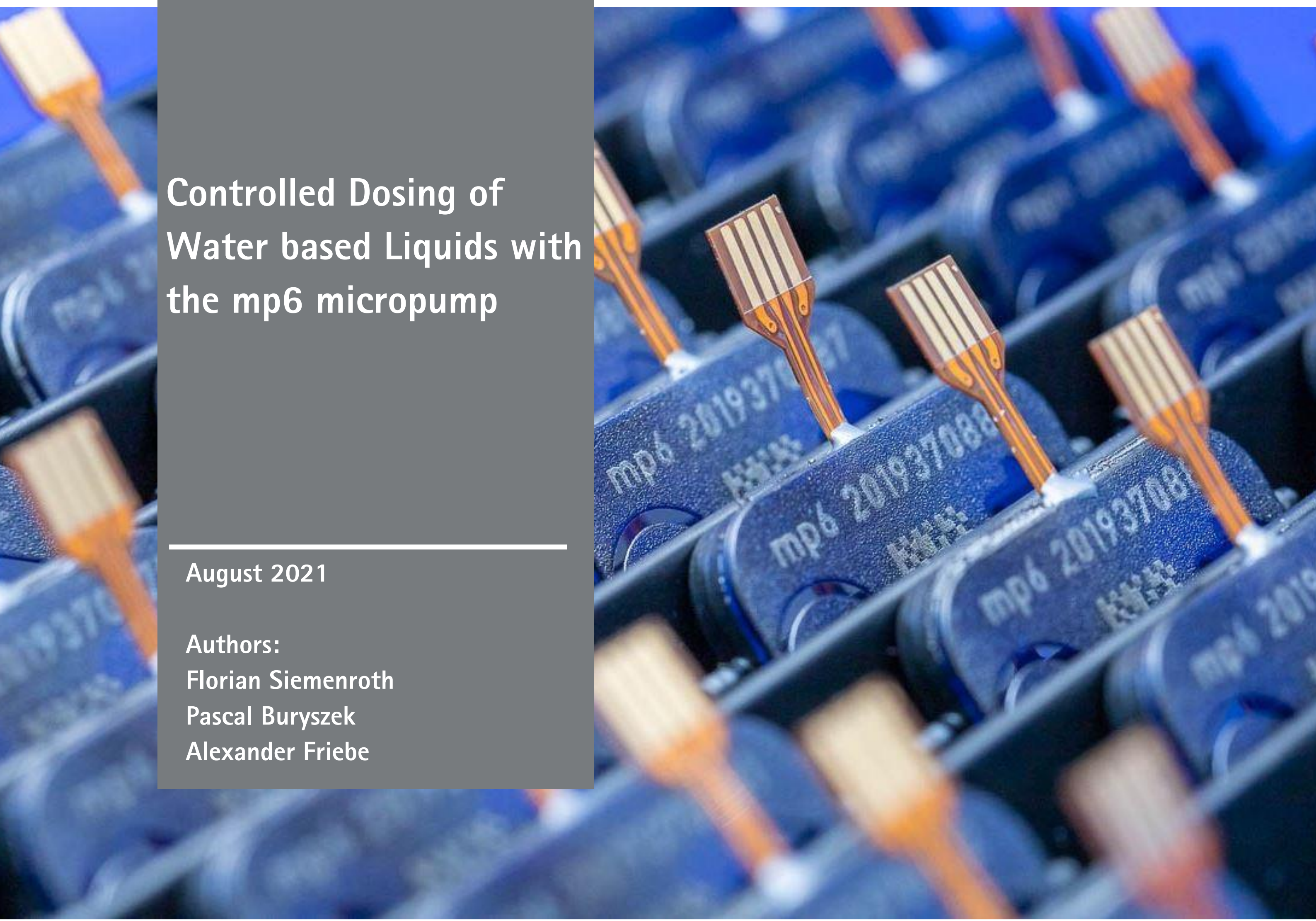
CASE STUDY

Bartels mikrotechnik

with passion for microfluidics



Controlled Dosing of Water based Liquids with the mp6 micropump

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Controlled fluid dosing

Medical, Lifescience, Automotive

The controlled dosing of drugs or compounds, dissolved in diverse kinds of liquids as a solution or dispersion (mostly water based) is of growing importance for, for example, medical treatments, technical as well as LiveScience applications. In that context, the attributes of "Single-Use, smart & Low-Budget" becomes more and more relevant.

For that purpose, this Case Study is demonstrating that our mp6 micropump is a suited tool in the range of "smart & Low-Budget", to achieve that goal with all its advantages. The results show the success of our product development in order to fulfill the customers' requirements: the mp6 micropump can be controlled very precisely using the mpSmart product line.

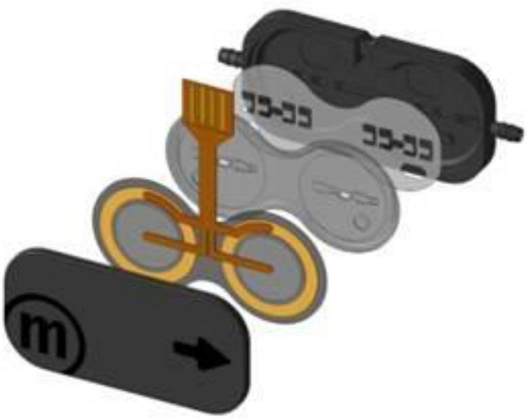
What is microfluidics?

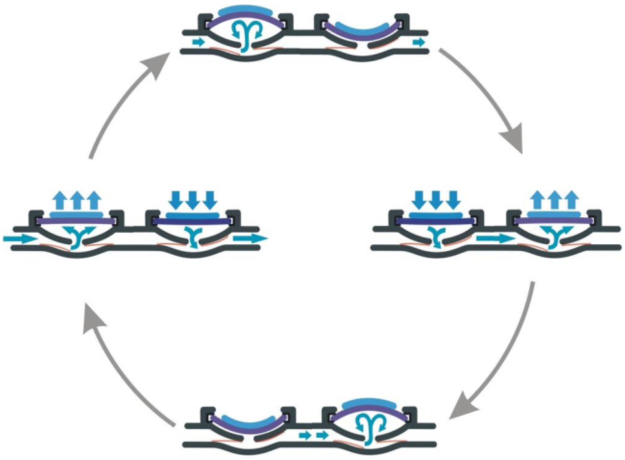
Microfluidics is the fine art of creation and manipulation of small portions of fluids, often realized by flow within small, sub-millimeter-scale channels. These small dimensions allow the fluid flow to be controlled with exquisite precision (Seifert, Thiele; 2020).

About the mp6 micropump

The available, industrialized and commercialized example is the mp6 micropump by Bartels Mikrotechnik GmbH. This micro pump is a positive displacement membrane pump utilizing piezo buzzers. The alternating displacement of the piezo acutators l lead to the following typical fluidic values of the pump:

- Liquids (eta = 1 mPas): q = 5 - 8000 µl/min in free flow and p > 600 mbar
- Gas: q > 25 ml/min in free flow and p > 150 mbar





About the Sensirion SLF3x series – Liquid Flow Sensors

Sensirion Sensors as flow controlling elements were used in this study, namely, Types SLF3S-0600F and SLF3S-1300F, which are calibrated for water and Isopropanol. These Sensors can be used bidirectional and exhibit a so called "Turn-Down-Ratio" of 1:200. In addition to the low weight and smallest dimensions, they show a quite low response time of ~20ms; obvious features of these CMOS-based Sensors are digital I2C-Interfaces. Figure 1 (left) shows a typical Sensor with plugs besides the working principal of a so called "calorimetric Dye" (right). The active element contains two temperature sensors and one heater in the centre. By readout the temperature sensor determines a digital value for the temperature difference and calculates the actual flux.

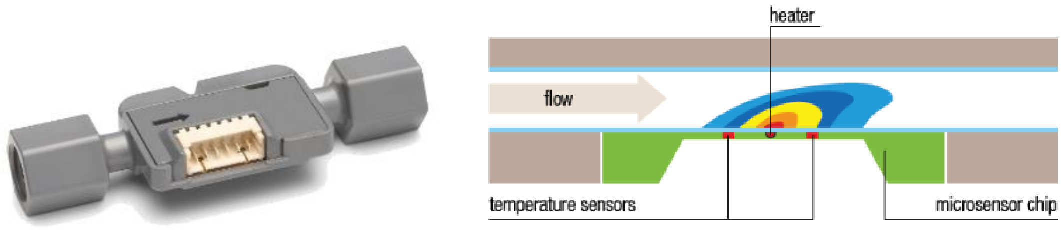


Figure 1:
Typical Sensor of the SENSIRION AG (left) and the working principal of these sensors (right).
References / Photos: SENSIRION AG

Two technical issues have to be considered in this case study. At first, our mp6 micropumps exhibit a certain tolerance in the range of ~10 % around the set specification (for water @ 250Vpp). Secondly, the produced flux is constant over a certain time range of seconds, but not strictly constant with respect to an evaluated short period of time within one pump cycle. As depicted in Figure 2, one can measure a pulsation which irritates a flow sensor with its short readout-interval. This problem can be significantly reduced by incorporation of the *mp-Damper*. This item contains a soft and thin membrane made of a flexible rubber material.

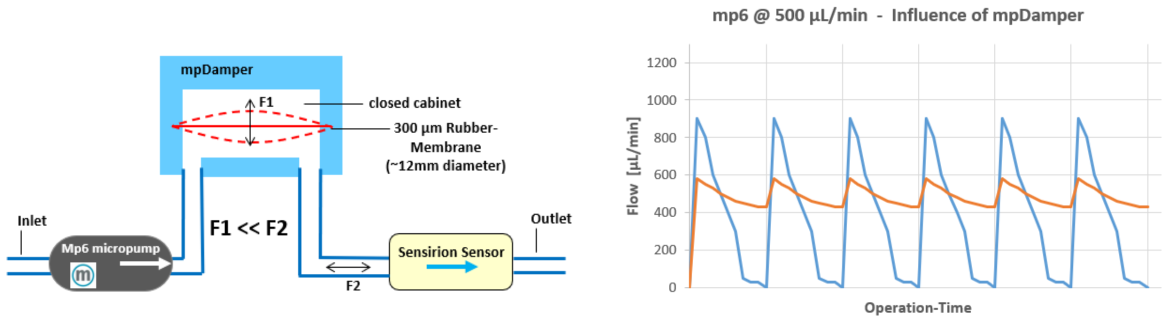


Figure 2:
Assemble of mp6 micropump and Sensirion Sensor, mp-Damper with working membrane (left) and high resolution Plot of the oscillating Flux of the mp6 micropump with and without mp-Damper (right).

Hence, to overcome these two facts in order to achieve a very precise flow, a regulated System (PI) has to be applied in addition to the mp-Damper. Figure 3 below show the block diagram of the complete Set-up.

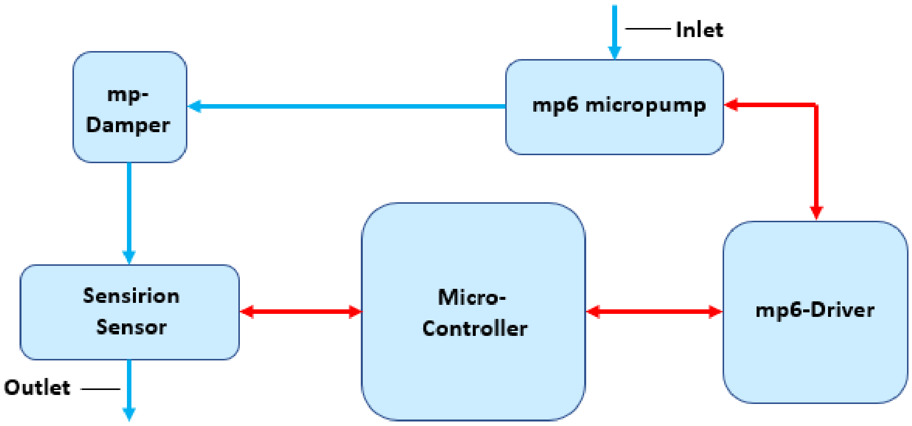


Figure 3:
Block diagram of the PI-regulated mpSmart system; electrical pathways (red) & liquid (blue).

The sensor, our mp6 micropump as well as the mp-Damper can be assessed as "Disposables", depending on the application. In case of simple aqueous media, the system can be both rinsed with pure water and dried afterwards. If slight aggressive aqueous solutions were dosed such as liquids with extreme pH-values (1 . . . 14) or even solvents like methanol (or solvent-water-mixtures), the liquid contacting parts should be changed after a certain time. A particular field of attention is a biotechnical application in dosing e.g. Cell-Culture-Media or protein-/ antibody-solutions. In contrast to that, the valuable electronic components are of course anytime reusable.

It is possible taking the above-mentioned technology and integrate that even further in the smart system. The PID regulation implemented on the microcontroller lets the sensor communicate with the micropump, so the user only needs to type in the desired flow rate and the system regulates the flow on its own. In general, we offer two kinds of these mpSmart systems – one for low flow applications and one for higher flows. During this phase of development, every system has been optimized for the corresponding range, using a well-suited driver chip; (Chip #A optimized from 10 V up to ~150 V, Chip #B optimized in the range of 10 . . . 250 V).

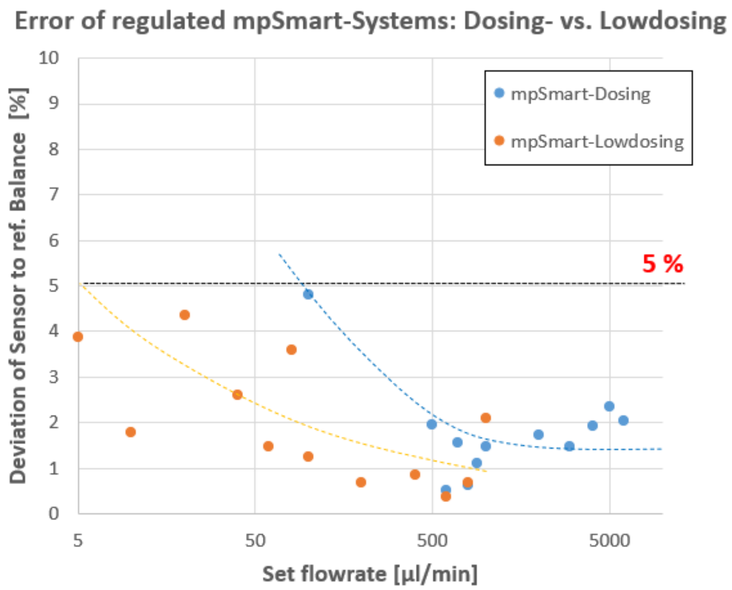


Figure 4:
Sensor error relative to the balance vs. set flowrate for both mpSmart systems; Lowdosing Sensor SLF3S-0600 and Dosing Sensor SLF3S-1300, respectively.

Due to the suited chip for every single application, we were able to keep the deviation relative to the real value below ~5% as shown in Figure 4 above; as a reference-standard we used an automatic high precision lab-balance (Sartorius AG). The following Table 1 below summarizes the optimal working ranges of both systems.

Table 1: Summary of Operation limits for mpSmart Dosing vs. Lowdosing incl. optimal Operation Parameters.

		Flux - Range - Data			optimal Operation Parameters	
	optimal Sensor	Value [µL/min]			Frequency [Hz] / Voltage [V*pp*]	
Model ID of mpSmart	(Sensirion AG)	*min.*	*max.*	max. Diviation [%]*	*min.*	*max.*
Lowdosing	SLF3S-0600	≥ 5	2000	5	8 / 10	100 / 150
Dosing	SLF3S-1300	100	7000	5	50 / 10	100 / 250

*** = Diviation Value relative to the "Reference" (=Precision-Balance) for for the optimal operation range.**

Figure 6 below shows a typical experimental Set-up in our Labs; for detailed demonstration, accessible on our YouTube-Channel (https://www.youtube.com/channel/UCYVrCs6MgpjEVNamwU7zVqw).

Figure 5:
Typical set-up for the application of the mpSmart Dosing.

A tandem of the mp6 micropump, mp-Damper as well as the Sensirion sensor represents the liquid transporting setup. The complete electronical system in located within a closed box. Below, Figure 6 compares three sensors, driven with the mp-Damper as well as one single test without. In all cases, Type SLF3S-0600 was used and all experiments were performed mpSmart-regulated.

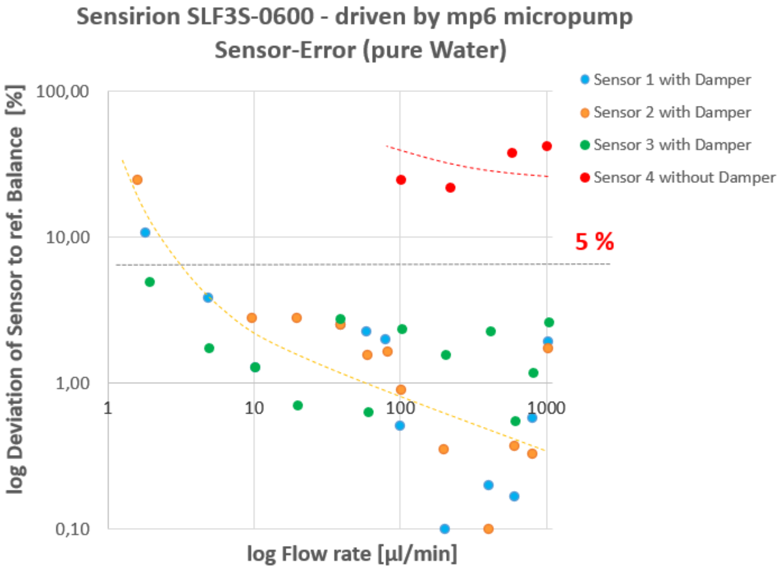


Figure 6:
mpSmart Lowdosing, comparison of four Sensors, Type SLF3S-0600; sensors were driven @ 5V.

Firstly, we can conclude that the sensors, driven with mp-Damper performed clearly below 5% relative deviation. Furthermore, the most values were determined to be 2% or smaller resulting in low flows of <10 µL/min. If the mp-Damper is not connected, the error increases drastically up to the ~25fold value (~50 %). This result confirmations the need of the mp-Damper. Figure 7, below, compares the data of Sensor 4 in detail. If the mp-Damper does not compensate the pulsation, the sensor indicates a too high value as compared to the reference balance.

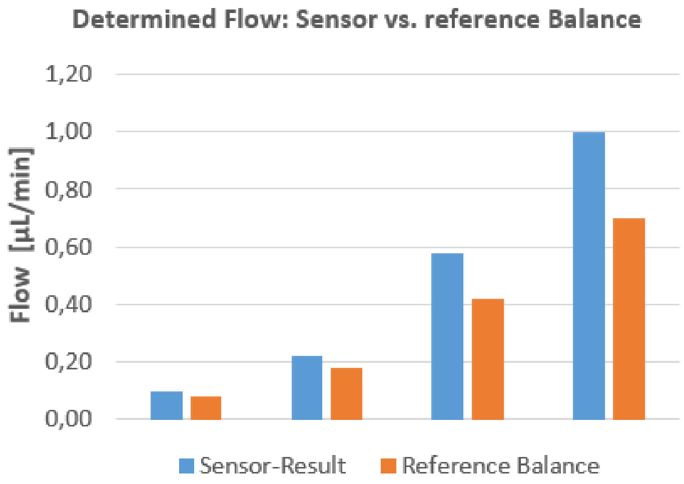


Figure 7:
Results of Sensor 4; Determined flow via Sensor Data vs. Lab-Balance (reference) @ selected operating voltage in the range of 10 . . . 150 V*pp* of the mp6 micropump.

A reason for the phenomena presented in Figure 7 could be the occurring pulsation. The liquid remains partially longer at the heating segment in the center of the sensor. This effect enlarges the temperature difference from sensor element 1 to sensor element 2. Even stronger of a multiple heated volume element of a single pulse as compared to a continuous laminar flux (has only one contact), resulting in higher measured flow rates.

Summary:

The combination of the thermal flow sensors from the Sensirion SLF3x Series and the mp6 micropump by Bartels Mikrotechnik gives users the chance to control and regulate the flow rate with a deviation of less than 5% compared to gravimetric measurement principles, e.g. lab-balance. This inline measurement opens the chance realizing dosing *and* recirculation options with highly accurate flow rates.

Components used:

- mp6 micropump by Bartels Mikrotechnik
- mp-Damper by Bartels Mikrotechnik
- mp-Low-/Highdriver
- SLF3x sensors by Sensirion
- Microcontroller

Acknowledgement:

Our partner, Sensirion from Stäfa, Switzerland, was instrumental in defining our research path, whereby we were able to develop a great solution for microfluidic dosing system. For that, we are extremely grateful and we are looking forward to our close collaboration. In case you are interested in the above-described microfluidic componenents or if you are interested in getting in touch with either one of us, Sensirion or Bartels Mikrotechnik, please feel free to contact us. You can find the contact details below.

Bartels Mikrotechnik is a globally active manufacturer and development service provider in the field of microfluidics. In the microEngineering division, the company supports industrial customers in the modification, adaptation and new development of high-performance and market-oriented product solutions through the innovative means of microsystems technology. The second division, microComponents, produces and distributes microfluidic products and systems, especially for miniaturized and portable applications. Our key products are micropumps that convey smallest quantities of gases or liquids and are used in a variety of ways in biotechnology, pharmaceuticals, medical technology and numerous other applications.

Bartels Mikrotechnik with passion for microfluidics!

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