WHEN PRECISION IS REQUIRED

Digitally compensated pressure transmitters show the limits of what is possible

The more important it becomes to have measuring accuracy, the more focused the pressure transmitters available on the market are on certain applications. Keller AG für Druckmesstechnik has developed a concept that removes the constraints that are placed on the measuring task by user requirements and opens up new degrees of freedom.

Digitally compensated pressure transmitters are available in many different forms for a wide range of applications (shown above: Series 35 X and Series 33 X).

Winterthur/Switzerland-based company Keller AG für Druckmesstechnik was already in the process of investigating digital temperature compensation concepts when microprocessor technology was still in its infancy, and was one of the first companies on the market to implement these concepts when it manufactured diving computers and digital pressure gauges. This concept was realized almost 10 years ago in Series 33 X, 35 X and 36 X: faster measuring and the use of analogue outputs instead of displays, and with a considerably wider temperature range.

Floating sensor

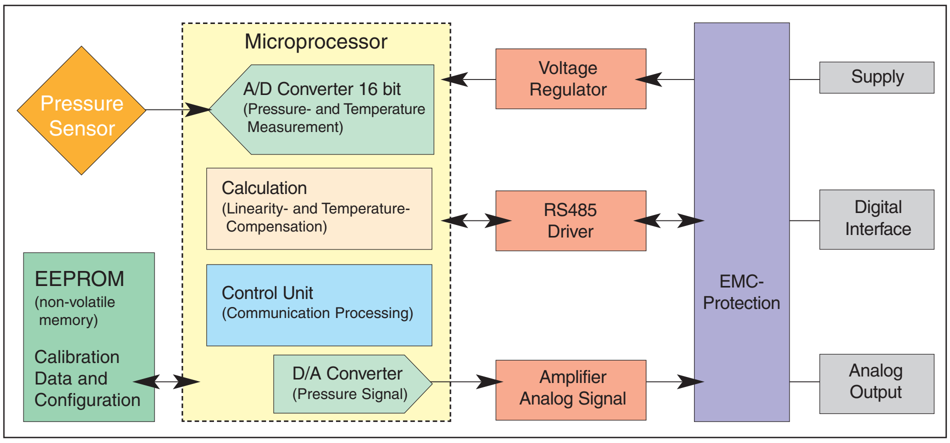
At the same time, electronic measuring procedures that were becoming increasingly accurate demanded the continuous development of oil-filled pressure measuring cells, because every mechanical connection between the silicon pressure sensor and some kind of housing was transmitting externally-induced force to the sensor and causing phantom measuring signals. This applies to the extent that spanner torque can cause the zero point of unfavorably designed pressure transducers to change during installation. If the materials of the pressure connection and the connecting nozzles differ from that of the measuring point, process-dependent force from temperature changes occurs during operation due to differing material expansion.

Even with a floating silicon sensor, it still demonstrates the typical temperature dependency of the TCN (TC zero point) and TCE (TC sensitivity) output signals, but this is now considered as a characteristic property of the individual sensor and reproducible as such. Ideally, the resistance measuring bridge of the pressure sensor itself should be used as a temperature sensor. Its overall resistance is individual and easy to measure in relation to the temperature. That which caused considerable problems when silicon pressure sensors were initially developed about 30 years ago can now be used in a beneficial way.
The non-linearity typical for the individual sensor at a given temperature can be reproduced extremely accurately with the latest micro-mechanical sensors. However, the effects are extremely temperature dependent. For this reason, pressure transmitters have to be calibrated at several temperatures, and possible measurement deviations are easiest to show using an area that is spanned by the pressure and temperature coordinates.

Reproducibility as the basis

Reproducible temperature and pressure data is the basis of the polynomic compensation that can be calculated using a microprocessor. Each measurement that is output by the pressure transmitter is mathematically calculated with reference to the support point data which has been determined during calibration in the factory. It has been shown that sensor-dependent and temperature-dependent deviations are easiest to correct using the following 3rd order polynom:

$$P(S,T) = A(T) \cdot S^0 + B(T) \cdot S^1 + C(T) \cdot S^2 + D(T) \cdot S^3$$



Block diagram of the digitally compensated pressure transmitter. As well as digital compensation using a microprocessor, the electric decoupling of the measuring signal and the output signal in particular provides completely new application benefits.

The temperature-dependent coefficients A(T) to D(T) are also calculated from a 3rd order polynom. During operation, the analogue signals from the pressure and temperature sensor are made available to the microprocessor via a 16-bit A/D converter. The microprocessor then calculates the relevant values for the compensation coefficients using the calibration data matrix stored in an EEPROM, and then the exact pressure values using the above-mentioned equation. A measuring time of approx. 2 ms means that these calculations are performed at least 400 times per second.

The analog output signal belonging to each measurement is generated in a completely flexible way in accordance with the parameterization performed by the user using D/A converters and subsequent output amplifiers. 0 to 10 V or 4 to 20 mA (2-wire technology) is available as a standard output, which is protected from polarity reversal and short circuits, as is the RS485 digital interface. It is independently scalable over wide ranges by generating the output signal from the values calculated in the microprocessor. A turndown by about factor 10, i.e. free assignment of the zero point and the end point of the output signal to a measuring value start and end point, or application-specific characteristic curves (e.g. filling level in horizontal tanks) are just as feasible as a fully inverted output signal.

All the parameterization you want

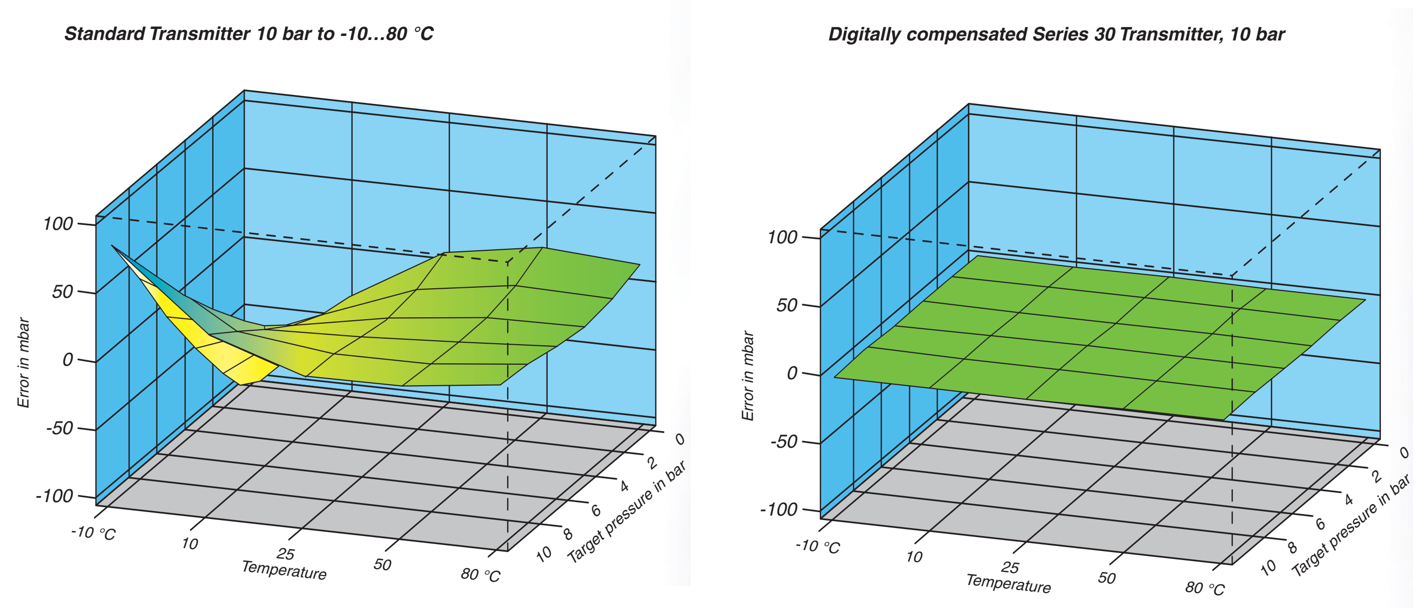
The key to application-specific parameterization is the RS485 interface. Basic information such as the serial number or the as-delivered state of the pressure measuring and temperature range can be established via this interface. The current pressure measurements can be output in different units. If the transmitter is used to record derived pressure-dependent process variables, they can be output in a mathematically correct way. These include the flow rate (pressure drop at an aperture), filling level or level (pressure at base of tank or in the sounding pipe at a defined depth), pressure difference (pressure difference determined using two measuring cells) or gas density (pressure at a given volume). In order to make optimum use of the transmitter in controlled processes, a digitally adjustable deep-pass filter is available for suppressing brief peaks.

The digital interface operates with an open master/slave protocol, whereby data transmission is safeguarded with a CRC16 checksum. Up to 128 transmitters can be interrogated in series during bus operation. Appropriate freeware is available for recording measurements with graphics, as are a DLL and driver for LabView for simplifying incorporation in other applications.

What does precision mean?

This article describes the properties of a series of high-precision pressure transmitters. The primary standards available in national reference laboratories for the pressure measuring value (pressure scales) provide measuring uncertainty (“accuracy”) of less than ±0.01%. In the calibration equipment of industrial pressure transmitter production you usually find traceable, automatic primary standards with measuring uncertainty of ±0.025%. They produce the reference values for calibrating the pressure sensors. This percentage information relates to the relevant pressure measuring point

Series 36 X W



The 3D display of the measurement error of a standard transmitter and a digitally compensated transmitter clearly shows the considerably improved suppression of temperature influences.

and designates the statistical deviation of many measurements at a given pressure. Unless otherwise specially indicated, the error tolerance band of pressure transmitters relates to the relevant end point of the measuring range (FS = full scale). Some manufacturers specify the non-linearity and hysteresis errors and the additional errors caused by temperature changes separately. For the sake of reliability, Keller AG uses the (total) error band method for a specified temperature range for digitally compensated pressure transmitters. In the temperature range between +10 °C and +40 °C the maximum measuring uncertainty (static conditions for temperature and pressure) is within ±0,05 %FS. The tremendous quality improvement that results from digital compensation is particularly evident in the low error band divergence of ±0,1 %FS with expansion of the compensated temperature range of -10 °C to +80 °C, i.e. from $\Delta T = 30$ K to $\Delta T = 90$ K.

Digital transmitter – optimized processes

There are many applications for producing accurate pressure measurements. Typical use thereof is in water supply company level measurements for monitoring the groundwater level or controlling pumps. In this case, the digital pressure transmitter can be scaled exactly in accordance with measuring point requirements. A measuring range expansion by a factor of up to x10 can be realized with the comparatively constant ambient temperature.

In chemical process engineering, high precision is required at various measuring points for exact process control. Particularly in the food industry a high degree of thermal repeat accuracy is required, i.e. reliable measurements after the performance of cleaning cycles. A special gap-free measuring head is already available for food production.

The accuracy of digitally compensated pressure transmitters is also in demand on engine and transmission test stands. Extreme temperature fluctuations in the vicinity of the test stands are compensated for in an optimum way and at 400 measurements per second, the transmitters usually exceed the required dynamics by a considerable degree.

Measuring the pressure and temperature in the same location in the pressure sensor makes digitally compensated pressure transmitters suitable for measuring gas density, e.g. in high-voltage switches that are filled with sulfur hexafluoride to avoid arcing. They are also used in oxygen cylinders, for example, for measuring the filling level.

The integrated microprocessor with digital interface and therefore access to the output signal parameters (depiction of measurements on signal values) opens up completely different application areas. These include filling level measurements in irregularly shaped tanks and the depiction thereof in real quantity units (e.g. liters) instead of the filling level. The mass flow rate can also be displayed directly via the pressure drop at a Venturi tube by using the root function and a connection to a second pressure transmitter.

Summary

The digital compensation of mechanically and thermally influenced measuring errors leads to extremely good measuring characteristics in conjunction with an optimized mechanical design. Sensors with extremely good long-term stability and an integrated temperature sensor are the prerequisite for precision. The quasi decoupling of the output signal from the measuring signal by the microprocessor used provides new freedom for displaying application-specific characteristic curves or measuring values. The pressure transmitters shown here represent a quantum leap in measuring quality for many applications.

Author:
Bernhard Vetterli, Dipl. El.-Ing.