User's Guide
HDC20XX Silicon

![Texas Instruments logo]

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ABSTRACT

This document is to familiarize the user with the HDC20XX family of devices by providing storage and handling guidance, software configuration examples, and pseudo code. The HDC Devices are integrated humidity and temperature sensors that provide RH Accuracy typ. ±2% RH, temperature accuracy typ. ±0.2 °C with 0.6µA active current. The devices measures humidity through a capacitive polymer dielectric. This sensing element is placed on the bottom of the HDC2010, and the top of the HDC2080, and HDC202x devices. The HDC2010 features a tiny 1.5mm × 1.5mm WLCSP (Wafer Level Chip Scale Package), making it the optimum choice in cost-sensitive or space-constrained humidity sensing applications. The HDC2080, HDC2021 and HDC2022 all feature a 3mm × 3mm WSON Package. The HDC2080, and HDC2010 sensing polymers are exposed directly to ambient air. On the HDC2021, the sensing element is protected during the assembly by factory-installed PI (Polyimide) tape. The HDC2022 sensing element is protected by a hydrophobic PTFE filter and is ideal for outdoor environments or anywhere condensation is expected. All of these HDC20xx family devices are factory calibrated and software-compatible with each other.

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1 HDC20XX Devices

1.1 HDC2010 in WLCSP

The HDC2010 is the only member of the HDC20xx family available in the 1.5mm × 1.5mm WLCSP/DSBGA package. The innovative DSBGA package of the HDC2010 has the RH sensing element placed on the underside of the device, rather than the topside (see Figure 1-1). The WLCSP package makes the HDC2010 an effective solution for cost- or space-constrained applications. For additional device information, see the HDC2010 data sheet.

Figure 1-1. HDC2010 in DSBGA Package

1.2 WSON Devices

1.2.1 HDC2080

The HDC2080 is the standard WSON device in the HDC20xx family, with no additional protection over the RH sensor window. Unlike the HDC2021 and HDC2022, the sensor window on the HDC2080 is not centered (see Figure 1-2). When using the HDC2080, care should be taken to ensure all of the requirements in Section 2 are followed. For more information on the HDC2080, please see the HDC2080 data sheet.

Figure 1-2. HDC2080 in WSON

1.2.2 HDC2021 with Assembly Protection Tape

The HDC2021 is pin-to-pin compatible with the HDC2080 and HDC2022. Unlike the HDC2080, the sensor opening on the HDC2021 is centered at the top of the package, and protected by a factory-installed polyimide cover tape (see Figure 1-3). The tape protects the humidity sensor element from pollutants that can be produced as part of the manufacturing process, such as SMT assembly, PCB board wash, and conformal coating. The tape must be removed after the final stages of assembly for accurate measurement of relative humidity in the ambient environment. For more device information, please see the HDC2021 data sheet.
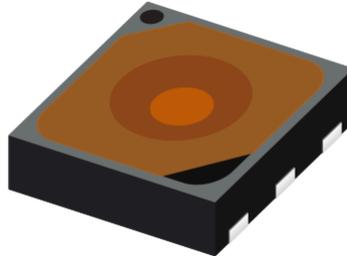
Figure 1-3. HDC2021 with removable polyimide assembly tape

1.2.3 HDC2022

The HDC2022 is identical to the HDC2021, but instead of the removable assembly tape, this device features an IP67 rated hydrophobic protective PTFE membrane over the sensing element (see Figure 1-4). This filter is intended to be left for the lifetime of the device, and protects with 99.99% filtration efficiency for particles down to 100 nm in size. For more information on the HDC2022 and filter, see the HDC2022 data sheet.

Figure 1-4. HDC2022 with IP67 rated device filter

2 Storage and Handling Guidelines

2.1 Exposure to Contaminants

Humidity sensors are not standard ICs and therefore must not be exposed to articles or volatile chemicals such as solvents or other inorganic compounds. The opening in the package exposes the sensing polymer to the environment and makes it susceptible to pollutants. Typical ambient conditions do not present a significant risk for chemical exposure but manufacturing and storage environments are a known source of volatile contamination. The HDC2021's factory-installed polyimide cover tape protects the device during manufacturing and assembly (see Figure 1-3). After tape removal the sensing element is again sensitive to contamination.

Exposure to a range of chemicals must be avoided or minimized. Exposure of the following chemicals is know to cause drift of the humidity output readings which may be irreversible:

- Solvents such as:
    - Toluene: C_7H_8
    - Acetone: $(CH_3)_2CO$
    - Ethanol: C_2H_6O
    - Methanol: CH_3OH
    - Isopropyl Alcohol: C_3H_8O
    - Di-isopropyl Ether: $C_6H_{14}O$
    - Ethylene Glycol: $(CH_2OH)_2$
    - Ethyl Acetate: $C_4H_8O_2$
    - Butyl Acetate: $C_6H_{12}O_2$
    - Methyl Ethyl Ketone: $CH_3C(O)CH_2CH_3$
- Acids such as:
    - Hydrochloric Acid: HCl
    - Sulfuric Acid: H_2SO_4
    - Nitric Acid: HNO_3
- Other Chemicals, including:
    - Ketenes
    - Ammonia: NH_3
    - Hydrogen Peroxide: H_2O_2
    - Ozone: O_3
    - Formaldehyde: CH_2O

Such chemicals are an integral part of epoxies, glues, adhesives, or reaction by-products that outgas during baking and curing processes.

The sense layer must not have direct contact with cleaning agents such as PCB board wash after soldering. Applying cleaning agents to the sense layer may lead to drift of the RH output or even complete breakdown of the sensor. Avoid strong blasts from aerosol dusters and use only low pressure oil free air dusting.

If it is necessary to expose the HDC to contaminants, concentration and exposure time must be reduced as much as feasible. Good ventilation (fresh air supply) aids in lowering the concentration of volatile chemicals, particularly solvents.

2.2 Packaging and Storage

TI's Humidity sensors are shipping in sealed anti-static tape and reel cavities. The sensors can be stored in a humidity and temperature controlled environment after being removed from the tape and reel cavity prior to assembly. Storage temperature and humidity limitations are defined by the MSL level of the sensor. Refer to the application note MSL Ratings and Reflow Profiles for details.

Do not store the humidity sensors within Anti-static polyethylene bags or packing materials (pink foam/wrap) as these materials emit gases that can affect the sensor. Metallized, anti-static seal-able bags are recommended for storage. Do not use adhesives or tape inside the storage container.

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2.2.1 Assembly

The HDC must be added in the last assembly step. In case the PCB passes through multiple solder cycles (as is the case for PCBs that have components on the top and bottom side), adding the HDC last reduces the risk of damage to the sensing polymer from contaminants or excessive heat. Contaminants such as those listed in Exposure to Contaminantsmust be avoided or minimized. Maximum assembly temperatures and exposure times must not be exceeded.

Note

It is important that *no-clean* solder paste is used and no board wash is applied once the sensor is assembled onto the PCB. To ensure proper device performance, these instructions should be communicated to board manufacturers before assembly.

2.2.2 Application in Extreme Environments

Some applications require the usage of the HDC in harsh environments. Ensure that the exposure of the sensor to the maximum limit of temperature and humidity operating conditions meets the data sheet guidelines. Limiting exposure to volatile organic compounds at high concentration and long exposure time is critical. Usage in harsh environments must be carefully tested and qualified.

Exposure to any aqueous solutions is highly discouraged. In the event some aqueous exposure cannot be avoided, the following guidelines should be followed:

- Exposure to acids or bases may affect humidity output accuracy readings
- Bases are less damaging than acidic solutions. All acids must be considered damaging to the sensor. Etching substances such as H_2O_2 or NH_3 at high concentrations can be damaging to the sensor.
- Corrosive solutions at very low concentrations are not damaging to the sensor itself. However, care must be taken to ensure that the solder contacts are not damaged.

3 Programming the HDC20x0 Devices

3.1 Device Functional Modes

The HDC20XX has two modes of operation: sleep and measurement mode. After power up, the HDC20XX enters sleep mode. In this mode, the HDC20XX waits for I²C instruction to set programmable conversion times, trigger a measurement/conversion, or read/write valid data. When a measurement is triggered, the HDC20XX wakes from sleep mode to enter measurement mode. In measurement mode, the HDC20XX coverts temperature or humidity values from integrated sensors through an internal ADC and stores the information in their respective data registers [0x00 - 0x03]. The DRDY/INT pin can be monitored to verify if data is ready after measurement conversion. The DRDY/INT pin polarity and interrupt mode is set according to the configuration of the Interrupt Enable and DRDY/INT Configuration registers. After completing the conversion, the HDC20XX returns to sleep mode.

Two different types of ADC conversions (measurement modes) are available in the HDC devices: Trigger on Demand and Auto Mode

In Trigger on Demand mode, and I²C command triggers each measurement conversion. After the conversion is complete, the device remains in sleep mode until a new trigger is sent.

Auto Mode is a continuous operation, adjusting the RESET and DRDY/INT Configuration Register enables the user to select from 7 different conversion frequencies (from 5Hz to 1/120Hz). In auto mode, the HDC20XX wakes from sleep to measurement mode based on the selected sample rate.

3.2 Single Acquisition

3.2.1 Startup Sequence

After power up, the HDC20XX is in sleep mode waiting for I²C command input. To configure the device to collect both the humidity and temperature data in a single acquisition mode, select TRIGGER ON DEMAND in the CONFIG register (0x0E), select the desired temperature and humidity resolutions and the temperature + humidity measurement configuration in the MEAS_CONFIG register (0x0F).

3.2.2 Reading Procedure

To initiate a single measurement, the bit MEAS_TRIG is set to 1 in the MEAS_CONFIG register. The device will exit from sleep mode and perform a single measurement. After the conversion, the device will update the respective measurement register and will return to sleep mode. The register can be accessed through a pointer mechanism. When reading from the HDC20XX, the current pointer location is used to determine which register to read – the pointer location points to the last written register address. To change the address for a read operation, a new value must be written to the pointer. This transaction is accomplished by issuing the slave address byte with the R/W bit set to 0, followed by the pointer byte.

The pointer auto increments, therefore it is possible to read all 4 bytes of information related to Temperature and humidity in a single transaction, as shown in Section 3.2.3.
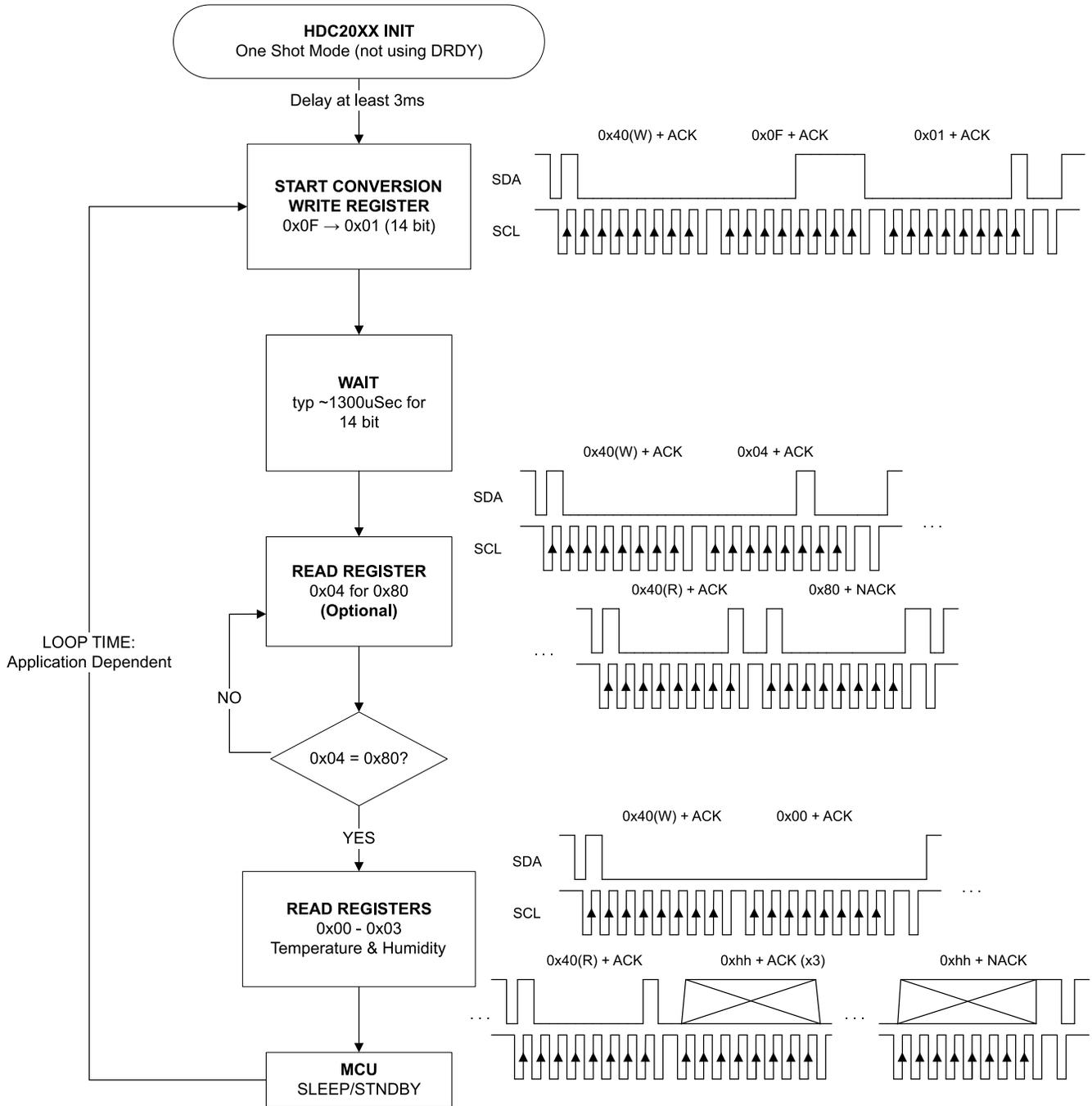
3.2.3 Example for Single Acquisition

Figure 3-1. Flowchart for single data acquisition mode

3.3 Continuous Acquisition

3.3.1 Startup Sequence

After power up, the HDC20XX is in sleep mode waiting for I^{2}C input commands. To configure the device to collect both the humidity and temperature data in continuous mode, select the desired Auto Measurement Mode (AMM) in CONFIG register (0x0E), and select the Temperature and Humidity resolutions and the temperature + humidity measurement configuration in MEAS_CONFIG register (0x0F).

3.3.2 Reading Procedure

To trigger the start of the measurements, the bit MEAS_TRIG is set to 1 in MEAS_CONFIG register (0x0F). The device will exit from sleep mode and will start to periodically convert the measurements based on the selected sample rate in the CONFIG register (0x0E). After each conversion, the device will update the measurement related registers and re-enter sleep mode. The register can be accessed through a pointer mechanism. When reading from the HDC20XX, the current pointer location is used to determine which register to read – the pointer location points to the last written register address. To change the address for a read operation, a new value must be written to the pointer. This transaction is accomplished by issuing the slave address byte with the R/W bit set to 0, followed by the pointer byte. The pointer auto increments, therefore it is possible to read all 4 bytes of information related to Temperature and humidity in a single transaction, this is shown in Figure 3-2 and Figure 3-3.

3.3.3 Example for Continuous Acquisition: Timer Based
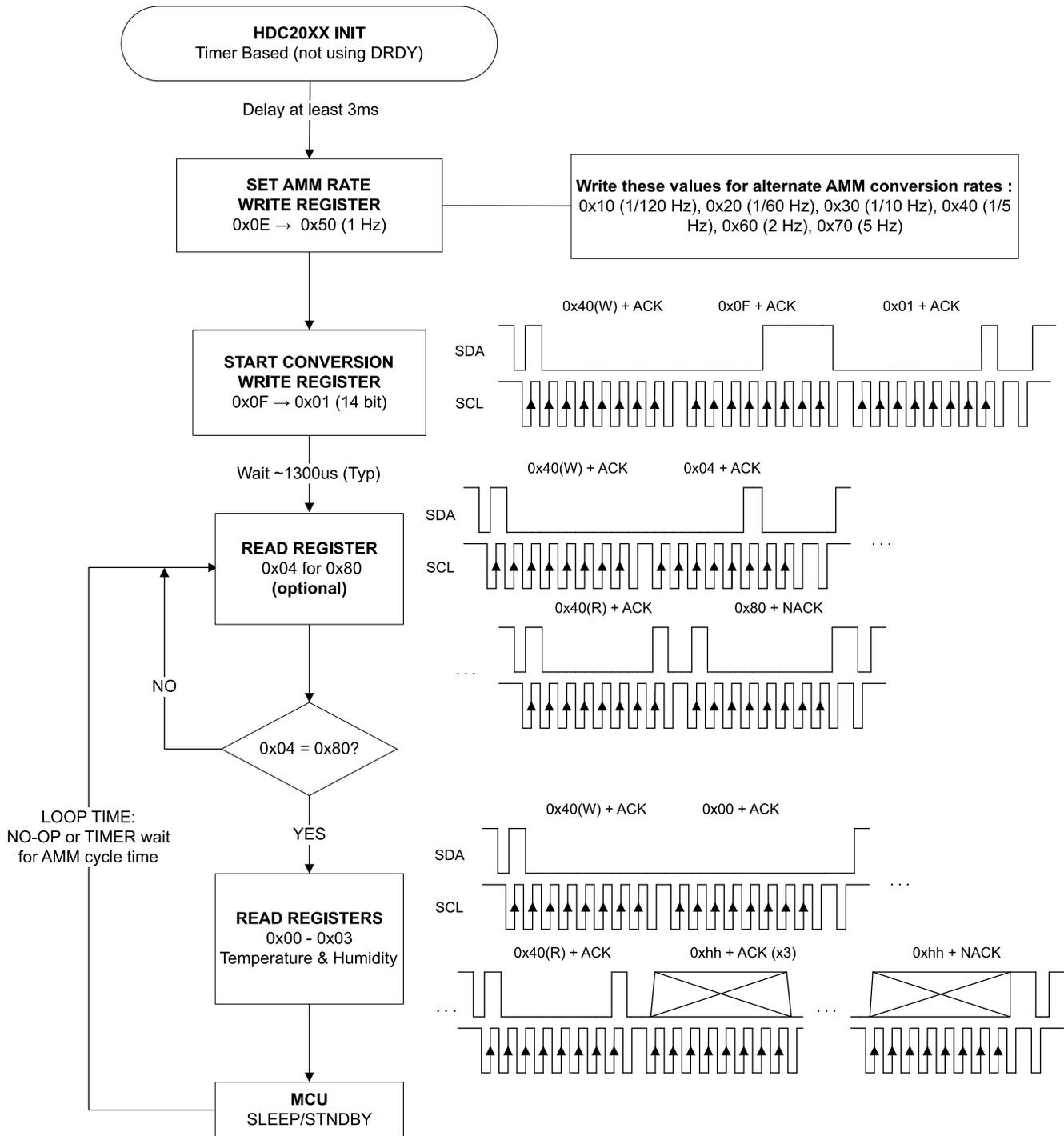

Figure 3-2. Flowchart for continuous data acquisition when using timer based polling

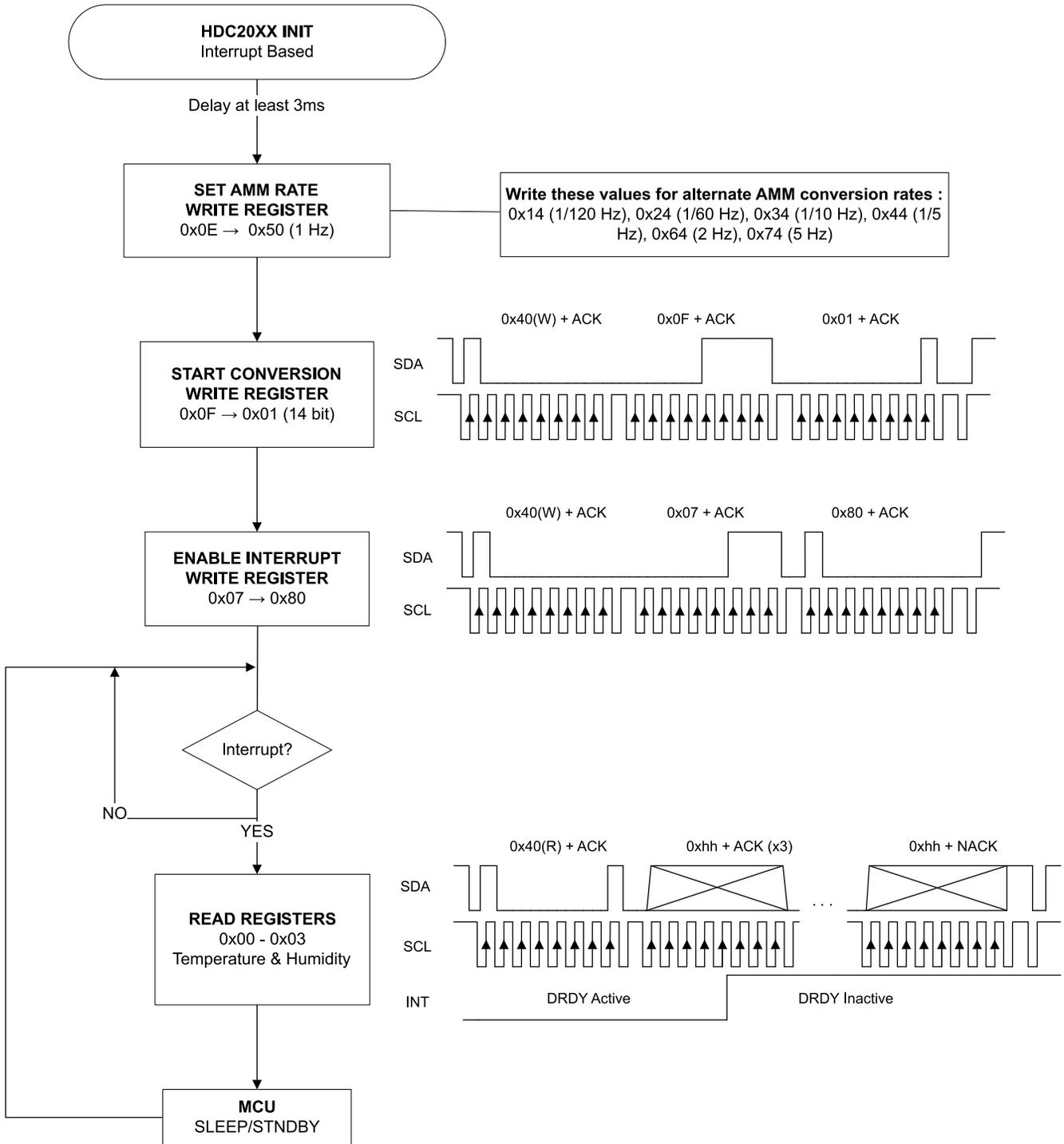### 3.3.4 Example for Continuous Acquisition: Interrupt Based

Figure 3-3. Flowchart for continuous data acquisition when using interrupt based polling

3.4 Interrupt Pin Functionality

Interrupt pin functionality is shared between Data Ready and Event Interrupt functionality. Enabling the interrupt pin for Data Ready (DRDY) can help reduce the power consumption of the system as the MCU/CPU will enter sleep when the HDC device is making temperature and humidity measurements, and awaken the MCU/CPU for communication through it's DRDY interrupt pin. To verify that data is ready after manual conversion, the DRDY/INT pin should be monitored. If monitoring this pin is not possible, it is recommended that the user program the device for auto mode and program the sampling rate of the device to perform periodic automatic conversions. Additionally, the DRDY/INT pin can be set for interrupt capability based on input alarm thresholds for either temperature or humidity measurements.

3.5 Understanding the Output Data

The measured temperature and humidity data are sent to the output register: TEMP_LOW, TEMP_HIGH, RH_LOW and RH_HIGH. The complete temperature and humidity data are represented as 16-bit numbers, so in order to translate to real world values it is necessary to concatenate the low and high register like so:

$$\text{TEMPERATURE}_{\text{LSB}} = \text{TEMP\_HIGH} <<8 + \text{TEMP\_LOW};$$

$$\text{HUMIDITY}_{\text{LSB}} = \text{RH\_HIGH} <<8 + \text{RH\_LOW};$$

Where:

- $\text{TEMPERATURE}_{\text{LSB}}$ is the 16 bit concatenation of the 8 bit temperature registers
- $\text{HUMIDITY}_{\text{LSB}}$ is the 16 bit concatenation of the 8 bit humidity registers

Convert the output value

Please note, these values are not in two's complement, so it is necessary to convert temperature and humidity to °C and %RH respectively using the following equations.

$$\text{TEMPERATURE}(°C) = \left(\frac{\text{TEMPERATURE}_{\text{LSB}}}{2^{16}} \right) \times 165 - 40$$

$$\text{HUMIDITY}(\%RH) = \left(\frac{\text{HUMIDITY}_{\text{LSB}}}{2^{16}} \right) \times 100$$

Temperature Calculation Example:

1. Output registers:

   TEMP_LOW = 0x5E;

   TEMP_HIGH = 0x64;

Temperature value in hex:

   $\text{TEMPERATURE}_{\text{LSB}}$ = 0x645E

Temperature value in decimal:

   $\text{TEMPERATURE}_{\text{LSB}}$ = 25694

Temperature value in degree C:

$$\text{TEMPERATURE}(°C) = \left(\frac{25694}{2^{16}} \right) \times 165 - 40 = 24.67°C$$

2. Output registers:

TEMP_LOW = 0x3B;

TEMP_HIGH = 0x29;

Temperature value in hex:

TEMPERATURE = 0x293B

Temperature value in decimal:

TEMPERATURE = 10555

Temperature value in degree C:

$$\text{TEMPERATURE}(°C) = \left(\frac{10555}{2^{16}}\right) \times 165 - 40 = 13.43°C$$

Humidity Calculation Example:

Output registers:

RH_LOW = 0xDC;

RH_HIGH = 0x42;

Humidity value in hex:

HUMIDITY_{LSB} = 0x42DC

Humidity value in decimal:

HUMIDITY_{LSB} = 17116

Humidity value in %RH:

$$\text{HUMIDITY}(\%RH) = \left(\frac{17116}{2^{16}}\right) \times 100 = 26.11\%RH$$

4 Using the HDC20XX Heater

The HDC20XX includes an integrated heating element that can be switched on briefly to prevent or remove any condensation that may build up in high humidity environments. Additionally, the heater can be used to verify functionally of the integrated temperature sensor. The operating range of the heater should be limited to –40°C to 85°C. For 3.3-V operation, the heater will have a typical current draw of 90 mA, and 55 mA at 1.8-V operation.

The settling time and peak temperature attainable by using the integrated heater will be largely dependent on the board layout and the operating voltage of the device. Figure 4-1 shows the heater response of the HDC2022EVM in the HDC2022EVM GUI. For reference, the HDC2022EVM settles around 105 °C within 2.5 minutes. Similar layout techniques such as cutouts and the use of small breakouts will provide the highest efficiency of heater operation.
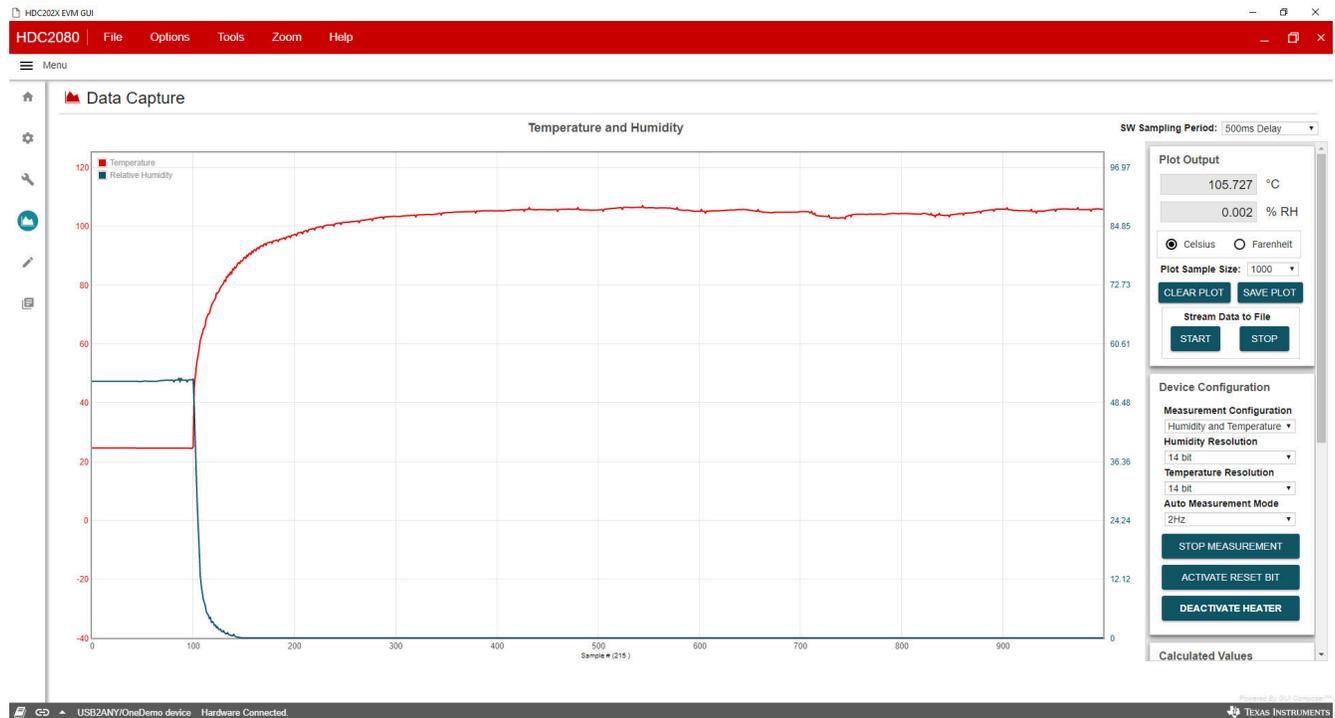

Figure 4-1. HDC2022EVM heater response

Appendix A

Table 5-1. Output Registers

Register Name	Address	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
TEMP_LOW	0x00	TEMP7	TEMP6	TEMP5	TEMP4	TEMP3	TEMP2	RES	RES
TEMP_HIGH	0x01	TEMP15	TEMP14	TEMP13	TEMP12	TEMP11	TEMP10	TEMP9	TEMP8
RH_LOW	0x02	RH7	RH6	RH5	RH4	RH3	RH2	RES	RES
RH_HIGH	0x03	RH15	RH14	RH13	RH12	RH11	RH10	RH9	RH8

5.1 Address 0x00 Temperature LSB

Table 5-2. Address 0x00 Temperature LSB Register

7	6	5	4	3	2	1	0
TEMP[7:0]							

Table 5-3. Address 0x00 Temperature LSB Field Descriptions

BIT	FIELD	TYPE	RESET	DESCRIPTION
[7:0]	TEMPERATURE [7:0]	R	00000000	Temperature LSB

5.2 Address 0x01 Temperature MSB

Table 5-4. Address 0x01 Temperature MSB Register

7	6	5	4	3	2	1	0
TEMP[15:8]							

Table 5-5. Address 0x01 Temperature MSB Field Descriptions

BIT	FIELD	TYPE	RESET	DESCRIPTION
[15:8]	TEMPERATURE [15:8]	R	00000000	Temperature MSB

The temperature register is a 16-bit result register in binary format (the 2 LSBs D1 and D0 are reserved bits, and must be set to 0 in formula). The result of the acquisition is always a 14-bit value, while the resolution is related to one selected in Measurement Configuration register. The temperature can be calculated from the output data with:

$$\text{TEMPERATURE}(^\circ C) = \left(\frac{\text{TEMPERATURE}[15:0]}{2^{16}} \right) \times 165 - 40$$

5.3 Address 0x02 Humidity LSB

Table 5-6. Address 0x02 Humidity LSB Register

7	6	5	4	3	2	1	0
HUMIDITY[7:0]							

Table 5-7. Address 0x02 Humidity LSB Field Descriptions

BIT	FIELD	TYPE	RESET	DESCRIPTION
[7:0]	HUMIDITY [7:0]	R	00000000	Humidity LSB

5.4 Address 0x03 Humidity MSB

Table 5-8. Address 0x03 Humidity MSB Register

7	6	5	4	3	2	1	0
			HUMIDITY[15:8]				

Table 5-9. Address 0x03 Temperature MSB Field Descriptions

BIT	FIELD	TYPE	RESET	DESCRIPTION
[15:8]	HUMIDITY[15:8]	R	00000000	Humidity MSB

The humidity register is a 16-bit result register in binary format (the 2 LSBs D1 and D0 are reserved bits, and must be set to 0 in formula). The result of the acquisition is always a 14-bit value, while the resolution is related to one selected in Measurement Configuration register. The humidity can be calculated from the output data with:

$$HUMIDITY\left(\%RH\right) = \left(\frac{HUMIDITY[15:0]}{2^{16}}\right) \times 100$$

5.5 Configuration Registers

Table 5-10. Configuration Registers

Register Name	Address	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
CONFIG	0x0E	SOFT_RES	AMM2	AMM1	AMM0	HEAT_EN	DRDY/ INT_EN	INT_POL	INT_MODE
MEASUR CONFIG	0x0F	TRES1	TRES0	HRES1	HRES1	RES	MEAS_CON FIG1	MEAS_CON FIG0	MEAS_TRI G

5.6 Address 0x0E Reset and DRDY/INT Configuration Register

Table 5-11. Address 0x0E Reset and DRDY/INT Configuration Register

7	6	5	4	3	2	1	0
SOFT_RES	AMM[2]	AMM[1]	AMM[0]	HEAT_EN	DRDY/INT_EN	INT_POL	INT_MODE

Table 5-12. Address 0x0E Reset and DRDY/INT Configuration Field Descriptions

BIT	FIELD	TYPE	RESET	DESCRIPTION
7	SOFT_RES	R/W	0	0 = Normal Operation mode, this bit is self-clearing 1 = Soft Reset EEPROM value reload and registers reset
[6:4]	AMM[2:0]	R/W	000	Auto Measurement Mode (AMM) 000 = AMM disabled. Trigger on demand. 001 = 1/120Hz (1 samples every 2 minutes) 010 = 1/60Hz (1 samples every minute) 011 = 0.1Hz (1 samples every 10 seconds) 100 = 0.2 Hz (1 samples every 5 second) 101 = 1Hz (1 samples every second) 110 = 2Hz (2 samples every second) 111 = 5Hz (5 samples every second)
3	HEAT_EN	R/W	0	0 = Heater off 1 = Heater on
2	DRDY/INT_EN	R/W	0	DRDY/INT_EN pin configuration 0 = High Z 1 = Enable
1	INT_POL	R/W	0	Interrupt polarity 0 = Active Low 1 = Active High

Table 5-12. Address 0x0E Reset and DRDY/INT Configuration Field Descriptions (continued)

BIT	FIELD	TYPE	RESET	DESCRIPTION
0	INT_MODE		0	Interrupt mode 0 = Level sensitive 1 = Comparator mode

5.7 Address 0x0F Measurement Configuration

Table 5-13. Address 0x0F Measurement Configuration Register

7	6	5	4	3	2	1	0
TRES[1]	TRES[0]	HRES[1]	HRES[0]	RES	MEAS_CONF[1]	MEAS_CONF[0]	MEAS_TRIG

Table 5-14. Address 0x0F Measurement Configuration Field Descriptions

BIT	FIELD	TYPE	RESET	DESCRIPTION
7:6	TRES[1:0]	R/W	00	Temperature resolution 00: 14 bit 01: 11 bit 10: 8 bit 11: NA
5:4	HRES[1:0]	R/W	00	Humidity resolution 00: 14 bit 01: 11 bit 10: 8 bit 11: NA
3	RES	R/W	0	Reserved
2:1	MEAS_CONF[1:0]	R/W	00	Measurement configuration 00: Humidity + Temperature 01: Temperature only 10: Humidity Only 11: NA
0	MEAS_TRIG	R/W	0	Measurement trigger 0: no action 1: Start measurement Self-cleaning bit when measurement completed

5 References

For related documentation, see the following:

1. Texas Instruments, HDC2080 Low-Power Humidity and Temperature Digital Sensor data sheet
2. Texas Instruments, HDC2010 Low-Power Humidity and Temperature Digital Sensor in WLCSP data sheet
3. Texas Instruments, HDC2021 High-Accuracy, Low-Power Humidity and Temperature Sensor With Assembly Protection Cover data sheet
4. Texas Instruments, HDC2022 High-Accuracy, Low-Power Humidity and Temperature Sensor With IP67 Rated Water and Dust Protection Cover data sheet
5. Texas Instruments, MSL Ratings and Reflow Profiles application report
6. Texas Instruments, Optimizing Placement and Routing for Humidity Sensors application report

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