# SHTxx Design Guide

## How to design-in a humidity and temperature sensor.

**Preface**

The SHTxx are humidity and temperature sensors of high quality. The digital interface and factory calibration allows a fast and easy implementation as well as full interchangeability. In order to take full advangtage of their outstanding performance and features a number of housing and PCB design rules need to be considered. This document lists this design rules and provides help during design-in phase. Please note that unbeneficial housing and/or PCB designs may cause significant temperature and humidity deviations as well as highly increased response times.

## Introduction

The accuracy of a measurement does not just depend on the sensor accuracy itself but also on the set up of the sensing system. The SHTxx sensors sample relative humidity and temperature of their direct environment. It is thus important that the local conditions at the sensor correspond to the conditions under test.

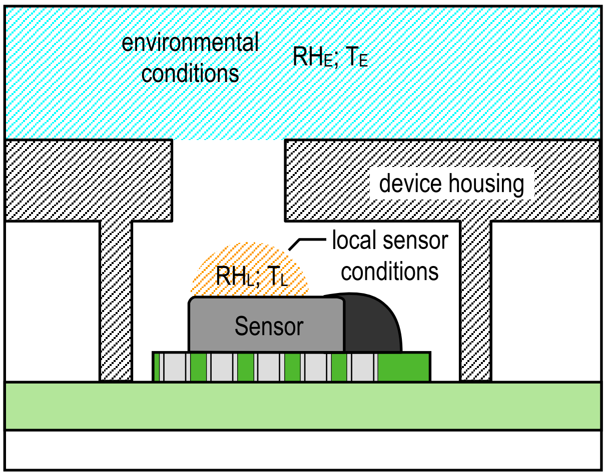



*Figure 1: The sensor measures the local conditions at the sensing element ($RH_L$; $T_L$). In order to achieve good measurements this local conditions need to correspond to the conditions of the environment under test (i.e. $RH_E$; $T_E$ ).*

For proper measurements using SHTxx sensors, temperature and relative humidity (RH) deviations between the sensor and the environment must be avoided. A usual root cause for temperature deviations are heat sources, while RH deviations are mostly caused by temperature deviations as well as slow response times. Please note that every temperature deviation will cause RH deviations due to the temperature dependence of the relative humidity, i.e. a deviation of 1°C at 90%RH will result in a 5%RH deviation. For further details please check the application note "Introduction to Relative Humidity"[1].

For each temperature or humidity change of the environment, the sensor requires a certain amount of time to equilibrate with the new environmental conditions. During this time the sensor readings may lag behind the actual values. This is called response time. To get precise data it is recommended to decrease the response time of the sensor system as good as possible. If the system must react on fast changes a sufficient fast response time is crucial.

How to effectuate a housing and PCB design to get accurate measurements with fast response times is descried in the following sections.

- Heating
- Humidity Response Time
- Temperature Response Time
- Design for harsh Environments
- Examples

## Heating

External heat sources close to the sensor or internal heating by heat dissipation of the sensor itself will cause increased temperature (and thus decreased RH) readings. To avoid heating of the sensor please consider the following:

- Self heating: The sensor should be less then 10% in active state.
- Heat conduction: The sensor should be thermally decoupled from all heat sources.
- Heat convection / radiation: Shield the sensor from heated air and heat radiation.

### Self heating

Due to the tiny size of the sensing elements even the small power consumption of the SHTxx sensor might cause self heating. As the power consumption is significantly increased while in active state (measuring + communicating) it is recommended to be less then 10% of the time in active state (see *Figure 2*) in order to avoid self heating. The number of readings that can be done per second depends on the resolution of the measurement and the sensor type. Please check the datasheet of the according sensor at [www.sensirion.com/humidity](www.sensirion.com/humidity) for further details.

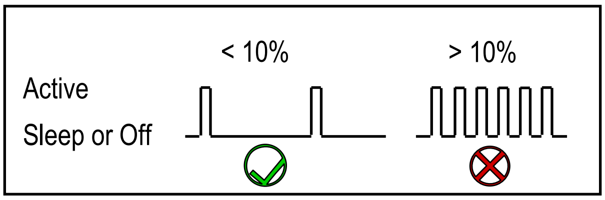



*Figure 2: Using the sensor more then 10% in active state may cause internal heating which results in a temperature and humidity deviation.*

### Heat conduction

The most common root cause for local heating of the sensor is due to thermal conduction from a nearby heat source (power electronics, microprocessors, displays, etc…). As thermal conduction mostly occurs through the metal on the PCB, thin metal lines and sufficient distances between the sensor and potential heat sources are recommended. Further, heat conduction can be decreased by milling slits in - and removing (etching) all unnecessary metal from the PCB around the sensor (see Figure *3*). Another possibility to decrease heat conuction to the sensor is the use of a flex print to connect the sensor to the PCB (see *Figure 8*).

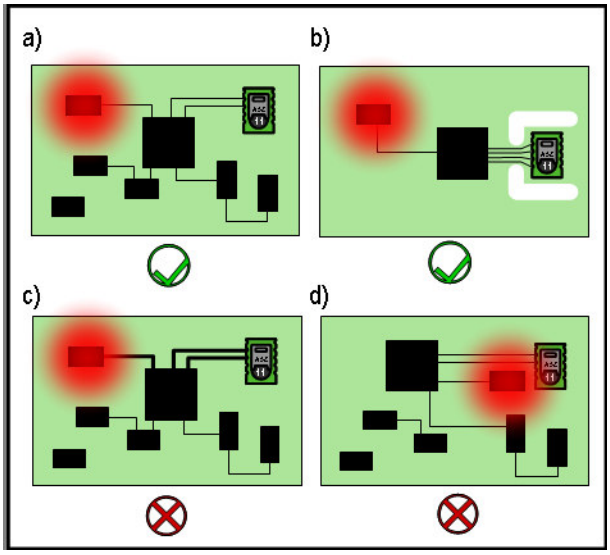



*Figure 3: a) Thin metal connections and sufficient distance to the heat source helps to avoid heat conduction. Please note to remove unnecessary metal on the PCB around the sensor. b) The milled slits (white lines) around the sensor decrease the thermal conduction through the PCB. c) Unnecessary metal, such as thick metal connections will increase heat transfer from the heat source to the sensor. d) Heat sources in close proximity will heat the sensor*

### Heat convection / radiation

Inside of electronic devices the air might be heated up by electronic components. Contact of heated air and the sensor shall be avoided by shielding the sensor physically from all heat sources (see *Figure 4*). Additionally there should be a sufficient heat transfer out of the devices to avoid the heating of the complete housing.

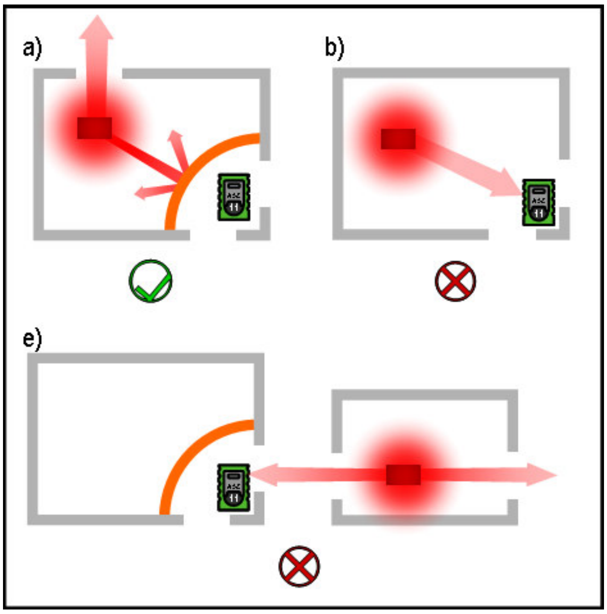



*Figure 4: a) A wall of the housing (orange) shields the sensor from the heated air. The opening on the top avoids the heating of the complete housing. b) The heated air gets in direct contact with the sensor which will cause increased temperature readings. c) Even heated air from nearby devices may influence the sensor readings.*

Do not expose the sensor to direct heat radiation (e.g. direct sunlight) to avoid heating. If the radiation is strong the complete housing should be shielded from the radiation (see *Figure 5*).

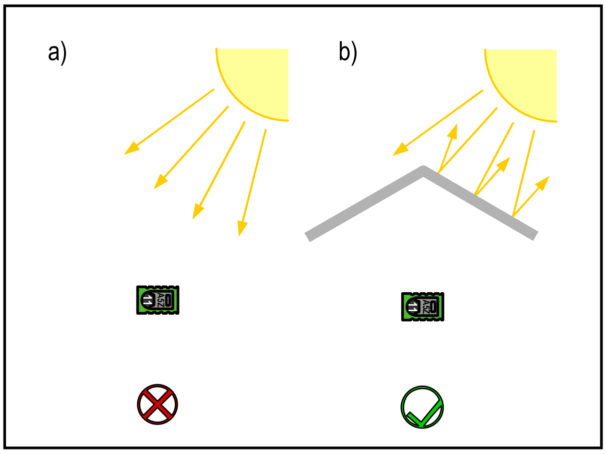



*Figure 5: Direct sunlight or other heat radiation may cause increased temperature readings.*

## Humidity Response Time

For proper humidity measurements it is important that the humidity at the sensor matches the one of the environment while acquiring data. Therefore the sensor should be connected as well as possible to environmental air. Housing designs with a large dead volume and/or small aperture may act as a separation of the sensor and environment (see *Figure 1)* which may result in highly increased response times. In order to achieve fast response times please consider the following:

- Place the sensor as close to the environment as possible.
- A design which allows an airflow over the sensor is preferred to a design with a single aperture.
- The dead volume (see *Figure 6*) should be as small as possible
- The aperture(s) should be as large as possible
- Filter membranes will slow down humidity response. Never use more then one membrane per aperture.
- There should be no material which can absorb humidity inside of the dead volume.

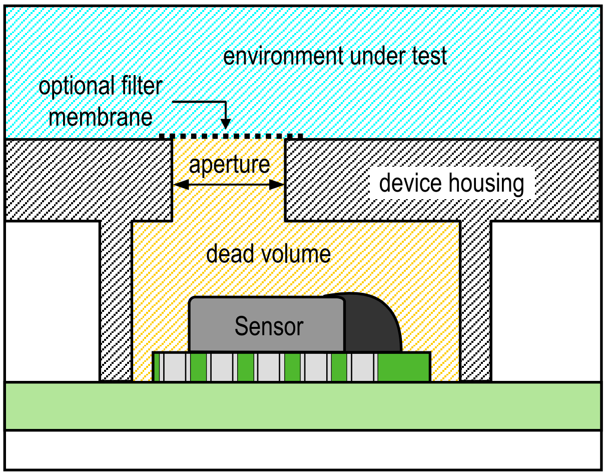



*Figure 6: This figure shows a schematic view of a sensor design-in. The volume around the sensor which is separated from the environment is called dead volume. The aperture is the cross section area which connects the dead volume and the environment. This example has an additional filter membrane which may help to protect the sensor (see below) but will slow down the response time.*

### Design with a possible Airflow

If there is an airflow over the sensor (see *Figure 7* a, d and e), the air inside of the dead volume is exchanged constantly. Such a design is favourable in terms of response times. Even if there is no defined flow (e.g. in a living room) a design with multiple openings and a possible flow is preferred. If there is no possibility to realize a design with airflow over the sensor, the following terms becomes more important.

### Dead Volume

The larger the dead volume the more air needs to be exchanged until the environmental and sensor conditions match each other. Large dead volume s will drastically increase the humidity response time. It is highly recommended to keep the dead volume as small as possible.

### Aperture Size

The aperture is the connection between environment and sensor. A bigger aperture allows a faster air exchange and therefore better humidity response times.

### Filter Membranes

Filter membranes may help to protect the sensor from harsh environments. But as they decrease the air exchange the response time will be slower. If a filter cap is required the size of the dead volume and the aperture becomes more important.

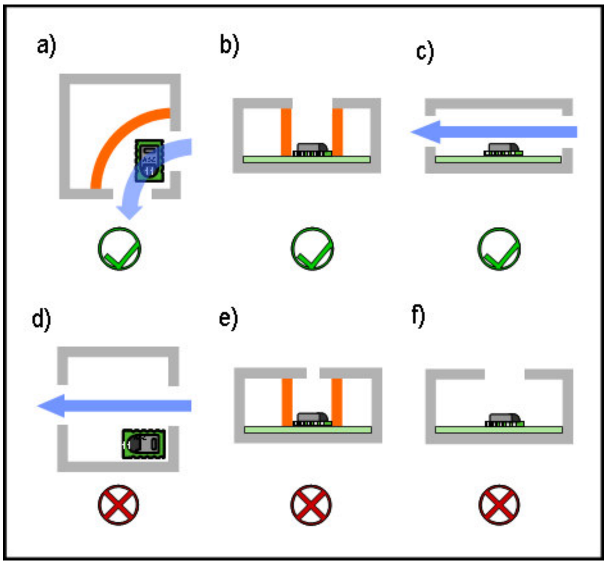



*Figure 7: Schematic view of different design-ins. a) This is the preferred design if ever possible. The small dead volume, sufficient aperture size and the air flow allow a fast humidity response time. b) The walls (orange) reduce the dead volume which will lead in combination with the large aperture to fairly good response times. c) The defined airflow goes directly over the sensor and therefore the local conditions at the sensor equilibrate quickly with the environmental conditions. If there is no defined flow this design is not recommended as the dead volume is too big. d-f) This designs will have slow humidity response times due to the following reasons: d) The airflow misses the sensor and the dead volume is large. e) The aperture size is too small in respect to the dead volume. f) The dead volume is large.*

## Temperature Response Time

Due to the thermal mass of a device it temperature reacts slow on changes of environmental temperature. In order to achieve fast temperature response times the following terms should be considered.

- Thermal coupling of the sensor to the environment under test should be as strong as possible.
- Thermal coupling of the sensor to the thermal mass of the housing (PCB) should be as weak as possible.

### Thermal coupling of the Sensor to the Environment

To achieve a good thermal coupling between the sensor and the environment the sensor should be placed as close to the environment as possible – best at a corner or at least at the edge of the device. An airstream of ambient air will additionally increase the coupling.

### Thermal coupling of the sensor to the thermal mass of the housing and the main PCB

In order to get a good decoupling of the sensor and the housing / PCB the heat conduction needs to be reduced as described in the heating section above (see *Figure 8*).

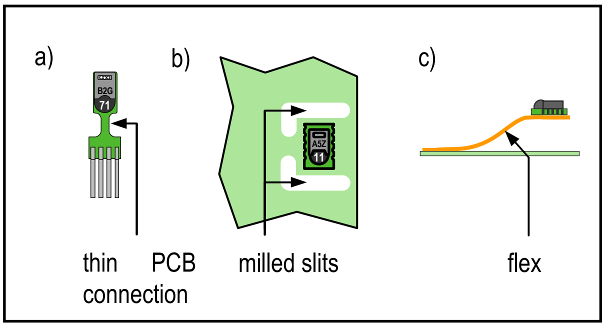


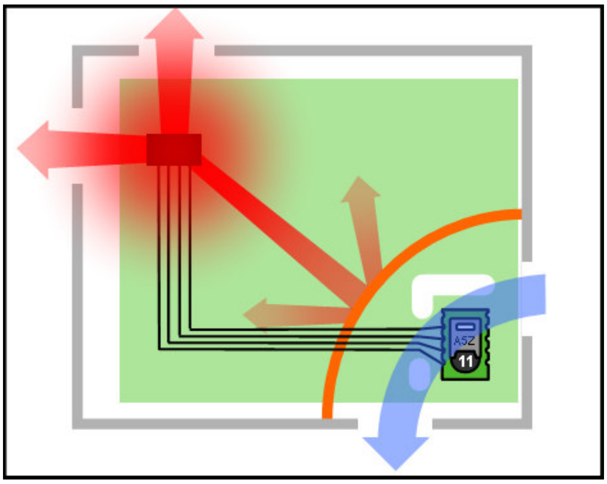

*Figure 8: The sensor may be thermally decoupled from the PCB by small PCB connections or with a flex.*

## Designs for harsh Environemts

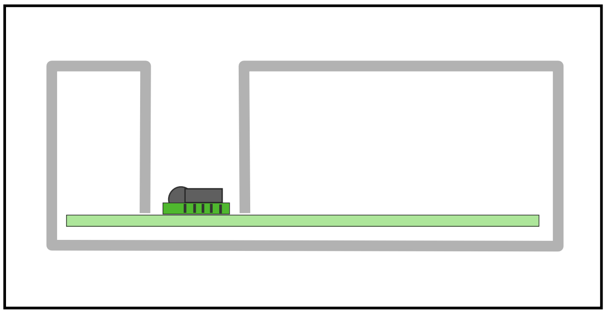
For the SHT1x and the SHT2x series there are filter caps available which can be used to achieve water and dust tight housings as well as good response times (see *Example 5 + 6)*. In order to achieve fast humidity response time they are design with a minimal dead volume. Detailed information about these filter caps may be found on:

## Examples

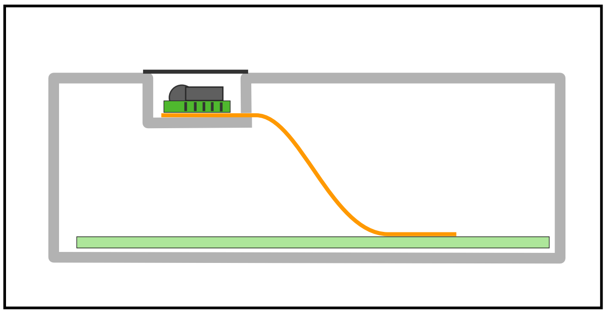
This chapter shows some different designs for different applications.



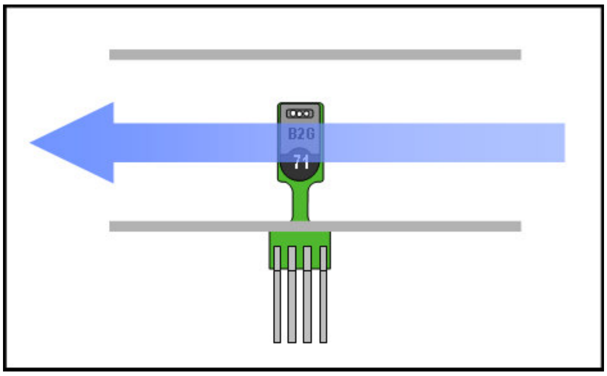
*Example 1: This is the most recommended design if no filter membrane is required. It well combines the rules above. The wall (orange) helps to shield the sensor from the heated air as well as it decreases the dead volume. The two openings allow an airflow over the sensor and the milled slits reduce thermal conduction through the PCB. Therefore this design provides fast response times as well as low influences from heating parts.*



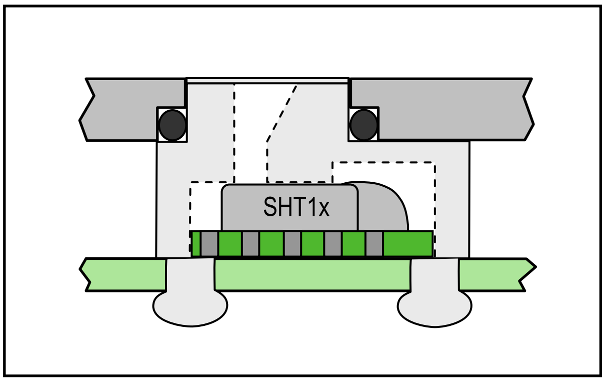
*Example 2: This is a more simple variation of Example 1. As there is no airflow the humidity response time is slower (depends on the distance of the sensor to the opening). With additional slits in the PCB the sensor could be shielded from external heating if required.*



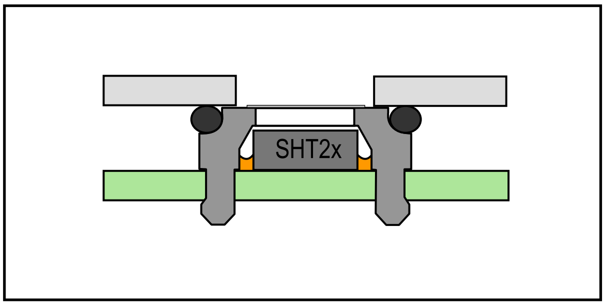
*Example 3: This is a more sophisticated version of Example 2 using a flex for thermal decoupling. Additionally there is a filter membrane to protect the sensor. The short distance between the sensor and the environment under test improves response times.*



*Example 4: This design shows an SHT71 inside of a tube with an airflow. The thin PCB connection decouples the SHT75 very well from the tube and grants a very fast thermal response time as well as reduced influence from temperature deviations between the tube and the airflow.*




*Example 5: The SF1 filter cap (for SHT1x)may help to design tight housings. The filter membrane protects the sensor and the housing from dust and water. Due to the very small volume between the sensor and the environment fast humidity response times can be achieved.*




*Example 6: The SF2 filter cap (for SHT2x) provides the same benefits like the SF1 (see Example 5).*

## Final remark

Please note that all rules and suggestions of this application note are term of simplified examples and may be not applicable for specific customer products. Therefore it is inevitable to carefully evaluate the design-in separately for each individual project. Please also read carefully the handling instructions during design-in phase and before production release.

## Revision History

| Date | Revision | Changes |
|---|---|---|
| 24 June 2010 | 1.0 | Initial release (DBO) |