Reduced Power Operation for SEN5x

Application note describing SEN5x reduced power mode

Summary

SEN5x is a combo sensor module measuring particulate matter (PM), volatile organic compounds (VOCs), NOx, as well as relative humidity and temperature (RHT). In its default Measurement mode, it provides new data at a sampling interval of one second. To reduce power consumption, the SEN5x features an additional operating mode in which laser and fan are switched off (RHT/Gas-Only Measurement mode, with no PM data).

A correct alternation of the Measurement and RHT/Gas-Only Measurement modes can reduce the power consumption and allows to operate the SEN5x sensor for an extended periods of time on a tight energy budget, thus making it possible to potentially use the SEN5x even in battery operated devices.

This document provides detailed instructions on how to choose a suitable sampling interval and subsequently implement a reduced power operation mode with the SEN5x.

1 Overview

The SEN5x sensor module features three different operating modes: Idle, Measurement and RHT/Gas-Only Measurement. When the sensor is powered up, the SEN5x automatically goes into Idle mode. Starting from Idle mode, the sensor can be put either into Measurement mode or RHT/Gas-Only Measurement mode. Figure 1 provides a description of all operation modes.

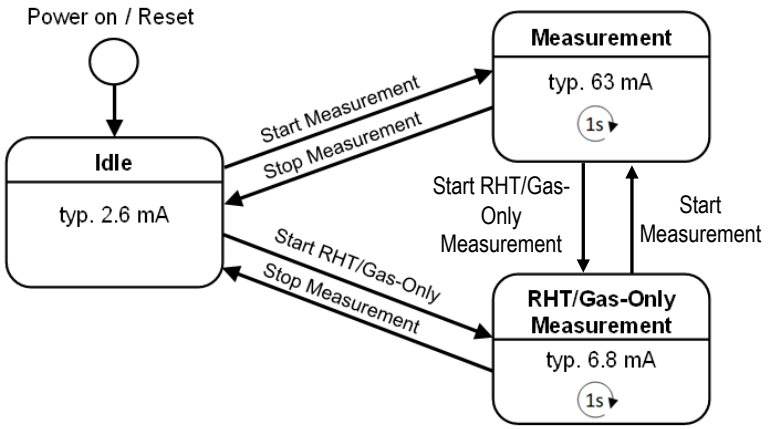

Figure 1: The different operating modes of the SEN5x sensor.

In the Measurement mode, SEN5x provides new data at a sampling interval of one second. In some applications, a PM value every one second is not necessary. In this situation, it is useful to switch the module to the RHT/Gas-Only Measurement mode, in which fan and laser are switched off, but the VOC, NOx, and RHT sensors (where present in the considered variant) are on. For SEN50, a reduced power mode is obtained switching between Measurement and Idle mode.

Reducing the time PM is measured allows to save power consumption considerably. Indeed, the full measurement mode has an average current consumption of 63 mA, while in the RHT/Gas-Only Measurement mode the current consumption is reduced to 6.8 mA. The features of the different modes are described in detail in the SEN5x datasheet.

A proper, alternating use of these operation modes as indicated in Figure 2 may reduce power consumption by a factor of 7-9 with only minimal compromises on sensor system performance.

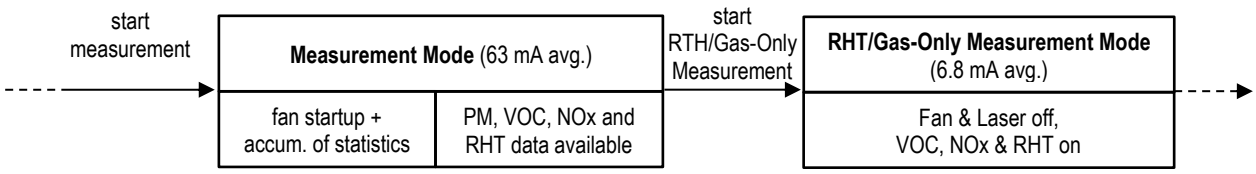

Figure 2: Illustration of one complete cycle of reduced power operation. The measurement mode is divided into two phases: The first phase in measurement mode is characterized by the fan starting up and the PM algorithm accumulating statistics. During this phase, the measurement data of the SEN5x is not stable and shall be discarded. In the second phase PM, VOC, NOx and RHT data are updated every second. From this mode the module can be switched to RHT/Gas-Only Measurement Mode where VOC, NOx and RHT data are updated every second. To obtain again the PM output the cycle is repeated. For SEN50, a reduced power operation is obtained switching between Measurement and Idle mode.

There are two main variables influencing the overall power consumption that need to be traded off with performance of the sensor system: the time spent in measurement mode, as well as the time spent in the RTH/Gas-Only Measurement mode.

Time in Measurement mode ↔ Ability to detect fast pollution events (High power consumption)

Time in RHT/Gas-Only Measurement mode ↔ Ability to identify trends and slow pollution events (Low power consumption)

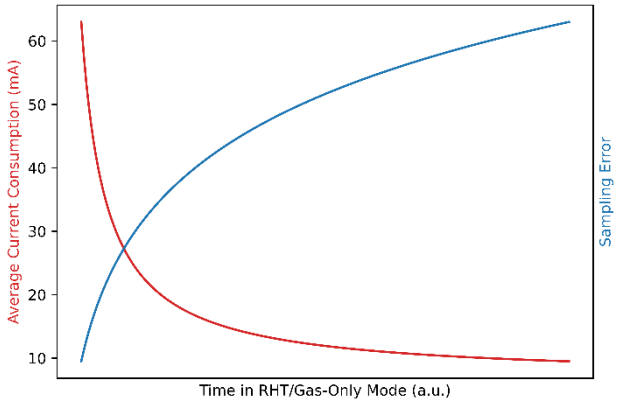

Figure 3: Schematic drawing showing the interplay between reducing average current consumption and increasing the sampling error. It is assumed that the sensor is cycled between the full Measurement Mode for fixed time and then switched to RHT/Gas-only Measurement Mode for x time, where x is plotted on the horizontal axis. Time is in arbitrary units (a.u.) since quantitative estimates depend strongly on the type and dynamics of particle events.

In the next sections the main points for choosing appropriate values both for the measurement mode and the RTH/Gas-Only Measurement mode are explained.

2 Optimizing the Time in Measurement Mode

When the sensor is put into measurement mode, the laser and fan are automatically turned on. To save power, it can be set to RHT/Gas-Only Measurement mode. However, different limiting factors for the minimal operation time of the full mode must be considered to maintain a high accuracy in the overall measurement.

2.1 Start-Up Time for Particulate Matter sensing

Due to the fan's inertia, it takes a few seconds until it reaches its target speed. This effect can also be observed in the sensor output during the first seconds.

As statistics is required for particulate matter sensing, the time until a typical stable output value is reached is also depending on the concentration of particles in the sampled air. In lower concentrations the sensor needs more time than in higher concentrations.

For a good compromise between accuracy and performance, it is recommended to operate the sensor for a minimum of 30/60s before using the measurement outputs.

Further optimization is possible by adapting the startup time to the actual measured concentration according to the typical start-up times given in section Particulate Matter Specifications of the SEN5x datasheet. Please note that the typical start-up times are mean values, the actual start-up time can vary for different sensors and different aerosols. Considering these possible variations, it can generally be said that for high concentrations of >100 #/cm^3, the measurement value is accurate enough after 16 seconds. Thus, the following example algorithm can be used to adapt the start-up time to the actual PM concentration:

- Measure after 16 seconds
  - If number concentration >100 #/cm^3 → measurement data OK to be processed
  - If number concentration ≤100 #/cm^3 → start-up not complete, measure again after 30 seconds
- Measure after 30 seconds → measurement data OK to be processed

If, for the benefit of a further reduced power consumption, a lower accuracy of the sensor output can be accepted, it is possible to further reduce the start-up time, but it is never recommended to go below 8 seconds.

For temperature and relative humidity, temperature compensation of self-heating from fan and laser is required for an accurate reading. The internal compensation is optimized to automatically compensate between these the two modes. At too high switching rates the compensation can become unprecise for built-in scenarios. Make sure to keep the time between switching the modes decently low so the temperature still is within the desired specs. Figure 4 shows an example for a

temperature measurement of a standalone module with multiple switching events between gas only and full measurement mode.

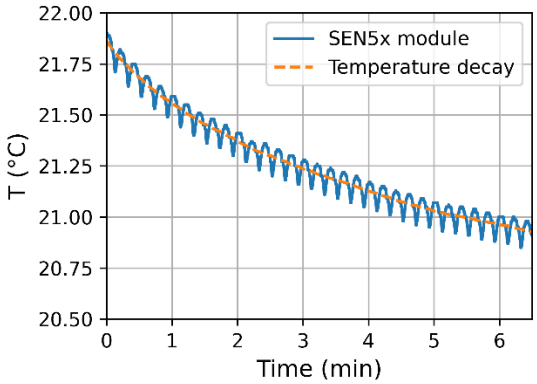

Figure 4: Automatic compensation of SEN5x. The orange dashed lines shows the overall (averaged) temperature trend, the blue line shows the temperature measured by the SEN5x module while switching between gas only and full measurement mode. Offsets and saw-tooth behavior in the compensated and uncompensated T-signals can be observed, depending on the design-in and cycle's parameters.

2.2 Averaging of Data for Particulate Matter sensing

After the start-up time, it is recommended to take several datapoints for the PM measurement and average those in order to obtain a stable measurement. A good starting point for best accuracy is to average the values of another 30 seconds of measurements after the start-up time, which results in a total time of 60 seconds in measurement mode. 5 shows a possible implementation code of this procedure.
A shorter averaging period will save power but may result in a reduced repeatability of the measurement. Whether or not this is acceptable, needs to be decided based on the power and accuracy requirements of the application.

Pseudo code for low-power measurement with particulate matter sensor

```
sensor(wake_up)
sensor(start)
sleep(30)
count = 0
PM2p5 = 0
while (count < 30):
  PM2p5 = PM2p5 + sensor(read_values.PM2p5)
  count = count + 1
  sleep(1)
average_PM2p5 = PM2p5 / 30
print(average_PM2p5)
sensor(stop)
sensor(sleep)
```

Figure 5: Typical Pseudo code for low-power application

3 Optimizing the Time in RHT/Gas-Only Mode

Choosing a suitable sampling interval highly depends on the environment and the use case. If the sensor is placed in an environment with quickly changing particle concentrations, it is recommended to either use the continuous mode or choose a short measurement interval of no longer than a few minutes.

A typical example of a fast and slow event can be seen in 6. The chosen sampling interval of 5 minutes is just enough to detect the first spike, whereas the sampling intervals of 15 minutes and 30 minutes completely miss the first spike. Only the second, slower event can also be detected with the chosen sampling intervals of 15 minutes and 30 minutes.

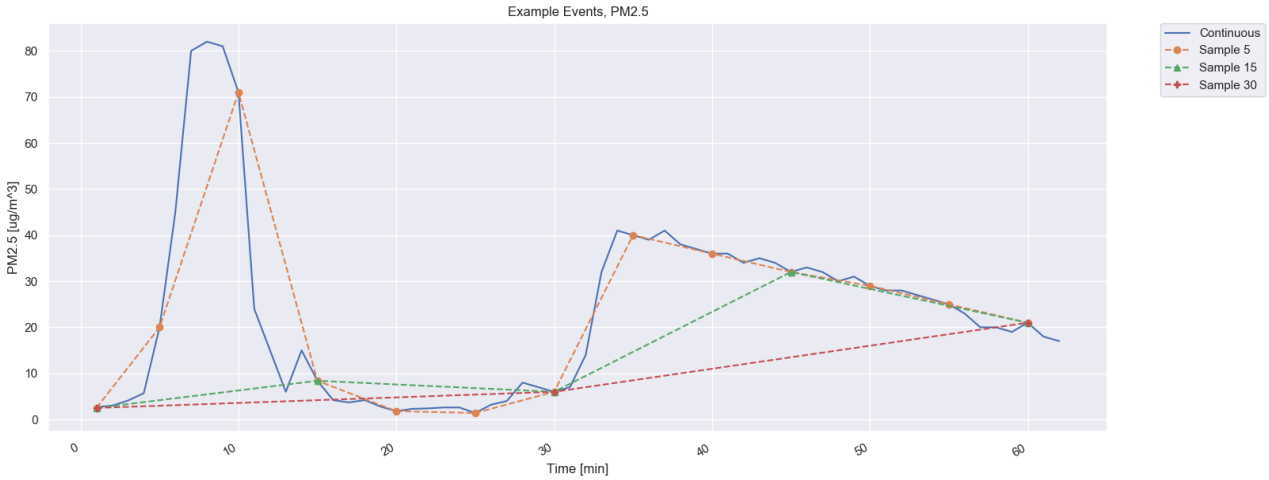

Figure 6: Example of fast event and slow event with different sampling time intervals

Most pollution events happen to only decline slowly over time. Therefore, an interval between different measurements of several minutes (>10 minutes) up to an hour can be sufficient for many applications. Based on our experience and field measurements, many events like cooking at home can be covered with a measurement interval of 15 minutes.

4 Revision History

Date	Version	Changes
August 2022	1.0	Initial version

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