Micropump Module

ID: PP-1

Prototyping Protocol

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Protocol Description: – (DCW-1)

In the field of tissue engineering, bioreactors are devices used to influence multiple biological processes, such as to aid in proliferation and differentiation of cells to develop new tissue [1]. To support tissue constructs in microfluidic systems, a bioreactor that uses peristaltic pumps is created and modified to allow for improved functioning. First, a stepper motor, or a brushless DC motor, is used for accurate rotational positioning that is set at high torque and low speed. This motor is controlled by a stepper motor driver, which is powered by a grounded 12 V motor supply. The schematic and wiring diagrams for the micropump are shown in Figures 1 and 2 respectively. To assemble the stepper motor, there are multiple steps to be taken. First, the four rollers must be assembled. For each roller, a ⅛” ID x ⅜” OD flanged ball bearing is sandwiched between two washers on a M3 x 8mm screw. The flanged portion of the bearing is positioned upwards on top of the rotor. A second washer is placed on top of the bearing to prevent friction between the outer portion and the rotating portion of the bearing. A small nut is screwed on the bottom flat platform of the rotor to secure the bearing in place. This process is repeated three more times to assemble all four rollers on the pump rotor. Next, to fully assemble the pump rotor, a thin nut is placed down the shaft of the motor to hold the set screw in contact with the shaft; this is done so that the rotor does not rotate independently on the shaft. This rotor is then pushed down onto the shaft of the stepper motor until the pump rotor is leveled with the shaft of the motor; the flat portion of the shaft must be in alignment with the set screw. A small nut is then placed into the hole of the shaft, which is then secured with a M3 x 6mm screw. Then, the pump housing unit is placed on top of the stepper motor by using the two M3 x 20mm screws. However, to shorten the length of these long screws, a nut is placed onto each screw. The pump housing unit is then screwed onto the motor, ensuring that the two holes for tubing are positioned towards the top of the motor. Finally, the tygon tubing is inserted through the two holes and secured so that the tubing is placed directly underneath the flanged bearings. The user is able to input different flow rates and tube diameters, and the Arduino code will set the appropriate control conditions.

To improve upon the design, the following changes will allow for a better user experience. As seen in the wiring diagram in Figure 1, a tri-color LED light will be added to the circuit to indicate whether the motor is turned on or off. It will turn green when the button is pushed and the motor is in motion. It will turn red when the button is pushed again and the motor is no longer in motion. In addition, a groove will be added within the pump housing unit for easier positioning of the tubing as can be seen in Figure 5. The housing unit will have an upward arrow to indicate the position to place the unit onto the stepper motor as shown in Figure 5. As a user, the arrow will aid in assembling the design, as placing the housing unit in the opposite direction caused the tube to be pushed downwards leading to pump malfunctioning. Moreover, there was difficulty in maintaining the tubing position on the rotating part of the pump rotor. To resolve this issue, a lower ledge (sheave) was added to the design of the bearings as shown in Figure 4; this new design prevents the tubing from slipping underneath the bearings. Likewise, a heat shrink tube will be added to one end of the tube as seen in the final rendering of the design in Figure 6. This will make the diameter of the tube bigger than the hole so it will prevent the tube from slipping into the housing unit. To make the overall experience of assembling the design easier, an exploded assembly view of the micropump was added as seen in Figure 3, which follows along the assembling description previously mentioned.

Schematics and Drawings

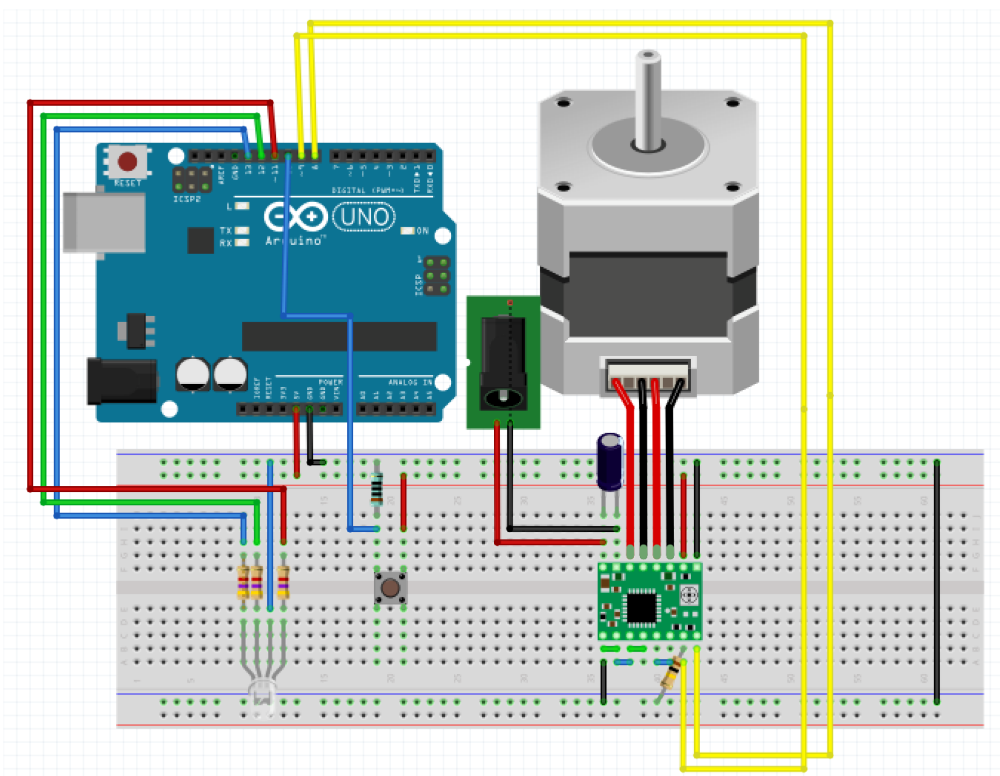

Figure 1. Circuit wiring diagram of the improved micropump design.

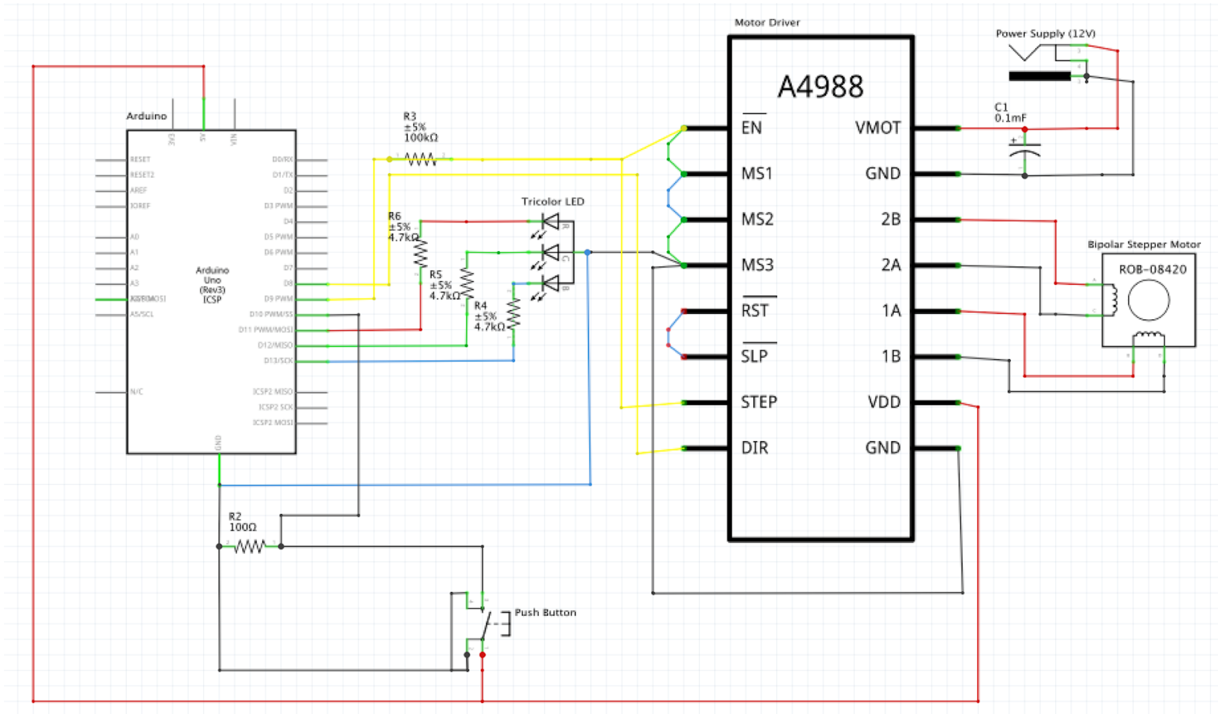

Figure 2. Schematic diagram of the improved micropump design.

Note: due to inability to find a 12 V power supply (wall adaptor) in Fritzing, a power jack was utilized instead in the wiring diagram and schematic above.

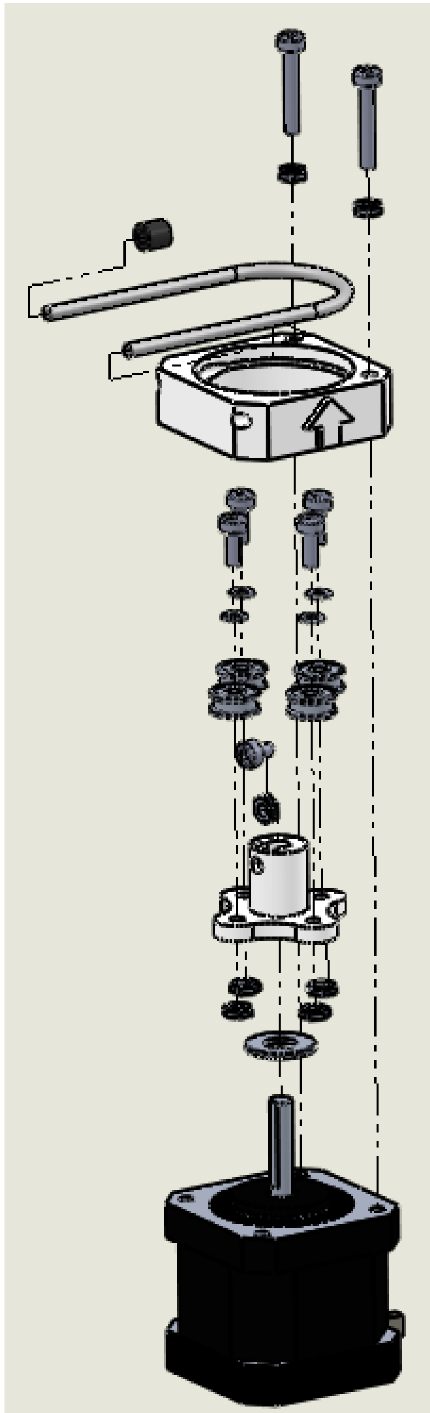

Figure 3. Exploded view of micropump assembly.

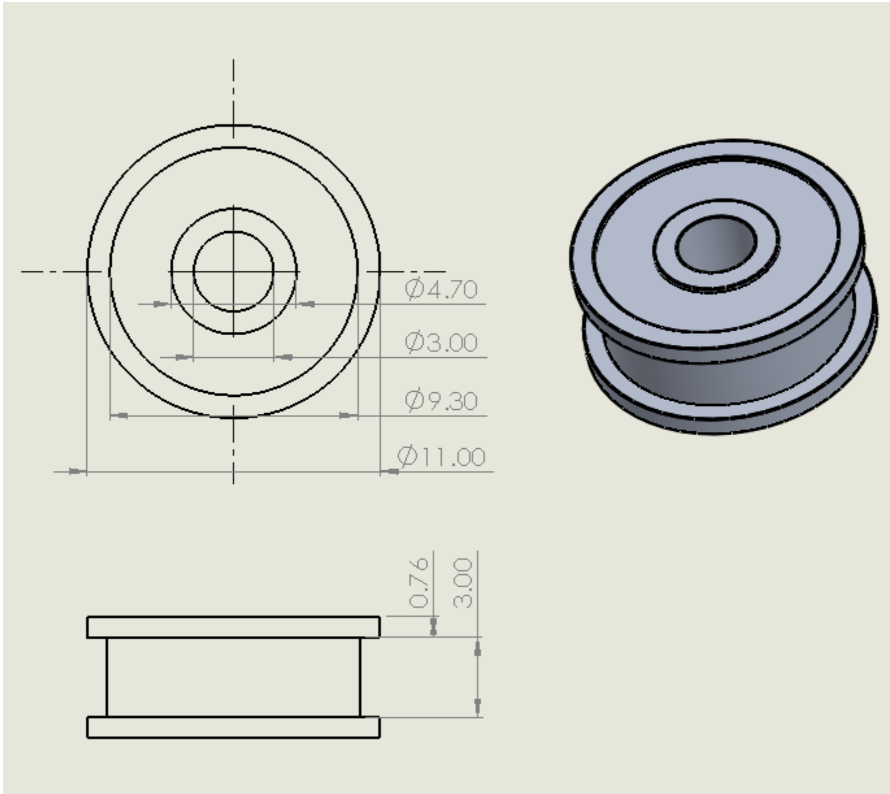

Figure 4. New bearing drawing.

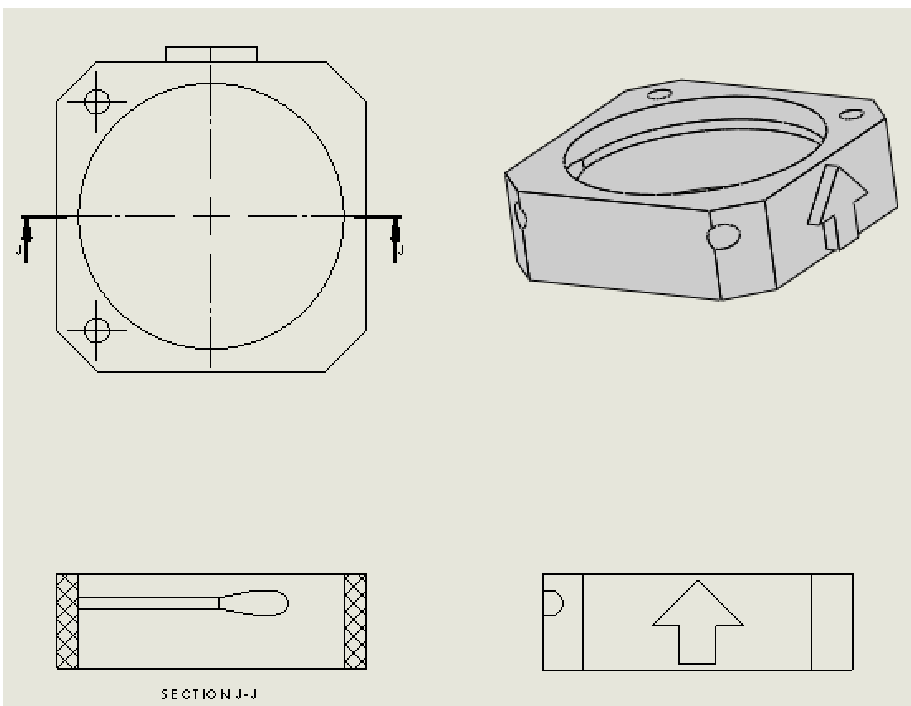

Figure 5. Cross-section of motor engine control unit with groove and direction arrow.

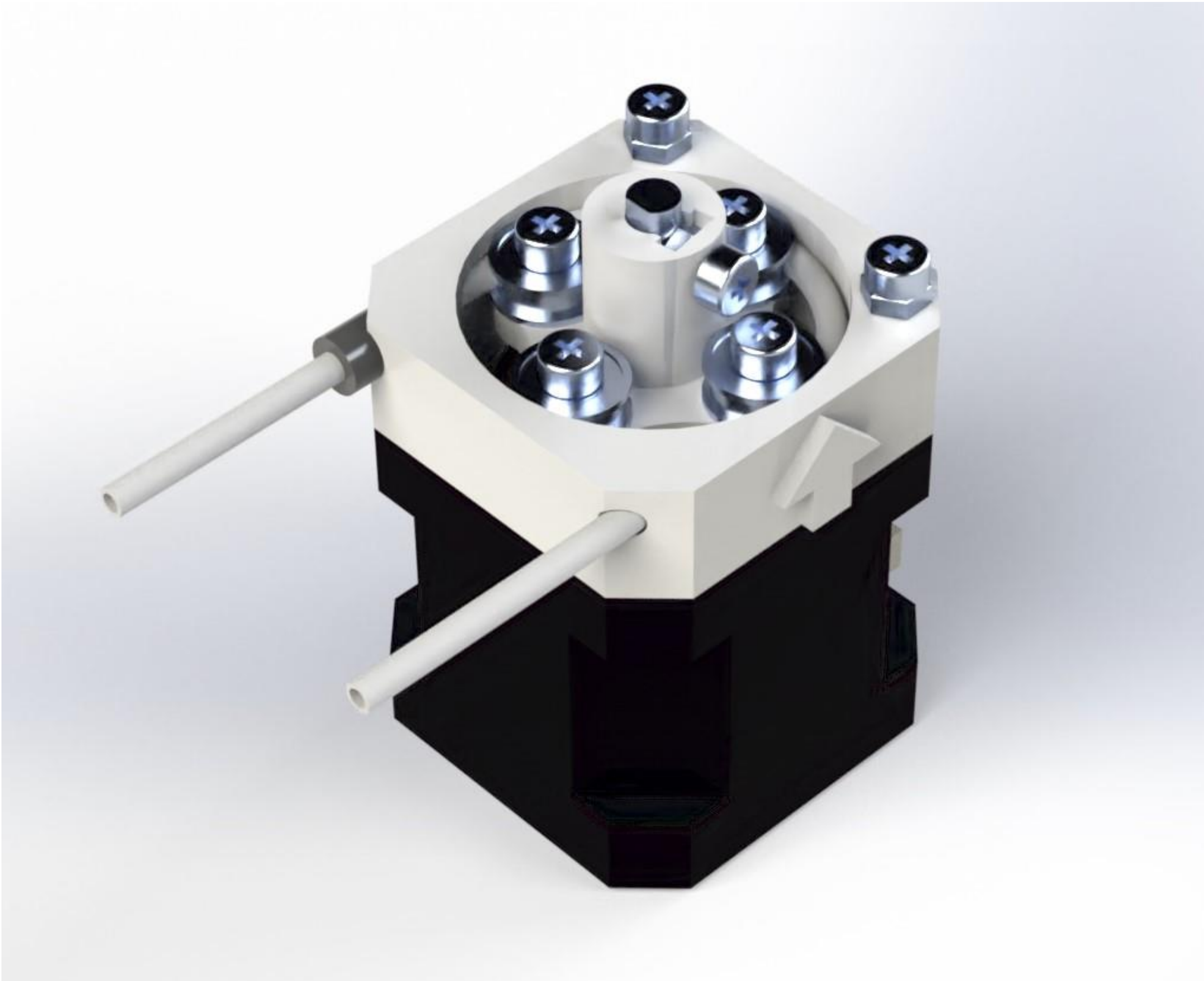

Figure 6. Final rendering of micropump.

Tools and Equipment

ID	Tool	Name / # if applicable	Location	Purpose
PT1	3D Printer, Flashforge Creator Pro	Paul	Design Lab	3D printing the pump rotor and pump housing unit
PT2	Side Cutter and 8" Spatula	N/A	Design Lab	Removing model from printer
PT3	Simplify3D	N/A	Design Lab Computer	Software for converting .stl file into. x3g file for FDM printing on Flashforge
PT4	Solidworks	N/A	Design Lab Computer	CAD software for modeling the pump rotor and pump housing unit
PT5	Safety Glasses	N/A	Design Lab	PPE
PT6	SD Card	N/A	Design Lab	To print the 3D part from .x3g file
PT7	Screwdrivers	N/A	Design Lab	To secure screws onto the stepper motor and pump rotor

Materials

ID	Material	Purpose
PM1	Polylactic Acid + (PLA+) 1.75mm Hatchbox, Gold	3D Printing the pump rotor and pump housing unit
PM2	Assorted Wires	Wires to connect the stepper motor to the circuit, to connect the circuit to the Arduino, and to connect the Arduino to the computer
PM3	4.6k Ω Resistor	Part of the filtering circuit
PM4	100 Ω Resistor	Part of the filtering circuit
PM5	220 Ω Resistor (3x)	Part of the filtering circuit
PM6	0.001 μF Capacitor	Part of the filtering circuit
PM7	Stepper motor	To rotate the motor shaft for precise positioning
PM8	Stepper motor driver	To control the stepper motor
PM9	12 V Supply	To power the stepper motor
PM10	Tri-color LED	To indicate if the motor is on or off
PM11	Pushbutton	To control (turn on/off) the motor pump and LED light
PM12	Heat shrink tubing	To prevent tygon tubing from slipping
PM13	M3 x 6mm	To hold the rotor and shaft in place
PM14	M3 x 8mm (4x)	To hold the bearings in place
PM15	M3 x 20mm (2x)	To secure the housing unit onto the motor

PM16	M3 thin nut	To prevent the rotor from rotating independently on the shaft
PM17	M3 nuts	To hold the screws in place
PM18	M3 Washers (4x)	For load distribution on a larger area andt o keep the screw from loosening

Computer Files

ID	FileName / Link	Purpose	Location
CF1	PumpRotor.sldprt	CAD File	/Micropump_AhmedinElkedwaniJesbergShin/3DPrintingFiles/PumpRotor.sldprt
CF2	PumpHousing.sldprt	CAD File	/Micropump_AhmedinElkedwaniJesbergShin/3DPrintingFiles/PumpHousing.sldprt
CF3	PumpRotor.stl	Solid Model for 3D print	/Micropump_AhmedinElkedwaniJesbergShin/3DPrintingFiles/PumpRotor.stl
CF4	PumpHousing.stl	Solid Model for 3D print	/Micropump_AhmedinElkedwaniJesbergShin/3DPrintingFiles/PumpHousing.stl
CF5	PumpRotor.x3g	x3g file generated in Simplify3D for the pump rotor	/Micropump_AhmedinElkedwaniJesbergShin/3DPrintingFiles/PumpRotor.x3g
CF6	PumpHousing.x3g	x3g file generated in Simplify3D for the pump housing	/Micropump_AhmedinElkedwaniJesbergShin/3DPrintingFiles/PumpHousing.x3g

3D Printer Settings

ID	Setting	Value	Expected Result on Final Print
PS1	Extruder Temperature	230 ˚C	230 ˚C melts PLA together better for a more solid part
PS2	Bed Temperature	60˚C	Doesn't let part peel up off the bed
PS3	Infill %	20%	Sufficient infill for mechanical strength and some flexibility
PS4	Infill Pattern	Rectilinear	Desired infill pattern
PS5	Raft (Y/N)	Y – 3 layers	Allows parts to be removed without damaging the bottoms
PS6	Support (Y/N)	N	A flat piece without unconventional overhangs so no supports are needed
PS7	Extruder Speed	2400 mm/min	Slows the printer down to accommodate the hot extruder; results in ideal prints but increases print time
PS8	Build Speed	2400 mm/min	Same as PS7

References

[1] Plunkett, N. & O'Brien, F.J. (2011). Bioreactors in tissue engineering. *Technology and Health Care*, *19*(1), 55-69. https://doi.org/10.3233/THC-2011-0605