Inexpensive Pressure Sensors with a Current Output

In addition to simple piezoresistive pressure transducers (mounted pressure sensing elements), whose temperature dependence and signal behaviour are well–known commodities, some companies (for example Motorola, Keller and Fujikura) include compensated or preamplified pressure sensors in their range of products. Preamplified pressure sensors in particular, which include integrated signal conditioning on the pressure chip, are increasingly being sold in price categories which are attractive even if large quantities are required. The output signal of these sensors is normally in a range of 0.5 to 4.5 V. These transmitters (transducers with signal conditioning) can be directly connected to an A/D converter or a microprocessor with only a few external components. This makes them ideally suited for use with a follow-on digital data processing or evaluation circuit. The deployment of these transmitters for industrial applications (0/4–20 mA) proves more complicated.

An inexpensive solution

Depending on the conditions given by the application (space, cost, accuracy, etc.), there are several ways of gaining a standard industrial analog signal. Discrete operational amplifier circuits are well-known from specialist journals and documentation. The following introduces an approach which highlights the advantages of an integrated solution. An easy and inexpensive way of gaining a standardised output current range will be described.

In the example given here, a preamplified pressure sensor from Fujikura (XFPM series) and the AM422 sensor interface IC from Analog Microelectronics are connected to form an easily adjustable sensor system.

Advantages of the AM422 integrated amplifier circuit

Voltage-to-current interface AM422 (Figure 1) is one of a series of interface ASICs for sensor technology AM422 is available as a 2– and 3–wire version and consists of the following three function blocks (the different versions are pin-compatible):

1. On the input side the input voltage range can be adjusted and an offset current added at the output via two operational amplifier stages.
2. At the output a conversion block allows the input voltage to be altered to an output current of 0–20 mA. The output activates an external transistor which minimises the power dissipation in the chip. The output current range can be easily adjusted via two external voltage dividers.
3. So that no additional voltage source is needed to power an external sensor, a high performance bandgap reference is integrated on AM422. The reference

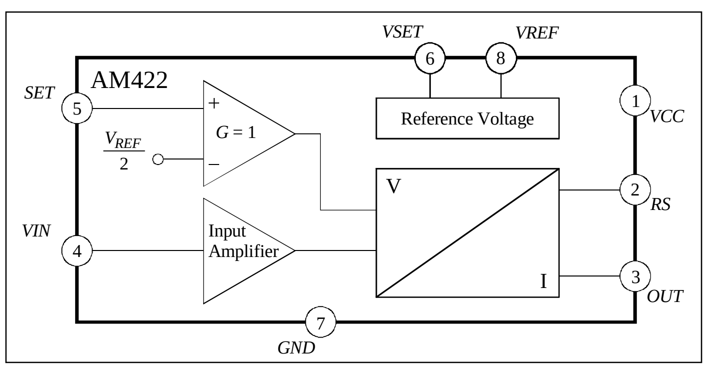

Figure 1: block diagram of the voltage–to–current transmitter AM422

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voltage can be set to 5 or 10 V via a simple pin connection. Any value between 4.5 and 10 V is possible if an additional external voltage divider is connected.

The IC also has integrated protection against reverse polarity and an output current limitation.

The XFPM series of pressure sensors

The pressure sensor used here is one of Fujikura's XFPM series, a range of preamplified, piezoresistive pressure sensing elements with an integrated signal conditioning circuit. The transmitters are temperature–compensated in a range of 0–85°C and work with a supply voltage of 5 volts. The output voltage range is specified to 0.2–4.7 V. In the application described here, a transmitter (gauge) in the range of 0–1 bar was chosen (XFPM-100KPG).

Description of the application

In the 3–wire application illustrated here (Figure 2) an output current range of 4–20 mA was used. The sensor is supplied with 5 volts by the IC. The specified tolerances of the sensor and the IC match, meaning a separate adjustment of the absolute value of the voltage reference is not required. The following external discrete elements are given:

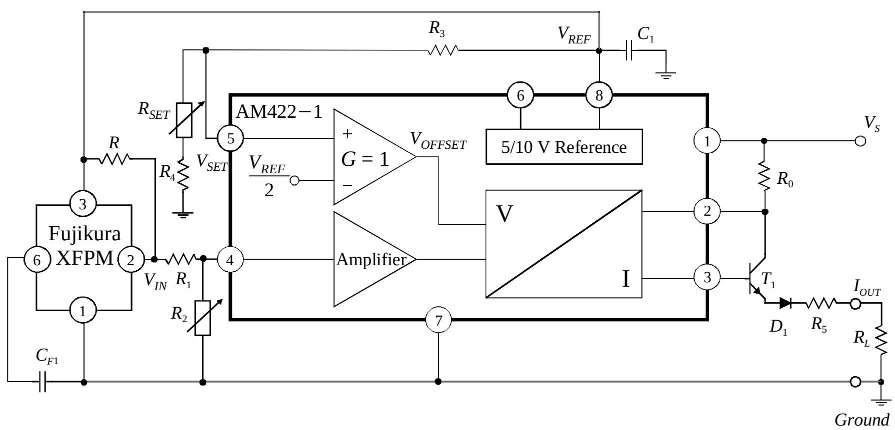

Figure 2: the application needs few external components

- from the sensor: R = 3,9 kΩ and C_{F1} = 680 pF
- from the IC: R_0 = 25 Ω, R_5 = 40 Ω, C_1 = 2,2 µF
- for the transistor T_1: $\beta_F = 50$
- for the diode D_1: V_{BR} = 35 V

The requirements of the application (input voltage and output current range) determine the values of the remaining external components.

With the relationship of the currents, the following general transfer function of the IC is valid:

$$I_{OUT}\,(V_{SET},V_{IN}) = I_{SET}\,(V_{SET}) + I_{IN}\,(V_{IN}) \qquad (1)$$

With the circuitry from Figure 2, the following equation ($V_{IN} = 0$) is given for the part of the offset current:

$$I_{OUT} \approx \frac{V_{REF}}{R_0} \cdot \frac{R_4 + R_{SET} - R_3}{2\left(R_3 + R_4 + R_{SET}\right)} \qquad (2)$$

For equal values of the resistors R_3 and R_4 the simple rule of calculation for the set resistor R_{SET} becomes

$$R_{SET} \approx \frac{4\,R_0\,R_4\,I_{SET}}{V_{REF}} \tag{3}$$

The output current range is set via the second voltage divider (R_1, R_2):

$$\Delta I_{OUT} = I_{OUT\max} - I_{SET} = \frac{V_{IN\max}}{2\,R_0} \cdot \frac{R_2}{R_1 + R_2} \tag{4}$$

The relation between the resistors then becomes

$$\frac{R_1}{R_2} = \frac{V_{IN\max}}{2\,R_0\left(I_{OUT\max} - I_{SET}\right)} - 1 \tag{5}$$

Values for the application

The values for the remaining external devices can be calculated from equations (1)–(5). A detailed description of how these values are calculated is not given in this article. This information is included in the AM422 data sheet. Please contact Analog Microelectronics or visit our Web site at:

http://www.analogmicro.de

The values for the external resistors are:

$R_3 = R_4 = 33$ kΩ

$R_1/R_2 \approx 4{,}625$

$R_{SET} \approx 2{,}178$ kΩ

With the potentiometers R_{SET} and R_2 the absolute errors of the system (the offset of the amplifier and the sensor) can be compensated in an easy and inexpensive way.

The accuracy of the whole systems can be improved by the choice of a suitable, temperature depending resistor R_0.

Accuracy

One of the reasons for using a sensor system – besides the price – is the accuracy of the entire solution. Taking the specifications from the sensor and IC data sheets, it is safe to assume that an accuracy of ±3% of the entire system is possible (with a temperature range of 0–80°C). But it can be shown that in practice a higher degree of accuracy is obtainable. Figure 3 shows the measurements of the temperature behaviour of the offset (*TCO*) and span (*TCS*). If we study the curves, we notice that the total system error is around ±1% in the specified temperature range.

The advantage of the system described here surely lies in the simple adjustment of the absolute errors. With the right choice of temperature-dependent resistor R_0 or external compensation network, the accuracy of the entire system with regard to the temperature behaviour can be greatly improved.

Conclusion

There are many different ways of measuring a pressure and making the evaluation over a corresponding current. In the application described here a way of solving the problem was shown using standard devices, allowing simple compensation of the entire system. Another advantage of the solution given here is the integrated AM422 amplifier circuit (SOP8 package or die), making the device suitable for small components.

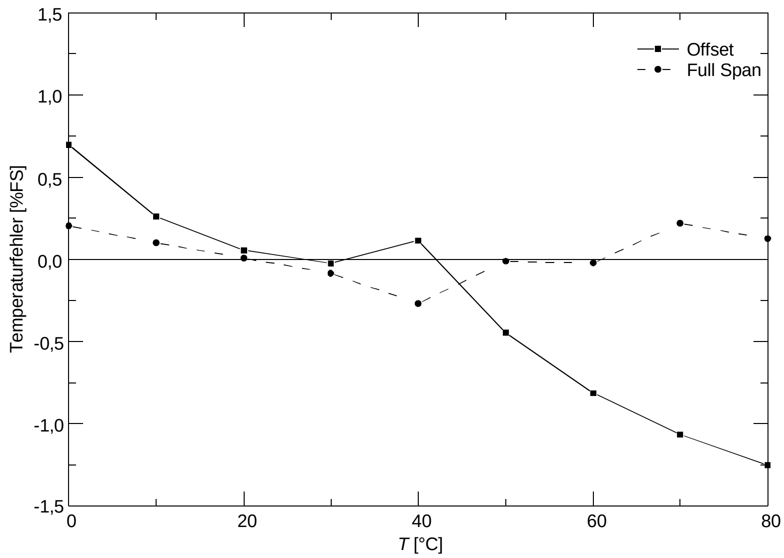

Figure 3: measurement curves of the temperature behaviour of the entire system

The attractive price of preamplified pressure sensors and the signal conditioning IC and the simple compensation of the entire system via two external voltage dividers, accurate enough for a great number of applications (only the absolute values are compensated), make the application described here an inexpensive alternative to other sensor systems, where the temperature errors have to be compensated on a much larger, more complicated scale.