SENSIRION

Application Note: ESD, Latch-Up and EMC

For all Sensirion Humidity and Temperature Sensors SHTxx

SHTxx humidity and temperature sensors (*i.e.,* the whole humidity and temperature sensor family of Sensirion) are qualified with respect to ESD (Electrostatic Discharge) and Latch-up compliant with all relevant standards (JESD 22 – A114, MIL Standard 883^{E} and JEDEC78). Due to their micro-integration and digital interface, supported by a CRC checksum, SHTxx sensors benefit from superior functional immunity against electromagnetic interferences (EMI) originated by *e.g.,* mobile phones, machinery and other RF radiating devices.

This application note elaborates on ESD and Latch-up and provides an insight into the protection circuits of the SHTxx sensors. In case improved ESD protection is required, an example of additional external ESD protection is suggested. In addition, information on electromagnetic compatible (EMC) design with the sensor is provided.

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1 ESD Protection

Electrostatic discharge (ESD) may damage integrated circuits without adequate protection. SHTxx sensors contain state of the art built-in ESD protection circuits on all pins. Functional schematics of ESD protection circuits are displayed in **Figure 1**.

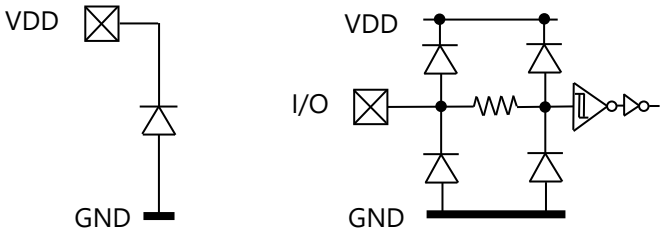

Figure 1. Functional schematic of ESD protection circuits for the VDD pad (left panel) and the I/O pads (right panel).

1.1 Human Body Model (HBM)

The sensors are tested using the Human Body Model for components (according to JESD 22 – A114 and MIL Std 883^{E}). The test circuit is shown in **Figure 2**.

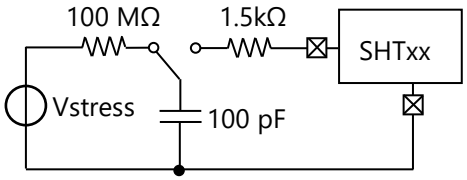

Figure 2. Human-Body Model test circuit. The 100 pF capacitor simulates the capacitance of the human body, the 1.5 kΩ value of the discharge resistor the internal resistance of the human body. The voltage (V_{stress}) is applied in pulses of 0.1 µs, positive and negative.

The maximal V_{stress} varies depending on the SHTxx model, as described in the corresponding datasheets. A device passes the test when no abnormal difference is observed between pre- and post- measurements (*e.g.*, pins current *vs.* voltage, chip consumption, …). A device qualified for a maximal V_{stress} rating of 4 kV means that the sensor also successfully passed stress levels of 0.5 kV, 1 kV and 2 kV.

The stress test was performed according to **Table 1**:

Stressed Pin	Reference	Polarity
SCL	GND	3 positive pulses followed by 3 negative pulses
SDA	GND	
SCL	VDD	
SDA	VDD	
GND	VDD	
SCL	SDA	

Table 1. Summary of the tested HBM configurations.

All SHTxx sensors successfully pass the Human-Body Model test, which is well accepted in the industry and confirms that SHTxx sensors are wdell protected for applications and handling with normal precautions.

For increased robustness, an external protection circuit according to **Figure 3** may be added.

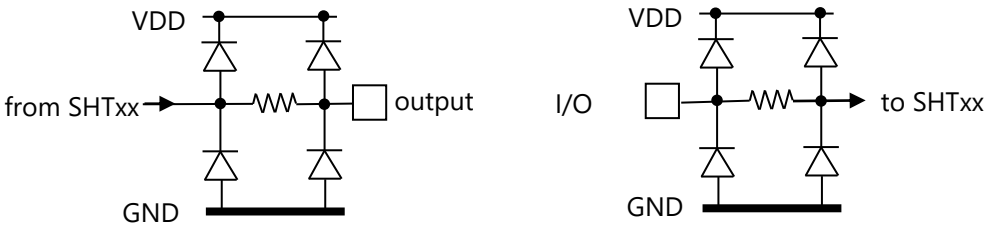

Figure 3. Additional external protection for SHTxx sensors

1.2 Charged Devide Model (CDM)

All SHTxx sensors are also tested using the Charged Device Model for components (according to JESD standard and AEC Q100). The usual setup for these tests is described in **Figure 4**.

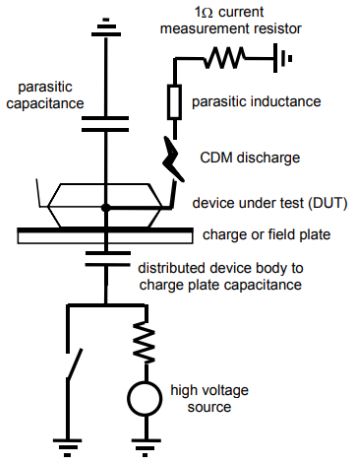

Figure 4. Charged Device Model test circuit for field induced charge.

In the setup above, the sensor is placed upside-down on a field plate. A high voltage source first charges the field plate through a 4 pF capacitor, charging the sensor itself. Then a pin under test is discharged and the resulting effect, *i.e.* the current on the pin is measured. This procedure is repeated for each pin.

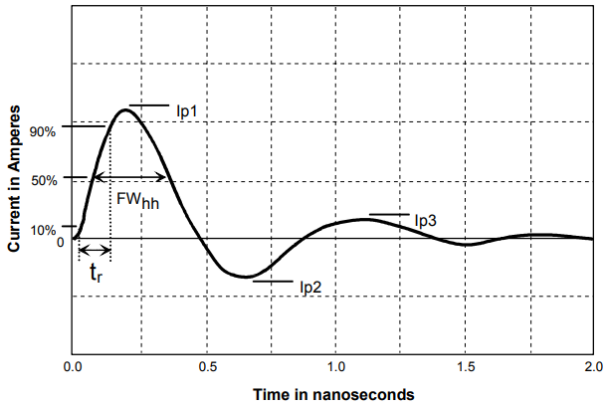

Figure 5. Typical CDM induced current waveform observed on the pin under test upon discharge.

Level (V)	Ip1 (A)	Ip2 (A)	Ip3 (A)	tr (ps)	FWHH (ps)
250	2.25	< Ip1/2	<Ip1/4	< 400	< 600
500	4.5				
1000	9				

Table 2. CDM specification (FWHH = Full Width at Half Height). The voltage level is applied from the source **Figure 4**.

Stress levels and executed qualification tests vary depending on the SHTxx model, as described in the corresponding datasheets. A device qualified for a rating of *e.g.,* 750 V means that both -750 V and 750 V have been applied and that the pin discharges respecting the above specifications. It also means that tests run at 125 V, 250 V and 500 V were successful, too.

1.3 Machine Model

The Machine Model is usually not measured, since it's redundant if HBM and CDM are already measured, based on JEDEC considerations AEC_Q100_Rev_H:
"AEC Q100-003 ESD Machine Model: Removed from JEDEC due to obsolescence. HBM and CDM cover virtually all known ESD-related failure mechanisms." [1]

2 Latch-Up

Isolation between individual diodes, transistors and capacitors on an integrated circuit is achieved by reverse biased PN junctions. These junctions form NPN and PNP structures with adjacent junctions which result in parasitic thyristors. These parasitic thyristors may be undesirably triggered in various ways:

- In case there is a voltage at the input or output of the sensor, which is more positive than the supply or more negative than the ground connection, current flows into the gate of the parasitic thyristor. If the amplitude and duration of the current are above a certain value, the thyristor is triggered. At long lines (several meters) and overshoots, the probability of triggering the thyristor must be considered.
- An electrostatic discharge can trigger the parasitic thyristor. Even if the duration of an electrostatic discharge is only a few tens of nanoseconds, the complete chip may be flooded with charge carriers. These carriers then flow off slowly resulting in triggering the thyristor.
- Eventually, the parasitic thyristor may be triggered by a high supply voltage – however it must be by far higher than the value given in the datasheet.

Although these conditions violate the specification given in the SHTxx datasheets, they may occur during uncontrolled events. The sensor was designed to comply with state-of-the-art precautions to reduce the thyristors sensitivity to the maximum, and hence to avoid latch-up in all aforementioned situations.

To verify the latch-up immunity, the SHTxx sensor has been tested according to JEDEC Std 78 and AEC Q100-004D).

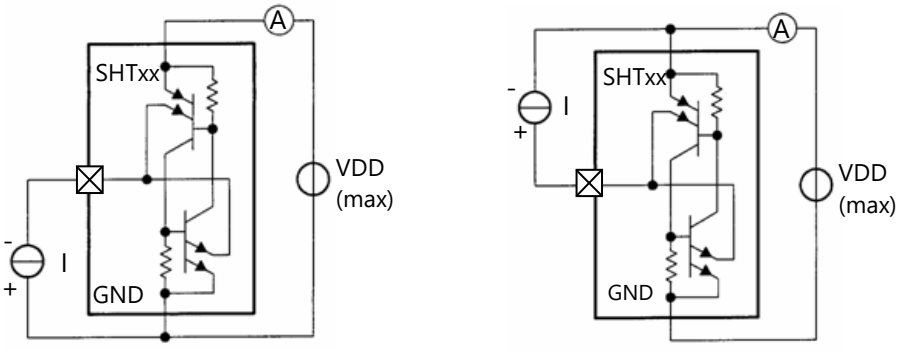

Figure 6. Latch-up test setup for respective pad and both positive and negative sign. The SHTxx is modeled here as a parasitic thyristor.

Referring to the setup described in **Figure 6**, the test consists in injecting a current *I* of ±100 mA at maximum stress voltage (MSV, standard 1.5*max(VDD)). The supply current *A* is measured before and after the latch up trigger-pulse. In case no difference between the values is observed and functionality of the device has not degraded the test is passed.

The test has been performed successfully on all pins of all SHTxx models.

3 EMC Protection

The SHTxx sensors are designed to retain reliable functionality in demanding environments, which comes with a number of advantages:

- Only few external components are required (*e.g.* pull-up resistors for I2C, see SHTxx datasheet). All susceptible circuit is integrated on the chip at micrometer scale making it inherently immune against RF radiation (originated for example by wireless devices).
- The digital I2C protocol allows for high S/N ratio.
- The I2C transmission frequency can be set arbitrarily to optimize the slopes of the signals and thus improve the susceptibility against bursts
- The CRC (cyclic redundancy check) allows for verifying whether the data transfer has properly been performed.

Sensirion recommends the following basic precautions when designing the circuit around the SHTxx sensors:

- A capacitor of 100 nF must be used between VDD and GND as close as possible to the sensor (compare datasheets).
- To minimize cross talk, SCL and SDA lines shall not run next to each other except for long ribbon or flat flexible cables.
- Reduce transmission frequency and slopes of the signals when using long cables. This is to reduce cross talk sensitivity, reflections and susceptibility against bursts. Slopes can be reduced by inserting a passive low pass filter, shown in **Figure 7**. Best results may be achieved when using a low pass filter on either side of the cable connection.

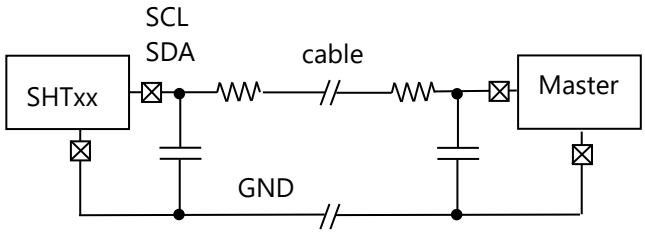

Figure 7. Reducing the slope of SCL and SDA line when using a long cable with the sensor.

4 Bibliography

[1] A. E. Council, "AEC - Q100," 30 May 2017. [Online]. Available: http://aecouncil.com/Documents/AEC_Q100_Rev_I.pdf.

5 Revision History

Date	Version	Pages	Changes
October 2003	1.0	all	Initial version
May 2005	1.1		
October 2006	1.2		
March 2009	1.3		
April 2023	2	All 3, 4	Formatting and rephrasing. Created ESD sub-chapter adding CDM and MM descriptions (consistent with SHT3x & SHT4x upgraded checks and datasheets specifications)

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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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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