Design-in Guide SCD4x CO_2 Sensor

Sensirion's miniaturized CO_2 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 unbeneficial housing and/or PCB designs may cause significant deviations in CO_2 and temperature readings, increased noise levels as well as significantly longer response times.

Overview: Key Design-in Recommendations

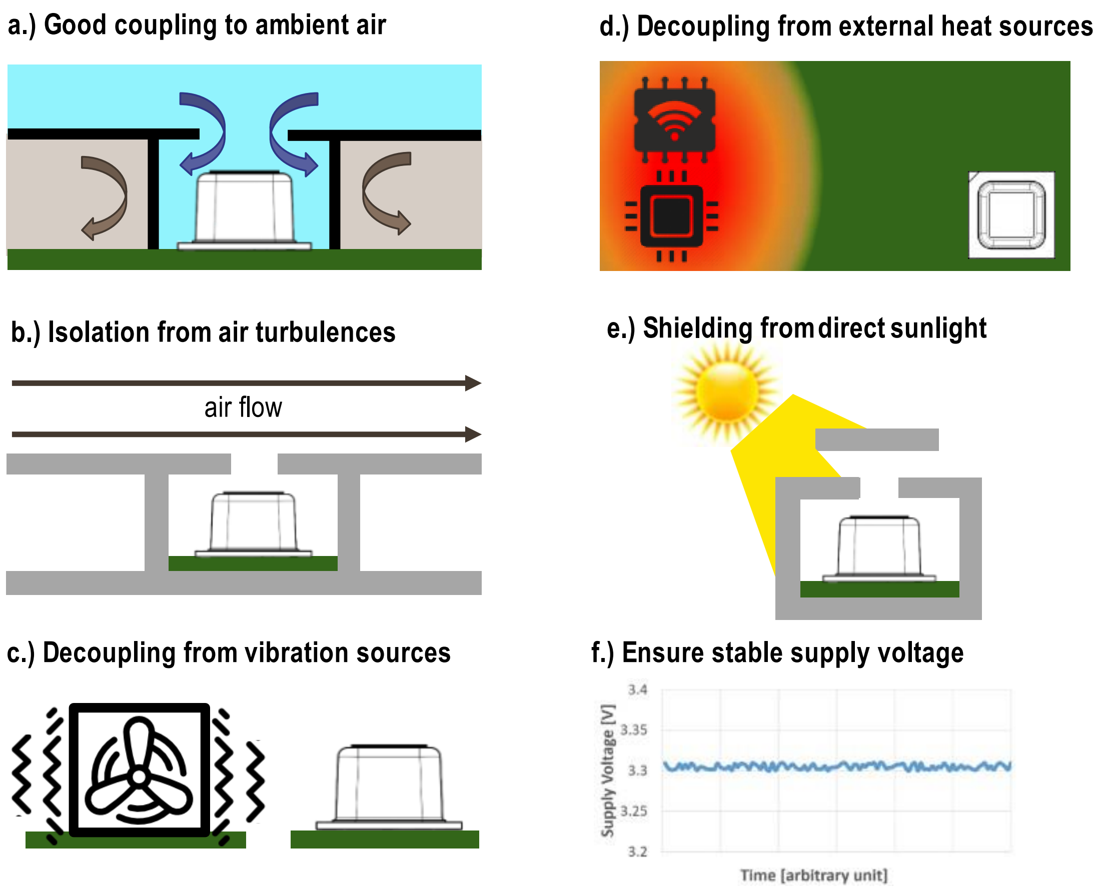

Figure 1: Most important design-in recommendations for the SCD4x CO_2, RH and T sensor. **(a)** Good coupling to ambient air thanks to a large opening in the device's housing in proximity to the sensor and a small dead volume. **(b)** Good isolation from air turbulence is achieved by placing the SCD4x 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 CO_2 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 CO_2 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.

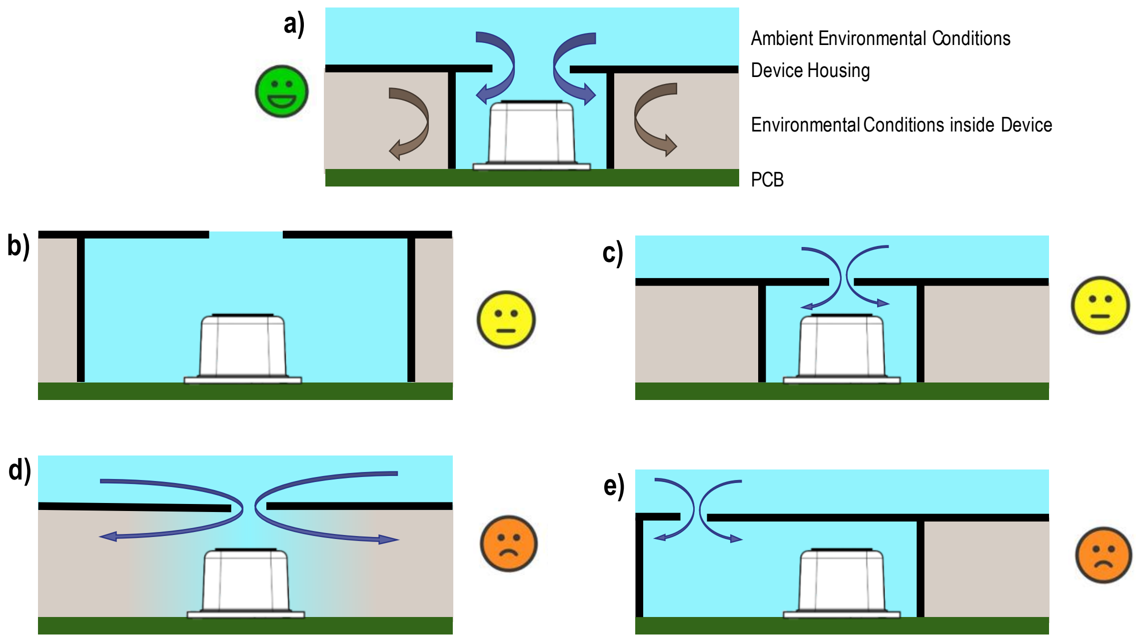

Figure 2: Sensor coupling to ambient environment. **(a)** Good exposure to the ambient air thanks to a large opening in proximity to the sensor and a small dead volume. **(b)** Moderate coupling to the ambient air due to large dead volume and **(c)** only a small opening in the device housing. **(d)** 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.

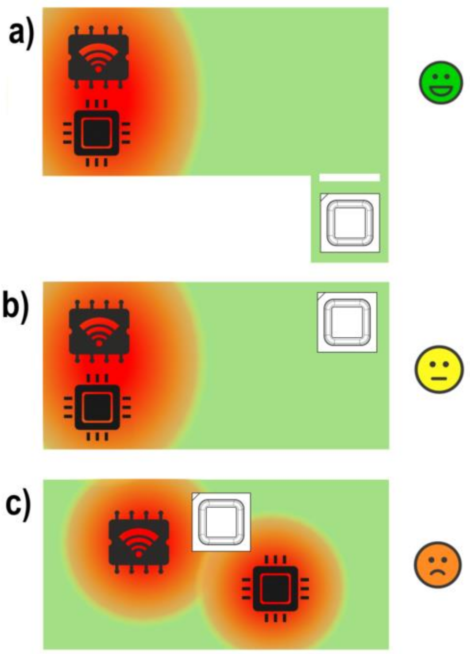

Figure 3: Sensor coupling to external heat sources (top view). The green color represents the customer PCB; the red circles indicate heat dissipating from self-heating components. **(a)** Superb decoupling from external heat sources enabled by a slit in customer PCB. **(c)** Poor decoupling from external heat sources due to the immediate proximity of self-heating components.

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.

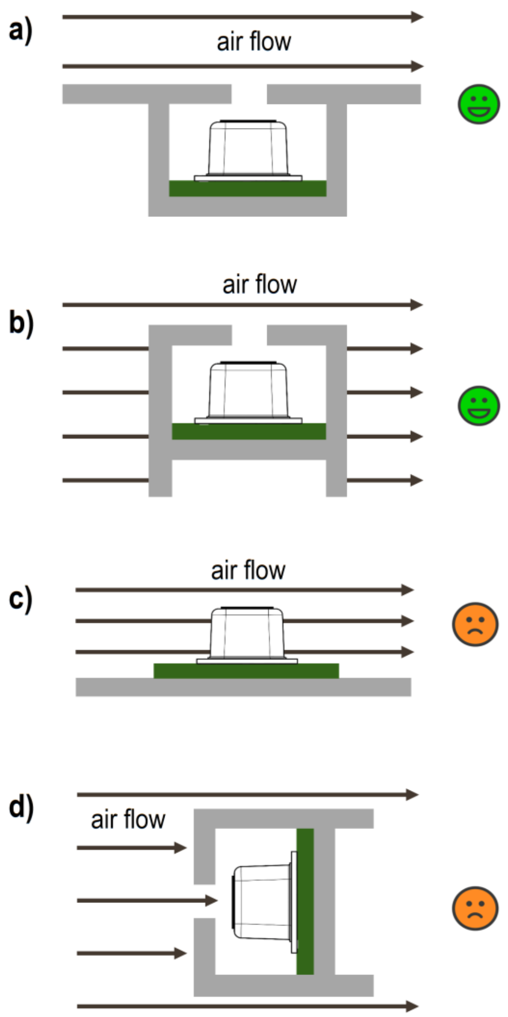

Figure 4: Isolation from air turbulences (side view). The grey structure represents the customer's device housing. **(a-b)** Good isolation. **(c-d)** Poor isolation, as the SCD4X is exposed to wind turbulences directly.

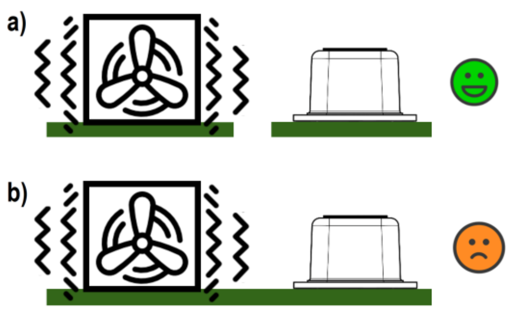

Figure 5: Decoupling from a vibration source (side view). **(a)** Good decoupling is realized with a gap in the support structure. **(b)** Poor decoupling since the PCB (green) serves as a bridge that transfers vibration to the sensor.

1.5 Shielding from sunlight

Exposing the SCD4x to direct sun light may introduce temperature offsets that affect the CO_2, 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**).

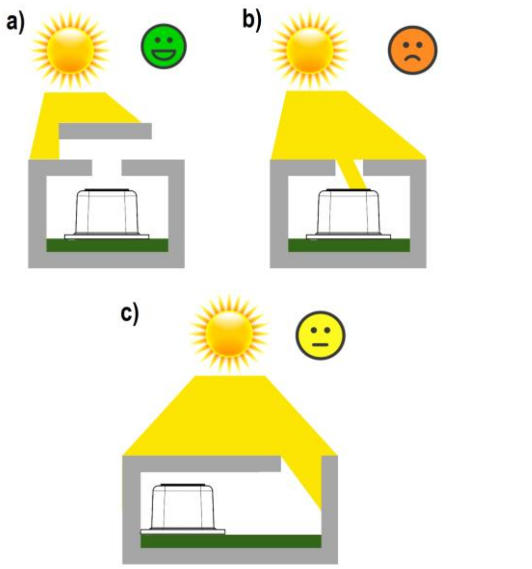

Figure 6: Sensor protection from sunlight (side view). **(a)** Good protection and **(b)** bad protection from incoming sunlight. **(c)** Good protection from sunlight, however, at the cost of bad coupling to ambient conditions.

1.6 Avoid large voltage fluctuations

Large voltage fluctuations negatively affect the noise-levels of the CO_2 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.

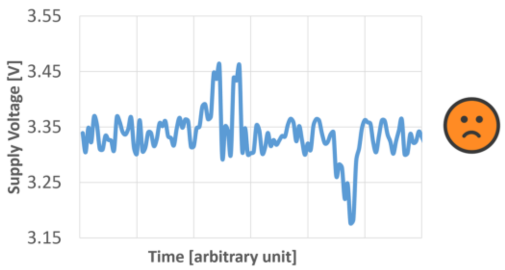

Figure 7: Schematic of non-constant supply voltage

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 CO_2 output. Deviations larger than 20 ppm between subsequent CO_2 readings indicate a need for improvement of the SCD4x design-in.

Lastly, determine the response time of the CO_2 output while running the SCD4x in high-performance mode (**Figure 8**). Sensirion recommends using a CO_2 cartridge to create a prompt increase in CO_2 concentration. Alternatively, one can exhale in close proximity to the investigated device a few times. In order to have a meaningful test, the CO_2 concentration should rise by at least 1000 ppm. After triggering the CO_2 event, the sensor's reaction time should be compared with Table 1.

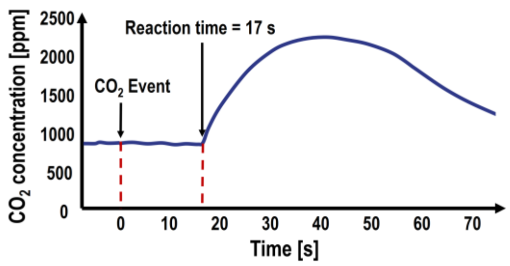

Figure 8: Schematic representation of the reaction time a CO_2 event at t = 0s.

Table 1: Quality of design in depending on reaction time of the CO_2 signal.

Reaction time	Design-in
Reaction time < 60 s	
Reaction time > 60 s	

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

Date	Version	Page(s)	Changes
January 2021	1	all	Initial version
March 2022	1.1	all	Minor revisions

SENSIRION

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

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.

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- 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;
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