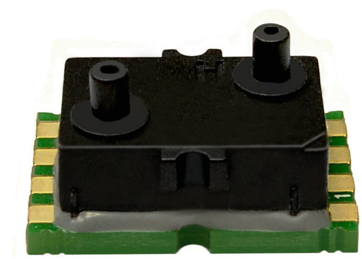
First Sensor

LME series – digital low differential pressure sensors



The LME differential low pressure sensors are based on thermal flow measurement of gas through a micro-flow channel integrated within the sensor chip. The innovative LME technology features superior sensitivity especially for ultra low pressures. The extremely low gas flow through the sensor ensures high immunity to dust contamination, humidity and long tubing compared to other flow-based pressure sensors.

Features

- Ultra-low pressure ranges from 25 to 500 Pa (0.1 to 2 inH_2O)
- Pressure sensor based on thermal micro-flow measurement
- High flow impedance
  - very low flow-through leakage
  - high immunity to dust and humidity
  - no loss in sensitivity using long tubing
- Outstanding long-term stability and precision with patented real-time offset compensation and linearization techniques
- Offset long term stability better than 0.1 Pa/year
- Total accuracy better than 0.5% FS typical
- On-chip temperature sensor
- Linearized digital SPI and analog outputs
- Small footprint, low profile, only 9 mm in height, and robust package
- Pressure ports for direct manifold assemblies
- Highly versatile to fit to application-specific mounting adaptors and manifolds
- Minimized internal volume and manifold mount option allow for fast gas purge time

Certificates

- Quality Management System according to EN ISO 13485 and EN ISO 9001
- RoHS and REACH compliant

Media compatibility

Air and other non-corrosive gases

Applications

Medical

- Ventilators
- Spirometers
- CPAP
- Sleep diagnostic equipment
- Nebulizers
- Oxygen conservers/concentrators
- Insufflators/endoscopy

Industrial

- HVAC
  - VAV
  - Filter monitoring
  - Burner control
- Fuel cells
- Gas leak detection
- Gas metering
- Fume hood
- Instrumentation
- Security systems

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Maximum ratings

Parameter	Min.	Max.	Unit
Supply voltage V_S	4.75	5.25	V_{DC}
Output current		1	mA
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
Vibration (1)		20	g
Mechanical shock (2)		500	g

Pressure sensor characteristics

Part no.	Operating pressure	Proof pressure (3)	Burst pressure (3)
LMES025U...	0...25 Pa / 0...0.25 mbar (0.1 inH_2O)	2 bar (30 psi)	5 bar (75 psi)
LMES050U...	0...50 Pa / 0...0.5 mbar (0.2 inH_2O)		
LMES100U...	0...100 Pa / 0...1 mbar (0.4 inH_2O)		
LMES250U...	0...250 Pa / 0...2.5 mbar (1 inH_2O)		
LMES500U...	0...500 Pa / 0...5 mbar (2 inH_2O)		
LMES025B...	0...±25 Pa / 0...±0.25 mbar (0.1 inH_2O)		
LMES050B...	0...±50 Pa / 0...±0.5 mbar (0.2 inH_2O)		
LMES100B...	0...±100 Pa / 0...±1 mbar (0.4 inH_2O)		
LMES250B...	0...±250 Pa / 0...±2.5 mbar (1 inH_2O)		
LMES500B...	0...±500 Pa / 0...±5 mbar (2 inH_2O)		

Gas correction factors (4)

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

(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.
(3) The max. common mode pressure is 5 bar.
(4) For example with a LMES500... sensor measuring CO_2 gas, at full-scale output the actual pressure will be:

$$\Delta P_{eff} = \Delta P_{Sensor} \text{ x gas correction factor} = 500 \text{ Pa x } 0.56 = 280 \text{ Pa}$$

ΔP_{eff} = True differential pressure,
ΔP_{Sensor} = Differential pressure as indicated by output signal

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Performance characteristics (5)

(V_S=5.0 V_{DC}, T_A=20 °C, P_{Abs}=1 bara, calibrated in air, output signal is non-ratiometric to V_S)

25 Pa and 50 Pa devices

Parameter	Min.	Typ.	Max.	Unit
Noise level (RMS)		±0.01		Pa
Offset warm-up shift			less than noise	
Offset long term stability (6)		±0.05	±0.1	Pa/year
Offset repeatability		±0.01		Pa
Span repeatability (9, 10)		±0.25		% of reading
Current consumption (no load) (7)		7	8	mA
Response time (t_{63})		5		ms
Power-on time			25	ms

Digital output

Parameter			Min.	Typ.	Max.	Unit
Scale factor (digital output) (8)	0...25/0...±25 Pa			1200		counts/Pa
	0...50/0...±50 Pa			600		counts/Pa
Zero pressure offset accuracy (9)				±0.1	±0.2	%FSS
Span accuracy (9, 10)				±0.4	±0.75	% of reading
Thermal effects	Offset	5...55 °C			±0.2	%FSS
		0...70 °C			±0.4	%FSS
	Span	5...55 °C		±1	±1.75	% of reading
		0...70 °C		±2	±2.75	% of reading

Analog output (unidirectional devices)

Parameter			Min.	Typ.	Max.	Unit
Zero pressure offset (9)			0.49	0.50	0.51	V
Full scale output				4.50		V
Span accuracy (9, 10)				±0.4	±0.75	% of reading
Thermal effects	Offset	5...55 °C			±15	mV
		0...70 °C			±30	mV
	Span	5...55 °C		±1.25	±2	% of reading
		0...70 °C		±2	±2.75	% of reading

Analog output (bidirectional devices)

Parameter			Min.	Typ.	Max.	Unit
Zero pressure offset (9)			2.49	2.50	2.51	V
Output	at max. specified pressure			4.50		V
	at min. specified pressure			0.50		V
Span accuracy (9, 10)				±0.4	±0.75	% of reading
Thermal effects	Offset	5...55 °C			±15	mV
		0...70 °C			±30	mV
	Span	5...55 °C		±1.25	±2	% of reading
		0...70 °C		±2	±2.75	% of reading

Specification notes (cont.)

(5) 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:

$$\Delta P_{eff} = \Delta P_{Sensor} \times 1\ \text{bara}/P_{abs}$$

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

(6) Figure based on accelerated lifetime test of 10000 hours at 85 °C biased burn-in.

(7) Please contact First Sensor for low power options.

(8) The digital output signal is a signed, two complement integer. Negative pressures will result in a negative output

(9) Zero pressure offset accuracy and span accuracy are uncorrelated uncertainties. They can be added according to the principles of error propagation.

(10) Span accuracy below 10% of full scale is limited by the intrinsic noise of the sensor.

Performance characteristics (cont.) [5]

(V_S=5.0 V_{DC}, T_A=20 °C, P_{Abs}=1 bara, calibrated in air, output signal is non-ratiometric to V_S)

100 Pa, 250 Pa and 500 Pa devices

Parameter	Min.	Typ.	Max.	Unit
Noise level (RMS)		±0.01		%FSS
Offset warm-up shift			less than noise	
Offset long term stability [6]		±0.05	±0.1	%FSS/year
Offset repeatability [11]		±0.02		Pa
Span repeatability [9, 10]		±0.25		% of reading
Current consumption (no load) [7]		7	8	mA
Response time (t_{63})		5		ms
Power-on time			25	ms

Digital output

Parameter			Min.	Typ.	Max.	Unit
Scale factor (digital output) [8]	0...100/0...±100 Pa			300		counts/Pa
	0...250/0...±250 Pa			120		counts/Pa
	0...500/0...±500 Pa			60		counts/Pa
Zero pressure offset accuracy [9]				±0.05	±0.1	%FSS
Span accuracy [9, 10]				±0.4	±0.75	% of reading
Thermal effects	Offset	5...55 °C			±0.1	%FSS
		0...70 °C			±0.2	%FSS
	Span	5...55 °C		±1	±1.75	% of reading
		0...70 °C		±2	±2.75	% of reading

Analog output (unidirectional devices)

Parameter			Min.	Typ.	Max.	Unit
Zero pressure offset [9]			0.49	0.50	0.51	V
Full scale output				4.50		V
Span accuracy [9, 10]				±0.4	±0.75	% of reading
Thermal effects	Offset	5...55 °C			±10	mV
		0...70 °C			±12	mV
	Span	5...55 °C		±1	±1.75	% of reading
		0...70 °C		±2	±2.75	% of reading

Analog output (bidirectional devices)

Parameter			Min.	Typ.	Max.	Unit
Zero pressure offset [9]			2.49	2.50	2.51	V
Output	at max. specified pressure			4.50		V
	at min. specified pressure			0.50		V
Span accuracy [9, 10]				±0.4	±0.75	% of reading
Thermal effects	Offset	5...55 °C			±10	mV
		0...70 °C			±12	mV
	Span	5...55 °C		±1	±1.75	% of reading
		0...70 °C		±2	±2.75	% of reading

Specification notes (cont.)

(5) 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:

$$\Delta P_{eff} = \Delta P_{Sensor} \times 1 \text{ bara}/P_{abs}$$

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

(6) Figure based on accelerated lifetime test of 10000 hours at 85 °C biased burn-in.
(7) Please contact First Sensor for low power options.
(8) The digital output signal is a signed, two complement integer. Negative pressures will result in a negative output
(9) Zero pressure offset accuracy and span accuracy are uncorrelated uncertainties. They can be added according to the principles of error propagation.
(10) Span accuracy below 10% of full scale is limited by the intrinsic noise of the sensor.
(11) Typical value for 250 Pa sensors.

Performance characteristics (cont.)

Temperature sensor

Parameter	Min.	Typ.	Max.	Unit
Scale factor (digital output)		95		counts/°C
Non-linearity		±0.5		%FS
Hysteresis		±0.1		% FS

Total accuracy (12)

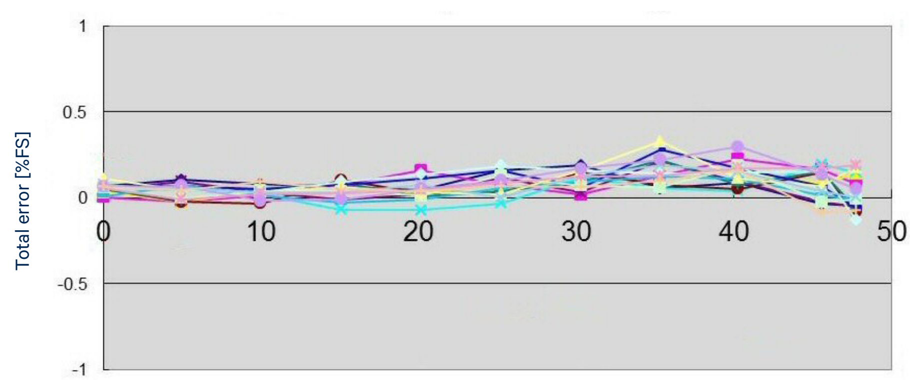

Fig. 1: Typical total accuracy plot of 16 LME 50 Pa sensors @ 25 °C (typical total accuracy better than 0.5 %FS)

Offset long term stability

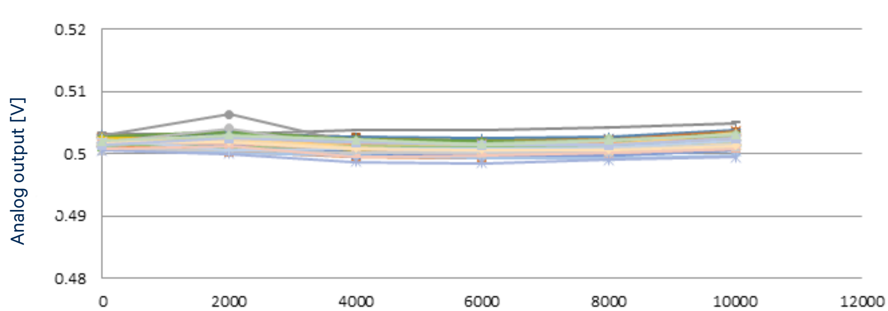

Fig. 2: Offset long term stability for LME 250 Pa sensors after 10,000 hours @ 85°C powered, equivalent to over 43.5 years @ 25 °C (better than ±2 mV / ±0.125 Pa)

Specification notes (cont.)

(12) Total accuracy is the combined error from offset and span calibration, non-linearity, repeatability and pressure hysteresis

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SPI – Serial Peripheral Interface

Introduction
The LME 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 LME 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 5 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. There are, however, some cases where it may be helpful to use 33Ω series resistors at both ends of the SPI lines, as shown in Figure 3.

Signal quality may be further improved by the addition of a buffer as shown in Figure 4. 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.

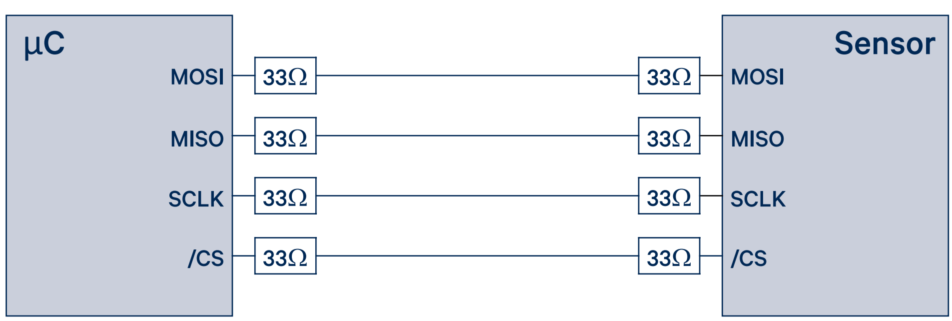

Fig. 3: Application circuit with resistors at both ends of the SPI lines

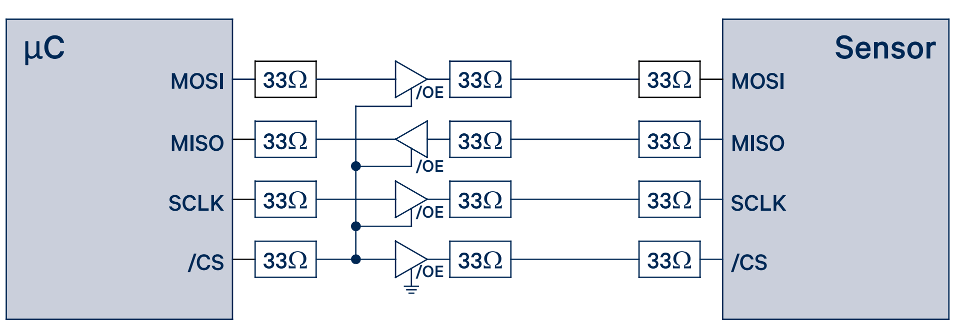

Fig. 4: Application circuit with additional buffer

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SPI – Serial Peripheral Interface (cont.)

Data read – pressure

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 5):

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 LME 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 (LMES250B...) 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.

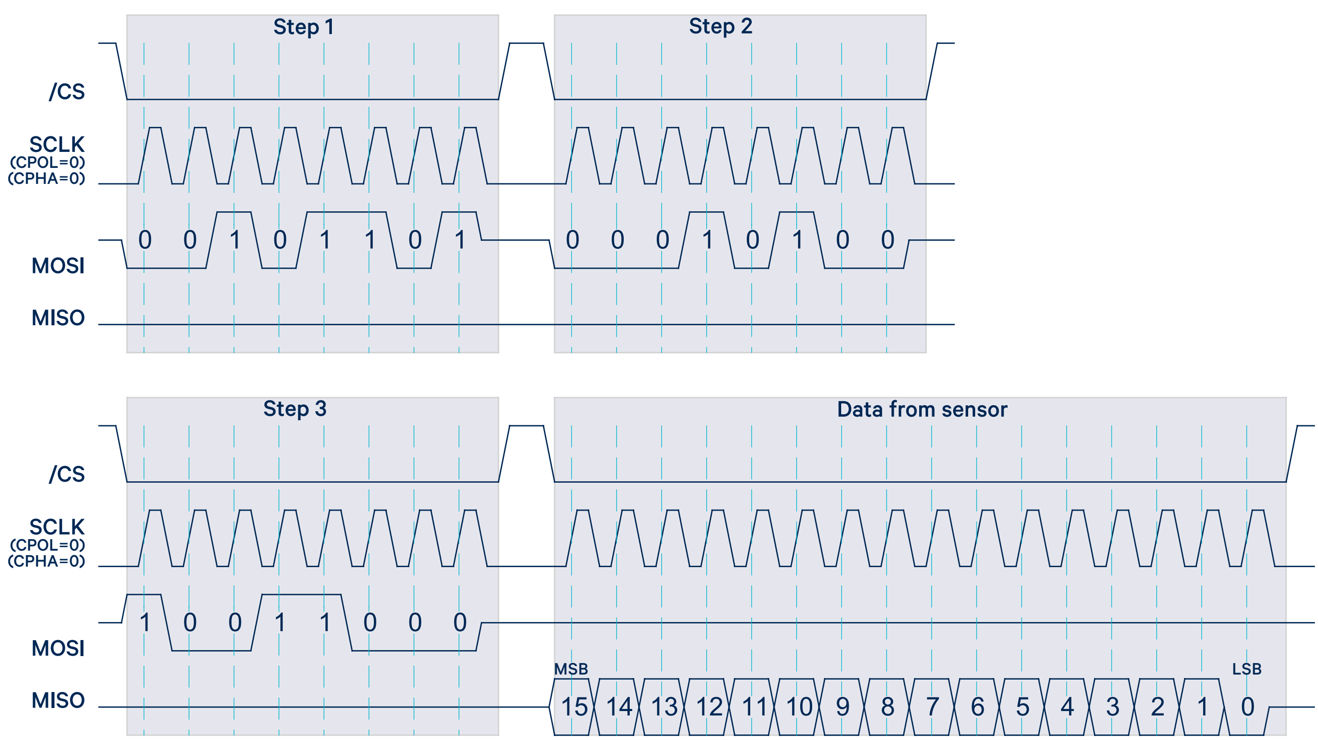

Fig. 5: SPI data transfer

SPI – Serial Peripheral Interface (cont.)

Data read – temperature

The on-chip temperature sensor changes +95 counts/°C over the operating range. The temperature data format is 15-bit plus sign in two's complement format. To read temperature, use the following sequence:

Step	Hexadecimal	Binary	Description
1	0x24	B00100010	Poll current temperature measurement
2	0x14	B00010100	Send result to data register
3	0x98	B10011000	Read data register

From the digital sensor output, the actual temperature can be calculated as follows:

$$\text{Temperature [°C]} = \frac{TS - TS_0 \text{ [counts]}}{\text{Scale factor}_{TS}\left[\frac{\text{counts}}{°C}\right]} + T_0 \text{ [°C]}$$

where
TS is the actual sensor readout;
TS_0 is the sensor readout at known temperature T_0 [(13)];
Scale factor_{TS} = 95 counts/°C

Specification notes (cont.)
(13) To be defined by user. The results show deviation (in °C) from the offset calibrated temperature.

SPI – Serial Peripheral Interface (cont.)

Interface specification

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
External clock frequency	f_{ECLK}	V_{CKSEL}=0	Min.		0.2		MHz
			Max.		5		
External master clock input low time	$f_{ECLKIN\ LO}$	$t_{ECLK}=1/f_{ECLK}$		40		60	$\%t_{ECLK}$
External master clock input high time	$f_{ECLKIN\ HI}$	$t_{ECLK}=1/f_{ECLK}$		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	
Maximum output load capacitance	C_{LOAD}	$R_{LOAD}=\infty$, phase margin >55°			200		pF
Input voltage, logic HIGH	V_{IH}			$0.8\times V_S$		V_S+0.3	V
Input voltage, logic LOW	V_{IL}					$0.2\times V_S$	
Output voltage, logic HIGH	V_{OH}	$R_{LOAD}=\infty$		V_S-0.1			
		R_{LOAD}=2 kΩ		V_S-0.15			
Output voltage, logic LOW	V_{OL}	$R_{LOAD}=\infty$				0.5	
		R_{LOAD}=2 kΩ				0.2	

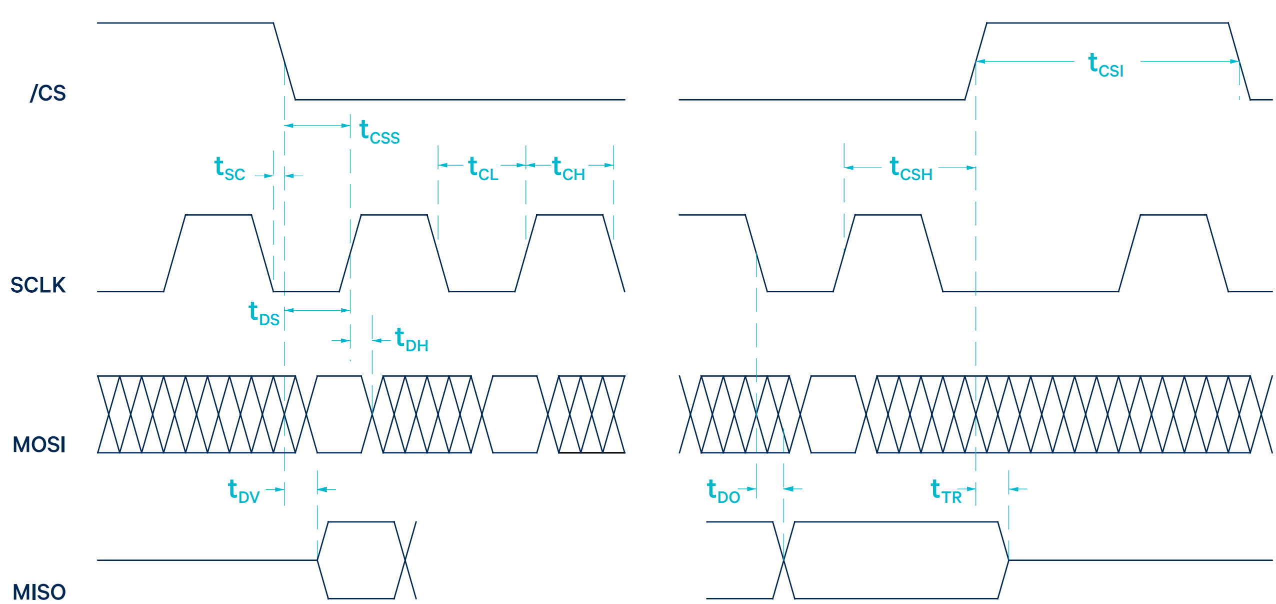

Fig. 6: SPI timing diagram

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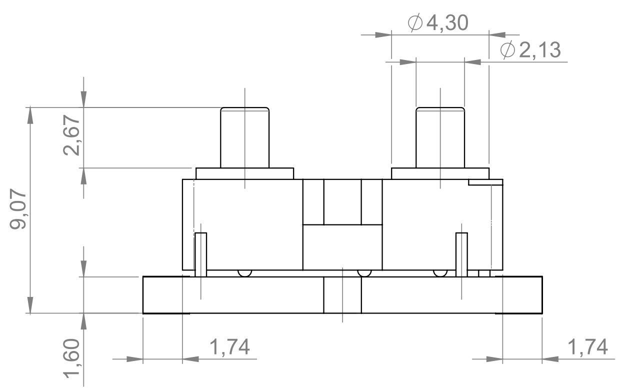
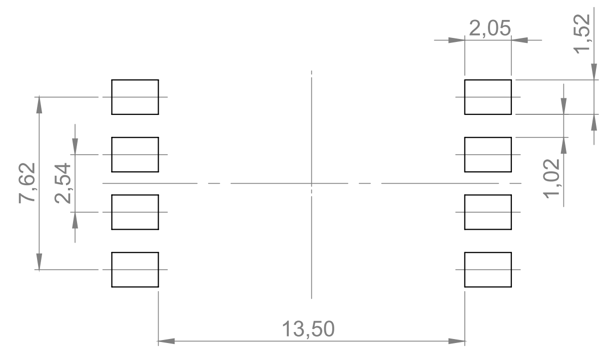
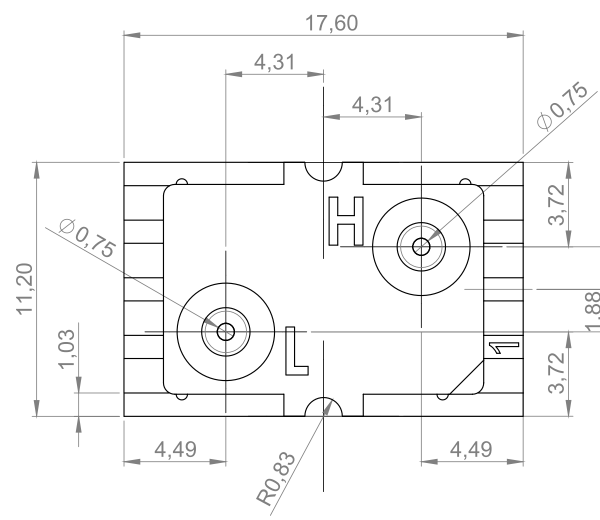
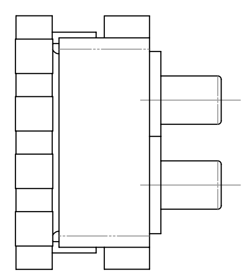
Dimensional drawing



Sensor PCB footprint





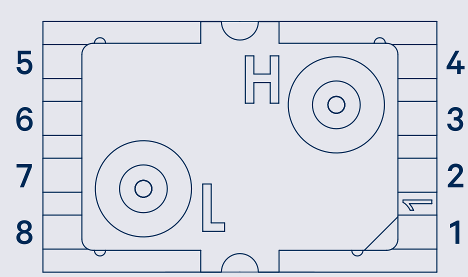


dimensions in mm,
all tolerances ±0.1 mm unless otherwise noted

Electrical connection

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

Pin	Function	Case 1: Digital signal output	Case 2: Analog signal output
1	V_S	+5V	+5V
2	GND	GND	GND
3	Vout	NC	High impedance analog input (e.g. op-amp, ADC)
4	Reserved	NC	NC
5	SCLK	Master device SCLK	GND
6	MOSI	Master device MOSI	GND
7	MISO	Master device MISO	GND
8	/CS	Master device (/CS)	V_S



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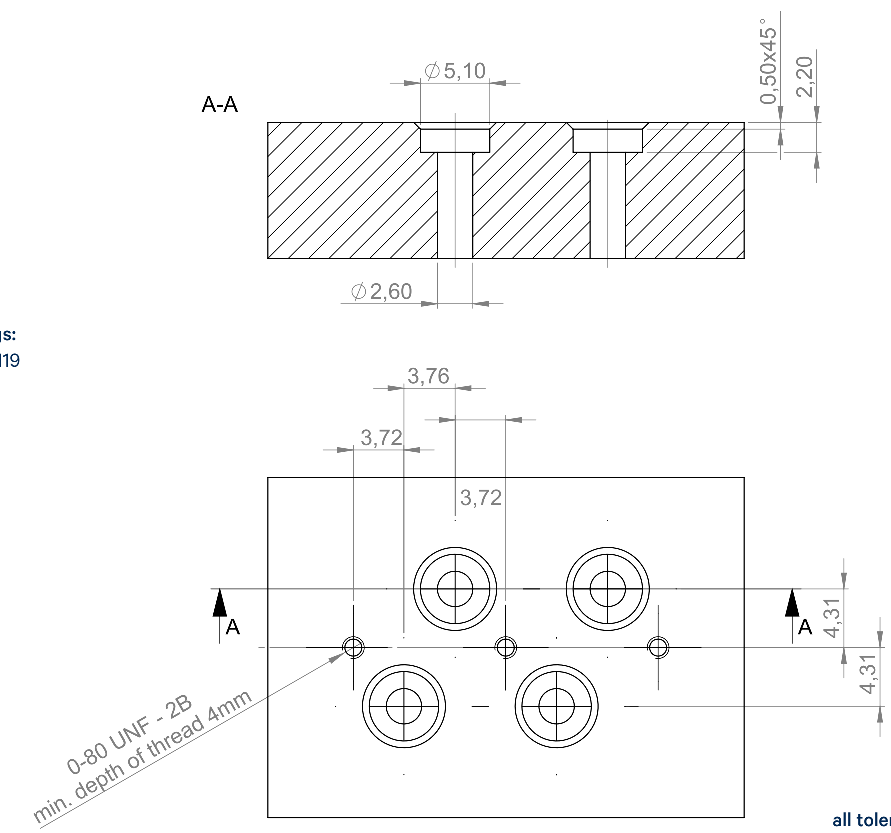
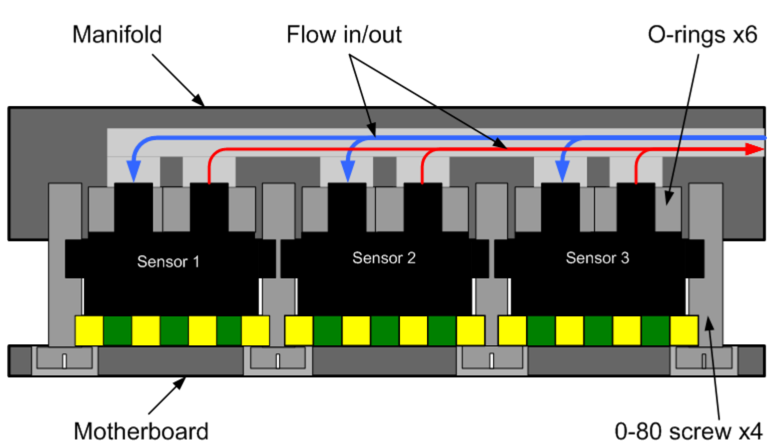
Manifold diagram for two side-by-side mounted sensors

Recommended O-rings:
Part number: 90025K119
www.mcmaster.com



dimensions in mm,
all tolerances ±0.1 mm unless otherwise noted

Manifold diagram for multiple side-by-side mounted sensors



Custom adaptor

The LME series pressure sensors can optionally be equipped with a custom adaptor for your application-specific mounting requirements. Please contact First Sensor for more information.

Fig. 7: 3D views of a custom adaptor for the LME pressure sensor

Gas mixture change (purge time)

The LME series pressure sensors feature minimized internal volume, which allows for fast response to gas mixture change and high pneumatic impedance at the same time. Purge time (T_P) can be estimated by the following equation:

$$T_P = \frac{V_{INT}}{F_{Norm}} = \frac{V_{INT}}{P_{Norm}/Z_P}$$

T_P = Purge time [s]
V_{INT} = Internal volume of the LME sensor [ml]
F_{Nom} = Nominal flow [ml/s]
P_{Nom} = Nominal pressure [Pa]
Z_P = Pneumatic impedance [kPa/(ml/s)]

The typical internal volume of the LME sensor (V_{INT}) is 0.04 ml. With a pneumatic impedance (Z_P) of 15 kPa/(ml/s) and a nominal pressure (P_{Nom}) of 250 Pa, the estimated purge time (T_P) is 2.4 seconds.

Ordering information

Series	Pressure range		Calibration		Housing	Output	Grade
LME	**S025**	**25 Pa (0.1 inH$_2$O)**	**B**	**Bidirectional**	**B [SMD, 2 ports, axial, same side]**	**6 [Non-ratiometric, 5 V supply]**	**S [High]**
	S050	**50 Pa (0.2 inH$_2$O)**	**U**	**Unidirectional**			
	S100	**100 Pa (0.4 inH$_2$O)**					
	S250	**250 Pa (1 inH$_2$O)**					
	S500	**500 Pa (2 inH$_2$O)**					