Instructions for assembling and operating Open Syringe Pump

These instructions assume all the parts have been printed/acquired, and the linear actuator (see Amazon link in Bill of Materials), fasteners, and tools are also in hand.

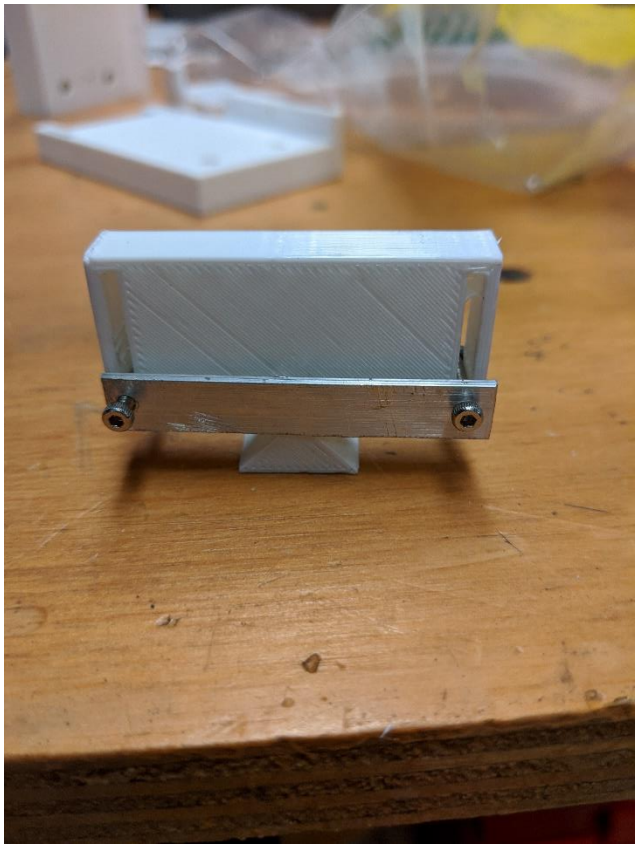
The Syringe Pump

1. Steel plates
    a. Cut a piece of hardened steel shim (<= 3 mm thick) to two rectangles.

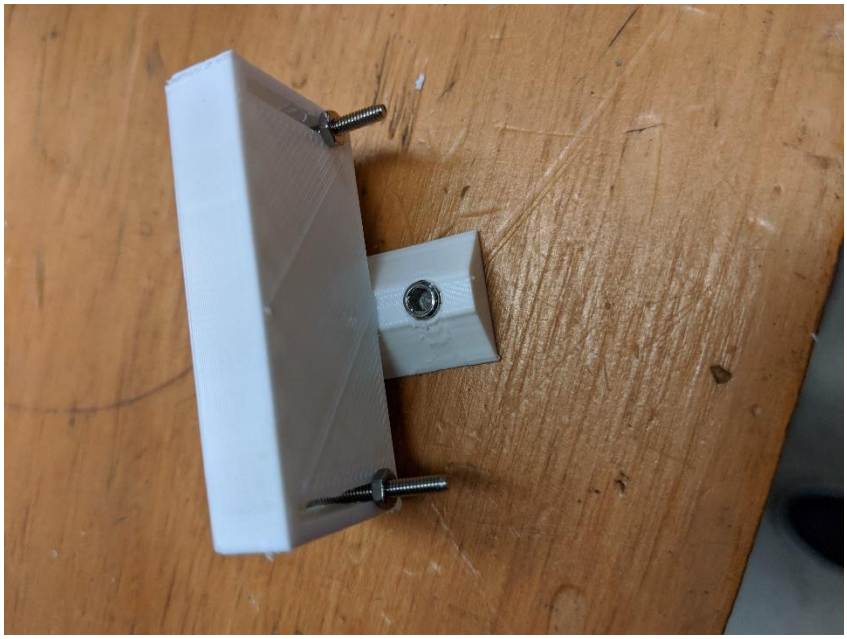
    b. Using the 3D printed “syringe_holder.stl” piece, mark on each steel plate where the holes should be drilled by sliding a drill bit into the holes through the opposite side. (Note: the top of the steel plates should not be above the lower edge of the concave portion of the syringe holder while marking the holes)

    c. Drill the marked holes using an M3 or 1/8” drill bit.

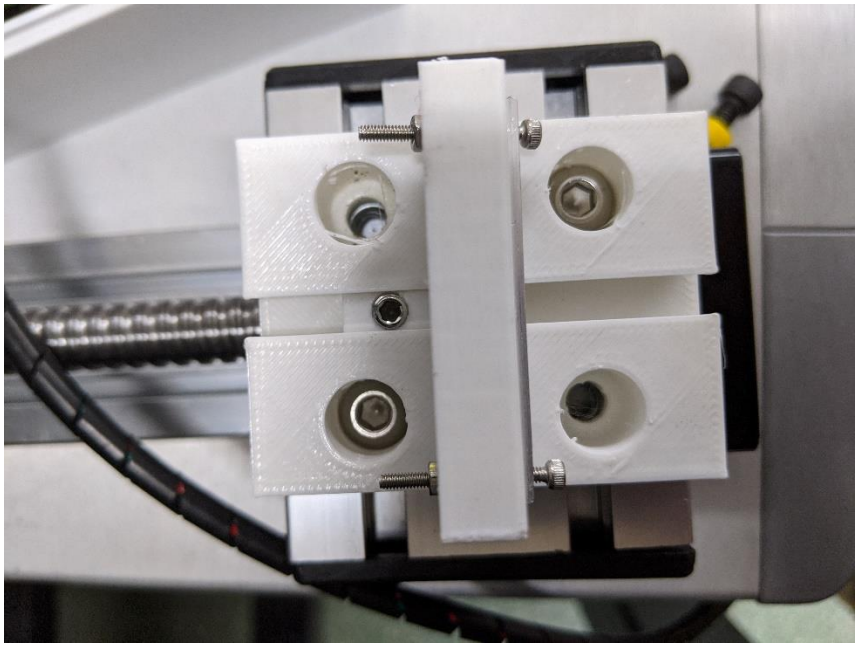
2. Plunger holder assembly
    a. Attach one of the steel plates to the “plunger_holder.stl” printed part.



    b. Insert an M5 set screw into the “plunger_holder.stl”.
    (Do not tighten)

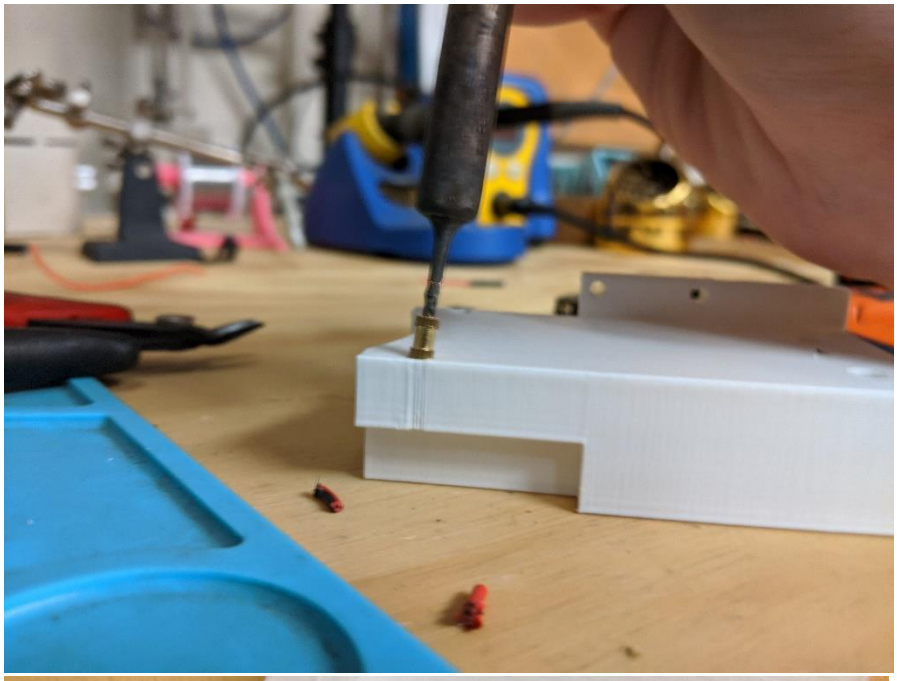


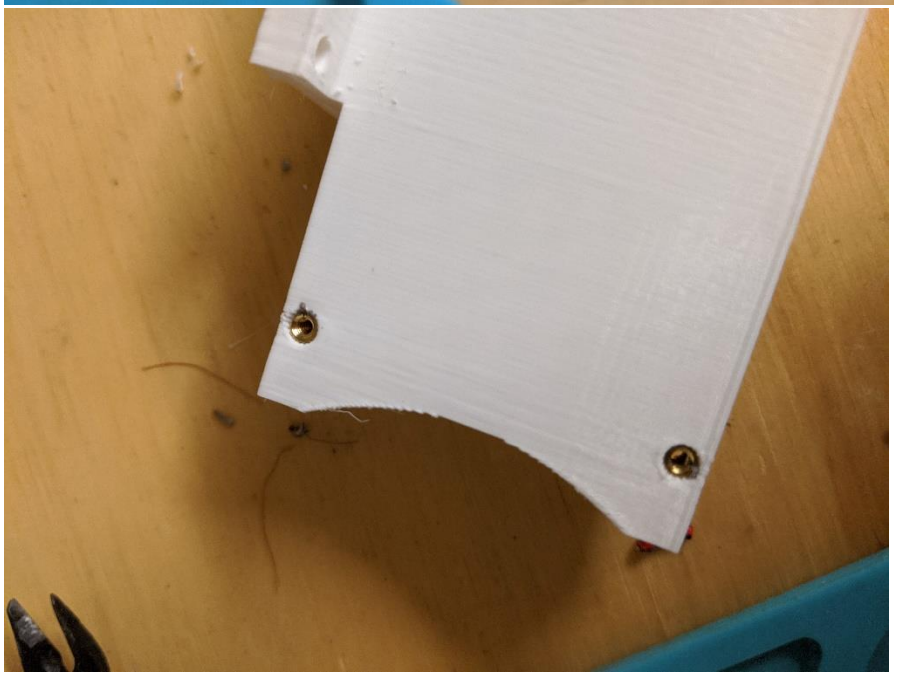
c. Attach the “plunger_holder_base.stl” to the linear actuator using 4 M6 screws.



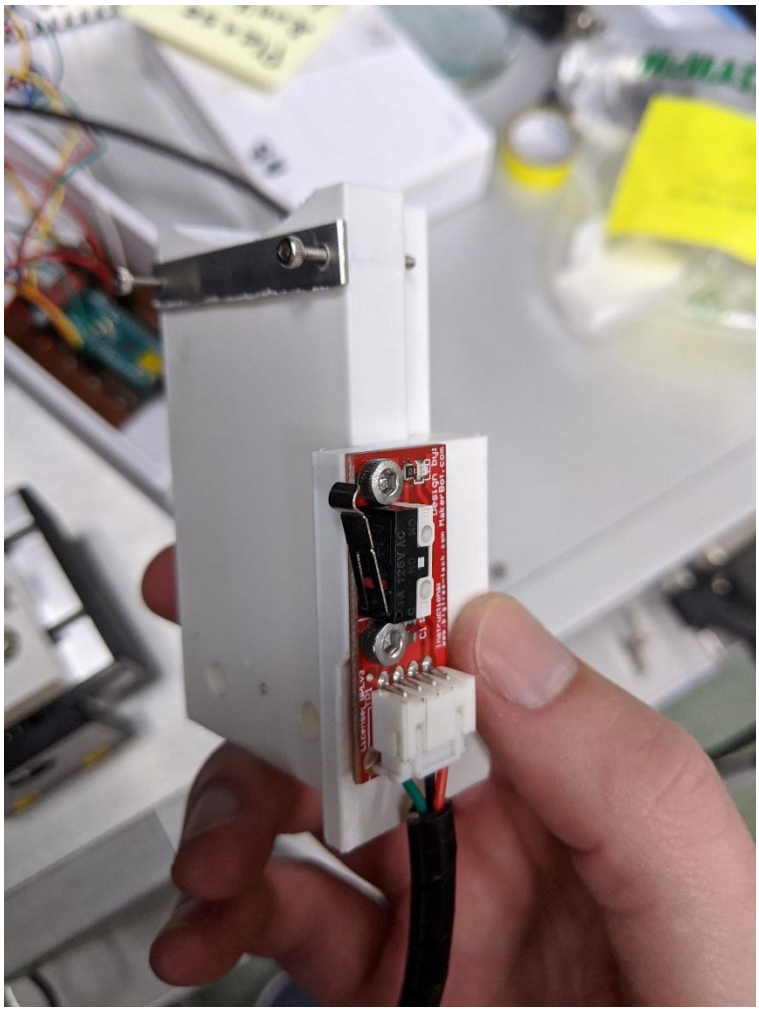
d. Slide the assembled plunger holder dovetail into the “plunger_holder_base.stl” printed part. Do not tighten the set screw.

3. Syringe holder assembly
    a. Using a soldering iron, place the brass threaded inserts into the holes on the “syringe_holder.stl” 3D printed part.

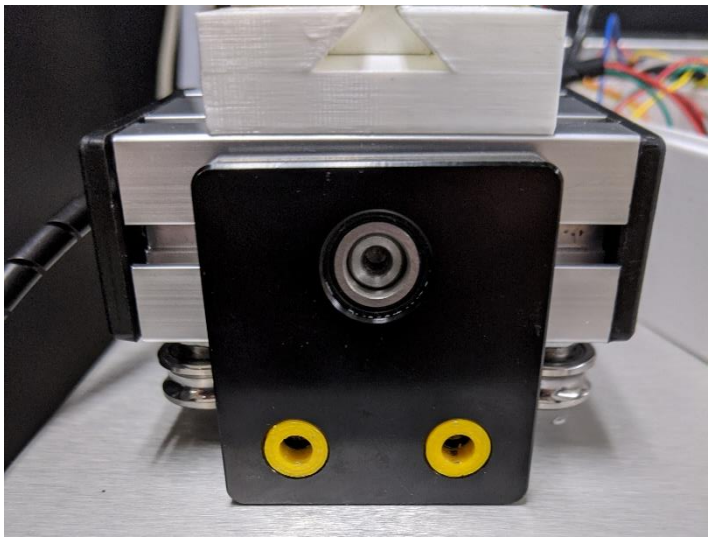




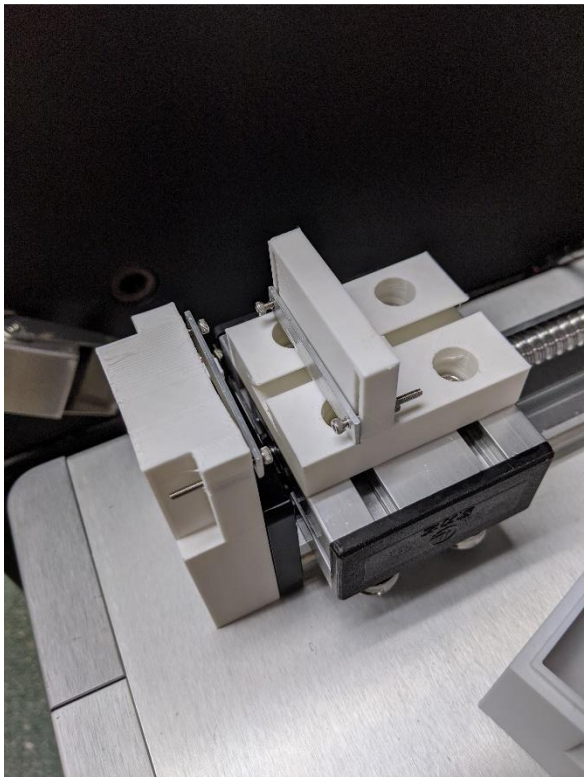
b. Attach the other steel plate to the back side of the “syringe_holder.stl” using 2 M2 screws. Using 2 M3 screws, attach the mechanical endstop to the base of the “syringe_holder.stl”.



c. Unscrew the two M5 screws at the end of the linear actuator. Place the two 3D printed “screw_hole_filler.stl” parts in the empty screw holes.

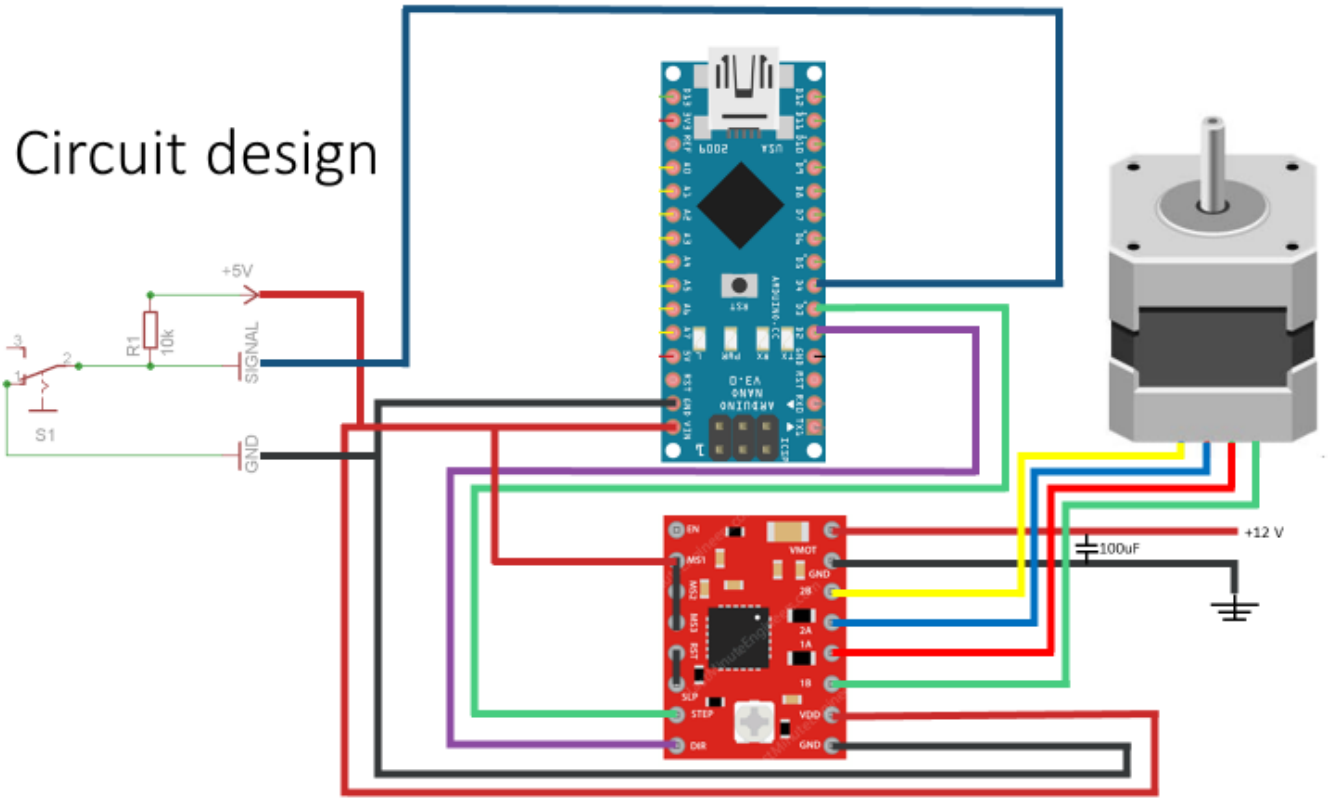


d. Attach the assembled syringe holder using the two M5 screws from the linear actuator to secure it in place.

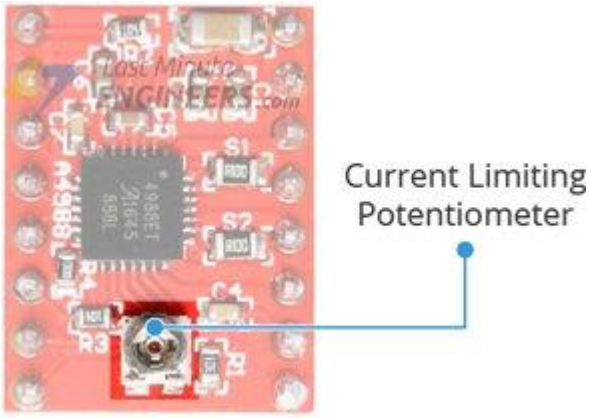


The Microcontroller

1. Refer to the wiring diagram below to wire the microcontroller hardware.



2. Using either screw terminals or solder, attach the 12 V power source and ground cables from the 12 V power supply to the VMOT and GND pins of the A4988 board. (note: the only way to power off the system is to unplug the power supply)
3. The 40-100 µF capacitor is in parallel with the 12V and ground in order to help protect the board.
4. Note: the A4988 driver is configured in the circuit to have 1/16 steps instead of the full steps. (The MS1, MS2, and MS3 pins are all connected)
5. Connect the Arduino d2 pin to the DIR pin on the A4988 driver, and the d3 pin to the STEP pin on the driver.
6. Connect the Arduino 5V pin to the MS1/MS2/MS3 pins on the driver.
7. Connect the RST and SLP pins on the driver.
8. Connect the Arduino 5V pin to the VDD pin on the driver.
9. Connect the Arduino GND pin to the GND pin on the driver.
10. Wire the endstop NC wire (green) to the d3 pin on the Arduino and the NO and ground to the 5V and GND pins on the Arduino, respectively.



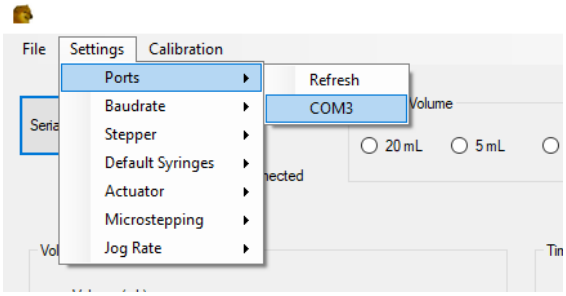
11. Using a multimeter and a small screwdriver, adjust the current limiting potentiometer on the driver so that the voltage read between the potentiometer and the GND pin is about 0.6 V. Follow this guide: https://ardufocus.com/howto/a4988-motor-current-tuning/ .
12. Connect the Nema 17 stepper wires to the 2B, 2A, 1B, 1A pins on the driver as shown in the diagram. If a different stepper motor is used than the one that comes with the actuator on Amazon, you will need to wire it according to that motor's specifications.
13. If when running the motor is loud/jumpy, adjust the potentiometer to reduce the reference voltage.

Software: Arduino Sketch

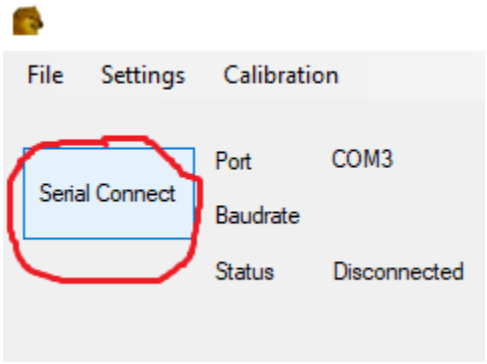
1. Download the Arduino IDE from the Microsoft store: https://www.microsoft.com/en-us/p/arduino-ide/9nblggh4rsd8?activetab=pivot:overviewtab
2. Load the sketch from the Github repository in the IDE environment.
3. Select the board "Arduino Nano" under the Tools tab.
4. Plug the Arduino into a USB port on the computer.
5. Select the appropriate COM port under the Tools tab.
6. Click the "Upload" button at the top of the page.
7. The Arduino LEDs should flash while the sketch is uploaded.
8. Keep the Arduino connected to the computer.

Software: Windows Application

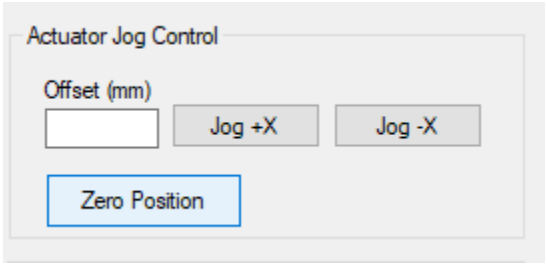
1. Download the executable file.
2. Run the executable file.
3. Click "Settings" and select the COM port for the Arduino that is plugged into the machine.



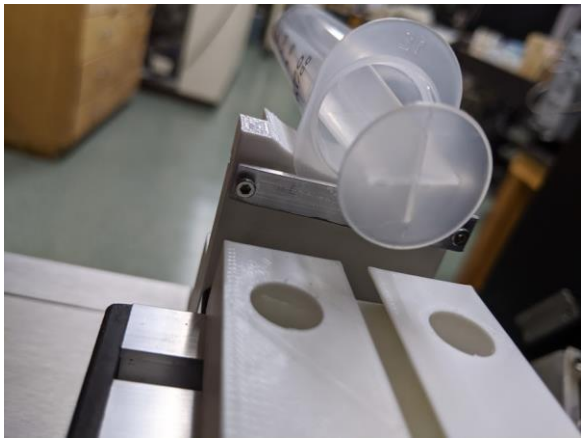
4. Click the “Serial Connect” button.



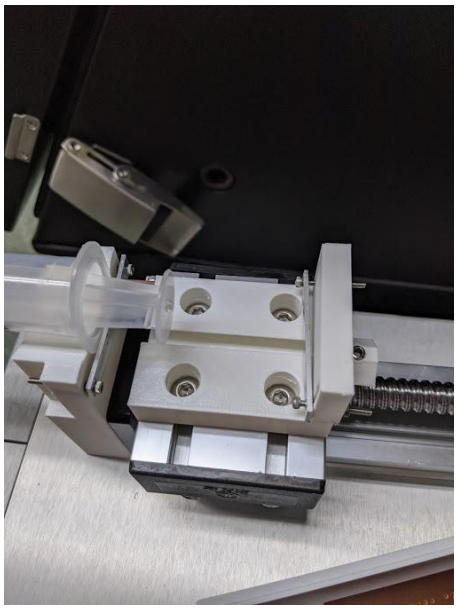
5. If the Arduino does not connect, try clicking the “Serial Connect” button again, or try a different COM port.
6. The status will show “Connected” if the Arduino is connected to the application.
7. Once connected, zero the position of the stepper by clicking the “Zero Position” button. (note: there should not be a syringe attached during this step)



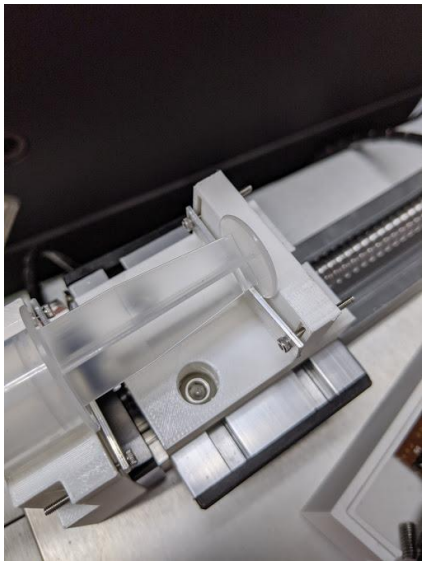
8. Attaching the syringe:
    a. Use the screws on the syringe_holder.stl part to grip the syringe flanges.



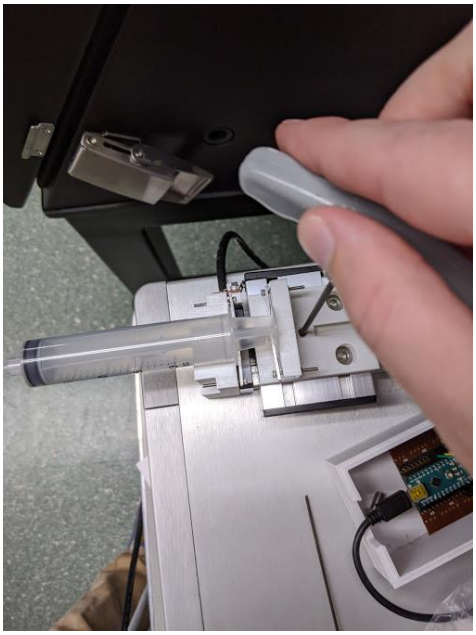
b. Pull the syringe plunger out to make it easier to attach the plunger holder.



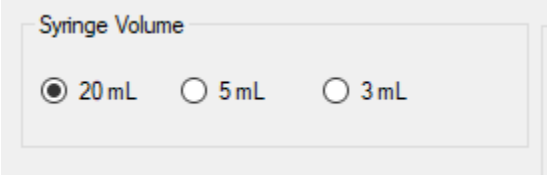
c. Attach the plunger to the plunger holder with the screws and steel plate.



d. Push the plunger and syringe holder all the way so that there is zero volume in the syringe.
e. Secure the plunger holder in place by tightening the set screw.

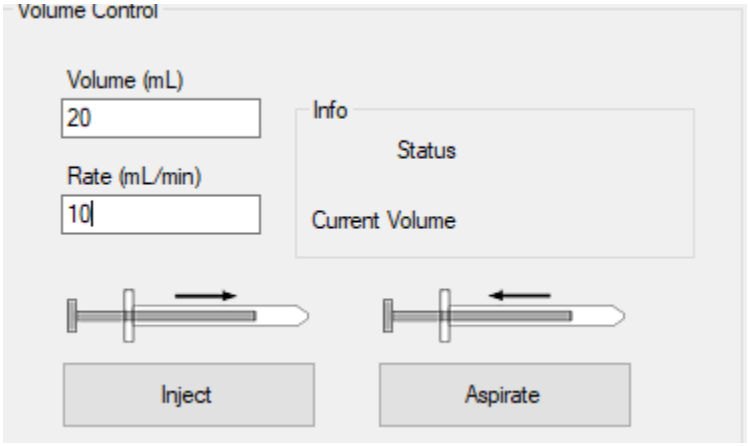


9. Make sure the syringe volume is selected in the application. (Note: the default syringe volumes can be changed in the settings).



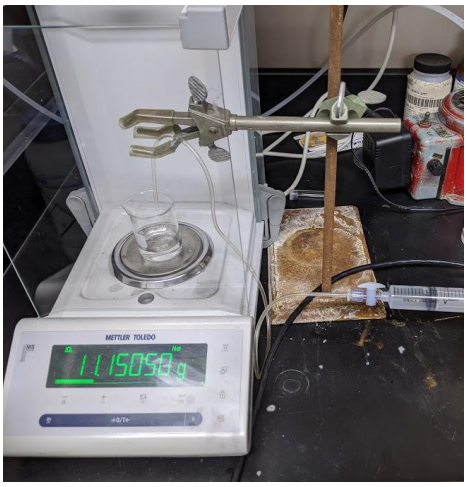
Syringe Calibration

1. Once the position is zeroed, a syringe is attached, and the correct volume selected, begin by aspirating a known volume of fluid, which can be anything less than or equal to the syringe volume. Typically, you should aspirate the entire syringe volume in order to make the calibration more accurate.
    a. Make sure the syringe is leading into whatever fluid you are aspirating.
    b. Type in the volume in the “Volume (mL)” textbox.

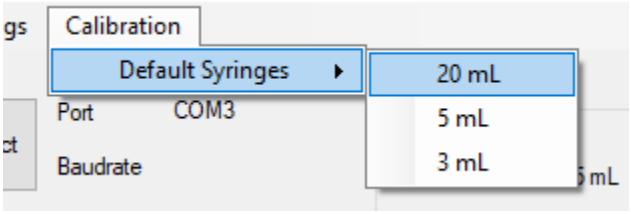


    c. Set a rate in the “Rate (mL/min)” textbox (usually 10/20 mL/min).

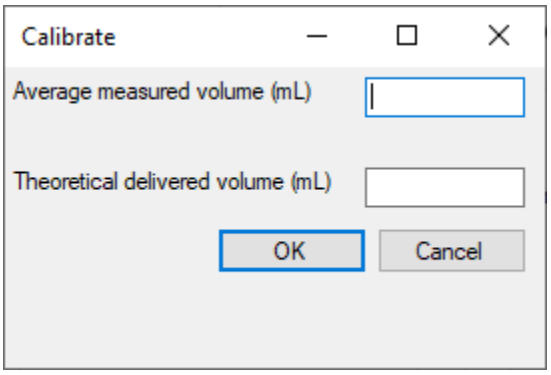
    d. Click the “Aspirate” button and wait for the Arduino to finish the operation.
2. Set a theoretical injection volume, for example you could set it at 0.5 mL.
3. Next, set up a beaker/container in an analytical balance with the syringe being able to inject directly into the container. Zero the weight of the container.



4. Using the windows application, inject your theoretical volume repeatedly and record the weight until the syringe is empty or the volume remaining is less than the theoretical volume.
    a. Type in the theoretical volume in the “Volume (mL)” textbox.
    b. Set a rate in the “Rate (mL/min)” textbox. (Rate has little effect on calibration)
    c. Click the “Inject” button.
5. Use the current temperature, pressure, and density of the fluid to calculate the volumes of each actual injection.
6. Average the actual injection volumes.
7. Under the “Calibration” tab, click the volume of syringe that you are calibrating.



8. Enter the average actual measured volume and the theoretical delivered volume into the appropriate fields and click “Okay”.


Calibrate
Average measured volume (mL)
Theoretical delivered volume (mL)
OK
Cancel