CASE STUDY

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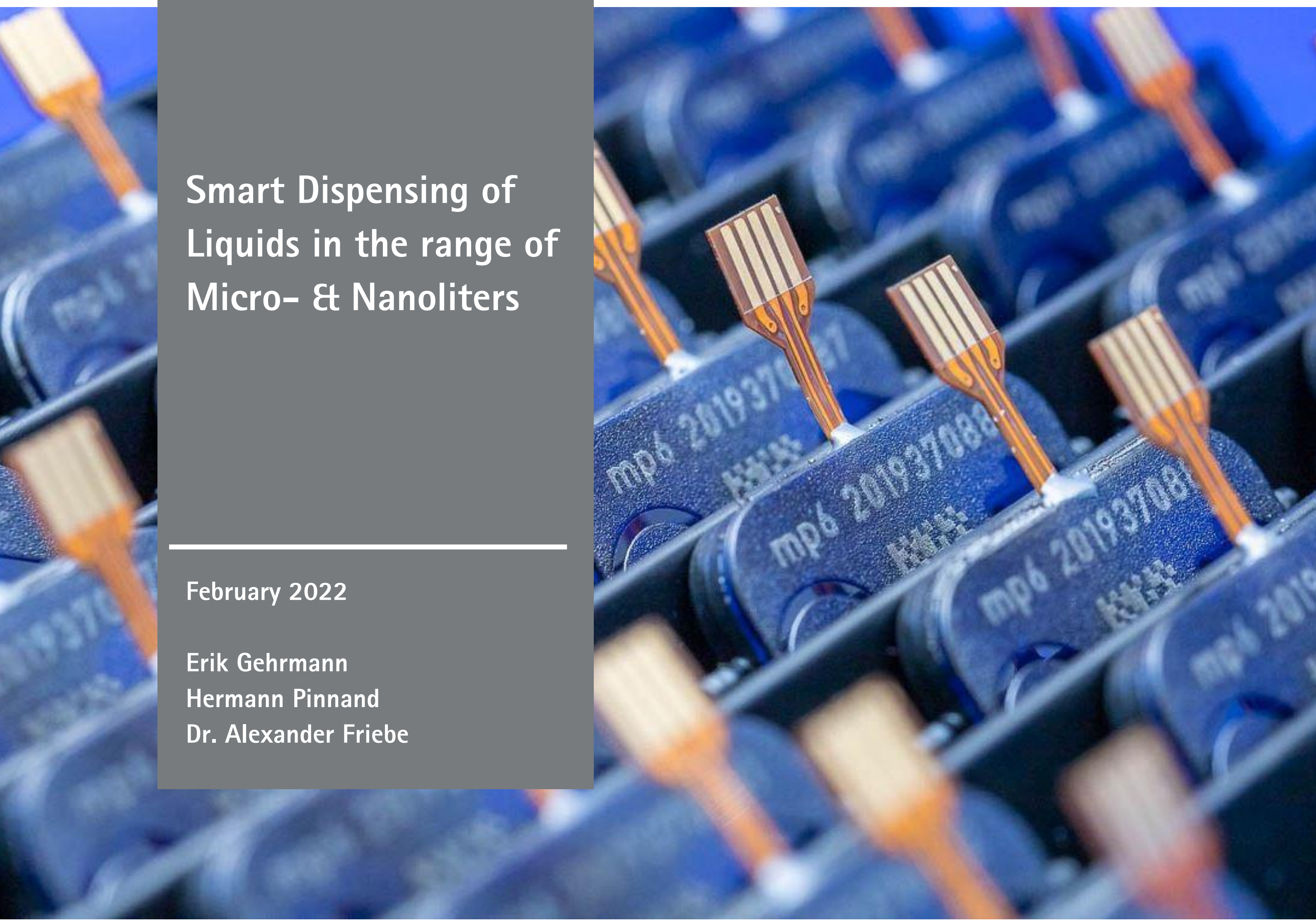
with passion for microfluidics



Smart Dispensing of Liquids in the range of Micro- & Nanoliters

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Simple dosing of nano volumes

Medical, Live Science, Automotive

Dispensing of very low amounts of liquid in medical, Life Science and automotive applications has to be performed many times within a controlled process. This case study demonstrates an innovative and smart way to solve that often-discussed issue with the help of the mp6 micropump. Detailed experimental series have shown us that a simply constructed setup can be a multitool to solve a wide range of tasks in that area.

Very precise and low quantities of volumes have to be dispensed in established and new applications – especially in the medical field. A good example in this area is the convective transportation of very expensive and/or highly effective drugs, dissolved in liquids into patient`s blood or in a microfluidic chip. Another possible application is that a very low amount of a liquid has to be dispensed batchwise in a certain time range elsewhere on a target-point, e.g. for a technical application. Herein, the corresponding liquids can come up with totally different physical properties such as viscosity or solvent power. Figure 1 shows our simple but effective setup used in this study featuring the components made by Bartels.

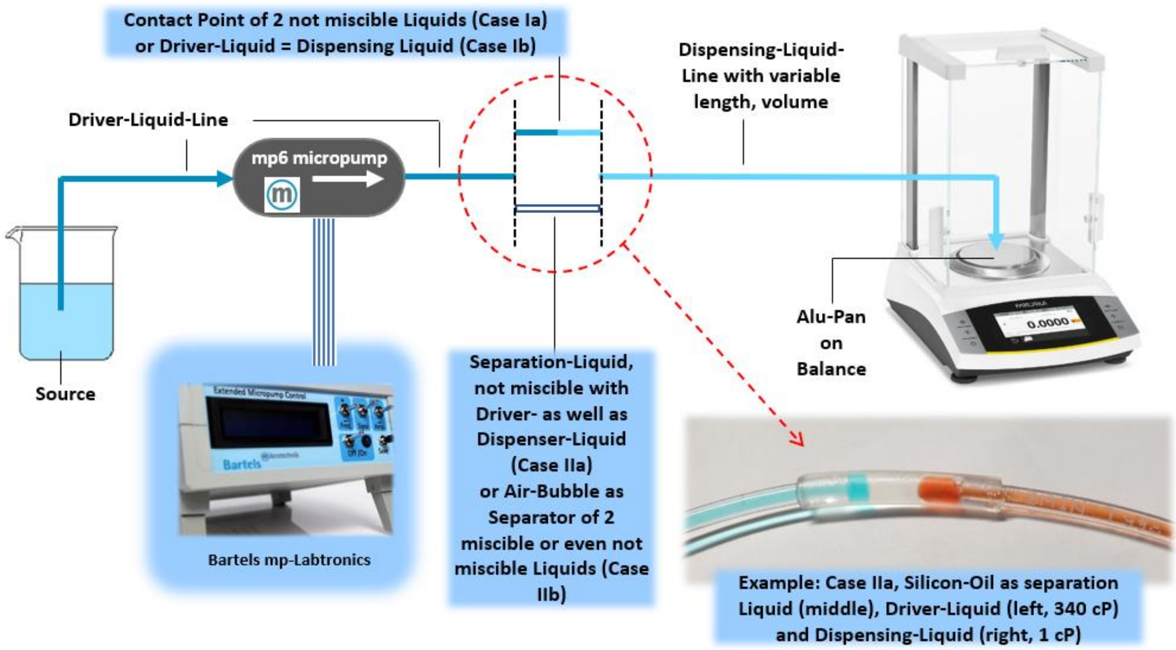

Figure 1:
Liquid source, mp6-micropump (Driver: mp-Labtronix), pipe system and precision balance.
Note: Case Ia, IIa as well as IIb = batchwise dispensing possible; 1b = unlimited dispensing possible.

The stream of liquid, which is transported by the pipe-system, can consist of species with different properties. In the easiest case, all pipes are filled with only one liquid with a certain viscosity (Case Ib, cf. Figure 1). Figure 2 summarizes the results of flow measurements using the highest voltage (250 Vpp) of the mp-Labtronix pump driving unit in dependency of the frequency. A set of different "model liquids" of increased viscosity has been used in this session.

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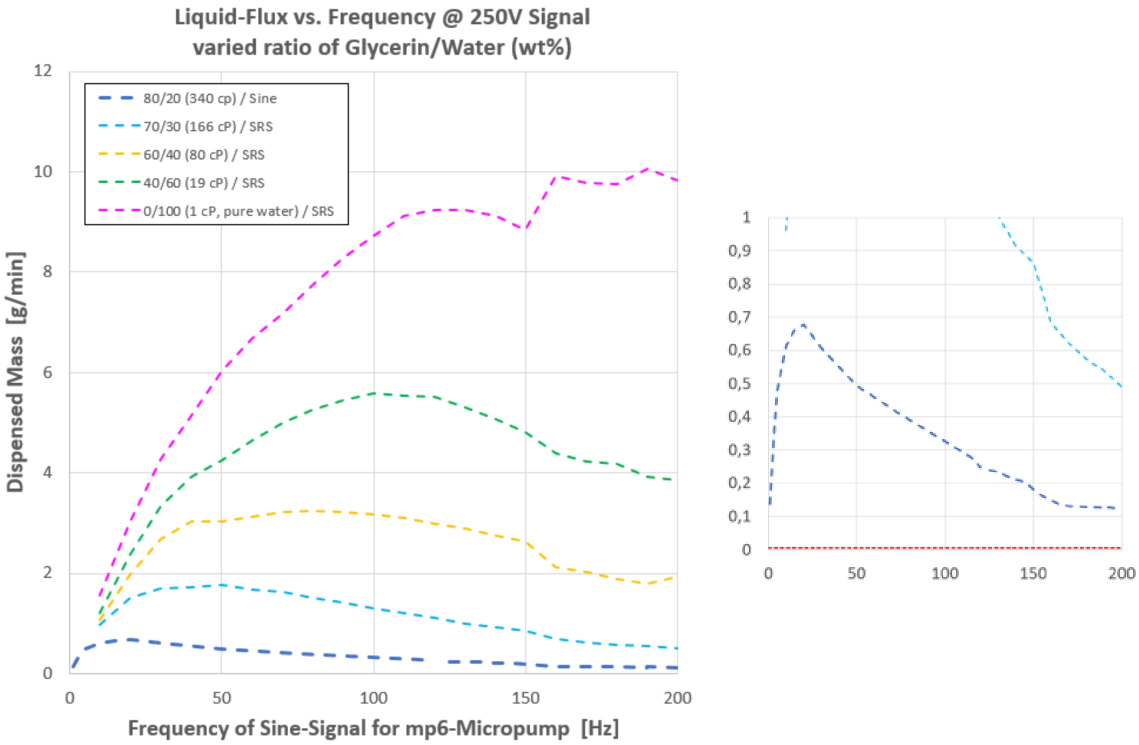

Figure 2:
left: Dependency of mp6-micropump`s flow vs. frequency in the range of 1 . . . 200 Hz with pure water (1 cP) and different mixtures of Glycerin / Water (wt%/wt%) of 40/60 (19 cP) . . . 80/20 (340 cP)
right: Blow up shows the so called "red line" @ 0,006 g/min.

Due to the mp6 micropump`s nature, we can detect a liquid flow maximum around ~ 120 . . .150 Hz at 250 Vpp for pure water (1 cP). When starting from this point and the viscosity of the solution is drastically increased, this maximum shifts to lower frequencies and the absolute value of the dispensed volume decreases. Finally, a frequency of 20 Hz corresponds to the maximum in case of a liquid with a viscosity of 340 cP.

Furthermore, the so called "red line" in the blow up of Figure 2 represents the borderline to nano dispensing. This value of liquid flux of 0,006 g/min corresponds to 100 nL/s (if density is 1g/cm^3) – even one magnitude less than 1 µL/s. To complete the already presented data which illustrates the possibilities of the mp6 micropump for water-like liquids having low viscosities of ~1 cP, we summarized some representative results in Figure 3.

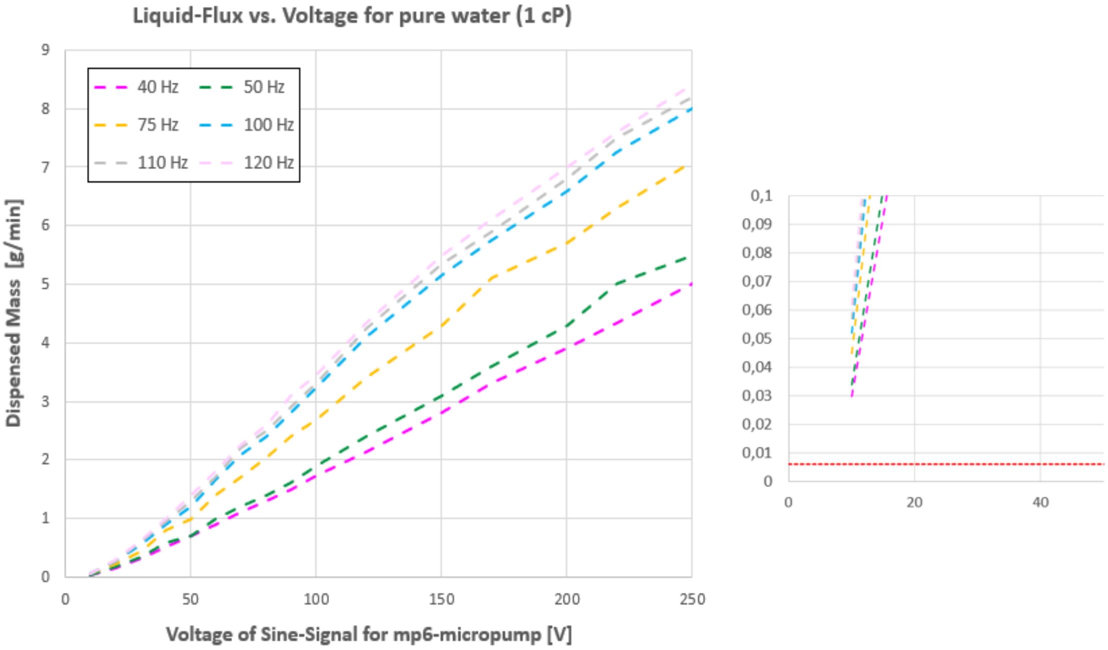

Figure 3:
left: Dependency of mp6 micropump`s flow vs. voltage of mp-Labtronix (Sine) in the range of ~10 . . . 250 V for pure water (1 cP) at selected frequencies
right: Blow up shows the "red line" at 0,006 g/min.

The blow up of Figure 3 shows clearly that the mp6 micropump alone is not able to perform controlled at very low voltages. Nano-Dispensing is not accessible. The results of our next experimental session are summarized in Figure 4. For that purpose, we selected a Glycerin/Water mixture of 80/20, combined with gradually reduced voltage.

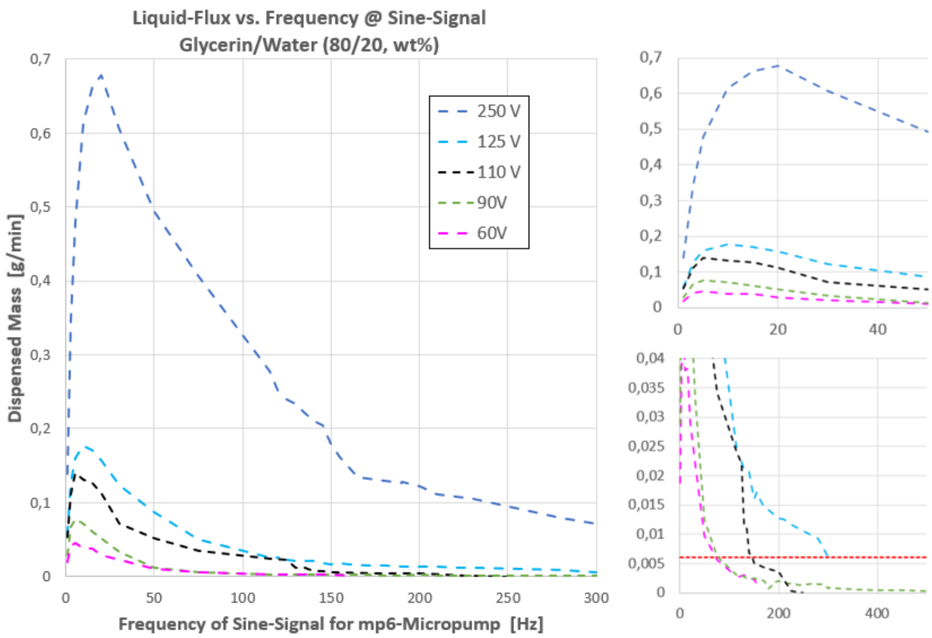

Figure 4:
left: Dependency of mp6 micropump`s flow vs. frequency in the range of 1 . . . 300 Hz using a mixture of Glycerin and Water (80/20, 340 cP)
right (above): Blow up to visualize the maximum-shift
right (below): Blow up shows the "red line" @ 0,006 g/min.

Figure 4 shows that the interplay between a sufficient viscosity of the used Liquid, now named as "driver liquid" (according to Figure 1), and a lowered voltage below 125V leads to a well-controlled liquid flow of 0,006 g/min (100 nL/s @ 1,0g/cm³) and less.

In order to verify these sets of data, we did two things. On the one hand we confirmed the reproducibility by repetitions (result is ±20% of the shown absolute value). On the other hand, we added a blue food dye (E133, Erioglaucin A, CAS 3844-45-9) to the Glycerine/Water mixture and incorporated a microfluidic chip as well as a transparent micro-scale in the setup. Subsequently, this chip has been positioned under a light microscope (Zeiss Discovery, 10-fold magnification) and we measured the time needed for a certain movement of the clearly visible blue liquid-meniscus. Figure 5 shows a representative example of this experimental session.

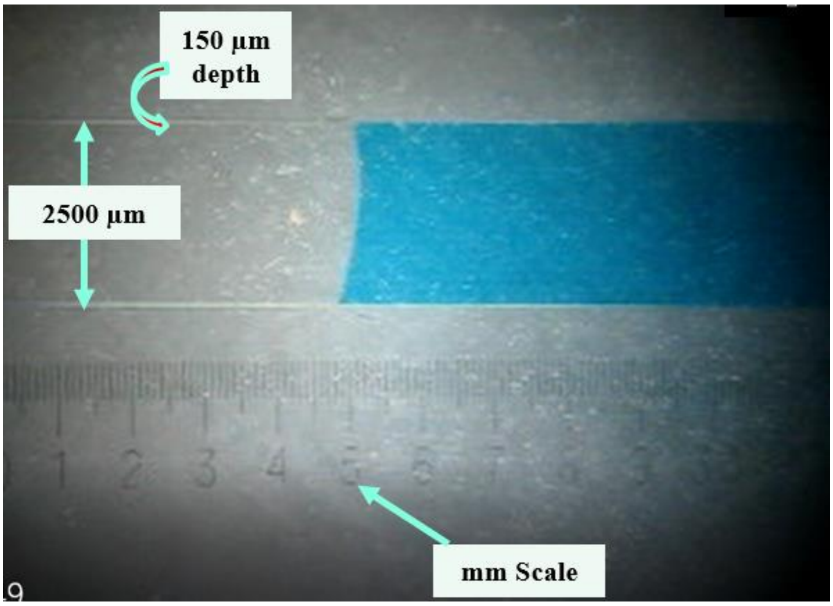

Figure 5:
Glycerin/Water (80/20, 340 cP) spiked with Erioglaucin A (E133, blue food dye), observed under a light microscope in a microfluidic chip (Source: microfluidic ChipShop, Jena; straight channel chip, lengthwise, Order number #10000246); adjustment mp-Labtronix: 60V Sine 125 Hz.

Under these conditions, the meniscus needed 13 s for the movement of 1 mm. Taking the chip dimensions in account, we calculated a flux of 0,034 µL/s. Including the density of the test liquid (~1,2 g/cm³), the mass flow can be determined to be ~0,041 mg/s which corresponds to ~0,003 g/min. This result fits in with the obtained data from Figure 4 (cf. blow up, right below).

In the fourth experimental session, we extended the range of viscosity and varied the voltage. During these experiments, the frequency was kept constant in several series. Figure 6 below demonstrates that many value pairs are available that facilitate a good control regarding the resulting flow in the range of interest. We suggest any costumer to claim this strategy as a guideline if the setup is driven manually - hence, if a certain application demands a specified flow. Every the mp6 micropump underlays a slight deviation; i.e., gravimetrical check (simplest way) is necessary. A complete automized process can be driven by a PID-regulation with a suited flow sensor (cf. *Outlook* below).

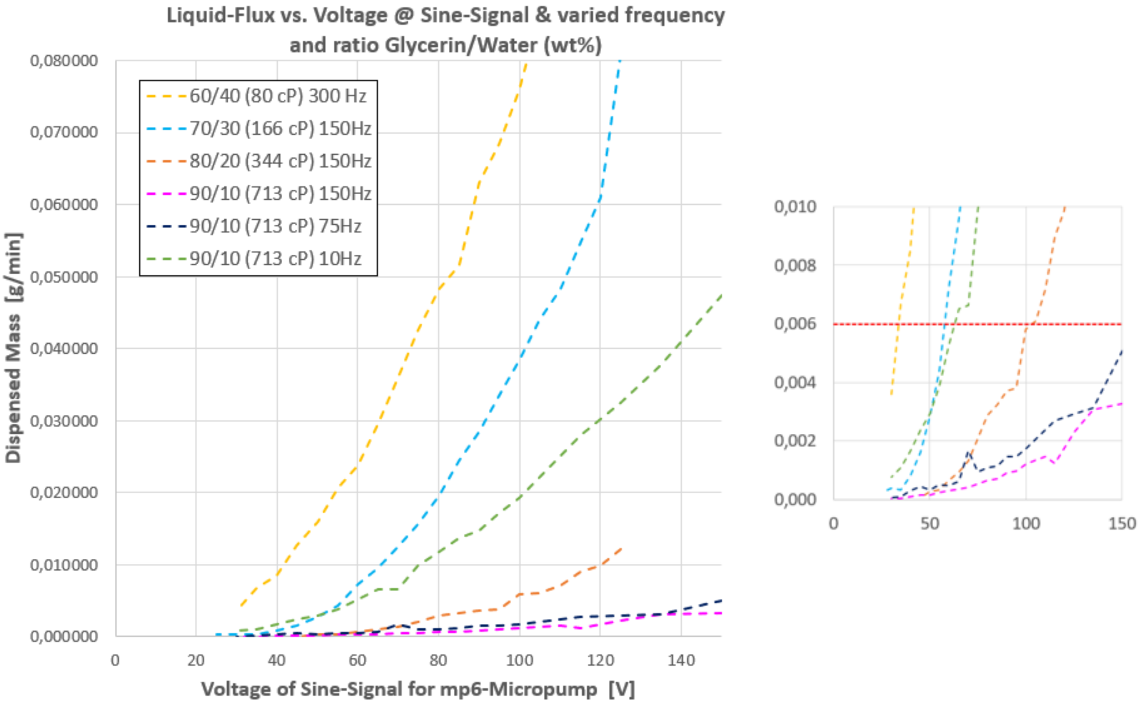

Figure 6:
left: Dependency of mp6 micropump`s flow vs. voltage of mp-Labtronix (Sine) in the range of 25 . . . 150 V using various Glycerin / Water mixtures (80. . . 713 cP) at selected frequencies
right: Blow up shows the "red line" at 0,006 g/min.

When a kind of "nano dispensing" liquid flow of below 0,006 g/min (100 nL/s @ 1,0g/cm³) is desired, the parameter can be chosen in that region as summarized in the blow up of Figure 6. The easiest way is starting close to the specific frequency related flow maximum of the certain liquid and to increase the frequency at a constant voltage. By comparing the figures 4 & 6 it is easy to estimate the correct starting point for your application.

In many real cases, the viscosity of the dispensed liquid is too low (< 50 cP) or, even very seldom higher than the tested model liquids in this study (> 1000 cP; cf. *Outlook* below). In those cases, we suggest separating driver and dispensing liquid using an introduced drop of medical silicone oil, or better, an air-bubble in the dispensing line. If the dispensed volumes are small enough since the process is performed in the "nano range", the dispensing line herewith acts as a reservoir. The dispensing liquid is pushed forward which ensures the control over the flow.

Conclusion:

This case study demonstrates that our mp6 micropump is usable in a very controlled way far beyond the values which can be described as "nano range" (< 100 nL/s) as long as

i. the viscosity of the liquid which has to be dispensed ("dispensing liquid") is >80 cP or
ii. the "dispensing liquid" is pushed forward in front of the "driver liquid" what has a viscosity of 80 . . . 700 cP.

This will be successful if both liquids are not miscible or both miscible liquids are separated by a "separator liquid" or an air-bubble.

Outlook:

Within 2022, we have foreseen a further Case study: "Follow up: Nano-Dispensing for any application" which will extend the current status of this content. In that study, we will establish the automation of Nano-Dispensing by a PI-regulated mp6-micropump/sensor-combination as well as the dosing of liquids in the full range of viscosity from 1 . . . ~20000 cP enabled by well selected driver-liquids.

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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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