ENS21x(A) Design Guidelines

Application Note

providing recommendations for ENS21x(A) handling, circuit-, PCB- and casing-design for best applicational performance.

ENS21x(A) Design Guidelines

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1 Introduction

The ENS21x(A) is a range of relative humidity and temperature sensors, where “x” represents the individual variant and “A” indicates optional automotive grade versions. All devices are encapsulated in a QFN4 package, equipped with I^2C slave interface. The ENS21x(A) are high sensitivity sensors designed for accurate relative humidity and temperature measurements. To benefit from this high accuracy, the design considerations in this application note are recommended.

2 Sensing Modality

2.1 Temperature Sensing

Temperature sensing is the measurement of degree or intensity of heat present in a substance or object. In order to obtain accurate measurement of temperature, the mode of heat transfer has to be understood. In temperature measurement, the important modes of heat transfer include conduction, convection and radiation. For example, in conduction, a warmer body influences the temperature measurement when it comes into thermal contact with the zone of detection. In convection, warmer matter (liquid or gas) flows past the sensor influencing the measurement. In radiation, heat is transferred through the emission of electromagnetic waves from all matter with temperature above absolute zero. This may result in heating up of the sensor. Nevertheless, it is important to identify the subject to be measured.

In case of environmental temperature sensors, the ambient temperature is the most-common subject of interest, less so is the temperature of its PCB or its casing. During a change in ambient temperature, readings of the sensor take some time before they eventually show a stabilized ambient temperature. The thermal mass of the sensor and the PCB (e.g. thickness of PCB, amount of solder used) it is mounted on, affects the response time of the readings. In any case the ENS21x(A) should have direct access to the environment for accurate relative humidity and temperature measurement.

2.2 Humidity Sensing

In environmental sensing of relative humidity, ambient temperature influences the measured readings, less so is the minute changes in atmospheric pressure. Therefore, recommendation for accurate measurement of relative humidity is similar to that for accurate measurement of temperature.

In the following chapters, considerations and recommendations are made to minimize the undesirable thermal influence due to conduction from parasitic heating (by microprocessor, regulators or other components), convection due to mechanical enclosure, influences from sunlight due to exposure to radiation, and to reduce thermal mass of the PCB on which the sensor is mounted.

3 Circuit Design Considerations

The typical application is shown in figure 1. Firstly note that the 0.1µF decoupling capacitor “C” is positioned as close as possible to the device.

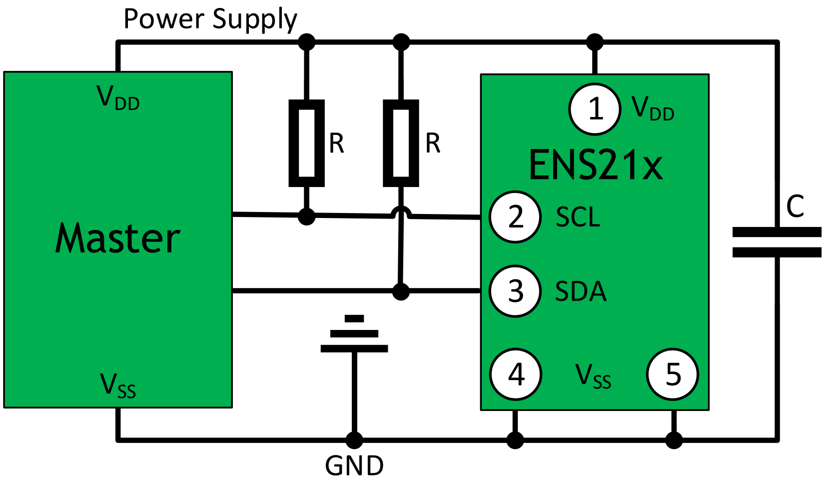

Figure 1: Recommended Application Circuit

The operating voltage range of ENS21x(A) is from 1.71V to 3.60V. If the power supply of the host in figure 1 is out of the range, e.g. 5V or 1.2V, a level shifter should be added between the host and the device.

V_{DD} should not be switched off or made floating when the I^2C bus is powered. When the I^2C bus is powered while V_{DD} is grounded or floating, the device will load the I^2C bus which might cause I^2C bus errors. If the IO domain of the host is in power down mode, the device will be safely in power down mode as well. In sleep mode the current consumption of all ENS21x(A) family members is so low that there is no advantage in powering it off.

The host is typically an MCU that operates as master on the I^2C bus. The pull up resistors of the I^2C bus should be placed close to the host. Refer to chapter 6 of I^2C-bus specifications[1] for more details on pull up resistor sizing.

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[1] UM10204, I^2C-bus specification and user manual, Rev. 6, 4 April 2014

4 PCB Layout Considerations

Heat conduction occurs mostly through the PCB, especially through the metallic ground plane. To minimize interference to the temperature measurement, the following PCB layout guidelines as shown in figure 2 are recommended.

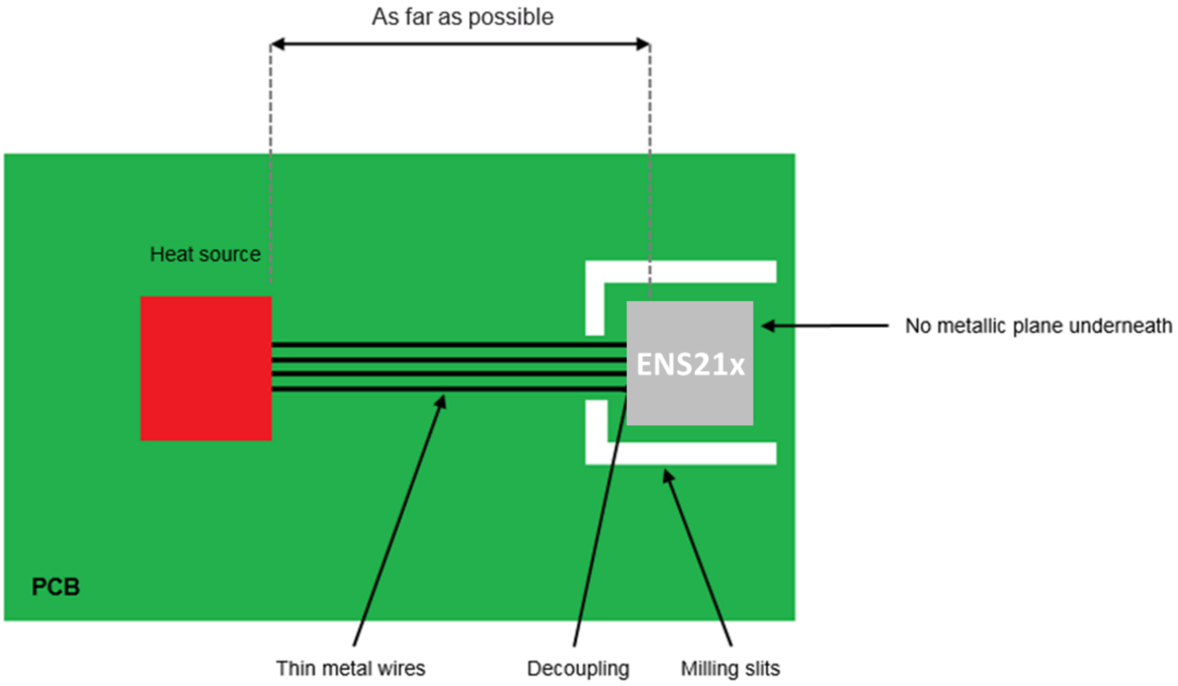

Figure 2: General Guidelines for PCB Layout

1. Place the sensor on the PCB as far as possible from any heat source such as voltage convertors, LCD backlights etc. to reduce heat conduction from the heat sources through the PCB.
2. Put milling slits around the sensor to reduce heat conduction from the heat sources.
3. Use thin PCB traces to interface with the sensor to reduce heat conduction through the traces.
4. Avoid using a metallic (e.g. copper) ground plane underneath the sensor to reduce heat conduction through the ground plane.
5. Place the decoupling capacitor as close as possible to the sensor. Generally speaking, noise caused by other circuit elements, e.g. a switch, is shunted through the capacitor. To achieve best performance, the decoupling capacitor should be placed as close as possible to the sensor. Figure 3 shows the decoupling capacitor of ENS21x(A).
6. To reduce the crosstalk and interference between clock line and data line of I^2C, the order of I^2C interface tracks is suggested as shown in figure 3. This arrangement reduces bus noise especially when traces are long, e.g. exceeding 10cm.

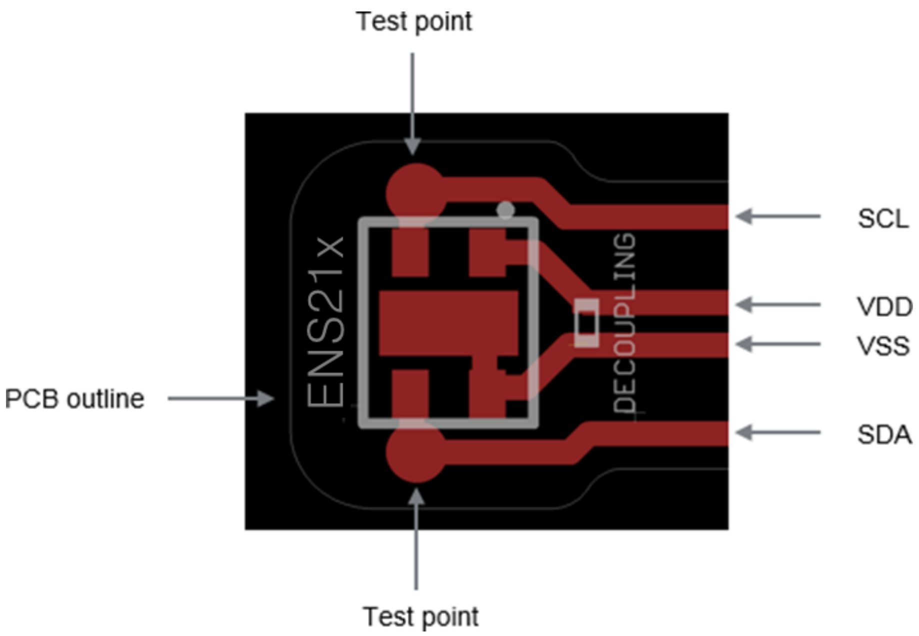

Figure 3: Sensor Decoupling

5 Casing Design Considerations

While designing the casing, the following precautions are advised to minimize heat conduction and convection from the heat source within the casing, and to maximize exposure to the environment. Figure 4 describes the general casing design guidelines.

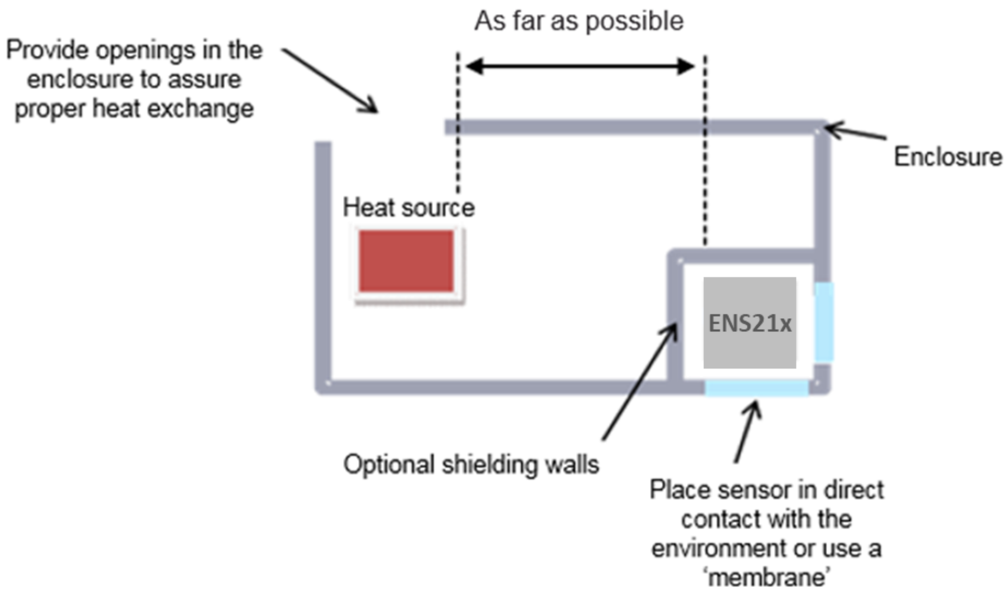

Figure 4: General Guidelines for ENS21x(A) Casing Design

1. Use a dedicated sensor compartment with shielding walls around the sensor to isolate the IC from heat sources.
2. Use a hydrophobic membrane that provides direct contact to the environment but protects against contamination (like dust and liquids) coming into contact with the sensor. The membrane shall be placed at the opening on the casing to facilitate air flow while keeping out moisture and contamination.
3. Provide milling slits to remove heat from sources such as voltage convertors and LCD backlight preventing heated air to build-up within the casing as shown in figure 5.
4. The sensor should be placed away from heat sources including direct sunlight, and should have direct access to the ambient relative humidity and temperature.
5. Maximize ambient airflow around the sensor to improve transient temperature response time.
6. Temperature is preferably measured at the front of the casing closest to the ambient relative humidity and temperature. The sensor shall be positioned as far away as possible from constructional elements, such as floors, ceilings or walls, to minimize impact of heat conduction.
7. If the casing is positioned up-right, locate the sensor as near to the bottom of the casing as possible to avoid exposure of airflow convection from heat sources, which is also shown in figure 6.

8. In general, if dust enters the casing it can potentially contaminate the open cavity of sensor and affect the accuracy of the relative humidity measurement. In order to prevent this, it is advised to use vertical milling slits at the top of the casing so that dust cannot enter directly from the top. Horizontal milling slits at the bottom can release any collected dust out of the casing by gravity. In this way the ambient air flow is safeguarded. See figure 5 and figure 6.

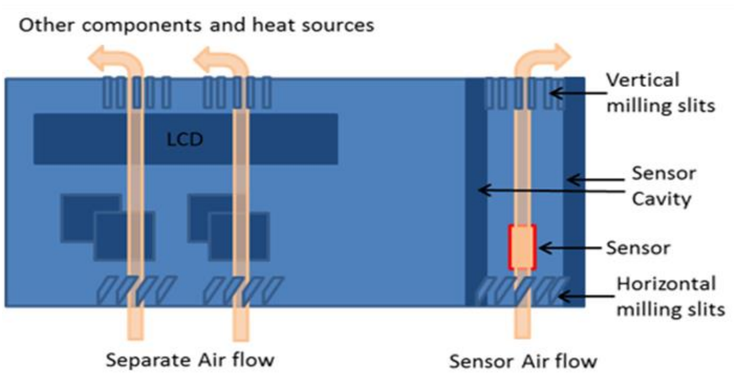

Figure 5: Guidelines for ENS21x(A) Chimney Design

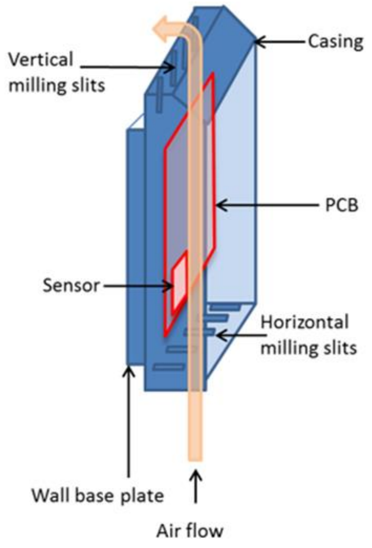

Figure 6: Plastic Overhang with Vertical Milling Slits at the Top

6 Low Power Design Considerations

For low power designs the following is recommended:

SCL and SDA lines of I^{2}C bus are pulled-up to V_{DD} and remains high when idle. Small leakage current through the SCL and SDA pins of the IC causes power loss through the pull-up resistors. Therefore, a reasonably high pull-up resistor is recommended which reduces leakage current, thus reducing power consumption at idle. However, high resistance compounded with trace capacitance causes clock skew during transmission, reducing the effective data rate of the I^{2}C bus. For effective balance between power consumption and signal integrity refer to I^{2}C-bus specifications[2].

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[2] UM10204, I2C-bus specification and user manual, Rev. 6, 4 April 2014

7 Storage, Handling and Operation

The ENS21x(A) moisture sensitivity level is 1 (MSL1), which corresponds to an unlimited out-of-bag lifetime at T = 30°C; RH = 85%RH maximum. The recommended storage conditions are 10 – 50°C and 20 – 60% relative humidity, preferably in the original sealed ESD bag.

Precautions should be taken to prevent electrostatic discharge (ESD) from damaging the sensor product.

All input and output pins are protected against electrostatic discharge (ESD) under normal handling. When handling ensure that the appropriate precautions are taken as described in JESD625-A or equivalent standards.

The following points should be taken into consideration during storage, handling and operation of the ENS21x(A).

1. Avoid use of cleaning agents (e.g. post soldering PCB board wash) on the exposed sensor area. Water-mark and corrosion to the humidity-sensitive polymer cause irreversible drift in the relative humidity measurement.
2. Avoid use of materials such as glue, soft plastics or wood in the vicinity of the sensor, since these materials can absorb or emit moisture. Also outgassing from plastics can damage the sensor if it is exposed for a long duration.
3. Exposure to the corrosive substances (both vapors and liquids) at high concentrations should be avoided as it can damage the sensor.
4. Exposure to Volatile Organic Compounds (VOCs) should be avoided.
    a. During manufacturing, transport and storage, VOCs may originate from outgassing of glues, adhesive tapes and packaging materials such as bags and (pink) foams. It is important to realize that VOC exposure can cause offset in sensor readings which may not recover naturally and may require a reconditioning procedure.
    b. In operation, VOCs might naturally be present in the environment as vapors of, for example, ethanol, acetone and isopropyl alcohol. Some of these contaminants can cause offsets in the sensor reading that may not recover naturally. The same holds for atmospheric pollutants such as ammonia, nitric oxide and chlorine.
5. Other general guidelines for handling of electronic components apply, e.g. ESD.

The sensor is not damaged by water immersion or condensation. The sensor will recover completely when the water evaporates.

Sensor readings are not impacted by high intensity light. This was validated by exposing the sensor to the complete spectrum of a Xe-arc lamp at light levels of 400W/m^2 in the range of 290-800 nm, in accordance with ASTM4459.

8 SMT Nozzle Selection

Because the ENS21x(A) use a cavity package, where the sensor is in direct contact with the environment, physical contact with the sensor should be prevented at all times. If required, dust particles can be removed by gently blowing air inside the cavity of the package. Do not brush or wipe.

The pick-up nozzle of the pick and place machine must be positioned in such a way on the component that it fully covers the cavity of the package, to avoid the leakage of air.

Due to the cavity with 1.125±0.050mm diameter on the top of ENS21x(A), when conduct SMT picking-up and placement of the sensor to a PCB board, it is recommended to use a nozzle with an inner diameter from 1.40mm to 1.70mm (see figure 7) to ensure that every placement of the ENS21x(A) is successful.

If there is no suitable nozzle size for a placement machine, a customized nozzle is required.

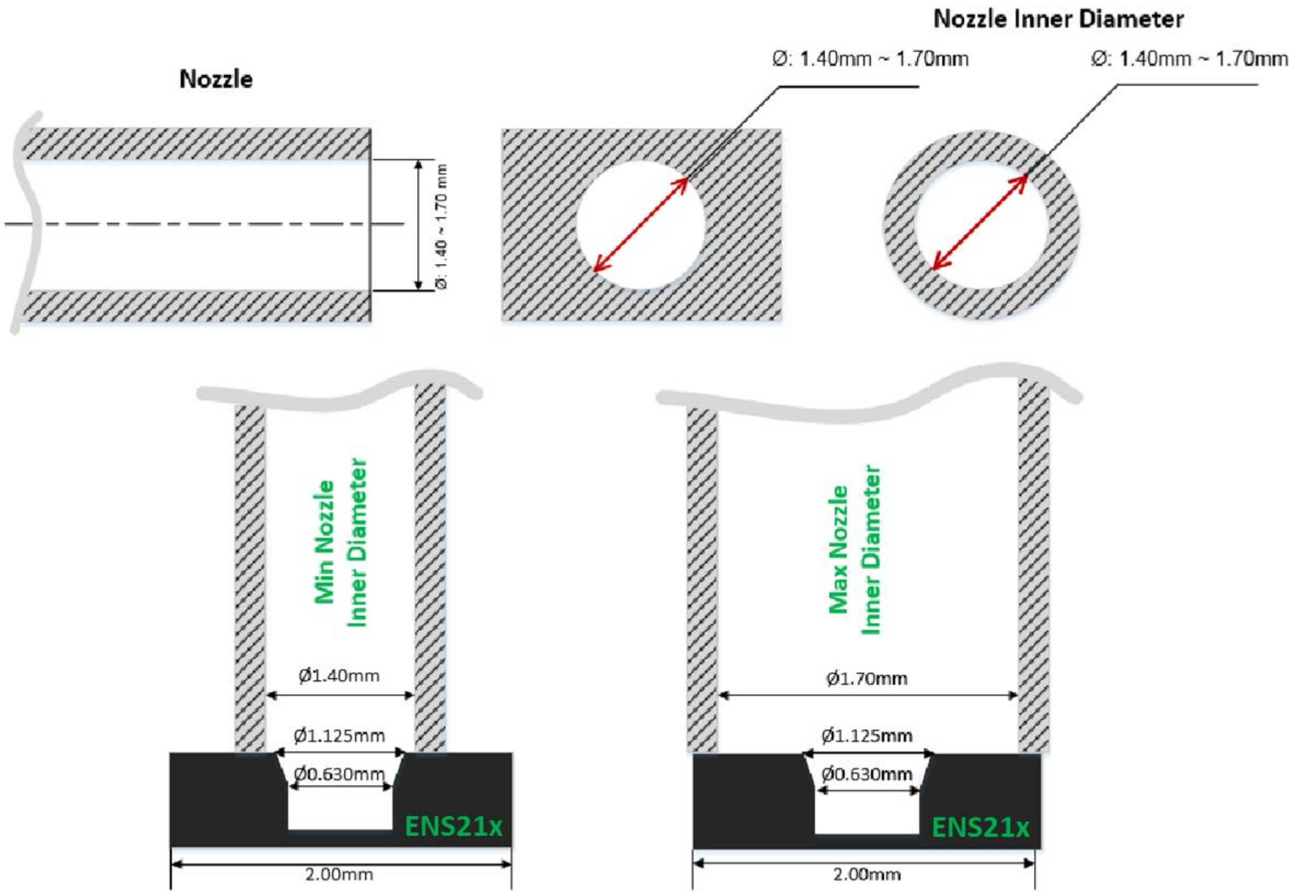

Figure 7: Nozzle Illustration with Inner Diameter from 1.40mm to 1.70mm

9 Effect of Soldering on Temperature Readout

The ENS21x(A) temperature sensor is specified for the bare product.

When actually soldered to the application PCB, a small shift in temperature reading will be induced. Main reason for this shift is a change of mechanical stress conditions exposed to the silicon die due to mismatch of thermal expansion coefficient of the involved materials. This is a commonly known issue and mainly affects tightly specified devices like accurate sensors or voltage references.

As this shift mainly depends on the solder profile and PCB type, it is not possible to accurately determine this shift in general.

For reference the output shift is characterized for soldering the product to a double sided 1.6mm thick, 35µm Cu pattern on FR4 test board as shown in figure 8 by Pb-free JEDEC solder profile at 260°C peak temperature. This results in a mean shift of +0.05K, with a 1-sigma standard deviation of 0.01K compared to the calibrated target. Therefore 0.05K must be subtracted from the product temperature reading.

For achieving highest accuracy in the application, it is recommended to determine this shift once per application and to compensate for it via software.

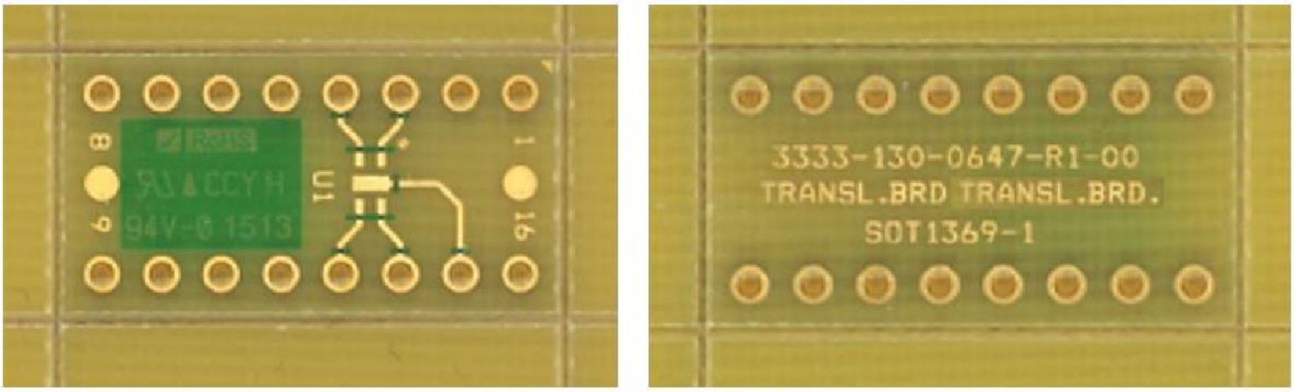

Figure 8: Test Board

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10 Long Term Drift (LTD) for RH Sensor

The physical aging of the sensor element may lead to a drift of the measured value compared to a reference sensor measurement. The thermal stability of the sensor element determines such a long term drift. In case of ENS21x(A), long term drift at 25°C is determined by exposing it to a High Temperature Storage Lifetime (HTSL) test at 150°C for 168 hours. This exposure covers the aging at 25°C for 19 years calculated with the Arrhenius model: the experimentally determined Ea in the case of ENS21x(A) is ~0.6eV. The sensor with largest drift during such an exposure determines the maximum long term drift. Note that the specified maximum value additionally contains some margin to compensate for the random errors in the experimental runs.

Table 1: Long Term Drift

Ambient Temperature	Typical	Max
25°C	0.25 %RH / year	0.5 %RH / year
60°C[3]	0.45 %RH / year	0.8 %RH / year

Values are linearized averages over the lifetime of the product. Due to non-linear behavior a larger drift is expected in the first years.

11 Real Time Drift (RTD) for RH Sensor

Capacitive relative humidity sensors may undergo a reversible drift during prolonged exposure to extreme humid conditions. Refer to the relevant ENS21x(A) datasheet for recommended operating conditions. The drift of the relative humidity sensor accumulates with each excursion outside the recommended operating conditions. The accumulated drift value over a number of humidity cycles is termed as the Real Time Drift (RTD). In case of the ENS21x(A), the RTD is determined by exposing sensor samples to relative humidity cycles from 40 %RH to 85 %RH with a cycling period of 2 hours at a constant temperature of 30°C (1hour/30°C/40 %RH + 1hour/30°C/85 %RH). The cycling test is done for minimum 150 cycles, and the drift value is extrapolated to 7,300 cycles (estimated number of cycles in 5 years for mobile and portable applications or 10 years for building automation applications) using a logarithmic model. The extrapolated RTD value of relative humidity for this reversible drift after 7,300 cycles is typically 6.2 %RH and maximum 9.2 %RH.

Please note that the RTD is a temporary offset which is reversible with slow kinetics after returning the product to the middle of the recommended operating conditions: approximately half of the offset is recovered after 10 weeks at 25°C/40%RH.

For a faster return of the sensor to its calibration accuracy limits, follow the reconditioning procedure provided in the relevant datasheet.

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[3] LTD at 60°C is determined by exposing at 150°C for 1008h

12 Maximum Supply Current

Table 2: Maximum Supply Current over Process Corners Averaged over Time

Maximum Values	T_A = 25 °C V_{DD} = 1.8V (3.3V)	T_A = 100 °C V_{DD} = 1.8V (3.3V)	Unit
Standby	0.06 (0.37)	1.1 (1.7)	µA
Continuous run mode	59 (59)	74 (76)	µA
T and RH measurement at 1Hz	7.1 (7.7)	10 (11)	µA

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15 Revision Information

Table 3: Revision history

Revision	Date	Comment	Page
1.0	2023-06-14	Initial version, replacing ENS210 Design Guidelines	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.

ScioSense is a Joint Venture of ams AG

Address:

Sciosense B.V.
High Tech Campus 10
5656 AE Eindhoven
The Netherlands

Contact:

www.sciosense.com
info@sciosense.com