

Selection Guide for Digital Pressure Indicators

INTRODUCTION

Choosing a digital pressure indicator used to be a relatively simple job. Like the early days of camcorders and VCR's, only a few manufacturers supplied them, with limited features, and they tended to be expensive. The past decade has seen improvements in pressure sensing technology (better accuracy, lower cost) along with an explosion in electronics and firmware integration and packaging. The good news is that we now enjoy a multitude of general purpose and application specific products but this variety of solutions makes the selection process a bit more complex.

Today, the term "digital pressure indicator" can cover a lot of ground. The general market place uses it to describe anything from traditional bench or panel mount devices to hand held devices and transducers used with digital panel meters, acquisition systems and so forth.

For our purposes, we will define a digital pressure indicator as a package that includes an integrated pressure sensor and digital display in a bench top or panel mounting enclosure.

The application for which a digital pressure indicator is being selected is key. It will ultimately drive the choice of a given product. There are two major challenges facing the specifying engineer.

Challenge number one is to understand the application requirements. This requires a well-defined set of performance and results criteria which in turn requires a good understanding of manufacturer's specs and jargon (see challenge number two).

Challenge number two *is* wading through the multitude of manufacturer's specifications and industry specific jargon (see challenge number one).

This apparent paradox does have a solution if you employ a selection guide to help simplify the process.

SELECTION GUIDE

The objective of this guide is to provide key questions to ask about the application. The resulting answers will in turn provide essential questions to ask of a potential supplier about a product and it's performance. Some key terms and concepts are defined within the following paragraphs while the remaining terms are included in the key terms section.

What is the environment? (check all that apply)

- Laboratory
- Outdoor
- Temperature Extremes
- Wet (NEMA4, 4X)
- Hazardous (FM I.S., Class, Division)
- High Vibration, Shock
- EMI/RFI

The answer to this question will indicate what type of enclosure is required along with whether or not an agency approval (FM, NEMA, etc.) is required.

What is its intended use?

- Process monitoring
- Control
- Calibration standard
- Dynamic Measurement
- Static Measurement

The answer to this question will indicate speed requirements (update rate) and output requirements (data logging, control, etc.).

What is the process Media?

- Non-reactive Liquid
- Non-reactive Gas
- Non-reactive Vapor*
- Reactive Liquid
- Reactive Gas
- Reactive Vapor
- Conductive Gas

Process media is important for two reasons. First is the obvious safety issue. Is the pressure media compatible with the product’s wetted materials. A mismatch of process media to wetted material could result in corrosion of the sensing element. This could result in erroneous measurement data and/or rupture of the sensing element. Second is a less apparent issue relating to conductive gasses and humidity. Conductive gas can have a significant effect on performance for some types of semiconductor based sensors because the fundamental output signal can be altered by the effect of a conductive gas on the sensing bridge or capacitor.

* Also see “What is the process temperature”

What is the pressure type?

- _____ Gauge
- _____ Absolute
- _____ Vacuum
- _____ Compound
- _____ Differential

The designation of pressure type is based on the location of the datum point and direction of measurement relative to atmospheric pressure as shown below.

Atmospheric Pressure	0 PSI Gauge, Vacuum, Compound
Full Vacuum	0 PSI Absolute

What is the Required Display Resolution?

- _____ 3 Digit
- _____ 3 ½ Digit
- _____ 4 ½ Digit
- _____ 5 Full Digit

It is important to understand how the manufacturer supports a product’s accuracy specification. This requires a conceptual understanding of how display resolution, pressure range, and the accuracy statement inter-relate.

The display resolution must be high enough to support the accuracy statement. Display resolution is usually described in terms of “numbers of digits”, for example, “3 and ½ digit, 4 and ½ digit, 5 full digit” and so on. This describes how many numeric symbols the display can represent. A half digit can only represent a 1 or “off” and is always in the leading or most significant digit position. A full digit can represent any numeric symbol from 0 through 9. For example a 3 digit display can represent a maximum numeric value of 999, a 3 ½ digit display can represent a maximum numeric value of 1999, a 4 ½ digit display can represent 19999 and 5 full digit display can represent 99999.

An equally important aspect of display resolution is found in accuracy specifications that provide a percent of reading or full span rating with an *additional* plus or minus one LSD (least significant digit). This can contribute significant additional uncertainty. For example, although a 4 ½ digit display can represent 19999 “counts”, a 300 PSI range with a 4 ½ digit display would be configured to provide a maximum display resolution of one part in 3000 so that the least significant digit increments in non-fractional values. Therefore, the least significant digit contributes an additional $\pm .033\%$ uncertainty. However, a 300 PSI range with a 3 ½ digit display would be configured to provide a maximum display resolution of 1 part in 300 which increases the additional uncertainty contributed by the least significant digit to $\pm 0.33\%$.

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Required pressure range(s)?

From _____ to _____

It is generally recommended that a full scale pressure range is specified so that the typical operating pressure occurs between 25 and 75 per cent of the full scale. For example, if a typical process measurement is required at 50 PSI, a full scale range of 100 PSI would be ideal.

There are products available that offer very good accuracy specifications but provide a limited choice of ranges. This is because it “makes sense” to offer ranges which optimize display resolution. For example, a 4 ½ digit display can provide a maximum of 19999 counts. Therefore “two’s” ranges like 0/2, 0/200, 0/2000 complement a display resolution of 19999 counts. Each of these ranges will use the maximum available display resolution, however, if the application calls for a range of 0/300 only 3000 counts will be used. Clearly, the result will be limited resolution and possible conflict with the unit’s accuracy rating and the application accuracy requirement.

What is the application “accuracy” requirement?

± _____ % of Reading

± _____ % of Span

Understanding the elements of an accuracy statement that are most important to your application is very important so this question involves some additional work.

By generally accepted standards (e.g. ASME B40.7, ANSI/ISA S51.1, and others) an accuracy statement typically includes the effects of linearity, repeatability and hysteresis (see key terms). The linearity component is handled in different ways depending on the manufacturer.

The technique used to describe linearity can have a significant effect on the total accuracy value. Generally accepted techniques include independent (best fit straight line), zero based, and terminal based linearity. They are characterized by the following:

Independent Best Fit Straight Line: A straight line is fit to a series of data points taken along the instruments FS range in such a way as to minimize the maximum deviation of any one value. This method can reduce the stated non-linearity by as much as 50%.

Zero Based: A straight line, fixed at the zero point, is fit to a series of data points taken along the instruments FS range in such a way as to minimize the maximum deviation of any one value.

Terminal Based: A straight line, fixed at the actual zero and full span values, is used as the datum point to determine the deviation of each reading. The maximum deviation of the individual readings is used to describe the linearity. This method tends to represent actual performance more reliably than the preceding methods.

Another consideration is which elements are included and how they are combined. A manufacturer’s accuracy specification will generally include the effects of non-linearity, non-repeatability and hysteresis.

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These can be presented as an algebraic sum or a root sum of the squares (RSS). RSS will yield a “better” accuracy number but it can be somewhat misrepresentative of some of the instruments actual performance characteristics. The following example provides a comparison of three methods of presenting an accuracy specification based on the same data set for Non-linearity (terminal point), hysteresis, and non-repeatability.

Non-linearity:	.07% FS
Hysteresis:	.02% FS
Non-repeatability:	.01% FS

Accuracy expressed as:

Terminal/Sum	BFSL/Sum	BFSL/RSS
.07	.035 (BFSL)	.035 (BFSL)
.02	.02	.02
<u>.01</u>	<u>.01</u>	<u>.01</u>
.10%	.07%	.04%

This example illustrates the importance of understanding a manufacturer’s accuracy specification and the method used to express it.

Accuracy as a percent of reading is defined as the difference between an instrument’s indicated value (IV) and a known standard value (SV) based on individual reading (R) values where:

$$\% R = \frac{SV - R}{IV} \times 100$$

Accuracy as a percent of span is defined as the difference between an instrument’s indicated value (IV) and a known standard value (SV) based on the instrument’s full span (FS) where:

$$\% FS = \frac{SV - IV}{FS} \times 100$$

What is the ambient temperature range?

From _____ to _____ °F
 From _____ to _____ °C

Changes in ambient temperature can have a significant effect on accuracy depending on how the instrument is compensated for change in temperature. It is important to understand the manufacturer’s specification.

There are products, which offer an accuracy specification that *includes* the effects of temperature, for example, ±0.05% FS including temperature from 20° to 120° F. Other products specify the temperature error separately, for example, ±0.01% of FS per °F from 73°F for zero and span.

What is the process temperature?

_____ °F
 _____ °C

Most pressure instruments cannot be compensated for the effects of extreme process media temperatures. For example, pressure measurements on superheated steam lines are a common requirement. In this case a pig tail siphon is installed between the pressure instrument and the steam line. The pig tail siphon provides additional surface area sufficient to cool and condense the process media to ambient temperature conditions that can be handled by the pressure sensor. Although process media temperature can be an important issue, keep in mind that the plumbing and process connector materials absorb a good deal of thermal energy in a dead end measurement system.

What are the Long Term Stability Requirements?

± _____ % for _____ months

This specification will typically be based on manufacturer’s data taken over a given period of time under reference or controlled conditions. The “real world” of applications introduces a variety of conditions which can affect the manufacturer’s specification such as temperature extremes, shock, vibration, power interruptions, etc.

Output Signals

Digital Output Signal

_____ RS232, 422
 _____ IEEE 488
 _____ RS 485
 _____ Other

Selecting a digital output signal is a function of the type of data acquisition equipment and or the requirement for multi-drop (multiple devices on the same line) operation. A digital output will typically mirror the digital display information.

Analog Output Signal

_____ 0/5 or 0/10 VDC
 _____ 4/20mA

Proportional analog output signals will also be determined by the requirements of the interface equipment. However, unlike digital outputs an analog output signal may or may not mirror the digital display’s value. Often an analog output is required to gain higher resolution or faster response.

How is the analog signal generated?

Some instruments offer an analog output signal which is derived directly from the sensor prior to digital correction and modeling. In this case the accuracy of the analog signal may be less than that of the digital display data. In other cases, the analog signal is created from the digitally corrected data utilizing a DAC (digital to analog converter). In this case the signal will carry the same accuracy specification as the digital display data but will often be slower and have less resolution.

The bottom line is to ask the right questions and determine which of the techniques provides the best compromise.

OTHER FEATURES

There are numerous optional features available which can enhance the usefulness and value of a product. Among these are:

- * Alarm Relays Drivers
- * Engineering Unit Select
- * Max/Min Tracking
- * Data Logging
- * Battery Power

It is beyond the scope of this guide to describe them all in detail but the same selection principles apply. Defining the application requirements to the point that specific questions can be asked of a manufacturer is the only way to be sure that the feature's capabilities will meet your expectations.

KEY TERMS

Accuracy - The difference between an instrument's indicated value and a known value generated by an accepted standard.

Accuracy, Reference - The accuracy of an instrument under defined "standard" conditions of temperature, relative humidity and mounting position.

Accuracy, Percent of Reading - An expression of the difference between an instrument's indicated value (IV) and a known standard value (SV) based on individual reading (R) values where:

$$\% R = \frac{SV - R}{IV} \times 100$$

Accuracy, Percent of Span - An expression of the difference between an instrument's indicated value (IV) and a known standard value (SV) based on the instrument's full span (FS) where:

$$\% FS = \frac{SV - IV}{FS} \times 100$$

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A/D Resolution - An analog to digital converter is a device that converts a sensor's pressure proportional analog signal to a digital signal. A/D converters are described as 12 bit, 14 bit, 20 bit, etc. The resolution of a 14 bit A/D converter is 2^{14} or 16384 "counts", a 20 bit converter (2^{20}) or 1048576 counts.

Display Resolution - The maximum numeric value that can be represented by a digital display for example:

3 digit, 4 and ½ digit, 5 full digit, etc. A half digit can only represent a 1 whereas a full digit can represent any numeric symbol from 0 through 9. A 3-digit display can represent a maximum numeric value of 999, a 4 1/2 digit display can represent 19999 and 5 full digit display can represent 99999.

Note: A/D resolution and firmware will determine the number of counts used in driving the display.

Hysteresis - The difference in an indicated pressure value, taken at the same point approached first an increasing then from a decreasing pressure, on the same pressure excursion.

Linearity - How closely a set of pressure readings, taken along the span of an instrument, approximates a straight line.

Linearity, Independent - A straight line is fit to a series of data points taken along the instruments FS range in such a way as to minimize the maximum deviation of any one value.

Linearity, Zero Based - A straight line, fixed at the zero point, is fit to a series of data points taken along the instruments FS range in such a way as to minimize the maximum deviation of any one value.

Linearity, Terminal (end) Point - A straight line, fixed at the actual zero and full span values, is used as the datum point to determine the deviation of each reading. The largest deviation of an individual reading is used to describe the linearity.

Repeatability - The difference in an indicated pressure value observed from a number of readings taken approached from the same (increasing or decreasing) direction.

Sample Rate, Conversion - A specification used to describe the speed of an A/D converter. This value is related to the display update rate.

Span - The algebraic difference between the upper and lower range values for example:
 0 to 100 PSI, Span = 100 PSI
 -15 to 100 PSI, Span = 115 PSI

Temperature, Ambient - The temperature of the atmosphere surrounding the indicator.

Temperature, Process - The temperature of the pressure media.

Temperature, Reference - The temperature at which a calibration and certification of the indicator accuracy is performed.

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Temperature Effect - Changes in the indicated value attributed to the effects of variations in ambient temperature (from reference temperature) on an indicator's electronics or the effects of process temperature on the indicator's pressure sensor.

Update Rate, Display - The time required for the displayed data to be updated. Usually expressed in terms of milliseconds or samples per second. For example, 250 mS or four times per second.

Suggested Reading

Each of the following publications provides additional information on specifications, applications, and terminology and definitions.

ANSI B40.2, Gauges - Pressure Indicating Dial Type - Elastic Element

ANSI B40.7, Gauges - Pressure Digital Indicating

ANSI/ISA-S51.1 – 1979 - Process Instrumentation Terminology

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