CPS150

Consensic

Data Sheet

Digital Barometer

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CPS150

Digital Barometer

Overview

The CPS150 is capacitive absolute pressure sensor solution with a fully calibrated pressure and temperature compensated digital output for low pressure applications, such as barometric sensing. Low current consumption (<1µA @ 25°C in Sleep Mode) and operating supply voltage range 2.3V to 5.5V targets battery and other low-power applications. A ceramic substrate and robust sensor design (single crystal silicon structure and backside pressure port) makes the CPS150 suitable for continuous operation under extreme temperatures and harsh environments.

The CPS150 SiP (System-in-a-Package) solution comprises of an ultra-small capacitive MEMS pressure sensor and a conditioning ASIC for accurate pressure measurements in factory calibrated ranges within 30 to 120kPa full scale. An integrated sigma-delta based ADC combined with internal calibration logic provides accurate pressure and temperature measurements to the application via the SPI or I²C interface. There is no need to separately download internal calibration coefficients and have the host microcontroller conduct complicated compensation calculations. Two selectable modes (Sleep and Update) and an external "Measurement Ready" pin ensure operational flexibility suitable for an unlimited range of applications.

Applications

- Altimeters
- Portable and Stationary Barometers
- Weather Stations
- GPS Applications
- Hard Disk Drives (HDD)
- Industrial Equipment
- Air Control Systems
- Vacuum Systems

Benefits

- Low Power Consumption. Excellent for Battery and Other Low-Power Applications
- External Clock not Required
- High Resistance to Sensing Media
- Ceramic Substrate for Extreme Temperatures and Harsh Environment Continuous Operation

Features

- Factory Calibrated Pressure and Temperature Sensor
- Programmable Temperature and Pressure Sample Rate and Resolution (8, 10, 12 or 14bit)
- Sampling Rates as Fast as 0.7ms @ 8-bit, 1.6ms @ 10-bit, 5.0ms @ 12-bit, 18.5ms @14-bit
- Supply Voltage: 3.0V ±10%
- Absolute Temperature Range: -40°C to +85°C
- Pressure Accuracy: <±0.2kPa (<±2.0mbar) @ 25°C
- Temperature Accuracy: ±1.0°C
- Internal Logic with Two Selectable States (Sleep and Update Mode)
- Altitude Resolution Better Than 1.0 meter (50cm) in Update Mode

Interfaces

- I²C ™* Compatible (100 and 400kHz)
- SPI (up to 800kHz), 3 Wire Half Duplex

Physical Characteristics

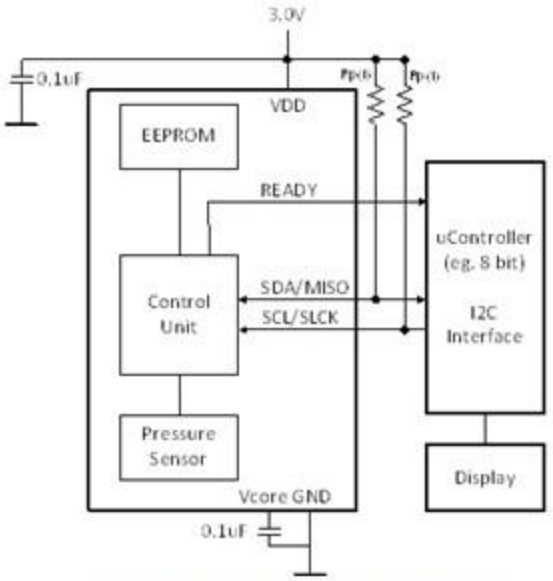
- Small Form Factor, 3 x 5 x 1.2mm (w x l x h)
- LGA Package, 8 Lead
- Ceramic Substrate
- Top Side Sensing Port

*I²C ™ is a registered trademark of NXP

RoHS Compliant

TYPICAL APPLICATION CIRCUIT

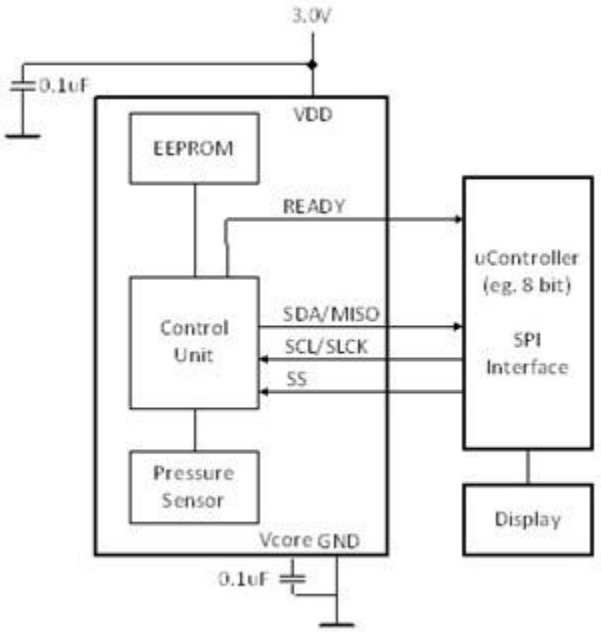
FIGURE 1: I²C CIRCUIT



CPS150 Digital Barometric Pressure Sensor

Note:
(1) Pull-up resistors for I2C, Rp=2.2kΩ to 10kΩ, typical 4.7kΩ

FIGURE 2: SPI CIRCUIT



CPS150 Digital Barometric Pressure Sensor

TABLE 1: ORDERING INFORMATION

PART NUMBER	OUTPUT MODE	OPERATION MODE	PACKAGE
CPS150-8LGA-C-100 [1]	I²C	Sleep [2]	8-Lead LGA, Metal Lid, Ceramic Substrate
CPS150-8LGA-C-200 [1]	SPI	Sleep [2]	8-Lead LGA, Metal Lid, Ceramic Substrate

[1] Packaging: Add –TR for Tape or –TU for Tube
[2] Contact us for Part Numbers on Different Operation Modes and Packages

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1 OPERATING CHARACTERISTICS

1.1 ABSOLUTE RATINGS

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Over Pressure					1000 (10)	kPa (bar)
Supply Voltage (with respect to GND)	V_{DD}		-0.3		6.0	V
Voltages at Analog I/O – In Pin	V_{INA}		-0.3		V_{DD} +0.3	V
Voltages at Analog I/O – Out Pin	V_{OUTA}		-0.3		V_{DD} +0.3	V
Storage Temperature	T_{STOR}		-50		130	°C

1.2 OPERATING CONDITIONS

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
PRESSURE SENSOR						
Range			30 (300)		120 (1200)	kPa (mbar)
Resolution				0.001 (0.01)		kPa (mbar)
Accuracy		70 to 115kPa @25°C	-0.2 (-2.0)	±0.10 (±1.0)	+0.2 (+2.0)	kPa (mbar)
		70 to 115kPa (0°C to 50°C Verified)	-0.3 (-3.0)	±0.10 (±1.0)	+0.3 (+3.0)	kPa (mbar)
TEMPERATURE SENSOR						
Range			-40		85	°C
Resolution		14-bit Mode	0.01	0.015	0.025	°C
Accuracy			-1	±0.75	+1	°C
OPERATION						
Supply Voltage to GND[1]	V_{SUPPLY}		2.3	3.0	5.5	V
Operating Temperature Range			-40		85	°C
External Capacitance Between V_{DD} Pin and GND	$C_{VSUPPLY}$			0.1		µF
External Capacitance Between V_{CORE} Pin and GND	C_{VCORE}			0.1		µF
I^2C Pull-Up Resistors	R_{PU}		1	2.2		kΩ
SDA/MISO Load Capacitance	C_{SDA}				200	pF

[1] Factory calibrated for Pressure and Temperature at 3.0V±10%. Output accuracy will be affected if used outside this range. Other ranges available upon request.

1.3 ELECTRICAL PARAMETERS

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
SUPPLY CURRENT						
Update Mode Current	I_{DD}	Worst Case Settings: 14-bit, 0ms Power Down		750	1100	µA
Sleep Mode Current	I_{SLEEP}	-40 to 85°C		1	5	µA
CAPACITANCE TO DIGITAL CONVERTER						
Resolution	RES		8		14	Bits
Sensor Excitation Frequency					$f_{SYS}/2$	kHz
EEPROM						
Erase/Write Cycles		@85°C			100k	
Data Retention		@100°C			10	Year
SYSTEM						
Trimmed System Frequency	f_{SYS}	All Timing in this Specification are Subject to this Variation		1.85		MHz
Start-Up-Time[2] Power-On to Data Ready	t_{STA}	Fastest and Slowest Settings	4.25		173	ms
Update Rate (Normal Mode)[2]	T_{RESP_UP}	Fastest and Slowest Settings	0.70		288	ms
Response Time (Sleep Mode)[2]	T_{RESP_SL}	Fastest and Slowest Settings	1.25		163	ms
Peak-to-Peak Noise @ Output (100 Measurements in 14-bit)[2]	N_{OUT}			5		LSB

[2] Parameter not tested during production, but guaranteed by design.

2 OUTPUT MODES

2.1 I²C AND SPI

Two-wire I²C and three-wire (half-duplex) SPI are available for reading data from the CPS150.

2.1.1 I²C FEATURES AND TIMING

The CPS150 uses an I²C compatible communication protocol with support for 100kHz and 400kHz bit rates. The factory setting for the I²C slave address is 0x28 and the communication is restricted to this address only.

See Figure 3 for the I²C timing and Table 2 for definitions of the parameters shown in the diagram.

FIGURE 1: I²C TIMING DIAGRAM

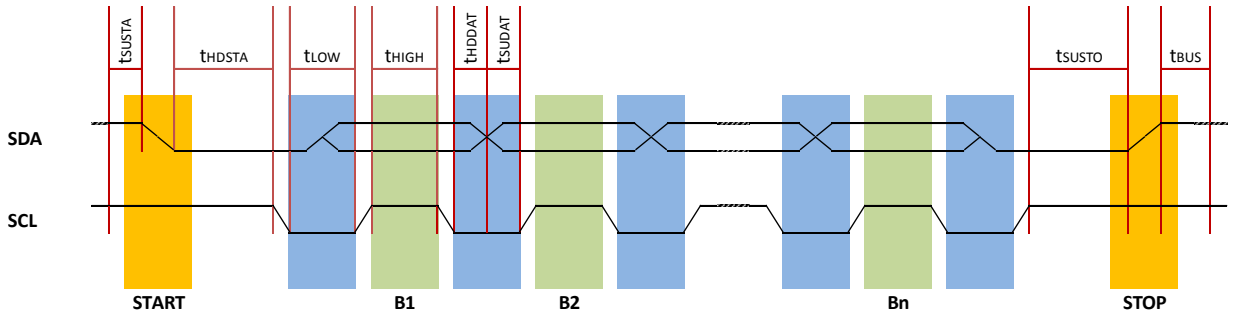


TABLE 2: I²C PARAMETERS

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
SCL Clock Frequency	f_{SCL}		100		400	kHz
Start Condition Hold Time Relative to SCL Edge	t_{HDSTA}		0.1			µs
Minimum SCL Clock Low Width [3]	t_{LOW}		0.6			µs
Minimum SCL Clock High Width [3]	t_{HIGH}		0.6			µs
Start Condition Setup Time Relative to SCL Edge	t_{SUSTA}		0.1			µs
Data Hold Time on SDA Relative to SCL Edge	t_{HDDAT}		0		0.5	µs
Data Setup Time on SDA Relative to SCL Edge	t_{SUDAT}		0.1			µs
Stop Condition Setup Time on SCL	t_{SUSTO}		0.1			µs
Bus Free Time Between Stop Condition and Start Condition	t_{BUS}		1			µs
[3] Combined low and high widths must equal or exceed minimum SCL period						

2.1.2 SPI FEATURES AND TIMING

SPI is available only as half-duplex (read-only from the CPS150) with support for up to 800kHz. The SPI interface can be programmed to allow the master to sample MISO on the falling-edge or rising-edge. The factory default is to sample MISO on the falling-edge.

See Figure 4 for SPI timing diagram and Table 3 for definitions of the parameters shown in the timing diagram.

FIGURE 2: SPI TIMING DIAGRAM

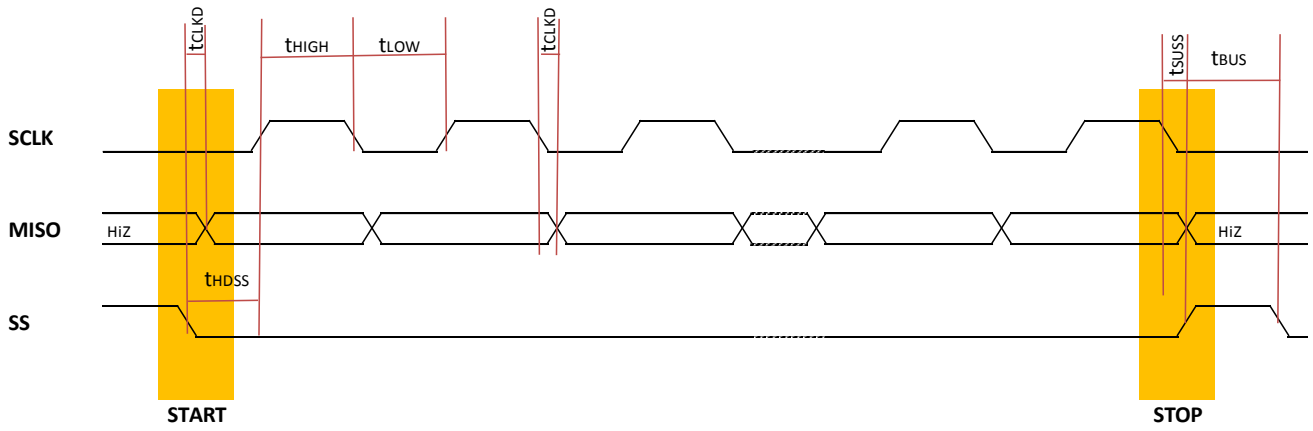


TABLE 3: SPI PARAMETERS

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
SCLK Clock Frequency	f_{SCL}		50		800	kHz
SS Drop to First Clock Edge	t_{HDSS}		2.5			µs
Minimum SCLK Clock Low Width [4]	t_{LOW}		0.6			µs
Minimum SCLK Clock High Width [4]	t_{HIGH}		0.6			µs
Clock Edge to Data Transition	t_{CLKD}		0		0.5	µs
Rise of SS Relative to Last Clock Edge	t_{SUSS}		0.1			µs
Bus Free Time Between Rise and Fall of SS	t_{SUS}		2			µs

[4] Combined low and high widths must equal or exceed minimum SCLK period

2.1.3 I²C AND SPI COMMANDS

Table 4 details the commands to interface with the device in the I²C and SPI modes.

TABLE 4: I²C AND SPI COMMANDS

TYPE	DESCRIPTION	SUPPORT	REFERENCE
Get Data (GD)	Used to Get Data in Update Mode	I²C and SPI	
Measurement Request (MR)	Used to Start Measurement in Sleep Mode	I²C and SPI	

2.1.4 GET DATA (GD)

The Get Data (GD) command is used to get data in Normal mode. With the start of communication (for I²C after reading the slave address; for SPI at the falling-edge of SS) the entire output packet will be loaded in a serial output register. The register will be updated after the communication is finished. The output is always scaled to 14-bits independent of the programmed resolution. The ordering of the bits is "big-endian".

2.1.4.1 I²C GET DATA

An I²C Get Data command starts with the 7-bit slave address and the 8th bit = 1 (READ). The device as the slave sends and acknowledges (ACK) indicating success. The number of data bytes returned by the device is determined by when the master sends the NACK and stop condition.

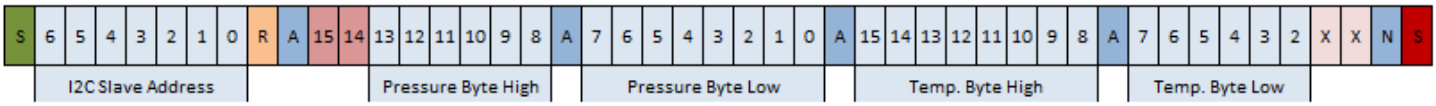
Figure 5 shows examples of receiving a total of 5 bytes. The first byte contains the I²C address followed by two pressure bytes and two temperature bytes. The first two bits of the Pressure Byte High are status bits. See Table 5.

TABLE 5: STATUS BITS

Status Bits	DESCRIPTION
00	Valid Data: Data has Not Been Retrieved Since the Last Measurement Cycle
01	Stale Data: Data has Already Been Retrieved Since the Last Measurement Cycle. The Device is in the Process of a New Measurement Cycle.
10	Not Applicable
11	Not Applicable

In Figure 5, the last two bytes returns 2 bytes of temperature data (14-bit accuracy) after the pressure data. The six MSBs of the last byte are the six LSBs of the temperature measurement. The last two bits of the fifth byte are undetermined and should be masked off in the application.

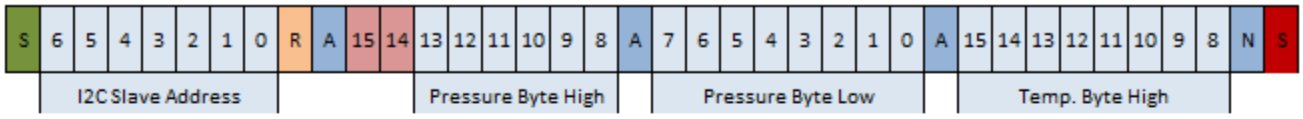
FIGURE 3: 7-BIT SLAVE ADDRESS FOLLOWED BY FOUR BYTES OF PRESSURE AND TEMPERATURE DATA



S = Start Condition
6 = Slave Address Bit
R = Read Bit (Read = 1)
A = Acknowledge (ACK)
= Status Bit
X = Not Used
N = Not Acknowledge (NACK)
S = Stop Condition

For lower resolution temperature accuracy, 8-bit, only the High Temperature Byte is needed and the data stream can be terminated after the first temperature byte. See Figure 6 below.

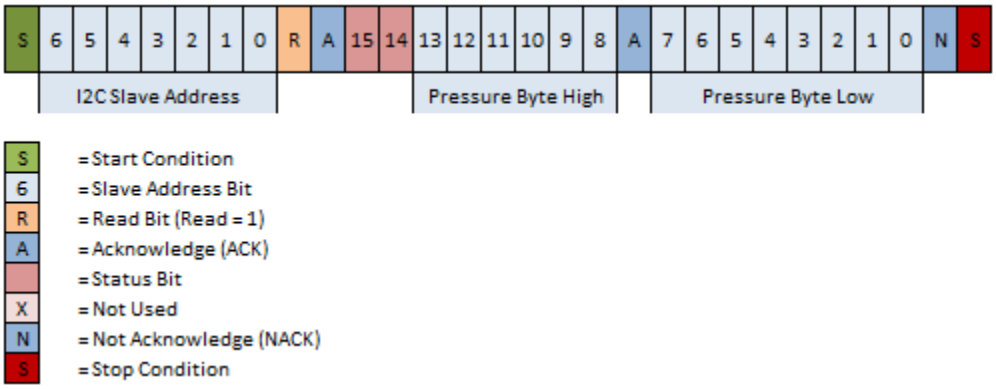
FIGURE 4: 8-BIT RESOLUTION TEMPERATURE DATA ONLY



S = Start Condition
6 = Slave Address Bit
R = Read Bit (Read = 1)
A = Acknowledge (ACK)
= Status Bit
X = Not Used
N = Not Acknowledge (NACK)
S = Stop Condition

For pressure data only, the data stream can be terminated after the second pressure byte. See Figure 7 below.

FIGURE 5: 7-BIT SLAVE ADDRESS FOLLOWED BY TWO BYTES OF PRESSURE DATA



2.1.4.2 SPI GET DATA

By default, the SPI interface will have data after the falling-edge of the SCLK. The master should sample MISO on the rising (opposite) edge of SCLK. The SPI protocol can handle high and low polarity of the clock line without configuration change.

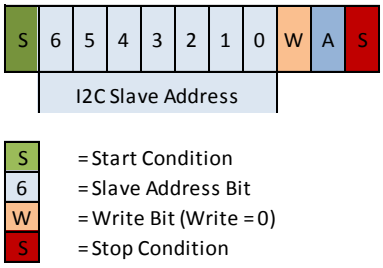
As seen in Figure 5, the entire output packet is 4 bytes (32 bits). The status byte comes first, followed by the high and low pressure sensor data bytes. Then, 14 bits of corrected temperature T[13:0] are sent, first the T[13:6] byte and then the {T[5:0],xx} byte. If the user only requires the corrected pressure sensor value, the read can be terminated after the 1st or 2nd byte. If the corrected temperature is required, but only at an 8-bit resolution, the read can be terminated after the 3rd byte is read.

2.1.4.3 I²C MEASUREMENT REQUEST

The I²C MR is used to wake up the device in Sleep Mode and start a complete cycle starting with a temperature measurement, followed by pressure measurements, followed by the DSP calculations, and then the results are written to the digital output register. As shown in Figure 8, the communication contains only the slave address and the WRITE bit (0) sent by the master. After the IC responds with the slave ACK, the master creates a stop condition.

Note: The I²C MR function can also be accomplished by sending "don't care" data after the address instead of immediately sending a stop bit.

FIGURE 6: MEASUREMENT REQUEST COMMAND (I²C MR)



2.1.4.4 SPI MEASUREMENT REQUEST

The SPI MR is used to wake up the device in Sleep Mode and start a complete cycle starting with a temperature measurement/temperature DSP calculation, followed by pressure measurements/pressure DSP calculations, and then the results are written to the digital output register. Executing an SPI MR command is a read of 8 bits, ignoring the data that is returned.

Note: The SPI MR function can also be accomplished by performing a full SPI Get Data (GD) (see section 2.1.4.2) and ignoring the invalid data that will be returned.

2.1.5 MEASUREMENT READY PIN

A rise on the Ready pin indicates that new data is ready to be retrieved from either the I²C or SPI interface. The Ready pin stays high until a Get Data (GD) command is sent; it stays high even if additional measurements are performed before the GD.

The Ready pin's output driver type can be either push-pull or open drain. Point-to-point communication most likely uses the full push-pull driver. If an application requires interfacing to multiple parts, then the open drain. The factory default is push-pull.

3 OPERATION MODES

The CPS150 is factory programmed in either Sleep Mode or Update Mode. In Sleep Mode, the CPS150 waits for commands from the master before taking measurements. In Update Mode, the measurements are taken at a fixed rate.

4 EEPROM

The EEPROM array contains the sensor calibration coefficients and the configuration bits for the analog front end, output modes, measurement modes, etc. The EEPROM is locked to prevent changes.

5 CALCULATING OUTPUT

After retrieving the data, the compensated output can be calculated by following the equations below.

5.1 PRESSURE OUTPUT

An example of the 14-bit compensated pressure with a full scale range of 30 to 120kPa can be calculated as follows:

Pressure [kPa] = (Pressure High Byte [5:0] x 256 + Pressure Low Byte [7:0]) / 2^14 x 90 + 30

5.2 TEMPERATURE OUTPUT

The 14-bit compensated temperature can be calculated as follows:

Temperature [°C] = (Temperature High Byte [7:0] x 64 + Temperature Low Byte [7:2] / 4) / 2^14 x 165 – 40

6 PACKAGE AND ASSEMBLY

The CPS150 is available in a small land grid array (LGA) package with a metal lid. There is a hole on the lid to allow for external pressure to the sensing diaphragm.

6.1 PIN LAYOUT

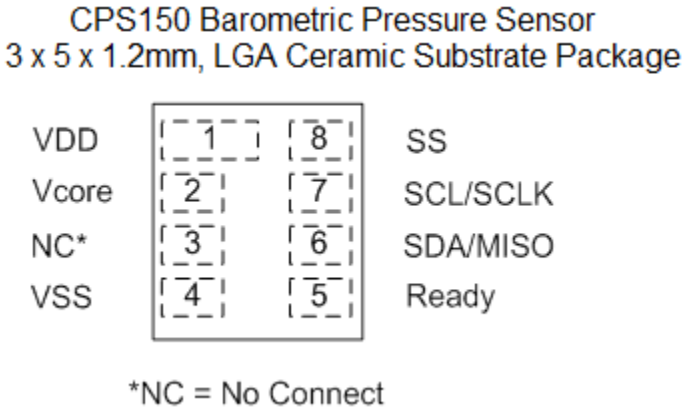


TABLE 6: CPS150 PIN DESCRIPTION

PIN	NAME	FUNCTION	NOTES
1	VDD	Supply Voltage	Always Connect to a 0.1µF Capacitor to Ground
2	VCORE	Core Voltage	Always Connect to a 0.1µF Capacitor to Ground
3	NC	Not Connected	Must Be Unconnected
4	VSS	Ground Supply	
5	READY	Ready Signal	If Not Used, Must Be Unconnected
6	SDA/MISO	I2C Data if in I2C Mode Master-In-Slave-Out if in SPI Mode	
7	SCL/SCLK	I^2C Clock if in I^2C Mode Serial Clock if in SPI Mode	
8	SS	Slave Select (input) SPI Mode	

6.2 MECHANICAL DRAWING

FIGURE 7: LGA WITH METAL LID PACKAGE

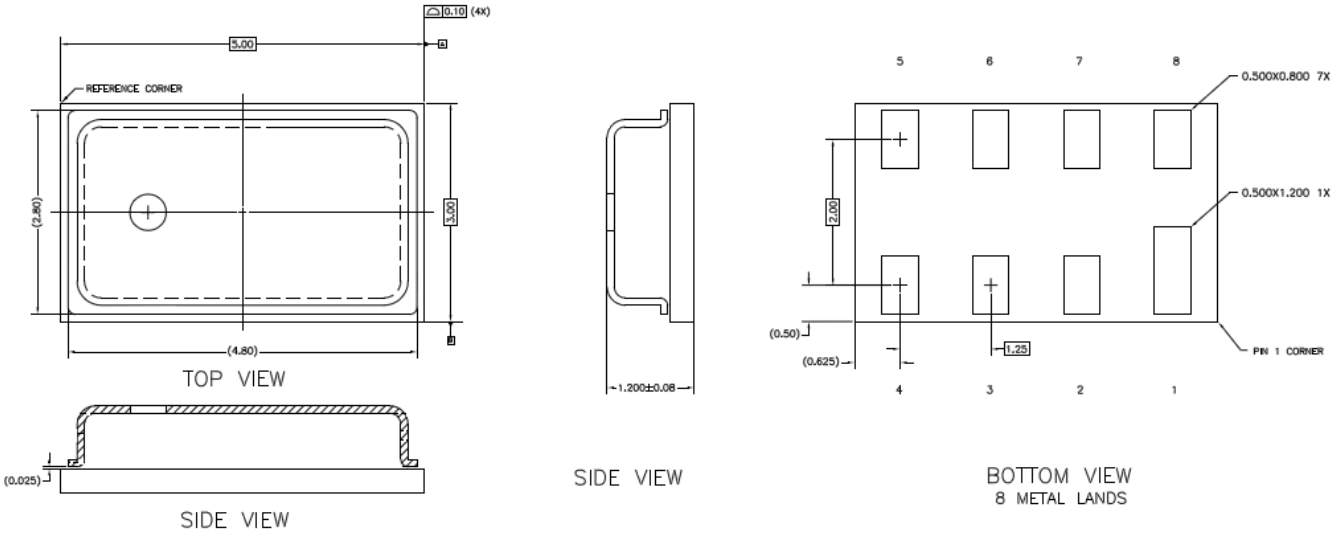


TABLE 7: MECHANICAL DIMENSIONS

DIMENSION	MIN.	TYP.	MAX.	UNITS
Length		5		mm
Width		3		mm
Height		1.2		mm
Pad 1 Length		0.5		mm
Pad 1 Width		1.2		mm
Pad 2 to 8 Length		0.5		mm
Pad 2 to 8 Width		0.8		mm
Pad Pitch (Y-Axis)		2.0		mm
Pad Pitch (X-Axis)		1.25		mm
Port Hole Diameter		0.5		mm

6.3 SOLDERING CONDITIONS

TABLE 8: PACKAGE REFLOW TEMPERATURE

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Soldering Peak Temperature	Less than 30 seconds (JEDEC-STD-020 Standard)			260	°C

7 DOCUMENT HISTORY

REVISION	DATE	DESCRIPTION
1.0	27-MAR-2012	Production Release
2.0	06-JUN-2012	Updated Contact Description and Product Overview
3.0	23-JUL-2012	Corrected Resolution Spec. to 0.001kPa
4.0	20-AUG-2012	Clarified Pressure and Temperature Accuracy LSL & USL

8 DISCLAIMER

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