Post Calibration Offset Correction on Pressure Sensors

Application Note

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Surface-mounted pressure sensors offer several advantages, including compact design, ease of integration, and cost-effectiveness. They are widely used in medical, consumer electronics, automotive, and industrial applications. These sensors are especially valuable in situations where **space, weight, and cost** are critical factors.

Reflow soldering is the preferred method for **attaching SMD pressure sensors** to PCBs through an automated process. However, exposure to **high temperatures during reflow** can introduce **mechanical stress**, leading to an **offset shift in sensor output**. The more sensitive the sensor, the more likely it is to experience an offset change after reflowing.

Additionally, **housing stress** can affect the sensor's output. During final assembly, protective housings apply **compression and torsion forces**, which can alter the sensor's calibrated response. These stresses must be accounted for to ensure accurate pressure readings.

SMD pressure sensors such as **Merit Sensor's CMS-SERIES Series and LP2-SERIES Series** are calibrated and thermally compensated pressure sensors designed with a built in Post Calibration Offset Correction (PCOC) feature that allows the correction of shifts caused by stresses after reflowing and/or assembling these parts into custom housings.

Post Calibration Offset Correction (PCOC) Instructions

Merit Sensor's **CMS-SERIES and LP2-SERIES Series** pressure sensors come with an integrated **Post Calibration Offset Correction (PCOC) function**, designed to **correct offset shifts** caused by **reflow soldering and housing assembly**. This feature allows users to **re-zero the sensor digitally**, ensuring accuracy without the need for external recalibration.

The internal **Sensor Signal Conditioner's** DSP (Digital Signal Processor) runs a 26-bit math core running a correction algorithm for precise calculus of pressure and temperature correction coefficients. The DSP supports a list of commands that can be used to execute specific functions including the PCOC that is specifically useful when the user's code doesn't include a function to re-zero the sensor after installation and to eliminate long term drift error.

PCOC is performed through **digital communication** via **I2C or SPI**, depending on sensor configuration. The correction process involves:

1. **Sending the PCOC command** (`0xD1`)
2. **Specifying the desired output level** ($XXXX_{HEX}$) at the current pressure level

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Post Calibration Offset Correction Example:

The example below shows the offset shift correction of a Merit Sensor LP2-SERIES Pressure Sensor. The correction was applied to the following part-number: **1440-0150-G002-S**

Device Setup

Example sensor: LP2-SERIES (Part Number: 1440-0150-G002-S):

- 150Pa Gage
- I2C address = 0x28
- Cyclic operation
- 3.3V
- I2C and analog default outputs
- Nominal Output at 0Pa = 10% FS@16-bit = 6554 counts
- Nominal Output at 150Pa = 90% FS@16-bit = 58981 counts
- Stable Pressure at PCOC procedure: 0PaG

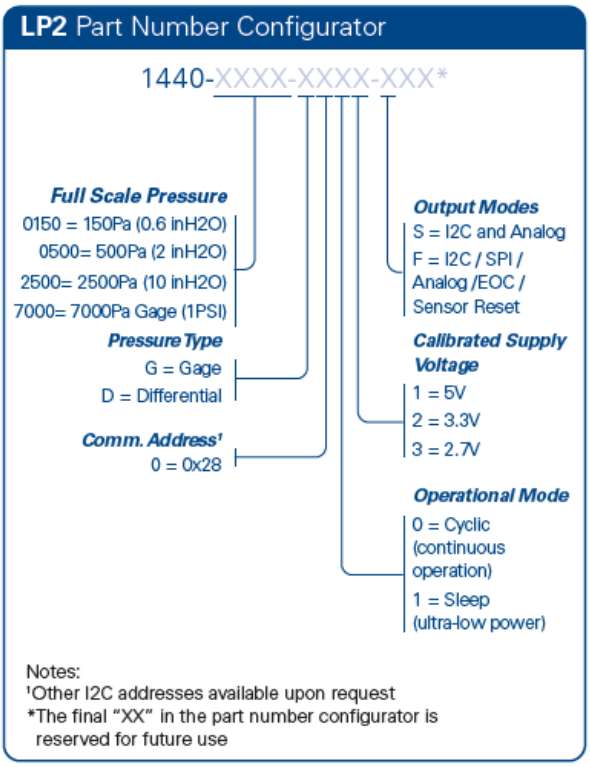

Figure 1 - LP2-SERIES Part Configurator

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Device Under Test zero pressure output (counts) before PCOC:

Measured Output Before PCOC Procedure (Figure 2**):**

- Sensor output at 0Pa: 6220 counts (average)
- Offset error: -333 counts (~0.56% Full-Scale error)

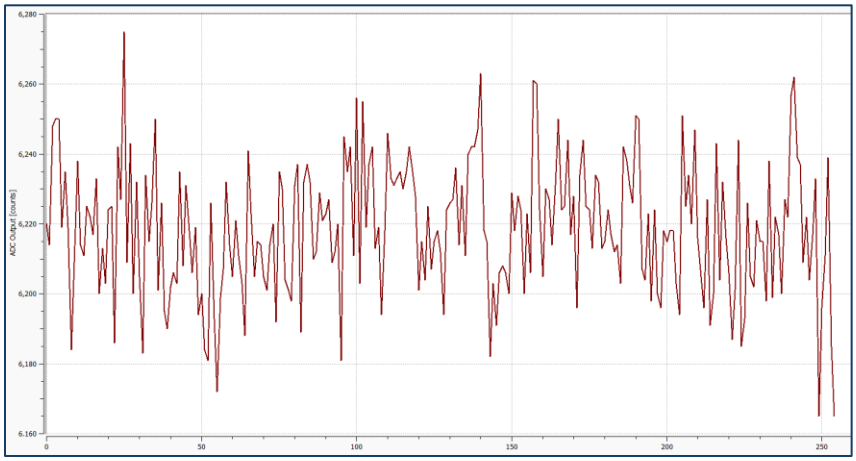

Figure 2 - Device Under Test output at P = 0PaG

Executing Post Calibration Offset Correction:

Steps for PCOC Process

1. Ensure the sensor is **exposed to a known and stable pressure**
2. Allow the sensor to warm up for accurate results:
    a. 30 seconds: Removes most warm-up errors
    b. 120 seconds: Ensures full thermal stabilization
3. Enter Command Mode
    a. Send **write command (**`0xA9`**)** to activate command mode
    b. Verify status: **Send a 1-byte read command**; sensor should respond `0x40` (confirming command mode is active)
4. Apply PCOC Correction
    a. Send **write PCOC command (**`0xD1`**)** followed by the **expected output value** (`0xD1199A`) for this specific device at 0PaG
5. Send **checksum update command (**`0x90`**)** to save new memory data
6. Cycle power or reset the sensor (when reset available) to finalize the correction
7. The PCOC procedure is now completed and can be repeated if new corrections are needed

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Sensor Output After PCOC Correction

Measured output after PCOC at 0Pa (Figure 3):

- Sensor Output at 0Pa: 6550 counts (average)
- Offset error reduced to -4 counts (~0.007% Full-Scale error)

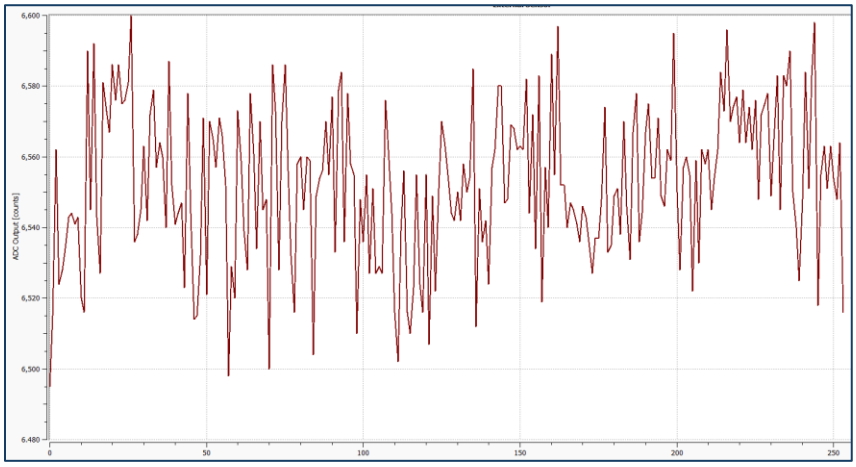

Figure 3 - Device Under Test output at P= 0PaG after the PCOC procedure

Precautions When using Post Calibration Offset Correction

To get the most from the PCOC procedure and avoid possible damage to its memory, please take the following precautions

1. Correct Memory Writing Procedures

Merit Sensor's LP2-SERIES and CMS-SERIES contain a Sensor Signal Conditioner (SSC) with an internal DSP running an algorithm that manages sensor functions. Incorrect memory writes can permanently damage the sensor. The SSC's pressure and temperature correction data as well as the SSC's configuration data are stored by an EEPROM. If these memory addresses are mistakenly re-written, it might cause abnormal behavior to the sensor's response.

Incorrect memory writes can lead to sensor malfunction, often resulting **in irreversible damage**. To prevent corruption, always follow the instructions provided in **Merit Sensor's** application notes and datasheets and **limit writing only to the provided memory addresses.**

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2. Stable Pressure and Temperature During the PCOC Process

The effectiveness of Post Calibration Offset Correction (PCOC) depends primarily on two factors: the accuracy of the correction data sent to the sensor and the stability of the applied pressure at the moment of correction. If the correction data is transmitted during an unstable pressure event, the sensor's internal digital signal processor (DSP) may reference a transient peak or plateau, leading to an incorrect offset correction.

Lower-range pressure sensors are more susceptible to variations in pressure. When performing PCOC on ultra-low-pressure sensors, especially when using atmospheric pressure as a reference, it is critical to ensure a stable environment. Avoid strong airflow and sudden temperature fluctuations, as these can introduce instability, compromising the correction accuracy.

If the PCOC process yields unsatisfactory results, the correction can be reapplied following the same procedural steps.

3. BFSL Pressure Sensors and PCOC

Best-Fit Straight Line (BFSL) calibration method distributes non-linearity errors across the ideal linear transfer function, typically distributing non-linearity errors between the extremes and center of the output response. Figure 4

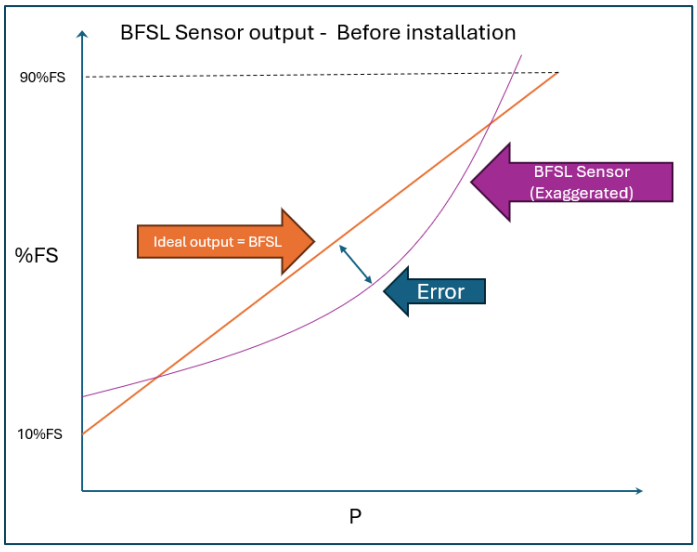

Figure 4 - BFLS Pressure Sensor expected response before installation

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Reflow soldering and encapsulation processes introduce mechanical stress to pressure sensors, potentially shifting their output response away from the ideal transfer function. Figure 5

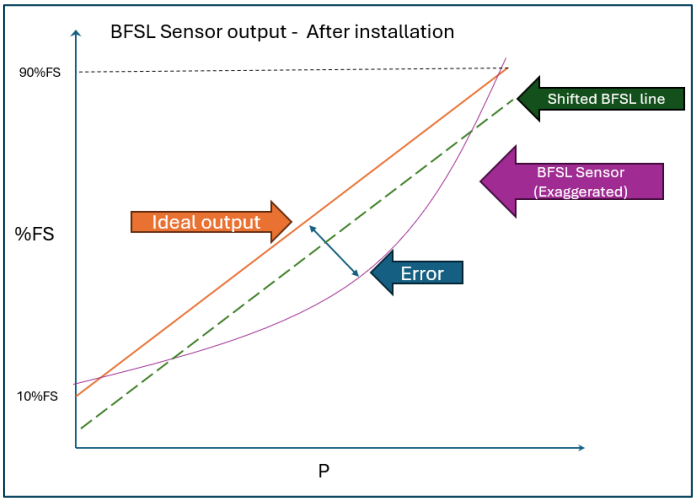

Figure 5 - BFSL line shifted after stress caused by assembly processes

Applying Post Calibration Offset Correction (PCOC) at different pressure points affects non-linearity behavior differently :

Bottom-scale pressure correction increases non-linearity error at mid pressure. Figure 6

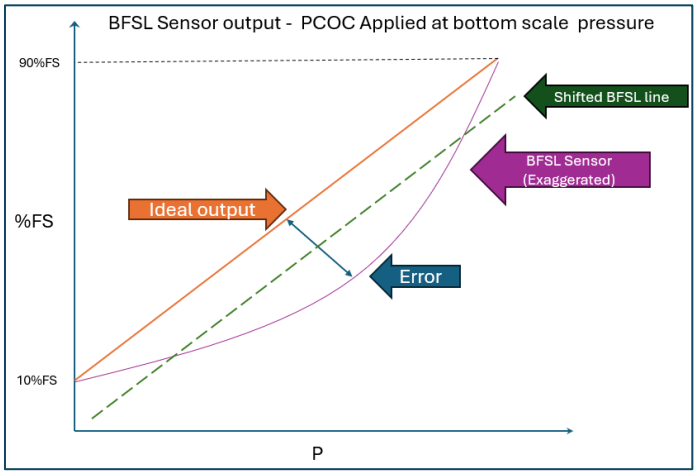

Figure 6 - PCOC Applied at Bottom Scale Pressure

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Mid-scale correction (common in differential pressure sensors) increases non-linearity error at bottom and top pressures.

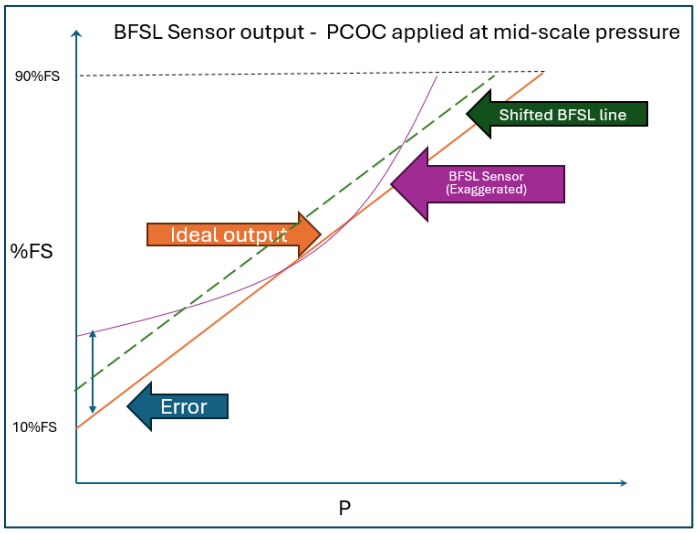

Figure 7 - PCOC Applied at Mid-Scale Pressure

Merit Sensor's amplified pressure sensors are engineered to minimize non-linearity errors through rigorous calibration testing, enabling simplified PCOC procedures for most applications. However, engineering validation tests on parts subjected to PCOC before mass production are recommended to ensure optimal performance.

4. Temperature Considerations in PCOC Calibration

Compensated pressure sensors are engineered to mitigate temperature-induced variations in pressure output. However, temperature shifts often lead to output variations in most pressure sensors. Sensors with higher pressure sensitivity are typically more susceptible to temperature-induced drift.

PCOC Procedure & Temperature Considerations: The Pressure Compensation Offset Calibration (PCOC) procedure effectively eliminates offset errors at the specific temperature at which it is executed. However, engineering evaluations during development phases should include testing across different operating temperature ranges when PCOC has not been applied at the sensor's intended working temperature. This ensures the sensor maintains expected performance across all operational conditions.

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The Post Calibration Offset Correction Procedure

Reflow soldering and housing-induced mechanical stress can cause pressure sensors to deviate from their original calibration values, leading to potential accuracy issues in the final application.

The PCOC (Post Calibration Offset Correction) feature default on **Merit Sensor's** LP2-SERIES and CMS-SERIES provides a straightforward method for mitigating these errors in systems that are not designed with an embedded zeroing function. With simple digital commands and taking few precautions, the PCOC procedure can improve the customer's final sensor assembly accuracy and allow future corrections to long term drift.

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