AMS 4711 - Precise level sensing with a low pressure transmitter

In terms of modern process automation level sensing means more than simply "tank half full" or "tank a quarter full". With suitable sensors the level of liquids can be precisely measured, thus obtaining valuable information on the process dynamics. In the following application notes AMSYS [1] demonstrates how measurements such as these can be simply and accurately taken for low level heights from 50 cm using the AMS 4711 pressure transmitter [2].

Pressure measurement with silicon sensing elements

Figure 1: *AMS 4711 pressure transmitter for liquid level sensing*

When measuring differential pressure two pressures are compared (P_1 and P_2) which are applied externally through a pressure supply (sensor housing) on the underside and topside of a silicon sensing element with a membrane construction (*Figure 2*). The following condition generally applies: $P_1 \leq P_2$ or vice versa $P_1 \geq P_2$. With most silicon-based differential pressure sensors the requirement is that just one pressure ratio ($P_1/P_2 \geq 1$ or $P_1/P_2 \leq 1$) can be recorded and evaluated. In general, measuring pressure with this restriction is called "differential pressure sensing". In comparison the measurement of relative pressure is considered to be a special form, with which the level can be sensed in open containers.

AMSYS GmbH & Co.KG
An der Fahrt 4
55124 Mainz
GERMANY

phone: +49 (0) 6131 469 875 0
fax: +49 (0) 6131 469 875 66
email: info@amsys-sensor.com
internet: www.amsys-sensor.com

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Figure 2 is an initial schematic diagram of how the deflection of the membrane on a differential pressure sensing element is to be perceived under various applications of pressure. The change in polarity in the output signal signifies a change in the direction of the membrane deflection.

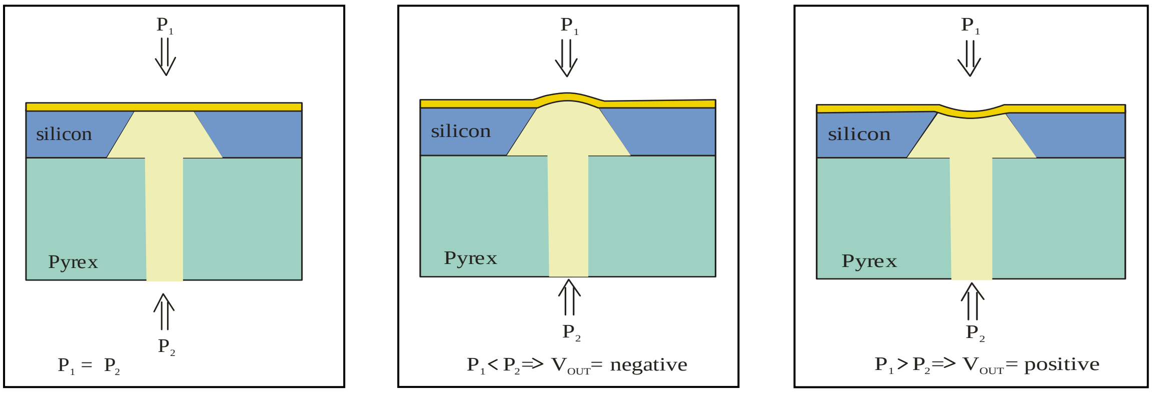

Figure 2: *how a piezoresistive sensing element functions in the measurement of differential pressure*

Measurement of relative pressure with silicon sensing elements

If one of the two pressures P_1 or P_2 is the same as the effective ambient pressure outside the sensor (e.g. atmospheric pressure P_{atmos}), we speak of a measurement in relative pressure. With the restriction that P_1 or $P_2 = P_{atmos}$ the relative pressure sensor is thus a differential pressure sensor which measures the difference in pressure in a recipient in relation to the ambient pressure. It must be noted whether the sensor is configured for the case $P_1 \leq P_2$ or $P_1 \geq P_2$.

Media resistance of AMS 4711

When sensing levels in a container filled with liquid the membrane comes into contact with the liquid provided that there is no air buffer between the liquid surface and the sensor membrane. With respect to the preconceived notion that silicon sensing elements cannot measure pressure in liquid media, underside pressurization is applied as in AMS 4711 [2]. Here, the medium to be measured only comes into contact with materials which are largely fluid resistant and cannot form any high-impedance bridges between the live contacts. On the reverse of the sensor in AMS 4711 these are ceramic, silicon oxide and glass.

The media-carrying connection nodes and housing consist of robust PA 6.6[1] which is largely media resistant. The only materials which could cause problems with various contact media are the adhesive joints on the sensor (sensing element on the substrate and housing components). In cases such as these the answer is to make the appropriate joins with media-resistant adhesive which is also strong enough (positive pressure) to withstand underside pressurization.

[1] *PA 6.6 is resistant to aliphatic and aromatic hydrocarbons, alkalis, brake fluids, esther, greases, ketones, fuels and coolants, solvents, cleaning agents and detergents, oils, fats, alcohols and water, among many other substances.*

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Level sensing

Level sensing with pressure sensors constitutes a relative pressure measurement where, for example, pressure P_1 is the ambient pressure and pressure P_2 is the ambient pressure plus the pressure generated by the weight of the head of liquid (hydrostatic pressure; see *Figure 2*).

$$P = P_{ambient} + P_{hydrost}$$

Figure 2 shall be used to explain Pascal's rule which forms the physical basis of level sensing with a pressure sensor.

For the hydrostatic pressure prevalent in a receptacle filled with liquid and open to the ambient pressure, the following applies (see *Figure 3*):

$$P_{hydrost}(h) = p \cdot g \cdot h \quad (Pa)$$

$$p = density = f(t) \quad (kg/m^3)$$

with

g = acceleration due to gravity = 9.32 m/s²

h = height of the liquid (m).

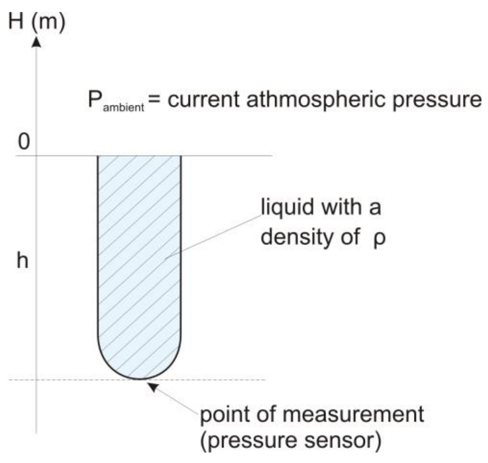

Figure 3: *hydrostatic pressure measurement*

At a constant liquid density of ρ = f(T) the pressure prevalent at the point of measurement is proportional to liquid height *h* (up to the point of measurement). To this must be added ambient pressure $P_{ambient}$ effective on the liquid surface.

If a relative pressure sensor is applied to the point of measurement (initially at the lowest point of the receptacle; see *Figure 3*), one side of which measures effective total pressure *P* and the other of which is connected to ambient pressure $P_{ambient}$, the effects of the ambient pressure on the topside and underside of the membrane stand out. This shows no deflection if, for example, $P_{ambient}$ were to be applied to both sides. Thus the membrane and with it the sensor only react to the difference between pressure $P_{ambient}$ and pressure P = $P_{ambient}$ + $P_{hydrost}(h)$, i.e. only to hydrostatic pressure $P_{hydrost}(h)$ in the receptacle.

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As only the differential pressure determines the deflection of the membrane, the measurement is irrespective of the magnitude of the ambient pressure. Accordingly, at an ambient pressure of P_{atmos} = 1,000 mbar and a maximum fill height of 50 cm, for instance, low-pressure sensor AMS 4711-0005-D (with a pressure range of 0 to 50 mbar) could be used. With a water column of 10 cm @ RT = 4°C the pressure sensor would indicate an output signal which is equivalent to a pressure of 10 mbar: 1/5 FSO = 0.8 V + 0.5 V = 1.3 V.

It is of course prudent to adapt the sensor’s pressure range to the measurement task or the maximum fill height, as otherwise the output signal would be decreased by the ratio between the sensor pressure range and the maximum hydrostatic pressure.

In practice various application-specific points must be taken into account when positioning the sensor to measure the fill height, points which define the measurement setup and can deviate considerably from the simplest version (*Figure 3*). One example is level sensing on an open tank using a reference receptacle (*Figure 4*).

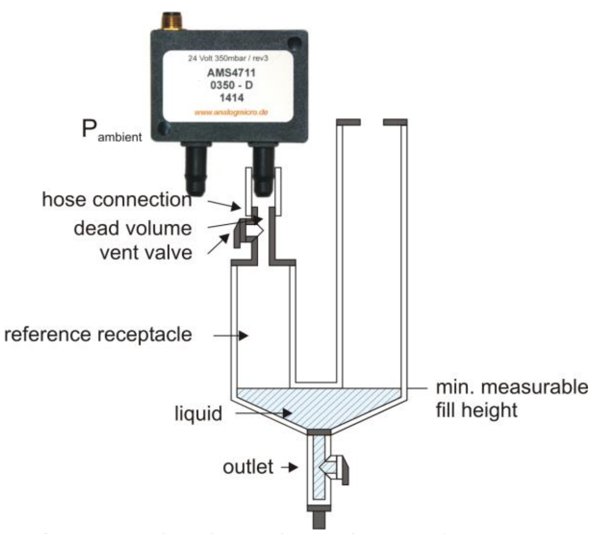

Figure 4a: *level sensing using a reference receptacle with a container which is practically empty*

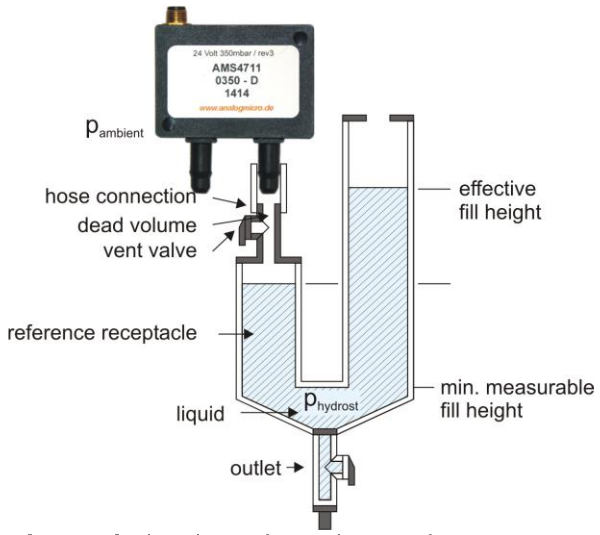

Figure 4b: *level sensing using a reference receptacle with a container which is practically full*

With this arrangement, it must be taken into account that there can be a dead volume in the reference receptacle and that the measurable fill level (effective fill level) is the distance between the liquid level in the receptacle and the liquid level in the reference receptacle. When determining the actual filling height, the distance between the surface of the reference receptacle and the lowest container point must be added.

For precise level sensing it must be observed that the dead volume between the liquid surface and membrane is filled with air which acts as a buffer against the liquid on the one hand yet is also dependent on temperature in its compressibility on the other. This means that with fluctuations in the liquid’s temperature the temperature-dependent dead volume has an impact on the fill height to be measured and should be taken into account in the evaluation with small deviations in fill height. Alternatively, a vent valve should be installed (*Figure 4*).

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In addition to the temperature-dependent dead volume, the temperature-dependent density of the liquid must be taken into account in a precise measurement. Depending on the required accuracy, an additional temperature sensor has to measure the temperature of the liquid that enters into the calculation of the filling level.

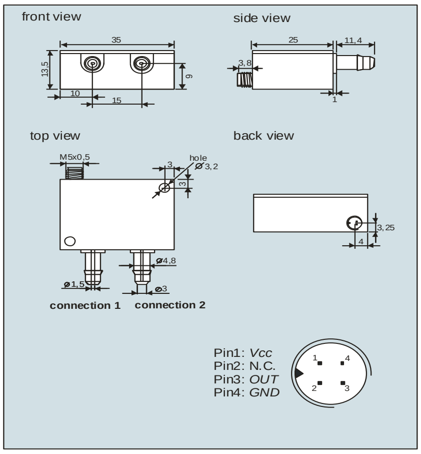

***Figure 5:** dimensions of AMS 4711 (given in mm)*

Description of AMS 4711

The miniaturized pressure transmitters in the AMS 4711 series [1] are high-precision, ready-to-use pressure sensors with a voltage output of 0…5 V. The sensors are calibrated, linearized and compensated for within the industrial temperature range of -25...85°C. The supply voltage can range from 7 to 36 V.

The differential version of the AMS 4711 has two side hose connections (dia. 4.8 mm). Electrical connection is through an M5 sensor plug. The sensors comply with IP67 and are suitable for external installation.

The sensor is affixed using two M3 screws which can be inserted through the two opposite corner holes in the housing.

The sensors are available in pressure ranges of 0–5 mbar to 0–350 mbar for differential/relative measurements and in ranges of 0–1 bar and 0–2 bar for absolute or differential/relative measurements. There is also a bidirectional, differential version supplied in the ±5, ±10, ±20, ±50 and ±100 mbar ranges. This allows negative and positive pressures to be measured. Finally, barometric pressure can be measured using the 700–1,200 mbar variant.

For the measurement of relative and differential pressure AMS 4711 has underside pressurization as a standard and is thus suitable for measuring pressure with one-sided media application in a number of different liquids and reactive gases. [2]

AMS 4711 has a resolution of 11 bits; where the LSB is ignored, AMS 4711-0005-D (5-mbar version) attains a vertical resolution of 50 cm/1,024 = 0.05 cm.

Besides the temperature-dependent dead volume the temperature-dependent density must also be considered for precision measurement. Depending on the required degree of accuracy, here the condition applies that an additional temperature sensor must measure the temperature of the liquid.

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Summary

AMS 4711 is a series of pressure transmitters which are designed for all types of pressure and a wide pressure range. At 5, 10 and 20 mbar they also cater for the low pressure range.

Like all other transmitters in the AMS 4711 series the AMS 4711-0005-D is a calibrated and compensated pressure transmitter with a high resolution which has been conceived for level sensing, among other applications. With this low-pressure transmitter low levels of tank liquid with minimum changes in the fill height can be measured with a vertical resolution of 0.5 mm. Where the geometric dimensions are known, it is thus possible to precisely determine the amount of inflowing or outflowing liquid.

Further information

[1] Product information AMS 4711: https://www.amsys-sensor.com/products/pressure-sensor/ams4711-analog-pressure-transmitter-5v-output

[2] Application note on underside pressurization: https://www.amsys-sensor.com/downloads/notes/ams4711-media-compatible-pressure-transmitter-for-industrial-applications-in-matchbox-format-amsys-515e.pdf

Contact

AMSYS GmbH & Co. KG
An der Fahrt 4
55124 Mainz
GERMANY

phone: +49 (0) 6131/469 875 0
fax: +49 (0) 6131/469 875 66
email: info@amsys-sensor.com
internet: https://www.amsys-sensor.com