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micromechanical
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Ready-to-mount ceramic sensors with integrated signal conditioning

Ready-to-mount ceramic sensors ME705

When modern pressure sensing technology is mentioned this is usually immediately associated with the use of micromechanical sensing elements which are silicon-based. If we examine this field more closely, however, we will discover that there are certain boundary conditions which make the use of semiconductor elements difficult if not impossible. These include, for example, clean room conditions required for assembly, strong temperature dependency, limited media compatibility and limited loading capabilities restricted by the design of the setup. These are reasons enough to explore possible alternatives. If we do so with the intention of using our application in a rough environment, then we inevitably come up with a solution which uses ceramic components (Figure 1).

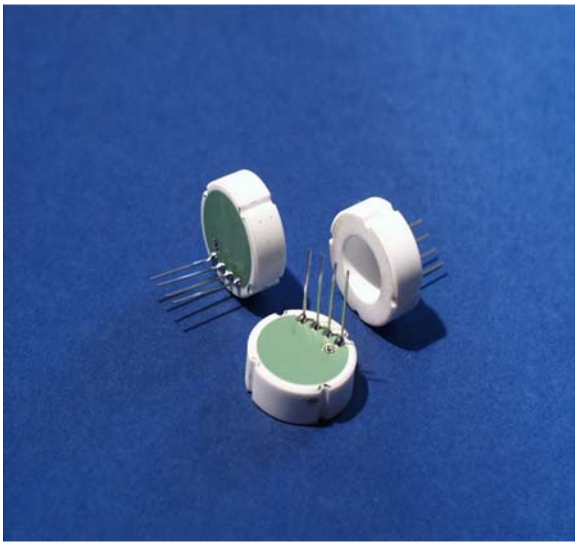

Figure 1: ME651 ceramic sensing elements

Ceramic was first used as a basic material for pressure sensors in pressure sensor technology in the mid-1970s. The progress since made in ceramic technology has resulted in these sensors today being mass-produced in series for a whole range of applications. Particularly in the fields of industrial, medical and automotive engineering the combination of ceramic and thick-film technology has proved successful. Typical areas of application include:

Brake systems (pneumatics), petrol or gas pumps, gear monitoring, lifting devices (hydraulics), dialysis machines, compressors and level indicators.

In principle ceramic pressure sensing elements are manufactured in the same way as conventional thick- or thin-film hybrid circuits. The basic material is aluminum oxide (Al_2O_3), structured according to the physical mode of action. We differentiate between capacitive and resistive sensing elements; in this article only resistive ceramic elements in tick-film technology shall be studied in further detail.

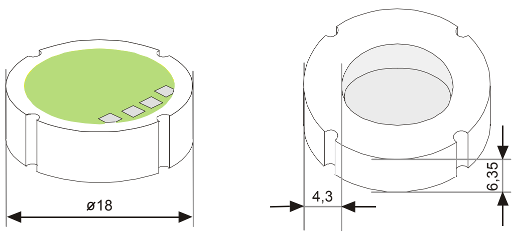

Figure 2: Dimensional drawing of resistive ceramic pressure sensing element ME651

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Resistive ceramic sensing elements

The resistive ceramic sensing element (ME651) in sensor ME705, manufactured by Metallux S.A. in Switzerland and marketed by AMSYS GmbH in Mainz, Germany (Figure 2), consists of a solid ring which has been completely covered in a thin ceramic membrane (the pressure-sensitive element). This can be glued on separately or produced monolithically with the ring in a molding. Either method produces a kind of miniature ceramic pot. One side of the membrane (the inside of the pot) is exposed to the medium. Owing to the outstanding chemical stability of ceramic materials this is resistant to most media. This applies in particular to aggressive media.

Using thick-film technology resistors and metal conductors are printed onto the other side of the membrane (the outside of the pot) using pastes of various conductivity which are sintered at high temperatures in a precisely-defined temperature profile. The burn process permanently affixes these components in the ceramic. Depending on the conductivity of the pastes dielectric layers or resistors with varying basic values of resistance are produced. The shape of the sintered structures makes it possible to dimension these resistances more accurately. The tick-film resistors are placed at the points of the greatest mechanical stress and connected up as a Wheatstone bridge circuit by screen printing on the metal layer.

The ceramic sensing element in sensor ME705 is an ME651 which is also available separately as a sensing element without electronic signal conditioning.

When pressure is applied to the membrane and it deflects two diagonal resistors are stretched, causing the remaining two to be compressed. The corresponding molecular shifts in the conductive components of the sintered pastes bring about a change in the resistors which to a large extent is proportional to the deflection and thus also proportional to the applied pressure. Finally, the bridge array of the resistors provides a differential, pressure-dependent output signal of approximately 2–5mV/V. With a supply voltage of 5V this results in a full-scale signal of max. 25mV.

Calibration and compensation

By trimming the resistors, which together with the bridge resistors form a compensation- and calibration network on the sensing element, the offset can be calibrated to almost zero (±0.2mV/V at 25°C). In the same manner, following the measurement of the offset as a function of the temperature the offset temperature coefficient (thermal offset shift) can be compensated for by trimming the PTC resistors (Figure 3). Here, typical values of ≤ ±0.5%FS are guaranteed between -25°C and 80°C for ME705.

Resistors are trimmed exclusively using laser apparatus which cuts into the resistors and increases the resistances to the required values by restricting the configuration of the electric field.

Without compensation the temperature coefficient of the span (change in thermal sensitivity) is typically ≤ ±0.02%FS/K. In industrial temperature ranges of -25°C to 80°C this is ≤ ±1%.

Accuracy – a combination of linearity, hysteresis and accuracy of repetition which cannot be compensated for – depends on the range of applied pressure and varies between ≤ ±0.2% and 1.5%FS.

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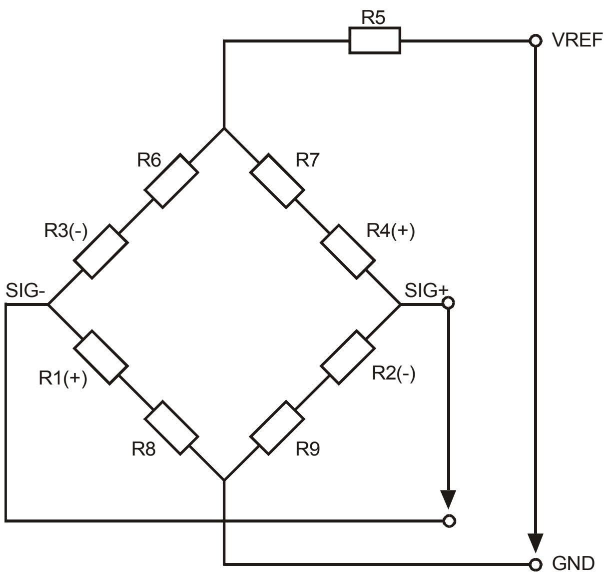

R1 … R4	Bridge resistors	10 kOhm +/- 20%
R5	Sensitivity compensation	600 Ohm … 13 kOhm
R6, R7	Offset compensation	570 Ohm … 13 kOhm
R8, R9	TC Offset compensation	2 … 40 Ohm
VREF	+ Supply voltage	5 … 30 VDC
GND	- Supply voltage	
SIG+	+ Output signal	
SIG-	- Output signal	

Figure 3: Compensation network of the ceramic sensing elements in ME705

Evaluation electronics

As the sensitivity of the ceramic sensing elements is comparatively low (2–5mV/V), the sensing element pressure signal must be amplified and its output values adapted to suit the requirements of the parent system.

In ME705 this is achieved with an analog integrated circuit (Figure 4). Here, an AM457 by Analog Microelectronics in Mainz, Germany, has been used which can generate an output signal of 0.2V to Vcc-0.2V. This IC has a low offset (0.1mV) and minimal offset drift (0.5µV/K) within a wide temperature range of -40°C to 125°C; its effect on the error rate of the sensing element is negligible. The device is ratiometric to the supply and includes various integrated protective circuits.

In order to generate an output voltage of 0.5V to 4.5V common to the automotive industry the offset and amplification factor (span) are calibrated by laser on a small external circuit board at the factory (Figure 5).

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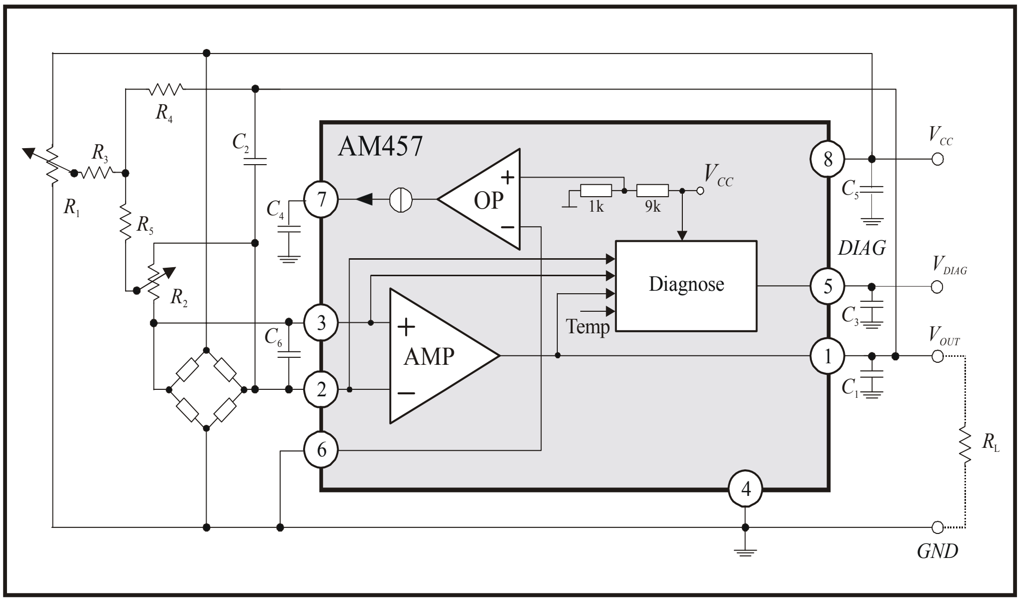

Figure 4: Signal conditioning of a ceramic sensing element using AM457

Figure 5: Ready-to-mount ME705

To increase immunity to electromagnetic irradiation EM705 has the circuit board mounted onto the sensing element with the evaluation IC very close to it (Figure 5). Due to the integrated circuitry the board is actually smaller in diameter than the sensing element (∅14mm), guaranteeing problem-free assembly. The total height of ME705 is given as 12mm. Four solder pads are included on the circuit board which act as connection points for a corresponding pin.

ME705 is supplied in a relative sensor version for various pressure ranges from 2 to 400 bar. The pressure steps are: 0 to 2, 0 to 5, 0 to 10, 0 to 20, o to 50, 0 to 100, 0 to 200 and 0 to 400bar. (1bar ≈ 15PSI)

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Mounting ceramic sensors

For reasons of reproducibility the mounting of ME705 must be as stress-free as possible. Two sources of help are available:

a) Recommendations for mounting ceramic sensing elements at www.amsys.de/products/ceramic.htm
b) Offset values following the mounting of ME705 in a package. The sensor is configured to an offset of 0.5V at the factory with an accuracy of ≤ ±1%FS; this value must be able to be reproduced following assembly. This otherwise causes an offset shift which must be corrected.

AMSYS GmbH stocks stainless-steel screw fittings with an external G1/4“ thread as prototype packages for the simple mounting of ME705 (Figure 6).

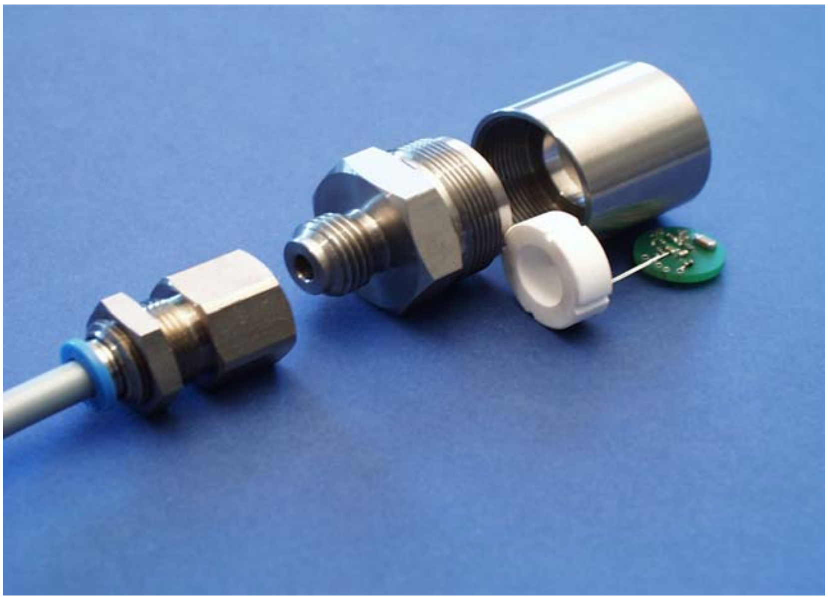

Figure 6: Prototype package for ceramic sensing elements

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Information:

Details and technical information on ME705: www.amsys.de/products/me705.htm
Technical information on AM457: www.analogmicro.de/english/standard/index.htm