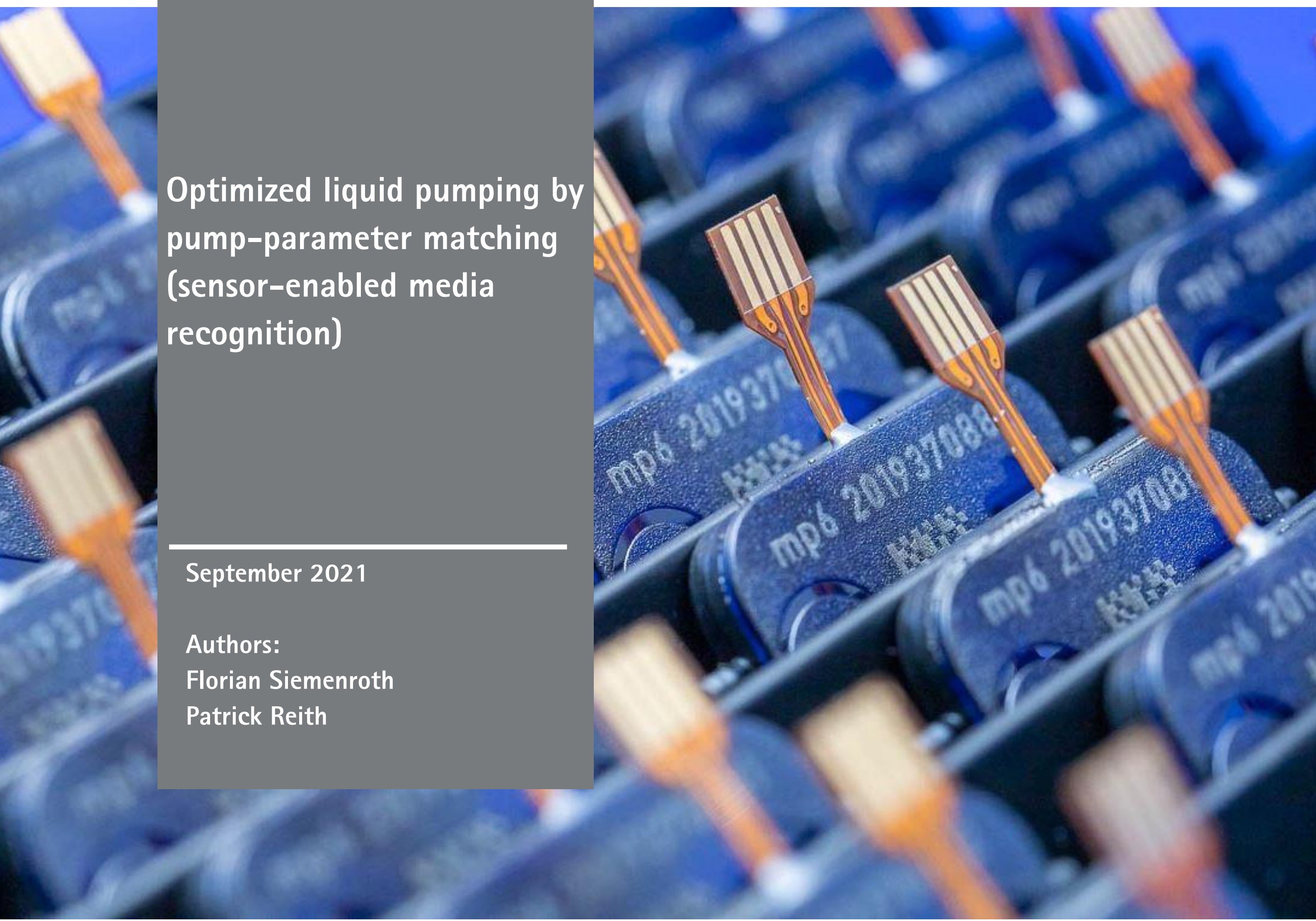
CASE STUDY

Bartels mikrotechnik

with passion for microfluidics



Optimized liquid pumping by pump-parameter matching (sensor-enabled media recognition)

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Smart adaption of pump parameters for different liquids

Digital and Smart Media Recognition

Membrane-based micropumps like the mp6 micropump can be controlled by the frequency (how often per second the membrane is actuated) and the driving voltage of the actuating elements (controlling the stroke of the membrane). Both parameters need to be adjusted to match the viscosity of the liquid and the desired flow rate. Especially applications in which different liquids are handled by the same pump profit from automating this manual step.

For that purpose, this Case Study is demonstrating that our mp6 micropump in conjunction with Sensirion's SLF3C-1300F sensor can recognize the liquid and with this creating the possibility to automatize the pump-parameter-adjustment.

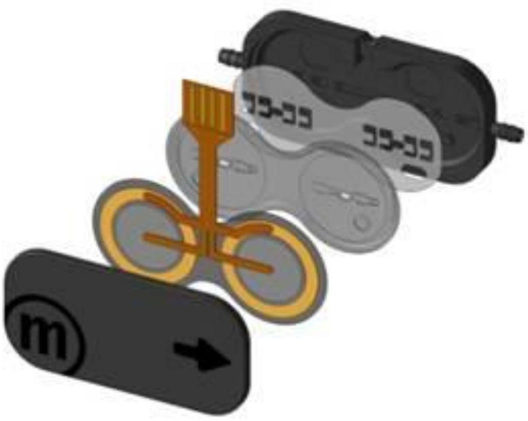
What is microfluidics?

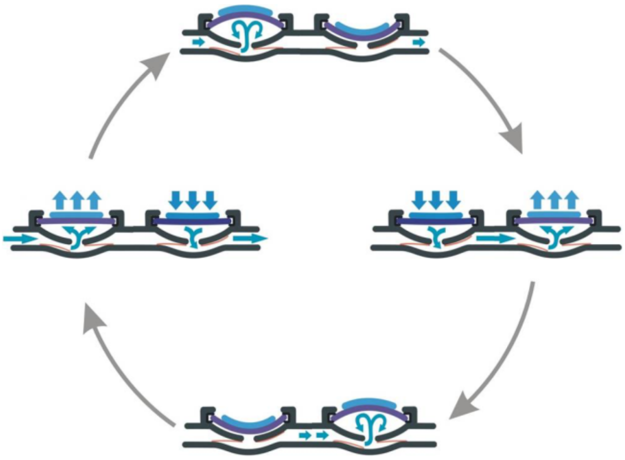
Microfluidics is the fine art of creation and manipulation of small portions of fluids, often realized by flow within small, sub-millimeter-scale channels. These small dimensions allow the fluid flow to be controlled with exquisite precision (Seifert, Thiele; 2020).

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 case study, namely, Type SLF3C-1300F, which is calibrated for water and Isopropanol. This sensor can measure flows of up to 40ml/min (SLF3C-1300F) with a turndown-ratio of 1:200 (ratio lowest to highest flow rate) and a response time of less than 20ms. In addition to the flow rate, the SLF3C offers a feature for a media recognition by measuring the thermal conductivity of the liquid inside the sensor: At zero-flow its heater-sensor-element is used to study thermal behaviour of the liquid, calculating the thermal conductivity, and passing the result to the user in arbitrary units (a.u.) ranging from 100 a.u. (air) to 10'000 a.u. (water).

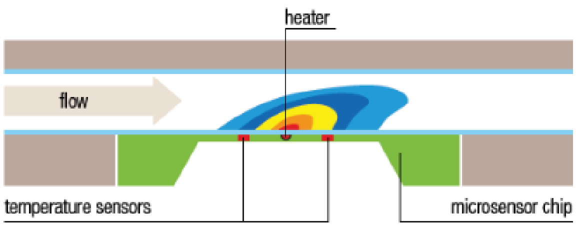
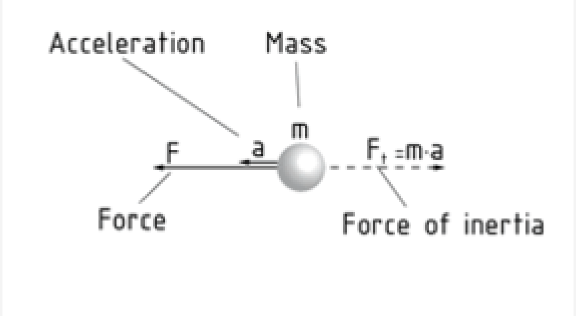


Figure 1:

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

Dependency of flow rate on pump parameters and the properties of the liquid

The pump principle of the mp6 micropump is based on the piezo effect, so a piezo actuator exerts a constant force on the fluid. If there are different fluids with different rheological characteristics, such as density or viscosity, the pump performs differently at the same parameters.

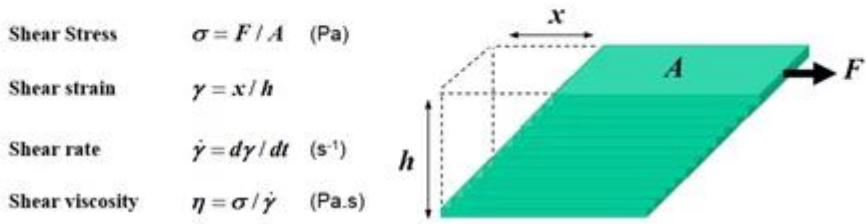


D'Alembert's auxiliary force on a body in motion

Source: https://glossar.item24.com/en/glossary-index/article/item//dalemberts-principle-2.html

When the density changes, the mass of a defined portion of liquid changes too. The piezo actuator only provides a constant force, so if the pump frequency is increased, the acceleration increases and therefore the force of inertia is increase as well. The constant force from the piezo actuator is overwhelmed and the performance is lower although the pump parameters are increased.

In very simple terms, the viscosity is a degree of "how easy or hard it is to move layers of liquid". This means that the more viscous a liquid is, the harder it is to move the layers of a liquid or the harder it is to move the liquid in general.



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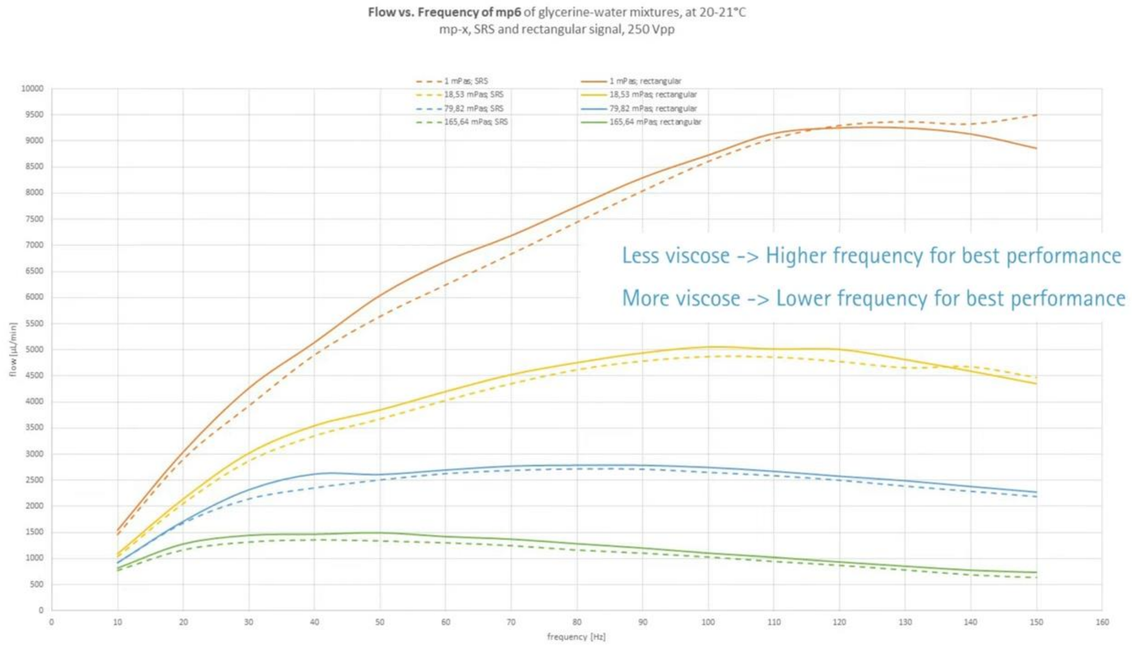
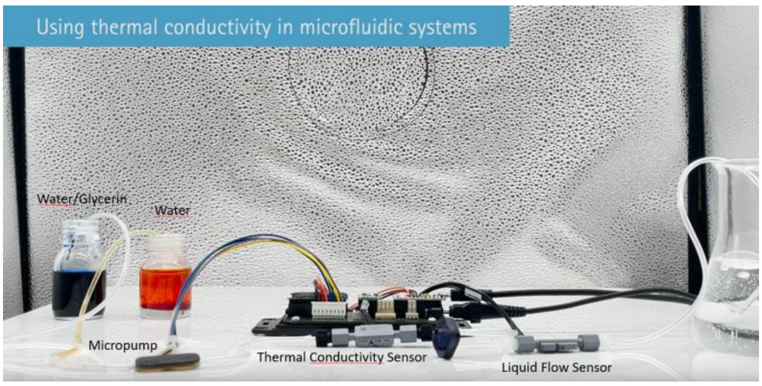


So, again, the shear stress counteracts the force of the piezo actuator, increasing the frequency would mean to increase a counteracting force of the piezo force which leads to a lower pump performance although the driving parameters (frequency) of the pump are increased.

Therefore, it is often necessary to know which fluid is meant to be pumped to adjust the mp6 micropump to its optimal working point. In an ideal case, one would use a viscosity sensor. As this would require an additional sensor, we use the SLF3C-1300F sensor which, beside the already used flow rate, also provides the thermal conductivity as output value. This we can use to distinguish between different media and use a look-up table for the viscosity in order to adjust the pump parameters.

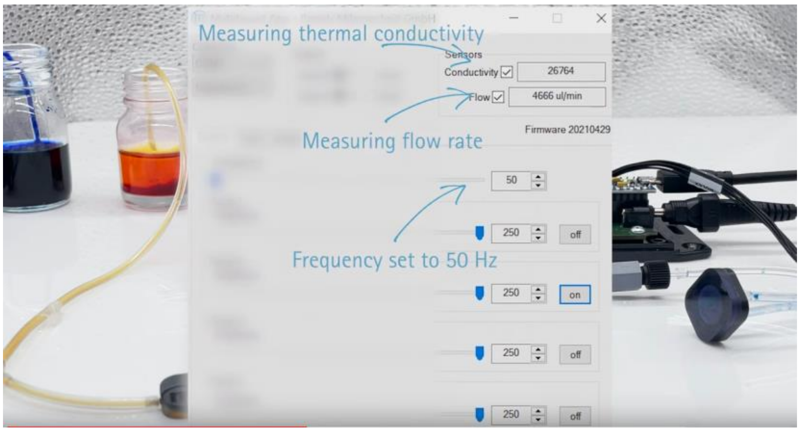
Sensor based media recognition and its application to adjust pump-parameters

Prior to the experiment, the thermal conductivity of the different media we want to distinguish was determined. Water was found to give an output of around 10'000 a.u. while our water/gylcerin-mixture gives approximately 7500 a.u.

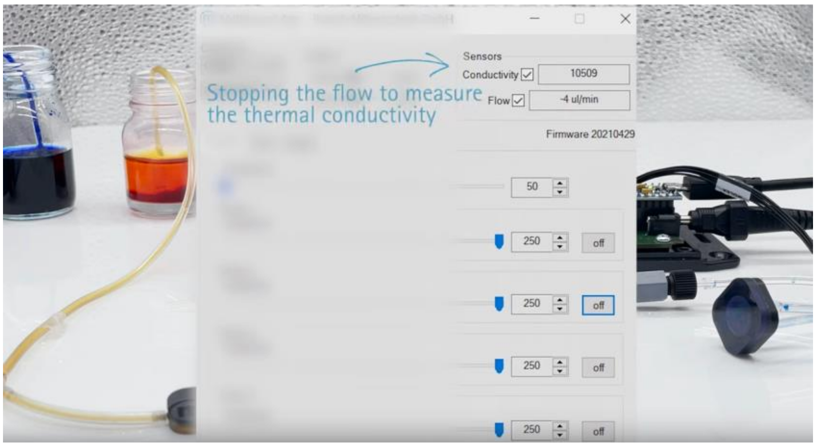


Fluid	Viscosity	Thermal Conductivity value measured	Frequency
Water	1cP	10500	~100 Hz
Water Glycerin mixture	18cP	7500	~50 Hz

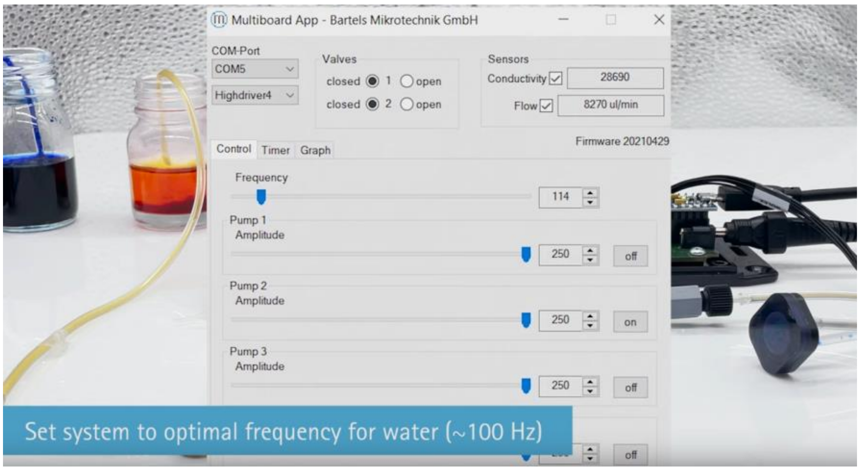
In our experiment, we now use the mp6 micropump to pump water. As you can see, that with a low frequency, we achieve a low pump rate.



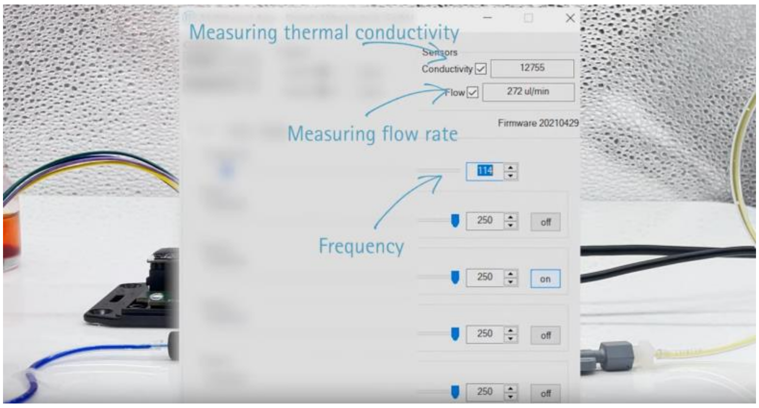
We then stop the flow and take a reading with the SLF3C-1300F. It gives us a value of 10'500 a.u. given the fact that we did not implement a temperature compensation for this experiment, this value is close enough to the calibrated value for water (10'000 a.u.) to identify the liquid in the pump as being water.



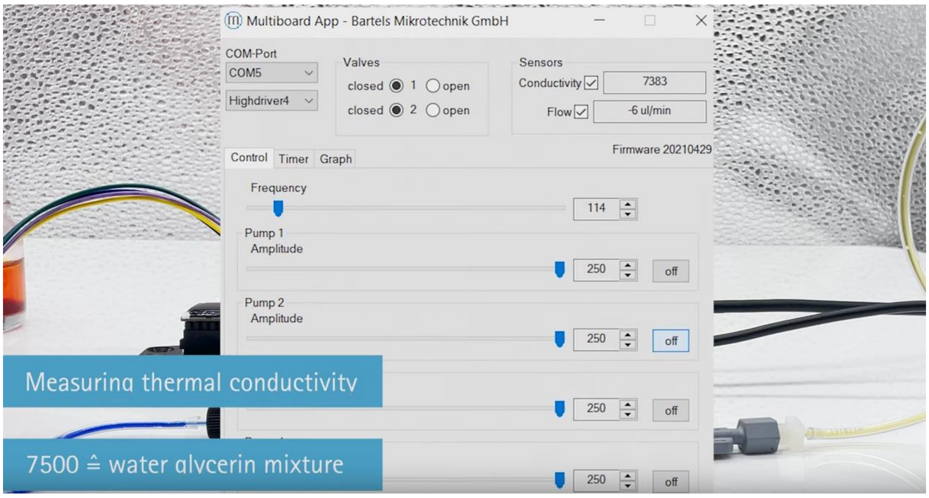
Next, we use a much higher frequency. It shows that the pump rate remains low. This indicates that our frequency is now too high. The water is not able to follow the rapid pump strokes. We therefore lower the actuation frequency of the pump a little bit and with this, hit the maximum pump rate. This frequency could also be saved in a look-up table as the optimum actuation frequency for pumping liquids that mainly contain water.



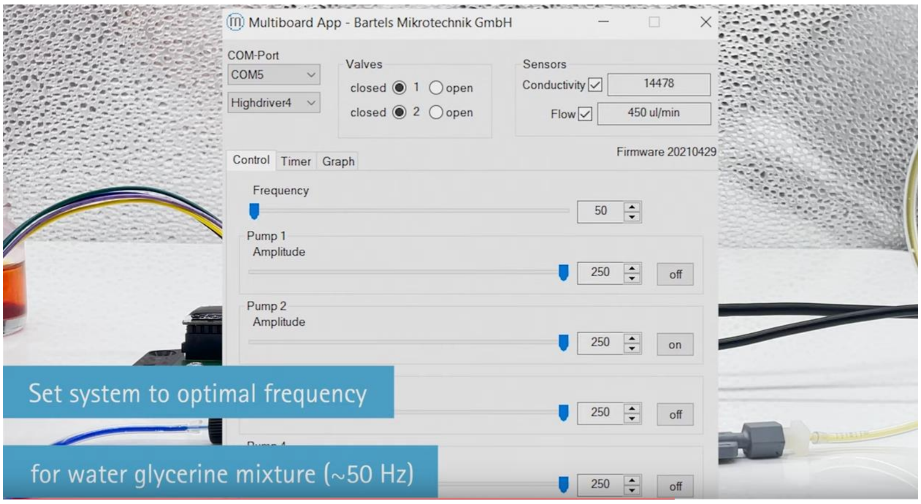
Afterwards we switch to a different liquid. A mixture between glycerin and water with a viscosity of 18 mPas. We use the same actuation frequency for the pump we found to be optimal with water. It shows that we achieve a very low pump rate.



Which makes sense, as the viscosity is way different from water. In order to optimize the pump rate, we increase the frequency. This leads to a further decrease of the pump rate. This means that the optimized frequency has to be lower. We use the SLF3C-1300F sensor to take a reading of the thermal conductivity and find it to be 7'500 a.u. this indicates that we have the glycerin/water mixture in our sensor and pump. We can clearly differentiate between the two liquids (water and water/glycerin).



We lower the actuating frequency and find the maximum pump rate at 50 Hz. We have now determined the optimal pump actuation frequency of water and our water-/glycerin mixture.



For future experiments we can identify with the SL3C-1300F-sensor with liquid is present in our system and choose the optimal pump frequency accordingly with a look-up table.

A video of the whole experiment can be found on your YouTube channel: https://www.youtube.com/watch?v=gnkpqsM-buY

Conclusion:

The performance of the mp6 micropump by Bartels Mikrotechnik depends on the viscosity of fluids. Utilizing the SLF3C-1300F sensor by Sensirion, which is capable on measuring the thermal conductivity of a liquid gives us the chance to distinguish between different liquids and thus assign the thermal conductivity to a specific liquid. Now, one can adjust the micropump to reach the optimal working point for a specific liquid. So, all in all, the SLF3C-1300F offers a reasonable solution to react smart and in-situ to rheological changes within a fluidic system.

As an outlook, the SLF3C-1300F can measure a specific property of a liquid, the thermal conductivity. This will also let us measure mixtures and its concentrations.

Components and systems used:

- mp6 micropump by Bartels Mikrotechnik
- SLF3C-1300F sensor by Sensirion
- mp-Multiboard inlc. mp-Highdriver4 by Bartels Mikrotechnik

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 system that can distinguish between different liquids. 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.

SENSIRION

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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