PICOSTRAIN

Application Note

Using PICOSTRAIN®
with piezo-resistive sensors

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1   Abstract

acam's PICOSTRAIN® technology provides resistance-to-digital converters (RDC) based on ratio-metric time-interval measurement. The converters are used in strain gage applications such as weighing scales, but lately there has been a focus on piezo-resistive sensors too. In comparison to the existing signal converters, PICOSTRAIN® has a number of advantages to offer and even the mechanical temperature adjustment process of the sensor can be simplified. This paper provides an overview about the use of PICOSTRAIN® technology with piezo-resistive sensors and points out differences and advantages compared to conventional electronic solutions.

1.1   Piezo-resistive sensors

Piezo-resistive sensors are typically high in their resistive value (5 to10 kΩ) and have a high sensitivity (5 to 20mV/V). The sensor commonly used is the Wheatstone-Bridge.

The sensor element itself is a semiconductor which changes its resistivity due to applied mechanical stress. The basic architecture is as follows:
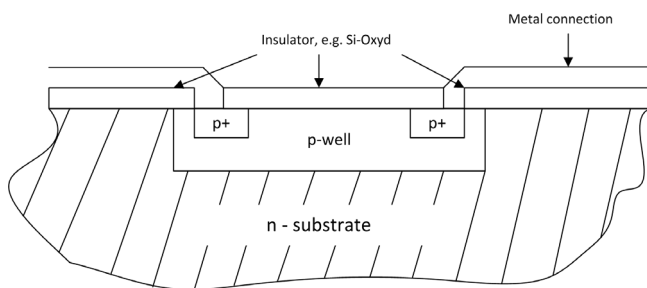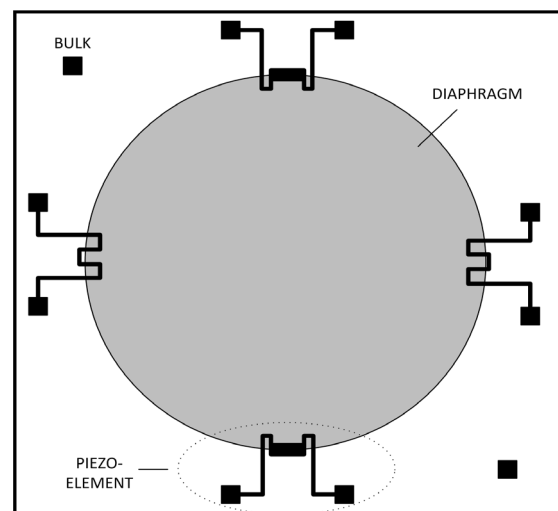
Figure1   Basic architecture

The piezo-resistive element is applied on a substrate which is normally mounted on a glass carrier. In a piezo-resistive pressure sensor there are several piezo-elements on one substrate later combined electrically together, e.g. to a Wheatstone bridge like shown in the following picture:
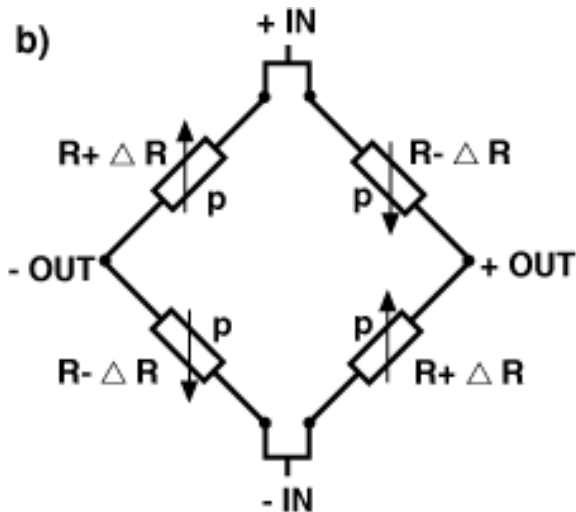

With PICOSTRAIN® it is possible to use a Wheatstone-configuration. An alternative connection – giving 0.6 bit more resolution – is to connect the elements as two half-bridges (which mean not to make the connection at +IN and –IN).

Important: The bulk must not be connected to the sensors circuitry at all. It should be left unconnected.

Figure2   Wheatstone bridge
Source: www.keller-druck.com [1]

2   Advantages of PICOSTRAIN® technology

The PICOSTRAIN® PS09 chip is designed in 0.18µ CMOS technology and is a complete system on chip with converter frontend, microprocessor and NVMs. The chip's supply voltage range is from 2.1V to 3.6V. The chip is mainly used in digital sensor applications.

The main advantages are:

- **High measurement rate** (up to 10 kHz with half bridge sensor, up to 5 kHz with full bridge sensor)
- **High accuracy** (up to 20.3 bits RMS with 20 mV/V sensor and 10 Hz)
- **Low current consumption** (1 to 3 mA at full speed depending on configuration and less than 10µA at low speed / medium resolution. The current specified includes sensor current)
- **No zero-offset trimming of sensor required**, works with any offset!
- **Convenient temperature correction of gain and offset by chip algorithm** (no trimming of resistors required)

[1] http://www.keller-druck.com/home_g/painfo_g/berichte_1984_g.asp

Typical configuration examples and performance:

• 5 kHz, 0.02% peak-peak (5000 div. or 12.3 bit), 2.1 mA

• 2 kHz, 0.01% peak-peak (10,000 div. or 13.2 bit), 1.25 mA

• 10 Hz, 0.0004% peak-peak (250,000 div. or 17.8 bit), 1.25 mA

3   Temperature compensation

Today's sensors (and electronics) are often not limited by accuracy but by temperature drift (gain and offset drift). To minimize the drift, zero-offset adjustment by trimming resistors is done and gain compensation by employing the 'current source approach' as shown below:
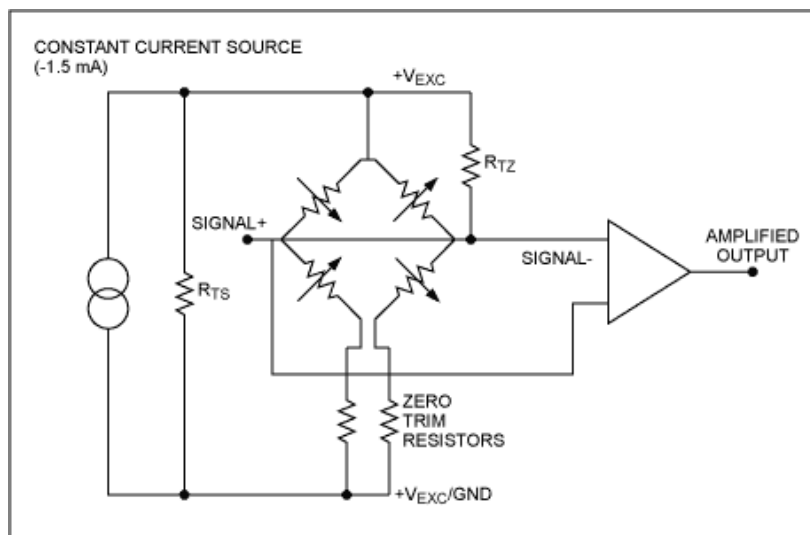

Figure3   Current source approach
Source: Maxim IC [2]

In this simple compensation approach the Wheatstone bridge is fed by a current source and various resistors are used for compensation. The drift of the bridge (resistors) over temperature TCR (~2500 ppm/K) is counteracted by the sensitivity drift TCS (~ -2000 ppm/K) which results in a remaining excitation drift over temperature of approx. 500 ppm/K which is quite high and not neglectable. For further stabilization, RTS (shunting the current source) is to limit remaining excitation drift. Similarly RTZ is for stabilization of offset drift over temperature. However, the overall degree of compensation is limited by this approach and the calibration of it somewhat cumbersome.

2 http://www.maxim-ic.com/app-notes/index.mvp/id/871, Fig. 1

This is where the PICOSTRAIN® temperature compensation excels: an algorithm inside the chip enables automatic and high-precision compensation. The sensor itself is used to sense the temperature (since it has a TCR of ~2500 ppm/K) and then combined with a standard 'off the shelf' fixed resistor with low temperature dependency (~100 ppm/K) to a ratio inside the chip which is then fed into the algorithm.

The compensation method is not limited by resistors and can therefore be adjusted for optimum performance. In other words, the external resistors like RTS and RTZ as well as the supply by a current source will be eliminated. Instead, two parameters (one for gain, one for offset) are used to adjust for the temperature drift.

The circuitry can be simplified significantly with PICOSTRAIN® as illustrated in the following illustration:

PS09

Fixed resistor
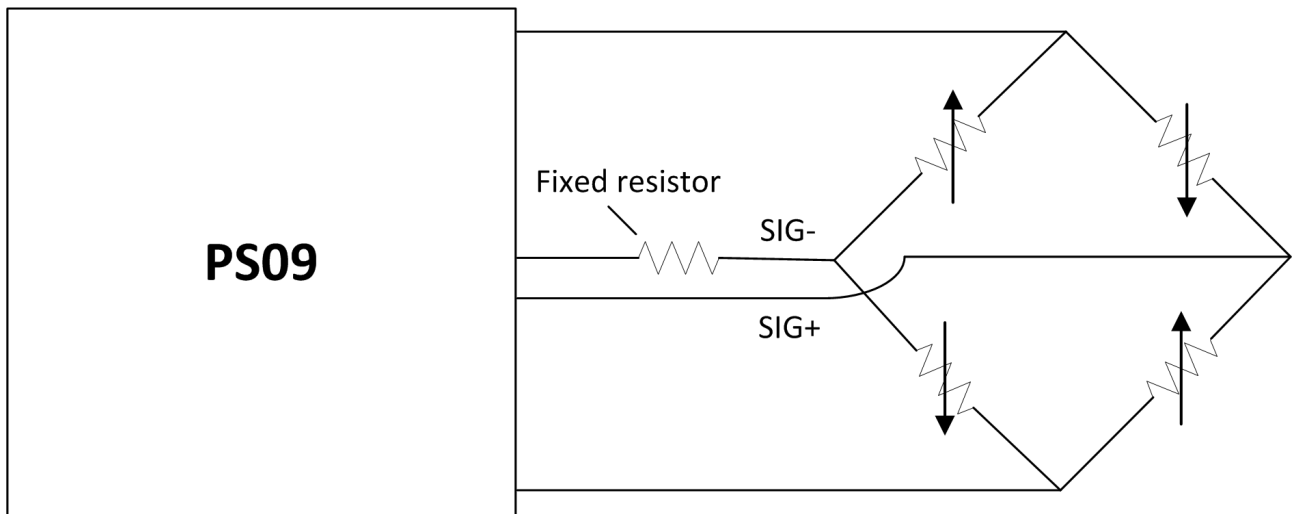
SIG-

SIG+

Figure4   Simplified circuit with PICOSTRAIN

The overall circuitry gets much simpler: except for one fixed resistor, there are no zero trim resistors, no shunt resistor RTS and no offset stabilization resistor RTZ. Instead of using the current source to supply the bridge, the sensor (here a Wheatstone) is directly connected to and supplied by the chip.

The PICOSTRAIN® temperature compensation works so well, that piezo-resistive sensors can be adjusted for impressive low gain and offset drift. Provided that the sensor shows little non-linearity, an offset drift as low as 3 ppm/K and a gain drift as low as 10 ppm/K can be achieved.

4   Summary & Conclusion

Piezo-resistive sensors are widely used in the industrial environment, for example with pressure sensors. Conventional electronic solutions usually cannot add value to make the manufacturing or calibration process of the sensor easier. PICOSTRAIN® can provide a simplification of the sensor design and calibration process by employing automatic temperature compensation leading to cost reduction and higher production quality. Together with the other chip features like high measurement rate and accuracy as well as low power consumption, overall product quality can be improved. The on-chip microprocessor enables compact single chip sensor designs with fully calibrated digital output.

5   Appendix

The following schematic represents a minimal circuitry for a piezo-resistive sensor design with PSO9. For further design-in information (schematic and layout design, configuration of PSO9) please refer to the PSO9 data sheet available from www.acam.de/products/picostrain.
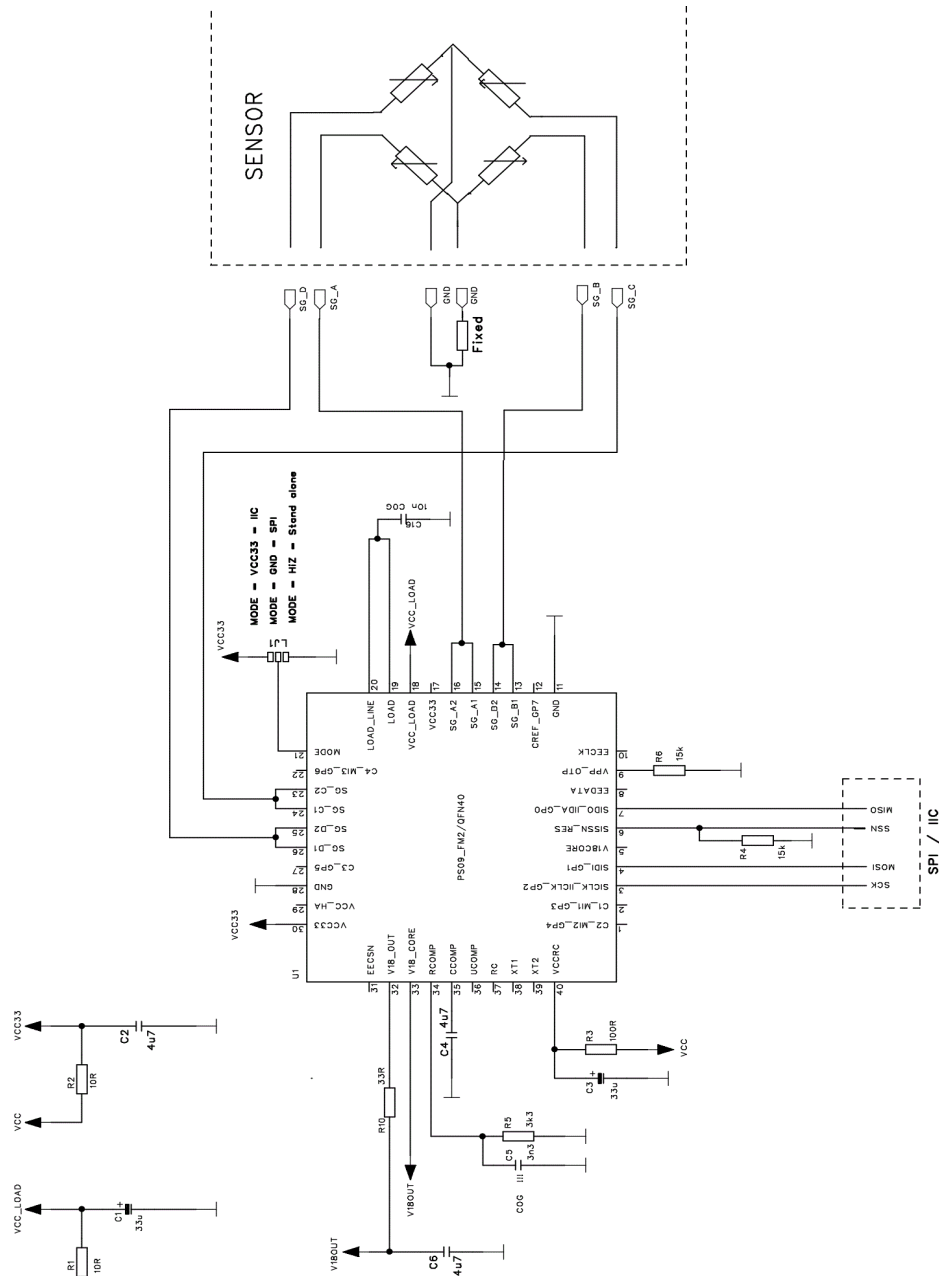
Figure5   Piezoresistive sensor design with PICOSTRAIN

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