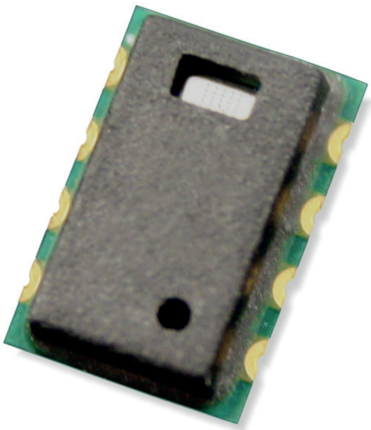
DATA SHEET

Digital humidity sensor

Description



Humidity measurement	
Measuring range	0 ...100% RH (non-condensing)
Accuracy	±2.0% RH (20...80%RH) see Figure 1
Hysteresis (50% RH)	±2.0% RH
Resolution Humidity	14 Bit (0.01% RH)
Linearity error	<2% RH
Response time t_{63}	7 s
Long-term drift	< 0.5% RH / a
Temperature measurement	
Measuring range	- 40...+125 °C
Accuracy	±0.3 °C see Figure 2
Reproducibility	±0.1 °C
Response time t_{63}	5 s
Resolution temperature	14 Bit (0.01 °C)
Long-term drift	< 0.05 °C / a
Operating data	
Operating voltage	2.3…5.5 V
Supply current (Active)	750µA (typical)
Supply current (Sleep)	0.6 µA (typical)
Operating temperature	-40...+125 °C
Operating range humidity	0...100% RH (non-condensing)
Grenzdaten	
Storage temperature	-55...+150 °C

Performance features

- Measuring range 0...100 % RH, -40...+125 °C
- calibrated and temperature compensated
- machine mountable
- microsystem design
- dimensions 4 x 6 x 1.9 mm
- accuracy ±2% RH, temperature ±0.3 °C
- operating voltage 2.3 ... 5.5V
- RoHS compliant

Applications

- Air conditioning
- Cooling
- Building control systems
- Ventilation
- Medical technology
- Weather stations

Features

Above all this sensor impresses with a excellent price/performance ratio. The basic accuracy of ±2% RH and ±0.3 °C is higher than the accuracy of most competitor products, with significantly better chemical resistance and long-term stability.
Despite the miniaturised dimensions of only 4x6x1.9 mm, this sensor offers a measuring range of 0...100% RH as well as -40...125 °C and thus offers a wide range of applications.
The integrated signal processing directly supplies the physical values of relative humidity and temperature as digital values a I2C-interface.
Due the precise factory calibration this sensor is fully interchangeable without adjustment.

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Digital humidity sensor

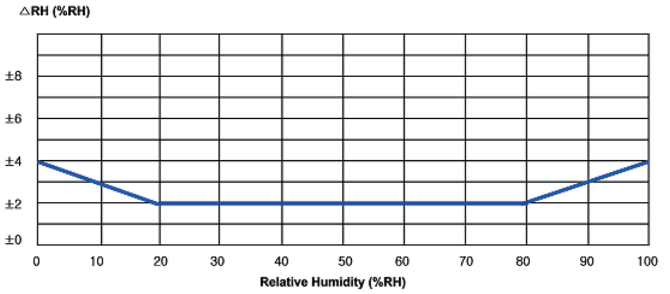


Abbildung 1: Typical RH% Accuracy at 25 °C

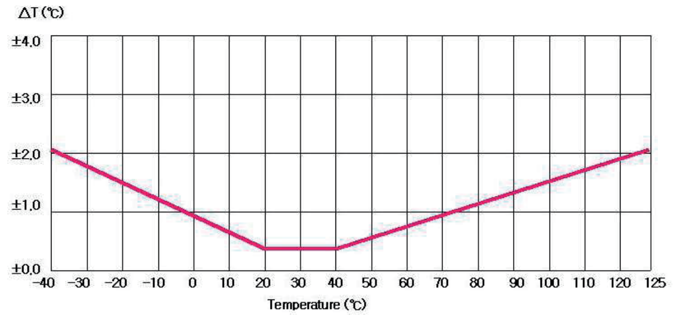
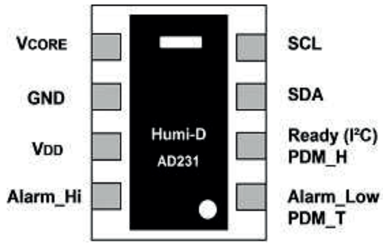


Abbildung 2: Typical Temperature Accuracy

Pin Connection



Information

Output	Accuracy	VDD	Mode
Digital I²C	±2% RH	3,3	Update
	±3% RH	5,0	
	±2% RH	3,3	Sleep
	±3% RH	5,0	
Analog PDM	±2% RH	3,3	Update
	±3% RH	5,0	

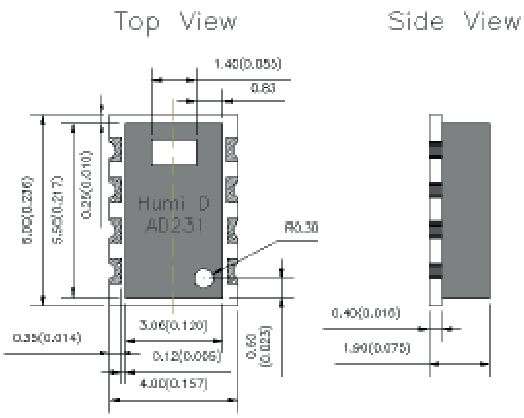
» Standard Digital (I²C) Output:

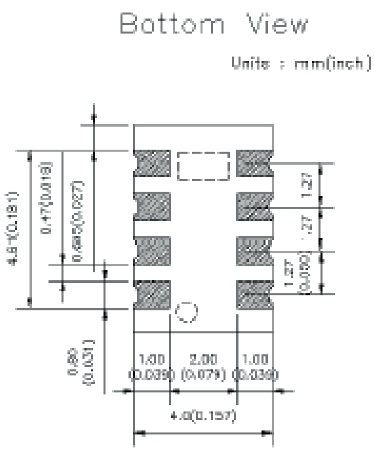
Factory setting is **Sleep Mode** and calibrated at **3.3 V**.
Humidity, temperature and 2 Alarm (Hi / Low) functions for relative humidity.

» Standard Analog (PDM) Output:

Update Mode is calibrated at **5.0 V**.
Humidity, temperature and an Alarm (high) function.

Dimensions





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Inhaltsverzeichnis

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1. General information

1.1 Preliminary consideration

To maximize the performance of the sensor, it is important to plan an appropriate location of the sensor at the design stage. Airflow and proper exposure to ambient air must be secured for the sensor to ensure expected performance.

Airflow holes must NOT be blocked. Any heat generating parts near the sensor will distort the proper measurement of relative humidity and temperature reading, and either should be avoided or measures should be taken to prevent heat transfer.

1.2 Operating conditions

The sensor‘s maximum and recommended normal operating condition is shown below (**Figure 1.1**). Within the normal range the sensor performs stable. Prolonged exposures to conditions outside normal range, especially at humidity over 90%RH, may temporarily offset the RH signal up to ±3%RH. When return to normal range, it will gradually recover back to the calibration state.

Re-conditioning procedure in **section 1.6** will help reduce this recovery time. Long term exposure to extreme conditions may also accelerate aging of the sensor.

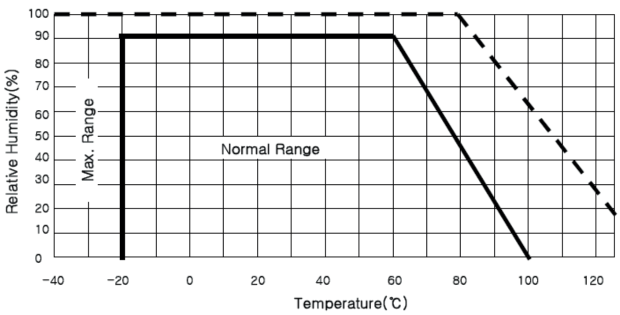


Figure 1.1: Operating conditions

1.3 Heating

Though within the accuracy tolerance, self-heating in the sensor IC may affect accurate measurement of temperature and RH%. The measurement error from self-heating can be reduced by keeping active state to the minimum, and by regulating the operating voltage within 3.3±0.5V or 5.0±0.5V.

In order to minimize the self heating, sampling time should be more than 180ms. (200ms recommended).

Other heat sources such as power electronics, microcontrollers, and display near the sensor may affect the accurate measurement. The location of Sensor near such heat sources should be avoided by maintaining distance or thermal buffer. Thin metal pattern, or even better, ´milling silts‘ around the sensor also may help reduce the error.

1.4 Soldering instruction

The sensor is designed for mass production reflow soldering process. It is qualified for soldering profile ccording to IPC/JEDEC J-STD-020D (see **Figure 1.2**) for Pb-free assembly in standard reflow soldering ovens or IR/Convection reflow ovens to withstand peak temperature at 240 °C and peak time up to 40 sec. For soldering in vapor phase reflow (VPR) ovens the peak conditions are limited to T_P < 240 °C with t_P <40sec and ramp-up/down speeds hall be limited to 10 °C/sec. For manual soldering, contact time should not exceed 4 seconds at up to 350 °C . No-Clean solder flux should be used.

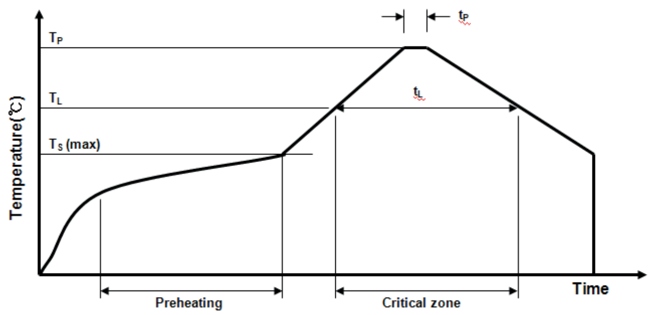


Figure 1.2: Soldering Profile (IPC/JEDEC Standard)
$T_P \leq 240$ °C, $t_P < 40$ sec, $T_L < 200$ °C, $t_L < 150$ sec.
Ramp-up/down speed < 5 sec

Note: Test or measurement right after reflow soldering may read an offset as the sensor needs time for stabilization from the soldering heat. The recovery time may vary depending on reflow soldering profile and ambient storage condition. For most of the standard reflow soldering profile, allow 12 hours of stabilization under room environment (23 3 C, 55 5%RH).

1.5 Storage and handling information

The sensor contains polymer based capacitive humidity sensor sensitive to environment and should NOT be handled as an ordinary electronic component.

Chemical vapors at high concentration may interface with the polymer layers, and coupled with long exposure time, may cause a shift in both offset and sensitivity of the sensor.

Despite the sensor endures the extreme conditions of -55...150 °C, 0...100%RH (non condensing), long term exposure in such environment may also offset the sensor reading. Hence, once the package is opened, it is recommended to store in clean environment of temperature at 5...55 °C and humidity at 10%~70%RH. The sensor is protected of ESD up to 4000V and Latchup of ±100 mA or (up to +8V / down to -4V) relative to VSS/VSSA, and also packed in ESD protected shipping material. Normal ESD precaution is required when handling in assembly process.

1.6 Reconditioning procedure

If the sensor is exposed or contaminated with chemical vapors, the following reconditioning procedure will recover the sensor back to calibration state.

<u>Baking</u>: 120 °C for 6 hrs
<u>Re-hydration</u>: 30 °C at > 80%RH for 24 hrs

1.7 Material contents

The sensor consists of sensor cell and IC (polymer / glass & silicon substrate) packaged in a surface mountable LCC (Leadless Chip Carrier) type package. The sensor housing consists of a PPS (Poly Phenylene Sulfide) cap with epoxy glob top on a standard FR4 substrate. Pads are made of Au plated Cu. The device is free of Pb, Cd and Hg.

RoHS compliant / REACH report available

1.8 Traceability information

The sensor is laser marked with product type and lot identification. Further information about individual sensor is electronically stored on the chip. The first line denotes the sensor type: HUMI-A for PDM output, HUMI-D for I²C output. Lot identification is printed on the second line with 5 digit alphanumeric code.

An electronic identification code stored on the chip can be decoded by Samyoung S&C only and allows for tracking on batch level through production, calibration and testing.

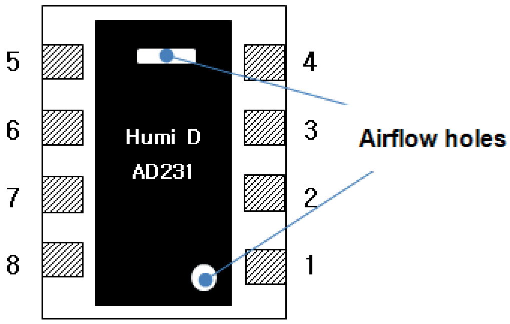
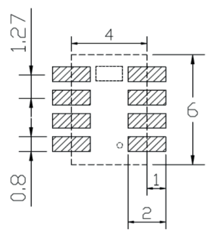


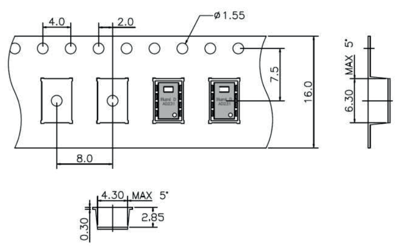
Figure 1.3: Laser marking

1.9 Shipping package

The sensor is provided in a tape & reel shipment packaging, sealed into antistatic ESD trays. Standard packaging sizes are 2,500 or 500 units per with sensor orientation and packing box dimensions are shown in **Drawing 2** and **Drawing 3** below.



Drawing 1: Land pattern



Drawing 2: Reel & Tape

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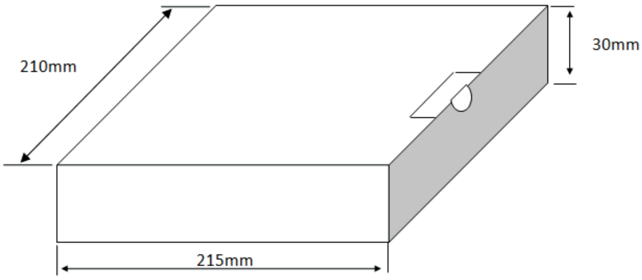
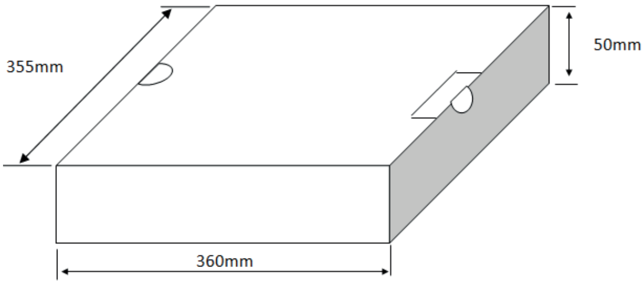
Inbox: 500 ea
Dimension: 215 x 210 x 30 mm
Weight: 0.25kg



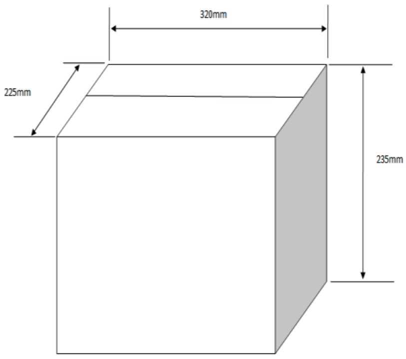
Drawing 3: Packing (Box)

Inbox: 2.500 ea
Dimension: 360 x 355 x 50 mm
Weight: 0.85kg



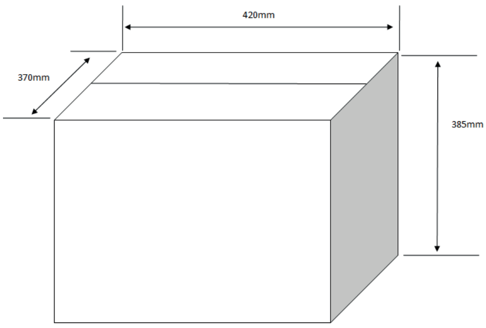
Drawing 3: Packing (Box)

Outbox: 5.000 ea (10 x Inbox 500)
Dimension: 320 x 380 x 255 mm
Weight: 3.15kg



Drawing 3: Packing (Box)

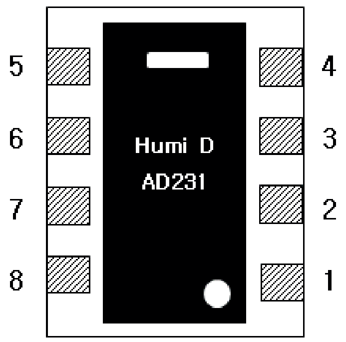
Outbox: 20.000 ea (8 x Inbox 2.500)
Dimension: 645 x 360 x 310 mm
Weight: 8.05kg



Drawing 3: Packing (Box)

2. Interface specification

2.1 Digital output (I²C Interface)



PIN Nr.	Name	Description
1	Alarm_low	Low alarm output
2	Ready	Reagy signal (Conversion complete output)
3	SDA	I²C data
4	SCL	I²C clock
5	V_{CORE}	Core voltage
6	VSS	Ground supply
7	VDD	Supply voltage (2.3...5.5V)
8	Alarm_High	High alarm output

2.1.1 Power pads (5.V_{CORE}, 6.VSS, 7.VDD)

The sensor is capable of operating on wide range of power supply voltage from 2.3V to 5.5V. Recommended supply voltage is either 3.3±0.5V or 5.0±0.5V. Power supply should be connected to VDD (power supply pad 7). VDD and VSS (Ground pad 6) should be decoupled with a 220nF capacitor.

Important: Vcore must not be connected to VDD, and it must always be connected to an external 100nF capacitor to ground. (see **Figure 2.1**)

2.1.2 Serial clock & data pads (3.SDA, 4.SCL)

The sensor s data is transferred in and out through the SDA pad while the communication between the sensor and microcontroller (MCU) is synchronized through the SCL pad. The sensor has an internal temperature compensated oscillator that provide time base for all operation, and uses an I²C-compatible communication protocol with support for 20 KHz to 400 KHz bit rates. External pull-up resistors are required to pull the drive signal high, that can be included in I/O circuits of micro-controller. (see **Figure 2.1**)

Further information about timing and communication between the sensor and microcontroller is explained in **Section 4**. Communicating with the sensor.

2.1.3 Alarm pads (1.Alarm Low, 8.Alarm High)

The alarm output can be used to monitor whether the sensor reading has exceeded or fallen below pre-programmed values. The alarm can be used to drive an open-drain load connected to VDD, or it can function as a full push-pull driver. If a high voltage application is required, external devices can be controlled with the Alarm pins, as demonstrated in **Figure 6.2**. The two alarm outputs can be used simultaneously, and these alarms can be used in combination with the I²C. Further information about Alarm control is explained in **Section 6**.

- VDD and Ground is decoupled by a 220nF capacitor.
- Vcore (Not Used) and Ground is decoupled by 100nF capacitor.
- Pull-up resistors should be included between the sensor and MCU.

2,3 V ≤ VDD ≤ 5,5 V

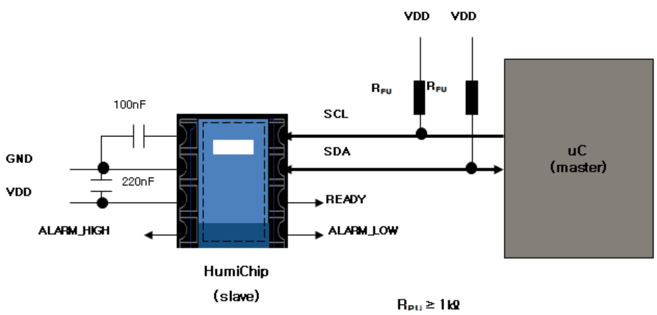
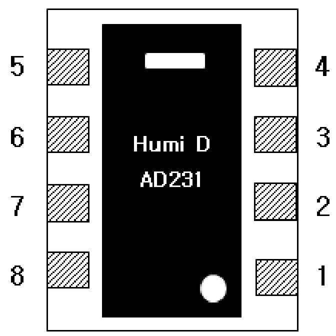


Figure 2.1: Typical application circuit (I²C)

2.2 Analog output (PDM)



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PIN Nr.	Name	Description
1	PDM_T	Temperature PDM
2	PDM_H	Humidity PDM
3	SDA	I²C data (Not used)
4	SCL	I²C clock (Not used)
5	V_{CORE}	Core voltage
6	VSS	Ground supply
7	VDD	Supply voltage (2.3...5.5 V)
8	Alarm_High	High alarm output

2.2.1 Power pads (5.V_{CORE}, 6.VSS, 7.VDD)

The sensor is capable of operating on wide range of power supply voltage from 2.3V to 5.5V. Recommended supply voltage is either 3.3±0.5V or 5.0±0.5V. Power supply should be connected to VDD (power supply pad 7). VDD and VSS (Ground pad 6) should be decoupled with a 220nF capacitor.

Important: Vcore must not be connected to VDD, and it must always be connected to an external 100nF capacitor to ground. (see **Figure 2.2**)

2.2.2 PDM output pads (1.PDM_T, 2.PDM_H)

Temperature PDM (Pulse Density Modulation) appears on the PDM_T / Alarm_Low pad (1) and corrected Humidity PDM appears on the PDM_H pad (2). When pad (1) is selected for Temperature PDM, Alarm_Low function is disabled and only one Alarm function (Alarm_High: pad 8) is usable.

Note: The sensor PDM output is pre-programmed in factory for Humidity and Temperature output mode.

2.2.3 Alarm pads (8.Alarm_High, 1.Alarm_Low (optional))

As the sensor PDM is factory set for Humidity and temperature output mode, only High Alarm output can be used in combination with the sensor PDM. If both high and low alarm functions are required, pad 1 and 8 will be programmed at factory to use as Alarm_Low and Alarm_High respectively with required high and low humidity values. In such case, the sensor will output corrected humidity PDM only, see **Section 6** for Alarm function.

2.2.4 Serial clock & data pads (3.SDA, 4.SCL)

For the sensor PDM output, both SDA and SCL pads are not used and must be connected to VDD.

2.2.5 Typical circuit connection

VDD and Ground is decoupled by a 220nF capacitor. Vcore (Not used) and Ground is also decoupled by a 100nF capacitor. SCL and SDL (not used) are connected to VDD. Between HumiChip® and MCU (C), Low Pass Filtering (see Section 5.2 for more information) with 10 k resistors and 6,400nF capacitors is added to create an Analog signal.

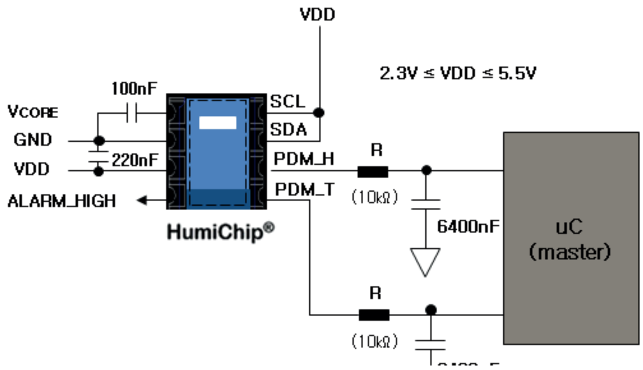

Figure 2.2: Typische Anwendungsschaltung (PDM)

Digital humidity sensor

3. Electrical specification

3.1 Absolute maximum rating

Table 3.1 shows the absolute maximum ratings for the sensor. Exposure to these extreme condition for extended period may deteriorate the sensor performance and accelerate aging. Functional operation is not implied at these conditions.

3.2 Electrical specification and recommended operating conditions

The operating conditions recommended for the sensor is given in **Table 3.2** and the electrical specification is shown in **Table 3.3**.

3.3 Output pad drive strength

Output pad drive strength at different supply voltages and operating temperatures are shown in **Table 3.4** and **Table 3.5**.

3.4 ESD/Latch-Up-Protection

All external module pins have an ESD protection of up to 4000V and a latch-up protection of ±100 mA or (up to +8V / down to -4V) relative to VSS/VSSA. The internal module pin V_{CORE} has ESD protection of up to 2000V. The ESD test follows the Human Body Model with 1.5kOhm/100pF based on MIL 883, Method 3015.7.

Parameter	Symbol	MIN	MAX	Unit
Supply voltage (V_{DD})	V_{DD}	-0,3	6,0	V
Supply voltage bei I/O pads	VIO	-0,3	V_{DD}+0,3	V
Storage temperature range	T_{STOR}	-55	150	°C
Junction temperature	T_j	-55	150	°C

Table 3.1: Absolute maximum rating

Parameter	Symbol	MIN	Typ	MAX	Unit
Supply voltage to Gnd	V_{SUPPLY}	2,3		5,5	V
Ambient temperature range	T_{AMB}	-40		125	°C
External capacitance between V_{DD} Pin and Gnd	$C_{VSUPPLY}$	100	220	470	nF
External capacitance between V_{CORE} and Gnd - Sleep	C_{VCORE_SM}	10		110	nF
External capacitance between V_{CORE} und Gnd - Update	C_{VCORE_UM}	90		330	nF
Pull-up SDA and SCL	R_{PU}	1	2,2		kΩ

Table 3.2: Recommended operating conditions

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Parameter	Symbol	Conditions	MIN	TYP	MAX	Units
		Supply				
Supply current (varies with update rate and ouput mode)	I_{DD}	At maximum update rate		750	1100	µA
Extra current with PDM enabled	I_{PDM}	At maximum update rate		150		µA
Sleep mode current	I_{sleep}	-40...+85 °C		0,6	1	µA
		-40...+125 °C		1	3	µA
		PDM Output				
Voltage range	V_{PDM_Range}	3 V±10%, 3,3 V±10%, 5 V±10%	10		90	$\%V_{SUPPLY}$
PDM frequency	f_{PDM}			$f_{SYS/8}$		KHz
Filter settling time[1]	t_{SETT}	0...90% LPFilter 10 kΩ/400nF			9,2	ms
Ripple[1]	V_{RIPP}	0...90% LPFilter 10 kΩ/400nF			1,0	mV/V
PDM additional error (including ratiometricity error)	E_{PDM}	-40...+125 °C		0,1	0,5	%
		Digital I/O				
Voltage output level low	V_{OL}			0	0,2	V_{SUPPLY}
Voltage output level high	V_{OH}		0,8	1		V_{SUPPLY}
Voltage input level low	V_{IL}			0	0,2	V_{SUPPLY}
Voltage input level high	V_{IH}		0,8	1		V_{SUPPLY}
		Total system				
Start-up-time Power-on (POR) to data ready	t_{STA}	At nominal frequency; fastest and slowest settins	4,25		55	ms
Update rate (Update mode)	t_{RESP_UP}	Fastest and slowest settings	0,70		165	ms
Response time (Sleep mode)	t_{RESP_SL}	Fastest and slowest settings	1,25		45	ms

Table 3.3: Electrical characteristics specifications

Output high drive strength (mA)						
V_{SUPPLY} (V)	-40 °C		-25 °C		+125 °C	
	Min	Typ	Min	Typ	Min	Typ
2,3	3,8	6,2	3,3	5,1	2,8	4,2
2,7	7,2	10,5	5,9	8,4	4,7	6,6
3,3	12,1	16,6	9,6	12,9	7,4	1,0
5,5	20,0	20,0	20,0	20,0	20,0	20,0

Table 3.4: Output high drive strength

Output high drive strength (mA)						
V_{SUPPLY} (V)	-40 °C		-25 °C		+125 °C	
	Min	Typ	Min	Typ	Min	Typ
2,3	10,8	16,0	8,8	12,6	6,9	9,5
2,7	20,0	20,0	16,0	20,0	11,7	14,9
3,3	20,0	20,0	20,0	20,0	18,2	20,0
5,5	20,0	20,0	20,0	20,0	20,0	20,0

Table 3.5: Output low drive strength

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4. Communication

4.1 Power-on sequence

On system power-on reset (POR), the sensor wakes as an I²C device regardless of the output protocol programmed in EEPROM. After power-on reset, it enters the command window. It then waits for a Start_CM command for 10 ms if Fast Startup bit is not set in EEPROM (Factory Setting) or for 3 ms if fast startup bit is set in EEPROM (see **Figure 4.1.2**). If the sensor receives the Start_CM command during the command window, it enters and remains in Command Mode. Command Mode is primarily used for initializing the sensor.

If during the power-on sequence, the command window expires without receiving a Start_CM or if the part receives a Start_NOM command in Command Mode, the device will immediately assume its programmed output mode and will perform one complete measurement cycle

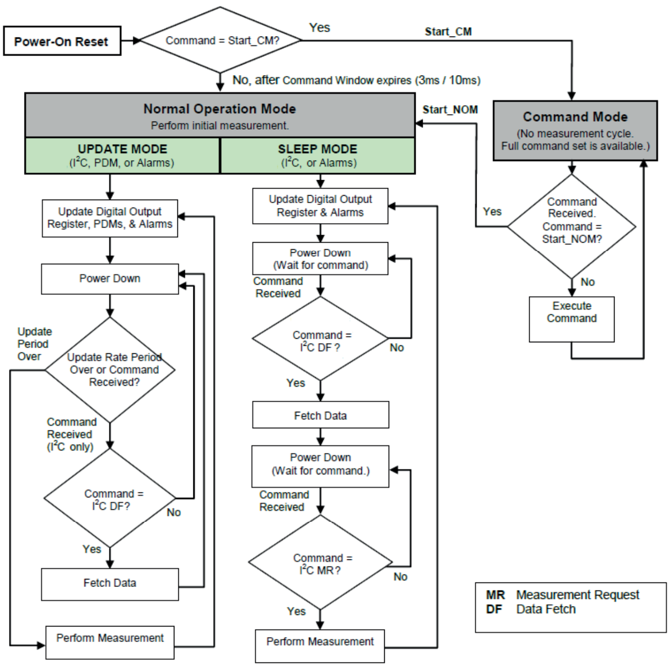

Figure 4.1.1: General operation

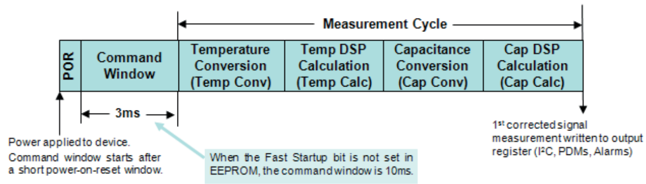

Figure 4.1.2: Power-on sequence with fast start-up bit set in EEPROM

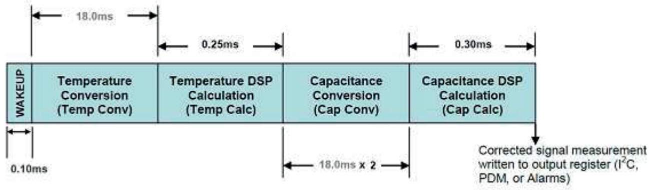

Figure 4.1.3: Measurement cycle timing

4.2 I²C Feautures and timing

The HumiChip® uses I2C-compatible communication protocol with support for 20kHz to 400kHz bit rates. The I2C slave address (0x00 to 0x7F) is selected by the Device_ID bits in the Cust_Config EEPROM word (see Table 6.1 for bit assignments).

See **Figure 4.2** for I²C Timing Diagram and **Table 4.1** for definitions of the parameters shown in the diagram.

Note: Detailed timing chart and reference programming code are available upon request.

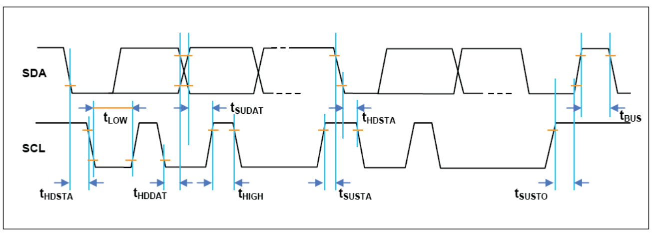

Figure 4.2: I²C Timing diagram

Digital humidity sensor

Parameter	Symbol	MIN	Typ	MAX	Unit
SCL clock frequency	f_{SCL}	20		400	kHz
Start condition hold time relative to SCL edge	t_{HDSTA}	0,1			µS
Minimum SCL clock low width[1]	t_{LOW}	0,6			µS
Minimum SCL clock high width[1]	t_{HIGH}	0,6			µS
Start condition setup time relative to SCL edge	t_{SUSTA}	0,1			µS
Data hold time on SDA relative to SCL edge	t_{HDDAT}	0		0,5	µS
Data setup time on SDA relative to SCL edge	t_{SUDAT}	0,1			µS
Stop condition setup time SCL	t_{SUSTO}	0,1			µS
Bus free time between stop condition and start condition	t_{BUS}	1			µS

[1] Combined low and high widths must equal or exceed minimum SCL period

4.3 Measurement modes

The sensor can be programmed to operate in either Sleep Mode or Update Mode. The measurement mode is selected with the Measurement_Mode bit in the sensor Config Register word. In Sleep Mode, the part waits for commands from the master before taking measurements (see **section 4.3.2**).

4.3.1 Data Fetch in update mode

In Update Mode, I2C is used to fetch data from the digital output register using a Data Fetch (DF) command.

Detecting when data is ready to be fetched can be handled either by polling or by monitoring the ready pin (see **section 4.8** for details on the ready pin). The status bits of a DF tell whether or not the data is valid or stale (see **Table 4.2** regarding the status bits). As shown in **Figure 4.3.1** after a measurement cycle is complete, valid data can be fetched. If the next data fetch is performed too early, the data will be the same as the previous fetch with stale status bits. As shown in **Figure 4.3.1**, a rise on the ready pin can also be used to tell when valid data is ready to be fetched.

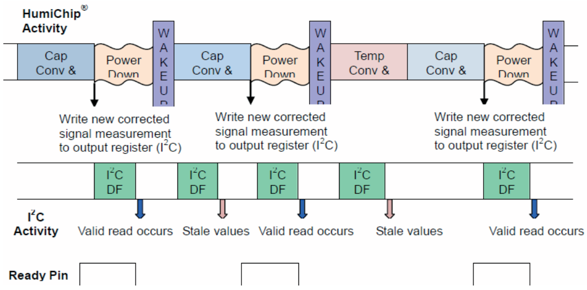

Figure 4.3.1: I²C Data Fetching in update mode

4.3.2 Data Fetch in sleep mode

In Sleep Mode, the sensor core will only perform conversions when the sensor receives a measurement request command (MR); otherwise, the sensor is always powered down. Measurement request commands can only be sent using I²C, so sleep mode is not available for PDM. The Alarms can be used in Sleep Mode but only in combination with I²C.

Note: Sleep mode power consumption is significantly lower than Update mode power consumption (see **Table 3.3** for exact values).

Figure 4.3.2 shows the measurement and communication sequence for sleep mode. The master sends an MR command to wake the sensor from power down. After the sensor wakes up, a measurement cycle is performed consisting of both a temperature and a capacitance conversion followed by the sensor core correction calculations.

At the end of a measurement cycle, the digital output register and Alarms will be updated before powering down. An I2C data fetch (DF) is performed during the power-down period to fetch the data from the output register. In I2C the user can send another MR to start a new measurement cycle without fetching the previous data. After the data has been fetched, the HumiChip® remains powered down until the master sends an MR command.

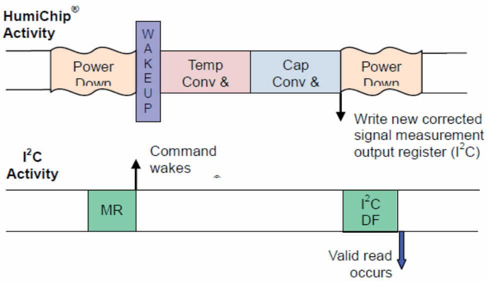

Figure 4.3.2: Measurement sequence in sleep mode

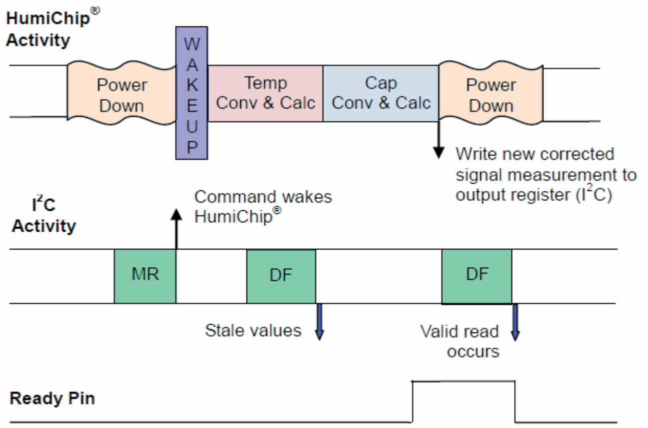

Figure 4.3.3: I²C Data Fetching in sleep mode

In Sleep Mode, I²C are used to request a measurement with a MR command and to fetch data from the digital output register using a Data Fetch (DF) command (see **section 4.7** for details on the MR command).

Detecting when data is ready to be fetched can be handled either by polling or by monitoring the Ready pin (see **section 4.8** for details on the ready pin). The status bits of a DF tell whether the data is valid or stale (see **section 4.4** regarding the status bits), but polling for the result must not be done before the time required for conversion has elapsed. As shown in **Figure 4.3.3** after a measurement cycle is complete, valid data can be fetched. If the next data fetch is performed too early, the data will be the same as the previous fetch with stale status bits. As shown in **Figure 4.3.3** a rise on the ready pin can also be used to tell when valid data is ready to be fetched.

Note: There is an 18us period when the measurement cycle completes that must have the bus unlocked. So wait for the measurement cycle to complete prior to reading the I²C bus. This can be determined using either the ready pin or by waiting a fixed amount of time as specified in **Figure 4.1.3**. Or use an I²C frequency of 60kHz or greater.

4.4 Status bits

Status bits (the two MSBs of the fetched high data byte, see **Table 4.2**) are provided in I²C but not in PDM. The status bits are used to indicate the current state of the fetched data.

Status bits (I²C)	PDM Output	Definition
00_B	Clipped normal output	Valid data: Data that has not been fetched since the last measurement cycle.
01_B	Not applicable	Stale data: Data that has already been fetched since the last measurement cycle.
10_B	Not applicable	Command mode: The sensor is in command mode.
11_B	Not used	Not used

Table 4.2: Status bits

4.5 I²C Commands

As detailed in **Table 4.3**, there are two types of commands which allow the user to interface with the sensor in the I²C.

Type	Description	Communication supported	Reference section
Data Fetch (DF)	Used to fetch data in any digital mode	I²C	**Section 4.6**
Measurement request (MR)	Used to start measurements in sleep mode	I²C	**Section 4.7**

Table 4.2: I²C Command bits

4.6 Data Fetch (DF)

The Data Fetch (DF) command is used to fetch data in any digital output mode. An I²C Data Fetch command starts with the 7-bit slave address and the 8th bit = 1 (READ).
The sensor as the slave sends an acknowledgement (ACK) indicating success. The number of data bytes returned by the sensor is determined by when the master sends the NACK and stop condition. **Figure 4.3** shows examples of fetching two, three and four bytes respectively. The full 14 bits of humidity data are fetched in the first two bytes. The MSBs of the first byte are the status bits. If temperature data is needed, additional temperature bytes can be fetched. In **Figure 4.3**, the three-byte data fetch returns 1 byte of temperature data (8-bit accuracy) after the humidity data. A fourth byte can be fetched where the six MSBs of the fetched byte are the six LSBs of a 14-bit temperature measurement. The last two bits of the fourth byte are undetermined and should be masked off in the application.

B+B SENSORS

Digital humidity sensor

4.7 Measurement request (MR)

A measurement request (MR) is a sleep-mode-only command sent by the master to wake up the sensor and start a new measurement cycle in I²C.

The I2C MR is used to wake up the device in Sleep Mode and start a complete measurement cycle starting with a temperature measurement, followed by a humidity measurement, and then the results can be fetched by master with I2C. As shown in Figure 4.4, the communication contains only the slave address and the WRITE bit (0) sent by the master. After the HumiChip® responds with the slave ACK, the master creates a stop condition.

Note: The I2C MR function can also be accomplished by sending „don't care" after the address instead of immediately sending a stop bit.

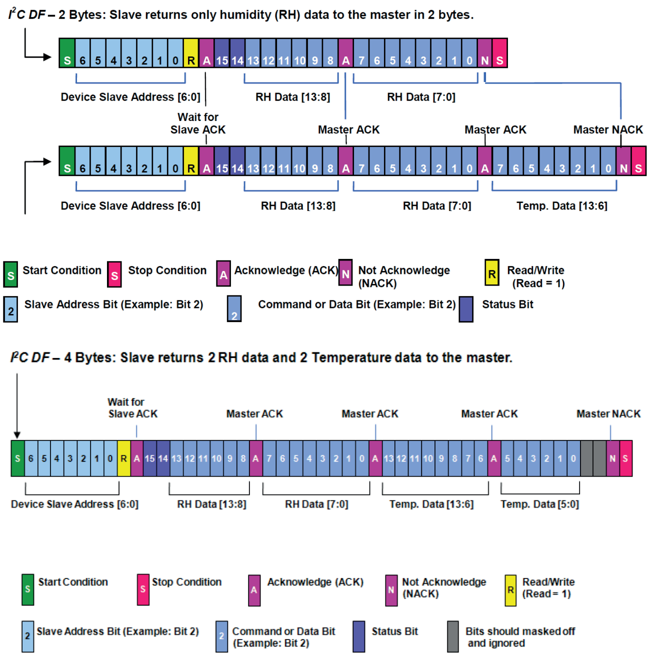

Figure 4.3: I²C Measurement packet reads

Feuchte & Temperatur Umrechnungsformel	
Feuchte Ausgang (%RH)	(RH_High [5:0] x 256 + RH_Low [7:0]) / 2^{14} x 100
Temperaturausgang (°C)	(Temp_High [7:0] x 64 + Temp_Low [7:2]/4) 2^{14} x 165 -40

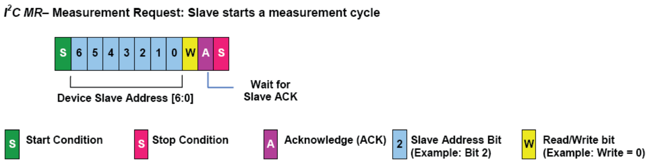

Figure 4.4: I²C Measurement request

4.8 Ready pin

A rise on the Ready pin indicates that new data is ready to be fetched from the I2C interface. The ready pin stays high until a Data Fetch (DF) command is sent; it stays high even if additional measurements are performed before the DF. The ready pin's output driver type is selectable as either full push-pull or open drain using the Ready_Open_Drain bit in EEPROM word ust_Config (see Table 6.1 for bit assignments and settings). Point-to-point communication most likely uses the full push-pull driver. If an application requires interfacing to multiple parts, then the open drain option can allow for just one wire and one pullup resistor to connect all the parts in a bus format.

4.9 Command mode

Command mode commands are only supported for the I²C protocol. As shown in **Figure 4.5**, commands are 4-byte packets with the first byte being a 7-bit slave address followed by 0 for write. The second byte is the command byte and the last two bytes form a 16-bit data field.

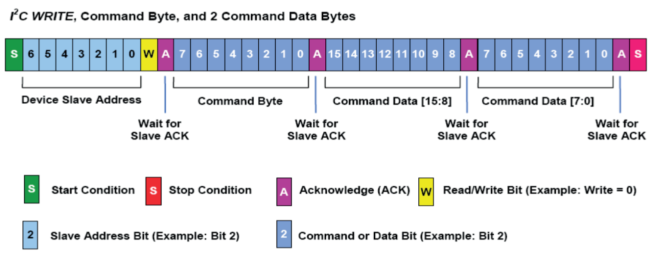

Figure 4.5: I²C Command format

4.10 Command encodings

Table 4.4 describes all the commands that are offered in Command Mode.

Note: Only the commands listed in **Table 4.4** are valid. Other encodings might cause unpredictable results. If data is not needed for the command, zeros must be supplied as data to complete the 4-byte packet.

Command Byte (8 Command-Bits (Hex))	Third and fourth Bytes (16 Data Bits (Hex))	Description	Response time
0x16 to 0x1F	0x0000	EEPROM Read of addresses 0x16 to 0x1F After this command has been sent and executed, a data fetch must be performed.	100 µs
0x56 to 0x5F	0xYYYY (Y = data)	Write to EEPROM addresses 0x16 to 0x1F The 2 bytes of data sent will be written to the address specified in the 6 LSBs of the command byte.	12 ms
0x80	0x0000	Start_NOM Ends command mode and transitions to normal operation mode.	
0xA0	0x0000	Start_CM Start command mode: used to enter the command interpreting mode. Start_CM is only valid during the power-on command window.	100 µs

Table 4.4: Command List and encodings

4.11 Command response and Data Fetch

After a command has been sent and the execution time defined in Table 4.4 has expired, an I²C Data Fetch (DF) can be performed to fetch the response. As shown in Figure 4.6, after the slave address has been sent, the first byte fetched is the response byte.

The upper two status bits will always be 10_B to represent Command Mode. The lower two bits are he response bits. Table 4.5 describes the different responses that can be fetched. To determine if a command has finished executing, poll the part until a busy response is no longer received. The middle four bits of the response byte are command diagnostic bits where each bit represents a different diagnostic (see **Table 4.6**).

Note: Regardless of what the response bits are, one or more of the diagnostic bits may be set indicating an error occurred during the execution of the command.

Note: Only one command can be executed at a time. After a command is sent another command must not be sent until the execution time of the first command defined in **Table 4.4** has expired.

For all commands except EEPROM Read, the data fetch should be terminated after the response byte is read. If the command was an EEPROM Read, then the user will fetch two more bytes as shown in **Figure 4.6**, example 3. If a Corrected EEPROM Error diagnostic was flagged after an EEPROM read, the user has the option to write this data back to attempt to fix the error. Instead of polling to determine if a command has finished executing, the user can use the Ready pin. In this case, wait for the ready pin to rise, which indicates that the command has executed. Then a data fetch can be performed to get the response and data (see **Figure 4.6**)

Encoding	Name	Description
00_B	Busy	The command is busy executing.
01_B	Positive Acknowledge	The command executed successfully.
10_B	Negative Acknowledge	The command was not recognized or an EEPROM write was attempted while the EEPROM was locked.

Table 4.5: Response bits

Bit Position	Name	Beschreibung
2	Korrigierter EEPROM Error	Bei der Ausführung des letzten Befehls ist ein korrigierter EEPROM-Fehler aufgetreten.
3	Nicht korrigierbarer EEPROM Error	Ein nicht korrigierbarer EEPROM-Fehler ist bei der Ausführung des letzten Befehls aufgetreten.
4	RAM Paritätsfehler	Ein RAM-Paritätsfehler ist während eines Mikrocontroller-Befehls bei der Ausführung des letzten Befehls.
5	Konfigurations-fehler	Ein EEPROM oder RAM-Paritätsfehler ist beim anfänglichen Laden der Konfigurationsregister aufgetreten.

Table 4.6: Command diagnostic bits

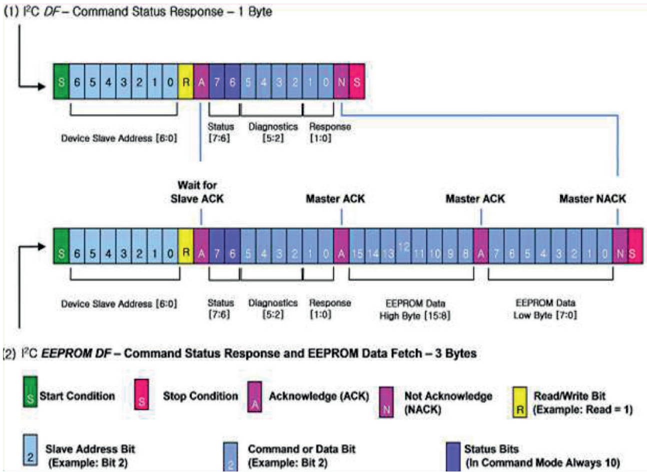

Figure 4.6: Command mode Data Fetch

4.12 EEPROM

The EEPROM array contains the calibration coefficients for gain and offset, etc., and the configuration bits for the analog front end, output modes, measurement modes, etc. The sensor EEPROM is arranged as 10 16-bit words see **Table 4.7**).

See **section 4.9** command mode for instructions on reading and writing to the EEPROM in Command Mode via the I²C interface. When programming the EEPROM, an internal charge pump voltage is used; therefore a high voltage supply is not needed.

EE-PROM Word	Bit Range	IC Default	Name	Description
16_{HEX}	13:0	0x3FFF	PDM_ Clip_High	PDM high clipping limit
17_{HEX}	13:0	0x0000	PDM_ Clip_Low	PDM low clipping limit
18_{HEX}	13:0	0x3FFF	Alarm_ High_On	High alarm on trip point
19_{HEX}	13:0	0x3FFF	Alarm_ High_Off	High alarm off trip point
$1A_{HEX}$	13:0	0x0000	Alarm_ Low_On	Low alarm on trip point
$1B_{HEX}$	13:0	0x0000	Alarm_ Low_Off	Low alarm off trip point
$1C_{HEX}$	15:0	0x0028	Cust_ Config	Customer Configuration (see **Table 6.1**)
$1D_{HEX}$	15:0	0x0000	Reserved	Reserved Word: **Do Not Change**; must leave at factory settings
$1E_{HEX}$	15:0	0x0000	Cust_ID2	Customer ID byte 2: For use by customer
$1F_{HEX}$	15:0	0x0000	Cust_ID3	Customer ID byte 3: For use by customer

Table 4.7: EEPROM word assignments

5. Converting PDM to analog signal

5.1 PDM (Pulse Density Modulation)

Both corrected humidity and temperature are available in PDM output. Humidity PDM appears on PDM_H (2) pad and Temperature PDM appears on the PDM_T (1) pad.

The PDM frequency is 231.25kH±15% (i.e., the oscillator frequency 1.85 MHz±15% divided by 8). Both PDMs output 14-bit values for Humidity and Temperature.

In PDM Mode, the sensor is programmed to Update Mode. Every time a conversion cycle has finished, the PDM will begin outputting the new value.

See **Figure 5.1** for PDM Timing Diagram.

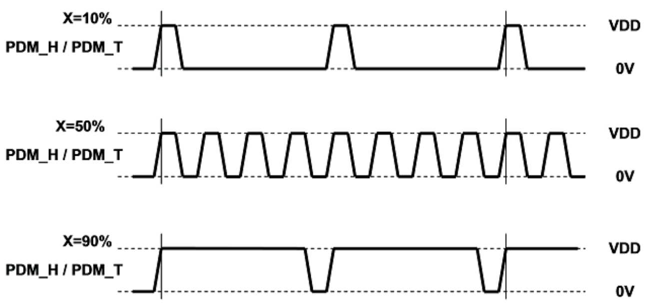

Figure 5.1: PDM signal timing diagram

5.2 Low pass filtering

An analog output value is created by low-pass filtering the PDM output; a simple first-order RC filter will work in this application.

Select the time constant of the filter based on the requirements for setting time and/or peak-to-peak ripple.

Important: The resistor of the RC filter must be ≥10kΩ.

Example			
	PDM_H / PDM_T		
Filter capacitance (nF)	Vpp Ripple (mV/V)	0 to 90% settling time (ms)	Desired analog output resoltion
100	4,3	2,3	8
400	1,0	9,2	10
1600	0,3	36,8	12
6400	0,1	147,2	14

For different (higher) resistor, the normalized ripple VPP(mV/V) can be calculated as:
VPP(mV/V) = 4324 / [R(kΩ) * C(nF)]

Or the setting time t_{SETT} for a 0% to 90% setting can be calculated as:
t_{SETT} (ms) = 0,0023 * R(kΩ) * C(nF)

Table 5.1: Low pass filter example for R=10kΩ

5.3 Analog output characteristics

5.3.1 Polynomial equation humidity

PDM_H [mV] = %RH / 100 * VDD[mV]

5.3.2 Polynomial equation temperature

PDM_T [mV] = ((T[°C] / 165) + 0,2424) * VDD[mV]

6. Alarm function (optional)

6.1 Alarm output

The alarm output can be used to monitor whether humidity reading has exceeded or fallen below preprogrammed values. The alarm can be used to drive an open-drain load connected to VDD as shown in **Figure 6.3** or it can function as a full push-pull driver. If a high voltage application is required, external devices can be controlled with the alarm pads, as demonstrated in **Figure 6.1** and **Figure 6.2.**

In standard the sensor PDM mode, only the high alarm can be used.

6.2 Alarm registers

Four registers are associated with the alarm functions: Alarm_High_On, Alarm_High_Off, Alarm_Low_On, and Alarm_Low_Off (see **Table 4.7**). Each of these four registers is a 14-bit value that determines where the alarms turn on or off. The two high alarm registers form the output with hysteresis for the Alarm_High pin, and the two low alarm registers form the output with hysteresis for the Alarm_Low pin. Each of the two alarm pins can be configured independently using Alarm_Low_Cfg and Alarm_High_Cfg located in EEPROM word Cust_Config (see **Table 6.1** for bit assignments).

Note: If two high alarms or two low alarms are needed, see **section 6.5** Alarm Polarity.

6.3 Alarm operation

As shown in **Figure 6.4** the Alarm_High_On register determines where the high alarm trip point is and the Alarm_High_Off register determines where the high alarm turns off if the high alarm has been activated. The high alarm hysteresis value is equal to Alarm_High_On Alarm_High_Off. The same is true for the low alarm where Alarm_Low_On is the low alarm trip point with Alarm_Low_Off determining the alarm shut off point. The low alarm hysteresis value is equal to Alarm_Low_Off Alarm_Low_On. **Figure 6.5** shows output operation flowcharts for both the Alarm_High and Alarm_Low pins.

6.4 Alarm output configuration

The user can select the output driver configuration for each alarm using the Output Configuration bit in the Alarm_High_Cfg and Alarm_Low_Cfg registers in EEPROM word Cust_Config (see **Table 6.1** for bit assignments). For applications, such as interfacing with a microcontroller or controlling an external device, select the full push-pull driver for the alarm output type. For an application that directly drives a load connected to VDD, the typical selection is the open-drain output type. An advantage of making an alarm output open drain is that in a system with multiple devices, the alarm outputs of each sensor can be connected together with a single pull-up resistance so that one can detect an alarm on any device with a single wire.

6.4 Alarm polarity

For both alarm pins, the polarity of the alarm output is selected using the Alarm Polarity bit in the Alarm_High_Cfg and Alarm_Low_Cfg registers in EEPROM word Cust_Config (see Table 6.1 for bit assignments). Another feature of the polarity bits is the ability to create two high alarms or two low alarms. For example, with applications requiring two high alarms, flip the polarity bit of the Alarm_Low pin, and it will act as a high alarm. However, in this case, the effect of the alarm low registers is also changed: the Alarm_Low_On register would act like the Alarm_High_Off register and the Alarm_Low_Off register would act like the Alarm_High_On register. The same can be done to achieve two low alarms: the Alarm_High pin would have the polarity bit flipped, and the two Alarm_High registers would have opposite meanings.

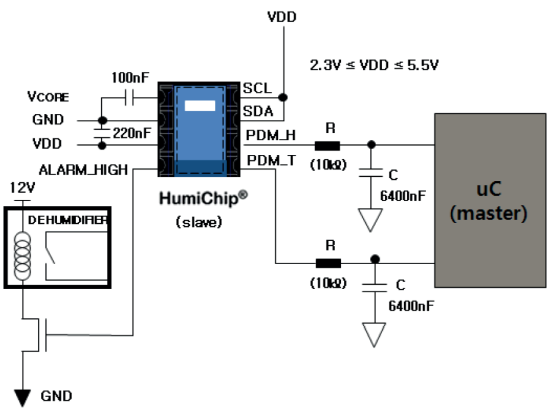

Figure 6.1: Bang-Bang humidity control (high voltage application)

DATA SHEET

Digital humidity sensor

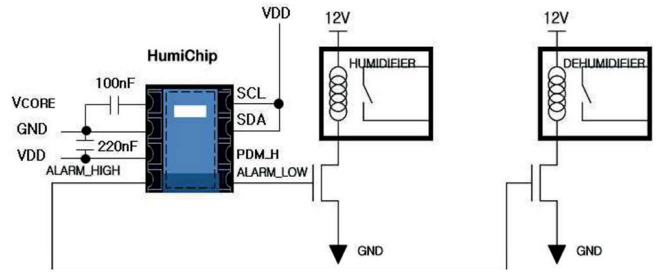

Figure 6.2: Bang-Bang humidity control (high voltage application)

I²C: 2 Alarms / humidity output (optional)

The sensor also can be directly installed to a device without MCU interface when only a switch on/off function is required at desired humidity level. (Bathroom Vent Fan, Humidifiers, Dehumidifiers)

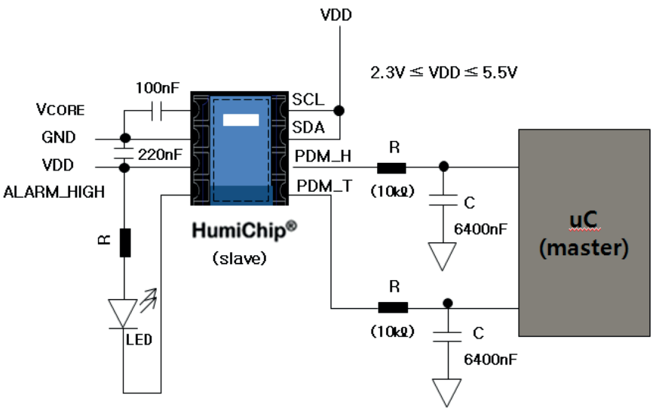

Figure 6.3: LED control with alarm function

1 Alarm / humidity output (optional)

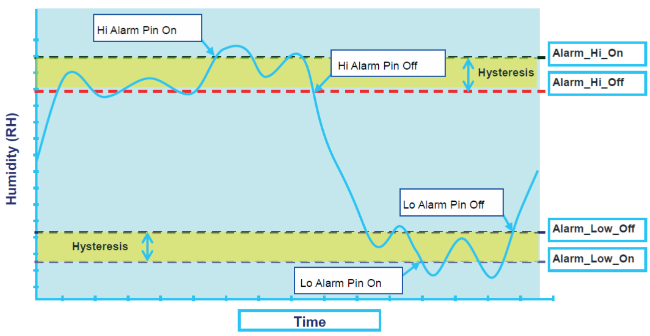

Figure 6.4: Example of alarm function

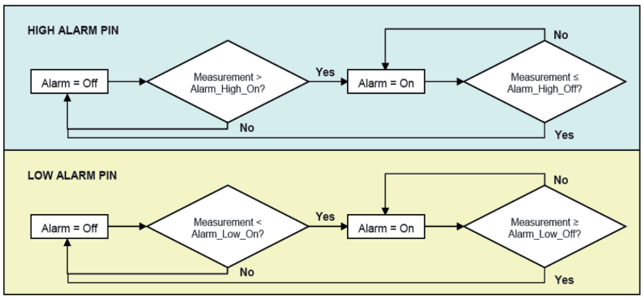

Figure 6.5: Alarm output flow chart

Bit Range	IC Default	Name	Description and Notes
6:0	0101000	Device_ID	I²C slave address
8:7	00	Alarm_Low_Cfg	Configure the Alarm_Low output pin: Bits / Description 7: Alarm Polarity: 0 = Active High, 1 = Active Low 8: Output Configuration: 0 = Full push-pull, 1 = Open drain
10:9	00	Alarm_High_Cfg	Configure the Alarm_High output pin: Bits / Description 9: Alarm Polarity: 0 = Active High, 1 = Active Low 10: Output Configuration: 0 = Full push-pull, 1 = Open drain
*12	0	Ready_Open_Drain	Ready pin is 0 = Full push-pull 1 = Open drain
*13	0	Fast_Startup	Sets the Command Window length: 0 = 10 ms Command Window 1 = 3 ms Command Window
15:14	00	Reserved	**Do Not Change** – must leave at factory settings

*Only applies to I²C output

Table 6.1: Cust_Config Bit assignments

Order number

Item	Order number
Digital humidity sensor	HYT131