ASP1400

Bidirectional Differential
Pressure Meter

_ Ultra low differential pressure from
100 Pa down to 0.002 Pa
_ Zero drift & offset free
_ Outstanding accuracy and resolution
_ Ultra fast response time
_ Fully calibrated & temperature compensated
_ Digital output signal

Preliminary Information as of October 2001

ASP1400 Product Summary

The ASP1400 differential pressure sensor is especially suited for measurements of ultra low pressure differences of gases and true mass flow measurements in bypass solutions.
The micro-machined silicon sensor element of the ASP1400 enables extremely long term stable and offset free measurements. Its leading performance is based on SENSIRION's unsurpassed CMOSens™ technology. With CMOSens™, the on-chip sensor element forms an integrated whole with the amplification and A/D converter circuit. This results in superior resolution, fast response time and large dynamic range at lowest power consumption.
All measurement data is fully calibrated and temperature compensated by means of an internal micro controller.

Mounted in rugged, chemically inert PBT housing the ASP1400 is suitable for a wide range of applications. Such include for example monitoring of clean room conditions, intrusion detection and almost unlimited bypass solutions in process control, building control as well as medical applications.
Bypass solutions allow a true mass flow measurement.
The sensor housing provides two inlets for measuring the differential pressure and withstands overpressures of 2 bar (29 psi).
The ASP1400 requires a supply voltage of 7…18Vdc and provides an RS-232 and SPI compliant electrical interface.

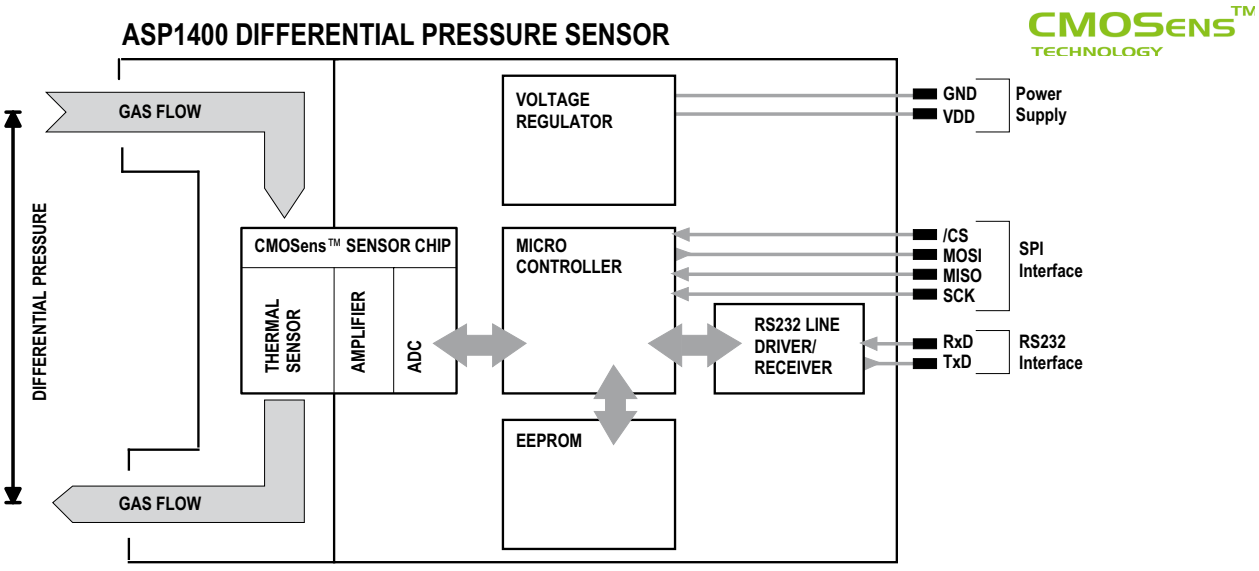


Figure 1: Block Diagram ASP1400 Differential Pressure Sensor with CMOSens™ technology

Introductory Description

Combining solid state sensor technology and commercial IC fabrication, the ASP1400 dynamic differential pressure sensor produced by SENSIRION provides unbeatable performance at very low cost. The lowest detectable differential pressure is 0.002 Pa, which corresponds to a force of only 0.00002g per cm^2 or a geographic height difference of only 0.16 mm. Covering at the same time a differential pressure range of more than 4 orders of magnitude, the ASP1400 sets a new standard wherever dynamic differential pressure has to be measured or controlled.
The ASP1400 device measures the differential pressure with a dynamic principle(1). The differential pressure induces a small gas flow through a tube of 1mm diameter. SENSIRION's unique CMOSens™ technology provides an extremely precise measurement of this gas flow even for very small differential pressures. In addition, the sensor signal is almost offset free and highly long term stable. You simply connect the gas differential pressure to be measured to the ASP1400 device to get an instantaneous differential pressure at a sampling rate of up to 7Hz (please contact us for sampling rates of up to 200Hz). The ASP1400 withstands overpressures up to 2 bar without any loss in precision.
Please note that absolute pressure (see section 1.4) and gas composition have to be well-known to achieve measurements of highest accuracy.

The ASP1400 differential pressure sensor allows an easy realization of high precision bypass solutions for true mass flow measurements. It has to be pointed out that the ASP1400 is based on the successful ASF1400 mass flow sensor. It measures differential pressure indirectly with the mass flow, which is generated through the applied differential pressure. Unlike with static differential pressure sensors, you therefore profit in bypass solutions directly from a true mass flow measurement.
In addition to differential pressure, the ASP1400 device also provides information about the temperature on the CMOSens™ sensor chip. Both differential pressure and temperature data are accessed through an RS-232 or SPI interface. The RS-232 interface allows you to connect the ASP1400 device directly to a PC or PDA using standard terminal software. The serial peripheral interface (SPI) also simplifies the use of the ASP1400 in smaller systems. If a special interface such as 4-20 mA current output or other is required, please contact SENSIRION for a customer specific solution.
In general, differential pressures of all gas types can be measured using the ASP1400 product. Calibration is done for dry air. Please contact SENSIRION, if you would like to use the sensor for applications with other gases.

To get you started quickly, an evaluation package including ASP1400 devices, software, cables, rubber hose and bypass is available from SENSIRION.

(1) Please note that a small gas flow through the sensor is inherent in the dynamic measurement principle. Thus, the ASP1400 is not suitable for applications where no gas flow is allowed.

CMOSens™ sensor technology

CMOSens™ is the base technology for all Sensirion multi sensor modules and sensor systems. The unification of semiconductor chip and sensor technology serves as a platform for highly integrated system solutions with excellent sensor precision and reliability. With CMOSens™, the on-chip sensor element forms an integrated whole with the high-end amplification and A/D converter circuit. Due to the compact single-chip design, CMOSens™ based sensors are very resistant to electromagnetic disturbances (EMC), another important technical advantage of this state of the art sensor technology. As a result, CMOSens™ based multi sensor modules offer an excellent sensor precision, a fast response time and a very large dynamic measurement range. In addition, the digital intelligence of the CMOSens™ sensor technology enables digital interfaces that permit an easy link with the system of the customer, a real advantage and benefit that results in ready-to-use problem solutions ("Mount&Sense").

1 Dynamic Differential Pressure Sensor Performance

Table 1: Overview ASP1400 Gas Sensor Performance

Parameter	Condition	Minimum	Typical	Maximum	Units
Differential Pressure					
Principle of measurement	Dynamic mass flow generated by differential pressure				
Dynamic Range	direct measurement	-100		100	Pa
	customer specific solutions		< 3500		Pa
Lowest Detectable Pressure	< 1 Pa		0.002		Pa
Medium	no liquids		Gas		
Calibration gas			Dry air(1)		
Resolution	$\Delta p \approx 100$ Pa, p_{abs}=1.013 bar		0.04		Pa
	$\Delta p < 1$ Pa, p_{abs}=1.013 bar		0.001		Pa
Overpressure Resistance				2	bar
Gas Flow(2)	air, 100 Pa diff. pressure		0.4		ln/min(3)
Repeatability	Range 0.5 Pa to 100 Pa		0.002% FS (4) 0.08 % m.V.		
Accuracy	dry air / 20 C / 966 mbar		0.05 % FS (5) 1.5 % m.V.		
Offset	20°C		0.004	0.02	% FS
Response Time (6)	depends on resolution setting (see Section 3, Table 2)	142		1280	ms
Operating Temperature		0 [32]		70 [158]	°C [°F]
Ambient Temperature Coefficient	Zero		< 0.002		% FS / °C
	Span		< 0.09		% m.V. / °C
Position sensitivity (inclination)	p_{abs}=1 bar, small air flow		±0.004		% FS
Temperature Sensor	Measures temperature inside the sensor, but not of the surrounding air(7)				
Dynamic Range		0		70	°C
Resolution			0.1		°C
Accuracy		3	2		°C

Note: All data for dry air at 20°C and 966 mbar unless otherwise noted.

(1) Contact us for other gases
(2) Due to dynamic measurement principle (see Figure 4)
(3) 1 ln/min = 1 norm liter per minute = 1 liter/min at 0°C and p = 1013.25 mbar
(4) Error = % of full scale (FS) or % of measured value, whichever is bigger.
(5) Accuracy:
0.05 % of full scale (FS) for measured values between 0-3.3% of full scale (i.e. 0-3.3 Pa) and
1.5 % of measured value (m.V.) for measured values between 3.3-100% of full scale (i.e. 3.3-100 Pa)
(6) For faster response times please contact SENSIRION for information about the ASP1430 differential pressure sensor.
(7) The sensors warms up by about 7°C (depending on supply voltage and ventilation).

1.1 Differential Pressure Characteristics

Figure 2 shows the differential pressure vs. the digital output of the ASP1400.

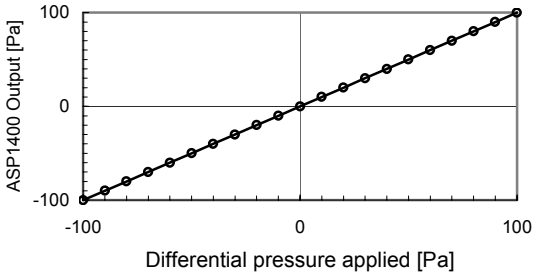


Figure 2: ASP1400 transfer characteristics.

1.2 Sensor Principle and Gas Types

The ASP1400 device measures differential pressure indirectly. The sensor effectively uses a calorimetric method, where fluid motion is converted into thermal information. A heating resistor on a thermally insulated membrane is kept above ambient temperature. In the presence of gas flow, the temperature distribution up- and downstream is disturbed. This asymmetry is then measured. Due to the minimal thermal mass of the membrane, symmetrical arrangement, and accurate temperature measurement, the revolutionary specifications of the ASP1400 devices are achieved.
The above mentioned thermal principle requires information about the gas type to be measured. The standard ASP1400 is calibrated for differential pressure measurements of dry air. Please contact SENSIRION, if you would like to use the sensor for applications with other gases.

In Figure 3 the repeatability of the ASP1400 devices is compared with the repeatability of a typical differential pressure sensor. It emphasizes the superior performance of the ASP1400 device.

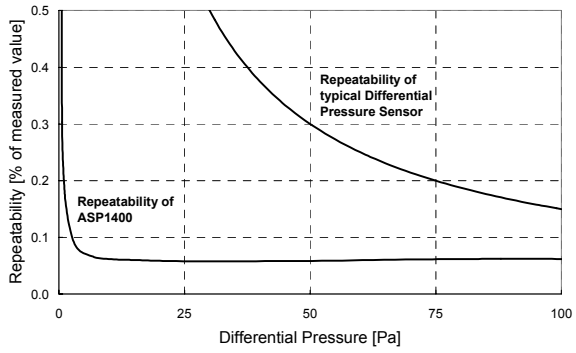


Figure 3: Comparison of the repeatability of the ASP1400 CMOSens™ sensor with a typical differential pressure sensor.

1.3 Gas Flow and Pressure Difference

The ASP1400 is calibrated for differential pressure measurements. However, there is a well defined relation between pressure drop and mass flow. This relationship is shown in Figure 4. On request the ASP1400 can also be calibrated to measure mass flow instead of differential pressure (for more details refer to the documentation of the SENSIRION Mass Flow Meter ASF1400).

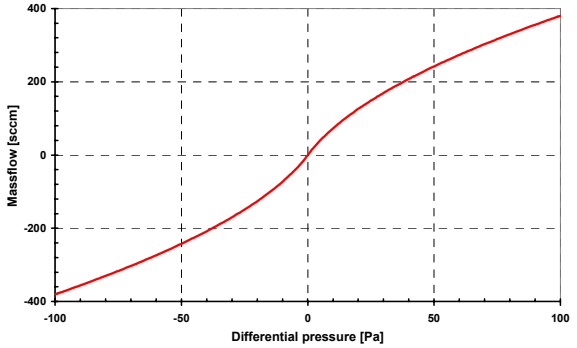


Figure 4: Differential Pressure vs. Mass Flow of ASP1400 device.

1.4 High Precision Differential Pressure Measurement in Bypass solutions

The ASP1400 differential pressure sensor is exceptionally well suited in conjunction with customer specific bypass configurations (see Figure 5). SENSIRION's expertise in packaging and flow measurement combined with the accurate low differential pressure measurement ability of the ASP1400, enables the design of novel bypass solutions over a wide dynamic range. In bypass applications, the ASP1400 can be calibrated for true mass flow measurements through the whole system.
A tube with flow restrictor and all required connection items are included in the Differential Pressure Sensor Evaluation Kit ASP1400 EK-P1, also available from SENSIRION AG.

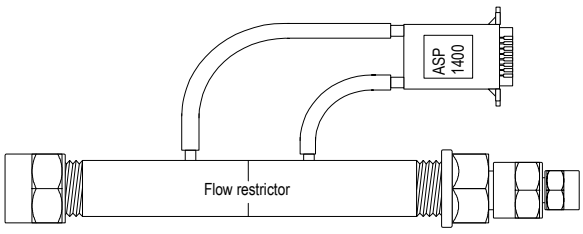


Figure 5: ASP1400 device using a bypass configuration. Shown tube with flow restrictor is included in the EK-P1 evaluation kit.

2 Pins and Digital Interface

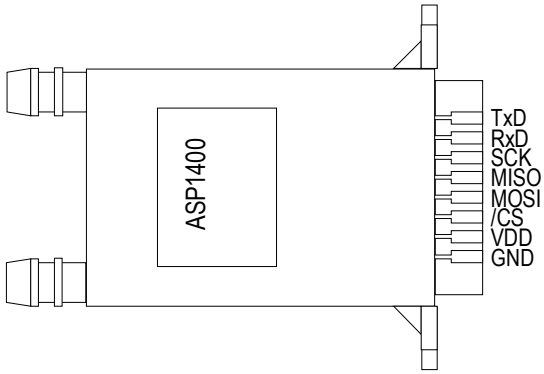


Figure 6: ASP1400 pin out.

GND and VDD (Power Supply)
The ASP1400 requires a voltage supply of between 7 V and 18 V. Since this voltage is internally regulated, there are no stringent requirements as far as ripple and stability are concerned.

2.1 RS-232 Interface

All configurations (see also Section 3) for the ASP1400 can be set using its RS-232 interface. To communicate with the ASP1400 via RS-232 the following pins are required:

RxD (Receiving Data Line)
TxD (Transmitting Data Line)
GND (Ground)

The RS-232 of the ASP1400 is configured as follows:

Baudrate	9600
Data Bits	8
Stop Bits	1
Parity	none
Protocol	none

With these settings, the ASP1400 device can be connected to any PC or PDA equipped with terminal software.
The measurement values are provided as a signed floating point number together with the corresponding unit (**Pa** for differential pressure, **C** for temperature). In case of an overflow, the output shows **oF**.

2.2 Serial Peripheral Interface (SPI)

To make measurement data available also for smaller systems or to cascade several ASP1400 devices, the ASP1400 provides a uni-directional SPI interface.
The configuration of the ASP1400 (as described in Section 3) has to be done using the RS-232 port. The SPI interface provides the measurement data as a 24 bit signed integer, where bit 0…22 defines the value and bit 23 the sign (0 indicates the positive, and a 1 the negative sign). The 24 bits are transmitted in 3 blocks, each consists of one byte. The MSB "most significant bit" (bit 23) is sent first.
Since the calibrated differential pressure and temperature output values of the ASP1400 sensor have floating point precision, the transmitted integer data is multiplied with an SPI factor. This factor is 100. Example: a received differential pressure SPI value of +1234 corresponds to a differential pressure of 12.34 Pa. Figure 7 shows the internal setup of the SPI inter-face lines and Figure 8 an example of cascading four ASP1400 devices using a single microcontroller.

Note:
With each additional sensor the capacitive load will increase, causing an increase of the output fall/rise time and an output signal deterioration.

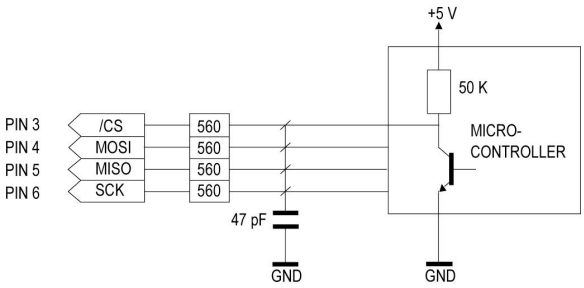


Figure 7: Internal ASF1400 SPI hardware.

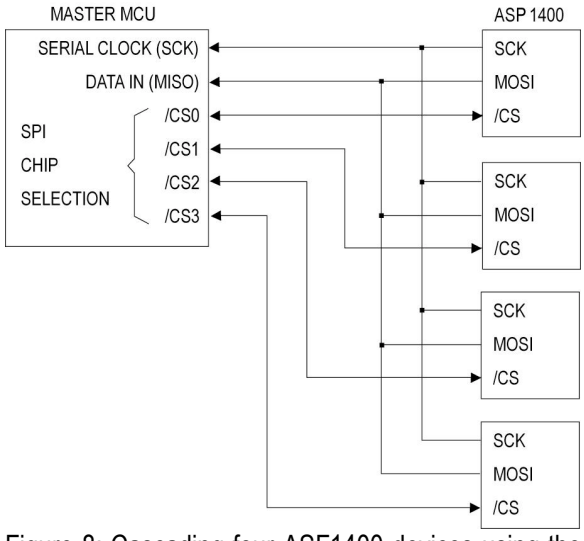


Figure 8: Cascading four ASF1400 devices using the SPI interface.

SCK (Serial Clock, Output)
The SCK synchronizes data transfer out of the device through the MOSI line. Data on the MOSI pin is ready after a falling edge of SCK (see Figure 9 and 10 for details).

/CS (Chip Select, Input or Output)
There are two SPI modes, namely the PUSH and the GET mode. In PUSH mode the /CS pin is controlled by the ASP1400 device which behaves like a master. Low going /CS announces a new data transfer.

In GET mode the data transfer is initiated externally by pulling /CS low. In this case, as soon as the measurement data is ready, it appears on the MOSI pin (see also Section 4.3).

MOSI (Master Out Slave In, Output)
MOSI is the serial data output of the ASP1400 device. Data is clocked out on the rising edge SCK with MSB first. This output goes into a high-impedance state when the device is not selected.

MISO (Master In Slave Out, Not Connected)
The ASP1400 firmware only supports a uni-directional SPI protocol. Therefore, the MISO pin should always left unconnected.

3 Configuration and Commands

The ASP1400 device accepts a set of commands through its RS-232 interface (see table 3 for valid commands; for correct settings of the RS-232 refer to Section 2.1).This allows the user to configure the ASP1400 device. Since the configuration is stored in the internal EEPROM, it is maintained after power breaks.

With the exception of the stop command "**s**", all commands have to be terminated by the return key ("↵", ASCII #10 or #13). After completion of a command, the ASP1400 returns "**ok**" and is ready to take a new instruction. Before entering a command, it may be necessary to clear the buffer by means of using "↵".

There is a trade-off between resolution and measurement time. Possible settings are listed in Table 2. Choosing 12 bit results in a measurement interval of 142 ms. With the max resolution of 15.2 bit, a new measurement is provided every 1280 ms. For faster sampling rates refer to the ASP1430 high speed sensor data sheet.

Table 2: Resolution settings using the **res=**value command and corresponding response times

res=	Resolution [bit]	Data interval [ms]
1	12.0	142
2	13.0	284
3	13.5	427
4	14.0	569
5	14.3	711
6	14.6	853
7	14.8	995
8	15.0	1138
9	15.2	1280

Table 3: Commands of the ASP1400 device.

Command	Output	Description
help↵	commands	Lists all available commands
ver↵	version	Provides type of sensor, software, hardware and customer version
get↵		Starts single measurement
go↵		Starts series of measurements
s	stop	Stops series of measurements
reset↵		Resets ASP1400 device
res=1..**9**↵	resolution	Sets resolution: 1 -> 12 bits; 9 -> 15 bits, see Table 2
res?	resolution	Shows actual setting
mod=**F** | T↵	mode	Selects Differential Pressure mode (F) or Temperature mode (T)
mod?	mode	Shows actual setting
Disp=**s**,d	display mode	Shows Differential Pressure (s) or Differential Pressure + Temperature (d) *no effect in the Temperature mode
Disp?	display mode	Shows actual setting
defspi=**P** | G↵	define SPI	Sets SPI in Push- (P) or Get mode (G), see also Section 4.3

Notes:

- Default settings are marked in **bold** letters
- The commands are not case sensitive.
- In order to send a new command to the ASP1400 make sure the ASP1400 is not in measurement mode. Issue therefore a stop command **s** first. After this, any instruction can be given to the ASP1400 and a new series of measurement can be started by **go**↵.
- Due to the limited write cycles allowed for the EEPROM, excessive configuration modifications should be avoided.

4 Specifications ASP1400

4.1 Absolute Maximum Ratings

Ambient storage temperature	-65°C to 150°C
Ambient operating temperature	0°C to 70°C
Overpresssure resistance	2 bar

4.2 Electrical Specifications

Table 3: ASP1400 DC Characteristics.

Parameter	Conditions	Min.	Typ.	Max.	Units
Power Supply DC	DC	7	9	18	V
Operating Current	VDD = 9 V, no load		20		mA
	VDD = 9 V, 3kΩ at RS232 output		27		mA
Power Dissipation	VDD = 9 V, no load		180		mW

Table 4: ASP1400 RS-232 Characteristics.

Parameter	Conditions	Min.	Typ.	Max.	Units
RS232 Output					
Output Voltage Swing	Transmitter output loaded with 3kΩ	±5	±9		V
Power-Off Output Resistance		300			Ω
Output Short Circuit Current			±18		mA
RS-232 Input					
Voltage Range		-15		15	V
Voltage Threshold					
Low		0.8	1.2		V
High			1.7	2.4	V
Hysteresis		0.2	0.5	1.0	V
Resistance		3	5	7	kΩ

Table 5: ASP1400 SPI Characteristics (refer to Figure 9 for a timing diagram).

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
Vol	Output Low Voltage	not connected	0	0.2	0.4	V
Voh	Output High Voltage	not connected	4.8	4.9	5	V
Vol	Output Low Voltage	Rl=100kΩ	0	0.2	0.5	V
Voh	Output High Voltage	Rl=100kΩ	2.4	4.45		V
Ioh	Output High Current	Vdd = 5V		-60		µA
Iol	Output Low Current	Vdd = 5V		0.3		mA
fop	SCK Frequency			87		kHz
tro	Output Rise Time	not connected		40		ns
tfo	Output Fall Time	not connected		26		ns
tro	Output Rise Time	Rl=100kΩ		42		ns
tfo	Output Fall Time	Rl=100kΩ		30		ns
tclh	Clock High Time			5.70		µs
tcll	Clock Low Time			5.80		µs
tcss	/CS Setup Time		15.0		27.0	µs
tst	Send Time				930	µs

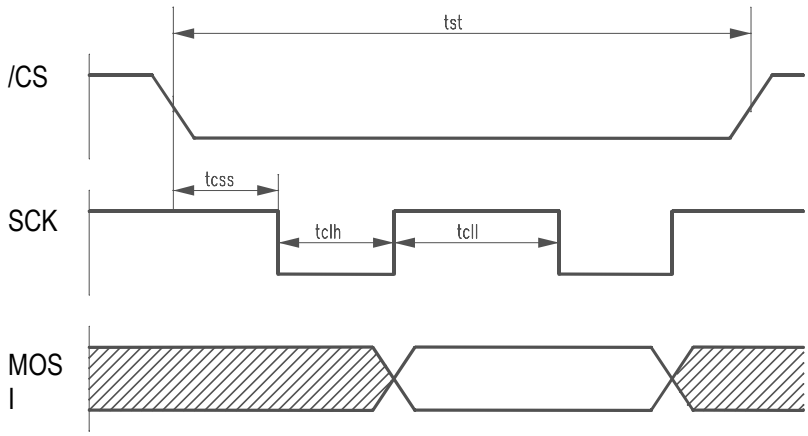


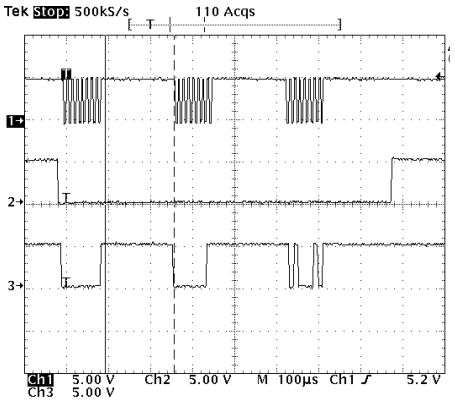
Figure 9: Timing Diagram of the ASP1400 SPI Interface.

4.3 SPI Push-Mode Detailed Description

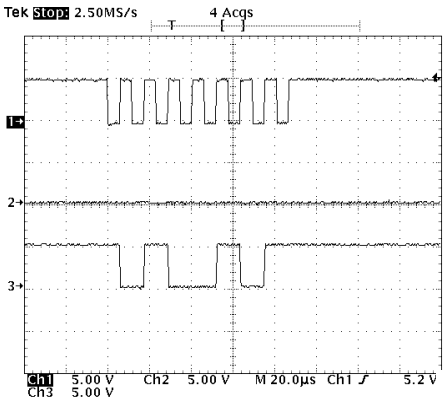
The subsequent scope diagrams further describe the ASP1400 device SPI mode data access protocol in PUSH mode.

1 = SCK Serial clock output
2 = /CS Chip select (Push-Mode)
3 = MOSI Serial data output

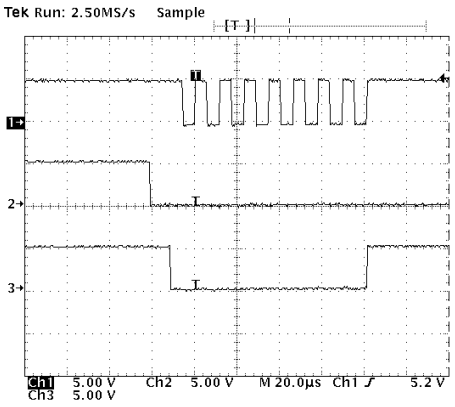
Complete read cycle (three bytes)



Close up of one byte



First byte



Third byte

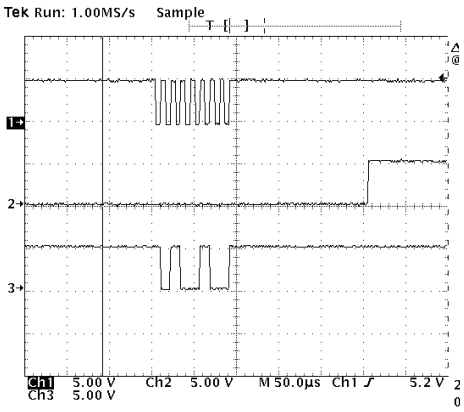


Figure 10: Sample for SPI read cycle of the ASP1400 in Push Mode.

5 Physical Dimensions and Mounting Information

The ASP1400 is mounted in chemically inert PBT housing. The rugged package has been designed to withstand over-pressures of up to 2 bar. Higher pressure packages of up to 10 bars are available on request.

Physical dimensions and mounting information are provided in Figure 11 and Table 6.

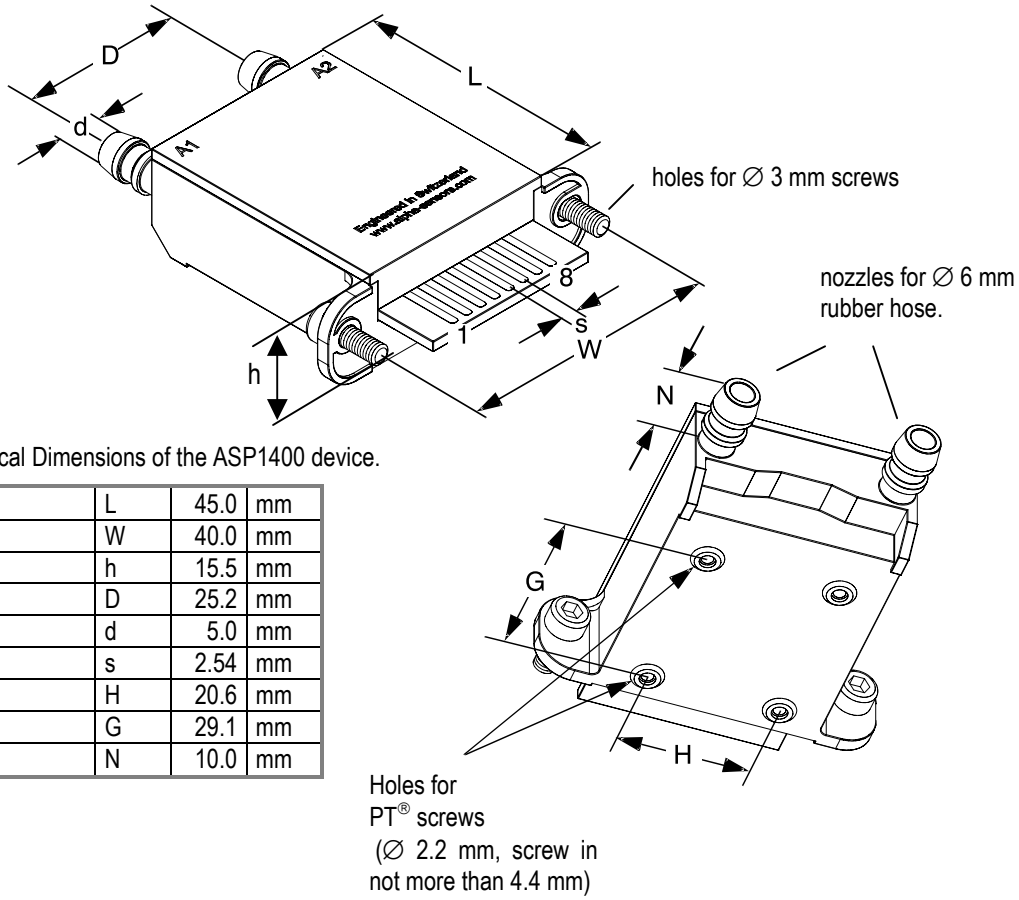


Table 6: Physical Dimensions of the ASP1400 device.

Length	L	45.0	mm
Width	W	40.0	mm
Height	h	15.5	mm
Distance	D	25.2	mm
Diameter	d	5.0	mm
Pitch	s	2.54	mm
Pitch	H	20.6	mm
Pitch	G	29.1	mm
Pitch	N	10.0	mm

Figure 11: Physical dimensions and mounting information of the ASP1400.

6 Ordering Information

For small ordering quantities the ASP1400 sensor can be ordered directly at Farnell on http://www.farnell.com. Farnell is a worldwide distributor of electrical, electronic and industrial component products.
When ordering ASP1400 series devices at SENSIRION please refer to the following part numbers. For the latest product information access SENSIRION's website on http://www.sensirion.com

Calibrated for Gas Type	Range	Packaging	SENSIRION Part Number
Synthetic air	± 100 Pa	2 bar	1-100012
Other gas types on request	± 100 Pa	2 bar	-

Notes:

- Packages to sustain common mode pressures of 10 bars are available on request.
- Special electrical interfaces such as 4-20 mA output or others are available on request.
- For faster sensor response times contact SENSIRION for information on the ASP1430.
- An evaluation kit including ASP1400 devices, evaluation software and other accessories such as bypass, rubber hose and cables can be ordered (Part Number 1-100032). For detailed information check out the description of the Differential Pressure Sensor Evaluation Kit ASP1400 EK-P1 on http://www.sensirion.com.

IMPORTANT NOTICES

The warranty for each SENSIRION AG product comes in the form of a written warranty which governs sale and use of such product. Such warranty is contained in the printed terms and conditions under which such product is sold, or in a separate written warranty supplied with the product. Please refer to such written warranty with respect to its applicability to certain applications of such product.

These products may be subject to restrictions on use. Please contact SENSIRION AG for a list of the current additional restrictions on these products. By purchasing these products, the purchaser of these products agrees to comply with such restrictions. Please contact SENSIRION AG for clarification of any restrictions described herein.

SENSIRION AG reserves the right, without further notice, to change the SENSIRION ASP1400 Differential Pressure Sensor product specifications and/or information in this document and to improve reliability, functions and design.

SENSIRION AG assumes no responsibility or liability for any use of the SENSIRION ASP1400 product. Application examples and alternative uses of the SENSIRION ASP1400 are for illustration purposes only and SENSIRION AG makes no representation or warranty that such applications shall be suitable for the use specified.
SPI is a trademark of Motorola. LabView is a trademark of National Instruments.

FCC and CE Statement

The ASP1400 product has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules (FCC CFR 47). These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one of more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and the receiver
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult a dealer or an experienced radio/TV technician for help.

CE

The ASP1400 device fully complies with norm EN 50081-1 (Emission Test for residential, commercial and light industry), EN 50081-2 (Emission Test for industrial environment) as well as EN 50082-1 (Immunity Test for residential, commercial and light industry) and EN 50082-2 (Immunity Test for industrial environment).

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