



Application Note

AN000391

ENS210

Design Guidelines

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1 General Description

ENS210 is a relative humidity and temperature sensor with I²C slave interface. It is encapsulated in a QFN4 package. ENS210 is a high sensitivity sensor designed to sense accurate relative humidity and temperature. To benefit from this high accuracy sensor, the design considerations in this application note are recommended.

2 Sensing Modality

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 includes *conduction*, *convection* and *radiation*. For example, in conduction, a warmer body influence 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 takes some time before it eventually shows 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 ENS210 should have direct access to the environment for accurate relative humidity and temperature measurement.

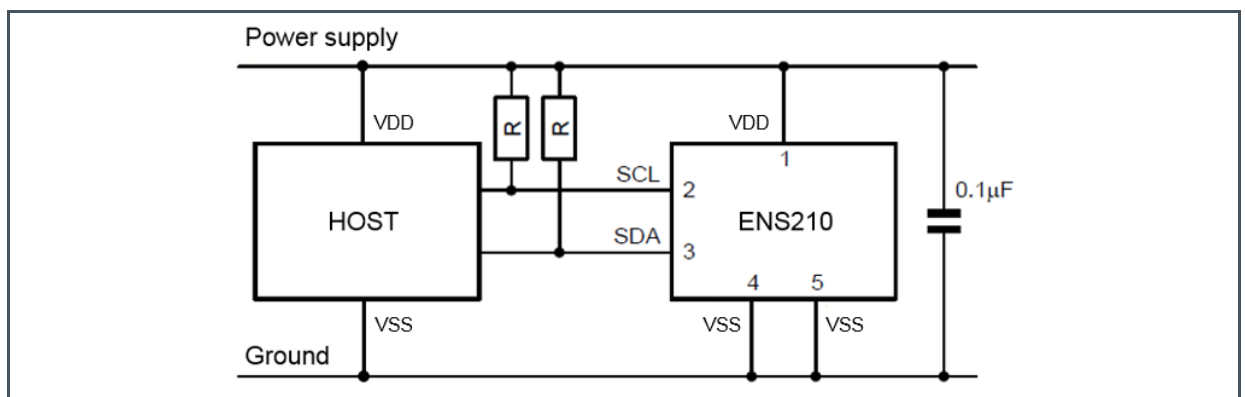
In environmental sensing of relative humidity, ambient temperature influences the measured readings, less so is the minute changes in atmospheric pressure. Therefore, recommendations for accurate measurement of relative humidity is similar to that for accurate measurement of temperature.

In the chapters that follow, 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 0.1 μF decoupling capacitor is positioned as close to ENS210 as possible.

Figure 1:
Recommended Application Circuit



The operating voltage range of ENS210 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 ENS210.

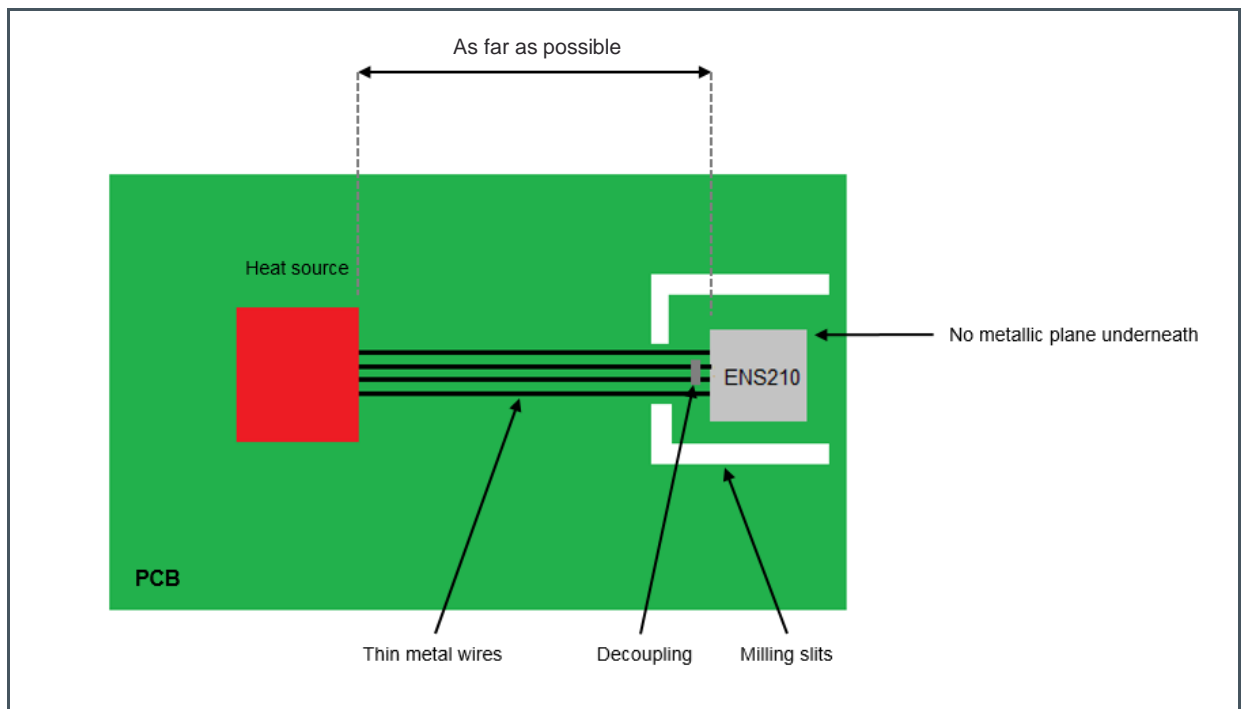
VDD should not be switched off or made floating when I²C bus is powered. When the I²C bus is powered while VDD is grounded or floating, ENS210 will load the I²C bus which might cause I²C bus errors. If the IO domain of the host is in power down mode the ENS210 will be safely in power down mode as well. In sleep mode the current consumption is so low that there is no advantage in powering off the ENS210 anyway.

The host is typically an MCU that operates as master on the I²C bus. The pull up resistors of the I²C bus should be placed close to the host. Refer to the chapter 7 of I²C-bus specifications [UM10204, I²C-bus specification and user manual, Rev. 6, 4 April 2014] for more details on pull up resistor sizing.

4 PCB Layout Considerations

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

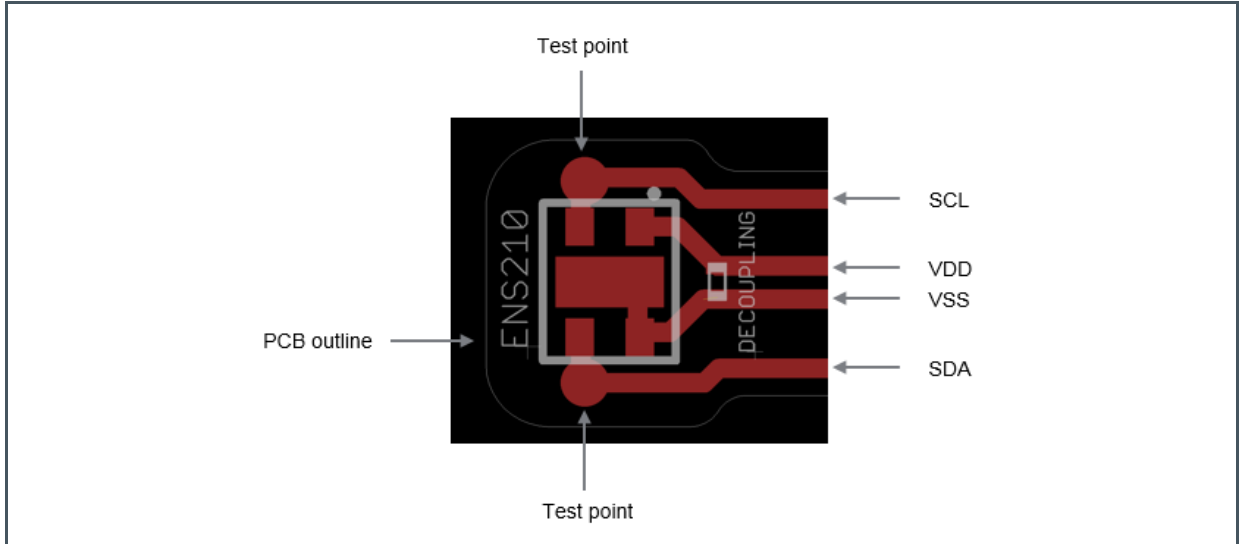
Figure 2:
General Guidelines for ENS210 PCB Layout



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 heat sources through PCB.
2. Put milling slits around the sensor to reduce heat conduction from heat sources.
3. Use thin PCB traces to interface with sensor to reduce heat conduction through the traces.
4. Avoid using metallic (e.g. copper) ground plane underneath the sensor to reduce heat conduction through ground plane.
5. Place the decoupling capacitor as close to sensor as possible. Generally speaking, noise caused by other circuit elements, e.g. switch is shunted through the capacitor. To achieve best performance, the decoupling capacitor should be placed as close to the sensor as possible. Figure 3 shows the decoupling capacitor of ENS210.

6. To reduce the crosstalk and interference between clock line and data line of I²C, the order of I²C interface tracks is suggested as shown in Figure 3. This arrangement reduces bus noise especially when traces are long, e.g. exceeds 10cm.

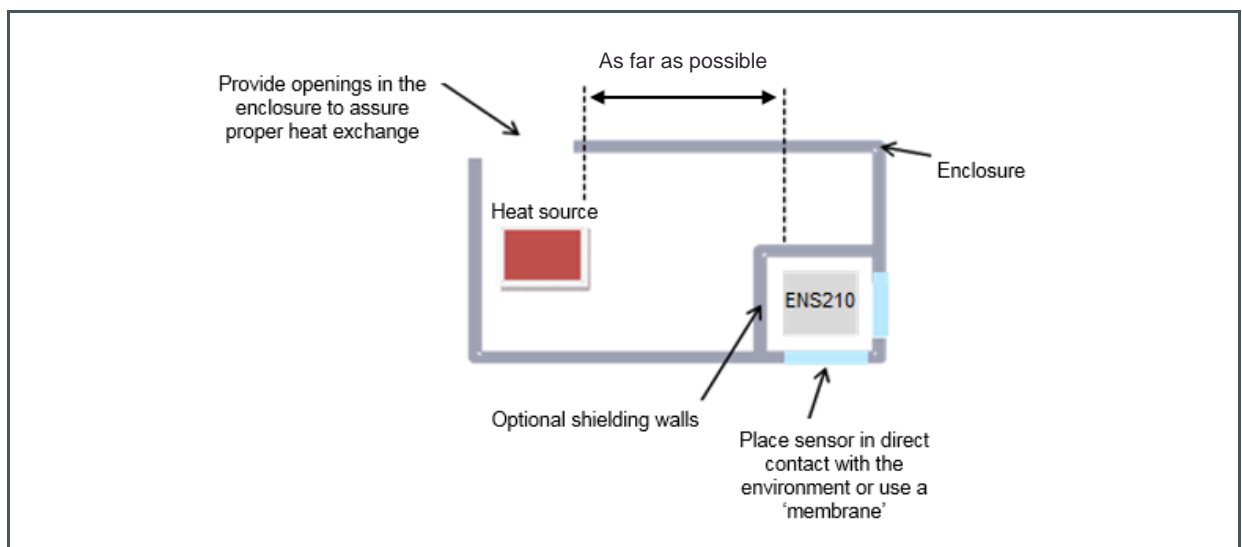
Figure 3:
ENS210 Decoupling



5 Casing Design Considerations

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

Figure 4:
General Guidelines for ENS210 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 provide direct contact to environment but protect against contamination like dust and liquids from coming into contact with the sensor. The membrane shall be secured 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 to prevent heated air from building up within the casing as shown in Figure 5.
4. ENS210 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. ENS210 shall be positioned as far away from constructional elements, such as floors, ceilings or walls, as possible to minimize impact of heat conduction.
7. If casing is positioned up-right, locate 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.

- In general, if dust enters the casing it can potentially contaminate the open cavity of ENS210 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 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 safe guarded. See Figure 5 and Figure 6.

Figure 5:
General Guidelines for ENS210 Chimney Design

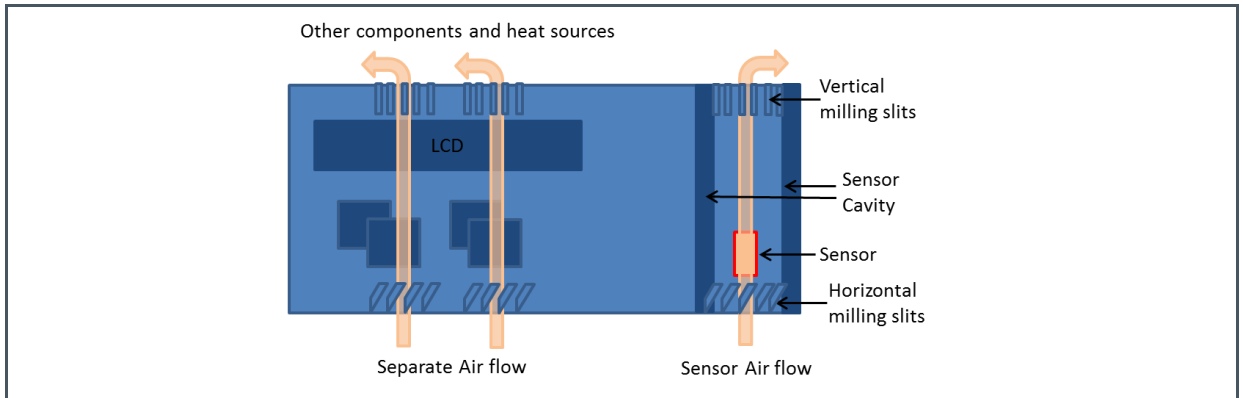
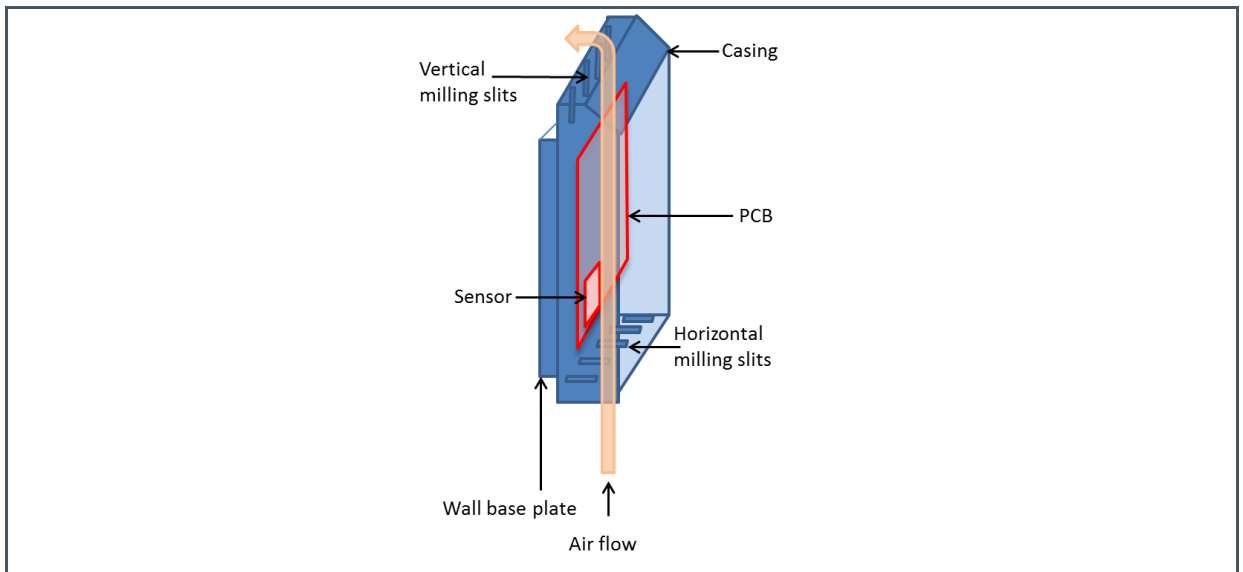


Figure 6:
Plastic Overhang with Vertical Milling Slits at the Top



6 Low Power Design Considerations

In some applications, the low power design is important and the following are recommended:

- SCL and SDA lines of I²C 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 I²C bus. For effective balance between power consumption and signal integrity, refer to I²C-bus specifications [UM10204, I²C-bus specification and user manual, Rev. 6, 4 April 2014].

7 ENS210 Handling

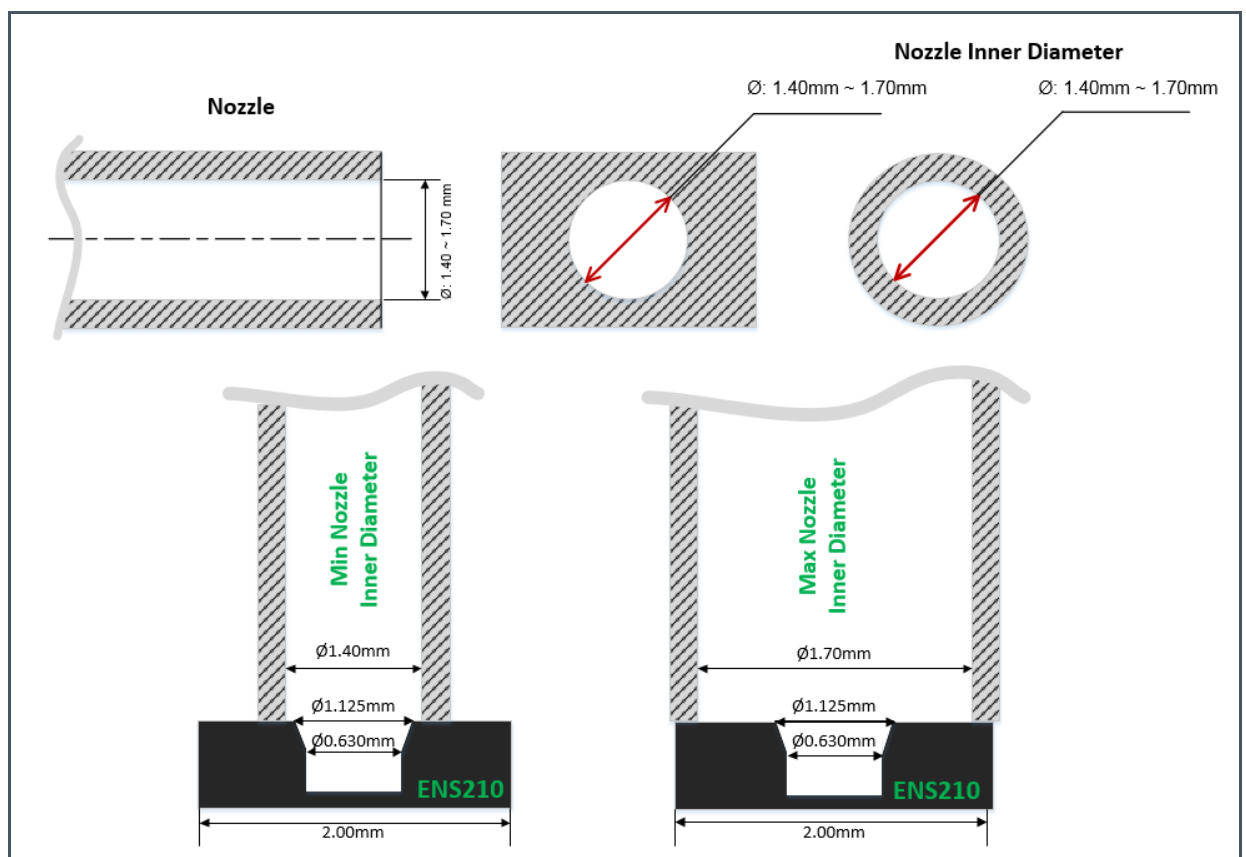
The following points should be taken into consideration when handling ENS210.

1. Avoid use of cleaning agents (e.g. post soldering PCB board wash) on the exposed sensor area. Water-mark and corrosion to humidity-sensitive polymer causes irreversible drift to relative humidity measurement.
2. Avoid use of materials such as glue, soft plastics or wood in the vicinity of the ENS210, since these materials can absorb or emit moisture. Also out gassing from plastics can damage the sensor if it exposed for 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 or limited as much as possible. During manufacturing, transport and storage, VOCs may originate from outgassing of glues, adhesive tapes and packaging materials such as bags and foams. It is important to realize that VOC exposure can cause offset in sensor readings which may not recover naturally and may require reconditioning procedure. In operation, VOCs might naturally be present in the environment as vapors of, for example, ethanol, acetone and isopropyl alcohol. It is important to realize that 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 applies, e.g. ESD.

8 ENS210 SMT Nozzle Selection

Due to a cavity with $1.125 \pm 0.050\text{mm}$ diameter on the top of ENS210, when conduct SMT picking-up and placement of ENS210 to a PCB board, it is recommended to use a nozzle with an inner diameter from 1.40mm to 1.70mm to ensure that every placement of ENS210 is successful. If there is no a suitable nozzle size for a placement machine, a customized nozzle is required.

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



9 Effect of Soldering on Temperature Readout

The ENS210 temperature sensor is specified for the bare product.

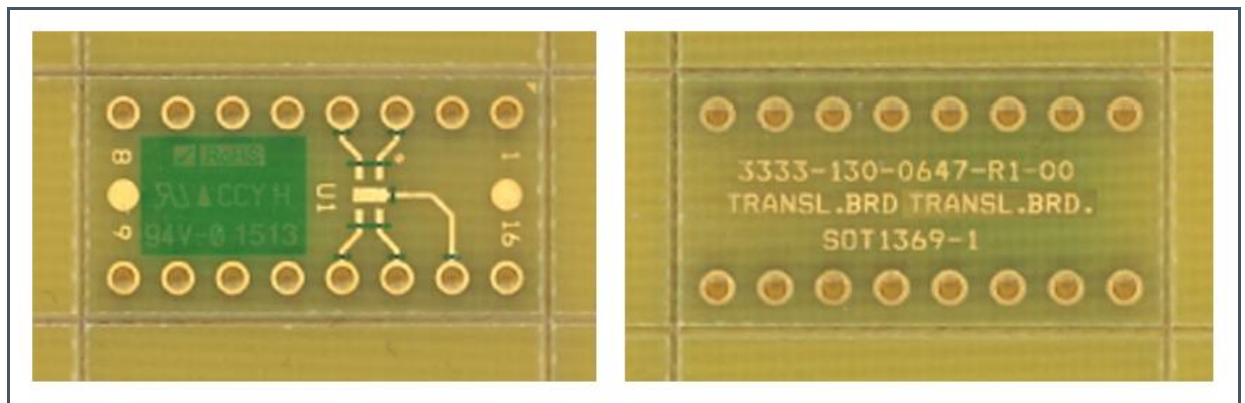
When actually soldered to the application PCB, a small shift in temperature reading will be induced. Main reason for this shift are changes in mechanical stress conditions exposed to the silicon die due to mismatch of thermal expansion coefficient of the involved materials. This is a commonly known issue 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, 35 μ m 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. So 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



10 Long Term Drift (LTD) for RH Sensor

The physical aging of the sensor element may lead to drift of the measured value compared to reference sensor measurement. The thermal stability of the sensor element determines such a long term drift. In case of ENS210, 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 6 years calculated with the Arrhenius model: the experimentally determined E_a in the case of ENS210 is ~0.5 eV. 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.

Figure 9:
Long Term Drift

Ambient Temperature	Typical	Max
25 °C	0.25 %RH / year	0.5 %RH / year
60 °C ⁽¹⁾	0.45 %RH / year	0.8 %RH / year

(1) LTD @60 °C is determined by exposing at 150 °C for 1008h

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 ENS210 datasheet for Recommended Operating Conditions. The drift of the Relative Humidity Sensor accumulates with each excursions outside the recommended operating conditions. The accumulated drift value over a number of humidity cycles is termed as real time drift. In case of ENS210, the real time drift 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 7300 cycles (estimated number of cycles in 5 years for mobile and portable applications or 10 years for HABA applications) using a logarithmic model. The extrapolated RTD value of relative humidity for this reversible drift after 7300 cycles is typically 6.2 %RH and maximum 9.2 %RH.

Please note that the real time drift is a temporary offset which is reversible with slow kinetics after returning the product to the middle of the Recommended Operating Conditions: approximately 50%RH 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 datasheet.

12 Maximum Supply Current

Figure 10:
Maximum Supply Current over Process Corners Averaged over Time

	T _A = 25 °C V _{DD} = 1v8 (3v3)	T _A = 100 °C V _{DD} = 1v8 (3v3)	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

13 Summary

This document explains various recommendations for circuit, PCB and casing design of ENS210 in an application. It also explains the handling guidelines for the sensor IC and the drift of measurement data over time. This when followed correctly will result in highly accurate relative humidity and temperature measurement system.

14 Revision Information

Changes from previous version to current revision v4-00	Page
Version 4-00: add SMT nozzle size requirements	13

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

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