AMS 5105 - Filter and ventilation system control with bi-functional pressure sensor

The following application notes issued by AMSYS GmbH & Co. KG in Mainz, Germany, describe how OEM pressure sensor/pressure switch AMS 5105 [1] is used in the filter and ventilation units found in air conditioning systems. Four different examples illustrate how easily the pressure sensor can be applied to indicate various malfunctions and show when best to change the filter.

Filters in air conditioning systems (HVAC) have a considerable impact on system reliability and energy efficiency. The filter's air flow resistance is the critical parameter here, this determined by the filter assembly (i.e. the type and size of filter and MERV rating) and the amount of soiling on the filter. In order to ensure that air conditioning systems function properly, for reasons of economy it makes sense to have the filter controlled by a monitoring system and maintained as necessary instead of replacing it after a certain interval regardless of the condition it is in.

Figure 1: *filter unit for an air conditioning system.*

Figure 2 shows a basic control system for monitoring filters in air conditioning units. It consists of a differential sensor and a control unit. The pressure sensor monitors the air flowing through the filter segment by measuring the difference of $\Delta p = P_1 - P_2$ (difference between the filter's input and output pressure). Provided that the ventilator operates at a constant speed and the filter is correctly installed, the air flow in the ventilation ducts depends on the type of filter used and the state of the filter. The filter type determines initial difference in pressure Δp_{ini} which is measured when a new filter is correctly installed in the air conditioning system. This value constitutes the minimum pressure during operation. During the course of operation, in most applications the filter is soiled by particles in the air flow. This causes an increase in the filter's flow resistance and thus a rise in the differential pressure. As a basic rule of thumb, we could say that a filter should be replaced when double Δp_{ini} is measured across the filter [2].

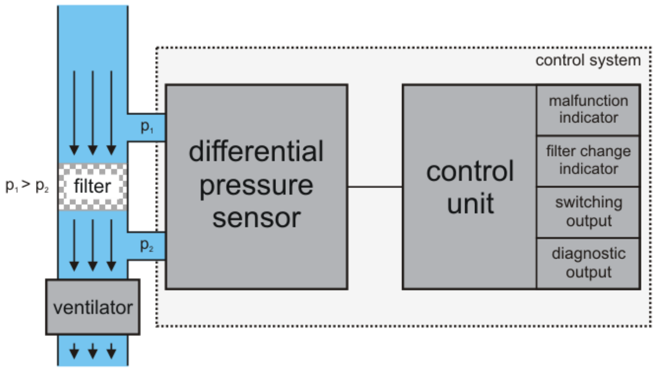

Figure 2: a simple HVAC monitoring system with the filter controlled by a differential pressure sensor.

The system depicted in *Figure 2* can also be used to detect malfunctions in the air conditioning unit. If the measured difference in pressure is $\Delta p_{fact} < \Delta p_{ini}$, the filter might be torn, the ventilation unit could be malfunctioning or there may be a leak in the ventilation ducts.

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In order to build a simple evaluation unit without the need for an external microcontroller, AMSYS suggests using double-function sensor AMS 5105. This OEM sensor is individually calibrated and temperature compensated and has an analog, ratiometric voltage output of 0.5 to 4.5 V plus two discrete, programmable, logical switching outputs. These are capable of supplying 4 mA in sink and source operation. As described in the AMS 5105 datasheet [1] and AMS 5105 USB starter kit user guide [3], the switching function (opener, closer), switching threshold, hysteresis and response time can be individually set for each switching output. All of these parameters can also be preconfigured by the manufacturer.

In its differential low-pressure variants of 5 mbar to 100 mbar the AMS 5105 is ideal for use in filter and ventilation monitoring systems. As illustrated by the following examples, the AMS 5105 can be used simply and inexpensively to realize a system which monitors malfunctions and indicates when the filter should be replaced.

Example 1: monitor with a filter change indicator and early warning function

Figure 3 shows a filter monitoring system with an early warning function which requires only a few components besides the AMS 5105. One of the sensor's pressure connectors is connected to the filter input side and the other pressure connector to the output side. Two LEDs are switched so that the state of the filter can be indicated. *LED 1*, connected to AMS 5105's SWITCH 1 switching output, is programmed to light up when the filter needs changing in the near future. *LED 2*, connected to switching output SWITCH 2 on AMS 5105, should indicate that the filter has to be changed as soon as possible.

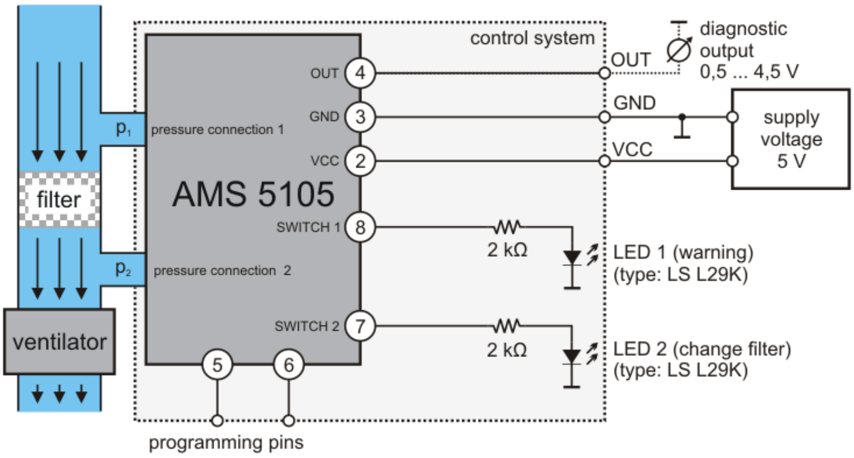

Figure 3: *simple HVAC filter control system with an early warning system.*

In this example both switching outputs on the AMS 5105 are used as closers, with the hysteresis typically set to 5% of the calibrated pressure range. Applying initial difference in pressure Δp_{ini}, the SWITCH 1 switching threshold is set to a warning threshold of $1.75 \cdot \Delta p_{ini}$, for example. The SWITCH 2 switching threshold is typically set to $2 \cdot \Delta p_{ini}$. *LED 1* thus lights up if the measured difference in pressure exceeds the warning threshold and *LED 2* is illuminated when double the difference in pressure is reached.

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The analog voltage output on AMS 5105 can be used with a voltmeter as a control unit here which displays information on the actual differential pressure.

If the analog value is greater than $2{\cdot}\Delta p_{ini}$, this indicates that the filter must be changed urgently; if the analog output voltage is lower than the corresponding value for a new filter, there is a malfunction in the air conditioning unit. The cause thereof could be a torn filter, a leak in the ventilation ducts, a damaged ventilator or a bridged filter.

Example 2: filter monitoring system with 24 V supply voltage and current outputs

The circuit shown above can be easily adapted for applications operated with a 24 V supply, in which electrical devices are to be turned on and off. *Figure 4* depicts the suggested circuitry for a filter monitoring system operated with 7 to 36 V and which, through its MOSFET power outputs, can also supply a current of 0.7 A to switching outputs S1 and S2. These outputs can be used to activate a warning siren or actuator (such as a throttle valve), for example. The suggested components with their integrated protective circuitry also guard the system against short circuits.

By using power MOSFET BSP 452 [5] outputs S1 and S2 follow the switching functions programmed on the AMS 5105. This enables the settings described in Example 1 for switching outputs SWITCH 1 and SWITCH 2 to then be used. This causes *LED 1* to light up and the load connected to S1 to be supplied with current if the differential pressure measured by the AMS 5105 exceeds initial difference in pressure Δp_{ini} by a factor of 1.75. When differential pressure $2{\cdot}\Delta p_{ini}$ is reached, *LED 2* is illuminated and the load connected to S2 is supplied with current.

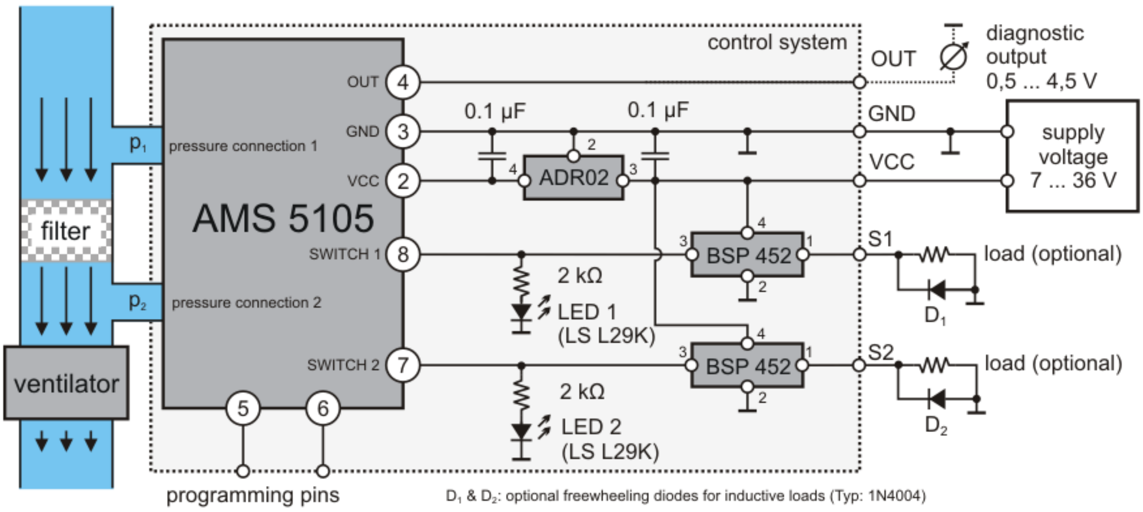

***Figure 4:** HVAC filter control system with current outputs.*

If the application requires a low-side switch, which connects ground through instead of the supply voltage, the BSP 75N [6] can be used in place of the BSP 452. In this case the load is directly connected to the supply voltage and the ground pin of the load to the BSP 75N.

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Example 3: filter and ventilator monitoring in air conditioning systems with a failure LED

With the help of the circuits in Examples 1 and 2 it is possible to indicate whether the filter has to be changed in the near future or immediately. Possible malfunctions can only be displayed with the help of the analog output. By using the circuitry shown in *Figure 4* and adjusting the switching functions and thresholds programmed on the AMS 5105 malfunctions at $\Delta p_{fact} < \Delta p_{ini}$ and $\Delta p_{fact} > 2\ \Delta p_{ini}$ and the point in time when the filter needs to be changed can be determined. In this example the analog output can be used as an indicator of the urgency of these measures.

To this end it makes sense to use an AMS 5105 differential pressure sensor with a maximum pressure of around five times the initial difference in pressure of Δp_{ini}. SWITCH 1 on the AMS 5105 is used as an opener and its switching threshold is set to $0.95 \cdot \Delta p_{ini}$. SWITCH 2 is programmed as a closer and $2 \cdot \Delta p_{ini}$ is used as the switching threshold. The hysteresis of both outputs is typically set to 1% of the calibrated pressure range which is equivalent to about 5% of Δp_{ini}. These settings cause SWITCH 1 to open at $0.95 \cdot \Delta p_{ini}$ on a rise in pressure and to close the switch at $0.9 \cdot \Delta p_{ini}$ when the pressure drops. SWITCH 2 closes the switch at $2 \cdot \Delta p_{ini}$ on a rising pressure and opens at $1.95 \cdot \Delta p_{ini}$ with a fall in pressure.

When these settings are used, both LEDs and S1 and S2 are off during normal operation. If the differential pressure exceeds $2 \cdot \Delta p_{ini}$, *LED 2* lights up and the load connected to S2 is supplied with current which can be used to signal that the filter needs replacing. *LED 1* turns on and the load at S1 is supplied with current if a malfunction occurs, with which the measured difference in pressure falls to below at least $0.9 \cdot \Delta p_{ini}$. These malfunctions include ventilator failure, a leak in the ventilation ducts and a torn or bridged filter and can trigger an emergency stop, for example.

Alternatively, AMS 5105’s switching outputs can also be operated in window mode (see the AMS 5105 USB starter kit user guide [3]), where the aforementioned switching thresholds and hysteresis for SWITCH 1 and SWITCH 2 are used. In this case *LED 1* indicates that the system is functioning properly and *LED 2* lights up when the filter has reached the end of its service life or a malfunction has occurred which has reduced the current difference in pressure to less than $0.9 \cdot \Delta p_{ini}$. In this case the analog output shows how far the pressure is above/below the alarm threshold which in turn indicates the degree of urgency.

Example 4: filter monitoring system with pressure measured at an aperture.

The circuitry in Example 2 can be used for this application. All that changes is the way in which the pressure is measured. Instead of measuring the difference between the filter’s input and output pressures the drop in pressure across an aperture downstream of the filter is determined. The advantage of this method is that the pressure sensor is protected against soiling by the filter.

When using an aperture to measure pressure, AMS 5105’s first pressure connector is connected between the filter and the aperture and the second after the aperture. Unlike in the aforementioned examples the drop in pressure decreases across the aperture should the air resistance of the filter increase. At a constant ventilator speed the air flow through a new, properly installed filter is greater than the air flow through a filter which has been in use for some time. The decreased air flow through the filter results in a lower difference in pressure across the aperture.

As the relation between the air flow through the filter and the drop in pressure at the aperture is non-linear, the switching thresholds described in the previous example can no longer be used. Instead, initial difference in pressure Δp_{ini}, the difference in pressure at the end of the filter's service life and the resulting switching thresholds for the AMS 5105 have to be determined and configured for each assembly.

In all of the given examples the analog output can be used for monitoring but also for configuration assistance.

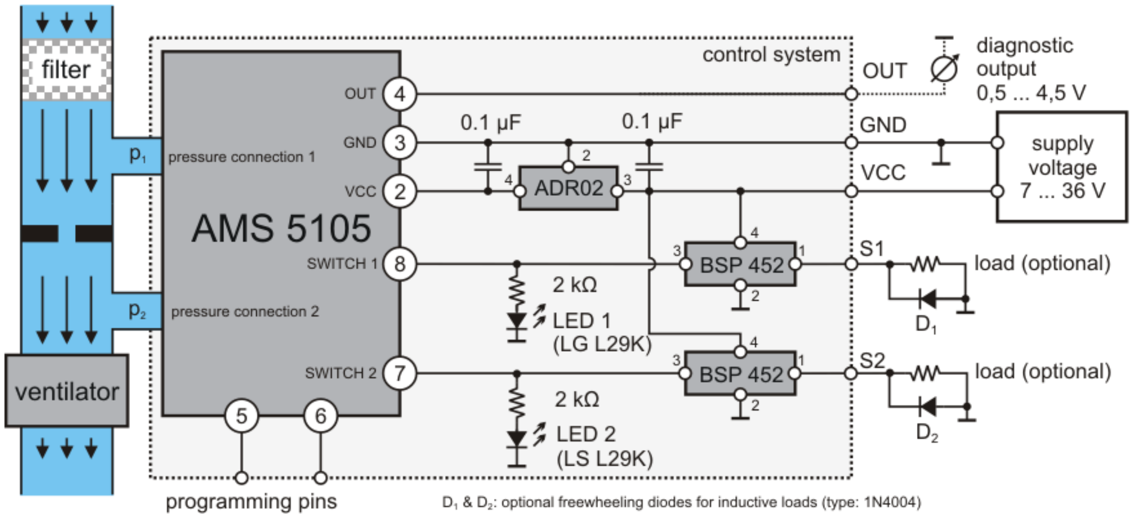

Figure 5: *HVAC filter control system with pressure measured across an aperture.*

Summary

With the help of double-function sensor AMS 5105 efficient control systems for monitoring filters can be realized. Options range from simple systems to units which trigger actuators depending on switching thresholds and enable continuous pressure state control with the help of an analog output. Switching characteristics such as the switching function, switching thresholds, response time and hysteresis can be configured on the AMS 5105.

The AMS 5105 is designed for inexpensive applications which use no additional microprocessor or where the processor capacity is reserved for other functions. The switching parameters can be set by the user with the help of the USB starter kit or by the manufacturer. The suggested circuits are thus suitable for applications which are to be configured once only and subsequently not changed.

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Further information

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

[2] The Energy and Filter Fact Handbook", Camfil, United States of America, 2014

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

[4] ADR02 datasheet (http://www.analog.com)

[5] BSP425 datasheet (http://www.infineon.com)

[6] BSP75N datasheet (http://www.infineon.com)

[7] LS L29K and LG L29K datasheets (see http://www.osram-os.com)

[8] 1N4004 datasheet (http://www.onsemi.com)

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