

Flüssigkeitsdosierung mit geregelten oder impulsgesteuerten Mikropumpen



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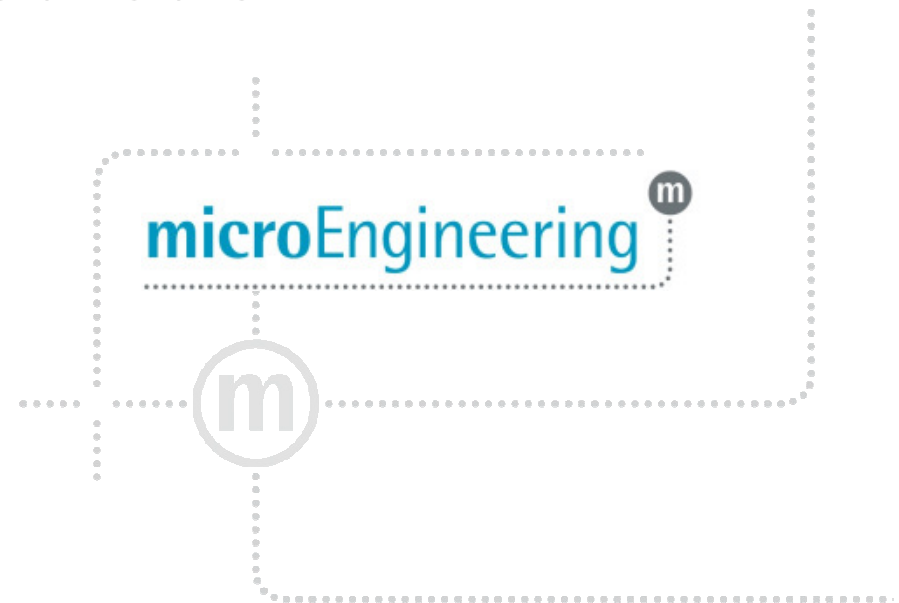
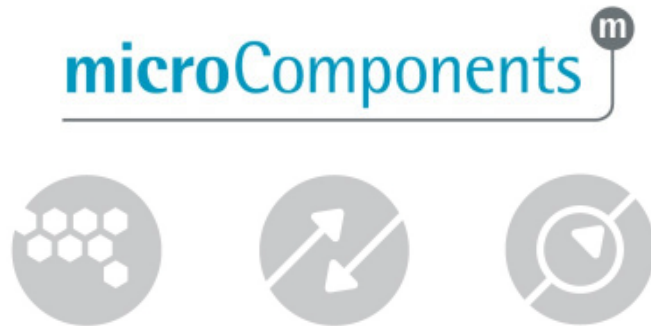
Outline

- Introduction – Bartels Mikrotechnik
- Micropumps
Setup – Characteristics – Applications
- Flow controlled pumps
 - Intrinsic flow control
 - Thermal flow sensors
- Impulse driven pumps
- Summary



Founded 1996 by Dr. Frank Bartels
Located in Dortmund / Germany

Two business divisions:

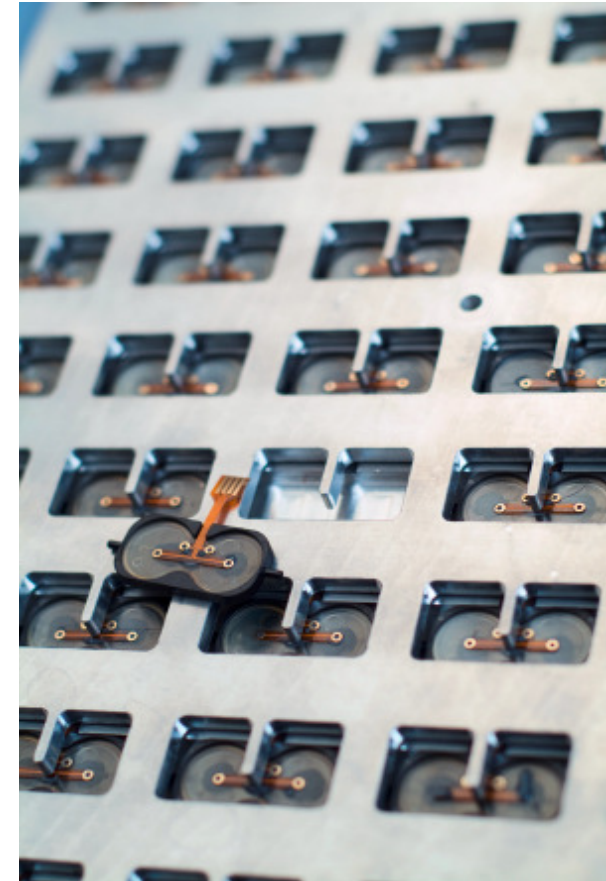


Ask an Expert for Active Microfluidics

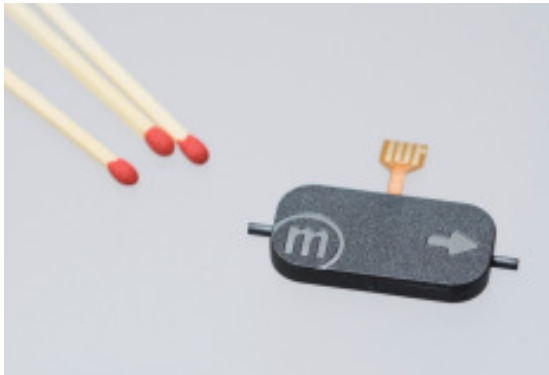
- Continuous / discontinuous fluid delivery
- Droplet based fluid handling
- Micro dosing
- Micro spraying / mist generation
- Active fluid process control
- Micro hydraulics

Outline

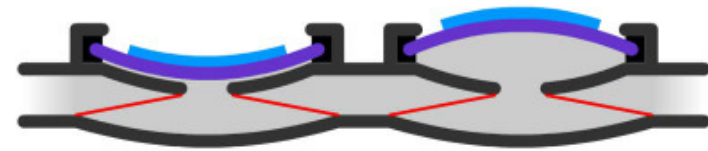
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Micropumps - Principle



Bartels^mikrotechnik



www.bartels-mikrotechnik.de

- Piezo based actuation
- Reciprocating membrane pump
- Double actuator configuration for increased performance



Micropumps – Main Characteristics

- Size 15x30x3.8 mm³
- Flow range 20 µl/min – 6000 µl/min
- Maximum backpressure 550 mbar
- Power consumption < 200 mW from battery voltages
- Lifetime >10 000 hours
- Sterilization resistant (EtO, Autoclave, Gamma*)



Applications - Examples



Microscopy

Diagnostics

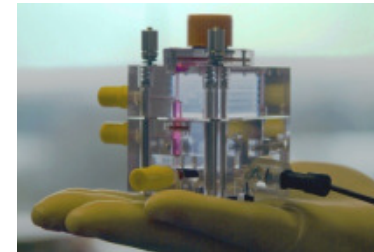


Industrial Sensors



Lubrication

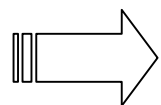
Biotechnology



Influences / Limits

- Changes of pump rate due to external influences require additional control features
- A “lowest volume flow” cannot be specified as it does not only depend on the pump itself. The pump is normally not less accurate in the low flow domain but the role of external influences increases significantly.

Typical issue: Single dosing volumes limited by droplet size



With closed loop controlled pumps or impulse driven dispensing, both limitations can be addressed

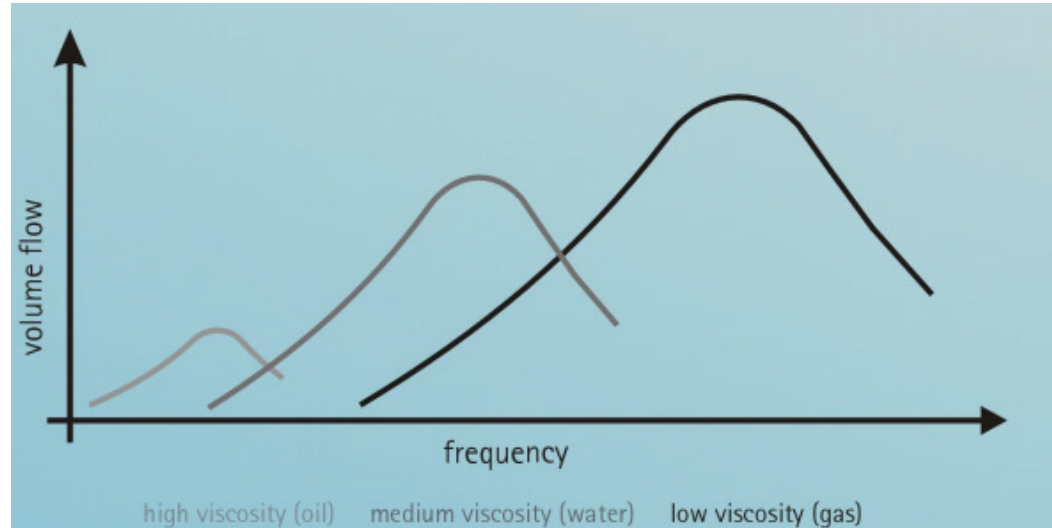
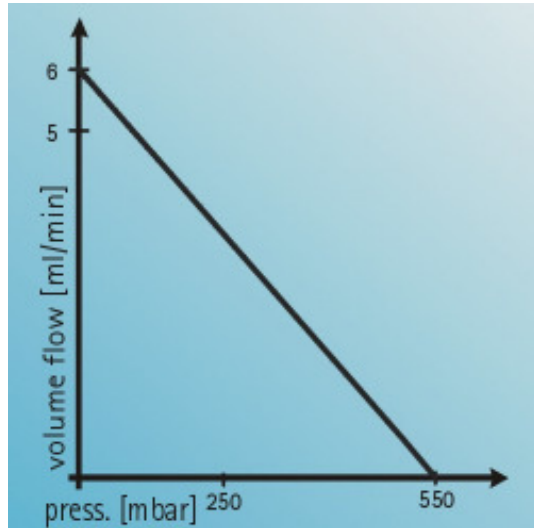


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Why flow control?

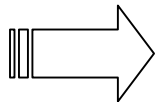


Flow rate is influenced by external factors as back pressure, temperature, viscosity, ...



Advantages of a flow controlled micropump

- Varying system conditions can be compensated
- Flow is stabilized
- Monitoring / Safety features can be implemented
 - Empty reservoir detection
 - Air bubble detection
 - Occlusion detection in front / behind the pump



The pump gains “intelligence”



Flow controlled mp6

Two possibilities of flow control

- Piezosensorpump
Intrinsic flow control by double actuator configuration
- Thermosensorpump
Hybrid setup with flow sensor

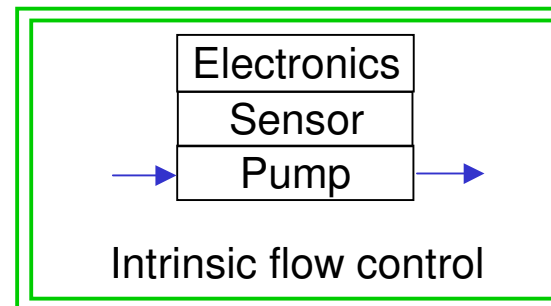
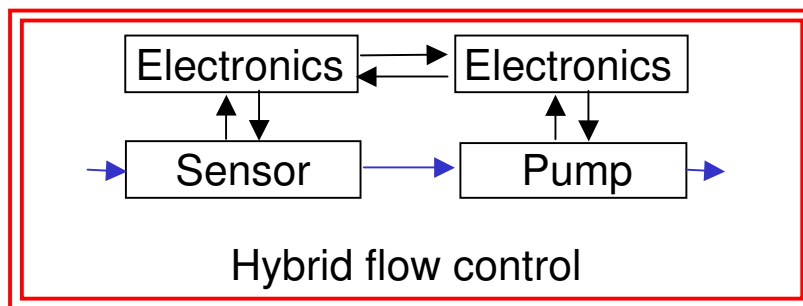


Why intrinsic flow control?

Typically, flow control is performed using a hybrid system of stand alone flow sensors in combination with the actuator (pump)

As this adds additional mechanical, fluidic and electrical interfaces, complexity, cost, size and power consumption increase as well.

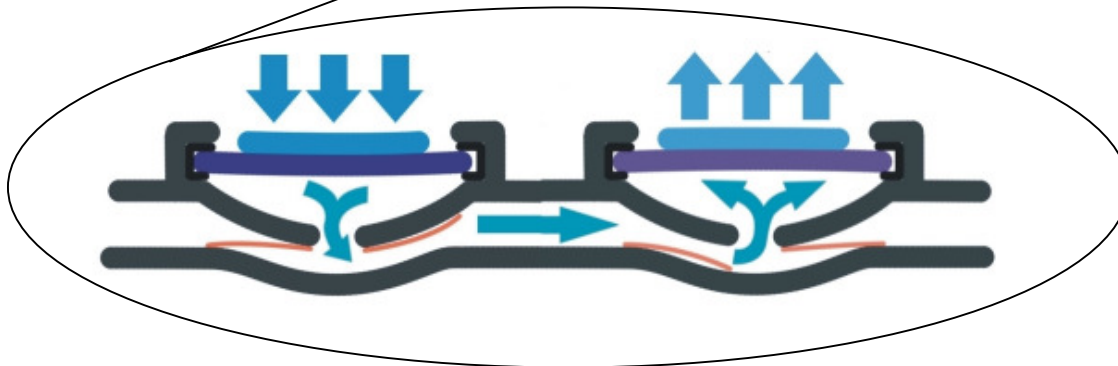
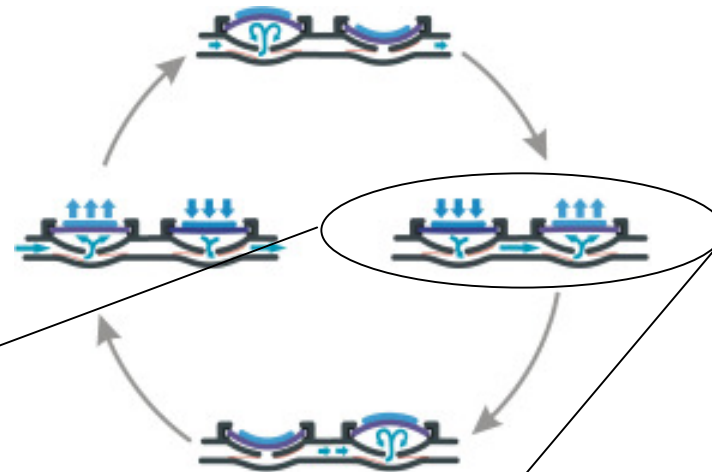
By using an intrinsic principle, complexity is lowered and no additional elements are introduced into the fluid path.



Technical principle

The mp6 pump has a double actuator set-up.

Both pump chambers “communicate” through the fluid path inside the pump.



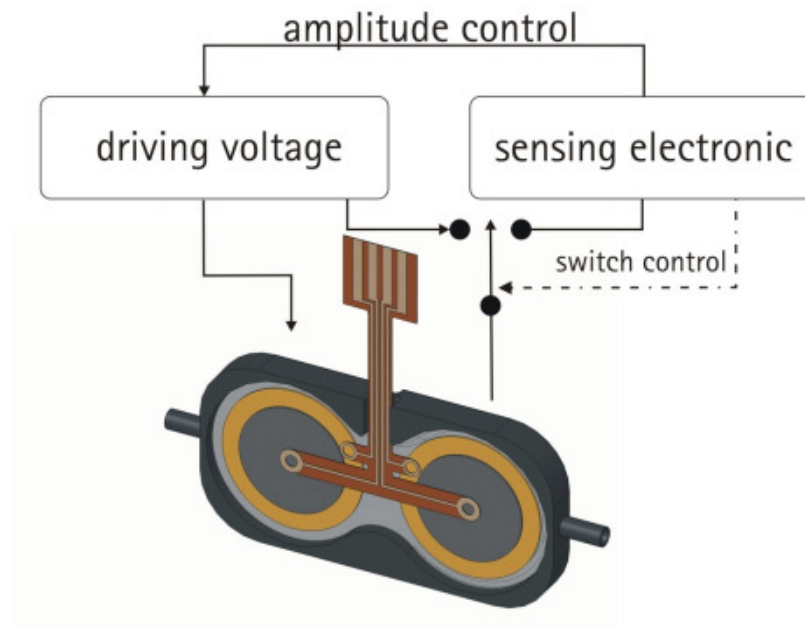
Technical principle

Due to its reversibility the piezo effect can be used for actuation and sensing.

In flow controlled mode the second actuator is used for pumping and sensing.

The complete process is based on the elements of the pump itself.

No additional sensor!

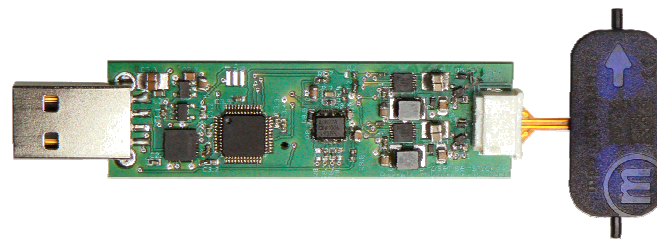


Main challenges

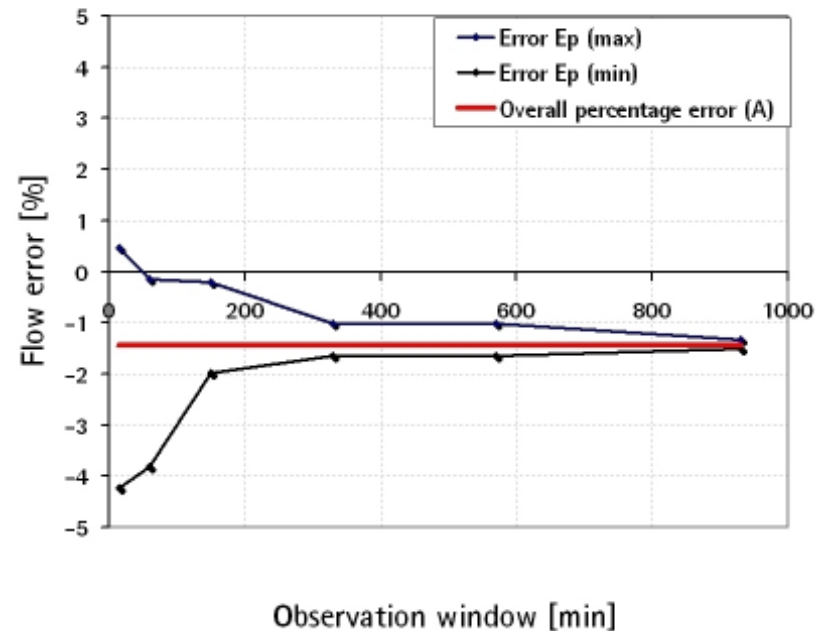
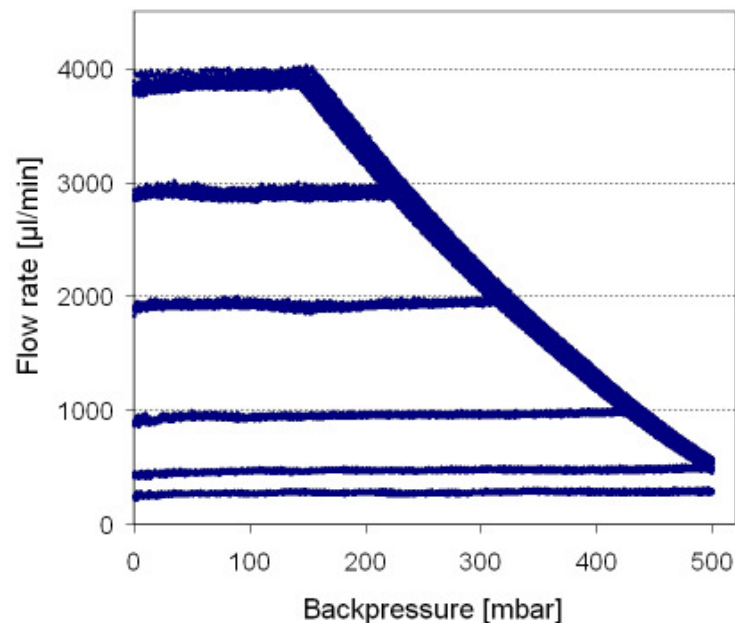
The feedback signals are in the <1 V range while the driving signal of the pump is in the order of 250 Vpp.

Using one of the piezos for sensing continuously would drop the pump performance by 50%.

Therefore the signal processing is realized by a PLL system. Both piezos are driven at a small frequency shift, so the signals can be processed with high resolution. Both piezos continuously contribute for full pump performance.



Performance data of the intrinsic flow control



- Graphs of 6 flow levels, 12 repetitions each
- Flow range between 500 – 5000 µl/min with +/- 10 % accuracy
- Constant flow rate until maximum pump performance

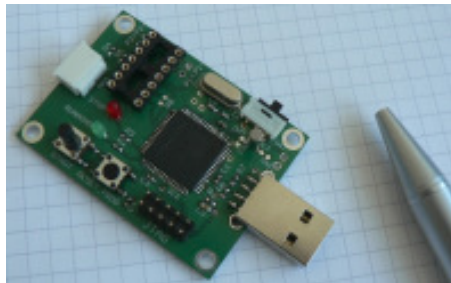
Summary of key properties

General

- 500 – 5000 $\mu\text{l}/\text{min}$ with $\pm 10\%$ accuracy proven
- Based on standard pump mp6, unbeatable cost effectiveness
- Low complexity
- Robust system with good gas bubble tolerance
- Patented technology

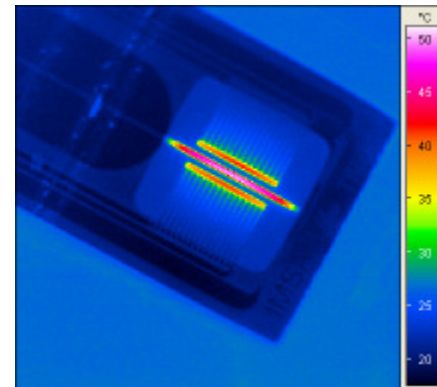
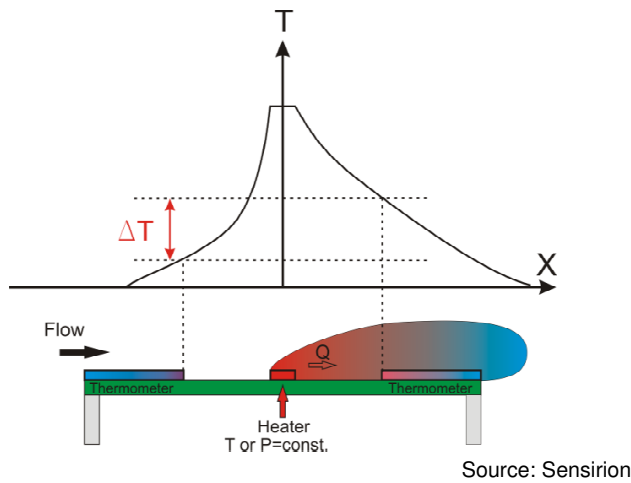
Additional features

- If necessary, a system approach including anti free flow, programmable electronics can be realized



Flow Control by Thermal Flow Sensor

For higher accuracies or flow ranges below 500 $\mu\text{l}/\text{min}$ a flow control can be realized by combining the micropump with a thermal flow sensor.

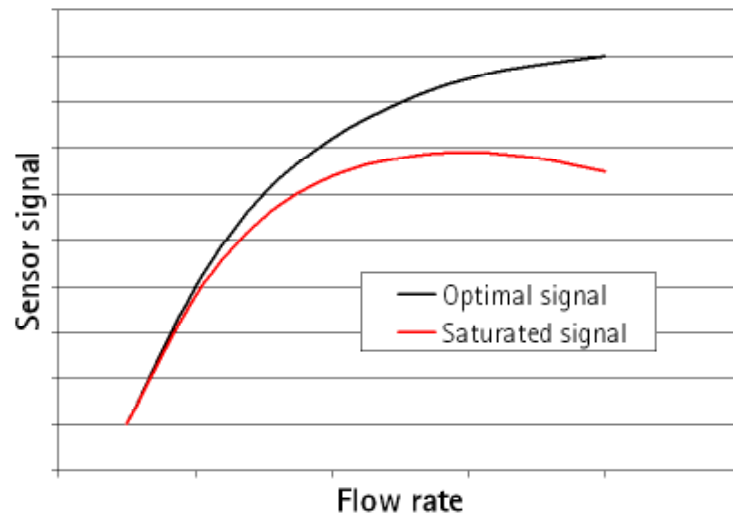


technical principle of thermal flow sensor



Hybrid Flow Sensing

Although the pump rate is in the range of up to 6 ml/min, the transient flow rate exceeds this value by a factor of two or more. Therefore pump and flow sensor need to be carefully adjusted in order to provide the optimal combination between accuracy and measurement range.



Unsuitable measurement ranges result in saturation and inconclusive data analysis.

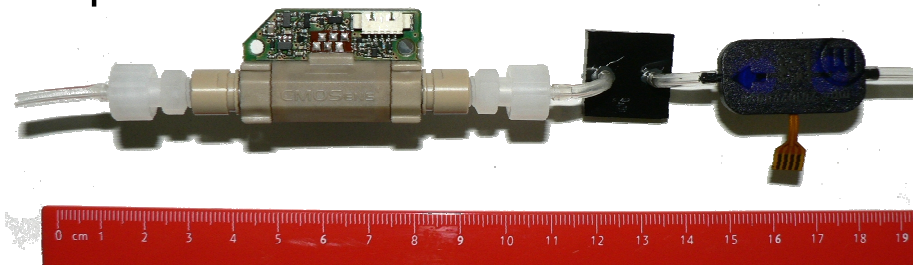


Performance of Thermo Sensor Pump

- Flow range between 60 - 5000 $\mu\text{l}/\text{min}$ with $\pm 5\%$ accuracy
- Prototyped module of integrated sensor and pump has been proven successfully



- For smaller quantities, a modular setup of stand alone flow sensor and pump is preferable



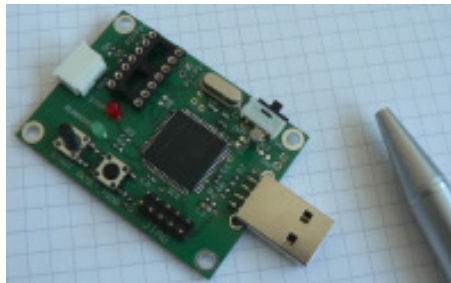
Summary of key properties

General

- 60 – 5000 $\mu\text{l}/\text{min}$ with $\pm 5\%$ accuracy proven
- Two concepts based on target quantity
 - Fully integrated sensor
 - Modular setup

Additional features

- If necessary, a system approach including anti free flow, programmable electronics can be realized



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Impulse driven pumps

By driving pumps in a pulsed mode in combination with suitable fluidic channels, a free liquid jet can be obtained.

Two general motivations:

- Avoid physical contact between sample and dosage head
- Dispense smaller volumes than a droplet, therefore avoid “dripping”



Source: Wikimedia



The principle

- Free fluid jets can be obtained at Weber numbers $We > 8$

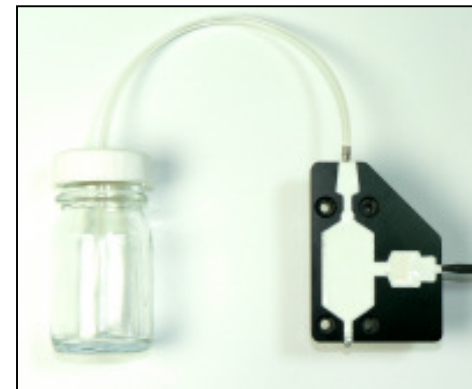
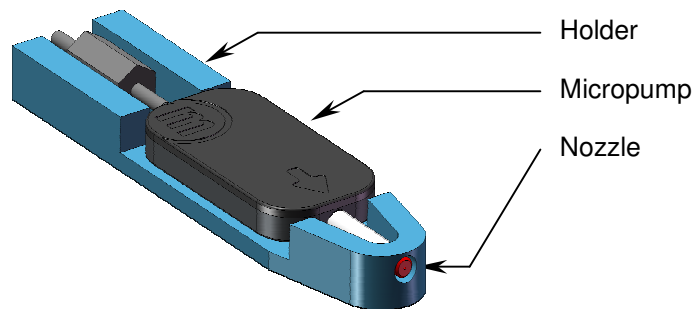
$$We = \frac{v^2 \cdot D \cdot \rho}{\sigma}$$

- ToDo: Increase the flow velocity “v”
- The micropump mp6 is used as a reliable, available and small core element of the system



The setup

- Combination of
 - Micropump
 - Nozzle (precision dependent on target deviation)
 - Check valve
 - Impulse driven electronics



Typical results

Dosing volume range: $< 1 \mu\text{l} \sim 50 \mu\text{l}$
Dosing cycles: $\sim 10 \text{ ms}$
Working distance: $0 - 80 \text{ mm}$, horizontal alignment possible

Sterilization is possible



High speed imaging (100 fps).
Dispensing of DI water using a 250 μm nozzle



Summary

- Bartels Micropumps have been introduced as a proven, off the shelf component for different applications
- To address more demanding applications, closed loop control and free jet dispensing were realized based on the pump platform
- The intrinsic sensor function provides innovative flow control without additional sensor elements
- The combination with a thermal flow sensor offers low flow rates and higher accuracies
- The mp6JET dispenser allows contact free dispensing in the microliter range. It can be combined with additional sensors





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