Sold in North America By:
Servoflo Corporation
75 Allen Street
Lexington, MA 02421 Tel: 781-862-9572

# Application Note

## Operating Micropumps with Air

In the following application note, the operation of the micro pumps from Bartels Mikrotechnik with gases will be discussed. All formulas and values listed below are considered typical or estimated values. The real results may vary based on the individual test and system conditions. Generally both the mp5 and the mp6 pump can be used with gases, but we recommend using the mp6-AIR as it is measured especially for air performance.

Also, as the mp6-AIR has a much lower target price than the mp5 due to the automated production and as it delivers almost triple the pressure when pumping gas, most of the details below will focus on the mp6-AIR pump.

### About the mp6-AIR

As most of the standard applications covered with the pumps are using liquid media, all pumps undergo an automatic quality control for flow rate and pressure generation with water. For the mp6-AIR, the standard mp6 pumps will be dried in an oven to remove the liquid remains. Then the pumps will rest for some time to acclimatize with the standard lab atmosphere. These pumps are then tested for air flow and air pressure similar like with water.

### Flow characteristics of the mp6-AIR

For the pump, an optimal frequency exists for each liquid. With water this is approximately at 150 Hz[1], with higher viscosities it is much lower. For gases the frequency is in general higher but driving a high frequency requires a certain electronic that is able keeping the driving signal intact.

In order to work at a reasonable sound level and at a reasonable energy consumption (or size of the driving electronics respectively) we typically consider the operation at a frequency of 300 Hz to be the standard working point of the pump with gases. If your flow rate requirement is a bit higher than specified, in most cases the pump can just be run at a higher frequency.

In the following figures, flow rate, outlet pressure and suction pressure are shown up to frequencies of 3 kHz for different driving signals and the maximum amplitude of 250 Vpp.

[1] The 150 Hz is an approximate value due to the ±15% exemplary tolerance of the pump. Therefore quality control and test data are based on 100 Hz as the pump tolerance is much smaller then.



Bartels Mikrotechnik GmbH, Konrad-Adenauer-Allee 11, 44263 Dortmund, Germany
www.bartels-mikrotechnik.de, microComponents@bartels-mikrotechnik.de
Tel: +49-231-47730-500, Fax: +49-231-47730-501

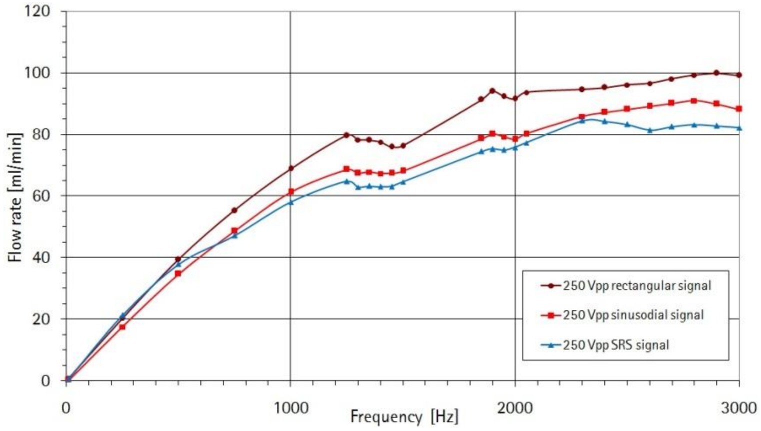


**Figure 1 Typical air flow of the mp6 micro pump**

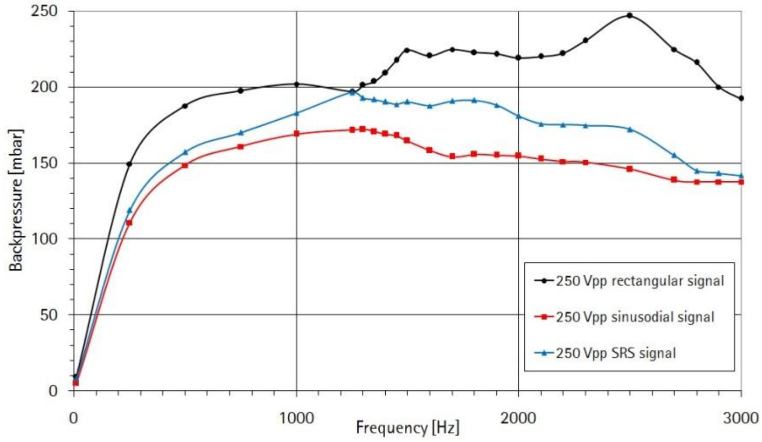


**Figure 2 Typical backpressure of the mp6 micro pump**

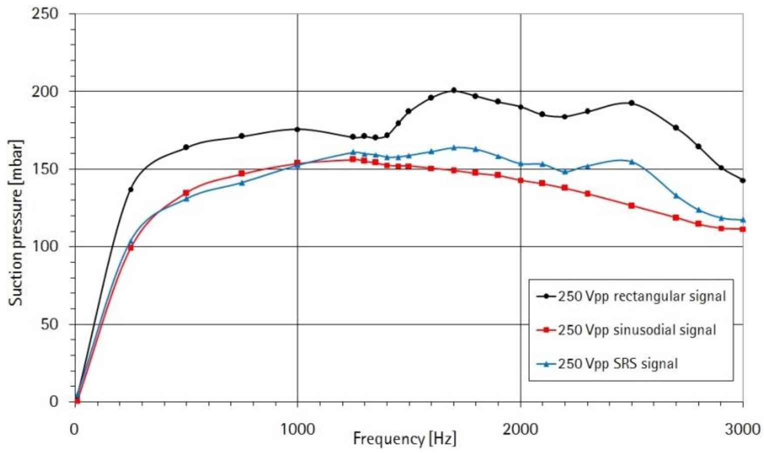


**Figure 3 Typical suction pressure of the mp6 micro pump**



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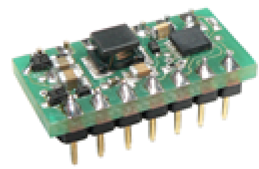
Until about 1000 Hz, the flow rates increase linearly with the frequency, assuming stable amplitudes of the driving signal under these conditions. The pressure increases almost linear until frequencies of about 300 to 400 Hz dependent on the waveform. As shown in the graphs, the rectangular signal provides the highest performance. Due to the fact that this signal produces a high noise level it is only recommended when highest performance is targeted. For most applications where noise level plays a large role, using a sine or SRS driving signal is better suited. The SRS signal is a specific signal that has been developed by Bartels Mikrotechnik in order to achieve a high performance level combined with a reduce noise generation.

**Possible electronic controller**

As compared to pumping liquid there are no issues with priming or air bubbles. A single pump will be able to achieve the flow with a deviation of less than 3% as a typical value. For quantity customers the pumps can be further sorted to achieve smaller variations.

With the controller **mp-x** the typical flow rate of the mp6-AIR for gas is 20 ml/min, achieved with SRS signal at 250 Vpp and 300 Hz (as this is the maximal setting of the mp-x). With same settings a pressure level of 100 mbar is possible.

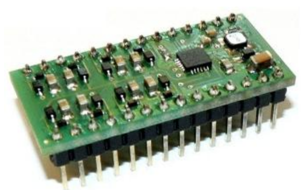

The **mp6-OEM** driving electronics is also capable to run the pump for gas applications, however there are some limits. With this driver the pump is specified to run between 85 - 270 Vpp of pump amplitude and 25 – 226 Hz of pump frequency. Higher frequencies are possible to achieve with additional circuitry, but the amplitude and signal quality degrade due to the limited energy conversion of the driving chip. So the overall performance of the driven pump will not increase linear anymore.



In comparison to the mp-x the mp6-OEM is weaker when pumping air; 11 ml/min and 50 mbar at 270 Vpp and 226 Hz. The evaluation kit mp6-EVA applies this controller.

Especially for gas application we have developed the **mp6-QuadOEM**. This driver is able to power four pumps in parallel with the same settings. The amplitude range is 0 – 260 Vpp and the frequency can be changed from 50 up to 800 Hz for different signal shapes. With the sine signal at 300 Hz a single pump delivers 18 ml/min of gas flow or 112 mbar of pressure. With a frequency of 800 Hz the flow rate increases to ~42 ml/min or the pressure to 147 mbar.

When combining pumps in parallel it is possible to add flow rates, a serial connection of pumps allows stacking the pressure. Although this is always possible with the pumps, the Quad series controllers with its four connection ports are best suited for this.



The Quad series consists of the evaluation board mp6-QuadEVA, this driver electronic mp6-QuadOEM and the mp6-QuadKEY that combines the OEM with an Arduino electronic.

| Gas performance | mp-x | mp6-OEM | mp6-EVA | mp6-QuadEVA | mp6-QuadOEM | mp6-QuadKEY |
|---|---|---|---|---|---|---|
| mp6-AIR, max amplitude @300 Hz | | | | | | |
| flow rate per pump | 20 ml/min | 11 ml/min | 11 ml/min | 18 ml/min [3] | 18 ml/min [3] | 18 ml/min [3] |
| pressure per pump | 100 mbar | 50 mbar | 50 mbar | 112 mbar [3] | 112 mbar [3] | 112 mbar [3] |
| | | | | | | |
| mp6-AIR, max amplitude @800 Hz | | | | | | |
| flow rate per pump | - | - | - | 42 ml/min [3] | 42 ml/min [3] | 42 ml/min [3] |
| pressure per pump | - | - | - | 147 mbar [3] | 147 mbar [3] | 147 mbar [3] |

[3] Measured with sine signal. Rectangular signal will exceed these values and create more noise.

**Figure 4 Comparison table for gas performance**

### Determining the driving parameters

As the real flow rate is dependent on the individual application conditions, the driving parameters need to be determined on an application specific basis. The two governing parameters are a) The amplitude or driving voltage (specified in Vpp) which determines how strong one single stroke is and b) The driving frequency (specified in Hz) which determines how many pump strokes are done per second.

In comparison to liquids, the flow rate can be adjusted with both the amplitude and the frequency, while it is still recommended to use mainly the amplitude for adjustment. One exception might be pulsations which are covered further below. As lowering the flow rate will also lower the maximum backpressure that can be produced by the pump, the effect of pressure changes in the system rise at lower flow rates. Therefore the pressures at in- and outlet should be kept at the same level when working far below the maximum flow rate.

### How we measure the mp6-AIR

As the inner volumes of the fluidic systems are very small, some specific guidelines need to be kept in mind when measuring flow rates and pressures using the mp6 micropumps. Because of the high operating frequencies, standing waves can appear within the tubes or fluidic channels. This in result may lead to wrong measurements or bad performance if flow meters are positioned in a node or antinode. At our facilities, a Sensirion ASF 1400 / 1430 sensor is used to obtain flow data.

Figure 5 shows the schematic of the reference setup to measure flow rates and pressures for air. The pump under test drags air through valve and flow sensor and pumps air out through another valve. The valves are used to measure pressure performance, forward and suction pressure. To minimize internal flow resistance the valves have internal diameters in the range of 1 mm. The pressure sensors, Honeywell 40PC015G, are simply connected via T-junctions. Tubing of 20 cm length is used between flow sensor and first valve and between pump and both pressure sensors. Tubing of 5 cm length is used between valves and pressure sensors.

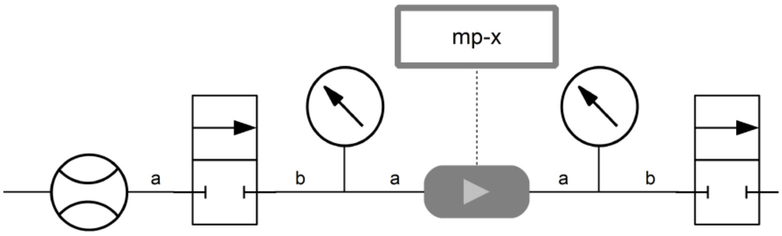



**Figure 5 Test setup at Bartels Mikrotechnik for measuring flow rate and pressure of mp6-AIR pumps:**
**From left to right: flow sensor, valve, pressure sensor, pump controlled by mp-x, pressure sensor, valve.**
**The tubing between are Tygon tubing of 1.3 mm inner diameter and the length: a = 20 ±2.5 cm and b = 5 ±0.1 cm.**

### Pulsations

Even though the Bartels micropumps have very small variations in flow over time compared to peristaltic or larger membrane pumps, they are not completely pulseless. As a rule of thumb, the maximum single stroke of the pump (at 250 Vpp) is about 1 µl. Using flexible tubing behind the pump, the pulsations will be very small already after a few centimetres of tubing. However, in some cases like combining the pumps with flow sensors or sensors for analytical measurements, the pulsations require further reduction. This can be solved by operating the pumps with a sine wave or by adding a damping element into the fluid path. Based on specific project requirements we can offer determining the right method to obtain low pulsations without adding much dead volume to the system.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