Fabrication and Configuration of Fluidic Logic Elements

March 1st, 2024

Fabrication Overview

All parts of the valve can be printed with commercially available desktop FDM printers. Our fabrication is done on Prusa MK3S+ printers, and the required CAD file, stl file, gcode, printer configurations are provided in this folder. The CAD drawing of the soft bi-stable valve cap part is shown below.(**Figure 1**) Each bi-stable valve consists of two caps, a body, and two pieces of extruded tubing. The caps and tubing are made from NinjaTech NinjaFlex 80A filament, while the body is made is Recreus Filaflex 60A filament. The spacer is a small piece cut from the extruded tubing.

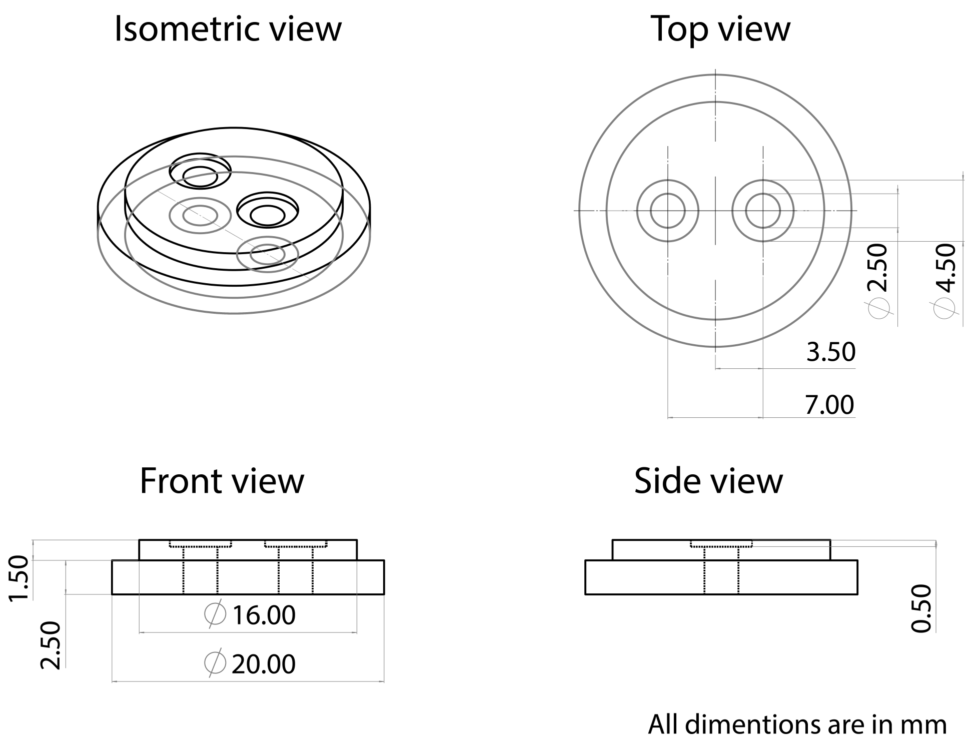

Figure 1: **CAD drawing of caps from soft bi-stable valve.**

Assembly Steps

For this stage, specific tools (**Figure 2A**) are required; they are essential for ensuring a successful assembly process.

- Flush cutter
- Cyanoacrylate adhesive (Superglue)
- Precision tweezers
- Protective gloves
- Vernier caliper
- 3D-printed assembly tool

Adhere to the following guidelines for the assembly of the soft bi-stable valve. We uploaded a video to YouTube, which elucidates further the assembly process: (https://www.youtube.com/watch?v=TnpLk_4bHIo)

1. Initiate the assembly with the cap and tubing. The tubing undergoes extrusion via a custom nozzle. Ensure that the thicker side of the tube faces inward to minimize the risk of kinking. **Figure 2B** illustrates an incorrect configuration where the thinner side of the tubing is oriented inward, leading to self-induced kinking. **Caution**: This step is crucial as it is a common source of assembly failure. Discard any tubing segments that exhibit a propensity to kink autonomously in any direction.

2. Use the following specified lengths for the tubing on the top and bottom sides of the soft bi-stable valve (**Figures 2C and 3B**):
   - Top: 11.5 mm + 1.5 mm spacer
   - Bottom: 8 mm

3. Prior to adhering the tubes, precondition the tubes by manually deforming them in various directions. This action reduces the tube's tendency to kink automatically (**Figure 2B**).

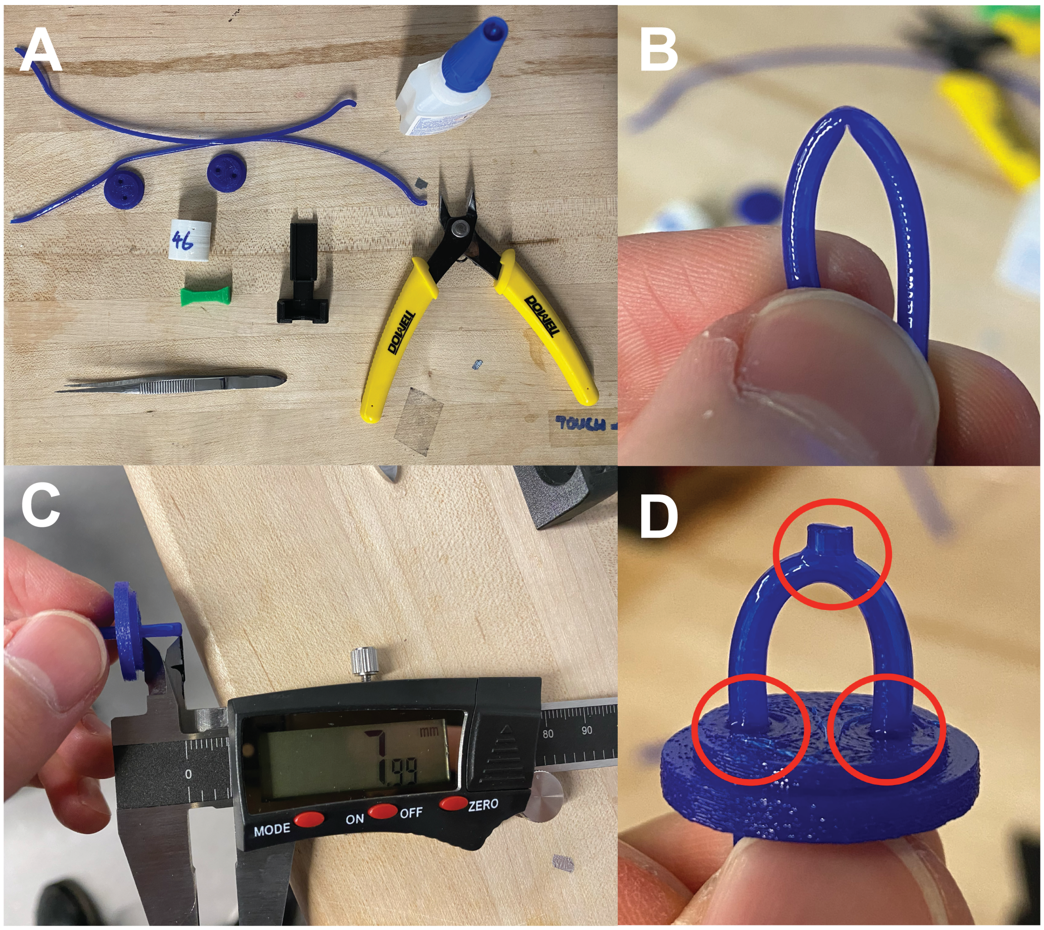

Figure 2: **Assembly process of soft bi-stable valve**. A) Essential tools and components for valve assembly. B) Illustration of incorrect tube orientation leading to self-kinking. C) Procedure for determining the bottom tube length. D) Guidelines for glue application points on the top tubing with spacer.

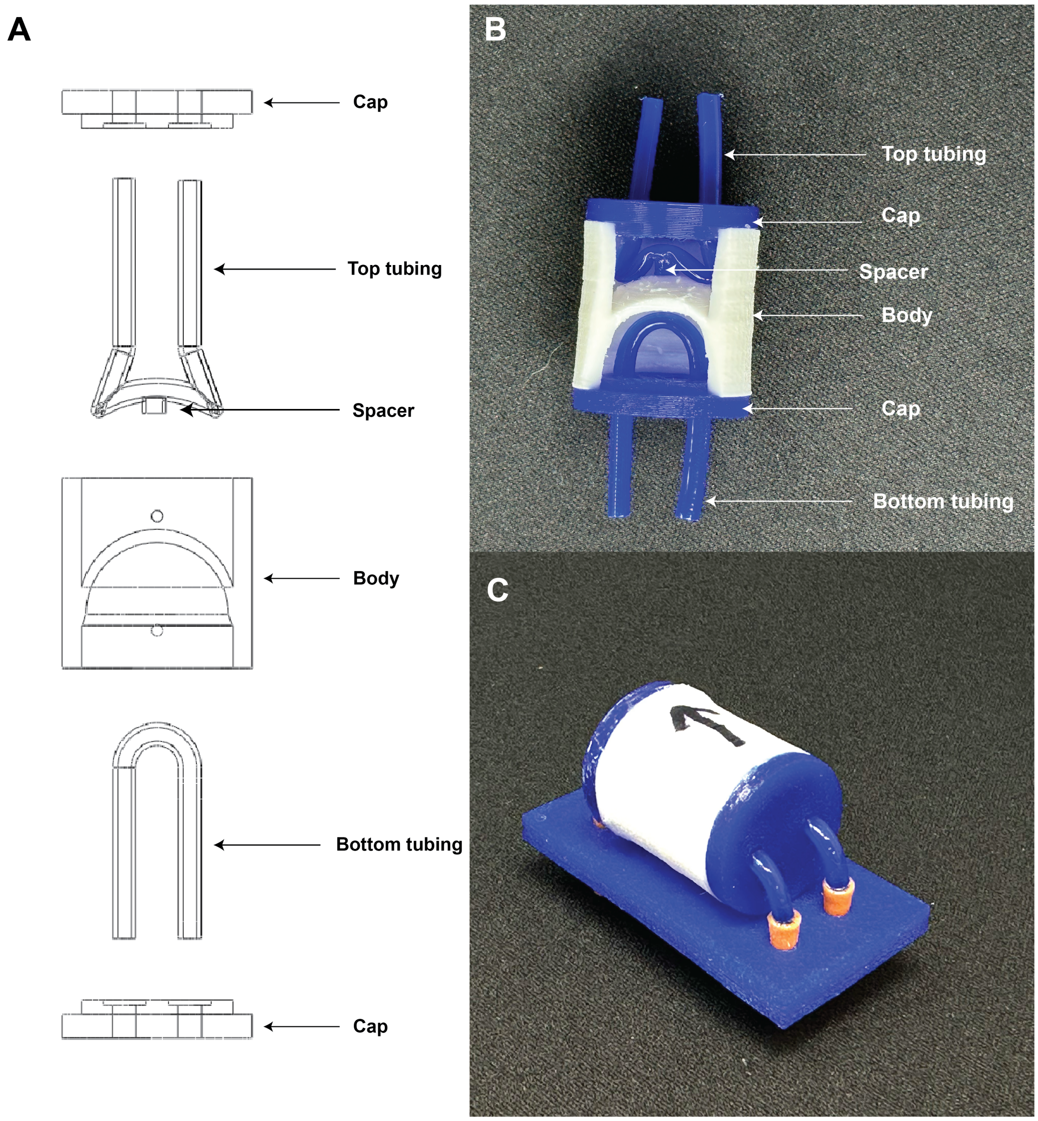

Figure 3: **The soft bi-stable valve.** A) The exploded view of the valve along with its components. B) Cut view of 3D printed valve and, C) fully assembled valve. D) CAD file of the cap.

4. Begin by inserting the top tube through the holes in the top cap. Ensure the tube lengths are as follows: 11.5 mm for the top tube and 8 mm for the bottom tube (**Figures 2C and 3**). Utilize a caliper for

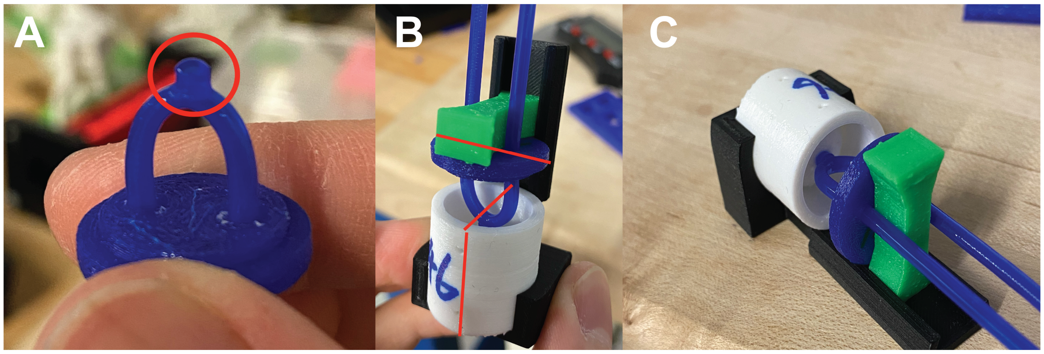

Figure 4: **Top tube assembly process.** A) Application of glue to the spacer on the top tubing. B) Utilization of 3D-printed tool to ensure tube's perpendicular alignment. C) Exertion of slight pressure for secure attachment of spacer to membrane.

measurements (**Figure 2C**). Cut a 1.5 mm long piece from the tubing and use it as the spacer for to the tubing (**Figures 3A and 3B**). Apply adhesive to the top of the tube and secure the spacer (**Figure 2D**).

5. Measure the tube lengths at the caps; the bottom tube has to measure 8 inches and the top tubing 11.5 + 1.5 inches (including spacer). Once the adhesive has fully cured, proceed to attaching the cap to the valve body.

6. Apply half a drop of adhesive to the top part of the spacer. Use the 3D-printed assembly tool from the Robotic Materials Group to gently press the spacer onto the center of the membrane (**Figures 4A and 4B**).

7. Confirm that the tube aligns perpendicularly with the holes in the membrane body. All three lines in **Figure 4B** should be mutually perpendicular. Ultimately adhere the cap to the valve body.

8. Exercise caution and protect your hands from getting in touch with the adhesive during this step. Generously apply adhesive around the cap before inserting it into the body. The adhesive should overflow, aiding in the sealing process.

9. For enhanced adhesion, apply additional adhesive to the top surface of

the cap (**Figure 5A**). This ensures that the cap adheres securely to the body from the inside.

10. Repeat the aforementioned procedure for the bottom tube. Note that no spacer is required, nor is there a need for adhering the bottom tubing to the membrane.

11. Employ clamps on both sides of the cap to secure the assembly (**Figures 5B and 5C**). Initiate clamping with the cap that is not under tension from the membrane, i.e., the bottom cap. You may be sacrificing a pair of gloves at this stage, which is acceptable.

12. Exercise caution in applying pressure during the assembly process; too much pressure can disjoin the valve from the cap. Excessive adhesive between the cap and body enhances the robustness of the seal and contributes to high-pressure retention. To ensure an airtight seal, a generous application of adhesive is recommended. This stage depicts the final opportunity to rectify any issues with non-perpendicular alignment, ensuring proper orientation.

13. Upon complete assembly of the valve, conduct a thorough examination to confirm its impermeability (**Figure 5D**). If your valve leaks air, document its print quality and points of failure.

Configuration Process

Initially, configure the valve as a NOT gate for testing. Include the corresponding truth table in your lab report. Subsequently, configure the valve as AND and OR gates, and include their respective truth tables as well.

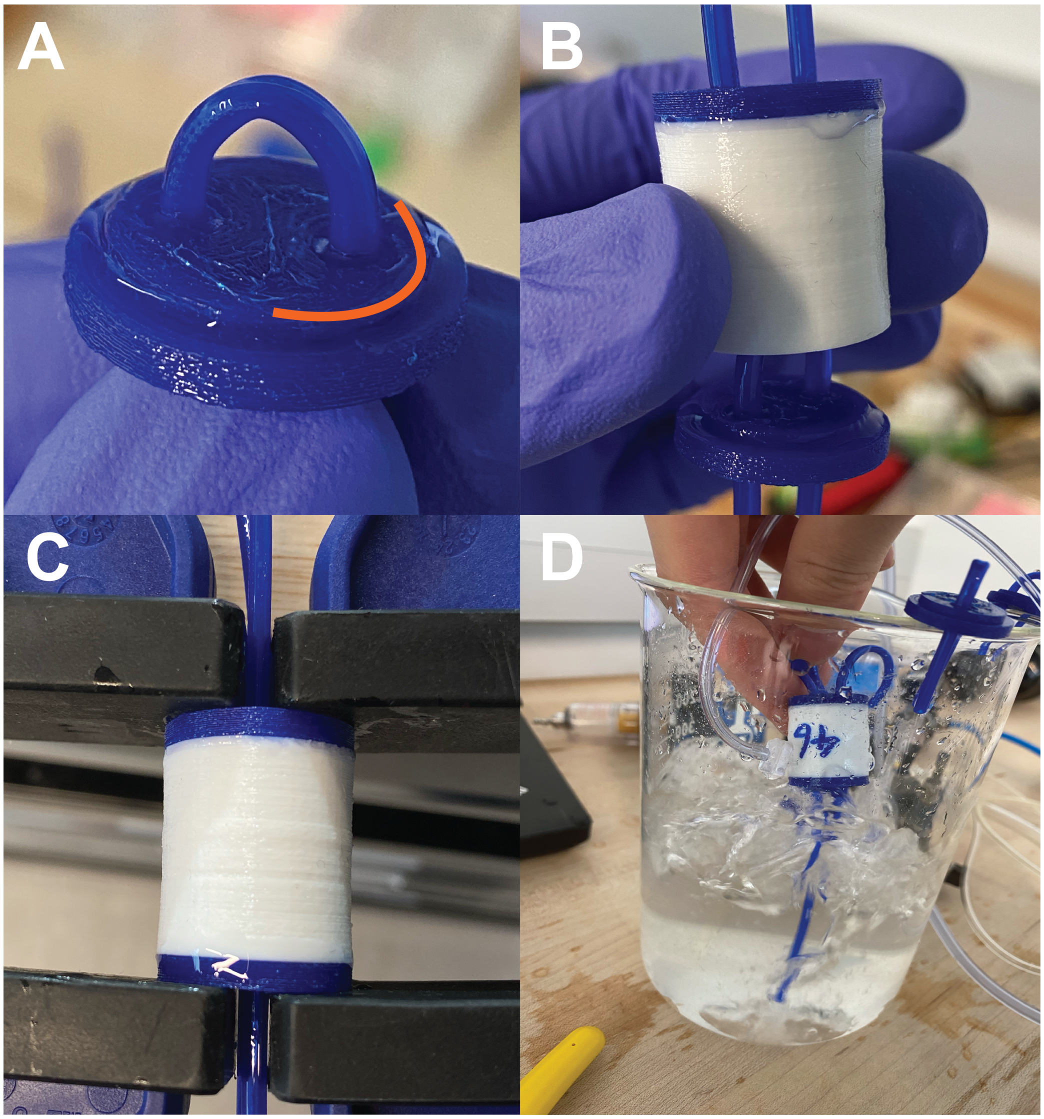

Figure 5: **Complete valve assembly process.** A) Application of adhesive to the cap for secure attachment to the body. B) Assembly of both bottom and top caps. C) Utilization of clamps for structural integrity. D) Device testing to verify absence of leakage and proper kinking.

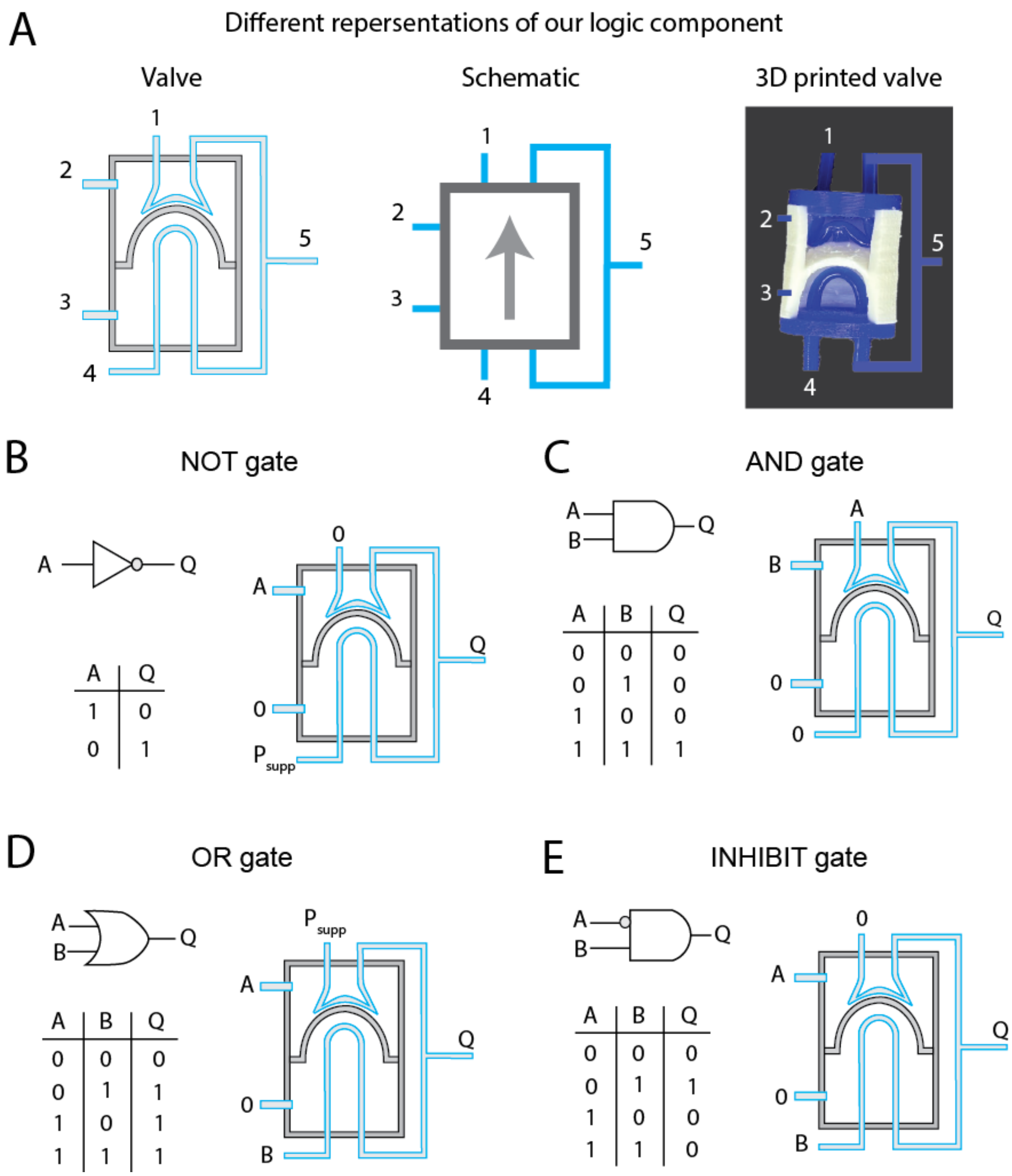

Figure 6: (A) three different representations of our 3D printable valve. They are used interchangeably in the article. (B-E) the different configurations of a 3D printable valve, including NOT, AND, OR, and INHIBIT logic gates.