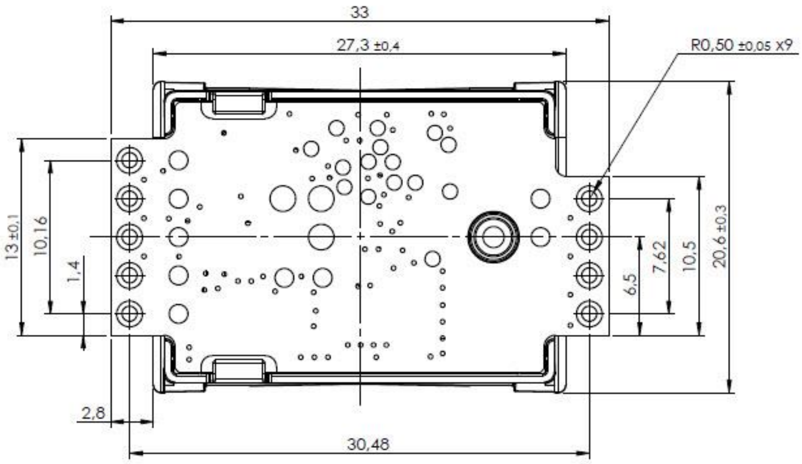
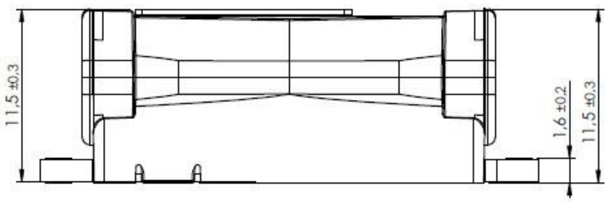
Customer Integration Guidelines
Senseair Sunlight HC-R

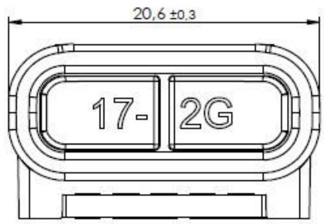
Standard Specifications

The product specification for Sunlight R32 can be found at Senseair's website www.senseair.com (under Sunlight product) or directly through this link: PSP12849

Physical Dimensions







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

Operating Environment Specification

Senseair Sunlight is intended for (but not limited to) commercial and residential buildings, industrial applications and indoor applications.

Temperature and humidity operating range

Accuracy is specified over the full temperature and humidity range. At freezing temperatures, there is a risk of micro-condensation and ice crystals forming inside the optical bench, which may impact the sensor reading temporarily.

Warm-up time

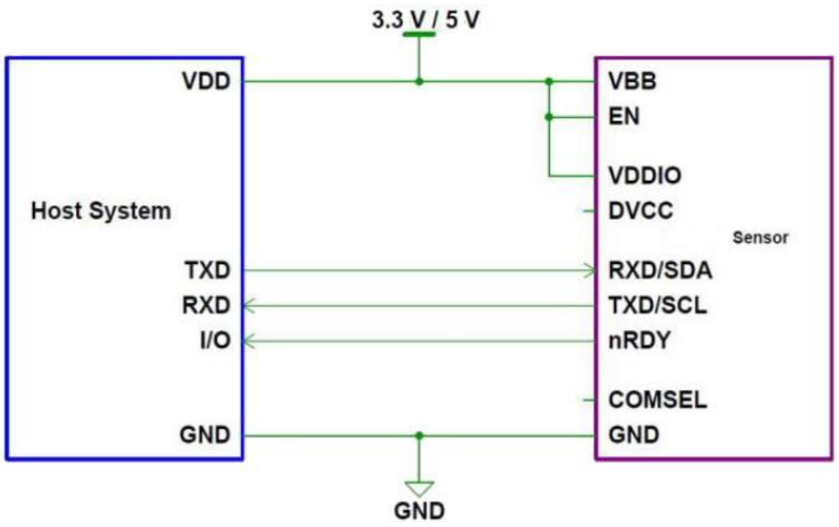
There is NO warm-up for Senseair Sunlight, the very first measurement after a reboot or power cycle is accurate to within stated accuracy specification and average RMS noise. This due to the miniscule circuitry-heating of Senseair Sunlight chipset, and with the typical integration of several samples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

This is important for integration design, as the power cycle in single measurement mode can be optimised greatly by only taking one measurement before reverting back to low-power sleep or shutdown, still getting a perfect measurement result. Every measurement is trustworthy with Senseair Sunlight!

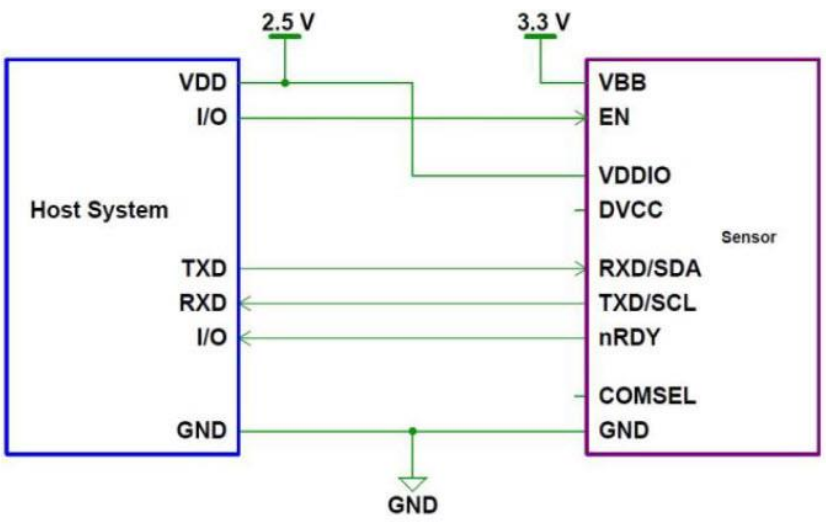
Please make distinction between Senseair Sunlight's warm-up and settling time from a shutdown and power-off, and full acclimatisation time to conform to a new steady-state from actual changes in the ambient environment.

Electrical Integration Illustration

Modbus over UART integration illustrations



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



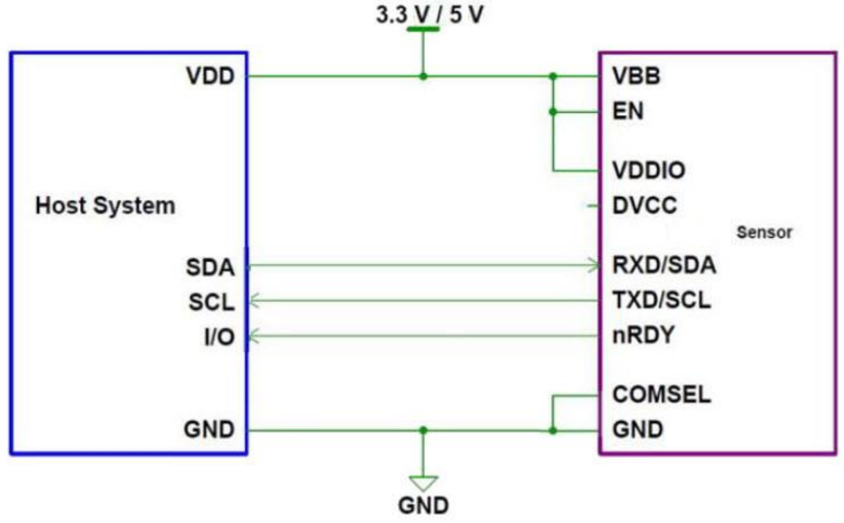
2.5V powered host and low-power integration example for continuous-mode or single-mode integration. Host controls and toggles EN-pin and powers VDDIO. Optionally, although not recommended, an additional GPIO -pin can be saved on host by leaving nRDY floating and implement synchronization and handshaking by worst-case timings.

If there is a considerable load on TxD/SCL (e.g. by using long wires), then the internal pull-up to VDDIO (100kOhm) might need assistance by adding a stronger (lower resistance) external pull-up to VDDIO.

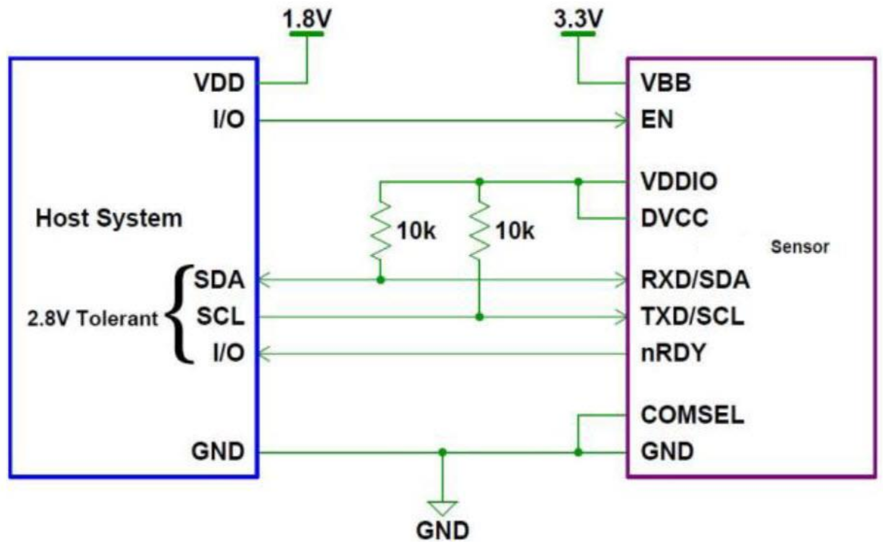
Modbus settings and registers

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

I²C integration illustrations



Example I²C integration strictly for continuous-mode operation of Sunlight, 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 Sunlight VDDIO is powered from DVCC: Host must be 2.8V tolerant.

The Senseair Sunlight 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.

I²C settings and registers

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

Reconfiguring the application fitness of Senseair Sunlight

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

Single measurement mode vs continuous measurement mode

One of the first integration design choices is whether to have the Senseair Sunlight 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 Sunlight, 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

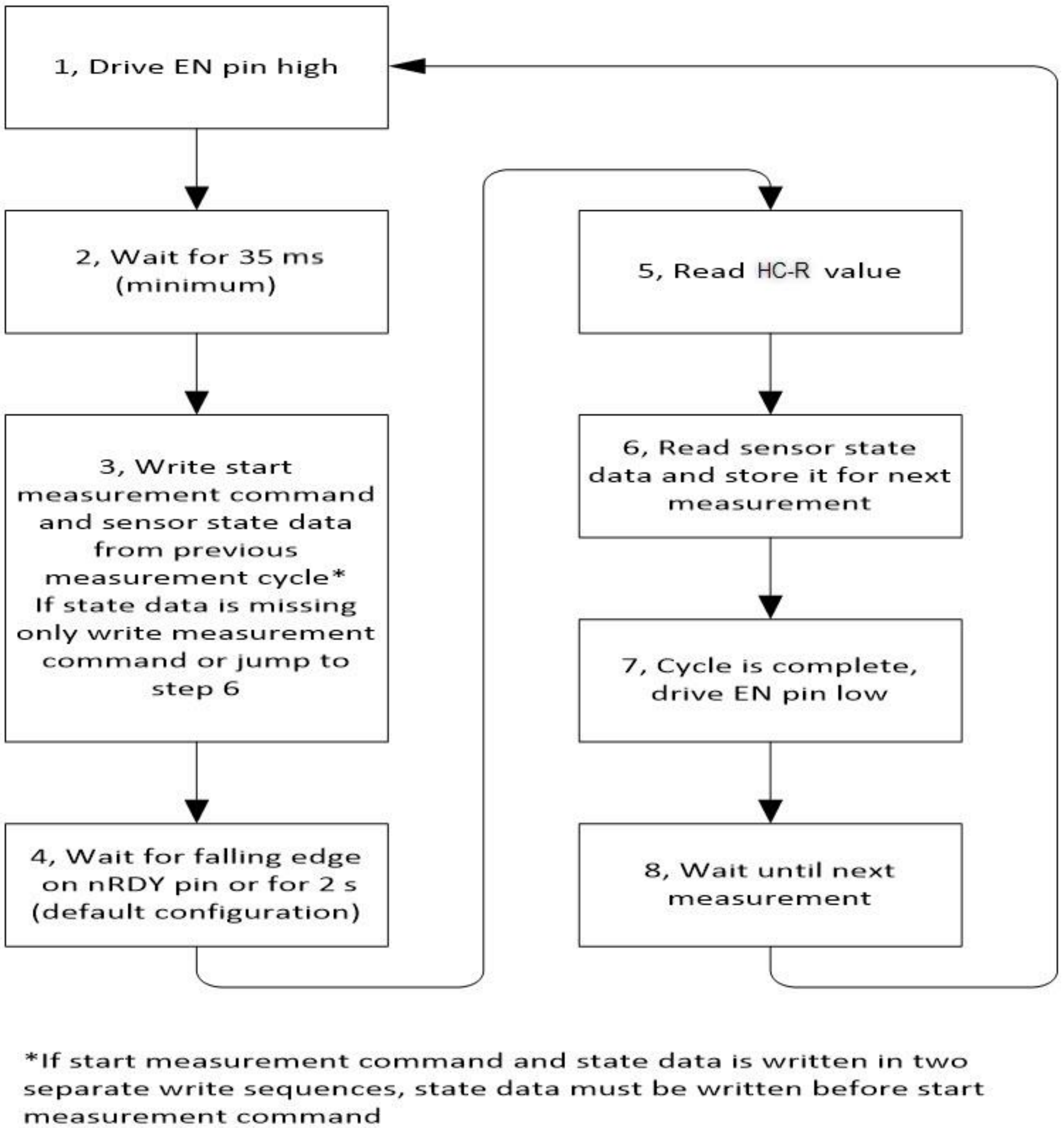
Single measurement mode allows Senseair Sunlight to be put into shutdown mode when not in use, compared to the normal low-power sleep of the microprocessor in-between operations.

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 Sunlight’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 Sunlight memory upon next boot-up cycle.

Single measurement mode gives the host full control of when measurements are done and is suitable if an event based or dynamic measurement scheme is planned, for example starting measurements by a motion sensor or to just have more frequent measurements during daytime.

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



Communication sequence for single measurement mode

The measurement period

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” x ”171ms”. Measurement period recommended to be set longer than “number of samples” x “T_Sample Max”/2(samples).

E.g. 8 samples will need 8 x (400/2) ms = 1600ms, suitable measurement period is 2s (2000ms).

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 amount 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.

The number of samples can be set to an even number from 2 to 1024, each one sample taking <200ms (171ms) to perform, so the maximum number would require a measurement period to be about 205 seconds, or close to 4 minutes, to have enough time to integrate through all of them before an actual measurement response value would be presented.

Additionally, the greatest number of samples that the Senseair Sunlight have time to fully perform and integrate an average value for, during the shortest possible 2s measurement period, is 10 samples.

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.

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 Sunlight is blind to any change happening while in standby and not actively sampling.

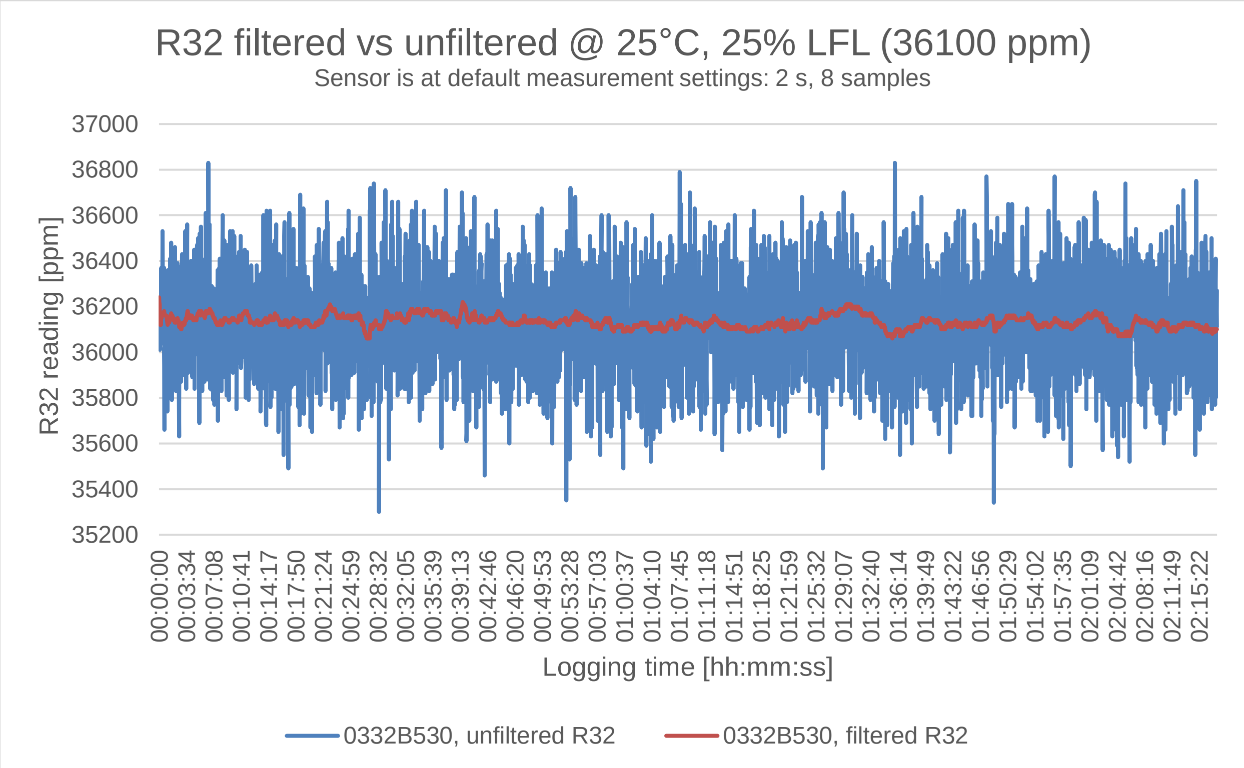
IIR filter on HC-R measurement readings

Senseair Sunlight implements a software IIR filter on concentration measurements, acting to suppress the HC-R reading noise across multiple measurements.

This filter increases 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 HC-R 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 HC-R 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.

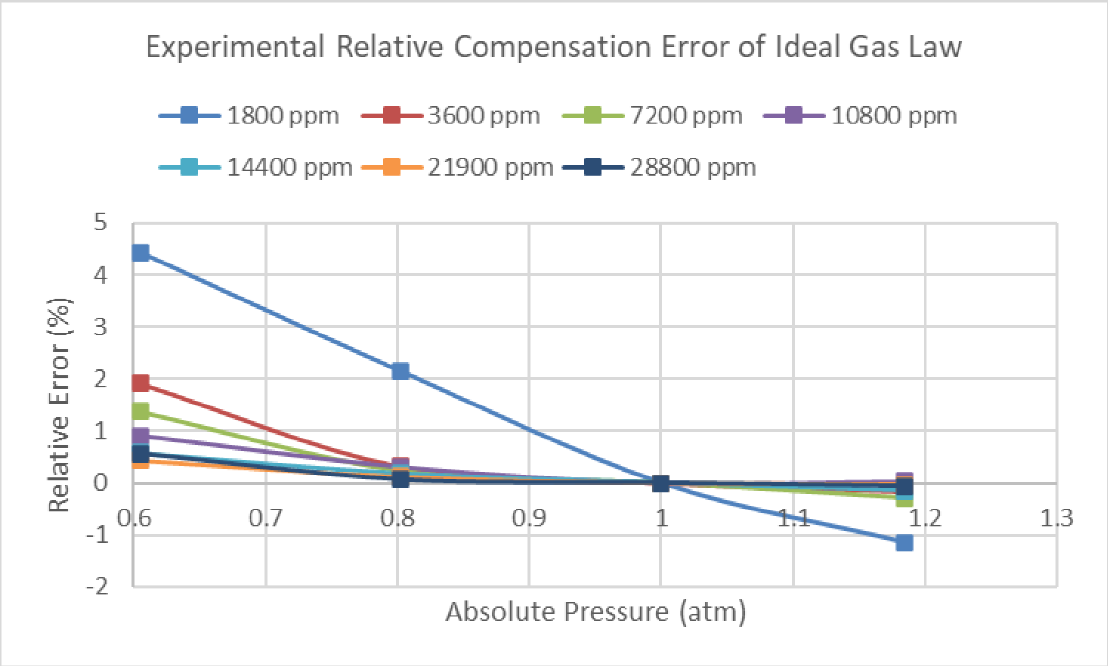


Atmospheric pressure effect on HC-R reading value

Pressure dependence in measured HC-R concentration is 1% change per kPa deviation from mean sea-level pressure (MSLP), 101.325kPa. This pressure dependence on HC-R reading is valid for typical atmospheric pressure variation around sea-level only.

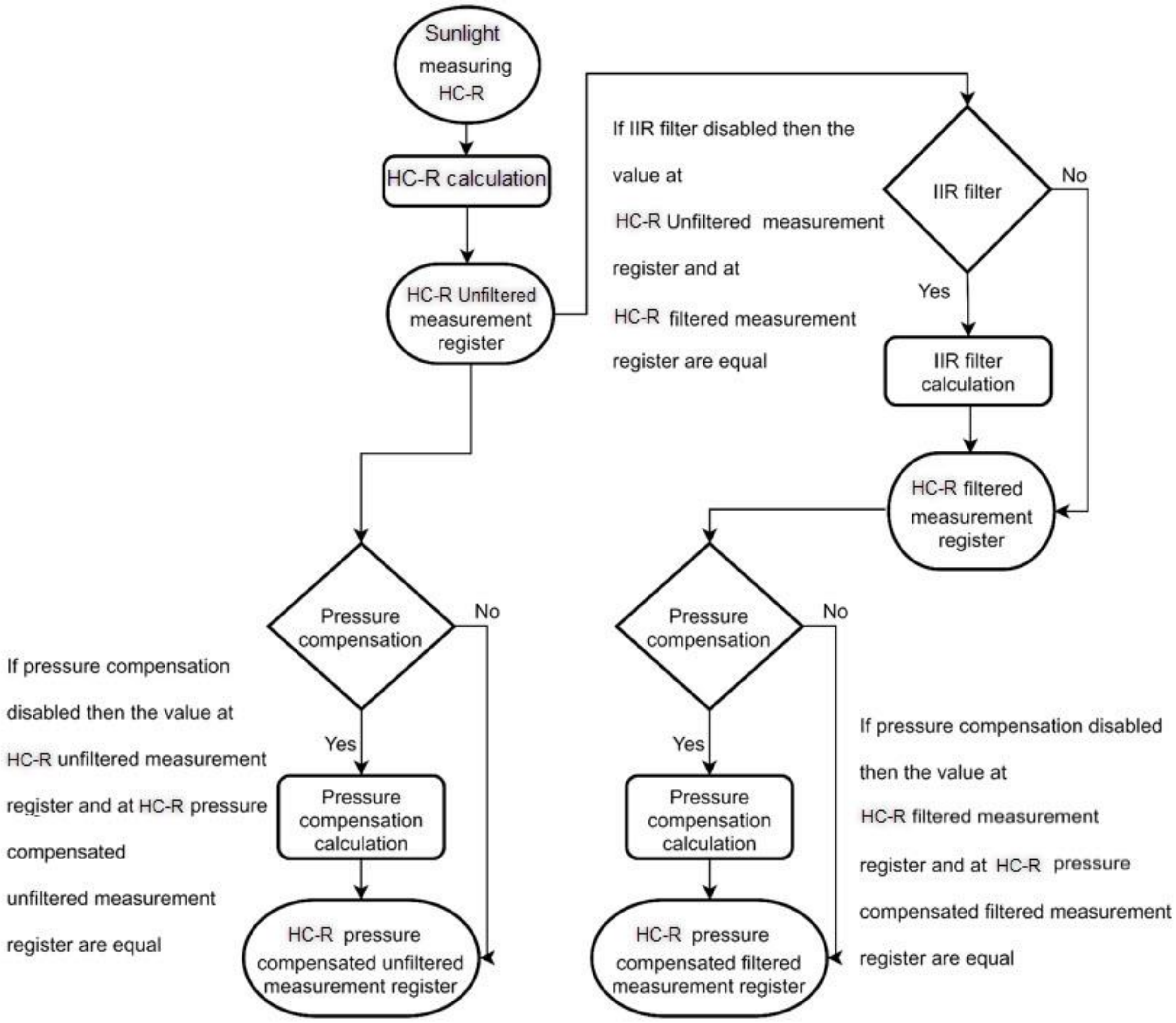
Senseair Sunlight has a software algorithm to compensate the atmospheric pressure effect on HC-R. To use the algorithm the user needs to provide pressure value to the sensor. In general, while barometric pressure increases then HC-R molecules increases inside this given volume (the sensor optical cavity), and the opposite is correct too.

The below diagram presents how much the barometric pressure can affect the HC-R reading.



HC-R measurement registers

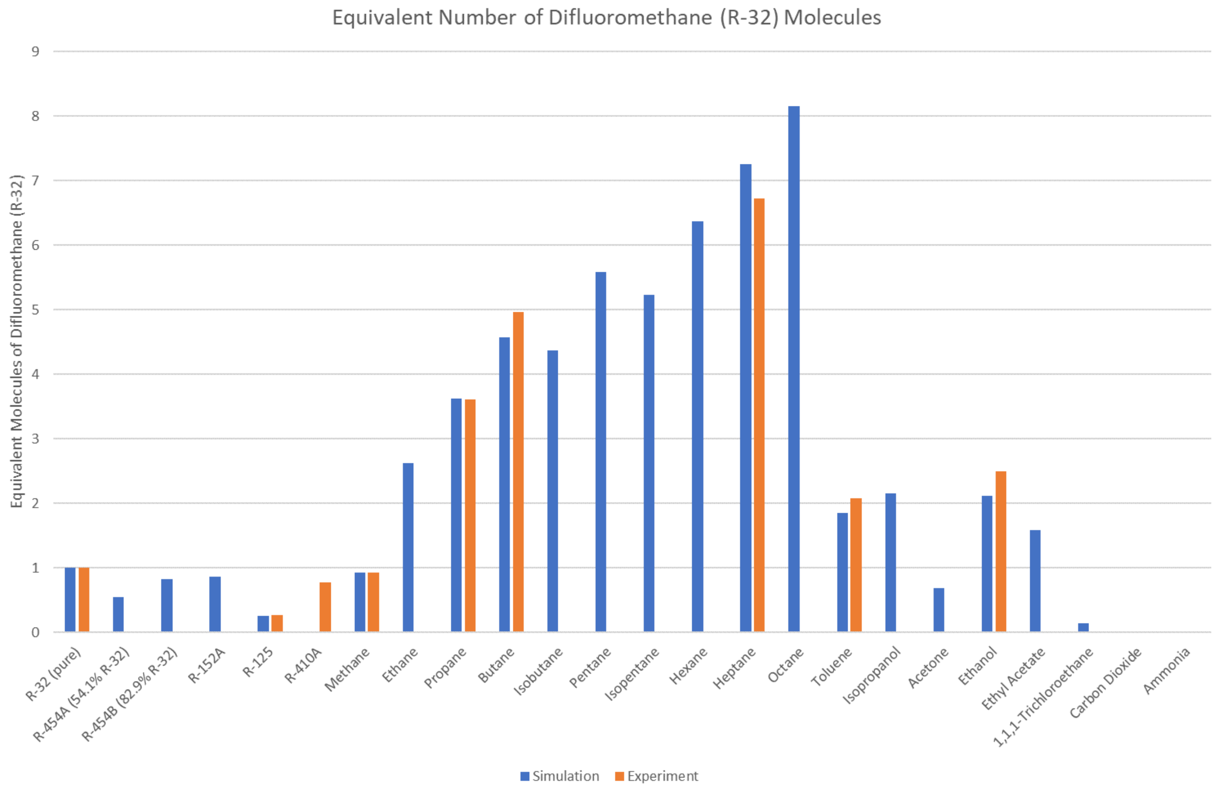
The below flowchart shows the connection between the 4 registers “HC-R unfiltered measurement register”, “HC-R filtered measurement register”, “HC-R pressure compensated unfiltered measurement register” and “HC-R pressure compensated filtered measurement register”, and how the values can be equal if both IIR filter and pressure compensating algorithms are disabled or not.



Cross sensitivity

Sunlight R32 is sensitive to molecules that contains C-H bounds and will detect them in different degree.

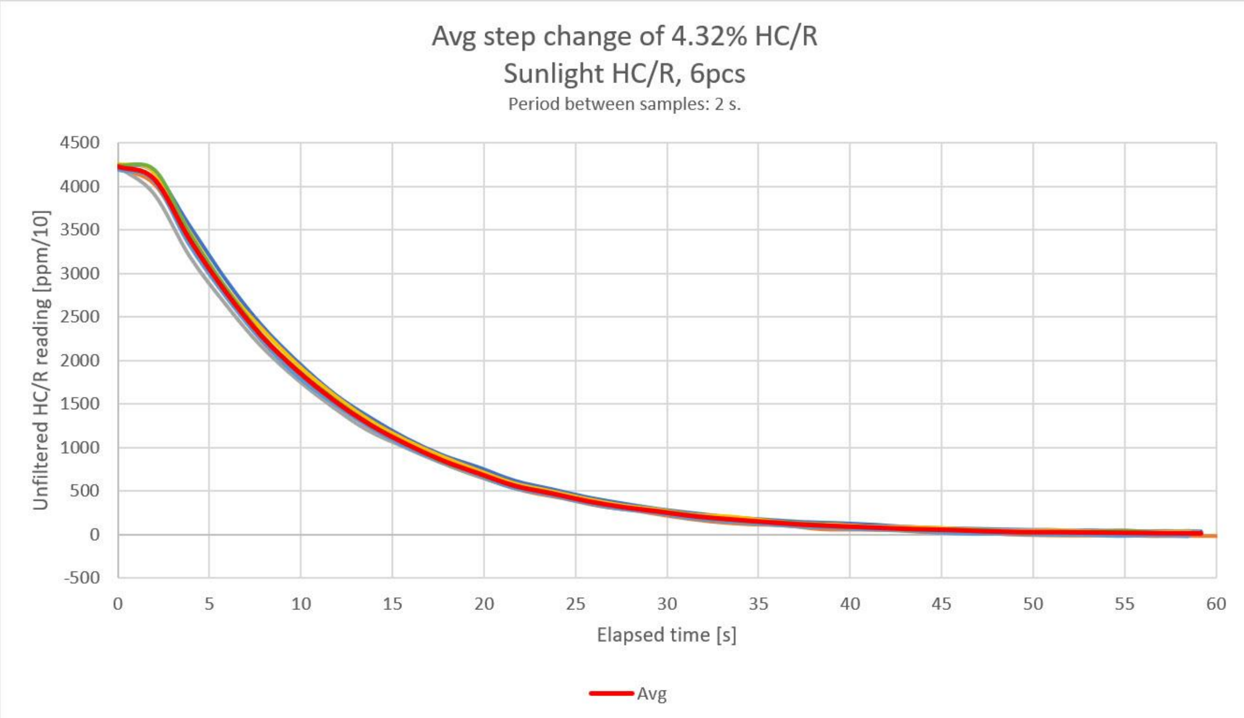
The graph below shows simulated and measured sensor response to a common selection of gases, compared to R32.



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 Sunlight sensor that changed from 43200ppm towards fresh air (0ppm).



Result :Response time $T_{90\%}$ = 24.8 ±2s

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.
- Minimising dead-volume of enclosure, ensuring no leakages that will inhibit diffusion of the full step change into optical sample cell.
- IIR filter active matters.

Low power integration

In order to realise even lower power consumption, there are few options for a system using Senseair Sunlight.

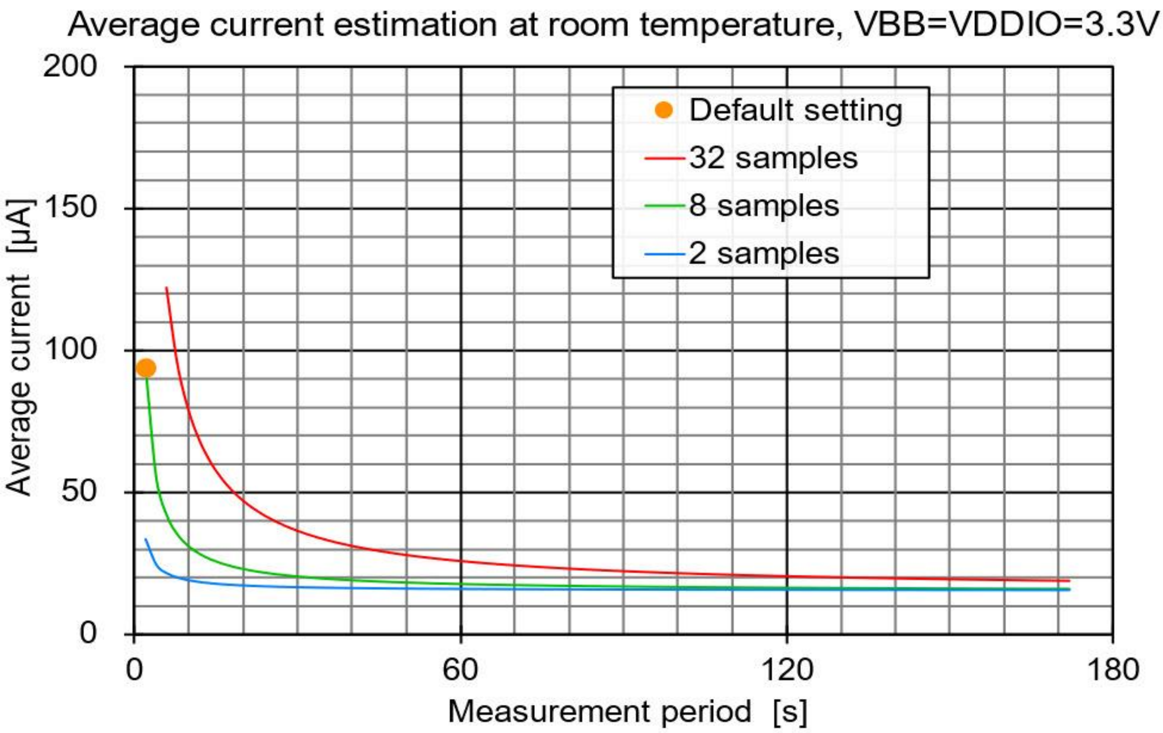
- Control of supplying voltage to VDDIO pin. It may reduce sleep leakage current to supply voltage to VDDIO only while communication and nRDY pin indication are needed.
- Switch of the host's communication pins input/output mode. It may reduce sleep leakage current to turn the host's pins for communication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

If a user considers using single-measurement mode, the extra power consumption overhead to read out and write back the sequential registers should be considered. During the reading/writing process, both Senseair Sunlight and the host system consume an amount of current 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 of the system.

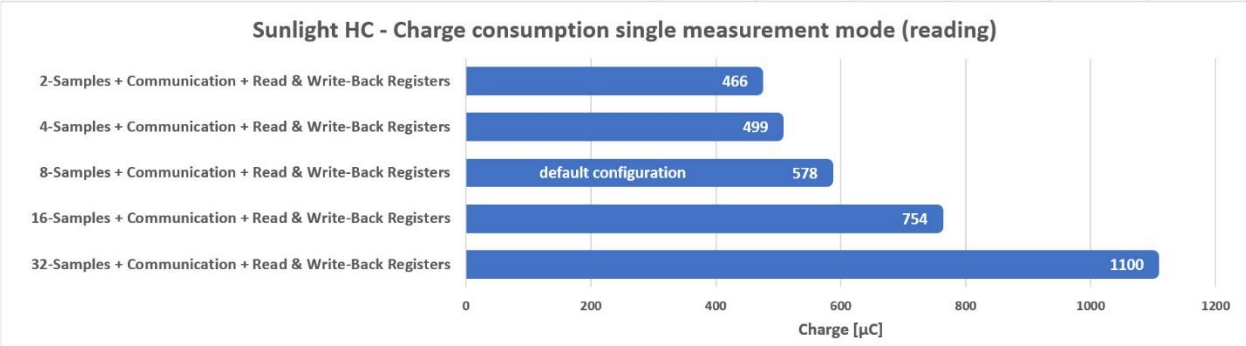
Current consumption

Power consumption diagram @ Continuous measurement mode

Default measurement settings: 2s, 8 samples.



Power consumption diagram @ single measurement mode



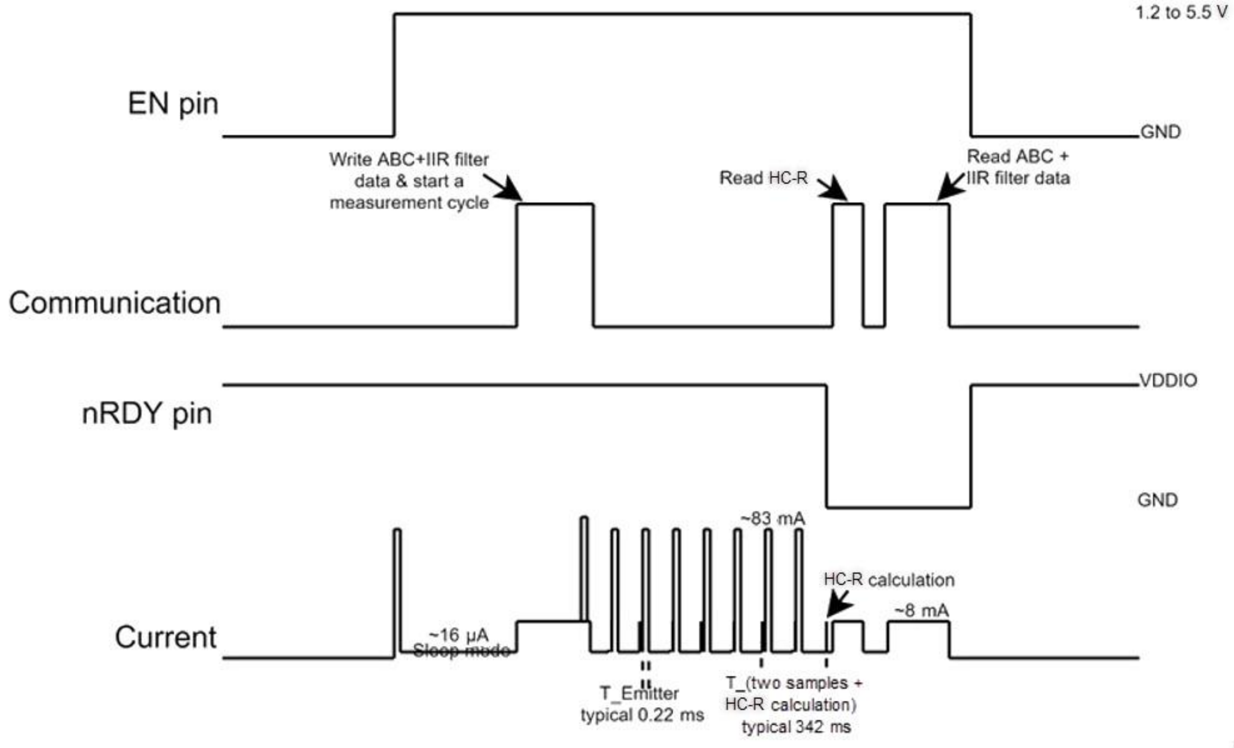
Sunlight Timings

Senseair Sunlight is recommended to be time synchronised with the host, to allow for implementation of Senseair Sunlight 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		342	400	Time per 2 samples. Min number of samples are two and always even number of samples.
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

Calibration types

The sensor will perform a calibration (Zero/Background/Target) based on data from the first measurement immediately after the calibration command was received, but the ABC and Forced ABC calibration will be based on stored data in ABC parameters registers.

After having performed the calibration, all following measurements will use the adjusted calibration parameters.

It is recommended that Calibration status register is cleared before initiating a calibration. The calibration is initiated by commands described in TDE5531 for I²C communication and TDE5514 for UART communication.

After sensor integration into the final product, performing one of the following calibrations (Zero or background or target calibration) is highly recommended.

Zero Calibration

Zero calibration is the most accurate recalibration routine and it is 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) or dry pressurised air free from hydrocarbons and refrigerants, displacing all previous air volume.

Background Calibration

A "fresh air" baseline environment is by default 0 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 fresh air, preferably by either open window or fresh air inlets.

Background calibration and ABC calibration share the same target value (fresh air = 0ppm), this value can be modified by changing the value at register "ABC Target" depending where the sensor will be placed.

See an example at TDE5531 for I²C communication and TDE5514 for UART communication.

Target Calibration

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

See an example at TDE5531 for I²C 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, HC-R-equivalent internal signal the sensor has measured during a defined time period. This time period is by default set to 720 hrs and can be changed by the host, it’s recommended to be something like a 30-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 never can be expected to occur, either by sensor locality or constant presence of HC-R emission sources, then ABC calibration can’t be used.

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 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** Indicates that initialization of analogue front end failed	Try to restart sensor by power on/off. Contact local distributor.
1	**I2C error** Attempt to read or write to not exiting addresses /registers detected.	Try to restart sensor by power on/off. Check wires, connectors and I^2C protocol implementation. Contact local distributor.
2	**Algorithm error** Corrupt parameters detected.	Try to restart sensor by power on/off. Contact local distributor.
3	**Calibration error** 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** Indicates internal interface failure.	Try to restart sensor by power on/off. Contact local distributor.

5	**Out of range** Indicates that the measured concentration is outside the sensor's measurement range. Flag is cleared at the start of a new measurement.	Perform suitable HC-R calibration (zero, background or target calibration). Contact local distributor. Note: This is not necessarily an error.
6	**Memory error** Error during memory operations	Try to restart sensor by power on/off. Contact local distributor.
7	**No measurement completed** Bit set at start-up, cleared after first measurement	0 – First measurement cycle completed 1 – No measurement completed 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** 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** 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. 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 a PC with Senseair standard software UIP5 installed, the Senseair Sunlight sensor can be easily evaluated before start designing the host system.

www.senseair.com