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MPL115A1

Miniature SPI digital barometer, 50 to 115 kPa

Rev. 8 — 10 October 2017

Data sheet: technical data

1 General description

The MPL115A1 is an absolute pressure sensor with a digital SPI output targeting low cost applications. A miniature 5 x 3 x 1.2 mm LGA package is ideally suited for the space constrained requirements of portable electronic devices. Low current consumptions of 5 μ A during Active mode and 1 μ A during Shutdown (Sleep) mode are essential when focusing on low-power applications. The wide operating temperature range spans from –40 °C to +105 °C to fit demanding environment conditions.

The MPL115A1 employs a MEMS pressure sensor with a conditioning IC to provide accurate pressure measurements from 50 to 115 kPa. An integrated ADC converts pressure and temperature sensor readings to digitized outputs via a SPI port. Factory calibration data is stored internally in an on-board ROM. Utilizing the raw sensor output and calibration data, the host microcontroller executes a compensation algorithm to render *Compensated Absolute Pressure* with ± 1 kPa accuracy.

The MPL115A1 pressure sensor's small form factor, low power capability, precision, and digital output optimize it for barometric measurement applications.

2 Features

- Digitized pressure and temperature information together with programmed calibration coefficients for host micro use.
- Factory calibrated
- 50 kPa to 115 kPa absolute pressure
- ± 1 kPa accuracy
- 2.375 V to 5.5 V supply
- Integrated ADC
- SPI Interface
- Monotonic pressure and temperature data outputs
- Surface mount RoHS compliant package

3 Applications

- Barometry (portable and desktop)
- Altimeters
- Weather stations
- Hard-disk drives (HDD)
- Industrial equipment
- Health monitoring
- Air control systems



4 Ordering information

Table 1. Ordering information

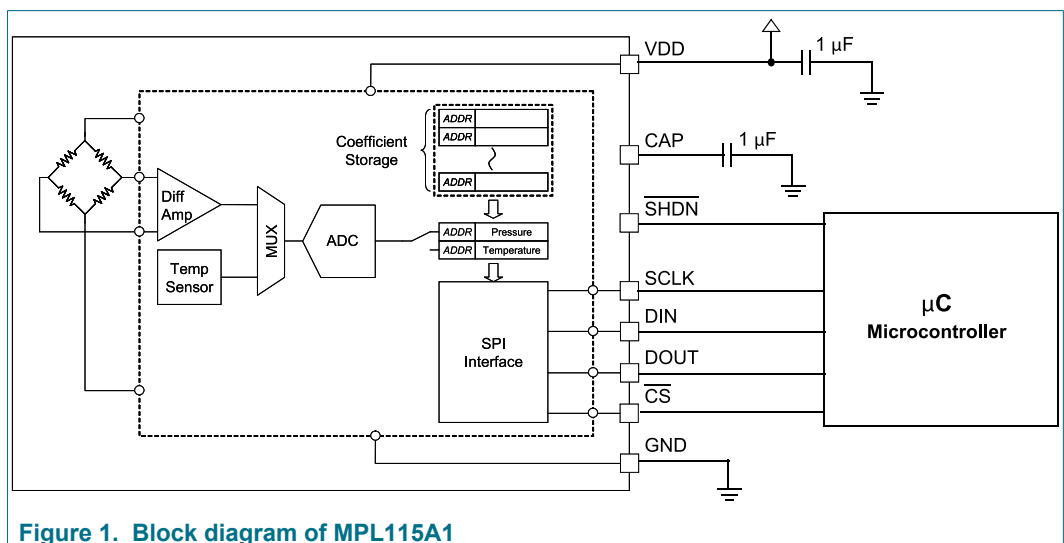
Type number	Package		Version
	Name	Description	
MPL115A1	TSON8	LGA 8 I/O, 3 X 5 X 1.25 PITCH, SENSOR 1.2MAX MM PKG	SOT1769-1

4.1 Ordering options

Table 2. Ordering options

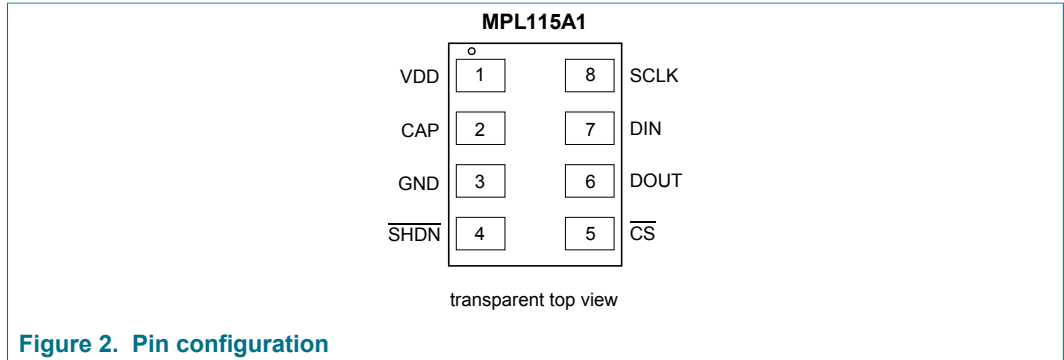
Device Name	Package Options	# of Ports			Pressure Type			Digital Interface
		None	Single	Dual	Gauge	Differential	Absolute	
MPL115A1	Tray	•					•	SPI
MPL115A1T1	Tape & Reel (1000)	•					•	SPI

5 Block diagram



6 Pinning information

6.1 Pinning



6.2 Pin description

Table 3. Pin description

Pin	Name	Function
1	VDD	Power Supply Connection. VDD range is 2.375 V to 5.5 V.
2	CAP	External Capacitor: Output decoupling capacitor for main internal regulator. Connect a 1 μF ceramic capacitor to ground.
3	GND	Ground
4	$\overline{\text{SHDN}}$	Shutdown: Connect to GND to disable the device. When in shut down the part draws no more than 1 μA supply current and all communications pins ($\overline{\text{CS}}$, SCLK, DOUT, DIN) are high impedance. Connect to VDD for normal operation.
5	$\overline{\text{CS}}$	Chip Select line.
6	DOUT	Serial data output
7	DIN	Serial data input
8	SCLK	Serial clock input.

7 Handling and Board Mount Recommendations

The sensor die is sensitive to light exposure. Direct light exposure through the port hole can lead to varied accuracy of pressure measurement. Avoid such exposure to the port during normal operation.

7.1 Methods of Handling

Components can be picked from the carrier tape using either the vacuum assist or the mechanical type pickup heads. A vacuum assist nozzle type is most common due to its lower cost of maintenance and ease of operation. The recommended vacuum nozzle configuration should be designed to make contact with the device directly on the metal cover and avoid vacuum port location directly over the vent hole in the metal cover of the

device. Multiple vacuum ports within the nozzle may be required to effectively handle the device and prevent shifting during movement to placement position.

Vacuum pressure required to adequately support the component should be approximately 25 inches Hg (85 kPa). This level is typical of in-house vacuum supply. Pickup nozzles are available in various sizes and configurations to suit a variety of component geometries. To select the nozzle best suited for the specific application, it is recommended that the customer consult their pick and place equipment supplier to determine the correct nozzle. In some cases it may be necessary to fabricate a special nozzle depending on the equipment and speed of operation.

Tweezers or other mechanical forms of handling that have a sharp point are not recommended since they can inadvertently be inserted into the vent hole of the device. This can lead to a puncture of the MEMS element that will render the device inoperable.

7.2 Board Mount Recommendations

Components can be mounted using solder paste stencil, screen printed or dispensed onto the PCB pads prior to placement of the component. The volume of solder paste applied to the PCB is normally sufficient to secure the component during transport to the subsequent reflow soldering process. Use of adhesives to secure the component is not recommended, but where necessary can be applied to the underside of the device.

Solder pastes are available in variety of metal compositions, particle size and flux types. The solder paste consists of metals and flux required for a reliable connection between the component lead and the PCB pad. Flux aids the removal of oxides that may be present on PCB pads and prevents further oxidation from occurring during the solder process.

The use of a No-Clean (NC) flux is recommended for exposed cavity components. Using pressure spray, wire brush, or other methods of cleaning is not recommended since it can puncture the MEMS device and render it unusable. If cleaning of the pcb is performed, Water Soluble (WS) flux can be used. However, it is recommended the component cavity is protected by adhesive Kapton tape, vinyl cap or other means prior to the cleaning process. This covering will prevent damage to the MEMS device, contamination, and foreign materials from being introduced into device cavity as result of cleaning processes.

Ultrasonic cleaning is not recommended as the frequencies can damage wire bond interconnections and the MEMS device.

8 Functional description

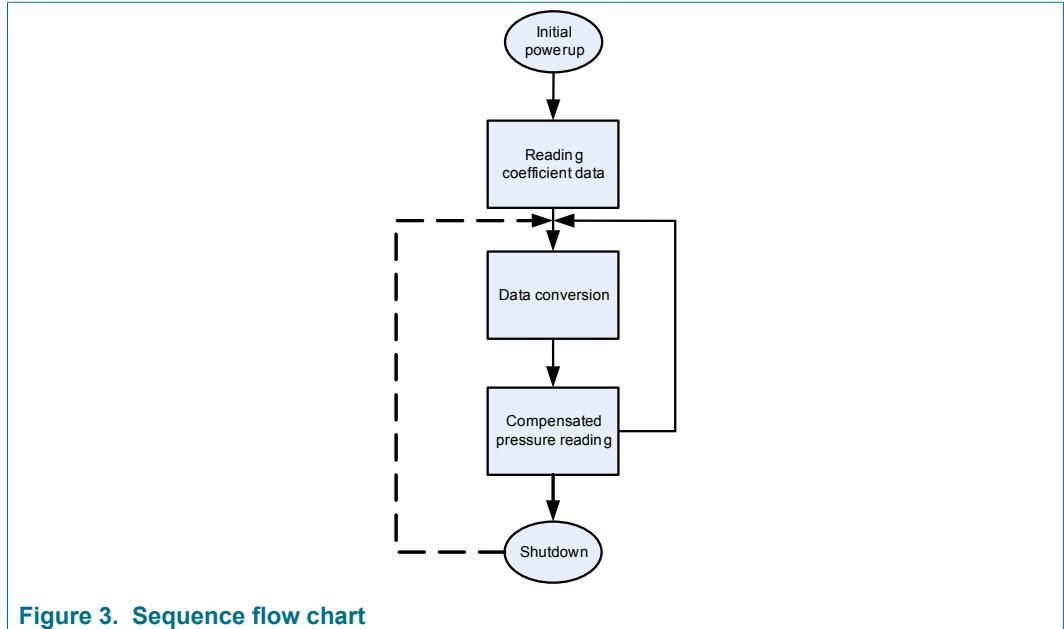


Figure 3. Sequence flow chart

The MPL115A interfaces to a host (or system) microcontroller in the user’s application. All communications are via SPI. A typical usage sequence is as follows:

Initial power-up

All circuit elements are active. SPI port pins are high impedance and associated registers are cleared. The device then enters standby mode.

Reading coefficient data

The user then typically accesses the part and reads the coefficient data. The main circuits within the slave device are disabled during read activity. The coefficients are usually stored in the host microcontroller local memory but can be re-read at any time.

Reading of the coefficients may be executed only once and the values stored in the host microcontroller. It is not necessary to read this multiple times because the coefficients within a device are constant and do not change. However, note that the coefficients will be different from device to device, and cannot be used for another part.

Data conversion

This is the first step that is performed each time a new pressure reading is required which is initiated by the host sending the CONVERT command. The main system circuits are activated (wake) in response to the command and after the conversion completes, the result is placed into the Pressure and Temperature ADC output registers.

The conversion completes within the maximum conversion time, t_c (see row 6, in [Table 11](#)). The device then enters standby mode.

Compensated pressure reading

After the conversion has been given sufficient time to complete, the host microcontroller reads the result from the ADC output registers and calculates the Compensated Pressure, a barometric/atmospheric pressure value which is compensated for changes in temperature and pressure sensor linearity. This is done using the coefficient data from the MPL115A and the raw sampled pressure and temperature ADC output values, in a compensation equation (detailed later). Note that this is an absolute pressure measurement with a vacuum as a reference.

From this step the host controller may either wait and then return to the Data Conversion step to obtain the next pressure reading or it may go to the Shutdown step.

Shutdown

For longer periods of inactivity the user may assert the $\overline{\text{SHDN}}$ input by driving this pin low to reduce system power consumption. This removes power from all internal circuits, including any registers. In the shutdown state, the Pressure and Temperature registers will be reset, losing any previous ADC output values.

This step is exited by taking the $\overline{\text{SHDN}}$ pin high. Wait for the maximum wakeup time, t_w (see row 7, in Table 11), after which another pressure reading can be taken by transitioning to the data Conversion step.

Table 4. Device memory map

Address	Name	Description
00h	Padc_MSB	10-bit Pressure ADC output value MSB
01h	Padc_LSB	10-bit Pressure ADC output value LSB
02h	Tadc_MSB	10-bit Temperature ADC output value MSB
03h	Tadc_LSB	10-bit Temperature ADC output value LSB
04h	a0_MSB	a0 coefficient MSB
05h	a0_LSB	a0 coefficient LSB
06h	b1_MSB	b1 coefficient MSB
07h	b1_LSB	b1 coefficient LSB
08h	b2_MSB	b2 coefficient MSB
09h	b2_LSB	b2 coefficient LSB
0Ah	c12_MSB	c12 coefficient MSB
0Bh	c12_LSB	c12 coefficient LSB
0Ch	reserved ^[1]	—
0Dh	reserved ^[1]	—
0Eh	reserved ^[1]	—
0Fh	reserved ^[1]	—

Address	Name	Description
10h	reserved	—
11h	reserved	—
12h	CONVERT	Start Pressure and Temperature Conversion

[1] This register is set to 00h. It is reserved, and was previously utilized as Coefficient values, c11 and c22, which were always 00h.

For values with less than 16 bits, the lower LSBs are zero. For example, c12 is 14 bits and is stored into 2 bytes as follows:

$$\begin{aligned}
 \text{c12 MS byte} &= \text{c12}[13:6] = [\text{c12}_{b13}, \text{c12}_{b12}, \text{c12}_{b11}, \text{c12}_{b10}, \text{c12}_{b9}, \text{c12}_{b8}, \text{c12}_{b7}, \text{c12}_{b6}] \\
 \text{c12 LS byte} &= \text{c12}[5:0] \& \text{"00"} = [\text{c12}_{b5}, \text{c12}_{b4}, \text{c12}_{b3}, \text{c12}_{b2}, \text{c12}_{b1}, \text{c12}_{b0}, 0, 0]
 \end{aligned}$$

8.1 Pressure, temperature and coefficient bit-width specifications

The table below specifies the initial coefficient bit-width specifications for the compensation algorithm and the specifications for Pressure and Temperature ADC values.

Table 5. Pressure, temperature and compensation coefficient specifications

	a0	b1	b2	c12	Padc	Tadc
Total Bits	16	16	16	14	10	10
Sign Bits	1	1	1	1	0	0
Integer Bits	12	2	1	0	10	10
Fractional Bits	3	13	14	13	0	0
dec pt zero pad	0	0	0	9	0	0

Example Binary Format Definitions:

- a0 Signed, Integer Bits = 12, Fractional Bits = 3 : Coeff a0 = S I₁₁ I₁₀ I₉ I₈ I₇ I₆ I₅ I₄ I₃ I₂ I₁ I₀ . F₂ F₁ F₀
- b1 Signed, Integer Bits = 2, Fractional Bits = 13 : Coeff b1 = S I₁ I₀ . F₁₂ F₁₁ F₁₀ F₉ F₈ F₇ F₆ F₅ F₄ F₃ F₂ F₁ F₀
- b2 Signed, Integer Bits = 1, Fractional Bits = 14 : Coeff b2 = S I₀ . F₁₃ F₁₂ F₁₁ F₁₀ F₉ F₈ F₇ F₆ F₅ F₄ F₃ F₂ F₁ F₀
- c12 Signed, Integer Bits = 0, Fractional Bits = 13, dec pt zero pad = 9 : Coeff c12 = S 0 . 000 000 000 F₁₂ F₁₁ F₁₀ F₉ F₈ F₇ F₆ F₅ F₄ F₃ F₂ F₁ F₀
- Padc Unsigned, Integer Bits = 10 : Padc U = I₉ I₈ I₇ I₆ I₅ I₄ I₃ I₂ I₁ I₀
- Tadc Unsigned, Integer Bits = 10 : Tadc U = I₉ I₈ I₇ I₆ I₅ I₄ I₃ I₂ I₁ I₀

Note: Negative coefficients are coded in 2's complement notation.

8.2 Compensation

The 10-bit compensated pressure output, Pcomp, is calculated as follows:

$$P_{comp} = a_0 + (b_1 + c_{12} \cdot T_{adc}) \cdot P_{adc} + b_2 \cdot T_{adc} \tag{1}$$

Where:

- P_{adc} is the 10-bit pressure ADC output of the MPL115A
- T_{adc} is the 10-bit temperature ADC output of the MPL115A
- a₀ is the pressure offset coefficient
- b₁ is the pressure sensitivity coefficient
- b₂ is the temperature coefficient of offset (TCO)
- c₁₂ is the temperature coefficient of sensitivity (TCS)

P_{comp} will produce a value of 0 with an input pressure of 50 kPa and will produce a full-scale value of 1023 with an input pressure of 115 kPa.

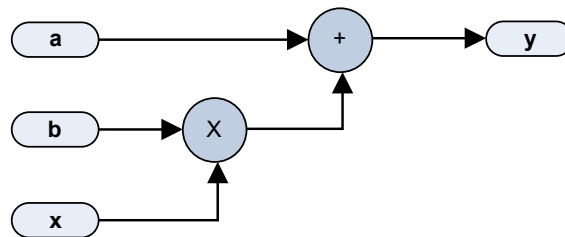
$$\text{Pressure (kPa)} = P_{comp} \cdot \left[\frac{115-50}{1023} \right] + 50 \tag{2}$$

8.3 Evaluation sequence, arithmetic circuits

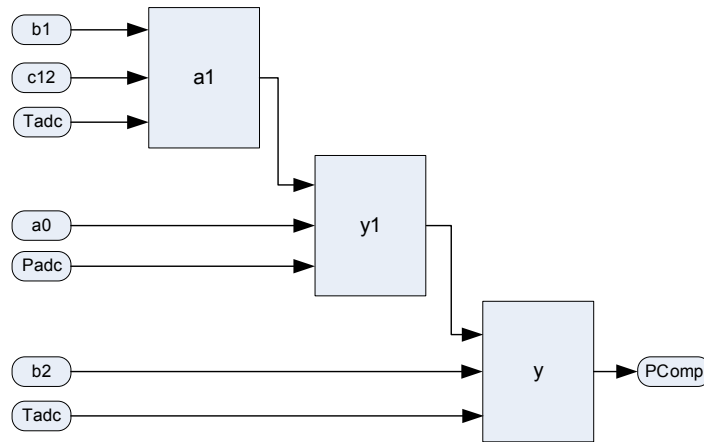
The following is an example of the calculation for P_{comp}, the compensated pressure output. Input values are in **bold**.

$$\begin{aligned} c_{12}x_2 &= \mathbf{c_{12}} \cdot \mathbf{T_{adc}} \\ a_1 &= \mathbf{b_1} + c_{12}x_2 \\ a_1x_1 &= a_1 \cdot \mathbf{P_{adc}} \\ y_1 &= \mathbf{a_0} + a_1x_1 \\ a_2x_2 &= \mathbf{b_2} \cdot \mathbf{T_{adc}} \\ P_{comp} &= y_1 + a_2x_2 \end{aligned}$$

This can be calculated as a succession of Multiply Accumulates (MACs) operations of the form $y = a + b \cdot x$:



The polynomial can be evaluated ([Equation 1](#)) as a sequence of 3 MACs:



Please refer to NXP application note AN3785 for more detailed notes on implementation.

8.4 SPI device read/write operations

All device read/write operations are memory mapped. Device actions e.g. "Start Conversions" are controlled by writing to the appropriate memory address location. All memory address locations are 6-bit (see [Table 2](#)).

The 8-bit command word comprises:

- the most significant bit which is the Read/Write identifier which is '1' for read operations and '0' for write operations.
- the 6-bit address (from [Table 4](#));
- the least significant bit which is not used and is don't care (X).

The device write commands are shown in [Table 6](#).

Table 6. SPI write command

Legend: X = don't care

Command	Binary	HEX ^[1]
Start Conversions	0010010X	24h

[1] The command byte needs to be paired with a 00h as part of the SPI exchange to complete the passing of Start Conversions.

The actions taken by the part in response to each command are as follows:

Table 7. SPI Write command description

Command	Action taken
Start Conversions	Wake main circuits. Start clock. Allow supply stabilization time. Select pressure sensor input. Apply positive sensor excitation and perform A to D conversion. Select temperature input. Perform A to D conversion. Load the Pressure and Temperature registers with the result. Shut down main circuits and clock.

SPI Read operations are performed by sending the required address with a leading *Read* bit set to '1'. SPI operations require that each byte be addressed individually. All data is transmitted most significant bit first.

Table 8. Example SPI Read Commands

Legend: X = don't care

Command	Binary	HEX ^[1]
Read Pressure MSB	1000000X	80h
Read Pressure LSB	1000001X	82h
Read Temperature MSB	1000010X	84h
Read Temperature LSB	1000011X	86h
Read Coefficient data byte 1	1000100X	88h

[1] The command byte needs to be paired with a 00h as part of the SPI exchange to complete the passing of stated command.

8.5 SPI timing

Table 9 and Figure 4 describe the timing requirements for the SPI system.

Table 9. SPI timing

Ref	Symbol	Function	Min	Max	Unit
1	<i>f</i>	Operating Frequency	—	8	MHz
2	tSCLK	SCLK Period	125	—	ns
3	tCLKH	SCLK High time	62.5	—	ns
4	tCLKL	SCLK Low time	62.5	—	ns
5	tSCS	Enable lead time	125	—	ns
6	tHCS	Enable lag time	125	—	ns
7	tSET	Data setup time	30	—	ns
8	tHOLD	Data hold time	30	—	ns
9	tDDLY	Data valid (after SCLK low edge)	—	32	ns
10	tWCS	Width CS High	30	—	ns

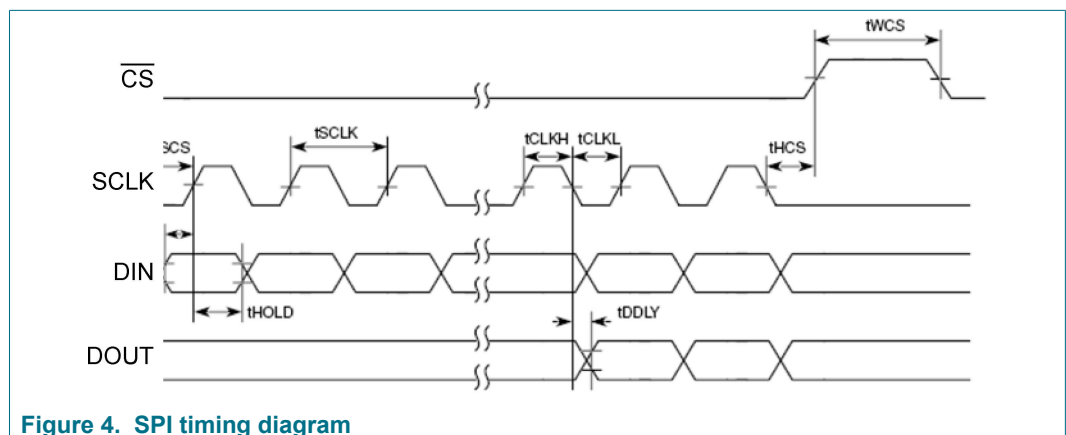


Figure 4. SPI timing diagram

8.6 Example of SPI reading of coefficients

These are MPL115A1 SPI commands to read coefficients, execute Pressure and Temperature conversions, and to read Pressure and Temperature data. The sequence of the commands for the interaction is given as an example to operate the MPL115A1. Utilizing this gathered data, an example of the calculating the Compensated Pressure reading is given in floating point notation.

SPI Commands (simplified for communication)

- Command to Write "Convert Pressure and Temperature" = 24h
- Command to Read "Pressure ADC High byte" = 80h
- Command to Read "Pressure ADC Low byte" = 82h
- Command to Read "Temperature ADC High byte" = 84h
- Command to Read "Temperature ADC Low byte" = 86h
- Command to Read "Coefficient data byte 1 High byte" = 88h

Read coefficients:

[CS=0], [88h], [00h], [8Ah], [00h], [8Ch], [00h], [8Eh], [00h], [90h], [00h], [92h], [00h], [94h], [00h], [96h], [00h], [00h], [CS=1]

Start pressure and temperature conversion, read raw pressure:

[CS=0], [24h], [00h], [CS=1], [3 ms Delay]

[CS=0], [80h], [00h], [82h], [00h], [84h], [00h], [86h], [00h], [00h], [CS=1]

Note: Extra [00h] at the end of each sequence to output the last data byte on the slave side of the SPI.

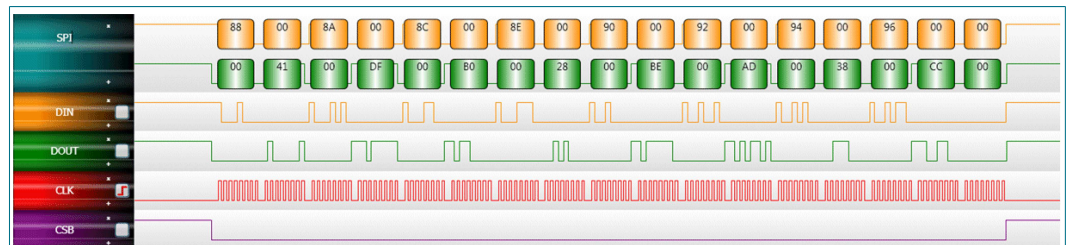


Figure 5. SPI read coefficient datagram

a0 coefficient MSB	=	41h			
a0 coefficient LSB	=	DFh	a0 coefficient	=	41DFh = 2107.875
b1 coefficient MSB	=	B0h			
b1 coefficient LSB	=	28h	b1 coefficient	=	B028h = -2.49512
b2 coefficient MSB	=	BEh			
b2 coefficient LSB	=	ADh	b2 coefficient	=	BEADh = -1.02069
c12 coefficient MSB	=	38h			
c12 coefficient LSB	=	CCh	c12 coefficient	=	38CCh = 0.00086665

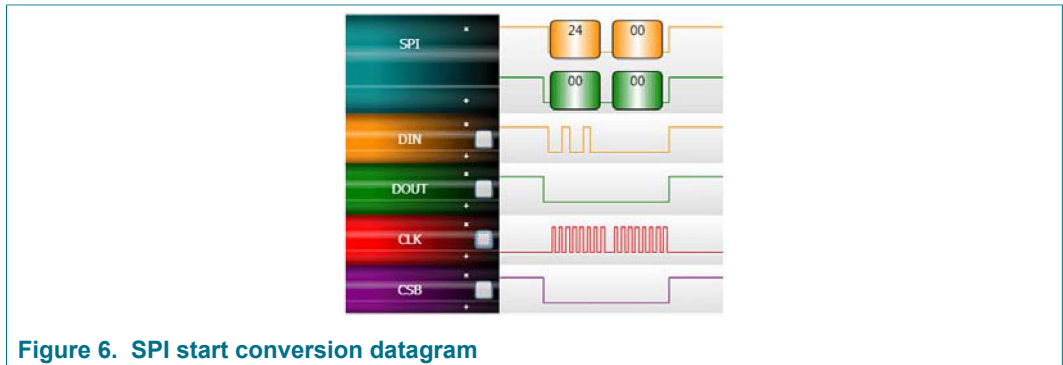


Figure 6. SPI start conversion datagram

Command to start pressure and temperature conversion, 24h

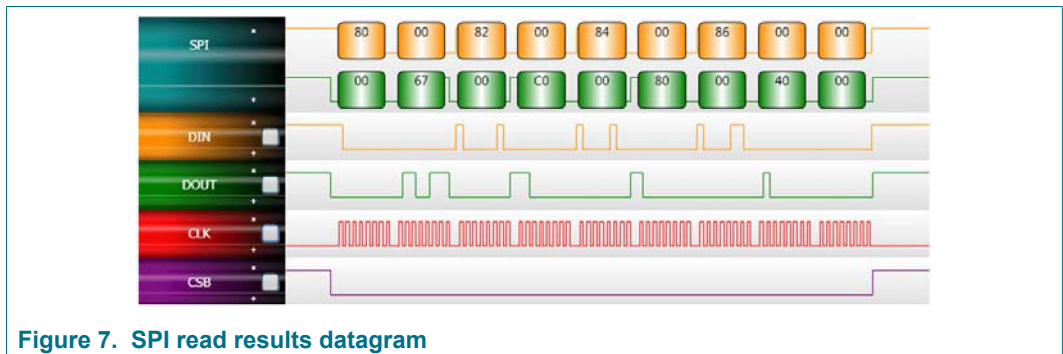


Figure 7. SPI read results datagram

Pressure MSB	=	67h			
Pressure LSB	=	C0h	Pressure	=	67C0h = 0110 0111 11 00 0000 = 415 ADC counts
Temperature MSB	=	80h			
Temperature LSB	=	40h	Temperature	=	8040h = 1000 0000 01 00 0000 = 513 ADC counts

8.7 Example of pressure compensated calculation in floating-point notation

a0 coefficient	=	2107.875
b1 coefficient	=	-2.49512
b2 coefficient	=	-1.02069
c12 coefficient	=	0.00086665
Pressure	=	415 ADC counts
Temperature	=	513 ADC counts

Pressure compensation

$$P_{comp} = a0 + (b1 + c12 \cdot T_{adc}) \cdot P_{adc} + b(c)$$

Using the evaluation sequence

The evaluation sequence is located in [Section 8.3](#).

c12x2	=	c12 * Tadc	=	0.00086665 * 513	=	0.44459
a1	=	b1 + c12x2	=	-2.49512 + 0.44459	=	-2.05052
a1x1	=	a1 * Padc	=	-2.05052 * 415	=	-850.96785
y1	=	a0 + a1x1	=	2107.875 + (-850.96785)	=	1256.90715
a2x2	=	b2 * Tadc	=	-1.02069 * 513	=	-523.61444
PComp	=	y1 + a2x2	=	1256.90715 + (-523.61444)	=	733.29270

$$\text{Pressure (kPa)} = P_{comp} \cdot \left[\frac{115-50}{1023} \right] + 50$$

$$= 96.59 \text{ kPa}$$

$$= 733.19 \cdot \left[\frac{115-50}{1023} \right] + 50$$

9 Maximum ratings

Table 10. Maximum ratings

Voltage (with respect to GND unless otherwise noted)

Symbol	Value	Units
V_{DD}	-0.3 to +5.5	V
\overline{SHDN} , SCLK, \overline{CS} , D_{IN} , D_{OUT}	-0.3 to $V_{DD} + 0.3$	V
Operating Temperature Range	-40 to +105	°C
Storage Temperature Range	-40 to +125	°C
Overpressure	1000	kPa

10 Mechanical and electrical characteristics

Table 11. Mechanical and electrical characteristics

$V_{DD} = 2.375\text{ V to }5.5\text{ V}$, $T_A = -40\text{ °C to }+105\text{ °C}$, unless otherwise noted. Typical values are at $V_{DD} = 3.3\text{ V}$, $T_A = +25\text{ °C}$.

Ref	Parameters	Symbol	Conditions	Min	Typ	Max	Units
1	Operating Supply Voltage	V_{DD}		2.375	3.3	5.5	V
2	Supply Current	I_{DD}	Shutdown ($\overline{SHDN} = \text{GND}$)	—	—	1	μA
			Standby	—	3.5	10	μA
			Average – at one measurement per second	—	5	—	μA
Pressure Sensor							
3	Range			50	—	115	kPa
4	Resolution			—	0.15	—	kPa
5	Accuracy		-20 °C to 85 °C	—	—	± 1	kPa
6	Conversion Time (Start Pressure and Temperature Conversion)	t_c	Time between start convert command and data available in the Pressure and Temperature registers	—	1.6	3	ms
7	Wakeup Time	t_w	Time between leaving Shutdown mode (\overline{SHDN} goes high) and communicating with the device to issue a command or read data.	—	3	5	ms
SPI Inputs: SCLK, \overline{CS}, D_{IN}							
8	SCLK Clock Frequency	f_{SCLK}	[1]	—	—	8	MHz
9	Low Level Input Voltage	V_{IL}		—	—	$0.3V_{DD}$	V
10	High Level Input Voltage	V_{IH}		$0.7V_{DD}$	—	—	V
SPI Outputs: D_{OUT}							
11	Low Level Output Voltage	VOL1	At 3 mA sink current	0	—	0.4	V
		VOL2	At 6 mA sink current	0	—	0.6	
12	High Level Output Voltage	VOH1	At 3 mA source current	V_{DD} -0.4	—	—	



NOTES:

1. ALL DIMENSIONS IN MILLIMETERS.
2. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994
3. STYLE:

PIN 1: VDD	PIN 5: CS
PIN 2: CAP	PIN 6: DOUT
PIN 3: GND	PIN 7: DIN
PIN 4: SHDN	PIN 8: SCLK

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TITLE: LGA 8 I/O, 3 X 5 X 1.25 PITCH SENSOR 2.0MM PKG	DOCUMENT NO: 98ASA10829D REV: B	STANDARD: NON-JEDEC
	SOT1769-1	19 JAN 2016

Figure 8. Package outline SOT1769-1 (TSON8)

12 Packing information

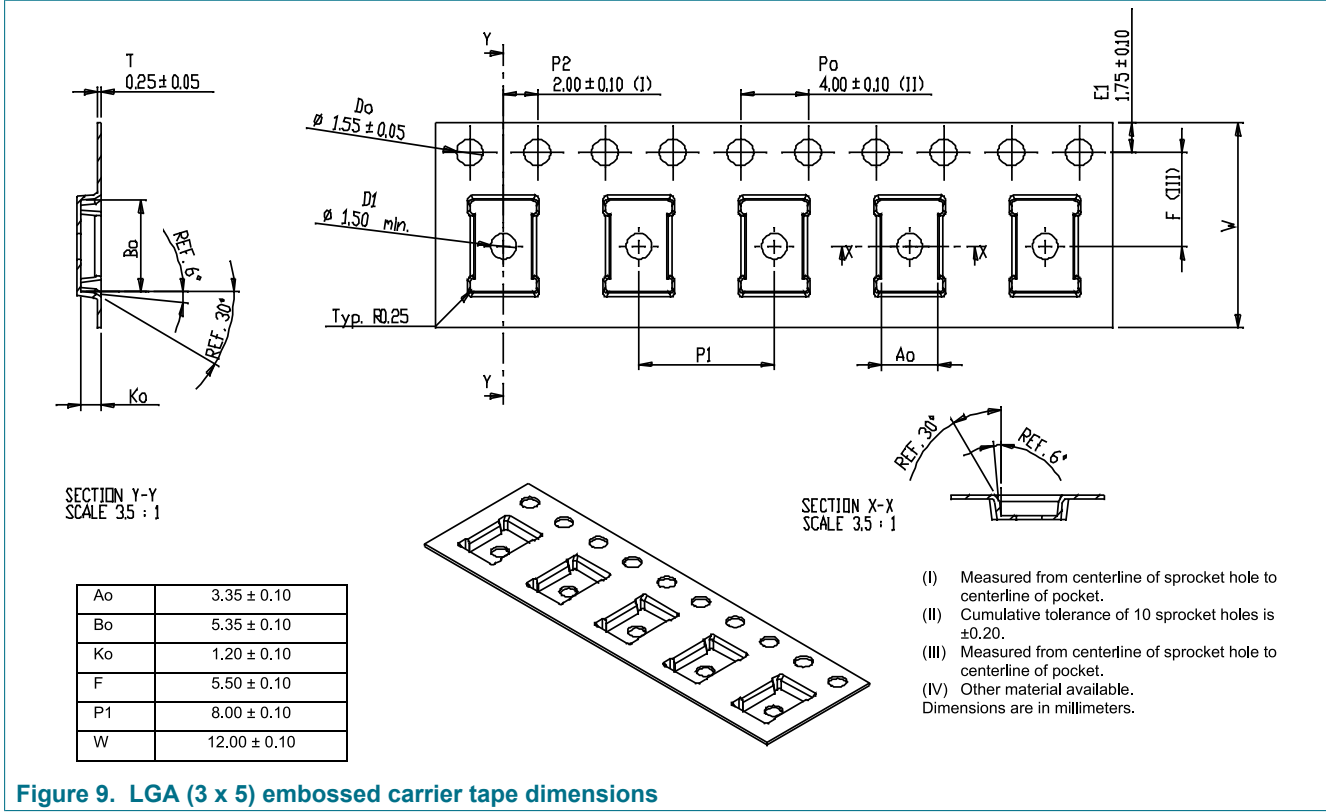


Figure 9. LGA (3 x 5) embossed carrier tape dimensions

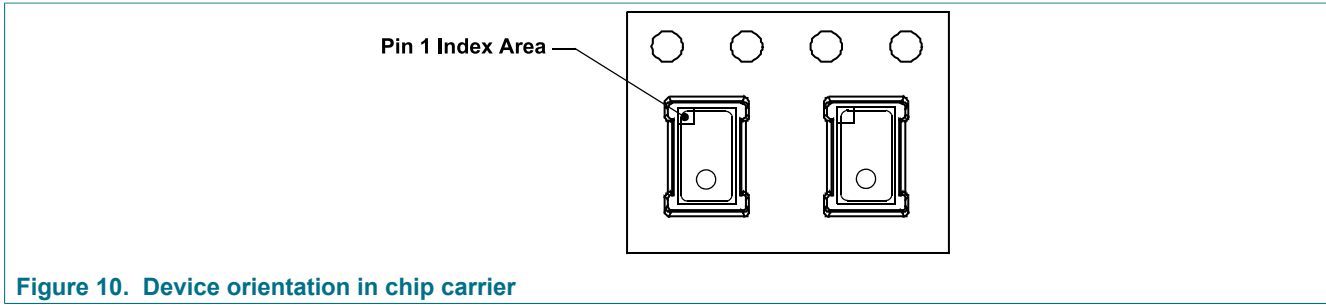


Figure 10. Device orientation in chip carrier

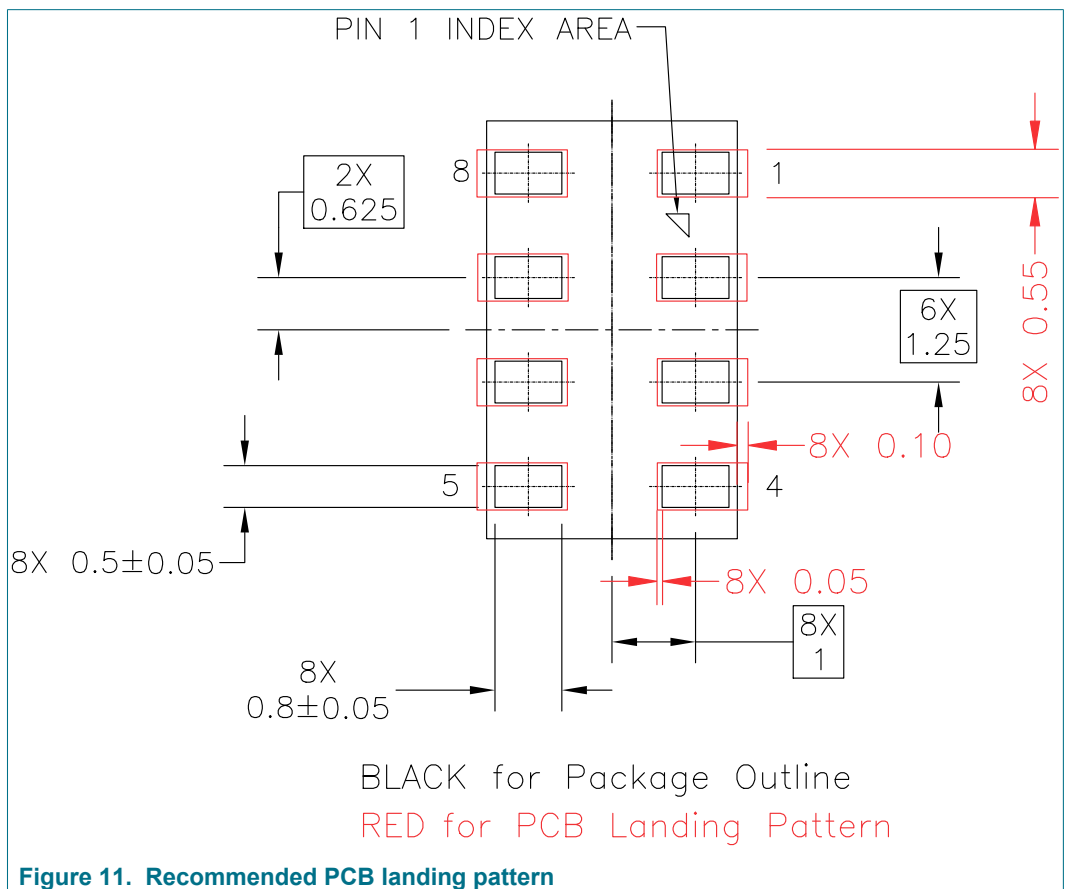
13 Soldering

1. Use SAC solder alloy, i.e., Sn-Ag-Cu, with a melting point of about 217 °C. It is recommended to use SAC305, i.e., Sn-3.0 wt.% Ag-0.5 wt.% Cu.
2. Reflow
 - Ramp up rate: 2 to 3 °C/s.
 - Preheat flat (soak): 110 to 130 s.
 - Reflow peak temperature: 250 °C to 260 °C (depends on exact SAC alloy composition).
 - Time above 217°C: 40 to 90s (depends on board type, thermal mass of the board/ quantities in the reflow).
 - Ramp down: 5 to 6 °C/s.
 - Using an inert reflow environment (with O₂ level about 5 to 15 ppm).

Note: The stress level and signal offset of the device also depends on the board type, board core material, board thickness and metal finishing of the board.

14 Soldering/landing pad information

The LGA package is compliant with the RoHS standard. It is recommended to use a no-clean solder paste to reduce cleaning exposure to high pressure and chemical agents that can damage or reduce life span of the Pressure sensing element.



15 Revision history

Table 12. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
MPL115A1 v.8	20171010	Technical data	—	MPL115A1 v.7
Modifications:	<ul style="list-style-type: none"> • The format of this data sheet has been redesigned to comply with the new identity guidelines of NXP Semiconductors. • Legal texts have been adapted to the new company name where appropriate. • Removed the first paragraph of Section 7. • Added Section 7.1 and Section 7.2 in Section 7 "Handling and Board Mount Recommendations" • Updated Figure 8. No technical changes. 			
MPL115A1 v.7	02/2013	Technical data	—	—

16 Legal information

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