AMS 5105 - Pressure sensor-switch combination with analog and 2 binary outputs

In measurement technology a principle distinction is made between measurement recorders (sensors) with a linear and binary output. The same applies to pressure sensing technology. Despite the many possible applications, a combination of both is very seldom offered, however. In the following AMSYS [1] shall demonstrate how a sensor with one analog, linear output and two binary outputs has been implemented and which benefits this combination has for the user, taking the piezoresistive OEM AMS 5105 pressure sensor [2] as an example.

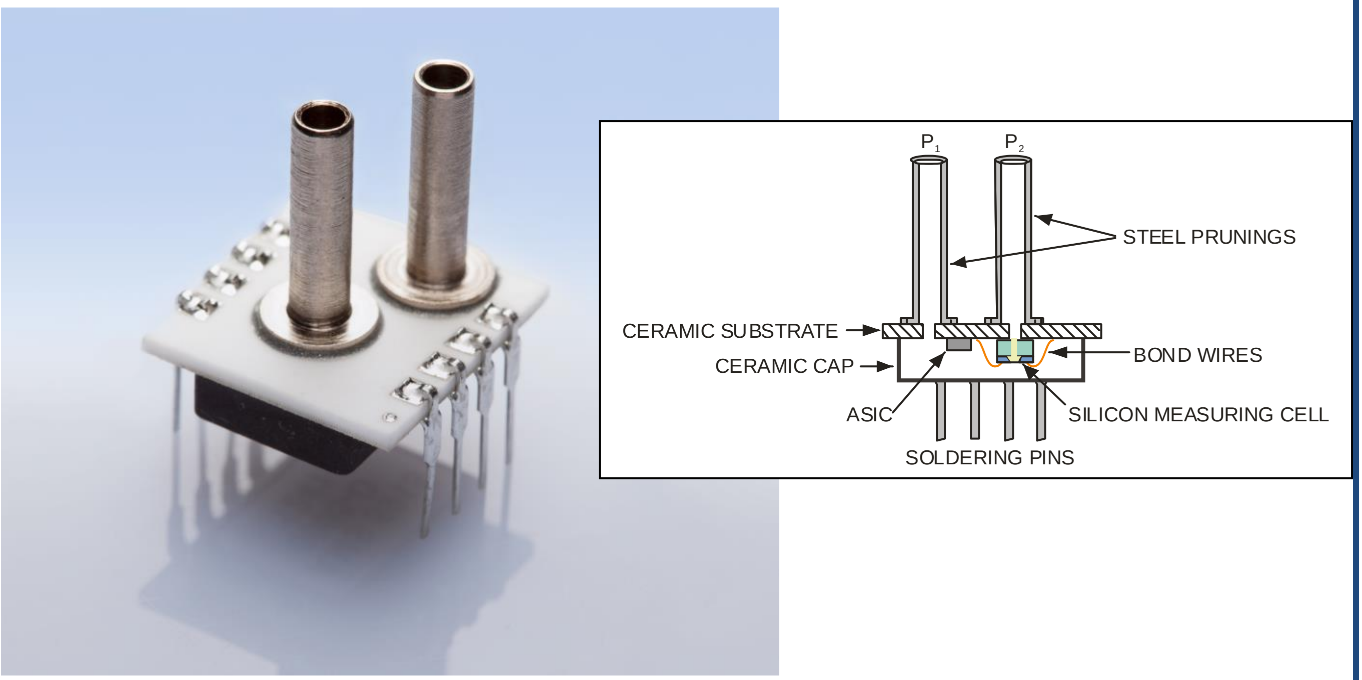

Figure 1: *side view and schematic section of the AMS 5105 pressure switch (by way of comparison: the ceramic substrate measures 15.2 x 15.2 mm²)*

Description of AMS 5105

The AMS 5105 series consists of OEM pressure sensors with two switching outputs and one linear voltage output. The different variants allow absolute/differential pressure and bidirectional differential pressure to be measured [3] within a wide pressure range (5 mbar to 7 bar). All of these OEM sensors are individually calibrated, linearized and temperature compensated for a temperature range of -25°C to 85°C during production. High-quality, piezoresistive silicon sensing elements combined with a state-of-the-art CMOS-ASIC yield very accurate measurement and good, long-term stability.

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A 15.2 x 15.2 mm^2 ceramic substrate with dual inline soldering pins and a ceramic housing give the AMS 5105 high mechanical stability and enable robust handling.

The AMS 5105 is designed for applications where the sensors are set to a configuration (switching function, switching point, hysteresis, switching delay, etc.) and do not have to be changed during their operating period. They are used as pressure sensors which do not need a processor or where the performance of a processor has to be used at system level for other tasks.

Regarding aspects of safety, they are especially suitable for applications which have to react directly (i.e. without intermediate data processing) to a change in pressure (for example, an emergency stop) or which require a reduced number of components.

Theory of operation

The actual measurement of pressure takes place in the AMS 5105's piezoresistive silicon pressure sensing element. Here, the pressure to be measured is converted into a differential, analog voltage signal which is proportional to the pressure. This voltage signal is then amplified in the downstream ASIC (see *Figure* 2) and transmitted to the ADC through a multiplexer, where it is converted into a 14-bit digital value.

In order to obtain standardized output values, during manufacture the digitized signals are electronically calibrated (i.e. calibrated, linearized and compensated) in the downstream µC block.

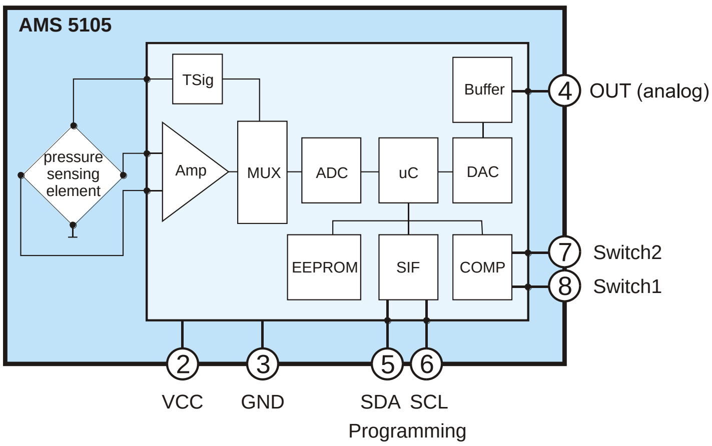

Figure 2: *block diagram of AMS 5105*

In order to calibrate the device, correction coefficients are determined at various pressures and temperatures for each individual sensor and stored in the EEPROM. In the microprocessor block on the ASIC a cyclic program is run which computes the corrected and normed, digital pressure signal based on the respective digitized pressure and temperature values and correction coefficients. The digital values calculated in this manner are written to the output register and cyclically updated (typically every 0.5 ms at a 14-bit ADC resolution).

The digital pressure is converted with the help of an internal DAC (11 bits) and can be read out as a ratiometric voltage (0.5–4.5 V).

The SIF or serial interface unit programs the ASIC and the output parameters in I²C format.

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Binary switching outputs

Binary signals are understand to be signals which have two values. This means that there are only two signal states. Applied to a suitable electronic circuit, this means that the output is either blocked or switched. We thus have an electronic switch.

Besides its linear U_{OUT} = 0.5–4.5 V output for the pressure AMS 5105 has two binary outputs, Switch1 and Switch2, with a logic low level of 0–10% V_{CC} and a high of 90–100% V_{CC}.

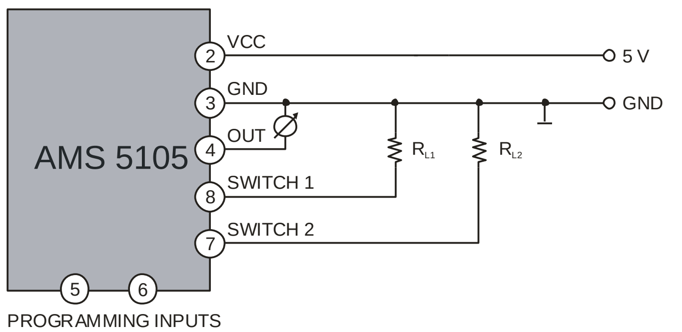

Figure 3: *block diagram of the AMS 5105 outputs*

In the digital part of the signal conditioning unit a corresponding value must be programmed as a switching value using the starter kit. When this value is reached, the output switches from low to high or vice versa. As both outputs are sink/source compatible (max. 4 mA), both outputs can be implemented as current outputs with a suitable load resistor array.

As the ASIC permits two switching points to be programmed at one output (Switch1 and/or Switch2), two-point switches (window mode) can also be realized.

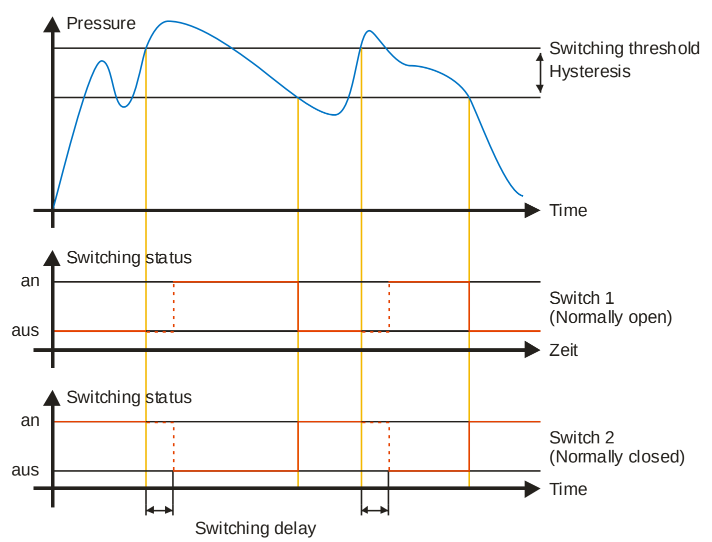

Figure 4: *example switch functions*

The respective outputs can have the following switching functions:

- Switching output deactivated
- Low-side switch
- High-side switch
- Two-point switch.

These can be individually configured by the user with software through an I²C interface (see *AMS 5105 starter kit*) or pre-set during manufacture. The switching function, switching threshold hysteresis and switching delay (*Figure 4*) can be programmed within a wide range.

All of the aforementioned possible settings can be set for both outputs independently.

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With applications which require a low switching current at the binary outputs (max. 4 mA for an LED display, for example), the opener, closer and/or two-point switch functions can be selected and directly implemented at each output. In particular, in this way the one output can be used to display the switching state of the other (for example with a diode circuit).
If larger switching currents are necessary (to drive a DC motor, for instance) or if higher operating voltages have to be switched, an external power stage must be added (such as a smart, low-side PROFET BSP75G power FET [5] (*Figure 5*) or a high-side ISP452 power FET [6] (*Figure 6*).
Using integrated circuitry allows industrial pressure monitors in particular to be produced which are distinguished by a number of protective functions.

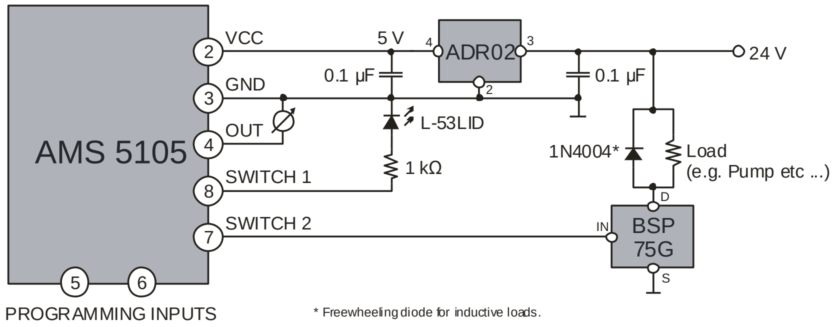

Figure 6: *wiring diagram with a low-side output stage*

Example circuits

The BSP75G is a vertical n-channel FET switch for low-side applications, with the ISP452 an n-channel FET for high-side applications.
The integrated protected functions are: short-circuit and input protection, overload, overvoltage and over-temperature protection with hysteresis. There is also an internal current limit function, shutdown on undervoltage with a restart and protection against ESD.

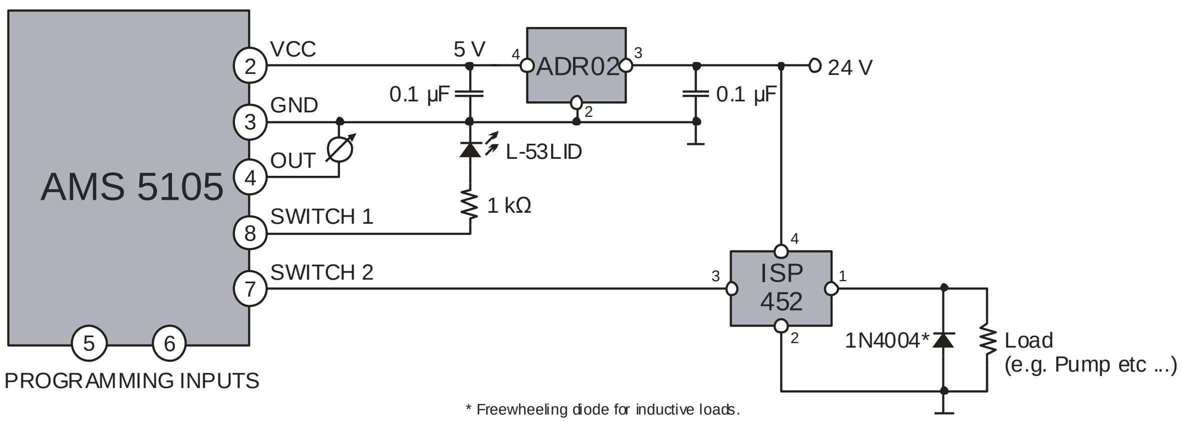

Figure 7: *wiring diagram with a high-side output stage*

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In the first approximation the following applies to piezoresistive sensing elements, such as those used in AMS 5105:

$V_{OUT} = S \cdot P \cdot V_S$ with S = sensitivity, P = active pressure and V_S = supply voltage.

We can see that output signal V_{out} from a piezoresistive silicon sensing element is directly dependent on supply voltage V_S. This means that the sensing element signal is synchronous with the change in the supply voltage, a phenomenon we describe as being "ratiometric". This behavior is also found in the AMS 5105 output signal of 0.5–4.5 V.

From the aspect of safety, this analog signal has the advantage of also acting as an inherent fault diagnosis. If the signal is 0 V even without pressure being applied, we know that no supply voltage is present (fractured wire). If the signal is between 0 and 0.5 V at minimum pressure, there is a fault in the ASIC or the calibration is incorrect. If the output signal is between 4.5 and 5 V at maximum pressure, the calibration must be faulty. If the signal is 5 V, we must assume that there is a short circuit after V_{cc}.

The analog signal can therefore be used to detect basic errors which cannot be instantly recognized on the digital signal.

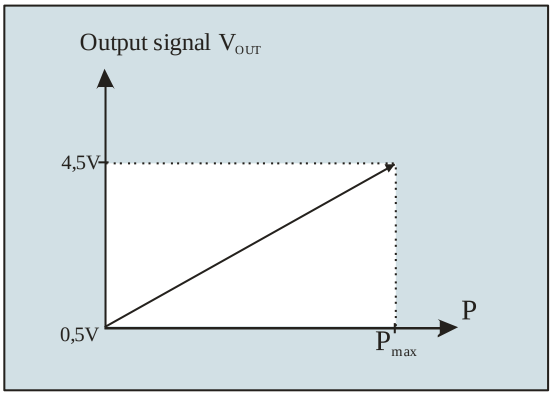

Figure 8: *calibrated analog output signal from AMS 5105*

This ratiometric output only applies to the analog outputs.

Applications: combination of linear and binary outputs

Using the AMS 5105 simple pressure switches (openers and/or closers) can be implemented with a status control or pressure indicator, for example, and also antivalent/ambivalent switching systems with pressure control.

In principle, the advantage of combining a linear analog output with binary switching outputs lies in the ability to directly control the pressure using the analog signal in an industrial system which must be switched depending on the pressure.

If the circuit is not properly switched in a system like this, such as due to an error in the switching system, by knowing the set switching point (50% max. pressure, for example) this incorrect behavior can be visually detected in the relevant analog output signal (half full-scale display). This is of particular significance in safety-relevant applications.

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Another example: if, in a switching application, the pressure is to be controlled prior to the switching point being reached – to reduce the speed at which the pressure changes, for instance – this can be realized based on the analog signal.

Yet another example would be as follows: as we cannot recognize the range we are in on the pressure characteristic from the switching state of a two-point switch, the relevant information can be read out at the analog output.

These are just a few examples which find repeated application in industrial environments and which can be implemented using the AMS 5105.

Summary

The AMS 5105, which combines a linear, analog output with two binary switching outputs, is designed for stand-alone applications without an additional microprocessor. All switching functions can be programmed by either the user or the manufacturer so that no additional digital electronics are required to implement pressure control systems (such as the direct activation of a relay with a switching control). Using the parallel outputs pressure switches with an internal control can be assembled without the need for additional circuitry.

The OEM sensors in the AMS 5105 series are available for all types of pressure measurement (for measuring absolute, relative, differential and bidirectional differential pressure). They can be used in their respective versions within a pressure range of 0–5 mbar to 0–7 bar.

Further information

[1] AMSYS homepage: https://www.amsys-sensor.com/

[2] AMS 5105 datasheet: https://www.amsys-sensor.com/downloads/data/ams5105-AMSYS-datasheet.pdf

[3] Application note on Measuring over-and underpressure bidrectionally with one sensor: https://www.amsys-sensor.com/downloads/notes/ams5812-measuring-over-and-underpressure-bidrectionally-with-one-sensor-amsys-510e.pdf

[4] AMS 5105 starter kit: https://www.amsys-sensor.com/en/products/accessory/starter-kit-for-pressure-switch-ams-5105/

[5] BSP75G datasheet: https://www.diodes.com/assets/Datasheets/BSP75G.pdf

[6] ISP452 datasheet: https://www.infineon.com/dgdl/Infineon-ISP452-DS-v01_01-en.pdf?fileId=db3a304412b407950112b42957ef40c3

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