microbridge

APPLICATION NOTE

MB-LPS1 ΔP Sensors: Immunity to Variations in Relative Humidity

ABSTRACT:

MB-LPS differential pressure (ΔP) sensors use a pressure-from-flow (thermal-anemometer-based) sensing principle, where differential pressure is inferred from tiny gas flows through a flow channel. The thermal-anemometer-based mechanism depends on gas transport and thermal properties, which may, in principle, vary with humidity.
Question: ➔ Are these sensors prone to variations in sensitivity as the humidity is changed?
Test: ➔ MB-LPS1 sensors under test are exposed to varying relative humidity levels, at three different temperatures 25C, 40C, 55C. Each sensor's output is compared to a control sensor held at the same temperature, and exposed to the same ΔP, but without variations in relative humidity.
Answer: ➔ Experimental evidence shows low variation, less than +/-1%.

This Application Note MBAPP56 is related to MBAPP54 "*MB-LPS ΔP Sensors: Advantages for High-Humidity Operation (Resistance to Water Obstruction)*".

INTRODUCTION:

MB-LPS series low-pressure sensors sense differential air (or other non-corrosive gas) pressure, inferring differential pressure 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.

The thermal-anemometer sensing mechanism involves transport and thermal properties of the tiny gas flow within the flow channel. This notion is most readily seen in the correction factor for sensitivity as a function of absolute ambient pressure and as a function of the gas whose pressure is being measured. *In principle*, these gas transport and thermal properties may vary with humidity (or relative humidity), leading to the question whether the sensor's sensitivity may be prone to variations as the humidity is changed in the gas whose pressure is being measured. ➔ This Application Note describes an experimental test to examine the question.

EXPERIMENTAL INVESTIGATION OF MB-LPS1 EXPOSED TO VARYING HUMIDITY:

The basic strategy of the test is illustrated in Figs. 1 and 2.

- A humidity chamber (ESPEC LHU-112), with controlled temperature and humidity, was used to house a pair of MB-LPS1 sensors having nominally same full-scale range and sensitivity. Such a pair of sensors with associated circuitry for connection to the data acquisition system, is shown in Fig. 1.
- Each pair of sensors consists of a reference sensor and a sensor under test. During the measurements, such a pair of sensors is inside the chamber and thus equilibrated at a common temperature. The reference sensor is intended to measure the same differential pressure, without variation in humidity.
- The reference sensor has one port open to the room ambient air, and one port connected to a common external pressure reservoir which will be used to apply a same differential pressure simultaneously across the pair of sensors.
    - Note that the silicone tubing connecting the reference sensor to the room ambient is 1/8"ID and has at least 15cm of its length inside the temperature-controlled chamber. Since the flow through the MB-LPS sensors is very slow (due to the high pneumatic impedance of the

sensors), the room air flow inside the tubing has substantially reached the chamber temperature by the time it reaches the reference sensor itself.

- The sensor under test has one port open to the humidity-and-temperature-controlled air inside the chamber, and one port connected to the same external pressure reservoir which is in common with the reference sensor.
- Before each measurement, with the fan of the oven turned off, the connection to the common external pressure reservoir was disconnected, and the corresponding ports of both sensors were exposed to the room ambient. In this state, the reference sensor’s output corresponded to its zero offset, while the sensor under test sensed the pressure difference between the chamber and the room.
    - *Important*: In no case did the two sensors’ outputs differ by more than 100mV during this zero-offset check, confirming that the pressure inside the chamber was within a few Pa of the room ambient pressure. (This was as expected since the chamber was not hermetically sealed).
- For each measurement, after reconnection of the common external pressure reservoir, the 10ml syringe was used to establish a negative pressure in the external pressure reservoir. A volume of roughly 5ml of air was pulled into the syringe, which reduced the pressure in the external pressure reservoir by a few hundred Pa. This effectively began pulling air into both sensors through their other (open) ports. The red arrows in Figs 1 and 2 show the direction of air flow in the silicone connection tubing and near the open port of the sensor under test.
    - This negative pressure immediately saturated the output of both sensors (since the established differential pressure was always greater than the full-scale range of the pair of sensors).
    - The estimated volume of air passing through the sensor under test in about 2 minutes was more than 2ml → effectively allowing the latent air inside the sensor packaging (<0.2ml) to be substantially replaced with air of known humidity.
    - After this “ventilation” procedure, the differential pressure was allowed to decrease until the sensors’ outputs were no longer saturated, and then the outputs were recorded and plotted in graphs such as in Fig. 3, at several points while the differential pressure reduced toward zero.
- Actually, four pairs of MB-LPS1 sensors were present in the chamber simultaneously. Only one is shown in Figs. 1 and 2. Each pair was individually-addressable electronically. The pairs consisted of:
    - Pair 1: unidirectional, 250Pa full-scale
        - B0211-0565 reference sensor
        - B0211-0566 sensor under test
    - Pair 2: unidirectional, 250Pa full-scale
        - B0211-0567 reference sensor
        - B0211-0568 sensor under test
    - Pair 3: unidirectional, 50Pa full-scale
        - B0211-0139 reference sensor
        - B0211-0140 sensor under test
    - Pair 4: unidirectional, 50Pa full-scale
        - B0211-0141 reference sensor
        - B0211-0142 sensor under test
- Testing was done at three chamber temperatures: 25℃, 40℃, and 55℃. The table (below, right) lists absolute humidity (from literature) at different temperatures and relative humidity (RH) values.
    - Note: absolute humidity is defined as the mass of the water vapor present per unit volume of moist gas at a given temperature and pressure.
- The table also shows (enclosed in red) which RH values were practically attainable in the humidity

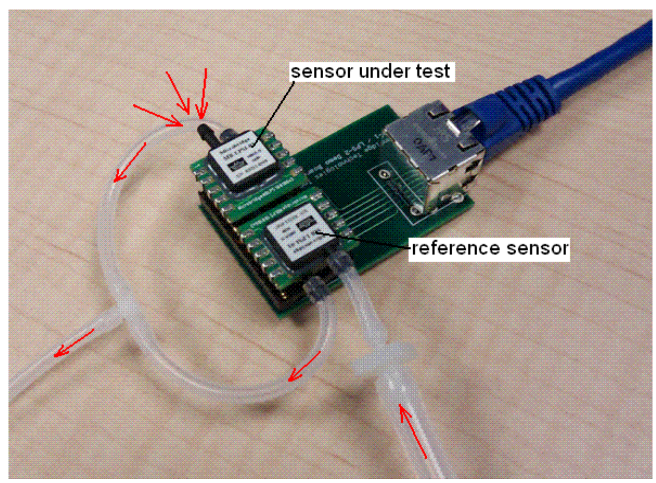

Fig. 1. Reference sensor and sensor under test on PCB for connection to data acquisition system.

Table 1:

Absolute Humidity [g/m^3] as function of temperature and relative humidity

	5°C	25°C	40°C	55°C
RH=20%	1.36	4.63	10.27	20.93
RH=26%	1.77	6.01	13.35	27.21
RH=40%	2.73	9.25	20.54	41.86
RH=60%	4.09	13.88	30.80	62.79
RH=80%	5.46	18.51	41.07	83.72
RH=97%	6.62	22.44	49.80	101.51

generated humidity/temperature levels

chamber used in this study. Very low humidity levels were not practically attainable, especially at low temperatures.

- The ambient atmospheric pressure outside the chamber was 101.9kPa, and the temperature was 21.5°C with RH 29%. Therefore, if RH were to affect the sensitivity of the sensors, the highest RH values should show the most significant changes in the sensor's sensitivity.

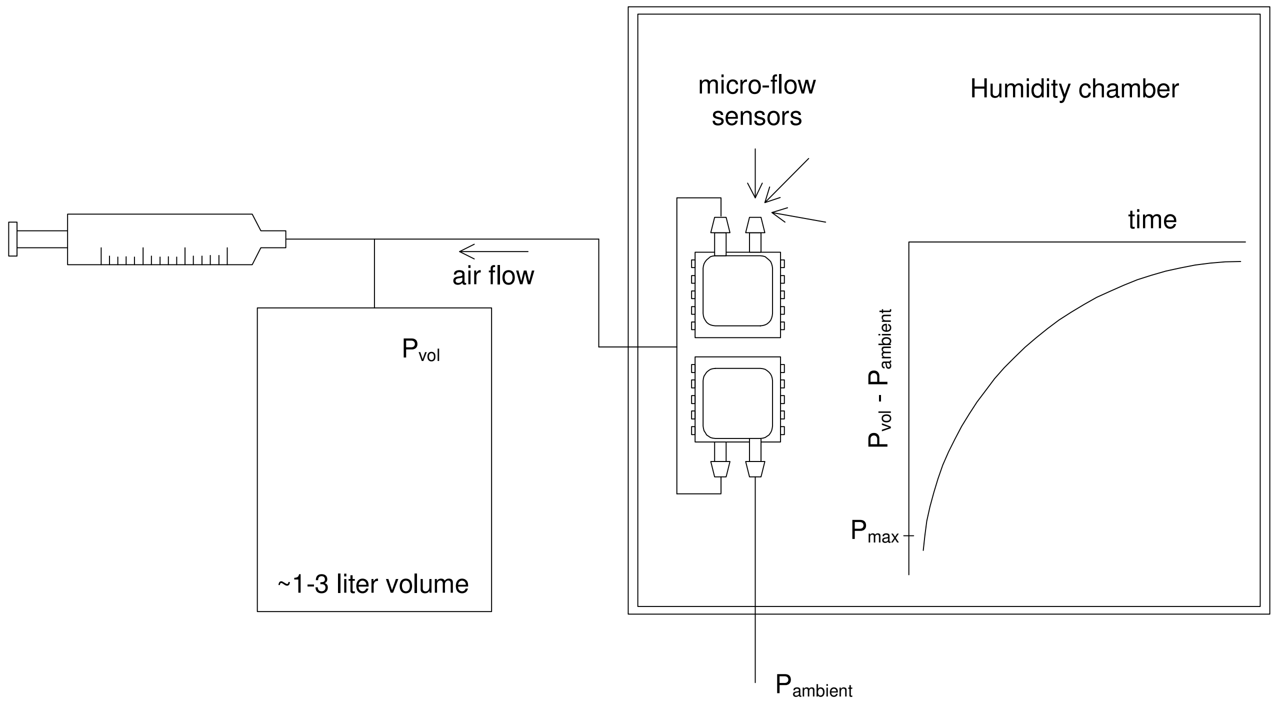

Fig. 2. Schematic of experimental setup.

- For each of the four pairs of sensors, at each temperature, a graph similar to Fig. 3 (below) was obtained, for all RH set points outlined in the table above (12 graphs, 48 curves). In Fig. 3, note that the five curves for the five different humidity settings are almost indistinguishable. For each of the 48 curves, the slope was calculated by a best-fit straight line method.
- At each temperature, the lowest available relative humidity was taken as the reference for normalization.
    - 60%RH at 25°C
    - 40%RH at 40°C
    - 26%RH at 55°C
  - The 48 normalized results are presented in Table 2 below.
- At 55°C, the greatest available range of %RH was available, from 26%RH to 97%RH.
- ***Main Result***: Over all temperatures, no humidity-induced change in sensitivity greater than +/-0.9% was observed.

Fig. 3.: Curves of sensor under test B0211-0566's ΔP reading vs. reference sensor B0211-0565's ΔP reading, for 5 different settings of Relative Humidity, all at 55℃.

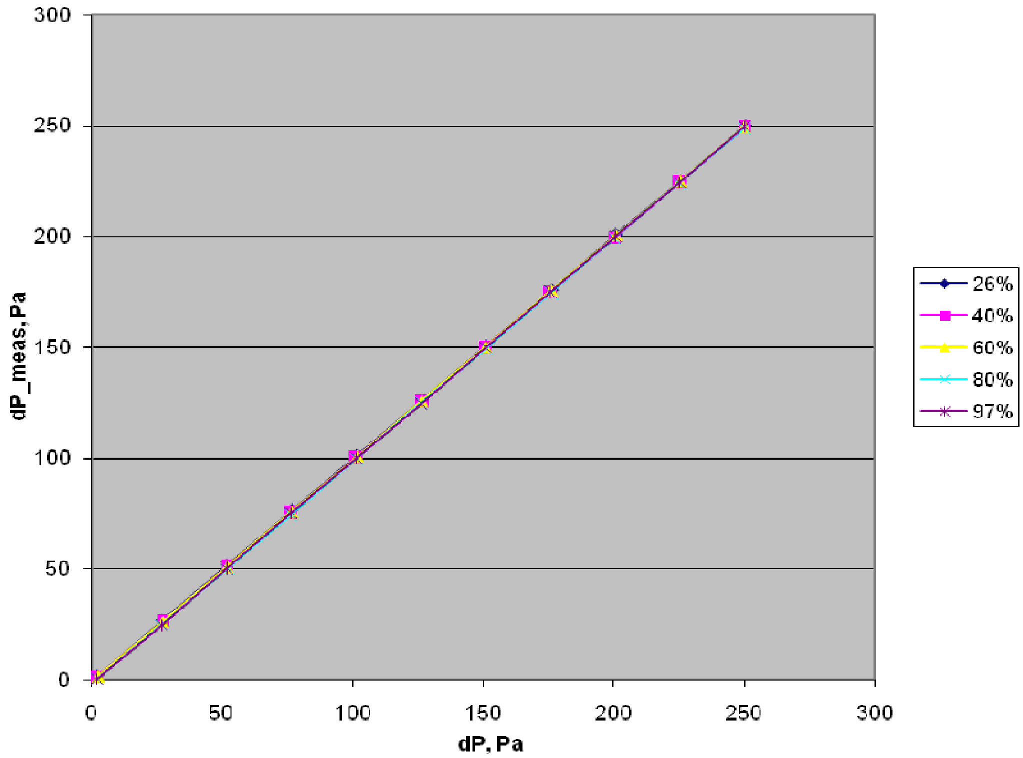

Table 2		Normalized Change in Sensitivity**		
Sensor Pair ID	**%RH**	**25℃**	**40℃**	**55℃**
B0211-0565	**26**			0.00%
B0211-0566	**40**		0.00%	0.09%
250 Pa full-scale	**60**	0.00%	0.16%	0.24%
	80	-0.19%	-0.09%	0.28%
	97	-0.43%	0.04%	0.51%
B0211-0567	**26**			0.00%
B0211-0568	**40**		0.00%	0.14%
250 Pa full-scale	**60**	0.00%	0.03%	0.48%
	80	-0.04%	-0.21%	0.73%
	97	-0.20%	-0.06%	0.89%
B0211-0139	**26**			0.00%
B0211-0140	**40**		0.00%	-0.24%
50 Pa full-scale	**60**	0.00%	0.38%	0.55%
	80	-0.60%	0.43%	0.33%
	97	-0.52%	0.66%	0.45%
B0211-0141	**26**			0.00%
B0211-0142	**40**		0.00%	0.23%
50 Pa full-scale	**60**	0.00%	0.42%	0.56%
	80	0.26%	0.61%	0.64%
	97	-0.43%	0.47%	0.80%
**** normalized to the sensitivity at the lowest available %RH.**				

CONCLUSION:

Over all three temperatures studied, 25℃, 40℃ and 55℃, no humidity-induced change in sensitivity greater than +/-0.9% was observed. Microbridge's pressure-from-flow sensors have substantial immunity to variations in ambient relative humidity.