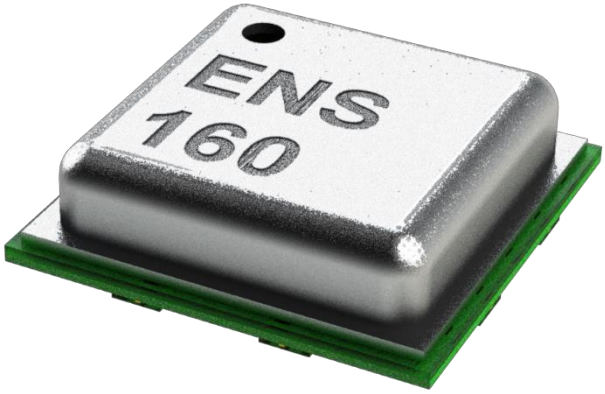
# ENS160




## Digital Metal Oxide Multi-Gas Sensor
## 数字金属氧化物多气体传感器

**ENS160 Datasheet**
**ENS160 数据表**
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# Digital Metal-Oxide Multi-Gas Sensor

# 数字金属氧化物多气体传感器

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 $CO_2$-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 and 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.

ENS160 是一种数字多气体传感器解决方案，基于金属氧化物MOX 技术，有四个金属氧化物传感器元件。每个传感器元件都有独立的热盘控制，可检测多种气体，例如挥发性有机化合物(VOC)，包括乙醇、甲苯以及氢气和二氧化氮，具有出色的选择性和精度。对于室内空气质量应用，ENS160 支持智能算法，以数字方式处理片上原始传感器测量值。这些算法可以计算等效 $CO_2$、TVOC、空气质量指数(AQI)，并进行湿度和温度补偿，以及基线管理-所有功能全部集成在芯片上！此外，还提供了一种开发选项，每个传感器元件可通过数字方式输出原始传感器测量值，以供定制。LGA 封装器件包括一个 SPI 和 I²C 接口，带有独立 VDDIO，可与主机处理器通信。ENS160 是一项专为批量生产和可靠性而设计的、成熟免维护技术。

## Key Features & Benefits

## 主要特点和优点

**TrueVOC™** air quality detection with industry-leading purity and stability, providing multiple outputs e.g. $eCO_2$ [1], TVOC and AQIs [2] in compliance with worldwide IAQ [3] -signal standards

**TrueVOC™**空气质量检测具有行业领先的纯度和稳定性，提供符合全球 IAQ[3]信号标准的多种输出，例如，$eCO_2$[1]、TVOC 和 AQI[2]。

**Independent sensor heater control** for highest selectivity (e.g. to ethanol, toluene, acetone, $NO_2$) and outstanding background discrimination

## Applications

## 应用

- Building Automation / Smarthome / HVAC[4]
- 楼宇自动化/智能家居/暖通空调[4]
  - Indoor air quality detection
  - 室内空气质量检测
  - Demand-controlled ventilation
  - 通风控制需求
  - Smart thermostats
  - 智能恒温器
- Home appliances
- 家用电器
  - Cooker hoods
  - 抽油烟机
  - Air cleaners / purifiers

[1] $eCO_2$ = equivalent $CO_2$ values for compatibility with HVAC ventilation standards

[1]$eCO_2$=符合暖通空调通风标准的 $CO_2$等效值

[2] AQI = Air Quality Index

[2]AQI=空气质量指数

[3] IAQ = Indoor Air Quality

[3]IAQ=室内空气质量

[4] HVAC = Heat, Ventilation and Air Conditioning

[4]HVAC=暖通空调

**独立传感器加热器控制，**可实现高选择性（例如，选择性检测乙醇、甲苯、丙酮、二氧化氮）和出色的环境检测。

**Immunity to siloxanes and humidity[5]**
**抗硅氧烷和抗湿性[5]**

**Hassle-free** on-chip heater drive control and data processing – no need for external libraries – no mainboard-CPU performance impacts
**一站式片**上加热器驱动控制和数据处理-无需外部库-不会影响主板-CPU 性能

**Interrupt on threshold** for low-power applications
**阈值中断**适用于低功耗应用

**Wide operating ranges**: temperature: -40 to +85°C; humidity: 5 to 95%[6]; VDD: 1.71 to 1.98V; VDDIO 1.71 to 3.6V
**宽工作范围**：温度：-40~85°C；湿度：5~95%[6]；VDD：1.71~1.98V；VDDIO 1.71~3.6V

- 空气滤清器/净化器
- IoT devices
- 物联网设备

## Properties
## 属性

- Small-3 x 3 x 0.9mm LGA package
- 小型 3 x 3 x 0.9mm LGA 封装
- Design-flexibility through standard, fast and fast mode plus I²C- and SPI- interfaces with separate VDDIO up to 3.6V
- 3.6V 独立 VDDIO，通过标准、快速和加速模式的 I²C 和 SPI 接口，实现灵活设计
- T&R packaged, reflow-solderable[7]
- T&R 封装，可回流焊[7]

[5] T/RH compensation via external T/RH-input
[5]通过外部 T/RH 输入进行 T/RH 补偿
[6] Non-condensing
[6]非冷凝
[7] See section “Soldering Information” for further details
[7]详见“钎焊信息”一节

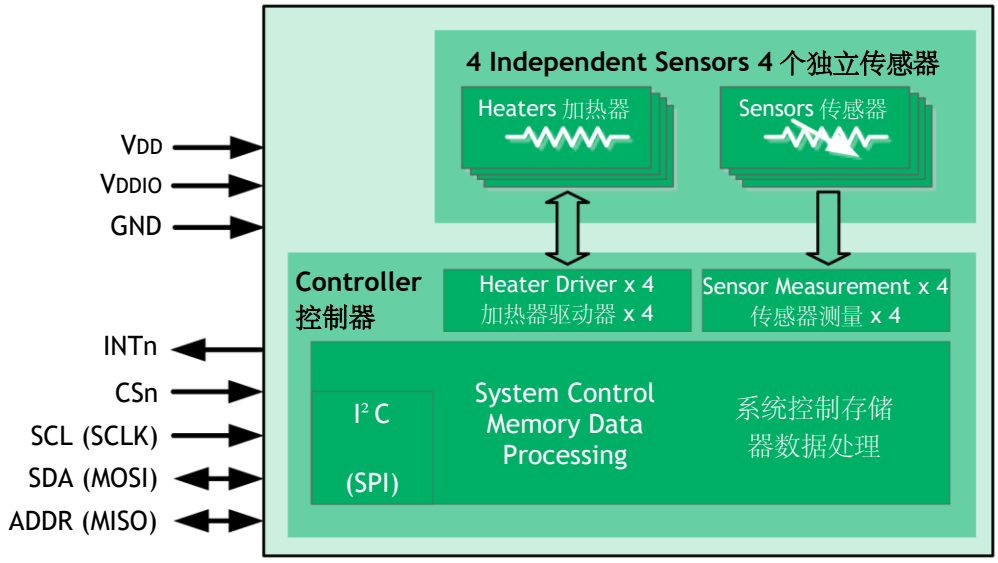
ScioSense

# Content Guide
# 内容指南

# 1 Block Diagram
# 1 框图

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.
ENS160 数字多气体传感器由四个基于金属氧化物（MOX）技术的独立加热器和气体传感器元件和一个控制器组成，详见下面的功能框图。

**Figure 1: Functional Blocks**
**图 1：功能模块**




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.
*加热器驱动器*控制着传感器工作模式，并为每个传感器元件的加热器供电。工作期间，加热器驱动器会将加热器调节到各自的设定点。

The *Sensor Measurement* block determines the value of the sensor resistance for each individual sensor element.
*传感器测量*模块能测定每个单独传感器元件的传感器电阻值。

The *System Control* block processes the resistance values internally to output calculated TVOC, $CO_2$-equivalents, AQIs and further signals on the digital interface.
*系统控制*模块可在内部处理电阻值，通过数字接口输出计算得出的 TVOC、等效$CO_2$、AQI 和其他信号。

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.
ENS160 包括一个标准的 2 线数字 *I²C 接口*(SCL, SDA)或 4 线数字 *SPI 接口*(SCLK, MOSI, MISO, CSn)，用于与主主机处理器通信。

On-chip memory is used to store calibration values.
片上存储器用于存储校准值。

# 2 Pin Assignment
# 2 引脚分配

Figure 2: Pin Diagram
图 2：引脚图

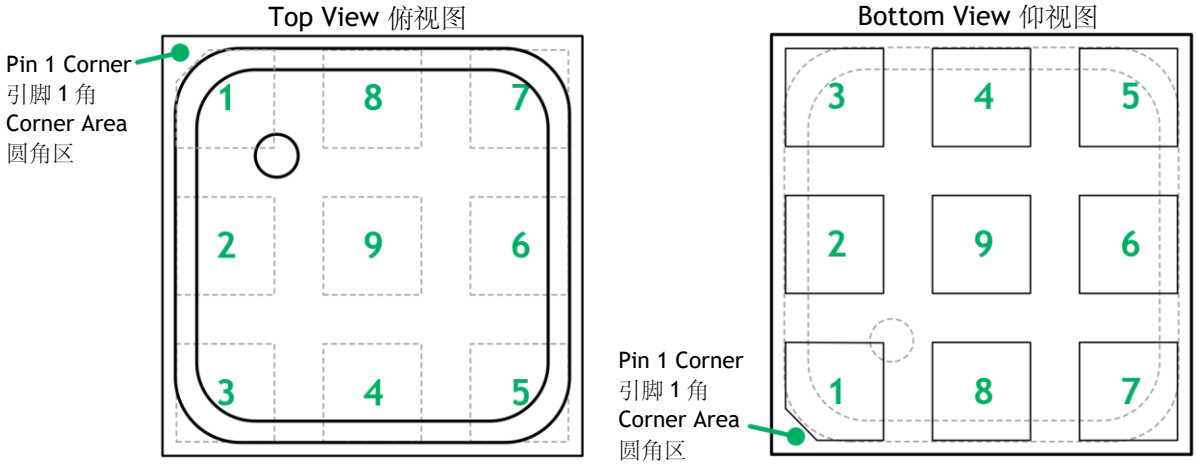



Table 1: Pin Description
表 1：引脚说明

| Pins<br>引脚 | Pin Name<br>引脚名 | Pin Type<br>引脚类型 | Description<br>描述 |
|---|---|---|---|
| 1 | MOSI / SDA | Input / Output<br>输入/输出 | SPI Master Output Slave Input / I²C Bus Bi-Directional Data<br>SPI 主输出从属输入/I²C 总线双向数据 |
| 2 | SCLK / SCL | Input<br>输入 | SPI Serial Clock / I²C Bus Serial Clock Input<br>SPI 串行时钟/I²C 总线串行时钟输入 |
| 3 | MISO / ADDR | Input / Output<br>输入/输出 | SPI Master Input Slave Output / I²C Address Select: I²C ADDR pin high -> 0x53 / ADDR pin low -> 0x52<br>SPI 主输入从输出/I²C 地址选择：I²C ADDR 引脚高电平->0x53/ADDR 引脚低电平->0x52 |
| 4 | VDD | Supply<br>电源 | Main Supply Voltage<br>主电源电压 |
| 5 | VDDIO | Supply<br>电源 | Interface Supply Pins<br>接口电源引脚 |
| 6 | INTn | Output<br>输出 | Interrupt to Host<br>中断主机 |
| 7 | CSn | Input<br>输入 | SPI Interface Select (CSn low -> SPI / CSn high -> I²C)<br>SPI 接口选择（CSn 低电平->SPI/CSn 高电平->I²C） |
| 8, 9 | VSS | Supply<br>电源 | Ground Supply Voltage<br>接地电源电压 |

Also see sections “I²C Operation Circuitry” and “SPI Operation Circuitry” for wiring.
有关接线，另请参见“I²C 工作电路”和“SPI 工作电路”两节。

# 3 Absolute Maximum Ratings
# 3 绝对最大额定值

**Table 2: Absolute Maximum Ratings**
**表 2：绝对最大额定值**

| Symbol<br>符号 | Parameter<br>参数 | Min<br>最小值 | Max<br>最大值 | Units<br>单位 | Comments<br>注释 |
|---|---|---|---|---|---|
| **Electrical Parameters<br>电气参数** | | | | | |
| $V_{DD}$ | Supply Voltage<br>电源电压 | -0.3 | 1.98 | V | |
| $V_{DDIO}$ | I/O Interface Supply<br>I/O 接口电源 | -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<br>输入接地 | -0.3 | 0.3 | V | |
| $I_{SCR}$ | Input Current (latch-up immunity)<br>输入电流（抗闩锁能力） | ± 100 | | mA | AEC-Q100-004 |
| **Electrostatic Discharge<br>静电放电** | | | | | |
| $ESD_{HBM}$ | Electrostatic Discharge HBM<br>静电放电 HBM | ± 2000 | | V | JS-001-2014 |
| $ESD_{CDM}$ | Electrostatic Discharge CDM<br>静电放电 CDM | ± 750 | | V | JS-002-2014 |
| **Operating and Storage Conditions<br>操作和储存条件** | | | | | |
| MSL | Moisture Sensitivity Level<br>潮湿敏感度等级 | | 1 | | Unlimited floor lifetime<br>无限车间寿命 |
| $T_{BODY}$ | Max. Package Body Temperature<br>封装本体最高温度 | | 260 | °C | IPC/JEDEC J-STD-020 |
| $T_{STRG}$ | Storage Temperature<br>储存温度 | -40 | 125 | °C | |
| $RH_{STRG}$ | Storage Relative Humidity<br>储存相对湿度 | 5 | 95 | % | Non-condensing<br>非冷凝 |
| $T_{AMB}$[1] | Operating Ambient Temperature<br>工作环境温度 | -40 | 85 | °C | |
| $RH_{AMB}$[1] | Operating Ambient Rel. Humidity<br>工作环境相对湿度 | 5 | 95 | % | Non-condensing<br>非冷凝 |

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

[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.

[1] ENS160 可在此范围内进行带电工作，但其气敏性能可能会有所不同。更多信息，请参阅"建议传感器操作"。

lifetime.
压力如超出所列的绝对最大额定值，即可能对器件造成永久性损坏。这些只是压力额定值。不暗示在这些或任何其他条件下，器件的功能工作可超出其电气特性。长时间暴露在绝对最大额定条件下可能会影响器件的可靠性和使用寿命。

**Important Note:** The ENS160 is not designed for use in safety-critical or life-protecting applications.
**重要说明：**ENS160 并非为安全关键或生命保护应用而设计。

# 4 Electrical Characteristics
# 4 电气特性

The following figure details the electrical characteristics of the ENS160.
下列数据详细说明了 ENS160 的电气特性。

**Table 3: Electrical Characteristics**
**表 3：电气特性**

| Symbol<br>符号 | Parameter<br>参数 | Conditions<br>条件 | Min<br>最小值 | Typ<br>类型 | Max<br>最大值 | Unit<br>单位 |
|---|---|---|---|---|---|---|
| $V_{DD}$ | Positive supply<br>正电源 | | 1.71 | 1.8 | 1.98 | V |
| $V_{DDIO}$ | IO Supply Voltage<br>IO 电源电压 | | 1.71 | | 3.6 | V |
| $I_{DD}$ | Average[1] Supply Current[2]<br>平均[1]电源电流[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]<br>峰值电源电流[4] | STANDARD (OP_MODE 0x02) | | 65 (<5ms) | | mA |
| $V_{IH}$ | High-level input voltage<br>高电平输入电压 | | 0.7x$V_{DDIO}$ | | | V |
| $V_{IL}$ | Low-level input voltage<br>低电平输入电压 | | | | 0.3x$V_{DDIO}$ | V |
| $V_{OH}$ | High-level output voltage<br>高电平输出电压 | MISO[5] [$I_{OH}$=5mA] | 0.8x$V_{DDIO}$ | | | V |
| | | INTN [$I_{OH}$=2mA] | 0.65x$V_{DDIO}$ | | | V |
| $V_{OL}$ | Low-level output voltage<br>低电平输出电压 | MOSI/SDA, MISO [$I_{OL}$=5mA] | | | 0.2x$V_{DDIO}$ | V |
| | | INTN [$I_{OL}$=2mA] | | | 0.35x$V_{DDIO}$ | V |

[1] Averaged over the sequence
[1]对序列求平均值
[2] Measured at VDD-pin at ambient temperature of 35°C
[2]环境温度为 35°C 时，在 VDD 引脚上测得
[3] Not a gas sensing mode
[3]非气体模式
[4] Initial (<5ms) current demand from VDD after the sensor is switched from IDLE (OP-Mode 1) to STANDARD operation (OP_MODE 2) [4]传感器从空闲模式（OP_MODE 1）切换到标准操作模式（OP_MODE 2）后，VDD 的初始电流需求（＜5ms）
[5] MOSI/SDA is open drain
[5]MOSI/SDA 为漏极开路

# 5 Air Quality Signal Characteristics
# 5 空气质量信号特征

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.

为了满足各种不同的应用需求，ENS160 提供了一系列（室内）空气质量输出信号，这些信号来自各种国家和国际标准以及事实标准。表 4 提供了此类信号的汇总，并在以下章节进行了进一步描述。

**Table 4: Air Quality Signal Output Characteristics**

表 4：空气质量信号输出特性

| Parameter<br>参数 | Range<br>范围 | Resolution<br>分辨率 | Unit<br>单位 | Comment<br>备注 |
|---|---|---|---|---|
| TVOC | 0 - 65 000 | 1 | ppb | For requirements outside these specified ranges please contact us<br>如果您的应用需求超出了规定的范围，请与我们联系。 |
| $eCO_2$ | 400 - 65 000 | 1 | ppm $CO_2$ - 等效<br>ppm $CO_2$ - 等效 | |
| AQI-UBA[1] | 1~5<br>1~5 | 1 | - | |

## 5.1 TVOC - Total Volatile Organic Compounds
## 5.1 TVOC——总挥发性有机化合物

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.

存在 5000 多种挥发性有机化合物，它们在室内被发现的可能性是室外的 2 到 5 倍。室内挥发性有机化合物是各种碳氢化合物，主要有两种来源：生物代谢物，即人体呼吸、蒸腾和新陈代谢产生的气味，以及建筑材料，包括家具和家庭用品等。众所周知，挥发性有机化合物会导致眼睛刺激、头痛、困倦甚至头晕——所有这些均以术语“病态建筑综合症”(SBS)概括。除了工业应用、舒适性（例如温度）或建筑保护（湿度）之外，挥发性有机化合物是通风的唯一根本原因。

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.

为了对挥发性有机化合物进行分组和分类，区域指南和行业偏好定义了一系列化合物和混合物作为参考。例如，乙醇、甲苯、丙酮、各种挥发性有机化合物的组合（例如，ISO16000-29）等。

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

ENS160 以乙醇作为基准，以获得最佳、最平衡的 TVOC 结果。

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

关于 ENS160 如何获得 TVOC 值，请参阅“寄存器”和“DATA_TVOC（地址 0x22）”。

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

[1]德国联邦环境署根据室内空气质量等级对 TVOC 输出信号进行了分类(UBA, 2007)

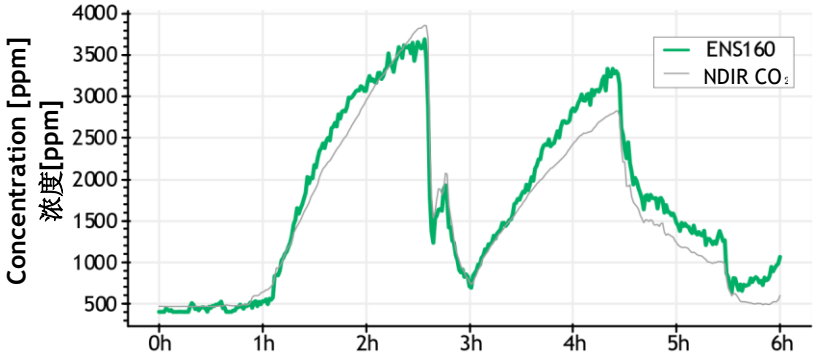
## 5.2 $eCO_2$ – Equivalent $CO_2$
## 5.2 $eCO_2$-等效$CO_2$

Due to the proportionality between VOCs and -$CO_2$ generated by humans, $CO_2$-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 Pettenkofer[2] in the 19th century) and the unavailability of suitable VOC measurement technology made $CO_2$ 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.

由于人类产生的挥发性有机化合物和 $CO_2$之间的比例关系，一直以来，$CO_2$值作为一个空气质量指标，反映了人类呼吸和蒸腾产生的挥发性有机化合物的总量（=TVOC）。这一定律（最早由 Max von Pettenkofer[2]在 19 世纪揭示）再加上缺乏合适的挥发性有机化合物测量技术，使得 $CO_2$成为了过去*和*现在封闭生活空间内居民导致空气污染的替代物，即控制通风需求作为当今的空气质量标准，也是暖通空调行业标准。

[2] Max von Pettenkofer (*1818 – †1901), German chemist and hygienist.
[2]Max von Pettenkofer (* 1818–1901)，德国化学家和卫生学家。

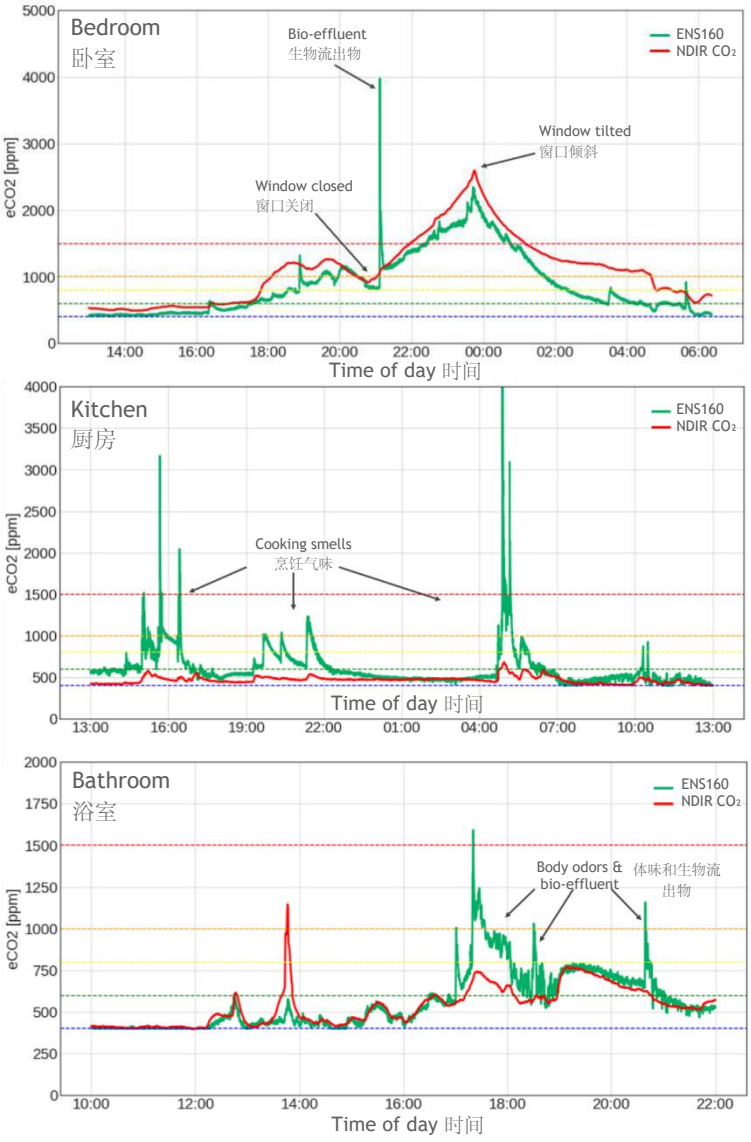
Figure 3: ENS160-based equivalent $CO_2$ ($eCO_2$) vs. NDIR-based $CO_2$ during two meeting sessions
图 3：两次会议期间，基于 ENS160 测出的等效$CO_2$($eCO_2$)与基于 NDIR 测出的 $CO_2$




The ENS160 reverses the proportional correlation of VOCs and $CO_2$ by providing a standardized output signal in ppm$CO_2$-equivalents from measured VOCs plus hydrogen, thereby adhering to today's $CO_2$-standards, as shown opposite: ENS160-based equivalent $CO_2$ estimate vs. $CO_2$ detected by an NDIR-sensor during two consecutive meeting sessions, interrupted by a lunch-break.

ENS160遵循挥发性有机化合物和 $CO_2$的相关比例，通过实测挥发性有机化合物和氢气，提供标准的输出信号（等效CO2单位为 ppm ），从而符合现行 $CO_2$标准，具体如下所示：两次连续会议期间（中间有一次午休），基于 ENS160 测出的等效$CO_2$估算值与 NDIR 传感器测到的 $CO_2$。

**Figure 4: Added value of ENS160's $eCO_2$ Outputs -where plain $CO_2$ sensors fail**
**图 4：ENS160 $eCO_2$输出的附加值-普通$CO_2$传感器失效的值**




A key advantage of the ENS160 is the capture of odors and bio- effluents that are completely invisible to $CO_2$-sensors. The opposite diagrams compare the ENS160's equivalent $CO_2$ output to an NDIR $CO_2$ sensor in typical indoor applications:
ENS160 的一个核心优势是捕捉 $CO_2$传感器完全发现不了的气味和生物代谢物。以下两个图表将 ENS160 的 等效$CO_2$输出与典型室内应用中的 NDIR $CO_2$传感器进行了比较：
$CO_2$ 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.
$CO_2$传感器既无法检测出卧室或浴室环境中令人不快的气味和生物代谢物，也无法检测出厨房或餐厅中的烹饪气味，而 ENS160 却可靠地报告了相应的气味。

Proven TrueVOC™ control-algo-rithms minimize sensor drift and ageing to provide reliable readings over lifetime, thereby making the ENS160's equivalent $CO_2$ output an affordable solution to complement or substitute real $CO_2$-based air- quality sensors in the HVAC domain.
成熟的 TrueVOC™控制算法可最大限度地减少传感器偏差和老化，在整个使用寿命期间提供可靠的读数，从而使 ENS160 的等效$CO_2$输出成为暖通空调领域的补充或替代真正基于 $CO_2$的空气质量传感器的经济解决方案。

The below table shows a typical classification of (equivalent) $CO_2$ output levels.
下表所示为（等效）$CO_2$输出水平的典型分类。

Table 5: Interpretation of $CO_2$ and Equivalent $CO_2$ Values
表 5：$CO_2$和 等效$CO_2$值的解释

| Output 输出 | | Comment / Recommendation 评论/建议 |
|---|---|---|
| $eCO_2$ / $CO_2$ | Rating 额定值 | |
| >1500 | Bad 差 | Heavily contaminated indoor air / Ventilation required 严重受污染的室内空气/需要通风 |
| 1000 - 1500 | Poor 较差 | Contaminated indoor air / Ventilation recommended 受污染的室内空气/建议通风 |
| 800 - 1000 | Fair 一般 | Optional ventilation 可选通风 |
| 600 - 800 | Good 良好 | Average 平均值 |
| 400 - 600 | Excellent 优秀 | Target 目标值 |

**Example:** A $CO_2$- or $eCO_2$-controlled ventilation application would invoke its ventilation fan speeds 1, 2 and 3 at the upper three levels “Fair”, “Poor” and “Bad”, respectively.
例如：$CO_2$控制或 $eCO_2$控制通风应用将分别在上述三个级别“一般”、“较差”和“差”调用其换气风机速度 1、2 和 3。

See section “Registers” and “DATA_$ECO_2$ (Address 0x24)” on how to obtain equivalent $CO_2$- values from the ENS160.
关于 ENS160 如何获得 $CO_2$等效值，请参见“寄存器”和“DATA_$ECO_2$（地址 0x24”章节。

## 5.3 AQI-UBA - Air Quality Index of the UBA[1]
## 5.3 AQI-UBA-UBA 空气质量指数[1]

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.
AQI-UBA 空气质量指数来自德国联邦环境署基于 TVOC 总信号的指南。尽管这是德国的一项地方性建议，但许多国家和组织都参考并采用了该指南。

Table 6: Air Quality Index of the UBA (German Federal Environmental Agency)
表 6：UBA 空气质量指数（德国联邦环境署）

[1] UBA = Umweltbundesamt – German Federal Environmental Agency
[1]UBA =Umweltbundesamt-德国联邦环境署

| AQI-UBA<br>AQI-UBA | | Hygienic Rating<br>卫生等级 | Recommendation<br>建议值 | Exposure Limit<br>暴露限值 |
|---|---|---|---|---|
| # | Rating<br>额定值 | | | |
| 5 | Unhealthy<br>不正常 | Situation not acceptable<br>情况不可接受 | Use only if unavoidable Intensified ventilation recommended<br>仅在不可避免的情况下使用，建议加强通风 | hours<br>小时 |
| 4 | Poor<br>较差 | Major objections<br>主要异议 | Intensified ventilation recommended Search for sources<br>建议加强通风，寻找源头 | <1 month<br>小于 1 个月 |
| 3 | Moderate<br>中度 | Some objections<br>一些异议 | Increased ventilation recommended Search for sources<br>增加通风，建议搜寻来源 | <12 months<br>小于 12 个月 |
| 2 | Good<br>良好 | No relevant objections<br>无相关异议 | Sufficient ventilation recommended<br>建议充分通风 | no limit<br>无限制 |
| 1 | Excellent<br>优秀 | No objections<br>无异议 | Target<br>目标值 | no limit<br>无限制 |

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

符合 UBA (Bundesgesundheitsblatt – Gesundheitsforschung Gesundheitsschutz 2007, 50:990–1005, DOI 10.1007/s00103-007-0290-y)的建议© Springer Medizin Verlag 2007

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

有关 ENS160 如何获取 AQI 值，请参见“寄存器”和 DATA_AQI（地址 0x21）章节。

# 6 Single Gas Signal Characteristics
# 6 单一气体信号特性

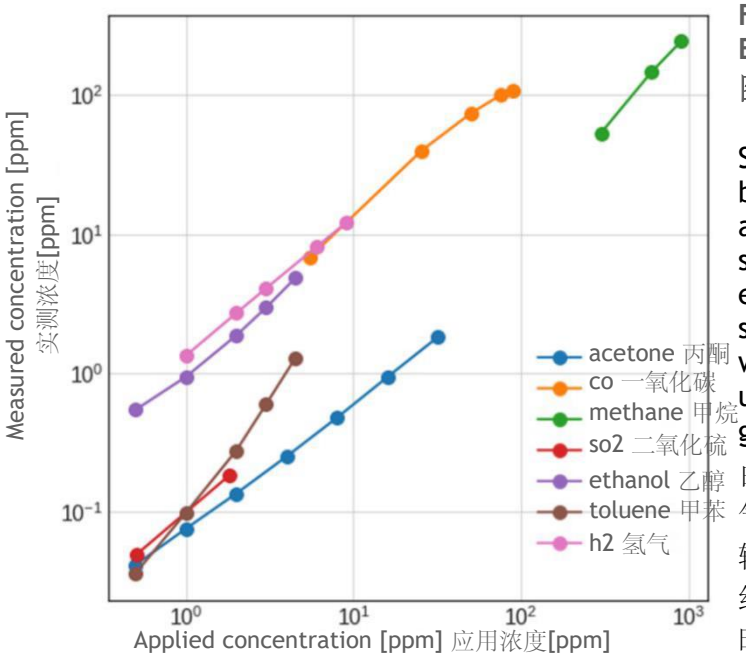



**Figure 5: Example Response of the ENS160 to Various Gases**
**图 5：ENS160 对各种气体的响应示例**

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.

由于金属氧化物传感器对还原气体和氧化气体都表现出了宽频灵敏度，因此其原始输出信号代表了存在的整个气体混合物的结果总和。当涉及到混合TVOC 或 AQI 应用时，这种总信号是有益的，但并不适用于单一气体的检测。

The opposite table shows the response of the ENS160 to a variety of individual gases that can be found indoors.
下表所示为 ENS160 对室内各种气体的响应。

The below table provides a list of selected gases that have been individually characterized.
下表列出了已单独表征的选定气体。

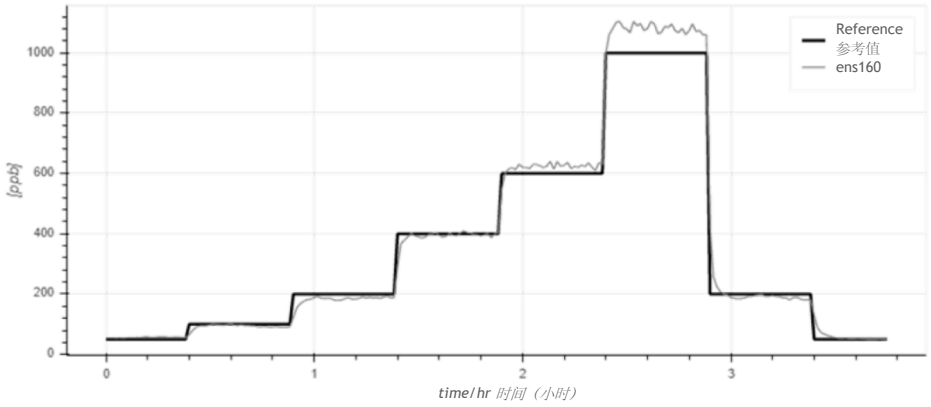
**Table 7: Single Gas Signal Characteristics**
**表 7：单一气体信号特性**

| Target Gas<br>目标气体 | Specified Range<br>指定范围 | Unit<br>单位 | Register<br>寄存器 | Comment<br>备注 |
|---|---|---|---|---|
| Ethanol<br>乙醇 | 0 to 6<br>0~6 | ppm | DATA_ETOH (0x22) = DATA_TVOC | Dedicated Register<br>专用寄存器 |
| Hydrogen<br>氢气 | 0 to 10<br>0~10 | ppm | R4raw = GPR_READ[6:7] | Riraw = raw resistance values that need to be calibrated to target gas. See text below.<br>Riraw =需要校准至目标气体的原始电阻值。见下文。 |
| Acetone<br>丙酮 | 0 to 32<br>0~32 | ppm | R4raw = GPR_READ[6:7] | |
| Carbon Monoxide<br>一氧化碳 | 0 to 90<br>0~90 | ppm | R4raw = GPR_READ[6:7] | |
| Toluene<br>甲苯 | 0 to 32<br>0~32 | ppm | R4raw = 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.

单一气体的测量值可从专用设备寄存器中获得，或根据上表中列出的传感器原始电阻值计算得出。详见“寄存器”和“气敏传感器原始电阻信号”章节。

**Figure 6: Example Response of the ENS160 to Ethanol**
**图 6：ENS160 对乙醇的响应示例**



# 7 Gas Sensor Raw Resistance Signals
# 7 气体传感器原始电阻信号

For two of its sensing elements the ENS160 provides individual outputs of raw sensor values.
由于有两个传感元件，ENS160 提供了原始传感器值的独立输出。

**Table 8: Gas Sensor Raw Resistance Signals**
**表 8：气体传感器原始电阻信号**

| Sensor<br>传感器 | Raw Value<br>原始值 | Range<br>范围 | Unit<br>单位 | Gen. Purpose Register<br>通用寄存器 | Comment<br>备注 |
|---|---|---|---|---|---|
| 1 | R1raw | [0..65535] | - | GPR_READ[0:1] | Arbitrary logarithmic units - no resistance values.<br>任意对数单位-无电阻值。 |
| 4 | R4raw | [0..65535] | - | GPR_READ[6:7] | Riraw require conversion to corresponding resistance value Rires [Ω] (see below)<br>Riraw 需要转换为相应电阻值 Rires[ω]（见下文） |

Gas sensor raw-values Riraw can be obtained from the ENS160's General Purpose Read Register (GPR_READ) for customer-specific signal post-processing.
(GPR_READ)用于客户特定的信号后处理。

Prior to use Riraw values require conversion to resistance values, using the following formula:
使用前，Riraw 值需要使用以下公式转换为电阻值：

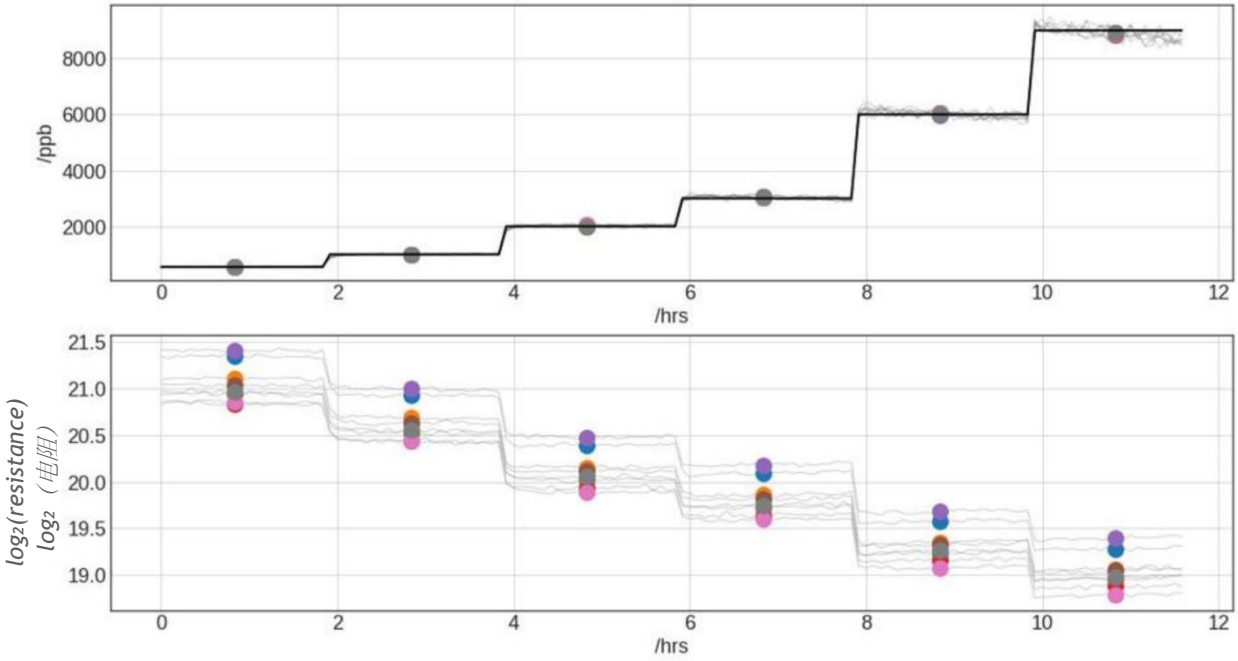
$$R_{ires}[\Omega] = 2^{\frac{R_{iraw}}{2048}}$$

See section "Registers" and GPR_READ (Address 0x48 – 0x4F) on how to obtain AQI-values from the ENS160.
关于ENS160 如何获得 AQI 值，请参见"寄存器"和 GPR_READ（地址 0x 48-0x4F）章节。

The below figures show the response of eight ENS160s to various hydrogen concentration[1] steps (upper diagram) and the corresponding raw sensor resistance Riraw (lower diagram).
下图所示为八个 ENS160 对各种氢气浓度[1]阶跃的响应（上图）和相应原始传感器电阻 Riraw（下图）。

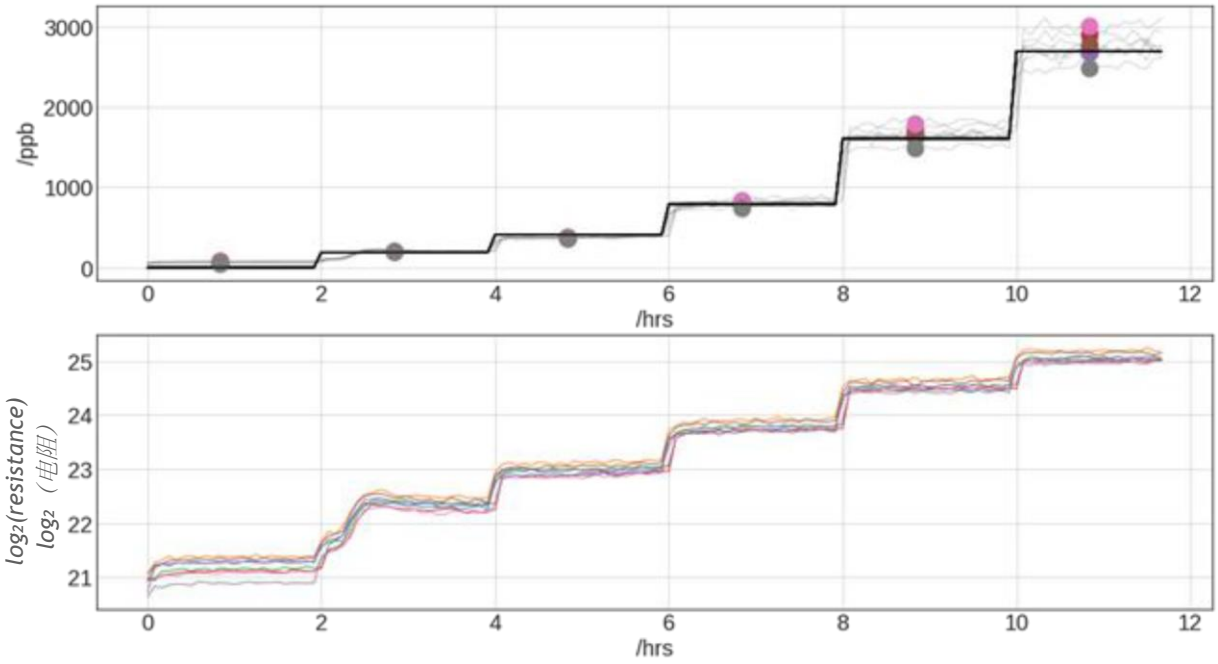
**Figure 7: Raw Sensor Signal Response to Hydrogen**
**图 7：原始传感器信号对氢气的响应**

[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 µL/m³
[1] 以 ppm（=百万分率）和 ppb（=十亿分率）表示的术语"浓度"是指空气中相应气体的体积分数：1 ppm=1mL/m³= 1000 ppb = 1000µL/m³


8000
6000
4000
2000
/ppb
0
2
4
6
8
10
12
/hrs
21.5
21.0
20.5
20.0
19.5
19.0
log2(resistance)
log2（电阻）
0
2
4
6
8
10
12
/hrs

The following figures show the response of eight ENS160s to various nitrogen dioxide concentration steps (upper diagram) and the corresponding raw sensor resistance Riraw (lower diagram).
下图所示为八个 ENS160 对各种二氧化氮浓度阶跃的响应（上图）和相应原始传感器电阻 Riraw（下图）。

**Figure 8: Raw Sensor Signal Response to Nitrogen Dioxide**
**图 8：原始传感器信号对二氧化氮的响应**




**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).
**注：**由于传感器原始电阻值的性质，这些信号未进行调整，即未对偏差、老化或交叉灵敏度（本底气体的干扰，包括湿度）进行补偿。

# 8 Signal Conditioning
# 8 信号调节

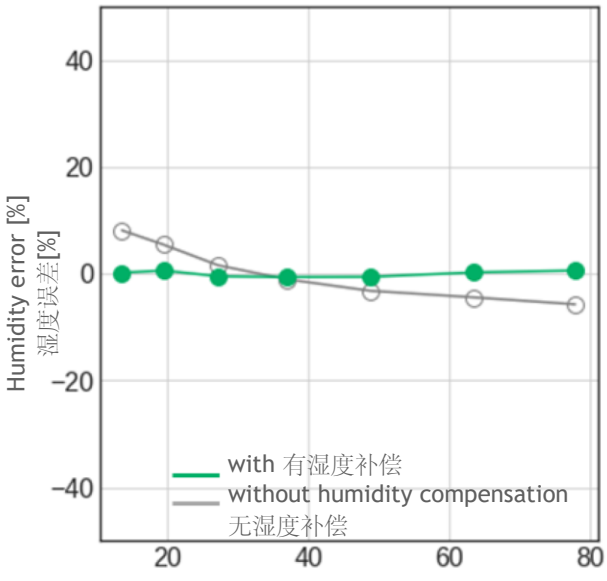
Chemical gas sensors are relative sensors that are susceptible to changes in their chemical and physical environments. Typical drivers are changes of the target gas(es), of the interfering background gas mixture and changes of the physical environment (air pressure, humidity, etc.). 化学气体传感器属于相对传感器，易受其化学和物理环境变化的影响。典型的驱动因素有目标气体、干扰本底气体混合物的变化以及物理环境（气压、湿度等）的变化。

## 8.1 Baselining
## 8.1 基线值

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.
作为 TrueVOC™技术的一部分，ENS160 采用了自动基线校准，具有对臭氧等氧化气体进行补偿的功能。此外，它还将当前基线值存储在非易失性存储器中，以便在重新给器件供电之后，甚至在断电之后，从环境空气的最新有效水平自动开始。

## 8.2 Humidity Behavior & Compensation
## 8.2 湿度性能和补偿

**Figure 9: Air Quality Signal with and without Humidity Compensation**
**图 9：有无湿度补偿的空气质量信号**




For use in normal air quality applications ($eCO_2$, 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.
如果在相对湿度范围为 20%至 80%之间的正常空气质量应用($eco_2$(TVOC, AQI)中使用，则 ENS160 无需外部湿度补偿，如对面图表所示。

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.
超出此范围（20%~80%RH）的极端湿度条件会影响输出信号，尤其是需要非常精确的测量值或单一气体测量值时。为了排除这些影响，ENS160 配备了温度和湿度补偿算法，该算法依赖于来自外部温

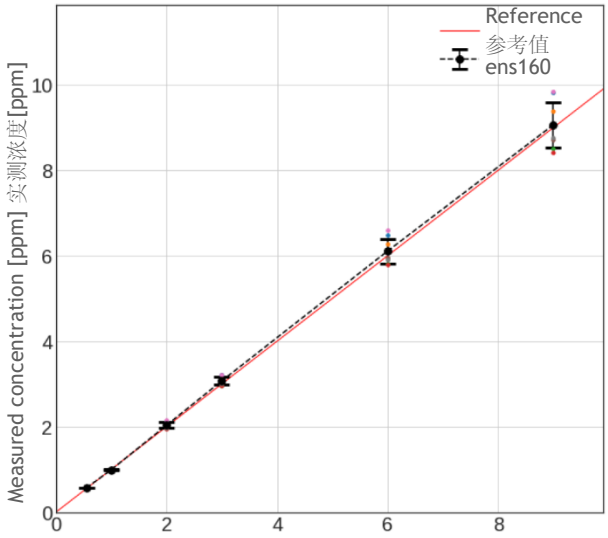
度和湿度传感器的数据（ENS160 与 ScioSense ENS21x 系列温度和湿度传感器配合良好，因为它们共享相同的信号格式），可以定期更新到内部寄存器进行处理。

**Note:** Unless otherwise stated, the humidity compensation discussed in this section works per default for all output signals except for sensor raw signals.
**注**：除非另有说明，否则本节讨论的湿度补偿默认适用于除传感器原始信号以外的所有输出信号。

See sections “Registers”, “TEMP_IN” and “RH_IN” for further information.
详见“寄存器”、“TEMP_IN””和“RH_IN”章节。

# 9 Output Signal Accuracy[1]
# 9 输出信号精度[1]

Figure 10: Output Signal Accuracy for Hydrogen
图 10：氢气输出信号精度

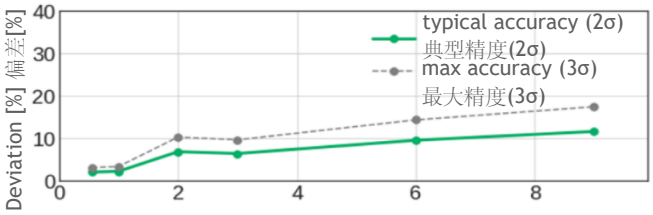



The ENS160 exhibits an excellent measurement accuracy and device-to-device variation.

ENS160 表现出优秀的测量精度和一致性。

The opposite diagrams show the non- linearity of several devices (left) and typical and maximum accuracies (bottom) for various hydrogen concentrations. A typical error of <12% of the measured value can be stated.

相应的图表显示了几个器件的非线性（左），以及不同氢气浓度的典型精度和最大精度（下）。可以看出，测量值的典型误差小于 12%。




# 10 Initial Start-Up and Warm-Up
# 10 初始启动和预热

Table 9: Initial Start-Up and Warm-Up Timings
表 9：初始启动和预热时序

| Parameter<br>参数 | Maximum Time<br>最长时间 | Comment<br>备注 |
|---|---|---|
| Initial Start-Up<br>初始启动 | 1 hour<br>1 小时 | See below for further details<br>参见下文了解更详细的信息。 |
| Warm-Up<br>预热 | 1 minute<br>1 分钟 | |

## 10.1 Initial Start-Up
## 10.1 初始启动

Initial Start-Up is the time the ENS160 needs to exhibit reasonable air quality readings after its

[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.

[1]所有值均是通过在具有规定环境条件、经过合适参考分析和至少 24 小时传感器预处理的气候室中的清洁、部分合成空气中进行试验测定所得，可能无法反映真实环境。除非另有说明，否则精度声明是在 25°C 和 50%相对湿度下经测试后确定的。

first ever power-on.
初始启动是指 ENS160 在首次通电后显示合理空气质量读数所需的时间。

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 $eCO_2$-, TVOC- and AQI-output signals to be used from first power-on after 1 hour of operation[2].
首次通电时，ENS160 传感器的原始电阻信号和灵敏度会发生变化。在运行的前 48 小时，电阻变化最大。因此，ENS160 采用启动算法，使我们可以在运行1 小时后[2]，从首次通电开始使用 $eCO_2$-、TVOC-和 AQI 输出信号。

## 10.2 Warm-Up
## 10.2 预热

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 expected.
关于“初始启动”调节或“预热”周期是指在空闲周期或断电后测量 VOC 之前，传感器的稳定性达到足够程度所需的时间。通常情况下，ENS160 需要 1 分钟时间预热，才能获得合理的空气质量读数。

[2] Slightly reduced signal accuracy may be encountered in early phase, thereafter.
[2]此后，在早期阶段可能会遇到信号精度略微降低的情况。

# 11 Gas Sensor Status and Signal Rating
# 11 气体传感器状态和信号等级

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.
状态标志是评估当前工作模式和输出信号可靠性的附加功能。该功能有助于应用程序有效管理时序，尤其是在初始启动或重新通电后。此外，还可以进行简单的信号质量评估和系统自检。

**Table 10: ENS160 Status and Signal Rating (Validity Flag)**
**表 10：ENS160 状态和信号等级（有效性标志）**

| Flag<br>标志 | Meaning<br>含义 | Implementation approach<br>执行方法 |
|---|---|---|
| 0 | Operating ok<br>运行正常 | Standard operating mode.<br>标准工作模式。 |
| 1 | Warm-up<br>预热 | During first minute after power-on.<br>通电后第一分钟内。 |
| 2 | Initial Start-up<br>初始启动 | During first hour after power-on. Only once in a lifetime.<br>通电后第一小时内。使用寿命内只有一次。 |
| 3 | No valid output<br>无有效输出 | Signals give unexpected values (very high or very low). Multiple sensors out of range.<br>信号给出的值超出预期（极高或极低）。多个传感器超出范围。 |

See “Validity Flag” in section “DATA_STATUS” for further information.
更多信息请参见“DATA_STATUS”部分的“有效性标志”。

# 12 Recommended Sensor Operation
# 12 建议的传感器使用

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.
为发挥出最佳性能，传感器应在正常室内空气中运行，室温范围为-5°C 至 60°C（典型值：25°C）；相对湿度：20%至 80%RH（典型值：50%RH），不冷凝，不存在腐蚀性或有毒气体。长时间暴露于不符合这些条件的环境中，传感器的性能和使用寿命会受到影响。

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.
另请参考“ENS160 设计指南和处理说明”，了解更多关于 ENS160 处理和最佳整合的信息。必须遵守本文档中的指南，才能使传感器发挥出最佳性能并延迟使用寿命。

**Important Note:** The ENS160 is not designed for use in any safety-critical or life-protecting application.
**重要说明：**ENS160 并不是为任何安全关键或生命保护应用而设计的。

# 13 Recommended Sensor Storage

# 13 建议的传感器储存方法

The guidelines under “Recommended Sensor Operation” also apply for sensor storage.
“建议的传感器操作方法”指南也适用于传感器的储存。

# 14 Host Communication
# 14 主机通信

The ENS160 is an I²C or SPI Slave device.
ENS160 是一个 I²C 或 SPI 从器件。

If the CSn 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).
如果 CSn 保持高电平，接口运行状态就和 I²C 从器件一样。上电时，可通过 MISO/ADDR 引脚的状态确定 I²C 地址的 LSB。I²C 从器件地址为 0x52（MISO/ADDR 低电平）或 0x53（MISO/ADDR 高电平）。

If the CSn pin is asserted (low) the interface behaves as an SPI slave. This condition is maintained until the next Power-on Reset.
如果 CSn 引脚被置有效（低电平），则接口运行状态和 SPI 从器件一样。这种状态会一直保持到下一次上电复位。

Both the SPI and I²C slave interfaces use the same register map for communication.
SPI 和 I²C 从器件接口利用相同的寄存器映射进行通信。

## 14.1 I²C Specification
## 14.1 I²C 规范

### *14.1.1 I²C Description*
### *14.1.1 I²C 描述*

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.
如果 MISO/ADDR 线在上电时保持低电平，则 ENS160 作为 I²C 从器件的 7 位固定地址为 0x52，如果 MISO/ADDR 线保持高电平，则 7 位固定地址为 0x53。

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].
I²C 接口支持标准模式(100kbit/s)、快速模式(400kbit/s)和加速模式(1Mbit/s)。关于 I²C 协议的详细信息符合 I²C 总线规范[UM10204，I²C 总线规范和用户手册，第 6 版，2014 年 4 月 4 日]。

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).
该器件具有从器件的所有强制性 I²C 协议特性：开始、停止、确认和 7 位从器件地址。不支持任何其他可选功能（10 位从器件地址、通用调用、软件复位或器件 ID），也不支持主器件功能（同步、仲裁、START 字节）。

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.
主机系统是一个 I²C 主器件，它可以首先发送单字节寄存器地址，从而将值直接读取或写入到其中一个寄存器。ENS160 实现了“自动增量”，这意味着可以在单个事务中读取或写入多个字节（例如，读

取多个 DATA_X 字节）。

### *14.1.2 I²C I/O and Timing Information*
### *14.1.2 I²C I/O 和时序信息*

**Table 11: ENS160 I2C I/O Parameters**
**表 11：ENS160 I²C I/O 参数**

| Parameter 参数 | Symbol 符号 | Standard 标准模式 | | Fast 快速模式 | | Fast Mode Plus 加速模式 | | Unit 单位 |
|---|---|---|---|---|---|---|---|---|
| | | Min 最小值 | Max 最大值 | Min 最小值 | Max 最大值 | Min 最小值 | Max 最大值 | |
| Low level input voltage 低电平输入电压 | $V_{IL}$ | -0.5 | 0.3x$V_{DDIO}$ | -0.5 | 0.3x$V_{DDIO}$ | -0.5 | 0.3x$V_{DDIO}$ | V |
| High level input voltage 高电平输入电压 | $V_{IH}$ | 0.7x$V_{DDIO}$ | 2.39 | 0.7x$V_{DDIO}$ | 2.39 | 0.7x$V_{DDIO}$ | 2.39 | V |
| Hysteresis of Schmitt trigger inputs 迟滞施密特触发器输入电压 | $V_{HYS}$ | - | - | 0.05x$V_{DDIO}$ | - | 0.05x$V_{DDIO}$ | - | V |
| Low-level output voltage @ 2mA sink current 低电平输出电压 @2mA 灌电流 | $V_{OL2}$ | - | - | 0 | 0.2x$V_{DDIO}$ | 0 | 0.2x$V_{DDIO}$ | V |
| Low-level output current @ 0.4V 低电平输出电流@0.4V | $I_{OL}$ | 3 | | 3 | | 20 | | mA |
| Output fall time from $V_{IHmin}$ to $V_{ILmax}$ 输出从 $V_{IHmin}$ 下降到 $V_{ILmax}$ 的时间 | $T_{OF}$ | | 250 | 20x$V_{DDIO}$ /5.5 | 250 | 20x$V_{DDIO}$ /5.5 | 250 | ns |
| Input current each I/O pin 每个 I/O 引脚的输入电流 | $I_I$ | -10 | 10 | -10 | 10 | -10 | 10 | µA |

Table 12: ENS160 I2C Timing Parameters[1]

表 12：ENS160 I²C 时序参数[1]

| Parameter<br>参数 | Symbol<br>符号 | Standard<br>标准模式 | | Fast<br>快速模式 | | Fast Mode Plus<br>加速模式 | | Unit<br>单位 |
|---|---|---|---|---|---|---|---|---|
| | | Min<br>最小值 | Max<br>最大值 | Min<br>最小值 | Max<br>最大值 | Min<br>最小值 | Max<br>最大值 | |
| SCLK clock frequency<br>SCL 时钟频率 | $f_{SCLK}$ | 0 | 100 | 0 | 400 | 0 | 1000 | kHz |
| Hold time (repeated) START condition. After this period, the first clock pulse is generated<br>保持时间（重复）“开始”状态。在该周期之后，系统将产生第一个时钟脉冲 | $t_{HD\_STA}$ | 4 | - | 0.6 | - | 0.26 | - | µs |
| LOW period of the SCLK clock<br>SCLK 时钟的低电平周期 | $t_{LOW}$ | 4.7 | - | 1.3 | - | 0.5 | - | µs |
| HIGH period of the SCLK clock<br>SCLK 时钟的高电平周期 | $t_{HIGH}$ | 4.0 | - | 0.6 | - | 0.26 | - | µs |
| Set-up time for a repeated START condition<br>重复“开始”状态的设置时间 | $t_{SU\_STA}$ | 4.7 | - | 0.6 | - | 0.26 | - | µs |
| Data set-up time<br>数据设置时间 | $t_{SU\_DAT}$ | 250 | - | 100[2] | - | 50[2] | - | ns |
| Data hold-time<br>数据保持时间 | $t_{HD\_DAT}$ | 0 3 | 3.45[4] | 0[3] | 0.9[4] | 0[3] | - | µs |
| Rise time of SDA and SCLK signals<br>SDA 和 SCLK 信号的上升时间 | $t_r$ | - | 1000 | 20 | 300 | 20 | 120 | ns |
| Fall time of SDA and SCLK signals<br>SDA 和 SCLK 信号的下降时间 | $t_f$ | - | 300 | 20x$V_{DDIO}$ /5.5 | 300 | 20x$V_{DDIO}$ /5.5 | 120 | ns |
| Set-up time for STOP condition<br>“停止”状态的设置时间 | $t_{SU\_STO}$ | 4.0 | - | 0.6 | - | 0.26 | - | µs |
| Bus free time between a STOP and START condition<br>“停止”和“开始”状态之间的总线空闲时间 | $t_{BUF}$ | 4.7 | - | 1.3 | - | 0.5 | - | µs |
| Capacitive load for each bus line<br>每条总线的容性负载 | Cb | - | 400 | - | 400 | - | 550 | pF |
| Noise margin at the LOW level<br>低电平下的噪声容限 | $V_{NL}$ | 0.1x$V_{DDIO}$ | - | 0.1x$V_{DDIO}$ | - | 0.1x$V_{DDIO}$ | - | V |

[1] All values referred to $V_{IH}$min and $V_{IL}$max levels

[1]所有值均指 $V_{IH}$min 和 $V_{IL}$max 电平

[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 trmax. $t_{SU\_DAT}$= 1000 + 250 = 1250ns (according to standard mode I²C bus specification) before the SCL line is released.

[2]快速模式 I²C 总线器件可以用于标准模式 I²C 总线系统，但是必须满足 tsu_dat>=250ns 的要求。如果器件没有延长 SCL 信号的低电平周期，就会自动出现这种情况。如果这种器件延长了 SCL 信号的低电平周期，则必须在 SCL 线释放之前将下一个数据位输出到 SDA 线 trmax. tsu_dat=1000+250=1250ns（根据标准模式 I²C 总线规范）。

[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

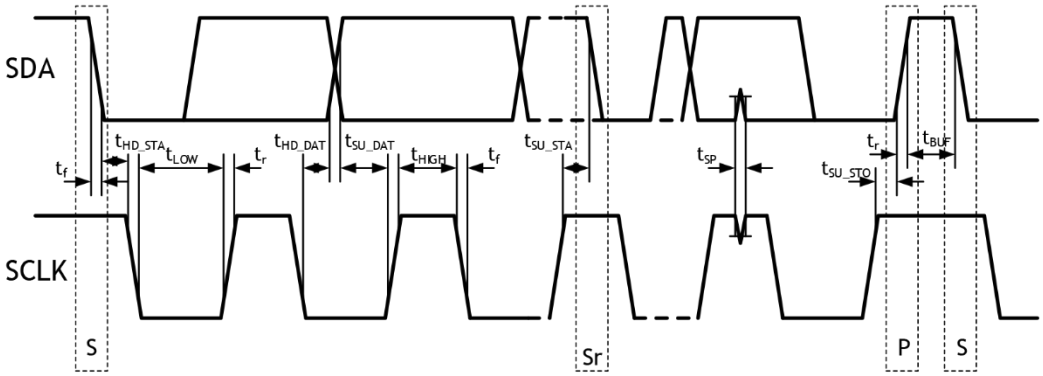
[3]该器件内部为 SDA 信号设置的保持时间至少为 300ns，以桥接 SCL 下降边缘的未定义区域

[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

[4]只有当器件没有延长 SCLK 信号的低电平周期时(tlow)，才需要满足最大 thd_dat

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Noise margin at the HIGH level<br>高电平下的噪声容限 | VNH | 0.2xVDDIO | - | 0.2xVDDIO | - | 0.2xVDDIO | - | V |

Figure 11: Definition of I2C Timing Parameters
图 11：I²C 时序参数的定义



### 14.1.3 I2C Read Operation
### 14.1.3 I²C 读取操作

After the START condition, in the first transaction:
“开始”状态后，在第一次通讯中：

- 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).
- I²C 主器件将 7 位从器件地址和 0 发送至 R/W 位（发送的字节为 0xA4 或 0xA6，具体取决于 MISO/ADDR 的上电值）。
- The I²C Master then sends the address of the first register to read.
- 然后，I²C 主器件会发送要读取的第一个寄存器的地址。

Then either after a RESTART condition (i.e. STOP followed by START)
然后在“重新启动”状态（即停止后启动）后

- 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).
- I²C 主器件将 7 位从器件地址和 1 发送至 R/W 位（发送的字节为 0xA5 或 0xA7，具体取决于 MISO/ADDR 的上电值）。
- The I²C Master then reads 1-n data bytes from sequential registers (if valid) until the transaction is concluded with a STOP condition.
- 然后，I²C 主器件会从顺序寄存器中读取 1-n 个数据字节（如果有效），直到事务以“停止”状态结束。

Figure 12: I2C Read Operation
图 12：I²C 读取操作

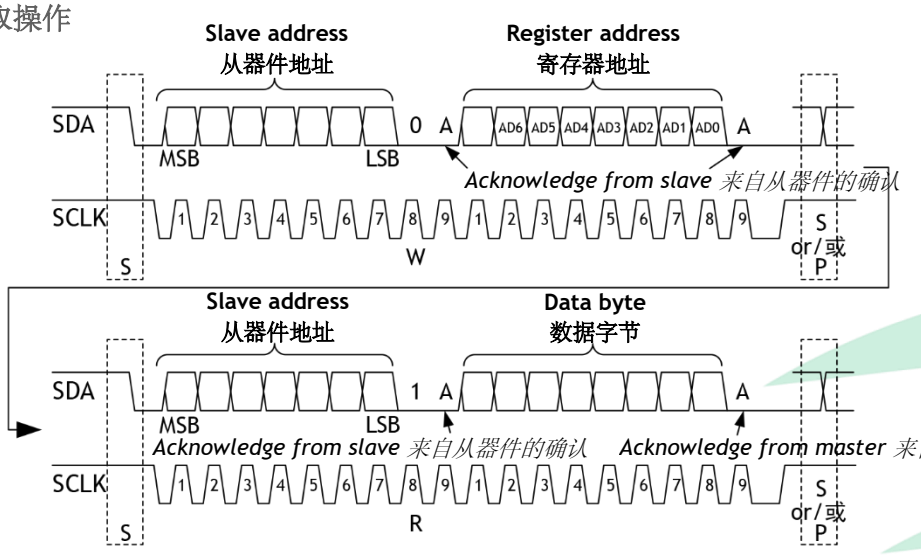
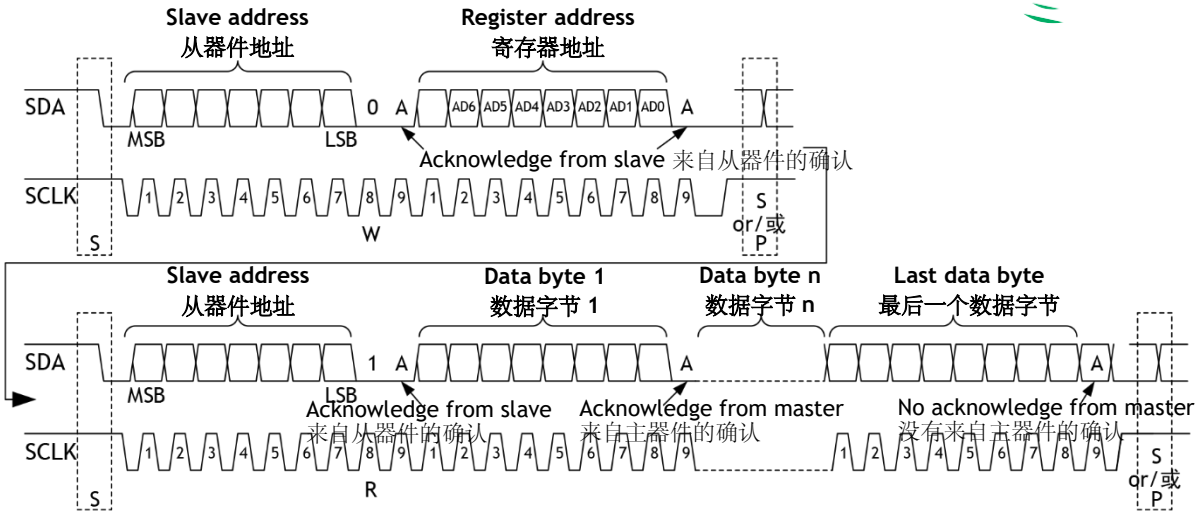



Figure 13: I2C Auto-Increment Read Operation
图 13：I²C 自动增量读取操作


Slave address
从器件地址
Register address
寄存器地址
SDA
SCLK
MSB
LSB
0
A
AD6
AD5
AD4
AD3
AD2
AD1
AD0
A
Acknowledge from slave 来自从器件的确认
S
W
S or/或 P
Slave address
从器件地址
Data byte 1
数据字节 1
Data byte n
数据字节 n
Last data byte
最后一个数据字节
1
A
Acknowledge from slave
来自从器件的确认
Acknowledge from master
来自主器件的确认
No acknowledge from master
没有来自主器件的确认
R

### 14.1.4 I2C Write Operation
### 14.1.4 I²C 写入操作

After the START condition, in a single continuous transaction:
“开始”状态后，在单个连续通信中：

- 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).
- I²C 主器件将 7 位从器件地址和 0 发送至 R/W 位（发送的字节为 0xA4 或 0xA6，具体取决于 MISO/ADDR 的上电值）。
- The I²C Master then sends the address of the first register to write.
- 然后，I²C 主器件会发送要写入的第一个寄存器的地址。
- 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.
- 之后，I²C 主器件会发送 1-n 个数据字节，这些数据字节将写入顺序寄存器（如果有效），直到事务以“停止”状态结束。

Figure 14: I2C Write Operation
图 14：I²C 写入操作

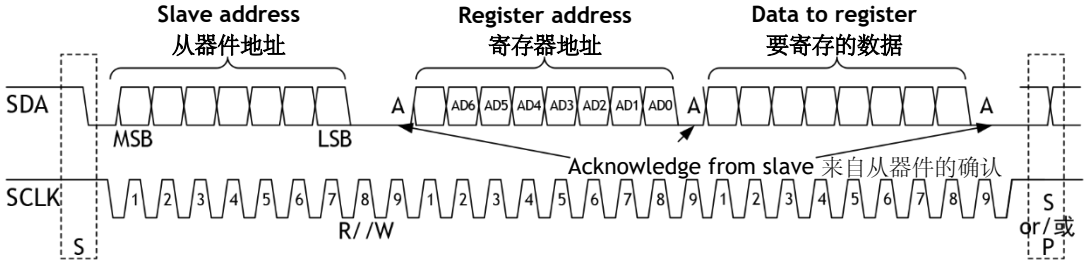
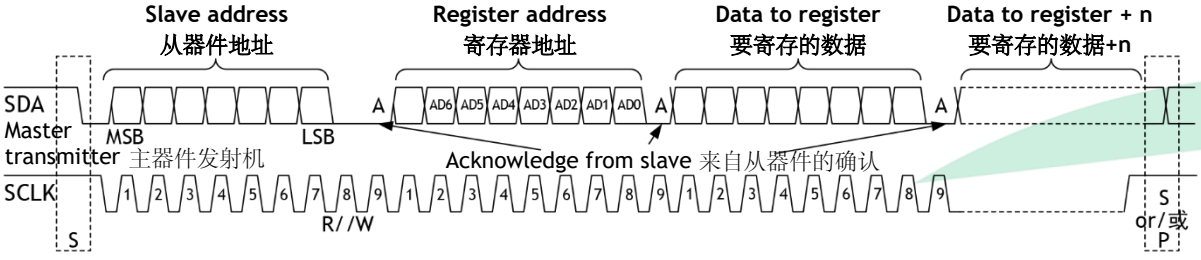



Figure 15: I2C Auto-Increment Write Operation
图 15：I²C 自动增量写入操作



## 14.2 SPI Specification
## 14.2 SPI 规格

### *14.2.1 SPI Description*
### *14.2.1 SPI 描述*

The SPI interface is a slave bus operating up to 10MHz clock-frequency.
SPI 接口是一个从器件总线，工作时钟频率高达 10MHz。

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.
它与 I²C 接口共享引脚。将 CSn 线置为有效低电平，以便选择 SPI 并启动 SPI 传输。一旦 CSn 线被置为有效低电平，ENS160 将不接受 I²C 通信，直到下一次上电复位。

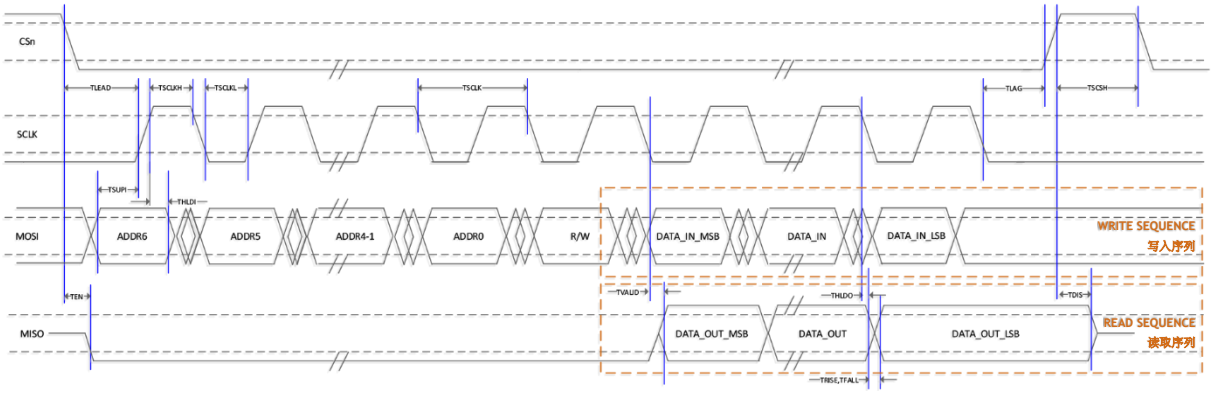
Data is clocked in on the rising edge of SCLK; most significant bit first.
数据在 SCLK 上升边缘进行时钟输入；最高有效位优先。

### *14.2.2 SPI Timing Information*
### *14.2.2 SPI 时序信息*

Table 13: SPI Timings
表 13：SPI 时序

| Parameter<br>参数 | Symbol<br>符号 | Condition<br>条件 | Min<br>最小值 | Typ<br>类型 | Max<br>最大值 | Unit<br>单位 |
|---|---|---|---|---|---|---|
| SPI Clock (SCLK) Frequency<br>SPI 时钟(SCLK)频率 | FSCLK | | | | 10 | MHz |
| CSn falling to MISO Enabled<br>启用“CSn 下降至 MISO”功能 | TEN | 25pF load<br>25pF 负载 | | | 20 | ns |
| CSn rising to MISO Disable<br>禁用“CSn 上升至 MISO”功能 | TDIS | 25pF load<br>25pF 负载 | | | 20 | ns |
| MOSI Setup Time before SCLK<br>SCLK 之前的 MOSI 设置时间 | TSUPI | | 15 | | | ns |
| MOSI hold time after rising SCLK<br>SCLK 上升后的 MOSI 保持时间 | THLDI | | 15 | | | ns |
| CSn low to first rising SCLK<br>SCLK 首次上升时的 CSn 低电平 | TLEAD | | 20 | | | ns |
| Last SCLK low to CSn high<br>到 CSn 高电平的最后一个 SCLK 低电平 | TLAG | | 20 | | | ns |
| SCLK High Time<br>SCLK 高电平时间 | TSCLKH | | 40 | | | ns |
| SCLK Low Time<br>SCLK 低电平时间 | TSCLKL | | 40 | | | ns |
| SCLK falling to MISO Valid<br>“SCLK 下降至 MISO”功能有效 | TVALID | 25pF load<br>25pF 负载 | | | 40 | ns |

Figure 16 SPI Timings Reference
图 16 SPI 时序参考


CSn
SCLK
MOSI
MISO
TLEAD
TSCLKH
TSCLKL
TSCLK
TLAG
TSCSH
TSUPI
THLDI
TEN
ADDR6
ADDR5
ADDR4-1
ADDR0
R/W
DATA_IN_MSB
DATA_IN
DATA_IN_LSB
WRITE SEQUENCE
写入序列
TVALID
THLDO
TDIS
DATA_OUT_MSB
DATA_OUT
DATA_OUT_LSB
READ SEQUENCE
读取序列
TRISE,TFALL

### 14.2.3 SPI Read Operation
### 14.2.3 SPI 读取操作

During a Read operation, data is clocked out on the falling edge of SCLK so it is stable for the following riding edge.
在读取操作期间，数据将在 SCLK 下降边缘进行时钟输出，从而在随后的上升边缘保持稳定。

MISO stays in high impedance mode until the device is selected (CSn low). Data on MISO is only valid on a Read operation.
在选择器件（CSn 低电平）之前，MISO 将保持在高阻抗模式。MISO 上的数据仅在读取操作时有效。

A transaction starts with the target address and R/W control bit in the first byte followed by the read or write data.
通信从目标地址和第一个字节的 R/W 控制位开始，然后是读取或写入数据。

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.
在读取操作中，地址的自动增量使多个寄存器能够按顺序读取。CSn 撤销（至高电平）可终止读取序列。

A Read SPI frame is composed as follows:
读取 SPI 帧由以下内容组成：

Table 14: Read SPI Frame
表 14：读取 SPI 帧

| Byte<br>字节 | Bit<br>位 | Name<br>名称 | Description<br>描述 |
|---|---|---|---|
| 0 | 7:1 | AD[6:0] | On MOSI: Address of the register to Read<br>在 MOSI 上：要读取的寄存器地址 |
| 0 | 0 | RW | On MOSI: 1: bytes are to be read, starting from AD[6:0].<br>在 MOSI 上：1：从 AD[6:0]处开始读取字节。 |
| 1 | 7:0 | RDATA[7:0] | Output on MISO; MOSI ignored<br>MISO 上的输出；MOSI 已忽略 |
| n | 7:0 | RDATA[7:0] | Output on MISO; MOSI ignored<br>MISO 上的输出；MOSI 已忽略 |

### 14.2.4 SPI Write Operation
### 14.2.4 SPI 写入操作

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.
在写入操作中，地址不会自动增量。可以通过交替使用地址和数据字节来执行多次写入。CSn 撤销（至高电平）可终止写入序列。

A Write SPI frame is composed as follows:
写入 SPI 帧由以下内容组成：

Table 15: Write SPI Frame
表 15：写入 SPI 帧

| Byte<br>字节 | Bit<br>位 | Name<br>名称 | Description<br>描述 |
|---|---|---|---|
| 0 | 7:1 | AD[6:0] | On MOSI: Address of the register to Write<br>在 MOSI 上：要写入的寄存器地址 |
| 0 | 0 | RW | On MOSI: 0: bytes are to be Written, at AD[6:0].<br>在 MOSI 上：0：在 AD[6：0]处写入字节。 |
| 1 | 7:0 | WDATA[7:0] | Input on MOSI; MISO Dummy Data<br>MOSI 上的输入；MISO 虚拟数据 |
| even<br>偶数 | 7:1 | AD[6:0] | On MOSI: Address of the register to Write<br>在 MOSI 上：要写入的寄存器地址 |
| even<br>偶数 | 0 | RW | On MOSI: 0: bytes are to be Written, at AD[6:0].<br>在 MOSI 上：0：在 AD[6：0]处写入字节。 |
| odd<br>奇数 | 7:0 | WDATA[7:0] | Input on MOSI; MISO Dummy Data<br>MOSI 上的输入；MISO 虚拟数据 |

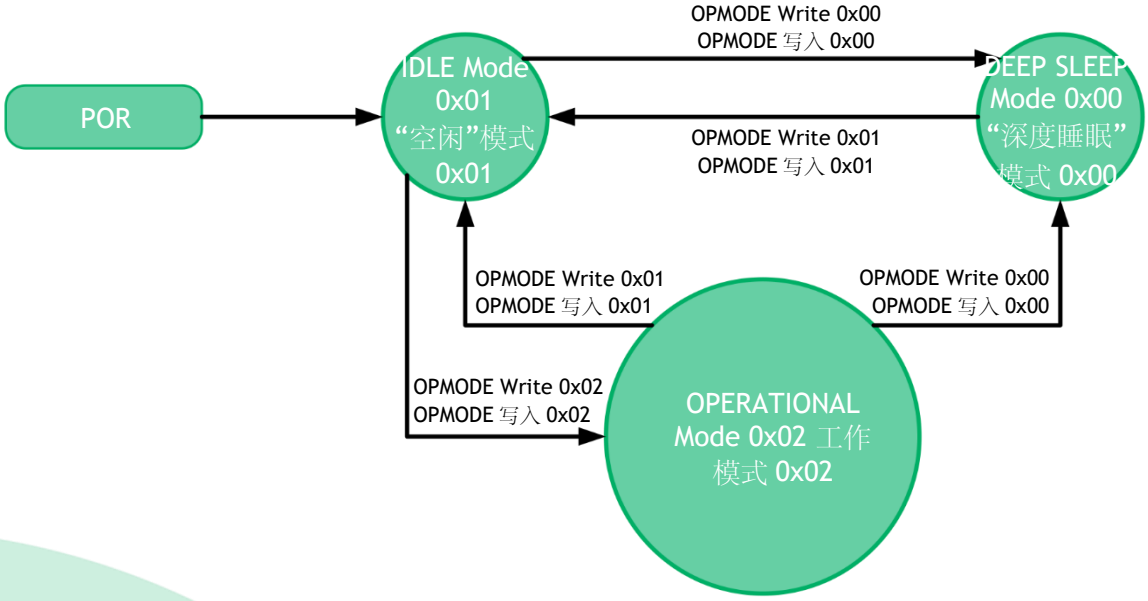
# 15 Operation
# 15 操作

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.
上电时，ENS160 将从复位状态进行自动配置，并准备采用 I²C 或 SPI 协议，通过串行总线发送命令。

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.
默认状态为 OPMODE 0x01，这是一个启用 ENS160 以便响应多个命令的“空闲”状态。在此模式下，它不能发挥气体传感器的作用。

OPMODE 0x00 is a very low power standby state, called DEEP SLEEP. Active OPMODEs are described further in the OPMODE Register section.
OPMODE 0x00 是一种功耗极低的待机状态，称为“深度睡眠”。有效 OPMODE 在“OPMODE 寄存器”部分有进一步描述。

Figure 17 Orchestration of Operational Modes
图 17 操作模式的编排




**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.
**注：** 当活性气体传感 OPMODE（例如，0x02 =标准）运行时，可通过中断（INTn）或轮询 DATA_STATUS 寄存器来通知新数据。气体传感 OPMODE 的输出将在 DATA_XXX 寄存器中出现，可随时读取。

# 16 Registers
# 16 寄存器

This section describes the registers of the ENS160 which enable the host system to
本节描述了 ENS160 的寄存器，这些寄存器使主机系统能够

- Identify the Device and version information
- 识别器件和版本信息
- Configure the ENS160 and set the operating mode
- 配置 ENS160 并设置工作模式
- Read back STATUS information, the calculated gas concentrations and Air Quality Indices
- 读回“状态”信息、计算气体浓度和空气质量指数

## 16.1 Register Overview
## 16.1 寄存器概述

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.
请注意，有些寄存器分布在多个地址上。例如，地址 0 处的 PART_ID 分布在 2 个地址上（其“大小”为 2）。寄存器将以小端序存储，因此 PART_ID 的 LSB 在地址 0 处，PART_ID 的 MSB 在地址 1 处。

Table 16: Register Overview
表 16：寄存器概述

| Address<br>地址 | Name<br>名称 | Size<br>规格 | Access<br>访问 | Description<br>描述 |
|---|---|---|---|---|
| 0x00 | PART_ID | 2 | Read<br>读取 | Device Identity 0x01, 0x60<br>器件标识 0x01、0x60 |
| 0x10 | OPMODE | 1 | Read / Write<br>读/写 | Operating Mode<br>工作模式 |
| 0x11 | CONFIG | 1 | Read / Write<br>读/写 | Interrupt Pin Configuration<br>中断引脚配置 |
| 0x12 | COMMAND | 1 | Read / Write<br>读/写 | Additional System Commands<br>附加系统命令 |
| 0x13 | TEMP_IN | 2 | Read / Write<br>读/写 | Host Ambient Temperature Information<br>主机环境温度信息 |
| 0x15 | RH_IN | 2 | Read / Write<br>读/写 | Host Relative Humidity Information<br>主机相对湿度信息 |
| 0x17 - 0x1F | - | 1 | - | Reserved<br>保留 |
| 0x20 | DEVICE_STATUS | 1 | Read<br>读取 | Operating Mode<br>工作模式 |
| 0x21 | DATA_AQI | 1 | Read<br>读取 | Air Quality Index<br>空气质量指数 |
| 0x22 | DATA_TVOC | 2 | Read | TVOC Concentration (ppb) |

| | | | | |
|---|---|---|---|---|
| | | | 读取 | TVOC 浓度(ppb) |
| **0x24** | DATA_ECO2 | 2 | Read<br>读取 | Equivalent $CO_2$ Concentration (ppm)<br>等效 $CO_2$浓度(ppm) |
| **0x26** | - | 2 | - | Reserved<br>保留 |
| **0x28** | - | 2 | - | Reserved<br>保留 |
| **0x2A** | - | 2 | Read<br>读取 | Reserved<br>保留 |
| **0x2C - 0x2F** | - | 1 | - | Reserved<br>保留 |
| **0x30** | DATA_T | 2 | Read<br>读取 | Temperature used in calculations<br>计算中使用的温度 |
| **0x32** | DATA_RH | 2 | Read<br>读取 | Relative Humidity used in calculations<br>计算中使用的相对湿度 |
| **0x34 - 0x37** | - | 1 | - | Reserved<br>保留 |
| **0x38** | DATA_MISR | 1 | Read<br>读取 | Data Integrity Field (optional)<br>数据完整性字段（可选） |
| **0x40** | GPR_WRITE[0:7] | 8 | Read/Write<br>读/写 | General Purpose Write Registers<br>通用写入寄存器 |
| **0x48** | GPR_READ[0:7] | 8 | Read<br>读取 | General Purpose Read Registers<br>通用读取寄存器 |

## 16.2 Detailed Register Description
## 16.2 寄存器的详细描述

### *16.2.1 PART_ID (Address 0x00)*
### *16.2.1 PART_ID（地址 0x00）*

This 2-byte register contains the part number in little endian of the ENS160.
这个 2 字节寄存器包含有 ENS160 的零件号（小端序形式）。

The value is available when the ENS160 is initialized after power-up.
该值在上电后 ENS160 初始化时可用。

**Table 17: Register PART_ID**
**表 17：寄存器 PART_ID**

| Address 0x00<br>地址 0x00 | | | | PART_ID |
|---|---|---|---|---|
| **Bits<br>数位** | **Field Name<br>字段名称** | **Default<br>默认值** | **Access<br>访问** | **Field Description<br>字段描述** |
| **0:7** | PART_ID_LSB | 0x60 | read<br>读取 | Lower Byte of Part ID<br>零件 ID 的低位字节 |
| **8:15** | PART_ID_MSB | 0x01 | read<br>读取 | Upper Byte of Part ID<br>零件 ID 的高位字节 |

### *16.2.2 OPMODE (Address 0x10)*
### *16.2.2 OPMODE（地址 0x10）*

This 1-byte register sets the Operating Mode of the ENS160. The Host System can write a new OPMODE at any time.
该 1 字节寄存器可设置 ENS160 的工作模式。主机系统可以随时写入新的 OPMODE。

Any current operating mode will terminate and the new operating mode will start.
任何当前工作模式都将终止，代之以新的工作模式。

**Table 18: Register OPMODE**
**表 18：寄存器 OPMODE**

| Address 0x10<br>地址 0x10 | | | | OPMODE |
|---|---|---|---|---|
| **Bits<br>数位** | **Field Name<br>字段名称** | **Default<br>默认值** | **Access<br>访问** | **Field Description<br>字段描述** |
| **7:0** | | 0x00 | R/W | Operating mode:<br>工作模式：<br>0x00: DEEP SLEEP mode (low power standby)<br>0x00:“深度睡眠”模式（低功耗待机）<br>0x01: IDLE mode (low-power)<br>0x01:“空闲”模式（低功耗）<br>0x02: STANDARD Gas Sensing Modes<br>0x02:标准气体传感模式 |

In DEEP SLEEP mode, ENS160 has limited functionality but will respond to an OPMODE write.
在“深度睡眠”模式下，ENS160 的功能有限，但会响应 OPMODE 写入。

Idle Mode is intended for configuration before running an active sensing mode.
在运行主动传感模式之前，可利用空闲模式进行配置。

0x02 (STANDARD) is an active gas sensing operating mode to indicate the levels of air quality or for specific gas detection.
0x02（标准）是一种主动气体传感工作模式，用于指示空气质量水平或检测特定气体。

### *16.2.3 CONFIG (Address 0x11)*
### *16.2.3 CONFIG（地址 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.
该1 字节寄存器可配置 INTn 引脚的动作，从而允许 ENS160 向主机系统发送信号，表明特定数据可用。

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).
当 ENS160 更新 GPR_Read 寄存器或“数据”寄存器时，或者当达到某个阈值时（通过“命令”模式设置），便可以（撤销）设置有效 INTn 引脚（极性可配置）。

A typical setting 0x23 would enable an active low interrupt (no pull-up required) when new output data is available in the DATA registers.
当“数据”寄存器中有新的输出数据可用时，典型设置 0x23 将启用低电平有效中断（不需要上拉）。

Table 19: Register CONFIG
表 19：寄存器 CONFIG

| Address 0x11<br>地址 0x11 | | | | CONFIG |
|---|---|---|---|---|
| Bits<br>数位 | Field Name<br>字段名称 | Default<br>默认值 | Access<br>访问 | Field Description<br>字段描述 |
| 7 | - | 0b0 | - | Reserved<br>保留 |
| 6 | INTPOL | 0b0 | R/W | INTn pin polarity:<br>INTn 引脚极性：<br>0: Active low (Default)<br>0:低电平有效（默认）<br>1: Active high<br>1:高电平有效 |
| 5 | INT_CFG | 0b0 | R/W | INTn pin drive:<br>INTn 引脚驱动：<br>0: Open drain<br>0:漏极开路<br>1: Push / Pull<br>1:推/拉 |
| 4 | - | 0b0 | - | Reserved<br>保留 |
| 3 | INTGPR | 0b0 | R/W | INTn pin asserted when new data is presented in the General Purpose Read Registers<br>当通用读取寄存器中出现新数据时，INTn 引脚将被设置为有效 |
| 2 | - | 0b0 | - | Reserved<br>保留 |
| 1 | INTDAT | 0b0 | R/W | INTn pin asserted when new data is presented in the DATA_XXX Registers<br>当 DATA_XXX 寄存器中出现新数据时，INTn 引脚将被设置为有效 |
| 0 | INTEN | 0b0 | R/W | INTn pin is enabled for the functions above<br>INTn 引脚的上述功能将启用 |

### *16.2.4 COMMAND (Address 0x12)*
### *16.2.4 命令（地址 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).
该1字节寄存器能够在 ENS160 上执行一些附加命令。该寄存器可以随时写入，但命令只能在“空闲”模式（OPMODE 0x01）下执行。

The COMMAND register allows multiple interactions with the system where data needs to be passed between the user/host and the ENS160.
“命令”寄存器允许与系统进行多次交互，交互过程中，数据需要在用户/主机和 ENS160 之间传递。

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.

通常情况下，请求数据（例如 GetHWVer、GetFWVer）后，所请求的数据将置于通用“读取”寄存器中，并且数据的输入（例如设置报警阈值）将首先存储在地址 0x40-47 处的通用“写入”寄存器中。

Below is a list of valid commands for the ENS160.
下面是 ENS160 的有效命令列表。

**Table 20: Register COMMAND**
**表 20：寄存器 COMMAND**

| Address 0x12<br>地址 0x12 | | | | COMMAND<br>命令 |
|---|---|---|---|---|
| Bits<br>数位 | Field Name<br>字段名称 | Default<br>默认值 | Access<br>访问 | Command<br>命令 |
| 7:0 | Command<br>命令 | 0x00 | R/W | 0x00: ENS160_COMMAND_NOP<br>0x00:ENS160_COMMAND_NOP<br>0x0E: ENS160_COMMAND_GET_APPVER – Get FW Version<br>0x0E:ENS160_COMMAND_GET_APPVER-获取 FW 版本<br>0xCC: ENS160_COMMAND_CLRGPR Clears GPR Read Registers<br>0xCC:ENS160_COMMAND_CLRGPR 可清除 GPR 读取寄存器 |

*16.2.4.1 ENS160_COMMAND_GET_APPVER*
*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.
发出 ENS160_COMMAND_GET_APPVER 后，ENS160 的固件版本将置于通用寄存器 GPR_READ0 和 GPR_READ1 中。如果配置为对 NEWGPR 作出反应，DATA_STATUS 中的 NEWGPR 位将得到设置，而 INTn 将被设置为有效。

**Table 21: GPR_READ Settings for ENS160_COMMAND_GET_APPVER Command**
**表 21：ENS160_COMMAND_GET_APPVER 命令的 GPR_READ 设置**

| Register<br>寄存器 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| GPR_READ0 | Release<br>发行 | | | | Version<br>版本 | | | |
| GPR_READ1 | Sub-Version<br>子版本 | | | | | | | |

*16.2.4.2 ENS160_COMMAND_CLRGPR*
*16.2.4.2 ENS160_COMMAND_CLRGPR*

After issuing ENS160_COMMAND_CLRGPR all GPR Read registers are cleared.
发出 ENS160_COMMAND_CLRGPR 命令后，所有 GPR 读取寄存器都将被清除。

### 16.2.5 TEMP_IN (Address 0x13)
### 16.2.5 TEMP_IN（地址 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.
该2 字节寄存器使主机系统能够将环境温度数据写入 ENS160 进行补偿。寄存器可随时写入。应首先写入 TEMP_IN_LSB，因为在写入 TEMP_IN_MSB 时会识别更新。

Table 22: Register TEMP_IN
表 22：寄存器 TEMP_IN

| Address 0x13<br>地址 0x13 | | | | TEMP_IN |
|---|---|---|---|---|
| Bits<br>数位 | Field Name<br>字段名称 | Default<br>默认值 | Access<br>访问 | Field Description<br>字段描述 |
| 0:7 | TEMP_IN _LSB | 0x00 | R/W | Lower Byte of TEMP_IN<br>TEMP_IN 低字节 |
| 8:15 | TEMP_IN_MSB | 0x00 | R/W | Upper Byte of TEMP_IN<br>TEMP_IN 高字节 |

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:
温度数据的格式与 ENS21x（ScioSense 温度和湿度传感器系列）中使用的格式相同，如下所示：

Table 23: Format of Temperature Data
表 23：温度数据的格式

| Byte 0x14<br>字节 0x14 | | | | | | | | Byte 0x13<br>字节 0x13 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| TEMP_IN Integer Part (Kelvin)<br>TEMP_IN 整数部分（开尔文） | | | | | | | | TEMP_IN Fractions<br>TEMP_IN 分数 | | | | | | | |

The ENS160 required input format is: temperature in Kelvin * 64 (with Kelvin = Celsius + 273.15).
ENS160 要求的输入格式是：温度（单位：开尔文）* 64（开尔文=摄氏度+273.15）。

**Example:** For 25°C the input value is calculated as follows: (25 + 273.15) * 64 = 0x4A8A.
**例如：**例如 25°C，输入值须按如下方式计算：(25+273.15)* 64=0x4A8A.

### 16.2.6 RH_IN (Address 0x15)
### 16.2.6 RH_IN（地址 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.
该2 字节寄存器使主机系统能够将相对湿度数据写入 ENS160 进行补偿。寄存器可随时写入。应首先写入 RH_IN_LSB，因为在写入 RH_IN_MSB 时会识别更新。

Table 24: Register RH_IN

表 24：寄存器 RH_IN

| Address 0x15<br>地址 0x15 | | | | RH_IN |
|---|---|---|---|---|
| **Bits**<br>**数位** | **Field Name**<br>**字段名称** | **Default**<br>**默认值** | **Access**<br>**访问** | **Field Description**<br>**字段描述** |
| **0:7** | RH_IN _LSB | 0x00 | R/W | Lower Byte of RH_IN<br>RH_IN 低字节 |
| **8:15** | RH_IN_MSB | 0x00 | R/W | Upper Byte of RH_IN<br>RH_IN 高字节 |

The format of the relative humidity data is the same as the format used in the ENS21x as shown below:
相对湿度数据的格式与 ENS21x 中使用的格式相同，如下所示：

**Table 25: Format of Relative Humidity Data**
表 25：相对湿度数据的格式

| Byte 0x16<br>字节 0x16 | | | | | | | | Byte 0x15<br>字节 0x15 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RH_IN Integer Part (%)<br>RH_IN 整数部分(%) | | | | | | | | RH_IN Fractions<br>RH_IN 分数 | | | | | | | |

The ENS160 required input format is: relative humidity in %rH * 512.
ENS160 要求的输入格式为：相对湿度(%rH)* 512。

**Example:** For 50% rH the input value is calculated as follows: 50 * 512 = 0x6400.
**例如：**例如 50%RH，输入值须按如下方式计算：50 * 512 = 0x6400.

### 16.2.7 DATA_STATUS (Address 0x20)
### 16.2.7 DATA_STATUS（地址 0x20）

This 1-byte register indicates the current STATUS of the ENS160.
该 1 字节寄存器可指示 ENS160 的当前状态。

**Table 26: Register DATA_STATUS**
**表 26：寄存器 DATA_STATUS**

| Address 0x20<br>地址 0x20 | | DATA_STATUS | | |
|---|---|---|---|---|
| **Bits<br>数位** | **Field Name<br>字段名称** | **Default<br>默认值** | **Access<br>访问** | **Field Description<br>字段描述** |
| **7** | STATAS | 0b0 | - | High indicates that an OPMODE is running<br>高电平表示 OPMODE 正在运行 |
| **6** | STATER | 0b0 | R | High indicates that an error is detected. E.g. Invalid Operating Mode has been selected.<br>高电平表示检测到错误。例如，选择了无效的工作模式。 |
| **5** | - | 0b0 | R | Reserved<br>保留 |
| **4** | - | 0b0 | R | Reserved<br>保留 |
| **2-3** | VALIDITY FLAG<br>有效性标志 | 0b00 | R | Status<br>状态<br>0: Normal operation<br>0:正常运行<br>1: Warm-Up phase<br>1:预热阶段<br>2: Initial Start-Up phase<br>2:初始启动阶段<br>3: Invalid output<br>3:无效输出 |
| **1** | NEWDAT | 0b0 | R | High indicates that a new data is available in the DATA_x registers. Cleared automatically at first DATA_x read.<br>高电平表示 DATA_x 寄存器中有新数据可用。首次读取 DATA_x 时自动清除。 |
| **0** | NEWGPR | 0b0 | R | High indicates that a new data is available in the GPR_READx registers. Cleared automatically at first GPR_READx read.<br>高电平表示 GPR_READx 寄存器中有新数据可用。首次读取 GPR_READx 时自动清除。 |

During operation, Bit 6 (STATER) of DATA_STATUS is asserted if an error has occurred.
在操作过程中，如果发生错误，DATA_STATUS 的位 6(STATER)将被置有效。

The meaning of the errors may be different, depending on the operation being undertaken.
根据正在进行的操作，错误的含义可能有所不同。

Further information regarding the error can be read from the GPR_READ registers.
更多关于错误的信息可以从 GPR_READ 寄存器中读取。

### 16.2.8 DATA_AQI (Address 0x21)

### *16.2.8 DATA_AQI（地址 0x21）*

This 1-byte register reports the calculated Air Quality Index according to the UBA.
该1 字节寄存器可输出基于 UBA 计算的空气质量指数。

**Table 27: Register DATA_ AQI**
**表 27：寄存器 DATA_ AQI**

| Address 0x21<br>地址 0x21 | | DATA_AQI | | |
|---|---|---|---|---|
| **Bits**<br>**数位** | **Field Name**<br>**字段名称** | **Default**<br>**默认值** | **Access**<br>**访问** | **Field Description**<br>**字段描述** |
| **0:2** | AQI_UBA | 0x01 | R | Air Quality Index according to UBA [1..5]<br>基于UBA 计算的空气质量指数[1..5] |
| **3:7** | Reserved<br>保留 | 0x00 | R | Reserved<br>保留 |

See section “AQI-UBA – Air Quality Index of the UBA” for further information.
更多信息请参见“AQI-UBA -UBA 空气质量指数”部分。

### 16.2.9 DATA_TVOC (Address 0x22)
### 16.2.9 DATA_TVOC（地址 0x22）

This 2-byte register reports the calculated TVOC concentration in ppb.
该2 字节寄存器可以 ppb 为单位输出计算的 TVOC 浓度。

**Table 28: Register DATA_TVOC**
**表 28：寄存器 DATA_TVOC**

| Address 0x22<br>地址 0x22 | | DATA_TVOC | | |
|---|---|---|---|---|
| **Bits<br>数位** | **Field Name<br>字段名称** | **Default<br>默认值** | **Access<br>访问** | **Field Description<br>字段描述** |
| **0:7** | TVOC_LSB | 0x00 | R | Lower Byte of DATA_TVOC<br>DATA_TVOC 低字节 |
| **8:15** | TVOC _MSB | 0x00 | R | Upper Byte of DATA_TVOC<br>DATA_TVOC 高字节 |

See section “TVOC – Total Volatile Organic Compounds” for further information.
更多信息请参见“TVOC-总挥发性有机化合物”部分。

### 16.2.10 DATA_$ECO_2$ (Address 0x24)
### 16.2.10 DATA_$ECO_2$（地址 0x24）

This 2-byte register reports the calculated equivalent $CO_2$-concentration in ppm, based on the detected VOCs and hydrogen.
该 2 字节寄存器可根据检测到的挥发性有机化合物和氢气，以 ppm 为单位输出计算的等效 $CO_2$浓度。

**Table 29: Register DATA_$ECO_2$**
**表 29：寄存器 DATA_$ECO_2$**

| Address 0x24<br>地址 0x24 | | DATA_$ECO_2$ | | |
|---|---|---|---|---|
| **Bits<br>数位** | **Field Name<br>字段名称** | **Default<br>默认值** | **Access<br>访问** | **Field Description<br>字段描述** |
| **0:7** | $ECO_2$_LSB | 0x00 | R | Lower Byte of DATA_$ECO_2$<br>DATA_$ECO_2$低字节 |
| **8:15** | $ECO_2$_MSB | 0x00 | R | Upper Byte of DATA_$ECO_2$<br>DATA_$ECO_2$高字节 |

See section “$eCO_2$ – Equivalent $CO_2$” for further information.
更多信息请参见“$eCO_2$-等效 $CO_2$”部分。

### 16.2.11 DATA_ETOH (Address 0x22)
### 16.2.11 DATA_ETOH（地址 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.
该 2 字节寄存器可以 ppb 为单位输出计算的乙醇浓度。对于双重用途，DATA_ETOH 寄存器是乙

醇校准的 DATA_TVOC 寄存器的虚拟镜像。

Table 30: Register DATA_ETH
表 30：寄存器 DATA_ETH

| Address 0x22<br>地址 0x22 | | | | DATA_ETOH |
|---|---|---|---|---|
| Bits<br>数位 | Field Name<br>字段名称 | Default<br>默认值 | Access<br>访问 | Field Description<br>字段描述 |
| 0:7 | ETH_LSB | 0x00 | R | Lower Byte of DATA_ETH<br>DATA_ETH 低字节 |
| 8:15 | ETH_MSB | 0x00 | R | Upper Byte of DATA_ETH<br>DATA_ETH 高字节 |

### *16.2.12 DATA_T (Address 0x30)*
### *16.2.12 DATA_T（地址 0x30）*

This 2-byte register reports the temperature used in its calculations (taken from TEMP_IN, if supplied).
该2 字节寄存器可输出其计算中使用的温度（如果提供，取自 TEMP_IN）。

Table 31: Register DATA_T
表 31：寄存器 DATA_T

| Address 0x30<br>地址 0x30 | | | | DATA_T |
|---|---|---|---|---|
| Bits<br>数位 | Field Name<br>字段名称 | Default<br>默认值 | Access<br>访问 | Field Description<br>字段描述 |
| 0:7 | DATA_T _LSB | 0x8A | R | Lower Byte of DATA_T<br>DATA_T 低字节 |
| 8:15 | DATA_T _MSB | 0x4A | R | Upper Byte of DATA_T<br>DATA_T 高字节 |

The format of the temperature data is the same as the format used in the ENS21x.
温度数据的格式与 ENS21x 中使用的格式相同。

Table 32: Format of Temperature Data
表 32：温度数据的格式

| Byte 0x30<br>字节 0x30 | | | | | | | | Byte 0x31<br>字节 0x31 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| TEMP_IN Integer Part (Kelvin)<br>TEMP_IN 整数部分（开尔文） | | | | | | | | TEMP_IN Fractions<br>TEMP_IN 分数 | | | | | | | |

The DATA_T storage format is: temperature in Kelvin * 64 (with Kelvin = Celsius + 273.15).
DATA_T 存储格式为：温度（开尔文）* 64（开尔文=摄氏度+273.15）。

**Example:** For a stored DATA_T value of 0x4A8A the temperature in °C is calculated as follows: 0x4A8A / 64 - 273.15 = 25°C.
例如：对于 0x4A8A 的存储 DATA_T 值，温度(°C)按如下方式计算：0x4A8A / 64 - 273.15 = 25°C.

See section “TEMP_IN” for further information.
更多信息请参见“TEMP_IN”部分。

### *16.2.13 DATA_RH (Address 0x32)*
### *16.2.13 DATA_RH（地址 0x32）*

This 2-byte register reports the relative humidity used in its calculations (taken from RH_IN if supplied).
该2 字节寄存器可输出其计算使用的相对湿度（如果提供，取自 RH_IN）。

Table 33: Register DATA_RH
表 33：寄存器 DATA_RH

| Address 0x32<br>地址 0x32 | | DATA_RH | | |
|---|---|---|---|---|
| Bits<br>数位 | Field Name<br>字段名称 | Default<br>默认值 | Access<br>访问 | Field Description<br>字段描述 |
| 0:7 | DATA_RH _LSB | 0x00 | R | Lower Byte of DATA_RH<br>DATA_RH 低字节 |
| 8:15 | DATA_RH_MSB | 0x64 | R | Upper Byte of DATA_RH<br>DATA_RH 高字节 |

The format of the relative humidity data is the same as the format used in the ENS21x.
相对湿度数据的格式与 ENS21x 中使用的格式相同。

Table 34: Format of Relative Humidity Data
表 34：相对湿度数据的格式

| Byte 0x32<br>字节 0x32 | | | | | | | | Byte 0x33<br>字节 0x33 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RH_IN Integer Part (%)<br>RH_IN 整数部分（%） | | | | | | | | RH_IN Fractions<br>RH_IN 分数 | | | | | | | |

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

DATA_RH 存储格式为：相对湿度(%rH)* 512。

**Example:** For a stored DATA_RH value of 0x6400 the relative humidity in % is calculated as follows: 0x6400 / 512 = 50%rH.
**例如：**对于 0x6400 的存储 DATA_RH 值，相对湿度(%)按如下方式计算：0x6400 / 512 = 50%rH.

See section “RH_IN” for further information.
更多信息请参见“RH_IN”部分。

### *16.2.14 DATA_MISR (Address 0x38)*
### *16.2.14 DATA_MISR（地址 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.
该1 字节寄存器可输出前一个次DATA_ read 通信（n 字节）的计算校验和。如果需要，它可以按一次单独的通信读取，以检查前一次通信的有效性。该值应与主机系统根据传入数据计算出的数字进行比较。

**Table 35: Register DATA_MISR**
**表 35：寄存器 DATA_MISR**

| Address 0x38<br>地址 0x38 | | DATA_MISR | | |
|---|---|---|---|---|
| **Bits<br>数位** | **Field Name<br>字段名称** | **Default<br>默认值** | **Access<br>访问** | **Field Description<br>字段描述** |
| **0:7** | DATA_MISR | 0x00 | R | Calculated checksum of the previous transaction<br>前一个事务的计算校验和 |

**Example:** C-code to calculate MISR on the received DATA, to compare with DATA_MISR:
**例如：**根据接收到的数据计算 MISR 并与 DATA_MISR 进行比较的 C 代码：

```
//  The polynomial used in the CRC computation in DATA_MISR
//                    76543210 bit weight factor
//
//    用于 DATA_MISR 76543210 位加权因子 CRC 计算的多项式
//
#define POLY 0x1D // 0b00011101 = x^8+x^4+x^3+x^2+x^0 (x^8 is implicit)
#定义 POLY 0x1D//0b00011101=x^8+x^4+x^3+x^2+x^0(x^8 为隐函数)
// 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.
// 每次在 0x20 至 0x37 的范围内从寄存器读取数据时，硬件寄存器
// DATA_MISR 都会使用 CRC 多项式(POLY)进行更新。每次读取寄存器时，
// 将调用“misr_update()”以使软件变量“misr”与硬件寄存器保持同步。
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;
}
静态 uint8_t misr=0;  //DATA_MISR 的镜像（0 为硬件默认值）
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.
// 通常情况下，当 I²C/SPI 事务完成时，系统会读取 DATA_MISR，并将其与
// 软件“misr”进行比较。这两个值应该相等。如果不相等，则存在 CRC 错
// 误：一个或多个字节在传输中损坏。
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.
// 一旦 CRC 错误，或者在没有调用更新()的情况下执行了事务，软件“misr”
// 就会与 DATA_MISR 不同步。读取 DATA_MISR 并调用“misr_set()”以恢复
// 同步。
void misr_set(uint8_t * val){
  misr=val;
}
```

### 16.2.15 GPR_WRITE (Address 0x40)
### 16.2.15 GPR_WRITE（地址 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).
主机系统的多个功能可使用该 8 字节寄存器向 ENS160 传输数据。当 ENS160 处于“深度睡眠”模式，或者处于工作模式的低功耗部分时，对这些寄存器的写入无效。写入操作只能在“空闲”模式下进行（OPMODE 0x01）。

Table 36: Register GPR_WRITE
表 36：寄存器 GPR_WRITE

| Address 0x40<br>地址 0x40 | | | | | GPR_WRITE0-7 |
|---|---|---|---|---|---|
| Address<br>地址 | Bits<br>数位 | Field Name<br>字段名称 | Default<br>默认值 | Access<br>访问 | Field Description<br>字段描述 |
| 0x40 | 0:7 | GPR_WRITE0 | 0x00 | R/W | General Purpose WRITE Register 0<br>通用“写入”寄存器 0 |
| 0x41 | 0:7 | GPR_WRITE1 | 0x00 | R/W | General Purpose WRITE Register 1<br>通用“写入”寄存器 1 |
| 0x42 | 0:7 | GPR_WRITE2 | 0x00 | R/W | General Purpose WRITE Register 2<br>通用“写入”寄存器 2 |
| 0x43 | 0:7 | GPR_WRITE3 | 0x00 | R/W | General Purpose WRITE Register 3<br>通用“写入”寄存器 3 |
| 0x44 | 0:7 | GPR_WRITE4 | 0x00 | R/W | General Purpose WRITE Register 4<br>通用“写入”寄存器 4 |
| 0x45 | 0:7 | GPR_WRITE5 | 0x00 | R/W | General Purpose WRITE Register 5<br>通用“写入”寄存器 5 |
| 0x46 | 0:7 | GPR_WRITE6 | 0x00 | R/W | General Purpose WRITE Register 6<br>通用“写入”寄存器 6 |
| 0x47 | 0:7 | GPR_WRITE7 | 0x00 | R/W | General Purpose WRITE Register 7<br>通用“写入”寄存器 7 |

### 16.2.16 GPR_READ (Address 0x48)
### 16.2.16 GPR_READ（地址 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).
ENS160 的多个功能可使用该 8 字节寄存器向主机系统传输数据。当新的 GPR_DATA 可用时，DATA_STATUS 寄存器的 NEW_GPR 位将被设置，而 INTn 引脚将被置有效（如果已配置）。

Table 37: Register GPR_READ
表 37：寄存器 GPR_READ

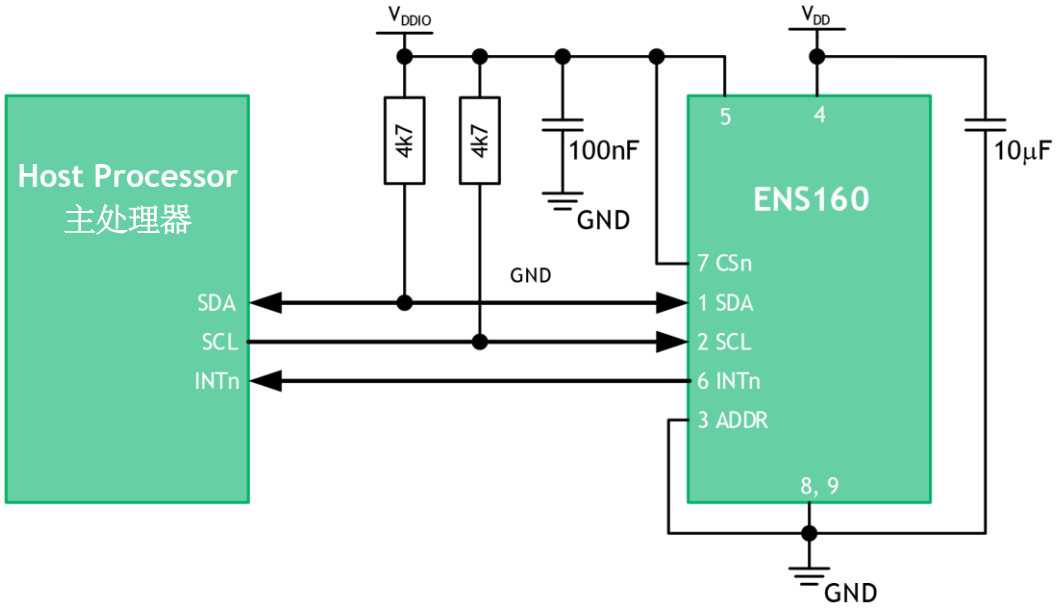
| Address 0x48<br>地址 0x48 | | | | | GPR_READ0-7 |
|---|---|---|---|---|---|
| Address<br>地址 | Bits<br>数位 | Field Name<br>字段名称 | Default<br>默认值 | Access<br>访问 | Field Description<br>字段描述 |
| 0x48 | 0:7 | GPR_READ0 | 0x00 | R | General Purpose READ Register 0<br>通用“读取”寄存器 0 |
| 0x49 | 0:7 | GPR_READ1 | 0x00 | R | General Purpose READ Register 1<br>通用“读取”寄存器 1 |
| 0x4A | 0:7 | GPR_READ2 | 0x00 | R | General Purpose READ Register 2<br>通用“读取”寄存器 2 |
| 0x4B | 0:7 | GPR_READ3 | 0x00 | R | General Purpose READ Register 3<br>通用“读取”寄存器 3 |
| 0x4C | 0:7 | GPR_READ4 | 0x00 | R | General Purpose READ Register 4<br>通用“读取”寄存器 4 |
| 0x4D | 0:7 | GPR_READ5 | 0x00 | R | General Purpose READ Register 5<br>通用“读取”寄存器 5 |
| 0x4E | 0:7 | GPR_READ6 | 0x00 | R | General Purpose READ Register 6<br>通用“读取”寄存器 6 |
| 0x4F | 0:7 | GPR_READ7 | 0x00 | R | General Purpose READ Register 7<br>通用“读取”寄存器 7 |

# 17 Application Information
# 17 应用信息

## 17.1 I²C Operation Circuitry
## 17.1 I²C 工作电路

The recommended application circuit for the ENS160 I2C interface operation is shown below:
ENS160 I²C 接口工作的推荐应用电路如下所示：

Figure 18: Recommended Application Circuit (I2C Operation)
图 18：建议的应用电路（I²C 工作）




**Note(s):**
注：

1. CSn must be pulled high (directly to VDDIO) to ensure I2C interface is selected
1. 必须将 CSn 拉高（直接拉至 VDDIO），以确保选择了 I²C 接口

2. MISO/ADDR should be pulled low or high to specify the LSB of the address
2. 应将 MISO/ADDR 拉低或拉高，以指定地址的 LSB

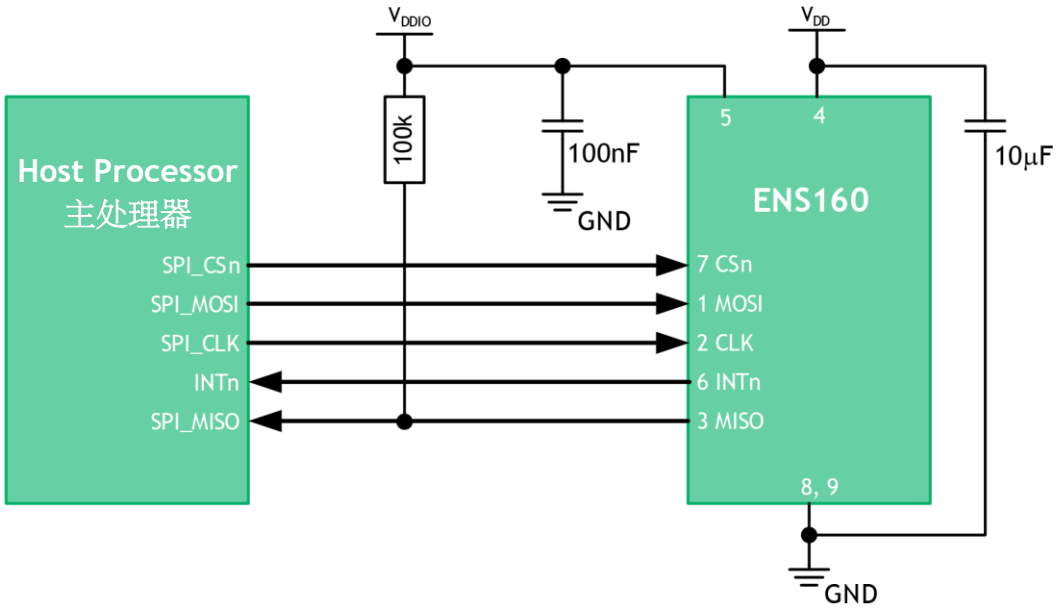
3. Pull-up resistors
3. 上拉电阻
   The above recommendation for pull-up resistance values applies to I2C standard mode only. Pull-up resistors for SCL and SDA are assumed to be part of the host system and should be selected dependent on the intended I2C data rate and individual bus architecture.
   上述关于上拉电阻值的建议仅适用于 I²C 标准模式。假设 SCL 和 SDA 的上拉电阻是主机系统的一部分，应根据预估的 I²C 数据速率和单个总线架构进行选择。

4. Decoupling capacitor must be placed close to the VDD (Pin 4) and VDDIO (Pin 5) supply pins of the ENS160
4. 去耦电容必须靠近 ENS160 的 VDD（引脚 4）和 VDDIO（引脚 5）电源引脚

## 17.2 SPI Operation Circuitry
## 17.2 SPI 工作电路

The recommended application circuit for the ENS160 for SPI interface is shown below:
ENS160 SPI 接口的建议应用电路如下所示：

Figure 19: Recommended Application Circuit (SPI Operation)
图 19：建议的应用电路（SPI 工作）



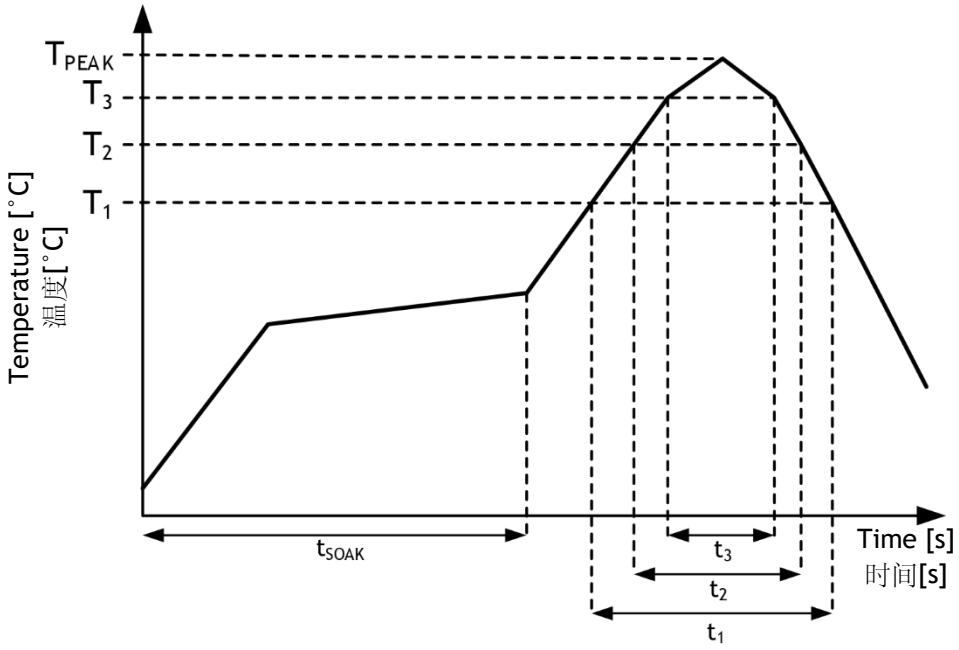

**Note(s):**
注：

1. Weak pull-up resistor may be required for MISO to define the level when tri-stated
1. 三态时，MISO 可能需要较小的上拉电阻来稳定电平
2. Decoupling capacitors must be placed close to the VDD (Pin 4) and VDDIO (Pin 5) supply pins of the ENS160
2. 去耦电容必须靠近 ENS160 的 VDD（引脚 4）和 VDDIO（引脚 5）电源引脚

# 18 Soldering Information
# 18 焊接信息

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.
ENS160 使用标准的 LGA 封装。根据 IPC/JEDEC J-STD-020D，该封装可以使用标准回流焊接工艺进行焊接。

Figure 20: Solder Reflow Profile Graph
图 20：回流焊接曲线图




The detailed settings for the reflow profile are shown in the table below.
下表显示了回流曲线的详细设置。

Table 38: Solder Reflow Profile
表 38：回流焊特征

| Parameter<br>参数 | Reference<br>参考值 | Rate / Unit<br>速率/单位 |
|---|---|---|
| Average temperature gradient in preheating<br>预热时的平均温度梯度 | | 2.5K/s |
| Soak time<br>保温时间 | tSOAK | 2..3 min |
| Soak temp range<br>保持温度范围 | Ts max | 200°C |
| | Ts min | 150°C |
| Time above 217°C ($T_1$)<br>温度超过 217°C ($T_1$)的时间 | $t_1$ | Max. 60s<br>最长 60s |
| Time above 230°C ($T_2$)<br>温度超过 230°C (T2)的时间 | $t_2$ | Max. 50s<br>最长 50s |
| Time above TPEAK -10°C ($T_3$) | $t_3$ | Max. 10s |

| | | |
|---|---|---|
| 温度超过 TPEAK -10°C ($T_3$)的时间 | | 最长 10s |
| Peak temperature in reflow<br>回流时的峰值温度 | $T_{PEAK}$ | 260°C |
| Temperature gradient in cooling<br>冷却时的温度梯度 | | Max. -5K/s<br>最高-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.
建议使用免清洗焊膏。不得有任何洗板过程，以防止清洁剂或其他液体材料接触传感器区域。

# 19 Package Drawings & Markings
# 19 封装图纸和标注

Figure 21: LGA Package Drawing
图 21：LGA 封装图纸

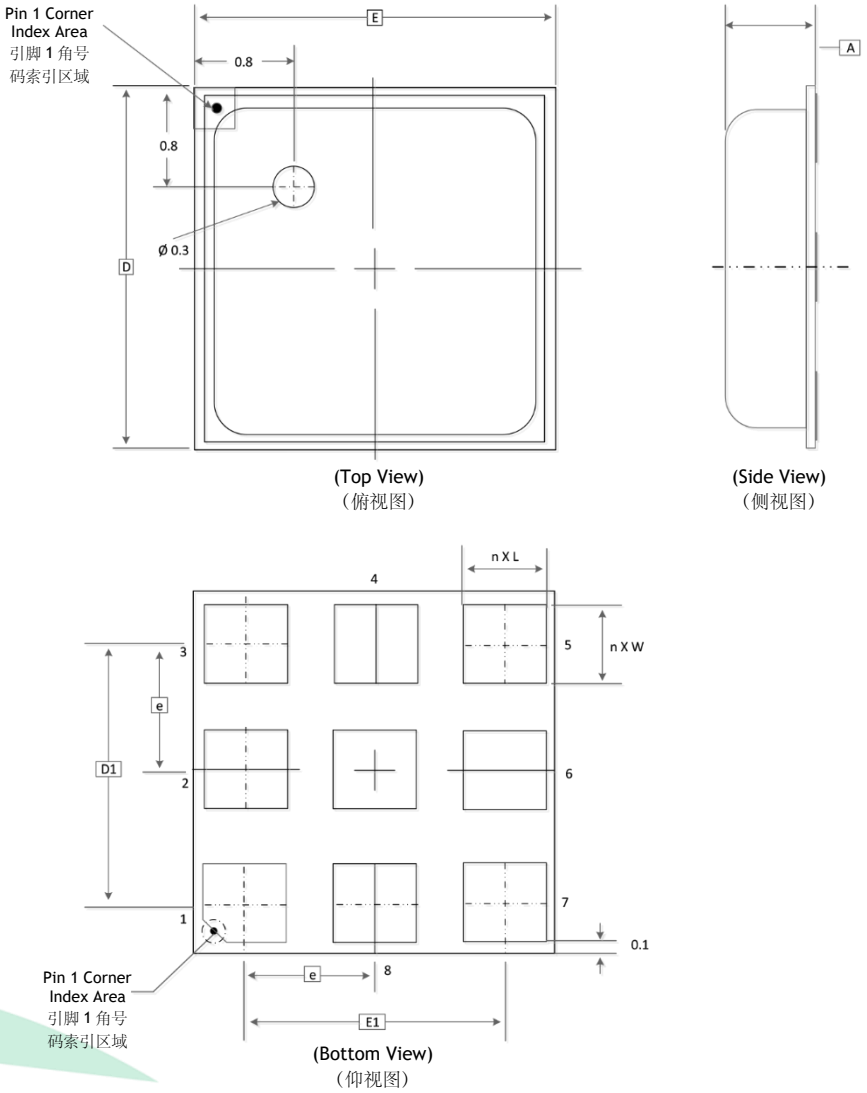
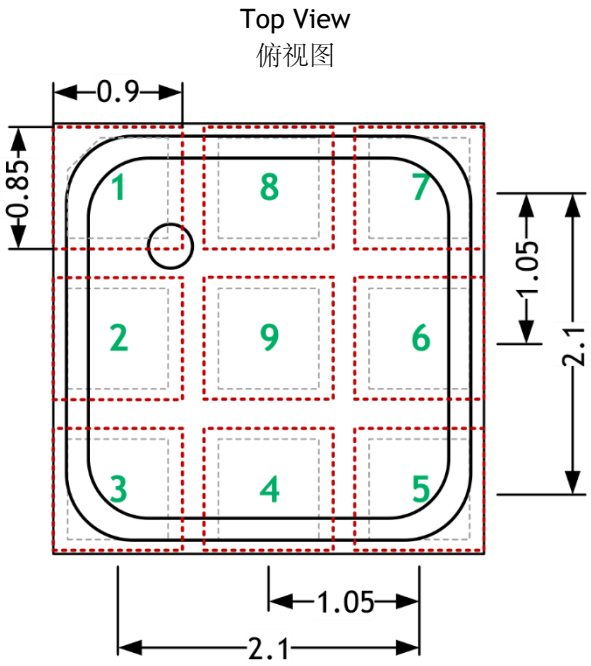



Table 39: LGA Package Dimensions
表 39：LGA 封装尺寸

| Parameter<br>参数 | Symbol<br>符号 | Dimensions<br>尺寸 | | |
|---|---|---|---|---|
| | | Min<br>最小值 | Nominal<br>标称值 | Max<br>最大值 |
| Total thickness<br>总厚度 | A | - | 0.83 | 0.9 |
| Body Size<br>主体尺寸 | D | | 3.0 | BSC |
| | E | | 3.0 | BSC |
| Lead Width | W | 0.65 | 0.7 | 0.75 |

| | | | | |
|---|---|---|---|---|
| 引脚宽度 | | | | |
| Lead Length<br>导线长度 | L | 0.65 | 0.7 | 0.75 |
| Lead Pitch<br>引线间距 | e | | 1.05 | BSC |
| Lead Count<br>引线数量 | n | | 9 | |
| Edge Lead Centre to Centre<br>边缘引线中心距 | D1 | | 2.1 | BSC |
| | E1 | | 2.1 | BSC |
| Note: All dimensions are in mm<br>注：所有尺寸均以毫米为单位。 | | | | |

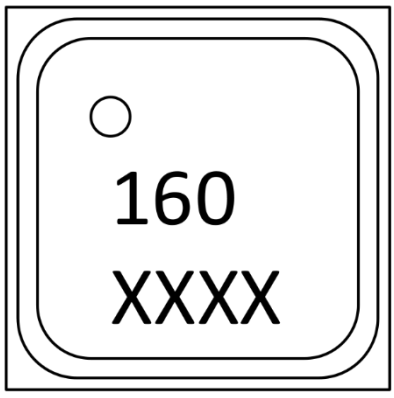
Figure 22: Recommend LGA Land Pattern for ENS160
图 22：建议ENS160 的LGA 焊盘布局




**Note(s):**
**注：**

1. All dimensions are in millimeters
1. 所有尺寸均以毫米为单位。
2. PCB land pattern in dotted lines
2. 以虚线表示的 PCB 焊盘布局
3. Add 0.05mm all around the nominal lead width and length for the PCB land pattern
3. 将 PCB 焊盘布局的标称引线宽度和长度增加 0.05mm

Figure 23: LGA Package Marking
图 23：LGA 封装标志



# 20 RoHS Compliance & ScioSense Green Statement
# 20 符合 RoHS 标准和 ScioSense Green 声明

**RoHS:** The term RoHS compliant means that ScioSense B.V. products fully comply with current RoHS directives. Our semiconductor products do not contain any chemicals for all 6 substance categories, including the requirement that lead does not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, RoHS compliant products are suitable for use in specified lead-free processes.
**RoHS**：术语“符合 RoHS 标准”是指 ScioSense B.V.产品完全符合现行有效的 RoHS 指令。我们的半导体产品不含有任何涉及 6 类物质的化学品，并且符合均质材料中铅含量（按重量计）不得超过 0.1%的规定。如果设计使用高温焊接，则符合 RoHS 标准的产品将适用于特定的无铅工艺。

**ScioSense Green (RoHS compliant and no Sb/Br):** ScioSense Green defines that in addition to RoHS compliance, our products are free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material).
**ScioSense Green（符合 RoHS 标准，无锑/溴）**：ScioSense Green 规定，除符合 RoHS 标准之外，产品还不含溴（Br）和锑（Sb）基阻燃剂[均质材料中的溴或锑含量（按重量计）不超过 0.1%]。

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## 22 Document Status
## 22 文件状态

Table 40: Document Status
表 40：文件状态

| Document Status 文件状态 | Product Status 产品状态 | Definition 定义 |
|---|---|---|
| Product Preview 产品预览 | Pre-Development 开发前 | 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.<br>本数据表中的信息基于开发规划阶段的产品理念。所有规范均为设计目标，我们对此不做任何保证，如有变更，恕不另行通知。 |
| Preliminary Datasheet 初步数据表 | Pre-Production 量产前 | 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.<br>本数据表中的信息基于开发的设计、验证或鉴定阶段的产品。本文档中展示的性能和参数仅为初步信息，我们对此不做任何保证，如有变更，恕不另行通知。 |
| Datasheet 数据表 | Production 量产 | 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.<br>本数据表中的信息基于试产扩量到全能力生产的产品，或基于符合我司标准保修条款（见《通用贸易条款》）项下规范的全能力生产。 |
| Datasheet (Discontinued) 数据表（停止使用） | Discontinued 中断 | Information in this datasheet is based on products which conform to specifications in accordance with the terms of ScioSense B.V. standard warranty as given in the General Terms of Trade, but these products have been superseded and should not be used for new designs.<br>本数据表中的信息基于符合我司标准保修条款（见《通用贸易条款》）项下规范的产品，但这些产品已过时，不应用于新设计。 |

## 23 Revision Information
## 23 修订信息

Table 41: Revision History
表 41：修订历史记录

| Revision<br>修订 | Date<br>日期 | Comment<br>备注 | Page<br>页码 |
|---|---|---|---|
| 0.95 | 2020-12-09 | Preliminary Version – Product Launch<br>初步版本-产品发布 | All<br>全部 |
| 0.9 | 2019-12-11 | Initial Version<br>初始版本 | All<br>全部 |

**Note(s) and/or Footnote(s):**
**注释和/或脚注：**

1. Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
1. 先前版本的页码和图号可能与本版本不同。
2. Correction of typographical errors is not explicitly mentioned.
2. 文中没有明确提及是否纠正了印刷错误。

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|---|---|
| **Headquarters:**<br>总部: | ScioSense B.V.<br>High Tech Campus 10<br>5656 AE Eindhoven<br>The Netherlands |
| **Contact:**<br>联系信息: | www.sciosense.com<br>info@sciosense.com |


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