LMI series – digital low differential pressure sensors

The LMI differential low pressure sensors are based on thermal flow measurement of gas through a micro-flow channel integrated within the sensor chip. The innovative LMI 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 5000 Pa (0.1 to 20 inH₂O)
- Pressure sensor based on thermal microflow 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
- Total accuracy better than 0.5% FS typical
- On-chip temperature sensor
- Two user-driven modes of operation
 - low power mode (400 μA standby current)
- continuous mode (5 ms sampling time)
- Ideal for battery-operated applications
- Linearized digital I²C output with 16 bit sigma-delta A/D conversion
- 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
- No position sensitivity

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
- Fume hood
- Instrumentation
- Security systems

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Maximum ratings

Parameter	Min.	Max.	Unit
Supply voltage V _s	2.7	3.6	
Soldering recommendations			
Reflow soldering, peak temperature		245	°C
Wave soldering, pot temperature		260	°C
Hand soldering, tip temperature		370	°C
Temperature ranges ⁽¹⁾			
Compensated	-20	+85	°C
Operating	-40	+85	°C
Storage	-40	+85	°C
Humidity limits (non-condensing)		97	%RH
Vibration ⁽²⁾		20	g
Mechanical shock ⁽³⁾		500	

Pressure sensor characteristics

Part no.	Operating pressure	Proof pressure ⁽⁴⁾	Burst pressure (4)
LMIS025U	025 Pa / 00.25 mbar (0.1 inH₂O)		
LMIS050U	050 Pa / 00.5 mbar (0.2 inH ₂ O)		
LMIS100U	0100 Pa / 01 mbar (0.4 inH ₂ O)		
LMIS250U	0250 Pa / 02.5 mbar (1 inH ₂ O)		
LMIS500U	0500 Pa / 05 mbar (1 inH ₂ O)		
LMIM012U	01250 Pa / 012.5 mbar (5 inH ₂ O)		
LMIM025U	02500 Pa / 025 mbar (10 inH ₂ O)		
LMIM050U	05000 Pa / 050 mbar (20 inH ₂ O)	2 bar	5 bar
LMIS025B	0±25 Pa / 0±0.25 mbar (0.1 inH ₂ O)	(30 psi)	(75 psi)
LMIS050B	0±50 Pa / 0±0.5 mbar (0.2 inH2O)		
LMIS100B	0±100 Pa / 0±1 mbar (0.4 inH₂O)		
LMIS250B	0±250 Pa / 0±2.5 mbar (1 inH₂O)		
LMIS500B	0±500 Pa / 0±5 mbar (2 inH₂O)		
LMIM012B	0±1250 Pa / 0±12.5 mbar (5 inH ₂ O)		
LMIM025B	0±2500 Pa / 0±25 mbar (10 inH ₂ 0)		
LMIM050B	0±5000 Pa / 0±50 mbar (20 inH ₂ O)		

Gas correction factors (5)

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) For temperature ranges above 85 °C please contact First Sensor.

(3) 5 shocks, 3 axes, MIL-STD-883E, Method 2002.4.

(4) The max. common mode pressure is 5 bar.

- (2) Sweep 20 to 2000 Hz, 8 min, 4 cycles per axis, MIL-STD-883, Method 2007. the ac
- (5) For example with a LMIS500... sensor measuring $\rm CO_{_2}$ gas, at full-scale output the actual pressure will be:

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

- ΔP_{eff} = True differential pressure
- ΔP_{Sensor}^{en} = Differential pressure as indicated by output signal

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Performance characteristics (6)

 $(V_s = 3.3 V_{DC'} T_a = 20 \text{ °C}, P_{abs} = 1 \text{ bara, calibrated in air, output signal is non-ratiometric to } V_s)$

Parameter			meter Min. Typ.	Тур.	Max.	Unit
Current consumption	Low-power mode	power mode active		3.5	4.5	
	(default)	sleep		0.4	0.75	mA
	Continuous mode			3.5	4.5	
Response time (t ₆₃)				5		
Power-on time					25	ms

25 Pa devices

Parameter		Min.	Тур.	Max.	Unit
Scale factor ⁽⁸⁾	025/0±25 Pa		1200		counts/Pa
Noise level (RMS)			±0.01		Pa
Offset warm-up shift				less than noise	
Offset long term stability (7)			±0.02		Pa/year
Offset repeatability			±0.01		Pa
Span repeatability ^{(9), (10)}			±0.25		% of reading
Zero pressure offset accuracy ⁽⁹⁾			±0.04	±0.1	Pa
Span accuracy ^{(9), (10)}			±0.75	±1.5	% of reading
Thermal effects (-2085 °C)	Offset			±0.1	Pa
	Span		±0.2	±0.5	% of reading per 10 °C

50 Pa devices

Parameter		Min.	Тур.	Max.	Unit
Scale factor ⁽⁸⁾	050/0±50 Pa		600		counts/Pa
Noise level (RMS)			±0.01		Pa
Offset warm-up shift				less than noise	
Offset long term stability ⁽⁷⁾			±0.02		Pa/year
Offset repeatability			±0.01		Pa
Span repeatability ^{(9), (10)}			±0.25		% of reading
Zero pressure offset accuracy ⁽⁹⁾			±0.04	±0.1	Pa
Span accuracy ^{(9), (10)}			±0.75	±1.5	% of reading
Thermal effects (-2085 °C)	Offset			±0.2	Pa
	Span		±0.2	±0.5	% of reading per 10 °C

Specification notes (cont.)

(6) 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:

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

 $\begin{array}{l} \Delta P_{eff} = \text{True differential pressure} \\ \Delta P_{sensor} = \text{Differential pressure as indicated by output voltage} \\ P_{abs} = \text{Current absolute common mode pressure} \end{array}$

- (7) Figure based on accelerated lifetime test of 1000 hours at 85 °C biased burn-in.
- (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.

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Performance characteristics (cont.) (6)

 $(V_s = 3.3 V_{DC'} T_a = 20 \text{ °C}, P_{abs} = 1 \text{ bara, calibrated in air, output signal is non-ratiometric to } V_s)$

Parameter		Min.	Тур.	Max.	Unit
Scale factor ⁽⁸⁾	0100/0±100 Pa		300		counts/Pa
Noise level (RMS)			±0.01		%FSS
Offset warm-up shift				less than noise	
Offset long term stability ⁽⁷⁾			±0.02		%FSS/year
Offset repeatability			±0.01		Pa
Span repeatability ^{(9), (10)}			±0.25		% of reading
Zero pressure offset accuracy ⁽⁹⁾			±0.04	±0.1	Pa
Span accuracy ^{(9), (10)}			±0.75	±1.5	% of reading
Thermal effects (-2085 °C)	Offset			±0.2	Pa
	Span		±0.3	±0.5	% of reading per 10 °C
250 Pa devices					
Parameter		Min.	Тур.	Max.	Unit
Scale factor ⁽⁸⁾	0250/0±250 Pa		120		counts/Pa
Noise level (RMS)			±0.01		%FSS
Offset warm-up shift				less than noise	
Offset long term stability ⁽⁷⁾			±0.02		%FSS/year
Offset repeatability			±0.02		Pa
Span repeatability ^{(9), (10)}			±0.25		% of reading
Zero pressure offset accuracy ⁽⁹⁾			±0.08	±0.25	Pa
Span accuracy ^{(9), (10)}			±0.75	±1.5	% of reading
Thermal effects (-2085 °C)	Offset			±0.5	Pa
	Span		±0.3	±0.5	% of reading per 10 °C
500 Pa devices					
Parameter		Min.	Тур.	Max.	Unit
Scale factor ⁽⁸⁾	0500/0±500 Pa		60		counts/Pa
Noise level (RMS)			±0.01		%FSS
Offset warm-up shift				less than noise	
Offset long term stability ⁽⁷⁾			±0.02		%FSS/year
Offset repeatability			±0.05		Pa
Span repeatability ^{(9), (10)}			±0.25		% of reading
Zero pressure offset accuracy ⁽⁹⁾			±0.15	±0.5	Pa
Span accuracy ^{(9), (10)}			±0.75	±1.5	% of reading
Thermal effects (-2085 °C)	Offset			±1	Pa

Specification notes (cont.)

(6) 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:

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

 $\begin{array}{l} \Delta P_{eff} = \text{True differential pressure} \\ \Delta P_{sensor} = \text{Differential pressure as indicated by output voltage} \\ P_{abs} = \text{Current absolute common mode pressure} \end{array}$

- (7) Figure based on accelerated lifetime test of 1000 hours at 85 °C biased burn-in.
- (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.

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Performance characteristics (cont.) (6, 11)

 $(V_s = 3.3 V_{DC'} T_a = 20 \text{ °C}, P_{Abs} = 1 \text{ bara, calibrated in air, output signal is non-ratiometric to } V_s)$

ParameterMin.Typ.Max.UnitScale factor $^{(0)}$ 01250/01250 Pa24incomepaOffset construction pathet1105incomePaOffset construction pathet1105PaincomeOffset construction pathet105100PaincomeSpan repeatability $^{(0)}$ 102510% of readingZaro pressure offset accuracy $^{(0)}$ 11±2.5PaincomeSpan accuracy $^{(0)}$ 115±3% of readingincomeincomeSpan accuracy $^{(0)}$ 0ffset10.3io.5% of readingZaro pressure offset accuracy $^{(0)}$ 0ffsetio.3io.5% of readingSpan accuracy $^{(0)}$ 0ffsetio.5PaincomeScale factor $^{(0)}$ 02500/02500 Pa12io.5PaOffset top tarm subility $^{(2)}$ 1±0.5Paio.5Offset top tarm subility $^{(2)}$ 1±0.5Pa/verOffset top tarm subility $^{(2)}$ 1±0.5Paio.5Span accuracy $^{(0)}$ 11±2.5Paio.5Span accuracy $^{(0)}$ 11±2.5Paio.5Span accuracy $^{(0)}$ 10±0.53.5% of readingSpan accuracy $^{(0)}$ 15±3.52.6Paio.5Span accuracy $^{(0)}$ 10±0.53.5% of readingSpan accuracy $^{(0)}$ 10±0.53.5% of reading </th <th>1250 Pa devices</th> <th></th> <th></th> <th></th> <th></th> <th></th>	1250 Pa devices					
Noise lavel (RMS)+0.5-0.6-	Parameter		Min.	Тур.	Max.	Unit
Noise lavel (RMS) Feator Pa Offset orgens tability (7) 50.5 Pa/year Offset orgens tability (90,000) 50.5 Pa Span repeatability (90,000) 110 22.5 Pa Span accuracy (00,00) 115 33 % of reading Span accuracy (00,00) 0ffset 12.5 Pa Span accuracy (00,00) 0ffset 12.5 % of reading per 10* Scale factor (00,00) 0ffset 12.0 % of reading per 10* Scale factor (00,00,0,0,0,0,0,0,00) 0.500,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,	Scale factor ⁽⁸⁾	01250/0±1250 Pa		24		counts/Pa
Offset long term stability ±0.5 Pa/year Offset repeatability ±0.5 Pa Span repeatability ±0.5 % of reading Zero pressure offset accuracy ±15 ±3.3 % of reading Span accuracy Offset ±2.5 Pa Span accuracy Offset ±15 ±3.3 % of reading Thermal effects (-2085 °C) Offset ±0.3 ±0.5 % of reading Span ±0.3 ±0.5 % of reading 10.3 ±0.5 % of reading Span accuracy Span ±0.3 ±0.5 % of reading 10.5 Scale factor 0				±0.5		Pa
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$\begin{array}{ c c c c c c } \hline \begin{tabular}{ c c c c } \hline \begin{tabular}{ c c c c c } \hline \begin{tabular}{ c c c c c } \hline \begin{tabular}{ c c c c c c c } \hline \begin{tabular}{ c c c c c c c } \hline \begin{tabular}{ c c c c c c c } \hline \begin{tabular}{ c c c c c c c } \hline \begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	Offset long term stability ⁽⁷⁾			±0.5		Pa/year
$\begin{array}{ c c c c } \hline Interval effect accuracy ^{(0)}(0) & \ Interval effects (-2085 °C) & Offset \\ \hline Interval effects (-2085 °C) & Offset \\ \hline Span & Interval effects (-2085 °C) & Interval effects (-2085 °C) & Interval effects (-2085 °C) & Offset \\ \hline Span & Interval effects (-2085 °C) & Offset \\ \hline Span & Interval effects (-2085 °C) & Interval effect (-2085 °C) & Interval effects (-2085 °C) & Interval effect (-2085 °C) & Interval ef$	Offset repeatability			±0.5		Pa
Span accuracy ($00,00$)Offset ± 15 ± 3 $\%$ of reading 2.5 Thermal effects (2085 °C)Offset 2.5 Pa Span ± 0.3 ± 0.5 $\%$ of reading per 10 °C2500 Pa devices ± 0.3 ± 0.5 $\%$ of reading per 10 °CParameterMin.Typ.Max.UnitScale factor ($0^{(0)}$ $02500/0\pm 2500$ Pa ± 0.5 Pa Offset log term stability ($7^{(7)}$ $02500/0\pm 2500$ Pa ± 0.5 Pa Offset log term stability ($7^{(0)}$ ± 0.5 Pa Pa Offset repeatability (9.00) ± 0.5 Pa $\%$ of readingSpan accuracy (9.00) ± 11 ± 2.5 $\%$ of readingSpan accuracy (9.00) ± 15 ± 3 $\%$ of readingThermal effects (-2085 °C)Offset Span ± 11 ± 5.5 $\%$ of readingSoloo Pa devices ± 11 ± 1.5 ± 3.5 $\%$ of reading per 10 °CSoloo Pa devices ± 0	Span repeatability ^{(9), (10)}			±0.25		% of reading
$\begin{array}{c c c c c c } \hline Triangle flex (2085 °C) & Offset \\ \hline Span & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0$	Zero pressure offset accuracy ⁽⁹⁾			±1	±2.5	Pa
Span ±0.3 ±0.5 % of reading per 10 °C 2500 Pa devices Parameter Vinit Vinit Scale factor (6) 02500/0±2500 Pa 12 Counts/Pa Noise level (RMS) 02500/0±2500 Pa 20.5 Pa Offset arm-up shift 20.5 Iess than noise Pa/year Offset repeatability (¹⁰ , (00) ±0.5 Pa Pa Span repeatability (¹⁰ , (00) ±0.25 Pa Pa Span accuracy (¹⁰ , (00) ±11 ±2.5 Pa Span accuracy (¹⁰ , (00) ±11 ±2.5 Pa Span accuracy (¹⁰ , (00) ±13 ±0.3 ±0.5 % of reading Span accuracy (¹⁰ , (00) ±13 ±0.3 ±0.5 % of reading or 10 °C Soloo Pa devices Span ±0.3 ±0.5 % of reading per 10 °C Soloo Pa devices Farameter Min. Typ. Max. Unit Scale factor (¹⁰) 05000/0±5000 Pa ±1 Pa Pa Noise level (RMS) 05000/0.	Span accuracy ^{(9), (10)}			±1.5	±3	% of reading
Z500 Pa devices Min. Typ. Max. Unit Scale factor ⁽⁸⁾ 02500/0±2500 Pa 12 counts/Pa Noise level (RMS) ±0.5 Pa Offset warm-up shift ±0.5 Pa/year Offset long term stability ⁽⁷⁾ ±0.5 Pa/sea Offset repeatability ±0.5 Pa Span repeatability ^{(9), (10)} ±0.25 % of reading Zero pressure offset accuracy ⁽¹⁰⁾ ±1 ±2.5 Pa Span accuracy ^{(10), (10)} ±1.5 ±3 % of reading Thermal effects (-2085 °C) Offset ±5.5 Pa Span ±0.3 ±0.5 % of reading per 10 °C Sole level (RMS) 05000/0±5000 Pa 6 counts/Pa Offset marm-up shift 11 Pa Pa Offset repeatability ^{(9), (10)} ±1 Pa Pa Offset repeatability ⁽¹⁰⁾ ±1 Pa Pa Offset repeatability ⁽¹⁰⁾ ±1 Pa Pa Offset repeatability ⁽¹⁰⁾ ±1<		Offset			±2.5	Pa
$\begin{array}{ c c c c } \hline Parameter & Min. Typ. Max. Unit \\ \hline Scale factor (3) 02500/0±2500 Pa & 12 & counts/Pa \\ \hline Noise level (RMS) & to 5 & Pa \\ \hline Offset warm-up shift & to 5 & Pa \\ \hline Offset warm-up shift & to 5 & Pa \\ \hline Offset matability (7) & to 5 & Pa \\ \hline Span repeatability (9).(10) & to 5 & 10 & Pa \\ \hline Span couracy (9).(10) & to 5 & 10 & Pa \\ \hline Span couracy (9).(10) & to 5 & 10 & Pa \\ \hline Span accuracy (9).(10) & to 5 & 10 & Pa \\ \hline Span accuracy (9).(10) & to 5 & 10 & No \\ \hline Span couracy (9).(10) & to 5 & 11 & 125 & Pa \\ \hline Span accuracy (9).(10) & to 5 & Pa \\ \hline Span accuracy (9).(10) & to 5 & Pa \\ \hline Span accuracy (9).(10) & to 5 & Pa \\ \hline Span accuracy (9).(10) & to 5 & Pa \\ \hline Span (Ste Star Star Star Star Star Star Star Star$		Span		±0.3	±0.5	% of reading per 10 °C
Scale factor (6) 02500/0±2500 Pa 12 counts/Pa Noise level (RMS) ±0.5 Pa Offset warm-up shift ±0.5 Pa/year Offset repeatability (7) ±0.5 Pa Offset repeatability (7) ±0.5 Pa Span repeatability (9, 00) ±0.5 Pa Zero pressure offset accuracy (9) ±1 ±2.5 Pa Span accuracy (9, 00) ±1.5 ±3 % of reading Thermal effects (-2085 °C) Offset ±1.5 ±3 % of reading Pa Span accuracy (9, 00) 05000/0±5000 Pa ±0.3 ±0.5 % of reading Pa Span accuracy (10) 11 ±1.5 ±3 % of reading Pa Span accuracy (10) 05000/0±5000 Pa ±0.3 ±0.5 % of reading Pa Solos level (RMS) 05000/0±5000 Pa ±1 Pa counts/Pa Offset long term stability (7) 1 ±1 Pa counts/Pa Offset long term stability (7) 1 ±1 Pa counts/Pa <t< td=""><td>2500 Pa devices</td><td></td><td></td><td></td><td></td><td></td></t<>	2500 Pa devices					
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Offset varue y shift interview (and y) interview (and y) <td< td=""><td>Scale factor ⁽⁸⁾</td><td>02500/0±2500 Pa</td><td></td><td>12</td><td></td><td>counts/Pa</td></td<>	Scale factor ⁽⁸⁾	02500/0±2500 Pa		12		counts/Pa
Offset long term stability (7) ±0.5 Pa Offset repeatability (9), (10) ±0.5 Pa Span repeatability (9), (10) ±0.25 % of reading Zero pressure offset accuracy (9), (10) ±1.5 ±3.2 % of reading Span accuracy (9), (10) ±1.5 ±3.2 % of reading Thermal effects (-2085 °C) Offset ±1.5 ±3.2 % of reading Span ±0.3 ±0.5 % of reading per 10 °C % of reading per 10 °C 5000 Pa devices % of reading per 10 °C % of reading per 10 °C Scale factor (8) 05000/0±5000 Pa 6 counts/Pa Noise level (RMS) ±1 Pa counts/Pa Offset repeatability (7) ±1 Pa Pa Offset repeatability (7) ±1 Pa Pa Offset repeatability (9), (10) ±1 Pa Pa Zero pressure offset accuracy (9), (10) ±2 ±5 Pa Zero pressure offset accuracy (9), (10) ±12 ±3 % of reading Zero pressure offset accuracy (9), (10) ±12 ±3 % of reading	Noise level (RMS)			±0.5		Pa
Offset repeatability ± 0.5 PaSpan repeatability ± 0.25 % of readingZero pressure offset accuracy ± 1 ± 2.5 PaSpan accuracy ± 1.5 ± 3 % of readingThermal effects (-2085 °C)Offset ± 1.5 ± 3 % of readingThermal effectsOffset ± 0.3 ± 0.5 % of reading per 10 °CSolo Pa devices ± 0.3 ± 0.5 % of reading per 10 °CParameterMin.Typ.Max.UnitScale factor ⁽⁸⁾ $05000/0\pm 5000$ Pa6counts/PaNoise level (RMS) $05000/0\pm 5000$ Pa6counts/PaOffset long term stability ⁽⁷⁾ 11 Pa/yearOffset long term stability ⁽⁷⁾ ± 1.5 ± 1.5 PaZero pressure offset accuracy ⁽⁸⁾ (10) ± 0.25 $\%$ of readingZero pressure offset accuracy ⁽⁹⁾ (10) ± 0.25 $\%$ of readingZero pressure offset accuracy ⁽⁹⁾ (10) ± 1.5 ± 3.3 $\%$ of readingZero pressure offset accuracy ⁽⁹⁾ (10) ± 1.5 ± 3.3 $\%$ of readingSpan accuracy ^{(9), (10)} ± 1.5 ± 3.3 $\%$ of readingThermal effectsOffset (-2085 °C) ± 1.5 ± 3.3 $\%$ of readingSpan (-585 °C) ± 0.3 ± 0.75 $\%$ of reading per 10 °C					less than noise	
Span repeatability ^{(9), (10)} ±0.25 % of reading Zero pressure offset accuracy ⁽⁹⁾ ±1 ±2.5 Pa Span accuracy ^{(9), (10)} ±1.5 ±3 % of reading Thermal effects (-2085 °C) Offset ±1.5 ±3 % of reading Span ±0.3 ±5 Pa % of reading per 10 °C 5000 Pa devices ±0.3 ±0.5 % of reading per 10 °C Scale factor ⁽⁶⁾ 05000/0±5000 Pa 6 counts/Pa Noise level (RMS) 05000/0±5000 Pa 6 counts/Pa Offset warm-up shift 1 Pa Pa Offset repeatability ⁽⁷⁾ ±1 Pa Pa/year Offset repeatability ^{(9), (10)} ±1 Pa % of reading Span accuracy ^{(9), (10)} ±1 Pa % of reading Zero pressure offset accuracy ^{(9), (10)} ±2 ±5 Pa Span accuracy ^{(9), (10)} ±1.5 ±3 % of reading Thermal effects Offset (-2085 °C) ±0.3 ±0.75 % of reading	Offset long term stability (7)			±0.5		Pa/year
Zero pressure offset accuracy (9) ± 1 ± 2.5 PaSpan accuracy $(9), (10)$ ± 1.5 ± 3.3 $\%$ of readingThermal effects $(-2085 \ ^{\circ}C)$ Offset ± 0.3 ± 0.5 \aleph of reading per 10 \ ^{\circ}CSpan ± 0.3 ± 0.5 $\%$ of reading per 10 \ ^{\circ}C5000 Pa devices ± 0.3 ± 0.5 $\%$ of reading per 10 \ ^{\circ}CParameterMin.Typ.Max.UnitScale factor (3) $05000/0\pm 5000 Pa$ 6counts/PaNoise level (RMS) $5000/0\pm 5000 Pa$ 6counts/PaOffset warm-up shift11PaPaOffset repeatability (7) ± 11 PaSpan repeatability $(9), (10)$ ± 12 ± 11 Zero pressure offset accuracy (9) ± 12 ± 5 Span accuracy $(9), (10)$ ± 1.5 ± 3.3 $\%$ of readingThermal effectsOffset (-2085 \ ^{\circ}C) ± 1.5 ± 1.5 ± 1.0 Span (-585 \ ^{\circ}C) ± 0.3 ± 0.75 $\%$ of reading per 10 \ ^{\circ}C				±0.5		Pa
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Span repeatability ^{(9), (10)}			±0.25		% of reading
$\begin{array}{c c c c c c c c c c c c c c c c c c c $				±1	±2.5	Pa
Span±0.3±0.5% of reading per 10 °C5000 Pa devicesParameterMin.Typ.Max.UnitScale factor ⁽⁸⁾ 05000/0±5000 Pa6counts/PaNoise level (RMS)±1PaOffset warm-up shift±1PaOffset long term stability ⁽⁷⁾ ±1Pa/yearOffset repeatability±1Pa/yearSpan repeatability ^{(9), (10)} ±1PaZero pressure offset accuracy ⁽⁹⁾ ±2±5Span accuracy ^{(9), (10)} ±1.5±3Thermal effectsOffset (-2085 °C)±0.3Span (-585 °C)±0.3±0.75Sola±0.75	Span accuracy ^{(9), (10)}			±1.5	±3	% of reading
5000 Pa devices Min. Typ. Max. Unit Scale factor ^(B) 05000/0±5000 Pa 6 counts/Pa Noise level (RMS) ±1 Pa Offset warm-up shift ±1 Pa/year Offset long term stability ⁽⁷⁾ ±1 Pa/year Offset repeatability ±1 Pa Span repeatability ^{(9), (10)} ±1 Pa Zero pressure offset accuracy ⁽⁹⁾ ±1.5 ±3 Span accuracy ^{(9), (10)} ±1.5 ±10 Pa Thermal effects Offset (-2085 °C) ±0.3 ±0.75 % of reading per 10 °C	Thermal effects (-2085 °C)	Offset			±5	Pa
$\begin{array}{c c c c c c c c c c c c c c c c c c c $		Span		±0.3	±0.5	% of reading per 10 °C
Scale factor ⁽⁸⁾ 05000/0±5000 Pa 6 counts/Pa Noise level (RMS) ±1 Pa Offset warm-up shift iess than noise Pa/year Offset long term stability ⁽⁷⁾ ±1 Pa/year Offset repeatability ⁽⁹⁾ . ⁽¹⁰⁾ ±1 Pa/year Span repeatability ^{(9), (10)} ±0.25 % of reading Zero pressure offset accuracy ⁽⁹⁾ . ⁽¹⁰⁾ ±1.5 ±3 % of reading Span accuracy ^{(9), (10)} 0ffset (-2085 °C) ±1.5 ±10 Pa Span (-585 °C) 5pan (-585 °C) ±0.3 ±0.75 % of reading per 10 °C	5000 Pa devices					
Noise level (RMS) ± 1 PaOffset warm-up shiftless than noiseless than noiseOffset long term stability (7) ± 1 Pa/yearOffset repeatability ± 1 PaOffset repeatability (9), (10) ± 1 PaZero pressure offset accuracy (9) ± 2 ± 5 Span accuracy (9), (10) ± 1.5 ± 3 Thermal effectsOffset (-2085 °C) Span (-585 °C) ± 0.3 ± 0.75	Parameter		Min.	Тур.	Max.	Unit
Offset warm-up shift less than noise Offset long term stability ⁽⁷⁾ ±1 Pa/year Offset repeatability ±1 Pa Offset repeatability ^{(9), (10)} ±0.25 % of reading Zero pressure offset accuracy ⁽⁹⁾ ±2 ±5 Pa Span accuracy ^{(9), (10)} ±1.5 ±3 % of reading Thermal effects Offset (-2085 °C) ±0.3 ±0.75 % of reading per 10 °C	Scale factor ⁽⁸⁾	05000/0±5000 Pa		6		counts/Pa
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Noise level (RMS)			±1		Pa
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $					less than noise	
Span repeatability ^{(9), (10)} ±0.25 % of reading Zero pressure offset accuracy ⁽⁹⁾ ±2 ±5 Pa Span accuracy ^{(9), (10)} ±1.5 ±3 % of reading Thermal effects Offset (-2085 °C) ±0.3 ±10.75 Pa Span (-585 °C) ±0.3 ±0.75 % of reading per 10 °C	Offset long term stability ⁽⁷⁾			±1		Pa/year
Zero pressure offset accuracy ⁽⁹⁾ ±2 ±5 Pa Span accuracy ^{(9), (10)} ±1.5 ±3.3 % of reading Thermal effects Offset (-2085 °C) ±1.3 ±10 Pa Span (-585 °C) ±0.3 ±0.75 % of reading per 10 °C				±1		Pa
Span accuracy ^{(9), (10)} ±1.5 ±3.2 % of reading Thermal effects Offset (-2085 °C) ±10 Pa Span (-585 °C) ±0.3 ±0.75 % of reading per 10 °C	Span repeatability ^{(9), (10)}			±0.25		% of reading
Diffset (-2085 °C) ±10 Pa Span (-585 °C) ±0.3 ±0.75 % of reading per 10 °C	Zero pressure offset accuracy ⁽⁹⁾			±2	±5	Pa
Span (-585 °C) ±0.3 ±0.75 % of reading per 10 °C	Span accuracy ^{(9), (10)}			±1.5	±3	% of reading
	Thermal effects	Offset (-2085 °C)			±10	Ра
(-205 °C) ±0.75 ±1.5 % of reading per 10 °C		Span (-585 °C)		±0.3	±0.75	% of reading per 10 °C
		(-205 °C)		±0.75	±1.5	% of reading per 10 °C

Specification notes (cont.)

E / 11823 / C

(6) 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:

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

 $\begin{array}{l} \Delta P_{\text{eff}} = \text{True differential pressure} \\ \Delta P_{\frac{S_{\text{ensore}}}{S_{\text{sensor}}}} = \text{Differential pressure as indicated by output voltage} \\ P_{\frac{1}{abs}} = \text{Current absolute common mode pressure} \end{array}$

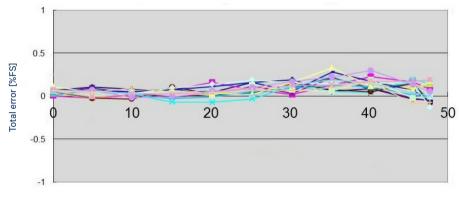
- (7) Figure based on accelerated lifetime test of 1000 hours at 85 °C biased burn-in.
- (8) The digital output signal is a signed, two complement integer. Negative pressures will result in a negative output
- (9) Zero pressure offset accuracy and span accuracy are uncorrelated uncertainties. They can 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) For pressure ranges 1250 Pa and 2500 Pa, more accurate absolute pressure correction procedures than in (6) might be needed. See Application Note "Absolute pressure correction of LME/LMI pressure sensors".

LMI series – digital low differential pressure sensors

Performance characteristics (cont.)

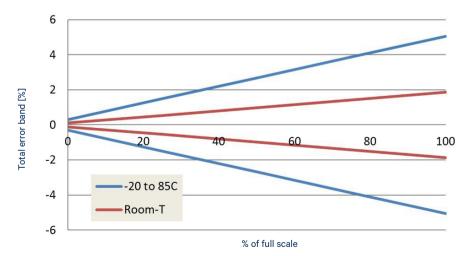
Temperature sensor				
Parameter	Min.	Тур.	Max.	Unit
Scale factor (digital output)		72		counts/°C

Total accuracy (12)



Pressure [Pa]

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





Specification notes (cont.)

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

LMI series – digital low differential pressure sensors

Noise plot

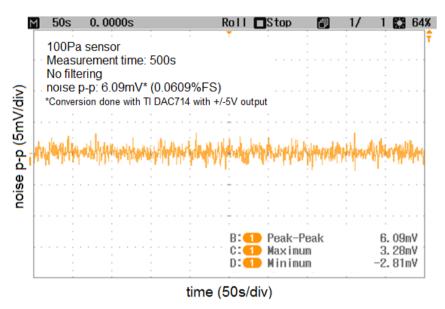


Fig. 3: Typical noise plot of a 100 Pa LMI sensor

LMI series – digital low differential pressure sensors

I²C bus interface specifications

Introduction

The LMI serial interface operates using a standard 2-wire I²C bus. For detailed specifications of the I²C protocol, see UM10204 - I²C Bus Specification and User Manual from NXP.

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.

Signal control

Bus not busy: During idle periods, both data line (SDA) and

clock line (SCL) remain HIGH.

START condition (S): A HIGH to LOW transition of SDA while SCL is HIGH is interpreted as START condition. START conditions are always generated by the master. Each initial request for a pressure value has to begin with a START condition.

STOP condition (P): A LOW to HIGH transition of SDA while SCL is HIGH defines a STOP condition. STOP conditions are always generated by the master. More than one request for the current pressure value can be transmitted without generation of intermediate STOP conditions.

DATA valid (D): The state of SDA represents valid data when, after a START condition, SDA is stable for the duration of a HIGH period of SCL. SDA should only change during a LOW period of SCL. There is one SCL pulse per bit of data.

Acknowledge (A): Data are transferred as bytes (i.e., 8 bits) on the serial bus, most-significant-bit (MSB) first. After each byte, the receiving device – master or slave – is obliged to pull SDA LOW to acknowledge the reception of data. The master device must generate an extra clock pulse for this purpose. When acknowledge is missed, the slave transmitter becomes inactive. The master device must either re-send the last command, or generate a STOP condition in this case.

Slave address: The I²C-bus master-slave concept requires a unique address for each device. The LMI device's address is modifiable based on the connection of the ADRO and ADR1 pins. ADRx connected to GND represents logic-0, whereas a connection to VS represents logic-1. This allows for four unique assignable addresses:

Base address (binary)	ADR1	ADR0	7-bit I²C address (binary)	7-bit I²C address (hexadecimal)
	0	0	1011100	0x5C
10111	0	1	1011101	0x5D
10111	1	0	1011110	0x5E
	1	1	1011111	0x5F

After generating a START condition, the master sends the address byte containing the 7-bit address, followed by a data direction bit (R/W). A "O" indicates a transmission from master to slave (WRITE), a "1" indicates a data request (READ).

MSB							LSB
1	0	1	1	1	ADR1	ADRO	R/W

DATA operation: The sensor starts to send 2 data bytes containing the current pressure value (shown in Fig. 4 as "Readout of result").

LMI series – digital low differential pressure sensors

I²C bus interface specifications (cont.)

I²C command set

The LMI device implements the following commands: Bytes to read from LMI Command Description Туре N/A 0x11 w Reset firmware 2 0x20 Start pressure conversion W/R 0x23 Retrieve electronic signature 54 W/R

Reset firmware

Writing this command to the LMI device resets the firmware's program counter. The LMI device does not return any data to be read.

Start pressure conversion

Writing this command to the LMI device starts a conversion of pressure data. When the conversion is complete, the LMI device returns the pressure data in two bytes. The 15-bit conversion result is clocked out least-significant byte first:

Low byte								High	byte						
MSB							LSB	MSB							LSB
D7	D6	D5	D4	D3	D2	D1	R	D15	D14	D13	D12	D11	D10	D9	D8

Data are delivered in two's complement format.

Ensure that the bytes are re-ordered and the R bit is kept, padding the value to 16 bits, such that converting output to Pascals via scale factor is correct:

High byte								Low byte							
MSB							LSB	MSB							LSB
D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	R

This command wakes the device from sleep and starts a conversion. This conversion-start command only needs to be sent once; consecutive I²C read commands commands (i.e., the sensor address with the R/W bit set to "1" may be sent to continuously acquire new data from the device.

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



LMI series – digital low differential pressure sensors

I²C bus interface specifications (cont.)

```
// The delay between consecutive read commands determines whether or not the
// device works in Continuous or low-power mode.
// Assumption: The sensor's address is defined with ADR0 = ADR1 = 0.
byte sensorAddress = 0x5c;
byte startConversionCommand = 0x20;
byte lowByte, highByte;
short pressureDataInCounts;
// Write the command to the bus (not shown in Fig. 4).
i2c.sendStartCondition();
i2c.beginTransmissionTo(sensorAddress); // Send 0xB8 (0x5C with R/W bit = 0).
i2c.writeByte(startConversionCommand); // Send 0x20.
i2c.sendStopCondition();
// Read the result from the LMI device.
i2c.sendStartCondition();
/* ----- READ1 in Fig. 4 ----- */
i2c.requestDataFrom(sensorAddress);
                                      // Send 0 \times B9 (0 \times 5C with R/W bit = 1).
/* ---- RESULT1 in Fig. 4 ---- */
                                    // Read first byte returned by sensor.
// Read second byte returned by sensor.
lowByte = i2c.readByte();
highByte = i2c.readByte();
i2c.sendStopCondition();
// Read the result again from the LMI device.
i2c.sendStartCondition();
/* ----- READ2 in Fig. 4 ----- */
i2c.requestDataFrom(sensorAddress); // Send 0xB9 (0x5C with R/W bit = 1).
/* ---- RESULT2 in Fig. 4 ---- */
lowByte = i2c.readByte();
                                       // Read first byte returned by sensor.
highByte = i2c.readByte();
                                      // Read second byte returned by sensor.
i2c.sendStopCondition();
```

// Repeat read steps as necessary.

LMI series – digital low differential pressure sensors

I²C bus interface specifications (cont.)

Electronic signature

Writing this command to the LMI devices retrieves the sensor's electronic signature. A sequence of 54 bytes should be read, providing the following information:

Sequence	Parameter	Size	Data type	Comment
0-1	Firmware version	2 bytes	byte[2] array	byte[1] -> major version number, byte[0] -> minor version number
2-12	Part number (11 characters)	11 bytes	char[12] array	
13-19	Lot number (7 characters)	7 bytes	char[7] array	e.g. CV7T001
20-21	Pressure range	2 bytes	unsigned int	0 to 65535, MSB-first
22	Output type	1 byte	char	e.g. U or B
23-24	Scale factor	2 bytes	unsigned int	0 to 65535, MSB-first
25-26	Calibration ID	2 bytes	2 x char	e.g. AA
27	Week number	1 byte	short int	0 to 255
28	Year number	1 byte	short int	0 to 255
29-30	Sequence number	2 bytes	unsigned int	0 to 65535, MSB-first
31-53	Reserved	23 bytes	0xFF	Reserved for future use

Sample output string as CSV:

Bytes 25-30 comprise the sensor's serial number.

The above string would translate to:

- Firmware version 1.2
- Part # LMIS100UB3S
- Lot # CV7T006
- Pressure range 100
- Output type U
- Scale factor 300
- Serial number AC0717-0001

LMI series – digital low differential pressure sensors

I²C bus interface specifications (cont.)

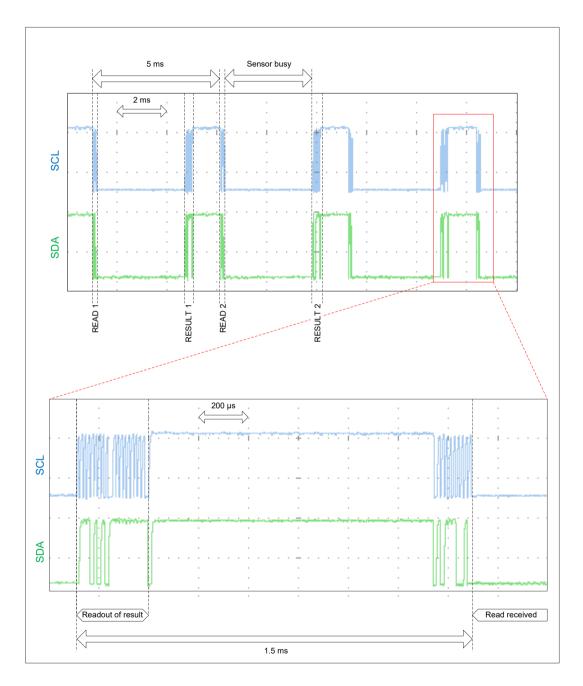
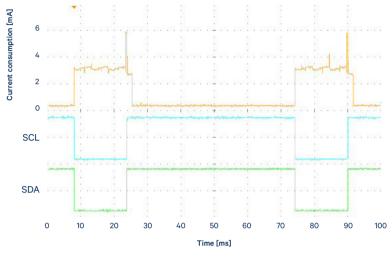


Fig. 4: Continuous mode operation

LMI series – digital low differential pressure sensors



I²C bus interface specifications (cont.)

Fig. 5: Low-power mode

Continuous vs low-power mode operation

LMI offers two modes of operation: <u>Continuous mode</u>, which provides a near-continuous stream of pressure data, and <u>low-power mode</u>, which wakes the device from sleep to serve pressure data "on-demand". The first measurement in either mode is available after a warm-up and conversion sequence, which takes approximately 25 ms. The device holds the SCL line low during warm-up and conversion, effectively blocking the I²C bus during this time.

Continuous mode and low-power mode differ only in how quickly subsequent I²C read commands (i.e., the sensor address with the R/W bit set to 1) are sent to the device. Specifically, if the time between the sensor starting to clock out a pressure result (marked as "readout of result" in Figure 4) and the time it fully receives the next I²C read command (marked as "read received" in Figure 4) is 1.5 ms or less, the device enters Continuous mode, which prevents the device from sleeping between conversions. Fresh data are available every 5 ms in this mode of operation. Conversely, if the time between the sensor starting to clock out a pressure result and the time it fully receives the next I²C read command is greater than 1.5 ms, the device enters low-power mode and returns to sleep until the next I²C read command is fully clocked in. So long as power remains available, the start-conversion command (0x20) does not need to be re-sent. Note that in this mode, the shortest possible refresh rate for data is once every 15-16 ms.

LMI series – digital low differential pressure sensors

I²C bus interface specifications (cont.)

Extended data readout

LMI devices will read out extended sensor data if the user desires. Instead of reading out only two bytes of pressure data, the user may choose to read out four bytes of data, corresponding to:

Byte 1	Byte 2	Byte 3	Byte 4			
Press	ure	Temperature				
Signed 15-	bit value	Signed 16-bit value after offset subtraction and correction				
LSB	MSB	LSB	MSB			

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

$$\text{Temperature [°C]} = \frac{\text{TS} - \text{TS}_0 [\text{counts}]}{\text{Scale factor}_{\text{TS}} \left[\frac{\text{counts}}{\text{°C}} \right]} + \text{T}_0 [°C]$$

where

TS is the actual sensor readout; TS₀ is the sensor readout at known temperature $T_0^{(13)}$; Scale factor_{TS} = 72 counts/°C

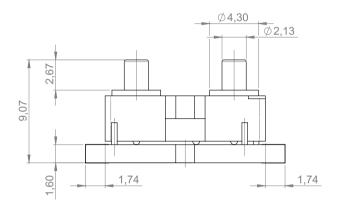
```
// The delay between consecutive read commands determines whether or not the
// device works in Continuous or low-power mode.
// Assumption: The sensor's address is defined with ADR0 = ADR1 = 0.
byte sensorAddress = 0x5c;
byte startConversionCommand = 0x20;
byte lowByte, highByte;
short pressureDataInCounts;
// Write the command to the bus (not shown in Figure 4).
i2c.sendStartCondition();
i2c.beginTransmissionTo(sensorAddress); // Send 0xB8 (0x5C with R/W bit = 0).
i2c.writeByte(startConversionCommand); // Send 0x20.
i2c.sendStopCondition();
// Read the result from the LMI device.
i2c.sendStartCondition();
i2c.requestDataFrom(sensorAddress);
                                     // Send 0 \times B9 (0 \times 5C with R/W bit = 1).
lowBytePressure = i2c.readByte();
                                    // Read low byte, pressure data.
highBytePressure = i2c.readByte();
                                    // Read high byte, pressure data.
                                     // Read low byte, temperature data.
lowByteTemperature = i2c.readByte();
highByteTemperature = i2c.readByte();
                                      // Read high byte, temperature data.
i2c.sendStopCondition();
```

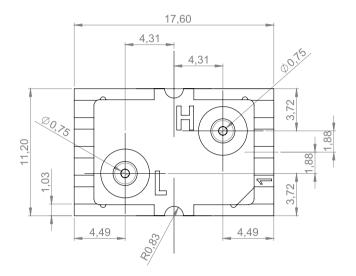
Specification notes (cont.)

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

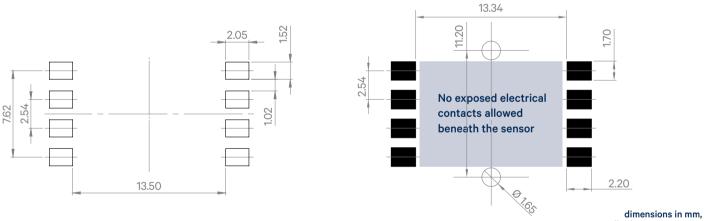
LMI series – digital low differential pressure sensors

Dimensional drawing





Suggested PCB land pattern



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

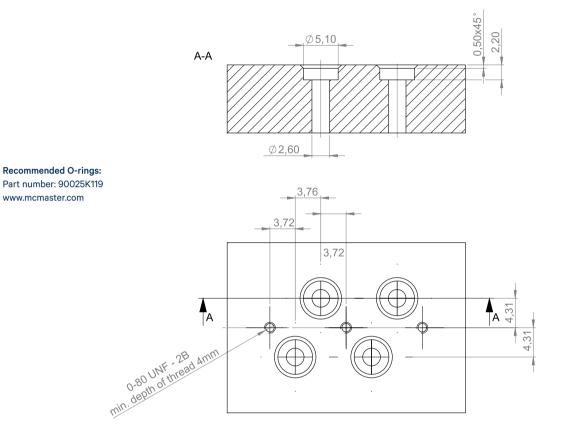
Electrical connection

Sensor PCB footprint

Pin	Function	
1	Reserved	5 1 4
2	Reserved	
3	GND	6 3
4	Vs	
5	ADR0	$7 \bigsqcup (\bigcirc)_{\square}$ $\bigsqcup 2$
6	ADR1	
7	SCL	
8	SDA	

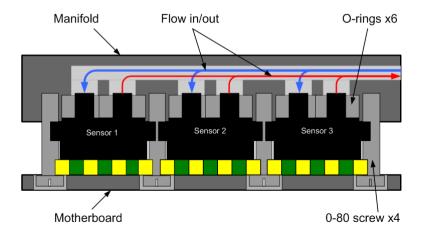
LMI series – digital low differential pressure sensors

Manifold diagram for two side-by-side mounted sensors



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

Manifold diagram for multiple side-by-side mounted sensors

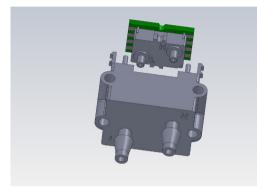


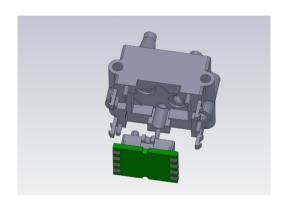
LMI series – digital low differential pressure sensors

Custom adaptor

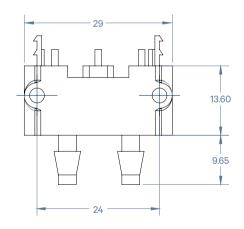
The LMI series pressure sensors can optionally be equipped with a custom adaptor for your application-specific mounting requirements. It is designed for applications where wider port spacing and diameter are needed. Please contact First Sensor for more information.

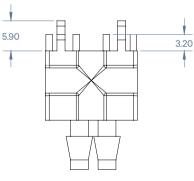
3D views of a custom adaptor for the LMI pressure sensor

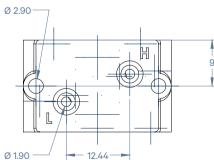


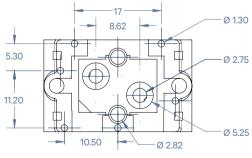


Dimensional drawing ZA009102 plug-in adaptor









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

dimensions in mm

LMI series – digital low differential pressure sensors

Gas mixture change (purge time)

The LMI 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 LMI 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 LMI 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			ibration	Housing	Output	Grade	
LMI	S025	25 Pa (0.1 inH ₂ O)	В	Bidirectional	B [SMD, 2 ports, axial, same side]	3 [Non-ratiometric, 3 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)	_					
	M012	1250 Pa (5 inH ₂ 0)	_					
	M025	2500 Pa (10 inH ₂ O)	_					
	M050	5000 Pa (20 inH ₂ O)	-					

Order code example: LMIS025UB3S

Accessories (order separately)

ZA009102 Plug-in adaptor with wider port spacing and diameter