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Designing an Innovative Pressure Actuator with an Integrated Source to Customize a Portable Pump for Microfluidic Systems

Mohammad Zein, Sousso Kelouwani, Marie Hébert*
Mechanical Engineering Department, Université du Québec à Trois-Rivières (UQTR), Trois-Rivières, Canada
*email : marie.hebert@uqtr.ca

ABSTRACT

Microfluidics handles fluids on a small scale with applications in various fields such as biotechnology, material synthesis, and water analysis. The performance of microfluidic devices significantly depends on the actuation system, notably, pneumatic pressure pumps, peristaltic pumps, and syringe pumps. The actuation of active and passive microfluidic systems requires competing objectives. Compared to others, pneumatic pressure pumps demonstrate high capabilities by providing significant performance for both stable flow (passive) and fast response (active). Most commercially available pressure pumps are expensive, lack customization options, and require an external pressure source. On the other hand, an open-source system addresses these limitations, making microfluidic technology more accessible in low-budget environments and for experts in application-focused fields.

A novel pressure pump is presented that overcomes the constraints of the current commercial and open-source models by implementing several strategies. The pump is equipped with an onboard compression system. This eliminates the need for an external pressure source, which is beneficial in environments with limited infrastructure but at the expense of system noise, heat generation and power. In addition, a pressure-actuating method is developed using two proportional solenoid valves per independent pressure output that interact to achieve the desired set pressure. The mechanism between the two valves is controlled by a designed PID control system. This provides an efficient and affordable pressure regulator, capable of maintaining precise pressure control at levels below 5 psi (0.344 bar). The novel pressure pump is characterized to confirm its satisfactory performance for parameters relevant to microfluidic applications. The proposed solution offers a cost-efficient alternative (less than $1000 CAD) with an accuracy of ±0.025 psi (±2 mbar) from the desired pressure, a fast settling time of less than 130 ms, along with a compact size, and customizability. The two proportional valves at the core of the pressure regulation are less costly than traditional EP transducers. Thus, the scaling of the cost with the amount of output is forecast to be financially advantageous as well.

Keywords: microfluidics, active, passive, pressure-driven flow, pneumatics, pump, open-source