Honeywell

Pressure Sensors

Application Advantages of Monolithic Fully Signal Conditioned Pressure Sensors

Application Sheet

⚠WARNING

MISUSE OF DOCUMENTATION

- The information presented in this application sheet is for reference only. Do not use this document as product installation information.
- Complete installation, operation, and maintenance information is provided in the instructions supplied with each product.

Failure to comply with these instructions could result in death or serious injury.

INTRODUCTION

Fully signal conditioned single chip pressure sensors are available in ranges from 1 psi to 500 psi and offer several advantages over discrete sensors with interface electronics. These devices have good to excellent linearity and are fully interchangeable within the set pressure range. They have a standard form factor and solderable ports. System designers realize many advantages when using the monolithic fully signal conditioned pressure sensors for new applications.

BACKGROUND

Honeywell has developed a family of silicon based piezoresistive single chip fully signal conditioned pressure sensors. These sensors provide high accuracy, wide operating temperature range, high reliability, and small package outline. These sensors are available for a relatively low cost.

It is important to define the parameters necessary to describe a pressure sensor. The ideal transfer function for a pressure sensor is:

Equation 1.

$$Vout = Sn*P + N$$

Where Sn is the sensitivity and N is the null set point. The transfer function is specified for a referenced supply voltage.

Parameters of interest for high accuracy sensor designs are: linearity, ratiometricity, stability, repeatability, hysteresis, null set point, span set point, null temperature shift and span temperature shift. However, accuracy specifications vary widely among manufacturers.

MAPPING SENSOR ACCURACY

When determining the accuracy of a pressure sensor, the most meaningful performance parameter is a total error specification over the entire operating range. The response map in Figures 1 and 2 (see page 2) shows, in a single picture, the total error over the entire operating range of pressure and temperature from all sources of error except ratiometricity. The z-axis is the output voltage deviation from an ideal sensor as a percentage of a full scale output. The y-axis is temperature in degrees Celsius. The x-axis is pressure. Figure 1 shows a 3D surface map of a typical monolithic 15 psi sensor. Figure 2 shows a 3D surface map of a typical temperature compensated discrete 15 psi sensor.

Figure 1 shows that the accuracy of the monolithic devices makes them easily interchangeable. This means the system user does not have to be concerned with calibration. If auto-zero can be used, the measurement becomes virtually error free. Monolithic fully signal conditioned devices have in-package laser trimming after characterization over temperature to adjust the offset, sensitivity, offset temperature compensation (TC) and sensitivity TC. As shown in Figure 1, this device achieves a 1% or less error over the response surface for a temperature range of –40°C to 125°C.

Figure 2 shows that temperature compensation for a discrete device is limited to about 0°C to 85°C. Discrete devices are typically compensated using series compensation. In this process, trimmable resistors, in series with the bridge, are positioned between both supply and ground. This compensation method relies on the relationship between the bridge resistors' TC and the bridge sensitivity TC being closely matched in opposite directions. Referring to Equation 1, the term Sn has the following relationship:

Equation 2.

$$Sn(t)=Sn(o)(1+\alpha T+ \beta T^2) Vb(t)/ Vb(o)$$

As can be seen from Equation 2, if the TC of sensitivity,

$$(Sn(t))$$

Figure 1. Monolithic Sensor Response Map

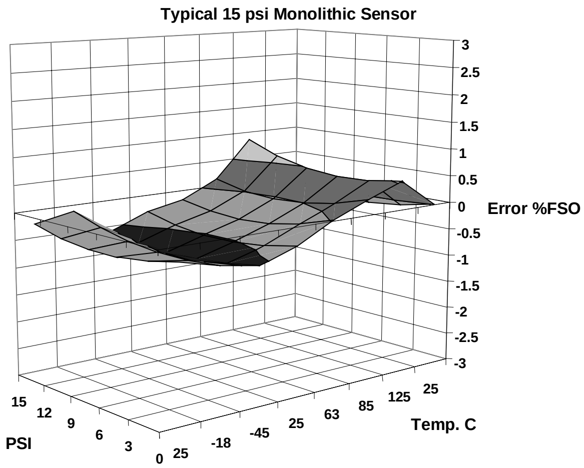
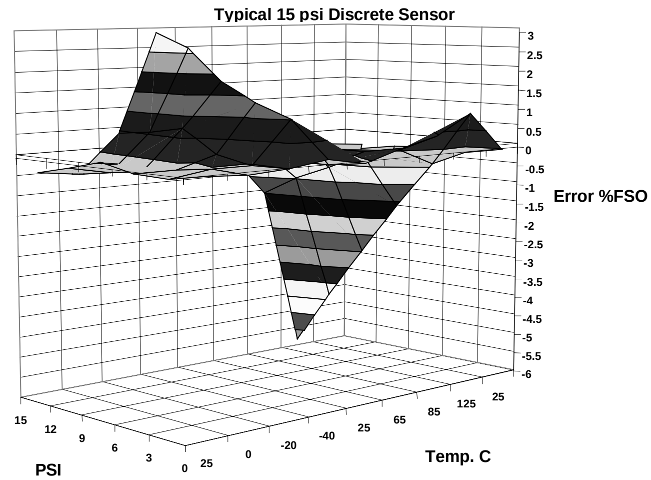


Figure 2. Discrete Sensor Reponse Map



is negative and the TC of the bridge voltage,

$$((1+\alpha T+\beta T^2)Vb(t))$$

is positive, the device can be designed to allow trimming the sensitivity TC.

Discrete sensors are sold as either uncompensated or compensated devices. Uncompensated sensors have a range of offsets and sensitivities based on the diaphragm dimensions and manufacturing process variations. These devices do not have temperature compensation. These sensors can not be used for applications requiring a total error accuracy of less than 10% without sophisticated external circuitry and test equipment to characterize each device.

Compensated devices have the null, sensitivity and sensitivity TC adjusted by thin film laser trimming. These sensors have a tighter error band than uncompensated devices. As seen in Figure 2, this type of compensation produces a 3% or less error over the response surface for a temperature range of 0°C to 85°C. Offset temperature compensation requires characterization over temperature to determine the proper compensation. Temperatures above 85°C or below 0°C quickly degrade the accuracy of compensated discrete devices.

DESIGNING FOR ACCURACY

Linearity, stability, hysteresis, ratiometricity, and repeatability are critical design parameters for high accuracy sensors. Diaphragm design begins with specifying the diaphragm sensitivity, linearity, and burst pressure requirements. The diaphragm side length sets the die size. These parameters require careful consideration: the sensitivity of the die is a function of the diaphragm side length to thickness given by the following:

Equation 3.

$$Vout=K*Vbridge*P*(L/T)**2$$

Linearity is a fourth order effect of the ratio of diaphragm side length to thickness and the pressure range given by the following:

Equation 4.

$$TBL=K*P*(L/T)**4$$

The burst pressure is related to the edge stress on the diaphragm and is given by the following:

Equation 5.

$$Stress=K*P*(L/T)**2$$

In Equations 4 and 5, K is a constant but is not the same value in each equation. P is pressure, while L and T represent the diaphragm length and thickness. As can be seen from Equations 3, 4, and 5, the larger and thinner the diaphragm, the more sensitive it becomes. However, linearity and burst pressure are degraded. In addition, for larger diaphragms, the die size and cost are increased.

Ratiometricity, stability, repeatability, and thermal hysteresis involve manufacturing process considerations, as does the mechanical interface used for mounting the silicon to the port. The mechanical properties of silicon provide a highly reliable diaphragm that tolerates burst pressures several times the operating pressure. The device has virtually no mechanical hysteresis when properly designed. Hysteresis for these devices is dominated by thermal incompatibilities between the silicon and the mounting materials. Monolithic sensor electronics are designed to be ratiometric and laser trimmed.

Supply voltage is also a consideration when selecting a ratiometric sensor. Discrete sensors have different nominal supply voltages over which their typical operation is specified. Usually this is to provide a desired sensitivity. Depending on the device, this may be 8 V, 10 V or even 12 V. Discrete sensors have differential output voltages of up to 100 mV. The requirement for full scale output of the diaphragm is related to the signal-to-noise ratio of the system. Because the output signals from the bridge must be routed for use, sufficient signal levels must be maintained for signal integrity.

The monolithic sensor is specified at a 5 V supply with a linear output from 0.5 V to 4.5 V. Integrated amplification of the bridge signal produces a sensor with high accuracy as measured with respect to the full scale output. Thus, the full scale output has been increased by an order of magnitude from millivolts to volts. With discrete sensors, amplification is required to interface the signal to a controller.

The monolithic sensor, shown in Figure 3, is built in a 6 pin DIP package that is easily mounted to a PC board. This small size optimizes PC board space. The port design is compatible with an O-ring interface that allows overpackaging if the system requires.

The sensor construction is highly reliable and offers excellent media compatibility. Standard silicon integrated circuit fabrication techniques are used to produce the die that is bonded to a glass stress isolation structure. This component is then solder mounted to the port to provide media compatibility with air, water, engine fuel, oil and transmission fluids.

System cost is always a trade off. Designers must achieve the required performance with a product that will provide a reasonable return. System designers look for components that will reduce manufacturing costs without compromising system performance. Although the price of a single chip fully compensated sensor is somewhat higher than a discrete sensor,

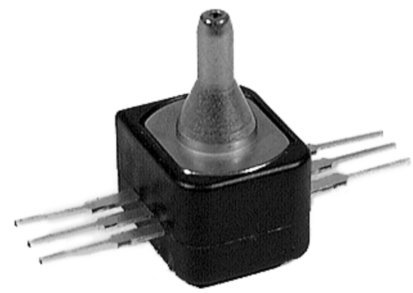


Figure 3. Monolithic Pressure Sensor

the single chip solution is more cost effective when the entire system is considered.

SUMMARY

The monolithic fully signal conditioned sensor offers many advantages when used in applications. The single chip fully compensated sensor is packaged in a 6-pin DIP that provides a small package outline that can be mounted directly to a PC board. This eliminates the cost associated with mounting brackets. The sensors operate from a 5 V supply and have a linear output from 0.5 V to 4.5 V providing a direct interface to an A/D input on a controller. Unlike discrete devices, the monolithic sensor requires no additional interface circuitry to perform the output signal function. This saves cost in several ways. Design time is saved by eliminating the interface electronics as well as simplifying the PC board design. The cost of the interface electronics is eliminated. Calibration over temperature can be very costly when attempting to match the performance of discrete and single chip devices. Conservation of board space is achieved with the use of a single component. This also reduces cost. Procurement costs are higher with a system that uses a discrete sensor with interface electronics as opposed to one that uses a single component.

Overall, a system designer should consider the total system cost by comparing the cost of the single chip fully compensated sensor with the cost of the discrete sensor with interface electronics to achieve the desired total error band.

Monolithic Pressure Sensors

WARRANTY and REMEDY

Honeywell warrants goods of its manufacture as being free of defective materials and faulty workmanship. Contact your local sales office for warranty information. If warranted goods are returned to Honeywell during the period of coverage, Honeywell will repair or replace without charge those items it finds defective. The foregoing is Buyer's sole remedy and is **in lieu of all other warranties, expressed or implied, including those of merchantability and fitness for a particular purpose**.

Specifications may change at any time without notice. The information we supply is believed to be accurate and reliable as of this printing. However, we assume no responsibility for its use.

While we provide application assistance, personally, through our literature, and the Honeywell website, it is up to the customer to determine the suitability of the product in the application.

For application assistance, current specifications, or name of the nearest Authorized Distributor, contact a nearby sales office. Or call:

1-800-537-6945 USA
1-800-737-3360 Canada
1-815-235-6847 International

FAX

1-815-235-6545

INTERNET

www.honeywell.com/sensing
info@micro.honeywell.com

Honeywell

Sensing and Control
Honeywell Inc.
11 West Spring Street
Freeport, Illinois 61032

www.honeywell.com

Printed with Soy Ink on 50% Recycled Paper

008044-1-EN IL50 GLO 1199 Printed in USA

Pressure and Force Sensors

Output Signal Adjustment and Temperature Compensation for 24PC and FS Series – Note #1

INTRODUCTION

Many pressure and force sensor applications require close control over performance parameters such as sensitivity, linearity, hysteresis, and others. Using computer controlled laser trimming on the 140/160PC and 240PC pressure sensors, MICRO SWITCH provides this close control and higher performance than can be achieved using discrete circuitry. Temperature compensation circuitry is an integral part of the device and is optimized on each unit as part of the calibration procedure. Null offset and Span are similarly controlled. No adjustment or recalibration by the user is required.

26 and 176PC sensors provide interchangeability from unit to unit and provide other limited temperature compensation. The 26 and 176PC are voltage excited.

The 24PC and FS feature a wider tolerance on null offset and Span and do not include temperature compensation. The following procedures can be used to set the null offset and Span to desired output values (0-100 mV typically) and to compensate for temperature shift.

OUTPUT SIGNAL ADJUSTMENT

Setting Null Offset to Zero

1. Measure null offset (lead 2 to 4).
2. For a negative null offset place a resistor from lead 1 (supply) to lead 2 (positive output). Expect values around 300K ohms **(Figure 1A).**
3. For a positive null offset place a resistor from lead 1 (supply) to lead 4 (negative output). Expect values around 300K ohms **(Figure 1B).**

Setting Span

1. Measure the bridge resistance (R_B) from lead 2 to 4 (output).
2. Measure Span.
3. Calculate a shunt resistor (R_S) using the following equation:

$$R_S = \frac{R_B}{\frac{K_M}{K_D} - 1}$$

Where:
K_M = measured Span
K_D = desired Span
Generally: $5K < R_S < 20K$ ohms

4. Install shunt resistor from lead 2 to 4 (output) as in **Figure 2.**

Figure 1A
If null offset is negative

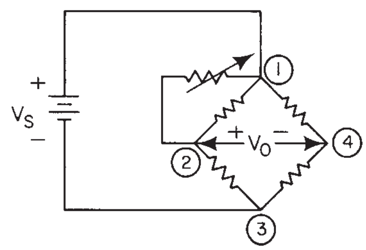


Figure 1B
If null offset is positive

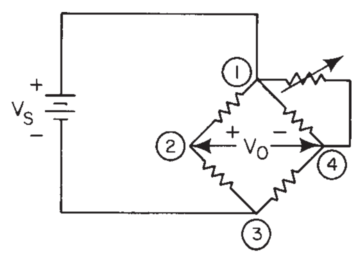
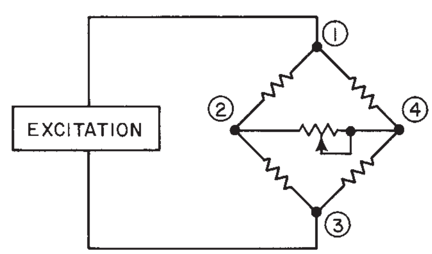


Figure 2
Setting Span



Pressure and Force Sensors

Output Signal Adjustment and Temperature Compensation for 24PC and FS Series – Note #1

TEMPERATURE COMPENSATION[1]

Introduction

The 24PC pressure and FS force sensors exhibit the following effects as temperature increases:

1. Pressure or force sensitivity decreases.[2]
2. The resistance of each piezoresistor increases.[2]

For illustration, consider the following piezoresistor model:

$R(P,T) = C_T(R_o + C_p k(25°C)P)$

Where:

R(P,T) is the value of the piezoresistance (ohm)

R_o is the unstressed (ambient) piezoresistance at 25°C

R_o $= R(P = O, T = 25°C)$

C_T is the change in R(P,T) with temperature.

$$C_T = \frac{R(P = O,T)}{R_o} \left(\frac{ohm}{ohm}\right)$$

k(25°C) is the pressure or force sensitivity at 25°C

$$k(25°C) = \frac{R(P, 25°C) + R_o}{P} \left(\frac{ohm}{psi\ or\ g}\right)$$

k(T) is the pressure or force sensitivity at applied temperature.

C_p is the change in pressure or force sensitivity with temperature.

$$C_p = \frac{k(T)}{k(25°C)} \quad \frac{ohm/psi\ or\ g}{ohm/psi\ or\ g}$$

P is the applied pressure (psi)

F is the applied force (g)

Nominal C_p and C_T characteristics are given in **Figure 3.**

Method #1

The circuit of **Figure 4** provides temperature compensation by combining a current source and positive feedback. Essentially, the change in C_T is partially cancelled by an opposite change in C_p.

For a different supply voltage, vary the 24.9K resistor. Make sure that the common mode input voltage and output voltage swing limitations of the amplifiers are not exceeded.

24PC sensors are less sensitive to temperature when current excited. We strongly urge that current excitation be considered as a means of minimizing errors due to temperature changes. Feel free to contact the application center to get an update on this subject.

Figure 3
24PC Nominal Piezoresistor Characteristics

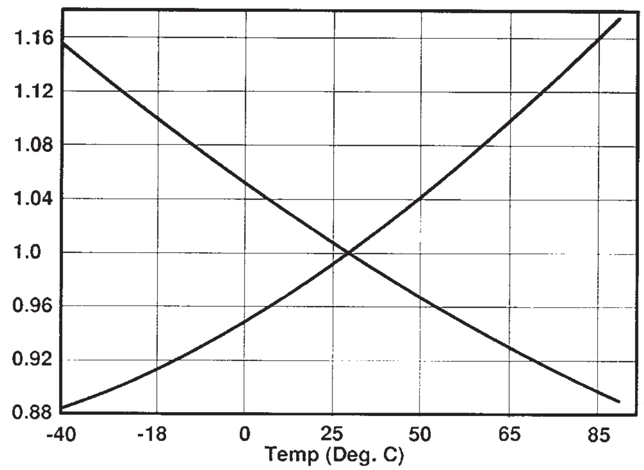
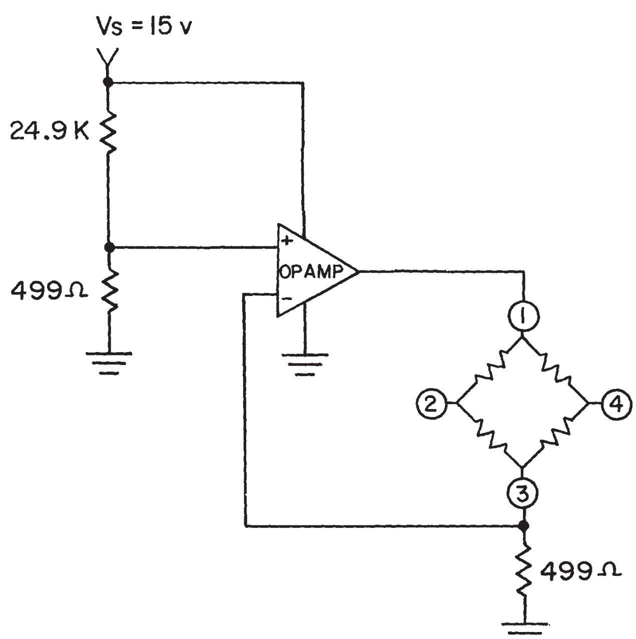


Figure 4
Temperature Compensation Method #1

Recommended Op Amps:
LM358—Dual Op Amp
LM124—Quad, military grade Op Amp



[1] Temperature Compensation Methods #1-2 affect the **sensitivity** of the sensor, not the null offset, in that the change in the slope of the output curve caused by temperature is minimized.
[2] Consistent from unit to unit within a narrow tolerance.

Pressure and Force Sensors

Output Signal Adjustment and Temperature Compensation for 24PC and FS Series – Note #1

Method #2

C_p is inversely proportional to temperature. To compensate for this effect, the voltage applied to the sensor bridge must be proportional to temperature. One approach is to connect a thermistor with a negative temperature coefficient (resistance decreases with temperature) in series with the bridge, as shown in **Figure 5A.** Thermistors with the exact resistance vs. temperature characteristics to compensate the bridge may not be readily available. An alternate approach is the use of a thermistor-resistor network to meet the required characteristics. Standard 1% resistor values (with a standard thermistor) are shown in **Figure 5B.** This method provides temperature compensation to within ±2% Span over the range of −10° to 50°C. The thermistor should be located close to the sensor, so they will experience the same thermal environment.

TEMPERATURE COMPENSATION TO CONTROL SHIFT OF NULL OFFSET

Null shift caused by temperature can be compensated using the circuit in **Figure 6.** However, it is required that the sensor first have sensitivity temperature compensation. In other words, you must use a 26 and 176 or a 24PC or FS employing one of Methods 1 or 2.

Null shift with temperature is unpredictable; therefore the sensors must be compensated individually.

1. Measure $V_{2\text{-}3}$ and $V_{2\text{-}4}$ at null over the temperature range of interest (room temperature (T_R), and some other temperature (T)).
2. Measure $R_{2\text{-}3}$ at room temperature.
3. Select R_1 for $V_n = V_{2\text{-}3}$ at room temperature.
4. Calculate the value of R_2 necessary to compensate the measured null shift.

$$R_2 = R_{2\text{-}3}\left[\frac{V_{2\text{-}3(T)} - V_{2\text{-}3\ (T_R)}}{V_{2\text{-}4(T)} - V_{2\text{-}4\ (T_R)}}\right]$$

5. Connect R_2 to terminal 2 if $V_{2\text{-}4(T)} - V_{2\text{-}4(T_R)}$ is positive. Connect it to terminal 4 if negative.

Figure 5
Temp. Comp. Method #2

Figure 5A

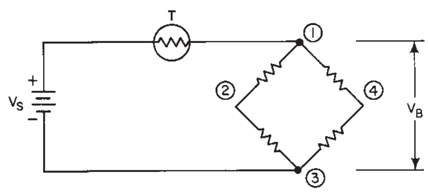
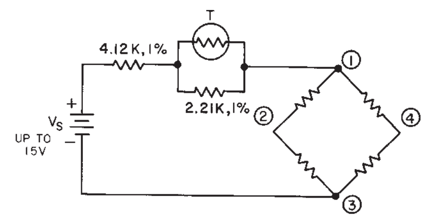


Figure 5B
Dale Thermistor 2M1501* or equivalent



***Dale Electronics, Inc.**
North Fork, NB

Figure 6
Null Temperature Compensation

(A) Customer supplied temperature compensation
(B) Built-in temperature compensation