Automatic baseline offset correction and forced compensation features of XENSIV™ PAS CO2

Automatic baseline offset correction and forced compensation scheme

About this document

XENSIV™ PAS CO2 is a highly accurate gas sensor using optical sub-components. As with other optical systems, XENSIV™ PAS CO2 sensor may experience an offset in its characteristics because of the mechanical stress resulting from the assembly process. Even small deviations from the recommended soldering profile parameters can be sufficient to push the sensor outside the specified accuracy corridor. Fortunately, this offset error is automatically corrected after one week of operation thanks to the automatic baseline offset correction (ABOC) feature. If, for specific application use cases, an immediate correction of the offset error is required, the device supports forced compensation scheme (FCS) enabling a fast and cost-effective offset calibration at the customer assembly line.

In this document, the implementation of these schemes will be discussed in detail.

Scope and purpose

The implementation of FCS and ABOC will be discussed for different application scenarios. Depending on the application requirements, either of these two schemes can be implemented.

Intended audience

Application engineers, system engineers and system architects of an application where XENSIV™ PAS CO2 will be used. Additionally, engineers responsible for XENSIV™ PAS CO2 assembly and installation.

Table of contents

1 Offset compensation features of XENSIV™ PAS CO2

The XENSIV™ PAS CO2 is a real CO_2 sensor that overcomes the size, performance and assembly challenges of existing CO_2 sensor solutions. Designed based on the unique photoacoustic spectroscopy (PAS) concept, the sensor becomes an exceptionally miniaturized optical instrument. As with other optical systems, XENSIV™ PAS CO2 sensor may experience an offset in its characteristics because of the mechanical stress resulting from the assembly process. Even small deviations from the recommended soldering profile parameters can be sufficient to push the sensor outside the specified accuracy corridor. Fortunately, this offset error is automatically corrected after one week of operation thanks to the automatic baseline offset correction (ABOC) feature.

If, for specific application use cases, an immediate correction of the offset error is required, the device supports forced compensation scheme (FCS). When using FCS after sensor assembly on PCB, the offset error is corrected and the sensor is forced back to its original accuracy. The FCS offset calibration feature has been conceived in such a way that it is fast, cost-effective and can be implemented with low effort at the customer assembly line.

In the rare occurrences when the offset error is higher than 150ppm, the use of FCS is recommended.

For both schemes, a reference CO_2 concentration needs to be considered. The reference value can be read from a reference sensor. Alternatively, after assembly, the XENSIV™ PAS CO2 can be exposed to the outside air where the average outdoor air CO_2 concentration can be considered as 400 ppm. In the following section, these two schemes are discussed in detail.

1.1 Application scenarios using Forced Compensation Scheme (FCS)

- **Scenario 1:** Immediate correction of offset error after assembly/reflow

  In this scenario FCS is recommended to be implemented at the assembly site. Before evaluating the accuracy of the sensor, it is recommended to perform FCS to minimize the offset shift.
- **Scenario 2:** The application conditions do not fulfill the primary condition of the ABOC scheme

  The raw signal of the sensor might drift over time due to aging, and implementing ABOC is the recommended mode of operation to mitigate such a drift. However, for applications where the sensor will not be regularly exposed to a minimum CO_2 baseline concentration during operation, the primary condition of the ABOC scheme is not fulfilled. Therefore, for such applications FCS could be used.

1.2 Application scenarios using ABOC

To correct the initial offset after assembly and slow drifts caused by aging during operation, the device supports ABOC. For instance, if the sensor takes one measurement per 60 seconds and is regularly exposed to outdoor air (for at least 30 consecutive minutes per week), ABOC should be utilized. Two possible scenarios are discussed below.

- **Scenario 1:** If the measurement rate is set to one measurement in 30 minutes or less, the sensor needs to be exposed to fresh air for at least 30 consecutive minutes within a week for the ABOC to function properly.
- **Scenario 2:** Alternatively, if the measurement rate is set to one measurement in more than 30 minutes, the sensor should be exposed to fresh air for at least the same amount of time as the measurement rate. For example, if the sampling frequency is set to one measurement per hour, then the sensor needs to be exposed to fresh air for at least one hour.

Note: Both FCS and ABOC can be used very easily using the Sensor2Go kit via GUI. For further details please, check the user manual of the Sensor2Go kit from this LINK.

2 Implementation of FCS and ABOC

2.1 Forced compensation scheme

Before implementing the FCS, the sensor needs to be exposed to the reference CO_2 concentration for 3 measurement points. Reference CO_2 concentration can be considered in two methods:

- **Method 1:** Expose the sensor to outdoor fresh air and consider the average outdoor CO_2 concentration is 400 ppm.
- **Method 2:** Expose the sensor to a known and stable CO_2 concentration within a sealed chamber. Reference CO_2 concentration needs to be within 350 ppm and 1500 ppm. A recommended reference sensor will be discussed in the next chapter.

To implement the FCS, two registers, CALIB_REF_H and CALIB_REF_L, must be programmed correctly. When FCS is enabled (MEAS_CFG.BOC_CFG = 10b), the device will use the next three measurements to calculate the compensation offset. It is recommended to wait long enough for the CO2 concentration to stabilize near the sensor, as well as ensuring stable ambient temperature and pressure. For this reason, at a measurement rate of one per 10 seconds, the device must be exposed to the reference conditions (CO2 concentration, temperature and pressure) for at least 30 seconds. Once the sequence comprising of three measurements for calculating the offset is completed, the device will automatically reconfigure itself with the newly computed offset applied to the following CO2 concentration measurement. It is important to note that after the compensation offset is computed, it should be stored in the non-volatile memory by using the save calibration command (SENS_RST = 0xCF). Figure 1 summarizes the implementation technique of the FCS scheme.

Note: The device's measurement rate must be 1 measurement per 10 s when triggering FCS. After implementing FCS, the ABOC data is reset and the device will automatically switch back to ABOC mode.

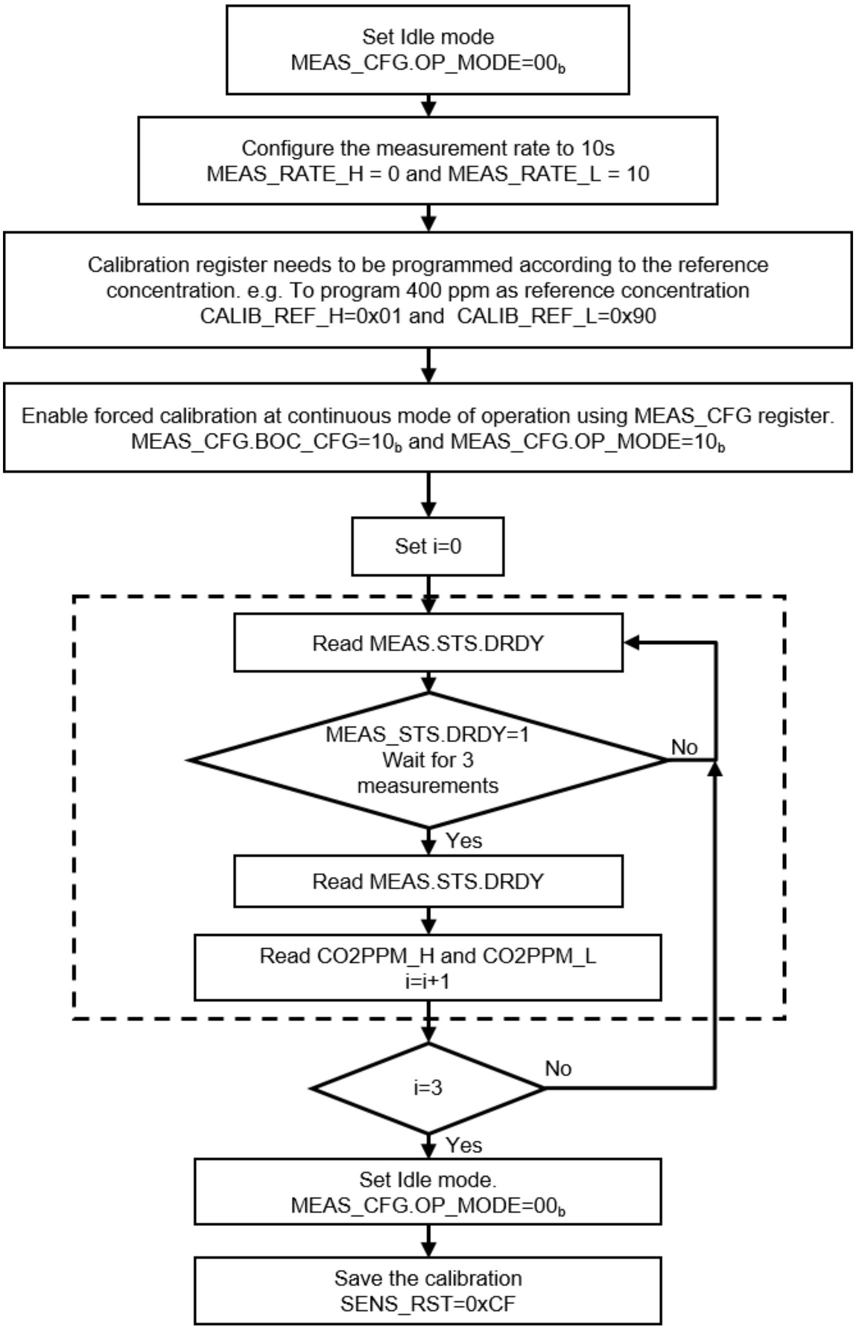

Figure 1 Process flow to implement FCS. 400 ppm has been considered as the reference concentration.

2.2 Automatic baseline offset correction

Per default XENSIV™ PAS CO2 is operating in continuous mode with ABOC enabled. Every week of operation, the device keeps track of the minimum value recorded over that time. The offset to the reference baseline is computed and used to calculate the correction factor to be applied for the week after. The offset update frequency is based on the accumulated operating time of the device and independent of the chosen sampling frequency. However, the time windows for which the device is powered off completely (**VDD3.3** not present) will not be considered. The offset computation scheme assumes that the maximum difference between two correction factors computed consecutively (week to week) remains within **+/-50 ppm**. To ensure proper operation of the ABOC scheme please ensure settings for the relevant scheme have been considered, as discussed in section 1.2. The implementation of the ABOC has been illustrated using the following figure.

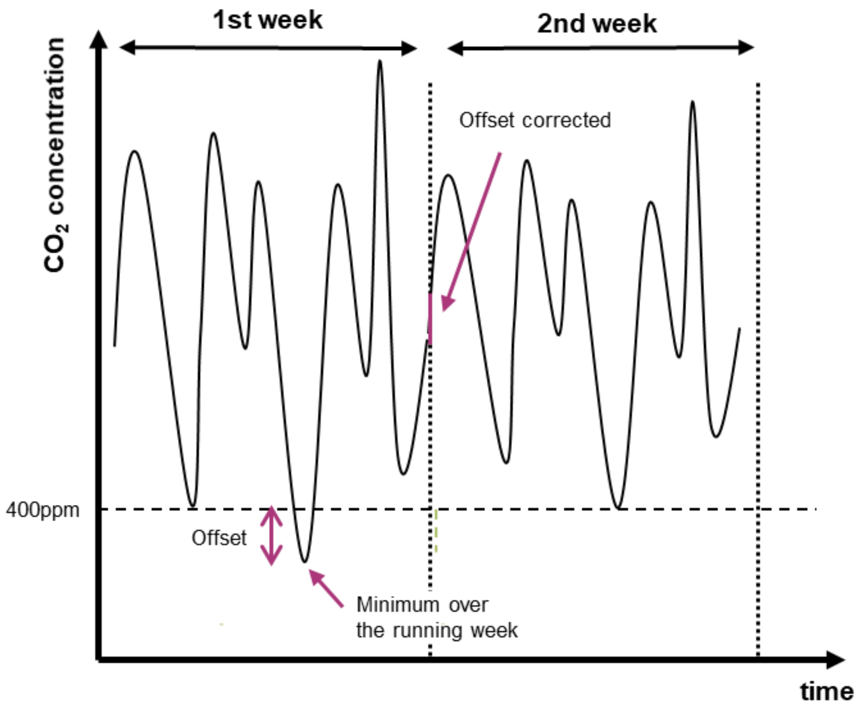

Figure 2 **Operation of the ABOC**

Note: *For the very first ABOC update, the capping assumption (maximum difference between two correction factors computed consecutively, week to week, remains within* ***+/- 50 ppm****) is not valid. The history of readings required for ABOC algorithm is stored in the non-volatile memory after one hour of continuous operation.*

If automatic baseline compensation is enabled (MEAS_CFG.BOC_CFG = 01_b), the latest valid computed correction factor is applied to the measured CO_2 concentration value. The offset correction is calculated based on the reference value programmed in register CALIB_REF_H and CALIB_REF_L.

Note: *The default reference CO_2 concentration is considered to be 400 ppm. The reference value should only be adjusted for a very specific application scenario.*

2.3 Automatic baseline offset correction in single shot mode

With firmware version 2.18, an extended ABOC functionality has been introduced, including support for single shot mode of operation. The firmware version can be retrieved from the PROD_ID register (address: 0x00), please refer to the "Register map description of the XENSIV™ PAS CO2" for more detailed information. This feature allows ABOC to be used in battery-powered applications where the supply voltages are switched off between two consecutive measurements. In single shot mode, the same ABOC scheme explained in section 2.2 is supported, overcoming the constraint of the power supply being continuously present and thus reducing power consumption. For more details on peak current, power consumption, and power optimization methodologies, please refer to the application note titled "Recommendation for optimizing power consumption for battery driven applications with XENSIV™ PAS CO2 sensor".

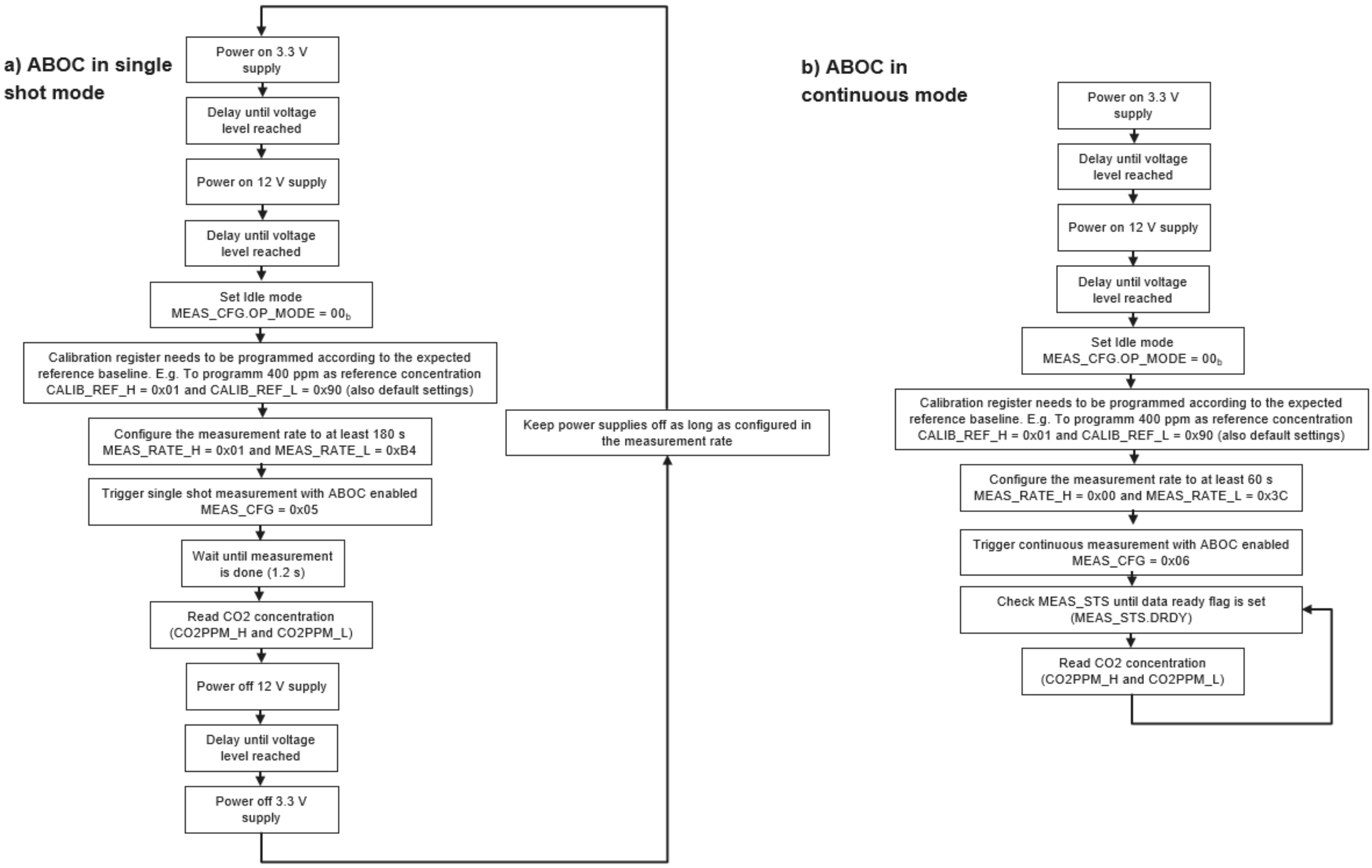

Figure 3 Process flow for ABOC in a) single shot mode, e.g. for battery powered operation and b) continuous node

Note: Please note the sequence for turning on and off the 3 V and 12 V supply voltage to not harm the sensor as well as ensure that both voltage levels reached the final and designed voltage before continuing with setting the idle mode. For each power cycle the sensor reverts to its default state, so all configurations must be reapplied. If applicable, pressure compensation can be applied before triggering the measurement.

Prerequisite for ABOC in single shot is a periodic measurement with a fixed interval. The fastest configurable measurement rate is 1 meas/ 3 minutes (=180s), faster sampling or dynamic changes in sampling rate may result in undesired behavior. As with ABOC in continuous mode (Section 2.2), the device tracks the minimum measured CO2 concentration over one week of operation, calculates the deviation from the configured reference baseline concentration, and applies a correction factor for the following week. In order for the ABOC to function correctly, it must be ensured that the sensor is exposed to the reference baseline concentration for at least one measurement. The flow chart in figure 3 summarizes the steps to enable ABOC in single shot mode.

3 Recommended reference sensor

Vaisala GMP343 is recommended as the reference CO_2 sensor. Further details of this product can be found on the product page.

Revision history

Document version	Date of release	Description of changes
V1.0	02.06.2021	Creation
V1.1	23.08.2021	Published
V1.2	15.12.2021	Update to Forced Compensation Scheme, new Title
V1.3	11.7.2022	Minor changes and rephrasing
V1.4	03.02.2023	Recommendations rephrased and specified based on customer feedback.
V1.5	25.10.2023	Section on ABOC in single shot mode added (FW v2.18)

Edition 2023-10-25

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about this document?

Email: erratum@infineon.com

Document reference
AN_2106_PL38_2106_095830