HS41xx

High-Performance Relative Humidity and Temperature Sensor with Analog Output

The HS41xx series is a highly accurate, fully calibrated automotive grade relative humidity and temperature sensor with an analog output. While the HS410x series comes in a standard package with an open air inlet, the HS411x series features a hydrophobic membrane, making it dust resistant and waterproof with IP67 rating. Both sensor versions, waterproof and non-waterproof, are available in two different accuracy classes, HS41x1 and HS41x3. The MEMS sensor features a proprietary sensor-level protection, ensuring high reliability and long-term stability.

Integrated calibration using a NIST traceable and verified production setup that is calibrated to ISO/IEC 17025 standards and temperature-compensation logic provides fully corrected RH and temperature values via an analog output. User calibration of the output data is not required.

The high accuracy, fast measurement response time, and long-term stability, combined with the small package size, makes the HS41xx ideal for a wide number of applications ranging from portable devices to products designed for harsh environments.

The HS41xx are digital sensors at their core. Measurements are then converted to ratio-metric analog output. This makes the HS41xx suitable for high-noise environment applications.

Physical Characteristics

- Supply voltage of 1.71V to 3.6V
- Operating temperature of -40°C to +105°C
- 2.5 × 2.5 × 0.9 mm DFN-style 8-LGA package

Product Image
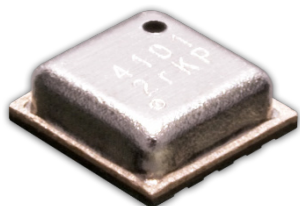
Features

- Humidity range: 0% to 100%RH
- Industrial grade, JEDEC qualified, -40°C to +105°C
- Automotive grade, AEC-Q100 qualified, Grade 2, -40°C to +105°C
- ESD Human Body Model, JESD22-A114, Class 2
- ESD Charged Device Model, JESD22-C101, Class C2
- NIST traceability for relative humidity and temperature
- Hydrophobic membrane, IP67 rating (HS411x)
- 10% to 90% ratio-metric analog output voltage
- RH accuracy: ±1.5%RH, typical (HS41x1)
- Fast RH response time: 4 seconds time constant, typical
- Temperature sensor accuracy: ±0.2°C, typical (HS41x1, -10°C to +80°C)
- Very low current consumption: 92µA average (3.3V supply)
- Excellent stability against aging and volatile compounds
- Highly robust protection from harsh environmental conditions and mechanical shock

Applications

- Climate control systems
- Instrumentation
- Home appliances
- Weather stations
- Building automation
- HVAC systems
- Medical equipment
- Data logging systems

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1. Pin Information

1.1 Pin Assignments
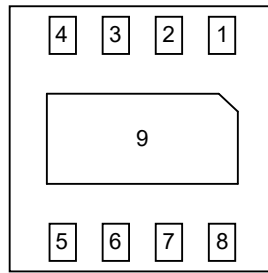
Figure 1. Pin Assignments – Top View

1.2 Pin Descriptions

Pin Number	Pin Name	Type	Description
1	VRH [0]	Out	Analog RH output voltage.
2	VSS	In	Ground.
3	VSS	In	Ground.
4	VT [0]	Out	Analog temperature output voltage.
5	VDD	In	Supply voltage.
6	NC [2]	-	Connect to V_{SS}, V_{DD} or leave floating
7	NC [2]	-	Connect to V_{SS}, V_{DD} or leave floating
8	VSS	In	Ground.
9	DAP	-	Connect to V_{SS} or leave floating

1. VRH and VT requires a capacitor (for more information, see Application Circuit).
2. "NC" stands for not connected / no connection required / not bonded.

1.3 Functional Diagram

Figure 2. Functional Diagram for HS41xx

2. Specifications

2.1 Absolute Maximum Ratings

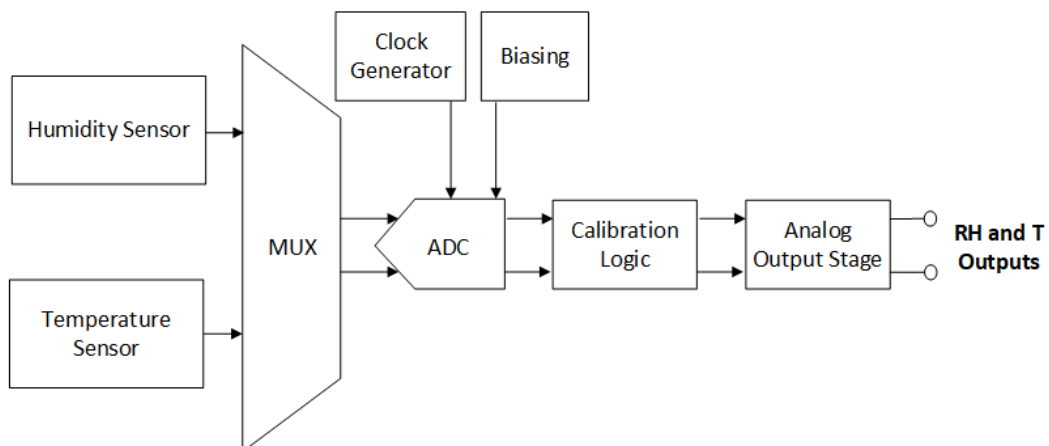*Caution*: The absolute maximum ratings are stress ratings only. Stresses greater than those listed below can cause permanent damage to the device. Functional operation of the HS41xx at absolute maximum ratings is not implied. Exposure to absolute maximum rating conditions might affect device reliability.

Parameter	Conditions	Minimum	Maximum	Unit
Supply Voltage	-	-0.3	3.6	V
Storage Temperature Range	Recommended 0 to 60°C	-40	125	°C

2.2 Recommended Operating Conditions

Important: The HS41xx series sensors are optimized to perform best in the more common temperature and humidity ranges of 10°C to 50°C and 20% RH to 80% RH, respectively. If operated outside of these conditions for extended periods, especially at high humidity levels, the sensors may exhibit an offset. In most cases, this offset is temporary and will gradually disappear once the sensor is returned to normal temperature and humidity conditions. The amount of the shift and the duration of the offset vary depending on the duration of exposure and the severity of the relative humidity and temperature conditions.[1] The time needed for the offset to disappear can also be decreased by using the procedures described in chapter 5.

Parameter	Condition	Minimum	Typical	Maximum	Unit
Operating Supply Voltage	-	1.71	3.3	3.6	V
Average Current	V_{DD} = 1.8V	-	82	95	µA
	V_{DD} = 3.3V	-	92	110	
Measurement Time	Humidity and temperature measurement	-	1.7	2.3	ms
Operating Temperature Range	-	-40	-	105	°C

1. At T_A = +25°C, V_{DD} = +1.71V to +3.6V unless otherwise noted.

3. Humidity and Temperature Sensor Performance

3.1 Humidity Sensor Specifications

Table 1. Humidity Sensor Specifications, T_A = +25°C, V_{DD} = 1.71V to 3.6V

Parameter	Condition		Minimum	Typical	Maximum	Unit
Range	-		0	-	100	%RH
Accuracy [1][2]	HS41x1	10% to 90%RH	-	±1.5	-	%RH
	HS41x3	20% to 80%RH	-	±2.5	-	
Resolution	14- bit		-	0.04	-	%RH
Hysteresis	-		-	-	±1.0	%RH
Non-Linearity from Response Curve	HS41x1	10% to 90%RH	-	±0.15	-	%RH
	HS41x3	20% to 80%RH				
Long-Term Stability			-	±0.1	-	%RH/Yr
Response Time Constant [3] (τ_H)	20% to 80% RH Still Air		3.0	4.0	6.0	sec

1. Monotonic increases from 10 to 90% RH after sensor has been stabilized at 50% RH.
2. For more information, see section 3.3.
3. Initial value to 63% of total variation. The response time depends on system airflow.

3.2 Temperature Sensor Specifications

Table 2. Temperature Sensor Specifications, T_A = +25°C, V_{DD} = 1.71V to 3.6V

Parameter	Condition		Minimum	Typical	Maximum	Unit
Range	-		-40	-	105	°C
Accuracy [1]	HS41x1	-10°C to 80°C	-	±0.2	-	°C
	HS41x3	0°C to 70°C	-	±0.25	-	
Resolution	-		-	0.01	-	°C
Response Time Constant [2] (τ_T)	-		-	>2.0	-	Sec.
Long-Term Stability	-		-	-	0.03	°C/Yr
Supply Voltage Dependency [3]	-		-	0.03	0.1	°C/V

1. For more information, see section 0.
2. Initial value to 63% of total variation. The response time depends on system thermal mass and air flow.
3. Temperature accuracy can be optimized for specified supply voltages upon request.

3.3   Humidity Sensor Accuracy Graphs

The typical and maximum relative humidity sensor accuracy tolerances are shown in the following figures.
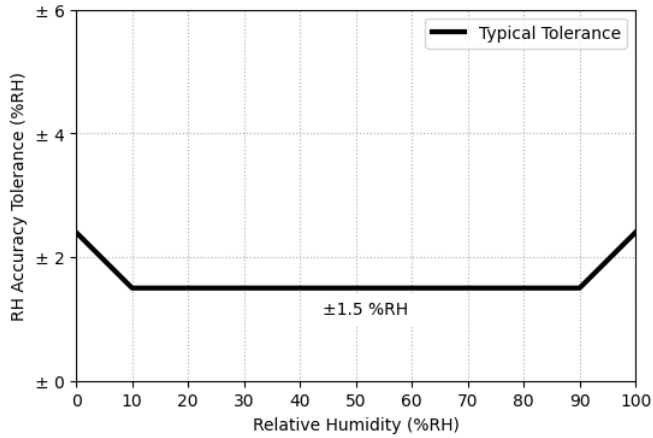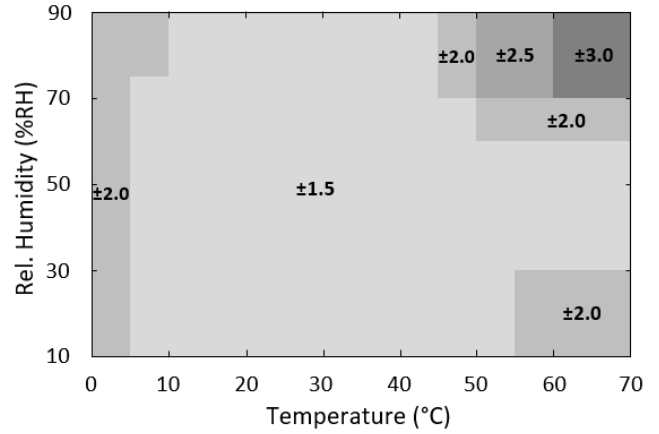

Figure 3. HS41x1 RH Accuracy Tolerance at 25°C

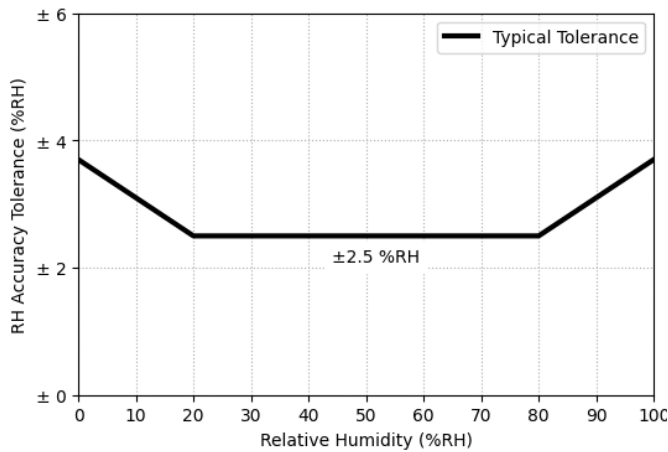
Figure 4. HS41x1 RH Accuracy over Temperature

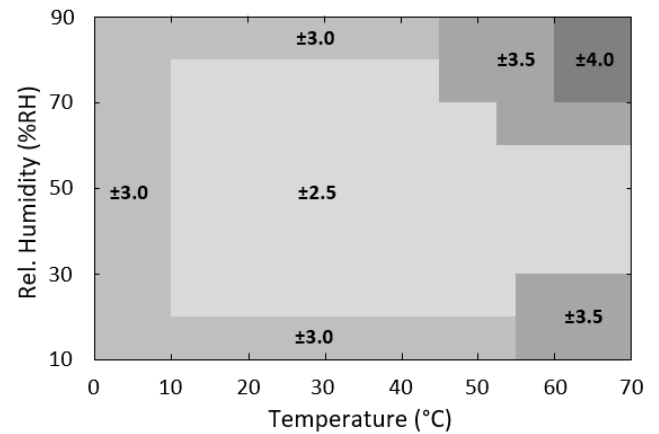**Figure 5. HS41x3 RH Accuracy Tolerance at 25°C**

Figure 6. HS41x3 RH Accuracy over Temperature

3.4   Temperature Sensor Accuracy Graphs

The typical and maximum temperature sensor accuracy tolerances are shown in the following figures.
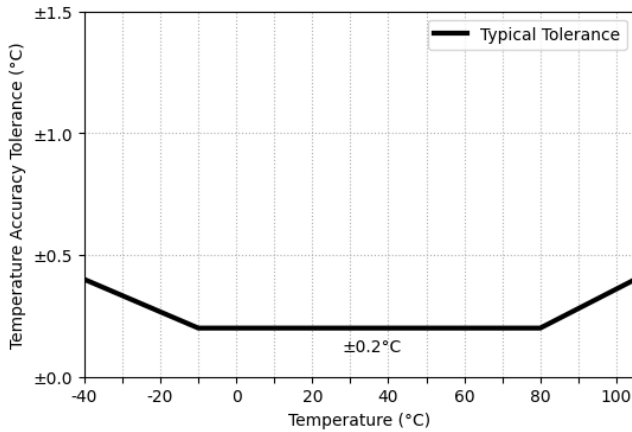

Figure 7. HS41x1 Temperature Sensor Accuracy
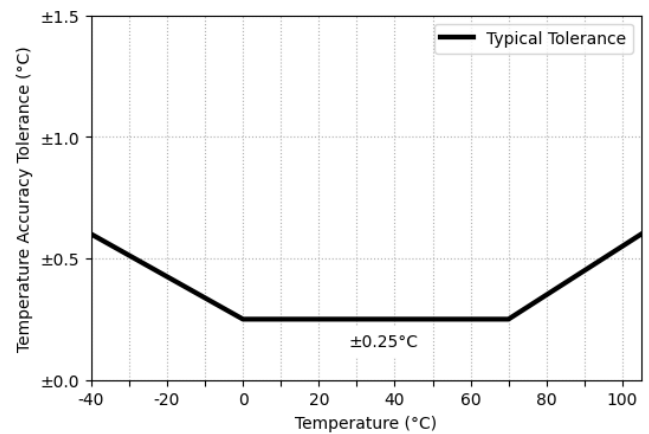Tolerance

Figure 8. HS41x3 Temperature Sensor Accuracy
Tolerance

4.   Sensor Startup

The HS41xx sensor requires a typical 100ms to start up, after which temperature and relative humidity measurement data will be provided on the corresponding pins.

5.   Conditioning

After soldering or prolonged storage outside the nominal storage conditions, a conditioning routine must be applied to ensure high sensor accuracy. Not following this routine will result in a slowly disappearing offset in the relative humidity readings. When a relative humidity sensor is exposed to the high heat associated with the soldering process, the sensor element tends to dry out. To avoid an offset in the relative humidity readings, the sensor element must be rehydrated after the soldering process.

Recommended rehydration process:

▪ A relative humidity of 75% RH at room temperature for at least 12 hours, or
▪ A relative humidity of 40% to 50% RH at room temperature for 3 to 5 days

To avoid relative humidity reading offset after prolonged storage outside the recommended storage conditions use the following procedure to recondition the humidity sensor.

1.   Bake at a temperature of 100°C with a humidity < 10% RH for 10 to 12 hours.

2.   Rehydrate the sensor at a humidity of 75% RH and a temperature between 20°C to 30°C for 12 to 14 hours.

6.   PCB Layout Guide

When designing the PCB, undesired heat transfer paths to the HS41xx must be minimized. Excessive heat from other components on the PCB will result in inaccurate temperature and relative humidity measurements. As such, **solid metal planes for power supplies should be avoided in the vicinity of the sensor** because these will act as thermal conductors. To further reduce the heat transfer from other components on the board, openings can be milled into the PCB as shown in Figure 9.
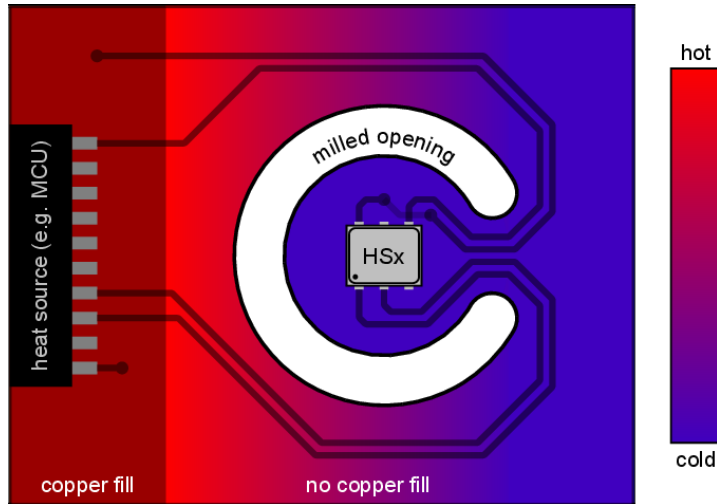
Figure 9. Milled PCB Openings for Thermal Isolation

7. Application Circuit

The HS41xx sensor requires a 2.2µF ceramic capacitor connected to the ground on both the VRH and VT outputs. It is also recommended to buffer the output of the relative humidity and temperature signals before processing the analog voltage. The buffer should have a low input leakage current, < 1nA, and a low input offset voltage, < 1mV, to ensure high signal integrity.
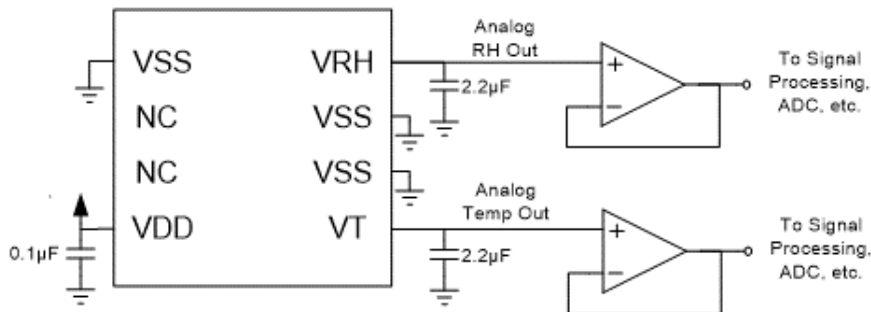

Figure 10. HS41xx Application Circuit

8. Converting Output Signal

The voltage levels of the filtered analog output signal are ratio-metric with V_{DD}. The default output range for the relative humidity and temperature is from 10% to 90%.

Each HS41xx sensor is individually calibrated so that a standard linear fitting equation can be used to obtain the measured temperature and RH value. Figure 11 and Figure 12 shows the RH and temperature graphically.

The relative humidity (in percent) and the temperature (in degrees Celsius) are calculated with Equation 1 and Equation 2, respectively.

$$Humidity \ [\%RH] = 125 * \frac{VRH}{VDD} - 12.5$$

Equation 1

$$Temperature \ [°C] = \ 181.25 * \frac{VT}{VDD} - 58.125$$
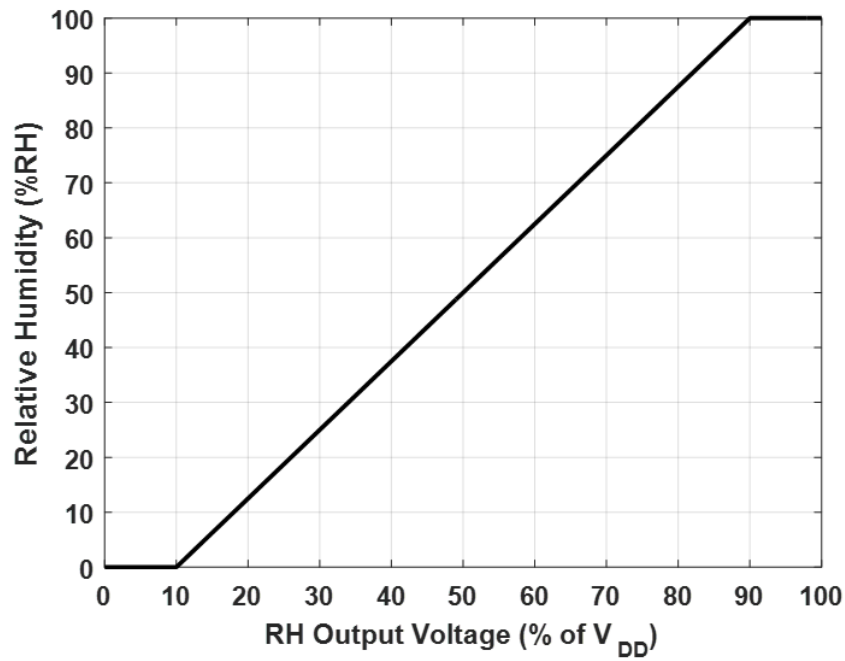
Equation 2

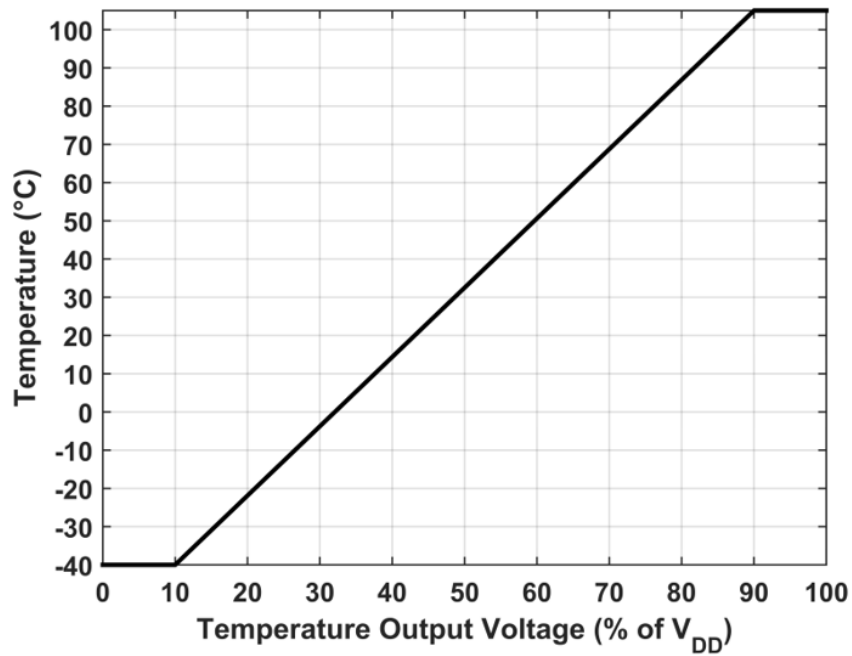**Figure 11. Relative Humidity vs. VRH Output Analog Voltage**

Figure 12. Temperature vs. VT Output Analog Voltage

9. Soldering Information

This section discusses soldering considerations for the HS41xx.

Standard reflow ovens can be used to solder the HS41xx series sensor to the PCB. The peak temperature (T_p) for use with the JEDEC J-STD-020D standard soldering profile is 260°C. For manual soldering, the contact time must be limited to 5 seconds at up to 350°C. In either case, if solder paste is used, it is recommended to use "no-clean" solder paste to avoid the need to wash the PCB.

When a relative humidity sensor is exposed to the high heat associated with the soldering process, the sensor element tends to dry out. To avoid an offset in the relative humidity readings, the sensor element must be rehydrated after the soldering process. Care must also be taken when selecting the temperatures and durations involved in the soldering process to avoid irreversibly damaging the sensor element.

The recommended soldering profile for a lead-free (RoHS-compliant) process is shown below.
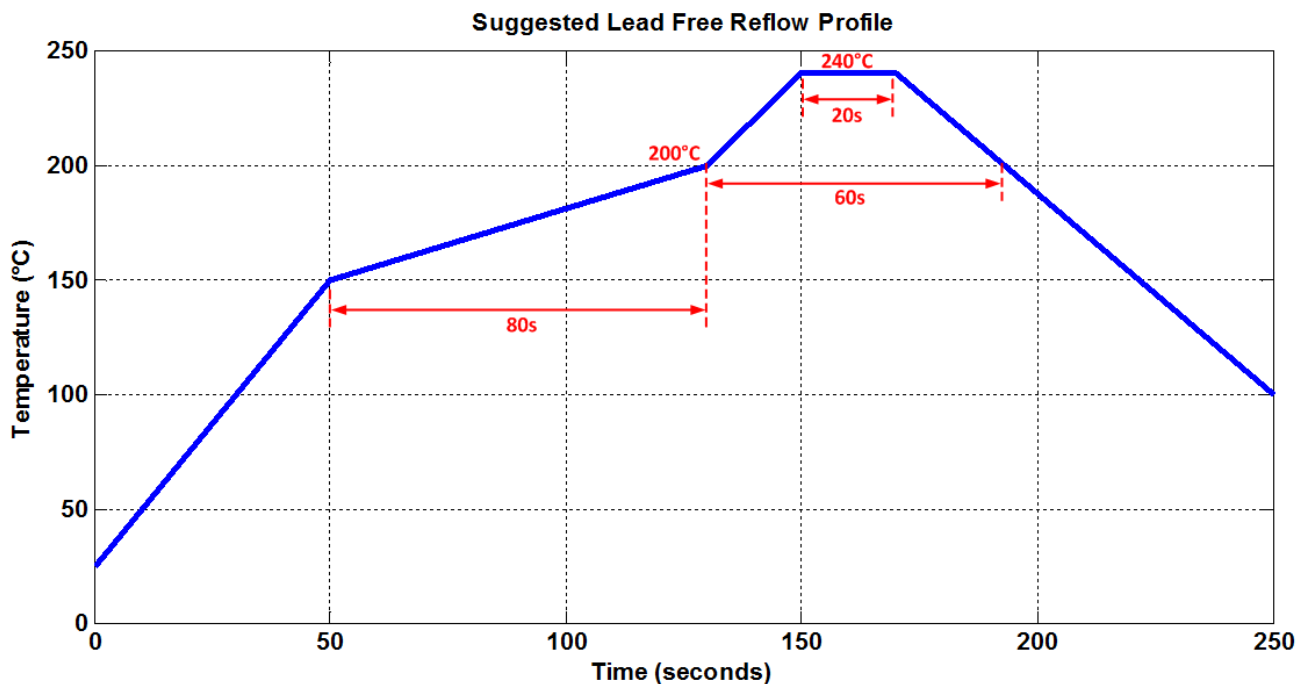

Figure 13. Recommended Soldering Profile

It is important to ensure this temperature profile is measured at the sensor itself. Measuring the profile at a larger component with a higher thermal mass means the temperature at the small sensor will be higher than expected.

For manual soldering, the contact time must be limited to **5 seconds** with a maximum iron temperature of **350°C**.

In either case, a board wash after soldering is **not** recommended. Therefore, if a solder paste is used, it is strongly recommended that a **"no-clean"** solder paste is used to avoid the need to wash the PCB.

After soldering, the recommended rehydration process of section 5 should be done. Otherwise, there may be an initial offset in the relative humidity readings, which will slowly disappear as the sensor get exposed to ambient conditions.

10. Storage and Handling

Recommendation: Once the sensors are removed from their original packaging, store them in metal-in antistatic bags.

Avoid using polyethylene antistatic bags as they may affect sensor accuracy.

The nominal storage conditions are 10 to 50°C, and humidity levels within 20% to 60%RH. If stored outside of these conditions for extended periods of time, the sensor readings may exhibit an offset. The sensor can be reconditioned and brought back to its calibration state by applying the procedure described in section 5.

11. Quality and Reliability

The HS41xx is available as a qualified product for consumer and industrial market applications. All data specified parameters are guaranteed if not stated otherwise.

12. Package Outline Drawings

The package outline drawings are located at the end of this document and are accessible from the Renesas website. The package information is the most current data available and is subject to change without revision of this document.

13. Marking Diagram
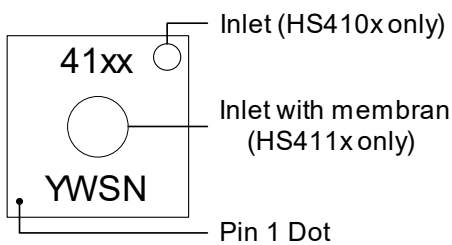
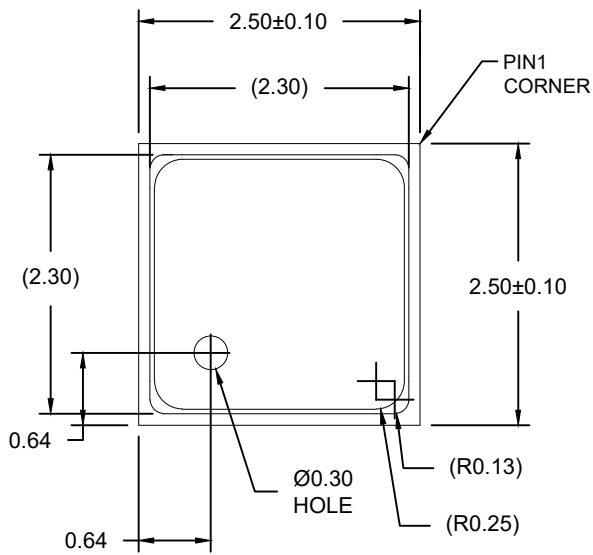**Mark legend:**

Line 1: Sensor type (for example, 4111)

Line 2:

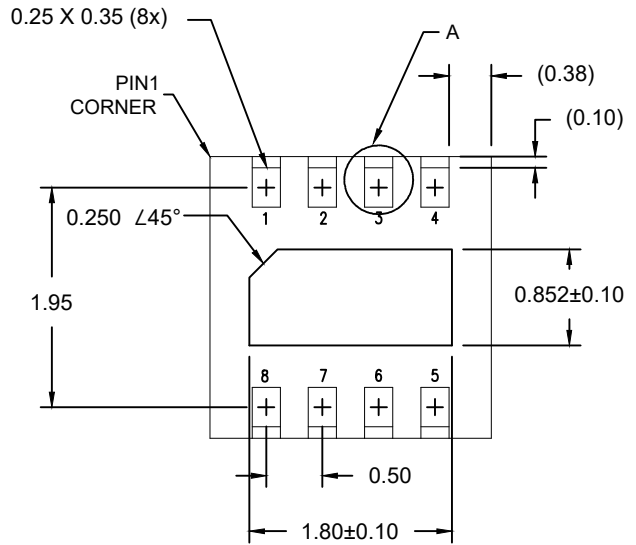|	
First character:	Year (for example, 3 = 2023)
Second character:	Week code (for example, X = 31)
Third and fourth character:	Test Release Sequence Number

14. Ordering Information

Part Number	Package Description	Carrier Type	Temperature Range
HS4101	Relative Humidity and Temperature Sensor, Analog Output. ±1.5% RH (Typical), 2.5 × 2.5 × 0.9 mm, 8-LGA	Reel	-40°C to +105°C
HS4103	Relative Humidity and Temperature Sensor, Analog Output. ±2.5% RH (Typical), 2.5 × 2.5 × 0.9 mm, 8-LGA	Reel	-40°C to +105°C
HS4111	Relative Humidity and Temperature Sensor, with Membrane, Analog Output. ±1.5% RH (Typical), 2.5 × 2.5 × 0.9 mm, 8-LGA	Reel	-40°C to +105°C
HS4113	Relative Humidity and Temperature Sensor, with Membrane, Analog Output. ±2.5% RH (Typical), 2.5 × 2.5 × 0.9 mm, 8-LGA	Reel	-40°C to +105°C

15. Revision History

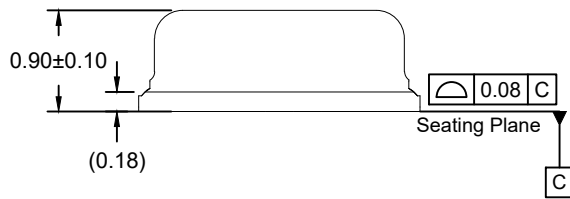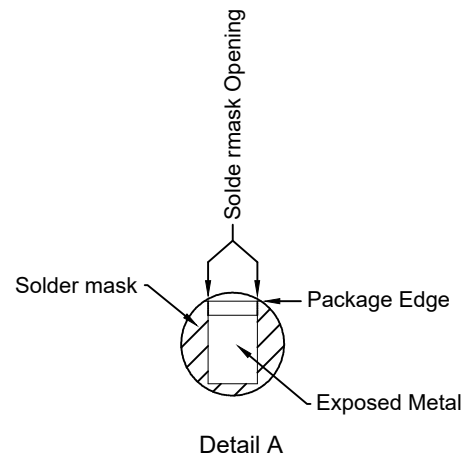| Revision	Date	Description
1.02	Jun 14, 2024	Updated PCB Layout Guide section.
1.01	Oct 05, 2023	▪ Added Functional Diagram ▪ Added Conditioning section ▪ Updated Pin Assignments and Pin Descriptions ▪ Updated performance characteristics
1.00	Aug 29, 2023	Initial release.

RENESAS

TOP VIEW

2.50±0.10
(2.30)
PIN1 CORNER
(2.30)
2.50±0.10
0.64
Ø0.30 HOLE
0.64
(R0.13)
(R0.25)

BOTTOM VIEW

0.25 X 0.35 (8x)
A
PIN1 CORNER
(0.38)
(0.10)
0.250 ∠45°
1.95
0.852±0.10
0.50
1.80±0.10

SIDE VIEW

0.90±0.10
0.08 C
Seating Plane
C
(0.18)

Detail A

Solder mask Opening
Solder mask
Package Edge
Exposed Metal
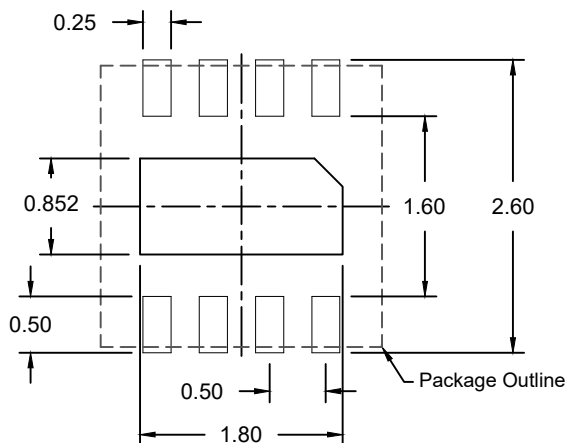
RECOMMENDED LAND PATTERN
(PCB Top View, NSMD Design)

0.25
0.852
1.60
2.60
0.50
0.50
1.80
Package Outline

NOTES:

1. JEDEC compatible
2. All dimensions are in mm, angles in degrees.
3. Use ±0.05 mm for non-toleranced dimensions.
4. Numbers in ( ) are for reference only.

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