CHARACTERIZATION OF PDMS MICROVALVES USING MUSIC
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ABSTRACT
This paper reports a novel microfluidic equalizer for characterizing the performance of polydimethylsiloxane (PDMS) microvalves using music. A custom LabView script was developed which controls the actuation of seven microvalves based on a series of thresholded bandpass filters. Each of the microvalves in turn controls the flow of dye into a main visualization chamber. Video recordings of the dynamic behavior of microvalves in response to music provide a visual and artistic demonstration of the microvalve performance.

KEYWORDS: Microvalves, Microfluidic Equalizer, Signal Processing

INTRODUCTION
Previously, we have demonstrated the fabrication of all-PDMS microvalves in order to control the selection, mixing, patterning, and flow rates of fluids. These valves have been actuated using manual [1] and pre-scripted [2] control methods in which the valves are switched into a desired state at a specified time point. Alternatively, another group has demonstrated the acoustically driven movement of droplets of fluid in response to specific musical tones amplified through resonance cavities. Here, we explore the operation of a microvalve-based flow device controlled using an audio signal processed by LabView software.

THEORY
The microfluidic equalizer device consists of seven valved dye channels connected to a large fluid chamber with three directional outputs. Flanking each dye channel are two constant background flows of water, which keep the dyes focused into separate streams (Figure 1). Our fabrication method uses two layers of PDMS, produced using standard SU-8 photolithography to integrate an elastomeric membrane, a fluid chamber (9.8 mm × 15.5 mm in area), fluid channels (200 µm wide), and valve control channels (100 µm wide).

During operation, a music source is fed into the computer's sound card, which is then processed by custom LabView software. The LabView script consists of seven bandpass filters, each actuating a different solenoid valve. The solenoid valves serve as computer-operated switches that pass either vacuum or positive pressure into the control channels of the device. If the amplitude of the music exceeds the set threshold in the assigned frequency range for a given bandpass filter, then the corresponding microvalve opens. Dye is thus able to flow into the visualization chamber through the microvalve.

EXPERIMENTAL
The fluid and control layers of the device were fabricated with thicknesses of 85 and 45 µm respectively using SU-8 2035 photoresist and replica molded in PDMS. The two layers were then bonded together, integrating a thin elastomeric membrane in between. Pressure-driven flow was used to introduce the dyes and rinse water into the device, while the...
control lines were connected to electromechanical solenoids under the control of the LabView script. An audio track was then fed into the computer while a video of the visualization chamber was captured. Sound acquisition duration was set to 20 msec, while the bandpass filter frequencies and threshold amplitudes were adjusted based on the audio source.

RESULTS AND DISCUSSION

Visual snapshots of the fluid chamber and microvalves during video recordings of music-driven microvalve operation are shown in Figure 2. When no audio signal was present, thin streams of the dyes flowed from the bottom source channels, as the control pressure applied to the microvalves was not sufficiently high to completely close off the fluid streams. When the threshold for a given frequency range was reached, the corresponding microvalve opened, resulting in a much greater amount of dye being released. The opening and closing of these seven different microvalves resulted in the individual streams being steered to the left and right based on laminar flow.

**Figure 2:** (a) Visualization of the fluid chamber during the music-microvalve operation. During operation, the fluid driving pressure was 3 psi, valve control pressure was ~10 psi, and the vacuum pressure was ~ -10psi. (b) A sequential visual demonstration of the dynamic response of microvalves to the Carmen Suite (Sarasate’s arrangement of Bizet’s Suite).

CONCLUSION

This microfluidic equalizer represents a unique method for the characterization of PDMS microvalves based on an active audio-microvalve interaction with straightforward and artistic visualization. By analyzing the individual frames captured of the device in operation, we are able to determine the response times of the individual microvalves and their maximum actuation frequencies. In addition to visualization of the deflection of the elastomeric membranes, the streams of dye flowing through the individual microvalves allow us to precisely determine their opening durations.

REFERENCES


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