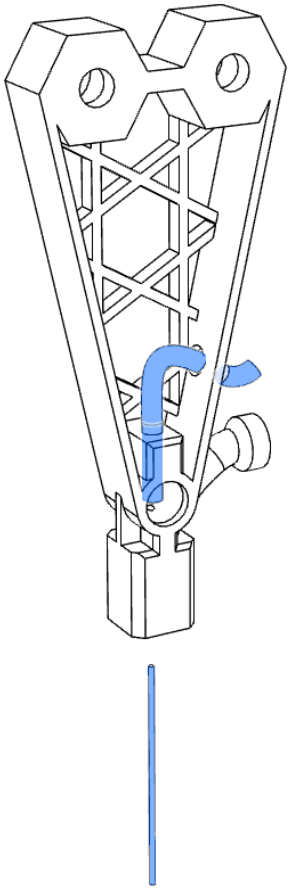
Electrode Holder

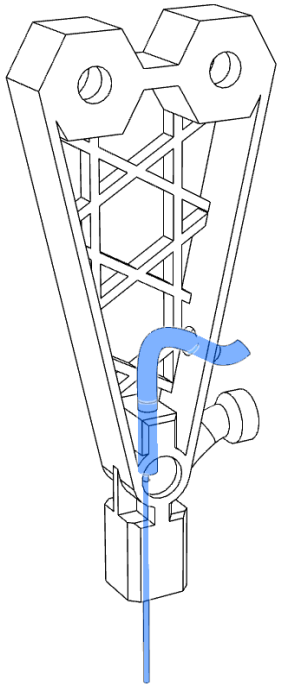
Required Parts:

- Assembled wiring harness
- Sewing needle
- Solder

Install black wire and sewing needle into holder as shown:

Apply solder and heat until low resistance is achieved between electrode and black wire. Copper plating of needle may help conductivity as may roughing of needle surface. It is important to make sure this connection is low resistance.



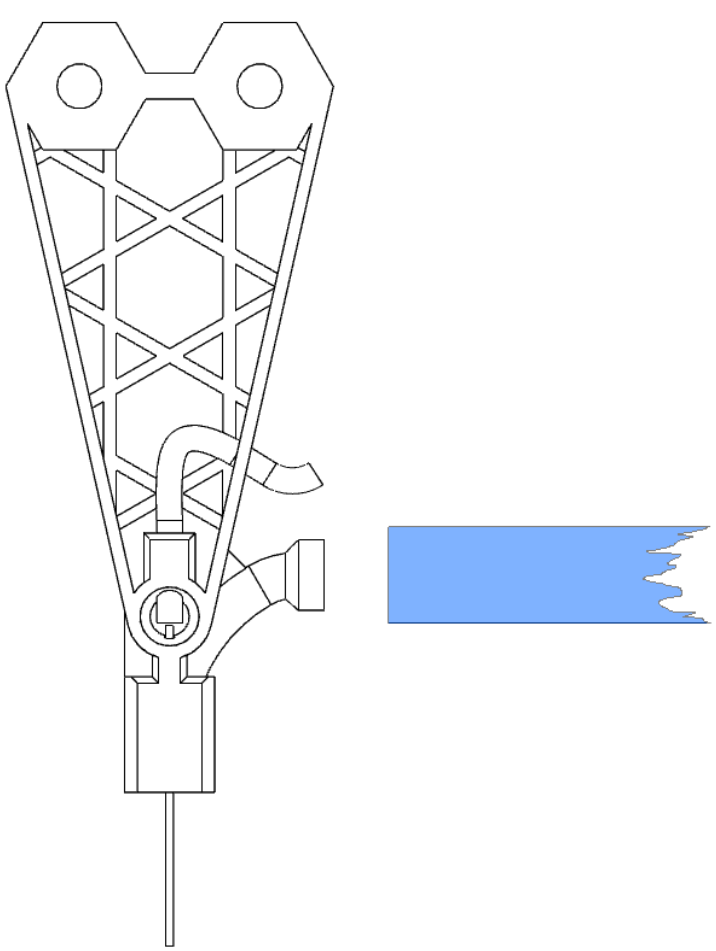


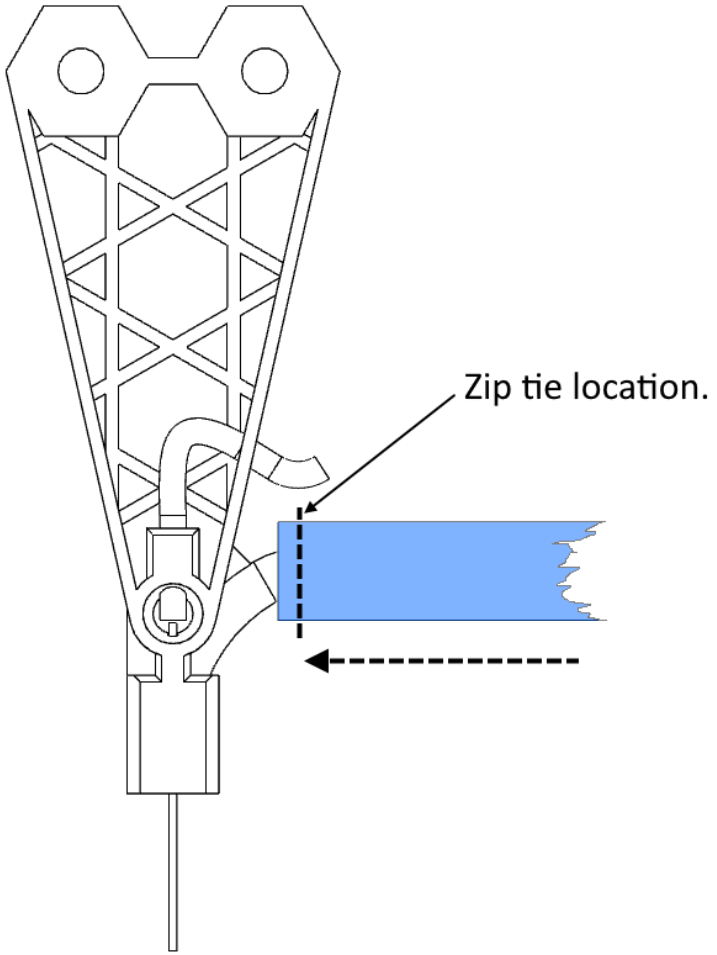
Pump

Required Parts:

- Pump
- Electrode Holder
- Zip Ties
- Tubing

Attach tubing to electrode holder and secure with zip tie as shown:





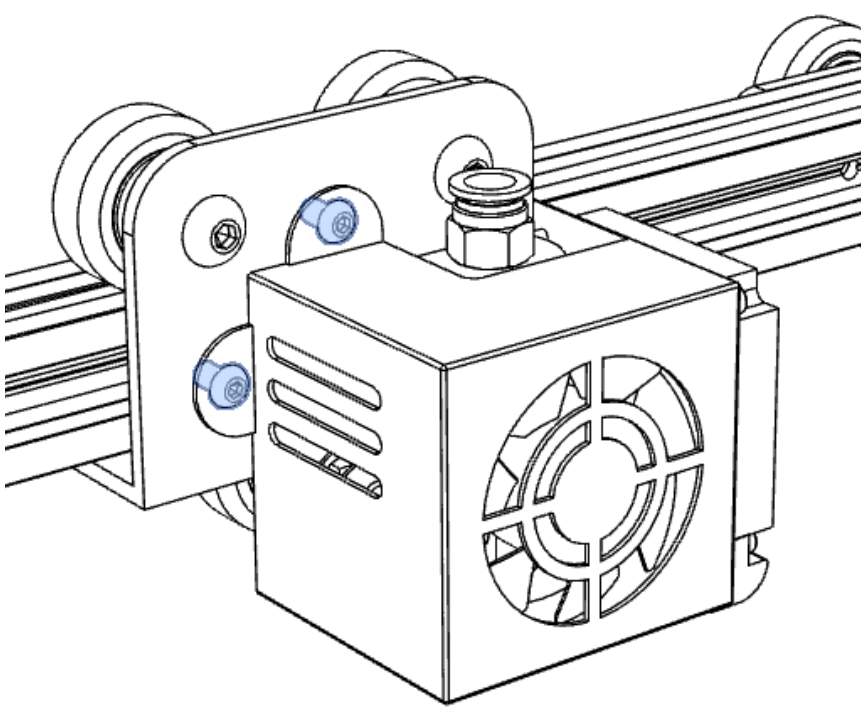
Installation

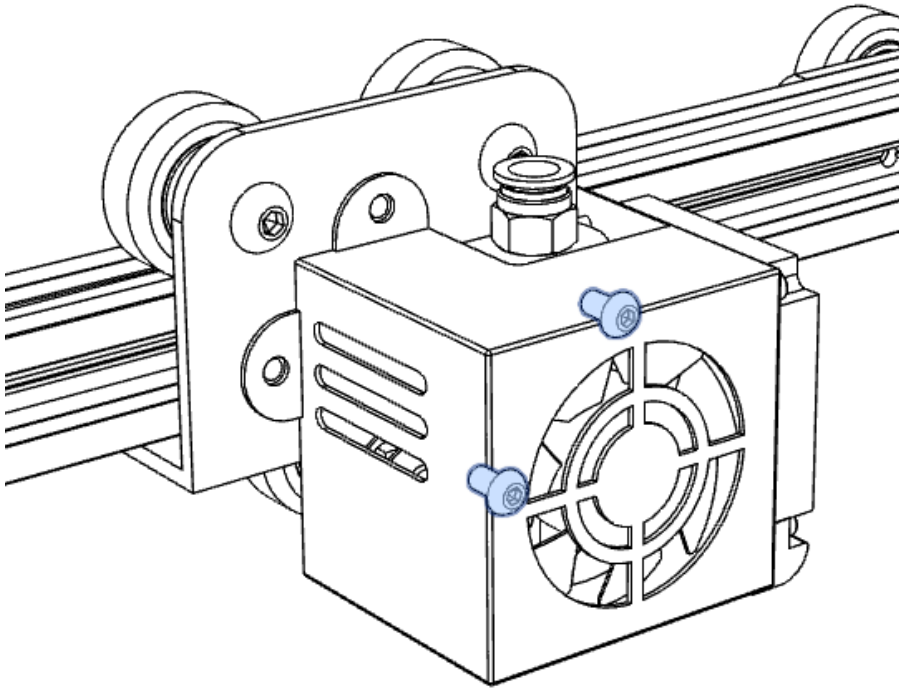
Preparing the Machine

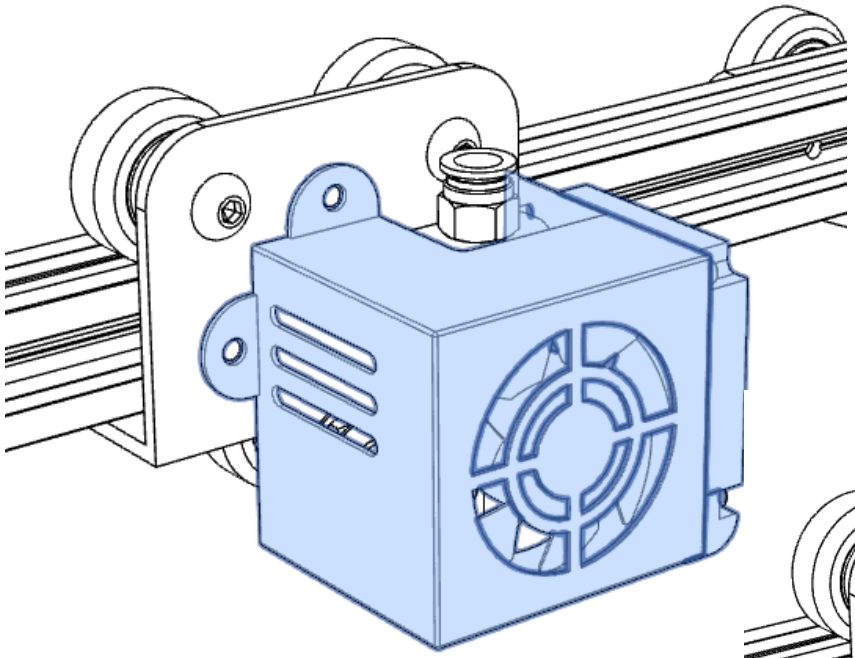
Required Tools:

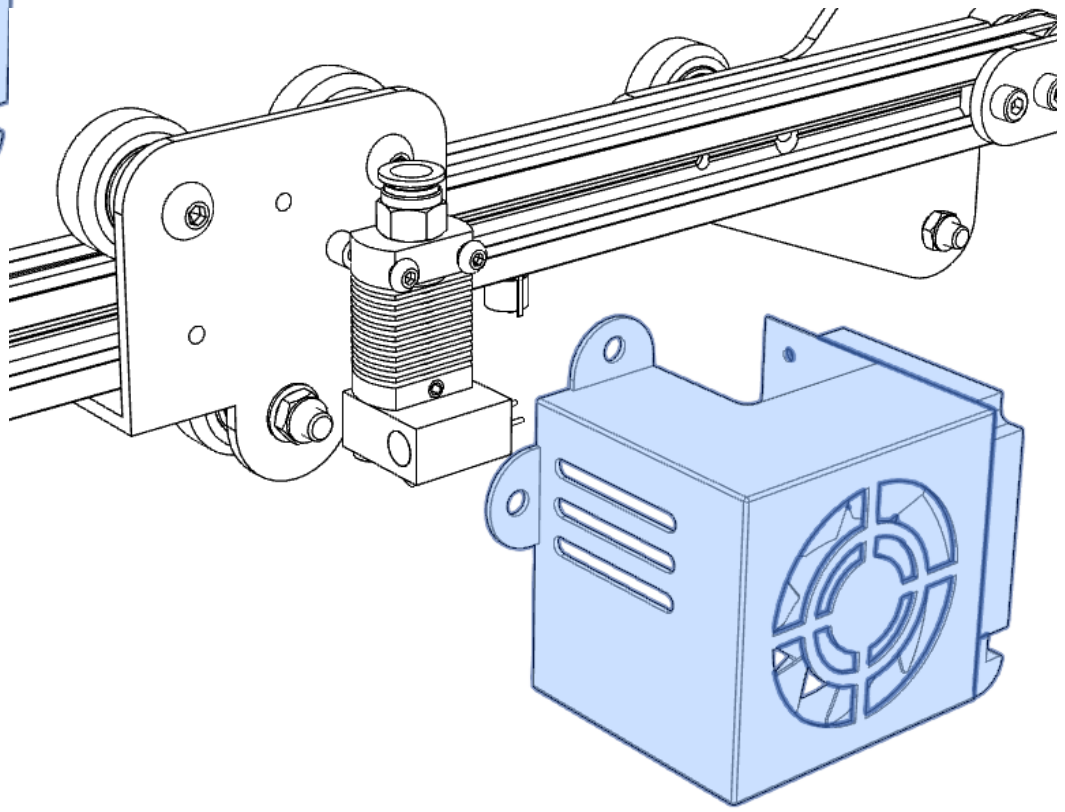
- M2 and M2.5 Allen Keys

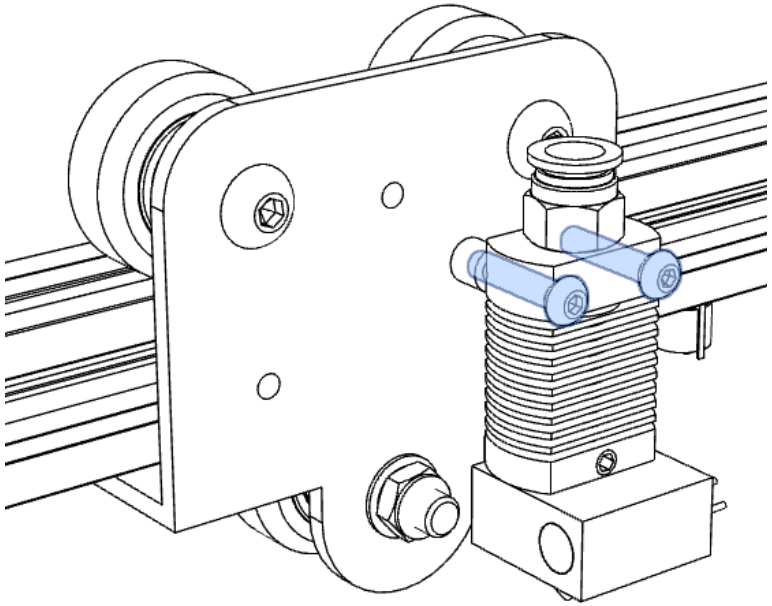
Remove Extruder Assembly as shown:

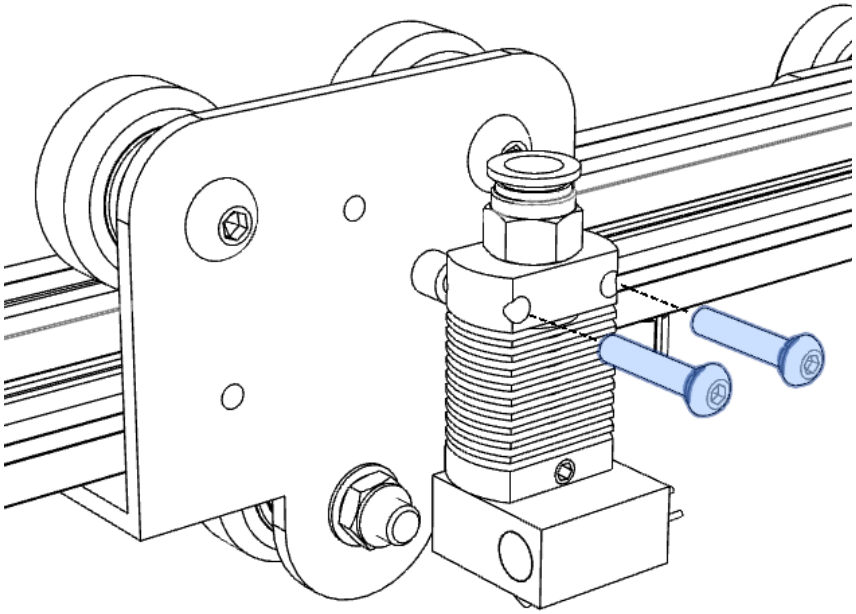


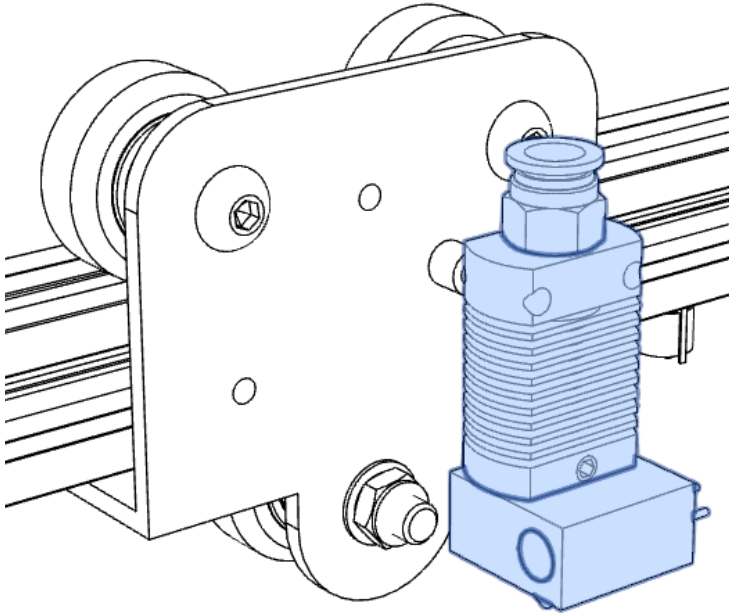


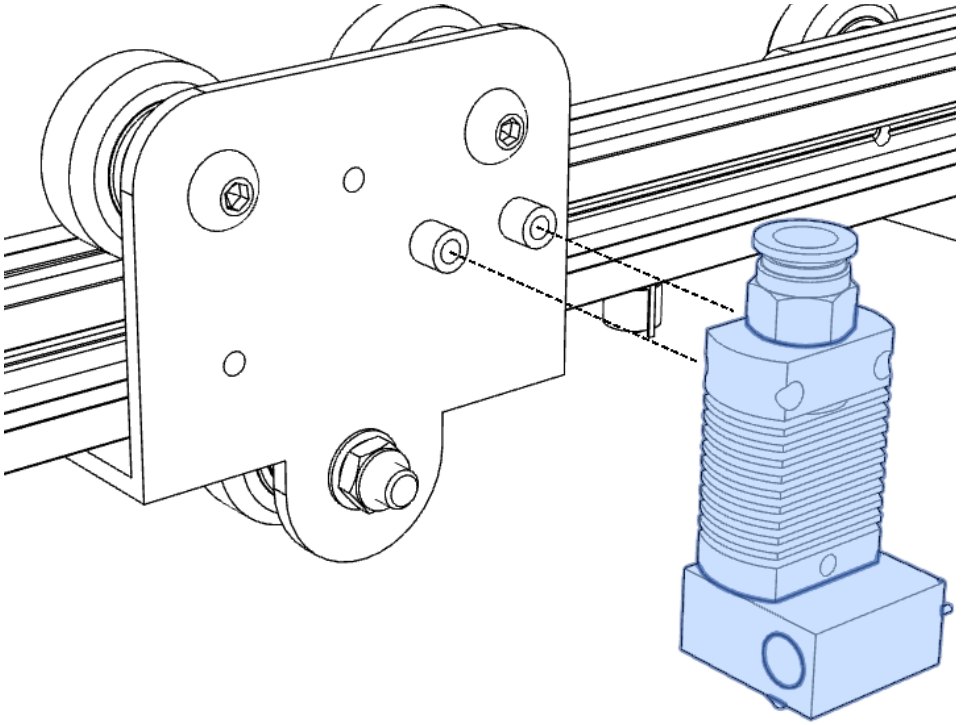








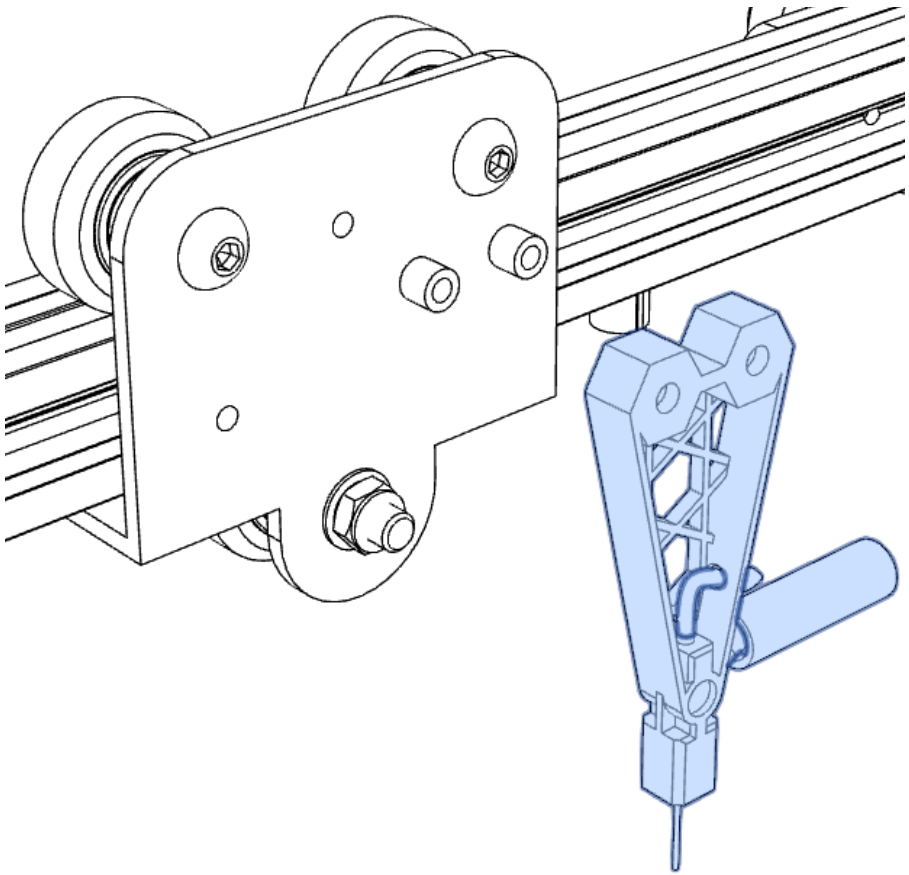


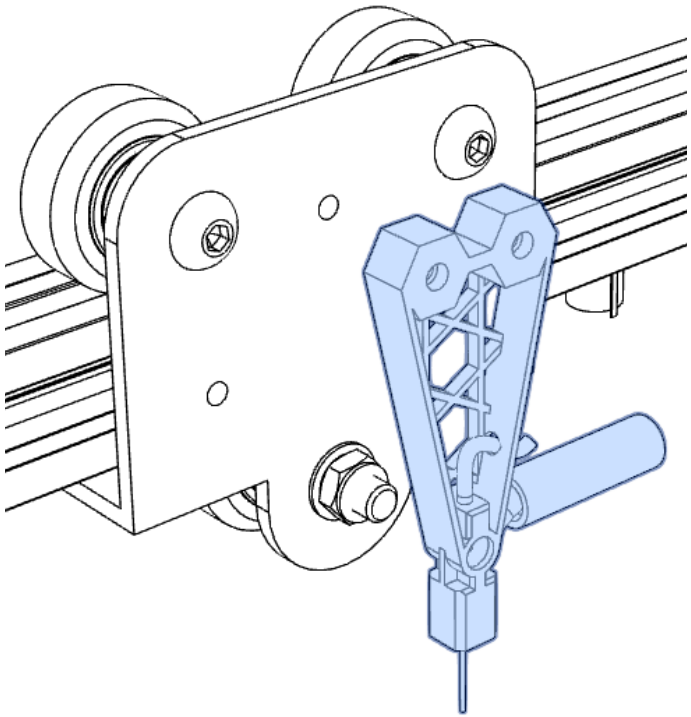


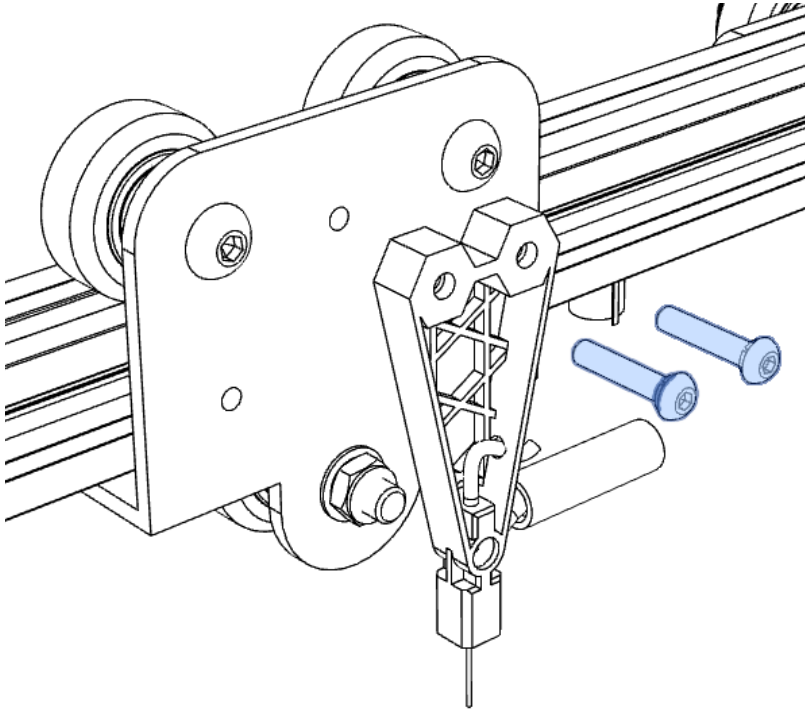
Installing the Valentine

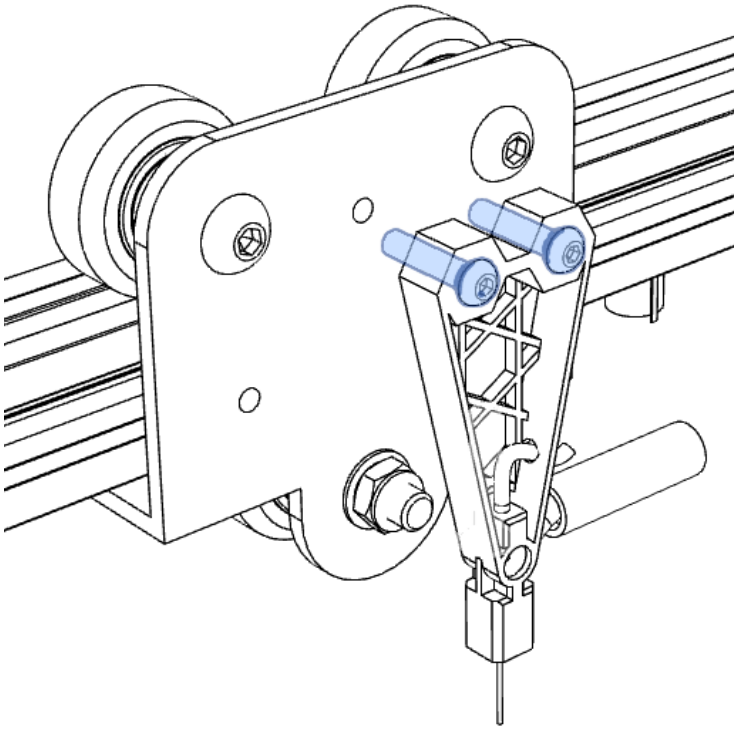
Electrode Holder

Install Assembled Electrode holder using 2 screws from Ender 3 Hotend as shown:



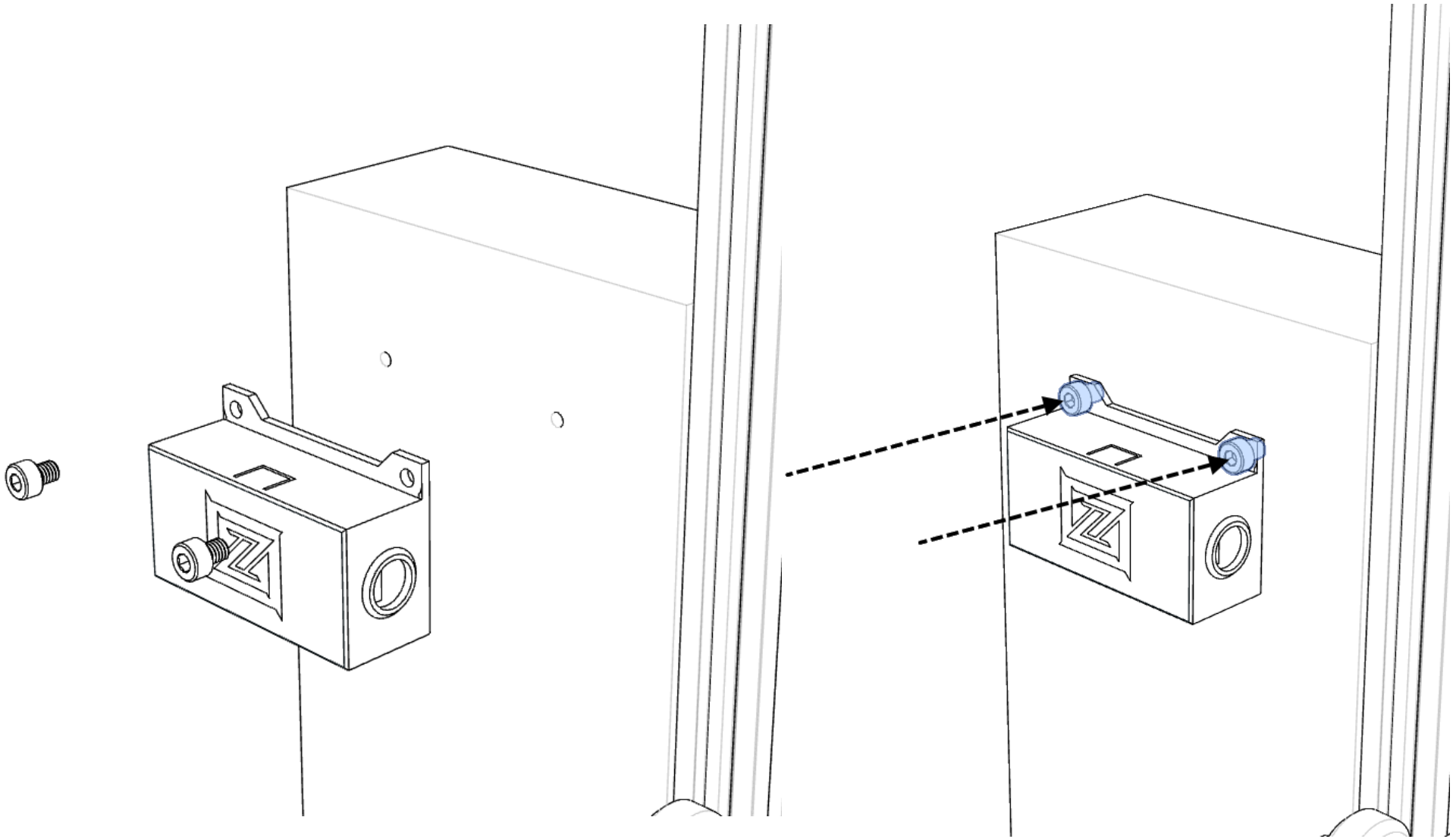




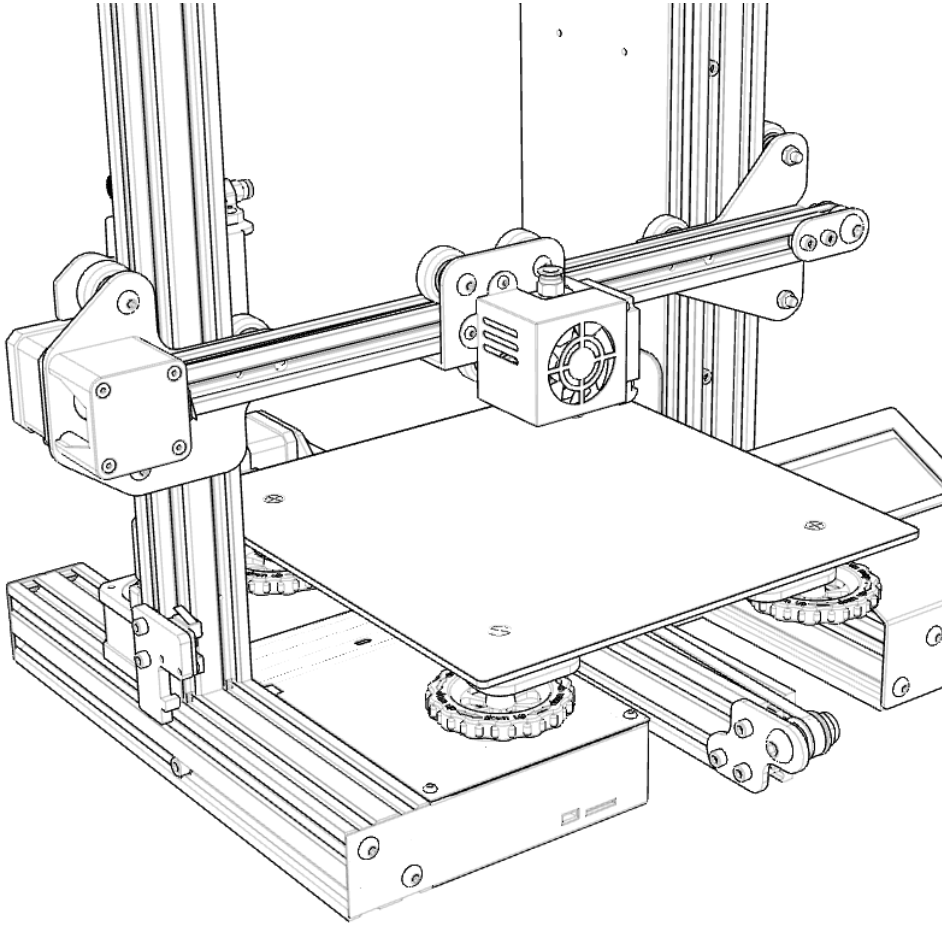


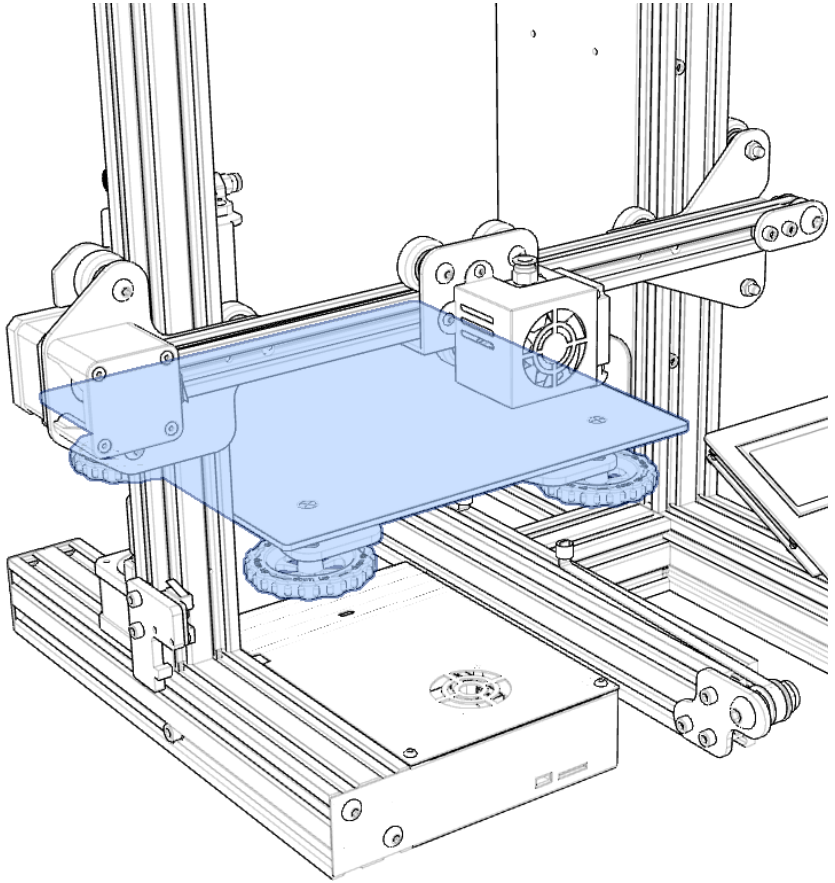
Relay Box

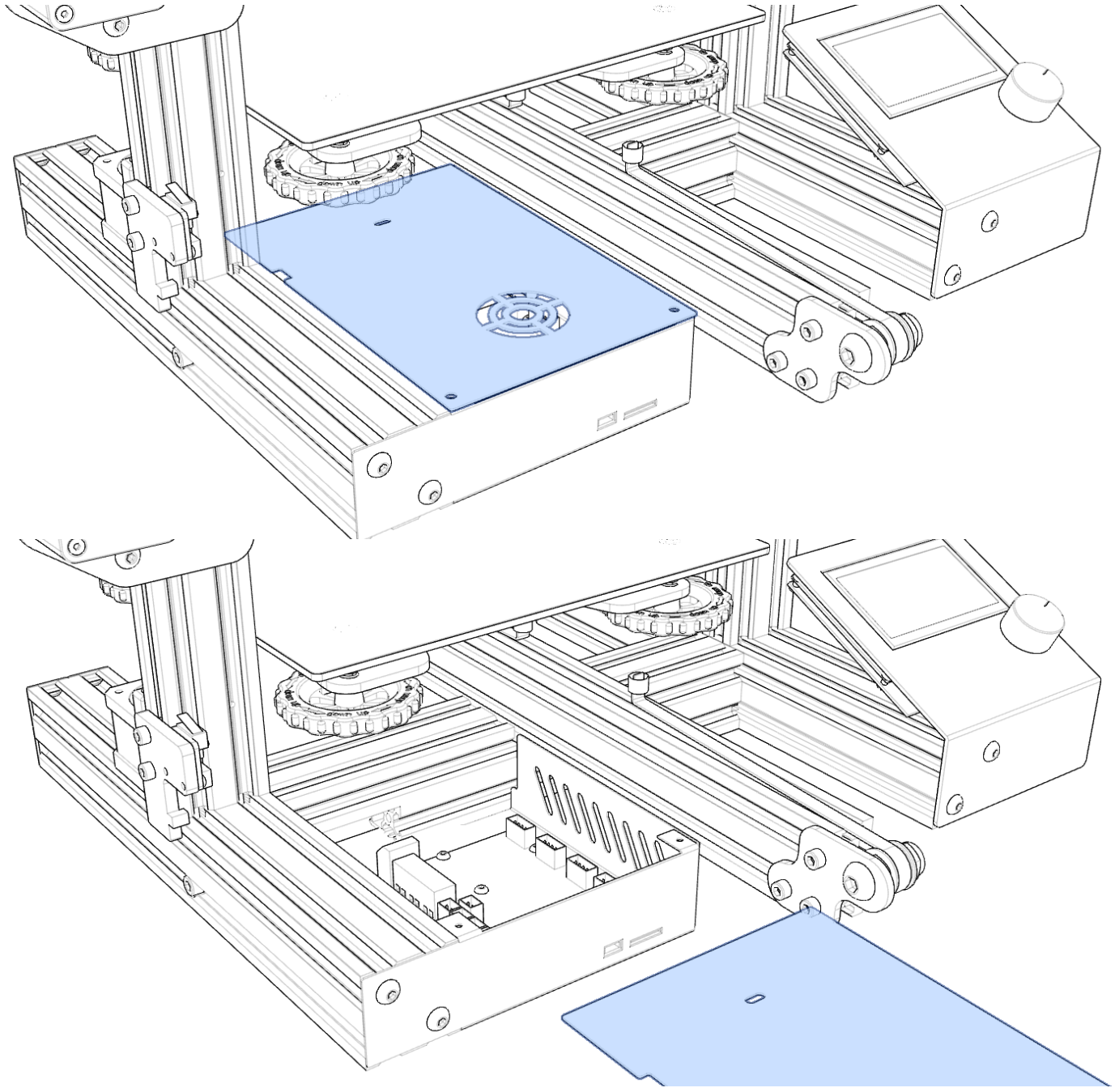
Install Assembled Relay Box as shown using 2 M4 screws:



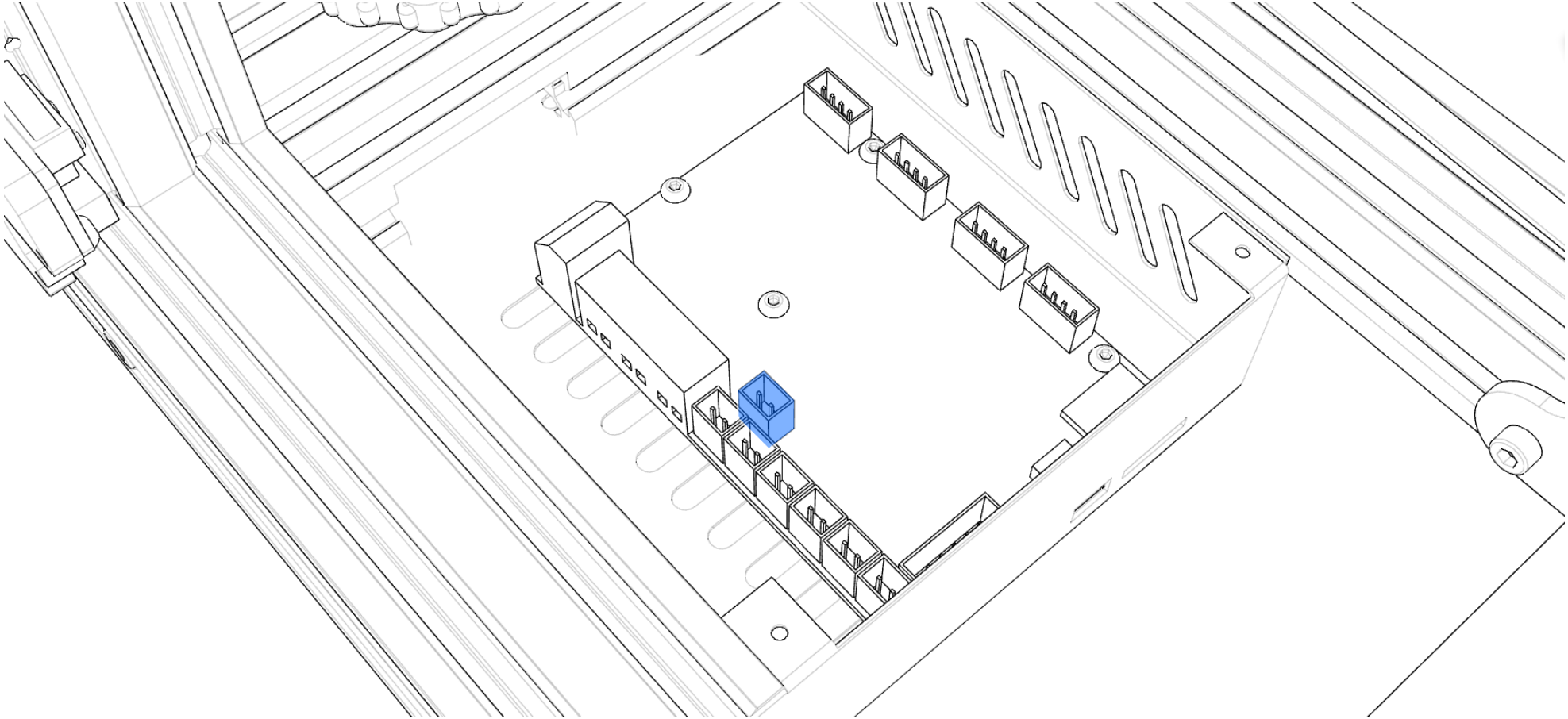
Relay Control Wire Installation







Install JST Connection in part cooling fan slot. Route of back of enclosure. Close Cover.



Machining Area

Remove the flexible print bed from Ender 3 and place down the machining basin.Securing with hot glue or something else removable may be useful to prevent shifting.

Final Checks and Test Cuts

Electrical Continuity

Before trying a cut, it's a good idea to test for electrical continuity between your electrode and the wire leading to the electrode holder. You want a very low resistance connection here. The same check would be applied to the workpiece and the positive supply wire leading out from the relay.

Electrolyte

For machining, you're going to need some electrolyte. I recommend maxing out on conductivity as this will increase your material removal rate(MRR) and the localization of the reaction is already taken care of by the flow itself. Generally I use 200g/L NaCl + 20g/L citric acid. Citric acid is important for keeping waste in solution and for capturing trace chromium released by the anode. It's cheap and can't really hurt to add it in this type of reaction.

Pump and Flow

The pump should only turn on when the electrode is on, so in order to check the flow, send the gcode command M106 or "fan on" to the Ender 3. This can also be done by using the "TEST_CUT.gcode" file included in this repo. Flow should be fast, laminar, and coaxial to your electrode. It may take some tweaking to make sure this is perfect. Coaxial flow is important for accuracy and the ability to machine in any direction.

First Cut

Now that you have your setup verified, it's time for your first cut! Place a piece of sheet metal in the workholder on your basin and fill up the tank so it's at least 3mm lower than the workpiece. This ensures proper isolation of the cut. Lower your Z axis manually so the electrode protrudes just below the workpiece. Electrode should be around 1 mm laterally away from the edge of the workpiece.

Again, verify that both workpiece and electrode are well connected to the circuit. Turn on the machine and begin "TEST_CUT.gcode". The feed rate of this file should be slow enough for cutting 1mm steel no problem. It's probably not the fastest rate you can cut, but it should work.

FAQ and Troubleshooting

Q. Can I cut metals other than steel? Will this work on aluminum?
A. Yes! This process should be able to cut any sheet metals without physically deforming them. Titanium is the only current limitation because of anodic formation of titanium oxides. This can be alleviated by short reverses of the polarity, but the relay is not capable of this.

Q. Will you be adding the ability to cut titanium?
A. Yes! Titanium is absolutely one of our current goals and will be facilitated by a move to an H-bridge reaction control. Ideally, we'll still be able to leave the firmware unchanged.

Q. Can I cut thicker metal than 1mm?
A. Technically yes you can cut thicker metal, but even 2mm steel ends up having an almost unacceptable taper to the cut. This appears to be due to the way the laminar flow of solution breaks up and begins to hug the sides of the cuts. I've cut up to 6mm steel, and I bet you could go even thicker than that. Chemically, there should be no limit to the thickness. You could do 25mm or thicker, even.

Q. How will you fix the taper on the cut?
A. There are a couple of methods in development right now. Currently we hope to develop a specific reaction controller PCB that can help us with that. It's kind of a complicated subject and more info is available on the Discord channel.

Q. You said you may sell kits, are those available?
A. No, kits are not currently available. While I do think that the current iteration of this project is in a usable state, kits are outside of my current capabilities. They may happen in the future or I might set up a kickstarter for it if there is interest, but I would do that for a more advanced version of Valentine. As it stands right now, the files are GPL 3.0 so others may fill the market gap.

Q. This seems too slow to be useful. Why would anyone use this?
A. 3D printing is also slow. This release is the culmination of many hours of work from 1 person. Hopefully, there will be interest in helping to develop the Valentine into something that can cut faster and thicker. As we better localize the reaction we will be cutting faster for the same MRR. Smaller reaction area with similar MRR equals faster feed rates.

Q. My machine just turned off during a cut. What happened?
A. Your electrode shorted to the workpiece. Turn off the printer immediately and retract the tool. A slower feed rate or better flushing may be required.

Q. How do I dispose of my waste?
A. Great question. Drying the waste is a great way to consolidate the floc that comes from the reaction. I would recommend taking it to a chemical disposal location in your area. Electroplaters may allow you to drop off waste for a fee. Once dried, your ECM waste may also be mixed in with waste oil and taken to a local disposal site. Check with your municipality and follow local laws. Almost anything is better than dumping it down the drain or into the garden.

Q. Why is this called “Valentine”? That doesn’t really mean anything.
A. Valentine is the name of Ender’s big sister in the novel Ender’s Game. Since this was initially designed for the Ender 3 and serves to significantly increase its capabilities, I thought it was appropriate. Also, it’s quite a bit snappier than “ZURAD Ender 3 ECM Mod”. Oh and the electrode holder kind of looks like a heart, so I’m going to roll with that.

Q. This is fake!
A. lol, lmao

Contribute

I’ve spent a huge amount of time and money trying to make this work. To support future development, please donate crypto to the project:

XMR: 482s7PDQWEiVxVWuUF3q6MbXrYjHV1TFcQAmT3ZM9H8MXUqJuG6TvsmBipanJfqu3m3n3cYpnb6VxHxgxUvToQBZ8bKf8vW

BTC: bc1qpdvgtazmmv82aekwx78ztl88d8e7suzmhjj20k

ETH: 0x0e542d2015dAB43A0Fab9C976AC97BB16FF7a605

LTC: LKGkJJo8R7Xpo35cTwubN9ykmGqZeDDKgp

BCH: qrpskdg850kdtqpp45up49ldyn9t7h04qqg4ucqk07

ZEC: t1af4tFNiM1hhDVh5zFKjLovYqLHFFNwMmJ

DOGE: DU2NfM7yaCD5jef6XobA3WUcG6byNZgSzu

To donate your time and expertise, please join me on my discord channel:

https://discord.gg/z4XNk7Hkgw

Special thanks to those of you who have already been diving headfirst into difficult problems with me. You make up for what I lack and together, I believe we’ll make an amazing tool that will change the way the world machines sheet metal.