Application Note
Using the Integrated Heater of SHT4x in High-Humidity Environments

Abstract

Polymer-based capacitive humidity sensors are best suited for operation at intermediate humidity levels. When exposed to high humidity environments (~>90%RH) for extended exposure times they develop a reversible, positive humidity offset. In the following, this offset is called *Creep*. It occurs when water molecules continuously soak the polymer without escaping from it. Original accuracy specifications are restored by itself through exposing the sensor to regular humidity and temperature conditions again. This process takes longer the more water is impregnated into the polymer. This document outlines how SHT4x's integrated on-chip heater can be used to mitigate creep and take highly accurate measurements. Two different approaches to creep-free operation are discussed: Continuous and single-shot measurement. In both cases, the thermal energy provided by the integrated heater removes excess water from the sensing polymer. In the continuous case the heater is activated periodically while for the single-shot, it is turned on only in case a measurement is due. Finally, best practices for this application are summarized.

Contents

1 Creep Definition

Polymer-based capacitive humidity sensors show best performances when operating within their recommended temperature and humidity range, i.e., 5 °C – 60 °C and 20 %RH – 80 %RH [1]. Long-term sensor exposure outside of these conditions, especially at relative humidity (RH) levels larger than 90%RH, may induce a reversible, positive RH offset. This effect will be called *Creep* in the following. Nevertheless, after returning into recommended operating conditions, the sensor gradually converges back to within accuracy specification by itself.
Sensirion defines the creep of a humidity sensor by its RH offset accumulated during exposure to 90%RH for 61 hours. The typical RH transient drift acquired over that period for different humidity sensors is illustrated in **Figure 1**. To get a reproduceable quantification of a sensor's creep, the first 30 min and the last 60 min of the RH transient are averaged, respectively. The difference of these two average values is attributed to creep.

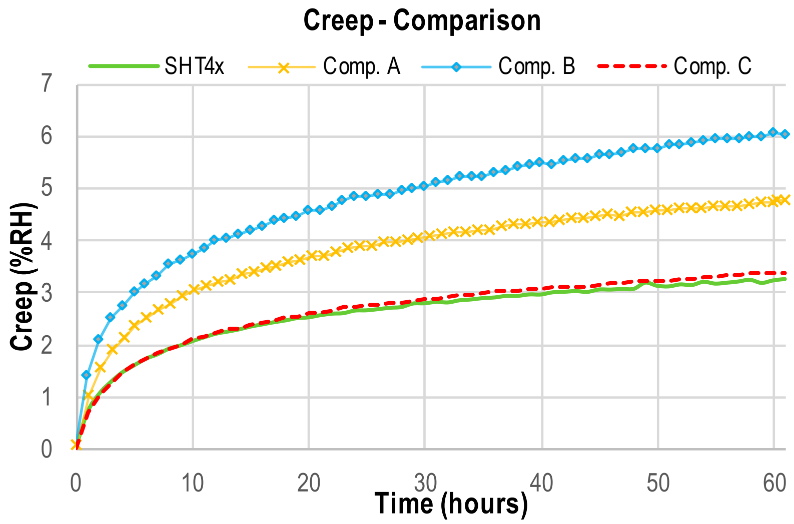

Figure 1 Creep comparison of multiple commercially available capacitive humidity sensors. All sensors are kept at 90 %RH over the whole measurement duration, and only the build-up of the creep offset is plotted here.

2 Creep Mitigation

2.1 Scope and Applications

This application note describes how creep can be efficiently mitigated when using Sensirion's SHT4x. It is achieved by heating the sensor using its integrated heater. Here, two different application scenarios are distinguished:

I) Continuous creep mitigation. The sensor is continuously exposed to a high relative humidity environment. Periodic heating of the sensor for a short period of time can reduce or even entirely mitigate creep.

II) Single-Shot creep mitigation. The sensor is exposed to an undefined environment, which might include a high relative humidity environment. Right before the measurement is taken, the heater is activated for a short period to reduce the effect of a potential creep offset.

Note:

> The usage of the heater enables reliable operation even in extreme environment. Moreover, no previous humidity information ("history") is needed when applying creep mitigation measures, making the SHT4x very versatile for many applications. However, it is worth to remind that the overall sensor's power consumption increases during the activation of the heater and that the sampling rate must be reduced.

2.2 Test Setup and Heater Commands

For evaluation two lots of SHT4x sensors were soldered on 1.5 mm thick printed circuit board (PCB). The PCB consists of FR-4 and the die pad of the sensors was not soldered to increase the peak temperature after the heat pulse. In the SHT4x family, a set of discrete heat powers and times is available to the user, see **Table 1**. The assembled PCBs were kept in a controlled humidity environment for upcoming experiments. At a base temperature of 25°C the activation of the heater at a given power and for a given time results in an average temperature increase also summarized in **Table 1**.

Command (hex)	0x15	0x1E	0x24	0x2F	0x32	0x39
Heating Power (mW)	20	20	110	110	200	200
Heating Duration (s)	0.1	1.0	0.1	1.0	0.1	1.0
Average ΔT (°C]	3	6	16	31	29	50

Table 1 SHT4x heater commands with related heating power, duration, and resulting temperature increase.

Attention:

The average temperature increase strongly depends on the heating commands, the thermal coupling to the sensor environment (thermal capacity, thermal conductivity) and on external parameters such as e.g., free and forced convection. The parameters listed in this Application Note were identified exemplarily for the described experimental setup. They shall serve as starting point for further device-specific engineering.

3 Continuous Creep Mitigation

If the sensor is permanently operated in high humidity environments, a periodic heater activation will mitigate the creep offset. To properly readout the correct value, the following scheme applies to each cycle execution: heating pulse, waiting time until thermal equilibrium is reached again (called equilibration time), read-out of creep-free RH signal. In this case, the highest measurement frequency is limited by the equilibration time for the sensor to reach ambient temperature again. It can be estimated by monitoring the temperature signal and comparing it to the temperature just before heating. Since the response time of the humidity sensor is temperature dependent, it is important to keep in mind that the results presented here were performed at 25 °C ambient temperature. In fact, the equilibration time would probably increase at temperatures below 25 °C because of the slower diffusion process of water molecules into the sensing polymer.
The creep reduction was evaluated exposing the sensors to 90 %RH over an extended period. With a periodic heating pulse of 200 mW for 1 second every minute and an equilibration time of 1min, **Figure 2** shows that the creep offset can be almost completely compensated for.
In principle, since the creep mitigation works independently of "creep severity", it should always be possible to do this once the best parameters are found since they only depend on humidity and environment conditions.

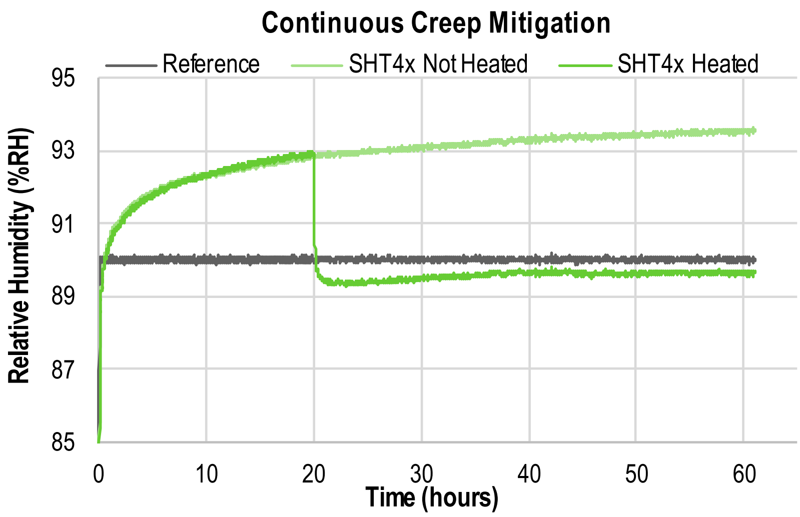

Figure 2 Continuous creep mitigation results. Both sensors were allowed to creep at 90 %RH, with one of the two turned into a periodic heating scheme after t = 20h. The heated sensor shows a reading within typical specifications while the not heated sensor develops further creep offset. Creep mitigation was achieved with following, continuous heating cycle: A 200mW-1s-heating-pulse every minute.

4 Single-Shot Creep Mitigation

In case the humidity history of the sensor is not known several consecutive heating pulses are used to increase thermal activation of the water-soaked polymer. The heating phase is then followed by an equilibration time in which the temperature reaches ambient again. Once the sensor is cooled down, the creep mitigated RH value is ready to be read. For example, the results reported in **Figure 3** were performed after an unknown sensor exposure to 90 %RH at 25 °C, causing the sensor to leave its typical specifications. In this case a heating period of 2 minutes using 200 mW pulses every two seconds was used. During the heating time, the RH signal is corrupted by the additional heat in the sensor. After a waiting time of two minutes, the sensor reports temperatures just as before the heating and is therefore equilibrated again. Now, the RH sensor can be operated within its typical specifications until the creep built-up gets significant again.

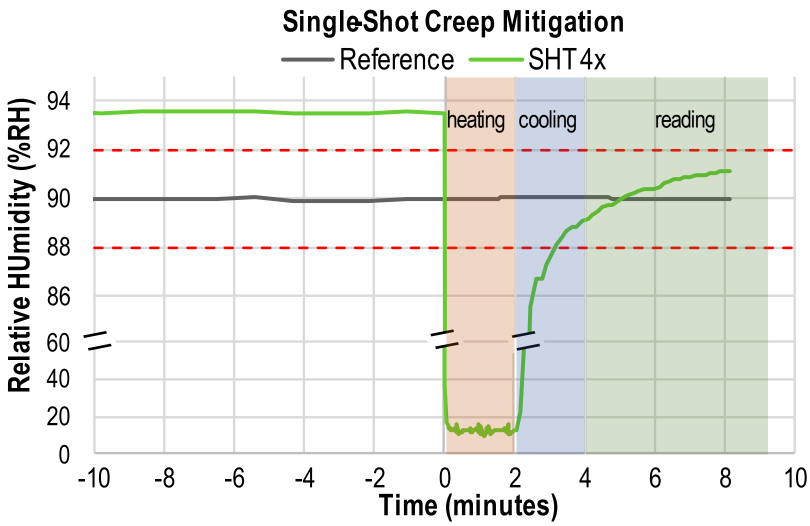

Figure 3 Single-shot creep mitigation of a pre-creeped sensor. At t = 0min a heating phase is started for two minutes. After a certain waiting time, “cooling”, the sensor is in thermal equilibrium again. Then, RH readings within typical accuracy specifications can be taken.

In this scenario it is important to thoroughly evaluate the equilibration time that is necessary for a correct measurement. Quite generally, heating times of a few minutes have been prooved sufficient, however need application specific engineering.

5 Creep Mitigation in Analog Sensors

For all digital versions of the SHT4x family, controlling the heater is achieved through its I2C commands listed in **Table 1**. In the analog version of the SHT4x family, the heater cannot be switched on by sending an input from the master. However, an on-chip anti-creep option for pre-selection will be available, see (SHT4xI-Analog datasheet). Once powered up, the sensor will periodically heat according to the selected option enabling creep-free measurement also for analog sensors.

6 Further Information

For further reading on the SHT4x specifications, communication, and heater details, please consult the SHT4x datasheet provided on the Sensirion download center: https://sensirion.com/products/downloads/

7 Revision History

Date	Version	Page(s)	Changes
April 2022	1	all	Initial release

8 Bibliography

[1] Sensirion, "SHT4x Datasheet," 2020. [Online]. Available: Datasheet SHT4x (sensirion.com).

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.

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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:

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