A MODULAR MICROFLUIDIC PARALLEL DISPENSING SYSTEM

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ABSTRACT

We report a microfluidic building block (MFBB) for the controlled and automated dispensing of liquid. The device architecture is based on two arrays of parallel fluidic resistors, with each resistor having a pneumatically controlled valve for modulating flow. A range of hydraulic resistances are used within each array resulting in a wide range of possible flow rate combinations and therefore a high dynamic range for dispensing liquid. A dynamic range of up to 1:128 in only 30 seconds was demonstrated. The device was additionally tested in combination with another MFBB sharing one Fluidic Circuit Board (FCB) and control script.

KEYWORDS: Automation, Dispenser, Microfluidic Building Block, Modular, Standardization,

INTRODUCTION

The controlled dispensing of liquids is of fundamental importance to numerous microfluidic devices, and is typically performed using large tabletop lab equipment or with microfluidics in a single integrated monolithic device. Discrete MFBBs serving standalone functions offer a potential alternative to this, and could be combined with other MFBBs to create more complex systems. Previously at µTAS we presented four different MFBBs following the ISO Workshop Agreement 23:2016 standard for improved compatibility on the same FCB [1]. Here we present an improved version of the liquid dispensing MFBB with a significantly improved dynamic range from 1:5 in a 7 second period to up to 1:128 in 30 seconds. Furthermore, we demonstrate it working in connection with the previously reported 64 chamber MFBB on the same FCB.

EXPERIMENTAL

A schematic overview of the working principle is shown in Figure 1a. The MFBB contains two fluid inlets, one purge inlet, three fluid outlets, and ten integrated valves in normally-closed configuration which can be actuated via the control lines (shown schematically in Figure 1b). The valve design is a modified version of a design by J. Loessberg-Zahl [2]. Each of the fluid inlets is connected in parallel to three channels with different hydraulic resistances. The fluid can be routed through any of these three channels using the valves. As a result, three different flow rates per inlet can be achieved for a single inlet pressure, and the dispensed volume then depends on how long the valves are left open.

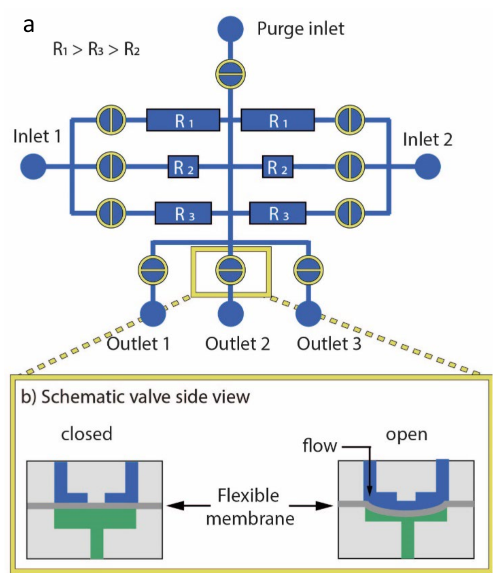

Figure 1 : a) Schematic diagram of the device's working principle. b) Schematic side view of the integrated valves

Each of the 4 layers which make up the device were fabricated by Computer numerical control (CNC) milling of Poly(methyl methacrylate) (PMMA) sheets, using a Viton rubber membrane for the valves. The layers were bonded together using thermal solvent bonding in a custom alignment tool. The MFBB was then attached to the FCB using a clamp, and interfaced with the FCB using O-rings. The FCB has integrated valves and is capable of supporting up to 3 independently addressable MFBBs through the use of a chip select function. The inlets of the FCB were connected to external reservoirs pressurized to 300 mbar, and the pneumatic control lines were controlled using LabVIEW with an external valve control block. A MATLAB script was created to automatically calculate valve state instructions for a user specified dispensing profile, allowing for further automation.

RESULTS AND DISCUSSION

The volume of de-ionized water dispensed through the high, medium and low hydraulic resistance channels for durations of 1 to 10 seconds can be seen in Figure 2a. The dynamic range of the system can be seen by the three different volumetric metering regimes (0 µL - 4µL, 4 µL - 40 µL, 40 µL - 140 µL) in which the MFBB can operate. The plots show linear behavior, which allows for a predictable volume to be dispensed through a combination of pulses from the 3 channels. In a 30 second period this full range can be covered, yielding at least a 1:128 dynamic range for resistor array 2 (red). This value was lower for resistor array 1 (blue) due to bubbles trapped in the low resistance valve, and as such achieved a dynamic range of at least 1:56. If more time is allowed for the profile generation then a higher dynamic range can be achieved. Figure 2b shows the outlet of the dispensing MFBB connected to the inlet of a MFBB with 64 individually addressable chambers. The chips are alternatingly controlled through the use of 'chip-select valves', allowing both devices to be automated using a single control script. For demonstrational purposes red and blue food coloring are used as inputs, and the resulting gradient was loaded into 32 of the 64 chambers of the MFBB (figure 2c).

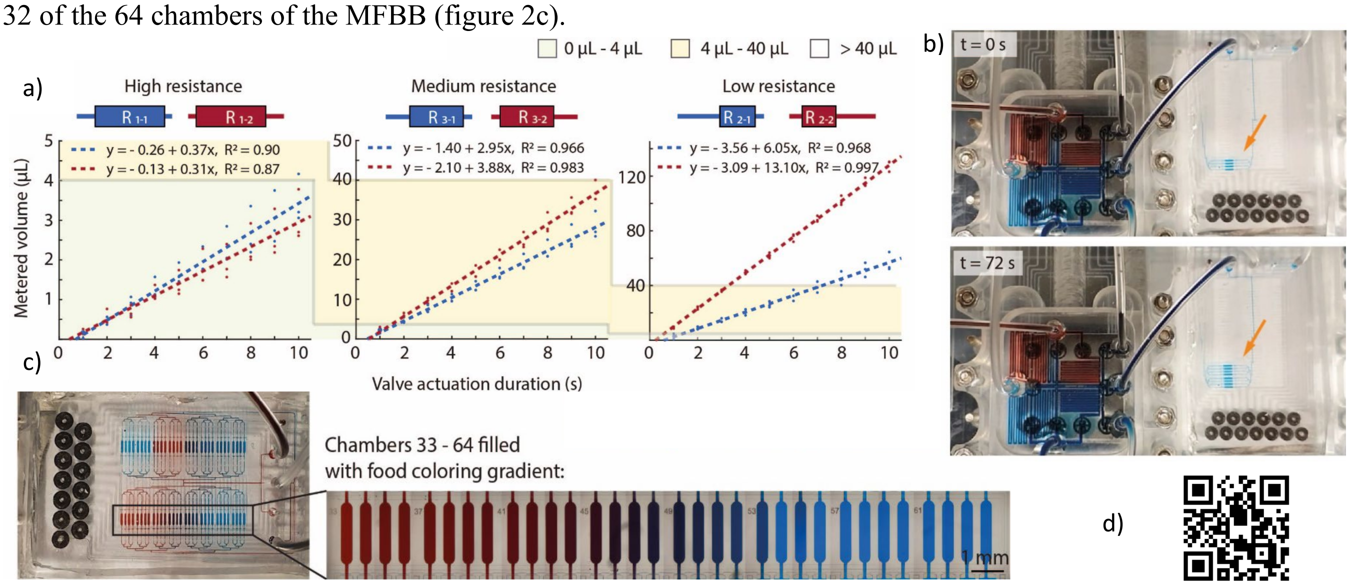

Figure 2: a) Dynamic range characterization in terms of flow rate through the three hydraulic resistors at 300 mbar. b) Video frames showing the dispensing MFBB (left)and 64 chamber MFBB (right) on the FCB and connected to each other with tubing. c) 64 chamber MFBB filled with a gradient of food coloring. d) QR code linking to a video of the MFBBs operating.

CONCLUSION AND OUTLOOK

A dispensing MFBB is presented, featuring an improved dynamic range of up to 1:128 in a 30 second period. The device was also demonstrated working together with a second MFBB, both using the same FCB and control script. The combination of multiple standardized, modular, and automatable MFBBs on a common FCB platform show great potential to accelerate research in both industry and academia. More precise control on hydraulic resistor geometry by using more refined fabrication methods should allow us better control and a higher dynamic range of the metered volume in the future.

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