Application Note

Flow Controlled Micropumps – Closing the gap towards medical applications

While the use of micropumps is constantly evolving in various markets, especially in medical devices the higher demands on accuracy and monitoring have prevented a wide use of these devices in infusion technology for example. As the safety and accuracy needs to be maintained in a range of environmental conditions, a controlled system is required. Flow controlled micro pumps, due to their small size, low power consumption and attractive price level can provide interesting solutions.

The micropump mp6 (figure 1) is a micro membrane pump actuated by a double configuration of piezo elements, in combination with passive valves. The two actuator stages have been combined in a single pump for the first time. Besides providing a pressure of up to 550 mbar, the double actuator principle assures self filling of the pump at startup and reliable function. Having only a single polymeric material certified in accordance to ISO 10993 and USP class VI in contact with the medium and the fact that the pump is produced by automated assembly, allowing tracking of components and process parameters paves the way towards medical use.

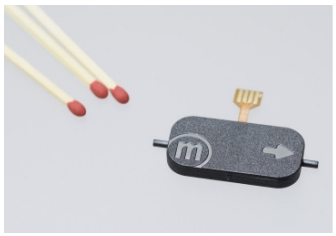

Fig. 1: Micropump mp6

However, looking at the behavior of membrane pumps, the performance is dependent on the pressure levels at the in- and outlet. On the other hand, viscosity changes for example due to temperature changes will result in varying flow rates. In membrane pumps this effect is observed stronger than in syringe pumps as membrane pumps do not exhibit high pressure stability, and are stronger affected by changes of the liquid itself. The demand for constant flow rates with low deviation at different environmental conditions like temperatures and pressures leads to the necessity of closed loop control of these pumps to be able to address medical applications.

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The flow control in micropumps can be realized by two different approaches:

Lower accuracy, in the order of 10%, as requested for passive solutions like drop infusion systems can be achieved based on a novel approach using the micropump with an intrinsic sensor function for the feedback signal. In high demanding dosing systems accuracies in the order of 2-5% can be achieved with hybrid systems consisting of micropumps in combination with thermal flow sensors.

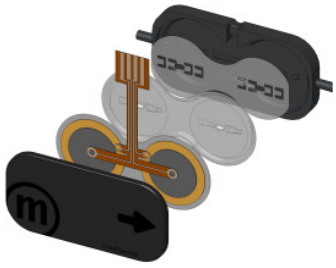

Fig. 2 Exploded view of micropump: Two identical pump stages can be seen, including the piezo actuators on top, down to the passive valves and housing parts.

Closed loop control with intrinsic sensor function

As the piezo effect of the actuators used in the micropump is reversible, it can not only be used for actuation but also for sensing. This enables having the flow sensing element directly linked to the pump itself without the use of additional components. As the micropump mp6 combines two single actuator stages in the same housing (figure 2), this approach can be used instantly. To achieve both pumping and feedback for the control circuit, the pump is switched between two modes (figure 3):

Full actuation mode: Both pump stages are working as actuators, providing full performance of the pump.

Sensing mode: The first pump stage is still actuated and provides fluid pulses; the second stage is switched to sensing which provides feedback on the pump strokes of the first actuator.

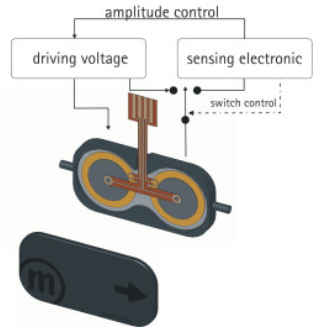

Fig. 3 Flow-sensing schematic of intrinsic sensor function

As the pump is operated at a frequency in the region of 100 Hz, switching between both modes does not result in a significant drop of pump performance. Still, as the piezos are not optimized for sensing purposes but effective actuation, this approach has limits in terms of accuracy and addressing very low flow rates.

Figure 4 shows the measured performance of a controlled mp6 micro pump with deionized water. While the micro pump exhibits the typical behavior of decreasing flow rates at increasing pressures, the flow remains almost constant while running the pump in controlled mode. After the general principle was proven at a flow rate of about 3 ml/min, in further experiments, the general performance range of the system was

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determined. Figure 5 shows the flow range that can be controlled by the piezo sensor approach. The accuracy of the systems has been determined with 10% so far in a range of down to 1 ml/min.

Looking at the overall complexity, from the pump side, this solution is fully based on a proven, mass produced component. Additional effort is of course needed at the driving electronics but as the signal processing is straightforward the unit keeps its portability and capability of being driven with batteries. Especially in applications where the micropump should be used as a disposable unit while the electronics is being reused, the full potential of this solution comes into play.

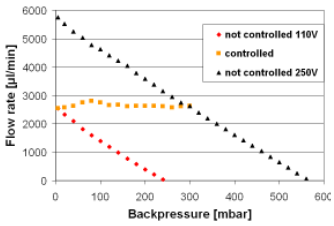

Fig. 4 First performance graph of piezo sensor controlled pump

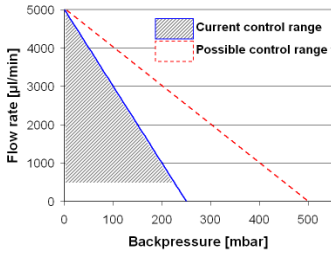

Fig. 5 Controllable flow range of piezo sensor

Closed loop control with thermal flow sensor

Widely known from other branches like the automotive industry, thermal flow sensors are used to monitor either gas or fluid flow. It has been shown that these sensors can be successfully combined with a micro pump. In this approach, the functional elements of the pump and the sensing element are completely separated from each other (figure 6).

Due to higher reproducibility of the sensors and stronger response, a better accuracy can be achieved with this solution. In addition especially small flow ranges can be covered with these sensors very well, which makes them suitable for high accurate application with low dosing volumes.

The results with micro flow sensors manufactured at the Institute for Microsensors, -actuators and -systems (IMSAS) Bremen fully integrated into the micropump (figure 6) show that 5% accuracy in the range of 60-5000 µl/min can be achieved. The flow accuracy can be further optimized so that for a decreased flow range flow accuracies in the region of 3 % can be achieved.

Fig. 6 Micropump with thermal sensor

Based on specific application requirements, Bartels Mikrotechnik is working on further development of both approaches towards the medical market.

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General Specifications	mp6*
type	piezoelectric diaphragm pump
pump medium	liquids, gases and mixtures
outer dimensions (without fluidic connectors)	30 x 15 x 3.8 mm³
fluidic connectors	tube clips, 1.6 mm outer diameter
operating temperature	0 - 70 °C
life time	> 5000 h[2]
materials in contact with media	PPSU
max. flow, water[1]	6 ml/min (100 Hz)
max. pressure, water[1]	550 mbar (100 Hz)
max. flow, air[1]	On request.
max. pressure, air[1]	On request.

* Typical values. Values can vary under application conditions. Content is subject to changes without notice.

[1] Values taken with electronic controller mp-x set to 250 V amplitude, SRS signal

[2] Conditions: DI water, room temperature, settings mp-x: 100 Hz, 250 V, SRS.

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