

LDE Series

Digital low differential pressure sensors

FEATURES

- Pressure ranges from 25 to 500 Pa (0.1 to 2 inH₂O)
- Pressure sensor based on thermal micro-flow measurement
- Calibrated and temperature compensated
- Analog output and digital SPI interface
- High flow impedance
 - very low flow-through leakage
 - high immunity to dust and humidity
 - no loss in sensitivity using long tubing
- RoHS and REACH compliant
- Quality Management System according to EN ISO 13485 and EN ISO 9001

MEDIA COMPATIBILITY

Air and other non-corrosive gases



SPECIFICATIONS

Maximum ratings

Supply voltage V_s	
LDE...3...	2.70 ... 3.60 V _{DC}
LDE...6...	4.75 ... 5.25 V _{DC}

Output current	1 mA
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Lead specifications

Average preheating temperature gradient	2.5 K/s
Soak time	ca. 3 min
Time above 217°C	50 s
Time above 230°C	40 s
Time above 250°C	15 s
Peak temperature	260°C
Cooling temperature gradient	-3.5 K/s

Temperature ranges

Compensated	0 ... +70 °C
Operating	-20 ... +80 °C
Storage	-40 ... +80 °C

Humidity limits (non-condensing)	97 %RH
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Vibration ¹	20 g
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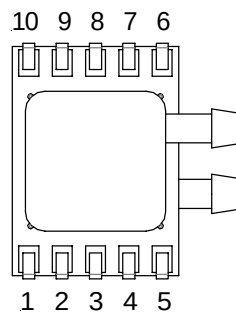
Mechanical shock ²	500 g
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Specification notes:

1. Sweep 20 to 2000 Hz, 8 min, 4 cycles per axis, MIL-STD-883, Method 2007.
2. 5 shocks, 3 axes, MIL-STD-883E, Method 2002.4.

ELECTRICAL CONNECTION

Top-down view



Pin	Function
1	Reserved
2	V_s
3	GND
4	Vout
5	Vout
6	SCLK
7	MOSI
8	MISO
9	/CS
10	Reserved

There are three use cases that will change the manner in which the LDE sensor is connected in-circuit. For detailed pin connections see page 11.

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PRESSURE SENSOR CHARACTERISTICS

Part no.	Operating pressure	Proof pressure ⁵	Burst pressure ⁵
LDES025U...	0...25 Pa / 0...0.25 mbar (0.1 inH ₂ O)	2 bar (30 psi)	2 bar (30 psi)
LDES050U...	0...50 Pa / 0...0.5 mbar (0.2 inH ₂ O)		
LDES100U...	0...100 Pa / 0...1 mbar (0.4 inH ₂ O)		
LDES250U...	0...250 Pa / 0...2.5 mbar (1 inH ₂ O)		
LDES500U...	0...500 Pa / 0...5 mbar (2 inH ₂ O)		
LDES025B...	0...±25 Pa / 0...±0.25 mbar (±0.1 inH ₂ O)		
LDES050B...	0...±50 Pa / 0...±0.5 mbar (±0.2 inH ₂ O)		
LDES100B...	0...±100 Pa / 0...±1 mbar (±0.4 inH ₂ O)		
LDES250B...	0...±250 Pa / 0...±2.5 mbar (±1 inH ₂ O)		
LDES500B...	0...±500 Pa / 0...±5 mbar (±2 inH ₂ O)		

GAS CORRECTION FACTORS¹⁰

Gas type	Correction factor
Dry air	1.0
Oxygen (O ₂)	1.07
Nitrogen (N ₂)	0.97
Argon (Ar)	0.98
Carbon dioxide (CO ₂)	0.56

Specification notes (cont.):

- Total accuracy is the combined error from offset and span calibration, linearity, pressure hysteresis and temperature effects.
- The sensor is calibrated with a common mode pressure of 1 bar absolute. Due to the mass flow based measuring principle, variations in absolute common mode pressure need to be compensated according to the following formula:

$$\Delta P_{\text{eff}} = \Delta P_{\text{sensor}} \times \frac{1 \text{ bar}}{P_{\text{abs}}}$$

- ΔP_{eff} = True differential pressure
 ΔP_{sensor} = Differential pressure as indicated by output voltage
 P_{abs} = Current absolute common mode pressure

- The max. common mode pressure is 2 bar.
- Figure based on accelerated lifetime test corresponding to 1 year of life.
- The digital output signal is a signed, two's complement integer. Negative pressures will result in a negative output.
- Please contact First Sensor for low power options.
- Non-linearity refers to a terminal based FSL (Fitting Straight Line) going through the actual zero pressure reading.
- For example with a LDES500... sensor measuring CO₂ gas, at full-scale output the actual pressure will be 500 Pa x 0.56 = 280 Pa.

$$\Delta P_{\text{eff}} = \Delta P_{\text{sensor}} \times \text{gas correction factor}$$

- ΔP_{eff} = True differential pressure
 ΔP_{sensor} = Differential pressure as indicated by output voltage

- For correct operation of LDE...3... devices, the device driving the SPI bus must have a minimum drive capability of ±2 mA.

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Digital low differential pressure sensors

PERFORMANCE CHARACTERISTICS⁴

LDE...6...

($V_S=5.0 V_{DC}$, $T_A=20\text{ °C}$, $P_{Abs}=1\text{ bara}$, calibrated in air, output signals analog and digital are non-ratiometric to V_S)

all 25 Pa and 50 Pa devices

Characteristics	Min.	Typ.	Max.	Unit
Non-linearity ⁹			$\pm(1\text{ \% of reading} + 0.5\text{ \%FSS})$	
Total accuracy ³	5...55 °C		$\pm(1.5\text{ \% of reading} + 1.5\text{ \%FSS})$	
	0...70 °C		$\pm(3.5\text{ \% of reading} + 1.5\text{ \%FSS})$	
Noise level		0.03		%FS
Offset warm-up shift			less than noise	
Offset long term stability ⁶		± 0.05	± 0.1	Pa/year
Current consumption (no load) ⁸		7	8	mA
Response time (t_{63})		5		ms
Power-on time			25	

Analog output (unidirectional devices)

Characteristics	Min.	Typ.	Max.	Unit
Zero pressure offset	0.49	0.50	0.51	V
Full scale span	3.97	4.00	4.03	
Full scale output		4.50		
Thermal effects	Offset	5...55 °C		mV
		0...70 °C		
	Span	5...55 °C	± 1.25	%FSS
		0...70 °C	± 1.75	

Analog output (bidirectional devices)

Characteristics	Min.	Typ.	Max.	Unit
Zero pressure offset	2.49	2.50	2.51	V
Full scale span	3.97	4.00	4.03	
Output	at max. specified pressure	4.50		
	at min. specified pressure	0.50		
Thermal effects	Offset	5...55 °C		mV
		0...70 °C		
	Span	5...55 °C	± 1.25	%FSS
		0...70 °C	± 1.75	

Digital output

Characteristics	Min.	Typ.	Max.	Unit
Scale factor (digital output) ⁷	0...25 / 0...±25 Pa	1200		counts/Pa
	0...50 / 0...±50 Pa	600		
Zero pressure offset tolerance	-0.2		+0.2	%FSS
Full scale span tolerance	-0.75		+0.75	
Thermal effects	Offset	5...55 °C		counts
		0...70 °C		
	Span	5...55 °C	± 1	%FSS
		0...70 °C	± 1.75	

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($V_S=5.0 V_{DC}$, $T_A=20\text{ °C}$, $P_{Abs}=1\text{ bara}$, calibrated in air, output signals analog and digital are non-ratiometric to V_S)

all 100 Pa, 250 Pa and 500 Pa devices

Characteristics	Min.	Typ.	Max.	Unit
Non-linearity ⁹			$\pm(1\text{ \% of reading} + 0.5\text{ \%FSS})$	
Total accuracy ³	5...55 °C		$\pm(1.5\text{ \% of reading} + 1.5\text{ \%FSS})$	
	0...70 °C		$\pm(3.5\text{ \% of reading} + 1.5\text{ \%FSS})$	
Noise level		0.03		%FS
Offset warm-up shift			less than noise	
Offset long term stability ⁶			± 0.1	%FSS/year
Current consumption (no load) ⁸		7	8	mA
Response time (t_{63})		5		ms
Power-on time			25	

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Zero pressure offset	0.49	0.50	0.51	V
Full scale span	3.97	4.00	4.03	
Full scale output		4.50		
Thermal effects	Offset	5...55 °C		mV
		0...70 °C		
	Span	5...55 °C	± 1	%FSS
		0...70 °C	± 2	

Analog output (bidirectional devices)

Characteristics	Min.	Typ.	Max.	Unit
Zero pressure offset	2.49	2.50	2.51	V
Full scale span	3.97	4.00	4.03	
Output		4.50		
	at max. specified pressure			
	at min. specified pressure	0.50		
Thermal effects	Offset	5...55 °C		mV
		0...70 °C		
	Span	5...55 °C	± 1	%FSS
		0...70 °C	± 2	

Digital output

Characteristics	Min.	Typ.	Max.	Unit
Scale factor (digital output) ⁷	0...100 / 0... ± 100 Pa	300		counts/Pa
	0...250 / 0... ± 250 Pa	120		
	0...500 / 0... ± 500 Pa	60		
Zero pressure offset tolerance	-0.1		+0.1	%FSS
Full scale span tolerance	-0.75		+0.75	
Thermal effects	Offset	5...55 °C		counts
		0...70 °C		
	Span	5...55 °C	± 1	%FSS
		0...70 °C	± 2	

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PERFORMANCE CHARACTERISTICS⁴

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all 25 Pa and 50 Pa devices

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Non-linearity ⁹			$\pm(1\text{ \% of reading} + 0.5\text{ \%FSS})$	
Total accuracy ³	5...55 °C		$\pm(1.5\text{ \% of reading} + 1.5\text{ \%FSS})$	
	0...70 °C		$\pm(3.5\text{ \% of reading} + 1.5\text{ \%FSS})$	
Noise level		0.03		%FS
Offset warm-up shift			less than noise	
Offset long term stability ⁶		± 0.05	± 0.1	Pa/year
Current consumption (no load) ⁸		14	16	mA
Response time (t_{63})		5		ms
Power-on time			25	

Analog output (unidirectional devices)

Characteristics	Min.	Typ.	Max.	Unit
Zero pressure offset	0.29	0.30	0.31	V
Full scale span	2.37	2.40	2.43	
Full scale output		2.70		
Thermal effects	Offset	5...55 °C		mV
		0...70 °C		
	Span	5...55 °C	± 1.25	%FSS
		0...70 °C	± 1.75	

Analog output (bidirectional devices)

Characteristics	Min.	Typ.	Max.	Unit
Zero pressure offset	1.49	1.50	1.51	V
Full scale span	2.37	2.40	2.43	
Output	at max. specified pressure		2.70	
	at min. specified pressure		0.30	
Thermal effects	Offset	5...55 °C		mV
		0...70 °C		
	Span	5...55 °C	± 1.25	%FSS
		0...70 °C	± 1.75	

Digital output

Characteristics	Min.	Typ.	Max.	Unit
Scale factor (digital output) ⁷	0...25 / 0...±25 Pa		1200	counts/Pa
	0...50 / 0...±50 Pa		600	
Zero pressure offset tolerance	-0.2		+0.2	%FSS
Full scale span tolerance	-0.75		+0.75	
Thermal effects	Offset	5...55 °C		counts
		0...70 °C		
	Span	5...55 °C	± 1	%FSS
		0...70 °C	± 1.75	

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	0...70 °C		$\pm(3.5\text{ \% of reading} + 1.5\text{ \%FSS})$	
Noise level		0.03		%FS
Offset warm-up shift			less than noise	
Offset long term stability ⁶			± 0.1	%FSS/year
Current consumption (no load) ⁸		14	16	mA
Response time (t_{63})		5		ms
Power-on time			25	

Analog output (unidirectional devices)

Characteristics	Min.	Typ.	Max.	Unit
Zero pressure offset	0.29	0.30	0.31	V
Full scale span	2.37	2.40	2.43	
Full scale output		2.70		
Thermal effects	Offset	5...55 °C		mV
		0...70 °C		
	Span	5...55 °C	± 1	%FSS
		0...70 °C	± 2	

Analog output (bidirectional devices)

Characteristics	Min.	Typ.	Max.	Unit
Zero pressure offset	1.49	1.50	1.51	V
Full scale span	2.37	2.40	2.43	
Output	at max. specified pressure	2.70		
	at min. specified pressure	0.30		
Thermal effects	Offset	5...55 °C		mV
		0...70 °C		
	Span	5...55 °C	± 1	%FSS
		0...70 °C	± 2	

Digital output

Characteristics	Min.	Typ.	Max.	Unit
Scale factor (digital output) ⁷	0...100 / 0... ± 100 Pa	300		counts/Pa
	0...250 / 0... ± 250 Pa	120		
	0...500 / 0... ± 500 Pa	60		
Zero pressure offset tolerance	-0.1		+0.1	%FSS
Full scale span tolerance	-0.75		+0.75	
Thermal effects	Offset	5...55 °C		counts
		0...70 °C		
	Span	5...55 °C	± 1	%FSS
		0...70 °C	± 2	

SPI - SERIAL PERIPHERAL INTERFACE

Note: It is important to adhere to the communication protocol in order to avoid damage to the sensor.

Introduction

The LDE serial interface is a high-speed synchronous data input and output communication port. The serial interface operates using a standard 4-wire SPI bus. The LDE device runs in SPI mode 0, which requires the clock line SCLK to idle low (CPOL = 0), and for data to be sampled on the leading clock edge (CPHA = 0). Figure 3 illustrates this mode of operation.

Care should be taken to ensure that the sensor is properly connected to the master microcontroller. Refer to the manufacturer's datasheet for more information regarding physical connections.

Application circuit

The use of pull-up resistors is generally unnecessary for SPI as most master devices are configured for push-pull mode. If pull-up resistors are required for use with 3 V LDE devices, however, they should be greater than 50 k Ω .

There are, however, some cases where it may be helpful to use 33 Ω series resistors at both ends of the SPI lines, as shown in Figure 1. Signal quality may be further improved by the addition of a buffer as shown in Figure 2. These cases include multiple slave devices on the same bus segment, using a master device with limited driving capability and long SPI bus lines.

If these series resistors are used, they must be physically placed as close as possible to the pins of the master and slave devices.

Signal control

The serial interface is enabled by asserting /CS low. The serial input clock, SCLK, is gated internally to begin accepting the input data at MOSI, or sending the output data on MISO. When /CS rises, the data clocked into MOSI is loaded into an internal register.

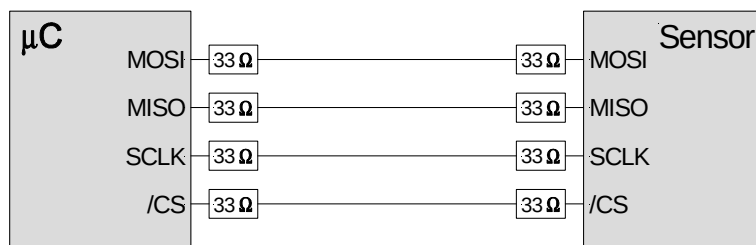


Fig. 1: Resistors at both ends of the SPI lines

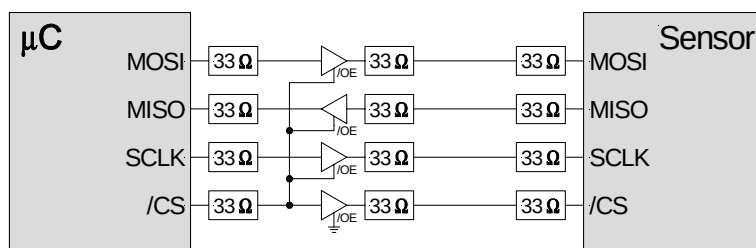


Fig. 2: Addition of a buffer

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SPI - SERIAL PERIPHERAL INTERFACE (cont.)

Note: It is important to adhere to the communication protocol in order to avoid damage to the sensor.

Data read

When powered on, the sensor begins to continuously measure pressure. To initiate data transfer from the sensor, the following three unique bytes must be written sequentially, MSB first, to the MOSI pin (see Figure 3):

Step	Hexadecimal	Binary	Description
1	0x2D	B00101101	Poll current pressure measurement
2	0x14	B00010100	Send result to data register
3	0x98	B10011000	Read data register

The entire 16 bit content of the LDE register is then read out on the MISO pin, MSB first, by applying 16 successive clock pulses to SCLK with /CS asserted low. Note that the value of the LSB is held at zero for internal signal processing purposes. This is below the noise threshold of the sensor and thus its fixed value does not affect sensor performance and accuracy.

From the digital sensor output the actual pressure value can be calculated as follows:

$$\text{pressure [Pa]} = \frac{\text{digital output [counts]}}{\text{scale factor} \left[\frac{\text{counts}}{\text{Pa}} \right]}$$

For example, for a ± 250 Pa sensor (LDES250B...) with a scale factor of 120 a digital output of 30 000 counts (7530'h) calculates to a positive pressure of 250 Pa. Similarly, a digital output of -30 000 counts (8AD0'h) calculates to a negative pressure of -250 Pa.

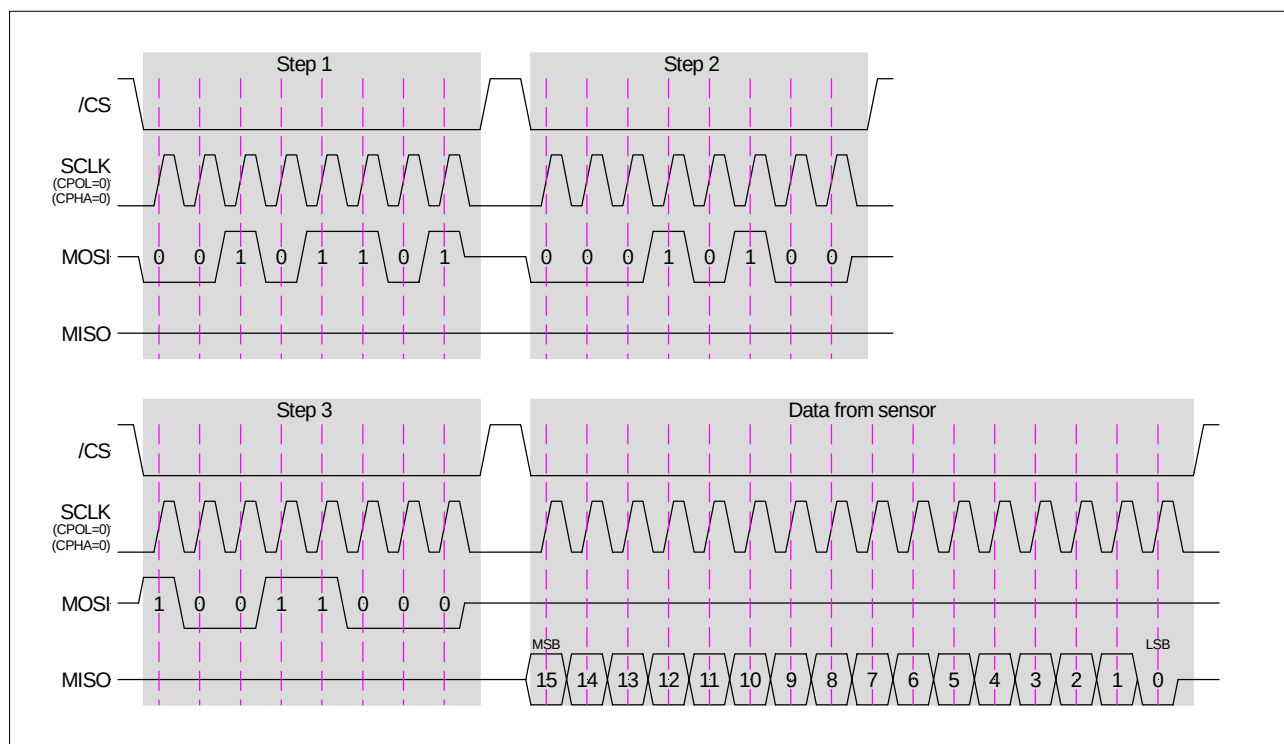


Fig. 3: SPI data transfer

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Interface specification

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
External clock frequency	f _{ECLK}	V _{CKSEL} =0 Min. Max.		0.2 5		MHz
External master clock input low time	t _{ECLKIN LO}	t _{ECLK} =1/f _{ECLK}	40		60	%t _{ECLK}
External master clock input high time	t _{ECLKIN HI}	t _{ECLK} =1/f _{ECLK}	40		60	
SCLK setup to falling edge /CS	t _{SC}		30			ns
/CS falling edge to SCLK rising edge setup time	t _{CSS}		30			
/CS idle time	t _{CSI}	f _{CLK} =4 MHz	1.5			μs
SCLK falling edge to data valid delay	t _{DO}	C _{LOAD} =15 pF			80	ns
Data valid to SCLK rising edge setup time	t _{DS}		30			
Data valid to SCLK rising edge hold time	t _{DH}		30			
SCLK high pulse width	t _{CH}		100			
SCLK low pulse width	t _{CL}		100			
/CS rising edge to SCLK rising edge hold time	t _{CSH}		30			
/CS falling edge to output enable	t _{DV}	C _{LOAD} =15 pF			25	
/CS rising edge to output disable	t _{TR}	C _{LOAD} =15 pF			25	
LDE...6... (5 V supply)						
Maximum output load capacitance	C _{LOAD}	R _{LOAD} =∞, phase margin >55°		200		pF
Input voltage, logic HIGH	V _{IH}		0.8×V _S			V
Input voltage, logic LOW	V _{IL}				0.2×V _S	
Output voltage, logic HIGH	V _{OH}	R _{LOAD} =∞ R _{LOAD} =2 kΩ	V _S -0.1 V _S -0.15			
Output voltage, logic LOW	V _{OL}	R _{LOAD} =∞ R _{LOAD} =2 kΩ			0.5 0.2	
LDE...3... (3 V supply) ¹¹						
Maximum output load capacitance	C _{LOAD}	R _{LOAD} =1 kΩ		15		pF
Input voltage, logic HIGH	V _{IH}		0.65×V _S			V
Input voltage, logic LOW	V _{IL}				0.35×V _S	
Output voltage, logic HIGH	V _{OH}	I _O =-20 μA	V _S -0.4			
Output voltage, logic LOW	V _{OL}	I _L =20 μA			0.4	

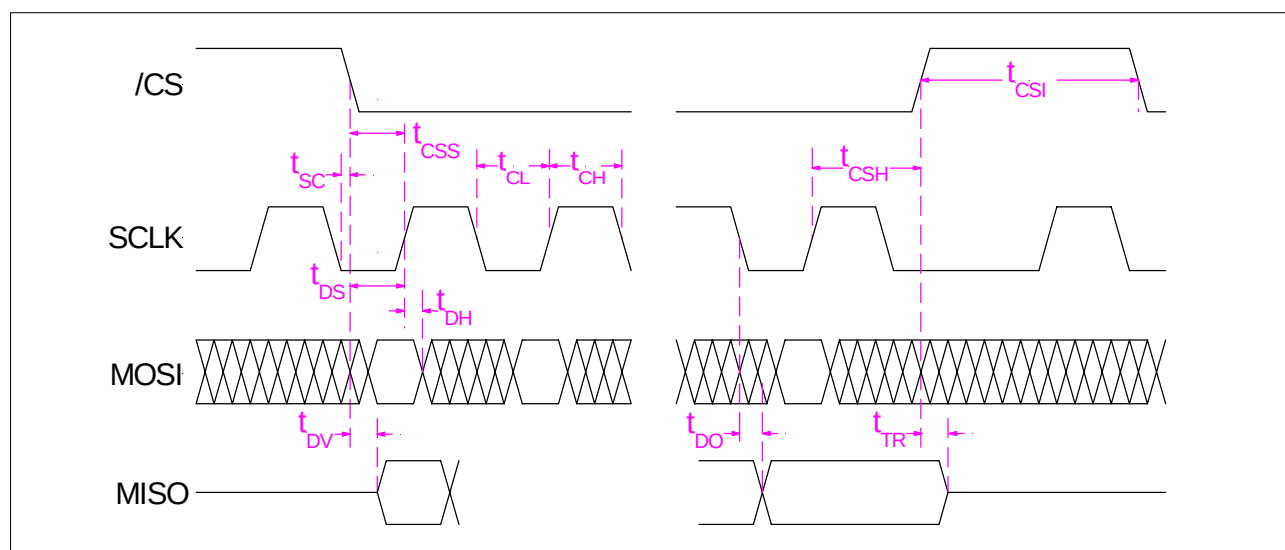


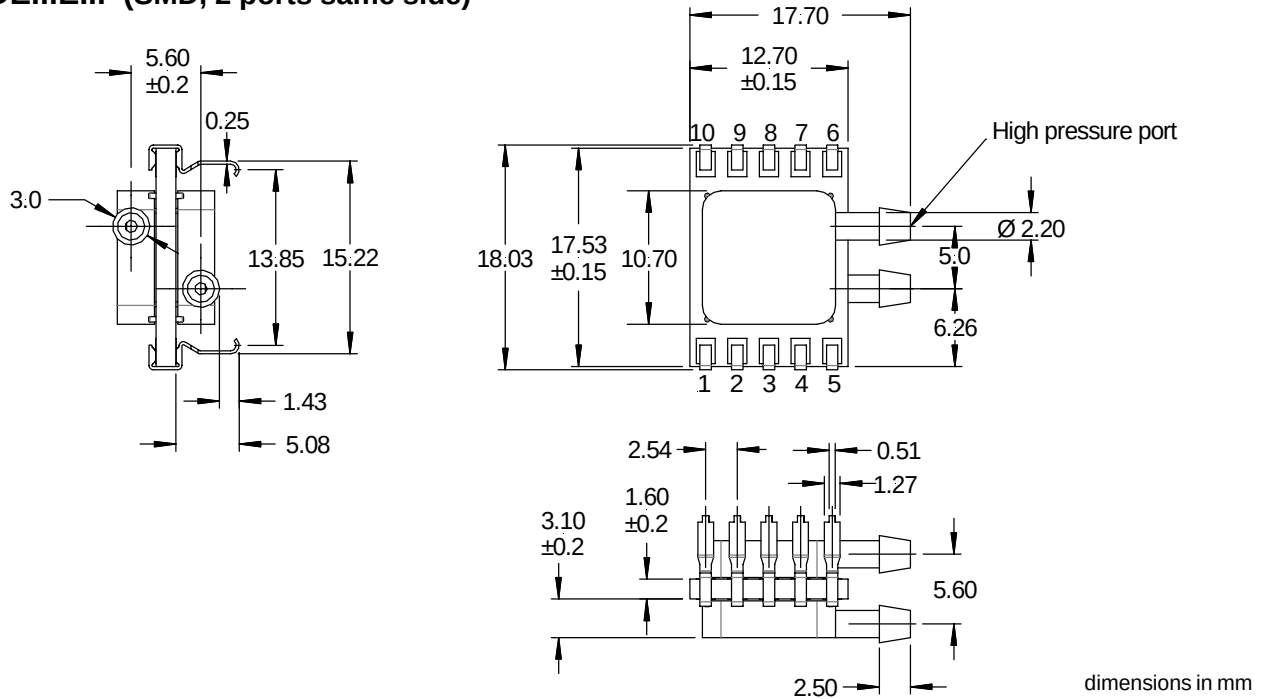
Fig. 4: Timing diagram

LDE Series

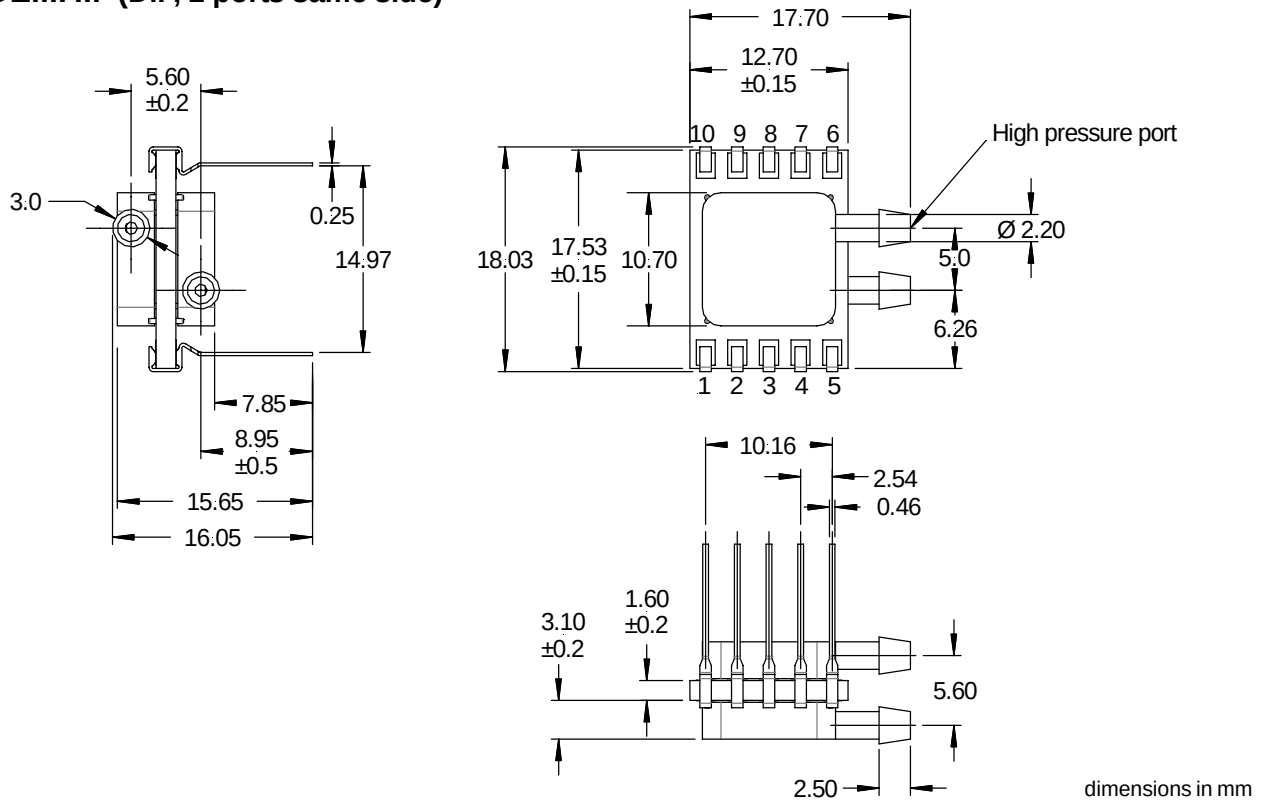
Digital low differential pressure sensors

OUTLINE DRAWING

LDE...E... (SMD, 2 ports same side)



LDE...F... (DIP, 2 ports same side)



LDE Series

Digital low differential pressure sensors

ELECTRICAL CONNECTION (cont.)

There are three use cases that will change the manner in which the LDE series device is connected in-circuit:

- Case 1: Reading of pressure measurement as a digital (SPI) signal;
- Case 2: Reading of pressure measurement as an analog (voltage) signal; and
- Case 3: Pin-to-pin compatible drop-in replacement for LBA series devices (5 V LDE devices only).

The connections for each such use case must be made as indicated below.

Pin	Function	Connection		
		Case 1: Digital signal output	Case 2: Analog signal output	Case 3: LBA drop-in replacement (5 V LDE only)
1	Reserved	NC	NC	GND
2	V _s	+5 V / +3 V	+5 V / +3 V	+5 V
3	GND	GND	GND	GND
4	V _{out}	NC	High-impedance analog input (e.g. op-amp, ADC)	High-impedance analog input (e.g. op-amp, ADC)
5	V _{out}	NC		
6	SCLK	Master device SCLK	GND	GND
7	MOSI	Master device MOSI	GND	GND
8	MISO	Master device MISO	GND	GND
9	/CS	Master device (/CS)	V _s	GND
10	Reserved	NC	NC	GND

ORDERING INFORMATION

Options	Series	Pressure range		Calibration		Housing		Output		Grade	
	LDE	S025	25 Pa (0.1 inH ₂ O)	B	Bidirectional	E	SMT, 2 ports same side	3	non-ratiometric, 3 V supply	S	High
		S050	50 Pa (0.2 inH ₂ O)	U	Unidirectional	F	DIP, 2 ports same side	6	non-ratiometric, 5 V supply		
		S100	100 Pa (0.4 inH ₂ O)								
		S250	250 Pa (1 inH ₂ O)								
		S500	500 Pa (2 inH ₂ O)								
Example: LDE S250 B F 6 S											

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