Sensor Specification Statement

How to Understand Specification of Relative Humidity Sensors

Preface

Reading specifications of relative humidity sensors quite often is unsatisfying: There is no common agreed standard for specifying humidity sensors. Hence it is difficult to navigate in specifications, statements may be misleading, testing sensors against specification needs clarification, and specifications of different sensor types are almost impossible to compare.

In this document Sensirion gives details on how the terms in specifications of Sensirion humidity and temperature sensors are to be understood. Furthermore, the test routines for the sensors against the various statements in the specifications are given, such that the user can test accordingly. This all shall lead to more satisfaction reading Sensirion's specifications.

Applicability

This document is applicable to all humidity and temperature sensors from Sensirion, e.g. SHT1x, SHT7x, and SHT2x.

Accuracy

Basic Considerations

Sensors components detecting relative humidity consist of a sensing element – a polymer in most of the 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.

However, to make humidity sensors applicable to commercial products and ease our lives at reasonable cost, these special effects must be brought to a simple understanding which can be tested with standard equipment which is commonly available. It is clear that such a simple understanding leaves some grey zones, which are not scientifically correctly covered. Still, a specification shall give the user a reliable tool to understand the sensors and plan his own devices.

For a simple but thorough understanding, the accuracy of relative humidity sensors may be divided into three different rather independent terms: Calibration accuracy, hysteresis and long term drift. Beyond this, short term stability is an issue and there are some effects at extreme conditions – i.e. very cold, hot, humid or dry environments.

Calibration Accuracy

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 – a high precision reference. Thus, the user shall be able to reproduce the value.

Sensirion specifies calibration accuracy with two different parameters:

Typical accuracy: The above mentioned variation of measured deviation against reference may be characterized by an average value and a coverage factor *k* (k=1 is equivalent to standard distribution σ in case of normal distribution). For typical tolerances of accuracy at a certain log point, Sensirion understands that for a sample, such as a batch, average values ±*2k* are located inside specified limits. With other words 95% of the sensors measure within this typical limits.

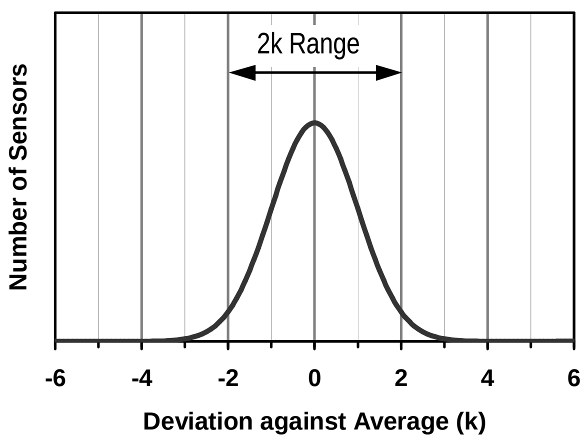

Figure 1 Distribution of sensor deviation around average. *2k* range must fit into typical specification band. The coverage factor *k* is equivalent to standard deviation σ in case of normal distribution.

***Maximum accuracy limit*:** Only sensors measuring within the maximum accuracy limit band qualify for sales. Hence, no sensors with tolerances outside the maximum limits are shipped to customers. Furthermore, a process capability index $C_{pk} = 1.33$ is targeted.

Maximum accuracy limits are specified for the full range of supply voltage if not stated otherwise. In general the specification is valid at 25°C; however, for SHT2x there is an extended specification for temperatures 0 – 80°C.

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 – giving enough dwell time. With other words, humidity sensors carry some memory of conditions experienced in recent past: Sensors with dry history carry some negative offset while sensors with humid history carry some positive offset. Hysteresis appears due to composition and design of the sensor element.

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

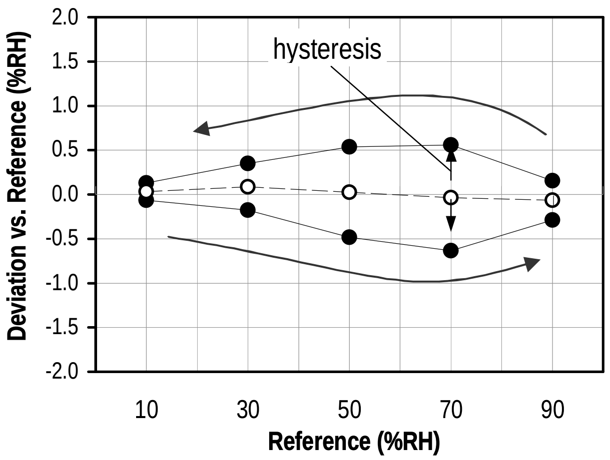

Figure 2 Example for hysteresis measurement. A path from dry to humid and one from humid to dry is measured – full dots on graph. Dwell time at each log point is 30 minutes. Open dots determine mean values – representing calibration accuracy.

Measuring Calibration Accuracy and Hysteresis

Calibration accuracy and hysteresis values are determined by running the sensor in a full humidity loop 10% → 30% → 50% → 70% → 90% → 90% → 70% → 50% → 30% → 10% with dwell times of half an hour at each log point. For the determination of calibration accuracy at a certain humidity value, the mean value is calculated from measured values of ascending and descending path. The difference of these measured values and mean value determine the value for 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 – compare Figure 3.

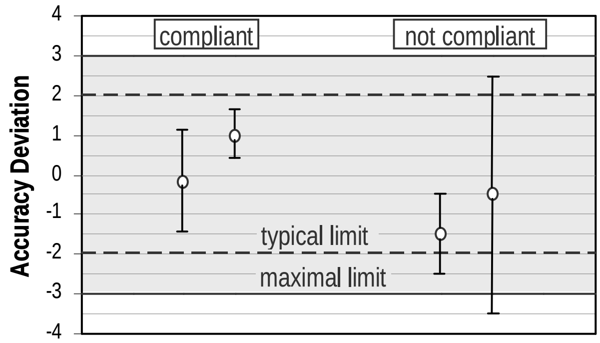

Figure 3 Examples for accuracy distributions complying (left side) or not complying (right side) with the specified accuracy range. Open dots represent average values. Error bars denote 2k range and must stay within typical limits.

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 so called High Temperature Operating Lifetime (HTOL) – operation at 125°C during 408 hours. The exposure at 125°C corresponds to aging at 25°C during a much longer time period, 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_x stand for durations (hours), T_1 corresponds to the high temperature (125°C in the example) and T_0 the low temperature (25°C). Please note that these temperatures must be put to Kelvin for above equation. E_a is the thermal activation energy, and k is the Boltzmann constant ($8.61 \cdot 10^{-5}$eV /K). With E_a in the range of 0.65eV within CMOS structures for the temperature sensor and 0.75eV for hydrolytic degradation within the humidity sensor element the storage at 125°C during 408 hours corresponds to duration at 25°C of 27 and 71 years, respectively.

Please note that aging within humidity sensor elements are very complex and difficult to simulate. The chosen activation energy is chosen as it is the lowest of the various processes and therefore leads to the shortest extension in the simulation.

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 the complex model and for higher base temperatures.

Stability and Extreme Conditions

Repeatability: Short term stability may be characterized by repeatability – repeated measurements with same sensor at constant conditions. The measure for such term is the standard deviation for the sample of repeatability measurements.

Creep: Capacitive humidity sensors undergo a reversible drift at very humid and very dry conditions. In case of Sensirion's humidity sensors, and at relative humidity > 80%RH – and the higher the stronger – the sensor reading creeps to the high. The reference value is given for constant exposure to 90%RH during 60hours. Please note that the creep value is explicitly denoted in the extended specification (Chapter 1 of the Users Guide of the Datasheet).

The same is true at very dry conditions – such as reflow soldering – and require re-hydration procedures to take the sensor to normal reading state.

More Terms

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 giving the right formula. Non-linearity values are included by the accuracy tolerance and shall not be considered as an additional term.

Response Time

Definition

For response times, Sensirion specifies a so called tau_63% (also 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 readings complete 63% of the step height. Please also see Figure 4.

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

For measuring the response time of the relative humidity sensor the volume of the climate chamber where the sensor is placed in must be kept very small. The step function of the changing environment – compare Figure 4 – shall be created by a rotary valve.

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

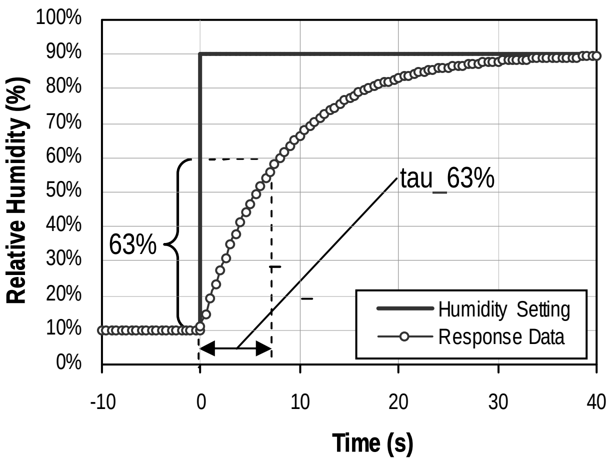

Figure 4 Measurement profile of response time testing for relative humidity.

For information on details how to qualify sensors and testing their performance please consult the Application Note "Testing Guide".

Electrical Specification

Supply Voltage

The ***Supply Voltage (VDD)*** 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, which may be applied during limited time, for some sensors are specified in the Users Guide of the respective Datasheet. The typical value defines the supply voltage at which the sensors are calibrated and at which outgoing quality control is performed.

Current and Energy Consumption

In operation the sensor pulls a certain ***Supply Current, IDD***. This current is different for sleep mode and measuring/communicating. Furthermore, in the sample of sensors there is a certain variation of current consumption – the average is specified as typical value while with minimum and maximum values the upper and lower limit is defined.

Power Dissipation (P) is calculated from Supply Current values: $P = IDD * VDD_{typ}$ where IDD is the Supply Current and VDD_{typ} held constant at typical Supply Voltage.

For calculating the average value the following assumption is made: One certain measurement at a certain resolution and at a certain measurement frequency is made. For example the settings for SHT21 are one 8bit measurement per second. The time for measuring and communication is derived from the respective Table, where a typical value shall be chosen (e.g. for SHT21, 3ms for an 8bit measurement). The time for communication may be neglected. The remainder of the measuring interval is considered to be sleep mode. The respective power dissipations are multiplied with respective times and divided by the full measurement interval. In the example of SHT21 the average energy consumption is calculated as follows: *(3ms * 900µW + 997ms * 0.5µW) / 1000ms = 3.2µW*.

Please note that additional power is consumed during start-up phase. For some of the sensor types this value is specified in the Users Guide of the respective Datasheet.

Revision History

Date	Revision	Changes
18 March 2010	1.0	Initial release

Headquarter and Sales Offices

[redacted]