

# CPS120

Preliminary r0.1  
January 2011

## Data Sheet

Digital Barometer



## Overview

The CPS120 is a high-quality, low-cost capacitive absolute pressure sensor solution with a compensated digital pressure and temperature output for low pressure applications, such as barometric sensing. Low current consumption (<1 $\mu$ A @ 25°C in Sleep Mode) and operating supply voltage range 2.3 V to 5.5V targets battery and other low-power applications. A robust sensor design (single crystal silicon structure and backside pressure port) makes the CPS120 suitable for extreme temperatures and harsh environments.

The CPS120 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 5 to 120kPa full scale. An integrated sigma-delta based ADC combined with internal calibration logic provides fully compensated temperature and pressure measurements to the application via the SPI or I<sup>2</sup>C interface. There is no need to separately download internal calibration coefficients and have the host microcontroller conduct complicated compensation calculations. The compensated values are simply scaled to produce highly accurate, compensated pressure and temperature measurements. Two selectable modes (Normal and Sleep) and an external “Measurement Ready” pin ensure operational flexibility suitable for an unlimited range of applications.

## Applications

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

## Benefits

- Fully Compensated Temperature and Pressure Output
- Low Power Consumption. Excellent for Battery and other Low-Power Applications
- Self-Clocking, No Need for External Clock
- High Resistance to Sensing Media

## Features

- Factory Calibrated Temperature & Pressure
- 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  $\pm$ 10%
- Absolute Temperature Range: -40°C to +125°C
- Pressure Accuracy: < $\pm$ 0.2kPa @ 25°C
- Temperature Accuracy:  $\pm$ 1.0°C
- Internal Logic with Two Selectable States (Normal and Sleep Mode)

## Interfaces

- Digital Output Interface for Connecting to External  $\mu$ C
- I<sup>2</sup>C™\* Compatible (100 and 400kHz)
- SPI (up to 800kHz) – 3wire

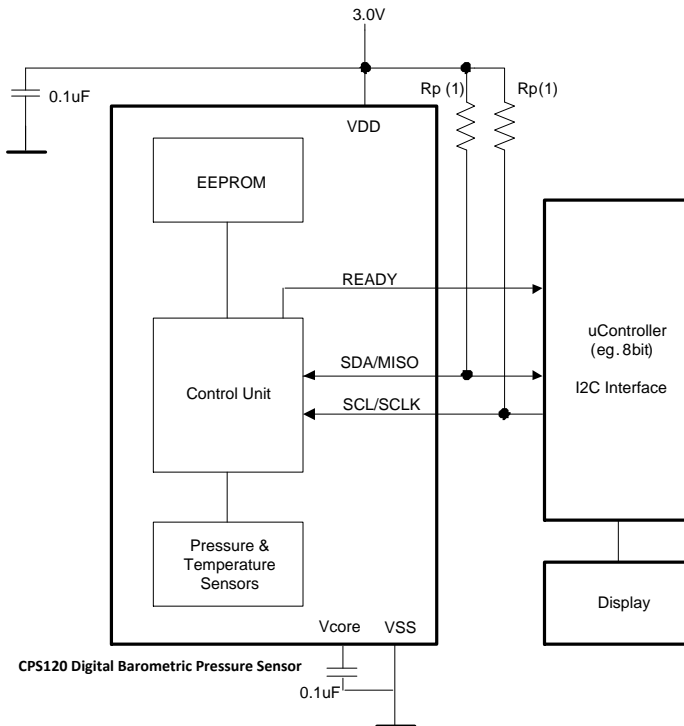
## Physical Characteristics

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

\*I<sup>2</sup>C™ is a registered trademark of NXP

---

## Typical Application Circuit



Note:  
 (1) Pull-up resistors for I2C,  $R_p=1k\Omega$  to  $10k\Omega$ , typical  $2.2k\Omega$

**TABLE 1: ORDERING INFORMATION**

| PART NUMBER       | TEMPERATURE RANGE | DIGITAL INTERFACE | PACKAGE              |
|-------------------|-------------------|-------------------|----------------------|
| CPS120-I2C-LGA-ML | -40 to 85°C       | I <sup>2</sup> C  | LGA 8-Lead Metal Lid |
| CPS120-SPI-LGA-ML | -40 to 85°C       | SPI               | LGA 8-Lead Metal Lid |

# CONTENTS

|       |  |    |
|-------|--|----|
| 1     | OPERATING CHARACTERISTICS .....            | 7  |
| 1.1   | ABSOLUTE RATINGS.....                      | 7  |
| 1.2   | OPERATING CONDITIONS .....                 | 7  |
| 1.3   | ELECTRICAL PARAMETERS .....                | 8  |
| 2     | NORMAL OPERATION MODE .....                | 9  |
| 2.1   | I <sup>2</sup> C AND SPI .....             | 9  |
| 2.1.1 | I <sup>2</sup> C FEATURES AND TIMING ..... | 9  |
| 2.1.2 | SPI FEATURES AND TIMING.....               | 10 |
| 2.1.3 | I <sup>2</sup> C AND SPI COMMANDS .....    | 12 |
| 2.1.4 | GET DATA (GD).....                         | 12 |
| 2.1.5 | MEASUREMENT READY PIN .....                | 15 |
| 3     | EEPROM .....                               | 16 |
| 4     | CALCULATING OUTPUT .....                   | 16 |
| 4.1   | PRESSURE OUTPUT.....                       | 16 |
| 4.2   | TEMPERATURE OUTPUT .....                   | 16 |
| 5     | PACKAGE AND ASSEMBLY .....                 | 17 |
| 5.1   | PIN LAYOUT .....                           | 17 |
| 5.2   | MECHANICAL DRAWING.....                    | 18 |
| 5.3   | SOLDERING CONDITIONS .....                 | 19 |
| 6     | DISCLAIMER.....                            | 20 |

---

## LIST OF TABLES

|          |   |    |
|----------|---|----|
| TABLE 1: | ORDERING INFORMATION .....              | 3  |
| TABLE 2: | I <sup>2</sup> C PARAMETERS .....       | 10 |
| TABLE 3: | SPI PARAMETERS .....                    | 11 |
| TABLE 4: | I <sup>2</sup> C AND SPI COMMANDS ..... | 12 |
| TABLE 5: | STATUS BITS .....                       | 12 |
| TABLE 6: | CPS120 PIN DESCRIPTION .....            | 17 |
| TABLE 7: | MECHANICAL DIMENSIONS.....              | 18 |
| TABLE 8: | PACKAGE REFLOW TEMPERATURE.....         | 19 |

---

## LIST OF FIGURES

|           |  |    |
|-----------|--|----|
| FIGURE 1: | I <sup>2</sup> C TIMING DIAGRAM .....  | 9  |
| FIGURE 2: | SPI TIMING DIAGRAM .....   | 11 |
| FIGURE 3: | 7-BIT SLAVE ADDRESS FOLLOWED BY FOUR BYTES OF PRESSURE AND TEMPERATURE DATA..... | 13 |
| FIGURE 4: | 8-BIT RESOLUTION TEMPERATURE DATA ONLY.....                                      | 13 |
| FIGURE 5: | 7-BIT SLAVE ADDRESS FOLLOWED BY TWO BYTES OF PRESSURE DATA .....                 | 14 |
| FIGURE 6: | MEASUREMENT REQUEST COMMAND (I <sup>2</sup> C MR).....                           | 15 |
| FIGURE 7: | LGA WITH METAL LID PACKAGE .....   | 18 |



# 1 OPERATING CHARACTERISTICS

## 1.1 ABSOLUTE RATINGS

| PARAMETER                            | SYMBOL     | CONDITIONS | MIN  | TYP | MAX            | UNITS |
|--------------------------------------|------------|------------|------|-----|----------------|-------|
| Over Pressure                        |            |            |      |     | 1000           | kPa   |
| 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                  | $T_{STOR}$ |            | -55  |     | 150            | °C    |

## 1.2 OPERATING CONDITIONS

| PARAMETER   | SYMBOL        | CONDITIONS           | MIN  | TYP   | MAX   | UNITS |
|---|---------------|----------------------|------|-------|-------|-------|
| <b>PRESSURE SENSOR</b>                              |               |                      |      |       |       |       |
| Range   |               |                      | 30   |       | 120   | kPa   |
| Resolution  |               |                      |      | 0.01  |       | kPa   |
| Accuracy  |               | @25°C, 70 to 115 kPa |      | ±0.15 |       | kPa   |
| <b>TEMPERATURE SENSOR</b>                           |               |                      |      |       |       |       |
| Range   |               |                      | -40  |       | 85    | °C    |
| Resolution  |               | 14-bit Mode          | 0.01 | 0.015 | 0.025 | °C    |
| Accuracy  |               |                      |      | ±1    |       | °C    |
| <b>OPERATION</b>                                    |               |                      |      |       |       |       |
| Supply Voltage to GND <sup>1</sup>                  | $V_{SUPPLY}$  |                      | 2.3  | 3.0   | 5.5   | V     |
| Ambient 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 <sup>2</sup> C Pull-Up Resistors                  | $R_{PU}$      |                      | 1    | 2.2   |       | kΩ    |
| SDA/MISO Load Capacitance                           | $C_{SDA}$     |                      |      |       | 200   | pF    |

<sup>1</sup> Factory calibrated for Pressure and Temperature at 3.0V±10%. Output accuracy will be affected if used outside this range.

### 1.3 ELECTRICAL PARAMETERS

| PARAMETER  | SYMBOL         | CONDITIONS   | MIN  | TYP  | MAX         | UNITS   |
|--|----------------|--|------|------|-------------|---------|
| <b>SUPPLY CURRENT</b>  |                |  |      |      |             |         |
| Normal Mode Current  | $I_{DD}$       | Worst Case Settings: 14-bit, 0ms Power Down                    |      | 750  | 1100        | $\mu A$ |
| Sleep Mode Current   | $I_{SLEEP}$    | -40 to 85°C  |      | 1    | 5           | $\mu A$ |
| <b>CAPACITANCE TO DIGITAL CONVERTER</b>  |                |  |      |      |             |         |
| Resolution   | RES            |  | 8    |      | 14          | Bits    |
| Sensor Excitation Frequency  |                |  |      |      | $f_{SYS}/2$ | kHz     |
| <b>EEPROM</b>  |                |  |      |      |             |         |
| Erase/Write Cycles   |                | @85°C  |      |      | 100k        |         |
| Data Retention   |                | @100°C   |      |      | 10          | Year    |
| <b>SYSTEM</b>  |                |  |      |      |             |         |
| Trimmed System Frequency   | $f_{SYS}$      | All Timing in this Specification are Subject to this Variation |      | 1.85 |             | MHz     |
| Start-Up-Time <sup>2</sup><br>Power-On to Data Ready                           | $t_{STA}$      | Fastest and Slowest Settings                                   | 4.25 |      | 173         | ms      |
| Update Rate (Normal Mode) <sup>2</sup>   | $T_{RESP\_UP}$ | Fastest and Slowest Settings                                   | 0.70 |      | 288         | ms      |
| Response Time (Sleep Mode) <sup>2</sup>  | $T_{RESP\_SL}$ | Fastest and Slowest Settings                                   | 1.25 |      | 163         | ms      |
| Peak-to-Peak Noise @ Output (100 Measurements in 14-bit) <sup>2</sup>          | $N_{OUT}$      |  |      | 5    |             | LSB     |
| <sup>2</sup> Parameter not tested during production, but guaranteed by design. |                |  |      |      |             |         |



## 2 NORMAL OPERATION MODE

### 2.1 I<sup>2</sup>C AND SPI

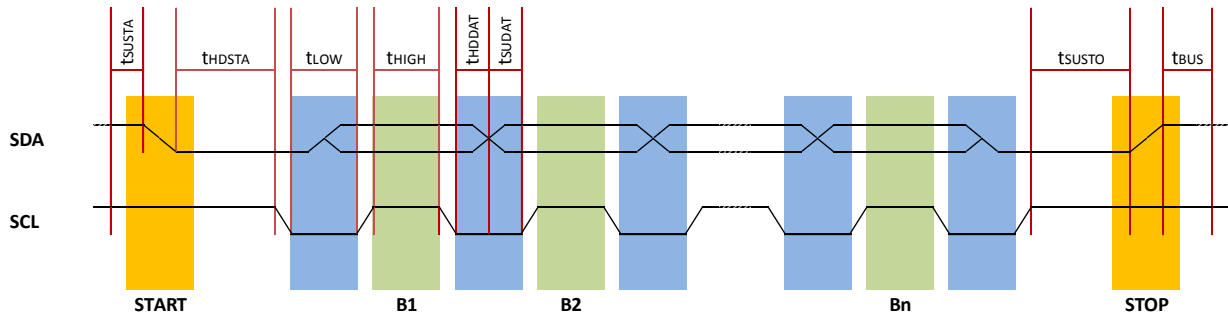
Two-wire I<sup>2</sup>C and three-wire (half-duplex) SPI are available for reading data from the CPS120.

#### 2.1.1 I<sup>2</sup>C FEATURES AND TIMING

The CPS120 uses an I<sup>2</sup>C compatible communication protocol with support for 100kHz and 400kHz bit rates. The factory setting for the I<sup>2</sup>C slave address is 0x28 and the communication is restricted to this address only.

See Figure 1 for the I<sup>2</sup>C timing and Table 2 for definitions of the parameters shown in the diagram.

FIGURE 1: I<sup>2</sup>C TIMING DIAGRAM



**TABLE 2: I<sup>2</sup>C PARAMETERS**

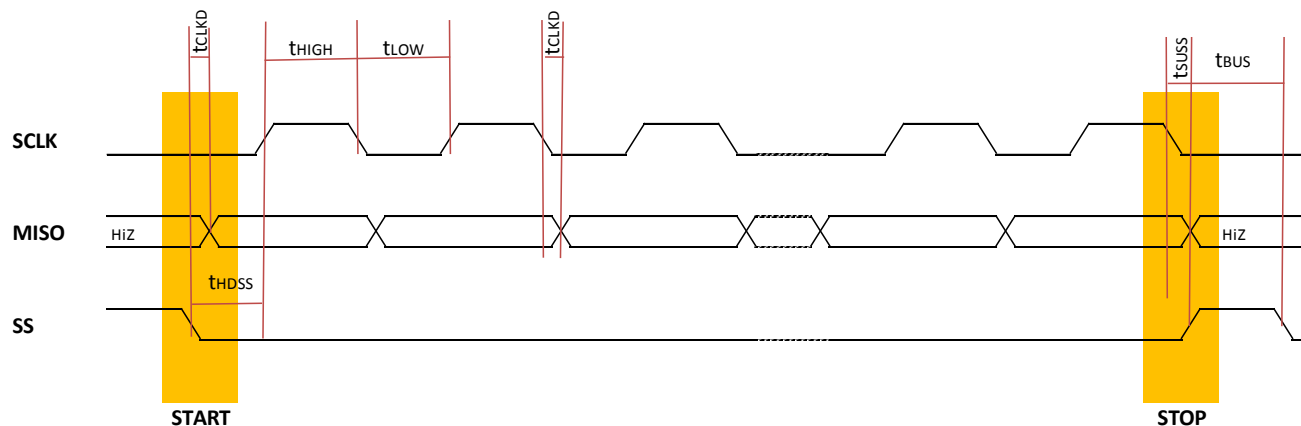
| PARAMETER   | SYMBOL      | CONDITIONS | MIN | TYP | MAX | UNITS   |
|---|-------------|------------|-----|-----|-----|---------|
| SCL Clock Frequency   | $f_{SCL}$   |            | 100 |     | 400 | kHz     |
| Start Condition Hold Time Relative to SCL Edge                                    | $t_{HDSTA}$ |            | 0.1 |     |     | $\mu$ s |
| Minimum SCL Clock Low Width <sup>3</sup>  | $t_{LOW}$   |            | 0.6 |     |     | $\mu$ s |
| Minimum SCL Clock High Width <sup>3</sup>   | $t_{HIGH}$  |            | 0.6 |     |     | $\mu$ s |
| Start Condition Setup Time Relative to SCL Edge                                   | $t_{SUSTA}$ |            | 0.1 |     |     | $\mu$ s |
| Data Hold Time on SDA Relative to SCL Edge  | $t_{HDDAT}$ |            | 0   |     | 0.5 | $\mu$ s |
| Data Setup Time on SDA Relative to SCL Edge                                       | $t_{SUDAT}$ |            | 0.1 |     |     | $\mu$ s |
| Stop Condition Setup Time on SCL  | $t_{SUSTO}$ |            | 0.1 |     |     | $\mu$ s |
| Bus Free Time Between Stop Condition and Start Condition                          | $t_{BUS}$   |            | 1   |     |     | $\mu$ s |
| <sup>3</sup> 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 CPS120) 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 2 for SPI timing diagram and Table 2 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 |     |     | $\mu s$ |
| Minimum SCLK Clock Low Width <sup>4</sup>  | $t_{LOW}$  |            | 0.6 |     |     | $\mu s$ |
| Minimum SCLK Clock High Width <sup>4</sup> | $t_{HIGH}$ |            | 0.6 |     |     | $\mu s$ |
| Clock Edge to Data Transition              | $t_{CLKD}$ |            | 0   |     | 0.5 | $\mu s$ |
| Rise of SS Relative to Last Clock Edge     | $t_{SUS}$  |            | 0.1 |     |     | $\mu s$ |
| Bus Free Time Between Rise and Fall of SS  | $t_{BUS}$  |            | 2   |     |     | $\mu s$ |

<sup>4</sup> Combined low and high widths must equal or exceed minimum SCLK period

### 2.1.3 I<sup>2</sup>C AND SPI COMMANDS

Table 4 details the commands to interface with the device in the I<sup>2</sup>C and SPI modes.

**TABLE 4: I<sup>2</sup>C AND SPI COMMANDS**

| TYPE                     | DESCRIPTION                             | SUPPORT                  | REFERENCE |
|--------------------------|---|--------------------------|-----------|
| Get Data (GD)            | Used to Get Data in Normal Mode         | I <sup>2</sup> C and SPI |           |
| Measurement Request (MR) | Used to Start Measurement in Sleep Mode | I <sup>2</sup> C 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 I<sup>2</sup>C 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 I<sup>2</sup>C GET DATA

An I<sup>2</sup>C Get Data command starts with the 7-bit slave address and the 8<sup>th</sup> 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.

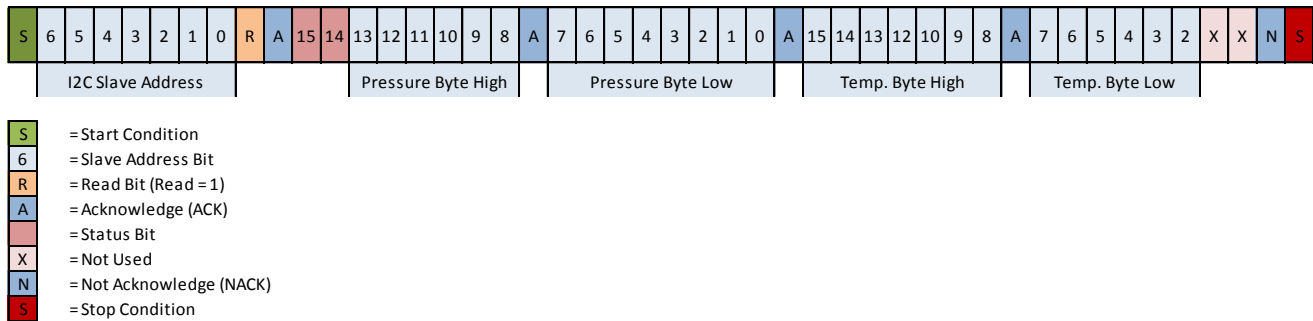
Figure 3 shows examples of receiving a total of 5 bytes. The first byte contains the I<sup>2</sup>C address followed by two pressure bytes and two temperature bytes. The first two bits of the Pressure Byte High are status bits. See Table 5.

**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   |

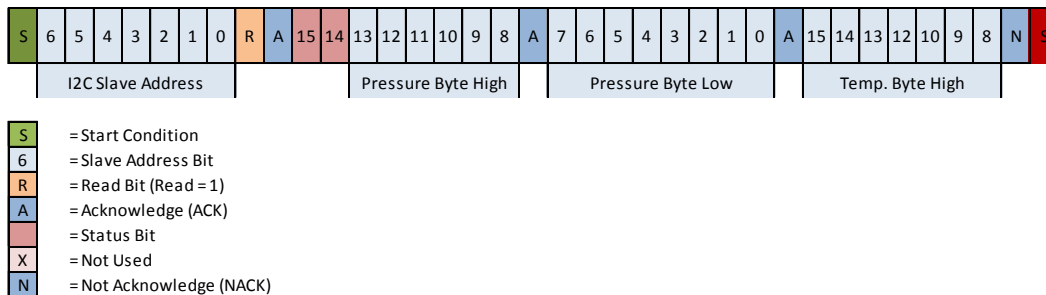
In Figure 3, the last two bytes returns 2 bytes of temperature data (14-bit accuracy) after the pressure data. The six MSBs of the last byte are the six LSBs of the temperature measurement. The last two bits of the fifth byte are undetermined and should be masked off in the application.

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



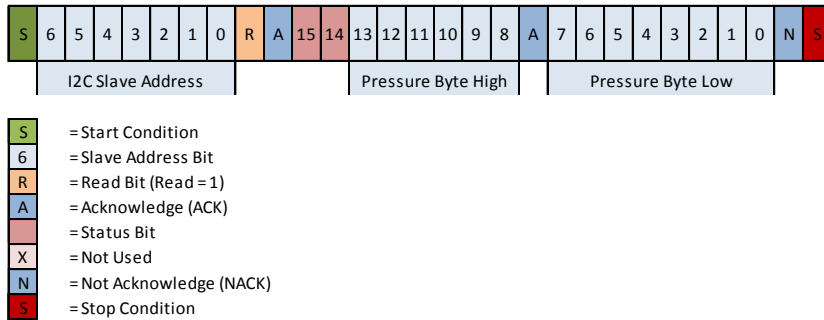
For lower resolution temperature accuracy, 8-bit, only the High Temperature Byte is needed and the data stream can be terminated after the first temperature byte. See Figure 4 below.

**FIGURE 4: 8-BIT RESOLUTION TEMPERATURE DATA ONLY**



For pressure data only, the data stream can be terminated after the second pressure byte. See Figure 5 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.

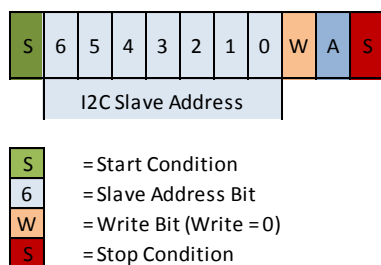
As seen in Figure 3, the entire output packet is 4 bytes (32 bits). The status byte comes first, followed by the high and low pressure sensor data bytes. Then, 14 bits of corrected temperature T[13:0] are sent, first the T[13:6] byte and then the {T[5:0],xx} byte. If the user only requires the corrected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

### 2.1.4.3 I<sup>2</sup>C MEASUREMENT REQUEST

The I<sup>2</sup>C 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 6, 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 I<sup>2</sup>C 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 (I<sup>2</sup>C 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 I<sup>2</sup>C 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 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.

### 4 CALCULATING OUTPUT

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

#### 4.1 PRESSURE OUTPUT

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

$$\text{Pressure [kPa]} = (\text{Pressure High Byte [5:0]} \times 256 + \text{Pressure Low Byte [7:0]}) / 2^{14} \times 90 + 30$$

#### 4.2 TEMPERATURE OUTPUT

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

$$\text{Temperature [}^{\circ}\text{C]} = (\text{Temp. High Byte [7:0]} \times 64 + \text{Temp. Low Byte [7:2]} / 4) / 2^{14} \times 165 - 40$$

\*This equation is for temperature range from -40 to 125°C.

---

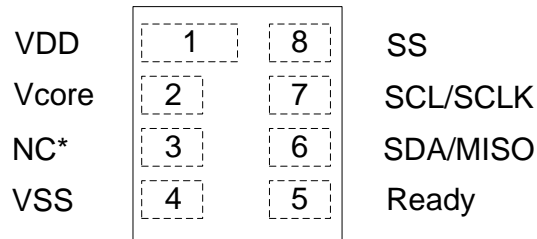


## 5 PACKAGE AND ASSEMBLY

The CPS120 is available in a small land grid array (LGA) package with a metal or FR4 lid. There is a hole on the lid to allow for external pressure to the sensing diaphragm.

### 5.1 PIN LAYOUT

CPS120 Barometric Pressure Sensor  
3 x 5 x 1.2mm, LGA Package



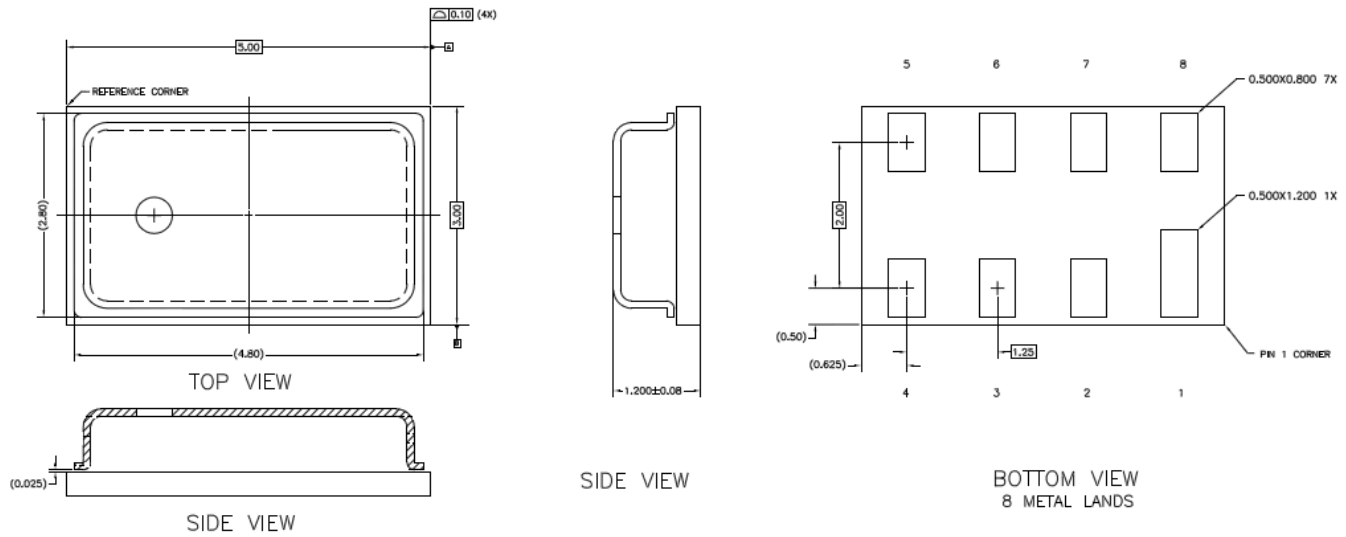
\*NC = No Connect

TABLE 6: CPS120 PIN DESCRIPTION

| PIN | NAME     | FUNCTION  | NOTES   |
|-----|----------|---|---|
| 1   | VDD      | Supply Voltage  | Always Connect to a 0.1 $\mu$ F Capacitor to Ground |
| 2   | VCORE    | Core Voltage  | Always Connect to a 0.1 $\mu$ F 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 | I <sup>2</sup> C Data if in I <sup>2</sup> C Mode<br>Master-In-Slave-Out if in SPI Mode |   |
| 7   | SCL/SCLK | I <sup>2</sup> C Clock if in I <sup>2</sup> C Mode<br>Serial Clock if in SPI Mode       |   |
| 8   | SS       | Slave Select (input) SPI Mode   |   |

## 5.2 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    |

### 5.3 SOLDERING CONDITIONS

**TABLE 8: PACKAGE REFLOW TEMPERATURE**

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