GAIN PROGRAMMING USING A MEAS PRESSURE SENSOR

APPLICATION NOTE

INTRODUCTION

MEAS offers a broad line of pressure transducers with low level output, temperature compensation, and a built-in gain programming resistor. This laser trimmed resistor programs the gain of an external (customer provided) amplifier to normalize the pressure sensitivity variation of the sensor. This allows the output of the amplifier to be independent of the sensor used, providing interchangeability and high level output at very low cost. This feature is available on all HIT, TO-8, and isolated diaphragm (ISO) products. Please refer to the individual product data sheets for more information.

BASIC CIRCUIT

The effective electrical model of the transducer, together with a basic signal conditioning circuit, is shown in Figure 1. The pressure sensor is a fully active Wheatstone bridge which has been temperature compensated and offset adjusted by means of thick film, laser trimmed resistors. The excitation to the bridge is a constant current which is supplied through the +EX and -EX pins. The low-level bridge output is at +O and -O, and the amplified span is set by the gain programming resistor (r).

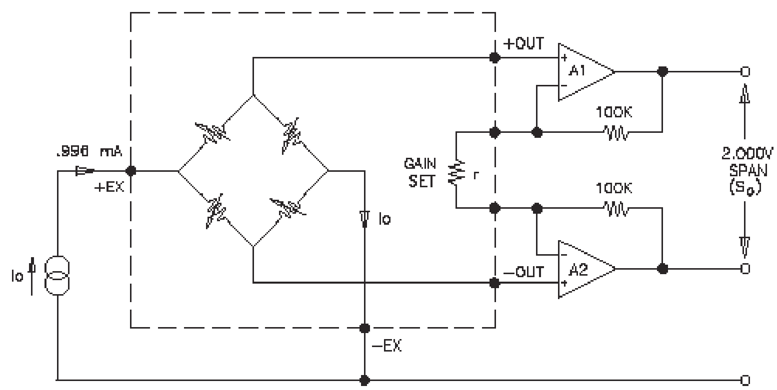

Figure 1 - Basic Configuration Gain - Programming Interchangeable Sensor

Resistor r is laser trimmed for each unit using the following algorithm:

$$r = \frac{200Si}{2-Si} \qquad [1]$$

Where: Si - sensor span value (V) at a reference excitation current (IO = 0.996 mA)

r - resistance in (kΩ)

The output span, So, at the differential output of amplifiers A1- A2 (see Figure 1) is then programmed as follows:

$$S_o = AS_i\left(\frac{r+2R}{r}\right) = 2A\left[\frac{R}{100} + \frac{S_i(100\text{-}R)}{200}\right]$$

Where: A = I/ IO, ratio of excitation current I to reference current IO (Figure 1)
R - feedback resistors, in [kΩ]
Si - sensor span at the input of the amplifier

If 100k feedback resistors are used, the expression for output span is simplified to:

So = 2A [3]

and is constant for all sensors independent of sensor span Si. The output span is also independent of the pressure range of the sensor. For other values of the feedback resistors (R), the output span (So) will vary with the sensor span (Si). Assuming I = IO, we can calculate So variations.

Table 1. Output Span (SO) Variation

R	SO(Si=40 mV)	SO(Si=90 mV)	SO variation [±%]
50 K	1.0200	1.0450	1.23
75 K	1.5100	1.5225	0.41
99 K	1.9804	1.9809	0.01
100 K	2.0000	2.0000	0.00
101 K	2.0196	2.0191	0.01
200 K	3.9600	3.9100	0.63
500 K	9.8400	9.6400	1.02

As shown in Table 1, a large deviation from the optimum feedback resistance of 100 k can be tolerated while still maintaining transducer interchangeability. For the optimum feedback resistance (100 k), calibration accuracy is a function of the accuracy of the excitation current, feedback resistors and sensor trimming. The inaccuracy caused by the excitation current and feedback resistors can be made negligible by the use of precision components. Therefore without pressure testing, a 1% system accuracy can be achieved. The standard gain programming resistor, r, has a TCR 50 ppm/°C and a trimming range of 2.5 to 12.5 kΩ. For volume orders, a custom trimming algorithm can be made to achieve any desired output span.

SIMPLE SIGNAL CONDITIONING CIRCUIT

The signal conditioning circuit shown in Figure 2 provides a precision constant current source for sensor excitation and an instrumentation amplifier with the gain programmed by sensor feedback resister r. To correct for pressure non-linearity or to generate output options other than 0-5V please refer to Technical Note TN-001, "Signal Conditioning for IC Pressure Sensors."

The current source is controlled by the 1% band-gap reference diode, VR. The reference current IO is defined by:

IO = (EO - eO)/R2 [4]

Where: E O - diode reference voltage: 1.235V ±1% (LT1034-1.2 or LT1004-1.2)

eO - offset of amplifier A1

R2 - feedback resistor

Selecting amplifier A1 with an offset voltage below 1 mV and a ±1% tolerance of resister R delivers current IO =0.996 mA with a typical accuracy of 1.08%.
The first differential stage of the instrumentation amplifier A2-A3 may have a zeroing potentiometer (P).
For 0P227 amplifiers, the zero range is typically 4 mV in reference to the input with a differential offset below 0.5 mV. This leaves about 3.5 mV zeroing range for the compensation of the sensor offset which typically is below 1 mV.

The second stage of the amplifier provides additional amplification R8/R5 and translates the differential floating voltage from the first stage into a single ended output voltage. Modifying equation [3] the expression for overall span (S) can be found as follows:

$$S = 2 \cdot A \cdot R8 / R5 = 5.000V \ @ \ A = 1 \qquad [5]$$

The overall accuracy of the span is effected by the accuracy of feedback resisters R 3 through R 8.
Using 0.1% resisters such as Mepco/Electra 5063Z, a typical gain error will be about 0.24%. The accuracy error may be decreased when matched thin film resistors are used such as Beckman 694-3-A. The combined span error of the entire signal conditioning circuit at a reference temperature will then typically be about 1.1% without any adjustment or pressure testing. This will be superimposed on the sensor's accuracy of 1%.
If additional calibration and normalization are desired, resister R2 can be replaced with a series combination of a potentiometer and a resistor (Figure 2). The potentiometer can be adjusted to set the bridge excitation current (I) to achieve the exact span voltage (S) with full scale pressure applied to the sensor.
If no pressure source is available, the gain error of the amplifier can be reduced by using the procedure outlined below. This method may be used instead of using the precision resisters discussed above for R2 through R8. The sensor span error of 1% will remain however. Calibration procedure:

- replace resistor r with an external resistor 7.50Ωk 0.1%
- check gain K of the instrumentation amplifier and calculate the gain ratio X (in reference to the ideal gain KO = 69.028V/V) where X = K/KO
- set current IO = 0.996/X(mA) by adjusting the potentiometer, thus completing calibration.

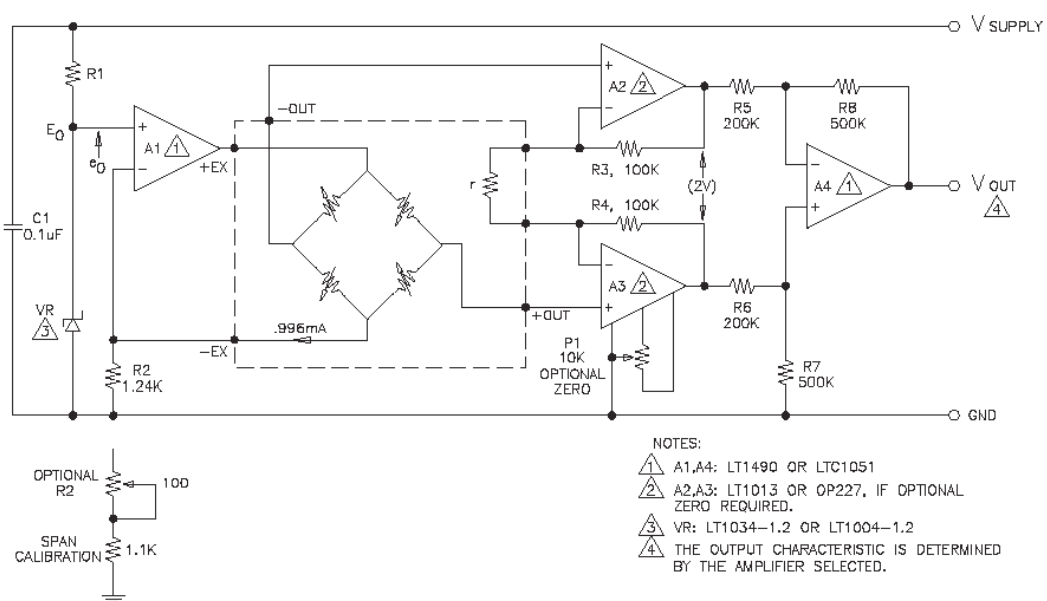

Figure 2 - Simple Signal Conditioning Circuit

Assuming a 6.4 kΩ (50ºC) maximum bridge resistance, a 0.996 mA bridge current and a 1.2V diode reference voltage, it follows that the maximum output voltage of amplifier A 1 can approach 7.7V. Also, the positive saturation voltage at 1 mA output current for the LTC1051 amplifier is 0.5V. Therefore, the minimum excitation voltage, which is a function of the current source and amplifiers used, would be 8.2V (7.7V + 0.5V) for the LTC1051. For the LT1490, the minimum excitation voltage should be 7.9V.
The maximum excitation voltage is limited by the voltage handling characteristics of the specific amplifier used.

ADDITIONAL INFORMATION

For a detailed discussion of the compensation circuit, and for output voltages other than 0-5V, please refer to Application Notes APP-01001 and APP-01005.

NORTH AMERICA
Measurement Specialties,
a TE Connectivity Company
45738 Northport Loop West
Fremont, CA 94538
Tel: 1-800-767-1888
Fax: 1-510-498-1578
Sales: customercare.frmt@te.com

EUROPE
Measurement Specialties (Europe), Ltd.,
a TE Connectivity Company
26 Rue des Dames
78340 Les Clayes-sous-Bois, France
Tel: +33 (0) 130 79 33 00
Fax: +33 (0) 134 81 03 59
Sales: customercare.lcsb@te.com

ASIA
Measurement Specialties (China), Ltd.,
a TE Connectivity Company
No. 26 Langshan Road
Shenzhen High-Tech Park (North)
Nanshan District, Shenzhen 518057
China
Tel: +86 755 3330 5088
Fax: +86 755 3330 5099
Sales: customercare.shzn@te.com

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