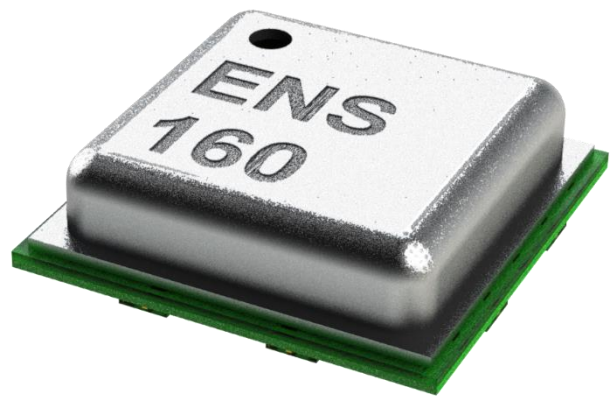




ENS160



Digital Metal Oxide Multi-Gas Sensor

ENS160 Datasheet

Revision: 0.95

Release Date: December 2020

Document Status: Preliminary / Pre-Production

Digital Metal-Oxide Multi-Gas Sensor

The ENS160 is a digital multi-gas sensor solution, based on metal oxide (MOX) technology with four MOX sensor elements. Each sensor element has independent hotplate control to detect a wide range of gases e.g. volatile organic compounds (VOCs) including ethanol, toluene, as well as hydrogen and nitrogen dioxide with superior selectivity and accuracy. For indoor air quality applications, the ENS160 supports intelligent algorithms to digitally process raw sensor measurements on-chip. These algorithms calculate CO₂-equivalents, TVOC, air quality indices (AQIs) and perform humidity and temperature compensation, as well as baseline management - all on chip! Moreover, a development option is available to digitally output raw sensor measurements from each sensor element for customization. The LGA-packaged device includes an SPI or I²C slave interface with separate VDDIO to communicate with a main host processor. The ENS160 is a proven and maintenance-free technology, designed for high volume and reliability.

Key Features & Benefits

TrueVOC™ air quality detection with industry-leading purity and stability, providing multiple outputs e.g. eCO₂¹, TVOC and AQIs² in compliance with worldwide IAQ³-signal standards

Independent sensor heater control for highest selectivity (e.g. to ethanol, toluene, acetone, NO₂) and outstanding background discrimination

Immunity to siloxanes and humidity⁴

Hassle-free on-chip heater drive control and data processing - no need for external libraries - no mainboard-CPU performance impacts

Interrupt on threshold for low-power applications

Wide operating ranges: temperature: -40 to +85°C; humidity: 5 to 95%⁵; V_{DD}: 1.71 to 1.98V; V_{DDIO} 1.71 to 3.6V

Applications

- Building Automation / Smarthome / HVAC⁶
 - Indoor air quality detection
 - Demand-controlled ventilation
 - Smart thermostats
- Home appliances
 - Cooker hoods
 - Air cleaners / purifiers
- IoT devices

Properties

- Small-3 x 3 x 0.9mm LGA package
- Design-flexibility through standard, fast and fast mode plus I²C- and SPI-interfaces with separate VDDIO up to 3.6V
- T&R packaged, reflow-solderable⁷

¹ eCO₂ = equivalent CO₂ values for compatibility with HVAC ventilation standards

² AQI = Air Quality Index

³ IAQ = Indoor Air Quality

⁴ T/RH compensation via external T/RH-input

⁵ Non-condensing

⁶ HVAC = Heat, Ventilation and Air Conditioning

⁷ See section "Soldering Information" for further details

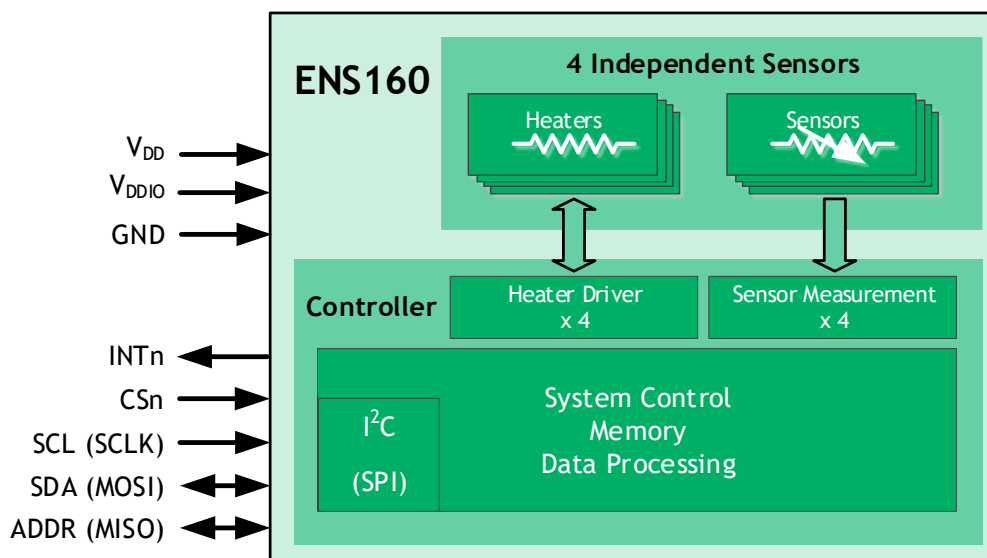
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1 Block Diagram

The ENS160 digital multi-gas sensor consists of four independent heaters and gas sensor elements, based on metal oxide (MOX) technology and a controller as shown in the functional block diagram below.

Figure 1: Functional Blocks



The *Heater Driver* controls the sensor operating modes and provides power to the *heaters* of each individual sensor element. During operation the heater driver regulates the heaters to their individual set-points.

The *Sensor Measurement* block determines the value of the sensor resistance for each individual sensor element.

The *System Control* block processes the resistance values internally to output calculated TVOC, CO₂-equivalents, AQIs and further signals on the digital interface.

The ENS160 includes a standard 2-wire digital *I²C interface* (SCL, SDA) or 4-wire digital *SPI interface* (SCLK, MOSI, MISO, CSn) for communication to the main host processor.

On-chip memory is used to store calibration values.

2 Pin Assignment

Figure 2: Pin Diagram

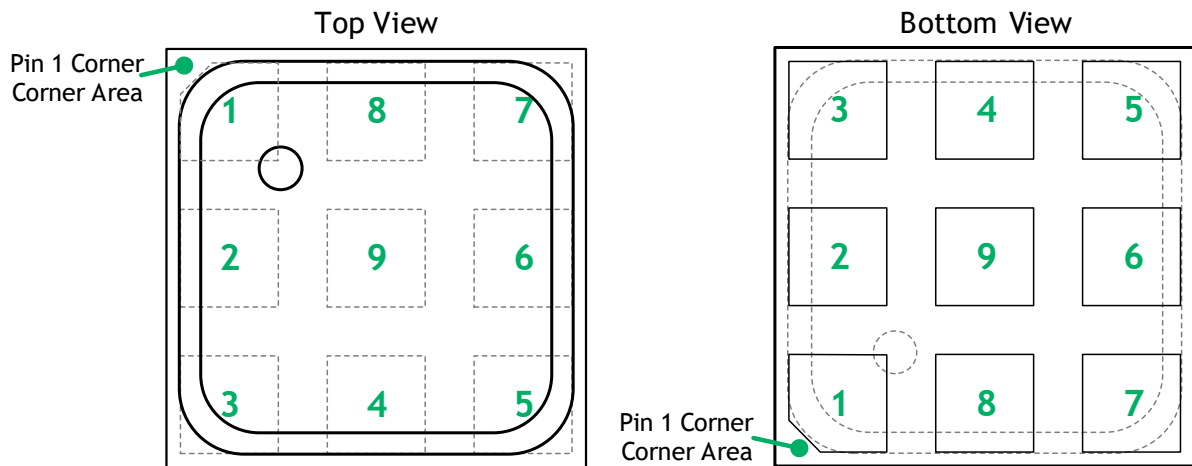


Table 1: Pin Description

| Pins | Pin Name | Pin Type | Description |
|------|-------------------|----------------|--|
| 1 | MOSI / SDA | Input / Output | SPI Master Output Slave Input / I ² C Bus Bi-Directional Data |
| 2 | SCLK / SCL | Input | SPI Serial Clock / I ² C Bus Serial Clock Input |
| 3 | MISO / ADDR | Input / Output | SPI Master Input Slave Output / I ² C Address Select: I ² C ADDR pin high -> 0x53 / ADDR pin low -> 0x52 |
| 4 | V _{DD} | Supply | Main Supply Voltage |
| 5 | V _{DDIO} | Supply | Interface Supply Pins |
| 6 | INTn | Output | Interrupt to Host |
| 7 | CSn | Input | SPI Interface Select (CSn low -> SPI / CSn high -> I ² C) |
| 8, 9 | V _{SS} | Supply | Ground Supply Voltage |

Also see sections “I²C Operation Circuitry” and “SPI Operation Circuitry” for wiring.

3 Absolute Maximum Ratings

Table 2: Absolute Maximum Ratings

| Symbol | Parameter | Min | Max | Units | Comments |
|----------------------------------|-----------------------------------|--------|------------------------|-------|--------------------------|
| Electrical Parameters | | | | | |
| V _{DD} | Supply Voltage | -0.3 | 1.98 | V | |
| V _{DDIO} | I/O Interface Supply | -0.3 | 3.6 | V | |
| V _{IO1} | MOSI/SDA, SCLK/SCL | -0.3 | 3.6 | V | |
| V _{IO2} | MISO/ADDR, INTn, CSn | -0.3 | V _{DDIO} +0.3 | V | |
| V _{SS} | Input Ground | -0.3 | 0.3 | V | |
| I _{SCR} | Input Current (latch-up immunity) | ± 100 | | mA | AEC-Q100-004 |
| Electrostatic Discharge | | | | | |
| ESD _{HBM} | Electrostatic Discharge HBM | ± 2000 | | V | JS-001-2014 |
| ESD _{CDM} | Electrostatic Discharge CDM | ± 750 | | V | JS-002-2014 |
| Operating and Storage Conditions | | | | | |
| MSL | Moisture Sensitivity Level | | 1 | | Unlimited floor lifetime |
| T _{BODY} | Max. Package Body Temperature | | 260 | °C | IPC/JEDEC J-STD-020 |
| T _{STRG} | Storage Temperature | -40 | 125 | °C | |
| RH _{STRG} | Storage Relative Humidity | 5 | 95 | % | Non-condensing |
| T _{AMB} ¹ | Operating Ambient Temperature | -40 | 85 | °C | |
| RH _{AMB} ¹ | Operating Ambient Rel. Humidity | 5 | 95 | % | Non-condensing |

Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated under Electrical Characteristics is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability and lifetime.

Important Note: The ENS160 is not designed for use in safety-critical or life-protecting applications.

¹ The ENS160 is electrically operable in this range, however its gas sensing performance might vary. Please refer to “Recommended Sensor Operation” for further information.

4 Electrical Characteristics

The following figure details the electrical characteristics of the ENS160.

Table 3: Electrical Characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|--------------|--|---------------------------------------|------------------------|-----------|------------------------|------|
| V_{DD} | Positive supply | | 1.71 | 1.8 | 1.98 | V |
| V_{DDIO} | IO Supply Voltage | | 1.71 | | 3.6 | V |
| I_{DD} | Average ¹ Supply Current ² | DEEPSLEEP (OP_MODE 0x00) ³ | | 0.01 | | mA |
| | | IDLE (OP_MODE 0x01) ³ | | 2 | 2.5 | mA |
| | | STANDARD (OP_MODE 0x02) | | 24 | | mA |
| I_{DD_PK} | Peak Supply Current ⁴ | STANDARD (OP_MODE 0x02) | | 65 (<5ms) | | mA |
| V_{IH} | High-level input voltage | | $0.7 \times V_{DDIO}$ | | | V |
| V_{IL} | Low-level input voltage | | | | $0.3 \times V_{DDIO}$ | V |
| V_{OH} | High-level output voltage | MISO ⁵ [$I_{OH}=5mA$] | $0.8 \times V_{DDIO}$ | | | V |
| | | INTN [$I_{OH}=2mA$] | $0.65 \times V_{DDIO}$ | | | V |
| V_{OL} | Low-level output voltage | MOSI/SDA, MISO [$I_{OL}=5mA$] | | | $0.2 \times V_{DDIO}$ | V |
| | | INTN [$I_{OL}=2mA$] | | | $0.35 \times V_{DDIO}$ | V |

¹ Averaged over the sequence

² Measured at V_{DD} -pin at ambient temperature of 35 °C

³ Not a gas sensing mode

⁴ Initial (<5ms) current demand from VDD after the sensor is switched from IDLE (OP-Mode 1) to STANDARD operation (OP_MODE 2)

⁵ MOSI/SDA is open drain

5 Air Quality Signal Characteristics

To satisfy a wide range of individual application requirements, the ENS160 offers a series of (indoor) air quality output signals that are derived from various national and international, as well as de-facto standards. Table 4 provides a summary of such signals, with further description in the following sections.

Table 4: Air Quality Signal Output Characteristics

| Parameter | Range | Resolution | Unit | Comment |
|----------------------|--------------|------------|-----------------------------|---|
| TVOC | 0 - 65 000 | 1 | ppb | For requirements outside these specified ranges please contact us |
| eCO ₂ | 400 - 65 000 | 1 | ppm CO ₂ .equiv. | |
| AQI-UBA ¹ | 1 to 5 | 1 | - | |

5.1 TVOC - Total Volatile Organic Compounds

More than 5000 VOCs exist, and they are two to five times more likely to be found indoors than outdoors. Indoor VOCs are various types of hydrocarbons from mainly two sources: bio-effluents, i.e. odors from human respiration, transpiration and metabolism, and building material including furniture and household supplies. VOCs are known to cause eye irritation, headache, drowsiness or even dizziness - all summarized under the term Sick Building Syndrome (SBS). Besides industrial applications, comfort aspects (e.g. temperature), or building protection (humidity), VOCs are the one and only root cause for ventilation.

To group and classify VOCs, regional guidelines and industry-preferences define a series of compounds and mixtures as reference. E.g. ethanol, toluene, acetone, combinations of the various groups of VOCs (e.g. ISO16000-29), and others.

The ENS160 supplies calibration to ethanol for best, most balanced TVOC-results.

Refer to “Registers” and “DATA_TVOC (Address 0x22)” on how to obtain TVOC-values from the ENS160.

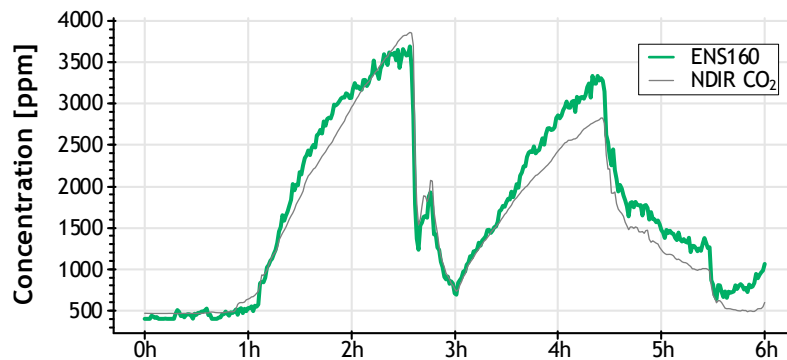
5.2 eCO₂ - Equivalent CO₂

Due to the proportionality between VOCs and -CO₂ generated by humans, CO₂-values historically served as an air quality indicator, reflecting the total amount of VOCs (=TVOCs) produced by human respiration and transpiration. This law (first revealed by Max von Pettenkofer² in the 19th century) and the unavailability of suitable VOC measurement technology made CO₂ the surrogate of inhabitant-generated air-pollution in confined living spaces of the past *and* the present, i.e. today’s standard air quality reference for demand-controlled ventilation - as adopted by most HVAC industry standards.

¹ Classified TVOC output signal according to the indoor air quality levels by the German Federal Environmental Agency (UBA, 2007)

² Max von Pettenkofer (*1818 - †1901), German chemist and hygienist.

Figure 3: ENS160-based equivalent CO₂ (eCO₂) vs. NDIR-based CO₂ during two meeting sessions



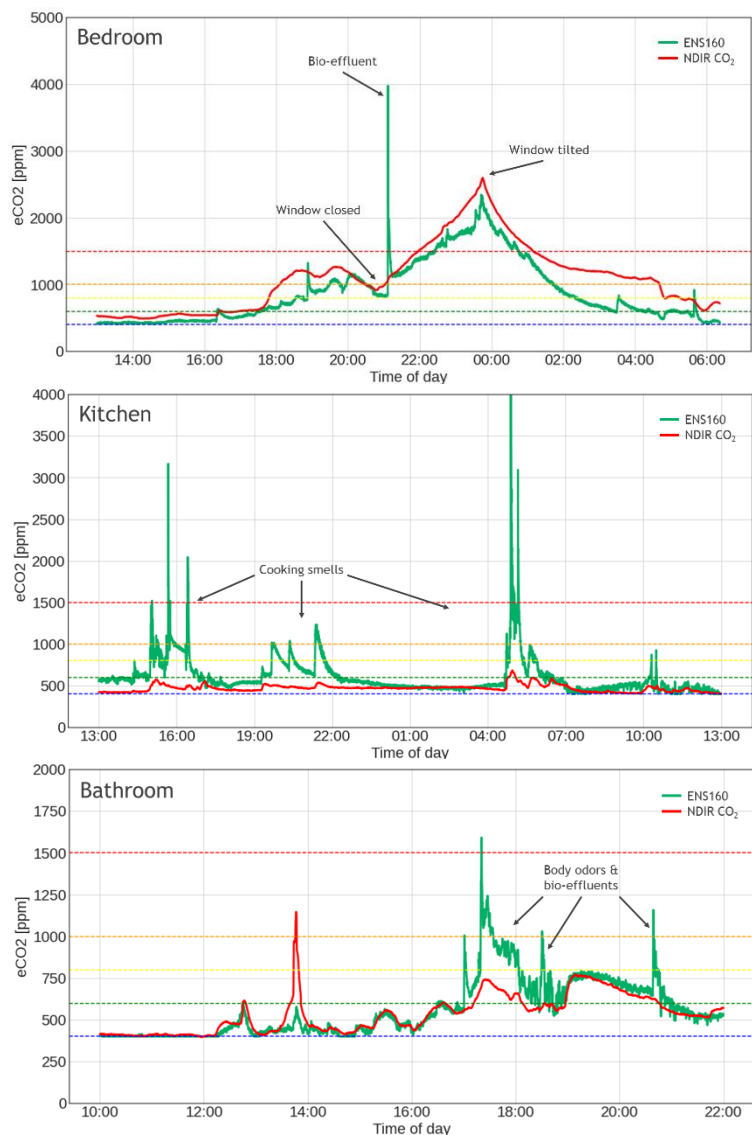
The ENS160 reverses the proportional correlation of VOCs and CO₂, by providing a standardized output signal in ppmCO₂-equivalents from measured VOCs plus hydrogen, thereby adhering to today's CO₂-standards, as shown opposite: ENS160-based equivalent CO₂ estimate vs. CO₂, detected by an NDIR-sensor during two consecutive meeting sessions, interrupted by a lunch-break.

Figure 4: Added value of ENS160's eCO₂ Outputs -where plain CO₂ sensors fail

A key advantage of the ENS160 is the capture of odors and bio-effluents that are completely invisible to CO₂-sensors. The opposite diagrams compare the ENS160's equivalent CO₂ output to an NDIR CO₂ sensor in typical indoor applications:

CO₂ sensors neither detect unpleasant odors and bio-effluents in bedroom or bathroom environments, nor cooking smells in kitchens or restaurants, whereas the ENS160 reliably reports such events.

Proven TrueVOC™ control-algorithms minimize sensor drift and ageing to provide reliable readings over lifetime, thereby making the ENS160's equivalent CO₂ output an affordable solution to complement or substitute real CO₂-based air-quality sensors in the HVAC domain.



The below table shows a typical classification of (equivalent) CO₂ output levels.

Table 5: Interpretation of CO₂ and Equivalent CO₂ Values

| Output | | Comment / Recommendation |
|------------------------------------|-----------|--|
| eCO ₂ / CO ₂ | Rating | |
| >1500 | Bad | Heavily contaminated indoor air / Ventilation required |
| 1000 - 1500 | Poor | Contaminated indoor air / Ventilation recommended |
| 800 - 1000 | Fair | Optional ventilation |
| 600 - 800 | Good | Average |
| 400 - 600 | Excellent | Target |

Example: A CO₂- or eCO₂-controlled ventilation application would invoke its ventilation fan speeds 1, 2 and 3 at the upper three levels “Fair”, “Poor” and “Bad”, respectively.

See section “Registers” and “DATA_ECO2 (Address 0x24)” on how to obtain equivalent CO₂-values from the ENS160.

5.3 AQI-UBA - Air Quality Index of the UBA¹

The AQI-UBA air quality index is derived from a guideline by the German Federal Environmental Agency based on a TVOC sum signal. Although a local, German recommendation, this guideline is referenced and adopted by many countries and organizations.

Table 6: Air Quality Index of the UBA (German Federal Environmental Agency)

| AQI-UBA | | Hygienic Rating | Recommendation | Exposure Limit |
|---------|-----------|--------------------------|--|----------------|
| # | Rating | | | |
| 5 | Unhealthy | Situation not acceptable | Use only if unavoidable Intensified ventilation recommended | hours |
| 4 | Poor | Major objections | Intensified ventilation recommended Search for sources | <1 month |
| 3 | Moderate | Some objections | Increased ventilation recommended Search for sources | <12 months |
| 2 | Good | No relevant objections | Sufficient ventilation recommended | no limit |
| 1 | Excellent | No objections | Target | no limit |

Recommendation according to the UBA, Bundesgesundheitsblatt - Gesundheitsforschung Gesundheitsschutz 2007, 50:990-1005, DOI 10.1007/s00103-007-0290-y © Springer Medizin Verlag 2007

See section “Registers” and DATA_AQI (Address 0x21) on how to obtain AQI-values from the ENS160.

¹ UBA = Umweltbundesamt - German Federal Environmental Agency

6 Single Gas Signal Characteristics

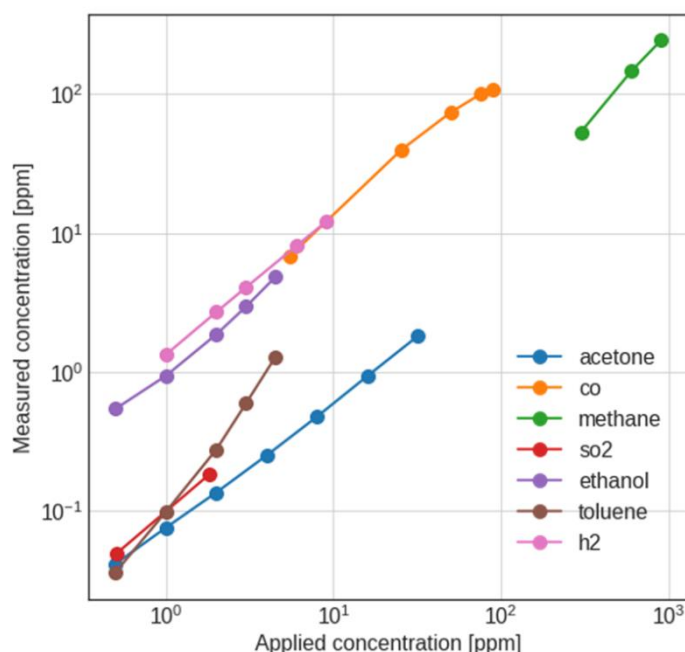


Figure 5: Example Response of the ENS160 to Various Gases

Since metal oxide sensors exhibit a broadband sensitivity to both reducing and oxidizing gases, their raw output signals represent the resulting sum of the entire gas mixture, present. Such sum-signals are beneficial when it comes to wideband TVOC- or AQI-applications, but unsatisfactory for the detection of single gases.

The opposite table shows the response of the ENS160 to a variety of individual gases that can be found indoors.

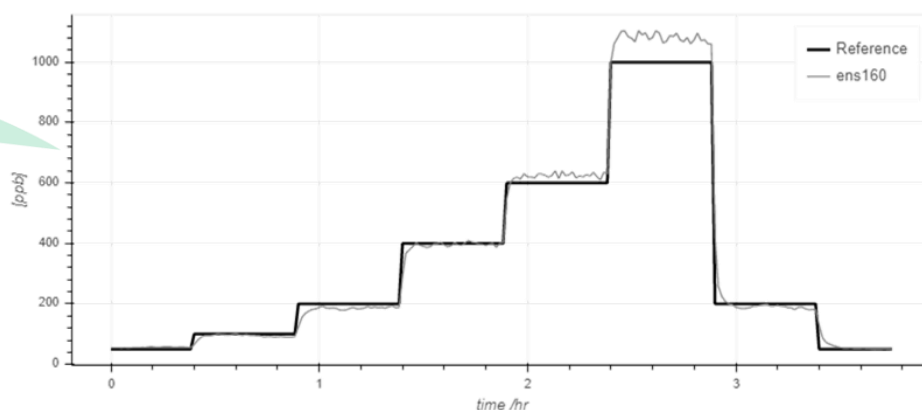
The below table provides a list of selected gases that have been individually characterized.

Table 7: Single Gas Signal Characteristics

| Target Gas | Specified Range | Unit | Register | Comment |
|-----------------|-----------------|------|-----------------------------------|--|
| Ethanol | 0 to 6 | ppm | DATA_ETOH (0x22) = DATA_TVOC | Dedicated Register |
| Hydrogen | 0 to 10 | ppm | R4 _{raw} = GPR_READ[6:7] | R _{raw} = raw resistance values that need to be calibrated to target gas. See text below. |
| Acetone | 0 to 32 | ppm | R4 _{raw} = GPR_READ[6:7] | |
| Carbon Monoxide | 0 to 90 | ppm | R4 _{raw} = GPR_READ[6:7] | |
| Toluene | 0 to 32 | ppm | R4 _{raw} = GPR_READ[6:7] | |

Measurement values for individual gases can be obtained from dedicated device registers or calculated from sensor raw resistance values as specified in above table. See sections “Registers” and “Gas Sensor Raw Resistance Signals” for further information.

Figure 6: Example Response of the ENS160 to Ethanol



7 Gas Sensor Raw Resistance Signals

For two of its sensing elements the ENS160 provides individual outputs of raw sensor values.

Table 8: Gas Sensor Raw Resistance Signals

| Sensor | Raw Value | Range | Unit | Gen. Purpose Register | Comment |
|--------|------------|------------|------|-----------------------|--|
| 1 | R_{1raw} | [0..65535] | - | GPR_READ[0:1] | Arbitrary logarithmic units - no resistance values. R_{1raw} require conversion to corresponding resistance value R_{ires} [Ω] (see below) |
| 4 | R_{4raw} | [0..65535] | - | GPR_READ[6:7] | |

Gas sensor raw-values R_{1raw} can be obtained from the ENS160's General Purpose Read Register (GPR_READ) for customer-specific signal post-processing.

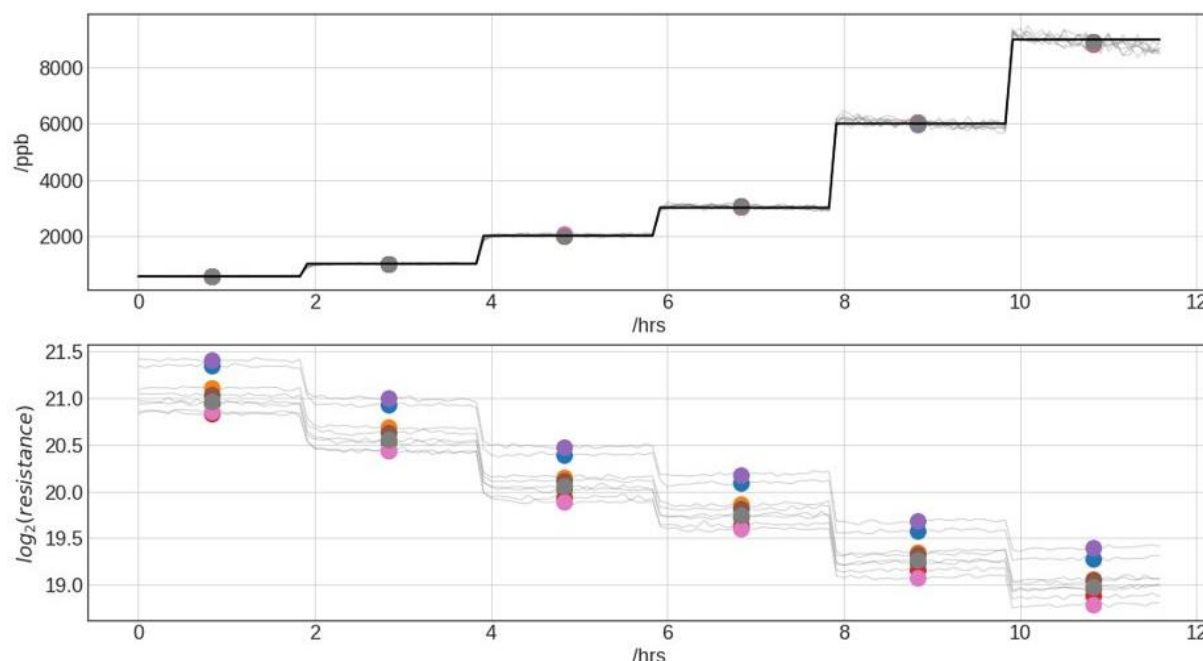
Prior to use R_{1raw} values require conversion to resistance values, using the following formula:

$$R_{ires}[\Omega] = 2^{\frac{R_{1raw}}{2048}}$$

See section "Registers" and GPR_READ (Address 0x48 - 0x4F) on how to obtain AQI-values from the ENS160.

The below figures show the response of eight ENS160s to various hydrogen concentration¹ steps (upper diagram) and the corresponding raw sensor resistance R_{1raw} (lower diagram).

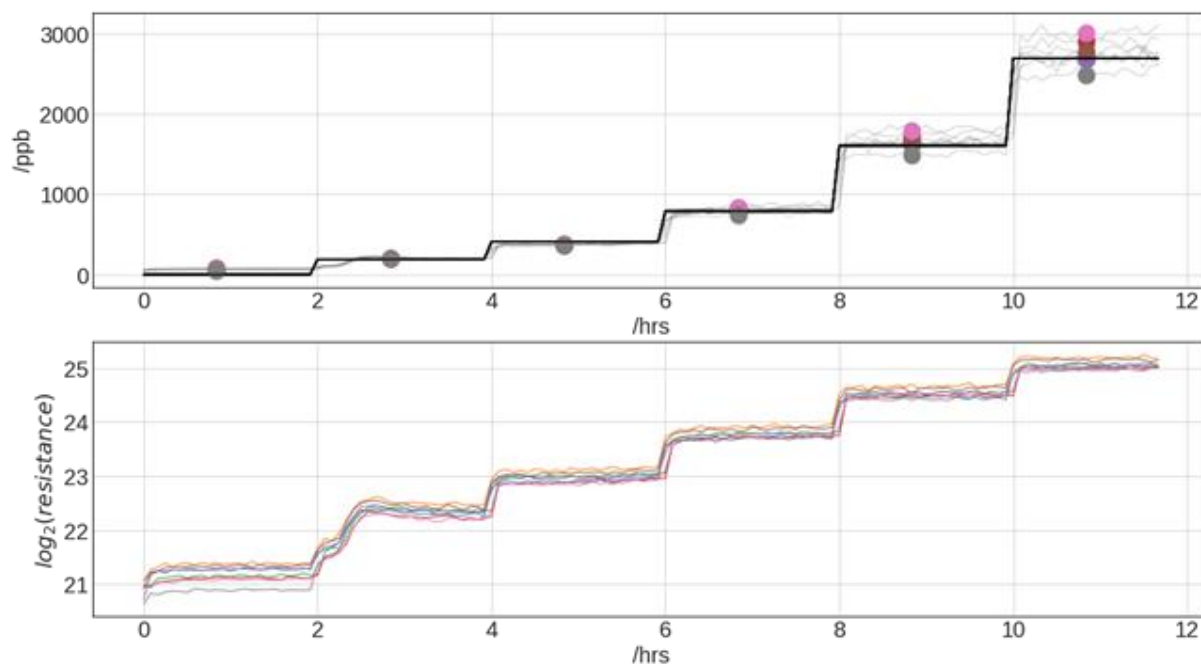
Figure 7: Raw Sensor Signal Response to Hydrogen



¹ Use of the term "Concentration" in ppm (= parts per million) and ppb (= parts per billion) means volume fractions of the respective gases in air: 1 ppm = 1 mL/m³ = 1000 ppb = 1000 μ L/m³

The following figures show the response of eight ENS160s to various nitrogen dioxide concentration steps (upper diagram) and the corresponding raw sensor resistance R_{iraw} (lower diagram).

Figure 8: Raw Sensor Signal Response to Nitrogen Dioxide



Note: Due to the nature of sensor raw resistance values, these signals are not conditioned, i.e. not compensated for drift, ageing or cross-sensitivity (interference of background gases including humidity).

8 Signal Conditioning

Chemical gas sensors are relative sensors that are susceptible to changes in their chemical and physical environments. Typical drivers are changes of the target gas(es), of the interfering background gas mixture and changes of the physical environment (air pressure, humidity, etc.).

8.1 Baselineing

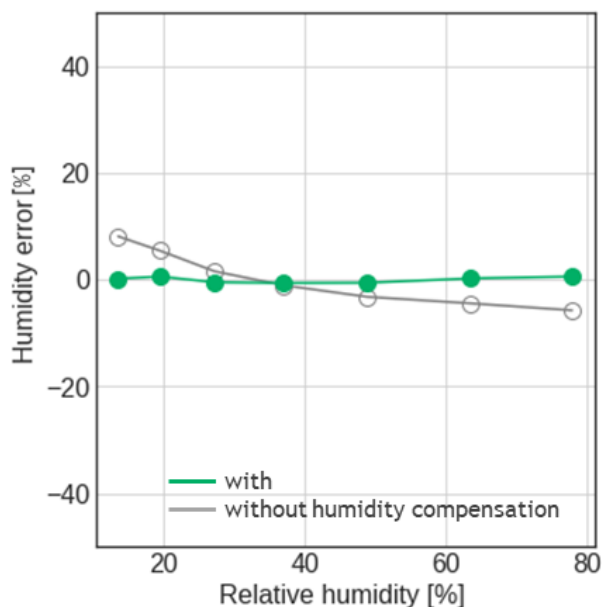
As part of the TrueVOC™ technology the ENS160 deploys an automatic baseline correction, featuring compensation for oxidizing gases such as ozone. It furthermore stores the current baseline value in non-volatile memory to automatically start from the latest valid level of background air after re-powering the device and even after a power outage.

8.2 Humidity Behavior & Compensation

Figure 9: Air Quality Signal with and without Humidity Compensation

For use in normal air quality applications (eCO₂, TVOC, AQI), operated in a relative humidity range between 20 and 80%, the ENS160 does not require external humidity compensation, as the opposite graph shows.

Extreme humidity conditions outside this range (20% - 80%RH) can influence the output signal, especially when very accurate or single gas measurements are required. To overcome such impacts, the ENS160 is equipped with a temperature and humidity compensation algorithm, relying on data from an external temperature- and humidity-sensor (the ENS160 works well with the ScioSense ENS21x family of temperature and humidity sensors as they both share the same signal format), that can be regularly updated to an internal register for processing.

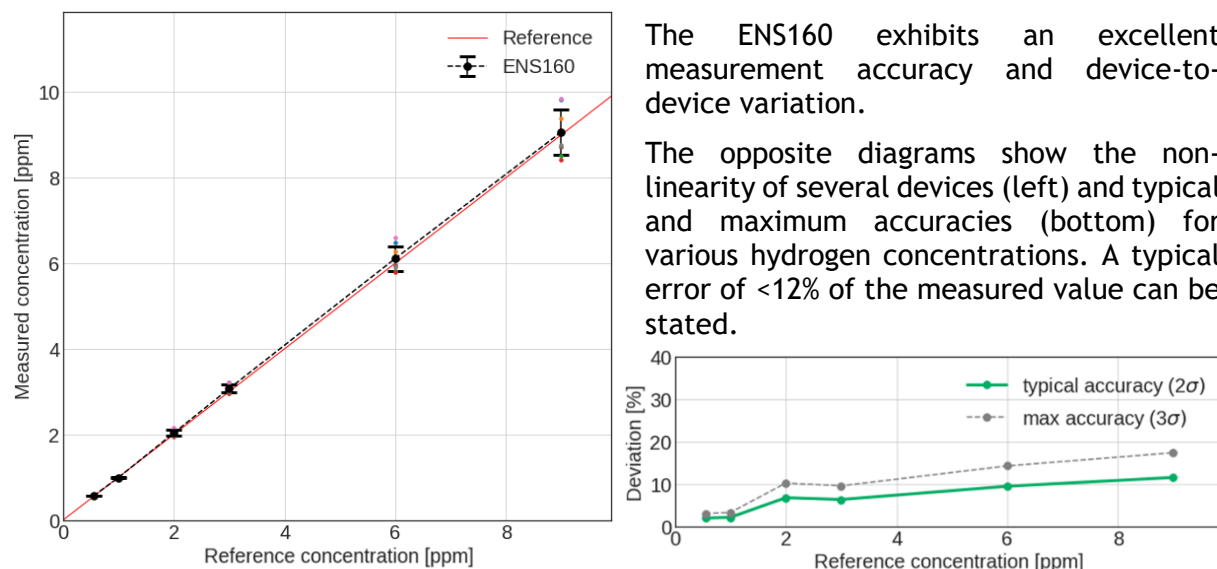


Note: Unless otherwise stated, the humidity compensation discussed in this section works per default for all output signals except for sensor raw signals.

See sections “Registers”, “TEMP_IN” and “RH_IN” for further information.

9 Output Signal Accuracy¹

Figure 10: Output Signal Accuracy for Hydrogen



10 Initial Start-Up and Warm-Up

Table 9: Initial Start-Up and Warm-Up Timings

| Parameter | Maximum Time | Comment |
|------------------|--------------|-------------------------------|
| Initial Start-Up | 1 hour | See below for further details |
| Warm-Up | 1 minute | |

10.1 Initial Start-Up

Initial Start-Up is the time the ENS160 needs to exhibit reasonable air quality readings after its first ever power-on.

The ENS160 sensor raw resistance signals and sensitivities will change upon first power-on. The change in resistance is greatest in the first 48 hours of operation. Therefore, the ENS160 employs a start-up algorithm, allowing eCO₂-, TVOC- and AQI-output signals to be used from first power-on after 1 hour of operation².

10.2 Warm-Up

Further to “Initial Start-Up” the conditioning or “Warm-Up” period is the time required to achieve adequate sensor stability before measuring VOCs after idle periods or power-off. Typically, the ENS160 requires 1 minute of warm-up before reasonable air quality readings can be expected¹.

¹ All values have been determined by tests in clean, partially synthetic air in a climate chamber-with stated environmental conditions, suitable reference analytics and sensor preconditioning of at least 24h, which may not reflect real-life environments. Unless otherwise noted, the accuracy statements have been carried out at 25°C and 50% relative humidity.

² Slightly reduced signal accuracy may be encountered in early phase, thereafter.

11 Gas Sensor Status and Signal Rating

The status flag is an additional feature assessing the current operational mode and the reliability of the output signals. It aids the application obligation to manage timings efficiently, in particular during initial start-up or after re-powering. Furthermore, a simple signal quality assessment and a system self-check is provided.

Table 10: ENS160 Status and Signal Rating (Validity Flag)

| Flag | Meaning | Implementation approach |
|------|------------------|--|
| 0 | Operating ok | Standard operating mode. |
| 1 | Warm-up | During first minute after power-on. |
| 2 | Initial Start-up | During first hour after power-on. Only once in a lifetime. |
| 3 | No valid output | Signals give unexpected values (very high or very low). Multiple sensors out of range. |

See “Validity Flag” in section “DATA_STATUS” for further information.

12 Recommended Sensor Operation

For best performance, the sensor shall be operated in normal indoor air in the range -5 to 60°C (typical: 25°C); relative humidity: 20 to 80%RH (typical: 50%RH), non-condensing with no aggressive or poisonous gases present. Prolonged exposure to environments outside these conditions can affect performance and lifetime of the sensor.

Please also refer to the “ENS160 Design Guidelines and Handling Instructions” for further information on handling and optimal integration of the ENS160. The guidelines in this document must be met for optimal sensor performance and long lifetime.

Important Note: The ENS160 is not designed for use in any safety-critical or life-protecting application.

13 Recommended Sensor Storage

The guidelines under “Recommended Sensor Operation” also apply for sensor storage.

14 Host Communication

The ENS160 is an I²C or SPI Slave device.

If the CS_n is held high, the interface behaves as an I²C slave. At power-up the condition of the MISO/ADDR pin is used to determine the LSB of the I²C address. The I²C slave address is 0x52 (MISO/ADDR low) or 0x53 (MISO/ADDR high).

If the CS_n pin is asserted (low) the interface behaves as an SPI slave. This condition is maintained until the next Power-on Reset.

Both the SPI and I²C slave interfaces use the same register map for communication.

14.1 I²C Specification

14.1.1 I²C Description

The ENS160 is an I²C slave device with a fixed 7-bit address 0x52 if the MISO/ADDR line is held low at power-up or 0x53 if the MISO/ADDR line is held high.

The I²C interface supports standard (100kbit/s), fast (400kbit/s), and fast plus (1Mbit/s) mode. Details on I²C protocol is according to I²C-bus specifications [UM10204, I²C-bus specification and user manual, Rev. 6, 4 April 2014].

The device applies all mandatory I²C protocol features for slaves: START, STOP, Acknowledge and 7-bit slave address. None of the other optional features (10-bit slave address, general call, software reset or Device ID) are supported, nor are the master features (Synchronization, Arbitration, START byte).

The Host System, as an I²C master, can directly read or write values to one of the registers by first sending the single byte register address. The ENS160 implements “auto increment” which means that it is possible to read or write multiple bytes (e.g. read multiple DATA_X bytes) in a single transaction.

14.1.2 I²C I/O and Timing Information

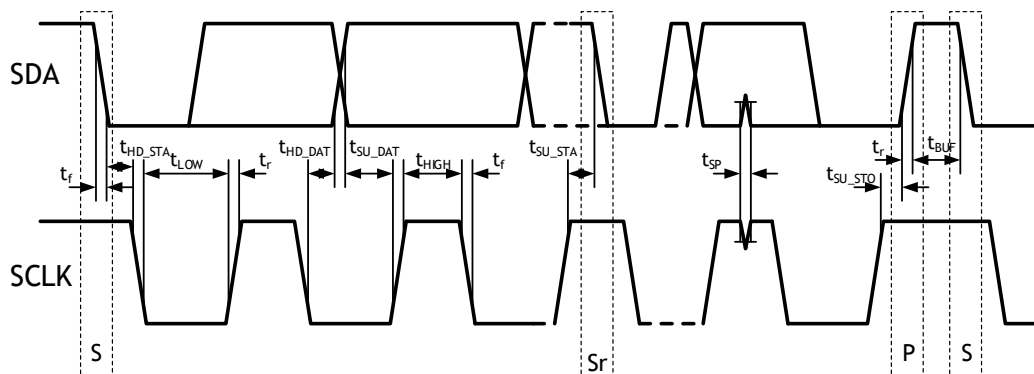
Table 11: ENS160 I²C I/O Parameters

| Parameter | Symbol | Standard | | Fast | | Fast Mode Plus | | Unit |
|--|------------------|-----------------------|-----------------------|----------------------------|-----------------------|----------------------------|-----------------------|------|
| | | Min | Max | Min | Max | Min | Max | |
| Low level input voltage | V _{IL} | -0.5 | 0.3xV _{DDIO} | -0.5 | 0.3xV _{DDIO} | -0.5 | 0.3xV _{DDIO} | V |
| High level input voltage | V _{IH} | 0.7xV _{DDIO} | 2.39 | 0.7xV _{DDIO} | 2.39 | 0.7xV _{DDIO} | 2.39 | V |
| Hysteresis of Schmitt trigger inputs | V _{hys} | - | - | 0.05xV _{DDIO} | - | 0.05xV _{DDIO} | - | V |
| Low-level output voltage @ 2mA sink current | V _{OL2} | - | - | 0 | 0.2xV _{DDIO} | 0 | 0.2xV _{DDIO} | V |
| Low-level output current @ 0.4V | I _{OL} | 3 | | 3 | | 20 | | mA |
| Output fall time from V _{IHmin} to V _{ILmax} | t _{OF} | | 250 | 20xV _{DDIO} / 5.5 | 250 | 20xV _{DDIO} / 5.5 | 250 | ns |
| Input current each I/O pin | I _i | -10 | 10 | -10 | 10 | -10 | 10 | μA |

Table 12: ENS160 I²C Timing Parameters¹

| Parameter | Symbol | Standard | | Fast | | Fast Mode Plus | | Unit |
|---|---------------------|-----------------------|-------------------|----------------------------|------------------|----------------------------|------|------|
| | | Min | Max | Min | Max | Min | Max | |
| SCLK clock frequency | f _{SCLK} | 0 | 100 | 0 | 400 | 0 | 1000 | kHz |
| Hold time (repeated) START condition. After this period, the first clock pulse is generated | t _{HD_STA} | 4 | - | 0.6 | - | 0.26 | - | μs |
| LOW period of the SCLK clock | t _{LOW} | 4.7 | - | 1.3 | - | 0.5 | - | μs |
| HIGH period of the SCLK clock | t _{HIGH} | 4.0 | - | 0.6 | - | 0.26 | - | μs |
| Set-up time for a repeated START condition | t _{SU_STA} | 4.7 | - | 0.6 | - | 0.26 | - | μs |
| Data set-up time | t _{SU_DAT} | 250 | - | 100 ² | - | 50 ² | - | ns |
| Data hold-time | t _{HD_DAT} | 0 ³ | 3.45 ⁴ | 0 ³ | 0.9 ⁴ | 0 ³ | - | μs |
| Rise time of SDA and SCLK signals | t _r | - | 1000 | 20 | 300 | 20 | 120 | ns |
| Fall time of SDA and SCLK signals | t _f | - | 300 | 20xV _{DDIO} / 5.5 | 300 | 20xV _{DDIO} / 5.5 | 120 | ns |
| Set-up time for STOP condition | t _{SU_STO} | 4.0 | - | 0.6 | - | 0.26 | - | μs |
| Bus free time between a STOP and START condition | t _{BUF} | 4.7 | - | 1.3 | - | 0.5 | - | μs |
| Capacitive load for each bus line | C _b | - | 400 | - | 400 | - | 550 | pF |
| Noise margin at the LOW level | V _{nL} | 0.1xV _{DDIO} | - | 0.1xV _{DDIO} | - | 0.1xV _{DDIO} | - | V |
| Noise margin at the HIGH level | V _{nH} | 0.2xV _{DDIO} | - | 0.2xV _{DDIO} | - | 0.2xV _{DDIO} | - | V |

Figure 11: Definition of I²C Timing Parameters



¹ All values referred to V_{IHmin} and V_{ILmax} levels

² A fast mode I²C bus device can be used in Standard mode I²C bus system, but the requirement t_{SU_DAT} ≥ 250ns must then be met. This will automatically be the case if the device does not stretch the LOW period of the SCL signal. If such a device does stretch the LOW period of the SCL signal, it must output the next data bit to the SDA line t_{rmax}. t_{SU_DAT} = 1000 + 250 = 1250ns (according to standard mode I²C bus specification) before the SCL line is released.

³ This device internally provides a hold time of at least 300ns for the SDA signal to bridge the undefined region of the falling edge of the SCL

⁴ The maximum t_{HD_DAT} has only to be met if the device does not stretch the LOW period (t_{LOW}) of the SCLK signal

14.1.3 I²C Read Operation

After the START condition, in the first transaction:

- The I²C Master sends the 7-bit slave address and 0 into the R/W bit (the byte sent would be 0xA4 or 0xA6 dependent on the power-up value of MISO/ADDR).
- The I²C Master then sends the address of the first register to read.

Then either after a RESTART condition (i.e. STOP followed by START)

- The I²C Master sends the 7-bit slave address and 1 into the R/W bit (the byte sent would be 0xA5 or 0xA7 dependent on the power-up value of MISO/ADDR).
- The I²C Master then reads 1-n data bytes from sequential registers (if valid) until the transaction is concluded with a STOP condition.

Figure 12: I²C Read Operation

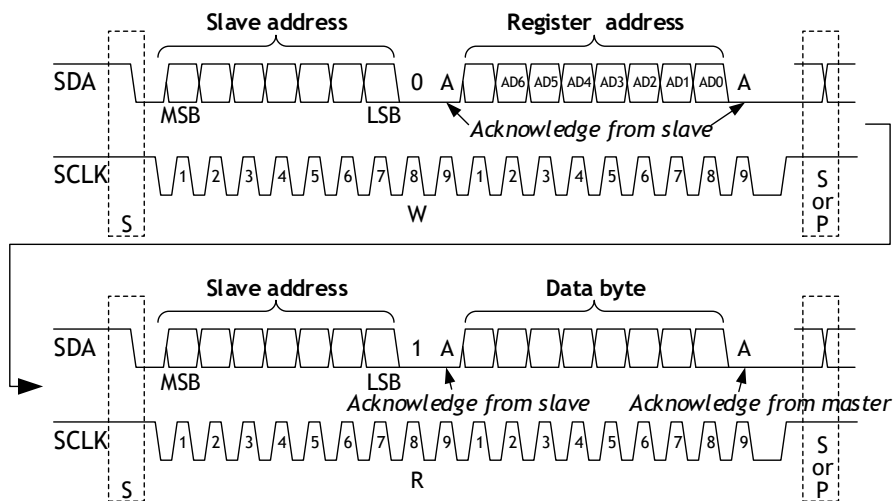
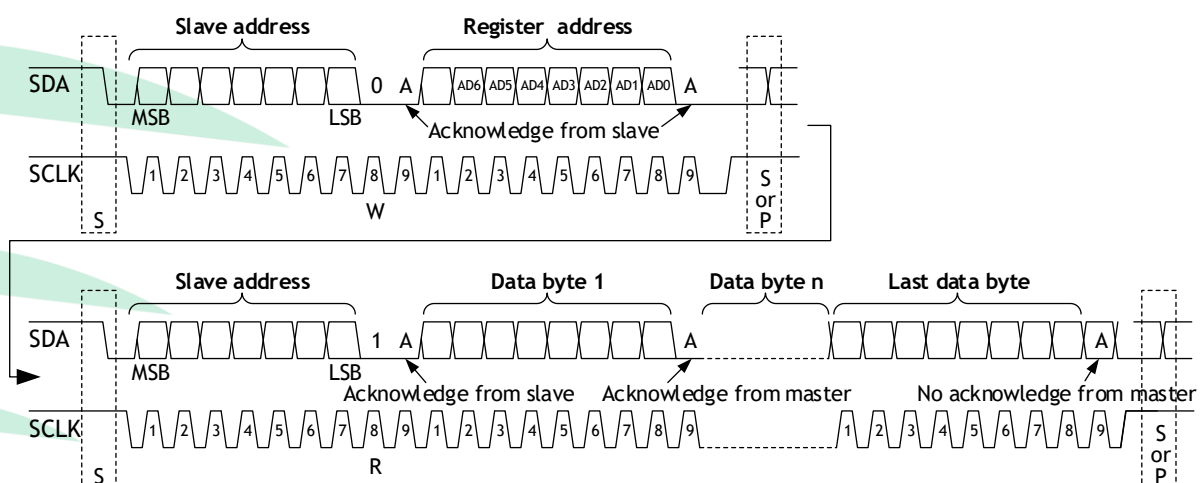


Figure 13: I²C Auto-Increment Read Operation



14.1.4 I²C Write Operation

After the START condition, in a single continuous transaction:

- The I²C Master sends the 7-bit slave address and 0 into the R/W bit (the byte sent would be 0xA4 or 0xA6 dependent on the power-up value of MISO/ADDR).
- The I²C Master then sends the address of the first register to write.
- The I²C Master then sends 1-n data bytes which are written into sequential registers (if valid) until the transaction is concluded with a STOP condition.

Figure 14: I²C Write Operation

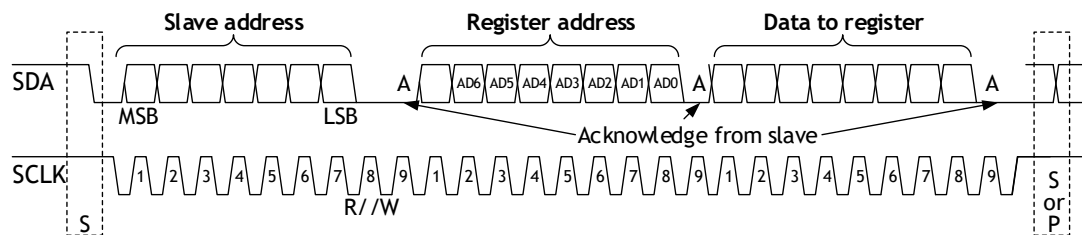
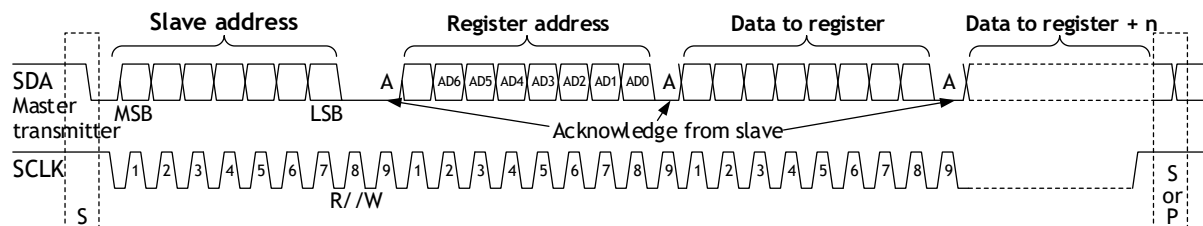


Figure 15: I²C Auto-Increment Write Operation



14.2 SPI Specification

14.2.1 SPI Description

The SPI interface is a slave bus operating up to 10MHz clock-frequency.

It shares pins with the I²C interface. SPI is selected and SPI transfer initiated by asserting the CSn line low. Once the CSn line has been asserted low the ENS160 will not accept I²C transactions until the next Power-On Reset.

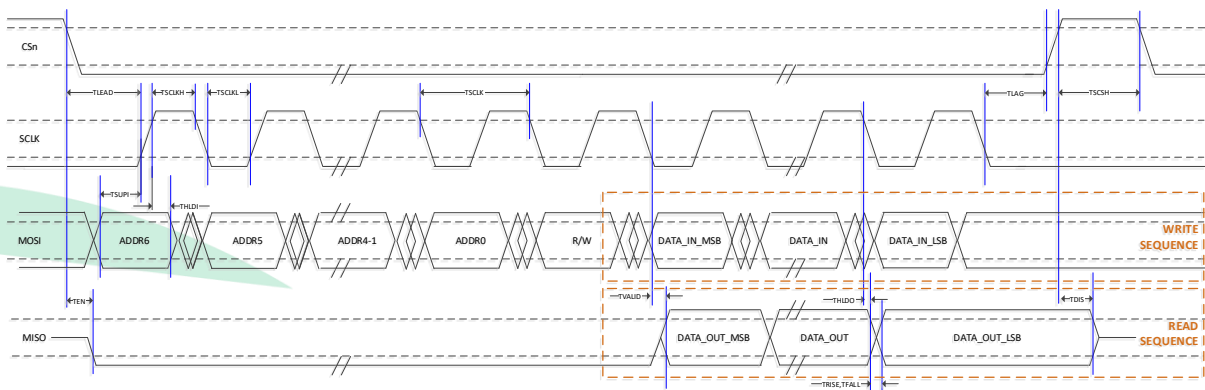
Data is clocked in on the rising edge of SCLK; most significant bit first.

14.2.2 SPI Timing Information

Table 13: SPI Timings

| Parameter | Symbol | Condition | Min | Typ | Max | Unit |
|----------------------------------|--------------------|-----------|-----|-----|-----|------|
| SPI Clock (SCLK) Frequency | F _{SCLK} | | | | 10 | MHz |
| CSn falling to MISO Enabled | T _{EN} | 25pF load | | | 20 | ns |
| CSn rising to MISO Disable | T _{DIS} | 25pF load | | | 20 | ns |
| MOSI Setup Time before SCLK | T _{SUPI} | | 15 | | | ns |
| MOSI hold time after rising SCLK | T _{HLDI} | | 15 | | | ns |
| CSn low to first rising SCLK | T _{LEAD} | | 20 | | | ns |
| Last SCLK low to CSn high | T _{LAG} | | 20 | | | ns |
| SCLK High Time | T _{SCLKH} | | 40 | | | ns |
| SCLK Low Time | T _{SCLKL} | | 40 | | | ns |
| SCLK falling to MISO Valid | T _{VALID} | 25pF load | | | 40 | ns |

Figure 16 SPI Timings Reference



14.2.3 SPI Read Operation

During a Read operation, data is clocked out on the falling edge of SCLK so it is stable for the following rising edge.

MISO stays in high impedance mode until the device is selected (CSn low). Data on MISO is only valid on a Read operation.

A transaction starts with the target address and R/W control bit in the first byte followed by the read or write data.

In a Read operation Auto-increment of the address enables multiple registers to be read in sequence. CSn de-asserting (to high) terminates the Read sequence.

A Read SPI frame is composed as follows:

Table 14: Read SPI Frame

| Byte | Bit | Name | Description |
|------|-----|------------|--|
| 0 | 7:1 | AD[6:0] | On MOSI: Address of the register to Read |
| 0 | 0 | RW | On MOSI: 1: bytes are to be read, starting from AD[6:0]. |
| 1 | 7:0 | RDATA[7:0] | Output on MISO; MOSI ignored |
| n | 7:0 | RDATA[7:0] | Output on MISO; MOSI ignored |

14.2.4 SPI Write Operation

In a Write operation, the address does not Auto-increment. Multiple writes can be performed by alternating Address and Data bytes. CSn de-asserting (to high) terminates the Write sequence.

A Write SPI frame is composed as follows:

Table 15: Write SPI Frame

| Byte | Bit | Name | Description |
|------|-----|------------|--|
| 0 | 7:1 | AD[6:0] | On MOSI: Address of the register to Write |
| 0 | 0 | RW | On MOSI: 0: bytes are to be Written, at AD[6:0]. |
| 1 | 7:0 | WDATA[7:0] | Input on MOSI; MISO Dummy Data |
| even | 7:1 | AD[6:0] | On MOSI: Address of the register to Write |
| even | 0 | RW | On MOSI: 0: bytes are to be Written, at AD[6:0]. |
| odd | 7:0 | WDATA[7:0] | Input on MOSI; MISO Dummy Data |

15 Operation

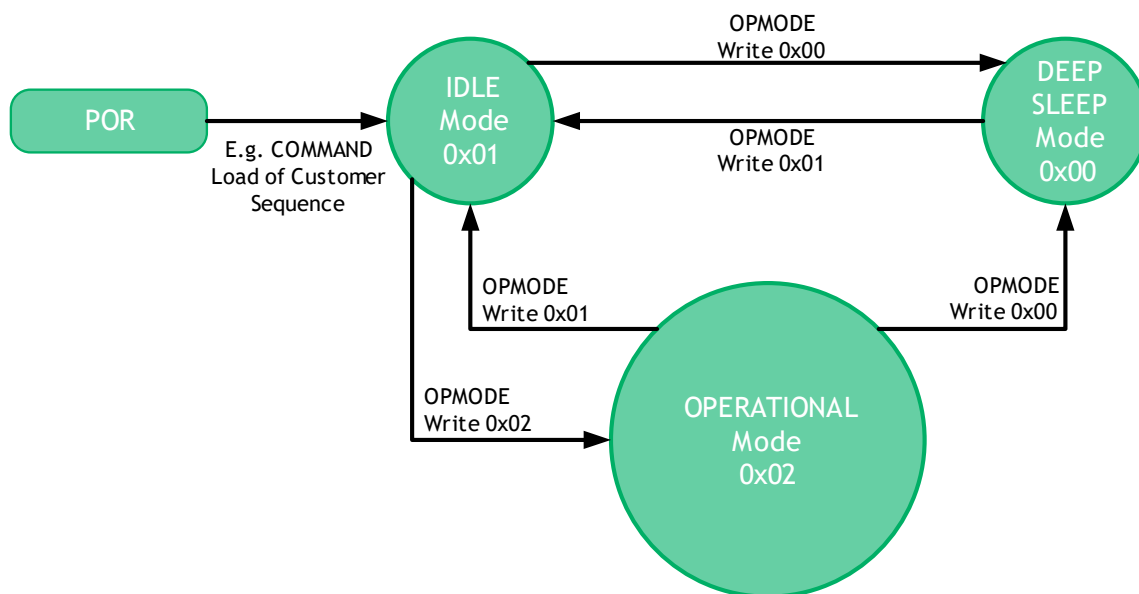
At power-up, the ENS160 configures itself from a reset state and prepares for commands over the serial bus via either I²C or SPI Protocols.

The default state is OPMODE 0x01, which is an IDLE condition that enables ENS160 so that it may respond to several commands. In this mode it is not operating as a gas sensor.

OPMODE 0x00 is a very low power standby state, called DEEP SLEEP.

Active OPMODEs are described further in the OPMODE Register section.

Figure 17 Orchestration of Operational Modes



Note: When the active gas sensing OPMODE (e.g. 0x02 = STANDARD) is running, new data is notified either via the interrupt (INTn) or by polling the DATA_STATUS register. The output of the gas sensing OPMODEs are presented in the DATA_XXX registers which can be read at any time.

16 Registers

This section describes the registers of the ENS160 which enable the host system to

- Identify the Device and version information
- Configure the ENS160 and set the operating mode
- Read back STATUS information, the calculated gas concentrations and Air Quality Indices

16.1 Register Overview

Note that some registers are spread over multiple addresses. For example, PART_ID at address 0 is spread over 2 addresses (its “Size” is 2). Registers are stored in little endian so the LSB of PART_ID is at address 0 and the MSB of PART_ID is at address 1.

Table 16: Register Overview

| Address | Name | Size | Access | Description |
|-------------|----------------|------|--------------|--|
| 0x00 | PART_ID | 2 | Read | Device Identity 0x01, 0x60 |
| 0x10 | OPMODE | 1 | Read / Write | Operating Mode |
| 0x11 | CONFIG | 1 | Read / Write | Interrupt Pin Configuration |
| 0x12 | COMMAND | 1 | Read / Write | Additional System Commands |
| 0x13 | TEMP_IN | 2 | Read / Write | Host Ambient Temperature Information |
| 0x15 | RH_IN | 2 | Read / Write | Host Relative Humidity Information |
| 0x17 - 0x1F | - | 1 | - | Reserved |
| 0x20 | DEVICE_STATUS | 1 | Read | Operating Mode |
| 0x21 | DATA_AQI | 1 | Read | Air Quality Index |
| 0x22 | DATA_TVOC | 2 | Read | TVOC Concentration (ppb) |
| 0x24 | DATA_ECO2 | 2 | Read | Equivalent CO ₂ Concentration (ppm) |
| 0x26 | - | 2 | - | Reserved |
| 0x28 | - | 2 | - | Reserved |
| 0x2A | - | 2 | Read | Reserved |
| 0x2C - 0x2F | - | 1 | - | Reserved |
| 0x30 | DATA_T | 2 | Read | Temperature used in calculations |
| 0x32 | DATA_RH | 2 | Read | Relative Humidity used in calculations |
| 0x34 - 0x37 | - | 1 | - | Reserved |
| 0x38 | DATA_MISR | 1 | Read | Data Integrity Field (optional) |
| 0x40 | GPR_WRITE[0:7] | 8 | Read/Write | General Purpose Write Registers |
| 0x48 | GPR_READ[0:7] | 8 | Read | General Purpose Read Registers |

16.2 Detailed Register Description

16.2.1 PART_ID (Address 0x00)

This 2-byte register contains the part number in little endian of the ENS160.

The value is available when the ENS160 is initialized after power-up.

Table 17: Register PART_ID

| Address 0x00 | | | | PART_ID |
|--------------|-------------|---------|--------|-----------------------|
| Bits | Field Name | Default | Access | Field Description |
| 0:7 | PART_ID_LSB | 0x60 | read | Lower Byte of Part ID |
| 8:15 | PART_ID_MSB | 0x01 | read | Upper Byte of Part ID |

16.2.2 OPMODE (Address 0x10)

This 1-byte register sets the Operating Mode of the ENS160. The Host System can write a new OPMODE at any time.

Any current operating mode will terminate and the new operating mode will start.

Table 18: Register OPMODE

| Address 0x10 | | | | OPMODE |
|--------------|------------|---------|--------|---|
| Bits | Field Name | Default | Access | Field Description |
| 7:0 | | 0x00 | R/W | Operating mode: 0x00: DEEP SLEEP mode (low power standby) 0x01: IDLE mode (low-power) 0x02: STANDARD Gas Sensing Modes |

In DEEP SLEEP mode, ENS160 has limited functionality but will respond to an OPMODE write.

Idle Mode is intended for configuration before running an active sensing mode.

0x02 (STANDARD) is an active gas sensing operating mode to indicate the levels of air quality or for specific gas detection.

16.2.3 CONFIG (Address 0x11)

This 1-byte register configures the action of the INTn pin which allows the ENS160 to signal to the host system that particular data is available.

The INTn pin can be (de-)asserted (polarity configurable) when ENS160 updates GPR_Read registers, or when it updates DATA registers, or when a certain threshold is reached (set through COMMAND mode).

A typical setting 0x23 would enable an active low interrupt (no pull-up required) when new output data is available in the DATA registers.

Table 19: Register CONFIG

| Address 0x11 | | | | CONFIG |
|--------------|------------|---------|--------|--|
| Bits | Field Name | Default | Access | Field Description |
| 7 | - | 0b0 | - | Reserved |
| 6 | INTPOL | 0b0 | R/W | INTn pin polarity: 0: Active low (Default) 1: Active high |
| 5 | INT_CFG | 0b0 | R/W | INTn pin drive: 0: Open drain 1: Push / Pull |
| 4 | - | 0b0 | - | Reserved |
| 3 | INTGPR | 0b0 | R/W | INTn pin asserted when new data is presented in the General Purpose Read Registers |
| 2 | - | 0b0 | - | Reserved |
| 1 | INTDAT | 0b0 | R/W | INTn pin asserted when new data is presented in the DATA_XXX Registers |
| 0 | INTEN | 0b0 | R/W | INTn pin is enabled for the functions above |

16.2.4 COMMAND (Address 0x12)

This 1-byte register allows some additional commands to be executed on the ENS160. This register can be written at any time, but commands will only be actioned in IDLE mode (OPMODE 0x01).

The COMMAND register allows multiple interactions with the system where data needs to be passed between the user/host and the ENS160.

Typically, a request for data (e.g. GetHWVer, GetFWVer) will result in the requested data being placed in the General Purpose READ Registers and an input of data (e.g. set alarm threshold) would first be stored in the General Purpose WRITE Registers at address 0x40-47.

Below is a list of valid commands for the ENS160.

Table 20: Register COMMAND

| Address 0x12 | | | | COMMAND |
|--------------|------------|---------|--------|---|
| Bits | Field Name | Default | Access | Command |
| 7:0 | Command | 0x00 | R/W | 0x00: ENS160_COMMAND_NOP 0x0E: ENS160_COMMAND_GET_APPVER - Get FW Version 0xCC: ENS160_COMMAND_CLRGPR Clears GPR Read Registers |

16.2.4.1 ENS160_COMMAND_GET_APPVER

After issuing ENS160_COMMAND_GET_APPVER, the firmware version of the ENS160 will be placed in General Purpose Registers GPR_READ0 and GPR_READ1. The NEWGPR bit in DATA_STATUS will be set and the INTn asserted if configured to react to NEWGPR.

Table 21: GPR_READ Settings for ENS160_COMMAND_GET_APPVER Command

| Register | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-----------|-------------|---|---|---|---------|---|---|---|
| GPR_READ0 | Release | | | | Version | | | |
| GPR_READ1 | Sub-Version | | | | | | | |

16.2.4.2 ENS160_COMMAND_CLRGPR

After issuing ENS160_COMMAND_CLRGPR all GPR Read registers are cleared.

16.2.5 TEMP_IN (Address 0x13)

This 2-byte register allows the host system to write ambient temperature data to ENS160 for compensation. The register can be written at any time. TEMP_IN_LSB should be written first as the update is recognized on a write to TEMP_IN_MSB.

Table 22: Register TEMP_IN

| Address 0x13 | | | | TEMP_IN |
|--------------|-------------|---------|--------|-----------------------|
| Bits | Field Name | Default | Access | Field Description |
| 0:7 | TEMP_IN_LSB | 0x00 | R/W | Lower Byte of TEMP_IN |
| 8:15 | TEMP_IN_MSB | 0x00 | R/W | Upper Byte of TEMP_IN |

The format of the temperature data is the same as the format used in the ENS21x (family of ScioSense temperature and humidity sensors) as shown below:

Table 23: Format of Temperature Data

| Byte 0x14 | | | | | | | | Byte 0x13 | | | | | | | |
|-------------------------------|---|---|---|---|---|---|---|-------------------|---|---|---|---|---|---|---|
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| TEMP_IN Integer Part (Kelvin) | | | | | | | | TEMP_IN Fractions | | | | | | | |

The ENS160 required input format is: temperature in Kelvin * 64 (with Kelvin = Celsius + 273.15).

Example: For 25°C the input value is calculated as follows: $(25 + 273.15) * 64 = 0x4A8A$.

16.2.6 RH_IN (Address 0x15)

This 2-byte register allows the host system to write relative humidity data to ENS160 for compensation. The register can be written at any time. RH_IN_LSB should be written first as the update is recognized on a write to RH_IN_MSB.

Table 24: Register RH_IN

| Address 0x15 | | | | RH_IN |
|--------------|------------|---------|--------|---------------------|
| Bits | Field Name | Default | Access | Field Description |
| 0:7 | RH_IN_LSB | 0x00 | R/W | Lower Byte of RH_IN |
| 8:15 | RH_IN_MSB | 0x00 | R/W | Upper Byte of RH_IN |

The format of the relative humidity data is the same as the format used in the ENS21x as shown below:

Table 25: Format of Relative Humidity Data

| Byte 0x16 | | | | | | | | Byte 0x15 | | | | | | | |
|------------------------|---|---|---|---|---|---|---|-----------------|---|---|---|---|---|---|---|
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RH_IN Integer Part (%) | | | | | | | | RH_IN Fractions | | | | | | | |

The ENS160 required input format is: relative humidity in %rH * 512.

Example: For 50% rH the input value is calculated as follows: $50 * 512 = 0x6400$.

16.2.7 DATA_STATUS (Address 0x20)

This 1-byte register indicates the current STATUS of the ENS160.

Table 26: Register DATA_STATUS

| Address 0x20 | | | | DATA_STATUS |
|--------------|---------------|---------|--------|--|
| Bits | Field Name | Default | Access | Field Description |
| 7 | STATAS | 0b0 | - | High indicates that an OPMODE is running |
| 6 | STATER | 0b0 | R | High indicates that an error is detected. E.g. Invalid Operating Mode has been selected. |
| 5 | - | 0b0 | R | Reserved |
| 4 | - | 0b0 | R | Reserved |
| 2-3 | VALIDITY FLAG | 0b00 | R | Status 0: Normal operation 1: Warm-Up phase 2: Initial Start-Up phase 3: Invalid output |
| 1 | NEWDAT | 0b0 | R | High indicates that a new data is available in the DATA_x registers. Cleared automatically at first DATA_x read. |
| 0 | NEWGPR | 0b0 | R | High indicates that a new data is available in the GPR_READx registers. Cleared automatically at first GPR_READx read. |

During operation, Bit 6 (STATER) of DATA_STATUS is asserted if an error has occurred. The meaning of the errors may be different, depending on the operation being undertaken. Further information regarding the error can be read from the GPR_READ registers.

16.2.8 DATA_AQI (Address 0x21)

This 1-byte register reports the calculated Air Quality Index according to the UBA.

Table 27: Register DATA_AQI

| Address 0x21 | | | | DATA_AQI |
|--------------|------------|---------|--------|---|
| Bits | Field Name | Default | Access | Field Description |
| 0:2 | AQI_UBA | 0x01 | R | Air Quality Index according to UBA [1..5] |
| 3:7 | Reserved | 0x00 | R | Reserved |

See section “AQI-UBA - Air Quality Index of the UBA” for further information.

16.2.9 DATA_TVOC (Address 0x22)

This 2-byte register reports the calculated TVOC concentration in ppb.

Table 28: Register DATA_TVOC

| Address 0x22 | | | | DATA_TVOC |
|--------------|------------|---------|--------|-------------------------|
| Bits | Field Name | Default | Access | Field Description |
| 0:7 | TVOC_LSB | 0x00 | R | Lower Byte of DATA_TVOC |
| 8:15 | TVOC_MSB | 0x00 | R | Upper Byte of DATA_TVOC |

See section “TVOC - Total Volatile Organic Compounds” for further information.

16.2.10 DATA_ECO2 (Address 0x24)

This 2-byte register reports the calculated equivalent CO₂-concentration in ppm, based on the detected VOCs and hydrogen.

Table 29: Register DATA_ECO2

| Address 0x24 | | | | DATA_ECO2 |
|--------------|------------|---------|--------|-------------------------|
| Bits | Field Name | Default | Access | Field Description |
| 0:7 | ECO2_LSB | 0x00 | R | Lower Byte of DATA_ECO2 |
| 8:15 | ECO2_MSB | 0x00 | R | Upper Byte of DATA_ECO2 |

See section “eCO₂ - Equivalent CO₂” for further information.

16.2.11 DATA_ETOH (Address 0x22)

This 2-byte register reports the calculated ethanol concentration in ppb. For dual use the DATA_ETOH register is a virtual mirror of the ethanol-calibrated DATA_TVOC register.

Table 30: Register DATA_ETH

| Address 0x22 | | | | DATA_ETOH |
|--------------|------------|---------|--------|------------------------|
| Bits | Field Name | Default | Access | Field Description |
| 0:7 | ETH_LSB | 0x00 | R | Lower Byte of DATA_ETH |
| 8:15 | ETH_MSB | 0x00 | R | Upper Byte of DATA_ETH |

16.2.12 DATA_T (Address 0x30)

This 2-byte register reports the temperature used in its calculations (taken from TEMP_IN, if supplied).

Table 31: Register DATA_T

| Address 0x30 | | | | DATA_T |
|--------------|------------|---------|--------|----------------------|
| Bits | Field Name | Default | Access | Field Description |
| 0:7 | DATA_T_LSB | 0x8A | R | Lower Byte of DATA_T |
| 8:15 | DATA_T_MSB | 0x4A | R | Upper Byte of DATA_T |

The format of the temperature data is the same as the format used in the ENS21x.

Table 32: Format of Temperature Data

| Byte 0x30 | | | | | | | | Byte 0x31 | | | | | | | |
|-------------------------------|---|---|---|---|---|---|---|-------------------|---|---|---|---|---|---|---|
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| TEMP_IN Integer Part (Kelvin) | | | | | | | | TEMP_IN Fractions | | | | | | | |

The DATA_T storage format is: temperature in Kelvin * 64
(with Kelvin = Celsius + 273.15).

Example: For a stored DATA_T value of 0x4A8A the temperature in °C is calculated as follows: $0x4A8A / 64 - 273.15 = 25^{\circ}\text{C}$.

See section “TEMP_IN” for further information.

16.2.13 DATA_RH (Address 0x32)

This 2-byte register reports the relative humidity used in its calculations (taken from RH_IN if supplied).

Table 33: Register DATA_RH

| Address 0x32 | | | | DATA_RH | |
|--------------|-------------|---------|--------|-----------------------|--|
| Bits | Field Name | Default | Access | Field Description | |
| 0:7 | DATA_RH_LSB | 0x00 | R | Lower Byte of DATA_RH | |
| 8:15 | DATA_RH_MSB | 0x64 | R | Upper Byte of DATA_RH | |

The format of the relative humidity data is the same as the format used in the ENS21x.

Table 34: Format of Relative Humidity Data

| Byte 0x32 | | | | | | | | Byte 0x33 | | | | | | | |
|------------------------|---|---|---|---|---|---|---|-----------------|---|---|---|---|---|---|---|
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RH_IN Integer Part (%) | | | | | | | | RH_IN Fractions | | | | | | | |

The DATA_RH storage format is: relative humidity in %rH * 512.

Example: For a stored DATA_RH value of 0x6400 the relative humidity in % is calculated as follows: $0x6400 / 512 = 50\%rH$.

See section “RH_IN” for further information.

16.2.14 DATA_MISR (Address 0x38)

This 1-byte register reports the calculated checksum of the previous DATA_ read transaction (of n-bytes). It can be read as a separate transaction, if required, to check the validity of the previous transaction. The value should be compared with the number calculated by the Host system on the incoming Data.

Table 35: Register DATA_MISR

| Address 0x38 | | | | DATA_MISR | |
|--------------|------------|---------|--------|---|--|
| Bits | Field Name | Default | Access | Field Description | |
| 0:7 | DATA_MISR | 0x00 | R | Calculated checksum of the previous transaction | |

Example: C-code to calculate MISR on the received DATA, to compare with DATA_MISR:

```
// The polynomial used in the CRC computation in DATA_MISR
//                               76543210 bit weight factor
#define POLY 0x1D // 0b00011101 = x^8+x^4+x^3+x^2+x^0 (x^8 is implicit)
// The hardware register DATA_MISR is updated with every read from a
// register in the range 0x20 to 0x37, using a CRC polynomial (POLY).
// For every register read, call `misr_update()` to keep the software
// variable `misr` in sync with the hardware register.
static uint8_t misr = 0; // Mirror of DATA_MISR (0 is hardware default)
uint8_t misr_update(uint8_t data) {
    uint8_t misr_xor= ( (misr<<1) ^ data) & 0xFF;
    if( misr&0x80==0 )
        misr= misr_xor;
    else
        misr= misr_xor ^ POLY;
}
// Typically, when an I2C/SPI transaction is completed, read DATA_MISR,
// and compare it with the software `misr`. They should equal. If not
// there is a CRC error: one or more bytes were corrupted in the transfer.
uint8_t misr_set(void) {
    return misr;
}
// Once the CRC is wrong, or transactions have been executed without
// calling update() the software `misr` is out of sync with DATA_MISR.
// Read DATA_MISR and call `misr_set()` to bring back in sync.
void misr_set(uint8_t * val) {
    misr= val;
}
```

16.2.15 GPR_WRITE (Address 0x40)

This 8-byte register is used by several functions for the Host System to pass data to the ENS160. Writes to these registers are not valid when the ENS160 is in DEEP SLEEP or during a low power portion of an operating mode. Writes should only be done during IDLE mode (OPMODE 0x01).

Table 36: Register GPR_WRITE

| Address 0x40 | | | | GPR_WRITE0-7 | |
|--------------|------|------------|---------|--------------|----------------------------------|
| Address | Bits | Field Name | Default | Access | Field Description |
| 0x40 | 0:7 | GPR_WRITE0 | 0x00 | R/W | General Purpose WRITE Register 0 |
| 0x41 | 0:7 | GPR_WRITE1 | 0x00 | R/W | General Purpose WRITE Register 1 |
| 0x42 | 0:7 | GPR_WRITE2 | 0x00 | R/W | General Purpose WRITE Register 2 |
| 0x43 | 0:7 | GPR_WRITE3 | 0x00 | R/W | General Purpose WRITE Register 3 |
| 0x44 | 0:7 | GPR_WRITE4 | 0x00 | R/W | General Purpose WRITE Register 4 |
| 0x45 | 0:7 | GPR_WRITE5 | 0x00 | R/W | General Purpose WRITE Register 5 |
| 0x46 | 0:7 | GPR_WRITE6 | 0x00 | R/W | General Purpose WRITE Register 6 |
| 0x47 | 0:7 | GPR_WRITE7 | 0x00 | R/W | General Purpose WRITE Register 7 |

16.2.16 GPR_READ (Address 0x48)

This 8-byte register is used by several functions for the ENS160 to pass data to the Host System. When New GPR_DATA is available the NEW_GPR bit of the DATA_STATUS register will be set and the INTn pin asserted (if configured).

Table 37: Register GPR_READ

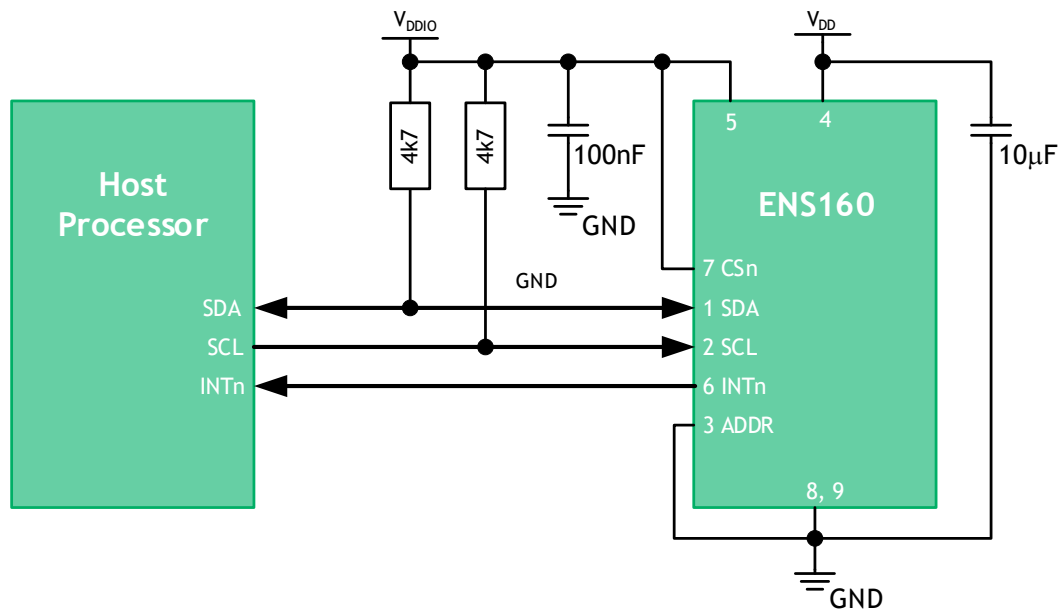
| Address 0x48 | | | | GPR_READ0-7 | |
|--------------|------|------------|---------|-------------|---------------------------------|
| Address | Bits | Field Name | Default | Access | Field Description |
| 0x48 | 0:7 | GPR_READ0 | 0x00 | R | General Purpose READ Register 0 |
| 0x49 | 0:7 | GPR_READ1 | 0x00 | R | General Purpose READ Register 1 |
| 0x4A | 0:7 | GPR_READ2 | 0x00 | R | General Purpose READ Register 2 |
| 0x4B | 0:7 | GPR_READ3 | 0x00 | R | General Purpose READ Register 3 |
| 0x4C | 0:7 | GPR_READ4 | 0x00 | R | General Purpose READ Register 4 |
| 0x4D | 0:7 | GPR_READ5 | 0x00 | R | General Purpose READ Register 5 |
| 0x4E | 0:7 | GPR_READ6 | 0x00 | R | General Purpose READ Register 6 |
| 0x4F | 0:7 | GPR_READ7 | 0x00 | R | General Purpose READ Register 7 |

17 Application Information

17.1 I²C Operation Circuitry

The recommended application circuit for the ENS160 I²C interface operation is shown below:

Figure 18: Recommended Application Circuit (I²C Operation)



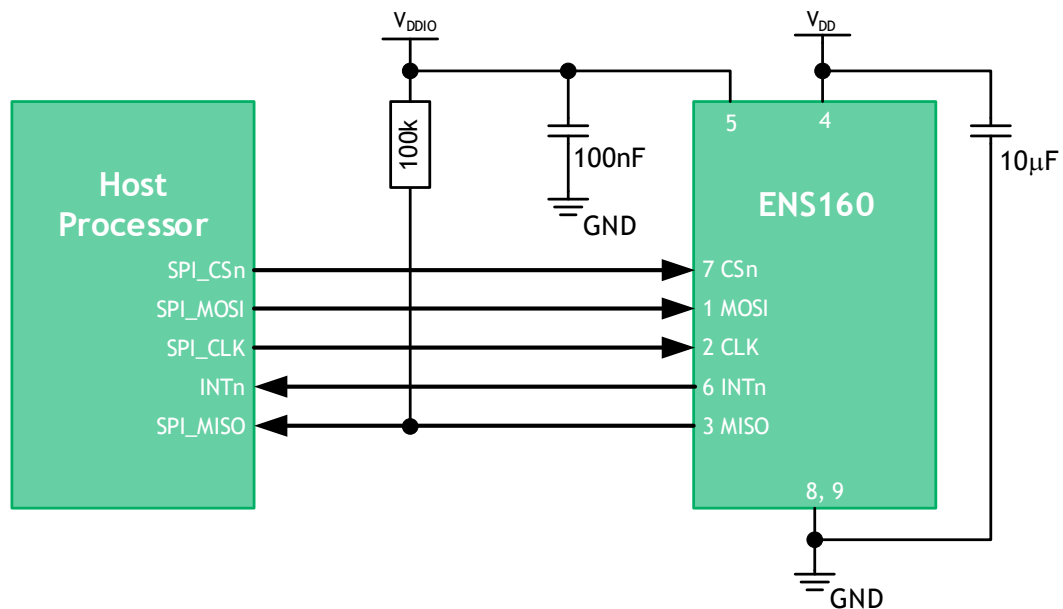
Note(s):

1. CSn must be pulled high (directly to V_{DDIO}) to ensure I²C interface is selected
2. MISO/ADDR should be pulled low or high to specify the LSB of the address
3. Pull-up resistors
The above recommendation for pull-up resistance values applies to I²C standard mode only. Pull-up resistors for SCL and SDA are assumed to be part of the host system and should be selected dependent on the intended I²C data rate and individual bus architecture.
4. Decoupling capacitor must be placed close to the V_{DD} (Pin 4) and V_{DDIO} (Pin 5) supply pins of the ENS160

17.2 SPI Operation Circuitry

The recommended application circuit for the ENS160 for SPI interface is shown below:

Figure 19: Recommended Application Circuit (SPI Operation)



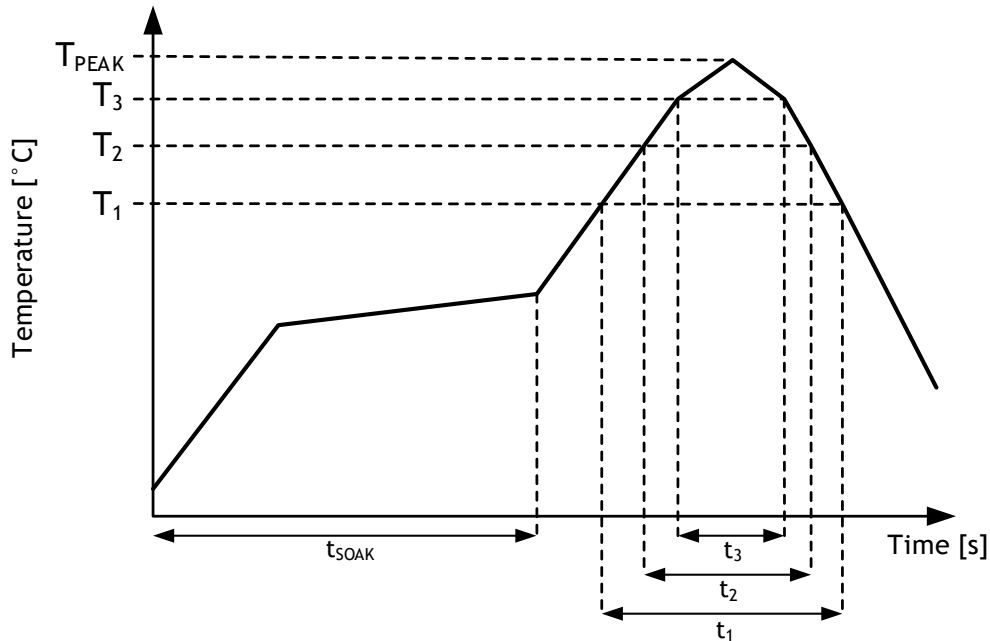
Note(s):

1. Weak pull-up resistor may be required for MISO to define the level when tri-stated
2. Decoupling capacitors must be placed close to the V_{DD} (Pin 4) and V_{DDIO} (Pin 5) supply pins of the ENS160

18 Soldering Information

The ENS160 uses an open LGA package. This package can be soldered using a standard reflow process in accordance with IPC/JEDEC J-STD-020D.

Figure 20: Solder Reflow Profile Graph



The detailed settings for the reflow profile are shown in the table below.

Table 38: Solder Reflow Profile

| Parameter | Reference | Rate / Unit |
|--|------------|-------------|
| Average temperature gradient in preheating | | 2.5K/s |
| Soak time | t_{SOAK} | 2..3 min |
| Soak temp range | T_s max | 200 °C |
| | T_s min | 150 °C |
| Time above 217 °C (T_1) | t_1 | Max. 60s |
| Time above 230 °C (T_2) | t_2 | Max. 50s |
| Time above $T_{PEAK} - 10$ °C (T_3) | t_3 | Max. 10s |
| Peak temperature in reflow | T_{PEAK} | 260 °C |
| Temperature gradient in cooling | | Max. -5K/s |

It is recommended to use a no-clean solder paste. There should not be any board wash processes, to prevent cleaning agents or other liquid materials contacting the sensor area.

19 Package Drawings & Markings

Figure 21: LGA Package Drawing

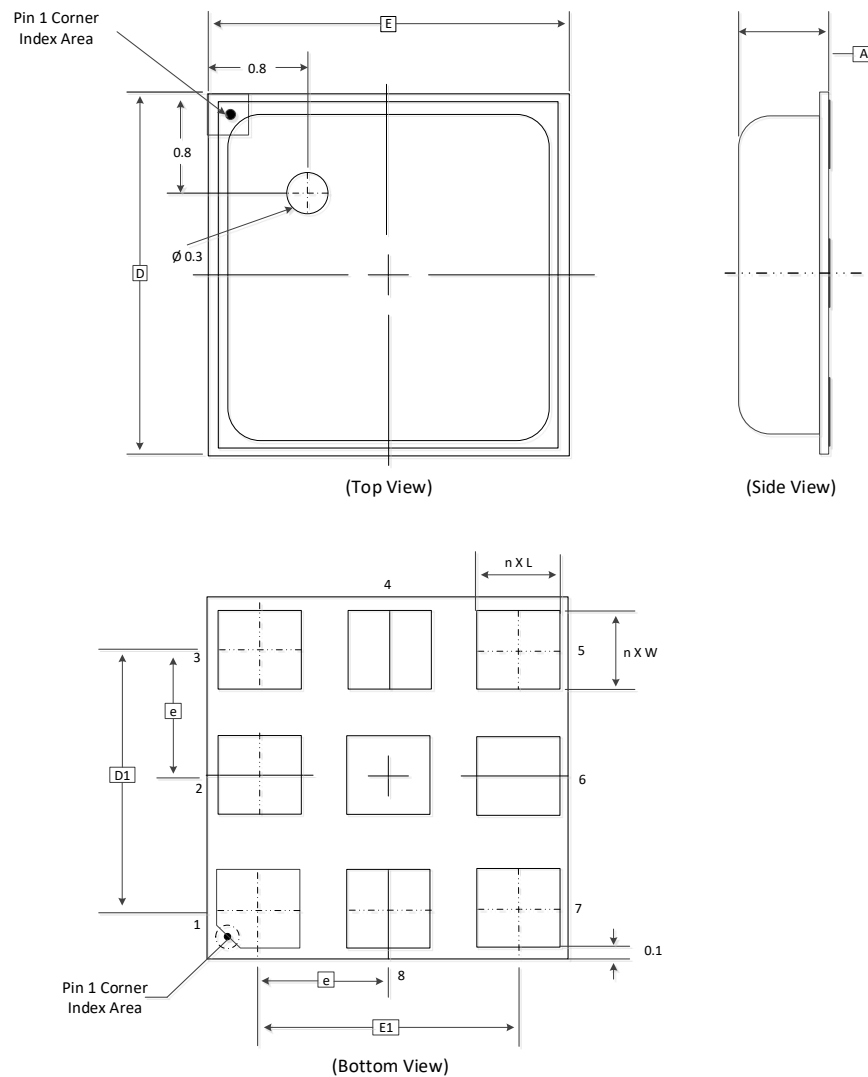
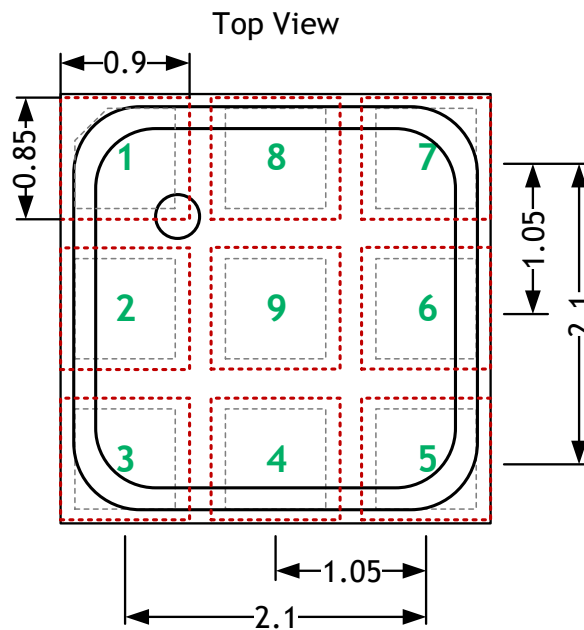


Table 39: LGA Package Dimensions

| Parameter | Symbol | Dimensions | | |
|----------------------------|--------|------------|---------|------|
| | | Min | Nominal | Max |
| Total thickness | A | - | 0.83 | 0.9 |
| Body Size | D | | 3.0 | BSC |
| | E | | 3.0 | BSC |
| Lead Width | W | 0.65 | 0.7 | 0.75 |
| Lead Length | L | 0.65 | 0.7 | 0.75 |
| Lead Pitch | e | | 1.05 | BSC |
| Lead Count | n | | 9 | |
| Edge Lead Centre to Centre | D1 | | 2.1 | BSC |
| | E1 | | 2.1 | BSC |

Note: All dimensions are in mm

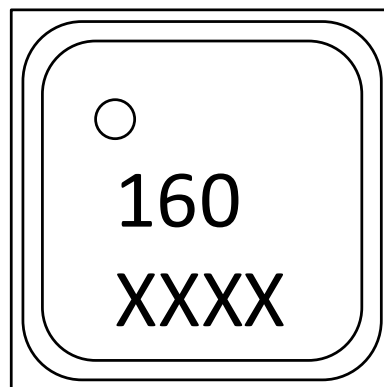
Figure 22: Recommend LGA Land Pattern for ENS160



Note(s):

1. All dimensions are in millimeters
2. PCB land pattern in **dotted lines**
3. Add 0.05mm all around the nominal lead width and length for the PCB land pattern

Figure 23: LGA Package Marking



20 RoHS Compliance & SciSense Green Statement

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22 Document Status

Table 40: Document Status

| Document Status | Product Status | Definition |
|--------------------------|-----------------|---|
| Product Preview | Pre-Development | Information in this datasheet is based on product ideas in the planning phase of development. All specifications are design goals without any warranty and are subject to change without notice. |
| Preliminary Datasheet | Pre-Production | Information in this datasheet is based on products in the design, validation or qualification phase of development. The performance and parameters shown in this document are preliminary without any warranty and are subject to change without notice. |
| Datasheet | Production | Information in this datasheet is based on products in ramp-up to full production or full production which conform to specifications in accordance with the terms of ScioSense B.V. standard warranty as given in the General Terms of Trade. |
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23 Revision Information

Table 41: Revision History

| Revision | Date | Comment | Page |
|----------|------------|--------------------------------------|------|
| 0.95 | 2020-12-09 | Preliminary Version - Product Launch | All |
| 0.9 | 2019-12-11 | Initial Version | All |

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.

SciSense is a Joint Venture of ams AG

Headquarters: SciSense B.V.
High Tech Campus 10
5656 AE Eindhoven
The Netherlands

Contact: www.sciosense.com
info@sciosense.com

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