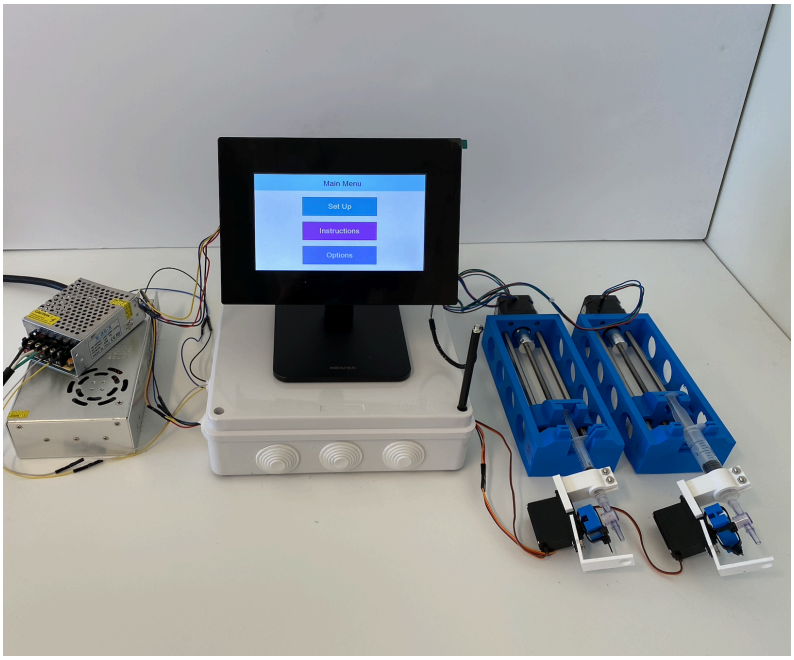
User Manual: Sustainable Chemistry Flow System



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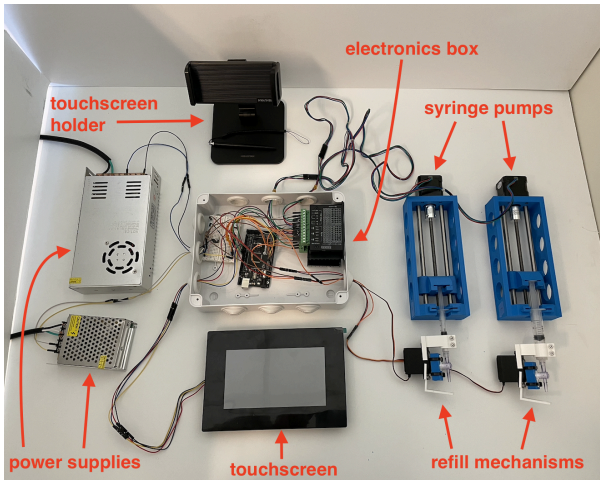
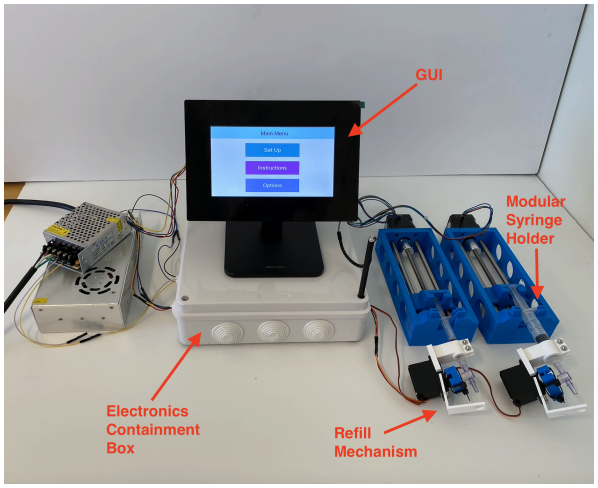
Overview

This DIY syringe pump system features a Nextion 7” display to control up to 4 syringe pumps simultaneously while allowing the user to select for each pump: diffusion or withdrawal mode, syringe size, and flow rate.





List of Parts

Parts for one syringe pump system:

Reference	Name	Quantity
1	Chassis (3D printed)	1
2	Carriage (3D printed)	1
3	Syringe_Holder (3D printed)	1
4	#mL_Syringe_Servo_Attatchment (# depending on syringe size. Possible values are 1,3,5,10 mL) (3D printed)	1
5	Servo_Stopcock_Attatchment (3D printed)	1
6	Tubing_Servo_Attatchment (3D printed)	1
7	Linear Ball Bearings (8mm bore, 15mm OD, 24mm length)	2
8	Linear Rods (8mm x 200mm)	2
9	Fully threaded rod (¼”-20, 7.1”)	1
10	Linear Coupler (5mm to 5mm)	1
11	¼”-20 Stainless Steel Hex Nut	1
12	Nema-17 Stepper Motor (40mm 64oz.in (45Ncm) 2A 4 Lead)	1
13	M3, 0.5 x 14 mm screws	4
14	Heat Set Insert (4-40, 0.135”)	2
15	Stopcock	1
16	4-40 ⅜” screws	2
17	4-40 ¾” screws	2
18	4-40 nuts	4

19	MakerHawk MG995 Metal Gear Waterproof Servo Motor	1
20	Arduino Mega 2560	1
21	12V Power Supply	1
22	5V Power Supply	1
23	Breadboard	1
24	3 Wire Power Cord	1
25	Nextion Intelligent Series 7” Resistive Touch Display	1
26	Jumper wires	1
30	Electronics Box	1
31	Zip ties	2

BOM with Purchasing Links:
https://docs.google.com/spreadsheets/d/1xHhwgEXxU9c9AX-A9w4pw_vKJEw8PYqTqlLdkky4oBc/edit#gid=0

List of Tools Used:

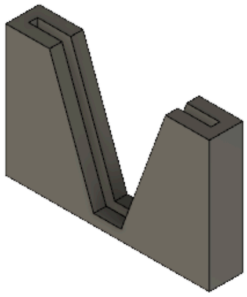
1. 3D printer
2. File
3. 5/64 allen wrench
4. Philips screwdriver
5. Needle Nose Pliers
6. Dremel/Lathe
7. 6-32 tap

3D Printing Instructions

The following files must be printed:

1. Chassis
2. Carriage
3. Syringe_Holder
4. #mL_Syringe_Servo_Attatchment (# depending on syringe size. Possible values are 1,3,5,10 mL)
5. Servo_Stopcock_Attatchment
6. Tubing_Servo_Attatchment

3D printing will depend on the printer and the 3D printing software used. It is recommended to look up tutorials for the specific software needed. In general, files must be inserted onto the 'print bed' of the 3D printing software. The default settings will be acceptable in most cases. For most of the componentes in this design it is recommended to print each piece on its largest flat side in order to avoid excess support material being generated. However, in the case of the Syringe_Holder [3], better results are obtained when it is printed standing up, ie in this orientation:



This prevents support material from interfering with the slot width.

Additionally, when printing the #mL_Syringe_Servo_Attachments [4], it is important to remove any excess material from the internal diameter. Excess material along the inner diameter may lead to the syringe plunger sticking where the excess material presses on the diameter of the syringe. In order to avoid this issue, the skirt option can be selected instead of the raft option for the base adhesion method.

Assembling the System

Syringe Pump Assembly Instructions

Note: These instructions are provided by the Croatt Research Group and have been slightly modified to fit the modifications made to the system.

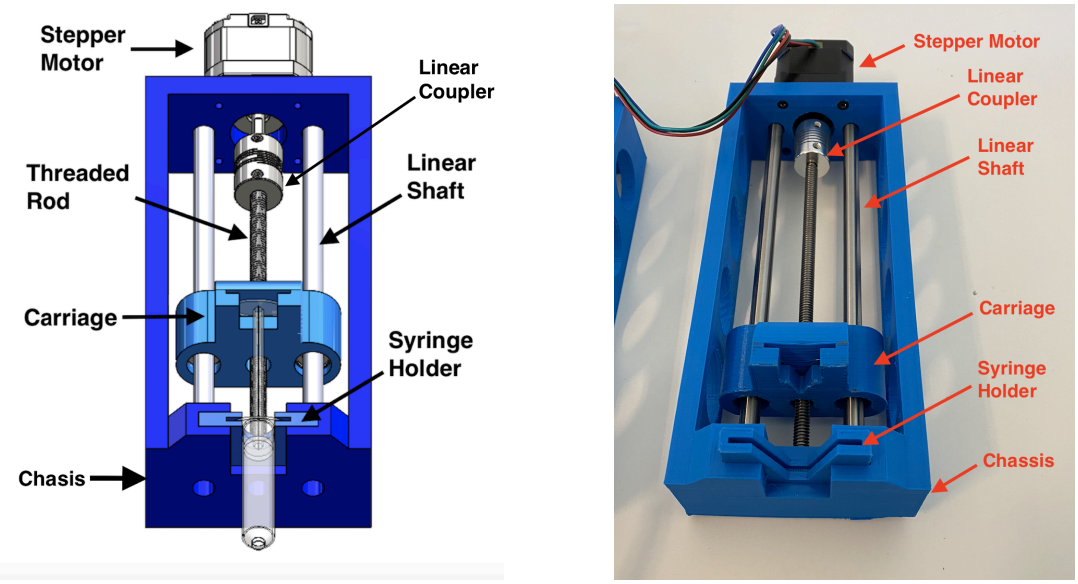
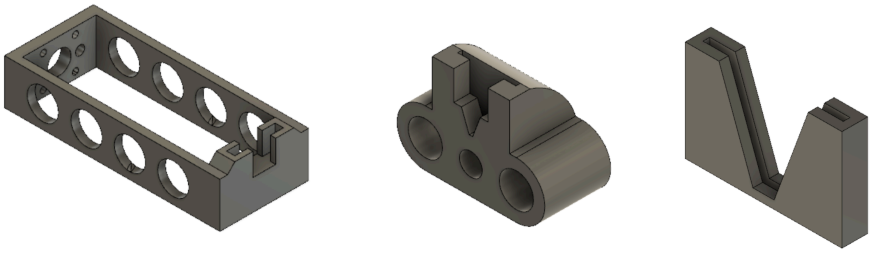


Fig. Complete Syringe Pump

1. 3D print the Chassis [1], Carriage [2], and Syringe_Holder [3].



Chassis Carriage Syringe Holder

2. Machine threaded rod. A ¼” - 20 fully threaded rod [9] will need to be cut to around 7.1” to fit inside the chassis. The threads will need to be removed from one end of the rod using a lathe, a dremel, or a file. A 0.5” section should be grinded down to a diameter of

about 5mm. Check to make sure the rod fits into the linear coupler [10], but do not tighten the screws to attach the two pieces yet.

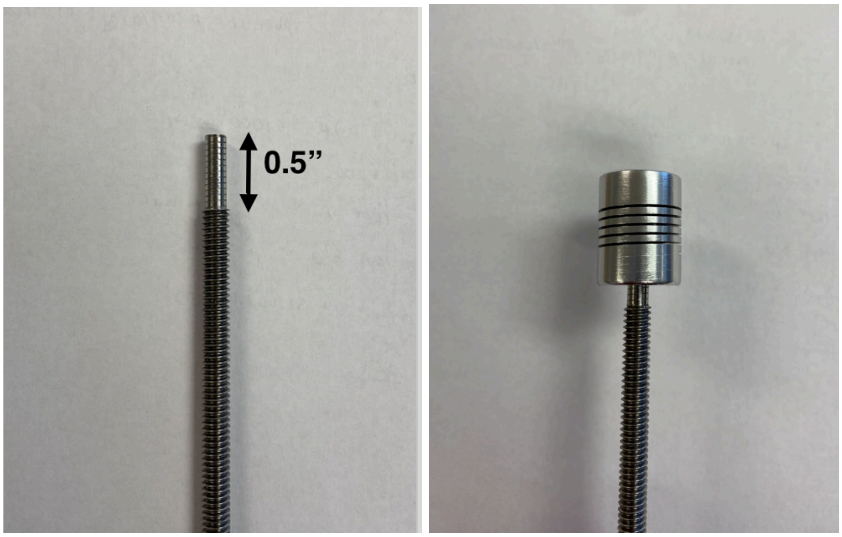


Fig. Step 2

3. Insert the ¼”-20 nut [11] into the bottom of the chassis and the linear ball bearings [7] into the two holes on the side of the carriage. Note: these components are meant to be tight fitting into the holes so some force may be required to insert them, but be careful not to crack the carriage.

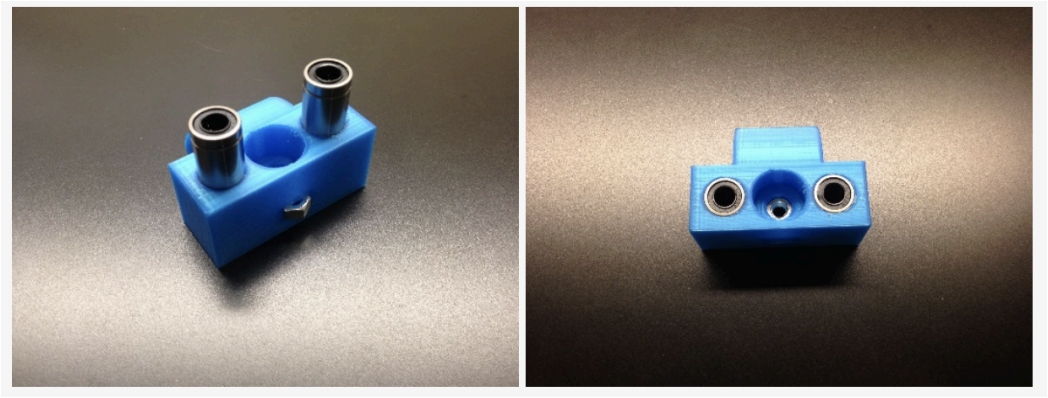
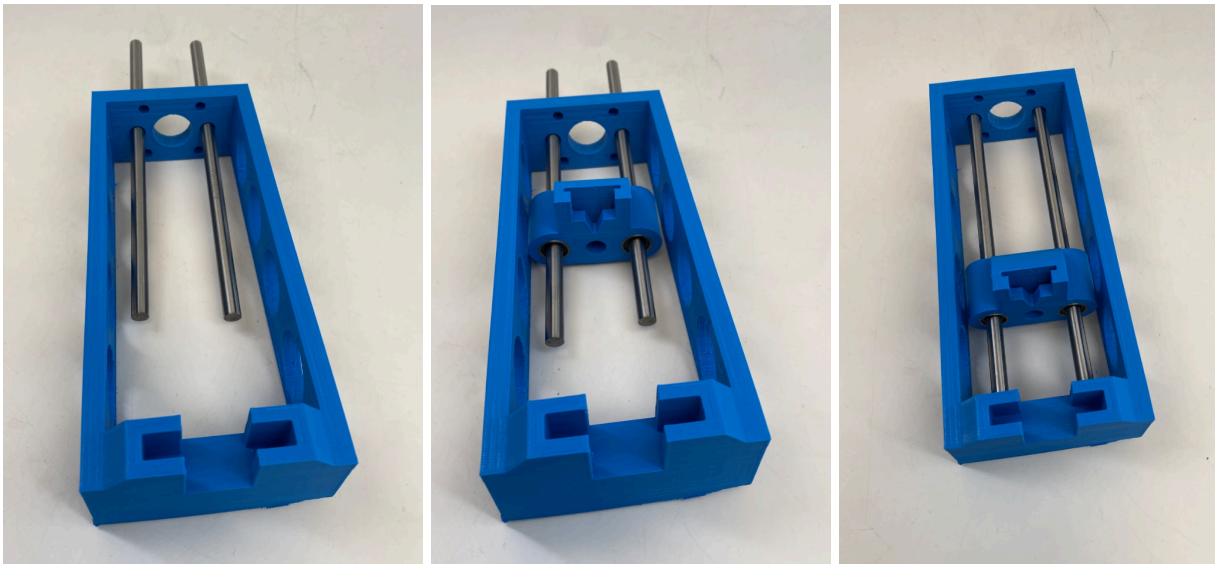


Fig. Step 3

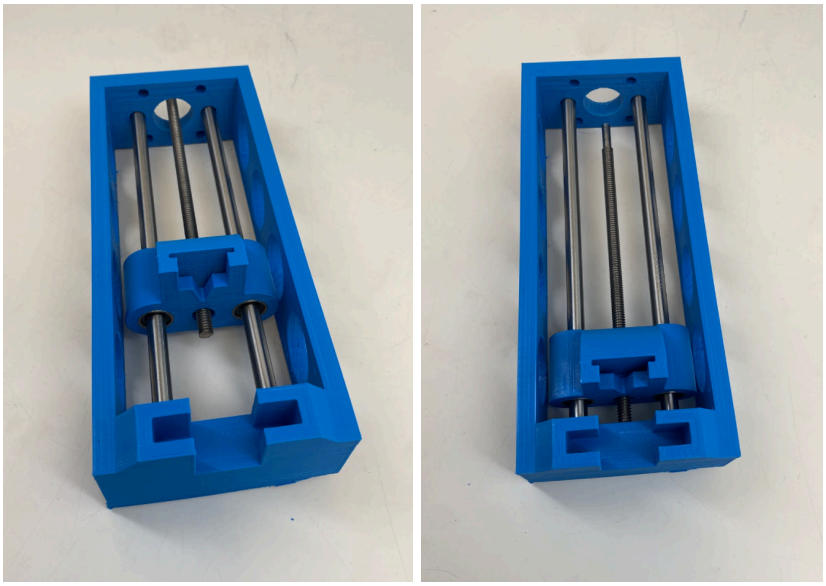
4. (a) Slide the two 8mm linear rods [8] into the holes one either side of the large centered hole on the chassis. (b) Slide the carriage onto the rods inside the chassis. Make sure the cutout on the carriage is facing the syringe holder side. (c) Insert the 8mm rods into the holes on the opposite side of the chassis.



(a) (b) (c)

Fig. Step 4

5. (a) Insert the threaded rod into the chassis and begin screwing it into the carriage. The end that has been ground down should be facing away from the carriage. Note: less screwing will be required if you begin screwing the rod into the carriage when the carriage is closer to the motor. (b) Screw the threaded rod through the carriage and into the hole on the other side of the chassis.



(a) (b)

Fig. Step 5

6. Slide the linear coupler onto the grinded down end of the threaded rod.

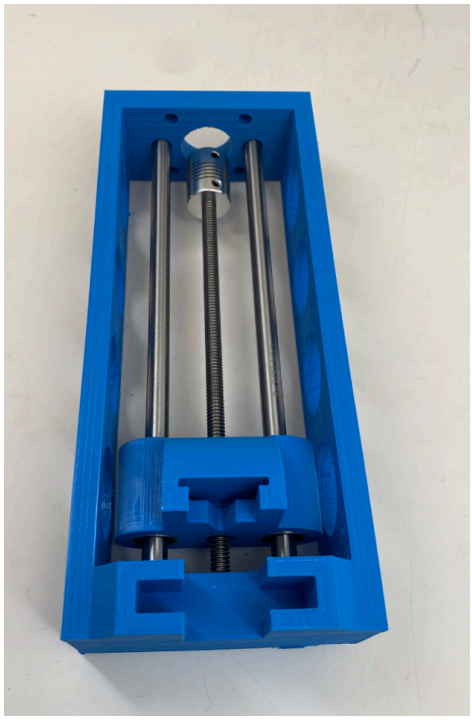


Fig. Step 6

7. Insert the shaft of the stepper motor [12] into the linear coupler. Secure the motor to the back of the chassis using four M3, 0.5 x 14 mm screws [13].

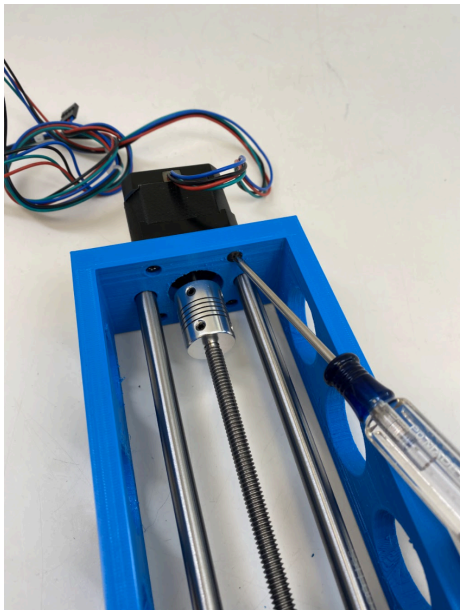


Fig. Step 7

8. Using a 5/64 allen wrench, tighten down the screws in the linear coupler to couple the stepper motor and threaded rod

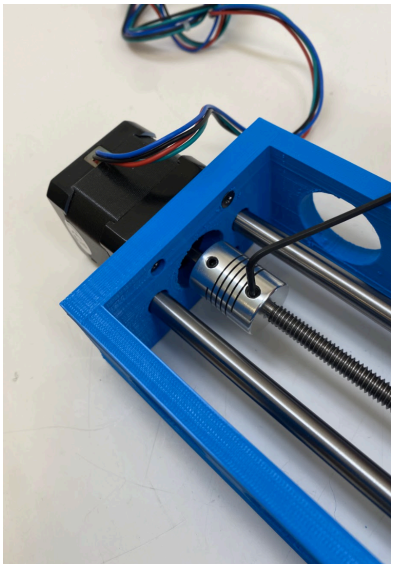


Fig. Step 8

9. Insert the Syringe_Holder [3] into the slot in the chassis. Note: if it is too tight of a fit the sides of the syringe holder can be filed down until it fits within the chassis.

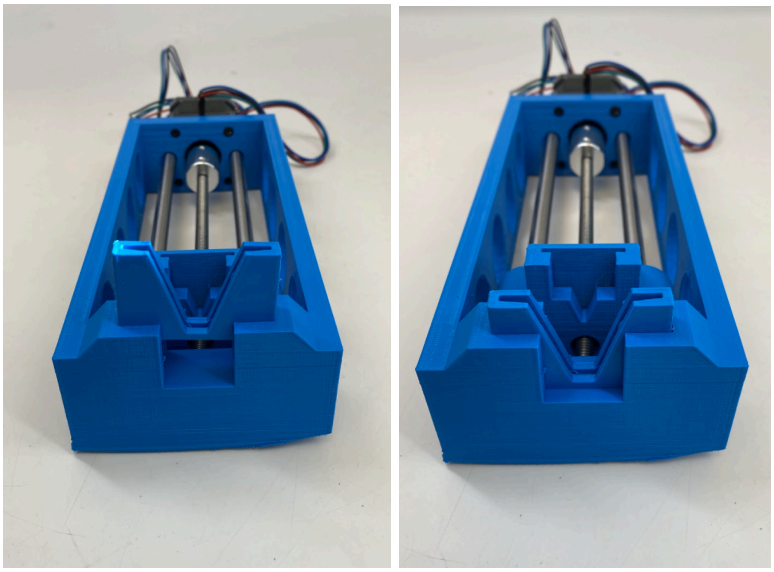
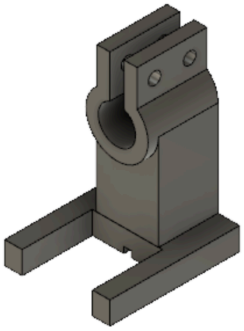


Fig. Step 9

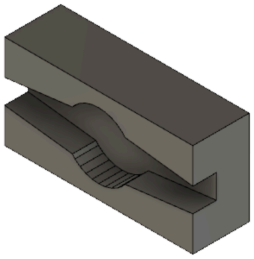
10. The syringe pump is now fully assembled.

Refill Mechanism Assembly Instructions:

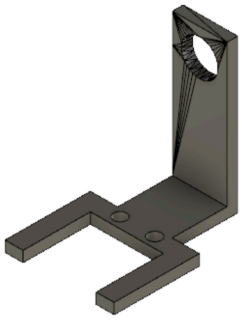
8. 3D print the #mL_Syringe_Servo_Attatchment [4], Servo_Stopcock_Attatchment [5], and the Tubing_Servo_Attatchment [6] files.



Syringe Servo Attachment



Servo Stopcock Attachment



Tubing Servo Attachment

9. Heat a solder iron to 450ºF.
10. Secure the syringe attachment in the upside down position so that it remains stable while the heat set insert is pressed into it.

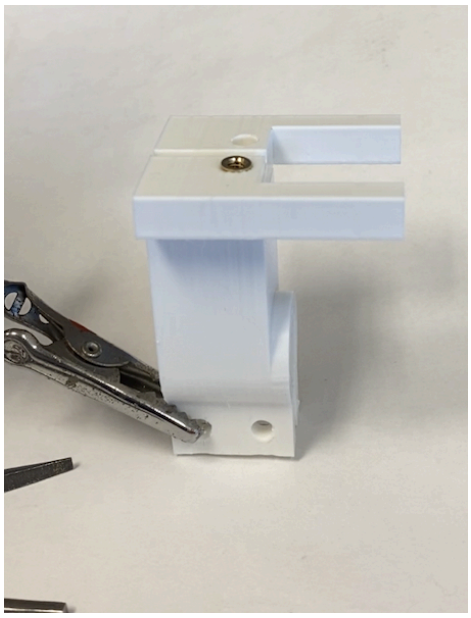


Fig. Step 10

11. Hold a 4-40, 0.135” heat set insert [14] with a pair of needle nose pliers. Insert the solder iron into the heat set insert. Hold in this position for a few seconds to allow the heat set insert to heat up.

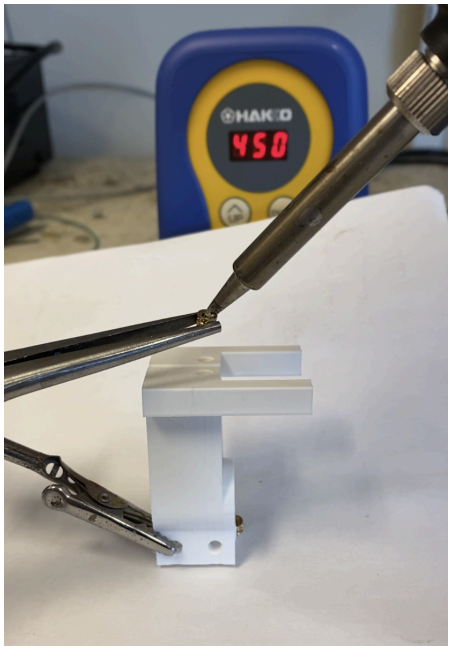


Fig. Step 11

12. Lower the heat set insert into the hole. The pliers can be used to guide it into the hole, then repositioned to apply force to push it into the hold. Make sure the solder iron doesn’t slip through the insert or filament may melt into the heat set insert and prevent a screw from screwing in properly.

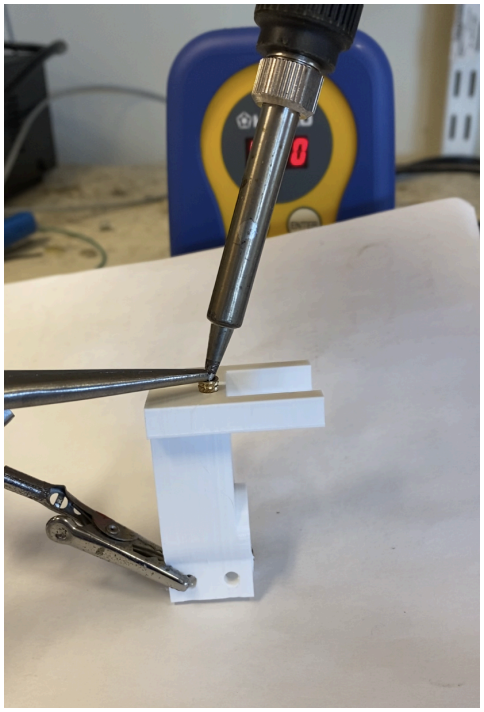


Fig. Step 12

13. Repeat this process for both holes on the bottom of the syringe-stopcock holder.

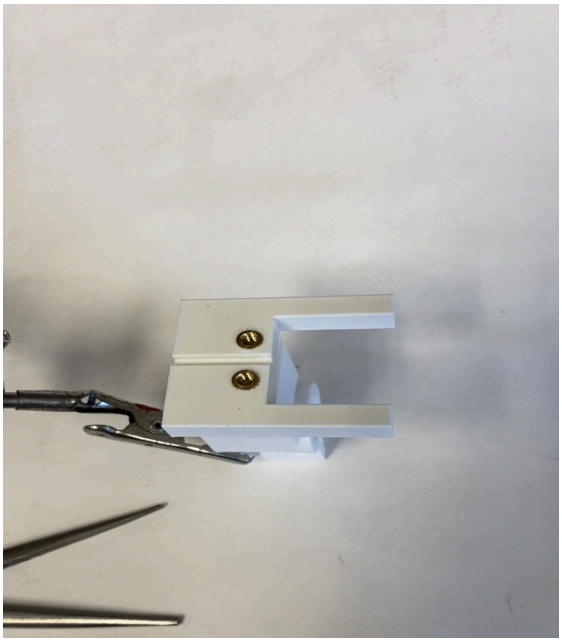


Fig. Step 13

14. Put the syringe in the #mL_Syringe_Servo_Attatchment but don’t secure it with screws through the top holes yet.

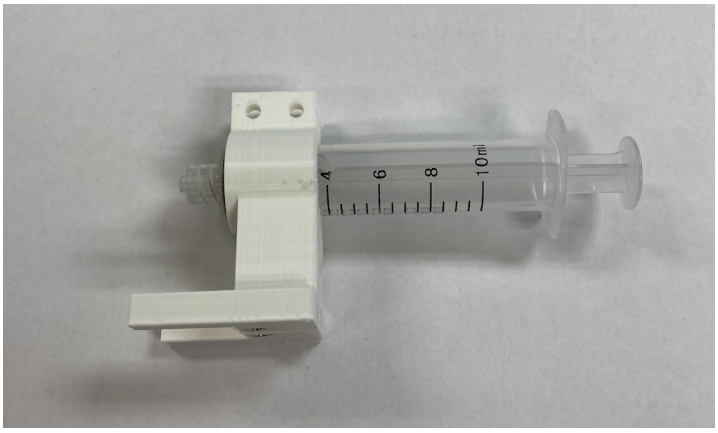


Fig. Step 14

15. Put the stopcock [15] in the Servo_Stopcock_Attatchment on the side with matching geometry.

Fig. Step 15

16. Screw the syringe into the stopcock.

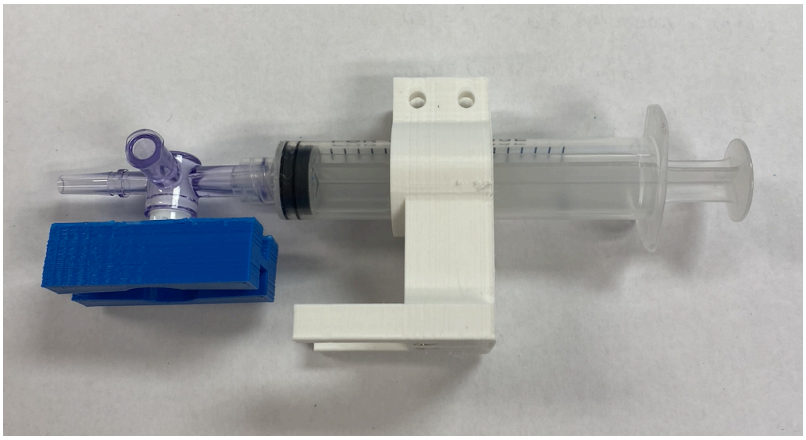


Fig. Step 16

17. Connect the servo motor as detailed in the Electronics Connection Instructions. Turn on the motor and let it calibrate itself. Continue with the process once the servo motor has calibrated itself as it will now be in its zero position.

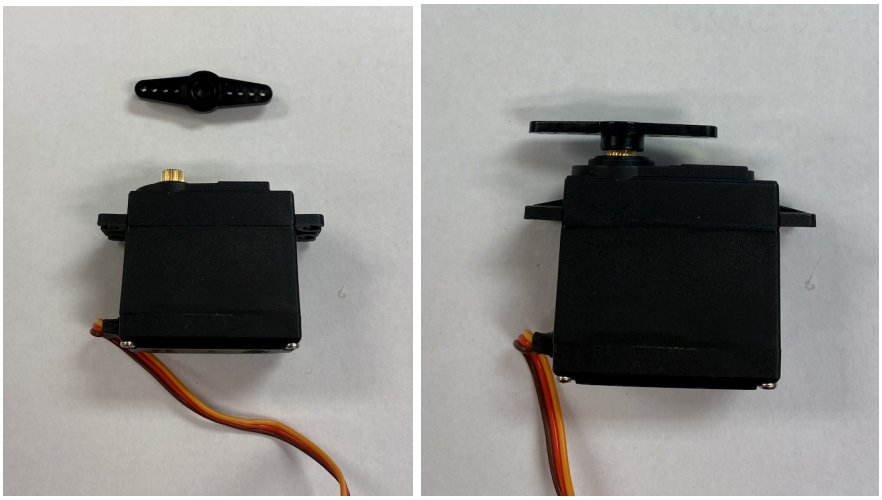


Fig. Step 18

18. Attach the dual point servo horn to the servo motor.

19. Attach the Servo_Stopcock_Attatchment to the servo. Push the #mL_Syringe_Servo_Attatchment forward so that it is fully in contact with the servo motor [21].

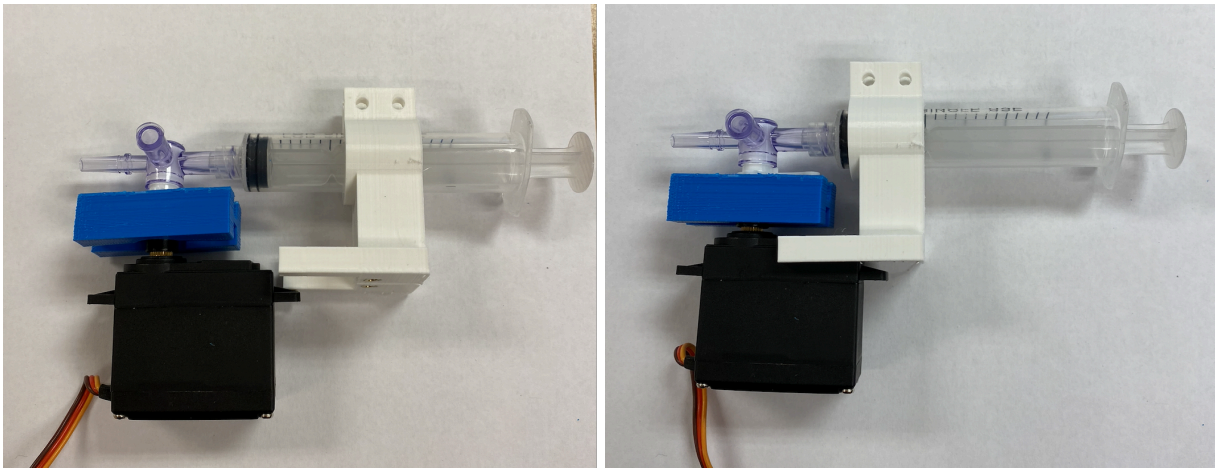


Fig. Step 19

20. Screw syringe holder into sevo using 4-40 ⅜” screws [16].

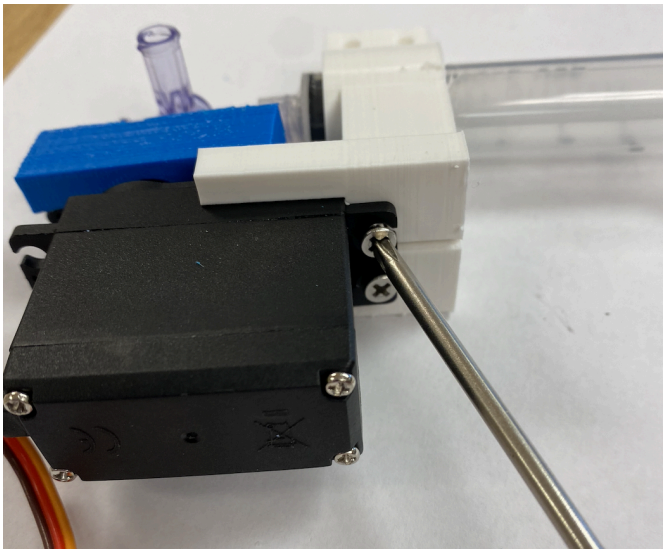


Fig. Step 20

21. Secure a syringe in the holder by inserting two 4-40 ¾” screws [17] and nuts [18] through the upper holes.

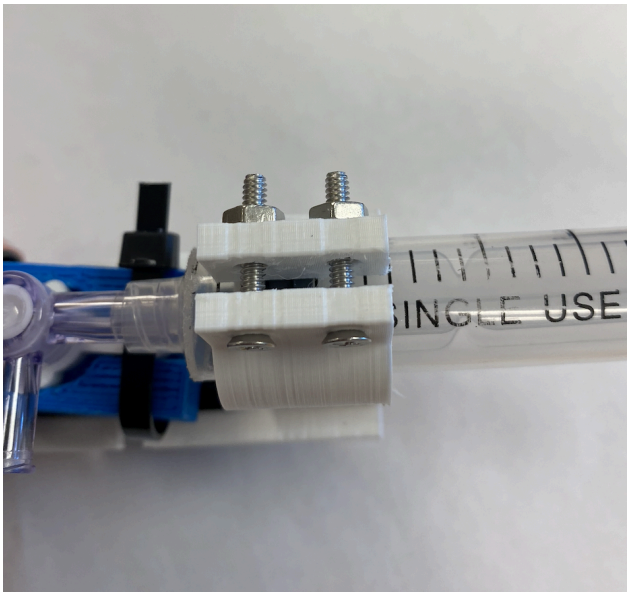


Fig. Step 21

22. Secure the Tubing_Servo_Attatchment to the servo motor using 4-40 ⅜” screws. This can be done by holding the nut above the hole with a pair of pliers to receive the screw.

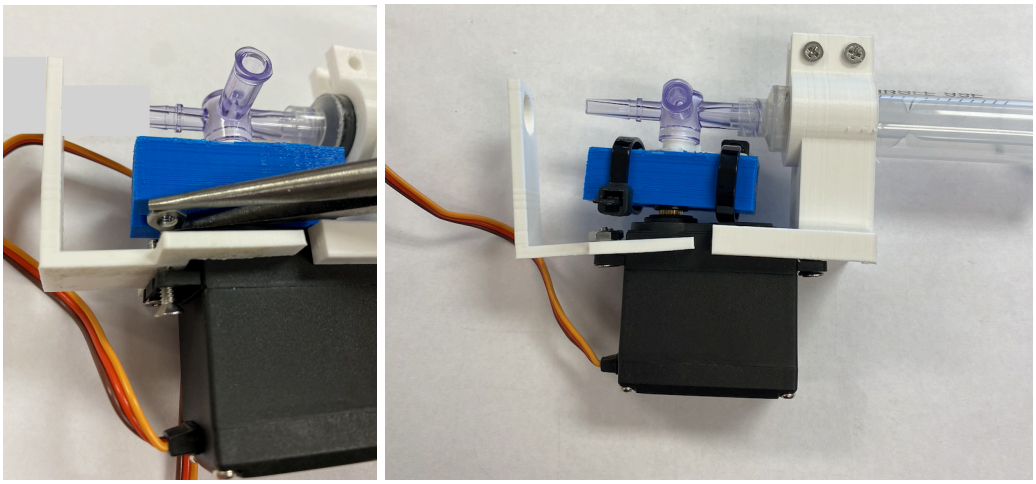


Fig. Step 22

23. Assemble the ¼-28 Fem to Fem Luer Tefzel [28] and 1/16 Peek Nut, SF Short [29] with the 1/16” tubing [27]. Attach to valve on the stopcock which is parallel with the syringe. Refer to the **Tubing Connection Instructions** below.

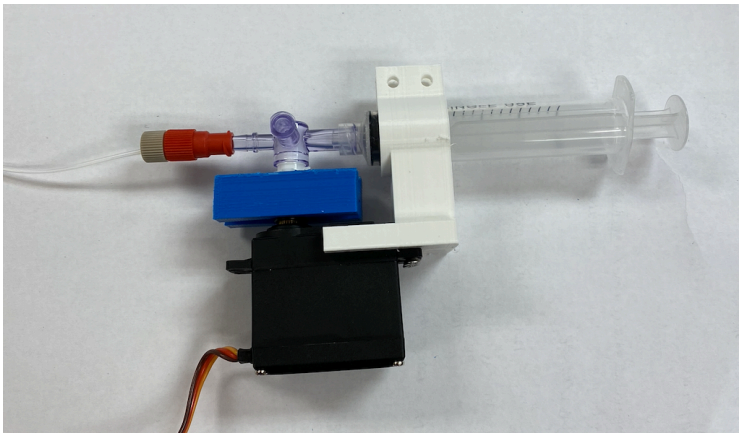


Fig. Step 23

24. Attach tubing to the valve of the stopcock which is 90 deg from the syringe. Refer to the **Tubing Connection Instructions** below.

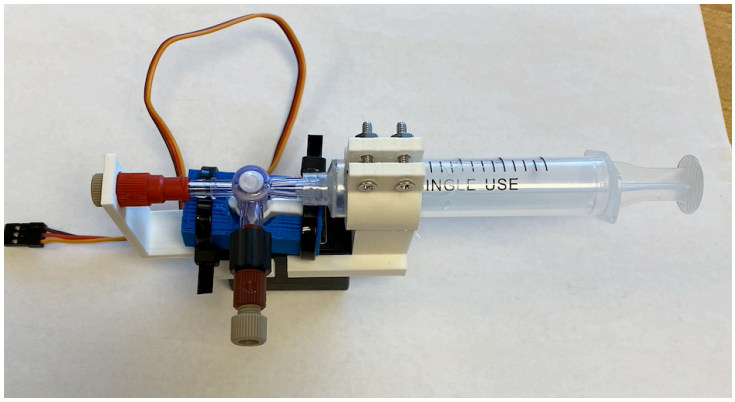
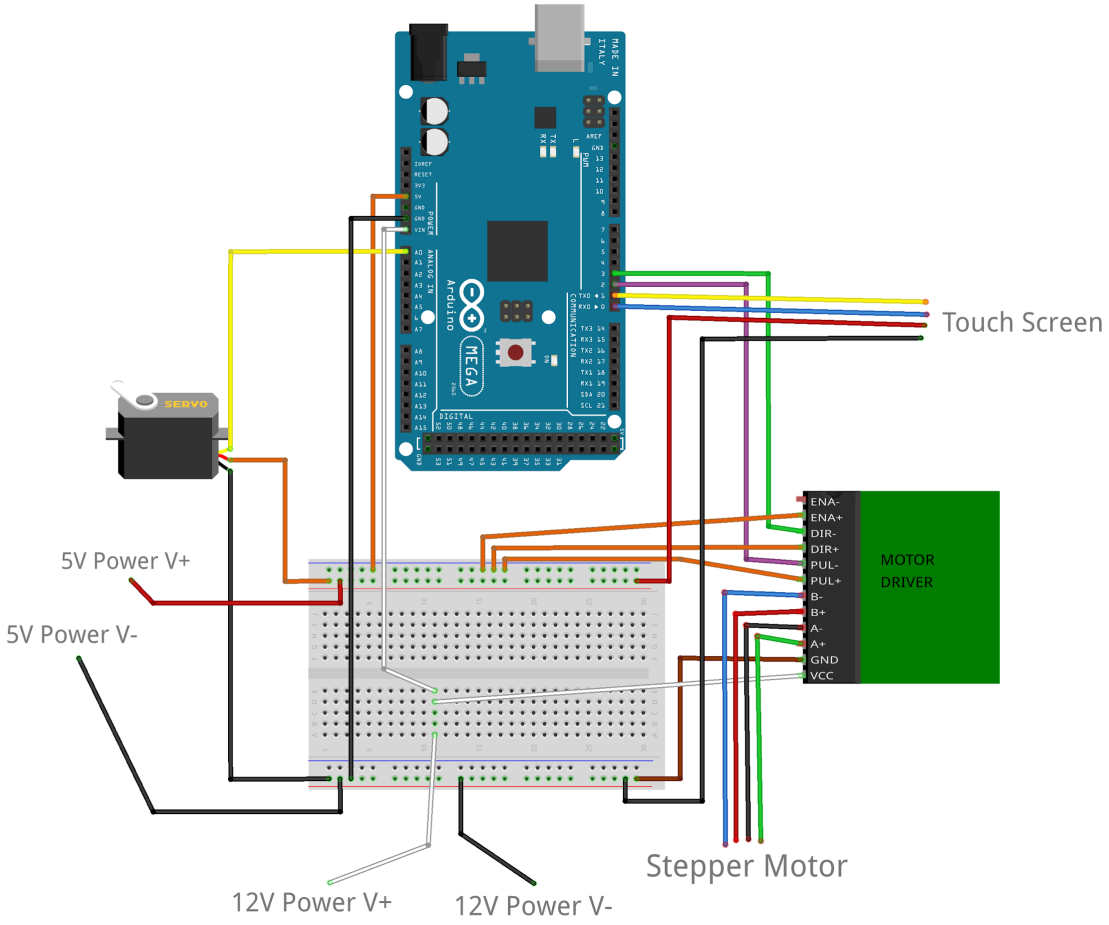


Fig. Step 24

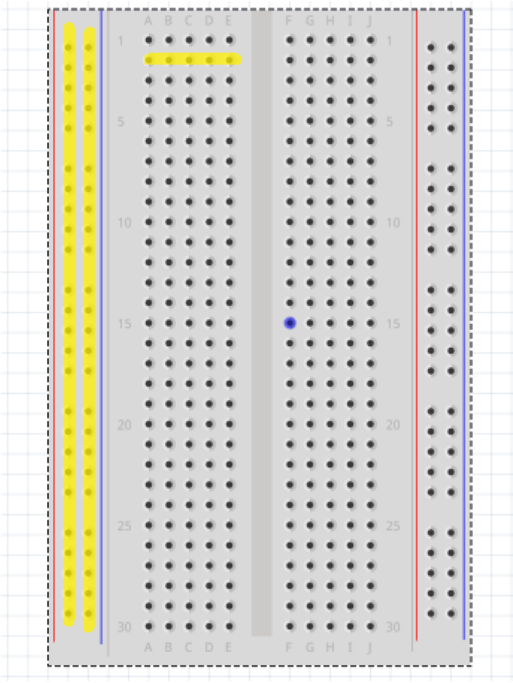
Electronics Connection Instructions

Below is a wiring schematic for the system. This section is divided into pairwise connections for each component.

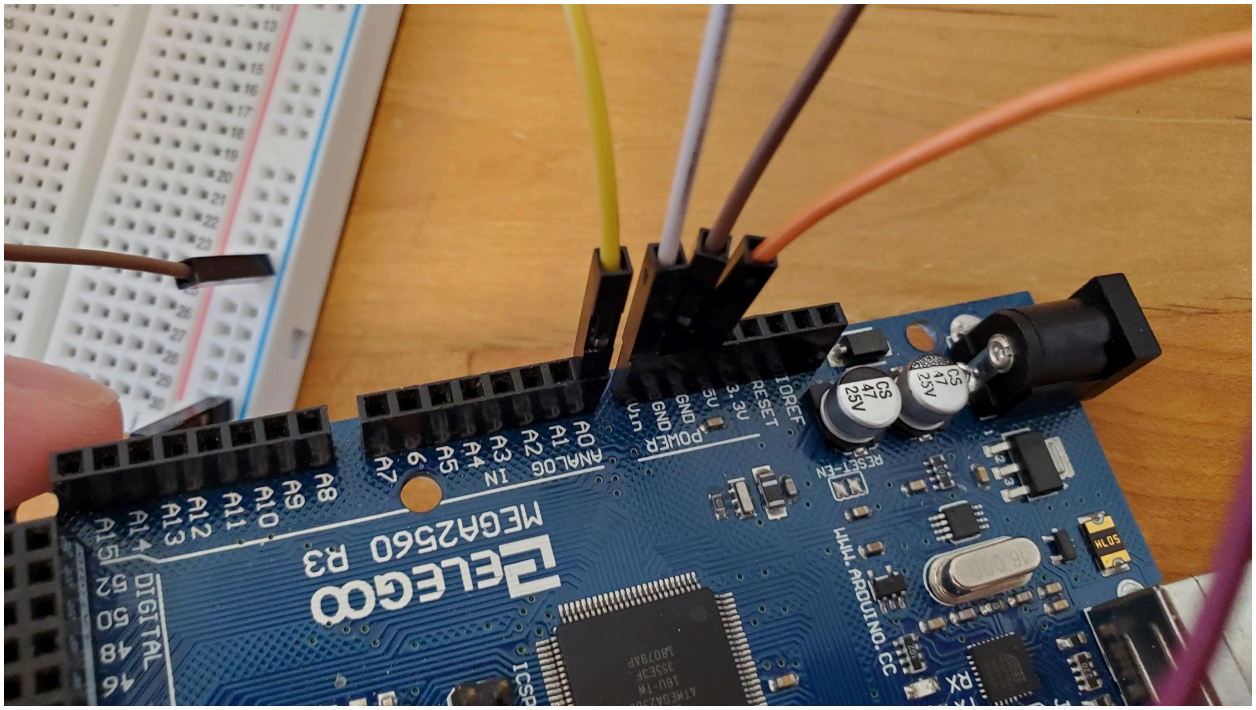


As the power supplies require a power cord with a 3-pronged open end, a picture is provided below to show which prong goes where on the power supplies. Note that The servo motor and touch screen will be getting 5V from an external power supply. Meanwhile, the 5V pin from the Arduino will provide 5V to the connections on the motor driver that require 5V.

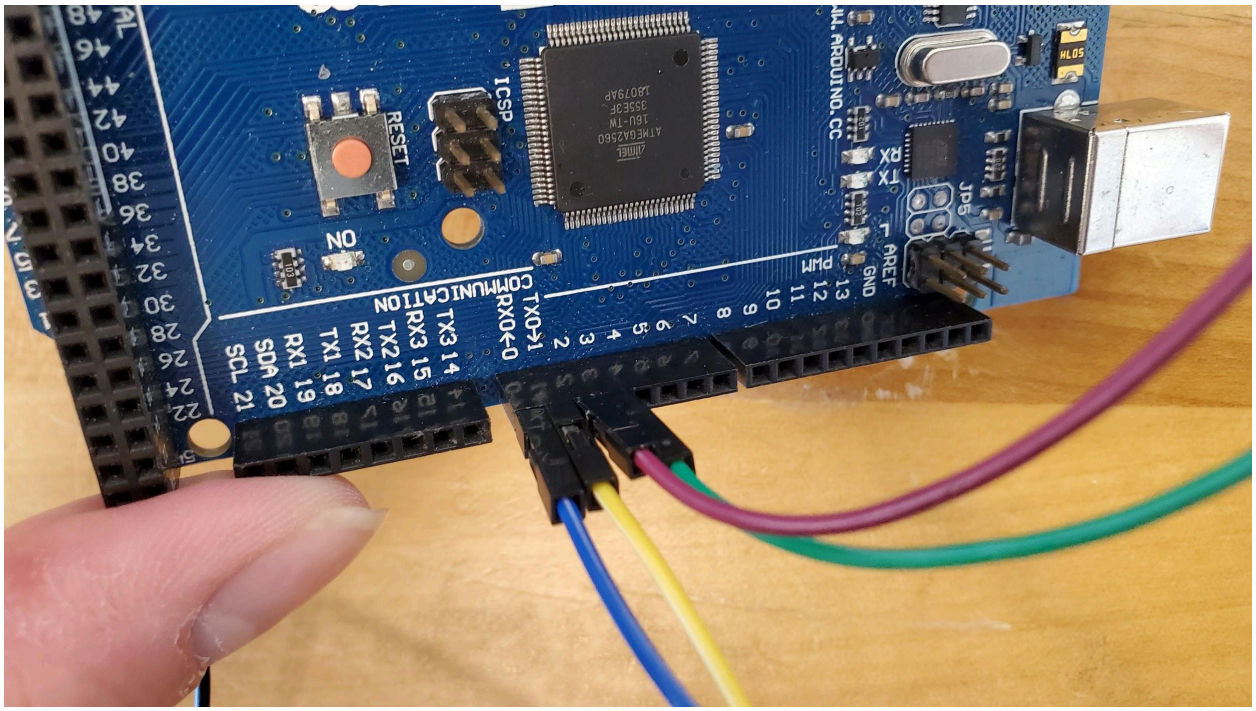
The black wire should go to L, the white wire should go to N, and the green wire goes to the ground symbol. The symbols might appear in different places on different power supplies, so make sure that the wires are plugged into the slot with the correct symbol.



These are the connected paths on a breadboard. On the outside, there are long rails that are typically used for power and ground connections. The numbered rows are connected horizontally up until the divider column in the middle.



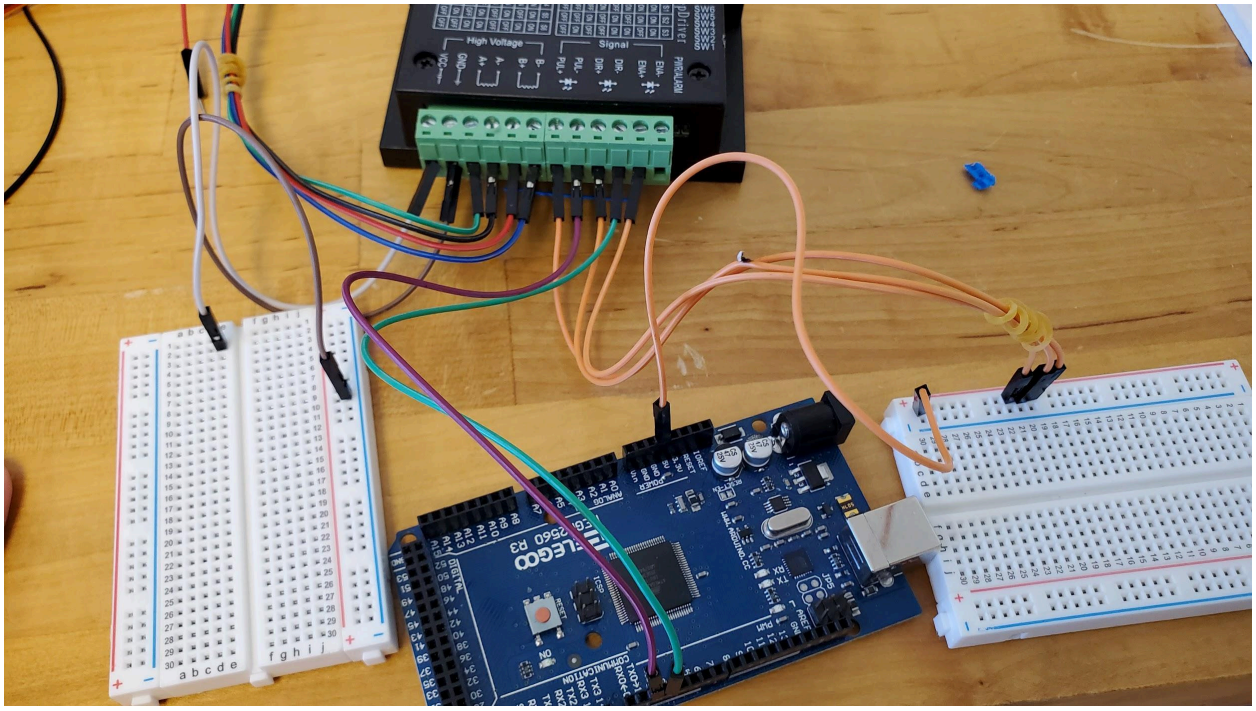
These are the pins that will be used on the left side of the Arduino. The white wire connects to the 12V+ power supply, the brown wire is connected to the ground rail on the breadboard. The A0 pin is the signal pin going to the servo motor. The orange 5V wire goes to the rail connected only to the 5V wires from the motor driver.



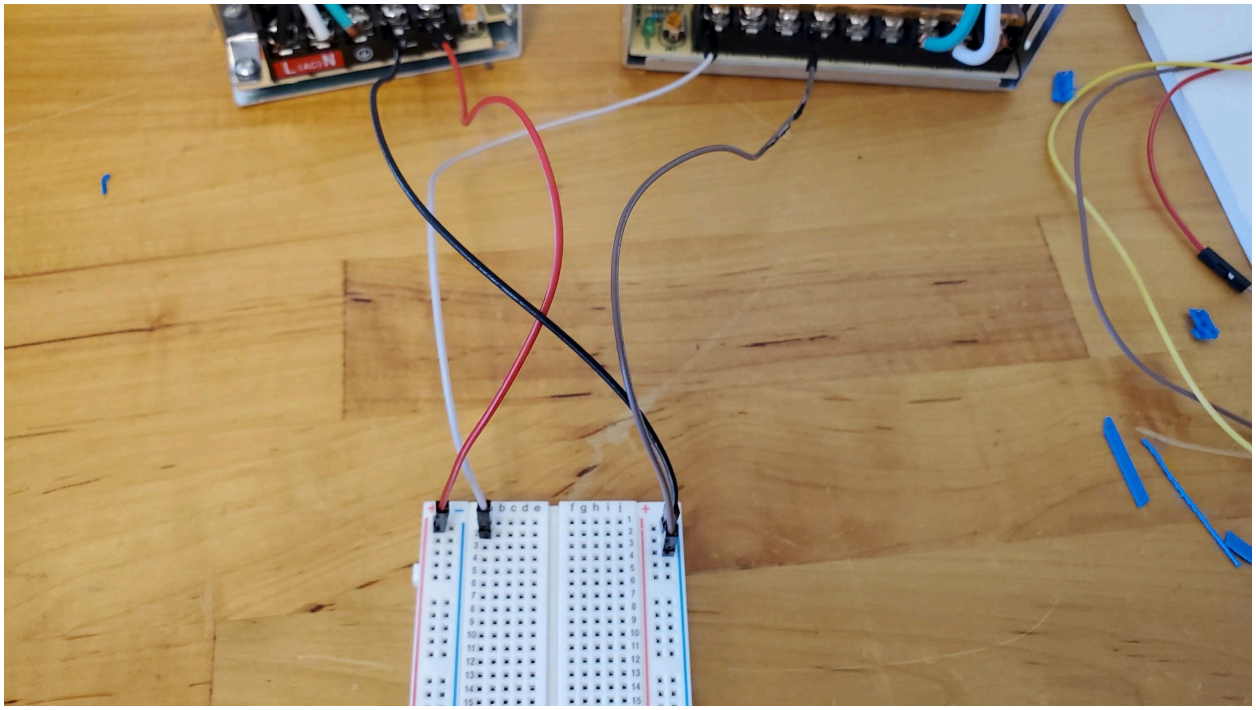
These are the pins that will be used on the right side of the Arduino. The blue and yellow wires will go to the touch screen and are colored according to the wires on the touch screen connector.

The green wire goes to the DIR- on the motor driver and the purple goes to the PUL- on the motor driver. These are the wirings on the Arduino for 1 pump, but if multiple pumps are added, then the purple and green wires should go into the corresponding pins: purple to even pins and green to odd pins, for each pair of consecutive numbered pins on the Arduino board (e.g. 2+3, 4+5, 6+7, …).

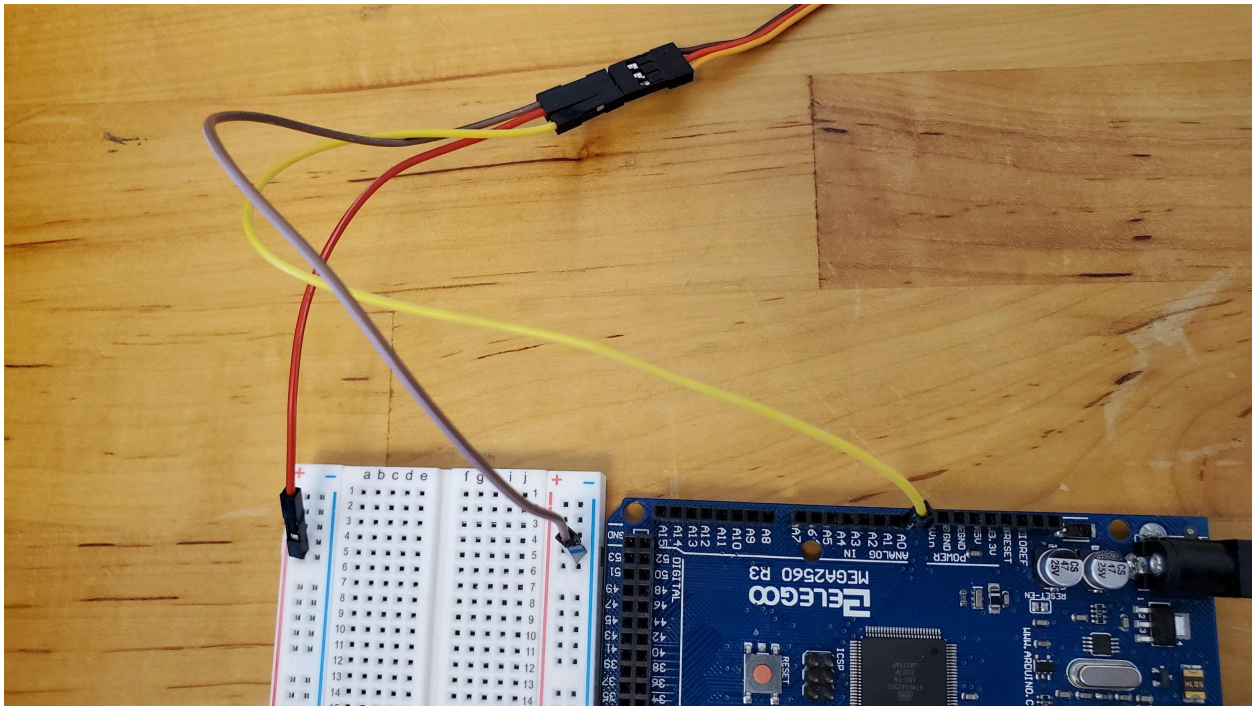
Below, connections are shown for each component for the sake of clarity. As such, not every connection will be shown in each image, only the ones pertaining to the particular component. Refer to the wiring diagram for a complete connection diagram.



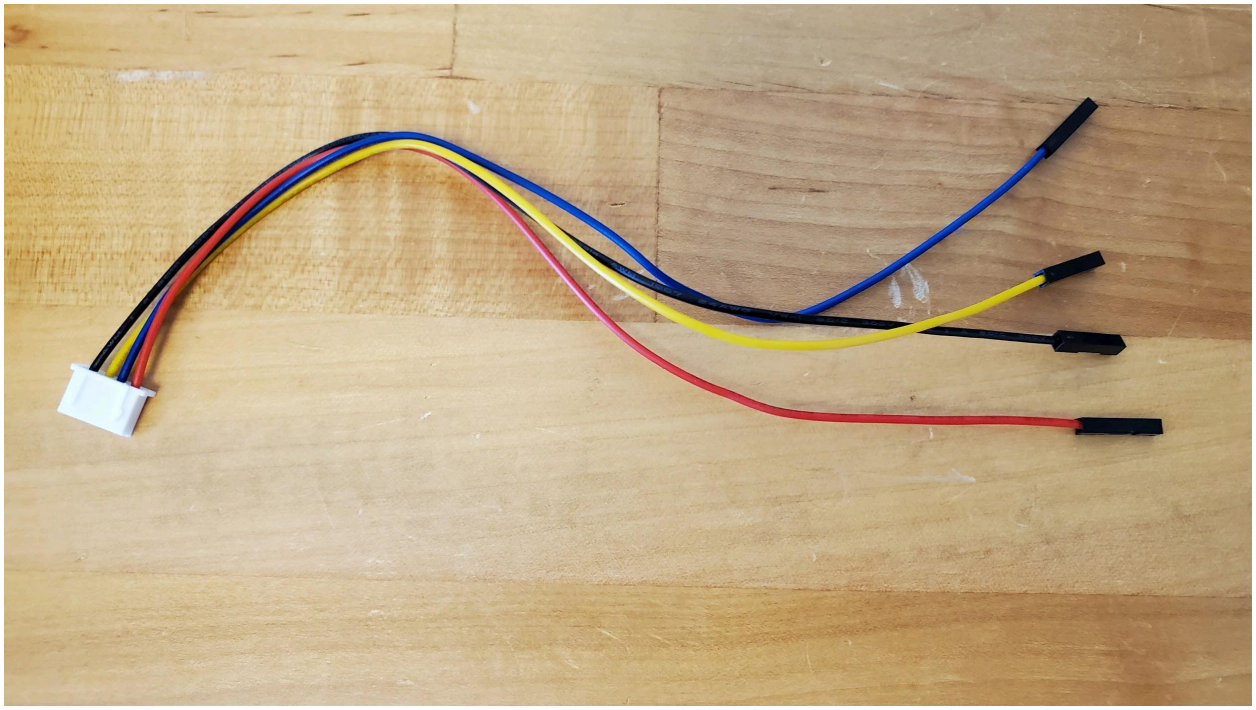
The wiring should look something like this with just the motor driver attached. The 5V from the Arduino and the 5V wires from the motor driver are connected to a different breadboard for clarity.



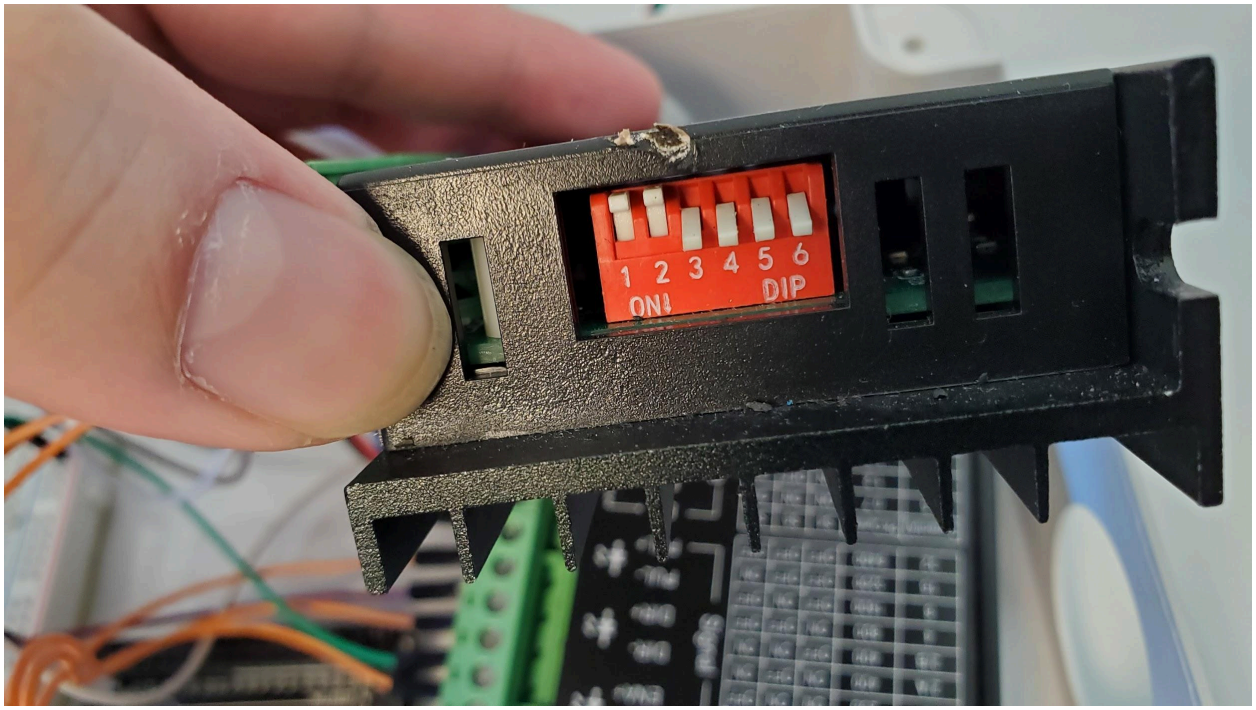
The power supplies should be connected to the breadboard like this. The wires from other components should be connected to the corresponding rails. Since the 12V+ is connected to row 2, the Arduino Vin, and the VCC from the motor drivers should also be hooked up to the same horizontal row. The leftmost rail is for the 5V+ side from the power supply. This should be connected to the servo motor and touch screen red wires. The rightmost rail is the ground rail for everything (black and brown wires). Note that the ground from power supplies (or V-, which is the same thing) is connected to this rail.



These are the rails and pins for where the servo should be connected. If more servo motors are required, add a wire from the next A# pin (e.g. A1, A2, …) and wire them to the 5V and ground rails accordingly.



As mentioned, this is the 4-pin connector going to the touch screen. The blue and yellow pins go to the Arduino and the red and black pins go to 5V and ground, respectively. The connector end simply goes into the touchscreen.

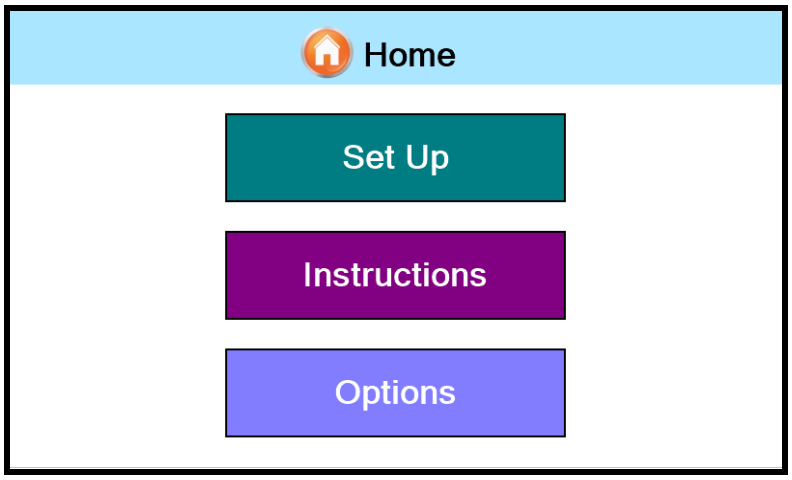


Make sure that the switches on the motor driver are as according to the image above. This sets the stepper to the 16 microsteps setting and provides 0.5A to the motor. The motor can run at higher amperage, but it will be noticeably louder and heat up more. Thus, it is recommended to run it at a lower, but sufficient amperage.

Controlling the Pump with the User Interface

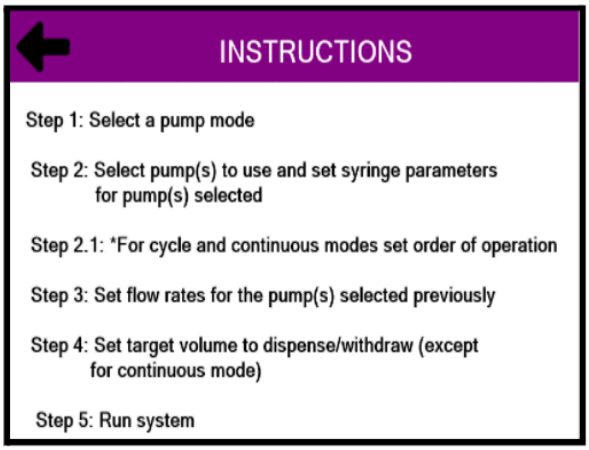
The purpose of this user interface is to be able to easily control up to four syringe pumps simultaneously. To familiarize the user with the graphical user interface (GUI), first a summary of the key pages of the user interface and their function is given. A walkthrough for each pump mode is later given to show how each mode is set up.

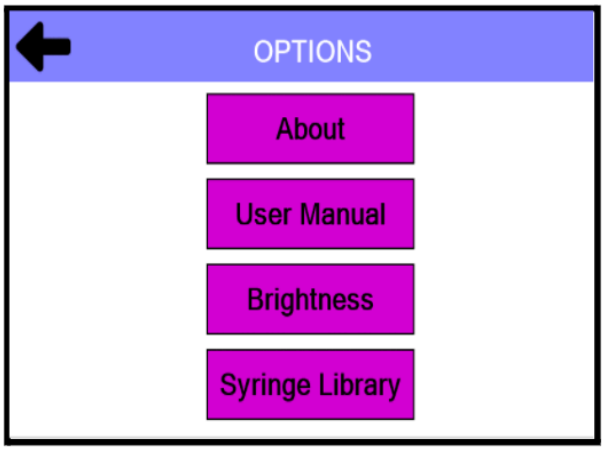
Home Page



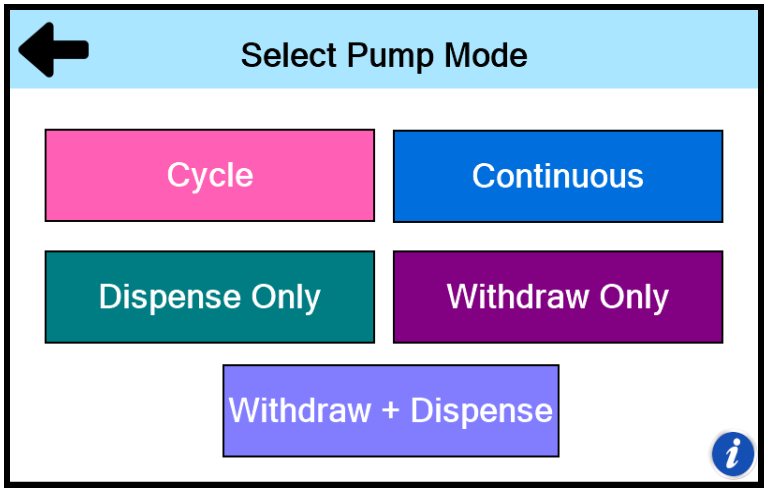
The start up screen shows the *Home* page of the DIY Flow Chemistry System user interface. The buttons on this page are **Set Up**, **Instructions** and **Options**. To begin setting up the system for operation, the **Set Up** button should be selected. The **Instructions** button will bring up a brief set of instructions on how to operate the syringe pump system. The **Options** button gives access to the user manual QR code, team website QR code, display brightness configuration, and the syringe library.

Instructions and *Options* Pages





Select Pump Mode Page



From the **Set Up** button the *Select Pump Mode* page of the user interface is brought up. Here the user selects a mode for the syringe pump(s) to operate on. In order to select a pump mode, the user must know what they are attempting to accomplish with the pump. There might

be one more than one mode that can help accomplish the user's goal, but one will most likely be more efficient than the other. As a result, it is important to know exactly what each pump mode does, which is explained next.

Description of Pump Modes

Cycle mode allows the user to set a target dispense volume that can be greater than a given syringe size. It accomplishes this by cycling between dispensing and withdrawing actions until the target dispense volume defined by the user is reached. Also, the user is able to set the order of the actions as either to dispense and then withdraw or to withdraw and then dispense. Therefore, regardless if the syringe is full, empty or has some amount of liquid inside, **Cycle** mode can be used in most circumstances where dispensing is needed.

Dispense mode is more limited than **Cycle** mode in that it only allows the user to dispense a target volume that is less than the current volume inside the syringe. No withdrawal is done in this mode. Therefore, this mode should only be used when the amount of volume to be dispensed is lower than the current volume inside the syringe. It is important to note that the maximum dispensable volume is calculated automatically in this mode based on the current volume. The volume is displayed on the corresponding page for reference.

Withdraw mode allows the user to refill the syringe to a target volume that is less than or equal to the difference between syringe size and the current volume inside the syringe. No dispensing is done in this mode. This mode should be used when the only goal is to refill the syringe(s). The maximum withdrawal volume is calculated and displayed automatically for reference on the corresponding page.

Withdraw + Dispense mode allows the user to completely refill a syringe and dispense a target volume that is less than the current volume inside the syringe. This mode is used when the goal is to refill an empty syringe and then to dispense a volume that is less than the current volume

inside the syringe. The maximum dispensable volume is displayed on the corresponding page for reference.

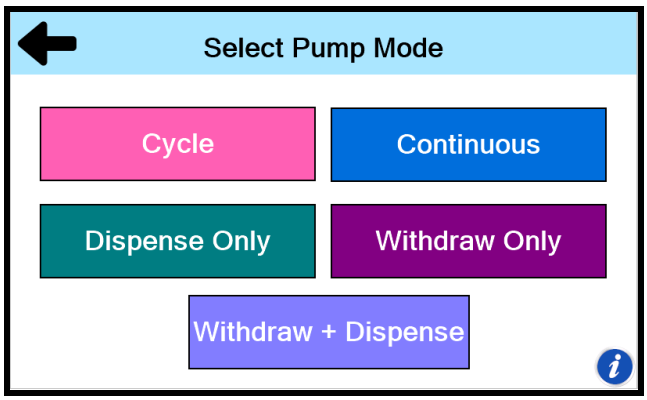
Continuous mode is similar to **Cycle** mode, but the difference is that no dispense target volume is set. Therefore, the pump continuously dispenses and withdraws until it is manually stopped. This mode can be used to quickly set the pump up and see if both directions are working as intended.

Step by Step Walkthrough

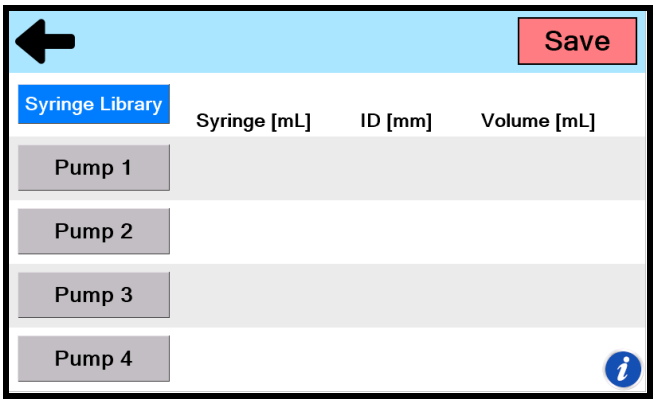
A step by step walkthrough for setting up the syringe pump system will now be given for each pump mode. For the purpose of these walkthroughs, two syringe pumps will be set up.

Cycle Mode

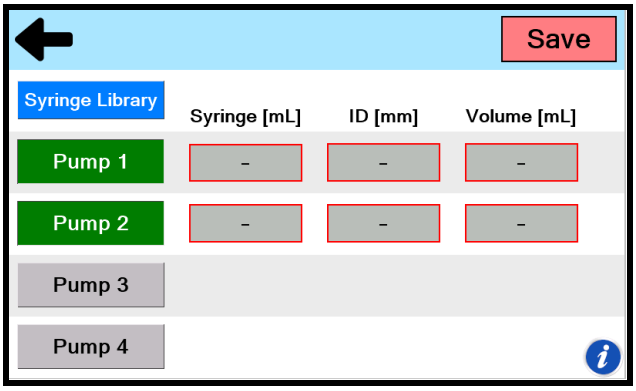
First, **Cycle** mode is selected from the *Select Pump Mode* page.



The following page is the *Syringe Parameters* page where the syringe size [mL], syringe inner diameter [mm], and current syringe volume [mL] are input. However, the syringe pump that will be used must first be selected.

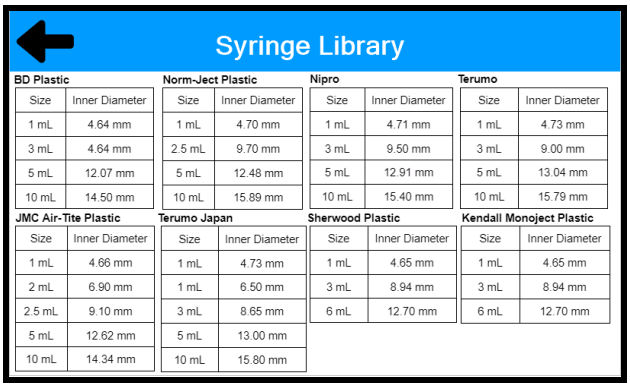


With the pump(s) selected, the syringe parameters for each pump can now be input.



Ensuring that the syringe parameters input here are accurate is the most important step of the entire process because inputting an incorrect value will lead to poor performance of the pump(s).

Tip #1: To ensure that the inner diameter value of the syringe is correct, a syringe library is included in this page to help reference inner diameters for various brands.



Syringe Library

BD Plastic

Size	Inner Diameter
1 mL	4.64 mm
3 mL	4.64 mm
5 mL	12.07 mm
10 mL	14.50 mm

Norm-Ject Plastic

Size	Inner Diameter
1 mL	4.70 mm
2.5 mL	9.70 mm
5 mL	12.48 mm
10 mL	15.89 mm

Nipro

Size	Inner Diameter
1 mL	4.71 mm
3 mL	9.50 mm
5 mL	12.91 mm
10 mL	15.40 mm

Terumo

Size	Inner Diameter
1 mL	4.73 mm
3 mL	9.00 mm
5 mL	13.04 mm
10 mL	15.79 mm

JMC Air-Tite Plastic

Size	Inner Diameter
1 mL	4.66 mm
2 mL	6.90 mm
2.5 mL	9.10 mm
5 mL	12.62 mm
10 mL	14.34 mm

Terumo Japan

Size	Inner Diameter
1 mL	4.73 mm
1 mL	6.50 mm
3 mL	8.65 mm
5 mL	13.00 mm
10 mL	15.80 mm

Sherwood Plastic

Size	Inner Diameter
1 mL	4.65 mm
3 mL	8.94 mm
6 mL	12.70 mm

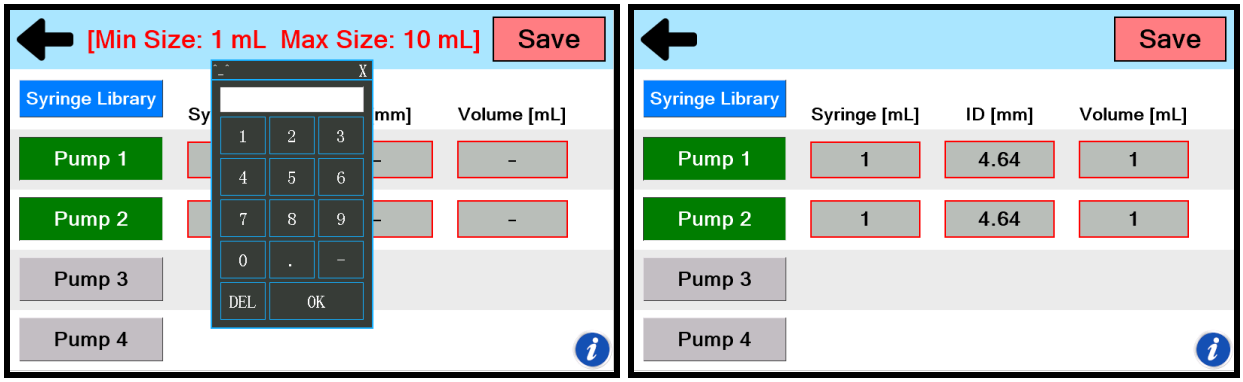
Kendall Monoject Plastic

Size	Inner Diameter
1 mL	4.65 mm
3 mL	8.94 mm
6 mL	12.70 mm

For example, we can say that we have 1 mL BD Plastic syringe on each pump.

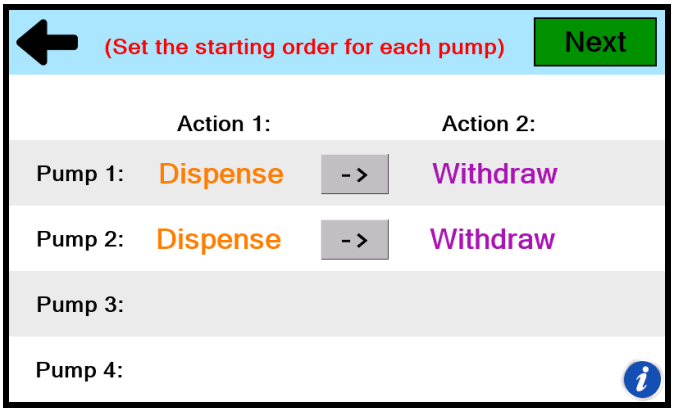
The syringe volume is read from syringe marks to get the current volume. For this case it is assumed that both syringes are full. Therefore, the following parameters are input. Selecting one of the gray buttons will bring up a numerical keyboard which is used to type in the value of the parameter.

Tip #2: You can erase syringe parameters by simply pressing the pump button for the pump that you wish to reset and then pressing it again to reactivate the pump.



Note: For this example, it was assumed that the 1mL syringe is full and therefore the current volume is 1 mL. However, it is essential that the current volume always be read beforehand to ensure that the correct volume is set.

Once the user confirms that syringe parameters are correct, the user can click the **Save** button which takes them to the *Order of Operations* page.

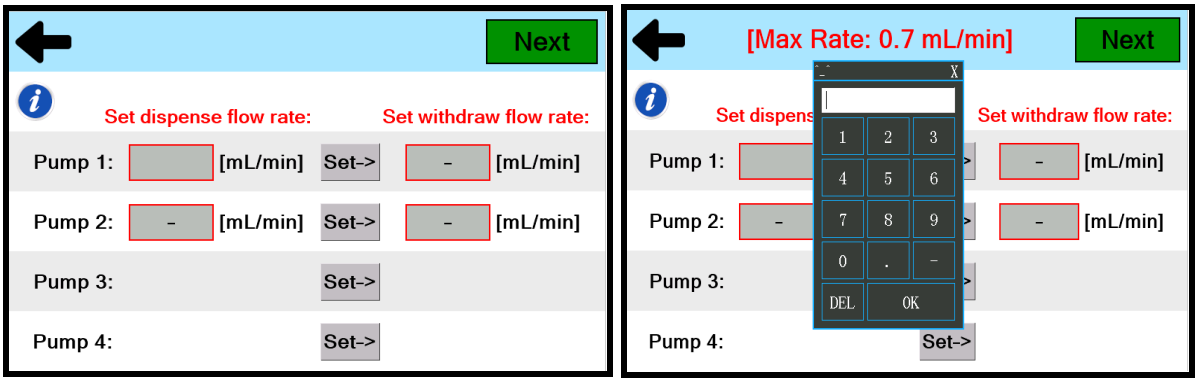


Here, the user sets the starting order of the operations for each pump. Either dispense and then withdraw or withdraw and then dispense can be set. It all depends on whether the syringe needs to be refilled first before dispensing. By default the order is set to dispense first and then to withdraw.

For our example, both 1 mL syringes are already full so the order of the operations is left untouched.

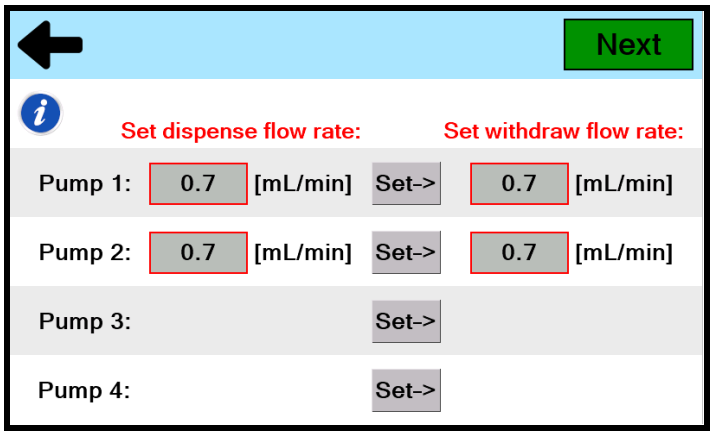
The next page is the *Flow Rates* page where the flow rates for dispensing and withdrawing are set for each pump. The flow rates set depend on the chemistry being performed, which is outside the scope of this user manual. However, a recommended maximum flow rate is displayed at the top of the page when each button for setting flow rate is pressed. It is suggested that the flow rate set does not exceed the max rate because that will lead to some inaccuracies with the syringe pump system. (For more information on this please refer to the report)

Note: The maximum flow rate for each syringe size (1,3,5,10 mL) will be different for each syringe size.



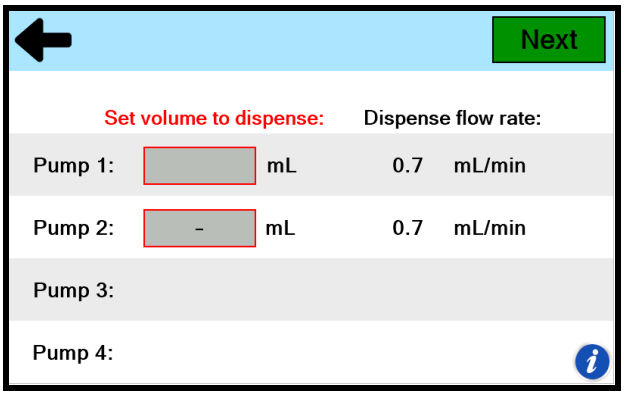
For this example, the suggested maximum flow rate will be used for both pumps.

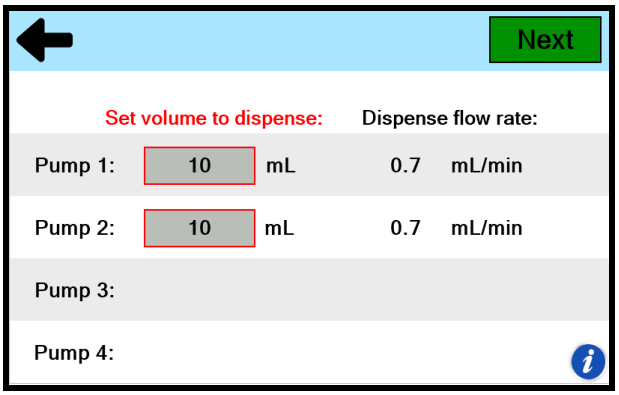
Tip #3: Use the **Set->** button to quickly set the withdraw flow rate to be the same as dispense flow rate.



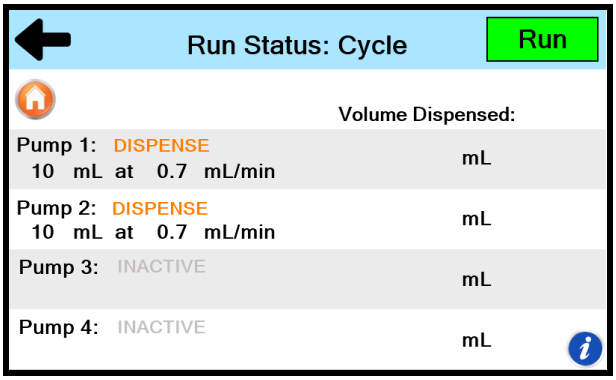
The following page is the *Dispense Volume* page where the total volume to be dispensed is set for each pump selected. For **Cycle** mode, any target dispense volume can be set. The system will run until the target volume set is dispensed.

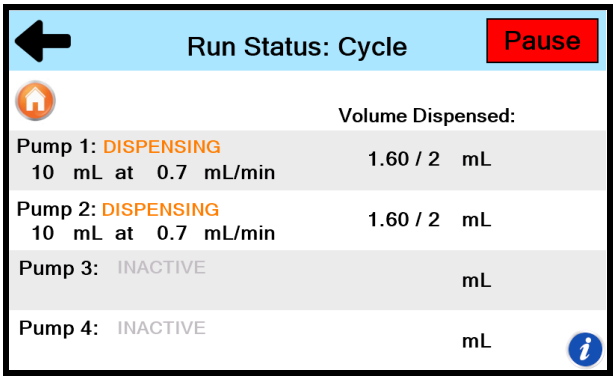
For this example, 10 mL will be set as the volume to dispense for each pump at a flow rate of 0.7 mL/min.





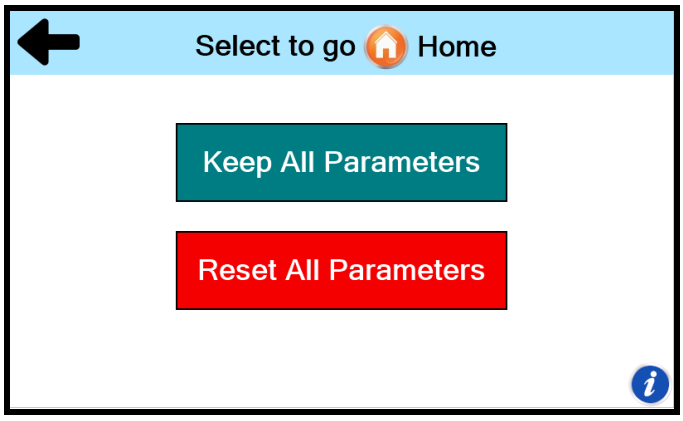
All the system parameters are now set and the syringe pump system is ready to be run. The following page is the *Run Status: Cycle* page where the system is run. On the left side of the screen is a brief description of the main operation that each syringe pump system selected will perform. On the right side of the screen is a tracker that continuously displays the current volume dispensed by each syringe pump as the system runs.





Once the operation of the syringe pump(s) is complete, the **Pause** button must be pressed to deactivate the system. Next, the orange **Home** button is pressed to continue to the *Home* page.

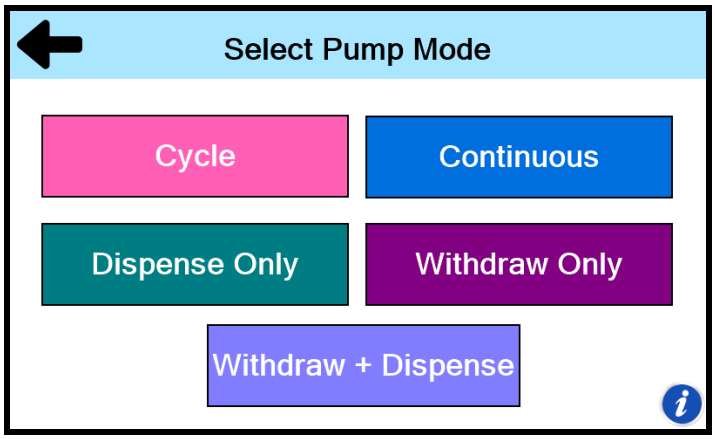
Before proceeding to the *Home* page, the user must choose if they intend to keep the syringe parameters by pressing the **Keep All Parameters** button or if the parameters should be reset by pressing the **Reset All Parameters** button instead. If the user intends to continue using the same syringe(s), then the **Keep All Parameters** button should be pressed to avoid having to input the syringe size and inner diameter all over again. However, it is important to note that the current volume parameter will always have to be updated by the user after each operation.



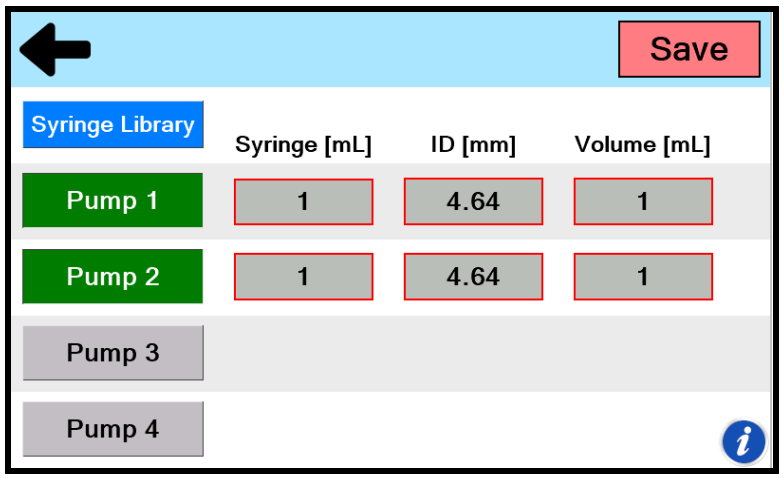
Dispense Only Mode

For the next walkthroughs, they will not be as in-depth as the previous one for **Cycle** mode since the main functionality of these modes is the same.

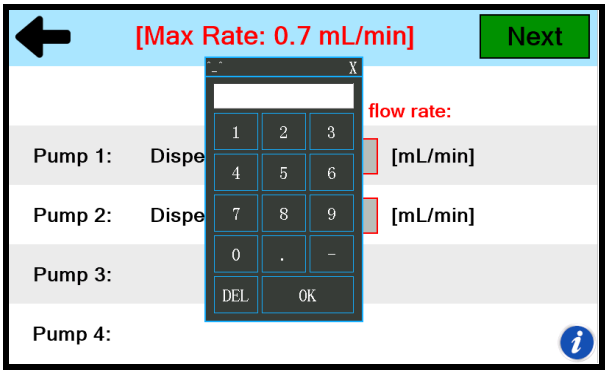
First, the **Dispense Only** button must be selected from the *Select Pump Mode* page to continue with dispense only mode.



Next, the pump(s) to be used are selected and the syringe parameters for each selected pump(s) is input on the *Syringe Parameters* page. (The previous configuration is used for this example.)

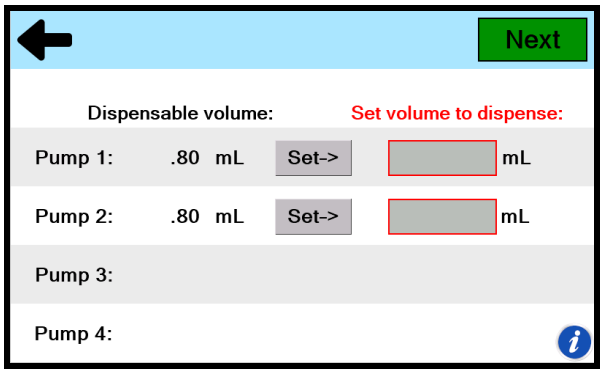


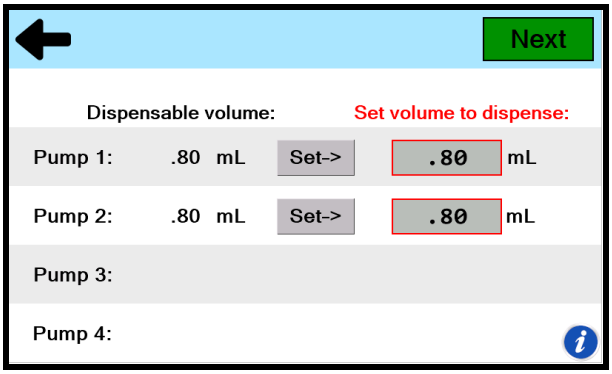
Press the **Save** button to proceed to the next step. The next page is the *Flow Rates* page where the dispense flow rate is set for each pump used. Here the maximum flow rate based on the syringe size is displayed at the top of the page for reference.



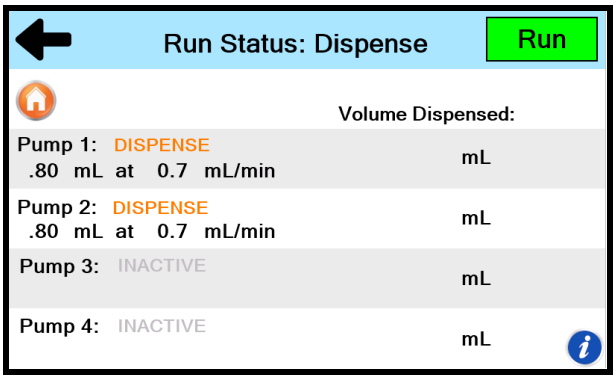
The next page is the *Target Volume to Dispense* page where the volume to dispense is set. However, since this is **Dispense Only** mode there is a limit on how much volume can be dispensed. That limit is displayed in the "Dispensable Volume:" column of the page. The volume to dispense can be set equal to or less than that specified limit.

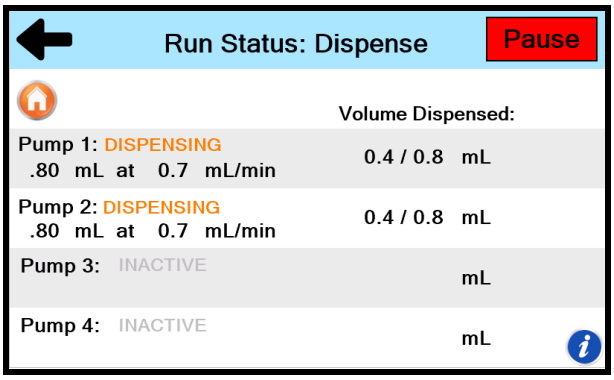
Note: You will not be able to proceed to the next step if the value for volume to dispense is set greater than the maximum dispensable volume.





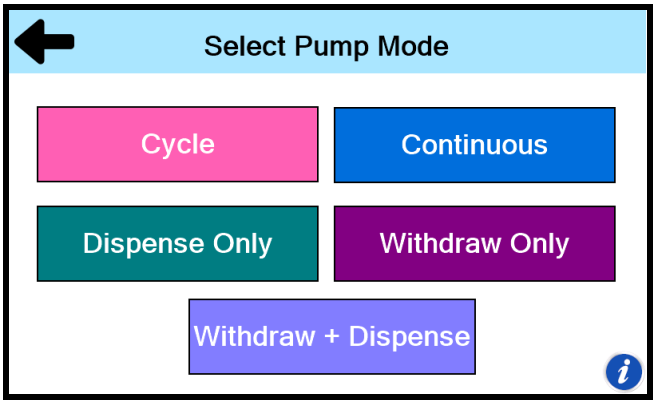
Finally, all the parameters have been set for **Dispense Only** mode and the *Run Status: Dispense* page is the current page. Press the **Run** button to start the dispensing operation. The run status pages for all the modes are identical. Once the system is done running, the same procedure for going to the *Home* page can be followed.



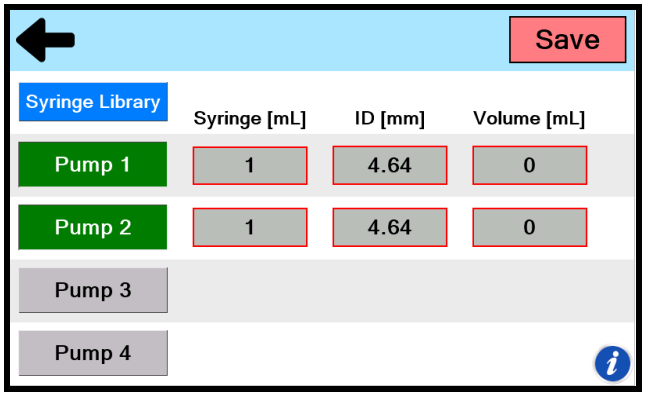


Withdraw Only Mode

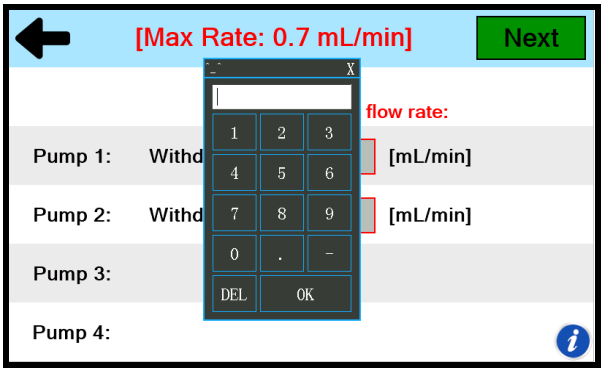
The **Withdraw Only** button is selected from the *Select Pump Mode* page to continue with withdraw only mode.



For this example, the syringe size and inner diameter remain the same, but we assume that the syringes are empty and need to be refilled using the withdraw only mode. Therefore, the only syringe parameter that changes is the current volume inside the syringe.

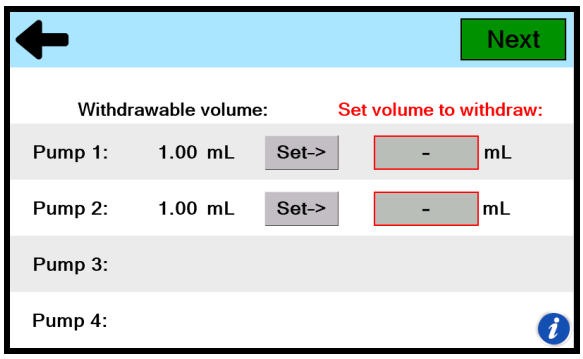


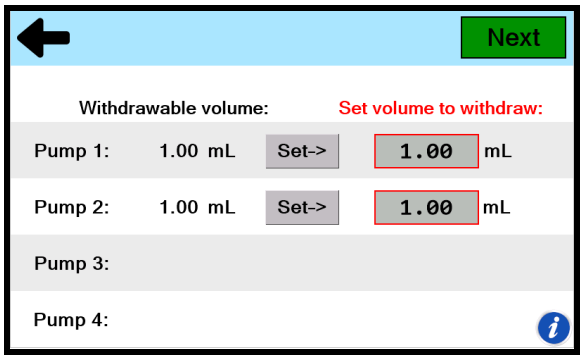
Next, the withdrawal flow rate for the selected pumps is to be set in the *Flow Rates* page. Again, the maximum flow rate is displayed at the top of the page for reference.



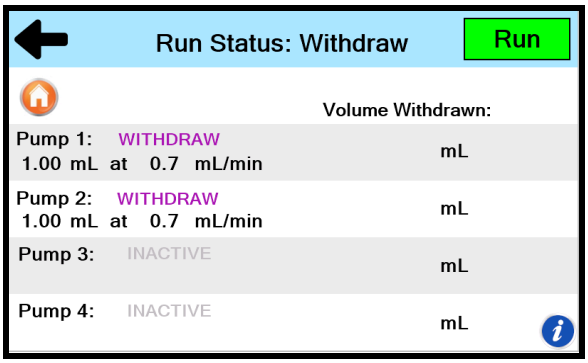
After setting the flow rate, the next step is to set the volume to be withdrawn in the *Target Volume to Withdraw* page. The maximum volume that can be withdrawn for each selected pump is displayed in the "Withdrawable volume:" column. The volume to be withdrawn must be lower than or equal to the value defined as the withdrawable volume for that specific pump. Inputting a value greater than the withdrawable volume prevents the user from proceeding to the next step.

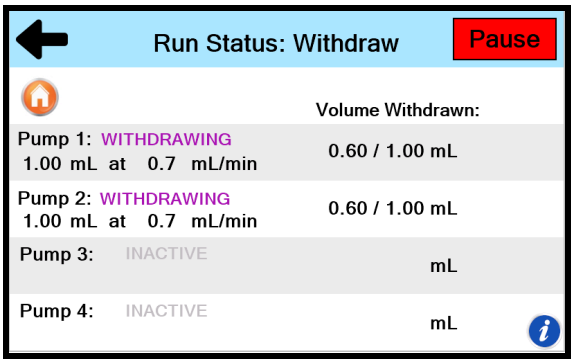
Note: If the user wishes to refill the syringe(s) completely, then they can just set the volume to withdraw as the same value as the withdrawable volume by pressing the **Set->** for the specific pump(s).





The last page for the withdraw only mode is the *Run Status: Withdraw* page which is identical to the previous run status pages. Therefore, it can be controlled like previously mentioned.

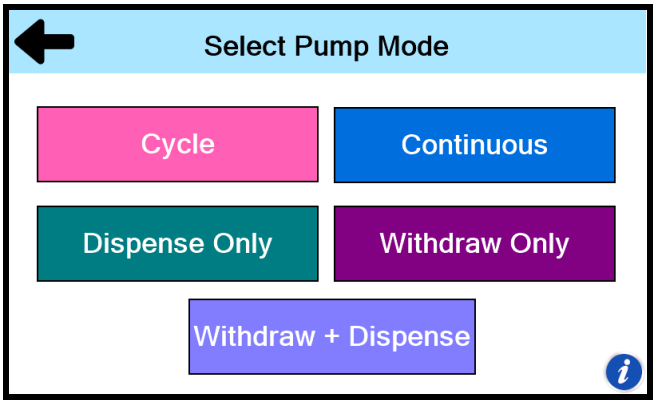




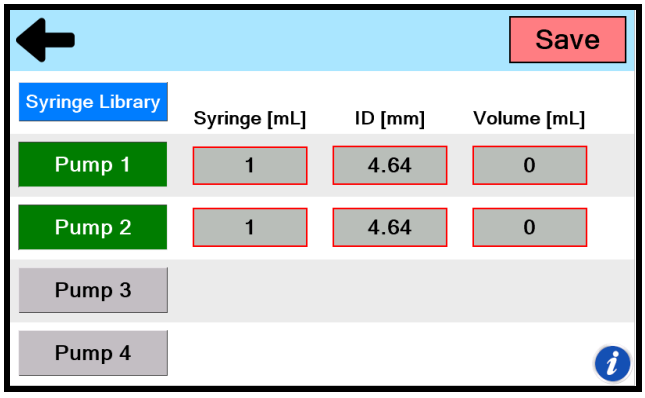
Withdraw + Dispense Mode

As mentionedSelect the **Withdraw + Dispense** button to begin setting up the system for this mode.

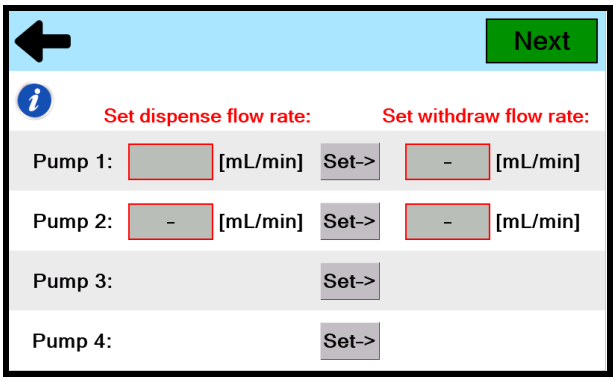
Note: In this mode it is assumed that the syringe is completely empty as it is placed in the syringe pump.

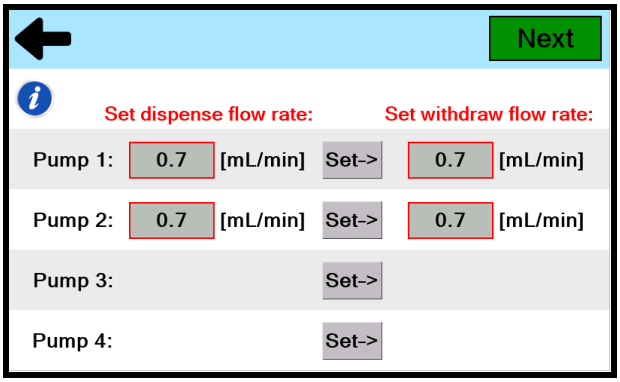


For this example, it is assumed that the syringe is empty since the first action of the syringe pump system will be to withdraw. (All the other parameters remain the same as before.)

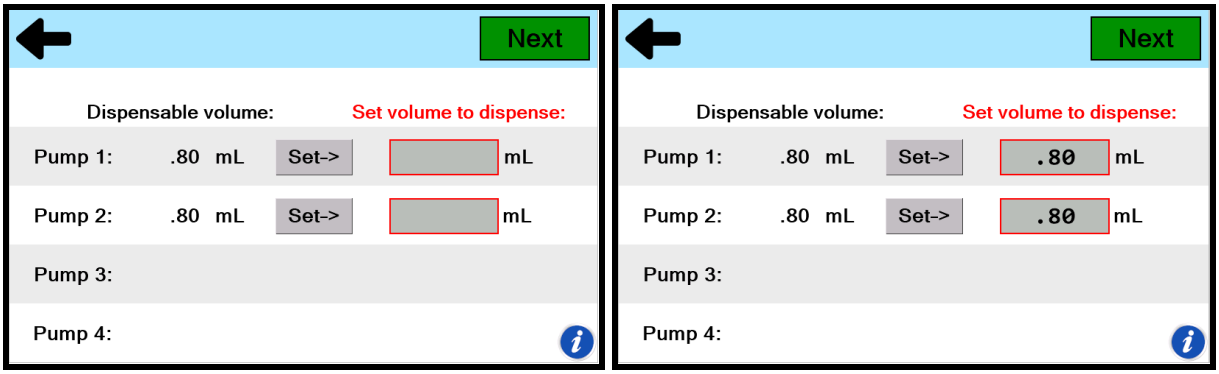


Next, the flow rates for the withdrawing action and the dispensing action are set in the *Flow Rates* page. The maximum flow rates based on the syringe size are displayed at the top of the page for reference.

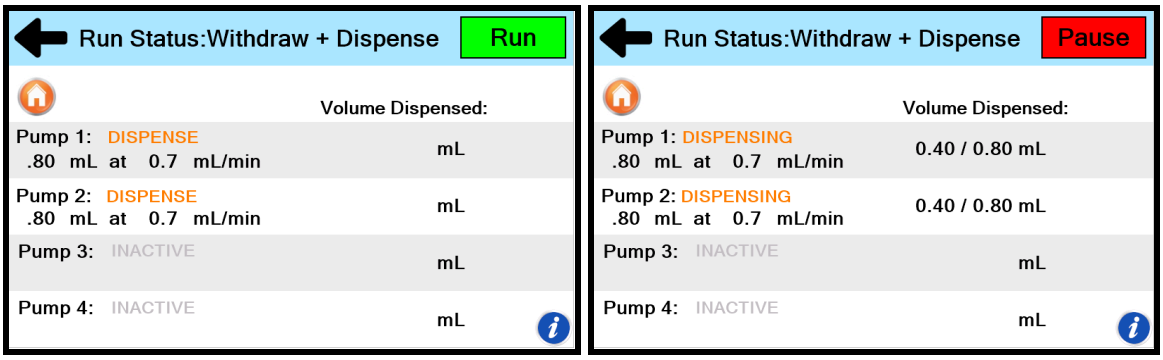




For the following page, the target volume to be dispensed by each pump must be set on the *Target Volume to Dispense* page. The volume to dispense has a limit which is based on the syringe size and is given by “Dispensable Volume:” on the left side of the screen.

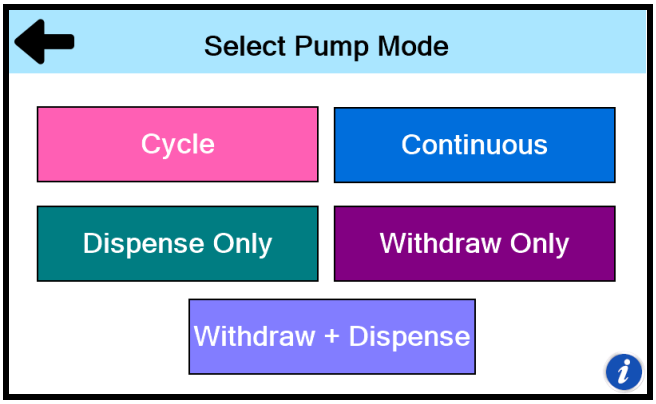


The run status page for this mode called *Run Status: Dispense + Withdraw* is the final page where the total volume dispensed by the pump can be tracked as in the other pump modes. All the other functions of this page are the same as in previous modes.

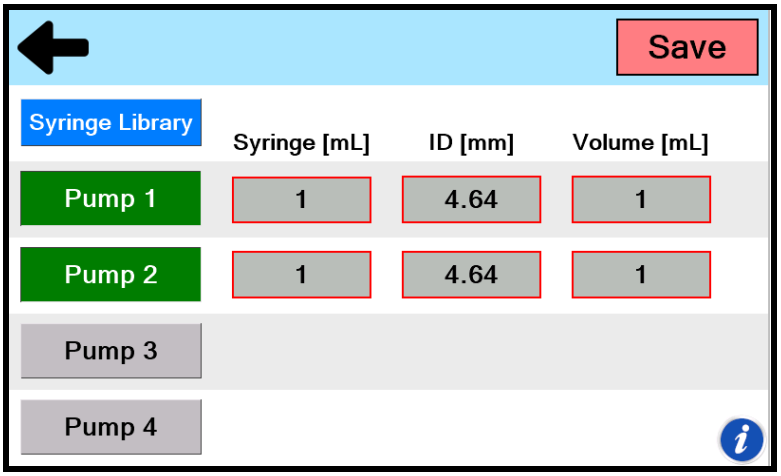


Continuous Mode

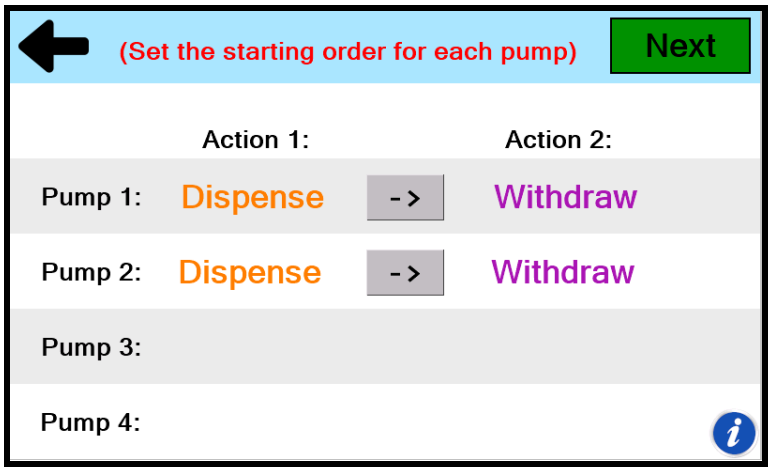
Begin by selecting the **Continuous** mode button from the *Select Pump Mode* page.



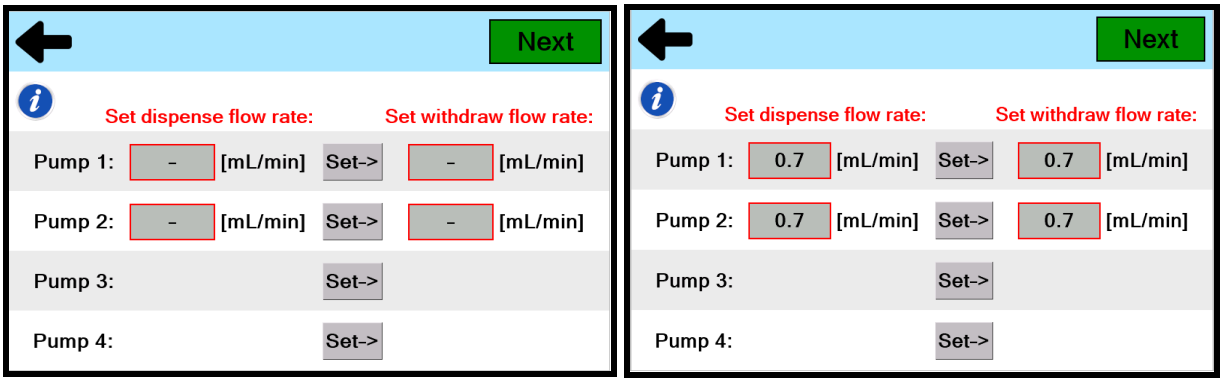
For the *Syringe Parameters* page one can input the syringe parameters for each pump that will be used. (The parameters from previous examples will be used.)



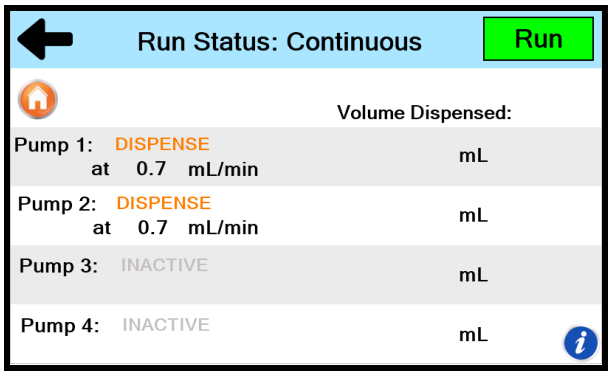
Next, the order for each action is set in the *Order of Operations* page. Since on the previous page both the syringes were set as having a current volume of 1 mL each, then it will make sense to dispense first. A withdrawal first action would be necessary if the syringe was empty.

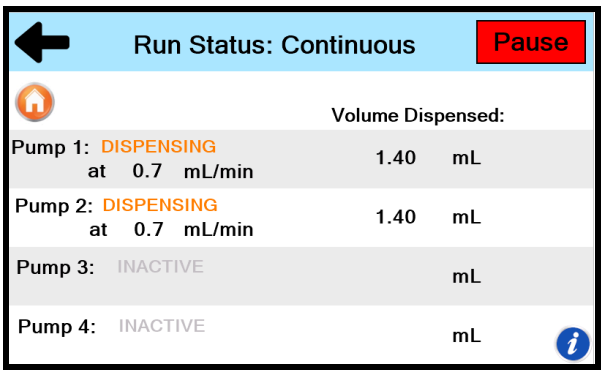


The next step is to set the dispense and withdraw flow rates for each that was selected previously. The maximum flow rates are displayed at the top of the page for reference.



Finally, the last step is to run the system in the *Run Status: Continuous* page. This page is different from the previous run status pages in that it does not include a target volume in the brief description of the operation on the left side. Nor does it have a target volume for the "Volume Dispensed:" tracker. The reason for this is because no target dispense volume is specified in this mode.


Run Status: Continuous
Run
Volume Dispensed:
Pump 1: DISPENSE
at 0.7 mL/min
mL
Pump 2: DISPENSE
at 0.7 mL/min
mL
Pump 3: INACTIVE
mL
Pump 4: INACTIVE
mL


Run Status: Continuous
Pause
Volume Dispensed:
Pump 1: DISPENSING
at 0.7 mL/min
1.40 mL
Pump 2: DISPENSING
at 0.7 mL/min
1.40 mL
Pump 3: INACTIVE
mL
Pump 4: INACTIVE
mL

Tubing Instructions

Tubing is only required if the user intends to perform flow chemistry experiments with the syringe pump system. Here the tubing instructions on how to connect the tubing to two syringe pump systems can be found. These instructions assume that the servo-motor mechanism will be used with the syringe pump system. The parts that are used for the connectors of the tubing are listed below.

A tubing tutorial filmed by the Croatt Research Group is available on youtube as well: https://www.youtube.com/watch?v=tzxWHxBi0SI

Parts for Tubing Connectors:

1. Tubing (Nylon or PFA) 1/16” OD (0.02 or 0.04” ID)
2. PEEK Nut 1/16” [LT-115X]
3. Super Flangeless Ferrule System (includes steel compression ring and ferrule) [P-250X]
4. PEEK Union [P-702]

Steps:

1. Take the steel compression ring and ferrule and with the flat side of the ring facing down place the ferrule on the top side of the ring.

2. Insert these parts with the flat end of the ring going first onto the narrow side of the PEEK nut. This assembly should be loose so be sure to hold onto it.
3. Run the tubing through the PEEK nut and then through the ferrule-ring assembly.
4. With the tubing sitting flat at the end of the ferrule-ring assembly, hand tighten the PEEK Union part onto the PEEK nut just until it cannot be screwed anymore with normal force. The union can be unscrewed after this.
5. *Two ends of tubing must have this type of assembly in order to connect the system together. Repeat these steps for the other end of the tubing, ensuring beforehand that the proper length of tubing is cut.



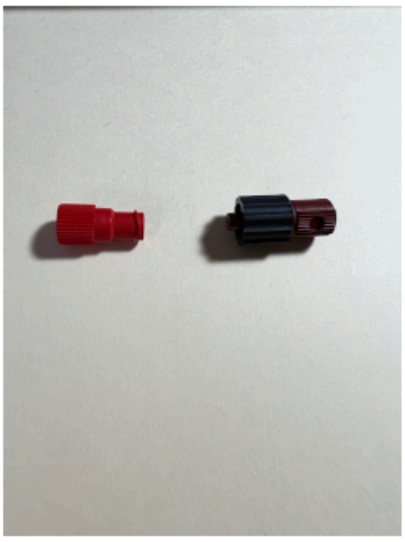
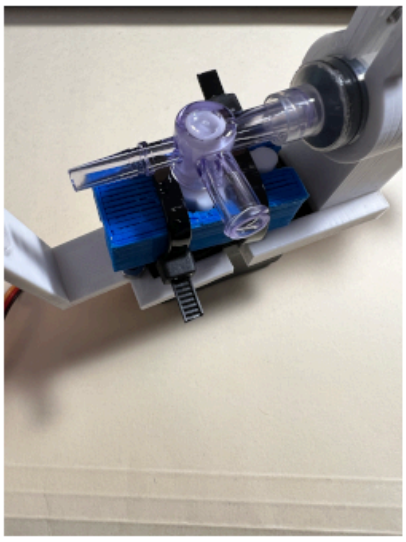
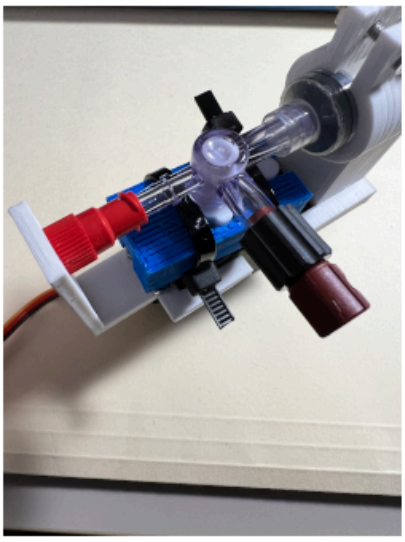
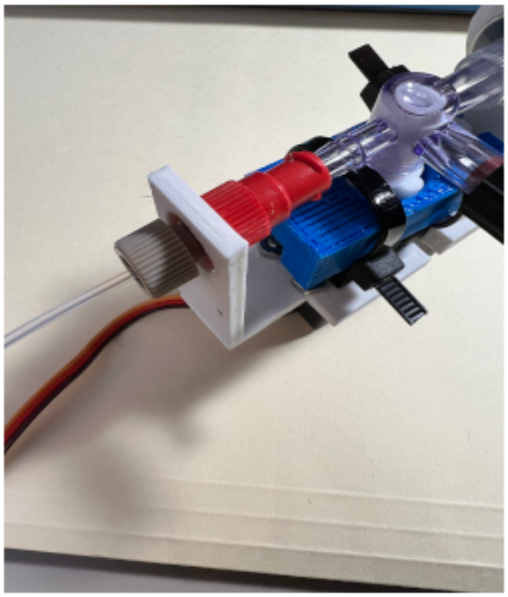


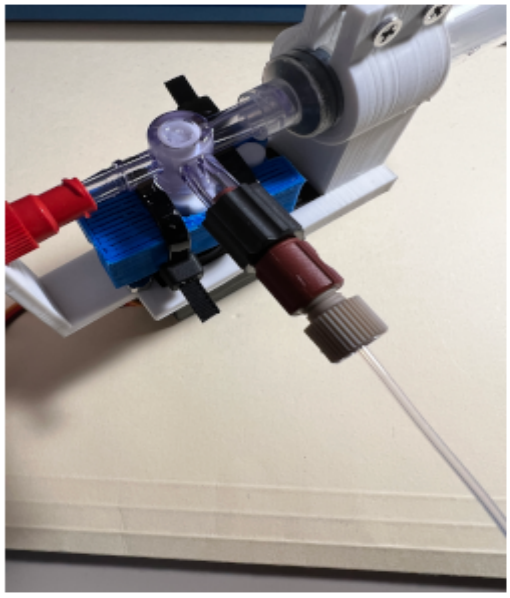
Parts for Connecting to the Syringe

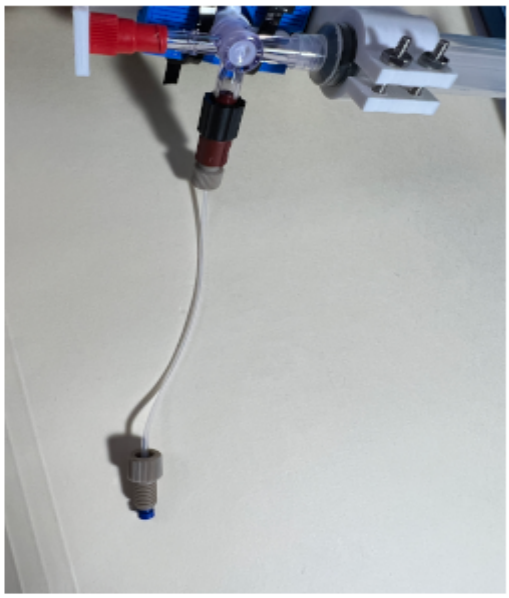
1. 1-4-28 Female to Female Luer [P-678]
2. 1/4-28 PEEK Male Luer Adapter [P-655]
3. PEEK Y-Assembly [P-512]

Steps:

1. Connect the red PEEK female to female luer by sliding it onto the smaller of the two openings of the stopcock valve. Ensure that the connection is not loose. If the servo-motor refill mechanism is not being used, then simply twist the same red PEEK onto the tip of the syringe. This is the dispensing end of the syringe pump.
2. With the other end of the tubing connector, tighten the nut onto one side of the PEEK Y-assembly. Another option that can be used here is a PEEK T-assembly.
3. For the refill side, take the red and black male luer adapter and hand tighten it onto the remaining opening of the stopcock valve using the black handle.
4. The other end of the tubing will use the same PEEK nut, but will have a blue plastic ferrule only instead of a ring and a ferrule. Steps 3 and 4 of the *Tubing Connector* assembly can be used to make the connection. This end of the tubing will be in direct contact with the reservoir for the refill mechanism.



DIY Syringe Pump System Data Sheet

Technical Specifications:

Mode: Dispense and Withdraw

Accuracy: Flow rates are within 10% of the expected value when the system is operated below its maximum flow rate conditions.

Syringe Size (Min/Max): 1 mL to 10 mL

Syringe Type: Plastic

Minimum Flow Rate: 0.5 mL/min (with 1mL syringe)

Maximum Flow Rate: 8 mL/min (with 10 mL syringe)

Maximum Linear Force (Theoretical): 593.3 N (133.3 lbf)

Display: Nextion 7” Intelligent Series Display (Enclosed)

Connectivity: Arduino

Power: 12V 30A DC (Stepper Motors) and 5V 5A DC (Servo Motors)

Motor Drive: 1.8° Nema-17 Stepper Motor with Micro-stepping

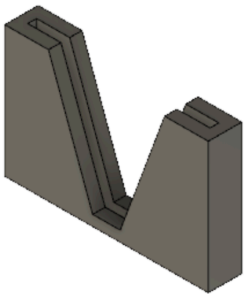
Step Resolution: 0.396 µm/step

3D Printing Modifications:

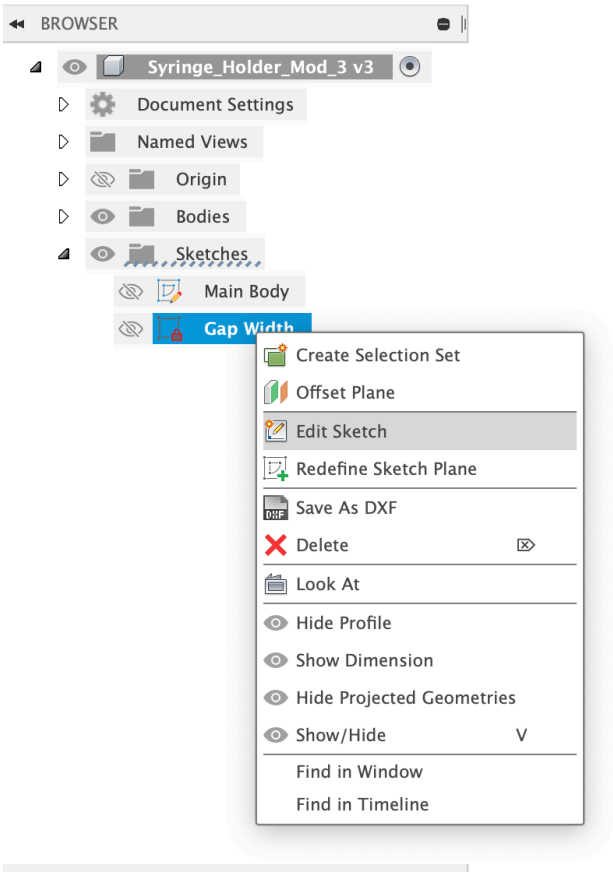
Syringe Holder

In the event that the syringe flange is too thick to fit inside the syringe holder (or too thin such that the syringe is not held with sufficient grip), a simple modification of the CAD file can fix this issue. Please note that the files must be edited using AutoDesk Fusion360 software so that the sketches are visible. Fusion360 is compatible with both PC and Mac.

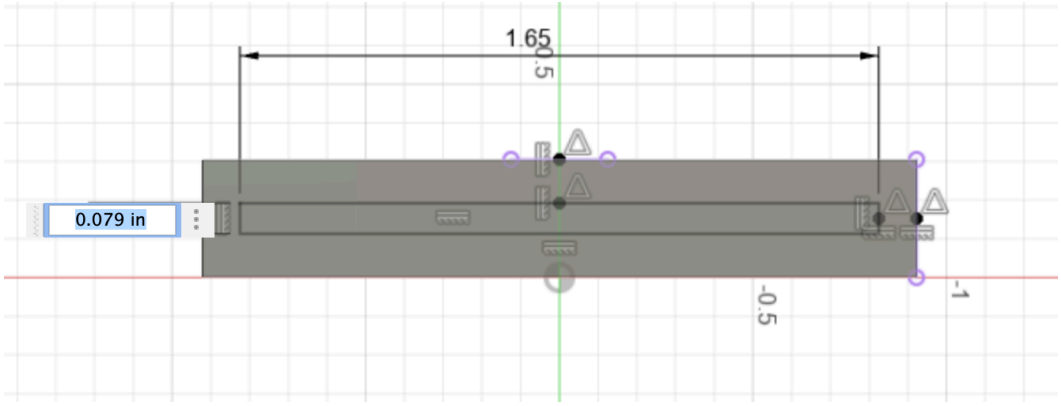
1. Open the Syringe Holder CAD File. The CAD should look like this:



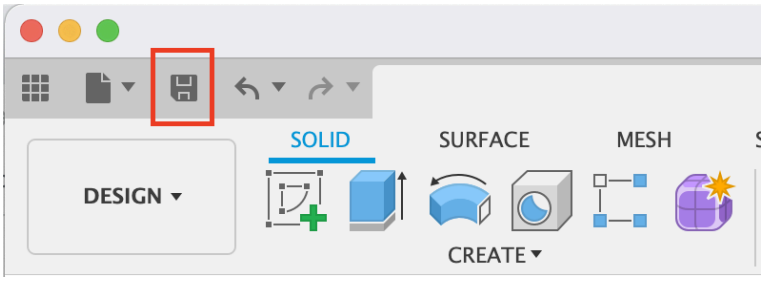
2. On the right-hand Browser, expand the Sketches pull-down option. Right click the ‘Gap Width’ sketch and select ‘Edit Sketch’.



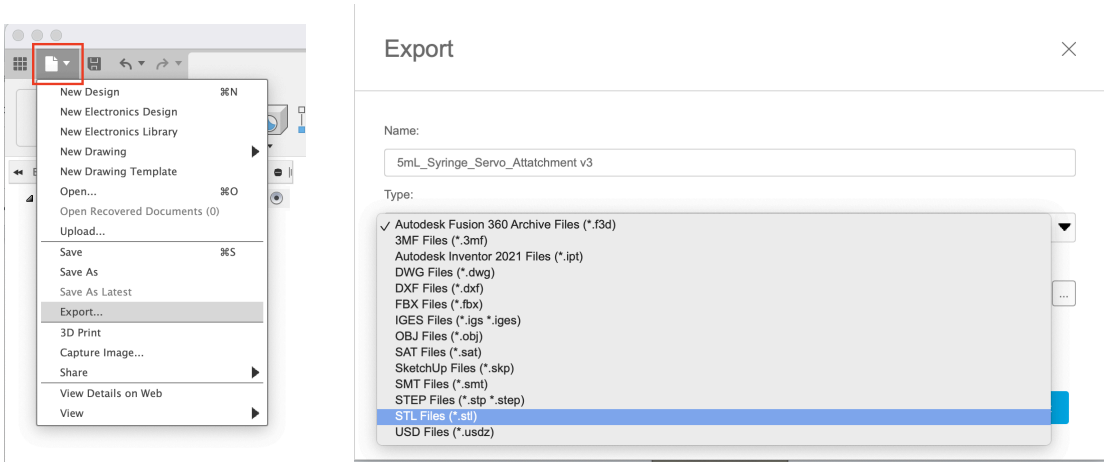
3. Once in sketch editing mode, double click on the dimension of the vertical side of the center rectangle. Modify this dimension to fit various syringe flange widths as needed.



4. Exit the sketch and save the file by clicking the ‘save’ icon on the upper right menu bar.



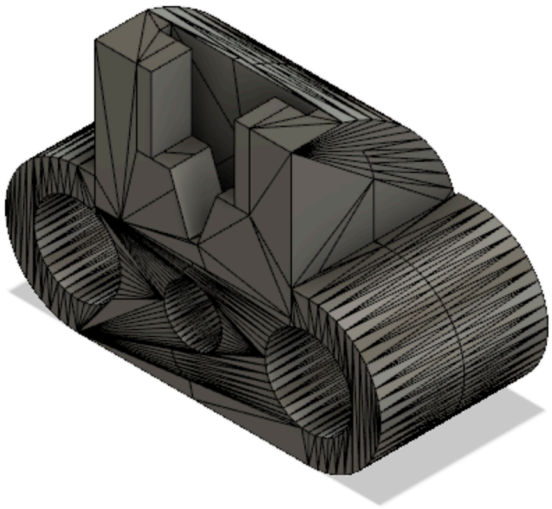
5. Export the file to STL for printing by selecting ‘Export…’ from the dropdown ‘File’ option on the upper right menu bar. Then select ‘STL Files *.stl’ from the Export dropdown menu.



Carriage

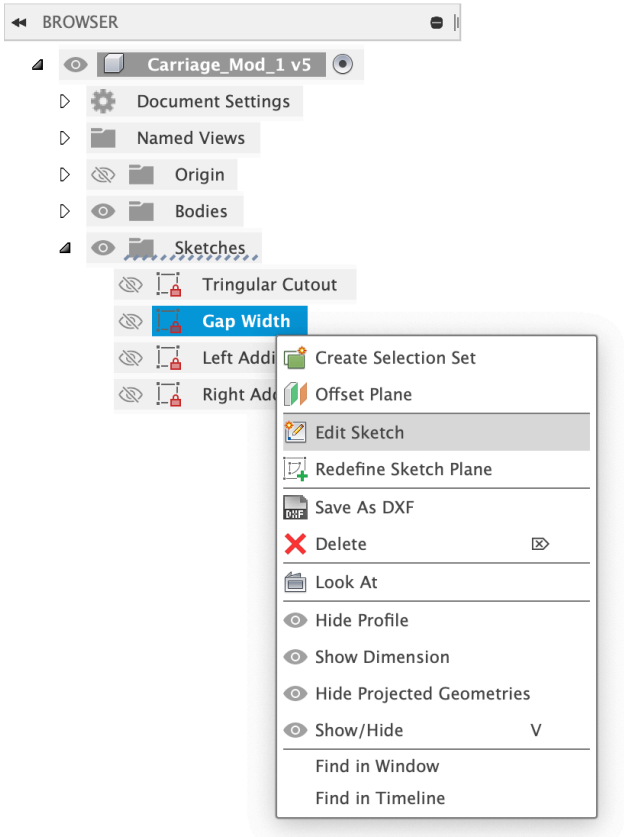
In the event that the syringe flange is too thick to fit inside the carriage (or too thin such that a gap is created between the syringe plunger which may affect the accuracy of the volume output), the CAD file can be modified.

1. Open the Syringe Holder CAD File. The CAD should look like this:

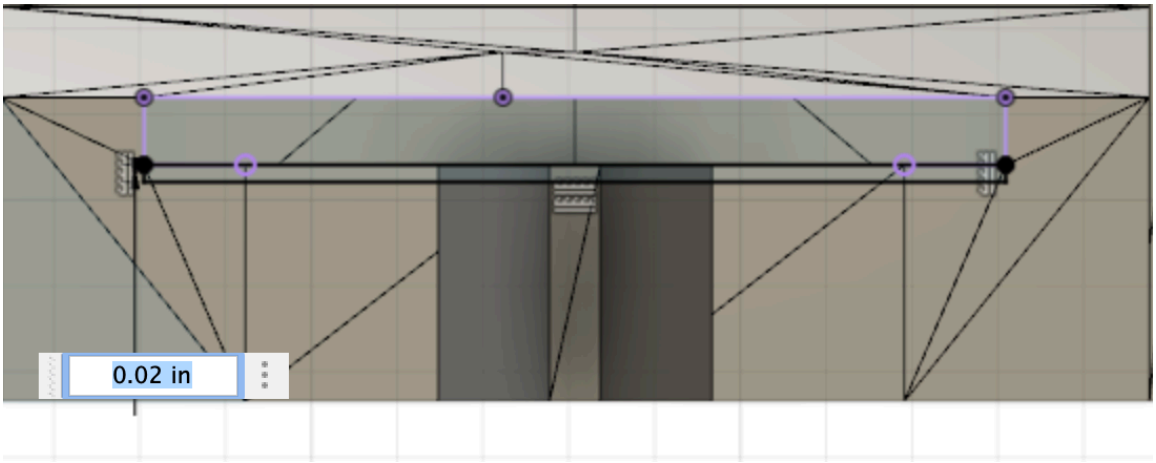


Note: the spliced faces are due to previous conversion from STL to CAD file. This will not affect how the file prints once it is converted to STL.

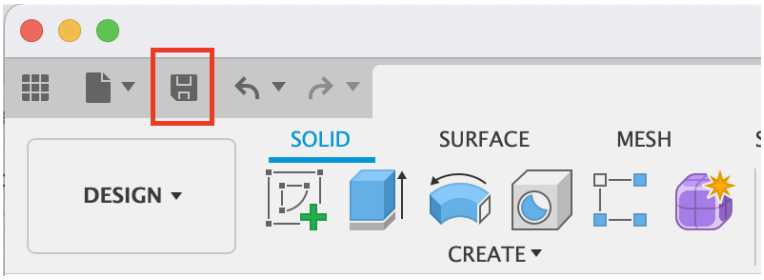
2. On the right-hand Browser, expand the Sketches pull-down option. Right click the ‘Gap Width’ sketch and select ‘Edit Sketch’.



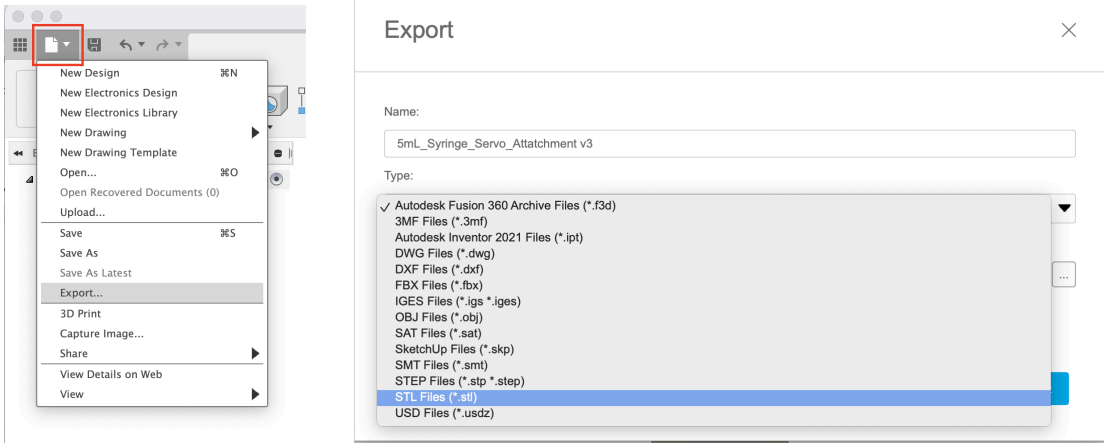
3. Once in sketch editing mode, double click on the dimension of the vertical side of the center rectangle. Modify this dimension to fit various syringe flange widths as needed. Note: the dimension is not the dimension of the overall gap width. The total gap width is 0.079” + 0.02” in this image.



4. Exit the sketch and save the file by clicking the ‘save’ icon on the upper right menu bar.



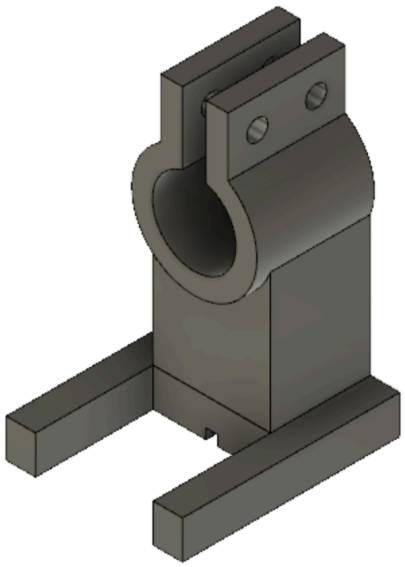
5. Export the file to STL for printing by selecting ‘Export…’ from the dropdown ‘File’ option on the upper right menu bar. Then select ‘STL Files *.stl’ from the Export dropdown menu.



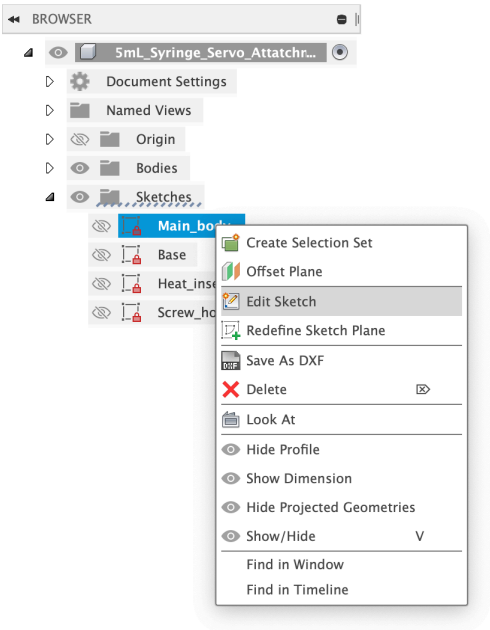
Syringe-stopcock

If the outer diameter of the syringe doesn't fit properly in the preized syringe-stopcock holder, modifications can be made to the CAD file.

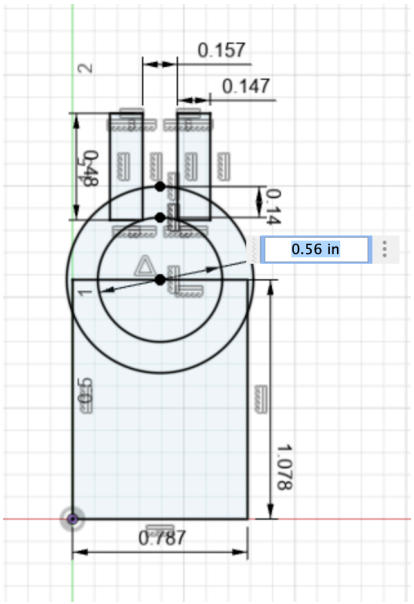
1. Measure the outer diameter of the syringe to be used using a pair of calipers. Record this measurement.
2. Open the #mL_Syringe_Servo_Attatchment CAD File. The CAD should look like this:



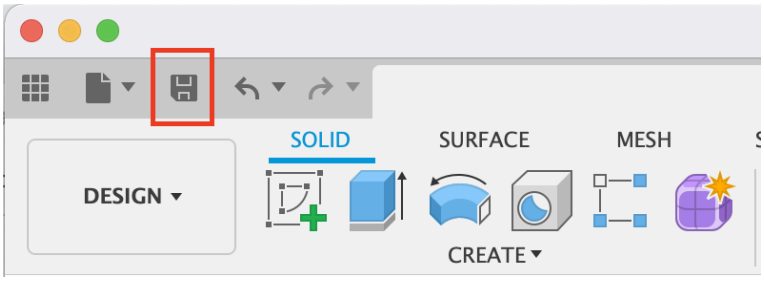
3. On the right-hand Browser, expand the Sketches pull-down option. Right click the 'Main_body' sketch and select 'Edit Sketch'.



4. Once in sketch editing mode, double click on the dimension of the inner diameter of the center circle. Modify this dimension to be the measured diameter of the syringe from step one, plus 0.01” for tolerance. Note: the sketch is constrained such that changing the inner diameter of the circle will also update the outer diameter to maintain a proper wall thickness.



5. Exit the sketch and save the file by clicking the ‘save’ icon on the upper right menu bar.



6. Export the file to STL for printing by selecting ‘Export…’ from the dropdown ‘File’ option on the upper right menu bar. Then select ‘STL Files *.stl’ from the Export dropdown menu.