A Simple Bar Graph Pressure Display

Technical Note

INTRODUCTION

Many applications that require pressure sensors and pressure monitoring devices also need a display to provide an easy-to-read determination of pressure. Historically, this has been available only with mechanical gauges. Now, using an integrated circuit pressure sensor in combination with an LED bar graph display, one can get a reliable low cost pressure display that has all the advantages of IC technology: no moving parts for high reliability, high accuracy, high cycle life, small size, and ease of interface with microprocessor systems for control. This application note describes the design details for a pressure indicator system incorporating Honeywell's low cost integrated circuit pressure sensor and a 10-segment LED bar graph display and driver module.

DESIGN CRITERIA

To make a pressure display system which could replace many of the old mechanical gauges in addition to being useful in a wide variety of new applications, this system was designed to meet the following criteria:

- Low Cost
- Operation from a single supply
- Compact size
- Easy to Read
- Easy to Manufacture

To make the design as low cost as possible, we used the SPX Series sensors. These low cost monolithic sensors give accurate readings for pressures between 0 psi to 1 psi and 0 psi to 30 psi so there are a wide variety of useful applications including:

- Monitoring pressure drops across industrial liquid filters in food processing, chemical processing, and sewage and filtration plants. (Pressure range: 0 psid to 30 psid) Here the user would be alerted when to change the filter or backwash the system.

- Monitoring pressure drops across industrial gas filters, including air conditioning, gas separation, flow monitoring, and high vacuum systems. (Pressure range: 0.0 psid to 0.5 psid)

- Turbo boost indicators on automobile engines. (Pressure range: -6 psig to 14 psig)

- Other applications include medical instrumentation and filtration equipment, computer filters, clean rooms, and an assortment of home appliances.

The basic design of this system is quite simple, as shown in Figure 1. The key features of this specific design are in its ease of adjustment and use of reliable, proven off-the-shelf components. To keep costs and number of components to a minimum, the SPX Series pressure sensor is combined with the NSM3914 LED driver/display module from National Semiconductor. As shown in Figure 1, only an amplifier is then needed to interface these two components. To complete the design, a resistor network is added for offset adjust since this is an unadjusted sensor and span temperature compensation has also been included to minimize errors over temperature.

FIGURE 1
Pressure Display Simple Block Diagram
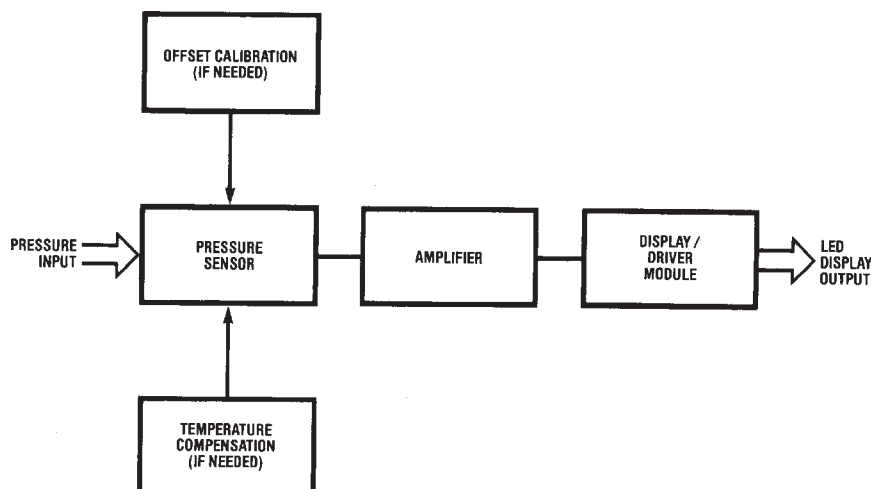
The specific circuit described in the following example can be easily modified to accomodate a wide variety of full-scale pressure ranges simply by changing the gain of the amplifier. See Table 1 for specific gain resistor values for the SPX Series. Also, since this circuit performs full calibration and temperature compensation, the design can very easily be adapted to Honeywell's other low cost series, such as the SX and LX06xxx devices.

TABLE 1
Nominal Gain Resistor Value for 10 LEDs'
Full-Scale Range

PRESSURE RANGE	DEVICE	R_s	
		R_6	R_P
0 to 1 psi	SPX50DN	909 k	2 k
0 to 10 psi	SPX50DN	909 k	20 k
0 to 15 psi	SPX100	6.9 k	20 k
0 to 30 psi	SPX200	6.9 k	20 k

Notes:
1) $R_S = 2R_N / A_V$-2
2) Calculation assumes R_N = 100 kOhm

DESIGN EXAMPLE
A LOW COST OIL FILTER MONITOR
To illustrate this low cost sensor display module, this example gives a specific application on monitoring the pressure drop across a typical industrial oil filter to determine its replacement status. A clean filter would typically have a 4 psid pressure drop, however, as dirt accumulates, the pressure drop across the filter progressively increases. At a pressure drop of 7 psid, the filter should be cleaned or replaced. Additionally, for this application, the pressure sensing system needs to . operate from a 5 V power supply and over a temperature range of 0 °C to 50 °C.

Sensor Selection: The lowest cost sensor available in the pressure range of 0 psid to 7 psid is the Honeywell SPX50D(N). Although specified from 0psid to 7.25 psid, the SPX50D(N) will actually operate linearly up to 10 psid. The expected output span over 0 psid to 10 psid will be 55 mV to 131 mV as determined from the following calculations:

Minimum Span (from SPX data sheet) is given by
$$\frac{800 \text{ µV/kpA}}{0.145 \text{ psi/kpA}} (10 \text{ psi}) = 55 \text{ mV}$$

Maximum Span is given by
$$\frac{1900 \text{ µV/kpA}}{0.145 \text{ psi/kpA}} (10 \text{ psi}) = 131 \text{ mV}$$

This span variation will be "calibrated out" by adjusting the amplifier gain. In addition to this span tolerance, the sensor's off-set or zero pressure output can also vary from 0 mV to 35 mV. This is adjusted by shunting one arm of the bridge as shown in Figure 2. Aside from this calibration, the other major error source which must be compensated for in most applications is the sensor's output changes due to temperature.

FIGURE 2
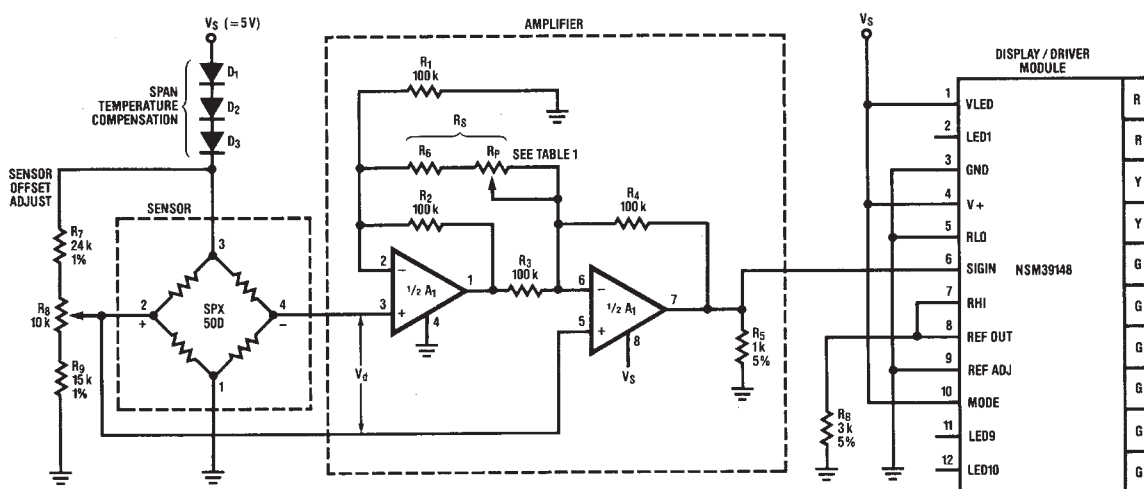
EQUATIONS:

$$V_0 = 2 \left(1 + \frac{R_N}{R_S}\right) V_D \quad ①$$

$$R_S = \frac{2 R_N}{A_V - 2} \quad ②$$

D_1, D_2, D_3 = IN914 OR EQUIVALENT
$R_1 = R_2 = R_3 = R_4 = R_N = 100$ K (CAN BE 100 K SIP)
A_1 = LM358 OR EQUIVALENT
R_B SETS THE CURRENT THROUGH EACH LED.

$$I_{LED} \cong 10 \left(\frac{1.25 \text{ V}}{R_B} + \frac{V_{FS}}{R_{divider}}\right) \quad ③$$

WHERE $R_{divider} = 10$ kΩ

$$I_{LED} \cong 10 \left(\frac{1.25 \text{ V}}{3 \text{ K}} + \frac{1.25 \text{ V}}{10 \text{ K}}\right) = 5.416 \times 10^{-3} \quad ④$$

Temperature Effects: The SPX50D's offset temperature error is typically 15 µV/°C (see SPX data sheet). To calculate the worst case offset error, we must assume a minimum sensitivity sensor. The worst case offset TC will be 1.36 %, as shown below.

$$\frac{15 \times 10^{-6} \ V/°C}{55 \times 10^{-3} \ V} \cdot (50 \ °C)(100) = 1.36 \ \%$$

where

    15 x10-6 V/°C= Offset TC
    55 x 10-3 V = Minimum Span
    50 °C = Temperature Range

Since this error can be tolerated in this application, offset temperature compensation will not be required.

In addition to the offset error, the sensor's span error with temperature must also be determined and added to the offset error to give the maximum overall temperature error. Typically, the SPX sensor's span will decrease at -2350 ppm/ °C. This error will be too large for some applications; however, it can be reduced substantially by adding three general purpose (IN914-type) silicon diodes (shown in Figure 2) in series with the sensor bridge. Since each diode has a voltage drop of 0.7 V and a TC of -2500 ppm/°C, and since the voltage across the entire diode/bridge network will remain constant, bridge voltage (V_B) will increase as the temperature increases, thereby partially compensating for the decrease in sensor sensitivity.
The diodes will also decrease the common-mode voltage of the SPX outputs which will allow the output of the amplifier to swing to ground (refer to Figure 2). Without the diodes, pin 1 of the LM358 would have to swing to V_S to force the output to zero. The LM358 data sheet indicates that the output will only swing to within 1.5 V of the positive supply. By decreasing the common-mode voltage, the diodes will allow the amplifier output to swing to ground. The span temperature errors with the diodes in the circuit can be determined from

$$V_B = V_S - XV_d$$

where

    V_S = Supply voltage
    V_B = Voltage across bridge
    SX = Number of diodes
and V_d = Voltage drop across each diode

Assuming a 5 V supply and typical silicon diodes, the above equation gives

$$V_B = 5 \ V - 3(0.7 \ V) = 2.9 \ V$$

Therefore, the top of the bridge is at 2.9 V and 3 diodes will increase this voltage by 5.25 mV/°C or 1810 ppm/°C. Thus, the three diodes will not fully compensate the sensor's negative span temperature coefficient; however, it will be reduced by combining the effects of the diodes as follows:
    -2350 ppm/°C + 1810 ppm/°C = -540 ppm/°C
    or 2.7 % over the compensated temperature
    range of 0 °C to 50 °C.

The Span TC Error(0 °C to 50 °C) = 2.7 %

The total temperature induced error will be the sum of the offset temperature error (1.36 %) and the span temperature error (2.7 %), which gives a total temperature induced error of 4.06 %. This error corresponds to the lowest sensitivity sensor, thus it represents a worst case condition. Higher sensitivity components can potentially reduce this error to 3.2 %.

Display Selection: For this example, the NSM39148 display was selected. This display features an arrangement of 6 green, 2 yellow, and 2 red LEDs, which can serve as an early warning of excessive filter degradation.

Amplifier Design: The dual op amp shown in Figure 2 was chosen because it operates well in applications where the common-mode input is near ground. It also features operation from a 5 V supply, high input impedance, and an output swing from 0 V to 1.2 V.

In order to light all ten segments of the display, it is necessary to provide the NSM39148 an input signal from 0 V to 1.2 V. The first LED will turn on at 120 mV, the second at 240 mV, and so on, leading to 1.2 V being required to turn on the 10th LED. The minimum and maximum output signals for the SPX50D is 55 mV and 131 mV, respectively, which will demand an amplifier gain between 9.16 and 21.8.

Using equation 2 from Figure 2, the range of R_S is calculated to be from 10.1 k to 27.9 k. To cover this range, a fixed 9.09 k 1 % metal film resistor(R_6) was combined in series with a 20 k multi-turn cermet pot(R_P).

Finally, a 1 k resistor was placed from the output of the amplifier to ground to enable the output of the amplifier to swing as close to ground as possible. This will prevent the first LED from turning on prematurely. The completed circuit, including the sensor, signal conditioning, and display module, is shown in Figure 2.

Adjustment Procedure: Only two simple, non-interactive adjustments are needed to set the initial offset and full-scale span. To adjust the offset, apply zero differential pressure to the sensor, then adjust R_8 for 0 V at Vd (sensor output between Pin 4 and Pin 2 of the SPX). To adjust the span, apply 10 psid to the sensor and adjust R_P until the 10th LED just lights.

Circuit Performance: As the pressure increases from 0 psid to 6 psid, the green LEDs 1 to 6 will progressively light up. At 7 psid the first yellow LED will light up, indicating that the filter should be changed. At 9 psid and 10 psid, the red LEDs will turn on, indicating a severely clogged filter. The maximum static error for this circuit will be within ±3 % and the expected error over temperature extremes should be within ±5 %.

CONCLUSION

By combining these two basic components, the SPX series sensor and the NSM3914 display module, with some simple signal conditioning circuitry, one can make a reliable, cost effective pressure display. The basic design illustrated here using an SPX sensor can easily be expanded to include other sensors such as the SX and LX06xxx Series.

Honeywell