# Customer Integration Guidelines
## Senseair Sunrise

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The Senseair Sunrise is very configurable and can be tailored to a wide range of specific application.

# Standard Specifications

@ PSP4731, Sunrise 006-0-0002
@ PSP11704, Sunrise 006-0-0007

Open the hyperlink under the PSP4731 or it can be found at Senseair website "www.senseair.com" under Sunrise product

# Electrical Specifications

## Electrical Pin Description

@ PSP4731, Sunrise 006-0-0002
@ PSP11704, Sunrise 006-0-0007

## Absolute maximum electrical ratings

@ PSP4731, Sunrise 006-0-0002
@ PSP11704, Sunrise 006-0-0007

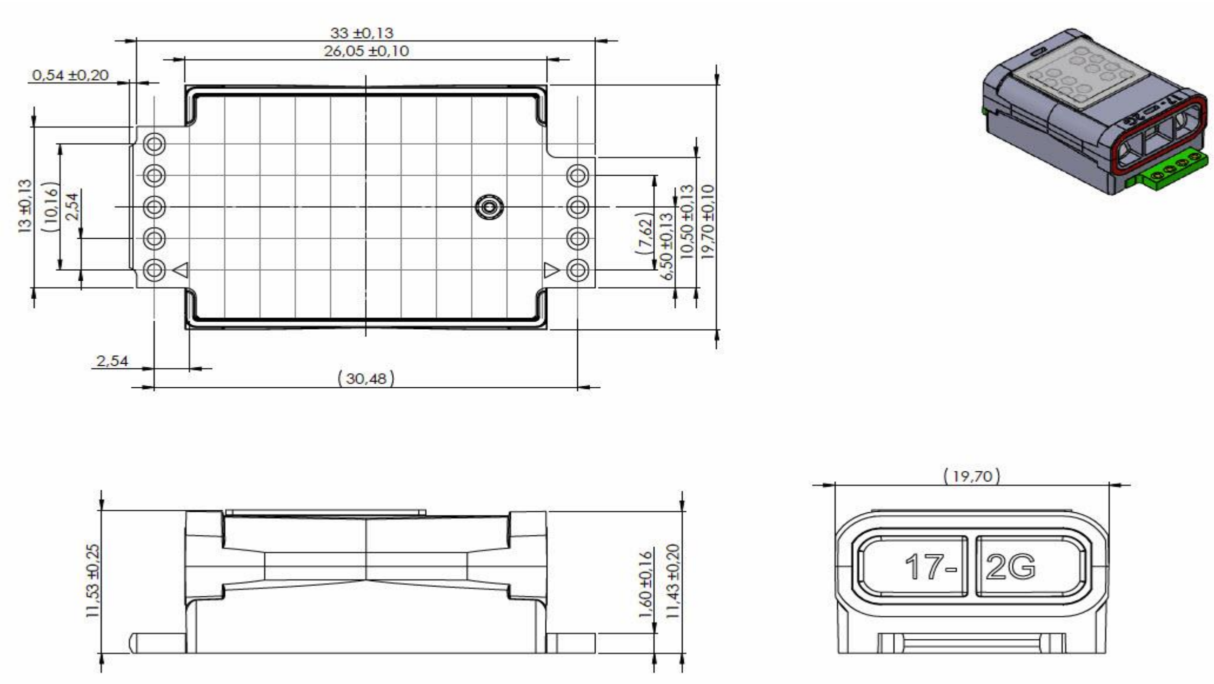
## Recommended operating electrical conditions

@ PSP4731, Sunrise 006-0-0002
@ PSP11704, Sunrise 006-0-0007

## Electrical and power characteristics

@ PSP4731, Sunrise 006-0-0002
@ PSP11704, Sunrise 006-0-0007

# Physical Dimensions




Refer to the Senseair Sunrise Handling Manual ANO4947 for considerations for mounting distances and correct mounting procedures.

## Operating Environment Specification

Senseair Sunrise is intended, but not limited, to commercial and residential buildings, industrial applications, and outdoor applications

### Temperature and humidity operating range

At higher than specified absolute humidity and relative humidity levels, stated accuracy cannot be guaranteed.

At lower temperatures than specified, e.g. freezing temperatures, there is risk of micro-condensation and ice crystals forming inside the optical bench, causing diffractions to the irradiated IR optical path, and greatly impacting performance. If operation below dew point or in freezing environments is required, please contact Senseair.

At higher temperatures than specified, the internal temperature-compensation for gas concentrations will be less accurate. If calibrated accuracy and function is required for wider temperature ranges, please contact Senseair.

### Warm-up time

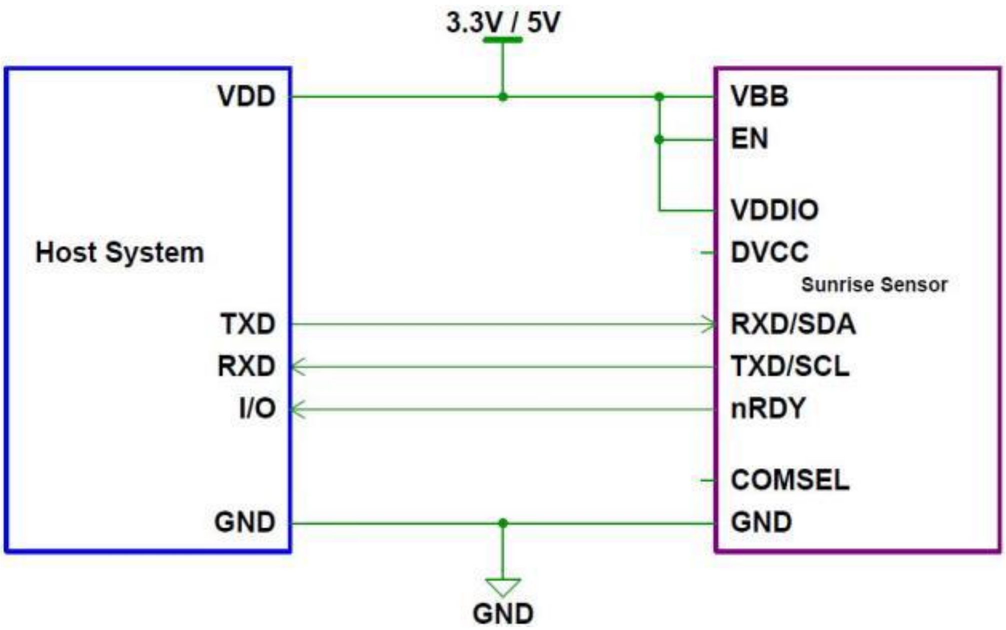
There is NO warm-up for Senseair Sunrise, the very first measurement would be accurate within stated accuracy specification and average RMS noise after a reboot or power cycle. This due to the miniscule circuitry-heating of Senseair Sunrise chipset, and with the typical integration of several samples per presented concentration value and measurement period.

This is important for integration design, as the power cycle in single measurement mode can be optimized greatly by working perfectly by only making one measurement before it reverts back to low-power sleep or shutdown. Every measurement is trustworthy with Senseair Sunrise.

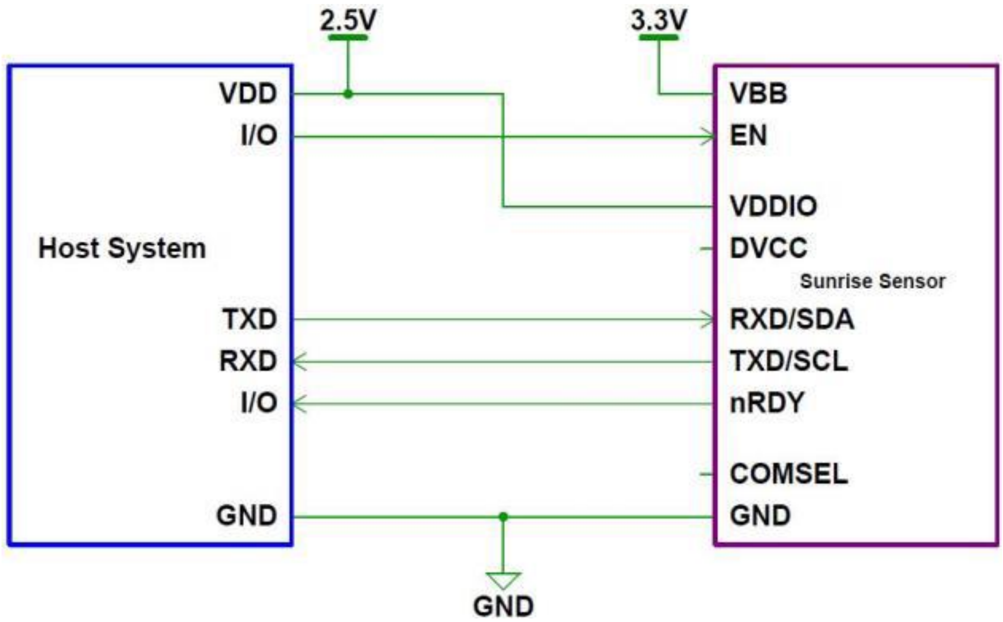
Please make distinction between Senseair Sunrise's warm-up and settling time from a shutdown and power-off, and full acclimatization time to conform to a new steady-state from actual changes in the ambient environment.

## Electrical Integration Illustration

### Modbus over UART integration illustrations




Modbus serial-line over UART. Integration strictly for continuous-mode operation of Sunrise, as EN-pin can't be toggled and VDDIO are driven by VBB. This will also consume more power.




2.5V powered host and low-power integration example for continuous-mode or single-mode integration. Host controls and toggles EN-pin and powers VDDIO externally from Sunrise's VBB.

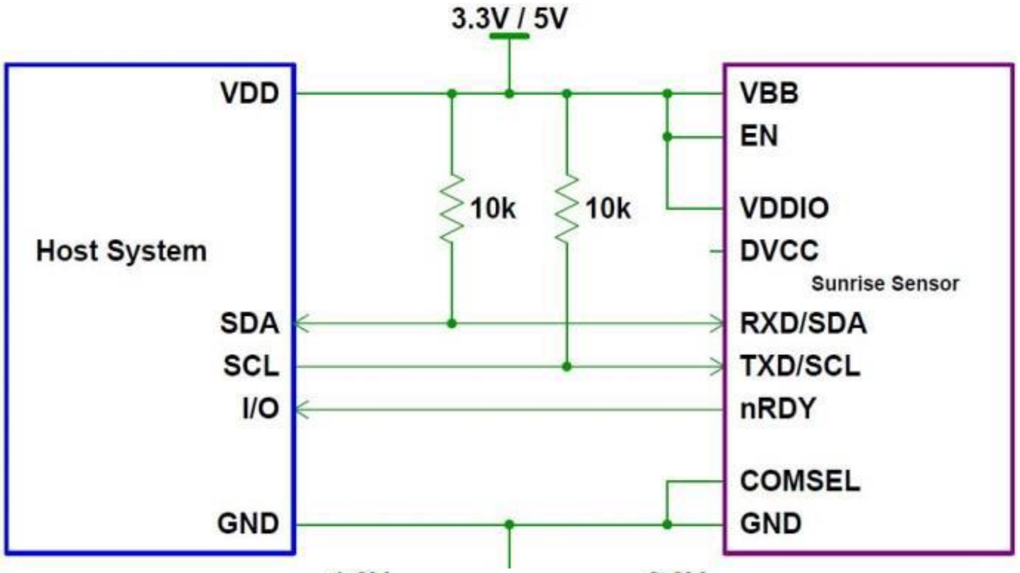
Optionally, although not recommended, an additional GDIO -pin can be saved on host by leaving nRDY floating and implement synchronization and handshaking by worst-case timings.

If there are high capacitance on TxD/SCL connection used (e.g. by long wires), then the internal pull-up to VDDIO on TxD (100 kΩ) might require that an external pull-up is added for assistance.

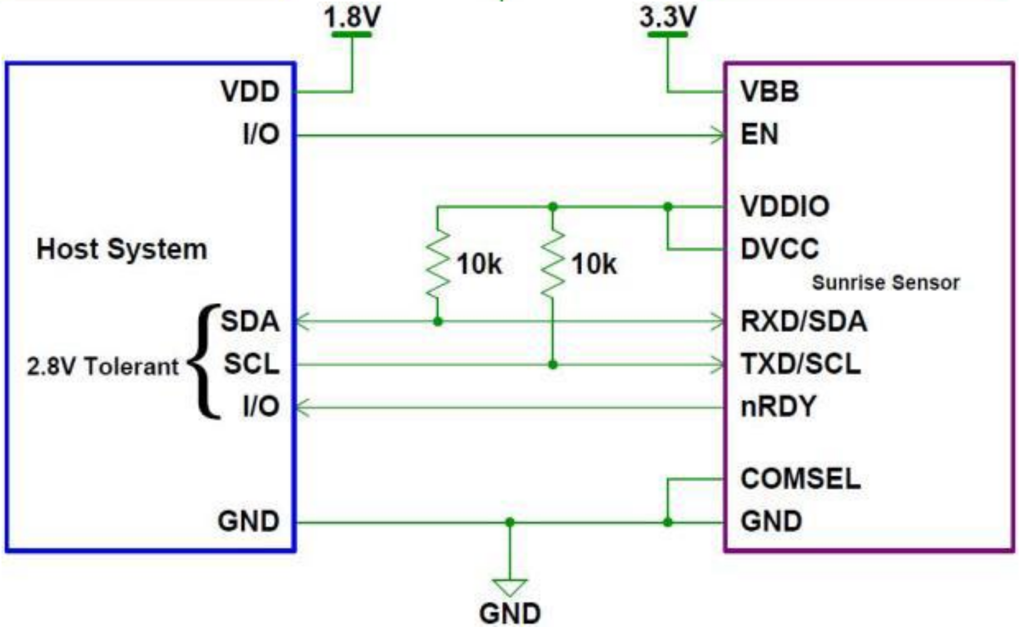
### Modbus settings and registers

Please check TDE5514 at Senseair website for more details and examples.

I2C integration illustrations




Example I2C integration strictly for continuous-mode operation of Sunrise, as EN-pin can't be toggled and VDDIO is driven by VBB. This will consume more power.




1.8V powered host and low-power I2C integration example for continuous-mode or single-mode integration. Host controls and toggles EN-pin and Sunrise VDDIO is powered from a 2.8V tolerant host source.

The Senseair Sunrise microcontroller's sleep feature, for lower power-consumption between actual memory operations, will wake the device up whenever there's a pulse detected on the SDA-line.

## I$^2$C settings and registers

Please check TDE5531 at Senseair website for more details and examples.

## Low power integration

In order to realise further low power consumption, there are few options for a system using Senseair Sunrise.

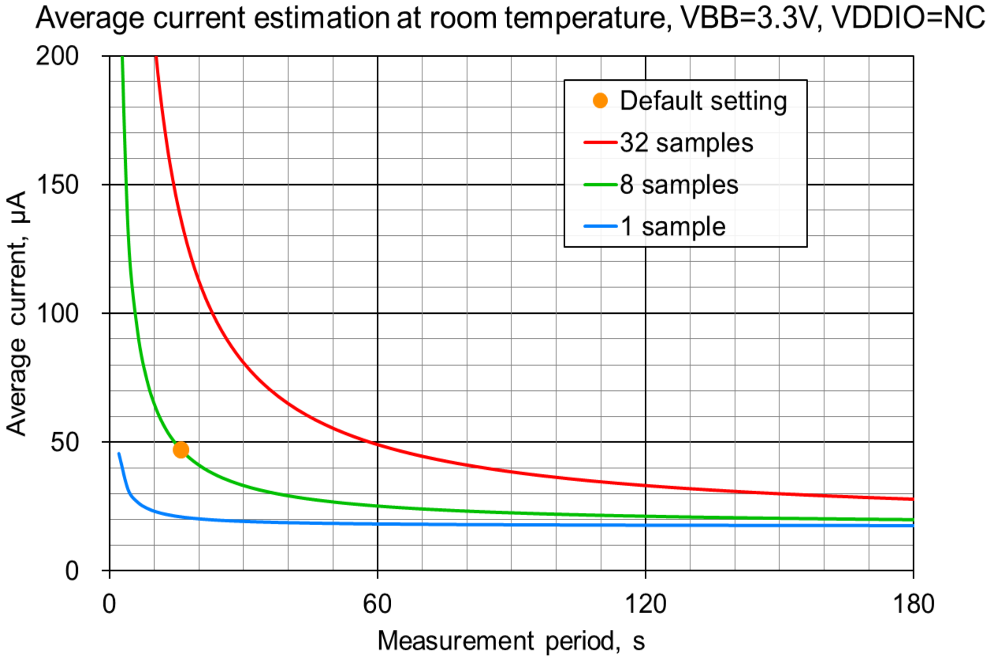
- Control of supplying voltage to VDDIO pin.
  It may reduce leak sleep current to supply voltage to VDDIO only while communication and nRDY pin indication are needed.
- Switch of the host's communication pins input/output mode.
  It may reduce leak sleep current to turn the host's pins for communication with Senseair Sunrise into high impedance mode while the communication is not needed.

And if a user considers using single-measurement mode, the extra power consumption overhead should be considered to read out and write back the needed and prepared sequential registers. During the reading/writing process, both Senseair Sunrise and the host system consume an amount of current/charge for the communications. So, the user should calculate which is preferred, continuous measurement mode or single measurement mode from a viewpoint of total current consumption over the system.

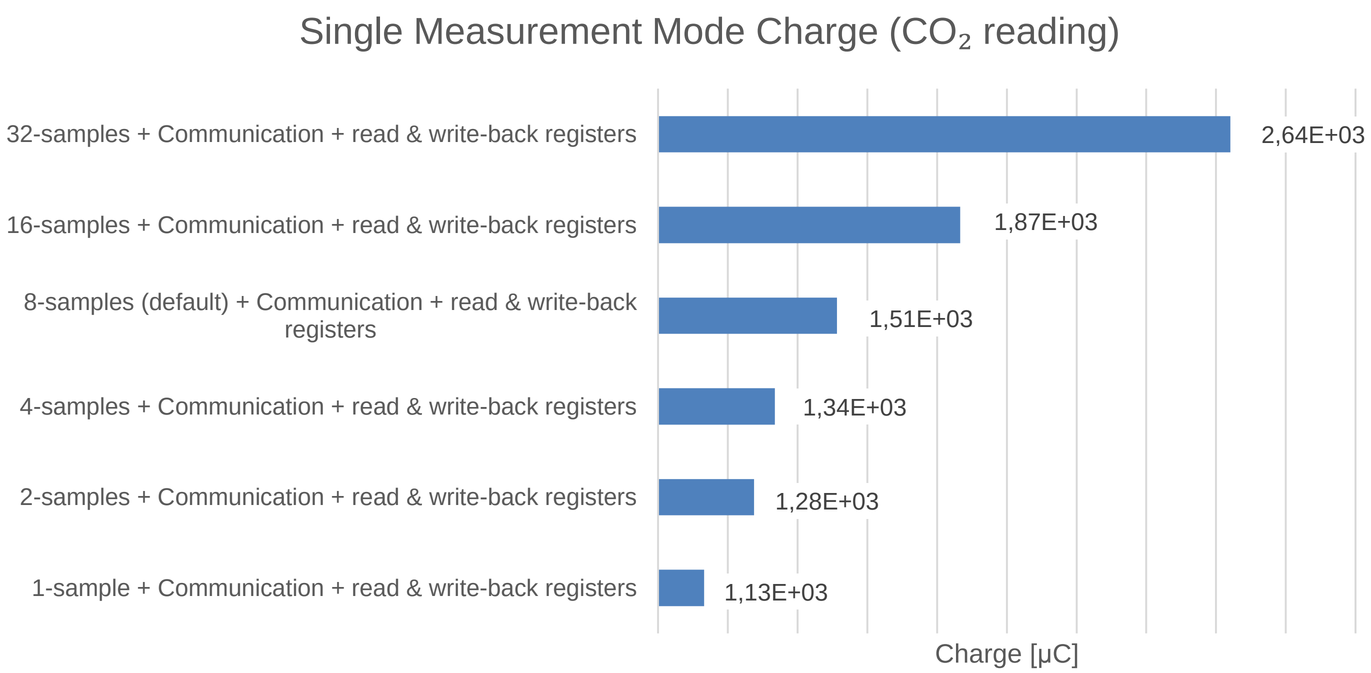
## Current consumption

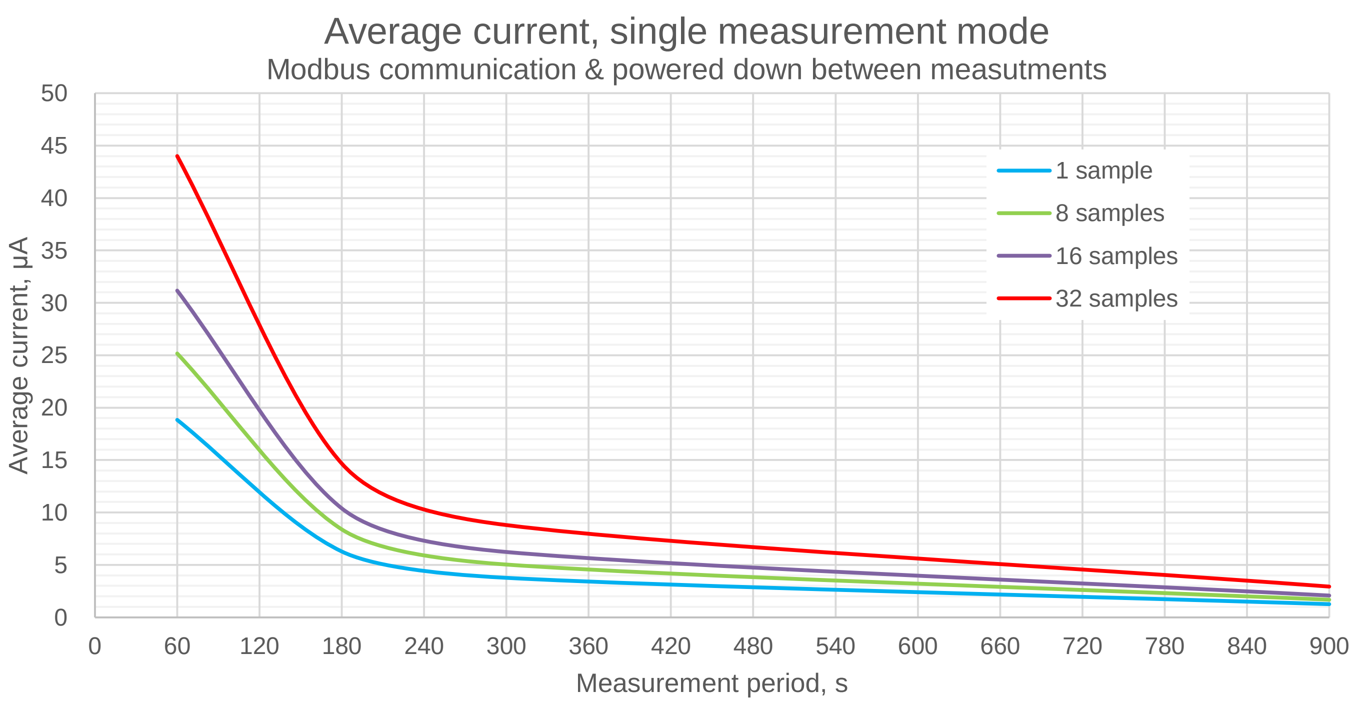
Power consumption diagram @ Continuous measurement mode

Default measurement settings: 16s, 8 samples



Power consumption diagram @ single measurement mode



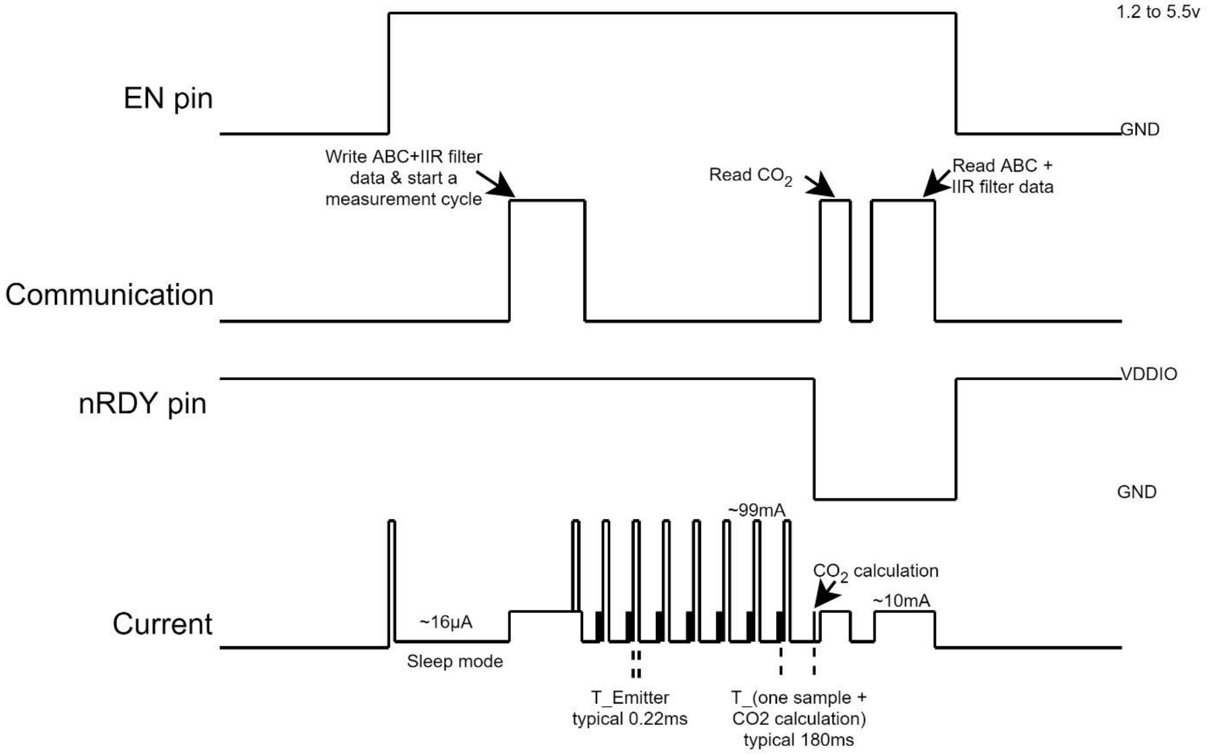

## Sunrise Timings

Senseair Sunrise is recommended to be time synchronized with the host, to allow for implementation of Senseair Sunrise without host polling the nRDY-pin, and hence save one GPIO pin.

Parameters for synchronising

| Parameters | Min [ms] | Typical [ms] | Max [ms] | Comments |
|---|---|---|---|---|
| T_Start | | 35 | | Ready for communication after MCU start |
| T_Sample | 160 | 180 | 300 | Time for one sample and $CO_2$ calculation, min and max time applied for temperatures between -40°C to +125°C |
| T_Emitter | | 0.22 | 0.25 | Emitter on time |

Below are the important timings and power consumption to model time-out responses in host, while in single-measurement mode




Communication, Timing diagram for single measurement mode

# Reconfiguring the application fitness of Senseair Sunrise

Senseair Sunrise is a highly flexible sensor, and it can be configured in multiple ways, generally by writing to registers set in firmware, for optimal application fitness.

## Single measurement mode vs continuous measurement mode

One of the first integration design choices is whether to have the Senseair Sunrise continuously make measurements with a fixed measurement period, or to power-up and react by performing a single measurement initiated by demand from host.

## Continuous measurement mode

Continuous measurement mode may be easier to integrate and design for, but can still allow for different measurement periods and different set number of samples on occasions. This requires nothing more than for these new changes to be written to Senseair Sunrise, followed by a command to initiate a soft reboot in firmware.

The total number of EEPROM write cycles should be less than 10000, this means that too frequent writes to these registers will lead to a corrupt EEPROM. When writing multiple (EE) registers in one sequence then this write cycle will be counted as just ONE write cycle out of the 10000 that are allowed writes to the EEPROM. All new written data to register (EE) can be read back after a sensor reset is completed.

Otherwise, the continuous measurement mode lends itself best to fixed measurement periods with the same predefined number of samples. Measurement accuracy, response time and power consumption will be predictable and can be optimized for onboard datalogging memory capabilities or monitoring control or safety needs, or balanced to match any potential upload bandwidth speeds and data rates to move filtered and condensed data over to a cloud server.

## Single measurement mode

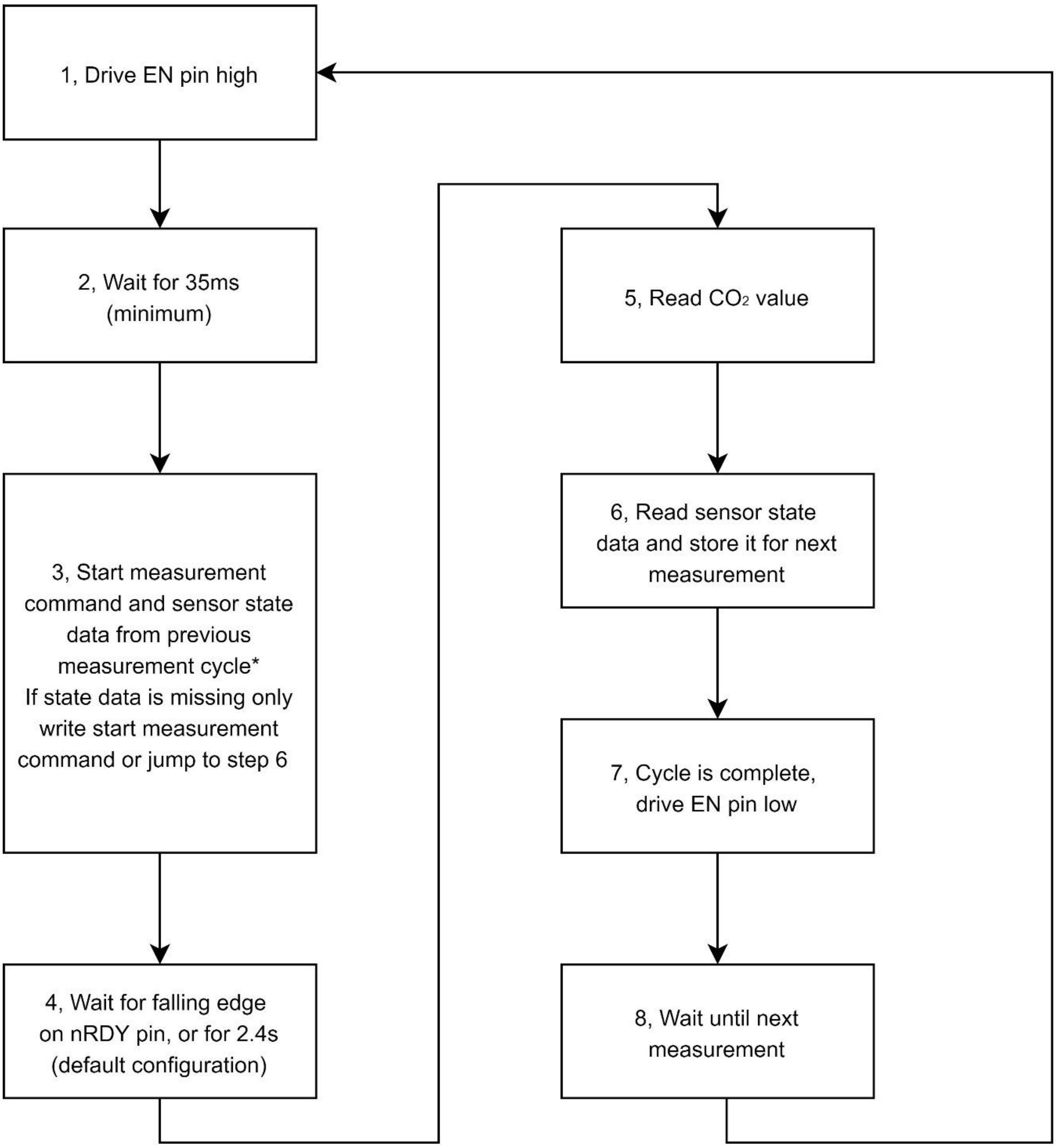
Single measurement mode allows Senseair Sunrise to be put into shutdown mode when not in use, compared to the normal low-power sleep of the microprocessor in-between operations.

When EN-pin is driven low, the internal voltage regulator powers down the circuitry and all volatile memory is lost. During shutdown mode, it’s even possible for power to be disconnected completely in-between the wanted measurement frequency by an external low-leakage switch.

As such, some critical timers and calibration parameters for Senseair Sunrise’s long-term maintenance-free operation need to be read and transferred to a retention memory on host prior this shutdown, and to be written back to Sunrise memory upon next boot-up cycle.

It’s important to highlight with this that, as Sunrise generates only miniscule circuitry-heating and hence don’t have a thermal acclimation time to reach steady-state (thermal equilibrium with its surrounding), warm-up time is zero. In addition, with the typical integration of several samples per measurement value for each measurement period, it can be concluded that even the very first reading from the first measurement period after boot-up and power-on, and If any kind of action or event-based or dynamic measurement frequency scheme is planned, e.g. to initiate and start measurements by a motion sensor or other switch, or to just have better data resolution and coverage during known time periods, e.g. more frequent measurements only during day time, or when lights are on. Then single measurement mode will allow this time- or event-control more effectively from the host.

Due to the extremely low-power consumption in shutdown mode, single measurement mode is often preferred when there is battery power involved.




*If start measurement command and state data is written in two separate write sequences, state data must be written before start measurement command

**Figure, Communication sequence for single measurement mode**

## The measurement periods

The largest impact to power consumption, measurement accuracy and application fitness is likely to be by selecting the measurement period, whether it be set and fixed in continuous mode, or more dynamic and resulting by single measurement mode controlled by the host.

The measurement period needs to be set as strictly longer than the number of samples times ”180ms”.

### Number of samples for integration per measurement

The second major design impact to power consumption and measurement accuracy comes by choosing the number of samples, the actual number of active measurements which the emitter will do, that will be integrated into a final measurement value during the set measurement period.

The default number of samples, to be performed and integrated into an average value per measurement, is set to 8.

It can be set to anything from 1 to 1024 number of times, each one sample taking <300ms (typical 180ms) to perform, so the maximum number would require a measurement period to be about 308 seconds, or close to 5 minutes, to have enough time to integrate through all of them before an actual measurement response value would be presented.

Adding more of these power-consuming samples, and also lowering the time the emitter is in standby by trimming the measurement period, will have a very large impact on accuracy as well as on power-consumption.

Measurement period recommended to be set longer than number of samples *times* T-sample max time "300ms/sample".
E.g. 16 samples will need 16* 300ms (T max time/sample) = 4800ms, the measurement period is 6s since 5s would be rounded up to nearest even number.

There will also be a marginal improvement to response time as the higher discreet sampling frequency can catch an ambient environment change happening earlier, instead of missing the start and first duration of the event until the next active measurement sampling period. Essentially, Senseair Sunrise is blind to any change happening while in standby and not actively sampling.

### IIR filter on $CO_2$ measurement readings

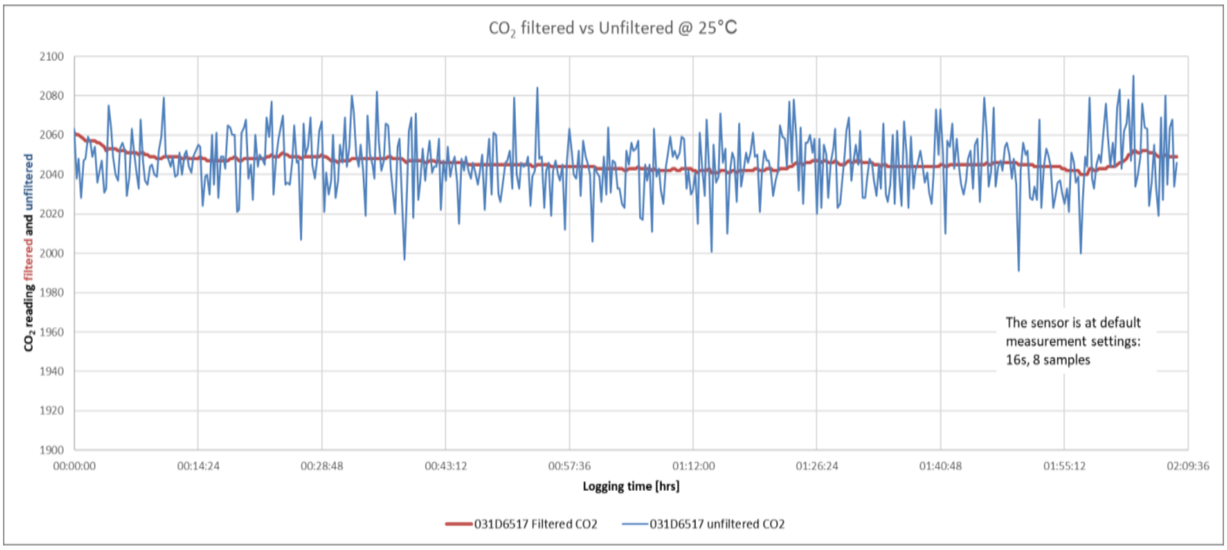
Senseair Sunrise implements a software IIR filter on concentration measurements, acting to suppress the $CO_2$ reading noise across multiple measurements.

This filter causes some additional lag in sensor response time by actively suppressing the full step change of each new perceived reading compared to the past one, and hence only allowing a fraction of the new change to propagate through and form the next $CO_2$ concentration measurement value (Static IIR filter).

This is highly effective in improving RMS noise under conditions when there are no actual changes to the environment in which the sensor is sampling. However, when there is a real change event happening, then a Dynamic IIR filter algorithm will modify the static fractional filter to decrease the $CO_2$ suppression, allowing a bigger part of the step change to propagate through, to help to indicate the environment's changes. Depending on how time-critical or how sensitive to noise and repeatability the system is, either of the data parameter can be more useful. This software algorithm is always calculated in parallel with the unfiltered concentration measurement.

IIR filter is enabled by default. The dynamic IIR filter depends on the static IIR filter, therefore if the static IIR filter desired to be disabled then it is necessary to disable also the dynamic IIR filter.

**For measurement periods more than 1 minute it's recommended to disable both IIR filtrations and increase the number of samples**. E.g., for 5 minutes measurement period, increase the number of samples from 8 (default) to 32 samples and disable both static and dynamic IIR filtration.

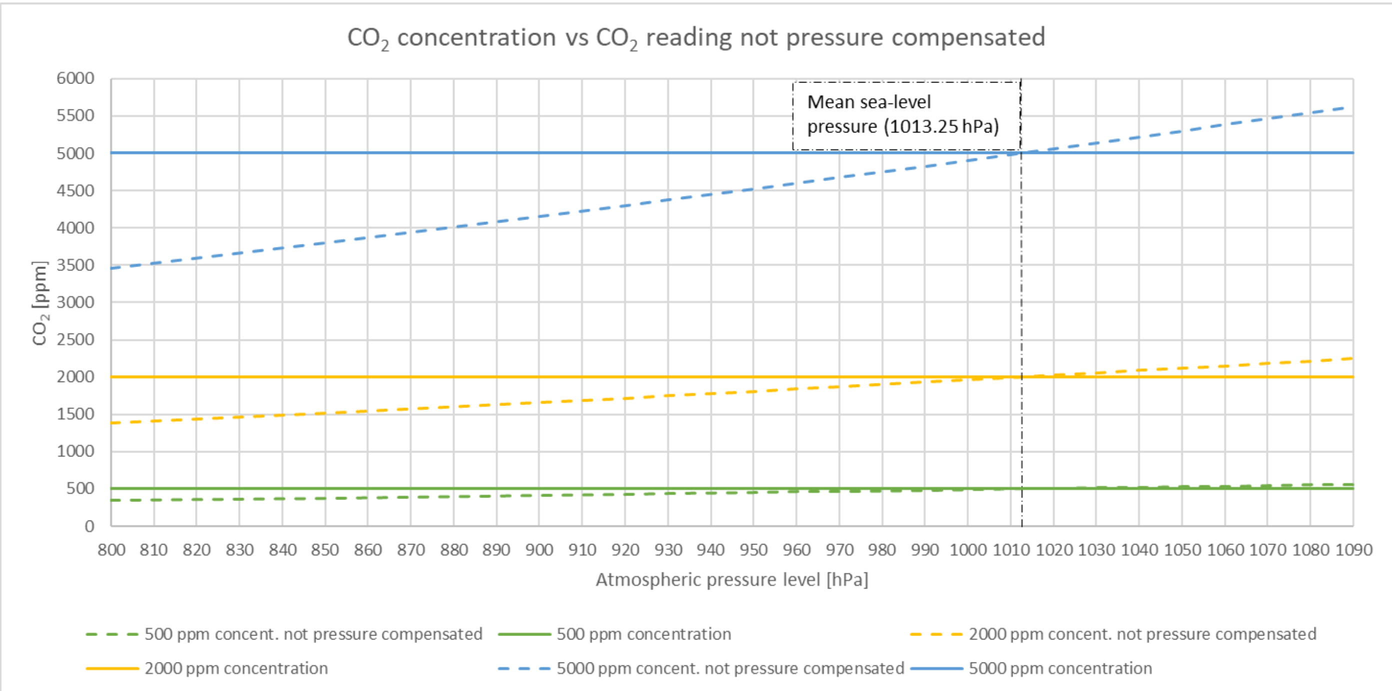



## Atmospheric pressure effect on $CO_2$ reading value

1.6% change in $CO_2$ concentration per kPa deviation from mean sea-level pressure (MSLP), 101.325 kPa. This pressure dependence on $CO_2$ reading is valid for typical atmospheric pressure variation around sea-level only.

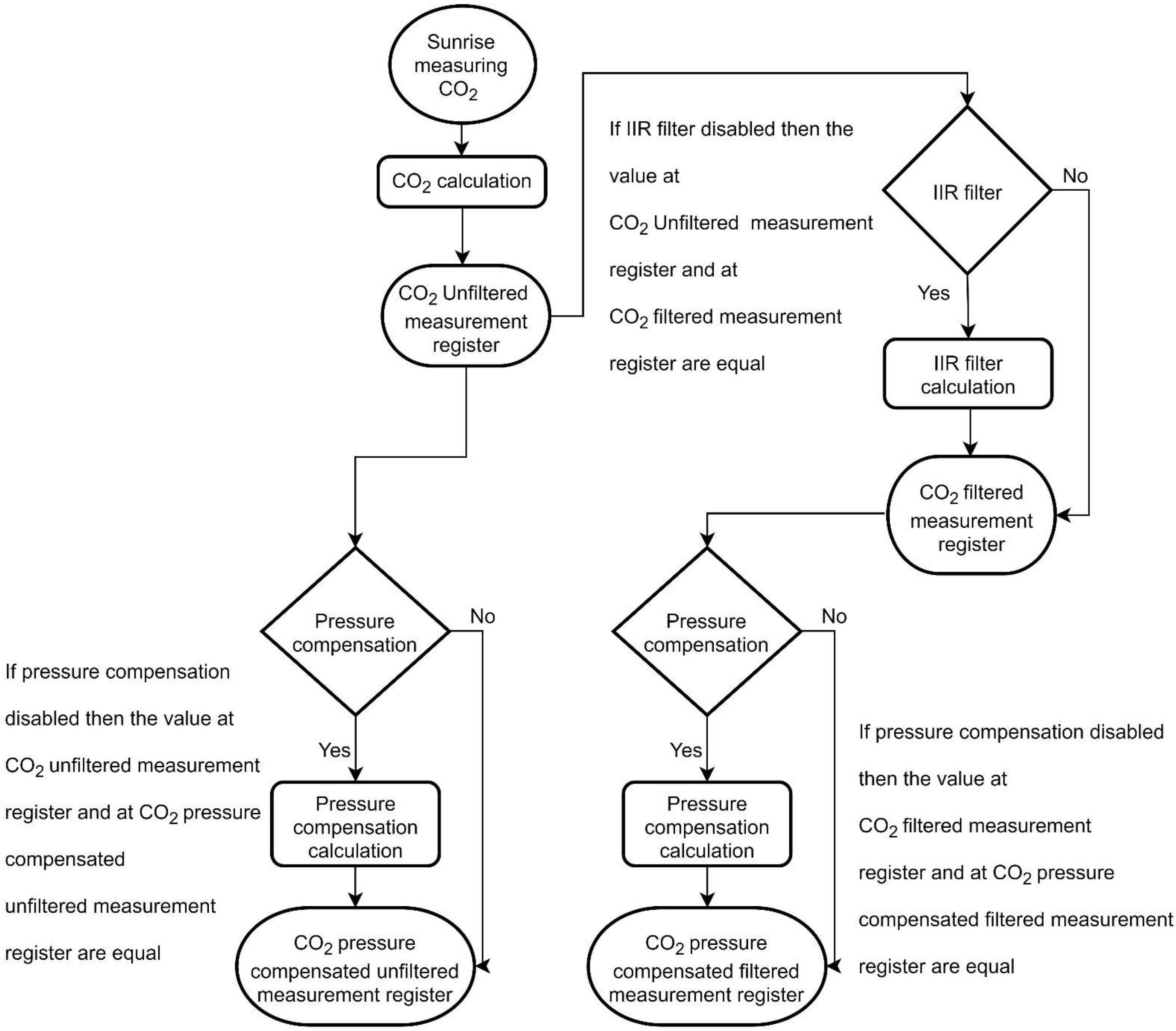
To increase the end-customer Sunrise experience, Senseair implemented a software algorithm to compensate the atmospheric pressure effect on $CO_2$. In general, while barometric pressure increases then $CO_2$ molecules increases inside this given volume (the sensor optical cavity), and the opposite is correct.

The below diagram presents how much the barometric pressure can affect the $CO_2$ reading inside a given volume but not the concertation.



$CO_2$ unfiltered measurement register,
$CO_2$ filtered measurement register,
$CO_2$ pressure compensated unfiltered measurement register and
$CO_2$ pressure compensated filtered measurement registers

The below flowchart shows the connection between these 4 registers and how the values can be equal if both IIR filter and pressure compensated algorithms disabled or not.



## Response times

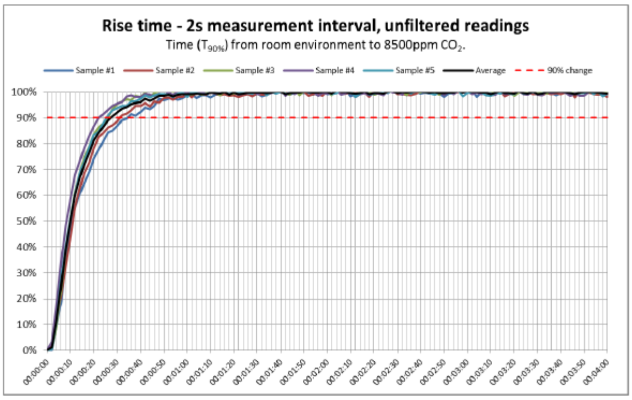
Response times depends mostly on the test setup, the definition of response time requirement and the sensor measurement period.

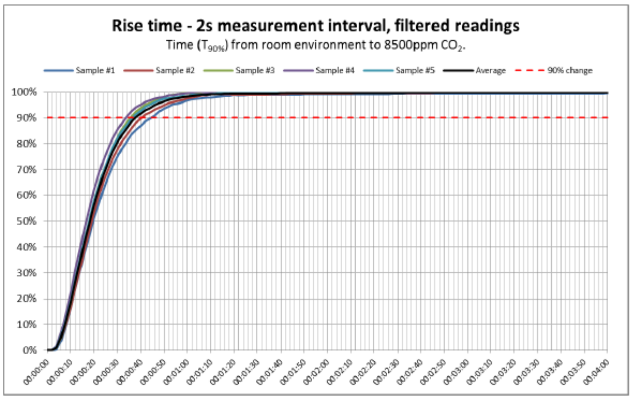
The below diagram/table tested at stable gas concentration in an enclosure with Sunrise sensor that changed from 8500 ppm to fresh air (400ppm) and the opposite. Gas flow rate is 1L/min

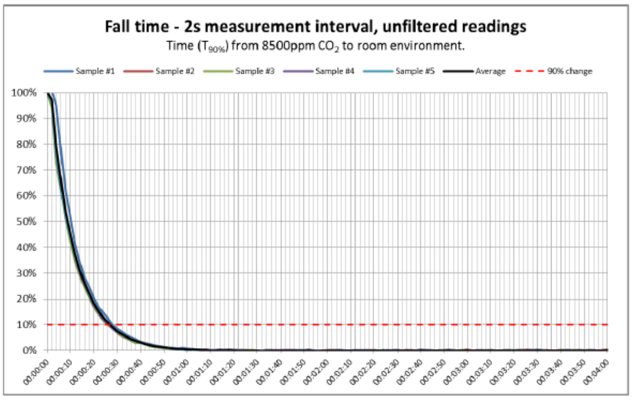
| | Unfiltered $CO_2$ measurement | Filtered $CO_2$ measurement |
|---|---|---|
| Response rise time $T_{90\%}$ | ~30s | ~40s |
| Response fall time $T_{90\%}$ | ~30s | ~35s |

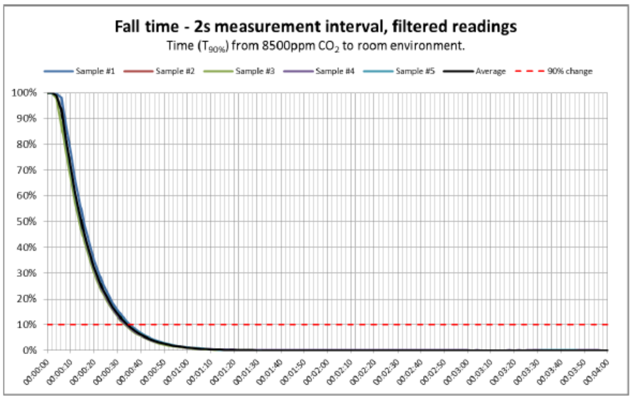
The concentration change step response is affected by these factors:

- Measurement period is controlled by application host (2s during the test).
- Transport model of gas matters, diffusion or convection flows
- Minimizing dead-volume of enclosure, ensuring no leakages that will inhibit diffusion of the full step change into optical sample cell.
- IIR filter active matters



## Calibration types

The sensor will perform a calibration (Zero/Background/Target) based on the first measurement immediately after the calibration command was received, but the ABC and Forced ABC calibration will be based on the stored data at ABC parameters registers.
After having performed the calibration all following measurements will use the adjusted calibration parameters.

It is recommended that Calibration status is cleared before initiating a calibration and the calibration is initiated by the commands see more details at TDE5531 for $I^2C$ communication and TDE5514 for UART communication.

### Zero Calibration

Zero-calibrations are the most accurate recalibration routine and are not at all affected performance-wise by having an available pressure sensor on host for accurate pressure-compensated references.

A zero-ppm environment is most easily created by flushing the optical cell of the sensor module and filling up an encapsulating enclosure with nitrogen gas, $N_2$, displacing all previous air volume concentrations. Another less reliable or accurate zero reference point can be created by scrubbing an airflow using e.g. Soda lime.

### Background Calibration

A “fresh air” baseline environment is by default 400 ppm at normal ambient atmospheric pressure by sea level. It can be referenced in a crude way by placing the sensor in direct proximity to outdoor air, free of combustion sources and human presence, preferably during either by open window or fresh air inlets or similar. Calibration gas by exactly 400ppm can be purchased and used.

Background calibration and ABC calibration share the same target value (fresh air = 400ppm), this value can be modified by changing the value at register “ABC Target” depending on where the sensor will be placed.

See an example at TDE5531 for $I^2C$ communication and TDE5514 for UART communication.

### Target Calibration

Target concentration calibration assumes that sensor is put into a target environment with a known $CO_2$ concentration. A target concentration value must be written to Target calibration register.

See an example at TDE5531 for $I^2C$ communication and TDE5514 for UART communication.

### ABC Calibration

The Automatic Baseline Correction algorithm is a proprietary Senseair method for referencing to “fresh air” as the lowest, but required stable, CO2-equivalent internal signal the sensor has measured during a set time period. This time period by default is 180hrs and can be changed by the host, it’s recommended to be something like an 8 day period as to catch low-occupancy and other lower-emission time periods and favourable outdoor wind-directions and similar which can plausibly and routinely expose the sensor to the most true fresh air environment.

If such an environment can never be expected to occur, either by sensor locality or ever-presence of CO2 emission sources, or exposure to even lower concentrations than the natural fresh air baseline, then ABC recalibration can’t be used.

In each new measurement period, the sensor will compare it to the stored one at the ABC parameters registers, and if new values show a lower CO2-equivalent raw signal while also in a stable environment, the reference is updated with these new values.

The ABC algorithm also has a limit on how much it is allowed to change the baseline correction offset with, per each ABC cycle, meaning that self-calibrating to adjust to bigger drifts or signal changes may take more than one ABC cycle.

### Forced ABC Calibration

It uses the same reference registers as the ones for ABC calibration (ABC parameters registers). This feature added in case the host wants to speed up the baseline correction and not to wait the whole ABC period.

Forced ABC calibration can be used only when the ABC is enabled.

## Error codes and action plane

| **ErrorStatus register** | | |
|---|---|---|
| **Bit** | **Error description** | **Suggested action** |
| 0 | **Fatal error**<br><br>Indicates that initialisation of analog front end failed | Try to restart sensor by power on/off.<br><br>Contact local distributor. |
| 1 | **I2C error**<br><br>Attempt to read or write to not exiting addresses/registers detected. | Try to restart sensor by power on/off.<br><br>Check wires, connectors and I2C protocol implementation.<br><br>Contact local distributor. |
| 2 | **Algorithm error**<br><br>Corrupt parameters detected. | Try to restart sensor by power on/off.<br><br>Contact local distributor. |
| 3 | **Calibration error**<br><br>Indicates that calibration has failed (ABC, zero, background or target calibration). | Try to repeat calibration. Ensure that the environment is stable during calibration. |
| 4 | **Self-diagnostics error**<br><br>Indicates internal interface failure. | Try to restart sensor by power on/off.<br><br>Contact local distributor. |

| | | |
|---|---|---|
| 5 | **Out of range**<br><br>Indicates that the measured concentration is outside the sensor's measurement range.  Flag is cleared at the start of a new measurement. | Perform suitable $CO_2$ calibration (zero, background or target calibration).<br><br>Contact local distributor. |
| 6 | **Memory error**<br><br>Error during memory operations | Try to restart sensor by power on/off.<br><br>Contact local distributor. |
| 7 | **No measurement completed**<br><br>Bit set at startup, cleared after first measurement | 0 – First measurement cycle completed<br><br>1 – No measurement completed<br><br>If sensor is used in single measurement mode and powered down between measurements this bit can be used to verify started measurement cycle has finished |
| 8 | **Low internal regulated voltage**<br><br>Flag is set if sensors regulated voltage is to low, this means supply voltage is lower than 2.8V. | Check power supply. |
| 9 | **Measurement timeout**<br><br>Flag is set if sensor is unable to complete the measurement in time. Flag is cleared after a successful measurement. | If flag is set permanently try to restart sensor by power on/off.<br><br>Contact local distributor. |
| 10 | Reserved | |
| 11 | Reserved | |
| 12 | Reserved | |
| 13 | Reserved | |
| 14 | Reserved | |
| 15 | Reserved | |

## Peripherals and Senseair Sunrise Evaluation Kit

By connecting the Senseair Sunrise Evaluation Kit to the PC where Senseair standard software UIP5 installed, the Senseair Sunrise sensor can be easily evaluated before start designing the host system.

## Revision history

| Date | Revision | Page (s) | Description |
|---|---|---|---|
| 2020-02-07 | 1-6 | All | Sunrise article number 006-0-0002 |
| 2021-04-12 | 7 | 3, 7, 8, 9<br>11, 12, 19 | Sunrise article number 006-0-0007<br>Page 3 Standard specification, electrical specification added PSP11704 for 006-0-0007. Physical dimensions adjusted for 006-0-0007<br>Page 7,8 Current consumption diagrams updated for continuous and single measurement modes<br>Page 9 Sunrise timing, parameters for synchronizing and communication diagram updated<br>Page 11 Single measurement mode, figure-communication sequence<br>Page 12 Timing adjusted based on max sampling time (300ms)<br>Recommendation to disable static & dynamic IIR filters and increase the number of samples if measurement period > 1 minute.<br>Page 19 Revision history added |
| 2021-04-27 | 8 | All | Senseair logotype modified |
| 2021-04-27 | 9 | 19 | Rev. 8 changes added to this table (Revision history) |
| 2021-07-28 | 10 | 3 | Hyperlinks updated |