SMT Thermal MEMS
Differential Pressure Sensor

MDP2000/3000

Features

- *Pressure range up to ±500Pa with high accuracy of ±3.0% m.v.*
- *Pressure based on thermal micro-flow measurement*
- *Outstanding hysteresis and repeatability*
- *Linearized and temperature compensated*
- *SPI with 16bit resolution*
- *Cost Effective*
- *RoHS and REACH compliant*
- *SMT Package*

Applications

- *Medical CPAP and Ventilator*
- *HAVC and building control solution*
- *Burner Control*
- *Filter Monitoring*
- *Process Control and Automation*

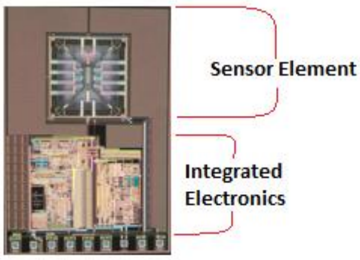

Image of flow sensor

General Description

MEMSIC's MDP2000 series MEMS differential pressure sensors measure ultra-low gas pressures covering the range of up to ±500Pa (±2 inH2O). The technology is based on MEMSIC's highly successful proprietary CMOS thermal accelerometers already sold in millions. MDP2000 series offers a wide dynamic range, superb long-term stability, and outstanding repeatability and hysteresis.

MEMSIC's thermal flow sensing element is monolithically integrated with CMOS signal processing circuitry and embedded software capable of providing SPI output of 15 bit digital raw counts. The polynomial fitting calibration coefficients are provided by QR code label for easy scanning to convert output to differential pressure..

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1. Performance

Parameter[1]	Value	Unit
Measurement Range	±500	Pa
Zero-point Accuracy	±0.5	Pa
Span Accuracy	± 3.0	% m.v
Linearity (Least Square)	0.5	%F.S
Gas Flow Through Sensor	100	ml/min
Zero-point Repeatability and Hysteresis[2]	0.2	Pa
Response Time/Communication Update Rate	8	ms
Span Repeatability and Hysteresis[3]	0.5	% m.v.
Over Pressure[4]	5	Bar
Temperature Compensation Coefficient	TBD	
Span Shift due to Temperature Variation	± 0.05	%m.v. per °C
Offset Shift due to Temperature Variation	< Noise	
Offset Stability	<0.1	Pa/year

1: All sensor specifications are valid with air as medium at 21°C temperatures with 1 standard atmospheric pressure 101325Pa), 50% RH, and a 3.3V DC power supply, unless otherwise specified.

2,3: Accuracy specifications apply over operating conditions. With 16-bit resolution, this accuracy represents the total combination of non-linearity, hysteresis, zero and span shift, repeatability and temperature effects.

4: MDP2000 operates based on thermal mass flow principle. Gas flow is required to measure the pressure difference.

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2. Environment

Parameter	Value	Unit
Operating Temperature	-20 to +80	°C
Storage Temperature	-40 to +125	°C
Relative Humidity (Non-Condensing)	To 95	%
Radiated Susceptibility	10	V/m
ESD	4/(8)	kV
Shock	50G @ 5 ms	G_{Peak}
Vibration (5-2000 Hz)	20	G_{rms}
Media Compatibility	N2, O2, Air	
Orientation Sensitivity	TBD	Pa
Protection	IEC IP30	

3. Electrical

Parameter	Description	Min	Typ	Max	Unit
Flow Output (SPI)	Positive Pressure	32768		65535	counts
	Negative Pressure	32768		0	
Temperature Output	SPI		10		bits
Temperature Resolution			0.3		ºC/LSB
A/D Sample Rate				150	Hz
SPI Clock Frequency			2		MHz
Supply Voltage		2.7	3.3	5.5	Vdc
Operating Current	Zero Flow			2.4	mA
	Max Flow Measurement			4.2	mA
Sleep Current				0.1	uA
Wake UpTime	@ 25 KHz Clock Frequency	100			ms

4. Material

Parameter	Description
Wetted Material	LCP, FR4, Silicon Nitrite, Epoxy, Gold

5. Serial Communication Interface

MDP2000/3000 employs 4-wire SPI interface to receive commands from an external host, as well as to report measured data. A timing diagram of a read/write operation is shown on Fig.1 below. Fig.2 shows the detailed SPI timing characteristics.

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The following four pins are involved in SPI communication:

- Serial Select (SS), active high, indicates beginning of a read/write event. This is controlled by the master device.
- MOSI (Master Out Slave IN). Since MDP2000/3000 is a slave, this is the input to the circuit.
- MISO (Master In Slave Out). This is the output of this circuit.
- SCK (Serial Clock) is driven by the master and determines timing of all events.

Since multiple devices can share SCK, MISO, and MOSI lines, MISO line driver is high impedance when SS is low. Every communication event begins with SS transitioning high, and ends when SS falls. There must be exactly 24 rising SCK edges between rising and falling edges of SS. The MOSI pin should only change on the falling edge of SCK, and remain stable during rising edges of SCK. The SPI timing characteristics is listed in Table 3. The SPI clock frequency is 2 MHz typical. If the Master wants to write to MDP2000/3000, the first bit in the transmission should be a 1, followed by 6-bit register address, MSB first. Then 1 bit is a no care followed by 16 bits, MSB first, to be written to the register. Six address bits allow up to 64 different registers. If the Master wants to read data from MDP2000/3000, the first data in the transmission should be a 0, followed by 6 address bits and a single no-care bit. Starting on the 9-th rising edge of the SCK, data can be read on MISO pin. It will be changing on the falling clock edge, and it should be latched on the rising edge. Output data is shifted MSB first.

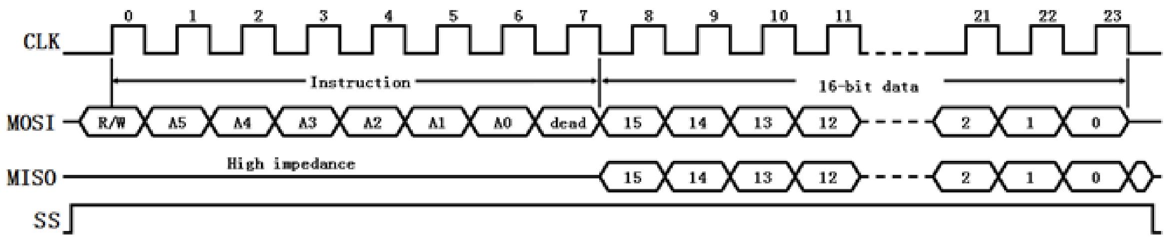

Figure 1: Read & Write Sequence

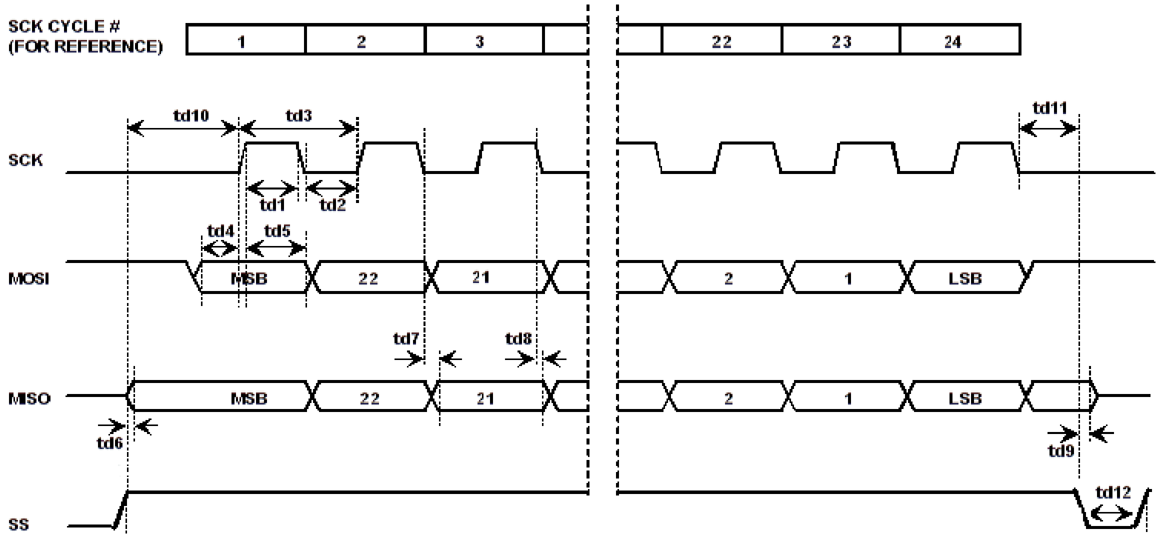

Figure 2: SPI Timing

5.1. Control Register Map

For MDP2000/MDP3000 SPI registers, please see the Table below.

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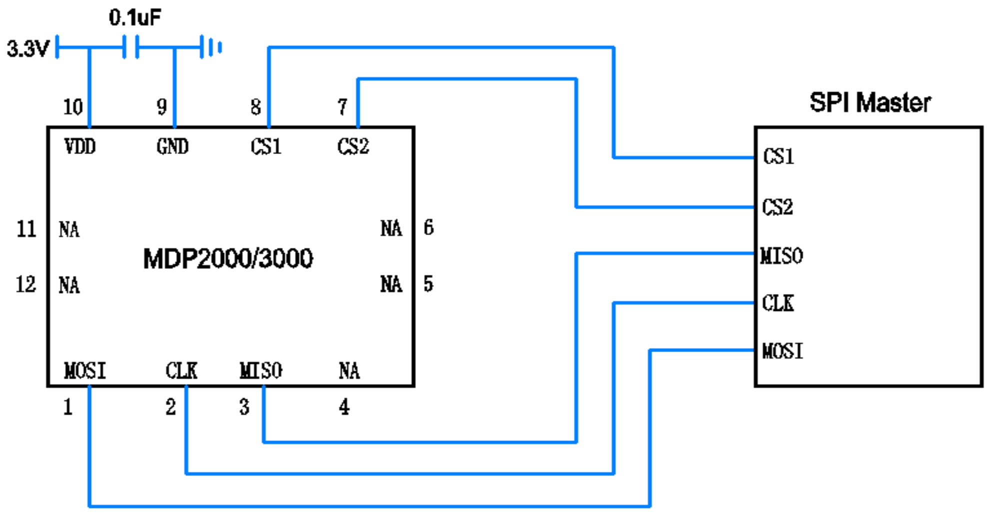
Address	Name	R/W, Master=0	R/W, Master=1	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0	Flow	R	Flow15	Flow14	Flow13	Flow12	Flow11	Flow10	Flow 9	Flow 8	Flow7	Flow 6	Flow 5	Flow 4	Flow 3	Flow2	Flow1	Flow0	N/A
2	Temp	R	N/A	N/A	N/A	N/A	N/A	N/A	T9	T8	T7	T6	T5	T4	T3	T2	T1	T0	N/A
4	Status	R/W	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Temp DRDY	Flow DRDY	Write 0's to clear
5	Control	W	RST	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Temp Dis	N/A	N/A	N/A	N/A	N/A	PD	N/A

Register 0 is 16-bit FLOW data output. This register is read-only.
Register 2 is Temperature data. Since this data is only 10 bits, six MSB's are set to 0. This register is read-only. The gas temperature sensor provides 10-bit (0.3°C/LSB) from -40°C to 85°C; $T_{Out(°C)}$ = (Tcount-426.2)/3.4176. The gas temperature sensor accuracy is +/-1ºC near at 25°C and +/-3°C near at -40°C and 85°C.
Please kindly note that the temperature sensor needs to be disabled firstly and then be enabled every time when the chip is powered up. This can avoid the instability issue of the temperature sensor. This setting can be done by writing 1 to TempDis bit (Bit6) in Control Register (Register5) to turn it off (Disable), followed by writing 0 to turn it on (Enable).
Register 4 is the Status register. When Flow and Temperature measurements are completed and the data is ready to be read, the 2 LSB's are set to 1. Bit 0 indicates Flow data is ready. Bit 1 indicates Temperature data is Ready. All the other bits are always 0's, which are not available.
Register 5 is Control register, Bit 0 is a power down bit. Writing a 1 into this location will put sensor into low power mode. This standby current is lower than 1μA. Bit 6 Temperature Disable. Writing a 1 into it turns off temperature sensor. All the other bits are not available.

Please kindly note that the temperature sensor need to be disabled firstly and then be enabled every time when the power is switched on to avoid the issue of the temperature sensor stability. This setting can be done by writing 1 to TempDis bit (Bit6) in Control Register (Register5) to turn it off (Disable), followed by writing 0 to turn it on (Enable).

5.2. Connection Diagram and Reference Design

The MDP2000 is offered one flow sensor while the MDP3000 includes two flow sensors for application requiring in-range fault detection. The schematic with a SPI interface is shown below.



Note: the capacitors should be placed as close as possible to the VDD pin

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5.3. Pinout Configuration

Pin No.	Name	Description
1	MOSI	Master Out, Slave In, SPI input pin
2	CLK	Serial clock for SPI bus
3	MISO	Master in Slave Out, SPI output pin
4	NA	Not available, should be left Not Connected.
5	NA	Not available, should be left Not Connected.
6	NA	Not available, should be left Not Connected.
7	CS2	Chip Select – Sensor 2, only available for MDP3000
8	CS1	Chip Select – Sensor 1
9	GND	SPI ground
10	VDD	SPI power supply, reference voltage (2.7V-5.5V)
11	NA	Not available, should be left Not Connected.
12	NA	Not available, should be left Not Connected.

6. Calibration Coefficients

The MDP2000/3000 outputs differential pressure and temperature digital raw counts with SPI interface as a response to differential pressure and offer two sets of calibration coefficients for MDP2000/3000. MEMSIC will provide the algorithm and coefficient, which customers could run on the external MCU.

The first set of calibration coefficients, defined as a0~a4, will be used to linearize the raw counts output vs. differential pressure. MDP2000/3000 will use 4^{th} order polynomial fitting linear function and the coefficients will be stored in the QR code label applied to the top side of the sensor, then customers can read them by scanning the QR label.

The second set of calibration coefficients, defined as C_T, will be used to compensate for temperature drift of the sensor. The temperature coefficient is a constant for MDP2000/3000.

Then, the final DP value after compensation, defined as DP_c, can be calculated as

Calculating Steps:

① Count = Count_raw -32768

③ DP_raw = a4*Count^4+a3*Count^3+a2*Count^2+a1*Count+a0

④ DP_c = DP_raw *(1+ C_T * (T_c - T_r))

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Count_raw : raw output from sensor (0~65535)
Count : subtracted 32768 by Count_raw (-32768~32767)
Count = Count_raw – 32768
DP_raw : DP in Pa(before linearization compensation)
DP_c : DP in Pa (after linearization compensation)
a0~a4 : coefficients of 4^{th} order polynomial for linearizing Count vs. DP_raw
T_c : actual temperature in degree C
T_r : reference temperature (=25℃)
C_T : coefficient of temperature compensation (/℃)

6.1. QR Label

The content of QR label compose of 11 character springs (CS) and all CSs are separated by one blank character, the definition of each CS is shown as bellow table.

CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9	CS10	CS11
SN No.	Forward a0	Forward a1	Forward a2	Forward a3	Forward a4	Reverse a0	Reverse a1	Reverse a2	Reverse a3	Reverse a4

CS1 is the series number which is unique to each device.
CS2~CS6 is Forward a0~a4 respectively, the coefficients of 4^{th} order polynomial of forward flow direction.
CS7~CS11 is Reverse a0~a4 respectively, the coefficients of 4^{th} order polynomial of reverse flow direction.

6.2. Temperature Coefficients

MDP2000/3000 use a constant as the temperature coefficient.

C_T = 0.745% (from MDP200 units)

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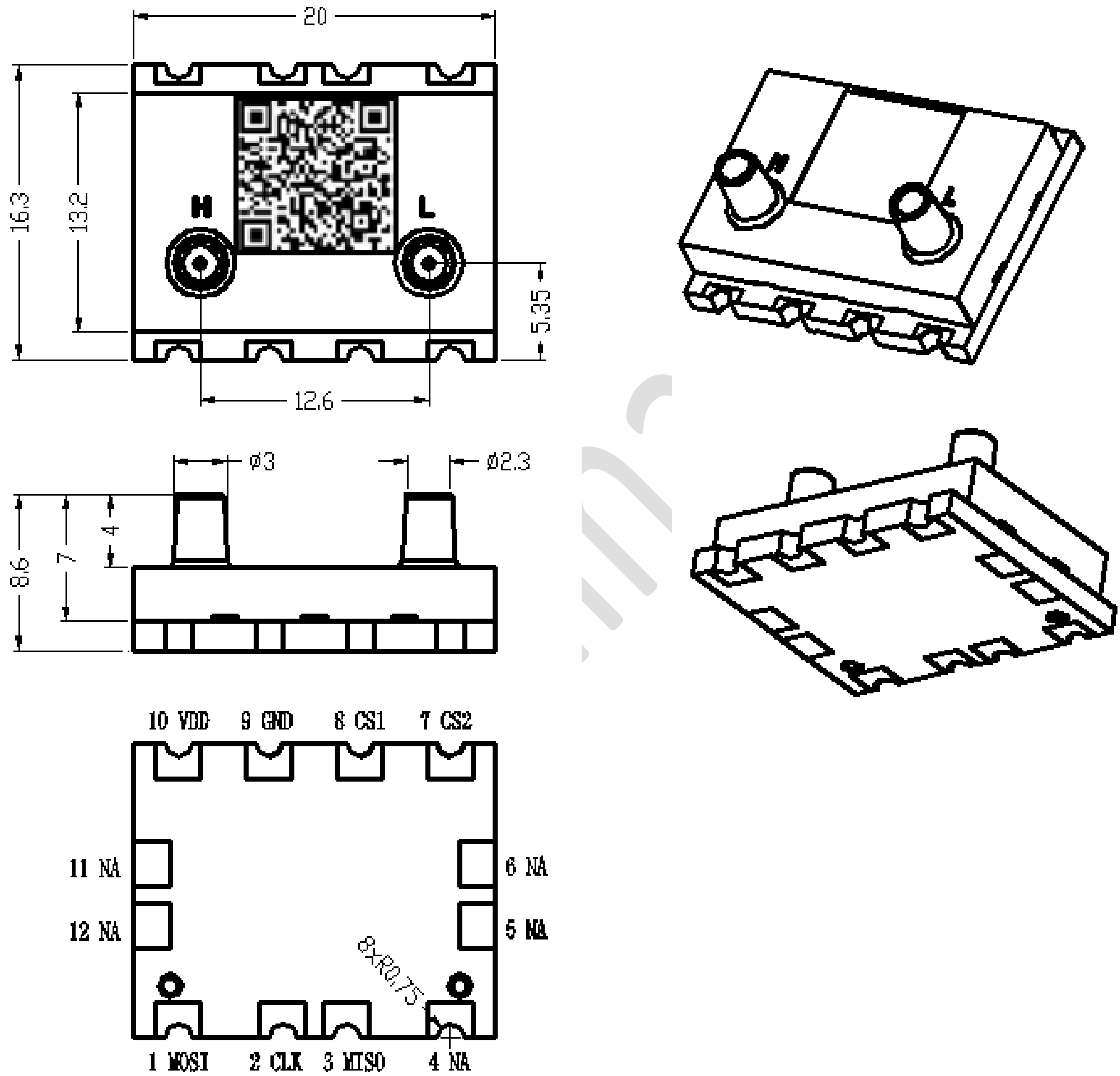
7. Mechanical Specifications

Note: All dimensions are in mm. The tolerance not specified is +/-0.1mm



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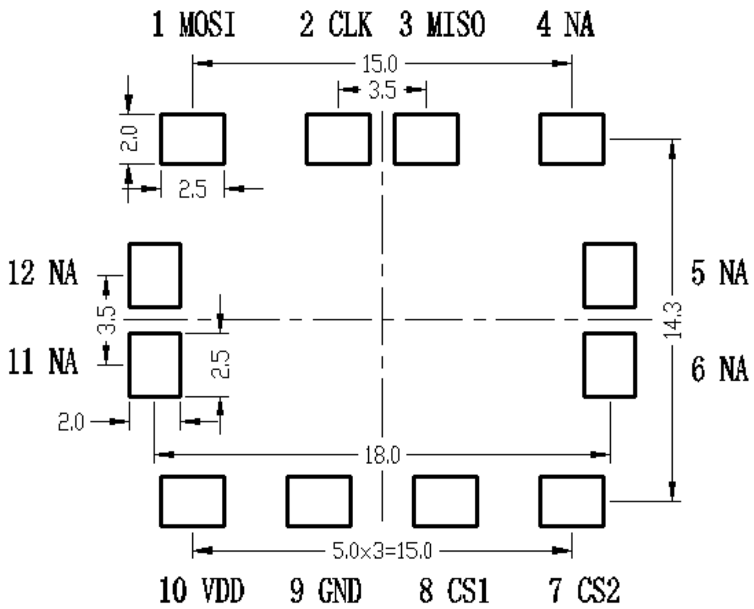
8. PCB Footprint



9. Effects on Hose Lengths

Since the MDP2000/MDP3000 series utilizes a thermal measurement principal with air flowing through the sensor, long tubing length has an impact to the sensor output due to frictional losses. The amount of impact depends on the hose material, internal diameter and total length leading to and away from the sensor. In general, tubing length shorter than 1 meter has less 1% (m.v.) impact. Refer to application notes on tubing length effect of MDP2000/MDP3000 series for details.

10. Altitude Correction

The MDP2000/MDP3000 series utilizes a thermal principal to measure pressure difference to achieve high sensitivity, robustness and stability. Changes in altitude from the calibration condition (sea level) require output adjustment as shown below:

Air pressure above sea level can be calculated as

$$p = 101325\ (1 - 2.25577\ 10^{-5}\ h)^{5.25588} \qquad (1)$$

where

p = air pressure (Pa)

h = altitude above sea level (m)

Example - Air pressure at Elevation 10000 m

The air pressure at altitude 10000 m can be calculated as

$$p = 101325\ (1 - 2.25577\ 10^{-5}\ (10000\ m))^{5.25588}$$

$$= \underline{26436}\ Pa$$

Altitude (meters)	Correction Factor
0	1.00
250	1.03
425	1.05
500	1.06
750	1.09
1000	1.13
1500	1.20
2000	1.27
3000	1.44

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