Effective and active temperature compensation of high-pressure MEMS pressure transducers for aerospace applications

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KEYWORDS

MEMS Pressure Transducer, Temperature compensation, Nonlinearity+Hysteresis.

ABSTRACT

In this Paper, we present the effect of active (programmable) temperature compensation for 0-200Bar in house developed Aerospace quality MEMS gauge Pressure Transducers using ZMD based IC. Two numbers of 0-200 Bar Gauge Pressure MEMS Transducer's raw output (in mV) was compared with temperature and span compensated amplified output values (in Volts). The drift values were calculated. The effect of Nonlinearity+Hysteresis, Full Scale Output (FSO) and Zero Offset for various input temperatures were tabulated and a graph was drawn. A Static hydraulic dead weight calibrator (Fluke Make P3125) was used and a linear relation between Pressure Vs Output was obtained. The raw output data in mV as well as temperature (-40ºC to +80ºC) compensated output (in Volts) was plotted with respect to input Pressure. The Non linearity +Hysteresis value after temperature compensation was found to be 0.3%FSO. Temperature drift values obtained were better than 2 x 10-4/FSO/ºC.

1. Introduction

Aerospace transducer requirement demands repeatable, stable, low hysteresis and linear output values at temperatures between -40ºC to +80ºC. At Centre for Nano Science and Engineering (CeNSE), IISc we have designed, developed, fabricated, packaged and tested MEMS based high Pressure Piezoresistive Gauge type Transducers to meet aerospace standards. The effect of temperature cycling between -40ºC to +80ºC was studied for 0-200bar Gauge Pressure Transducer. The raw output of as fabricated Pressure Transducer (without electronics) for five equal intervals of ascending and descending Pressure values at --40ºC, +25ºC and +80ºC was plotted (Fig.1). The deviation in Full scale (mV) output was noticeable which varies from 140.840mV to 201.622mV and Zero Offset values also vary from -16.202mV to -29.209mV. These deviations to be compensated to achieve a single near linear relation and this was achieved by active temperature compensation using ZMD 31050 IC [7]. The mV output is amplified to Volts and by programming ZMD IC for the required zero offset and Full-scale output values, a linear relationship between input pressure and output was achieved (Fig.2). The overall Nonlinearity + hysteresis is found to be better than 0.3%FSO.

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Fig 3 clearly shows the improvement in Zero offset, span, Full scale output (F.S.O) and nonlinearity + Hysteresis values before and after active temperature compensation. In this way any aerospace MEMS Pressure Transducer output can be standardized and temperature compensated to the desired specifications. These tests were carried out using Hot & Cold enclosure (Votsch VCL 7003) and Hydraulic Dead weight calibration setup as shown in Fig.4. The overall maximum temperature drift values obtained between -40ºC, +25ºC and +80ºCwas found to be better than 6×10-5/FSO/ºC.

2. Experimental

MEMS Pressure sensor was mounted on the hydraulic calibrator adopter (Fig 4) and calibrated for 0-200 bar input pressure in five ascending and five descending steps of equal intervals of 40 bar. The output voltage (mV) was noted down for each interval without electronics. This Senor was mounted in the Hot and Cold chamber to calibrate in different temperatures (+25ºC, -40ºC, +25ºC, +80ºC). After one hour of stabilization in each temperature sensor was calibrated and noted down the change in the output voltage. Again, the calibration was carried out connecting to the signal conditioning IC ZMD 31050 (Fig.5, 6) to compensate the sensor for above temperatures. Thus, amplified output (in Volts) was tuned by programming to the required values and again calibrated in different (+25ºC, -40ºC, +2º°C, +80ºC) temperatures.

3. Result and Discussions

A packaged 0 - 200 bar MEMS pressure sensor was calibrated using pressure calibration system which consists of a hydraulic dead weight tester (Fluke P-3125), DC power supply (Gwinstek GPD-2303S) and a Digital multimeter (Agilent 34401A). The MEMS Sensor Bridge was excited by 5V DC. The output of the mounted sensor was measured at five equal pressure intervals in ascending as well as in descending steps after stabilizing in each step for one minute. For Thermal characterization, the pressure sensor was loaded in a Hot and Cold chamber having connected to the above referred set-up. The calibration was repeated at +25°C, -40ºC, +25ºC and +80ºC by noting pressure, output and temperature after stabilizing at each temperature for an hour.

The output characteristic of the pressure sensor under said temperatures (without electronics) are shown in Fig 1. It can be seen from Fig.1 that the Non-linearity, Zero offset and span is not the same between -40ºC to 80ºC. Table 1 shows the Pressure Versus raw output characteristics of 0-200 bar pressure sensor along with Nonlinearity+Hysteresis values calculated using least squares best fit straight-line method.

The pressure sensors used in aerospace and automotive industry should operate stably between -40ºC to 80ºC. The output of the sensor to be corrected or compensated at various Pressure inputs with respect to temperature. It can be seen from Fig.2 that the non-linearity, zero offset and span is almost the same between -40ºC to +80ºC after compensation as shown in Table 2. The sensor output with and without electronics is Plotted as shown in Fig.3.

Table 1
Pressure Vs raw output (without Electronics) under temperature cycling.

Pressure (Bar)	Output voltage (mV)		
	@ -40°C	@ 25°C	@ 80°C
0	-16.202	-27.516	-29.209
40	27.945	10.215	5.047
80	72.056	47.715	39.191
120	115.667	85.037	73.198
160	158.827	122.188	107.090
200	201.622	158.890	140.840
160	158.844	122.121	107.113
120	115.598	85.185	72.933
80	71.978	47.889	38.887
40	27.926	10.318	4.776
0	-16.316	-27.524	-29.356
Max NL & Hy (% FSO)	0.41	0.32	0.15
Span (mV)	217.824	186.406	170.049

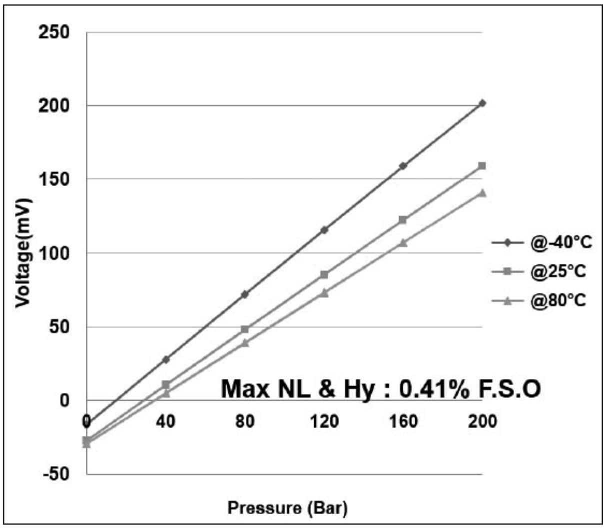

Fig. 1. Pressure Vs raw output with temperature.

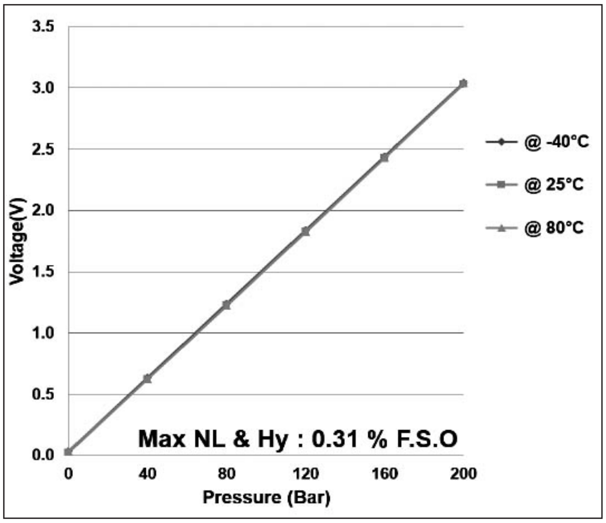

Fig. 2. Pressure Vs output voltage with electronics.

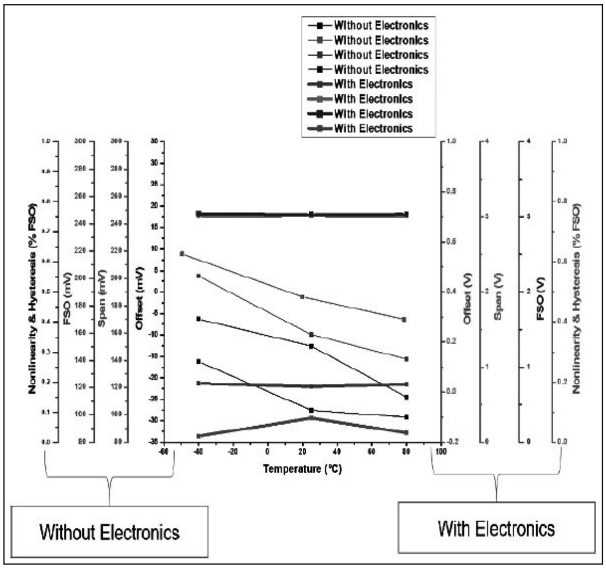

Fig. 3. Temperature compensation of MEMS Pressure transducer with and without electronics.

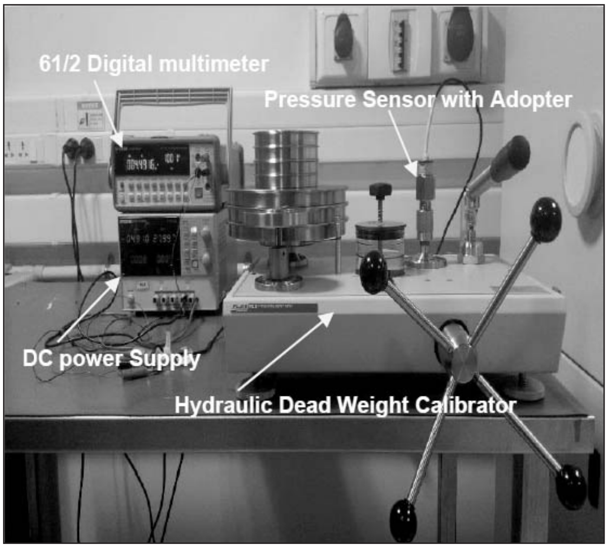

Fig. 4. Pressure transducer mounted on the hydraulic pressure calibrator.

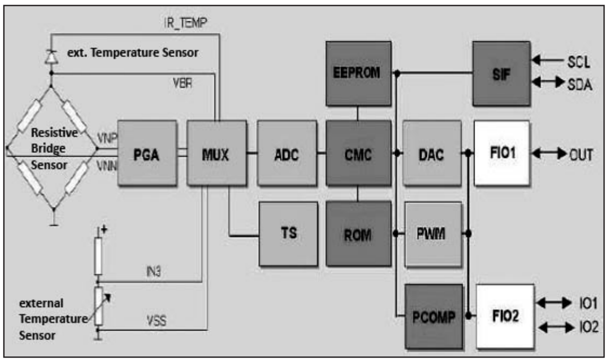

Fig. 5. ZMD31050 block diagram.

Table 2
Pressure Vs output voltage with Electronics under temperature cycling.

Pressure (Bar)	Output voltage(V)		
	@ -40°C	@ 25°C	@ 80°C
0	0.035	0.022	0.031
40	0.637	0.622	0.625
80	1.238	1.222	1.222
120	1.840	1.826	1.825
160	2.442	2.428	2.428
200	3.044	3.033	3.039
160	2.442	2.429	2.428
120	1.840	1.827	1.824
80	1.238	1.224	1.222
40	0.637	0.624	0.625
0	0.035	0.022	0.031
Max NL & Hy (% FSO)	0.02	0.08	0.31
Span (V)	3.009	3.011	3.008

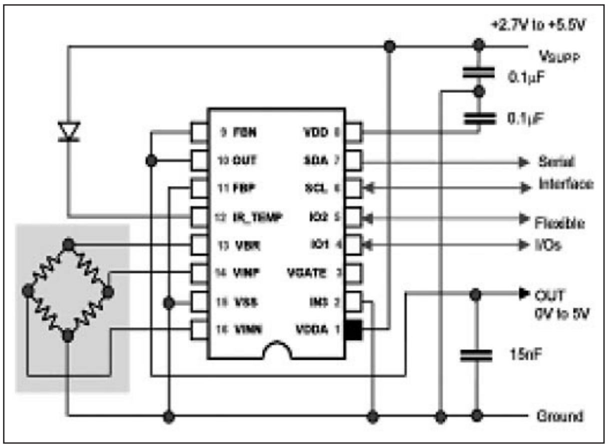

Fig. 6. ZMD 31050 IC temperature compensation circuit.

4. Conclusion

This work has demonstrated an effective and active temperature compensation technique for high range MEMS pressure transducers to meet the requirement of aerospace, automotive and industrial standards. The result also shows that the temperature compensation improves the accuracy, Sensitivity, Nonlinearity + Hysteresis, Span, Zero Offset, Full Scale Output of the MEMS pressure transducer.

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6. References

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7. ZMD31050- *Advanced Differential Sensor Signal conditioner*- Application Note.

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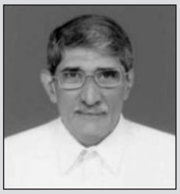

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