SENSIRION

SCD4x Low Power Operation

Sensirion's SCD4x product family enables cost efficient CO_2 measurement at high accuracy within a tiny form factor. For many of its applications, optimizing power consumption is a key requirement. To help achieve this, SCD4x sensors feature a range of high-performance and low power operation modes. This guide is intended to help you find and operate the SCD4x at the optimal trade-off point between sensor performance and energy efficiency as based on your application's needs. It provides an overview of the sensor's measurement modes, their features and the sensor's typical power consumption in each mode.

1 The Power-Performance Trade-Off

Performing a CO_2 measurement is the most significant part of the power consumption of the SCD4x. Consequently, adapting the sampling period is the simplest and most effective way to optimize sensor's power consumption. However, increasing the sampling period comes at the cost of also increasing the response time to external changes in CO_2 concentration, as more time passes before the sensor provides a new data point. Furthermore, taking fewer measurements over time also increases the noise level observed in the output signal. This occurs because higher sampling periods generally decrease the feasibility of filtering or averaging over several data points to alleviate signal noise.

The resulting trade-off between power consumption and sensing performance needs to be considered carefully to best meet all requirements set forth by the intended application.

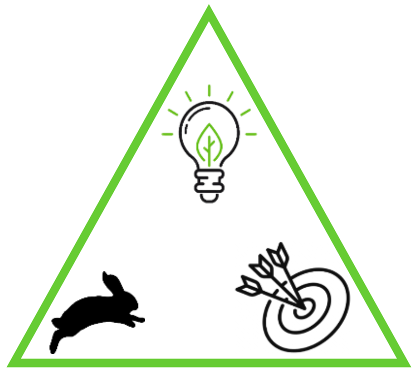

Figure 1: The three-way trade-off to be mastered for low power applications

2 Operation Modes

SCD4x CO_2 sensors feature up to four different operation modes with different features and capabilities: two periodic measurement modes and two single shot modes. An overview of the typical average supply current required by the sensor at different sampling periods and 3.3 V is provided in Table 1 below.

Measurement mode	Sampling Period	Typical average supply current at 3.3 V	Typical average supply current at 5 V
High performance mode	5 sec	15 mA	11 mA
Low power mode	30 sec	3.2 mA	2.8 mA
Idle single shot mode	60 sec (1 min)	1.5 mA	1.1 mA
	300 sec (5 min)	450 µA	360 µA
Power-cycled single shot mode	600 sec (10 min)	250 µA	180 µA
	1200 sec (20 min)	130 µA	90 µA
	3600 sec (1 h)	43 µA	30 µA

Table 1: Overview of typical average supply current by operation mode

2.1 High-Performance Mode

This mode represents the standard periodic measurement mode for SCD4x sensors as initiated using the *start_periodic_measurement* command detailed in section 3.5 of the SCD4x datasheet. It features a fixed update interval of 5 seconds and is the recommended operation mode for applications requiring relatively fast response times and detailed knowledge of the evolution of the CO_2 concentration over time. Automatic Self Calibration (ASC) is activated by default in this measurement mode to ensure long-term sensor accuracy. Note that this is the only available operation mode for SCD42.

2.2 Low Power Mode

Low power mode operation allows for measurement of the ambient CO_2 concentration with a longer, fixed sampling period of 30 seconds. This reduces the average power consumption of the sensor by more than 80% as compared to high-performance mode operation. It is initiated using the *start_low_power_periodic_measurement* command detailed in section 3.8 of the datasheet. ASC is featured and activated by default also in this measurement mode.

2.3 Idle Single Shot Operation (SCD41 only)

For idle single shot operation, the SCD41 performs individual measurements only on-demand using the *measure_single_shot* command detailed in section 3.10 of the datasheet. Thus, the energy required for taking a CO_2 reading is consumed only when a measurement is needed, allowing for significant reductions in the average power consumption of the sensor as compared to the periodic measurement modes. In between measurements, the sensor remains powered-up and in the idle state. This enables flexible adjustment of the sampling period to the sensing requirements of the application.

ASC is available and enabled by default for idle single shot operation. However, it is recommended to adjust the sensor's standard ASC period parameter depending on the average sampling period achieved during idle single shot operation. Please consult section 5.2 of this document for details.

2.4 Power Cycled Single Shot Operation (SCD41 only)

The sensor is powered down between single shot measurements in this mode, which eliminates the idle power consumption of the sensor. This can be achieved either by cutting and later re-applying the supply voltage to the sensor or by using the *power_down* / *wake_up* commands described in Table 2 below and in section 3.10 of the datasheet. Single shot measurements are requested using the *measure_single_shot* command just as in idle single shot operation.

Command	Hex. Code	Sequence type	Max. command duration [ms]
power_down	0x36e0	write	1
wake_up	0x36f6	write	20

Table 2: Commands for Power Cycling

Because the sensor requires one single shot measurement to stabilize after power cycling, the CO_2 reading of the initial single shot after startup should always be discarded. This makes power cycled single shot operation preferable to idle single shot operation only when the average sampling period is above 380 seconds.

Note: ASC is not supported for power cycled single shot operation.

3 Typical Power Consumption

Figure 2 provides an overview of the average power consumption that can be expected from SCD4x sensors at a supply voltage of 3.3 V, depending on the operation mode and the sampling period. The included data markers visualize the sampling periods provided as examples in Table 1. Note that whether ASC is enabled does not influence the sensor's power consumption.

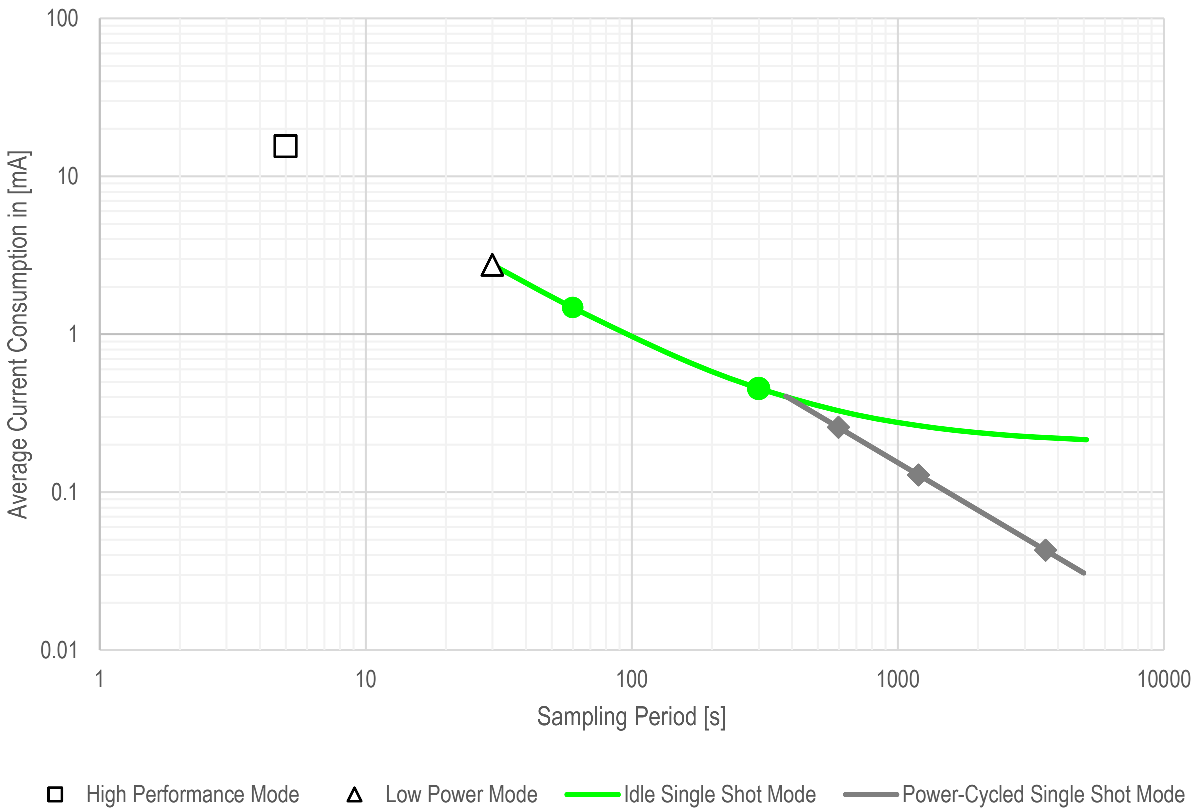

Figure 2: Typical Average Current Consumption by Operation Mode and Sampling Period at 3.3 V

On short timescales, the power consumption profile of SCD4x is characterized by two phases: Sensor data acquisition and idle operation. During data acquisition, the sensor exhibits a pulsed current profile that may reach the sensors specified peak supply current. During the idle phase between samples, the required current returns to less than 200 µA. Figure 3 provides a schematic illustration of this characteristic. The sensor's power supply should be designed with respect to the peak current and maximum peak-to-peak voltage ripple (without the sensor) as specified in the datasheet.

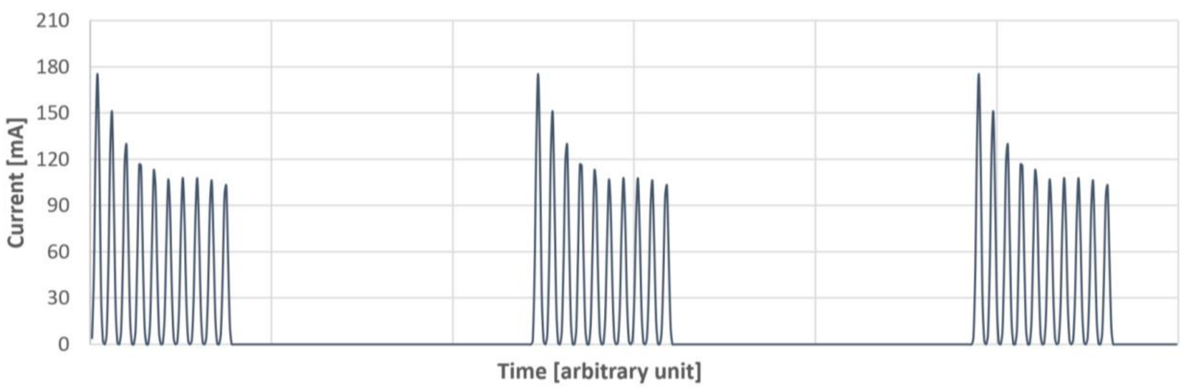

Figure 3: Schematic illustration of the current profile of SCD4x sensors

3.1 High Performance & Low Power Mode

The average current consumption that can be expected from the sensor during continuous measurement in either high-performance or low power mode is detailed in Table 3 below.

Parameter	Symbol	Conditions	Min.	Typical	Max.	Units
Average current consumption for periodic measurement in high-performance mode	I_{DD}	V_{DD} = 3.3 V		15	18	mA
		V_{DD} = 5 V		11	13	mA
Average current consumption for periodic measurement in low power mode		V_{DD} = 3.3 V		3.2	3.5	mA
		V_{DD} = 5 V		2.8	3	mA

Table 3: Average current consumption during operation in continuous measurement modes

3.2 Idle Single Shot Mode

As measurements are only taken on demand in idle single shot mode, the current consumption of the sensor varies depending on the resulting average sampling period. The average current consumption that can typically be expected from the SCD4x in idle single shot mode can be calculated using Equation 1:

$$I_{avg} = I_i + \frac{q_{ss}}{T_s}$$

I_{avg} Average power consumption [mA]

T_s Average sampling period [s]

I_i Idle current $\begin{cases} 0.20\ \text{mA}, & \text{V}_{\text{dd}} = 3.3\ \text{V} \\ 0.17\ \text{mA}, & \text{V}_{\text{dd}} = 5\ \text{V} \end{cases}$

q_{ss} Additional charge per idle single shot $\begin{cases} 77\ \text{mC}, & \text{V}_{\text{dd}} = 3.3\ \text{V} \\ 54\ \text{mC}, & \text{V}_{\text{dd}} = 5\ \text{V} \end{cases}$

Equation 1: Typical average current consumption in idle single shot mode

3.3 Power Cycled Single Shot Mode

If the sensor is powered up to obtain only one single useful CO_2 reading at a time, the typical average current consumption can be obtained using Equation 2. Note that the following formula assumes performing the useful single shot measurement immediately following the initial discarded single shot required for sensor stabilization.

$$I_{avg} = \frac{q_{pcss}}{T_u}$$

I_{avg} Average current [mA]

T_u Average useful sampling period [s]

q_{pcss} Total charge per useful single shot $\begin{cases} 154\ \text{mC}, & \text{V}_{\text{dd}} = 3.3\ \text{V} \\ 108\ \text{mC}, & \text{V}_{\text{dd}} = 5\ \text{V} \end{cases}$

Equation 2: Typical average current consumption in power cycled single shot mode

4 Typical Command Sequences

The following figures provide a flowchart overview of typical command sequences for operating SCD4x in each of its operation modes. For detailed descriptions of all available I²C commands and their implementation, please consult section 3 of the sensor datasheet. Please also see our online collection of sample code and drivers for SCD4x to accelerate your prototyping and development.

4.1 High Performance Mode

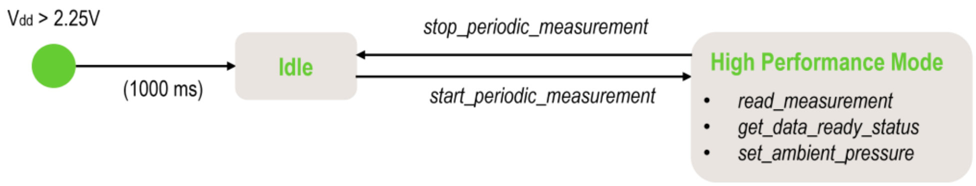

Figure 4: Command Flowchart for High Performance Mode Operation

4.2 Low Power Mode

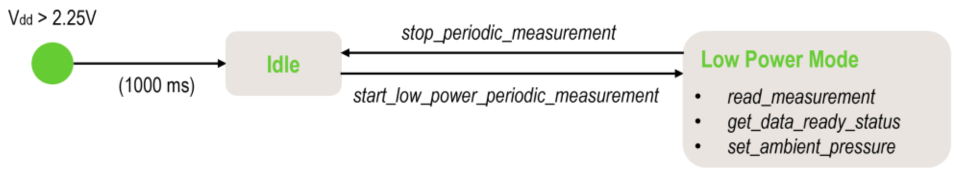

Figure 5: Command Flowchart for Low Power Mode Operation

4.3 Idle Single Shot Mode (SCD41 only)

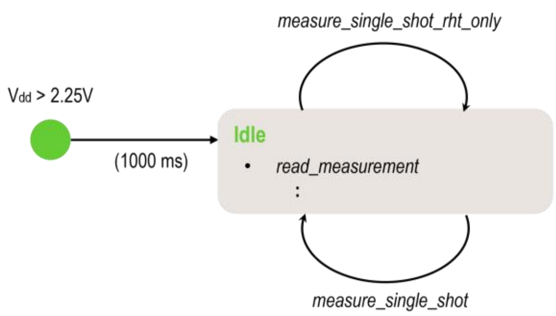

Figure 6: Command Flowchart for Idle Single Shot Mode Operation

4.4 Power Cycled Single Shot Mode (SCD41 only)

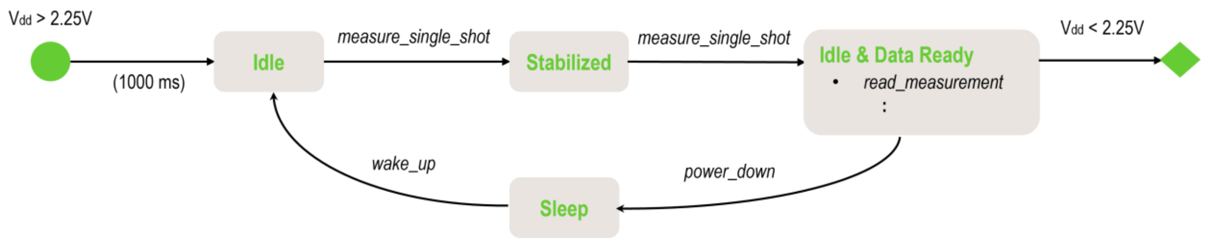

Figure 7: Command Flowchart for Power-Cycled Single Shot Mode Operation

5 Field Calibration for Low Power Operation Modes

5.1 Performing Forced Recalibration (FRC):

FRC enables quickly restoring highest baseline accuracy with the assistance of a CO_2 reference value. Typically, FRC is applied to compensate for drifts originating from the sensor assembly process or other extensive stresses. Before applying the *perform_forced_calibration* command detailed in section 3.7.1 of the datasheet, the sensor is to be run for > 3 minutes using the operation mode and sampling rate intended for field use in an environment with known, homogeneous, and constant CO_2 concentration and at the same supply voltage used in the field.

For idle single shot mode, if the average sampling period intended for field use is more than or equal to 60 seconds, the run-up to performing FRC is to be done for 5 minutes at a sampling period of 1 minute. The same procedure also applies to performing FRC if the sensor is to be operated in power-cycled single shot mode in the field.

5.2 Optimizing ASC for Idle Single Shot Mode Operation

For idle single shot mode, ASC will default to self-calibration periods optimized for an average sampling rate of 5 minutes. If the average sampling period deviates significantly from this, it is recommended to adjust the initial and standard ASC period parameters onboard the sensor.

The initial period represents the number of readings after powering up the sensor for the very first time to trigger the first automatic self-calibration. The standard period represents the number of subsequent readings periodically triggering ASC after completion of the initial period. Sensirion recommends adjusting the number of samples comprising initial and standard period to 2 and 7 days at the average intended sampling rate, respectively.

The number of single shots for initial and standard period can be adjusted onboard the sensor using the commands detailed in Table 4 below. Note that the parameter value represents twelve times the number of single shots defining the length of either period. Furthermore, this parameter must be an integer and a multiple of four.

Example: Average sampling rate: 3 minutes
Standard period: 7 days = 3360 single shots → Standard period parameter value = 280
Initial period: 2 days = 960 single shots → Initial period parameter value = 80

To save changes to ASC parameters to non-volatile memory, the *persist_settings* command detailed in section 3.9.1 of the datasheet is required. The history of readings needed for performing ASC is automatically stored to non-volatile memory after each complete batch of 48 idle single shots was performed without power cycling in between.

Command	Hex. Code	Sequence type	Parameter length incl. CRC [bytes]	Response length incl. CRC [bytes]	Max. command duration [ms]
get_automatic_self_calibration_initial_period	0x2340	read	-	3	1
set_automatic_self_calibration_initial_period	0x2445	write	3	-	1
get_automatic_self_calibration_standard_period	0x234b	read	-	3	1
set_automatic_self_calibration_standard_period	0x244e	write	3	-	1

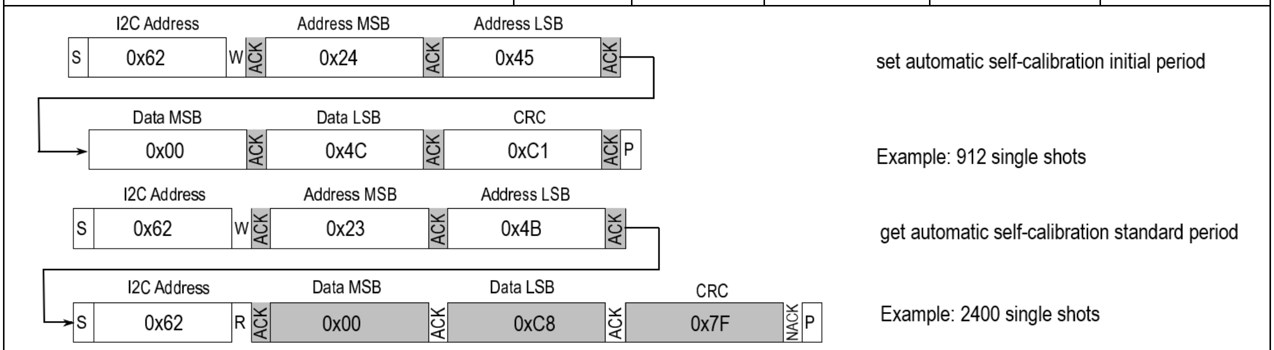

Table 4: Commands for Adjusting ASC Period Duration

Disclaimer

This document is meant as a guideline and cannot be considered as complete. It is subject to changes without prior notice.

Revision History

Date	Version	Page(s)	Changes
July 2022	1	all	Initial release

Important Notices

Warning, Personal Injury

Do not use this product as safety or emergency stop devices or in any other application where failure of the product could result in personal injury. Do not use this product for applications other than its intended and authorized use. Before installing, handling, using or servicing this product, please consult the data sheet and application notes. Failure to comply with these instructions could result in death or serious injury.

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ESD Precautions

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- such defects shall be found, to SENSIRION's reasonable satisfaction, to have arisen from SENSIRION's faulty design, material, or workmanship;
- the defective product shall be returned to SENSIRION's factory at the Buyer's expense; and
- the warranty period for any repaired or replaced product shall be limited to the unexpired portion of the original period.

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