ENS161 Hardware and Software Guidelines

Application Note

This document provides recommendations for circuit, PCB, and housing of the ENS161. It also covers software guidelines for the sensor IC and other key aspects for proper evaluation of the ENS161. Following these guidelines will result in a fast, reliable, and powerful gas sensor performance for detecting invisible threats and proactively adjusting ventilation settings.

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1 General Description

The ENS161 is a multi-gas sensor with I^2C and SPI interface using a LGA package with an opening. Composed of a metal oxide layer (MOX) on a sensing chip and a heater underneath, the sensor´s MOX changes its electrical resistance depending on the ambient gas composition, from which the air quality can be derived. The principle is very straightforward: oxidizing gases elevate resistance, while reducing gases lower resistance.

The ENS161 offers effortless integration, reliable performance and low-power modes, with minimal system requirements. Supported with improved and intelligent algorithms, the sensor automatically turns raw data into total Volatile Organic Compound (TVOC), equivalent CO_2 (eCO_2) and additional air quality indices, without any overhead needed by the end user.

To benefit from these features, it is recommended to follow the design considerations in this application note.

2 Sensing Modality

The ENS161 is a broadband gas sensor, based on metal oxide (MOX) technology with four sensor elements supporting isothermal and low-power operating modes plus an unrivaled wealth of fully processed output signals.

The broadband sensitivity refers to the sensor´s ability to identify various gas concentrations across different chemical compositions instead of a single gas, since the main purpose of MOX technology is monitoring indoor air quality. From building materials to everyday activities like cooking, our indoor spaces are inundated with volatile organic compounds (VOCs), an ever-present yet invisible threat, often ignored or underestimated.

The MOX technology uses tin dioxide (SnO2), a granular semiconductor material, applied to an electrode structure and being sensitive to gases when heated to temperatures from 200 to 400°C. The MOX sensor operates by absorbing oxygen from the air onto its semiconductor particles, capturing electrons and creating a depletion zone in the material. By adjusting this zone based on the presence of gases, it is possible to measure gas concentration and gather crucial data on air quality and environmental conditions. This method, utilizing semiconductor materials to detect changes in the air's chemical composition, provides a faster response time and greater accuracy compared to other technologies, revolutionizing environmental monitoring.

The independent hotplate control allows the detection of a wide range of VOCs including ethanol, toluene, hydrogen and oxidizing gases with superior sensitivity. The ENS161 supports intelligent algorithms to process raw sensor measurements on-chip. These algorithms calculate TVOC- and CO_2-equivalents, various air quality indices (AQIs) and perform humidity and temperature compensation, as well as baseline management, all on chip.

These real-time outputs allow for proactive adjustments to ventilation settings, ensuring a consistently healthy indoor environment based on your occupancy needs. While not immediately life-threatening, gases in closed spaces can have negative consequences over time, potentially leading to various health issues. Embracing efficient ventilation technologies creates comfortable indoor environments, safeguarding the planet.

Raw sensor measurements can be read for further customization. The LGA-packaged device includes SPI and I^{2}C slave interfaces to communicate with a main host processor.

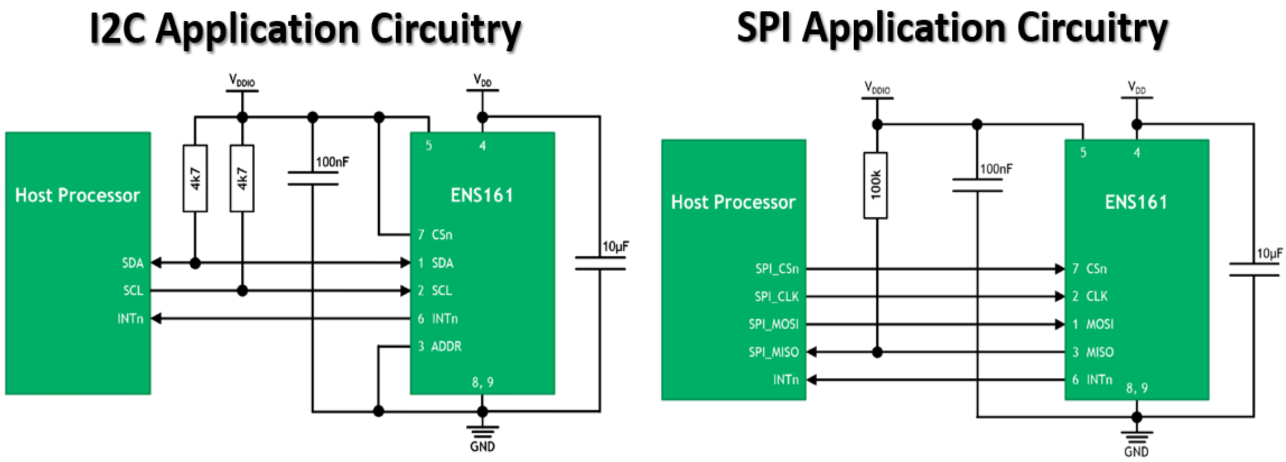
The ENS161 is a proven and maintenance-free technology, designed for high volume and reliability.

In the chapters that follow, considerations and recommendations are made to integrate ENS161 into an electronic system with ease and to fully leverage the benefits. Beginning with electrical, followed by mechanical integration, insightful recommendations will be provided to ensure a clear and systematic process.

3 Circuit Design Considerations

The typical application is shown in Figure 1. The ENS161 includes SPI and I^{2}C slave interfaces to communicate with a main host processor.

Figure 1:
Recommended Application Circuit (I2C and SPI)



I2C Application Circuitry

SPI Application Circuitry

The operating voltage range V_{DD} of ENS161 is from 1.71V to 1.98V. If the power supply of the host in Figure 1 is out of the range, e.g. 3V3 or 5V, a level shifter should be added between the host and ENS161.

The minimum supply voltage V_{DD} is 1.71V and it must not drop below this value to ensure reliable operation. A good power supply decoupling is recommended, therefore decoupling capacitors need to be placed near pins 4 (V_{DD}) and 5 (V_{DDIO}), respectively 10 µF and 100 nF. V_{DDIO} is the I/O interface supply with an operating voltage range from 1.71V to 3.6V:

If using I2C communication, pin 7 (C_{Sn}) must be pulled high to select I2C mode, while pin 3 (MISO/ADDR) should be pulled low or high to specify the address LSB. ´High' refers to V_{DDIO}. In case of SPI, see the above circuit: Weak pull-up resistor may be required for MISO to define the level when tri-stated.

In a test setup, when configuring the operational mode, please take care of proper contacts: transient resistance from jumper wires could introduce a momentary drop in resistance and, therefore, a resulting current drop potentially causing a reset in ENS161.

4 PCB Layout Considerations

In order to preserve optimal performance, the following PCB layout guidelines are recommended.

Package and PCB

- The ENS161 features an open LGA package for standard reflow soldering (IPC/JEDEC J-STD-020D). Please use no-clean solder paste and avoid board wash processes to protect the sensor area.
- The PCB materials proven are PI and FR4, while the housing materials are PA, ABS, ABS-GF, PC, PEEK, PTFE. As a rule of thumb, any gas absorbing/desorbing materials should be avoided; please be also aware that polymers may release VOCs at high temperatures.

Package on PCB

- During the placement on the PCB, please make sure there is sufficient air exchange and venting at any time.
- During pick and place, please limit Z-axis force to 10 N.
- Gap underneath the sensor should be kept between 30 and 50um to avoid stress on the sensor.
- ENS161 should always be assembled as lasted part

Conformal coating

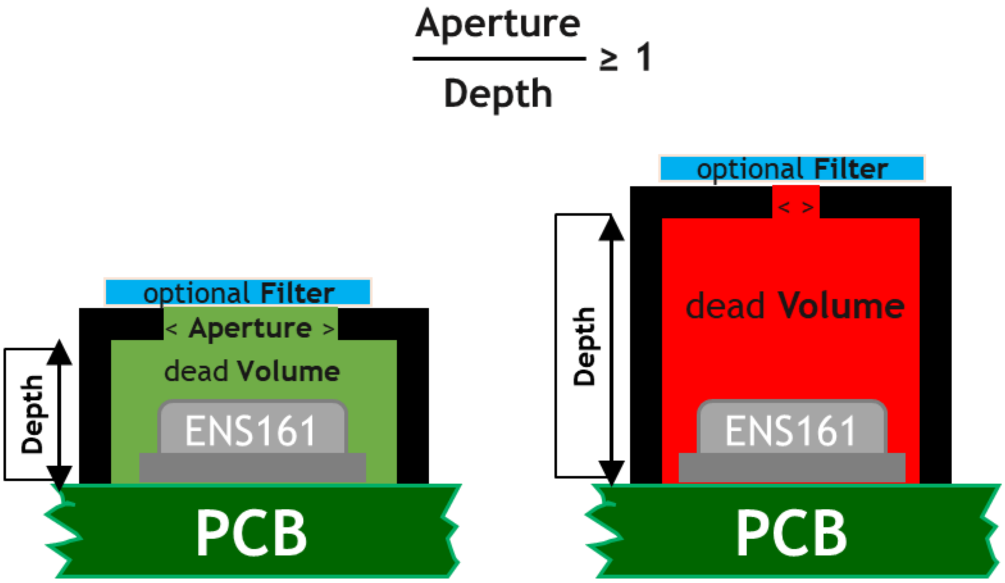
- Conformal coating or lacquer must not touch the sensor at all; if it is going to be used, please ensure to allow an exclusion area around the sensor. A thickness of either 0.5 millimeter or 1 millimeter is suitable, provided the coating does not come into contact with the sensor.

5 Housing Design Considerations

ENS161 doesn´t have any critical problems of interference, apart from ensuring efficient gas interaction/ventilation. While designing the casing, the following precautions are advised to maximize exposure to the environment.

The MOX sensor should be placed in its own enclosure cavity to minimize dead volume and enhance gas interaction efficiency. This separation ensures more accurate readings and better sensor performance. In case the housing´s volume is high, or ventilation cannot be guaranteed, cavity´s aperture and depth should be at least equal: the larger the aperture, the better.

Figure 2:
Housing Design: ratio between Depth and Aperture



For challenging conditions and extra protection, membranes or filters can be implemented on the cavity aperture to shield the housing from particles or water.
Furthermore, in case the sensor must be protected during the production process, we highly recommend using kapton tape or siloxane- and VOC -free materials only.

ENS161 should be placed away from heat sources including direct sunlight and should have direct access to the ambient conditions.

6 ScioSense Sensor Fusion Algorithm

Cutting-edge Sensor Fusion Algorithms from ScioSense enhance the performance of ENS161, ensuring the production of reliable and easily accessible data for end-users. Through continuous refinement, ScioSense has optimized the ENS161 for seamless integration and to deliver actionable insights to our valued customers.

Here are the five key results achieved by the algorithms governing the gas sensor ENS161:

1. ENS161 has a temperature and humidity compensation algorithm for more accurate results even in extreme humidity conditions. Connecting an external temperature/humidity (ENS21x highly recommended) and then giving the values to the right registers, the sensor automatically returns the corrected values.
2. ENS161 employs different Indoor Air Quality algorithms with continuous baseline correction, featuring compensation for oxidizing gases and ensuring accurate and up-to-date readings.
3. ENS161 allows for a fast Response Time: In standard mode, the sensor achieves a response time of just 1 second for T_{69}, enabling swift detection and response to changes in air quality.
4. Through the innovative proprietary algorithms, ENS161 offers a low power and ultra-low power mode ideal for energy-sensitive applications, consuming down to 150uA.
5. ENS161 provides equivalent CO_2 (eCO_2) readings calculated by using the “Reverse Metabolic Rule” (reversing the “Pettenkofer law” to achieve signal compatibility between eCO_2 and CO_2) while considering the proportional correlation of VOCs and CO2 as well. The equivalent value is comparable to our CO_2 reference sensor (non-directional).

Moreover, ENS161 introduces expanded output formats, including the addition of AQI-S, a Relative Air Quality Index widely used in many applications.

7 Software Guidelines

Regarding the Software part, little programming expertise is needed: the code and the libraries for Arduino IDE are public and available on: https://github.com/sciosense. These are the steps for setting up the sensor and measurement and therefore relying on efficient ventilation methods within your environment:

1. Include the libraries

```
#include <ScioSense_ENS16x.h>
#include "ens16x_i2c_interface.h"
using namespace ScioSense;
```

2. Choose the operating mode

```
ens161.startStandardMeasure();
```

OR

```
ens161.startLowPowerMeasure();
```

OR

```
ens161.startUltraLowPowerMeasure();
```

3. Setup the sensor

```
     ens161.setInterruptPin(2);
        ens161.writeConfiguration
     (
        ENS161::Configuration::InterruptEnable;
        ENS161::Configuration::NewGeneralPurposeData;
        ENS161::Configuration::NewData;
     );
ens161.startStandardMeasure();
```

4. Retrieve the measurements

```
Serial.print("\tRS3:");Serial.println(ens161.getRs3()); //Raw Resistance of hotplate3
Serial.print("AQIUBA:");Serial.print((uint8_t)ens161.getAirQualityIndex_UBA()); //Indoor Air Quality according to German Federal Office for Environment
Serial.print("\tAQIScioSense:");Serial.print(ens161.getAirQualityIndex_ScioSense()); //Indoor Air Quality according to ScioSense
Serial.print("\tTVOC:");Serial.print(ens161.getTvoc()); //Total VOC
```

```
Serial.print("\tECO2:");Serial.println(ens161.getEco2());    //Equivalent CO2
```

No additional initialization is needed. Integrated MCU eliminates concerns about the timing, wake-up operations or compensation processes. Data processing is entirely handed on-chip, without requiring post-processing steps or the use of additional libraries. The ENS161 algorithms allow a low power mode and, an ultra-low power for applications with minimal energy consumption requirements (down to 150µA).

Therefore, only the few steps mentioned are required to set up serial communications and reading the sensors data.

8 Low Power Design Considerations

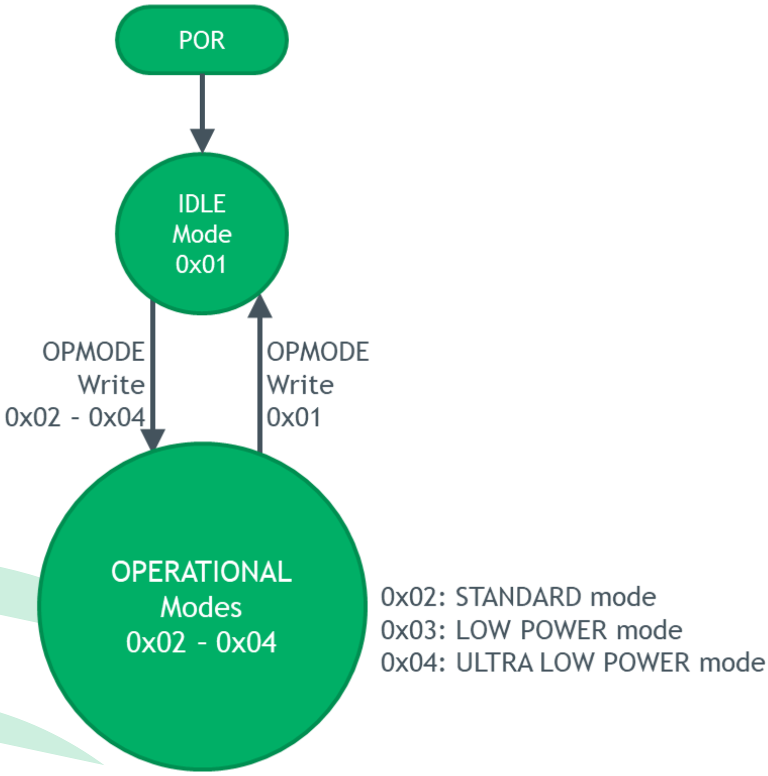
As environmental concerns grow, energy efficiency becomes increasingly important. ENS161 incorporates energy-saving features designed to enhance efficiency and minimize power consumption. Let's delve into these aspects in this section.

ENS161 offers three operating modes based on the energy consumption requirements of the target application and how many measurements over time the application needs.

1. The sensor offers a Standard Mode where measurements are collected every second at a current consumption of 12mA.
2. In the Low Power Mode, measurements are performed every minute, this means that the heater underlying the hotplate is off for 57s and on for 3s. The average current consumption is around 700uA.
3. In the Ultra Low Power Mode, measurements are performed every 5 minutes, meaning that the heater is off for 299s and on for 1s. The average current consumption is around 150uA.

When transitioning between different operating modes, such as from **Standard Mode** to **Low Power**, or from **Low Power** to **Ultra Low Power**, it's essential to include an interim step into IDLE MODE. This intermediate IDLE step serves as a configuration phase before entering an active sensing mode. Failing to include this IDLE step may lead to inconsistencies or errors in the sensor's behavior. Therefore, it is recommended to adhere to this protocol to ensure smooth and reliable operation.

Figure 3:
ENS161 Operating Modes Diagram



ENS161 offers tremendous flexibility in terms of energy consumption. However, it's important to be aware that frequently toggling between active operating modes is not advisable.

If the operating mode is changed and after idle periods, it is advisable to wait for the warm-up time in order to ensure adequate sensor stability. Typically, it´s recommendable to wait up to 3 minutes in standard mode and up to 60 minutes in the other cases.

Additionally, the number of measurements should be sufficient to detect significant changes in the application where it's deployed.

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10 Revision information

Table 1: Revision history

Revision	Date	Comment	Page
Version 1.0	2024-05-02	First version	

Note(s) and/or Footnote(s):

1. Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
2. Correction of typographical errors is not explicitly mentioned.

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