Design-in Guide SCD4x CO₂ Sensor

Sensirion’s miniaturized CO₂ sensor combines smallest package with highest performance. To take full advantage of the SCD4x performance and its integrated features, a number of design rules need to be considered for housing and PCB design. This guide describes an easy-to-implement and affordable design-in of the sensor. Please note that unfavorable housing and/or PCB designs may cause significant deviations in CO₂ and temperature readings, increased noise levels as well as significantly longer response times.

Overview: Key Design-in Recommendations

- **a.** Good coupling to ambient air
- **b.** Isolation from air turbulence
- **c.** Decoupling from vibration sources
- **d.** Decoupling from external heat sources
- **e.** Shielding from direct sunlight
- **f.** Ensure stable supply voltage

**Figure 1:** Most important design-in recommendations for the SCD4x CO₂, RH and T sensor.  
(a) Good coupling to ambient air thanks to a large opening in the device’s housing in proximity to the sensor and a small dead volume.  
(b) Good isolation from air turbulence is achieved by placing the SCD4x in a separate compartment not directly exposed to the air flow.  
(c) Good decoupling from a vibration source is realized by mechanically decoupling the support structure.  
(d) Good decoupling from external heat sources such as MCU or Wi-fi module. Heat sources with varying intensity are especially problematic for the accuracy of the temperature output of the SCD4x, which features only constant temperature offset compensation. Since hot air has the tendency to rise, it is recommended to place the sensor in the lowest part of the device.  
(e) Shielding from direct sunlight thanks to the addition of a light-shade in the device housing.  
(f) Ensure stable supply voltage: Voltage ripple peak to peak < 30 mV.
1 Placement of sensor

1.1 Coupling to ambient air

The SCD4x interacts with the environment to sense the ambient CO₂ concentration, relative humidity and temperature. Therefore, coupling it to ambient conditions using a suitable device design is of uttermost importance. Insufficient exposure of the sensor to ambient air can result in significantly increased response times and greater temperature offset. General design-in recommendations are illustrated in Figure 2.

Ideally, the sensor is placed as close as possible to the device’s outer shell, with a large opening allowing for sensor exposure. The larger and closer the opening, the better the air exchange between the sensor’s direct surrounding and ambient conditions.

The sensor should be sealed from air entrapped in the device’s housing to minimize the dead volume (i.e. the volume of air surrounding the sensor inside a device housing). Large dead volumes can increase the response time of the sensor significantly.

1.2 Decoupling from external heat sources

External heat sources in direct proximity to the SCD4x can affect the measured temperature significantly. Thus, the SCD4x should be decoupled from heat sources as depicted in Figure 3. Because the RH (relative humidity) and T (temperature) signals are required for on-chip signal compensation of the CO₂ output, decoupling the sensor from heat sources is relevant also for customers that do not leverage the RH and T output for their application. Significant heat sources within devices typically include the CPU, the display, the Wi-fi module, voltage regulators and batteries.

While heat sources with constant heating can be compensated with the built-in temperature offset, compensation of non-constant heat sources is complex.

To minimize the effect of external heat sources, the sensor should be placed in the device’s coldest part. Typically, lowest self-heating can be achieved by placing the SCD4x in the lowest part of a device and having maximal distance to self-heating components.

Figure 2: Sensor coupling to ambient environment. (a) Good exposure to the ambient air thanks to a large opening in proximity to the sensor and a small dead volume. (b) Moderate coupling to the ambient air due to large dead volume and (c) only a small opening in the device housing. (d) Poor coupling as the sensor is not separated from other air entrapped inside the device’s housing and (e) due to a small opening far away from the sensor.
1.3 Isolation from air turbulences

Air flow as present in e.g. ducts can generate pressure drops, back pressure and dynamic fluctuations leading to increased sensor noise and reduced accuracy. Therefore, it is recommended to isolate SCD4x from air flow and air turbulences. This can be achieved by placing the sensor in a volume separated from the main air flow (Figure 4).

1.4 Decoupling from vibration sources

Vibrations with high amplitudes can affect the noise level of the SCD4x. Lower frequency vibrations tend to be most critical.

To minimize noise, the sensor should be decoupled from vibration sources. This is best achieved if no stiff material (such as a PCB or a metal bar) connects a vibration source to the sensor (see Figure 5). If this cannot be realized, damping elements such as rubber supports can be introduced to mitigate increased noise levels.
1.5 Shielding from sunlight

Exposing the SCD4x to direct sun light may introduce temperature offsets that affect the CO₂, RH and T outputs. Additionally, direct sunlight can accelerate sensor ageing. Thus, it is recommended to protect the sensor from direct sunlight. This can be achieved by a suitable design-in or by using a light shade (see Figure 6).

![Figure 6: Sensor protection from sunlight (side view). (a) Good protection and (b) bad protection from incoming sunlight. (c) Good protection from sunlight, however, at the cost of bad coupling to ambient conditions.]

1.6 Avoid large voltage fluctuations

Large voltage fluctuations negatively affect the noise-levels of the CO₂ reading. Avoid parallel use of the sensor’s current supply for other components with high current consumption with large transients. Voltage ripples must be below 30 mV peak to peak during sensor operation. Stable supply voltage is best achieved with a low dropout (LDO) regulator.

![Figure 7: Schematic of non-constant supply voltage]

2 Design-in sanity check

A quick sanity check can provide insights on the quality of the design-in within prototypes. Operate the device under normal / typical conditions for 15 minutes to allow for complete thermal equilibration.

If the temperature and / or the relative humidity output is leveraged by the customer device, the output temperature should be compared with a temperature reference. We propose using a Sensirion SHTxx evaluation kit as RH and T reference. Note that the reference sensor should be isolated from heat sources. If the temperature deviation is higher than 0.5 °C, Sensirion recommends adapting the temperature offset accordingly via the sensor’s digital interface (see SCD4x datasheet).

Also investigate the noise level of the CO₂ output. Deviations larger than 20 ppm between subsequent CO₂ readings indicate a need for improvement of the SCD4x design-in.

Lastly, determine the response time of the CO₂ output while running the SCD4x in high-performance mode (Figure 8). Sensirion recommends using a CO₂ cartridge to create a prompt increase in CO₂ concentration. Alternatively, one can exhale in close proximity to the investigated device a few times. In order to have a meaningful test, the CO₂ concentration should rise by at least 1000 ppm. After triggering the CO₂ event, the sensor’s reaction time should be compared with Table 1.

![Figure 8: Schematic representation of the reaction time a CO₂ event at t = 0s.]

<table>
<thead>
<tr>
<th>Reaction time</th>
<th>Design-in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction time &lt; 60 s</td>
<td>☺</td>
</tr>
<tr>
<td>Reaction time &gt; 60 s</td>
<td>☹</td>
</tr>
</tbody>
</table>

Table 1: Quality of design in depending on reaction time of the CO₂ signal.
Disclaimer
This document is meant as a guideline and cannot be considered to be complete. It is subject to changes without prior notice.

Revision History

<table>
<thead>
<tr>
<th>Date</th>
<th>Version</th>
<th>Page(s)</th>
<th>Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 2021</td>
<td>1</td>
<td>all</td>
<td>Initial version</td>
</tr>
<tr>
<td>March 2022</td>
<td>1.1</td>
<td>all</td>
<td>Minor revisions</td>
</tr>
</tbody>
</table>
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.

If the Buyer shall purchase or use SENSIRION products for any unintended or unauthorized application, Buyer shall defend, indemnify and hold harmless SENSIRION and its officers, employees, subsidiaries, affiliates and distributors against all claims, costs, damages and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if SENSIRION shall be allegedly negligent with respect to the design or the manufacture of the product.

ESD Precautions

The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take customary and statutory ESD precautions when handling this product.
See application note “ESD, Latchup and EMC” for more information.

Warranty

SENSIRION warrants solely to the original purchaser of this product for a period of 12 months (one year) from the date of delivery that this product shall be of the quality, material and workmanship defined in SENSIRION’s published specifications of the product. Within such period, if proven to be defective, SENSIRION shall repair and/or replace this product, in SENSIRION’s discretion, free of charge to the Buyer, provided that:

- notice in writing describing the defects shall be given to SENSIRION within fourteen (14) days after their appearance;
- 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.

This warranty does not apply to any equipment which has not been installed and used within the specifications recommended by SENSIRION for the intended and proper use of the equipment. EXCEPT FOR THE WARRANTIES EXPRESSLY SET FORTH HEREIN, SENSIRION MAKES NO WARRANTIES, EITHER EXPRESS OR IMPLIED, WITH RESPECT TO THE PRODUCT. ANY AND ALL WARRANTIES, INCLUDING WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, ARE EXPRESSLY EXCLUDED AND DECLINED.
SENSIRION is only liable for defects of this product arising under the conditions of operation provided for in the data sheet and proper use of the goods. SENSIRION explicitly disclaims all warranties, express or implied, for any period during which the goods are operated or stored not in accordance with the technical specifications.

SENSIRION does not assume any liability arising out of any application or use of any product or circuit and specifically disclaims any and all liability, including without limitation consequential or incidental damages. All operating parameters, including without limitation recommended parameters, must be validated for each customer’s applications by customer’s technical experts. Recommended parameters can and do vary in different applications.
SENSIRION reserves the right, without further notice, (i) to change the product specifications and/or the information in this document and (ii) to improve reliability, functions and design of this product.

Copyright © 2021, by SENSIRION. CMOSens® is a trademark of Sensirion. All rights reserved

Headquarters and Subsidiaries

SENSIRION AG
Laubisruetistr. 50
CH-8712 Staefa ZH
Switzerland
phone: +41 44 306 40 00
fax: +41 44 306 40 30
info@sensirion.com
www.sensirion.com

SENSIRION Inc., USA
phone: +1 312 690 5858
info-us@sensirion.com
www.sensirion.com

Sensirion Korea Co. Ltd.
phone: +82 31 337 7700~3
info-kr@sensirion.com
www.sensirion.com/kr

Sensirion Inc., USA
phone: +1 312 690 5858
info-us@sensirion.com
www.sensirion.com

Sensirion Japan Co. Ltd.
phone: +81 3 3444 4940
info-jp@sensirion.com
www.sensirion.com/jp

Sensirion China Co. Ltd.
phone: +86 755 8252 1501
info-cn@sensirion.com
www.sensirion.com/cn

Sensirion Taiwan Co. Ltd
phone: +886 3 5506701
info@sensirion.com
www.sensirion.com

To find your local representative, please visit www.sensirion.com/distributors