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APPLICATION NOTE

Flow measurement using Microbridge's MB-LPS2 micro-flow-based differential pressure (ΔP) sensors

ABSTRACT:

In the design of a flow-measurement system, the choice of ΔP sensor tracks closely the design of the duct/tube with its flow-to-pressure conversion element. For a given air-flow conduit with its conversion element, the ΔP sensor must have full-scale differential pressure measurement range sufficient to measure the desired full-scale flow, and it must have fine-enough differential pressure resolution to resolve the desired minimum flow. Typically, for a given air-flow conduit with its conversion element, these needed parameters of differential pressure must be found experimentally. To aid customers in selecting or customizing a suitable differential pressure sensor, this Application Note describes how the needed information is measured.

FLOW MEASUREMENT USING DIFFERENTIAL PRESSURE SENSORS:

Differential pressure (ΔP) sensors are often used to measure differential pressure generated by gas flow passing through an air-flow duct or "flow tube". This type of measurement implies that the sensor is connected in parallel to the main air-flow. As illustrated in Fig. 1, the two ports of the sensor are connected across the element which converts volume flow or linear air flow velocity into differential pressure.

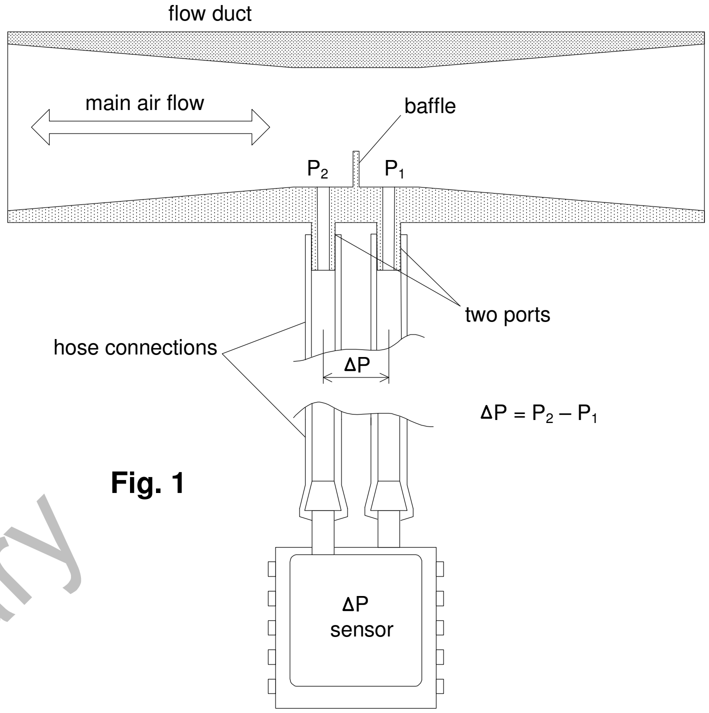


Fig. 1

In Fig. 1, the conversion element is a simple baffle blocking part of the flow cross section. Conversion elements, designed differently for different applications and in use for decades, include Pitot tubes, Venturi tubes, calibrated diaphragms, and special flow-to-pressure converters used in respiration equipment such as Fleisch or Lilly tubes. The construction of these conversion elements is (must be) guided by the specific requirements of their usage within the specific application. For example, it may be important that the element work with humidified or dusty air. Perhaps most importantly, conversion elements influence the full-scale flow-measurement range, as required for a particular application – for example, ranging from units of l/min to 1000's of l/min. They can work in ducts with cross-section of more than several hundreds of cm^2 (HVAC applications) or in flow tubes with diameter of ~1-2cm. In some applications these elements must work for years without re-calibration, in others, they need to work for only a few minutes (e.g. disposable flow tubes) or may be intended to be re-calibrated before each use. In some applications an overall accuracy of ~10%FS is acceptable, while in other applications accuracy ~1-2%FS, or better, is essential. It is obvious that one type of flow-to-pressure conversion element successfully used in one application may be quite inappropriate in another application.

In the design of a flow-measurement system, the choice of ΔP sensor tracks closely the design of the duct/tube with flow-to-pressure conversion element. For a given air-flow conduit with its conversion element, the ΔP sensor must have full-scale differential pressure measurement range sufficient to measure the desired full-scale flow, and it must have fine-enough differential pressure resolution to resolve the desired minimum flow. Typically, for a given air-flow conduit with its conversion element, these needed parameters of differential pressure must be found experimentally.

AIR-FLOW CONDUIT CHARACTERIZATION EXAMPLE:

A customer-specific air-flow conduit, in this case a flow tube, having its internal flow-to-pressure conversion element, was selected for characterization. Note that, at the beginning of this procedure, the flow-to-pressure conversion of the tube was not known. A Microbridge sensor MB-LPS2-02-100U5N was selected for the first test, having full-scale 250Pa (1"wc), unidirectional, corresponding to analog output between 0.5V and 4.5V, as shown in Fig. 2. The tested sensor has a ΔP measurement dynamic range of roughly 10000x, and resolution of ΔP measurement at low ΔP approximately 0.01%.

Fig. 3 shows schematically the experimental setup, including the MB-LPS2 connected across the tube's conversion element. An Ametek air blower generated a variable air flow, monitored by TSI flowmeter model 40211 (measurement range 0 – 300 lpm; resolution about 0.05 lpm). The analog output of the MB-LPS2 sensor was monitored by a DMM.

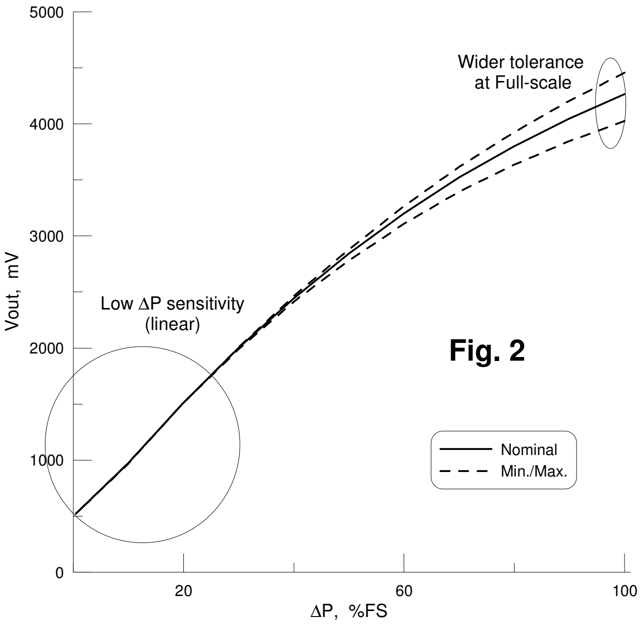


Fig. 2

The sensor's measured output voltage is plotted vs. TSI flow-measurement output, in Figs. 4a and 4b. Fig. 4a shows the entire range of flows which are measurable using this particular flow tube with the MB-LPS2-02-100U5N. Fig. 4b focuses on low flows. The noise of the sensor is below about +/-0.5mV. As shown in Fig. 4b, the output signal at 0.235 lpm is about 1mV higher than the output at zero-flow (blocked flow tube). The minimum detectable flow is significantly below this **0.235 lpm**. With this particular flow tube, the 250Pa operating range of this LPS2-series sensor limits the air flow measurement range to about **75 lpm**.

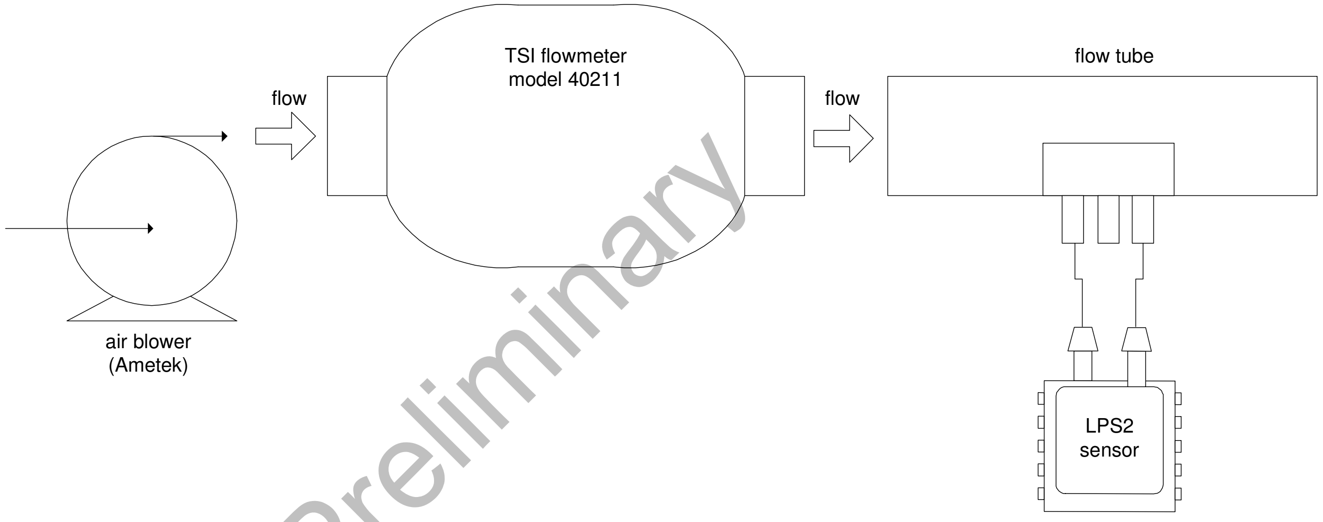


Fig. 3: Schematic of the experimental setup.

Note that the curve for MB-LPS2-02-100U5N in Fig. 4a is non-linear with several regions of different curvature. The shape of the curve is affected by the combination of both the flow-to-pressure conversion characteristic of the air-flow conduit, and the sensor’s non-linear output characteristic illustrated in Fig. 2. Typically the flow-to-pressure conversion is heavily non-linear (for simple-shaped tubes with simple-shaped flow-to-pressure conversion elements, often ΔP varies roughly as the square of flow). Typically the non-linear analog output from a flow measurement system of this type (where the analog output comes from a differential pressure sensor), needs to be calibrated and linearized by a lookup table.

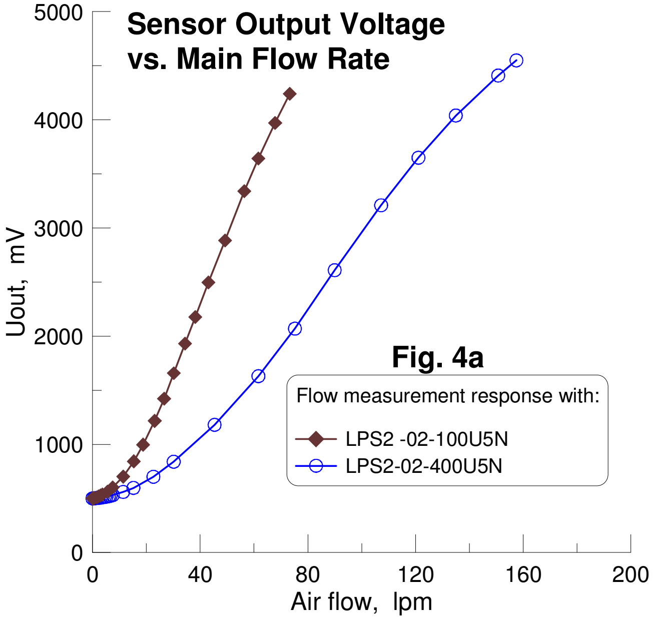
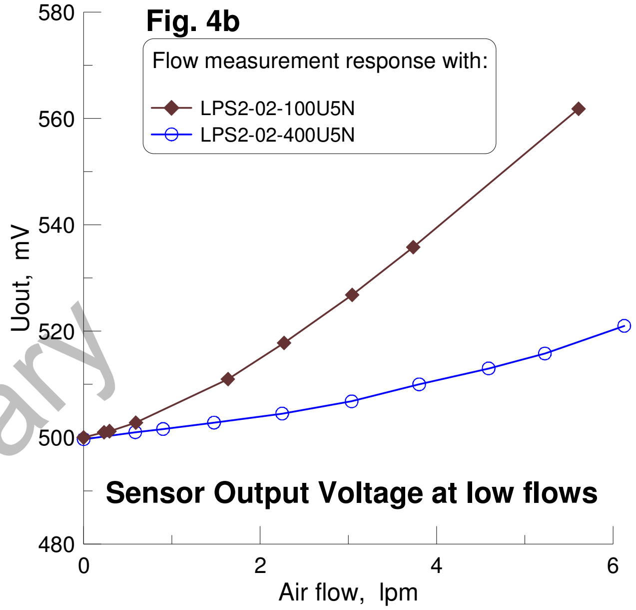


Fig. 4a

Fig. 4b



ADAPTING THE SELECTION:

If the full-scale range (75 lpm described above) is not the desired range, a different MB-LPS2-series sensor can be tested. The adapted MB-LPS2 full-scale range would be suggested by the flow-to-pressure conversion function. For example, for a simple-shaped conversion element, the full-scale pressure should vary roughly as the square of the desired full-scale flow. Then if, instead of 75 lpm, an air flow range of 150 lpm were desired (double the 75 lpm which was found above), an MB-LPS2-series sensor would be chosen having full-scale differential pressure range roughly $2^2 = 4$ times larger → roughly 4"wc ~ 1000Pa. This would be MB-LPS2-02-400U5N. Note that this estimate of the required full-scale differential pressure is only approximate, (still requires experimental verification), because the particular characteristics of the given air-flow conduit and conversion element may vary significantly.

Fig. 5 shows the output voltage vs. ΔP, for three different sets of sensors (described in more detail below). The set called "LPS2-02-400U5N" has response curves similarly-shaped and similarly-curved to the MB-LPS2-02-100U5N sensor used in the measurements described above, but instead of 250Pa full-scale they have ~1000Pa full scale. One sensor from this set was connected to the same flow tube and experimental apparatus as described above. This sensor's output voltage is plotted vs. TSI flow-measurement output in Figs. 4a and 4b, for comparison with the MB-LPS2-02-100U5N. Again the noise of the sensor is about +/-0.5mV. As seen in Fig. 4b, the system can resolve **0.5 lpm** flow, while also reaching the desired max flow **150 lpm** in Fig. 4a.

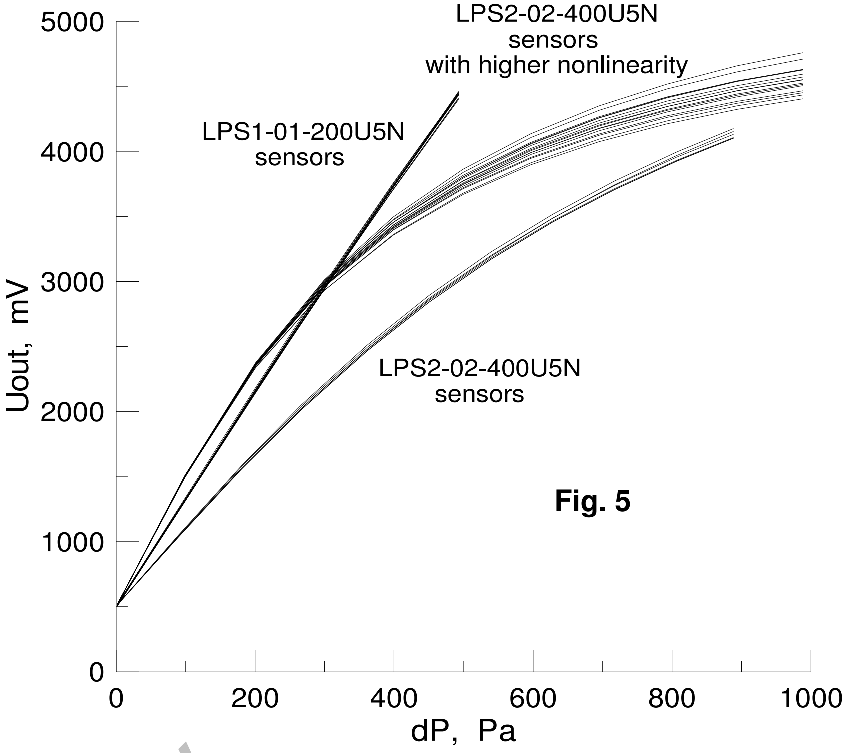


Fig. 5

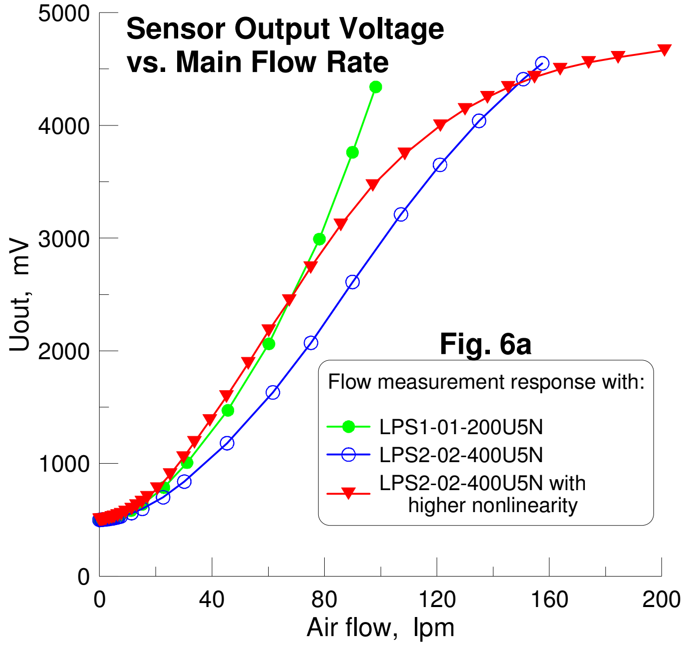
ADAPTING / CUSTOMIZING THE SENSOR:

What if a finer resolution is needed, while maintaining the same maximum flow measurement? MB-LPS2-series sensors can be customized to give a wider dynamic range (full-scale differential pressure divided by minimum detectable differential pressure), with the tradeoff of increasing the non-linearity and increasing the measurement-uncertainty at high ΔP.

Fig. 5 (output voltage vs. ΔP), compares the set of LPS2-02-400U5N (6 sensors) mentioned above with a new set of customized MB-LPS2 sensors having wider dynamic range and higher non-linearity, and with a set of MB-LPS1 sensors (MB-LPS1-01-200U5N). Note the different sensitivities at low ΔP.

- A set of 6 MB-LPS2-02-400U5N sensors. These sensors have sensitivity at low ΔP approx 6mV/Pa, significantly lower sensitivity at high ΔP, and moderately wider tolerance at high ΔP.
- A set of 16 customized MB-LPS2 sensors called "LPS2-02-400U5N sensors with higher non-linearity", also having significantly higher dynamic range. These sensors have sensitivity ~10mV/Pa at low ΔP, and much lower sensitivity at high ΔP. Also, while the slopes are consistent at low ΔP, they are subject to a much wider tolerance at high ΔP.
- A set of 14 MB-LPS1-01-200U5N sensors, having linear response and significantly smaller dynamic range of ΔP measurement (~1000x). These sensors have sensitivity ~8mV/Pa throughout their ΔP range.

Figs. 6a and 6b compare output voltage vs. flow for three sensors, one from each of the three different sets shown in Fig. 5. Fig. 6a shows substantial differences in the range of flow that can be measured by each of the three sensors, with the same air-flow conduit. “LPS2-02-400U5N with higher nonlinearity” can measure up to 200 lpm, significantly greater than “LPS2-02-400U5N”, while “MB-LPS1-01-200U5N” can measure up to roughly 100 lpm.



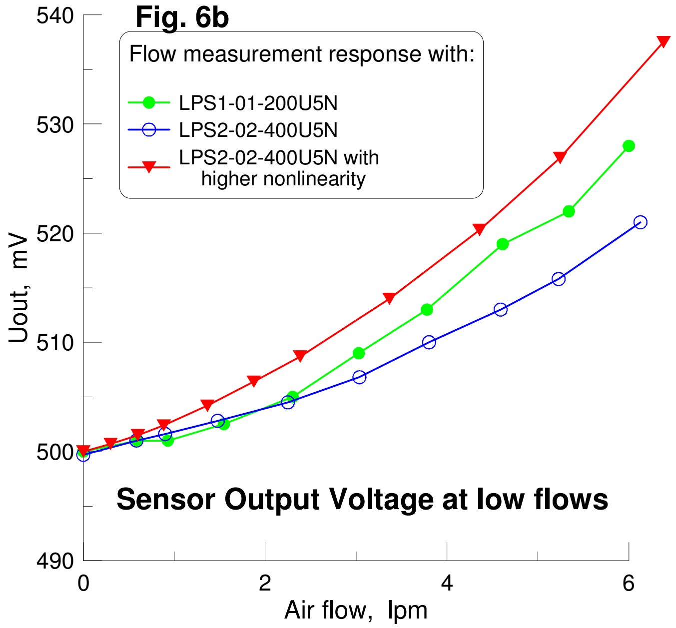


Fig. 6b shows the sensor output at low flows. The resolution at low flows is determined by both the sensitivity (slope) and the noise-level of the sensor output. Figs. 7a and 7b show noise traces for (a) LPS2-02-400U5N with higher nonlinearity (~+/-0.5mV), and (b) MB-LPS1-01-200U5N (~+/-3mV). In this flow-measurement configuration with this particular flow tube, LPS1 cannot resolve flow below about 1 lpm, while “LPS2-02-400U5N with higher nonlinearity” can resolve flows down to 0.5 lpm and below, better than found above for “LPS2-02-400U5N”.

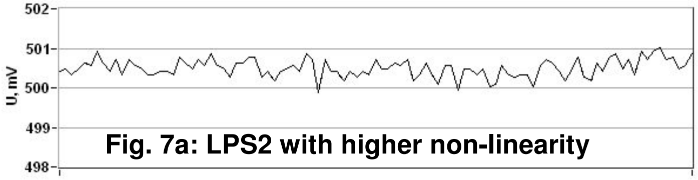


Fig. 7a: LPS2 with higher non-linearity

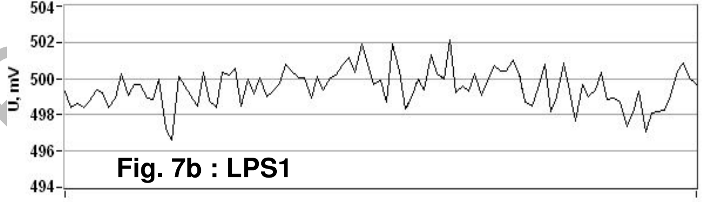


Fig. 7b : LPS1

GENERAL DESCRIPTION OF MB-LPS ΔP SENSORS (MB-LPS2 AND MB-LPS1):

MB-LPS series low-pressure sensors sense differential air (or other non-corrosive gas) pressure, inferring differential pressure between its two ports from nano-liters per second gas-flow through an integrated air-flow channel having high pneumatic impedance (flow-impedance). The transducer is a MEMS-based thermal-anemometer on a monolithic silicon chip. Rejustor technology combined with CMOS circuitry provides on-chip-integrated analog-only electronics for compensation and conditioning.

Some important features of Microbridge MB-LPS sensors:

- Typical gas flow through Microbridge's MB-LPS sensors does not exceed 2-3µl/s which is intended to be far lower than the main flow being measured in most macroscopic flow-measurement applications (for example in the HVAC air duct or other air-flow conduit). Note that this by-pass configuration provides the best protection of the sensor against dust and liquid content which may be present in the main flow.

- There are two main types of MB-LPS sensors → sensors with (a) linear, and (b) nonlinear pressure response.

    - (a) The operating measurement range of "linear" sensors varies from ≤25Pa to ≥500Pa. The sensors have dynamic range of ~1000x (resolution 0.1%), which is enough for many applications (see MB-LPS1 datasheet).

    - (b) The operating measurement range of "nonlinear" sensors can be from below 250Pa to ~2500Pa. The sensors can be customized to have dynamic range of pressure measurement from below 10000x to greater than 20000x. These sensors with nonlinear pressure response have higher resolution of pressure measurement at low ΔP (≤0.01% of full scale ΔP), and lower sensitivity and resolution at high ΔP (see MB-LPS2 datasheet).

- The sensors provide amplified output (0.5 – 4.5V), have low power consumption, powered by 5VDC, have temperature compensation of Offset and Sensitivity, and have small size. One of the biggest advantages is that they operate by using at least 100 times less flow passing through the sensor than the sensors manufactured by the competitors, which provides substantially greater immunity to contamination by small particles in the main flow (see Microbridge's app note MB-APP51 re dust test).

MB-LPS sensors can be calibrated such that they can operate with almost all existing air-flow conduits.

⇨ Contact Microbridge with your specific requirements.