SENSIRION
THE SENSOR COMPANY

Testing at Ambient Conditions

Preface

Sensirion Humidity & Temperature sensors are individually tested and fully factory-calibrated by Sensirion and it should not be necessary to test the sensor function after assembly. However, it may be desired to test the sensor during in-line or final test as a way to verify that the sensor had been correctly stored, handled and assembled.

While equipment and techniques exist, to measure temperature and relative humidity accurately, those may not be feasible or cost efficient for mass production. Testing at ambient conditions instead may provide an appropriate compromise. To prevent instable ambient conditions that lead to large spread in the measurements, several guidelines should be considered relating to the design of the test jig, the test procedure and the test environment.

Applicability

This document is applicable to products that contain Sensirion SHTxx relative humidity & temperature sensors and will undergo relative humidity (RH) and temperature (T) test at ambient conditions. This may apply to test of sensors on PCB or inside final products. This application note provides step-by-step guidelines for realizing a capable test system:

1. selection of an appropriate reference sensor
2. hardware design of the test jig
3. software design of the test jig
4. setting up the test environment
5. defining the operation procedure
6. considering temporary humidity offset caused by high temperature assembly processes
7. analyzing the capability of the measurement system
8. defining appropriate test limits

Overview

Sensirion sensors are individually tested and fully factory calibrated by Sensirion. Verification of the calibration by the customer is not required. However, it may be appropriate for the customer to test the sensor after assembly, to verify that it had been correctly stored, handled and assembled.

Testing humidity and temperature sensors accurately requires the use of a climate chamber combined with accurate measurement equipment for reference. Due to the cost and limited throughput, such setups are rarely appropriate for mass production.

For verifying a pre-calibrated sensor after assembly it may be sufficient and most appropriate to test at ambient conditions. Sensirion SHTxx humidity & temperature Sensors are very sensitive environmental sensors. Hence, they are as well responding very sensitively to the test environment. For a capable test setup, the following main points need to be considered:

- select an accurate reference sensor
- optimize temperature coupling between the reference sensor(s) and the device under test
- optimize humidity coupling between the reference sensor(s) and the device under test
- minimize temperature and humidity gradients and turbulences in the test environment

It is important that the device under test (DUT) and the reference sensor(s) are at the same absolute temperature. This may be obvious for temperature measurement, but it is equally important for accurate measurement of relative humidity. As relative humidity is strongly temperature dependent, any temperature difference between the DUT and the reference will lead to a deviation in the relative humidity measurement.

Reference Sensor

The humidity and temperature values measured by the Device Under Test (DUT) need to be compared to the values of a reference sensor. The accuracy of the reference sensor directly affects the over-all measurement accuracy/capability of the setup. Therefore, the reference sensor needs to be sufficiently accurate in humidity and temperature.
Sensirion's pin-type SHT85 humidity & temperature sensor is recommended as a reference sensor.

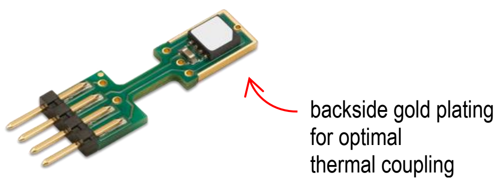

Figure 1 Sensirion SHT85 humidity and temperature sensor

SHT85 offers high accuracy of ±1.5 %RH and ±0.1°C, a digital interface for easy integration and allows for a flexible jig design. The Sensor is gold plated on the backside, allowing for an excellent temperature coupling to a surface or the environment. For more information on the SHT85 please refer to https://sensirion.com/products/catalog/SHT85/

To reduce variations and fluctuations of the measured reference value, two reference sensors may be implemented. The average of both temperature values and the average of both humidity values may be used as the reference values.

Test Jig Design for Sensors on PCB

The following design recommendations apply to test jigs for rigid or flexible PCBs.

Optimized Thermal Coupling

The best strategy is to couple the sensors not only via the air but to thermally couple them through the test jig. This should ensure more accurate measurements of temperature and humidity as well as shorter settling times.

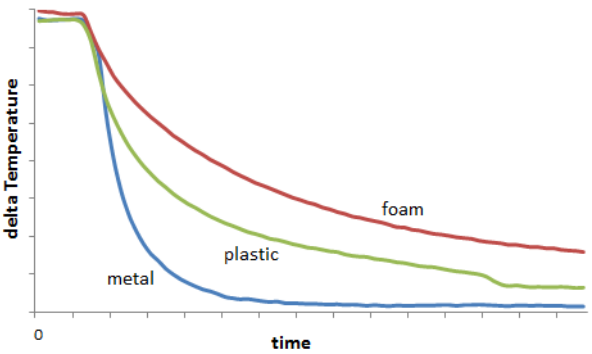

Figure 2 Exemplary data showing several sensors approaching reference value. Different materials have been used to couple the sensors to the reference sensor. Metal offers the best thermal coupling, resulting in the fastest settling times. Coupling sensors through e.g. plastic or foam requires significantly longer settling times and may lead to less accurate measurements.

To ensure an optimal thermal coupling between the reference sensor(s) and the sensor under test:

- Use a **metal insert** from e.g. aluminum or copper. Ensure the metal insert is not creating short circuits on the DUT.
- In case there are components on the back-side of the DUT: add cavities to the insert of the jig.
- Place the **reference sensor as close as mechanically possible to the sensor under test** (i.e. within a couple of millimeters only, if mechanically possible).

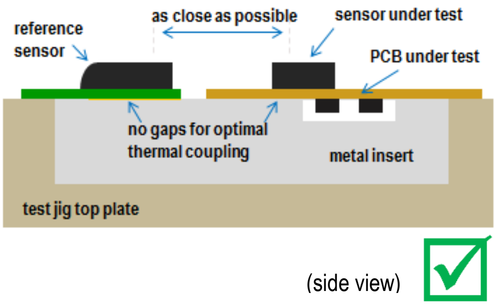

Figure 3 Good example of PCB test jig with a metal insert, ensuring good thermal coupling between the reference sensor and the sensor under test as well as a minimum distance between them.

- Ensure the **reference sensor** is in **good contact with the metal insert** of the jig. If necessary, use a clip to hold down the reference sensor but ensure the sensor cavity is not obstructed.
- Ensure the **DUT** is in **good contact with the metal insert** of the jig. If necessary, add a spring that presses the DUT onto the metal insert of the jig. It is recommended to press down close to the sensor but <u>not</u> onto the sensor directly as this could lead to particles in the sensor cavity and obstruction of the sensor cavity.
- Ideally, include two reference sensors. This will allow automatic detection of any problems with the reference sensors themselves.

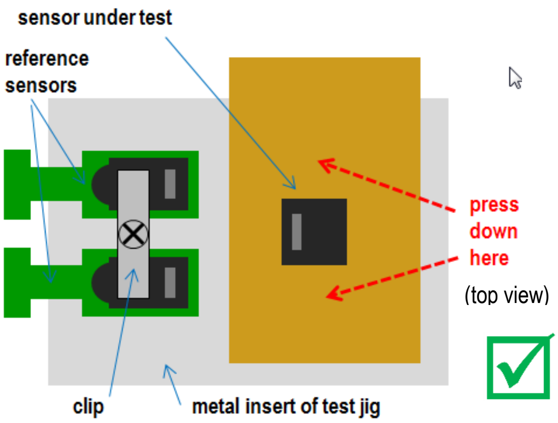

Figure 4 Good example of PCB test jig with clip holding down two reference sensors to ensure good thermal coupling to the metal insert. The reference sensors and the sensor under test are placed at minimum distance to each other.

- **De-couple the metal insert** from any component on the DUT that may heat up during test.

- **De-couple (insulate) the metal insert** from any heat source in the environment (e.g. isolate from any hot electronic circuits inside the test jig).
- Preferably no electronics are located inside the mechanical test jig. If electronics are added inside the test jig, it is recommended to add ventilation inside of the jig to **prevent self-heating of the jig**.

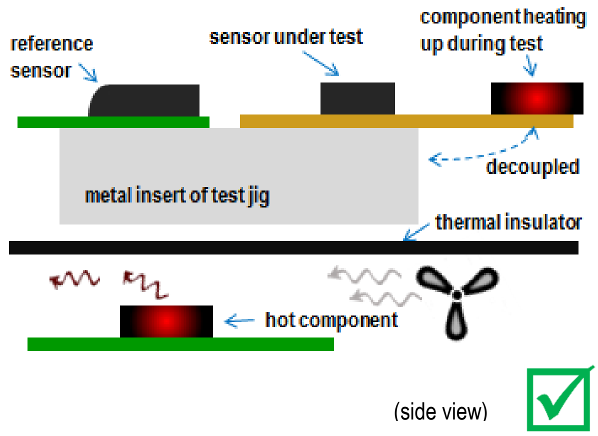

Figure 5 Good example of PCB test jig with the metal insert being decoupled from components on the DUT that heat up during test. Metal insert is insulated from the self-heating of the electronics inside the jig. Additionally the electronics of the jig are ventilated to prevent too much self-heating.

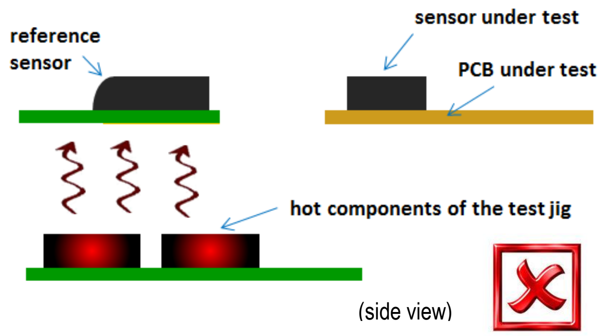

Figure 6 Bad example of PCB test jig. Sensor under test and reference sensor are not sufficiently close together and have to rely on the thermal coupling through air alone. Additionally, there are heat sources below the sensors creating a thermal imbalance.

- Design the **volume of the metal insert rather large**. The larger its thermal mass, the more it will help stabilize the temperature of the reference sensor and DUT.
- Extend the metal insert beyond the area of test and include **space to pre-stage units before test**. During pre-staging the unit's temperature will have time to adjust to the temperature at which it will be tested. This will help reduce settling times.
- Prevent the operator from touching the metal insert as the operator's body temperature may cause a temperature variation of the metal insert.

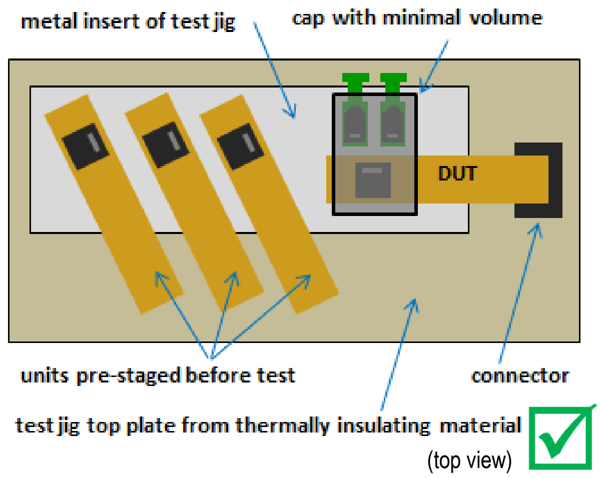

Figure 7 Good example of test jig top plate from thermally insulating material (e.g. plastic), preventing the operator to easily touch the metal insert of the test jig. The metal insert is large enough to provide space for pre-staging several units before test, allowing the units to adjust to the temperature of the jig.

Optimized Coupling of Humidity

To ensure an optimal humidity coupling, the reference sensor(s) and the sensor under test need to be exposed to the same, undisturbed atmosphere during test:

- Enclose the reference sensor(s) and the sensor under test within a **cap of minimal volume**, insulated from the external environment. (Make the volume under the cap as small as mechanically possible, e.g. only a very few cm^3. Ensure the cap is not obstructing the cavities of the sensors.) The smaller the volume, the shorter the settling times required for a stable measurement. The cap as well shields the sensors from turbulences, thereby reducing measurement variation. At the same time, the cap can press down the PCB onto the metal insert of the jig as suggested in Figure *4*.

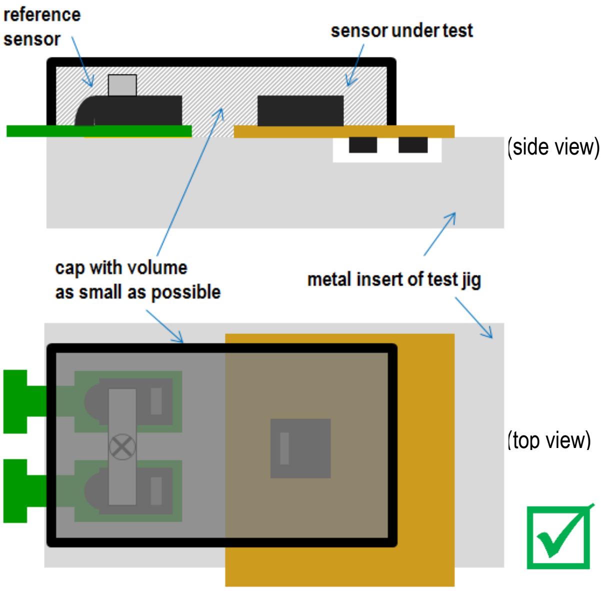

Figure 8 Good Example of small cap enclosing just the reference sensors and the sensor under test, minimizing the volume under the cap as much as possible.

Test Jig Design for Sensors Inside a Housing

In case of final products, the humidity and temperature sensor is typically mounted inside a plastic housing. A housing restricts the airflow and therefore a sensor in a housing will always react slower than a sensor without housing. This implies that longer settling times are required during test for sensors in a housing.

The reference sensor(s) must be coupled to the sensor under test through the surrounding air/atmosphere. Following recommendations help optimize the thermal and humidity coupling:

- Place the reference sensor as close as possible to the sensor under test (i.e. within a couple of millimeters only, if mechanically possible). Only increase the distance if the reference sensor might otherwise be warmed up by dissipating heat from the unit under test itself.

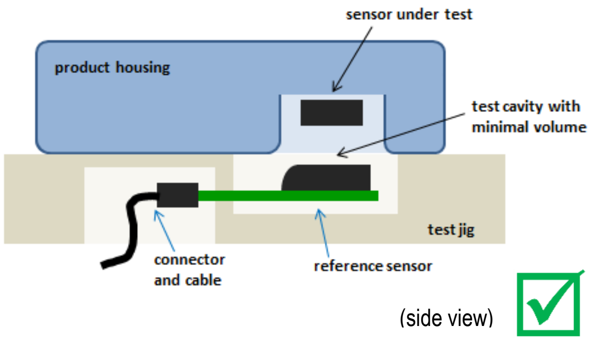

Figure 9 Good example of test jig for sensor in a housing, with sensor under test aligned just next to the reference sensor, creating a small cavity with minimal volume, protected from any turbulence in the environment.

- Enclose the reference sensor(s) and the sensor under test within a **cap of minimal volume**, insulated from the external environment. (Make the volume under the cap as small as mechanically possible, e.g. only a very few cm^3. Ensure the cap is not obstructing the cavities of the sensors.) The smaller the volume, the shorter the settling times required for a stable measurement. The cap as well shields the sensors from turbulences, thereby reducing measurement variation.

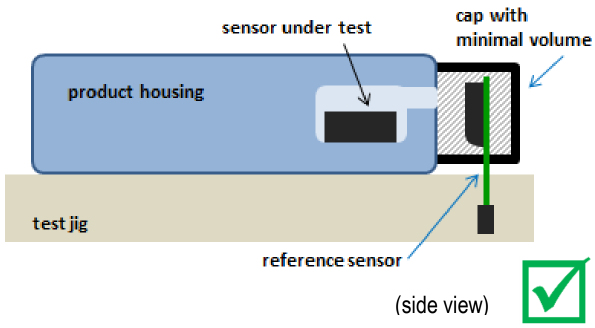

Figure 10 Good example of reference sensor mounted inside a cap, covering the sensor opening of the product housing. The volume inside the cap is minimized, at the same time protecting the sensors from turbulences in the environment.

- If enclosing the sensors with a cap is not possible, **shield** them **from turbulences as much as possible**.

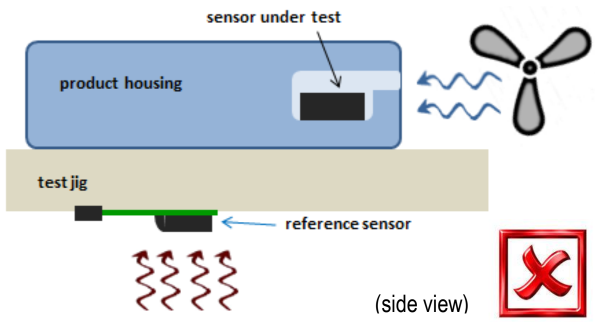

Figure 11 Bad example with reference sensor located far from the sensor under test. Reference sensor is exposed to hot air, while the sensor under test is cooled by a ventilator and/or air conditioning, creating a thermal imbalance. Neither sensor is shielded from turbulences.

- If the unit is warm or warming up during test it should be decoupled from the surface of the test jig (this is to prevent the test jig warming up over time, leading to a temperature drift during a production run)

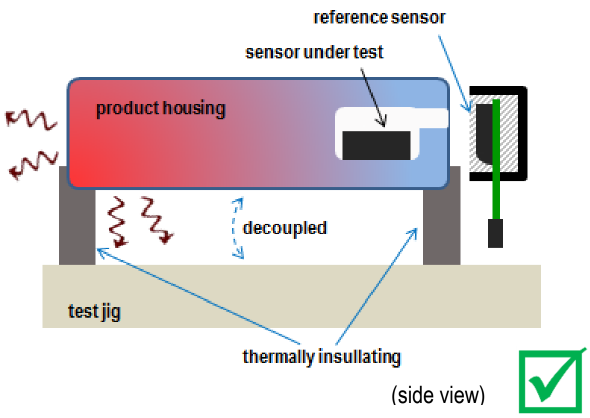

Figure 12 Good example of self-heating unit, placed on thermally insulating stilts to decouple it from the test jig surface, preventing heating up of the jig. Note that the cap around the reference sensor is as well detached from the device under test, to prevent it from heating up (and no longer represent the environment correctly).

Test Software Design

When designing the software for the test jig, please consider the following recommendations:

- As much as possible, **prevent** any component on the DUT to **heat up** during test (or the sensor under test may heat up through conductance of heat).
- Prevent self-heating of the sensors. (Sensors should only be active/measuring during maximum 10% of the time or sensor will start to self-heat slightly, which may influence the temperature measurement.)
- If more than one reference sensor is used, test their humidity and temperature values **against each other**, to detect any problem related to the reference sensors.
- Read out all sensors at the end of the test sequence. Ensure the sensor signals had **sufficient time to settle** to a stable value before performing the measurements (see below).
- Test the humidity and temperature values of the sensor under test relative to the reference sensor(s). If more than one reference sensor is used, test relative to the **average values of the reference sensors**.
  $T_{delta} = T_{sensor\_under\_test} - T_{reference\_average}$
  $RH_{delta} = RH_{sensor\_under\_test} - RH_{reference\_average}$
- **Datalog** all measured values and always **maintain the signs** of all values. (This will allow to properly analyze the capability of the measurement setup and performance of the production.)
- Use appropriate test limits (see below).
- In case the test fails, test again after some additional waiting time (**immediate retest**). If the second measurement is pass, the sensor under test can be considered pass. (This will help reduce problems due to variations in the test environment and it is more efficient than the operator having to start the test again.)

As mentioned in above list, there needs to be sufficient time for the sensors to reach stable values.
To be able to evaluate appropriate setting/waiting times the test setup should be able to measure and log a device repeatedly in 1 second fixed intervals. The values measured for several units can then be plotted to derive an appropriate waiting time.

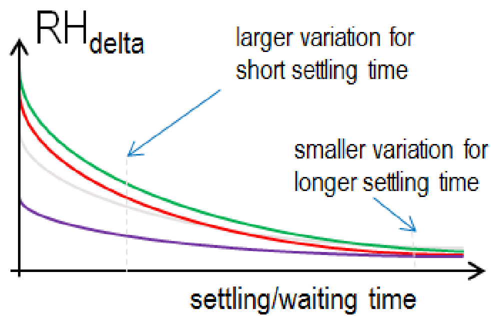

Figure 13 Graph showing RH_{delta} measurements of several units over time. The longer the waiting time the more accurate is the measurement (the closer it is to the final value).

Settling time depends on many factors. Following the recommendations outlined in this document will allow shorter settling times. Shorter settling times imply that the test system can reach higher throughput.
As can be seen from Figure *13* the longer the waiting time is the smaller are as well the offset and variation in the measurement. Reducing the waiting time increases the variation and offset error in the measurement. Hence there is a compromise between tight test limits and short waiting times.

Test Environment

The test environment can have a significant impact on the capability of the measurement setup.

The local humidity and temperature on the test jig may significantly differ from other areas in the production room. This implies that devices for test may be at a different temperature and humidity level when arriving at the test station and require longer settling times.

- **Pre-stage units before test** on top of (or just beside) the test jig, to allow units to adjust to local temperature and humidity (compare Figure 7).

Nearby heat sources (e.g. hot equipment), ventilation, air conditioning as well as the movement of operators and other production personnel can add significant local variations and turbulence to the air around the test jig. These turbulences will add variation to the measurement.

- **Reduce heat sources** (e.g. heating or hot equipment) near the test jig
- **Prevent direct sunlight** or areas that do heat up during the day
- **Avoid hot lighting** onto the area. Use fluorescent lights instead.

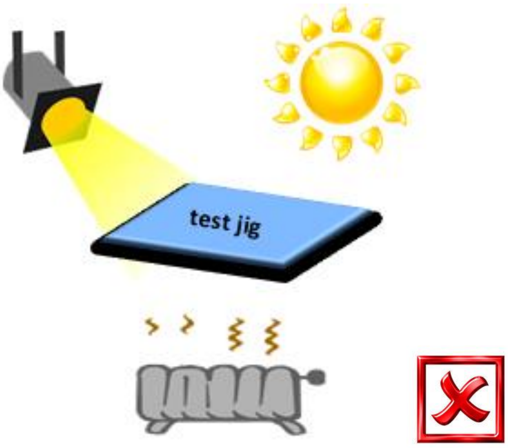

Figure 14 Bad example of a test jig that is exposed to different heat sources – direct sunlight, a strong spotlight and a heating system.

- Do not place the test jig directly exposed to a strong draught from air-conditioning.
- Do not place the test jig next do doors or windows, as this could lead to significant draught of air with different temperature and humidity.
- Limit movement of equipment and production personnel in the area of the test jig in order to reduce turbulences.
- **Avoid fast moving air over the sensor**. E.g. do not use fans to blow directly at the sensors as it may lead to discrepancies between the sensors (Note: same as a human, a sensor that is exposed to a wind will feel a 'chill factor' and not correctly measure the real air temperature but a lower than actual temperature.).

To limit the effect of draughts and turbulences in the air, it is recommended to shield the jig and create a gentle flow of air over the test jig may help reduce turbulences and operator influence.

- Make the test jig accessible for operation on the front side only. **Shield the test jig from turbulence** on all other sides.
- Add a computer fan into the top cover of the shielding to **create an even and gentle air flow** over the test jig and ensure that the air sucked by the fan is at relatively stable temperature and humidity. It shall be assessed, if an ionizer fan is required (instead of an ordinary computer fan).

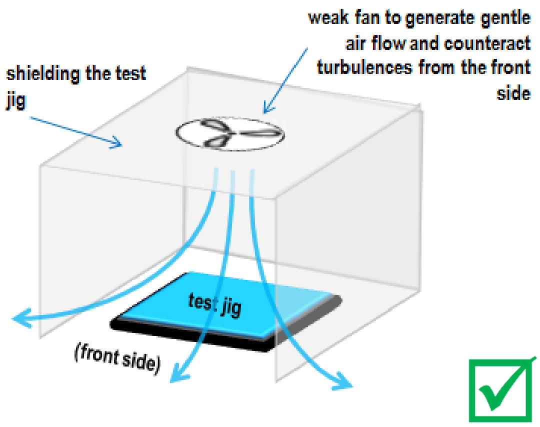

Figure 15 Shielding the test jig to the left/right/back/top reduce turbulences at the test jig. Access for operation is from the front side only. A small fan in the top cover ensures a gentle air flow towards the operator, further reducing the effect of turbulence near the jig.

Operation Procedure

The handling instructions for handling of electronic components (ESD protection) apply. As well, the general handling instructions for Sensirion Humidity & Temperature Sensors apply.
Additionally adhering to the following operation guidelines may help further reduce measurement variance:

- **Handle** the units **as far as possible from the sensor**. This will minimize the effect of the operator's body heat on the measurement.

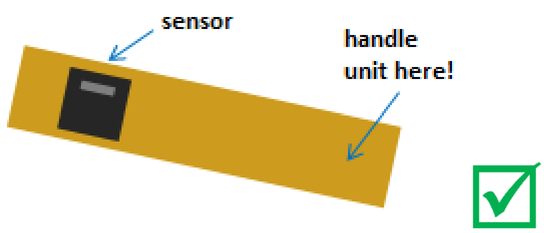

Figure 16 Handle the units before test as far away from the sensor as possible to prevent the operator's body heat to warm up the DUT.

- To reduce the impact of the operator's breath (exhaled air is rather warm and humid), the operator may be wearing a face mask.

The local humidity and temperature on the test jig may significantly differ from other areas in the production room. This implies that devices for test may be at a different temperature and humidity level when arriving at the test station and require longer settling times.

- **Pre-stage units before test** on top of (or just beside) the test jig, to allow units to adjust to local temperature and humidity (compare Figure 7).

Temporary Offset in Humidity Measurements

Sensirion Humidity & Temperature Sensors are factory-calibrated. However, any assembly processes that expose the sensor to high temperature, will cause a temporary offset in the humidity value. The reflow soldering process (that exposes the sensor to temperatures above 240°C) typically causes a temporary offset of about -1 %RH to -2 %RH. Other processes exposing the sensor to high temperatures may cause a similar offset.
This offset is only temporary and will slowly recover once the sensor is exposed to ambient conditions.

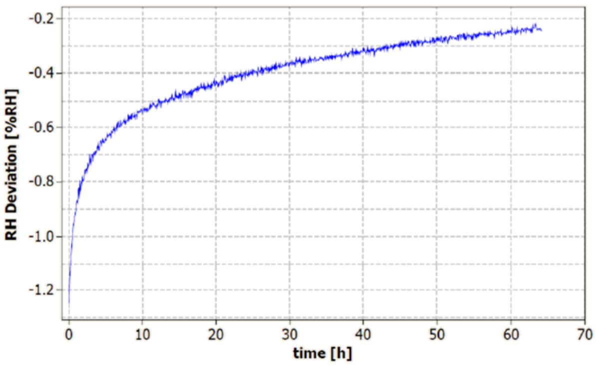

Figure 17 Mean deviation from initial calibration when sensor is exposed to ambient conditions of 25°C and 50 %RH directly after reflow soldering process (representative plot)

To accelerate the recovery process the units may undergo a so called reconditioning process (refer to application note on reconditioning). However, as the recovery will happen naturally at ambient conditions, it is in most cases not necessary to undergo such a reconditioning process. The temporary offset may just need to be considered when defining the test limits (see below).

Note that only the humidity value may be affected by a temporary offset while the temperature value will remain unaffected by processes at high temperature.

Measurement System Analysis

For a capable test setup only a minor percentage of total variation is attributed to hardware (good repeatability) and operator (good reproducibility) and the majority of variation is directly related to the units under test.

Once the test jig has been built and the initial test environment and procedures have been defined it is highly recommended to perform a Measurement System Analysis (MSA) to understand the repeatability and reproducibility of measurements. If the MSA should reveal a low measurement capability – i.e. a lot of the total variation is attributed to the hardware and/or the operator procedure – the test setup/procedure should possibly be improved.

If the MSA should reveal problems related to the temperature measurement as well as the humidity measurement, it is recommended to first address the problems on the temperature measurement. As relative humidity is temperature dependent, any improvement on the temperature measurement will improve the relative humidity measurement at the same time. Once the MSA results for temperature are satisfying, any remaining problems related to relative humidity may be addressed.

If the MSA reveals a low reliability and reproducibility but it is not possible to further improve the capability of the setup, the results of the MSA at least provides an understanding of the limitations and accuracy of the setup.

Test Limits

Once an optimized test system is available, appropriate test limits need to be defined. Test limits need to consider all of the following main factors:

- Specified accuracy of the reference sensor(s) (see datasheet)
- Specified accuracy of the sensor under test (see datasheet)
- Variation caused by the measurement system (see section

Measurement System Analysis)
- For humidity only: any temporary offset that is still present when testing the sensors (see section Temporary Offset in Humidity Measurements)

Initial test limits should be verified using a Process Capability (Cpk) Analysis. Once the initial test limits are defined, the production performance should be reviewed regularly and limits adjusted as needed.

In case units get repeatedly tested throughout the production flow (e.g. 1st test on PCB, 2nd test in sub-assembly, 3rd test of final product), test limits at each stage should be more relaxed than for the previous test stage (guard banding of limits). The larger the variation caused by the test setup (see section Measurement System Analysis), the larger this relaxation of subsequent limits should be. This is to prevent that units that marginally passed one test would marginally fail a subsequent test just because of variation caused by the test setup.

Disclaimer

The above given restrictions, recommendations, materials, etc. do not cover all possible cases and items. This document is not to be considered complete and is subject to change without prior notice.

Revision History

Date	Revision	Changes
2013-07-17	1	initial revision
2013-10-01	2	Added self-heating unit with housing.
2022-10-17	3	Confidentiality change from D3 to D1, removed water mark, adapted document to SHT85, updated disclaimer note

Important Notices

Warning, Personal Injury

Do not use this product as safety or emergency stop devices or in any other application where failure of the product could result in personal injury. Do not use this product for applications other than its intended and authorized use. Before installing, handling, using or servicing this product, please consult the data sheet and application notes. Failure to comply with these instructions could result in death or serious injury.

If the Buyer shall purchase or use SENSIRION products for any unintended or unauthorized application, Buyer shall defend, indemnify and hold harmless SENSIRION and its officers, employees, subsidiaries, affiliates and distributors against all claims, costs, damages and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if SENSIRION shall be allegedly negligent with respect to the design or the manufacture of the product.

ESD Precautions

The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take customary and statutory ESD precautions when handling this product. See application note "ESD, Latchup and EMC" for more information.

Warranty

SENSIRION warrants solely to the original purchaser of this product for a period of 12 months (one year) from the date of delivery that this product shall be of the quality, material and workmanship defined in SENSIRION's published specifications of the product. Within such period, if proven to be defective, SENSIRION shall repair and/or replace this product, in SENSIRION's discretion, free of charge to the Buyer, provided that:

- notice in writing describing the defects shall be given to SENSIRION within fourteen (14) days after their appearance;
- such defects shall be found, to SENSIRION's reasonable satisfaction, to have arisen from SENSIRION's faulty design, material, or workmanship;
- the defective product shall be returned to SENSIRION's factory at the Buyer's expense; and
- the warranty period for any repaired or replaced product shall be limited to the unexpired portion of the original period.

This warranty does not apply to any equipment which has not been installed and used within the specifications recommended by SENSIRION for the intended and proper use of the equipment. EXCEPT FOR THE WARRANTIES EXPRESSLY SET FORTH HEREIN, SENSIRION MAKES NO WARRANTIES, EITHER EXPRESS OR IMPLIED, WITH RESPECT TO THE PRODUCT. ANY AND ALL WARRANTIES, INCLUDING WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, ARE EXPRESSLY EXCLUDED AND DECLINED.

SENSIRION is only liable for defects of this product arising under the conditions of operation provided for in the data sheet and proper use of the goods. SENSIRION explicitly disclaims all warranties, express or implied, for any period during which the goods are operated or stored not in accordance with the technical specifications.

SENSIRION does not assume any liability arising out of any application or use of any product or circuit and specifically disclaims any and all liability, including without limitation consequential or incidental damages. All operating parameters, including without limitation recommended parameters, must be validated for each customer's applications by customer's technical experts. Recommended parameters can and do vary in different applications.

SENSIRION reserves the right, without further notice, (i) to change the product specifications and/or the information in this document and (ii) to improve reliability, functions and design of this product.

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