Honeywell

Pressure Transducer Accuracy in Application

Technical Note

After taking environmental (and hence, reliability) requirements into account, the second most important consideration for transducer selection concerns the required accuracy of the device. The concepts and formulas presented here provide a tool with which a user can calculate transducer accuracy for the specific conditions of his application.

A SYSTEM MODEL

To see how transducer performance parameters are related to system accuracy, consider the IC pressure transducer system shown in Figure 1. The problem is to determine the magnitude of error for given values of the major input (applied pressure) and the minor inputs (temperature, time and excitation voltage). The error sources are inherent to the transducer, but the magnitude of error from each one may depend on the major and minor inputs to the transducer system.

To simplify our model, we first divide the error sources into two groups: those that are dependent on applied pressure and those that are not. Figure 2 gives a typical response curve for the transducer, with applied pressure, P_A, on the X - axis and output voltage signal, V_S, on the Y - axis. P_{REF} is the pressure used as a reference in measuring transducer errors. For each of Honeywell's transducers, this is defined as the minimum value of the operating pressure range given in the data sheet. V_O, the offset voltage, is the transducer output signal obtained when the reference pressure is applied. P_{MAX} is the high endpoint pressure applied to the device and this yields an output voltage, V_{MAX} - the range and span are then

FIGURE 1

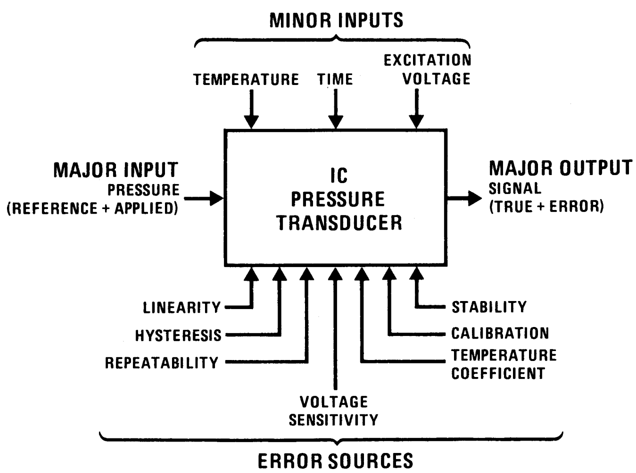
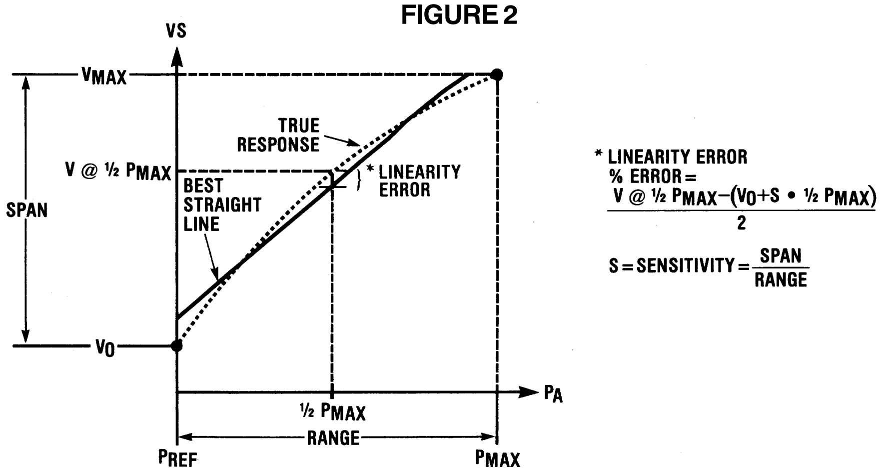


FIGURE 2



defined as (P_{MAX} - P_{REF}) and (V_{MAX} - V_O) respectively. Device sensitivity, S, is the slope of the line, (Span/Range), and has units of volts/psi.

Because Honeywell's transducers are inherently linear, the output signal can be given by:

$$V_S = V_O + S \bullet (P_A - P_{REF}) = V_O + \text{Span} \bullet \frac{(P_A - P_{REF})}{\text{Range}}$$

As a further result, the error in output signal, ΔV_S, can be expressed as:

$$\Delta V_S = \Delta V_O + \Delta\text{Span} \bullet \frac{(P_A - P_{REF})}{\text{Range}}$$

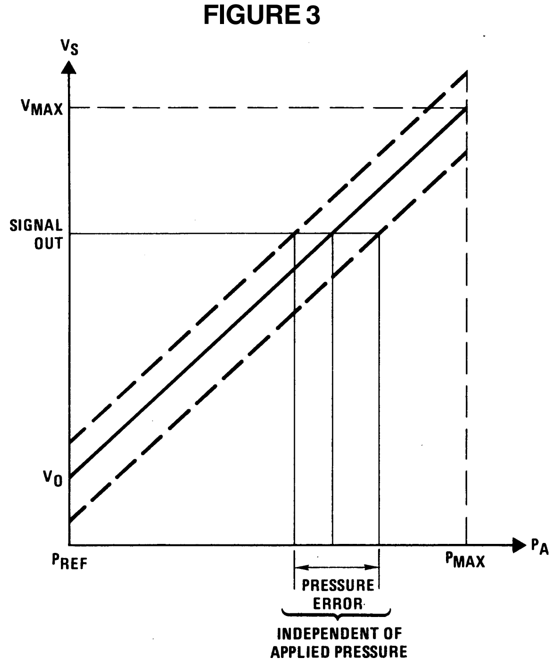
This equation shows that ΔVo, the offset error, is independent of applied pressure while

$$\Delta\text{Span.} \bullet \frac{(P_A - P_{REF})}{\text{Range}},$$

the span error, is proportional to the applied pressure range, (P_A - P_{REF}).

Offset errors, being independent of the major input variable (applied pressure), are equivalent to system common-mode errors, as shown in Figure 3. Because the offset error is the same regardless of pressure, it has the effect of translating the response line up or down, while the slope or sensitivity remains constant.

FIGURE 3



Span errors, being proportional to applied pressure, are equivalent to system normal-mode errors, as shown in Figure 4. Because the span error increases linearly with applied pressure, it has the effect of rotating the response line around the offset-reference pressure point. While independent, the offset and span error groups both contain errors that are dependent on the minor input variables, as shown in Table 1. These coefficients are used to specify the errors in Honeywell's pressure transducers and to calculate overall accuracy.

SYSTEM ACCURACY

With the errors divided into 2 groups of independent coefficients, we can now compute both the worst-case error and the most probable error for any IC pressure transducer system.

Worst-Case Error: The worst-case overall error ϵ_{WC} is obtained by simple addition of all applicable errors:

$$\epsilon_{WC} = \sum_{1}^{n} \epsilon_j$$

where ϵ_j is the error resulting from the j[th] error coefficient and n is the number of error terms included In the calculation.

Most Probable Error:

The most probable error ϵ_{MP} is obtained by computing the square root of the sum of the squares:

$$\epsilon_{MP} = \sqrt{\sum_{1}^{n} \epsilon_j^2}$$

FIGURE 4

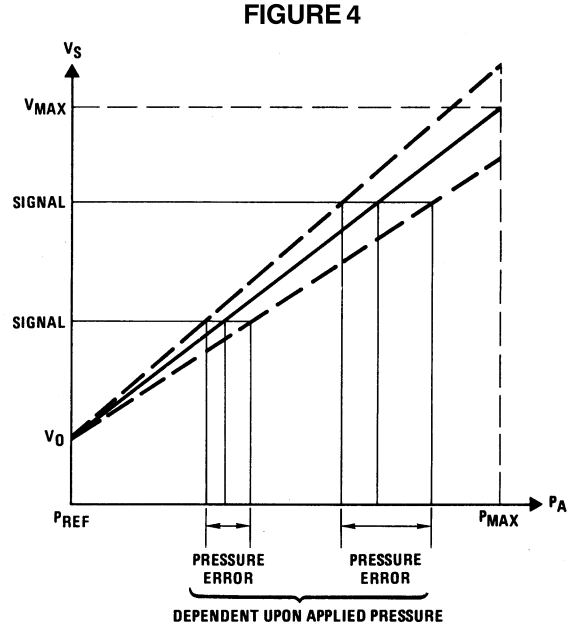


TABLE 1: OFFSET AND SPAN ERRORS	
OFFSET (Common-Mode)	**SPAN (Normal-Mode)**
Calibration	Calibration
Repeatability	Linearity-Hysteresis-Repeatability
Stability	Stability
Temperature Coefficient	Temperature Coefficient
Excitation Voltage Coefficient	Excitation Voltage Coefficient

We can now select the applicable error coefficients, calculate the error terms, ϵ_j, from the specifications given for any individual pressure transducer, and plug into the appropriate formula above to get system accuracy.

ACCURACY SPECIFICATIONS

By convention, system accuracy is expressed in the dimensions of the major input variable, in this case, psi. However, transducer accuracy is typically expressed as percent of full span (% FS). Fortunately, the transposition from one dimension to the other is analytically simple. An error coefficient expressed as % FS is changed to psi by multiplying by the range, (P_{MAX} - P_{REF}). of the device under consideration and dividing by 100. So the user can perform accuracy calculations in either dimension, both % FS and psi error values are given in the data sheets for linearity, hysteresis, repeatability, stability, and temperature coefficient.

Three additional points should be noted relative to the data sheet accuracy specifications. Offset calibration error is given directly as volts, since this is the parameter most users actually measure. To convert from volts to % FS, divide offset calibration error by the span voltage (typically 10 V for signal-conditioned devices) and multiply by 100. If psi is desired, divide offset calibration error by the device sensitivity (mV/psi) and multiply by 1000 (mV/V). In a similar fashion, sensitivity calibration error is given directly as mV/psi. To convert to % FS, divide by the device sensitivity and multiply by 100. (Because these are linear devices, the ratio of sensitivity error to sensitivity is the same as the ratio of span error to span.) To get psi, divide sensitivity calibration by the sensitivity and multiply by the range.

Finally, supply voltage coefficient (voltage regulation error) is given directly as percentage of supply voltage change. Conversion to psi from % FS would use the same technique discussed in the first paragraph of this page.

OFFSET SPECIFICATIONS

The offset characteristics are measured at reference temperature with reference pressure applied. Although measured at the reference pressure, offset errors given in the data sheet, ΔV_O, are the same regardless of pressure and should be used in the accuracy formulas without any modification for user pressure range. They are defined as follows:

Offset Calibration: Defines the offset voltage and its maximum deviation from unit to unit, including long-term stability (1 year). The deviation is specified in volts and must be divided by full span voltage to express the error band as % FS, or divided by sensitivity to express it as psi, for accuracy calculations.

Offset Temperature Coefficient (TC_O): Defines the maximum deviation in offset voltage as temperature is varied from T_{REF} (25 °C [77 °F]) to any other temperature, T, in the operating temperature range. It is specified as % FS/°C or psi/°C and must be multiplied by the temperature difference $|T — T_{REF}|$ to obtain the error at T as % FS or psi. For example, the maximum error for the operating temperature range of Honeywell's hybrid transducers (0 °C to 85 °C [32 °F - 185 °F]) would be:

$TC_O \bullet (T_{MAX} - T_{REF}) = TC_O \bullet$ (85 °C - 25 °C [185 °F - 77 °F]) = $TC_O \bullet$ (60 °C [140 °F]).

Offset temperature coefficient is factory calibrated at 25 °C ±3 °C [77 °F ±37°F] and at 80 °C ±3 °C [176 °F ±37 °F]. Any calculation of temperature related error must account for these temperature variations. Typically, errors would be calculated between two points that are at least 15 °C [39 °F] apart.

Offset Repeatability: Defines the maximum deviation in offset voltage when applied pressure is cycled through its full range.

Offset Stability: Defines the maximum deviation in offset voltage over a one year period, during which time the pressure and temperature do not exceed their specified maximum ratings.

SPAN SPECIFICATIONS

Full span corresponds to the entire operating pressure range, (P_{REF} - P_{MAX}). specified on the data sheet for each device type. This yields a span voltage, measured at the reference temperature, equal to (V_{MAX} - V_O). If an application utilizes a transducer's full operating pressure range, then the span error values given in the data sheet, ΔSpan, can be plugged directly into the error formulas to determine system accuracy. However, if only part of the range is used, the data sheet span errors must be reduced proportionally, since they are a linear function of applied pressure. This is accomplished by taking the actual pressure range used in the application, dividing by the range of the device, and then multiplying each of the data sheet span errors by this ratio (which is a number between 0 and 1). Note that although application span error,

$$\Delta \text{Span} \cdot \frac{(P_A - P_{REF})}{\text{Range}},$$

is defined to include P_{REF}, this is not a user requirement. Span error is simply

$$\Delta \text{Span} \bullet \frac{\text{User Range}}{\text{Range}}$$

for any user range. The data sheet span errors, ΔSpan, are specified as follows:

Sensitivity Calibration: Sensitivity is defined as span divided by the range, (V_{MAX} - V_O)/(P_{MAX} - P_{REF}). Sensitivity calibration defines the maximum deviation of sensitivity from unit to unit, including long term span stability(1 year). The deviation is specified as mV/psi and must be divided by the sensitivity to express the error as % FS, or divided by the sensitivity and multiplied by the range to express it as psi, for accuracy calculations.

Span Temperature Coefficient (TC_S): Defines the maximum deviation in span voltage as temperature is varied from T_{REF} to any T in the specified operating temperature range. The coefficient is specified as % FS/°C or psi/°C and must be multiplied by the temperature difference $|T - T_{REF}|$ to obtain the span error as % FS or psi.

Linearity-Hysteresis-Span Repeatability: Linearity defines the maximum deviation of output voltage over the full operating pressure range from this BSL. Hysteresis and span repeatability define the transducer's ability to reproduce an output voltage when cycled through its full operating pressure range. This error is generally lumped with linearity error because it is small by comparison and is usually contained within any real measurement of linearity.

Span Stability: Defines the maximum deviation in span voltage over a one year period during which time pressure and temperature do not exceed their specified maximum ratings.

SYSTEM ACCURACY CALCULATIONS

Voltage Regulation

In the example calculations that follow, we will assume that user excitation voltage is sufficiently regulated so as to make the voltage regulation error, $\in_{VR}$, negligible ($\leq$ 0.1 % FS). $\in_{VR}$ is an output signal change due solely to a change in excitation voltage. The percent regulation required to satisfy this condition is derived as follows. For signal-conditioned devices, $\in_{VR}$ is given by:

$$\in_{VR} = 0.5\,\% \bullet \Delta V_e$$

where 0.5 % is the specified transducer output voltage change to excitation voltage change and ΔV_e is the excitation voltage deviation [from nominal (15 V)]. To keep the regulation error below 0.1 % FS, the required external power supply regulation is given by:

$$\frac{\Delta V_e}{V_e} = \left(\frac{1}{0.5\%}\right) \bullet \left(\frac{\epsilon_{VR}}{V_e}\right) = 200 \bullet \left(\frac{\epsilon_{VR}}{\text{Span}}\right) \bullet \left(\frac{\text{Span}}{V_e}\right)$$

Since $\frac{\epsilon_{VR}}{\text{Span}} = 0.1\%$,

$$\frac{\Delta V_e}{V_e} = 20\% \bullet \left(\frac{\text{Span}}{V_e}\right)$$

For Span = 10V and V_e = 15V,

$$\frac{\Delta V_e}{V_e} = 20\% \bullet \left(\frac{2}{3}\right) = \pm 13\ \%\ \text{Regulation}$$

which holds for any signal-conditioned pressure transducer.

For monolithics, which do not have any internal regulation or signal conditioning, the formulation is not quite as neat since output characteristics vary from device to device.

However, as an approximation, it can be assumed that output signal changes are roughly proportional to changes in excitation voltage. Therefore, to ensure $\in_{VR}$ = 0.1 % FS would require a power supply with =0.1 % regulation.

If the signal conditioning or monolithic regulation requirements calculated above are met, then regulation error can be eliminated from essentially all error calculations, with the possible exception of ultra-high accuracy applications. However, the greater the deviation from these requirements, the more necessary it becomes to include $\in_{VR}$ in the accuracy calculations. Since both ΔVO and ΔSpan are affected, $\in_{VR}$ would be included in both segments of the error calculation.

Interchangeable vs. Calibrated Accuracy

Interchangeable Accuracy: In calculating overall accuracy, the first question is whether each pressure transducer will be field calibrated upon installation or replacement. If you're going to just plug it in with no adjustments, you'll need the interchangeable accuracy, which allows for unit-to-unit calibration errors.

Calibrated Accuracy: If you intend to calibrate each device upon installation, you will want to use the calibrated accuracy, $\in_C$, which holds only for one specific transducer. The calibrated overall accuracy excludes Honeywell's calibration errors, but includes all other applicable specified errors including stability, TC, linearity, hysteresis, and repeatability.

Example Calculations

The LX1604D is chosen to show how error calculations would be performed for a typical pressure transducer under various conditions. Analogous procedures apply to any Honeywell IC pressure transducer and can be extended for use in evaluating errors in a complete pressure system.

Table II is a reproduction of the applicable LX1604D data on page 5-5. The LX1604D operating pressure range is -15 psid to +15 psid. Therefore, P_{REF} = -15 psid, P_{MAX}= +15 psid, and Range = (P_{MAX}- P_{REF}) = 30 psid. V_O (at - 15 psid) = 2.5 V (from the offset calibration column) and V_{MAX}=V_O + S • (P_{MAX} - P_{REF}) = 2.5 + (0.333)(30) = 12.5 V (where the sensitivity value is obtained from the sensitivity calibration column and converted into V/psi). Therefore, Span = V_{MAX} - V_O = 10V.

To be consistent with Table 1, the data divides the error terms into two categories: those for offset, ΔV_O, and those for span, ΔSpan. Table 2 further identifies each component of error as follows: ΔV_{O1} is the offset calibration error, ΔV_{O2} is the offset temperature coefficient error, ΔV_{O3} is the offset repeatability error, and ΔV_{O4} is the offset stability error. Likewise, sensitivity (and thus span) calibration error is $\Delta Span_1$, $\Delta Span_2$ is the span temperature coefficient error, $\Delta Span_3$ is the combined linearity, hysteresis, and repeatability error,and $\Delta Span_4$ is the span stability error. As mentioned previously, where appropriate, both % FS and psi errors are included.

The following calculations are performed using % FS error values. However, completely analogous results would be obtained using psi errors (psi results for each calculation are included for reference purposes).

Maximum ErroróCase 1

The maximum possible error would occur for the case where the full temperature and pressure ranges are used. Under these temperature conditions, each temperature coefficient is converted to % FS by multiplying the data sheet errors by (T_{MAX} - T_{REF}) = (85 °C – 25 °C [185 °F - 77 °F]) = 60°C [140 °F]. Then:

$$\Delta V_{O2} = 0.03x60 = 1.8\%\ FS$$

and

$$\Delta Span_2 = 0.03 \times 60 = 1.8\%\ FS$$

Since the full pressure range is being used, it is not necessary to decrease any of the span errors proportionally. The % FS table values would be plugged directly into the accuracy formulas.

The only conversion remaining is to change calibration errors in the data to % FS. Offset calibration is converted by dividing by span voltage (10 V) and multiplying by 100 while sensitivity calibration is converted by dividing by sensitivity (333 mV/psi) and multiplying by 100.

$$\Delta V_{O1} = \frac{100(0.35)}{10} = 3.5\%\ FS$$

and

$$\Delta Span1 = \frac{100(6.7)}{333} = 2\%\ FS$$

Offset Characteristics						
Offset Calibration $V \pm t \Delta V$	Temperature Coefficient ΔV_{o2}		Repeatability ΔV_{o3}		Stability ΔV_{o4}	
	±% FS/°C	±psi/°C	±% FS/°C	±psi/°C	±% FS	±psi
2.5 ±0.35	0.03	0.009	0.4	0.12	1.7	0.5
Span Characteristics						
Sensitivity Calibration mV/psi $\Delta Span_1$	Temperatrue Coefficient $\Delta Span_2$		Linearity Hysteresis & $\Delta Span_3$		Stability $\Delta Span_4$	
	±% FS/°C	±psi/°C	±% FS	±psi±	% FS	±psi
333 ±6.7	0.03	0.09	0.67	0.20	0.3	0.1

Having all % FS values, it is now possible to calculate $\in_I$, interchangeable overall error, and $\in_C$ calibrated overall error, worst-case and most probable error values.

For interchangeable overall error, offset stability, ΔVO4, and span stability, ΔSpan4, are eliminated. The remaining offset and span errors are plugged into the $\in_{WC}$ and $\in_{MP}$ formulas to yield

Worst-case: ϵ_{WCI}

$$= \Delta V_{O1} + \Delta V_{O2} + \Delta V_{O3} + \Delta Span_1 + \Delta Span_2 + \Delta Span_3$$

$$= \underbrace{(3.5 + 1.8 + 0.4)}_{\text{Offset}} + \underbrace{(2 + 1.8 + 0.67)}_{\text{Span}} = \pm 10.17\ \%FS$$

Most probable: ϵ_{MPI}

$$= \sqrt{\Delta V_{O1}^2 + \Delta V_{O2}^2 + \Delta V_{O3}^2 + \Delta Span_1^2 + \Delta Span_2^2 + \Delta Span_3^2}$$

$$= \sqrt{\underbrace{3.5^2 + 1.8^2 + 0.4^2}_{\text{Offset}} + \underbrace{2^2 + 1.8^2 + 0.67^2}_{\text{Span}}} = \pm 4.83\ \%FS$$

This corresponds to ±3.05 psid and ±1.45 psid respectively.

For calibrated overall error, both calibration errors, ΔV_{O1} and $\Delta Span_1$, are eliminated from the above calculation and the two stability errors, ΔV_{O4} and $\Delta Span_4$ are inserted.

Worst-case: ϵ_{WCC}

$$= \Delta V_{O2} + \Delta V_{O3} + \Delta V_{O4} + \Delta Span_2 + \Delta Span_3 + \Delta Span_4$$

$$= \underbrace{(1.8 + 0.4 + 1.7)}_{\text{Offset}} + \underbrace{(1.8 + 0.67 + 0.3)}_{\text{Span}} = \pm 6.67\ \%FS$$

Most probable: ϵ_{MPC}

$$= \sqrt{\Delta V_{O2}^2 + \Delta V_{O3}^2 + \Delta V_{O4}^2 + \Delta Span_2^2 + \Delta Span_3^2 + \Delta Span_4^2}$$

$$= \sqrt{\underbrace{1.8^2 + 0.4^2 + 1.7^2}_{\text{Offset}} + \underbrace{1.8^2 + 0.67^2 + 0.3^2}_{\text{Span}}} = \pm 3.17\ \%FS$$

This corresponds to ±2.00 psid and ±0.95 psid respectively.

Reducing Temperature ErrorsóCase 2

Since the temperature coefficients are two of the main error components, a reduced temperature range can greatly reduce overall error. For 80 % effective temperature compensation (reducing effective range from 60 °C to 12 °C [140 °F to 50 °F]), the offset and span temperature coefficients would be

ΔV_{O2} = 0.03 X 12 = 0.36 % FS

and

$\Delta Span_2$ = 0.03 x 12 = 0.36 % FS

The interchangeable overall errors would then be reduced to

Worst-case: ϵ_{WCI}

$$= (3.5 + \underbrace{0.36}_{} + 0.4) + (2 + \underbrace{0.36}_{} + 0.67) = \pm 7.29\ \%FS$$

Reduced TC Errors

Most probable: ϵ_{MPI}

$$= \sqrt{3.5^2 + 0.36^2 + 0.4^2 + 2^2 + 0.36^2 + 0.67^2}$$

$$= \pm 4.14\ \%FS$$

This corresponds to ±2.19 psid and ±1.24 psid respectively, reduced from ± 3.05 psid and ±1.45 psid in Case 1.

A corresponding improvement is achieved for the calibrated accuracy:

Worst-case: ϵ_{WCC}

$$= (\underbrace{0.36}_{} + 0.4 + 1.7) + (\underbrace{0.36}_{} + 0.67 + 0.3) = \pm 3.79\ \%FS$$

Reduced TC Errors

Most probable: ϵ_{MPC}

$$= \sqrt{0.36^2 + 0.4^2 + 1.7^2 + 0.36^2 + 0.67^2 + 0.3^2}$$

$$= \pm 1.96\%FS$$

This corresponds to ±1.14 psid and ±0.59 psid respectively, reduced from ±2.00 psid and ±0.95 psid by 80 % effective temperature compensation.

Reduced Pressure RangeóCase 3

When the full specified pressure range of a particular device is not being used, all span errors should be reduced by the ratio R, where R is defined as:

$$R = \frac{\text{User Range}}{\text{Device Specified Range}}$$

Assume, for example, that the user application is for +5 psid to +15 psid. Then R=10 psid/30 psid = 0.333, and each application span error would be

$\Delta Span_1$ = 2x0.333= ±0.67 % FS
$\Delta Span_2$ = 0.03 x 0.333 = ±0.01 % FS/° C
$\Delta Span_3$ = 0.67x0.333= ±0.22 % FS
$\Delta Span_4$ = 0.3x0.333= ±0.1 % FS

If Case 2 conditions above are maintained, then the inter-changeable overall errors would now be reduced to

Worst-case: ϵ_{WCI}

$$= (3.5 + 0.36 + 0.4) + \underbrace{(0.67 + 0.12 + 0.22)}_{\text{Reduced Span Errors}} = \pm 5.27\ \%FS$$

Most probable: ϵ_{MPI}

$$= \sqrt{3.5^2 + 0.36^2 + 0.4^2 + 0.67^2 + 0.12^2 + 0.22^2}$$

$$= \pm 3.61\ \%FS$$

This corresponds to ±1.58 psid and ±1.08 psid respectively, reduced from ± 2.19 psid and ±1.24 psid in Case 2.

NOTE: The reduced pressure range decreases span error values only. Offset errors remain unchanged!

For calibrated overall error

Worst-case: ϵ_{WCC}

$$= (0.36 + 0.4 + 1.7) + \underbrace{(0.12 + 0.22 + 0.1)}_{\text{Reduced Span Errors}} = \pm 2.90\ \%FS$$

Most probable: ϵ_{MPC}

$$= \sqrt{0.36^2 + 0.4^2 + 1.7^2 + 0.12^2 + 0.22^2 + 0.1^2}$$

$$= \pm 1.80\ \%FS$$

This corresponds to ±0.87 psid and ±0.54 psid, respectively, reduced from ± 1.14 psid and ±0.59 psid in Case 2, by using 1/3 of the LX1604D pressure range.

Auto-Reference CompensationóCase 4

A powerful, easy-to-use, and generally applicable technique, auto-referencing, can often eliminate all offset errors by period sampling of the offset voltage at reference pressure. With this technique, (see Section 6), only the span errors apply. Again, using the LX1604D specifications and assuming all Case 3 conditions hold, the interchangeable accuracy is:

Worst-case: ϵ_{WCI}

$$= \underbrace{(0.67 + 0.12 + 0.22)}_{\text{Span Errors}} = \pm 1.01\ \%FS$$

Most probable: ϵ_{MPI}

$$= \sqrt{0.67^2 + 0.12^2 + 0.22^2} = \pm 0.72\ \%FS$$

This corresponds to ±0.30 psid and ±0.22 psid, respectively, reduced from ± 1.58 psid and ± 1.08 psid in Case 3. Calibrated overall error would be

Worst-case: ϵ_{WCC}

$$= \underbrace{(0.12 + 0.22 + 0.1)}_{\text{Span Errors}} = \pm 0.44 \ \%FS$$

Most probable: ϵ_{MPC}

$$= \sqrt{0.12^2 + 0.22^2 + 0.1^2} = \pm 0.27 \ \%FS$$

This corresponds to ±0.13 psid and ±0.08 psid, respectively, reduced from ±0.87 psid and ±0.54 psid in Case 3.

Auto-Reference + Temperature ControlóCase 5

For very high accuracy applications, both auto-referencing and complete temperature range reduction may prove valuable. In these cases, the additional temperature compensation may take the form of a temperature-controlled chamber designed to hold temperature within a few degrees of T_{REF} (which may be shifted to a higher temperature to allow use of an oven). In such a case, the only errors included are linearity, hysteresis, span repeatability and either span calibration or span stability. For interchangeable accuracy, span calibration error is included:

Worst-case: ϵ_{WCI}

$$= \underbrace{(0.67 + 0.22)}_{\substack{\text{Span Errors} \\ \text{without TC}}} = \pm 0.89 \ \%FS$$

Most probable: ϵ_{MPI}

$$= \sqrt{0.67^2 + 0.22^2} = \pm 0.71 \ \%FS$$

This corresponds to ±0.27 psid and ±0.21 psid respectively.

For calibrated accuracy, span stability error is including:

$$\text{Worst-case: } \epsilon_{WCC} = \underbrace{(0.22 + 0.1)}_{\substack{\text{Span Errors} \\ \text{without TC}}} = \pm 0.32 \ \%FS$$

$$\text{Most probable: } \epsilon_{MPC} = \sqrt{0.22^2 + 0.1^2} = \pm 0.24 \ \%FS$$

This corresponds to ±0.10 psid and ±0.07 psid respectively.

Periodic Span CalibrationóCase 6

With overall error down to a fraction of a psi, resulting from auto-referencing and temperature control, the periodic recalibration of span may become worthwhile. Since the span stability error is a slowly aging variation of span voltage, a periodic recalibration may well reduce this error by an order of magnitude. This procedure eliminates calibration error, so only calibrated accuracy applies.

$$\text{Worst-case: } \epsilon_{WCC} = (0.22 + \underbrace{0.01}_{\substack{\text{Reduced Stability} \\ \text{Error}}}) = \pm 0.23 \ \%FS$$

$$\text{Most probable: } \epsilon_{MPC} = \sqrt{0.22^2 + 0.01^2} = \pm 0.22 \ \%FS$$

This corresponds to ±0.07 psid in both cases.

Linearity CompensationóCase 7

For ultra-high accuracy applications, the remaining error, linearity-hysteresis-span repeatability, must be reckoned with. The hysteresis and repeatability components of this coefficient are so small as to approach the noise in the operational amplifier included in the signal-conditioned IC pressure transducer. This noise is about 0.4 % FS for a 1 kHz bandwidth and may require narrow bank filter techniques if ultra-high accuracy is to be achieved. We do know, however, that the linearity error is a large fraction of the remaining error, perhaps as high as 90 %, and that it can be successfully compensated via curve-fitting techniques to reduce overall calibrated error to about ±0.1 % FS, worst-case.

SUMMING IT UP

The foregoing offers the reader a quantitative technique for separating transducer errors and evaluating their contribution to system accuracy, as well as describing several methods for system optimization. It is hoped that this will encourage the transducer user to take a closer look at system requirements as they relate to each of the parameters and optimization techniques discussed, thereby allowing him to make optimum accuracy/cost design tradeoffs. Too often, transducer application specifications are unnecessarily tight, simply because an analysis similar to the one performed above has not been done. The result of this over-specification is unnecessary cost.

Pressure Transducer Accuracy in Application

Technical Note

WARRANTY/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 Buyerís sole remedy and is in lieu of all other warranties, expressed or implied, including those of merchantability and fitness for a particular purpose.**

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