Assembly of the Smoky Mountain Scientific Syringe Pump

Jack Summers
summers@wcu.edu

Figure 1. Assembled syringe pump

Introduction: Welcome to the world of open-source electromechanical fluidics. We hope you find these instructions useful. Figure 1 shows the fully assembled syringe pump. The syringe pump is composed of a number of inter-relating parts. Many of the parts are plastic pieces that are fabricated by 3D printing (Figure 2). Other parts are purchased and used as received or after minor modification. These include the drive screw and drive nut, steel rails, motors and various pieces of hardware. A third category includes parts that are fabricated especially for the pump. These include the electronic board and stainless steel retaining clips. A bill of materials is provided at the end of these instructions with a list of suppliers that we use.

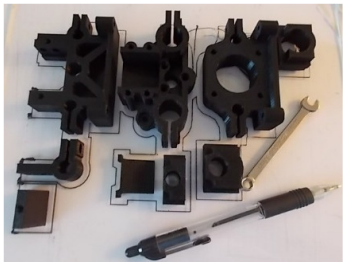

Figure 2. 3D printed plastic parts

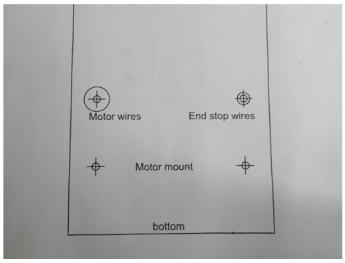

Figure 3. Bottom end of syringe pump template.

Part 1, Mounting platform: The syringe pump should be mounted on a platform that will allow it to stand with the syringe vertical or horizontal. In the vertical position it is easy to remove air bubbles. We make our platforms out of ¾" plywood. We start by cutting pieces to a four inch width. One piece of this is cut to a ten inch length. We cut the paper template out and affix it to the platform with spray adhesive, being sure to keep the bottom of the template (Figure 3) aligned with one end of the platform. The line along the bottom of the template aligns with the end of the motor in the finished assembly. The template gives positions where holes for the mounting screws can be pre-drilled. Positions for holes to pass wires through the platform are indicated on the template as well. The hole for the motor wires is ½" (13 mm) to allow a 4 wire Molex connector through. Once the holes are drilled, we remove the template and remove residual adhesive using turpentine. With the holes drilled, we attach spacer blocks to the back of the platform to keep the electronics box off of the benchtop.

Part 2. Mechanicals: Figure 2 shows the 3D printed plastic parts that are used to build the syringe pump. From the top left, the parts are the syringe mount, carriage body, motor mount and 10 mL syringe holder. The second row contains the end stop, outer wedge, and one and three mL syringe mounts. The item on the third row is the inner wedge. The syringe pump is built from three assemblies, the carriage, motor mount and syringe mount. Each of these is described below.

Part2a, Carriage assembly: The carriage is the assembly that holds the syringe plunger. It is the piece that rides on the rails between the two ends. Step 1 is to insert the linear bearings into the appropriate slots in the carriage. This is shown in Figure 3. It is helpful to pry the ears apart with a screwdriver. Be careful doing this that you don't break the plastic part. Once the bearings are in place, you can screw it in place using 12 mm M3 machine screws, washers and nylon lock nuts. I don't think this is necessary, since the fit of the bearings is pretty tight.

Figure 3. Inserting linear bearing into carriage assembly

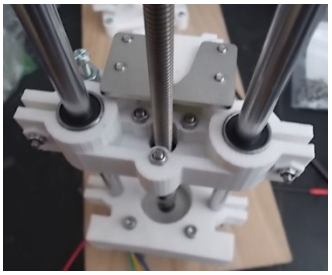

Figure 4. Views of carriage assembly. On left, a view from back showing drive nut and linear bearings. On right, a front view, showing stainless steel plunger support and the nuts that hold the drive nut.

The next step is attaching the drive nut. The drive nut is a plastic piece that bolts to the carriage body. It is connected using three _mm M3 machine screws, washers and Nylon lock nuts. The assembly with the drive nut and bearings in place is shown in Figure 4 and 5. Figure 4 also shows the 3" machine screw that is used to activate the end stop limit switches. This machine screw is held in place with four nuts. You need to do something to prevent these from loosening. Lock nuts might work. Locktight might work.

The carriage holds the syringe plunger by a mechanism that includes two wedges and a stainless steel clip. The inner wedge is used to adjust the plunger tension. To prepare this piece, a #6 nut is placed on the bottom and drawn into it's recess using a machine screw (Figure 5). The inner and outer wedges and stainless clip are assembled into the carriage assembly as shown in Figure 6.

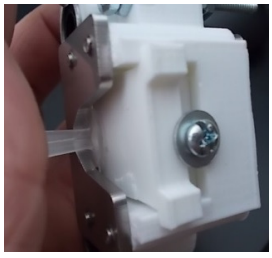

Figure 5. Plunger holding assembly on carriage. On left is a view of the inner wedge fitted with #6 nut. The view on the right shows inner and outer wedges assembled into carriage. Tightening the screw presses outer wedge against syringe plunger

Part2b, rails: The rails are 7.5" 8 mm chromed steel rods. These can be cut to length using an abrasive blade on a table saw using the jig shown in Figure 6.

Figure 6. Jig for cutting rails and drive screws with abrasive disk on table saw. Note aluminum sheet for spark arresting on top and end stop for lengths.

Part2c, Motor mount assembly: The motor is attached to the motor mount using 18 or 20 mm M3 machine screws (Figure 7). The motor is attached to the same side of the mount as the mounting screw "ears". This allows access to the mounting screws after the rails are attached. The motor shaft is connected to the drive screw using a 5mm to ¼" shaft coupling. Set screws for this coupling require 7/64# Allen wrench. Motor mount to rail connections may be supported using 16 mm bolts, washers and nylon lock nuts.

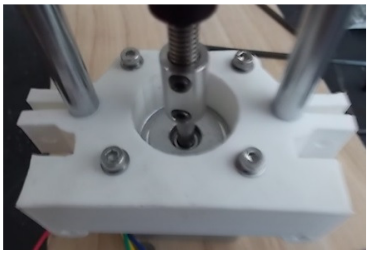

Figure 7. Motor end.

Part2d, motor side limit switch assembly: The limit of travel on the motor side is established by a limit switch mounted on a 3d printed plastic support that rides on the right side rail. The limit switch is attached using machine screws. The assembly can be seen in Figure 1 toward the bottom left corner.

Part2d, Syringe mount assembly: The syringe mount is the front part of the pump, Figure 8. The syringe mount also connects the front limit switch. The limit switch is connected using __ mm 2.5 M machine screws and nuts. The nuts are fitted into inside of the plastic syringe mount and drawn into the recess as shown in Figure 9.

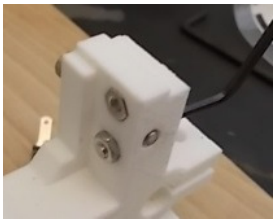

Figure 9. Nuts for limit switch are drawn into the syringe end holder.

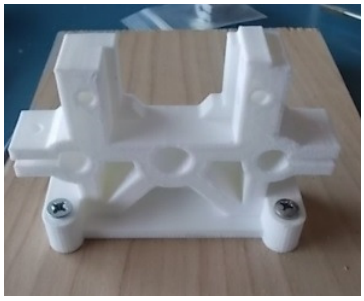

Figure 8. Syringe end holder screwed to plywood support.

The stainless steel syringe barrel retaining plate is attached to the syringe mount using two __ mm M3 machine screws.

The syringe barrel is held in our syringe pump by the plastic syringe holder. This is illustrated in Figure 10. As shown in Figure 2, the syringe barrel and its holder fit into the syringe mount while the plunger is held on the carriage by the stainless steel barrel retaining plate. Before attaching the syringe, loosen the mechanisms on both the barrel and plunger retaining plates. The barrel is held by two wedges on the carriage assembly. The inner wedge has a machine screw that draws it up against the outer wedge, which holds the plunger against the retaining plate. Use a phillips screwdriver to loosen he machine screw and push the wedges back to make room for the syringe plunger.

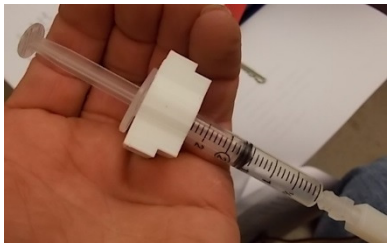

Figure 10. Syringe in holder.

The Use a 2.5 mm hex wrench to loosen the 3M machine screws (in the foreground of Figure 11) that hold the barrel retaining plate. It can be helpful to unscrew one of these machine screws entirely. Once the plate is loose, the syringe and holder are slid into the slot in the syringe mount and the machine screws may be tightened.

Figure 11. Syringe holder in mount held in place by syringe retaining plate.

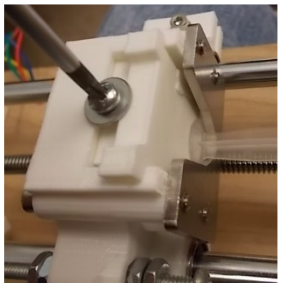

Figure 12. Adjusting the wedges to hold the plunger against its retaining plate.

Part 3, Electronics: Electronic hardware includes a purple circuit board, green motor driver board, a red microcontroller board, two limit swiches and a toggle switch. The toggle switch is used to run the pump when filling or emptying without the use of the computer interface. Trust me, this is handy when trying to get bubbles out or just filling prior to use. Three wires are soldered to the switch as shown in Figure 13. Note that the center wire (red) connects to the purple board at one of the wire pads labled "vcc" (the furthest right connection on the bottom of the left photo in Figure 14). The yellow and green wires are connected to the pads labelled A and B, respectively.

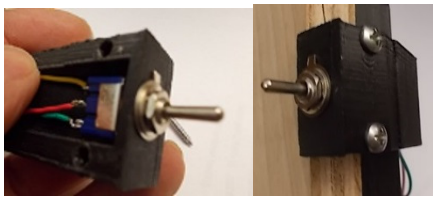

Figure 13. Fill switch assembly

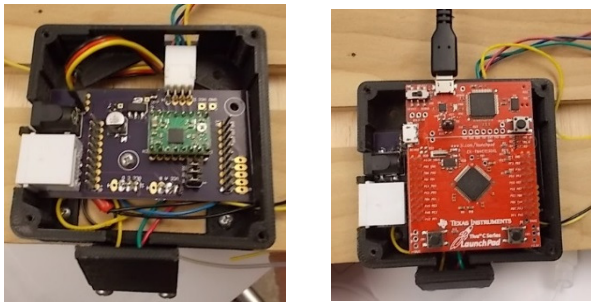

Figure 14. Wiring box set up for automatic titrator. On the left is the lower (purple) board with the pololu motor driver (green board) soldered in place. In the photo on the right, the red Tiva C LaunchPad board has been attached.

Wires from the limit switches enter the electrical box through a hole that is on the lower right in Figure 4, but cannot be seen. Both limits switches require a 3.3 volt source. Solder a short wire to the second vcc wire pad on the lower part of the purple board and pig-tail together two additional wires that will run to the two limit switches. The return wires from the two switches are soldered to the wire pads labelled C and D on the purple board.

Just above the green motor driver board in Figure 14 is a four conductor right angle Molex connection for the motor wires. Cut the wires from the motor to an appropriate length and crimp female molex connectors to each. Insert the metal molex connectors into the white plastic shroud so that they will connect in the following order from left to right: red, green, blue, yellow. Note that the "tabs" on the plastic shroud are pointing up and the wires

are away from you. Black jumpers just below the driver board allow selection of different microstepping options. For further information on the driver board, see https://www.pololu.com/product/1182. The following hardware items shown in Figure 14 are for autotitration only and can be left out of the build for a syringe pump: The white connector on the lower left is a Brittish Telecommunications Analog connector where Vernier Instruments sensors (like their pH probe) are connected. On the upper left, you can see a three wire connector for a servo motor that drives an automated valve in the autotitrator. The electronic hardware on the upper left of the board includes a voltage converter, capacitors and resistors that provide 6 volt power for the servo. These can be eliminated from the syringe pump build.

The red microcontroller board is attached to the purple board by aligning the two 10-pin headers on the purple board with the outer set of sockets on the bottom of the red board and pressing the two together. Make sure that the micro-usb port on the red board is facing upwards as shown in Figure 14.

Part 4, Valve assembly: The valve assembly is optional. You can run a syringe pump without it and you can run an autotitrator without it. It is kind of expensive and is a pain in the butt to build. The valve assembly is shown in Figure 15. It consists of a servo motor, servo mount, valve, valve mount and a servo to 1/8" shaft coupler. The pain in the butt part is attaching the coupler to the valve. This fitting is poorly designed and requires a whole lot of force to get the coupler connected to the shaft of the valve. The order of operation is: Screw the servo mount to the platform and attach the servo to its mount. Then put the valve on its mount and place the coupler on the valve stem. Squeeze the coupler with a big pair of channel lock type plyers and torque the mounting screw as hard as you can. Once you have this together, connect the coupler to the servo and screw the valve mount to the platform.

Figure 15. Valve Assembly.

Part 5, Software: Microcontroller software (written in the program Energia) and user interfaces (written in the program Processing) are available free of charge. You can download the most recent versions of the Energia and Processing programs for free from www.energia.nu and www.processing.org, respectively. Demonstrations of the syringe pump user interfaces is provided as a youTube at https://www.youtube.com/watch?v=2SJURHZQL1g. The autotitrator is demonstrated at https://www.youtube.com/watch?v=B33HSJ1ckLA. A video demonstrating the calibration functions of the autotitrator is at https://www.youtube.com/watch?v=jQvXyl5cbrk.