SPX50, SPX100, SPX200
Integrated Circuit Pressure Sensors

FEATURES

- ■ Low Cost

- ■ 0–7 psi to 0–30 psi Pressure Ranges

- ■ Absolute and Differential (Gage) Devices

- ■ <0.1% Full-scale Combined Linearity and Hysteresis Error

- ■ Easily Mounted with Tie Wrap, Screws, or Soldered to PC Board.

- ■ Small Internal Volume For Fast Response

APPLICATIONS

- ■ Medical Equipment

- ■ Automotive

- ■ Computer Peripherals

- ■ Industrial Controls

GENERAL DESCRIPTION

The SPX Series feature an integrated circuit piezoresistive pressure sensor which provides an output voltage proportional to applied pressure. These devices use ion implanted resistors in an integral silicon diaphragm to transform the related shear stress, due to pressure, into an electrical output.

The Absolute (A) devices have an internal vacuum reference and an output voltage proportional to absolute pressure. The Differential (D) devices allow application of pressure to either side of the diaphragm and can be used for gage or differential pressure measurements.

The basic SPX package (i.e., SPX50D) has a compact plastic/aluminum housing which can be o-ring sealed or glued into a pressure connection fitting. The "N" package provides easy connections for plastic tubing. Both packages feature a standard 4-pin SIP for easy PC board mounting and electrical connection.

Although Sensym offers signal-conditioned transducers, these devices feature only the basic shear stress IC pressure sensor element. This greatly reduces unit cost and allows the electronic designer greater freedom in implementing transducer circuits. These devices are especially useful in applications requiring circuit flexibility, or compatibility with microprocessors.

SCHEMATIC DIAGRAM
(Equivalent Circuit)

ELECTRICAL CONNECTION

1) Ground   2) +OUTPUT
3) +Vs   4) –OUTPUT
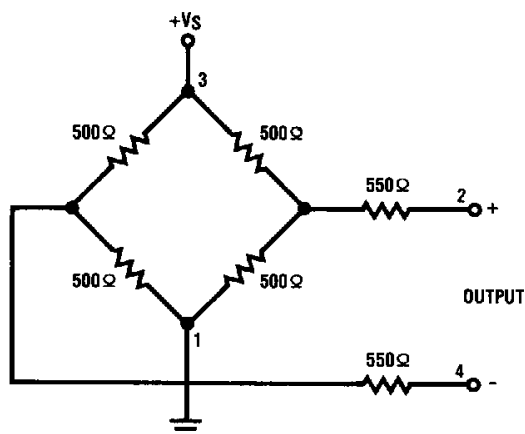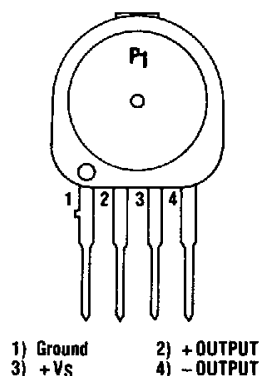
Note: Polarity applies for positive pressure applied to the high pressure port, P₁.

PRESSURE SENSOR CHARACTERISTICS

SPX50, SPX100, SPX200

Maximum Ratings (For All Devices)

Supply Voltage, V_S 6 V_{DC}

Temperature Range

    Operating   –40°C to +125°C

    Storage   –55°C to +125°C

Common-mode Line Pressure   60 psig

Lead Temperature

    (Soldering, 10 seconds)   300°C

Proof Pressure   Two Times Operating Pressure

Burst Pressure   Three Times Operating Pressure

SPX50 PERFORMANCE CHARACTERISTICS (See Note 1)

Characteristic	Min.	Typ.	Max.	Unit
Operating Pressure Range (Note 1)	0	—	50	kPa
Supply Current	—	6.0	—	mA$_{DC}$
Full-scale Span (Note 2)	40	60	95	mV
Zero Pressure Offset	0	20	35	
Sensitivity	800	1200	1900	µV/kPa
Combined Linearity and Hysteresis (Note 3)	—	±0.10	±0.50	%FS
Repeatability (Note 4)	—	±0.50	—	
Temperature Coefficient of Offset (Note 5)	—	±15	—	µV/°C
Temperature Coefficient of Span (Note 6)	–2550	–2350	–2050	ppm/°C
Temperature Coefficient of Resistance (Note 6)	1150	1350	1550	
Input Resistance	400	500	600	Ω
Output Impedance	—	1600	—	
Response Time (10% to 90%) (Note 7)	—	1.0	—	ms
Long Term Stability of Offset and Sensitivity (Note 8)	—	0.10	—	%FS

SPX100 PERFORMANCE CHARACTERISTICS (See Note 1)

Characteristic	Min.	Typ.	Max.	Unit
Operating Pressure Range (Note 1)	0	—	100	kPa
Supply Current	—	6.0	—	mA$_{DC}$
Full-scale Span (Note 2)	40	60	95	mV
Zero Pressure Offset	0	10	35	
Sensitivity	400	600	950	µV/kPa
Combined Linearity and Hysteresis (Note 3)	—	±0.10	±0.50	%FS
Repeatability (Note 4)	—	±0.50	—	
Temperature Coefficient of Offset (Note 5)	—	±15	—	µV/°C
Temperature Coefficient of Span (Note 6)	–2550	–2350	–2050	ppm/°C
Temperature Coefficient of Resistance (Note 6)	1150	1350	1550	
Input Resistance	400	500	600	Ω
Output Impedance	—	1600	—	
Response Time (10% to 90%) (Note 7)	—	1.0	—	ms
Long Term Stability of Offset and Sensitivity (Note 8)	—	0.10	—	%FS

SPX200 PERFORMANCE CHARACTERISTICS (See Note 1) SPX50, SPX100, SPX200

Characteristic	Min.	Typ.	Max.	Unit
Operating Pressure Range (Note 1)	0	—	200	kPa
Supply Current	—	6.0	—	mA$_{DC}$
Full-scale Span (Note 2)	40	60	95	mV
Zero Pressure Offset	0	10	35	
Sensitivity	200	300	475	μV/kPa
Combined Linearity and Hysteresis (Note 3)	—	±0.10	±0.50	%FS
Repeatability (Note 4)	—	±0.50	—	
Temperature Coefficient of Offset (Note 5)	—	±15	—	μV/°C
Temperature Coefficient of Span (Note 6)	−2550	−2350	−2050	ppm/°C
Temperature Coefficient of Resistance (Note 6)	1150	1350	1550	
Input Resistance	400	500	600	Ω
Output Impedance	—	1600	—	
Response Time (10% to 90%) (Note 7)	—	1.0	—	ms
Long Term Stability of Offset and Sensitivity (Note 8)	—	0.10	—	%FS

Specification Notes: (For All Devices)

Note 1: Reference Conditions: Supply Voltage, $V_S = 3V_{DC}$, $T_A = 25°C$, Common-mode Line Pressure = 0 psig, Pressure Applied to P_1; 1.0 kPa equals 0.145 psi.

Note 2: Span is the algebraic difference between the output voltage at full-scale pressure and the output at zero pressure.

Note 3: This is the algebraic sum of the percent of errors due to linearity and hysteresis given the following definitions:

$$\% \text{ FS error} = \frac{V_{1/2 \text{ full-scale}} - \left\{ \left(\frac{V_{\text{full-scale}} - V_{\text{offset}}}{\text{full-scale pressure}} \right) \times (1/2 \text{ full-scale pressure}) + V_{\text{offset}} \right\}}{2 V_{\text{full-scale}}} \times 100\%$$

Hysteresis — the maximum output difference at any point within the operating pressure range for increasing and decreasing pressure.

Note 4: Maximum difference in output at any pressure with the operating pressure range and temperature within +10°C to +85°C after:
a) 100 temperature cycles, −40°C to +125°C
b) 1.0 million pressure cycles, 0kPa to full-scale span.

Note 5: Slope of the endpoint straight line from −40°C to +125°C.

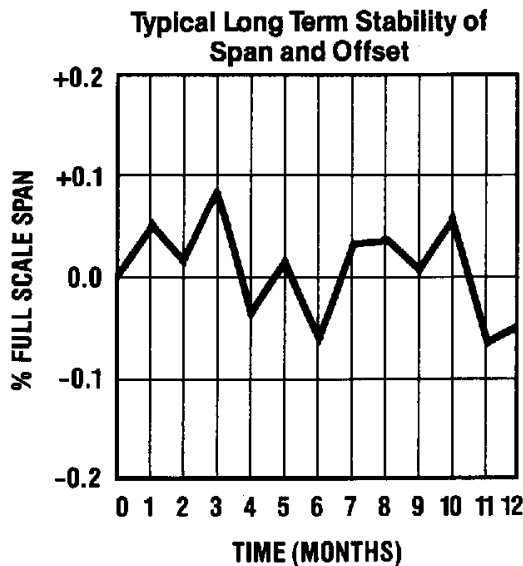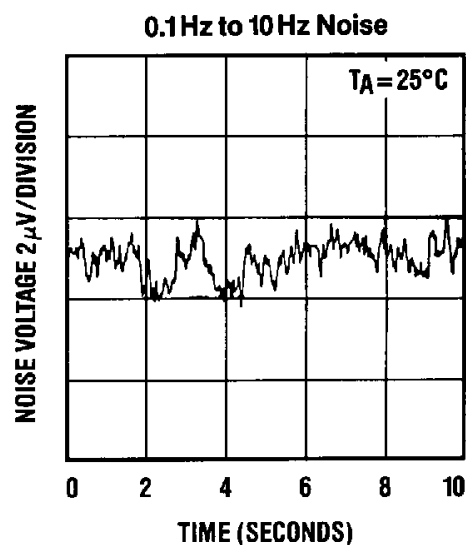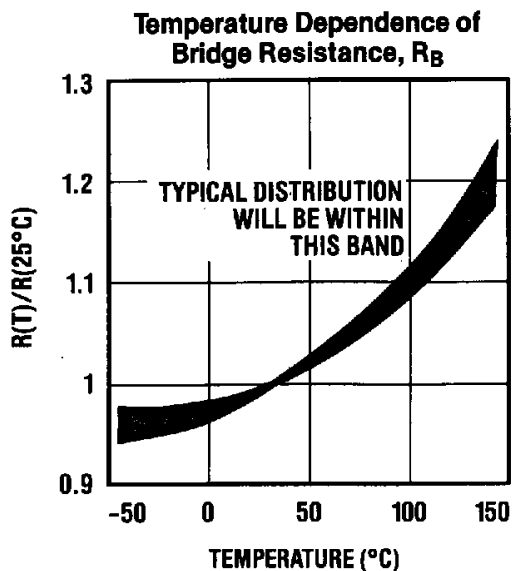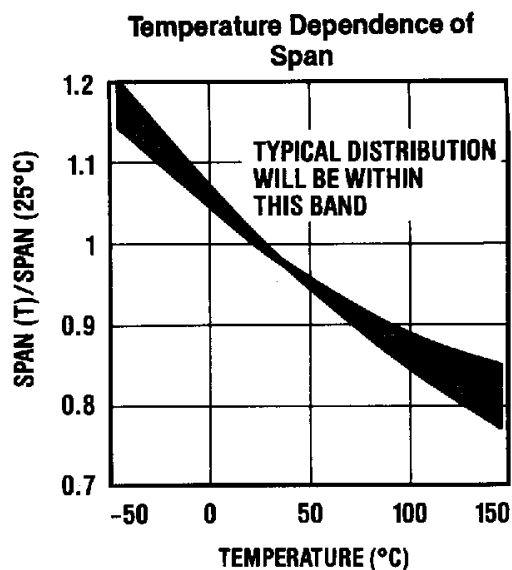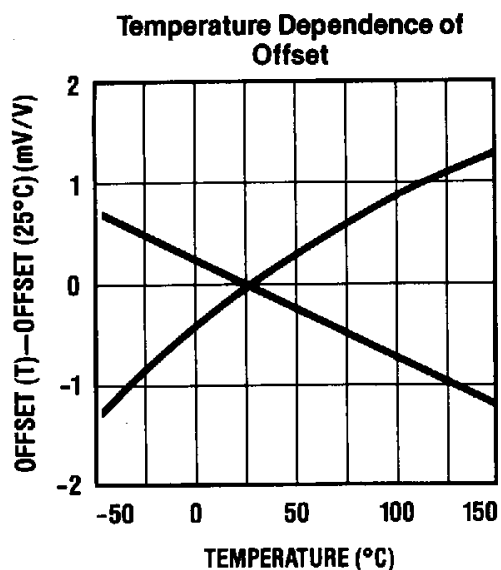**Note 6:** This is the best straight line fit for operation between 0°C and 70°C. For operation outside this temperature, contact factory for more specific applications information.

Note 7: Response time for a 0kPa to full-scale span pressure step change.

Note 8: Long term stability over a one year period.

Temperature Dependence of Offset

Temperature Dependence of Span

TYPICAL DISTRIBUTION WILL BE WITHIN THIS BAND

Temperature Dependence of Bridge Resistance, R_B

TYPICAL DISTRIBUTION WILL BE WITHIN THIS BAND

0.1 Hz to 10 Hz Noise

$T_A = 25°C$

Typical Long Term Stability of Span and Offset

DEFINITION OF TERMS

General Terms

Absolute Pressure: Pressure measured relative to a vacuum. Usually expressed in pounds per square inch absolute (psia). Typically equated with barometric pressure.

Differential Pressure: The pressure difference measured between two pressure sources. Usually expressed in pounds per square inch differential (psid). When one source is a perfect vacuum, the pressure difference is called *absolute pressure.* When one source is the local ambient, the pressure is called *gage pressure.*

Gage Pressure: Pressure measured relative to ambient pressure (psig). Obtained by leaving one port of SPXxxD type devices open to the atmosphere.

kPa: Kilopascal 1.0 kPa equals 0.145 psi.

Vacuum: A perfect vacuum is the absence of gaseous fluid.
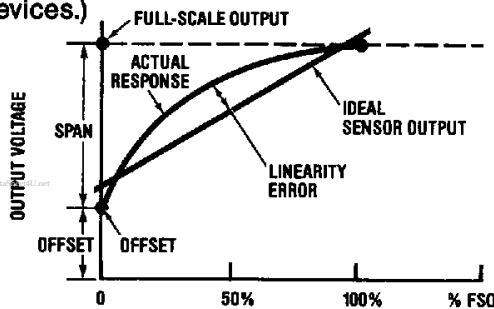
Transducer Parameters

Burst Pressure: The maximum pressure that can be applied to a transducer without rupture of either the sensing element or transducer case.

Common-Mode Pressure — Maximum: The maximum pressure that can be applied to both ports simultaneously of a differential transducer.

Full-Scale Output: The actual voltage reading obtained at the endpoint of the pressure range.

Linearity: The maximum deviation of measured output at constant temperature (25°C) from "best straight line" determined by three points (offset pressure, full-scale pressure, and one-half full-scale pressure).

Offset Voltage: The transducer output signal at zero pressure, (0 psig for gages and differential, 0 psia for absolute devices.)

Operating Pressure Range: The specified range over which a transducer is intended to measure, specified by the upper and lower limits.

Over-Pressure — Maximum: The maximum *normal mode* (measured) pressure that can be applied without changing the transducer's performance or accuracy beyond the specified limits. This would be applied to either port of a differential transducer. This is also called proof pressure.

Reference Pressure: The pressure used as a reference in measuring transducer errors.

Reference Temperature: The temperature used as reference in measuring transducer errors.

Sensitivity: The ratio of output signal voltage change to the corresponding input pressure change. Sensitivity is determined by computing the ratio of span to the specified input pressure range.

Span: The arithmetic difference in transducer output signal measured at the specified minimum and maximum operating pressures. (Full-scale output — offset)

Temperature Coefficient of Offset Voltage: This defines how the offset voltage will change with temperature when a fixed voltage is applied to the bridge. For the SPX series, the offset TC is typically $\pm 15 \mu V/°C$ with 3V applied to the bridge.

A straight line definition, using temperature end points, is used although the offset TC is slightly non-linear.

Temperature Coefficient of Resistance: This defines the manner in which the bridge input resistance changes with temperature. For the SPX series, the resistance TC is always positive at approximately $+1350$ ppm/°C. This means that for every 1°C rise in temperature, the resistance "seen" by the bridge voltage will typically rise by 0.135% of its nominal value.

Temperature Coefficient of Span: The span TC defines the manner in which the span/sensitivity changes with temperature. For the SPX series, the span TC is always negative at approximately -2350 ppm/°C. This means that for a fixed voltage applied to the bridge, the sensitivity will decrease 0.235% for every 1°C rise in temperature.

PRESSURE UNIT CONVERSION CONSTANTS
(Most Commonly Used — Per International Conventions)

	PSI[1]	In. H$_2$O[2]	In. Hg[3]	kPa	millibar	cm H$_2$O[4]	mm Hg[5]
PSI[1]	1.000	27.680	2.036	6.8947	68.947	70.308	51.715
In. H$_2$O[2]	3.6127×10^{-2}	1.000	7.3554×10^{-2}	0.2491	2.491	2.5400	1.8683
In. Hg[3]	0.4912	13.596	1.000	3.3864	33.864	34.532	25.400
kPa	0.14504	4.0147	0.2953	1.000	20.000	20.2973	7.5006
millibar	0.01450	0.40147	0.02953	0.100	1.000	1.01973	0.75006
cm H$_2$O[4]	1.4223×10^{-2}	0.3937	2.8958×10^{-2}	0.09806	0.9806	1.000	0.7355
mm Hg[5]	1.9337×10^{-2}	0.53525	3.9370×10^{-2}	0.13332	1.3332	1.3595	1.000

Notes: 1. PSI — pounds per square inch   2. at 39°F   3. at 32°F   4. at 4°C   5. at 0°C

MECHANICAL AND MOUNTING CONSIDERATIONS

Basic Sensor Element

The basic sensor element (i.e. SPX50D) was designed to allow easy interface with additional cases and housings which then allow pressure connection. The device can be mounted with an O-ring, gasket, or RTV seals on one or both sides of the device. The device can then be glued or clamped into a variety of fixtures and the leads can be bent as necessary to allow for ease of electrical connection. However, caution is advised as repeated bending of the leads will cause eventual breakage.

For absolute and gage applications, pressure should be applied to the top side of the device. (See Physical Construction Drawing.) For differential applications, the top side of the device (P_1) should be used as the high pressure port and the bottom (P_2) as the low pressure port.

The basic SPX package has a very small internal volume which allows fast response in many applications. Typical internal volumes are 0.06 cubic centimeters for P_1 and 0.001 cubic centimeters for P_2.

Packaged Sensor

The packaged sensor (i.e. SPX50DN) is designed for convenient pressure connection and easy PC board mounting. For mounting the device horizontally to the PC board, the leads can be bent down. The packaged sensor can be attached to the board using either tie wraps or standard mounting screws. For pressure attachment, tygon or silicon tubing is recommended.

All versions of the packaged sensor have two (2) tubes available for pressure connection. For absolute devices only, the top port (P_1) is active. Applying pressure through the other port will result in pressure dead ending into the backside of the silicon sensor. If this occurs, the device will not give an output signal with pressure.

For gage devices, pressure is also intended to be applied to the top port (P_1). For differential pressure applications, the top port (P_1) should be used as the high pressure port and (P_2) should be used as the low pressure port.
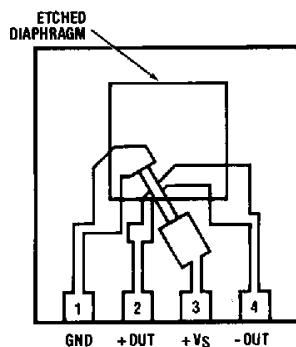
GENERAL DISCUSSION   SPX50, SPX100, SPX200

Output Characteristics

The SPX series devices give a voltage output which is directly proportional to applied pressure. The devices will give an increasing positive going output when increasing pressure is applied to pressure port P_1 of the device. If the devices are operated in the backward gage mode, the output will increase with decreases in pressure. The devices are ratiometric to the supply voltage. Changes in supply voltage will cause changes in the transfer curves, offset voltage, and full-scale span.

User Calibration

SPX series devices feature the basic IC pressure sensor element. This will keep overall system costs down by allowing the user to select calibration and temperature compensation circuits which specifically match individual application needs. In most cases, the primary signal conditioning elements to be added to the SPX by the user are: offset and span calibration and temperature compensation. Some typical circuits are shown in the application section.

Vacuum Reference (Absolute Devices)

Absolute sensors have a hermetically sealed-in vacuum reference chamber. The offset voltage on these units is therefore measured at vacuum, 0 psia. Since all pressure is measured relative to a sealed-in vacuum reference, all changes in barometric pressure or changes in altitude will cause changes in the device output.

Media Compatibility

SPX devices are compatible with most non-corrosive gases. Because the circuitry on the devices is coated with a protective silicon gel, many otherwise corrosive environments can be compatible with the sensors. As shown in the physical construction diagram below, fluids must generally be compatible with silicon gel, plastic, and aluminum for forward gage use and RTV, silicon, glass and aluminum for backward gage or differential applications. For questions concerning media compatibility, contact the factory.

Basic Sensor Chip
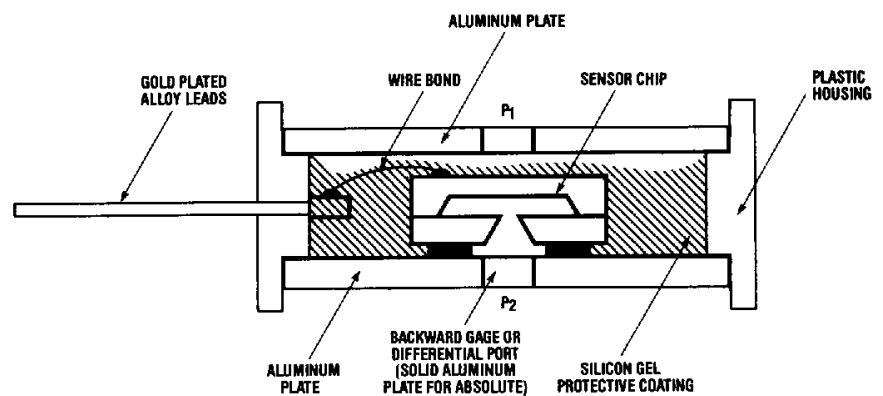
Physical Construction

APPLICATION INFORMATION
General

The SPX family of pressure sensors functions as a Wheatstone bridge. When pressure is applied to the device (see Figure 1) the resistors in the arms of the bridge change by an amount, Δ.
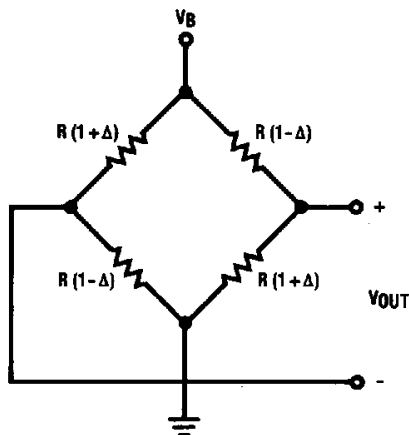

Figure 1.

The resulting differential output voltage V_O, is easily shown to be $V_O = V_B \times \Delta$. Since the change in resistance, is directly proportional to pressure, V_O can be written as:

$$V_O = S \times P \times V_B \pm V_{OS} \qquad (1)$$

Where: V_O is the output voltage in mV.
$\quad$ S is the sensitivity in mV/V per psi
$\quad$ P is the pressure in psi
$\quad$ V_B is the bridge voltage in volts.

V_{OS}, is the offset error (the differential output voltage when the applied pressure is zero). The offset voltage presents little problem in most applications, since it can easily be corrected for in the amplifier circuitry, or corrected digitally if a microprocessor is used in the system.

Temperature Effects

In this discussion, for simplicity of notation, the change of a variable with temperature will be designated with a dot (·) over the variable. for example,

$$\dot{S} = \frac{\text{change in sensitivity}}{\text{change in temperature}} = \frac{\partial S}{\partial T}$$

From equation (1), and ignoring the V_{OS} term, it is seen that for a given constant pressure, the output voltage change, as a function of temperature*, is:

$$\dot{V}_O = \dot{S} P V_B \qquad (2)$$

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*It should be noted that temperature in this discussion is the temperature of the silicon die. The die temperature will be dependent upon internal power dissipation, ambient temperature and, in some cases, the working fluid temperature.

Thus, in order for output voltage to be independent of temperature, the voltage across the bridge, V_B, must change with temperature in the "opposite direction" from the sensitivity change with temperature. From the typical curves for the temperature dependence of span (span = $S \times P \times V_B$), it can be seen that the sensitivity change with temperature is slightly non-linear and can be correlated very well with an equation of the form:

$$S = S_O \left[(1 - \beta T_D) + \varrho T_D^2 \right] \qquad (3)$$

where T_D is the temperature difference between 25°C and the temperature of interest, S_O is the sensitivity at 25°C, and beta (β) and rho (ϱ) are correlation constants.

Fortunately, between 0°C and 70°C the change in sensitivity with temperature is quite linear, and excellent results can be obtained over this temperature range by ignoring the second-order temperature dependent term.

Operating outside the 0°C to 70°C temperature range will require a more rigorous mathematical approach and the use of non-linear compensating circuitry, if accuracy of better than ±1% is required. Because the majority of SPX applications fall within the 0°C to 70°C operating temperature range, the discussion and circuit designs given here will ignore the non-linear effects.

Thus:

$$S = S_O (1 - \beta T_D) \qquad (4)$$

Substituting equation (4) into equation (1), and ignoring V_{OS}, it can be shown that the necessary bridge voltage, V_B, will be of the form:

$$V_B = \frac{V_{BO}}{(1 - \beta T_D)} = V_{BO} \left[(1 + \beta T_D + (\beta T_D)^2 + \ldots) \right]$$

where V_{BO} is the bridge voltage at 25°C.

This equation is again non-linear. However, for the temperature range of interest, and since β is small (0.235%/°C from the electrical tables), the above expression can be accurately approximated by:

$$V_B = V_{BO} \left[1 + \beta T_D \right]$$

with less than 1% error. Thus to compensate for a negative 2350 ppm/°C sensitivity change with temperature, the bridge voltage should increase with temperature at a rate of +2350 ppm/°C.

The above value of bridge voltage change will be used in the circuit discussions that follow. That is to say, the required change in terms of ppm/°C is:

$$\left(\frac{\dot{V}_B}{V_B} \right) = +2350 \text{ ppm/°C}.$$

APPLICATION INFORMATION (Continued)

SPX50, SPX100, SPX200

The bridge input resistance*, R_B, also changes with temperature and is quite linear in the temperature range of interest. The bridge resistance has a temperature co-efficient of typically:

$$\left(\frac{\dot{R}_B}{R_B}\right) = +1350 \text{ ppm/°C.}$$

This term enters into several compensation circuit equations, particularly when the bridge excitation is from a constant current source.

To summarize, the following list indicates how the sensor variables can be accomodated:

- Full-scale span from device to device:
  Make the gain adjustment in the op amp circuitry

- Temperature coefficient of sensitivity:
  1) temperature compensate the bridge or
  2) temperature compensate the op amp gain

- Offset voltage:
  Adjustment in op amp circuitry

- Offset voltage temperature coefficient:
  Usually can be ignored. For more precise design requirements, contact the factory for information on how to compensate for this term.

Bridge Compensation Circuits

Although thermistors can be used to temperature compensate the bridge (and in fact will be required for extended temperature operation), they are inherently non-linear, difficult to use in volume production, and more expensive than the circuit approaches shown here, which use inexpensive semiconductor devices. The circuits shown have been designed to incorporate a minimum number of adjustments and allow interchangeability of devices with little variation from device to device.

In general, equations for the bridge voltage and its change with temperature are given to enable the user to modify or adjust the circuitry as required.

1. Diode String (Figure 2)

For systems using 5V or 6V supplies, this method of compensating for the effects of span over temperature is the lowest cost solution. The diodes are small signal silicon diodes, such as 1N914 or 1N4148, and do not have to be matched. The diodes should have a forward drop (ϕ) of about 0.7V at 6mA current.
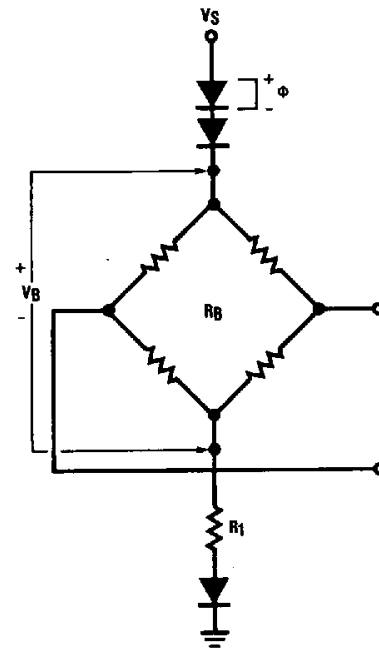

Figure 2. Diode String Span Compensation

a) $V_B = \alpha [V_S - 3\phi]$

b) $\left(\dfrac{\dot{V}_B}{V_B}\right) = \dfrac{\left(\dfrac{\dot{R}_B}{R_B}\right)}{\left(1 + \dfrac{R_B}{R_1}\right)} - \dfrac{3\left(\dfrac{\dot{\phi}}{\phi}\right)}{\left(\dfrac{V_S}{\phi} - 3\right)}$

c) $\alpha = \dfrac{R_B}{R_1 + R_B}$

d) $\left(\dfrac{\dot{\phi}}{\phi}\right) \approx -2500 \text{ ppm/°C for silicon diodes}$

Figure 2 Equations

For example, solving equation (b) for R_1 when

$$V_S = 5.0 \text{ V}$$

$$\phi = 0.7 \text{ V}$$

$$\frac{\dot{R}_B}{R_B} = +1350 \text{ ppm/°C}$$

$$\frac{\dot{V}_B}{V_B} = 2350 \text{ ppm/°C}$$

$$R_B = 500 \text{ } \Omega$$

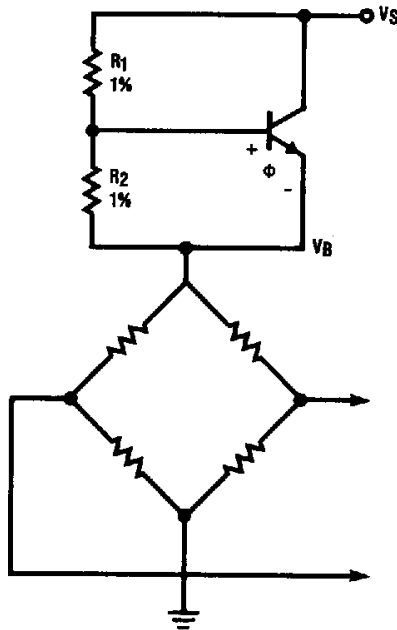Gives: $R_1 = 333\Omega$ (use closest 1% tolerance, 332Ω)

Substituting this value of R_1 into equation (c) to solve for α and then using equation (a) will result in a bridge voltage of $V_B = 1.74$V @ 25°C. This can then be used with equation (1) to determine the expected span. If precision temperature compensation is required for each device, resistor R_1 should be a 500Ω pot.

**The input resistance is the resistance "seen" by the bridge voltage, V_B, with no power applied.

For operation with $V_S = 6V$, four diodes (with no resistor) in series will result in a bridge voltage of about 3.2V and a temperature coefficient of about 2200ppm/°C.

2. Transistor Compensation Network

Figure 3 uses a single transistor to simulate a diode string, with the equations as shown. The values shown in Table 1 were found to give excellent results over 0°C to 100°C. Again, if precision temperature compensation is required for each device, resistor R_1 should be a 500Ω pot.

a) $V_B = V_S - \alpha \, \phi$

b) $\left(\dfrac{\dot{V}_B}{V_B}\right) = -\left(\dfrac{\dot{\phi}}{\phi}\right)\left(\dfrac{\alpha}{\dfrac{V_S}{\phi} - \alpha}\right)$

c) $\alpha = 1 + \dfrac{R_1}{R_2}$

d) $\left(\dfrac{\dot{\phi}}{\phi}\right) \approx -2500 \text{ ppm/°C}$

Figure 3.

| V_S	$R_1 \Omega$	$R_2 \Omega$
5V	402	150
6V	429	133

Table 1. Selected R Values vs. V_S for Figure 3.

3. Constant Current Excitation (Figure 4)

The circuits shown in Figures 2 and 3, although simple and inexpensive, have one drawback in that the voltage across the bridge is determined by the compensation network. That is, the compensation network is determined and what voltage is "leftover" is across the bridge. The circuit of Figure 4 solves this problem and

allows the bridge voltage to be independently selected. In Figure 4, the bridge is driven from a constant current source, the LM334, which has a very well known and repeatable temperature coefficient of +3300ppm/°C. This temperature coefficient (TC), in conjunction with the TC of the bridge resistance, is too high to compensate the sensitivity TC, hence resistor R_2 is added to reduce the total circuit TC.

The circuit of Figure 4 is also the preferred circuit to use in battery operated equipment. For battery operation, the top of resistor R_2 should be connected to a micropower reference voltage zener such as the LM336. In this manner, the voltage across the bridge is compensated for temperature but is totally independent of the battery voltage. The equations given will still apply, provided V_S is replaced by V_Z, the zener voltage.
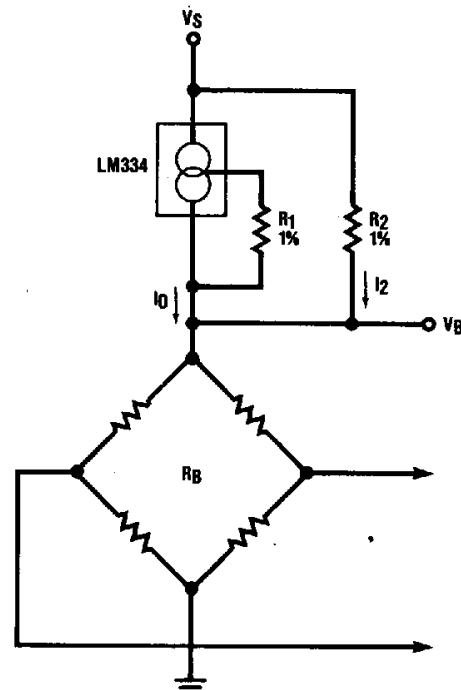
a) $V_B = \alpha (V_S + I_O R_2)$

b) $\left(\dfrac{\dot{V}_B}{V_B}\right) = \left(\dfrac{\dot{R}_B}{R_B}\right)(1 - \alpha) + \left(\dfrac{\dot{I}_O}{I_O}\right)\left[1 - \alpha\left(\dfrac{V_S}{V_B}\right)\right]$

c) $\alpha = \dfrac{R_B}{R_2 + R_B}$

d) $\left(\dfrac{\dot{I}_O}{I_O}\right) = 3300 \text{ ppm/°C}, \quad \dfrac{\dot{R}_B}{R_B} = +1350 \text{ ppm/°C}$

e) $I_O = \dfrac{67.7 \text{ mV}}{R_1}$

Figure 4.

The design steps are straightforward:

1) Knowing V_S and the desired bridge voltage V_B, solve equation (b) for α.

2) Now, solve equation (c) for R_2, letting $R_B = 500\Omega$.

3) Solve equation (a) for I_O.

4) Find R_1, or its nearest 1% tolerance value from equation (e).

Table 2 gives experimentally determined, specific 1% resistor values in ohms, for several popular system voltages which will result in V_B of approximately $3.0 V_{DC}$ @ 25°C. For best results, the resistors should be 1% metal film with a low temperature coefficient.

V_S	R_1	R_2
5V	16.9	866
9V	24.9	1700
12V	24.9	2440

Table 2. Selected R Values vs. V_S for Figure 4.

Amplifier Design

There are hundreds of instrumentation amplifier designs, and the intent here will be to briefly describe one circuit which:

- does not load the bridge
- involves minimal components
- provides maximum performance

The choice of the operational amplifiers to use is based on individual cost/performance trade-offs. The accuracy will be primarily limited by the amplifier's common-mode rejection, offset voltage drift with temperature and noise performance. Low cost, low performance devices, such as the LM324 can be used if the temperature

range is limited to 25°C ± 15°C and an accuracy of ±2% is adequate. For more precise applications, amplifiers such as the LT1014 and LT1002 have been found to be excellent. For example, a design using the temperature compensation circuit shown in Figure 4, in conjunction with the op amp circuit shown in Figure 5, exhibited a worst case full-scale span error of less than 0.8% from 0°C to 100°C, with the error being less than 0.2% from 25°C to 75°C.

For the amplifier configuration shown, the gain equation is:

$$A_V = \frac{V_O}{V_{IN}} = \frac{R_4}{R_3}\left[1 + \tfrac{1}{2}\left\{\left(\frac{R_2}{R_1}\right) + \left(\frac{R_3}{R_4}\right)\right\} + \frac{R_2 + R_3}{R_5}\right]$$

By setting: $R_1 = R_2$ (which is performed to set the common-mode rejection) and $R_3 = R_4$, the equation is simplified to:

$$A_V = \left(2 + \frac{R_2 + R_3}{R_5}\right)$$

In most applications, the common-mode adjustment is necessary since the voltage on the bridge (V_B) is designed to change with temperature (to compensate for the span TC). As a result, the common-mode voltage at the output arms of the bridge will also change. The amplifier must reject this common-mode signal or considerable error will result.
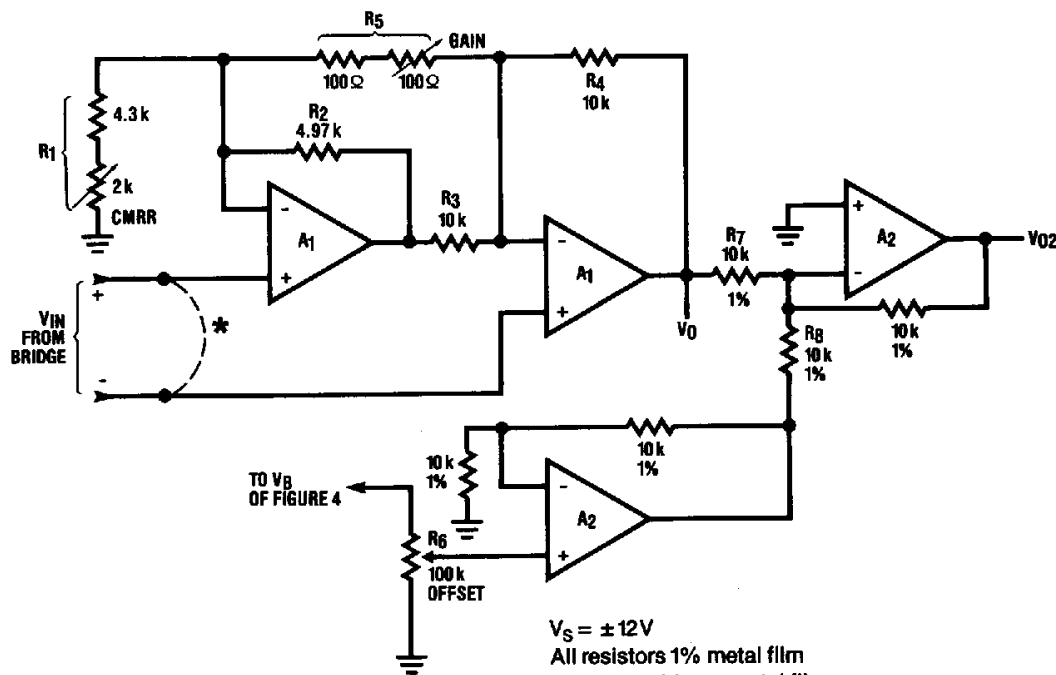
$V_S = \pm 12V$
All resistors 1% metal film
All pots multi-turn metal film
A_1, A_2 LT1002CN — Linear Technology Corp.
*See adjustment procedure
10k 1% R's can be thin film resistor array (Bourns, Beckman, etc.)

Figure 5.

APPLICATION INFORMATION (Continued)
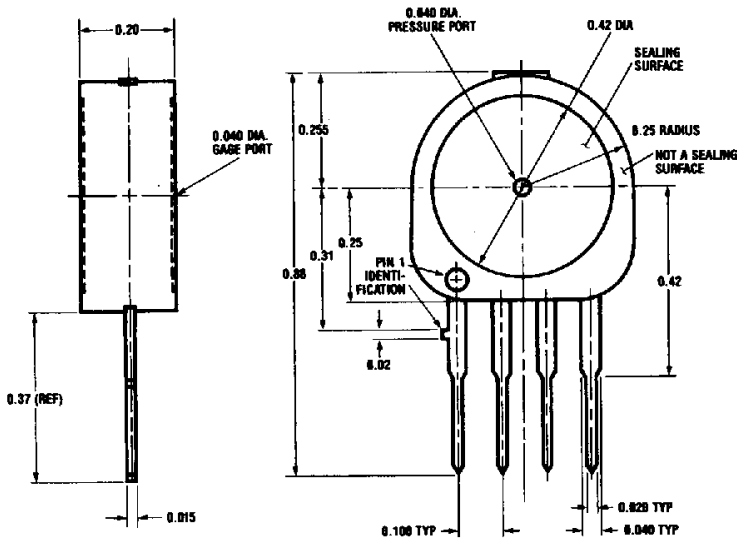
Adjustment Procedure:

A. With zero input pressure:

    1. Adjust the common-mode rejection by adjusting R_1. This can be quickly and accurately done by jumpering the two bridge arms together (see dashed line in Figure 5) and adjusting R_1 until the voltage at V_O is at 0.000 V.

    2. Adjust the offset voltage (R_6) to set the output voltage at V_{O2} to be 0.000 V.

B. Apply the full-scale pressure and adjust the gain (R_5) to give the desired output span voltage at V_{O2}.

    Because the initial offset adjustment (step 2 above) was made for an unknown gain, the offset adjustment (R_6) will have to be readjusted.

    This process should be repeated until the desired span is obtained.

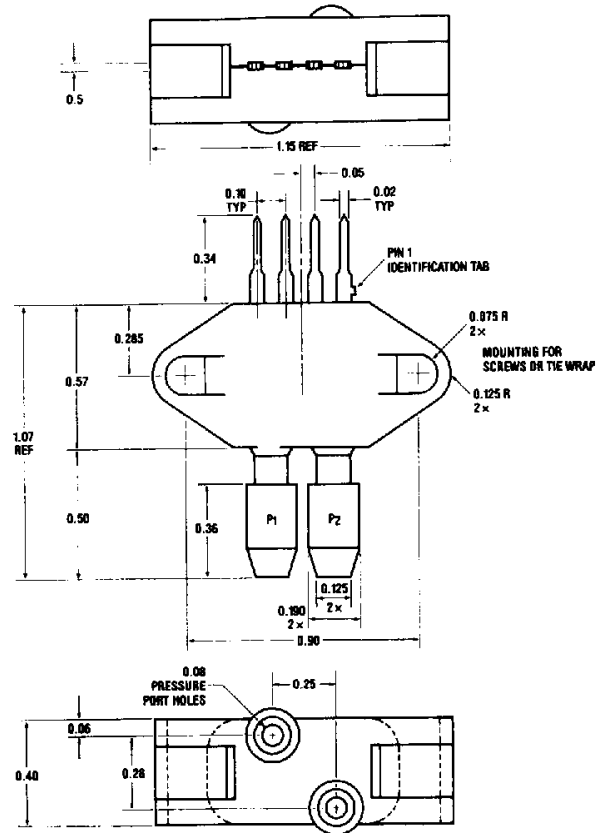## SPX50, SPX100, SPX200
Factory Compensated Devices

This application note provides the necessary information for temperature compensating and calibrating the SPX sensors. In some cases, the customer may find that SPX devices which have been factory adjusted for temperature compensation and span are more economical for a particular application. Sensym does offer devices with this feature. For more information on these factory calibrated and compensated SPX series devices, please contact your nearest Sensym sales office or the Sensym factory.

Button Sensor
SPXxxA,D

Packaged Sensor Element
(N Package)
SPXxxA,D(N)

TYPICAL WEIGHT: 1 GRAM

TYPICAL WEIGHT: 4.5 GRAMS

ORDERING INFORMATION
To order, use the following part numbers:

Basic Sensor Element
Absolute:
  0–15 psia SPX100A
  0–30 psia SPX200A

Differential and Gage:
  0–7 psid SPX50D
  0–15 psid SPX100D
  0–30 psid SPX200D

Packaged Sensor (N Package)
Absolute:
  0–15 psia SPX100AN
  0–30 psia SPX200AN

Differential and Gage:
  0–7 psid SPX50DN
  0–15 psid SPX100DN
  0–30 psid SPX200DN