

FEATURES

- Board mount pressure sensor series with digital output: I2C / SPI
- Calibrated and temperature compensated
- Differential/relative, bidirectional differential, absolute and barometric sensor versions
- Wide variety of pressure ranges: from ultra low pressure of 1.25 mbar (125 Pa) up to 2 bar
- Piezoresistive sensor with high precision digital signal conditioning
- Total accuracy < 0.1 %FSO at room temperature for pressure ranges from 200 mbar up to 2 bar
- TEB < 0.25 %FSO (-25 ... 85 °C) for pressure ranges from 200 mbar up to 2 bar
- Ultra low current consumption in sleep mode, ideal for battery powered applications
- Measurement speed up to 250 Hz
- Supply voltage: 1.7 V up to 3.6 V
- Digital output via I2C / SPI interface: 24 bit values for pressure and temperature
- Programmable I2C-address
- Ceramic DIP-8 package (width: 0.6 inch)
- Package options for tubing or manifold mount (O-Ring sealing)
- RoHS compliant

TYPICAL APPLICATIONS

- Static and dynamic pressure measurement
- Gas flow measurement
- Fluid level measurement
- Medical instrumentation
- Heating, Ventilation and Air Conditioning (HVAC)
- Battery powered and mobile applications
- Vacuum monitoring

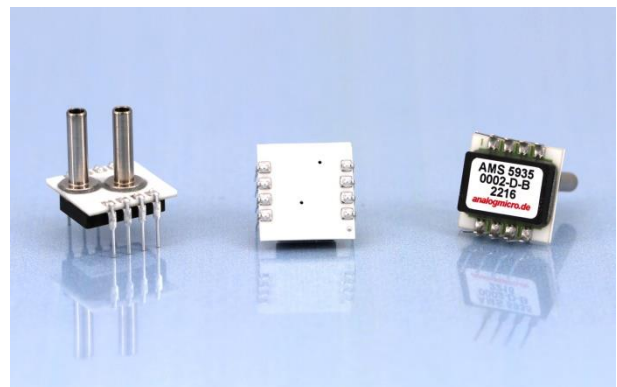
GENERAL DESCRIPTION

The digital pressure sensors in the AMS 5935 series are high-resolution 18-bit board mount sensors which provide pressure and temperature measurement data via an I2C / SPI interface. They are extensively calibrated and compensated, leading to high precision and high stability measurement data over a wide temperature range of -25 to 85 °C. With an ultra low current consumption and a supply voltage range of 1.7 ... 3.6 V, the AMS 5935 pressure sensors are especially suitable for battery-powered applications.

The AMS 5935 combine a micromachined, high quality piezoresistive pressure sensing element with a signal conditioning ASIC in a ceramic dual in-line package (DIP) for assembly on printed circuit boards (PCBs). Two package variants are available: one with vertical pressure ports for hose connection and one for O-ring sealing (N-package type for manifold mount).

Multiple pressure ranges for various pressure types are available for the sensors in the AMS 5935 series: differential (relative) pressure sensors in ranges from 0 ... 2.5 mbar up to 0 ... 1 bar, absolute pressure types from 0 ... 500 mbar up to 0 ... 2 bar and 700 ... 1200 mbar for barometric measurements. Bidirectional differential sensors are available in pressure ranges from -1.25 ... +1.25 mbar up to -1 ... +1 bar.

Custom specific pressure ranges or modifications are available on request.



PRESSURE RANGES

Sensor types with vertical pressure ports (metal tubes for hose connection)

Sensor type (code)	Pressure type	Pressure range in mbar	Burst pressure ¹⁾ in bar	Pressure range in Pa	Burst pressure in kPa
Ultra low pressure ranges					
AMS 5935-0002-D-...	differential / relative ²⁾	0 ... 2.5	> 0.2	0 ... 250	> 20
AMS 5935-0005-D-...	differential / relative	0 ... 5	> 0.2	0 ... 500	> 20
AMS 5935-0010-D-...	differential / relative	0 ... 10	> 0.2	0 ... 1000	> 20
AMS 5935-0001-D-B-...	bidirectional differential	-1.25 ... 1.25	> 0.2	-125 ... 125	> 20
AMS 5935-0002-D-B-...	bidirectional differential	-2.5 ... +2.5	> 0.2	-250 ... +250	> 20
AMS 5935-0005-D-B-...	bidirectional differential	-5 ... +5	> 0.2	-500 ... +500	> 20
AMS 5935-0010-D-B-...	bidirectional differential	-10 ... +10	> 0.2	-1000 ... +1000	> 20
Low pressure ranges					
AMS 5935-0020-D-...	differential / relative	0 ... 20	> 0.4	0 ... 2000	> 40
AMS 5935-0035-D-...	differential / relative	0 ... 35	> 0.4	0 ... 3500	> 40
AMS 5935-0050-D-...	differential / relative	0 ... 50	> 1	0 ... 5000	> 100
AMS 5935-0100-D-...	differential / relative	0 ... 100	> 1	0 ... 10000	> 100
AMS 5935-0020-D-B-...	bidirectional differential	-20 ... +20	> 0.4	-2000 ... +2000	> 40
AMS 5935-0035-D-B-...	bidirectional differential	-35 ... +35	> 0.4	-3500 ... +3500	> 40
AMS 5935-0050-D-B-...	bidirectional differential	-50 ... +50	> 1	-5000 ... +5000	> 100
AMS 5935-0100-D-B-...	bidirectional differential	-100 ... +100	> 1	-10000 ... 10000	> 100
Standard pressure ranges					
AMS 5935-0200-D-...	differential / relative	0 ... 200	> 1.7	0 ... 20000	> 170
AMS 5935-0350-D-...	differential / relative	0 ... 350	> 1.7	0 ... 35000	> 170
AMS 5935-0500-D-...	differential / relative	0 ... 500	> 5	0 ... 50000	> 500
AMS 5935-1000-D-...	differential / relative	0 ... 1000	> 5	0 ... 100000	> 500
AMS 5935-0200-D-B-...	bidirectional differential	-200 ... +200	> 1.7	-20000 ... +20000	> 170
AMS 5935-0350-D-B-...	bidirectional differential	-350 ... +350	> 5	-35000 ... +35000	> 500
AMS 5935-0500-D-B-...	bidirectional differential	-500 ... +500	> 5	-50000 ... +50000	> 500
AMS 5935-1000-D-B-...	bidirectional differential	-1000 ... +1000	> 5	-100000 ... +100000	> 500
AMS 5935-0500-A-...	absolute	0 ... 500	> 5	0 ... 50000	> 500
AMS 5935-1000-A-...	absolute	0 ... 1000	> 5	0 ... 100000	> 500
AMS 5935-1500-A-...	absolute	0 ... 1500	> 5	0 ... 150000	> 500
AMS 5935-2000-A-...	absolute	0 ... 2000	> 5	0 ... 200000	> 500
AMS 5935-1200-B-...	absolute (barometric)	700 ... 1200	> 5	70000 ... 120000	> 500

Table 1: AMS 5935 standard pressure ranges (other pressure ranges on request)

Notes:

- 1) Burst pressure is defined as the maximum pressure which may be applied to one pressure port relative to the other port (or while only one pressure port is connected) without causing leaks in the sensor.
- 2) Relative pressure is the difference between applied pressure and atmospheric pressure. It is often also called gage or gauge pressure.

Sensor types for manifold assembly (-N package option without tubes for O-ring sealing)

Sensor type (code)	Pressure type	Pressure range in mbar	Burst pressure ¹⁾ in bar	Pressure range in Pa	Burst pressure in kPa
Ultra low pressure ranges					
AMS 5935-0002-D-N-...	differential / relative ²⁾	0 ... 2.5	> 0.2	0 ... 250	> 20
AMS 5935-0005-D-N-...	differential / relative	0 ... 5	> 0.2	0 ... 500	> 20
AMS 5935-0010-D-N-...	differential / relative	0 ... 10	> 0.2	0 ... 1000	> 20
AMS 5935-0001-D-B-N-...	bidirectional differential	-1.25 ... 1.25	> 0.2	-125 ... 125	> 20
AMS 5935-0002-D-B-N-...	bidirectional differential	-2.5 ... +2.5	> 0.2	-250 ... +250	> 20
AMS 5935-0005-D-B-N-...	bidirectional differential	-5 ... +5	> 0.2	-500 ... +500	> 20
AMS 5935-0010-D-B-N-...	bidirectional differential	-10 ... +10	> 0.2	-1000 ... +1000	> 20
Low pressure ranges					
AMS 5935-0020-D-N-...	differential / relative	0 ... 20	> 0.4	0 ... 2000	> 40
AMS 5935-0035-D-N-...	differential / relative	0 ... 35	> 0.4	0 ... 3500	> 40
AMS 5935-0050-D-N-...	differential / relative	0 ... 50	> 1	0 ... 5000	> 100
AMS 5935-0100-D-N-...	differential / relative	0 ... 100	> 1	0 ... 10000	> 100
AMS 5935-0020-D-B-N-...	bidirectional differential	-20 ... +20	> 0.4	-2000 ... +2000	> 40
AMS 5935-0035-D-B-N-...	bidirectional differential	-35 ... +35	> 0.4	-3500 ... +3500	> 40
AMS 5935-0050-D-B-N-...	bidirectional differential	-50 ... +50	> 1	-5000 ... +5000	> 100
AMS 5935-0100-D-B-N-...	bidirectional differential	-100 ... +100	> 1	-10000 ... +10000	> 100
Standard pressure ranges					
AMS 5935-0200-D-N-...	differential / relative	0 ... 200	> 1.7	0 ... 20000	> 170
AMS 5935-0350-D-N-...	differential / relative	0 ... 350	> 1.7	0 ... 35000	> 170
AMS 5935-0500-D-N-...	differential / relative	0 ... 500	> 5	0 ... 50000	> 500
AMS 5935-1000-D-N-...	differential / relative	0 ... 1000	> 5	0 ... 100000	> 500
AMS 5935-0200-D-B-N-...	bidirectional differential	-200 ... +200	> 1.7	-20000 ... +20000	> 170
AMS 5935-0350-D-B-N-...	bidirectional differential	-350 ... +350	> 5	-35000 ... +35000	> 500
AMS 5935-0500-D-B-N-...	bidirectional differential	-500 ... +500	> 5	-50000 ... +50000	> 500
AMS 5935-1000-D-B-N-...	bidirectional differential	-1000 ... +1000	> 5	-100000 ... +100000	> 500
AMS 5935-0500-A-N-...	absolute	0 ... 500	> 5	0 ... 50000	> 500
AMS 5935-1000-A-N-...	absolute	0 ... 1000	> 5	0 ... 100000	> 500
AMS 5935-1500-A-N-...	absolute	0 ... 1500	> 5	0 ... 150000	> 500
AMS 5935-2000-A-N-...	absolute	0 ... 2000	> 5	0 ... 200000	> 500
AMS 5935-1200-B-N-...	absolute (barometric)	700 ... 1200	> 5	70000 ... 120000	> 500

Table 2: AMS 5935 pressure ranges for manifold assembly (other ranges on request)

Notes:

- 1) Burst pressure is defined as the maximum pressure which may be applied to one pressure port relative to the other port (or while only one pressure port is connected) without causing leaks in the sensor.
- 2) Relative pressure is the difference between applied pressure and atmospheric pressure. It is often also called gage or gauge pressure.

MAXIMUM RATINGS

Parameter	Minimum	Typical	Maximum	Units
Maximum supply voltage: $V_{S,max}$			3.6	V
Operating temperature: T_{op}	-25		85	°C
Storage temperature: T_{amb}	-40		125	°C
Common mode pressure: $p_{CM}^{1)}$			16	bar

Table 3: Maximum ratings

Note:

- 1) Common mode pressure is defined as the maximum pressure, which can be applied simultaneously on both pressure ports of a differential or bidirectional pressure sensor without causing damages, while no differential pressure is applied.

SPECIFICATIONS

All parameters apply to $T_{op} = 25\text{ °C}$ and $V_S = 3.3\text{ V}$, unless otherwise stated.

Parameter	Minimum	Typical	Maximum	Units
Digital output signal (pressure) ¹⁾				
@ specified minimum pressure (see "pressure range") ²⁾		$0.1 \cdot 2^{24}$		counts
@ specified maximum pressure (see "pressure range") ²⁾		$0.9 \cdot 2^{24}$		counts
Full span output (FSO) ³⁾		$0.8 \cdot 2^{24}$		counts
without pressure (bidirectional differential)		$0.5 \cdot 2^{24}$		counts
Digital output signal (temperature) ⁴⁾				
@ minimum temperature $T = -25\text{ °C}$		$0.09 \cdot 2^{24}$		counts
@ maximum temperature $T = 85\text{ °C}$		$0.75 \cdot 2^{24}$		counts
Total accuracy ⁵⁾ (pressure measurement) @ $T = 25\text{ °C}$				
Pressure ranges: $\pm 1.25\text{ mbar}$, $0 \dots 2.5\text{ mbar}$			± 0.6	%FSO
Pressure ranges: $\pm 2.5\text{ mbar}$, $0 \dots 5\text{ mbar}$			± 0.5	%FSO
Pressure ranges: $\pm 5\text{ mbar}$ up to $\pm 100\text{ mbar}$			± 0.3	%FSO
Pressure ranges: $0 \dots 10\text{ mbar}$ up to $0 \dots 100\text{ mbar}$			± 0.3	%FSO
Pressure ranges: $0 \dots 200\text{ mbar}$ up to $0 \dots 2\text{ bar}$			± 0.1	%FSO
TEB/Overall error ⁶⁾ (pressure meas.) @ $T = -25 \dots 85\text{ °C}$				
Pressure ranges: $\pm 1.25\text{ mbar}$, $0 \dots 2.5\text{ mbar}$			± 1.5	%FSO
Pressure ranges: $\pm 2.5\text{ mbar}$, $0 \dots 5\text{ mbar}$			± 1.0	%FSO
Pressure ranges: $\pm 5\text{ mbar}$ up to $\pm 100\text{ mbar}$			± 0.5	%FSO
Pressure ranges: $0 \dots 10\text{ mbar}$ up to $0 \dots 100\text{ mbar}$			± 0.5	%FSO
Pressure ranges: $0 \dots 200\text{ mbar}$ up to $0 \dots 2\text{ bar}$			± 0.25	%FSO
Total error for temperature measurement				
All types of AMS 5935 $T = -25 \dots 85\text{ °C}$			± 1.5	%FSO
Long term stability			< 0.5	%FSO/a
Supply voltage range (V_S)	1.7	3.3	3.6	V

Parameter	Minimum	Typical	Maximum	Units
Resolution A/D converter	18			bits
Resolution pressure signal ⁷⁾	17		18	bits
Resolution temperature signal			16	bits
Current consumption (in sleep mode)			250	nA
Current consumption (in active mode)			2	mA
Time in active mode / single measurement time with 0xAA _{Hex}		4.0		ms
Time in active mode / 4x oversampling meas. time with 0xAD _{Hex}		14.5		ms
Start-up time (V _S ramp up to ready for first measurement)		2.5		ms
Maximum measurement speed (using 0xAA _{Hex})		250		Hz
I²C-interface				
Input high level	80		100	% V _S
Input low level	0		20	% V _S
Output low level	0		20	% V _S
Load capacitance @ SDA			100	pF
Clock frequency SCL		100	400	kHz
Pull-up resistor	1		20	kΩ
Pressure changes	10 ⁶			
Compensated temperature range	-25		85	°C
Weight		3		g
Media compatibility	See "Specification notes" ^{8), 9)}			

Table 4: Specifications

SPECIFICATION NOTES

- 1) The digital pressure output signal is not ratiometric to the supply voltage.
- 2) The pressure ranges with specified minimum and maximum pressure are listed in *Table 1* and *Table 2*.
- 3) The Full Span Output (FSO) is the algebraic difference between the output signal at the specified maximum pressure and the output signal at the specified minimum pressure (see *Table 1* and *Table 2*).
- 4) The digital temperature output signal is not ratiometric to the supply voltage. The temperature output value is the overall sensor temperature. It is measured at the sensor's signal conditioning ASIC and is influenced by the measurement media's temperature, the ambient temperature, the sensor's self-heating and the thermal conductivity of the material in contact to the sensor (e.g. PCB, mounting assembly, pressure hoses).
- 5) Total accuracy is defined as the maximum deviation of the measurement value from the ideal characteristic curve at room temperature (RT) in %FSO including the adjustment errors (offset and span), nonlinearity, pressure hysteresis and repeatability. Nonlinearity is the measured deviation from the best fit straight line (BFSL) across the entire pressure range. Pressure hysteresis is the maximum deviation of the output value at any pressure within the specified range when the pressure is cycled to and from the minimum or maximum rated pressure. Repeatability is the maximum deviation of the output value at any pressure within the specified range after 10 pressure cycles.
- 6) The TEB (total error band or overall error) is defined as the maximum deviation of the measurement value from the ideal characteristic curve in %FSO across the entire temperature range (-25 ... 85 °C).
- 7) For the pressure ranges 0 ... 2.5 mbar and -1.25 ... +1.25 mbar the minimum resolution is 16 bit.
- 8) Media compatibility of pressure port 1 (for a description of port 1 see *Figure 7* and *Figure 8*): clean, dry gases, non-corrosive to silicon, RTV silicone rubber, epoxy, gold (alkaline or acidic liquids can destroy the sensor). For standard packages with tubes the media compatibility of the nickel-plated steel tubes has to be considered, too.
- 9) Media compatibility of pressure port 2 (for a description of port 2 see *Figure 7* and *Figure 8*): fluids and gases non-corrosive to silicon, Pyrex, RTV silicone rubber. For standard packages with tubes the media compatibility of the nickel-plated steel tubes and its epoxy adhesive has to be considered, too.

FUNCTIONAL DESCRIPTION

The pressure sensors in the AMS 5935 series combine a high quality, membrane-based piezoresistive silicon sensing element with a modern mixed-signal CMOS ASIC for signal-conditioning in a ceramic package. This enables a low total error band, excellent temperature behavior and long-term stability.

AMS 5935's functional principle is explained using *Figure 1*.

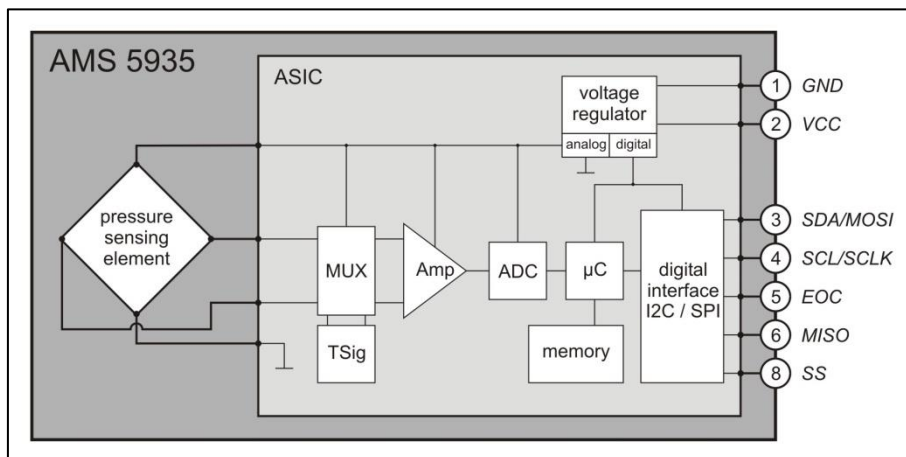


Figure 1: Functional principle

The physical pressure applied to AMS 5935's pressure port(s) is converted into a differential voltage signal at AMS 5935's piezoresistive pressure sensing element. This differential voltage is signal-conditioned and converted into a standardized digital output signal in the following way:

At first, the sensing element's differential voltage signal is transmitted through the multiplexer and amplifier block to the A/D converter block (ADC), where it is converted into a digital signal with 18 bit resolution. This digitized signal is then mathematically processed by the ASIC's integrated microcontroller unit (µC) to obtain a calibrated and temperature compensated output signal. For this purpose, the µC uses a correction algorithm and individual correction coefficients that are stored in the ASIC's memory during AMS 5935's factory calibration. This enables sensor-specific calibration and correction (i.e. linearization and temperature compensation) of the digitized pressure signal. The temperature signal, which is required for temperature compensation, is generated in the ASIC's temperature reference block and transmitted via the multiplexer to the amplifier and then to the ADC, where it is digitized, too. Using its correction algorithm the microcontroller calculates the current corrected and standardized pressure and temperature measurement data (24 bit pressure value and 24 bit temperature value), which are written to the ASIC's output register then. The readout of the standardized digital output values for pressure and temperature from the output registers can be done via the sensor's digital I2C / SPI interface. For I2C communication PIN3 (SDA) and PIN4 (SCL) are used and PIN3 (MOSI), PIN4 (SCLK), PIN6 (MISO) and PIN8 (SS) for SPI communication. AMS 5935's digital output values (for pressure and temperature) are not ratiometric to the supply voltage.

AMS 5935's functional blocks are powered by a stabilized voltage supply, which is divided into two parts. The digital part supplies the microcontroller, memory and digital interface and the analog part powers the sensing element, MUX, amplifier and ADC.

To reduce the sensor's current consumption the sensor features a sleep mode. After powering up it immediately enters sleep mode, wherein only the ASIC's digital part is powered and waits for a command on the I2C / SPI interface. To obtain measurement data from AMS 5935 a measurement request has to be sent on the digital interface. Upon reception of the measurement request the ASIC enters active mode, the sensor's analog part is powered up and the measurement cycle is started. Depending on the used command the sensor either performs a single measurement or four measurements from which it calculates the mean value. After completion of the measurement cycle (duration: 4.0 ms for single measurement, 14.5 ms for four-fold measurement) the corrected pressure and temperature data are stored in the output register and the ASIC returns to sleep mode. The standardized digital 24 bit output values for pressure and temperature can be read from the sensor's digital interface via I2C / SPI, without waking the sensor from sleep mode.

INITIAL OPERATION

Electrical Connection

The electrical connection of AMS 5935 sensors is typically made by soldering them directly on a printed circuit board or by mounting them on a suitable socket.

Depending on whether the I2C or SPI protocol should be used for data readout, different pins have to be connected.

For data readout using I2C the basic circuit for the AMS 5935 sensor is shown in *Figure 2*. It is sufficient to connect PIN1 (GND), PIN2 (VCC) and the I2C-bus lines to PIN3 (SDA) and PIN4 (SCL).

Important: Each bus line (SDA and SCL) has to be connected to the positive supply voltage (pin Vcc with $V_{S,typ} = 3.3\text{ V}$) via a pull-up resistor. Please add pull-up resistors (10 kΩ are recommended) to your bus line if they are not integrated in the I2C-master.

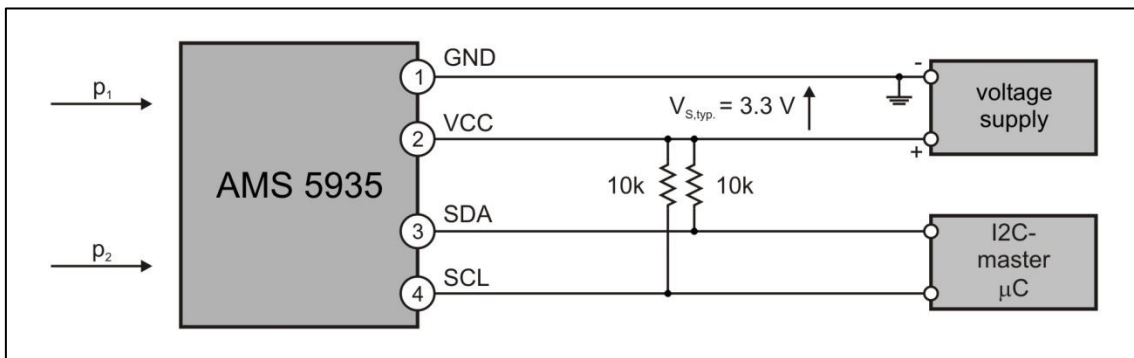


Figure 2: Principle electric circuitry for I2C communication

In order to read out the data using SPI, the basic circuit for the AMS 5935 sensor is shown in *Figure 3*. For SPI communication PIN1 (GND), PIN2 (VCC) and the SPI-bus lines to PIN3 (MOSI), PIN4 (SCLK), PIN6 (MISO) and PIN8 (SS) have to be connected.

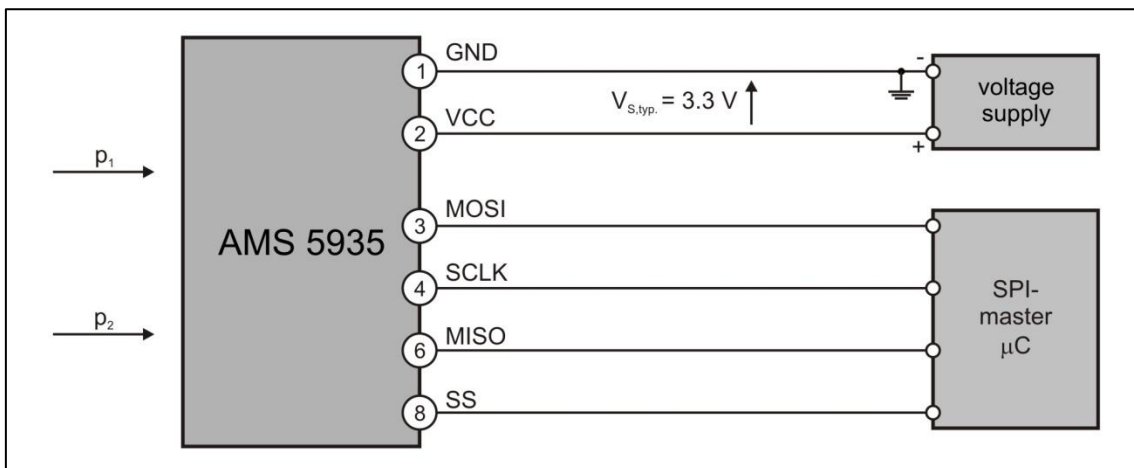


Figure 3: Principle electric circuitry for SPI communication

Regardless of the communication protocol used, PIN5 (EOC) can additionally be connected to a microcontroller and used to determine whether a started measurement cycle has been completed and the measurement data are ready for readout. It is on low level (logic 0) during the measurement cycle and turns to high level (logic 1) as soon as the measurement data can be read from the output register.

Pressure Connection

The pressure connection is established by mounting hoses / flexible tubing on the sensor's metal pressure ports or by sealing the pressure ports of the N-type package via O-rings to a suitable flange. Depending on the sensor type and the type of measuring pressure, one or two of the pressure ports have to be connected to the measuring medium / volume, as described in the table below:

Sensor type	Pressure type to measure	Port 1	Port 2	Requirement
AMS 5935-xxxx-D	differential	connected to p_1	connected to p_2	$p_1 \leq p_2$
	positive gage	open	connected to p_2	$p_2 \geq p_{\text{ambient}}$
	negative gage (vacuum)	connected to p_1	open	$p_1 \leq p_{\text{ambient}}$
AMS 5935-xxxx-D-B	differential (bidirectional)	connected to p_1	connected to p_2	$p_1 \geq p_2$ or $p_1 \leq p_2$
AMS 5935-xxxx-A	absolute pressure	connected to p_1	not connected	$p_1 = \text{meas. pressure}$
AMS 5935-xxxx-B	barometric pressure	connected to p_1	not connected	$p_1 = \text{meas. pressure}$

wherein p_1 = pressure at port 1 and p_2 = pressure at port 2. For port declaration see *Figure 7* and *Figure 8*. The media compatibility of pressure ports 1 and 2 can be found in "Specification notes", 7 and 8.

Notes:

- 1) For pressure connections up to 2 bar we recommend a silicone tubing (inner diameter $\varnothing = 2$ mm, outer diameter $\varnothing = 6$ mm) and above 2 bar PU or PA tubing. Suitable tubing can be found on [AMS 5935's product page](#).
- 2) Except for pin 7 unused pins have to be left unconnected. Pin 7 is internally not connected.
- 3) ESD precautions are necessary, it is essential to ground machines and personnel properly during assembly and handling of the device.

COMMUNICATION USING THE DIGITAL INTERFACE

For data readout AMS 5935 pressure sensors provide a digital interface which is able to communicate via the I2C or SPI protocol. The basic circuit for I2C communication is shown in *Figure 2* and for SPI communication in *Figure 3*.

In the following sections I2C communication is described in detail. For information on SPI communication please contact info@analogmicro.de.

I2C Communication (Basics)

Communication via I2C requires two bus lines: a serial data line (SDA) and a serial clock line (SDL). SDA and SCL are bidirectional lines, which are connected to the positive supply voltage using pull-up resistors.

I2C communication follows a simple master-slave principle, where AMS 5935 always operates as slave. The master can be a microcontroller, computer or a starter kit for example. Data transfer is always initialized by the master, which sends the sensor's 7 bit address followed by the data direction bit. If the data direction bit is "0" (read), the sensor answers with the data in its output register. If the data direction bit is "1" (write) the sensor receives the master's command and processes it.

AMS 5935's I2C communication adheres to the standard I2C communication protocol (given in *Figure 4*) with the following communication phases:

Idle period (bus is free)

When the bus is free, both I2C-bus lines (SDA and SCL) are pulled up to supply voltage level ("high level").

Start S (start condition)

Prior to any data transfer on the bus a start condition has to be generated. The start condition is always sent by the I2C-master. The start condition is defined as a transition from "high level" to "low level" on the SDA line while the SCL line is still on "high level". The I2C communication with AMS 5935 is always initiated by a start

Stop P (stop condition)

The stop condition is always generated by the I2C-master after a data transfer has been completed. The stop condition is defined as a transition from "low level" to "high level" on the SDA line while the SCL line is still on "high level". The I2C communication with AMS 5935 is always terminated by a stop condition.

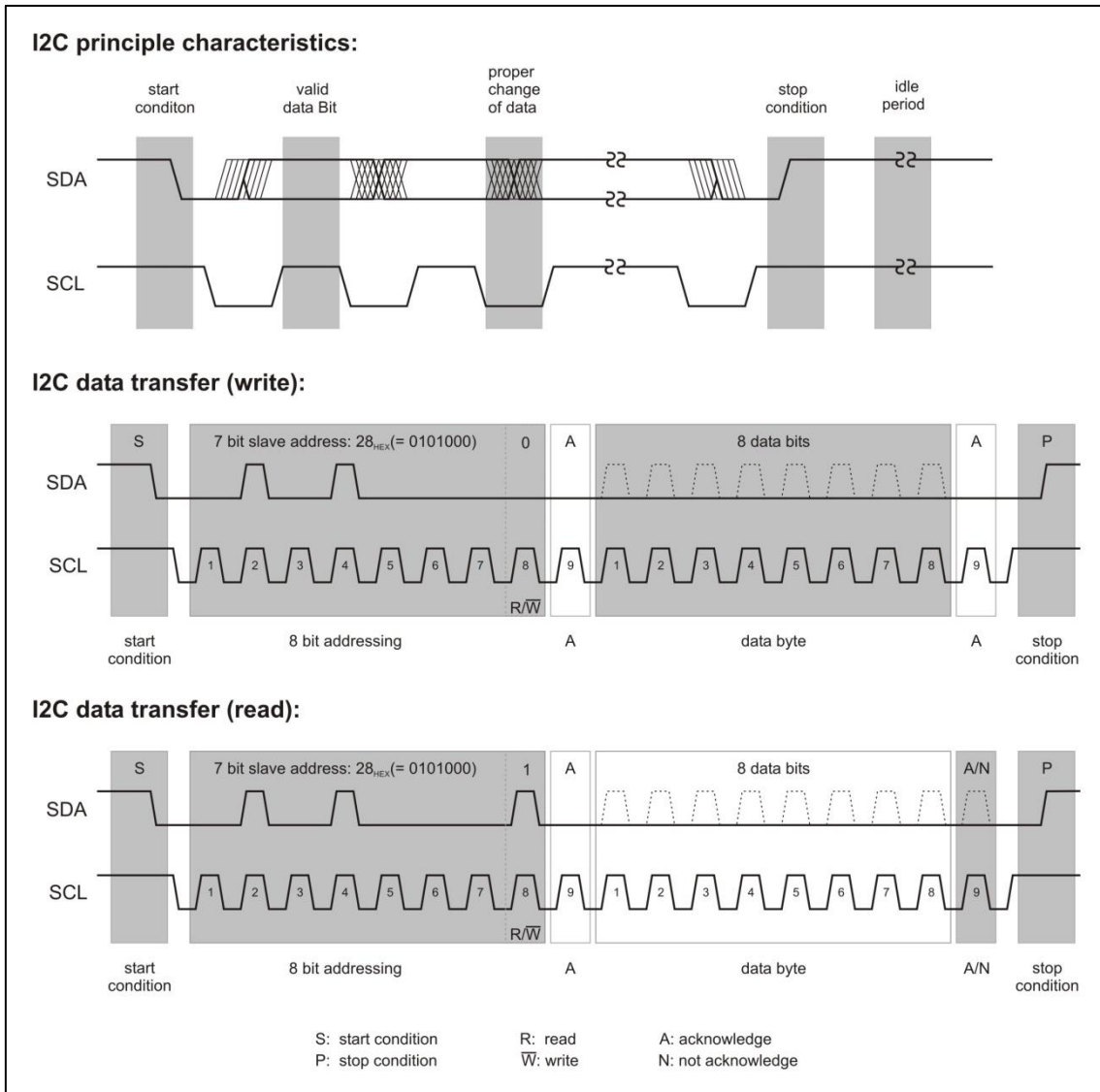


Figure 4: Standard I²C protocol

Valid data

Data is transmitted in bytes = 8 bit, starting with the most significant bit. Each data bit is transmitted with the related clock pulse generated by the master. The transmitted bits are only valid when, following a start condition, the level on the SDA line is constant as long as the SCL line is on “high level”. Changes to the SDA level must be made while the SCL line is on “low level”.

Acknowledge A / Not Acknowledge N

After a byte has been transmitted the respective receiver (master or slave) has to send an acknowledge (additional acknowledge bit) confirming the correct receipt of the data. For this purpose the master generates an extra acknowledge-related clock pulse. The receiver sends the acknowledge bit by pulling the SDA line down to “low level” during the additional clock pulse. If the receiver pulls the SDA line up to “high level” during the acknowledge-related clock pulse, it is interpreted as not acknowledge and the communication between master and slave is stopped.

Addressing / Slave address (I²C-address AMS 5935)

After the start condition the master sends an addressing byte (the first byte after the start condition) which determines which slave is selected. The addressing byte contains the individual 7 bit slave address of the selected slave (AMS 5935) and a data direction bit (R/\overline{W}). A "0" for the data direction bit indicates a transmission from master to slave (the master wishes to transmit data to the selected slave) or a "1" indicates a data request from the master (the master wants to read data from the slave).

The pressure sensors in the AMS 5935 series have a factory-programmed 7 bit slave address of $0x28_{Hex}$ (0101000_{bin}), which is stored in the sensor's memory.

On request each AMS 5935 can be ordered with an individual 7 bit slave address programmed at the factory. Using [AMS 5935's USB starter kit](#) the customer can program the individual slave address himself.

In general 7 bit addressing allows 128 different addresses. If more than one AMS 5935 should be connected to the same I²C-bus, each pressure sensor requires an individual slave address. Since the addresses $0x04_{Hex}$ to $0x07_{Hex}$ are internally used by AMS 5935 they cannot be used as I²C address. 124 addresses remain for the user's purpose.

Notes:

There are three differences of AMS 5935's communication protocol compared to the original I²C communication protocol:

- 1) A stop condition directly after a start condition without clock pulses in between is not allowed. This creates a communication error for the next communication.
- 2) A second start condition (restart) during data transmission when SCL is still high is not allowed.
- 3) Between the start condition and the first rising SCL edge a falling SDA edge is not allowed.

Data readout from AMS 5935 via the I2C-interface

By default, AMS 5935 is in sleep mode after powering up. To wake the sensor from sleep mode and start a measurement, a data request has to be sent from the I2C master to the sensor. After the measurement has been processed (4.0 ms for single measurement, 14.5 ms for four-fold measurement) the I2C master can read the data from the sensor's output register.

Start measurement cycle (Data request)

To start the measurement cycle, the master has to send a data request: 0xAA_{Hex} for single measurement or 0xAD_{Hex} for four-fold oversampling. This is described using *Figure 5*.

At first the master generates a start condition on the I²C-bus lines. Following the start condition the master sends the addressing byte containing the 7 bit slave address of the AMS 5935 (programmed to 0x28_{Hex} = 0101000_{bin} at the factory) and the data direction bit (0 for a data request). The selected pressure sensor answers to the addressing byte with an acknowledge bit during the acknowledge-related clock pulse. The master can now either send the command 0xAA_{Hex} or 0xAD_{Hex}.

The command 0xAA_{Hex} triggers a single pressure and temperature measurement and the storage of the measurement values in the output register. The command 0xAD_{Hex} triggers an oversample measurement. Four pressure and temperature measurements are executed and the mean value of these corrected and temperature compensated pressure values and of the four temperature values is calculated. These mean values are stored in the output buffer. There is no power down between the four measurements. The 0xAD_{Hex} command is recommended if low-noise signals are important for your application.

After the respective measurement command has been sent, AMS 5935 answers with an acknowledge bit indicating that the command has been understood. For this purpose, the master generates another acknowledge-related clock pulse.

The data request is finished with a stop condition sent by the I2C master.

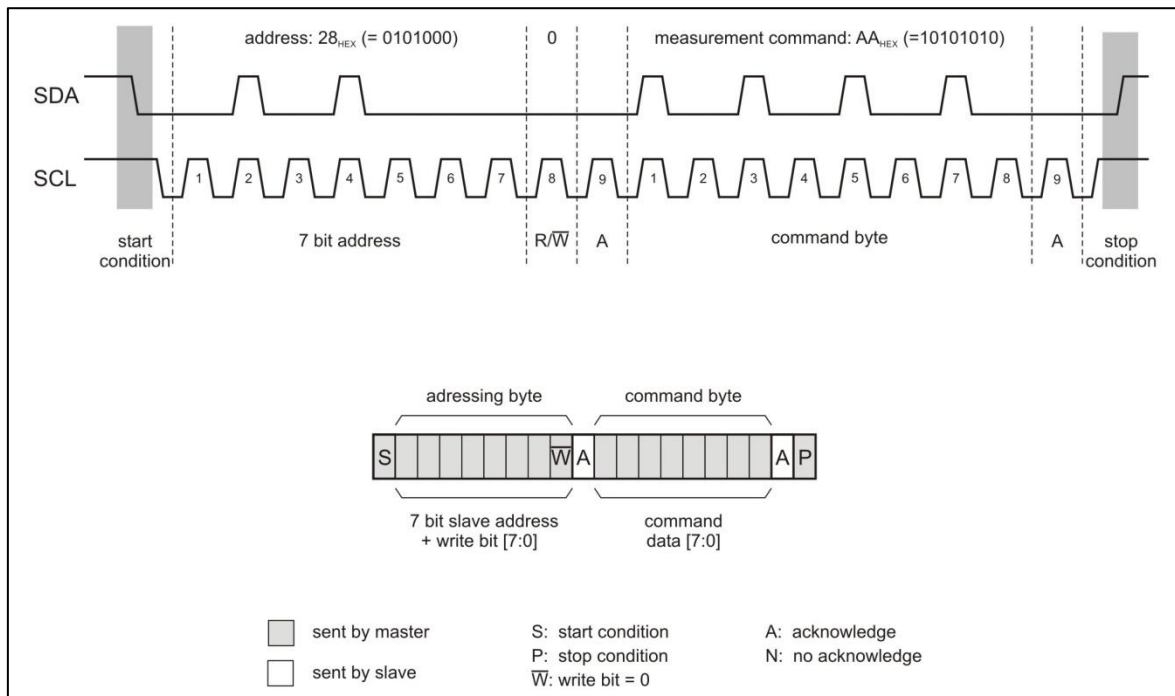


Figure 5: Starting a single measurement (data request with command 0xAA_{Hex})

Read measurement data (I2C read)

After 4.0 ms for a single measurement and 14.5 ms for a four-fold oversample measurement the measurement cycle is finished and data can be read from the sensor’s output register (see *Figure 6*).

To initiate the data readout the I2C master generates a start condition and sends the sensor’s 7 bit I2C address followed by the data direction bit (R = “1”). Again the sensor answers with an acknowledge bit during the acknowledge-related clock pulse and starts to send the data stored in its output register to the master.

For a complete pressure and temperature measurement 7 bytes are send. The first byte contains the sensor’s status, the next three bytes the sensor’s 24-bit pressure measurement value and the last three bytes the 24-bit temperature measurement value. The measurement data always start with the most significant byte and each byte begins with the most significant bit. On each transferred data byte, the I2C master sends an acknowledge bit, which confirms the correct receipt of the data. After the seventh byte the master stops the readout by sending a not-acknowledge bit and a stop condition.

If less than the complete seven data bytes are required the master can stop the data transfer after each byte by sending a not-acknowledge bit and a stop condition. For example, this allows to read the status byte only or to stop the readout after the pressure measurement data.

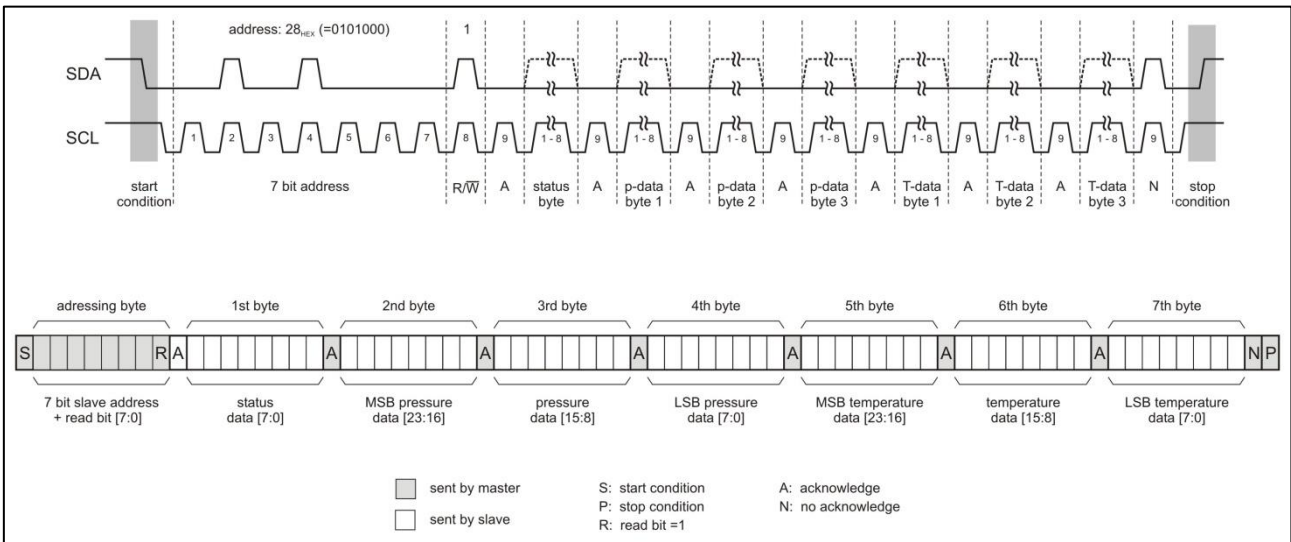


Figure 6: Data readout of the digital pressure and temperature values

Can be performed after 4.0 ms for single measurement and 14.5s for four-fold measurement

The status byte, which is sent as the first byte, contains the following information:

status bit	7	6	5	4	3	2	1	0
default	0	1	0	0	0	0	0	0
meaning	-	-	0, if sensor data is ready	-	-	0, if integrity test was passed	-	0, if sensor is not in overflow

Table 5: AMS 5935’s status byte

Status bit 5 / busy: If the measurement cycle is not finished and still running the bit is “1”. In this case the data in the output register is not valid and the data readout has to be repeated. AMS 5935 will not accept a new command as long as the bit is “1”. The bit turns to “0” if the sensor data is ready. In general, if 0xAA_{Hex} was sent the measurement data are ready after 4.0 ms and if 0xAD_{Hex} was sent, the data can be read after 14.5 ms.

Status bit 2 / memory check: During power up AMS 5935 checks its memory. In general, this bit should be “0”. If it is “1” an error occurred during the startup process which indicates, that the sensor does not work properly.

Status bit 0 / overflow indication: This bit indicates, if AMS 5935 encountered an error during signal-conditioning. It is “0” if the sensor data is valid. If it is “1” the measurement should be repeated.

Calculating the current pressure and temperature value

The digital output values for pressure (24 bit value) and temperature (24 bit value) have to be converted in order to generate the desired information on pressure and temperature in physical units.

The current pressure in the desired physical unit (e.g. mbar) is calculated from the digital pressure value using the following equations:

$$p = \frac{Digoutp(p) - Digoutp_{min}}{Sensp} + p_{min} \quad \text{with} \quad Sensp = \frac{Digoutp_{max} - Digoutp_{min}}{p_{max} - p_{min}} \quad (1)$$

wherein

p is the current pressure in the desired physical unit (e.g. mbar, Pa),

p_{min} and p_{max} are the specified minimum and maximum pressure values in the desired physical unit (e.g. in mbar) depending on the specific pressure range (see *Table 1* and *Table 2*)

$Digoutp(p)$ is the current digital 24-bit pressure measurement value in counts,

$Digoutp_{min}$ is the digital pressure measurement value at the minimum specified pressure in counts,

$Digoutp_{max}$ is the digital pressure measurement value at the maximum specified pressure in counts,

$Sensp$ is the sensitivity of the pressure sensor (e.g. in counts/mbar, counts/Pa).

The current sensor temperature in °C is calculated from the digital temperature output value using the following equation:

$$T = \frac{(DigoutT(T) \cdot 165)}{2^{24}} - 40 \quad (2)$$

Therein T is the current sensor temperature in °C and $DigoutT(T)$ is the current 24 bit digital temperature output value in counts.

Example:

At the digital output of an AMS 5935-0005-D-B (-5 ... 5 mbar bidirectional differential sensor) the following data bytes 1 ... 7 are read:

Byte 1: 0x40_{Hex} Byte 2: 0xB9_{Hex} Byte 3: 0x12_{Hex} Byte 4: 0xD4_{Hex} Byte 5: 0x62_{Hex} Byte 6: 0xAA_{Hex}
 Byte 7: 0x33_{Hex}

Byte 1 is the status byte and not necessary for the calculation.

Taking bytes 2, 3 and 4 the current 24-bit digital pressure value is:

$$Digoutp(p) = B9\ 12\ D4_{Hex} \text{ counts} = 12128980_{Dec} \text{ counts}$$

and with byte 5, 6 and 7 the digital temperature value is:

$$DigoutT(T) = 62\ AA\ 33_{Hex} \text{ counts} = 6466099_{Dec} \text{ counts}$$

For AMS 5935-0005-D-B the following values are specified:

$$p_{min} = -5 \text{ mbar}, \quad p_{max} = 5 \text{ mbar} \quad \text{and} \quad Digoutp_{min} = 0.1 \cdot 2^{24}, \quad Digoutp_{max} = 0.9 \cdot 2^{24}$$

Using these values and equation (1) the current pressure in mbar can be calculated:

$$p = \frac{(12128980 - 0.1 \cdot 2^{24}) \text{ counts}}{(0.8 \cdot 2^{24} / 10) \text{ counts / mbar}} + (-5) \text{ mbar} = 2.787 \text{ mbar}$$

Using equation (2), the current sensor temperature in °C is calculated as:

$$T = \frac{(6466099 \cdot 165) \text{ counts} \cdot ^\circ\text{C}}{2^{24} \text{ counts}} - 40 \text{ } ^\circ\text{C} = 23.6 \text{ } ^\circ\text{C}$$

DIMENSIONS AND PINOUT

AMS 5935 pressure sensors come in a dual-in-line package (DIP-08, width: 600 mil) for assembly on printed circuit boards (PCB).

The pinout and dimensions of AMS5935's dual-in-line package are shown in *Figure 7* for sensor types with vertical metal tubes (for connection with pressure hoses) and in *Figure 8* for sensor types for manifold assembly (-N option without tubes).

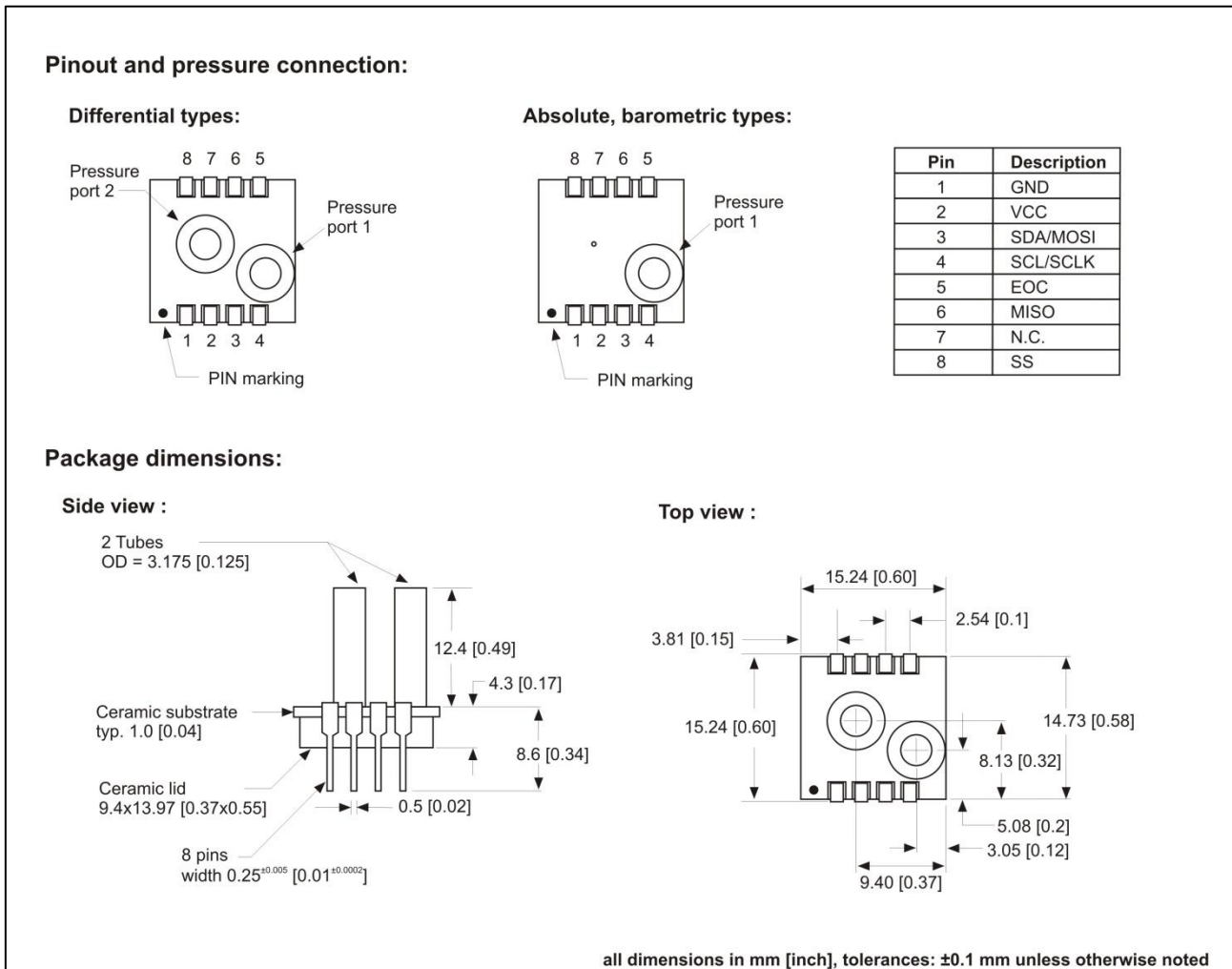


Figure 7: Dimensions of sensor types with vertical metal tubes

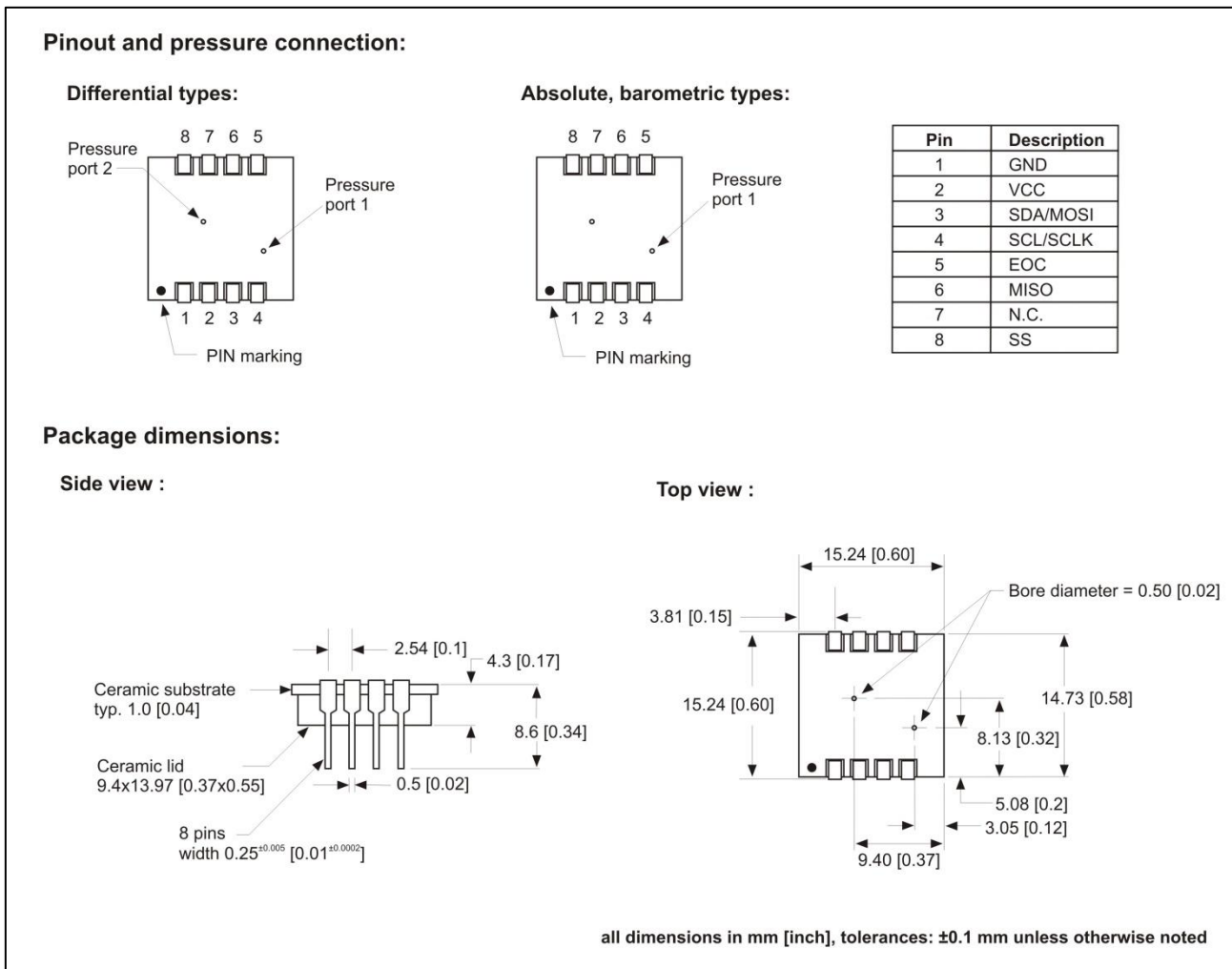


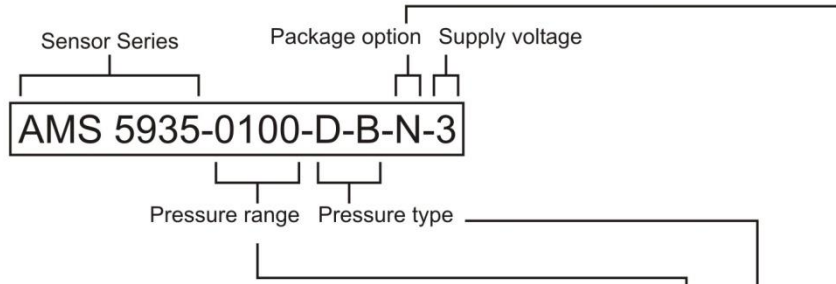
Figure 8: Dimensions and pinout of AMS 5935 for manifold assembly (-N option without tubes)

Notes on “Dimensions and Pinout” (Figure 7 and Figure 8):

- 1) Except for pin 7 unused pins have to be left unconnected.
- 2) Packages with SMT Pins (J-Lead) are available on request.
- 3) Relative / gage variants with one single tube are available on request.
- 4) Pressure port 2 applies pressure to the piezoresistive silicon sensing element’s backside and is therefore compatible with non-corrosive liquids. For media compatibility of pressure port 1 and port 2 see "Specification notes", 7 and 8.
- 5) For automatic soldering (lead-free wave or reflow soldering) of AMS 5935 a peak temperature of 250°C for a maximum of 20 to 30 seconds is recommended. A typical temperature profile for Pb-free assembly is given by IPC/JEDEC J-STD-020D, Table 5-2.

INFORMATION FOR ORDERING

Ordering code:



Pressure range code	mbar	Pa	psi	inH ₂ O
0001	1.25	125	0.018	0.501
0002	2.5	250	0.036	1.003
0005	5	500	0.073	2.007
0010	10	1000	0.145	4.014
0020	20	2000	0.290	8.029
0035	35	3500	0.507	14.051
0050	50	5000	0.725	20.073
0100	100	10000	1.450	40.146
0200	200	20000	2.901	80.292
0350	350	35000	5.076	140.512
0500	500	50000	7.251	200.731
1000	1000	100000	14.50	401.463
1200	1200	120000	17.40	481.755
1500	1500	150000	21.75	602.194
2000	2000	200000	29.01	802.926

Code	Pressure type	Available pressure ranges
D	Differential / relative (gage)	0 ... 2.5 mbar to 0 ... 1 bar
D-B	Bidirectional differential	-1.25 ... +1.25 mbar to -1 ... 1 bar
A	Absolute	0 ... 500 mbar to 0 ... 2 bar
B	Barometric (absolute)	700 ... 1200 mbar

Code	Package option
	Standard package with tubes for hose connection
N	Manifold mount package

ADDITIONAL EQUIPMENT

Ordering code	Description
USB starter kit AMS 5935	A USB starter kit interfacing AMS 5935 to a Windows PC (Windows 10 or 11) via a USB port. It consists of two PCBs and software. The kit can be used for quick and easy evaluation of AMS 5935, data readout, data logging and to change AMS 5935's I2C address.
AMS 5935 – Arduino PCB	An adapter PCB board, which can be used to interface AMS 5935 with an Arduino Uno. A library and example code for Arduino's IDE is available for download at www.analog-micro.com .
AMS 5935 Arduino Nano Kit	A kit used to interface AMS 5935 to an Arduino Nano directly. It consists of two PCBs, an AMS Arduino Nano Shield and an AMS 5935 Mini PCB, as well as a matching ribbon cable. A library and example code for Arduino's IDE is available for download at www.analog-micro.com .

For more information on additional equipment see [AMS 5935's product page](#)

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