SENSIRION

Sensor Specification Statement and Testing Guide
Understanding and testing the specifications of RHT sensors

Abstract

Reading specifications of relative humidity sensors can often be unsatisfying as there is no common agreed standard for specifying humidity sensors. Statements may therefore be misleading, testing sensors against specification can require clarification, and comparing specifications of different sensors is often challenging. To alleviate the issue, this document details how Sensirion humidity and temperature sensors specifications are to be understood. Furthermore, methodologies for testing the sensors against various statements in the specifications are given, such that the user can test the sensors accordingly.

Applicability

This document is applicable to all SHTxx humidity and temperature sensors from Sensirion.

Contents

1 Specifications

1.1 General considerations

Sensor components detecting relative humidity consist of a sensing element – a polymer in most cases – which absorbs and desorbs water molecules, depending on the surrounding conditions. The process of gaseous molecules entering and leaving solid material is quite sophisticated and bears many special effects.

To make humidity sensors applicable to commercial products, these special effects must be brought to a simple understanding, which can be tested with standard, commonly available equipment. Such simplification will of course leave some grey zones, which are not scientifically covered. But the resulting specifications should give the user a reliable tool to understand the sensors and integrate them into his own devices.

Accuracy of relative humidity sensors can be characterized by three different, rather independent terms: calibration accuracy, hysteresis and long-term drift. Beyond this, short-term stability, extreme conditions behavior (i.e. in very cold, hot, humid or dry environments), and non-linearity are also to be considered.

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1.2 Accuracy - Calibration

Calibration accuracy is the main component of an accuracy specification. It provides information on deviation of the individual sensor readings in equilibrium state against a high precision reference at the time of calibration (which is understood to be about the time of sale). Major causes for tolerance on calibration accuracy are in-batch variation (e.g. homogeneity of conditions within calibration chamber), batch-to-batch variation, precision of calibration reference, and stability of sensors. Calibration accuracy is measured against a dew point mirror i.e. a high precision reference. Thus, the user should be able to reproduce the value. Sensirion specifies calibration accuracy with two different parameters: the maximal and the typical accuracy.

Accuracy distribution: For an ensemble of sensors such as a production lot, the variation of the measured deviation against the reference follows a normal distribution. It is characterized by an average value μ and a standard deviation σ.

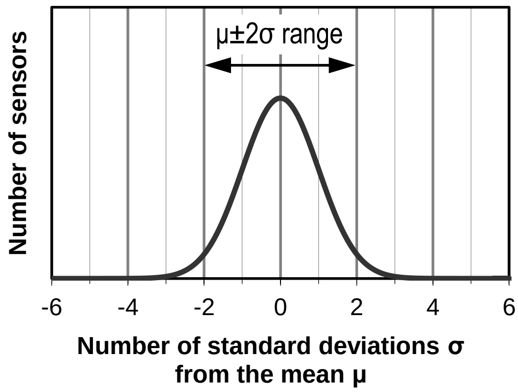

Figure 1 Distribution of sensor deviation around average. The μ±2σ range is targeted to fit within the typical accuracy limits, while the μ±4σ range is targeted to fit within the maximal accuracy limits.

Typical accuracy: The accuracy distribution of the ensemble up to μ±2σ is targeted to fit within the typical accuracy limits.

***Maximal accuracy*:** The accuracy distribution of the ensemble up to μ±4σ is targeted to fit within the maximal accuracy limits. This is equivalent to targeting a process capability index $C_{pk} \geq 1.33$. A one-hundred percent end test and a sample test ensure that only sensors satisfying the maximal accuracy limits qualify for sales.

Accuracy limits are specified for the full range of supply voltage unless stated otherwise. RH accuracies for different temperatures are stated in the respective sensor datasheets.

1.3 Accuracy - Hysteresis

The hysteresis value is the difference of measured values of the same sensor at a certain log point accruing from dry environment on one hand and humid environment on the other hand – given enough dwell time. In other words, humidity sensors carry some memory of conditions experienced in their recent past. Sensors with a dry history carry some negative offset while sensors with a humid history carry some positive offset. Hysteresis is due to the composition and design of the sensor element.

As the hysteresis does not depend on the quality of calibration but is dependent on the exposure range while in application, this value is understood to be *additional* to calibration accuracy.

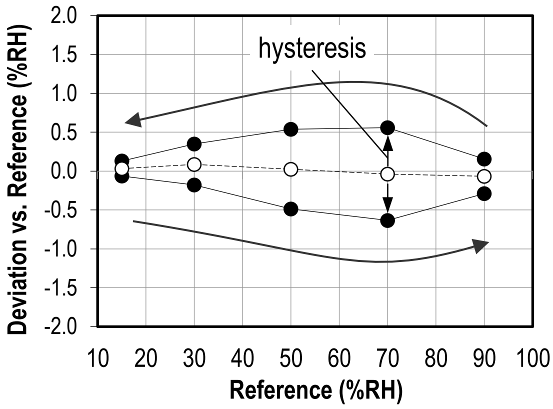

Figure 2 Example for hysteresis measurement. A path from dry to humid and one from humid to dry is measured (full dots on graph). Dwell time at each log point is 40min. Open dots represent the mean values i.e. calibration accuracy.

Calibration accuracy and hysteresis values are determined by running the sensor in a full humidity loop 15% → 30% → 50% → 70% → 90% → 90% → 70% → 50% → 30% → 15% with dwell times of 40 minutes at each log point. For the determination of calibration accuracy at a certain humidity value, the mean value is calculated from the measured values of the ascending and the descending path. The difference between the measured values and the mean values determines the hysteresis.

From a sample of sensors an average value and standard deviations of the various calibration accuracy values can be determined. With these values compliance of typical limits can be checked (see **Figure 3**).

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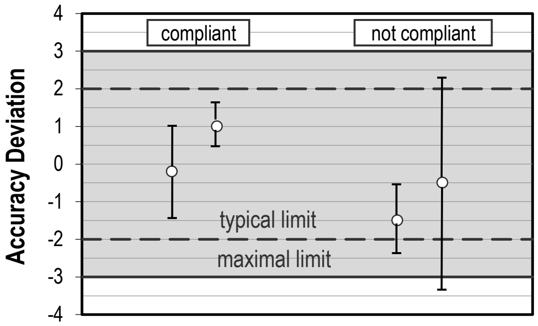

Figure 3 Examples for accuracy distributions complying (left side) or not complying (right side) with the specified accuracy limits. Open dots represent average values. Error bars denote the $\mu\pm2\sigma$ range and are targeted to remain within typical limits.

1.4 Accuracy - Long-term drift

The aging of the sensor element may lead to drift of the measured value compared to reference. Such a long-term drift is about random – it may move to the upper or lower side or may change direction in the course of time. The long-term drift value is a maximal limit for such drift per year.

In the case of Sensirion, long term drift is determined by exposing a sample of sensors to High Temperature Operating Lifetime (HTOL) with operation at 125°C for 408 hours. This exposure is equivalent to aging at 25°C for a much longer duration, which can be calculated with the following formula:

$$t_{T_0} = t_{T_1} \cdot exp\left(\frac{E_a}{k} \cdot \left(\frac{1}{T_1} - \frac{1}{T_0}\right)\right)^{-1}$$

T_1 corresponds to the higher temperature (125°C in the example) and T_0 to the lower temperature (25°C). Note that these temperatures must be expressed in Kelvin in the equation above. t_1 and t_0 stand for the durations (hours) spent at T_1 and T_0 respectively. k is the Boltzmann constant ($8.61*10^{-5}$ eV/K) and E_a is the thermal activation energy.

With E_a ~ 0.65eV for degradation within CMOS structures and E_a ~ 0.75eV for hydrolytic degradation within the humidity sensor element, one gets that storage at 125°C for 408 hours corresponds to 27 and 71 years spent at 25°C, respectively for CMOS structures and the sensing element. Note that aging within humidity sensor elements is very complex and difficult to model. Activation energies are chosen as the lowest among various processes and therefore leads to the worst-case consideration.

The sensor with largest drift during such an exposure divided by the calculated exposure at 25°C determines the long-term drift value per year. The specified value additionally contains some margin to compensate for modelling assumptions and for higher base temperatures.

1.5 Short-term stability

Short term stability may be characterized by ***repeatability*** – repeated measurements with the same sensor in identical conditions. The measure for such term is the standard deviation for the sample of repeatability measurements.

1.6 Extreme conditions

Capacitive humidity sensors undergo a reversible drift at very humid and very dry conditions. In case of Sensirion humidity sensors, and at relative humidity > 80%RH – and the higher the stronger – the sensor reading creeps to higher values. The reference value is given for constant exposure to 90%RH for 60 hours. The same is true at very dry conditions – such as reflow soldering – where the sensor reading creeps to lower values. A re-hydration procedure is then required to take the sensor back to its normal reading state.

1.7 Non-linearity

This term stands for systematic deviations outside the calibrated log points. Such deviations of the sensor output as well as temperature compensation may be corrected by a linearization formula. Hence non-linearity may be made very small by using the appropriate formula. Non-linearity values are included by the accuracy tolerance and shall not be considered as an additional term.

1.8 Response time

For response times, Sensirion specifies a so-called $\tau_{63\%}$ (read "tau 63%") or equivalently $\tau_{1/e}$ time. For a sensor exposed to an abruptly changing environment (step function of measured physical value), the sensor reading approaches the final value typically on an exponential function over time. The $\tau_{63\%}$ time extends from the moment of the environmental change at the sensor until the sensor reading reaches 63% of the step height (see **Figure 4**).

When testing response time, it is important that all other parameters, except the one to be tested, remain constant. Also, one must ensure that there is no dead time between the step function initiated by the system and the sensor experiencing the step function.

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For temperature measurements the thermal mass and thermal conductivity of the substrate play an important role. Therefore, temperature response time values are specified very vaguely.

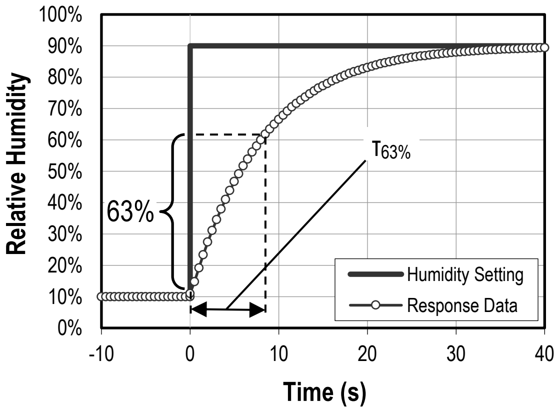

Figure 4 Measurement profile of response time testing for relative humidity.

1.9 Supply voltage

The ***supply voltage (V_{DD})*** range is defined with an upper and a lower limit, plus a typical value. Any supply voltage in that range may be used for continuous operation. Absolute maximum voltages that may be applied for a limited time only are specified in the datasheet of the respective sensors. The typical value defines the supply voltage at which the sensors are calibrated and at which quality control is performed.

1.10 Current and energy consumption

During operation the sensor pulls a certain ***supply current (I_{DD})***. This current is different in idle state than while measuring/communicating. Furthermore, in an ensemble of sensors there is a certain variation in current consumption. The average of the ensemble is specified as typical value, while minimum and maximum values define the lower and upper limits.

The ***power consumption (P)*** is calculated as $P = I_{DD} * V_{DD}$ with I_{DD} the supply current and V_{DD} a specified constant supply voltage.

To determine the average value of power consumption over time, we consider a specific measurement resolution and measurement frequency (indicated in the datasheet of the respective sensor). The average power consumption is then the power consumption averaged between the time spent measuring and the time spent in idle state over a measurement interval. The average supply current over time for the specified measurement resolution and frequency is related to the average power consumption through the constant supplied voltage V_{DD}.

Note that additional power is consumed during start-up phase or during operation of other sensor functionalities.

2 Testing

2.1 Preparation

For calibration and end testing of RHT sensors, Sensirion is using expert calibration equipment and procedures guaranteeing highest precision and reliability. To ensure consistent testing of Sensirion SHTxx relative humidity & temperature sensors the following preparation items should be carefully considered:

a) *Test Objects:* The test series should consist of at least 5-10 sensors, which should be taken out of the original packaging.

b) *Conditioning:* Make sure that sensors have not been contaminated prior to the testing. Original packaging should not have been fixed with scotch tape, and packaging should not have been stored in plastic bags. If you are unsure whether sensors might have been contaminated or not, follow the re-conditioning procedure (80-90°C [176-194°F] at < 5%RH for 24h (baking) followed by 20-30°C [70-90°F] at > 74 %RH for 48h (re-hydration)).

c) *Re-hydration after soldering:* In case sensors have been soldered to a PCB board please make sure that the re-hydration procedure (20-30°C [70-90°F] at >74%RH for 48 hours) has been applied after soldering.

d) *Test set-up:* Make sure that test and reference sensor experience identical humidity and temperature conditions. If possible, make use of a professional humidity chamber. If such a chamber is not available to you, put the reference and test sensor into a closed box and give the set-up time to homogenize. Please make also sure that there are no humidity absorbing materials (silicone sealing, rubber, etc.), nor contaminating materials present near the sensor. More information on contamination can be found in the info sheet “Handling Instructions”.

e) *Reference sensor:* The reference sensor should be of high reliability. If possible, use a dew point mirror or recently calibrated RH probes.

2.2 Testing RH Accuracy

It is recommended to run the following test profile: Set temperature to 25°C (77°F) and run a low – medium – high RH profile (e.g. 15% – 30% – 50% – 70% – 90%) and check hysteresis with a high – medium – low RH profile (e.g. 90% – 70% – 50% – 30% – 15%). See **Figure 5**. Allow at least 40 minutes settling time at each relative humidity set-point, before starting a measurement. For the first set point, a longer waiting time might be required to allow the temperature to stabilize (~3 hours for temperature changes <30°).

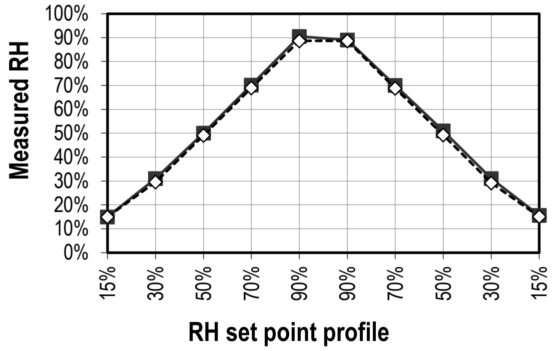

Figure 5 Measurement profile for accuracy testing (full squares: reference, open diamonds: test sensor).

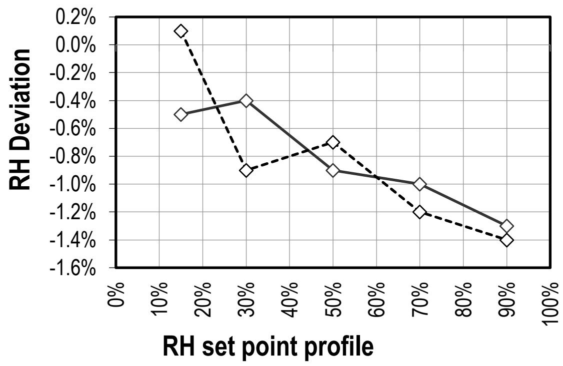

Figure 6 RH deviation profile, full line: ascending order, hatched line: descending order.

It is also recommended to operate the SHTxx sensors with the Sensirion SEK Evaluation Kit to avoid communication or conversion errors.

IMPORTANT: Relative humidity is highly temperature dependent. During the measurement, the temperature of reference and test sensor must show the same value to make RH values comparable. For your test records it is highly recommended to note RH and T for each set-point and sensor.

2.3 Testing T accuracy

For testing temperature accuracy, the same general procedures apply as for RH. Due to the very high temperature accuracy of SHTxx sensors, additional improvements to the measurement set-up need to be applied. Consider especially point e) of the preparation guidelines: the best practice is to use a reference which is much more accurate than the sensors (ideally by a factor 10). To make sure that the sensors measure the same temperature as the reference, and therefore to make the measurements valid, consider the following best practices:

a) *Thermal coupling*: Attach the sensors and the reference to a highly temperature conducting material. This can be achieved easily by attaching them to a piece of metal such as copper. More thermal mass is advantageous.

b) *Homogeneity*: Place the sensors and the reference close to each other to limit the influence of air flows or heating/cooling effects inside the test chamber. Additionally, use a measurement chamber which is as small as possible. This can be achieved by putting a small measurement box in a bigger climate chamber.

c) *Settling time*: Similar to the testing of RH accuracy, a long settling time is required before measurement to let the system reach equilibrium (~3 hours for temperature changes below 30°). When choosing the settling time, due consideration should be given to the thermal masses involved in the measurement setup.

2.4 Testing RH response time

For properly measuring RH response times a test set-up should guarantee a step function from dry air to humid air at the very same temperature, or vice versa. Therefore, the test set-up in **Figure 7** is recommended. The sensor is placed into a climate chamber whose volume must be very small to allow for fast environmental change dynamics. A rotary valve controls the air intake of the chamber, enabling to switch between dry air and humid air. It is a crucial element for creating a step function in environmental condition. Dry air is taken from a compressed, oil-free air tank – while humid air is taken from a humidity chamber. As the compressed air cools down with expansion, the temperature shall be brought to room temperature by a heater. The heater alternatively can be placed between air bottle and rotary valve or between rotary valve and test chamber. The tubing between the valve and the test chamber shall be kept as short as possible. This allows for an abrupt change from dry to humid air. A flow rate of the dry

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air and humid air of at least 1 m/s is recommended to avoid that the setup is limiting the response time.

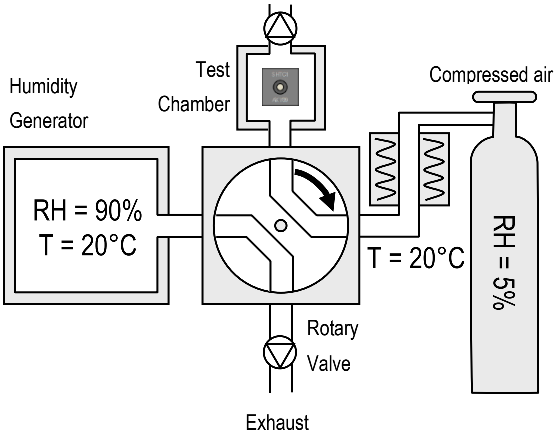

Figure 7 Response time test set up. Dry air from compressed air is blown into test chamber with sensor – a heater makes sure the air is at room temperature. With a rotary valve the relative humidity is taken from a humidity chamber and therefore abruptly changed from low to high.

To start the measurement, blow dry air into the sensor box and give the sensor time to display a constant value. It should be in the range of 5 - 10% RH. Control the temperature carefully as well. Then change the air source abruptly and make sure the temperature remains constant. To avoid any temperature changes it is recommended to run the measurement at ambient temperature.

The data should behave roughly inverse exponential (see **Figure 4**). The SHTxx sensors readings should reach 63% of the full RH step within the $\tau_{63\%}$ of the sensor. For example, if the RH step is between 10%RH and 90%RH, then the RH value shall read >60%RH within $\tau_{63\%}$ seconds. Note that the last percentage points of the response curve to complete the full step will develop with a lower time constant.

There is an alternative option to measure response time in a very simple and effective way – which, however, may not fulfill scientific standards: put the sensor into a humidity chamber with high humidity (90%RH for example) or if no humidity chamber is available, put the sensor into a closed box with an open glass of water. Make sure that the temperature inside the chamber or box is equal to the outside temperature. Start measuring (for example with the Sensirion SEK Evaluation Kit) and when the values are high and stable remove the sensor from the box or chamber and expose it to the outside conditions. Give the sensor enough time to stabilize the RH value and in this way define the full RH step. The response time can then be derived from the data.

3 Revision History

Date	Revision	Changes
18. March 2010	1.0	Initial release
07. June 2018	1.1	Update for new sensors
19. April 2021	2	Merged testing guide into document; visual and text update

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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.

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