SENSIRION
THE SENSOR COMPANY

Low-Power Operation

Of the SPS30 Particulate Matter Sensor

Preface

The SPS30 particulate matter (PM) sensor is an optical laser-based PM sensor. In its default measurement mode, it measures the particle concentration at a sampling interval of one second. For reducing power consumption, the SPS30 features 2 additional operating modes apart from the measurement mode: idle and sleep mode. A correct application of those modes can reduce the power consumption and allows to operate the SPS30 sensor for extended periods of time on a tight energy budget, thus making it possible to use the SPS30 in battery operated devices.
This document provides detailed instructions on how to choose a suitable sampling interval and subsequently implement a low-power operation mode with the SPS30.

1 Overview

The SPS30 sensor module features 3 different operating modes: measurement, idle and sleep. When the sensor is powered up, the SPS30 automatically goes into idle mode (see Figure 1 as well as the SPS30 datasheet, section "Functional Overview" for more details). Starting from idle mode, the sensor can be put either into measurement mode or sleep mode. The continuous measurement mode with a sampling interval of 1s increases the current to 45 - 65 mA. In sleep mode the current consumption is reduced by roughly a factor of 1000 compared to the measurement mode.

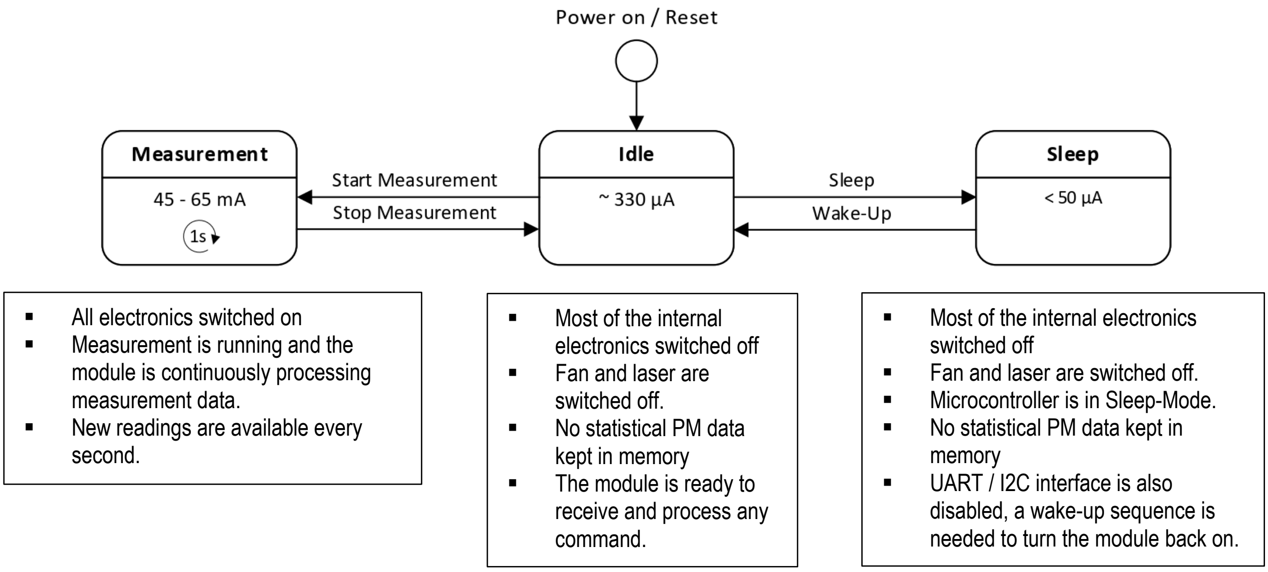

Figure 1: The different operating modes of the SPS30 PM sensor.

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

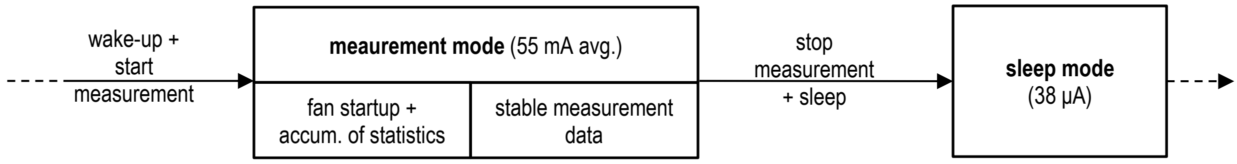

Figure 2: Illustration of one complete cycle of low-power operation. The first phase in measurement mode is characterized by the fan starting up and the PM algorithm accumulating statistics. During this phase the measurement data of the SPS30 is not stable and shall not be used.

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 sleep mode between measurements.

Time in measurement mode ↔ accuracy of measurement output

Time in sleep mode ↔ ability to detect short pollution events

2 Optimizing the Time in Measurement Mode

When the sensor is put into measurement mode from the idle state, the laser and fan are automatically turned on. Because of the inertia of the fan, it takes a few seconds until the fan reaches its target speed. This effect can also be observed in the sensor output during the first seconds. Due to the need for statistics, 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.

2.1 Start-Up Time

For a good compromise between accuracy and performance, it is recommended to operate the sensor for a minimum of 30s 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 1.1 Specification Overview of the SPS30 datasheet (typical start-up time). 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 >300 #/cm3, 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 >300 #/cm3 → measurement data OK to be processed
    - If number concentration ≤300 #/cm3 → 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 not recommended to go below 8 seconds.

2.2 Averaging of Measurement Data

After the start-up time, it is recommended to take several sensor output values 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. 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.

3 Optimizing the Time in Sleep 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 Figure 3. 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.

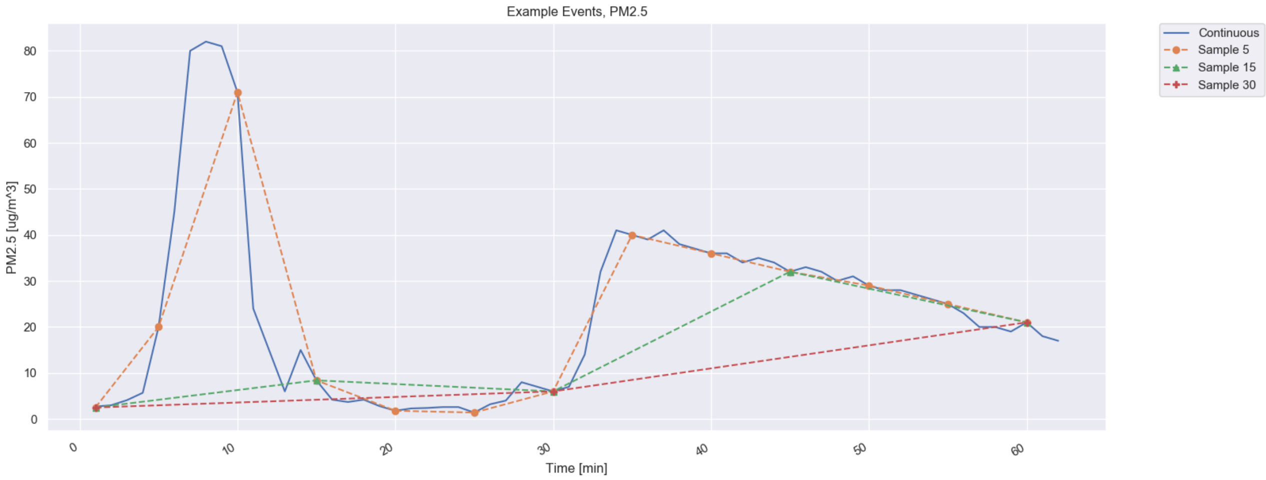

Figure 3: Example of fast event and slow event with different sampling time intervals

Luckily, most real-world 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. An example of a possible implementation is shown in section 4.

4 Implementation Example

Figure 4 shows a typical indoor PM event. The blue curve shows the output of a continuously measuring sensor, whereas the orange curve shows the output of a pulsed sensor with a sampling window of one minute every 15 minutes. This field measurement shows a cooking event, which was started on the 24th April at 8 pm. As it can be seen, it takes almost 24 hours for the indoor PM2.5 value to reach the level prior to the cooking event.
Moreover, the typical startup behavior of the particulate matter sensor can be observed in the orange curves. As previously described, for best performance it is recommended to only use the sensor output values obtained after the start-up time of the sensor is complete.

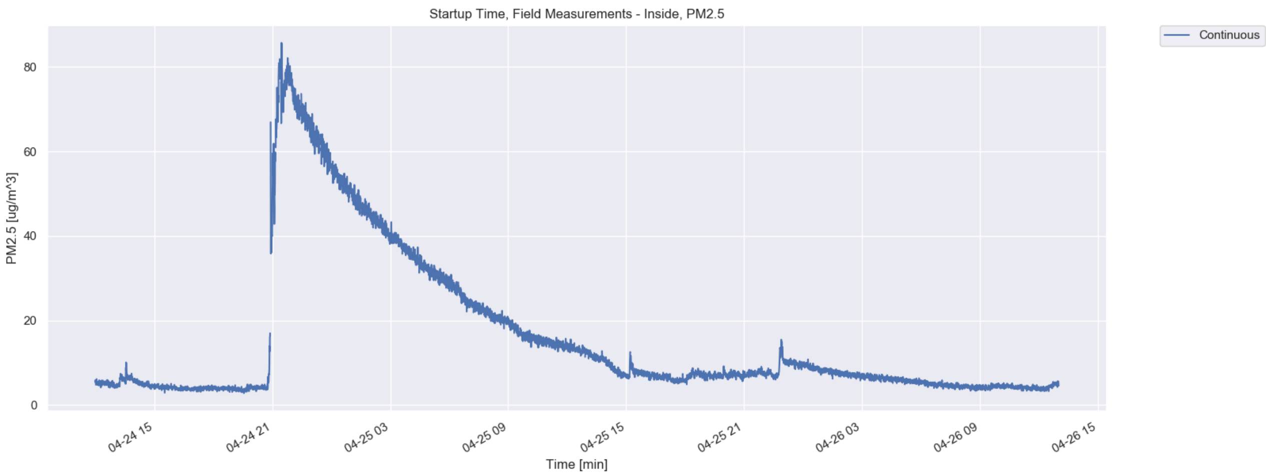

Figure 4: A typical indoor cooking event with fast increase and a slow decrease, measured in continuous measurement mode.

For the use case shown in this implantation example, it was chosen to wait for 30 seconds before averaging another 30 seconds of measurement data. Figure 5 shows a possible implementation of this procedure.

Pseudo code for low-power measurement with particulate matter sensor

```
sensor(wake_up)
sensor(start)
sleep(30)
count = 0
PM2p5 = 0
for (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

The result of the algorithm above on the collected data can be seen in Figure 6. The mean values (orange) are perfectly aligned with the continuous measurement signal of the other sensor.

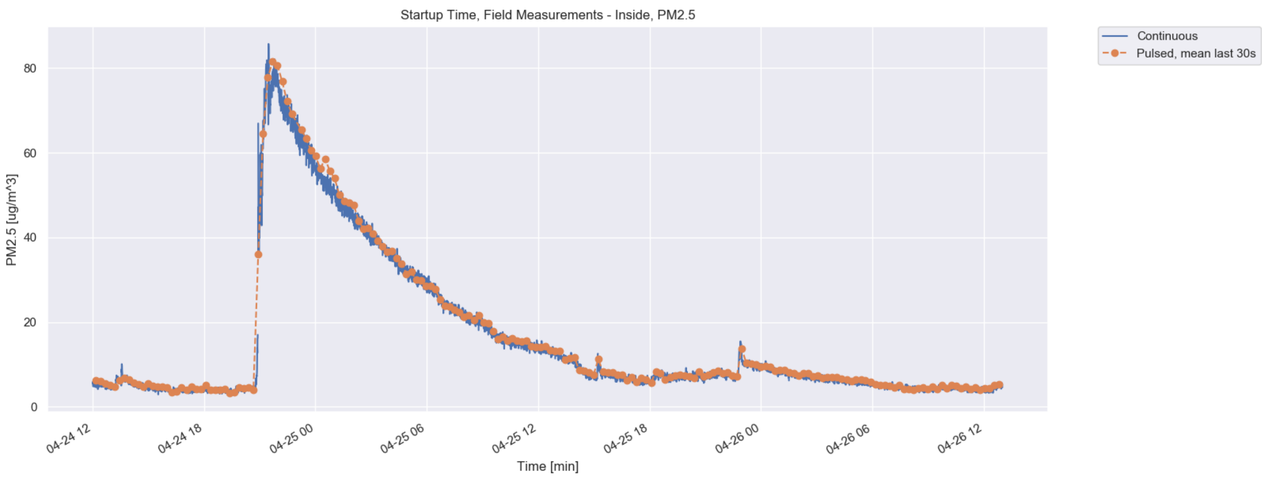

Figure 6: A typical indoor cooking event with fast increase and a slow decrease can be perfectly measured with the proposed implementation example. Blue curve: continuous measurement. Orange curve: 60 seconds measurement time represented by one data point as an average of the last 30 seconds, 15 minutes sleep time.

5 SPS30 Average Current Consumption

As can be seen in Figure 7, the power consumption can be dramatically reduced by proper selection of time spent in measurement mode and time spent in sleep mode. For the implementation example given in the previous section with 60 seconds measurement time and 15 minutes sleep time the **current consumption is reduced by a factor of 15** (avg. 3.5mA), as compared to continuous measurement (avg. 55mA). Depending on the application and the chosen measurement and sleep times, the power consumption can be even further reduced.

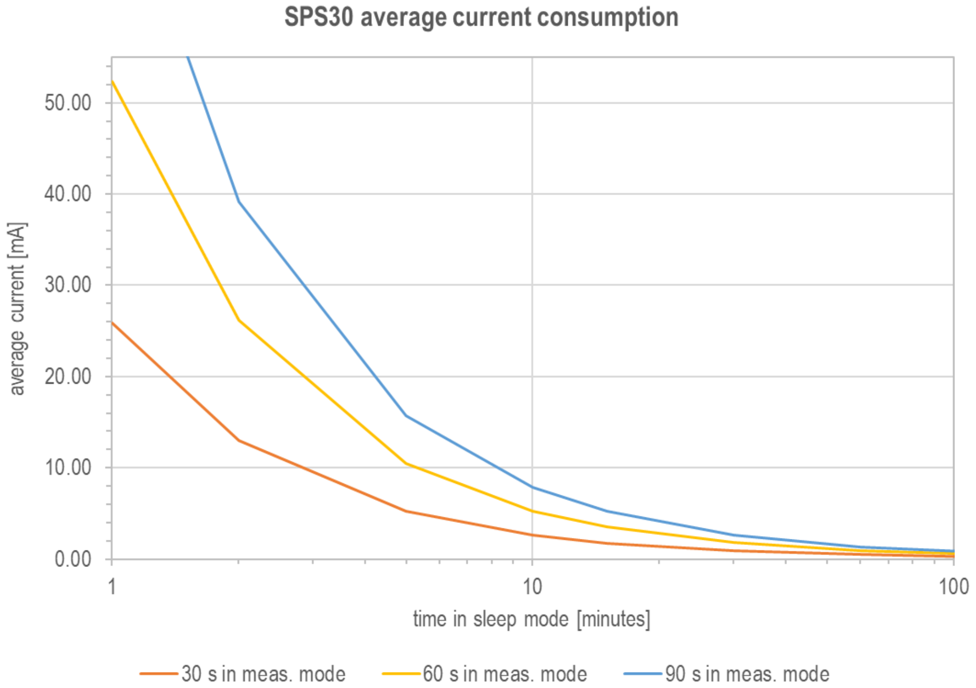

Figure 7: Average current consumption for different times in measurement (30/60/90 seconds) mode and sleep mode (from 1 minute to 100 minutes). Please note the logarithmic scale of the x-axis.

Under the assumption that the SPS30 represents the main electrical load in the application, the implementation example with an average current of 3.5 mA allows to run the application on four AA batteries (assuming 2000 mAh capacity each) for a duration of 2000 mAh / 3.5 mA = 571 h = **3.4 weeks.**

6 Revision History

Date	Version	Page(s)	Changes
18. August 2020	1	all	Initial version

7 Important Notices

7.1 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.

7.2 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.

7.3 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.

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