Transient Response of Pressure Sensors

OVERVIEW

One of the issues on pressure sensors is the transient response to sudden changes in pressure, as shown in the picture below. The ultimate transient response is set by a number of parameters including:

- *Pressure System Mechanical compliance,*
- *Pressure System properties (do such effects as "water-hammer" transients occur),*
- *Damping of the pressure signal from the Pressure vessel to the Sensor, and*
- *The Sensor itself.*

Typically, pressure sensor companies have estimated the response time based on several factors and have rated the response in a very conservative fashion (typically 1 mSec for high-pressure parts). Few have offered graphical data to support the typical response time suggested in the data sheet.

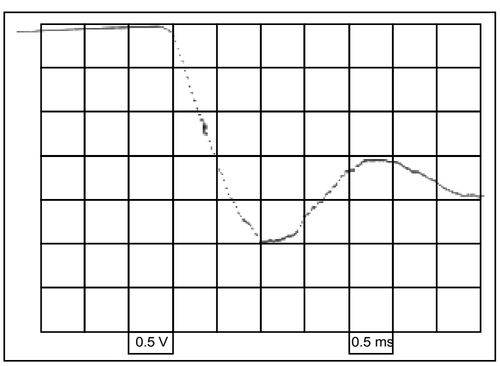

Figure 1 - Transient Response of a SM5103-015

THEORETICAL RESPONSE

The mechanical response of a pressure sensor is set by the mechanical response of the diaphragm. This is a spring-mass system. As such, computer modeling can be used to determine the theoretical response.

SMI has two basic structures in the pressure sensors. The first is a classical flat diaphragm structure 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.

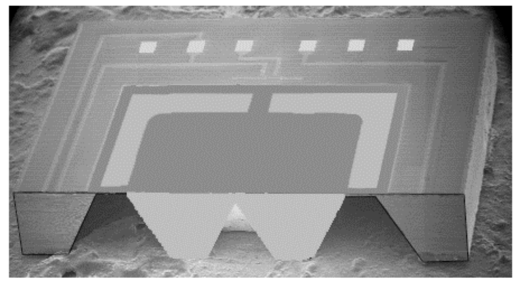

Figure 2 - Cross section of SMI Low pressure Sensor Die

Using classic plate bending analysis, the resonance for a 2mm X 2mm X 20 micron structure is in the range of 70 kHz. Under these conditions, the mechanical system, and not the sensor, primarily sets the response time.

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 2 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 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).

The net conclusion is that the response of the die is, theoretically, much better than is possible to measure with the physical test system.

TEST APPROACH

A number of approaches can be used to check or quantify the response time of a pressure sensor. One of the simplest is a "balloon test". In this case, a balloon is inflated with a pressure that produces a reasonable output from the sensor. The balloon is connected directly to the sensor to

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minimize damping of the response by a pressure manifold.

A data storage system is then set to record a transient response once the balloon is popped. The advantage of popping the balloon is that the event is of very short duration and there is minimal dead-volume. This does require a high data rate to acquire meaningful data. Also, it does require a balloon that is reasonable stretched at the rated pressure. Most balloons are inflated easily with less than 2 PSI; thus, this type of test works best for parts in the 1 to 5 PSI range.

RESULTS

Shown in Figure 3 below is the transient response as recorded for a 5852-015 part. The 1.5 PSI pressure die (SM5103-015) that is used in the 5852-015 is also used in SM5350, SM5450, SM5551, SM5552, SM5651, and SM5652. As such, the results presented here should be common to all of these devices. The 5852-015 was chosen because it gave a high-amplitude output vs pressure.

The plot shows a 2 volt transient step. The 10 to 90% fall time is approximately 0.7 mSec. The plot also shows that the response has a 2 mSec resonance (500 Hz). Based on this data, one should expect the SMI 5103-003 to give about a 1.5 mSec response time. However, as noted above, the theoretical response of the sensor itself should be 10X faster.

CONCLUSIONS

A technique has been reported to allow users to evaluate the transient response of pressure sensors. When the approach was applied to the SM5852-015 part, a step response of 0.7 mSec was achieved.

Based on the theoretical response of the sensor (45.5 kHz), even this approach likely is detecting the mechanical transient associated with the pressure system and ***not*** the sensor itself.

Thus, based on the recorded data and the theoretical performance of the part, the general specification of a response time of less than 1 mSec is likely due to the

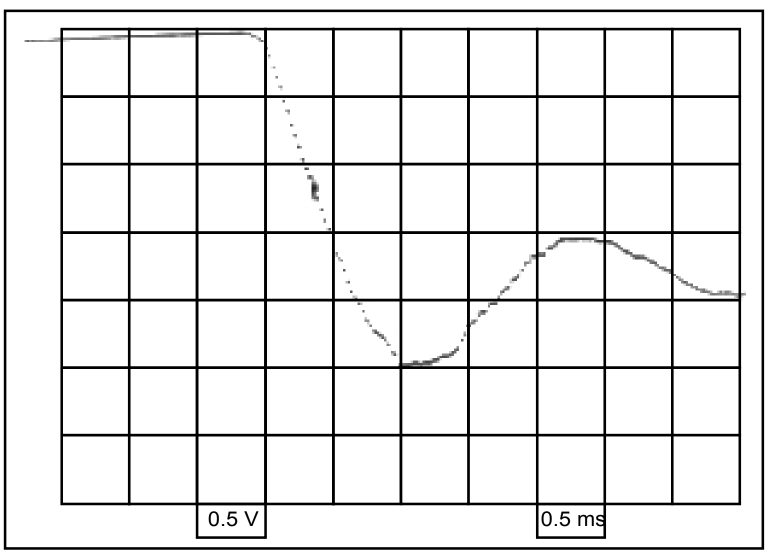

Figure 3 - Transient Response of 5852-015 Part