TI Designs
±2% Accurate Humidity-Sensing Reference Design Supporting 2-m Wire Communication

TI Designs

The TIDA-00972 reference design provides a sensor module level solution for accurate and reliable relative humidity and temperature sensing. The sensor module utilizes a digital humidity and temperature sensor from TI to provide high-accuracy sensing results. An integrated communication bus buffer enables robust communication over meters of wiring distance. The reference design addresses the key considerations of development and manufacturing of the sensor module with test results.

Design Resources

TIDA-00972	Design Folder
HDC1080	Product Folder
TCA9517	Product Folder
HDC1080EVM	Tools Folder

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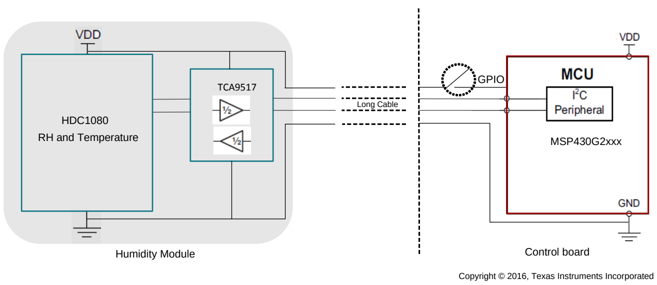
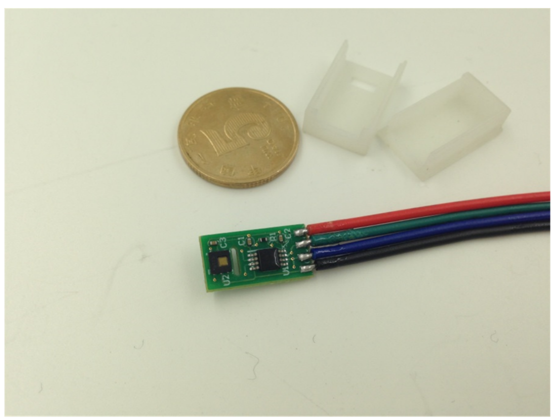
Design Features

- High Accuracy Module With Compact Size:
  - Relative Humidity Accuracy ±2% (Typical)
  - Temperature Accuracy ±0.2°C (Typical)
  - PCB Size of 15.7 mm × 7.6 mm
- Very Low Power Consumption During Operation and Idle:
  - 1.5 mA With I^2C Buffer, 1.2 µA Without I^2C Buffer
  - Supply Cut During Idle
- Support Long-cable I^2C Communication Over Common Wire (AWG24 With 2-m Length)
- Supports Both 5-V and 3.3-V Power Supply
- Competitive BOM Cost With Low Component Count
- Reliable Operation in Harsh Environment

Featured Applications

- Refrigerators
- Air Conditioners
- Washers and Dryers
- Microwave Ovens





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1 System Overview

1.1 System Description

Relative humidity (RH) is the ratio (at a fixed temperature) between actual water vapor and saturation water vapor expressed as percentage (saturation is the max water vapor). RH is of high interest regarding many home appliance applications because understanding and controlling RH can help to achieve better comfort in living environments, to extend the freshness of stored fruit or vegetables, to improve bakeries, to control the drying of clothes more efficiently, and so forth. Therefore, RH measurement is a measurement that is being increasingly implemented into various home appliance applications at the time of this writing, such as air conditioners, humidifiers, dehumidifiers, refrigerators, ovens, washers, and dryers.

Relative humidity sensors can be placed on the control board of the system or can be set to operate as an off-board sensor module connected to the control board through cables.

Among different technologies for measuring relative humidity, capacitive humidity-sensing technology is widely used by home appliance, industrial, commercial, and even weather telemetry applications because this type of sensing technology utilizes many of the advantageous principles used in semiconductor manufacturing to yield sensors with minimal long-term drift and hysteresis.

One of the latest digital humidity sensors from Texas Instrument's, the HDC1080, is based on capacitive humidity-sensing technology and offers excellent accuracy (±2%) in a small package size (3×3-mm PWSON) with very-low-power consumption (1.3 µA at 1 sps).

This TI Design addresses the component selection, design theory, design and manufacturing considerations, and test results of an off-board RH sensor module using the HDC1080 device. The design also demonstrates the performance of the sensor across a wide range of operating conditions after the module has been fully assembled.

1.2 Key System Specifications

Table 1. Key System Specifications

PARAMETER	SPECIFICATION
Accuracy	Relative humidity accuracy: ±2% (typical)
	Temperature accuracy: ±0.2°C (typical)
RH long-term drift	RH long-term drift: ±0.25% RH/yr
RH operating range	RH operating range: 0% to 100% RH range
Operating temp range	Operating temp range: –20°C to +85°C
Operating voltage range	2.7 V to 5.5 V
Current consumption	Current consumption of humidity module while working: (11-bit RH and temp measurement) 1.5 mA with I^{2}C buffer, 1.2 µA without I^{2}C buffer
	Current consumption of humidity module while standby: Condition 1.5 mA with I^{2}C buffer, 200 nA without I^{2}C buffer; Shut down by GPIO power supply
Output resolution	Output resolution of humidity module: 11-bit or 14-bit selectable
EMI performance	EN – 61000-4-2 (ESD) 2 kV for the module pins to GND
PCB size	15.7 mm × 7.6 mm
Wire length	Up to 2-m AWG24 or equivalent

1.3 Block Diagram

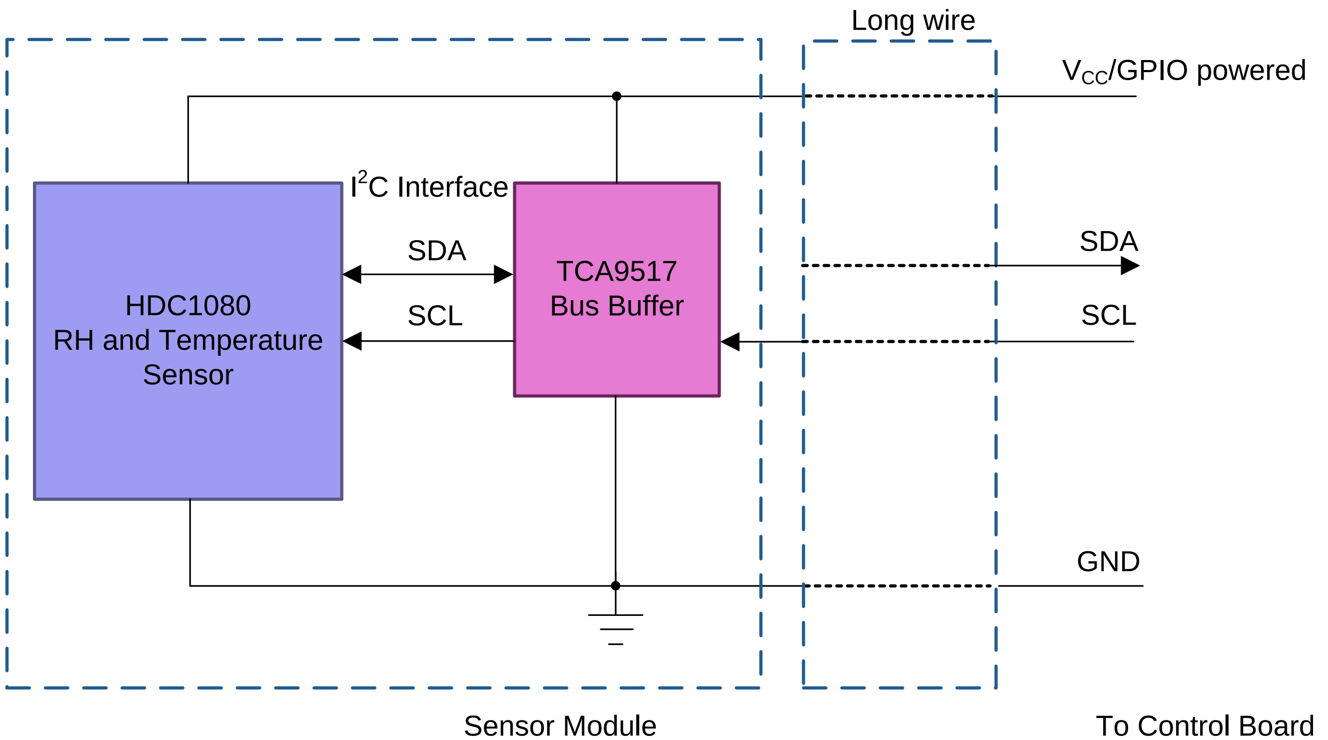

Figure 1. Block Diagram

1.4 Highlighted Products

The TIDA-00972 TI Design features the following devices:

- **HDC1080:**
  - Low-power, high-accuracy digital humidity sensor with temperature sensor
- **TCA9517:**
  - Level-shifting I²C bus repeater

1.4.1 HDC1080

The HDC1080 is a digital humidity sensor with an integrated temperature sensor that provides excellent measurement accuracy at very low power (see Figure 2). The HDC1080 device operates over a wide supply range and is a low-cost, low-power alternative to competitive solutions in a wide range of common applications. The humidity and temperature sensors have been factory calibrated by default.

Features:

- Relative humidity accuracy ±2% (typical)
- Temperature accuracy ±0.2°C (typical)
- Excellent stability at high humidity
- 14-bit measurement resolution
- 100-nA sleep mode current
- Average supply current:
  - 710 nA at 1sps, 11-bit RH measurement
  - 1.3 µA at 1sps, 11-bit RH and temperature measurement
- Supply voltage 2.7 V to 5.5 V
- Small 3×3-mm device footprint
- I^2C interface

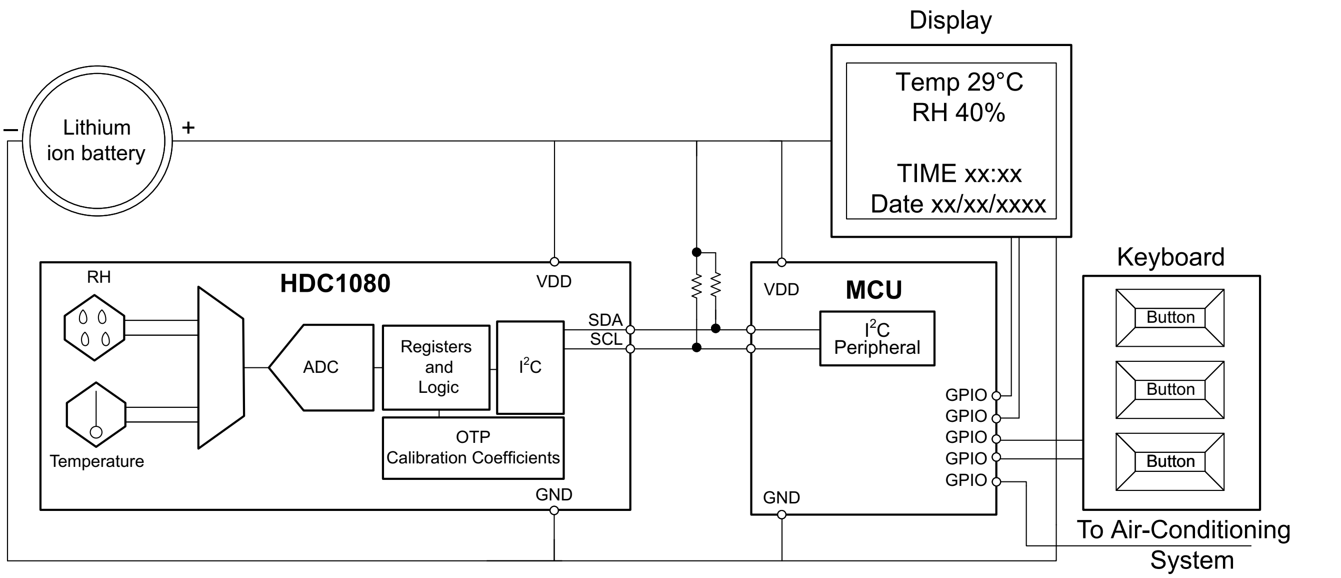

Figure 2. Typical Application Schematic HVAC

1.4.2 TCA9517

The TCA9517 is a bidirectional buffer with level-shifting capabilities for I2C and SMBus systems. The device provides bidirectional voltage-level translation (up translation and down translation) between low voltages (down to 0.9 V) and higher voltages (2.7 V to 5.5 V) in mixed-mode applications (see Figure 3). This device enables I2C and SMBus systems to be extended without degradation of performance, even during level shifting.

The TCA9517 buffers both the serial data (SDA) and the serial clock (SCL) signals on the I2C bus, which enables the connection of two buses of up to 400-pF bus capacitance in an I2C application.

The TCA9517 has two types of drivers: A-side drivers and B-side drivers. All inputs and I/Os are overvoltage tolerant to 5.5 V, even when the device is unpowered (VCCB = 0 V, VCCA = 0 V, or both).

Features:

- Two-channel bidirectional buffer
- I2C bus and SMBus compatible
- Operating supply voltage range of 0.9 V to 5.5 V on A-side
- Operating supply voltage range of 2.7 V to 5.5 V on B-side
- Voltage-level translation from 0.9 V through 5.5 V to 2.7 V through 5.5 V
- Footprint and functional replacement for PCA9515B
- Active-high repeater-enable Input
- Open-drain I2C I/O
- 5.5-V tolerant I2C and enable input support mixed-mode signal operation
- Accommodates standard mode and fast mode I2C devices and multiple masters
- High-impedance I2C pins when powered-off
- Latch-up performance exceeds 100 mA per JESD 78, Class II
- ESD protection exceeds JESD 22
  - 5500-V human-body model (A114-A)
  - 200-V machine model (A115-A)
  - 1000-V charged-device model (C101)

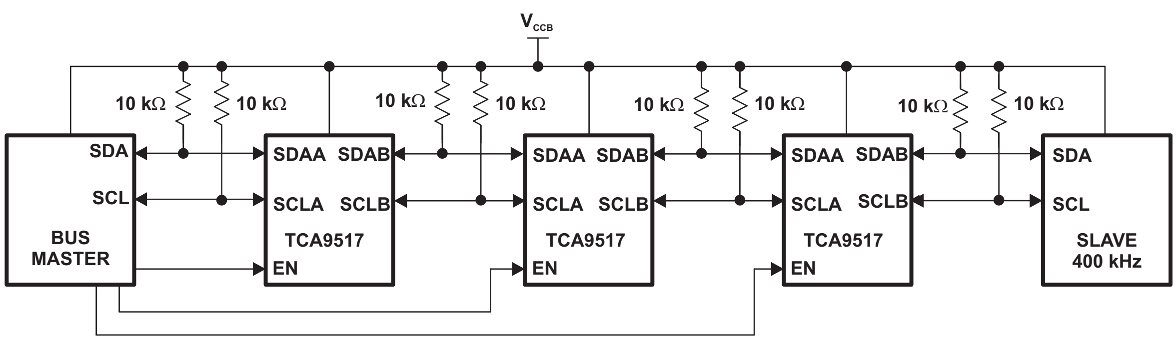

Figure 3. Typical Series Application

2 System Design Theory

This design targets an off-board relative humidity and temperature sensor module for home appliance applications such as refrigerators, air conditioners, washers, dryers, and so forth. Relative humidity sensing results that are accurate can help existing equipment to improve the overall system performances such as freshness retention, comfort level, and energy efficiency.

Integrated relative humidity sensors use polyimide dielectric layers to absorb moisture in the ambient air and detect the change of the permittivity of the dielectric material. This design addresses the concerns relating to different production procedures applied to the sensor device, such as re-hydration and conformance coating by comparing the test results of different sensor modules produced with or without these procedures.

To enable accurate dew point calculation, this guide also addresses the layout guidelines for the module to prevent heat mass from accumulating to other PCB components.

2.1 Humidity

Humidity is the presence of water vapor in air (or any other gas). In ambient air there is typically about 1% water vapor, but this can vary to a large extent. Dry environments can cause irritation of the respiratory tract, skin, and eyes. A dry environment also increases the chances of an electrostatic discharge from the body to a conductive surface. Humidity is expressed in several different ways:

Relative humidity: Relative humidity is the amount of moisture in the air compared to what the air can "hold" at that temperature. This parameter is the most common-used measure of humidity. Relative humidity is usually expressed as a percentage, with the symbol “%rh”; for example, “the humidity is 51 %rh.” The term relative humidity is commonly abbreviated to RH (note this is different from the unit symbol: %rh). Equation 1 is used to calculate RH:

$$RH\% = \frac{P_{\text{water vapor}}}{P_{\text{saturation water vapor}}} \times 100 \tag{1}$$

where:

- $P_{\text{water vapor}}$ is the pressure of the water vapor in the air at given temperature
- $P_{\text{saturation water vapor}}$ represents the max quantity of water vapor that the air can hold at given temperature

Dew point (or dew-point temperature): Dew point is the temperature at which condensation (dew) occurs if a gas has been cooled at a constant pressure. Dew point is a useful measure for two reasons:

1. The dew point indicates what temperature to keep a gas at to prevent condensation
2. Dew point is an absolute measure of the gas humidity (at any temperature) and relates directly to the amount of water vapor present (partial pressure of water vapor)

The dew point is expressed in temperature units. The dew point can be calculated by using the relative humidity and temperature as inputs (see Equation 2).

$$D_P = \frac{\lambda \times \left(\ln\left(\frac{RH}{100}\right) + \frac{\beta \times T}{\lambda + T} \right)}{\beta - \left(\ln\left(\frac{RH}{100}\right) + \frac{\beta \times T}{\lambda + T} \right)} \tag{2}$$

For the range from –45°C to 60°C, Magnus parameters are given by β = 17.62 and λ = 243.12°C.

2.2 Interfacing Sensor Module

The HDC1080 sensor includes an I^2C interface. In this design, the HDC1080 device works as an off-board humidity sensor which is connected to the control board through a four-pin connector.

Figure 4 shows the schematic of the HDC1080 sensor board.

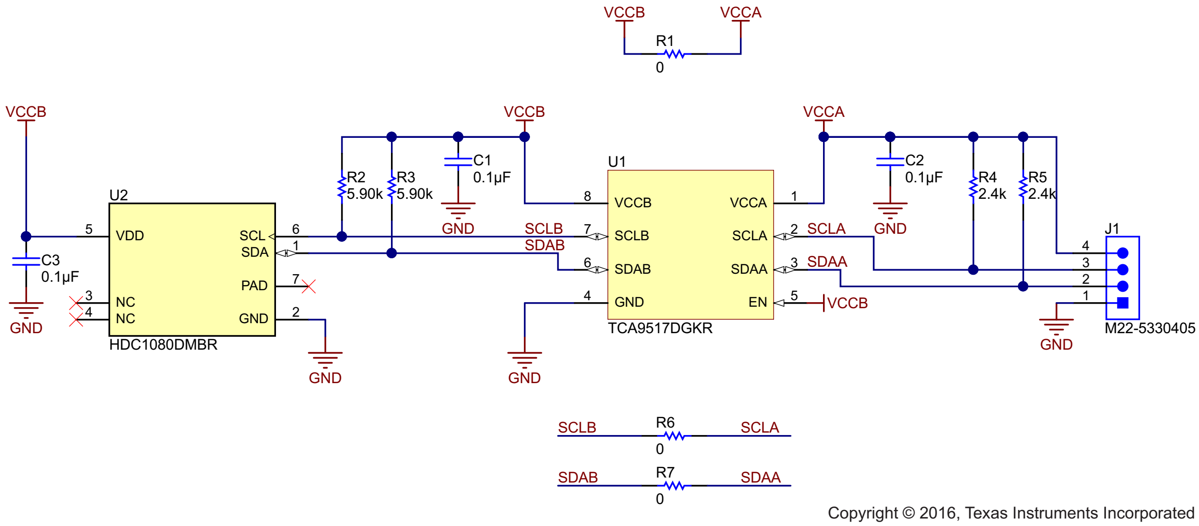

Figure 4. HDC1080 Sensor Board Schematic

After power up, the HDC1080 device is in sleep mode per default. In this mode, the HDC1080 waits for I^2C input including commands to configure the conversion times, read the status of the battery, trigger a measurement, and read measurements. When the device receives a command to trigger a measurement, the HDC1080 wakes from sleep mode and switches into measurement mode. After completing the measurement, the HDC1080 device returns to sleep mode, which avoids unnecessary heat generation and saves power.

The device is also equipped with an integrated heater element. The heater is an integrated resistive element that can be used to test the sensor or to drive condensation off the sensor. The heater can be activated using HEAT, which is bit 13 in the *Configuration Register*. The heater helps to reduce the accumulated offset after long exposure at high humidity conditions.

Figure 5 shows the control flow of the device.

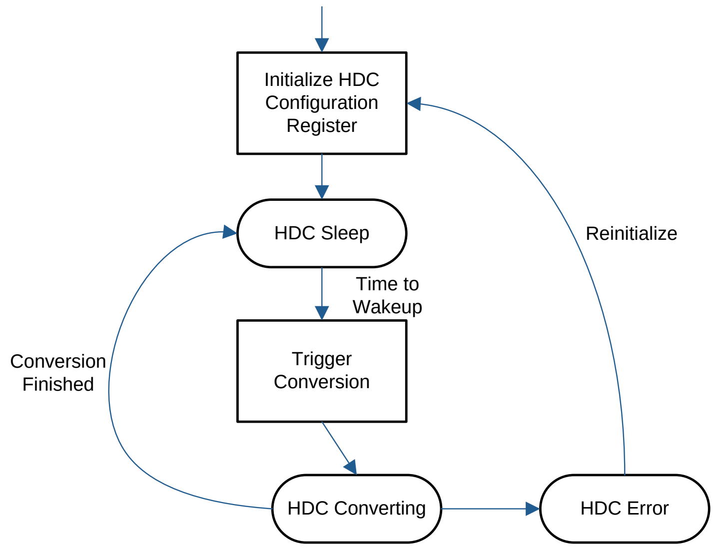

Figure 5. Flow Chart of HDC1080 Control

2.3 I^2C Pull-Up Resistor Calculation

The TIDA-00972 sensor module includes onboard I^2C pullup resistors. The maximum sink current of the HDC1080 device is 3 mA. To further enhance the current drive capability of the I^2C communication lines, which is especially helpful for long wire connections in harsh environments, an I^2C bus repeater with higher current drive capability, the TCA9517 device, is used on the sensor module.

The following steps show how to calculate the pullup resistor values.

A strong pullup (small resistor) can interfere with the capability of an integrated circuit (IC) to drive a valid low level on an I^2C pin. The V_{OL} level that can be read as a valid logical low by the input buffers of an IC determines the minimum pullup resistance R_P(min). R_P(min) is a function of V_{CC}, V_{OL} (max), and I_{OL}, as Equation 3 shows:

$$R_P(\text{min}) = \frac{(V_{CC} - V_{OL}(\text{max}))}{I_{OL}} \tag{3}$$

The maximum pullup resistance is limited by the bus capacitance (C_b) because of I^2C standard rise-time specifications. If the pullup resistor value is too high, the I^2C line may not rise to a logical high before it is pulled low. The response of an RC circuit to a voltage step of amplitude V_{CC}, starting at time t = 0 is characterized by the time constant RC. The voltage waveform can be written as the following Equation 4:

$$V(t) = V_{CC} \times \left(1 - e^{\frac{-t}{RC}}\right) \tag{4}$$

As Equation 5 shows, for $V_{IH} = 0.7 \times V_{CC}$:

$$V_{IH} = 0.7 \times V_{CC} = V_{CC} \times \left(1 - e^{\frac{-t1}{R_p \times C_b}}\right) \tag{5}$$

As Equation 6 shows, for $V_{IL} = 0.3 \times VCC$:

$$V_{IL} = 0.3 \times V_{CC} = V_{CC} \times \left(1 - e^{\frac{-t2}{R_p \times C_b}}\right) \tag{6}$$

The rise time for the I^2C bus can be written as the following Equation 7:

$$t_r = t_2 - t_1 = 0.8473 \times R_p \times C_b \tag{7}$$

As Equation 8 shows, the maximum pullup resistance is a function of the maximum rise time (t_r):

$$R_P(\text{max}) = \frac{t_r}{(0.8473 \times C_b)} \tag{8}$$

With a given I^2C communication interface specification, the R_P(min) and R_P(max) can be calculated according to Equation 3 and Equation 8. The value of the pullup resistor can be selected based on the trade-off for the power consumption and speed between R_P(min) and R_P(max).

In this design, the parameters of the I^2C interfaces are:

- Module-to-system control board (TCA9517 A side):
  - V_{CC} = 3.3 V
  - V_{OL}(max) = 0.2 V (per TCA9517)
  - I_{OL} = 6 mA (per TCA9517)
  - C_b = 470 pF (parasitic capacitance generated by wiring and trace on PCB, max 550 pF)
  - t_r = 1000 ns (standard mode I^2C at 100 kbps)
- TCA9517 to HDC1080 (TCA9517 B side):
  - V_{CC} = 3.3 V
  - V_{OL}(max) = 0.6 V (per TCA9517)
  - I_{OL} = 3 mA (per TCA9517)
  - C_b = 200 pF (parasitic capacitance generated by wiring and trace on PCB, max 400 pF)
  - t_r = 1000 ns (standard mode I^2C at 100 kbps)

The pullup resistor values on each side are:

- TCA9517 A side: R_P(max) = 2.511 kΩ, R_P(min) = 517 Ω
- TCA9517 B side: R_P(max) = 5.901 kΩ, R_P(min) = 900 Ω

To limit the operating and standby current consumption of the module, the largest possible pullup resistor values are recommended. For this design, a 2.4-kΩ pullup resistor has been selected on the A side and a 5.9-kΩ pullup resistor has been selected on the B side of the I^2C bus repeater (TCA9517).

Pullup resistors on the A side of the bus repeater of the I^2C communication interface can be further reduced according to the practical situation of the application such that the parasitic capacitance is larger to ensure the quality of the signal.

3 Getting Started Hardware and Firmware

3.1 Hardware

Figure 6 shows the compact dimension of the sensor module hardware board in units of mm.

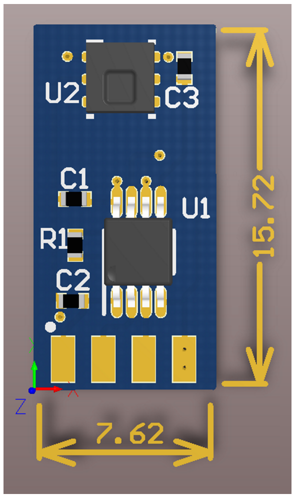

Figure 6. Sensor Module Dimension

As Figure 7 shows, the module comes with a 15-cm cable harness of four-wire AWG-24, which ends with an SM-type, male, disconnectable, crimp-style wire-to-wire connector of 2.54-mm pitch (JST SMP-04V-B).

Figure 7. Wire Connectors

Table 2 shows the pin map of the sensor module.

Table 2. Sensor Module Pin Map

PIN NUMBER	WIRE COLOR	NAME	DESCRIPTION
1	Red	VCC	Supply voltage
2	Green	SCL	Serial clock line for I^2C, on A side of bus repeater, 24-kΩ pullup on module
3	Blue	SDA	Serial data line for I^2C, on A side of bus repeater, 24-kΩ pullup on module
4	Black	GND	Ground

NOTE: The dot indicator on the sensor module board indicates pin number 1 (VCC).

3.2 Firmware

Source file *drv_hdc10x0.c* and *drv_hdc10x0.h* have been provided for controlling the HDC1080 device in this design and can be reused to customize applications based on TI MSP430™ microcontrollers (MCUs).

In *drv_hdc10x0.c*, the following function calls are implemented:

void hdc10x0Init(void):

This function initializes the set values of the HDC10x0 registers into predefined global variables; Later on, the set values are to be written into the HDC10x0 registers.

void hdc10x0SetConfiguration(regCONFIGURATION_t) and

void hdc10x0GetConfiguration(regCONFIGURATION_t*):

These two software-driver-level function calls set and retrieve the configuration register of the HDC10x0.

void hdc10x0TriggerConversion(enum_hdcRegAddr_t):

Because the HDC10x0 family of devices work in sleep mode by default, the application must trigger the conversion of the HDC10x0 by an I^2C command. This function call triggers the conversion of the HDC10x0 device. In this design, this function is defined as static.

void hdc10x0ReadConversionResults(void):

This function reads out the conversion results on both humidity and temperature from the HDC10x0 device and converts the results into units of %RH and °C. In this design, this function is defined as static.

This design includes the register bit map as well as the register address enumerates in *drv_hdc10x0.h* to make coding with hdc10x0 registers easier. Figure 8 shows an example of the register bit map.

```
//HDC1050 Register bit definitions
typedef union regCONFIGURATION{
    struct
    {
        uint16_t    RESERVED0    : 8;    //0-7
        uint16_t    HRES         : 2;    //8-9
        uint16_t    TRES         : 1;    //10
        uint16_t    BTST         : 1;    //11
        uint16_t    MODE         : 1;    //12
        uint16_t    HEAT         : 1;    //13
        uint16_t    RESERVED1    : 1;    //14
        uint16_t    RST          : 1;    //15
    }bit;
    uint16_t byte;
}regCONFIGURATION_t;
```

Figure 8. STATUS Register Bit Map

4 Testing and Results

4.1 Test Setup

To evaluate the performance and robustness of the sensor module, four differently-preconditioned and coated variants of the sensor modules of TIDA-00972 were tested, see Table 3. The coating was applied around the device package excluding the sensor window. Such coating can be applied to counter potential corrosion in very harsh environments.

Table 3. Sensor Variants

VARIANT	PRE-CONDITIONING	COATING
1	N	N
2	N	Y
3	Y	N
4	Y	Y

Sensor modules under test are connected to an MSP430 LaunchPad™ Development Kit through 1.5-m CAT5e wires and put into the humidity or temperature chamber for tests. The results are captured and logged over the test duration and compared with the reference sensor from the VAISALA. Figure 9 shows the test setup for measuring the accuracy and consistency of the sensors.

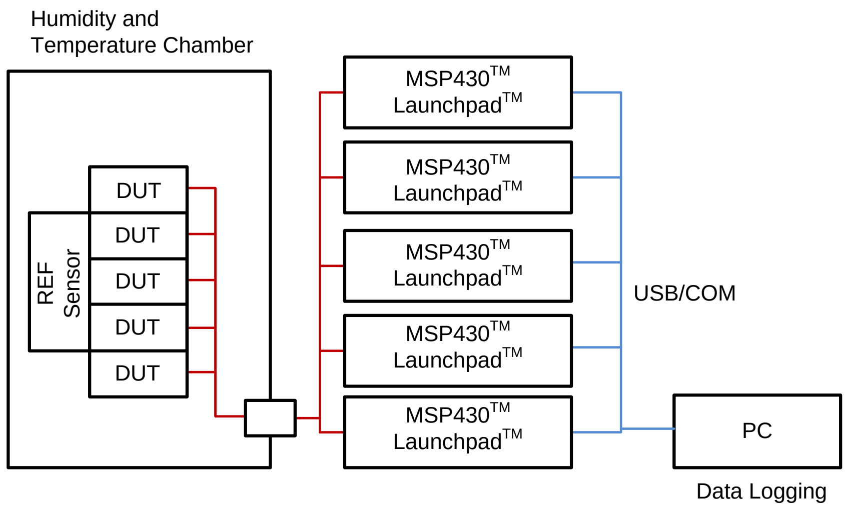

Figure 9. Test Setup Block Diagram

The humidity and temperature chamber used is a ESPEC BTL-433 temperature and humidity chamber with a temperature range of –20°C to 180°C and a humidity range of 10% to 95% RH.

Figure 10 shows the test bench setup in the lab environment.

Figure 10. Test Setup With Humidity and Temperature Chamber

As Figure 11 shows, the test chamber is equipped with a circulation fan inside to ensure homogenous temperature and humidity distribution in the chamber.

Figure 11. Inside Test Chamber

For an accurate result comparing to the reference sensor, the sensor modules under test must be placed as close to the reference sensor as possible. Figure 12 shows the placement of the sensors under test and the reference sensor.

Figure 12. Sensor Placement Under Test and Reference Sensor

The reference sensor used during the test is a VAISALA HM70 + HMP76 temperature and humidity sensor with a calibrated accuracy of:

- RH ±0.6% at 0% to approximately 40%
- RH ±1% at 40% to approximately 97%
- Temperature ±0.1°C

Figure 13 shows the reference sensor equipment.

Figure 13. HM70 and HMP76 From VAISALA

Refer to Section 8 to view the calibration certification of the equipment.

4.2 Test Data

This subsection details the accuracy, consistency, and drift of the humidity sensors under different temperature and humidity conditions.

Figure 14 shows the test profile devised for the conducted humidity accuracy and consistency test. The humidity target value is increased in seven steps from 20% to 90% and then decreased again. The test profile avoids abrupt humidity steps to minimize errors caused by different settling behavior of the sensors. This profile was tested for two different target temperatures at 43°C and 83°C. These temperatures were chosen to test below 45°C and below 85°C. The first half of this subsection addresses both the accuracy and consistency test results of humidity and temperature measurements at a target temperature of 43°C. The second half of this subsection show similar test results for a target temperature of 83°C.

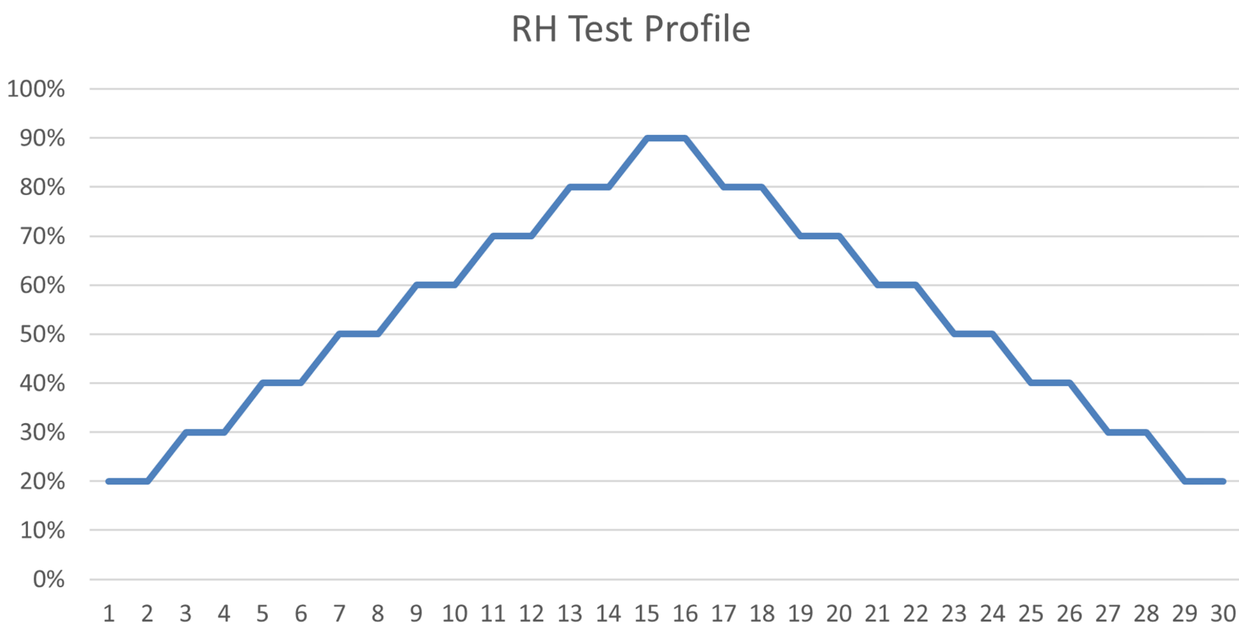

Figure 14. Humidity Profile Setup for Test

The following Figure 15 shows the measured humidity versus the absolute time on the axis of the abscissas (x-axis) for a target temperature of 43°C in the measurement chamber. The relative humidity measured with the sensor module *RH % Sensor1* and the reference sensor *RH % REF* are plotted in percent on the primary axis of the ordinate (y-axis) on the left side. The measured relative humidity of both sensors matches the target value over the course of the six hours of the test duration. The difference between the value measured with the sensor module and the reference sensor *RH Diff* is shown in percent as well, but referred to the secondary y-axis on the right side. The instantaneous difference shows some momentary fluctuations, which is to be expected because of airflow turbulence, humidity variations, and different settling time constants. The long-term average difference is well within the ±3% tolerance window. This tolerance window is the sum of the accuracy of the sensor modules and the reference sensor assuming an absolutely homogeneous and constant humidity distribution that neglects the effect of humidity variations within the test chamber. As the reference sensor contribution is ±1% tolerance, this result demonstrates the HDC1080 device to be well within ±2% accuracy over the complete, tested, relative humidity range from 10% to 90% at a temperature of 43°C. This result also indicates a higher actual accuracy versus the HDC1080 device specification, which, for example, loosens up below 20% RH to ±3% at 10% RH and above 60% to ±3% at 70% RH and ±4% above 80% (see Figure 16 from the HDC1080 data sheet[2]). So the HDC1080 device does outperform its RH accuracy specification.

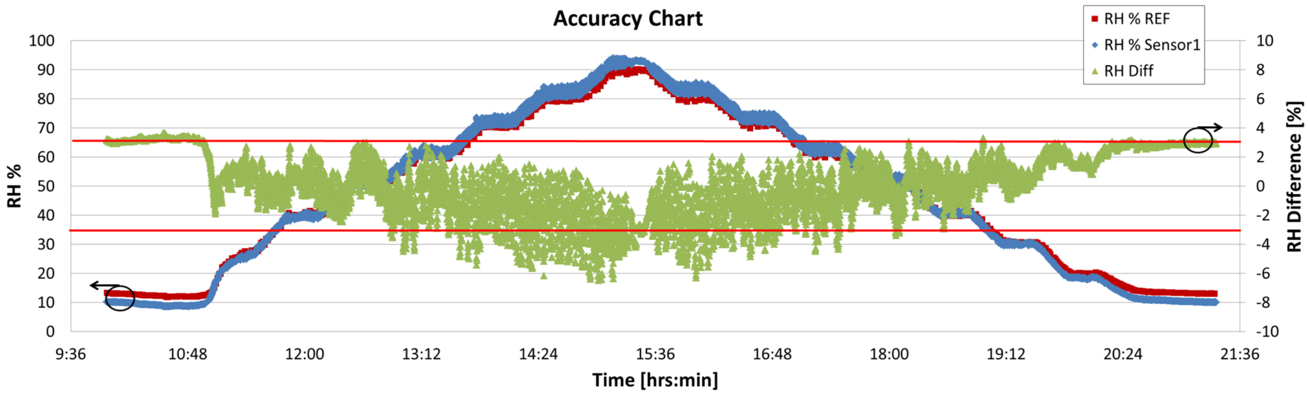

Figure 15. Humidity Accuracy Test Result Under 43°C

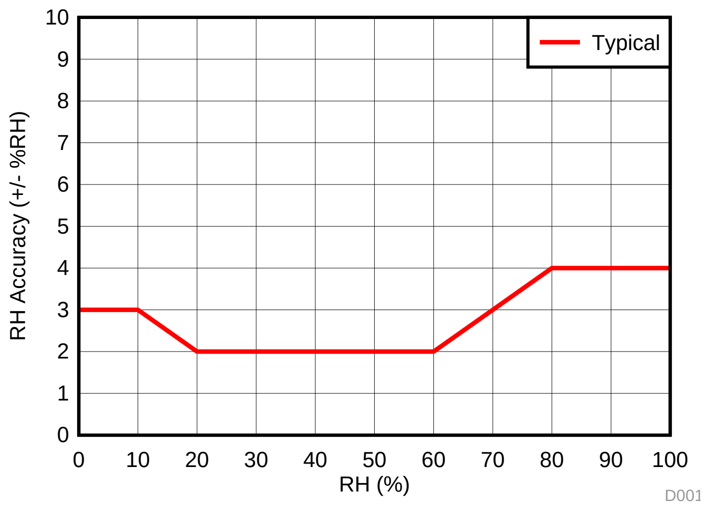

Figure 16. HDC1080 Humidity Accuracy Specification Versus Relative Humidity

Figure 17 shows the measured temperature versus the absolute time on the x-axis for a temperature target of 43°C in the measurement chamber. The absolute temperature measured with the sensor module *RH % Sensor1* and the reference sensor *RH % REF* in °C is plotted on the primary y-axis. The measured temperature of both sensors matches the target value over the test duration and shows minimum offset and a slightly slower response characteristic of the reference sensor. The difference between the temperature value measured with the sensor module and the reference sensor *Temp Diff* is referred again to the secondary y-axis. The instantaneous difference shows some fluctuations, which is to be expected because of airflow turbulence, consequent temperature variations, and difference in response characteristics. In consideration of all the effects, the difference is well within a ±0.2°C tolerance window and demonstrates the HDC1080s accuracy at 43°C to be highly superior to ±0.2°C.

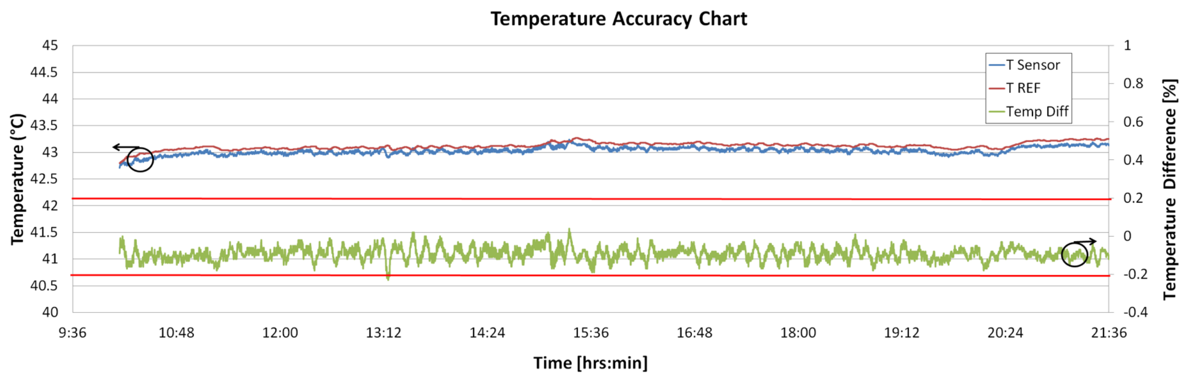

Figure 17. Temperature Accuracy Test Result Under 43°C

Figure 18 shows the measured humidity of different sensors versus time on the x-axis for the 43°C target temperature in the measurement chamber. The y-axis of the plot shows the relative humidity in percent. The different curves reflect the measured humidity with the sensor module *RH % Sensor1*, the differently preconditioned and coated sensor variants as described in Table 3, *RH % Sensor2* through *RH % Sensor5*, and the reference sensor *RH % REF*. The measured relative humidity values of all module variants are in very good agreement, which proves the high consistency and robust, process-variant-independent-humidity measurement accuracy of the HDC1080 device.

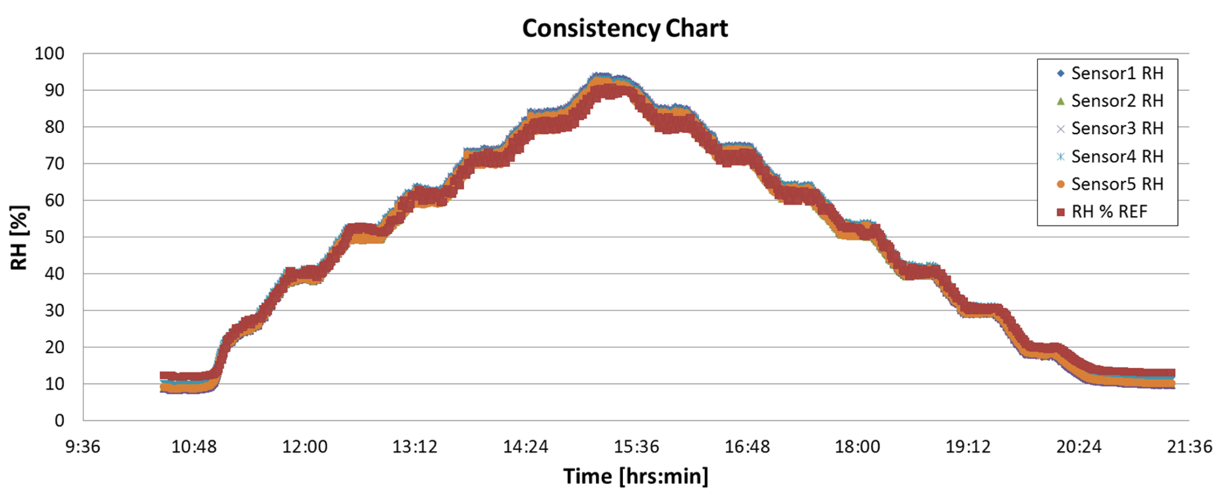

Figure 18. Humidity Consistency Test Result Under 43°C

Figure 19 shows the measured temperature on the y-axis versus time on the x-axis for the measurements with a 43°C target temperature. The plotted curves reflect the absolute temperature measured with the sensor module *Sensor1 Temp*, the differently preconditioned and coated sensor variants as described in Table 3, *Sensor2 Temp* through *Sensor5 Temp*, and the reference sensor *T REF* in °C. The measured temperature values of all variants are in very good agreement, which proves the high consistency and robust, process-variant-independent temperature accuracy of the HDC1080 device.

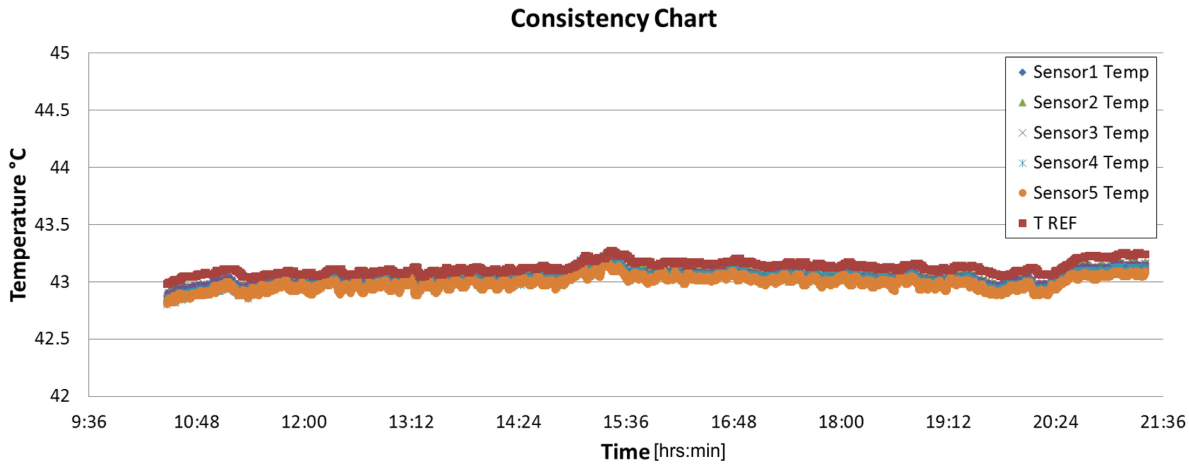

Figure 19. Temperature Consistency Test Result Under 43°C

So far the first half of this subsection shows that the HDC1080 device meets or even exceeds both its humidity and temperature measurement accuracy specification at a target temperature of 43°C. So, for the second half of this subsection consider the results of similar tests for a high-target temperature of 83°C.

Figure 20 shows the measured humidity versus time for a target temperature of 83°C. The relative humidity measured with the sensor module *RH % Sensor1* and the reference sensor *RH % REF* is referred to primary y-axis in percent. During this test, the humidity target value increases in five steps from 20% to 90% and then decreases again. The measured relative humidity of both sensors matches the target value over the course of the six hours of the test duration. The difference between the value measured with the sensor module and the reference sensor *RH Diff* is depicted in percent as well and is referred to the secondary y-axis on the right side. The instantaneous difference shows some small momentary fluctuations because of airflow turbulence and humidity variations. The long-term average difference is well within a ±2% tolerance window. This tolerance window is defined by the accuracy of the sensor modules and the reference sensor assuming an absolutely homogeneous and constant humidity distribution that neglects the effect of humidity variations within the test chamber. The reference sensor contribution is ±1% tolerance, so the HDC1080 accuracy contribution is within ±1% over the complete, tested relative humidity range from 10% to 90% at a temperature of 83°C. This result again indicates higher actual accuracy versus the HDC1080 device specification, which loosens up below 20% RH, for example, to ±3% at 10% RH and above 60% to ±3% at 70% RH and ±4% above 80% (see the preceding Figure 16). So at 83°C the HDC1080 device also outperforms its RH accuracy specification.

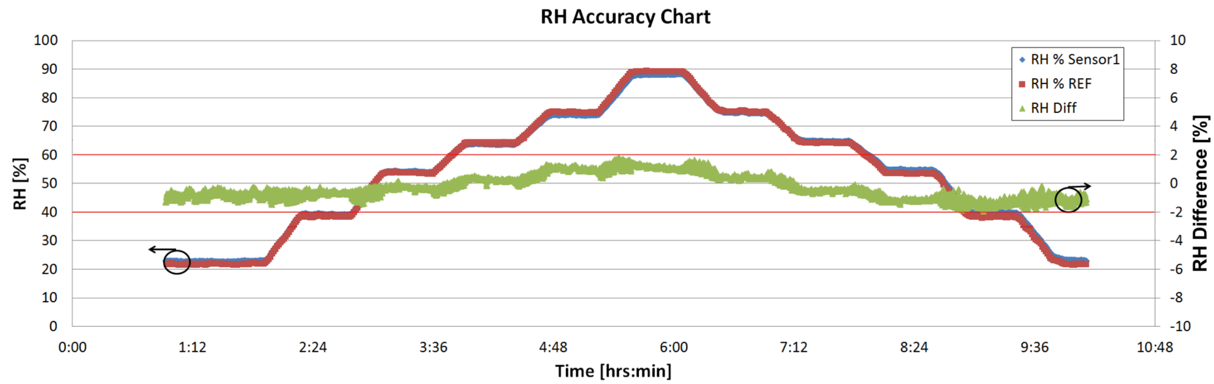

Figure 20. Humidity Accuracy Test Result Under 85°C

Figure 21 shows the measured temperature versus the absolute time on the x-axis for the test with a temperature target of 83°C. The primary y-axis plots the absolute temperature measured with the sensor module *RH % Sensor1* and the reference sensor *RH % REF* in °C. The temperature does rise above the 83°C target value because of the temperature regulation inaccuracy of the temperature chamber. The measured temperature of both sensors matches each other well over the test duration. The minimum offset between both curves is constant and the response characteristics of the reference sensor is slower again. The difference of the temperature value measured with the sensor module and the reference sensor *Temp Diff* is referred again to the secondary y-axis. The instantaneous difference shows some variation, which is to be expected because of airflow turbulence, consequent temperature variations, and the difference in response speed. Considering all the effects, the difference is well within a ±0.3°C tolerance window. Considering the reference sensors ±0.1°C contribution, this result demonstrates the HDC1080 accuracy below 85°C to be better than ±0.2°C.

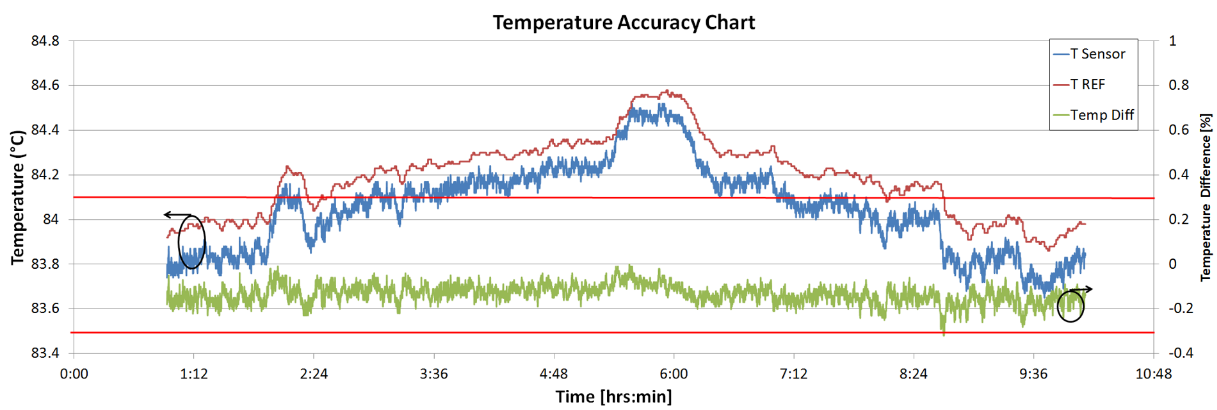

Figure 21. Temperature Accuracy Test Result Under 85°C

Figure 22 shows the measured humidity versus time on the x-axis for an 83°C target temperature in the measurement chamber. The relative humidity curves measured with the sensor module *RH % Sensor1*, *RH % Sensor2* through *RH % Sensor5*, and the reference sensor *RH % REF* refer to the y-axis in percent. *RH % Sensor2* through *RH % Sensor5* are the differently preconditioned and coated sensor variants as described in Table 3. The measured relative humidity values of all variants are in very good agreement, which again proves the high consistency and robust, process-variant-independent-humidity measurement accuracy of the HDC1080 device.

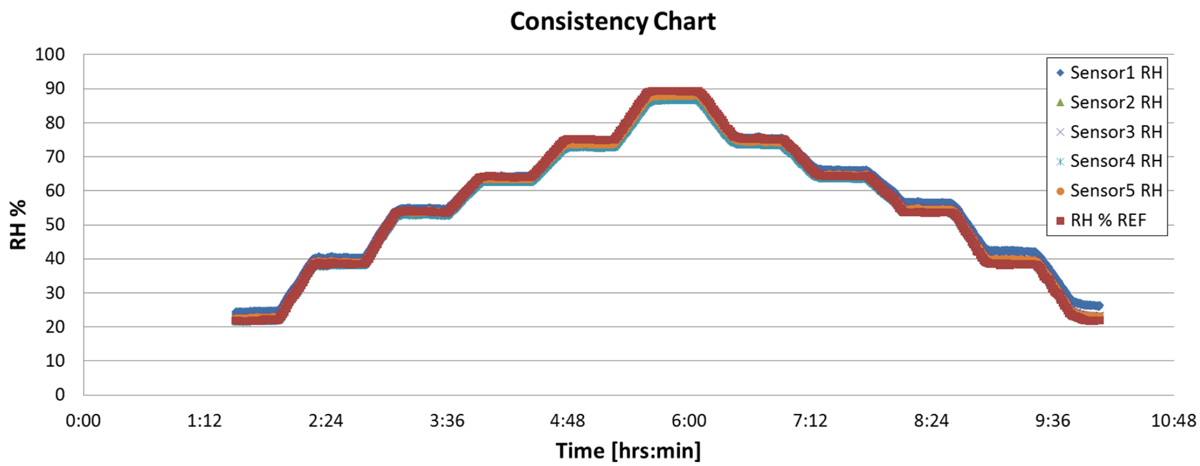

Figure 22. Humidity Consistency Test Result Under 85°C

Figure 23 shows the measured temperature on the y-axis versus time on the x-axis for the measurements with an 83°C target temperature. The data plotted is the absolute temperature measured with the sensor module Sensor1 Temp, the differently preconditioned and coated sensor variants as described in Table 3, *Sensor2 Temp* through *Sensor5 Temp*, and the reference sensor *T REF* in °C. The measured temperature values of all variants are in very good agreement, which proves the high consistency and robust, process-variant-independent-temperature measurement accuracy of the HDC1080 device.

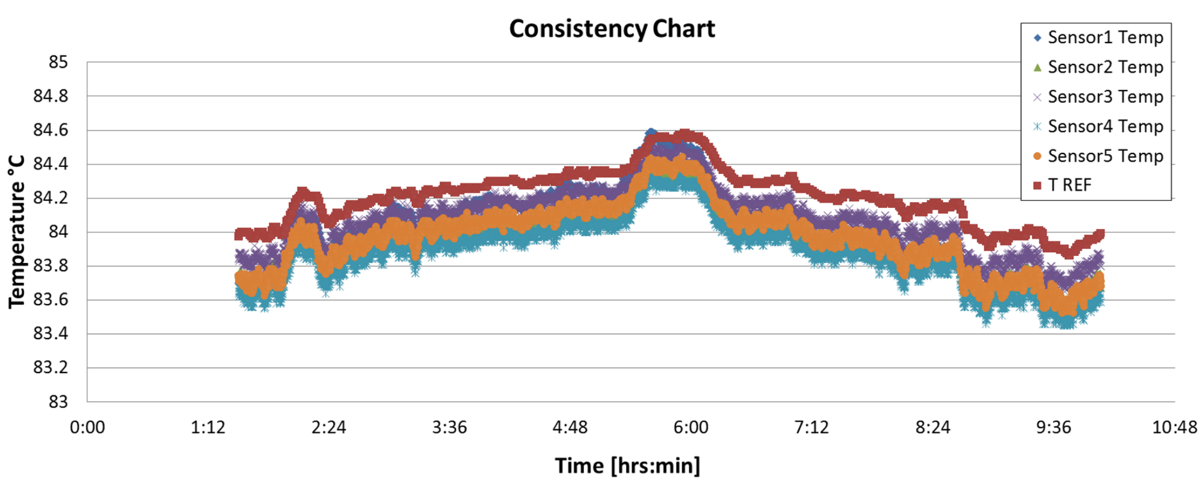

Figure 23. Temperature Consistency Test Result Under 85°C

5 Design Files

5.1 Schematics

To download the schematics, see the design files at TIDA-00972.

5.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-00972.

5.3 PCB Layout Recommendations

Because there is room for improvement with respect to the layout of the sensor modules, TI suggests to follow the suggestions in the HDC1080 data sheet[2] on how to reduce heat mass, minimize the thermal coupling with other parts of the sensor module, and achieve a low decoupling-loop area and inductance:

- Solder the DAP pad and leave it floating.
- Minimize PCB copper coverage and trace density and avoid ground pour and copper planes around the sensor device.
- Separate the sensor device from the rest of the board by cutout.
- Place a decoupling capacitor close to the HDC1080. Close the current loop through the HDC1080 device and the decoupling capacitor with short traces to minimize the loop area and loop inductance and maximize decoupling efficiency.

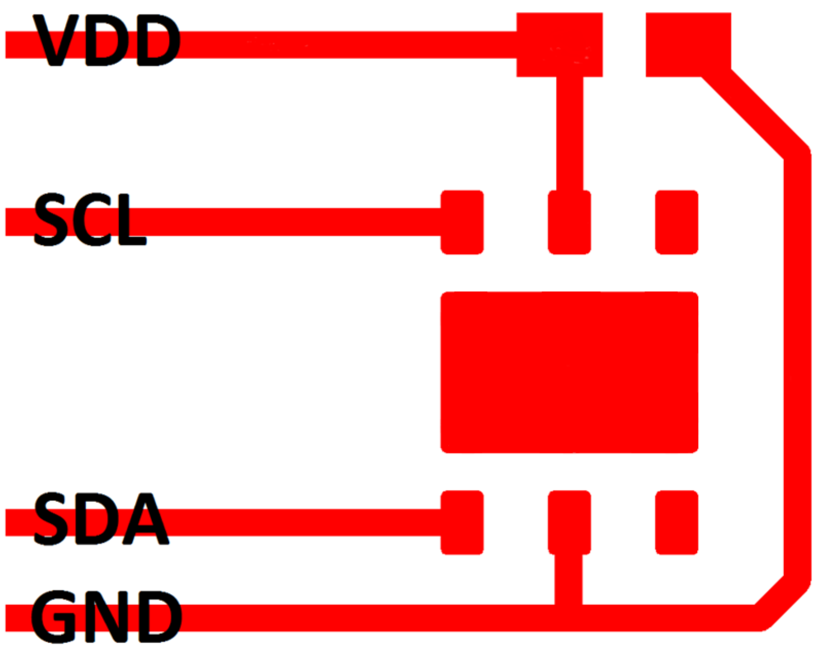

Figure 24. PCB Recommendations

5.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-00972.

5.4 Gerber Files

To download the Gerber files, see the design files at TIDA-00972.

5.5 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-00972.

6 Software Files

To download the software files, see the design files at TIDA-00972.

7 Related Documentation

1. Texas Instruments, *Noise Analysis in Operational Amplifier Circuits*, Application Report (SLVA043)
2. Texas Instruments, *HDC1080 Low Power, High Accuracy Digital Humidity Sensor with Temperature Sensor*, HDC1080 Data Sheet (SNAS672)

7.1 Trademarks

All trademarks are the property of their respective owners.

8 Certificates

Figure 25 shows the calibration certificate and accuracy of the reference sensor.

VAISALA

1 (1)
Certificate report no. H33-15350035

CALIBRATION CERTIFICATE

Instrument Humidity and Temperature Probe HMP76
Order code
Serial number L3520061
Manufacturer Vaisala Oyj, Finland
Calibration date 26th August 2015

The above instrument was calibrated by comparing the readings of the instrument to working standards of the manufacturer. The reference humidity was calculated from dewpoint temperature and temperature readings with the exception of the driest condition that was measured as relative humidity. Dewpoint temperature was measured with a 373 LHX dewpoint meter. Temperature and relative humidity were measured with two factory working standards. At the time of shipment, the instrument described above met its operating specifications.

The 373 LHX dewpoint meter has been calibrated at Centre for metrology and accreditation (MIKES) by using a MIKES working standard traceable to National Institute of Standards and Technology (NIST). The temperature readings of the factory working standards have been calibrated at an ISO/IEC 17025 accredited calibration laboratory (FINAS), Vaisala Measurement Standards Laboratory (MSL) by using MSL working standards traceable to NIST. The relative humidity readings of the factory working standards have been calibrated at the Vaisala factory by using a 373 LHX dewpoint meter.

Humidity calibration results

Reference humidity %RH	Reference temperature °C	Observed humidity %RH	Observed probe temperature °C		Humidity difference %RH	Permissible difference %RH
+ 0.2	+ 22.06	+ 0.1	+ 22.07		- 0.1	±1.0
+ 12.5	+ 22.08	+ 13.1	+ 22.08		+ 0.6	± 1.0
+ 32.8	+ 22.08	+ 33.6	+ 22.08		+ 0.8	± 1.0
+ 53.5	+ 22.09	+ 54.2	+ 22.09		+ 0.7	± 1.0
+ 74.1	+ 22.11	+ 74.2	+ 22.11		+ 0.1	± 1.0
+ 93.4	+ 22.13	+ 93.4	+ 22.13		0.0	± 1.7

Temperature calibration results

Reference temperature °C	Observed probe temperature °C	Temperature difference °C				Permissible difference °C
+ 22.11	+ 22.11	0.00				± 0.10

Equipment used in calibration

Type	Serial number	Calibration date	Certificate number
MBW 373LHX	10-0310	2015-02-10	M-15H005
PTU303 / T	H0730002	2014-10-01	K008-X01689
HMT337 / T	E0840007	2014-10-01	K008-X01686
PTU303 / RH	H0730002	2015-07-21	H33-15301001
HMT337 / RH	E0840007	2015-07-21	H33-15301002

Uncertainties (95 % confidence level, k=2)
Humidity ± 0.6%RH @ 0...40%RH, ± 1.0%RH @ 40...97%RH
Temperature ± 0.10 °C.
Ambient conditions / Humidity 39 ± 5%RH, Temperature 22 ± 1 °C, Pressure 1008 ± 1 hPa.

Technician

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Figure 25. Calibration Certificate of Reference Sensor

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (September 2016) to A Revision **Page**

- Changed from .pdf to .xml format 1
- Changed title from *Accurate Humidity Sensing Solution Supporting Low-cost 2m Wire Communication* to *±2% Accurate Humidity-Sensing Reference Design Supporting 2-m Wire Communication* 1
- Added Copyright and Trademark notices to all block diagrams, tables, and titles 1
- Deleted physical schematic, BOM, and layer plots then replaced with links to most current material available on TI.com 21

IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

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