Sensym Application Dept.

INTRODUCTION

The SCX series if sensor provide a very cost effective method to measure pressures in the full scale range from 1 psi to 150 psi. The SCX series incorporates integral thick film passive networks to compensate the bridge for span, span temperature effects, and offset voltage. With preset factory compensation of the above parameters, the SCX family becomes a very cost effective component to use by simply adding gain to the sensor's output.

This application note discusses the design of a low cost, but high performance amplifier which can be used with the SCX devices when it is desirable, or necessary, to operate the device from a single supply voltage.

The amplifier discussed will operate equally well over a supply range from +5 V to +15 V and provides an output voltage that will swing within millivolts of the power supply and ground. The design makes use of a minimum number of components and is easy to produce in volume manufacturing due to the fact that the adjustments that are required are totally non-interactive. An example is given for the design of a tension control system for a magnetic tape air bearing.

AMPLIFIER DESIGN

The output of the sensor is given by the following equation:

$$V = SV_S P \pm V_{OS} \qquad (1)$$

where:

- V is the differential output voltage of the bridge in mV
- S is the sensitivity in mV/v per PSI
- V_S is the voltage applied to the top of the bridge
- P is the applied pressure in PSI.
- V_{OS} is the differential output voltage (error) that is present when the applied pressure is zero.

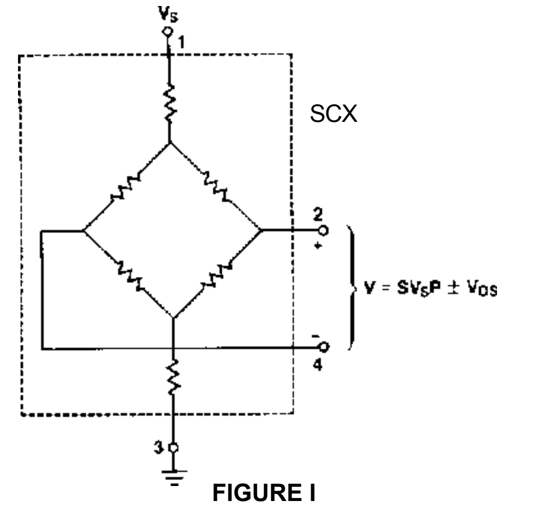

FIGURE I

The first term on the right side of the equation, S • V • p, is known as the *SPAN*. From the SCX data sheet, the span will be found to be in the range of 18 mV (for SCX01) to 100 mV (for SCX100), and the offset voltage, V_{OS}, ranges from ±300 µV to ±500 µV, when operated from a bridge supply voltage of 12.0 volts. Since the span and offseet voltage are both ratiometric to the supply voltage, these parameters can be easily calculated for supply voltages other than 12 volts. For example, for V_S equal to 5.0 volts, the span and the offset should be 5/12 of the data sheet guaranteed parameters.

Because the output voltage given in equation 1 is a differential output, the amplifier must perform the function of converting the differential output to a single-ended output referred to ground. Secondly, the design must provide a method of eliminating the V_{OS} term so that the voltage at the output of the amplifier does not contain this error term. Thirdly, since the common-mode voltage appearing at the arms of each output is approximately one half of V_S, the amplifier should not provide gain to this common-mode voltage. That is to say, the amplifier circuit should have very high common-mode rejection. The amplifier should not load the bridge, which would cause additional errors, and of course the amplifier circuit should amplify the signal to provide the desired output voltage. Finally all adjustments necessary to provide the above functions should be non-interactive. The circuit shown in figure 2 meets all of these requirements.

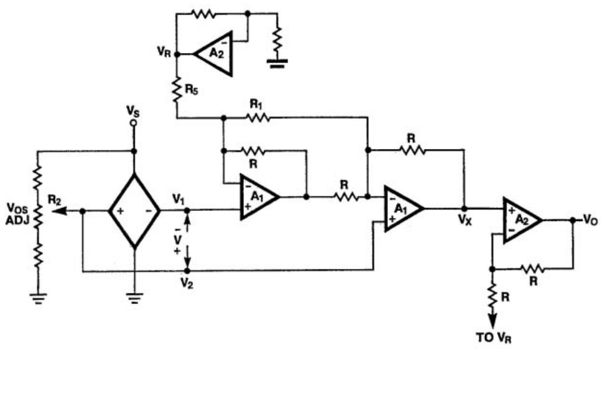

FIGURE II

Neglecting the small error terms of the op amps, the equation for the first stage output voltage. V\ in terms of the bridge arm voltages, V_1 and V_2, 5 given by

$$V_X = V_2 \left[2 + \frac{2R}{R_1}\right] - V_1 \left[1 + \left(\frac{R}{R_5}\right) + \frac{2R}{R_1}\right] + V_R \left[\frac{R}{R_5}\right] \quad (2)$$

Now, consider this equation if there is no offset voltage from the bridge and no pressure applied. Then $V_1 = V_2 = Vcm$, where Vcm is the common-mode voltage. Substituting this into equation 2 we have.

$$V_X = V_c \left[1 - \frac{R}{R_5}\right] + V_R \left[\frac{R}{R}\right] \quad (3)$$

Since it is required that there be zero voltage gain to the common-mode voltage, we can adjust R_5 to be equal to R.

When this is accomplished, equation *2* becomes

$$V_X = (V_2 - V_1) \left[2 \left(1 + \frac{R}{R_1}\right)\right] + V_R$$

or

$$V_X = V A_V + V_R \quad (4)$$

where AV is the voltage gain, given by

$$AV = 2 \left[\left(1 + \frac{R}{R_1}\right)\right] \quad (5)$$

and V is the differential input voltage (output of the bridge) given in equation 1.

It should be noted that since resistor R_5 does not appear in the equation for AV, once the common-mode rejection adjustment is made, the gain adjustment and common-mode rejection adjustment are non-interactive. From equation 5, it can be seen that the gain can be easily set by adjusting R1.

The offset error, V_{OS} can be adjusted to zero by adjusting R_2 (see figure 2), so the expression for the input voltage is simply

$$V = SV_S P \quad (6)$$

From equation 4, when there is zero pressure applied, the output voltage will be equal to V_R which is simply any convenient reference voltage that is desired to denote zero pressure. V_R could be at ground potential, how ever this would require that the output of op amp A_1, be capable of swinging clear to ground while operating from ground. The output Swing of some amplifiers can get close to ground if there is zero bad current required, hut in the real word, not even CMOS amplifiers will truly swing to ground. Establishing a positive voltage to represent zero pressure also eliminates the problem of "Do I have zero pressure or do have a short?"

The output stage (amplifier A2) provides a non-inverting gain of 2 to signal V_X and a gain of minus one to the reference voltage V_R. That is

$$V_0 = 2V_X - V_R \quad (7)$$

Using V_X from equation 4, and substituting into equation 7 we arrive at the final overall equation

$$V0 = V \left[4\left(1 + \frac{R}{R_1}\right)\right] + VR \quad (8)$$

An output stage buffer has been incorporated to minimize any loading effects that could feed back to the man gain storage and to make use of the output swing capability of the LM10, which is used for and can swing very dose to either supply rail.

The output swing capability of amplifier A1 (LT1013) is to within 1 V of the positive supply and to within 50 mV of ground. By incorporating the buffer stage with a gain of 2, the output swing at V_0 is to within 100 mV of ground and to within 100 mV of the positive supply.

DESIGN EXAMPLE

Consider the following design:
For a tape motion control system, an air bearing is used which measures a full scale differential air pressure of two PSI. It is desired that the output voltage be from 1 to 6 V while operating from a regulated +12 V system supply.

Selecting the SCX05DN, the design steps are as follows:

1. Determine the output span of the sensor. From the SCX05DN data sheet it is found that the output span with a 12 V supply is 60 mV ± 0.6 mV. Therefore, for 2 PSI the expected span will be 24 mV ± 0.24 mV.

2. Determine the total gain required. Since the amplified output span is 5 V (from 1 V to 6 V) it is found that the required gain range is $205 < AV < 211$. For R = 100 K, the range of R_1 can be found to be from 1,93 to 1,99 K. To provide a smooth adjustment, using a 15 turn metal film or cermet pot, select R_1 to be 1,91 K resistor in series with a 100 Ω pot.

The final design, with circuit values, is shown in figure 3. Although this design is for a single +12 V supply the circuit is capable of operating with a single supply from 5 to 15 V with a total quiescent current drain of less than 5 mA over this supply range.

Also, because there are seven 100 K resistors (denoted as RA), a resistor array has been used. This provides excellent matching and tracking with temperature, as well as minimal cost and PC board space.

ADJUSTMENT PROCEDURE

1. Without pressure applied:

   (a) Short the bridge arms together at points A and B shown in figure 3. Adjust R_5, the common-mode rejection pot, until. V_X, the voltage at pin 3 of A_2, is equal to V_R, the voltage at pin 1 of A_2. This is easily accomplished by placing a digital volt meter between these pins and adjusting for 0.00.The reasoning behind this is found in equation 3.

   (b) Remove the short, and adjust R_2, the offset adjust pot, until V_X is again equal to VR.

   (c) Adjust R_0, the reference adjust pot, to get an output voltage, V_0, equal to 1.00 V.

2. Apply the full scale pressure of 2 PSI. Adjust R_1, the gain adjust pot, until the output, V_0, is 6.00 volts.

CONCLUSION

The SCX family of pressure sensors is extremely popular due to the fact that they are pre-trimmed for span, span TC and offset voltage. They offer a very economical method to sense pressures from 1 PSI to 150 PSI. Because many industrial systems have only one power supply available, this application note discusses a circuit which provides excellent performance, easy adjustment, requires little power, minimal PC board space, and is low cost.

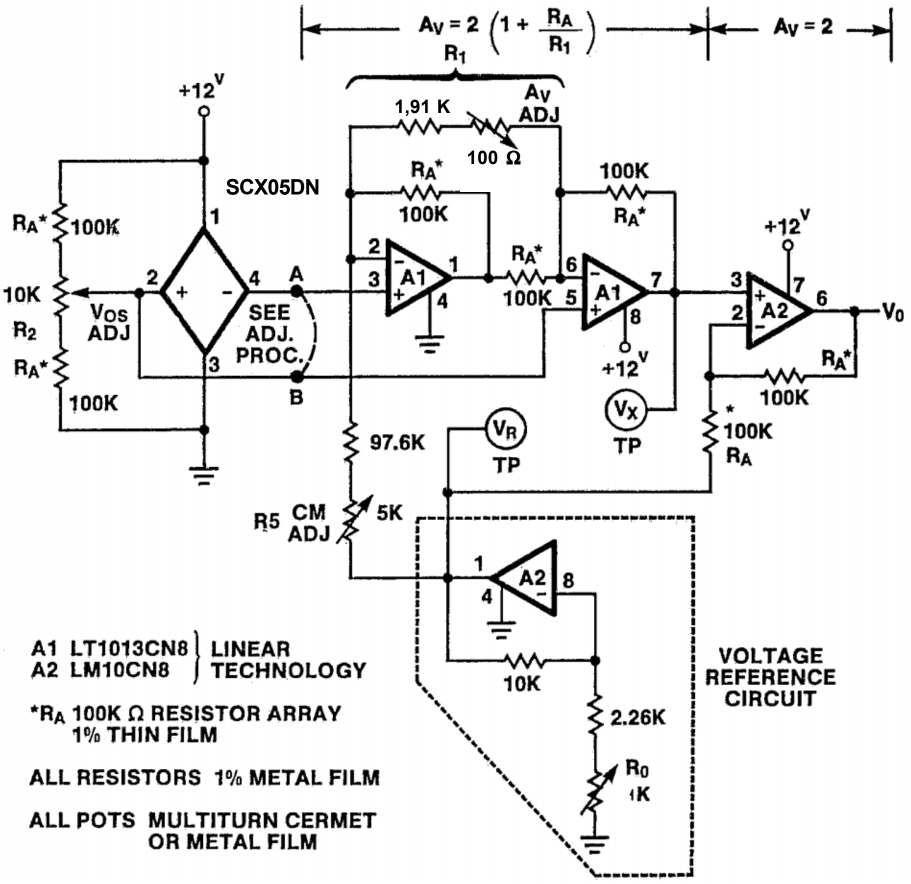

FIGURE III

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