g Sensitivity of Low-Pressure Sensors

OVERVIEW

As pressure sensors are made more and more sensitive in order to measure very low pressures, the more issues with respect to orientation or artifact in the signal due to vibration or acceleration arise.

Thus, if a low-pressure sensor in one orientation (pins down towards Earth, for instance) is measured for zero, and then is rotated to another position, then the zero may change, due to the effect of gravity on the sensor.

This shows up in two areas. The first is simply the orientation dependency of zero. The second is a signal artifact that shows up when a part is put into a vibrational environment. An example would be where a very low-pressure sensor for measuring in HVAC application is mounted near a motor.

THEORETICAL RESPONSE

Every pressure sensor has a spring constant that is used to transduce pressure into a useable signal. The stiffer the spring, the more pressure has to be applied for a given deflection. Further, with structure, there is a certain mass. The combination of a spring and a mass makes a device that will exhibit some sensitivity to acceleration.

SMI has two basic structures in the pressure sensors. The first is a classical flat diaphragm structures and is used in the SMI 5 PSI and above die. The structure has a distributed mass (the diaphragm thickness times diaphragm area) and the mechanical spring constant that sets the deflection. Using classic plate bending analysis, the resonance for a 2mm X 2mm X 20 micron structure is in the range of 70 kHz.

Mechanical models and actual measurements have shown that such flat diaphragm devices in this pressure range have g sensitivities such that at 20,000 to 40,000 g's, the output is equivalent to exerting a 5 PSI pressure on the sensor (include some SM23 data). Thus, in this case, if a 5 PSI part has a 100 mV output at 5 PSI, then the a 1 g acceleration change will show an offset change in the range of 5 microvolts.

On the lower pressure structures, SMI uses a boss-structure where the diaphragm is thicker in the middle than on the edge as shown in Figure 1 below. This can be modeled with the thin edge as a spring and the central boss as a mass. With this approach, classic deflection models show

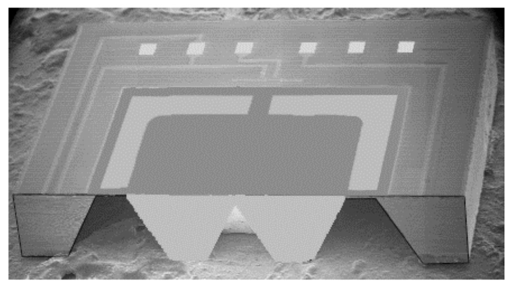

Figure 1 - Cross section of SMI Low pressure Sensor Die

that the boss should give a resonance of about 45.5 kHz for the 1.5 PSI part and a resonance of 22.8kHz for a 0.3 PSI part (square root of 5 due to the 5X difference in sensitivity).

TEST APPROACH

To determine g-sensitivity, the simplest approach is just to place device flat on a table, measuring the offset and then flipping the device upside-down and measuring the offset again. The change in offset is the effect of a 2-g change in acceleration. In doing this test, it is necessary to know how the sensor die is mounted in the package. In the SMI packages, the die are always mounted parallel to the largest flat surface of the package. Thus, in the SM5600 package, for instance, the die is mounted parallel to the cap and perpendicular to the pins.

Because the output changes are sufficiently low, a precision DVM, as well as an amplifier at the measurement site, is recommended.

RESULTS

Shown below are the results of tests on 4 standard SMI types:

SM5552-001 ➔ 0.15 PSI FS part
SM5552-003 ➔ 0.30 PSI FS part
SM5552-030 ➔ 3.00 PSI FS part
SM5502-005 ➔ 5.00 PSI FS part

Three parts from each types were tested. Of the parts, the SM5552-001 (0.15 PSI part), has a special reduced-mass design for low-g sensitivity. The SM5502-005 (5 PSI part) is a standard flat diaphragm device.

As shown in Table 1, the g-sensitivity of 5552-003 and the 5552-030 scale 1 to 1 manner. The 10X more sensitive part is 10X more sensitive to g-sensitivity. By this analysis, if no design changes had been implemented between the die for the 5552-003 and the 5552-001, then the expected %FS/g would be about 0.4%. In stead, because of the special design in the 5552-001 die, the sensitivity is 0.03%/g, not 0.4%/g.

The 5552-001 has on average, a 37 microPSI/g sensitivity. This compares to about 500 microPSI/g for both the 5552-003 and 5552-030. The 5502-005 has 92 microPSI/g.

CONCLUSIONS

The g-sensitivity of several of the SMI die designs have been measured in SM5500 series designs. The results show that positional sensitivity of especially the 5552-001 is very low (about ±0.03% FS error for ±1-g), meaning that the device can be used successfully in applications such as in hand-held gauges where orientation of the instrument may vary thru-out the life of the product.

			UN-AMPLIFIED					AMPLIFIED				
			Subjected To Acceleration					(200x)		(Adjusted)		
Part Type	PSI	Test ID No.	+1g (mV)	-1g (mV)	Sens. (mV/g)	Nominal FS (mV)	% Sens. (FS/g)	+1g (mV)	-1g (mV)	Sens. (mV/g)	Nominal FS (mV)	% Sens. (FS/g)
5552	**0.15**	1	0.594	0.583	0.006	25	0.02%	91.4	87.2	0.011	25	0.04%
		2	0.768	0.751	0.009	25	0.03%	127.4	126.1	0.003	25	0.01%
		3	0.488	0.474	0.007	25	0.03%	80.1	78.1	0.005	25	0.02%
AVERAGE					**0.007**		**0.03%**			**0.006**		**0.03%**
5552	**0.3**	1	-0.677	-0.785	0.054	25	0.22%	-156.3	-177.3	0.053	25	0.21%
		2	-0.643	-0.750	0.054	25	0.21%	-152.0	-171.2	0.048	25	0.19%
		3	-0.718	-0.826	0.054	25	0.22%	-170.0	-190.0	0.050	25	0.20%
AVERAGE					**0.054**		**0.22%**			**0.050**		**0.20%**
5552	**3.0**	1	0.474	0.464	0.005	25	0.02%	74.2	73.0	0.003	25	0.01%
		2	0.640	0.629	0.006	25	0.02%	107.1	105.4	0.004	25	0.02%
		3	0.592	0.581	0.006	25	0.02%	96.6	94.5	0.005	25	0.02%
AVERAGE					**0.005**		**0.02%**			**0.004**		**0.02%**
5502	**5.0**	1	0.201	0.200	0.001	50	0.001%	18.8	18.4	0.001	50	0.002%
		2	0.201	0.198	0.002	50	0.003%	19.3	19.0	0.001	50	0.002%
		3	0.200	0.197	0.002	50	0.003%	17.6	17.2	0.001	50	0.002%
AVERAGE					**0.001**		**0.002%**			**0.001**		**0.002%**