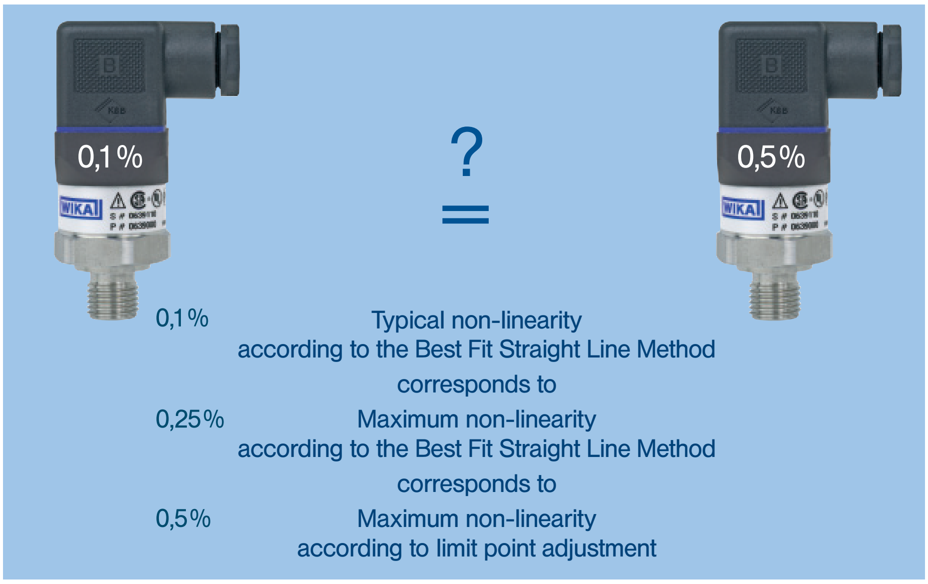
Do You Know the Accuracy of your Pressure Sensor?

Find your Way Out of the Waze of Accuracy Data?

Accuracy has its price: The more accurate measurement, the more expensive the measuring instruments. On the other hand, a lack of accuracy might cost even more, in particular if the product quality suffers because of it. Therefore accuracy should play an important role when deciding upon a sensor. However, you can only make the right choice if you find your way in the "maze" of accuracy data. Here the author explains the most important parameters and selection criteria using the example of an industrial pressure sensor.



▲ **Fig. 1: Comparison**

The term "Accuracy" exists only in the users' language. It is not defined in any standard. Nevertheless, it can be found in many data sheets for sensors. Unfortunately, there is no common idea of what accuracy means. There is not "one accuracy" but a large number of different specifications with regard to accuracy, all of them together describe the "accuracy" of a device.

The relevant factors for pressure sensors with regard to accuracy are defined uniquely across all standards. Yet manufacturers' data can hardly be compared to each other as the manufacturers decide for themselves what information is specified in the data sheet and how.

Even if two manufacturers use the same terms, it cannot be guaranteed that they both mean the same. Frequently, important additions are just left out. This means: Two devices having the same "accuracy" at first sight might differ considerably if looked at more closely. The same applies for the opposite case as the example in figure 1 demonstrates.

The following sections explain the reason why two different sensors presumably belonging to different accuracy classes have almost identical accuracy.

Non-linearity

For many users, non-linearity is the most significant and therefore most often used accuracy datum. However, non-linearity is often incorrectly referred to as linearity. Non-linearity describes how "curved" or "nonlinear" a characteristic curve is. It describes the highest possible deviation between characteristic curve and ideal straight line.

Generally, there are three methods for determining this ideal straight line: Limit point adjustment, minimum value adjustment (BFSL) and origin adjustment, with the last being the most unusual.

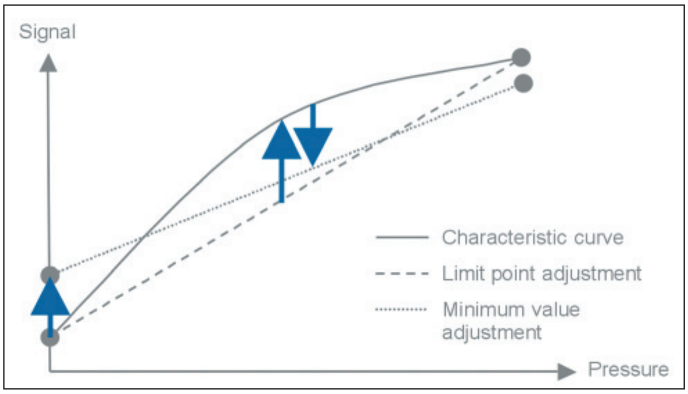
In the case of non-linearity according to limit point adjustment, the ideal straight line goes through the initial and end point of the curve; with the BFSL method (Best Fit Straight Line), the reference line is selected in a way that the maximum positive deviation and the maximum negative deviation are identical. Non-linearity according to limit point adjustment gives the largest absolute value compared to minimum value adjustment but is most comprehensible for the user. Non-linearity according to minimum value adjustment is the more significant value in many cases because It describes the potential of the characteristic curve.

The actual degree of difference between non-linearity according to limit point adjustment and according to BFSL method, depends on the typical form of the characteristic curve of a particular pressure sensor. Non-linearity may be twice that according to limit point adjustment.

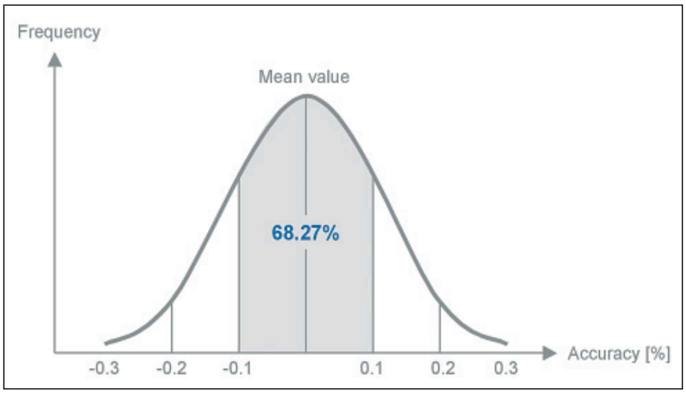
Unfortunately, it is impossible in many data sheets to recognise according to which method non-linearity has been determined. Data can often only be compared after having consulted the manufacturer (figure 2).

Typical Values

There are no two the same products. This also applies to the accuracy of pressure sensors. Actually, non-lineari-



▲ **Fig. 2: Non-linearity**



▲ **Fig. 3: Typical values**

ty of a large number of devices will be considerably better than the maximum value specified in the data sheet. Only this way it can be ensured that the deviation does not exceed a certain maximum value due to tolerances or variations. This (improved) accuracy is described as typical value. Therefore such accuracies are often marked with "typ." (figure 3).

However, hardly any manufacturer specifies clearly how many devices actually fulfil this "typical accuracy". Generally, you can assume that a "typical accuracy" corresponds to 1 sigma of the Gaussian distribution, i.e. about 68.27% of the devices comply with this typical value.

If a typical accuracy is given, the user knows that the manufacturer does not guarantee that 100% of the delivered devices comply with the given accuracy. Depending on the spread of the measured values, the maximum value can be twice or three times as high as the typical value.

By the way, typical values can be found not only with non-linearity but also with other accuracy specifications.

Measurement Error

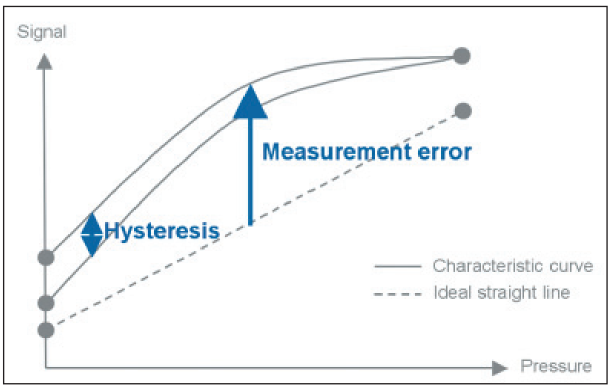
Probably the most "reliable" value is the measurement error. It can be determined without any extra effort directly from the characteristic curve and contains all relevant errors at room temperature, such as non-linearity, hysteresis, non-repeatability and error of measurement at the beginning and end of the measuring range. If the user operates the device at room temperature, this is the actual error with which the pressure is measured (figure 4).

The measurement error is the largest deviation between actual characteristic curve and ideal straight line. Hysteresis is defined as maximum deviation of the characteristic curve in descent and ascent. Non-repeatability is the largest deviation obtained in three measurements under identical conditions.

Unfortunately, the manufacturer specifies the measurement error very seldom because – understandably – it is always greater than non-linearity. Generally, non-linearity is given, and the measurement error at beginning and end of the measurement range is stated separately. The last two in practise are refered to as zero point error and span error with the span being the difference between lower end of scale and full scale value.

Temperature Error

No matter whether non-linearity or measurement error are used: All these accuracy specifications describe a pressure sensor at room temperature. If the working temperature is higher or lower, a temperature error must be also considered.



▲ **Fig. 4: Measurement error and hysteresis**

The temperature error is often indicated as temperature co-efficient based on an interval of 10 K. The zero point co-efficient and gain co-efficient are indicated separately. A device having sufficient accuracy at room temperature might have an error twice as large at 10K deviation (figure 5).

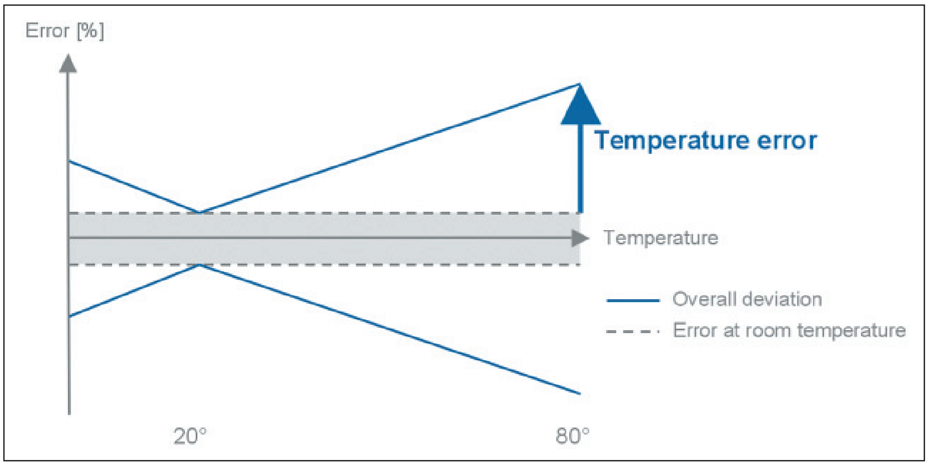
Many people do not know that they have to add the temperature co-efficients of zero point and span to calculate the error of the full scale value.

Temperature errors might also result from deviations of the medium or ambient temperature.

Stability

The accuracy given in data sheets usually describes the condition of a device at the end of the production process. The device can already be exposed to environmental conditions affecting its accuracy negatively from the moment of leaving the manufacturer's company or warehouse or during transport.

It is not important how accurate the device is or if it is of a very high quality, every device changes its accuracy during its service life. This change is called long-term drift or long-term stability. The dimension of this drift is largely influenced by the operating conditions, i.e. pressures, temperatures and other influences to which the device is exposed. In



▲ **Fig. 5: Temperature error**

many cases, stability has a larger influence on the overall deviation than e.g. non-linearity. Values twice or three times as high are not unusual.
Stability data stated by the manufacturer can hardly be compared. Different standards describe very different tests for determining stability. Furthermore, none of these tests is an actual copy of the real conditions of use. This is not possible because the conditions vary too much from application to application. Consequently, stability data are only valid for uses in laboratories or under reference conditions.
However, even if used under reference conditions, it is almost impossible to obtain comparable data. You cannot make time go faster. And all attempts to simulate a time lapse effect by means of thermal shocks and other methods are just attempts.

In Practice

Hysteresis and non-repeatability are pretty much the only errors you have to live with. All other errors can be minimised or even eliminated with some effort.
This works easiest and clearest using the offset error. The user can read the offset error hassle-free in unpressurised condition and enter it as offset in the corresponding evaluation instrument.
In order to eliminate the span error, the pressure must be regulated exactly at full scale value. This is often not possible as there is no reference value for the pressure. In order to make the pressure sensor not to measure worse than before, the reference pressure should be three times more accurate than the intended accuracy.
Non-linearity can only be minimised with certain effort by the user, for example, by deducting it in the connected electronic system based on points. Even in this case, a highly accurate standard of measurement is required.
Nevertheless, these errors are completely irrelevant in some applications, and only non-repeatability is important. If, for example, the task consists of always regulating the same pressure, the error can be compensated easily if it is known; the rest is non-repeatability and long-term stability.
The temperature error can be estimated quite easily at constant working temperatures but if your application covers a larger temperature range, it is much more difficult. Unfortunately, many users still assume that pressure sensors do not have an extra temperature error within the nominal temperature range. However, the nominal temperature range is just the range for which the temperature coefficients are valid.
Most manufacturers recommend to calibrate the pressure sensors once a year, to control whether they still meet their specifications. The device is not readjusted but the actual change, i.e. the drift, is analysed. If the drift is higher than the value specified by the manufacturer, this might be an indication for a defective device. The higher the instability, the more probability that the sensor is defective. In this case, process reliability can no longer be guaranteed if the device is still being used.
This check does not require much effort. Often it is sufficient to check if the zero point of the unpressurised device has changed. If the device can neither be checked in the system nor dismounted for examination, you should at least set a high value on a very good stability and respect it in your accuracy specifications.
Unfortunately, these are not the only possible sources of error. Vibrations, electromagnetic interferences, mounting position of the sensor, power supply and even the load of the evaluation instrument might affect the accuracy of your pressure sensor. Therefore, individual consulting by a specialist is recommended in many cases.

Conclusion

Do you know the exact accuracy of your sensor? Is it as good as you have expected? Or is it too good? You are the only person to decide which errors are relevant for you and which are not. The manufacturers' application consultants explain which product characteristics are important for it and how they can be implemented in your application. This ensures that you reach your targets with optimum input. We would be glad to advice you in finding out which is the accuracy you presently have and which is the one you actually need.

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