HumiChip®

Humidity & Temperature Solution

Features

♦ **Fully Calibrated & Temperature Compensated**

♦ **Digital or Analog Output with Alarm Function**

♦ **Precision & Accuracy** (±2%RH, ±0.3°C, 14 bit)

♦ **Free Operating Voltage** (min 2.3V to max 5.5V)

♦ **Low Current Consumption**

♦ **SMD Package for Automated Assembly**

♦ **Reliable in Harsh Environment**

Product Summary

HumiChip® offers the most advanced and cost effective humidity and temperature sensing solution for virtually any type of applications.

Capacitive polymer sensor chip developed and fabricated in-house and CMOS integrated circuit with EEPROM are integrated into one embedded system in a reflow solder-able SMD package.

Individually calibrated and tested, **HumiChip**® performs ±2% from 20% to 80%RH (±3% over entire humidity range), and yet, is simple and ready to use without further calibration or temperature compensation.

HumiChip® provides linear output signals in various interfaces to customer requirements - the **standard I²C interface**, **PDM** convertible to analog signal, and an **Alarm function** for preset control at min/max humidity.

Designed and manufactured by industry leading humidity and temperature sensing technology of **SAMYOUNG S&C** – field proven in HVAC and Auto industry for over 10 years, **HumiChip**® offers another sensible sensing solution for excellent reliability, high accuracy, and cost effective sensing applications.

Application

Energy Saving HVAC Control

Air Conditioning, Refrigeration, IAQ monitoring, Vent Fans, Home Appliances, Humi/Dehumidifiers

Process Control & Instrumentations

Medical Instruments, Handheld Devices, Weather Stations, Food Processing, Printers, RFIDs …

Automobile & Transportation

Cabin Climate Control, Defogging Control Condensing Preventive Devise …,

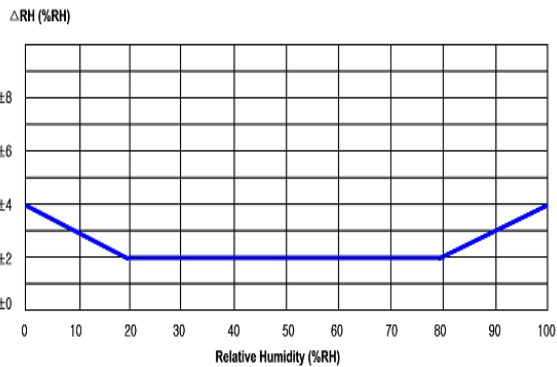### Mass Quantity Application

OEM custom specification available

Sensor Performance

Relative Humidity (RH%)

Custom Accuracy Tolerance Available

Resolution	**14 bit** (0.01%RH)
Accuracy[1]	**±2.0** %RH (20~80%RH)*
Repeatability	**±0.2** %RH
Hysteresis	**±2.0** %RH
Linearity	**<2.0** %RH
Response time[2]	**7.0** sec (τ 63%)
Temp Coefficient	**Max 0.13** %RH/℃ (at 10~60℃, 10~90%RH)
Operating range	**0 ~ 100** %RH (Non-Condensing)
Long term drift	**<0.5** %RH/yr (Normal condition)

Temperature (°C)

Resolution	**14 bit** (0.01℃)
Accuracy[3]	**±0.3** ℃ **(Figure 2)**
Repeatability	**±0.1** ℃
Response time[4]	**5.0** sec (τ 63%)
Operating range	**- 40 ~ 125** ℃
Long term drift	**<0.05** ℃/yr (Normal condition)

1. *Accuracies measured at 25℃, 5.0V.*
2. *Measured at 25℃, 1m/sec airflow for achieving 63% of step from 33%RH to 90%RH*
3. *Accuracies measured at 25℃, 5.0V.*
4. *Min 5.0 sec, Max 20 sec*

Figure 1. Typical RH% Accuracy at 25℃

Figure 2. Typical Temperature Accuracy

Dimensions

Units : mm (inch)

Top View   Side View   Bottom View

Humi D
AD231
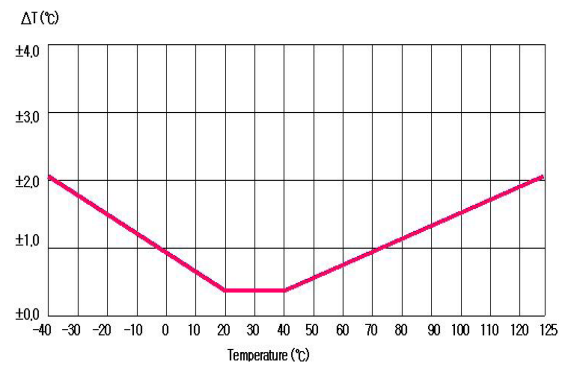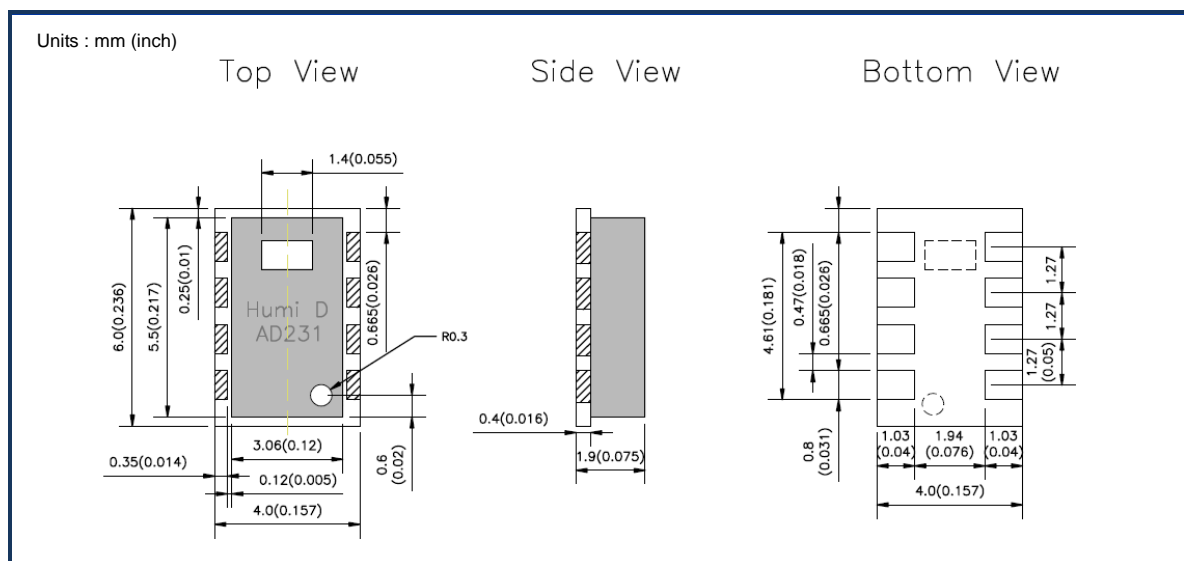
Electrical Specification

Supply Voltage[*1]	min 2.3V ~ max 5.5V
Supply Current (I$_{DD}$)	750 µA (typical)
Sleep Current (Isleep)[*2]	0.6 µA (typical)

*1.   Lower than 2.7V supply voltage may increase the accuracy tolerance of the Temperature.
*2.   at -40 ~ 85℃
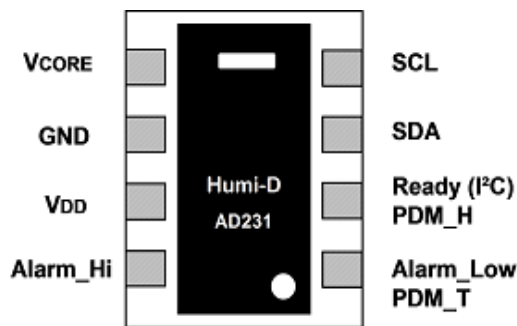
Environmental

Operating Temperature	- 40 ~ 125℃
Operating Humidity	0~100%RH (non condensing)

Pin Connection

Absolute Maximum Rating

Parameter	Min	Max
Supply Voltage (V$_{DD}$)	**-0.3V**	**6.0V**
Storage Temp	**-55℃**	**150℃**
Junction Temp	**-55℃**	**150℃**

Soldering Information

Standard or IR Solder Reflow.
Tp: 260℃, tp: 40 sec. (qualify Pb free profile)

Package Contents

Capacitive polymer RH Sensor,
PTA (Proportional to Absolute) Temperature sensor integrated ASIC chip in LCC (Leadless Chip Carrier) package, SMD.
RoHS Compliant

Shipping

Reel & Tape: 2,500 / 500 ea

Ordering Information

Output		Accuracy	VDD	MODE	Ordering P/N
D	I²C	±2%RH	3.3	Update	HCPD- 3V-U2
		±3%RH	5.0		HCPD- 5V-U3
		±2%RH	3.3	Sleep	HCPD- 3V-S2
		±3%RH	5.0		HCPD- 5V-S3
A	PDM	±2%RH	3.3	Update	HCPA- 3V-U2
		±3%RH	5.0		HCPA- 5V-U3

➢ Standard **Digital (I²C) Output :**

Factory setting is **Sleep Mode** and calibrated at **3.3V.**

Humidity, Temperature, and 2 Alarm (Hi / Low) functions for relative humidity.

➢ Standard **Analog (PDM) Output :**

Update Mode is calibrated at **5.0V**.

Humidity, Temperature, and an Alarm (high) function.

◆ **For more detail Part Numbers**,
     Please refer to the Table 7-1

Application Guide

CONTENTS

1. General Information

2. Interface Specification

3. Electrical Specification

4. Communicating with HumiChip[®]

5. Converting PDM to Analog Signal

6. Alarm Function (Optional)

List of Tables and Figures

Tables

Figures

Drawings

Humidity and Temperature Conversion Formula

☞ **Demo Kit** (EVB01-HCP) is available.
A reference program source code can be downloaded from www.samyoungsnc.com

1. General Information

1.1 Preliminary Consideration

To maximize the performance of **HumiChip®**, 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 **HumiChip®** to ensure expected performance. Airflow holes must NOT be blocked. Any heat generating parts near **HumiChip®** 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

HumiChip®'s maximum and recommended normal operating condition is shown below (**Figure 1.1**). Within the Normal Range **HumiChip®** 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.
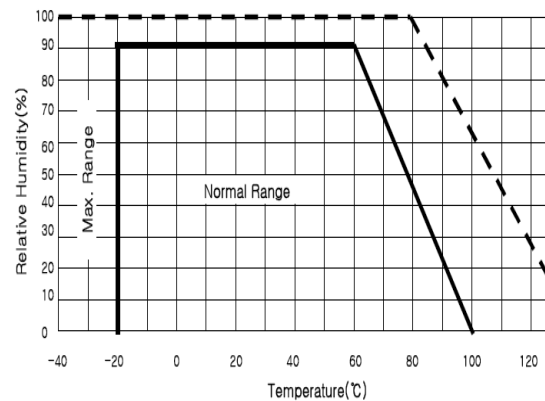
Figure 1.1   Operating Conditions

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 slits' around the sensor also may help reduce the error.

1.4 Soldering Instruction

HumiChip® is designed for mass production reflow soldering process. It is qualified for soldering profile according 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℃ and peak time up to 40 sec. For soldering in Vapor Phase Reflow (VPR) ovens the peak conditions are limited to $T_P <$ 240℃ with t_P <40sec and ramp-up/down speeds shall be limited to 10℃/sec. For manual soldering, contact time should not exceed 4 seconds at up to 350℃. No-Clean solder flux should be used.

Figure 1.2   Soldering Profile
IPC/JEDEC standard
$T_P \leq 240℃$, $t_P < 40sec$, $T_L < 200℃$, $t_L < 150sec$.
Ramp-up/down speed < 5℃/sec.

Important: Test or measurement right after soldering may read an offset as the sensor needs time for Hydration. The recovery time may vary depending on reflow soldering profile and ambient storage condition.

If the offset exceeds accuracy range, the following Hydration process will bring the sensor back within original accuracy range.

Hydration: 32±2℃ 85±5%RH, Duration: 45±5hrs (None Baking, Max time(50hrs) recommended)

Contact our **customer support** for customized recovery measures specific to your reflow soldering process. [support@samyoungsnc.com]

For **Land Pattern** drawing & dimensions, see **Drawing 1** on page 9**.**
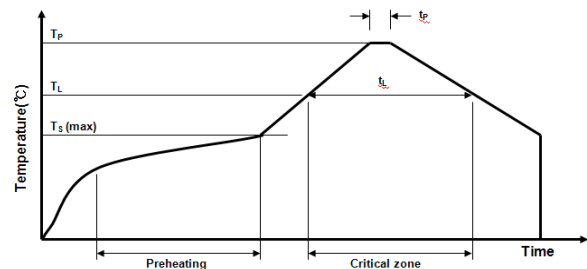
1.5 Storage and Handling Information

HumiChip® 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℃, 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℃ and humidity at 10%~70%RH.

HumiChip® is protected of ESD up to 4000V and Latchup of ±100㎃ 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 **HumiChip**® is exposed to extreme conditions or contaminated with chemical vapors, the following reconditioning procedure will recover the sensor back to calibration state.

Baking: **80±2℃ for 24±2hrs** and
Hydration: **32±2℃ 85±5%RH for 45±5hrs**
(Max 50hrs recommended)

1.7 Material Contents

HumiChip® 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

HumiChip® 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

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

Drawing 1   **Land Pattern**
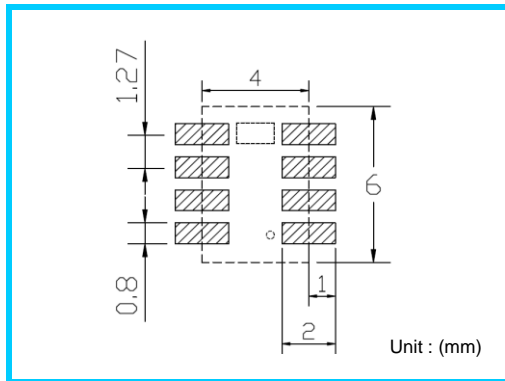
Drawing 2   **Packing Reel & Tape**
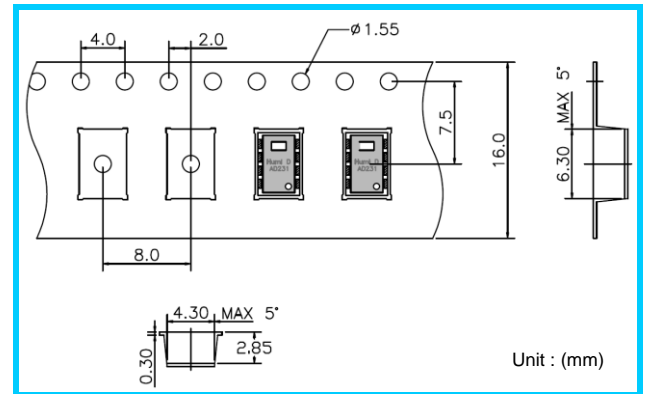
Drawing 3   **Packing (Box)**

Inbox: 500ea
Dimension: 215 x 210 x 30 mm
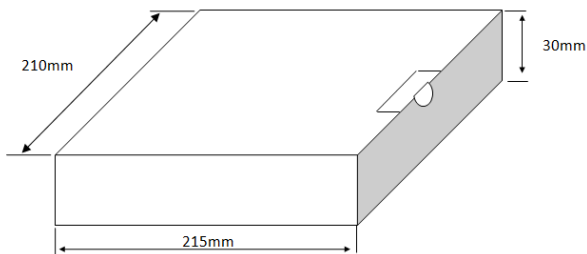
Inbox: 2,500ea
Dimension: 360 x 355 x 50 mm
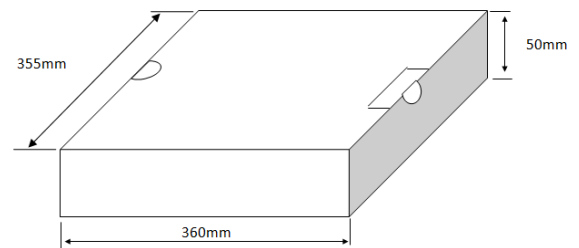
Outbox: 5,000ea (5 x Inbox 500)
Dimension: 320 x 225 x 235 mm
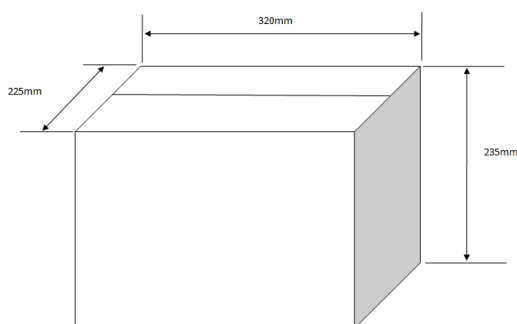
Outbox: 20,000ea (8 x Inbox 2500)
Dimensions: 420 x 370 x 385 mm
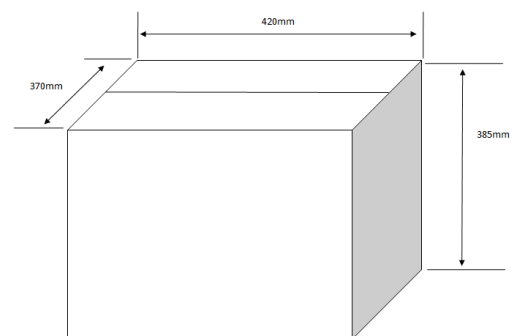
2. Interface Specification

2.1   Digital Output (I²C Interface)
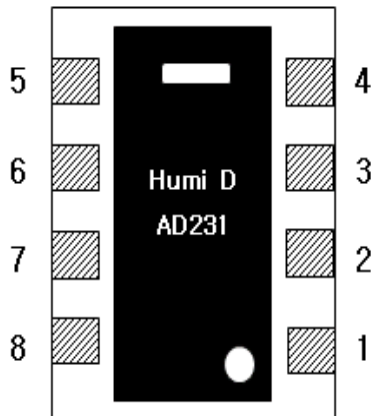
Pin-No	Name	Description
1	Alarm_low	Low alarm output
2	Ready	Ready signal (conversion complete output)
3	SDA	I²C data
4	SCL	I²C clock
5	V_{CORE}	Core voltage
6	VSS	Ground supply
7	VDD	Supply voltage (2.3-5.5V)
8	Alarm_High	High alarm output

2.1.1   Power Pads (5.VCORE, 6.VSS, 7.VDD)

HumiChip® 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 **HumiChip**® and microcontroller (MCU) is synchronized through the SCL pad.
HumiChip® 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 microcontroller. (see **Figure 2.1**)
Further information about timing and communication between the sensor and microcontroller is explained in Section 4. Communicating with **HumiChip**®.

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**.

Figure 2.1 Typical Application Circuit (I2C)

‣ 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 **HumiChip®** and MCU.
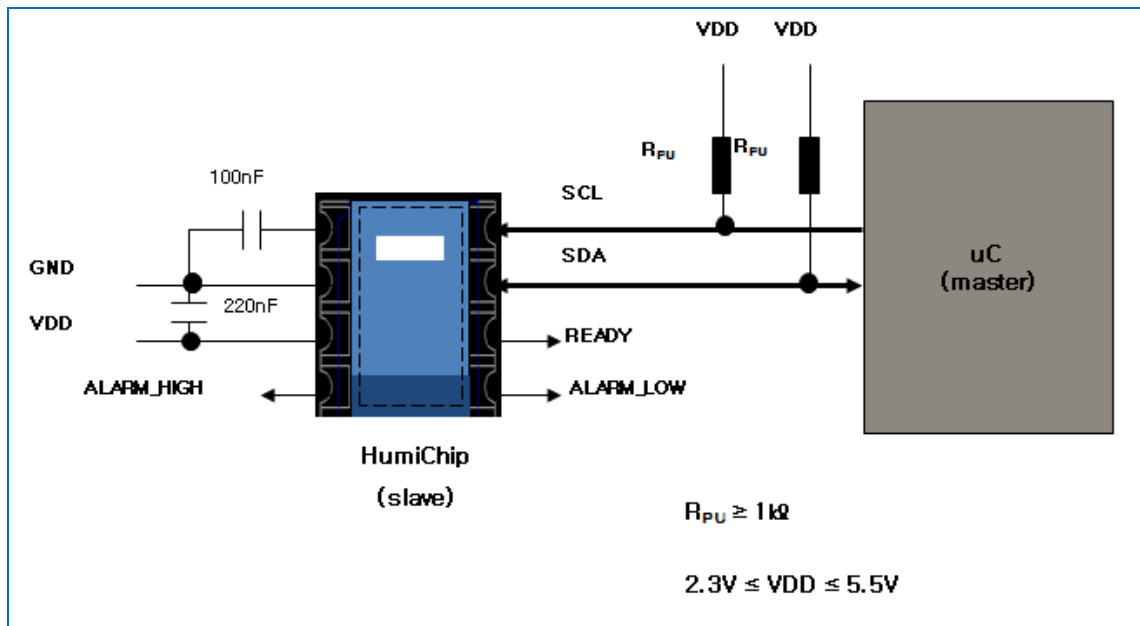
2.2   Analog Output (PDM)
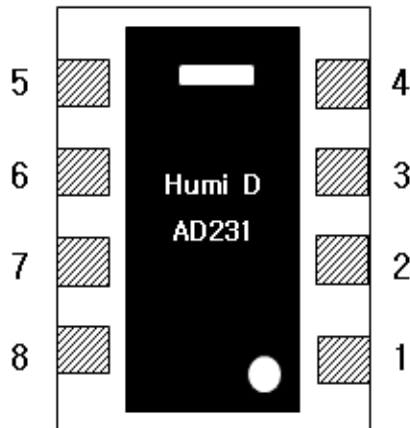
Pin-No	Name	Description
1	PDM_T	Temperature PDM
2	PDM_H	Humidity PDM
3	SDA	I2C data (Not Used)
4	SCL	I2C clock (Not Used)
5	VCORE	Core voltage
6	VSS	Ground supply
7	VDD	Supply voltage (2.3-5.5V)
8	Alarm_High	High Alarm output

2.2.1   Power Pads (5.VCORE, 6.VSS, 7.VDD)

HumiChip® 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: HumiChip® 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 **HumiChip**® PDM is factory set for Humidity and Temperature output mode, only High Alarm output can be used in combination with **HumiChip**® 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, **HumiChip**® will output corrected humidity PDM only,

See **Section 6** for **Alarm function**.

2.2.4 Serial Clock & Data Pads (3.SDA, 4.SCL)

For **HumiChip®** 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 (μC), **Low Pass Filtering** (see **Section 5.2** for more information) with 10 kΩ resistors and 6,400nF capacitors is added to create an Analog signal.

Figure 2.2   Typical Application Circuit (PDM)
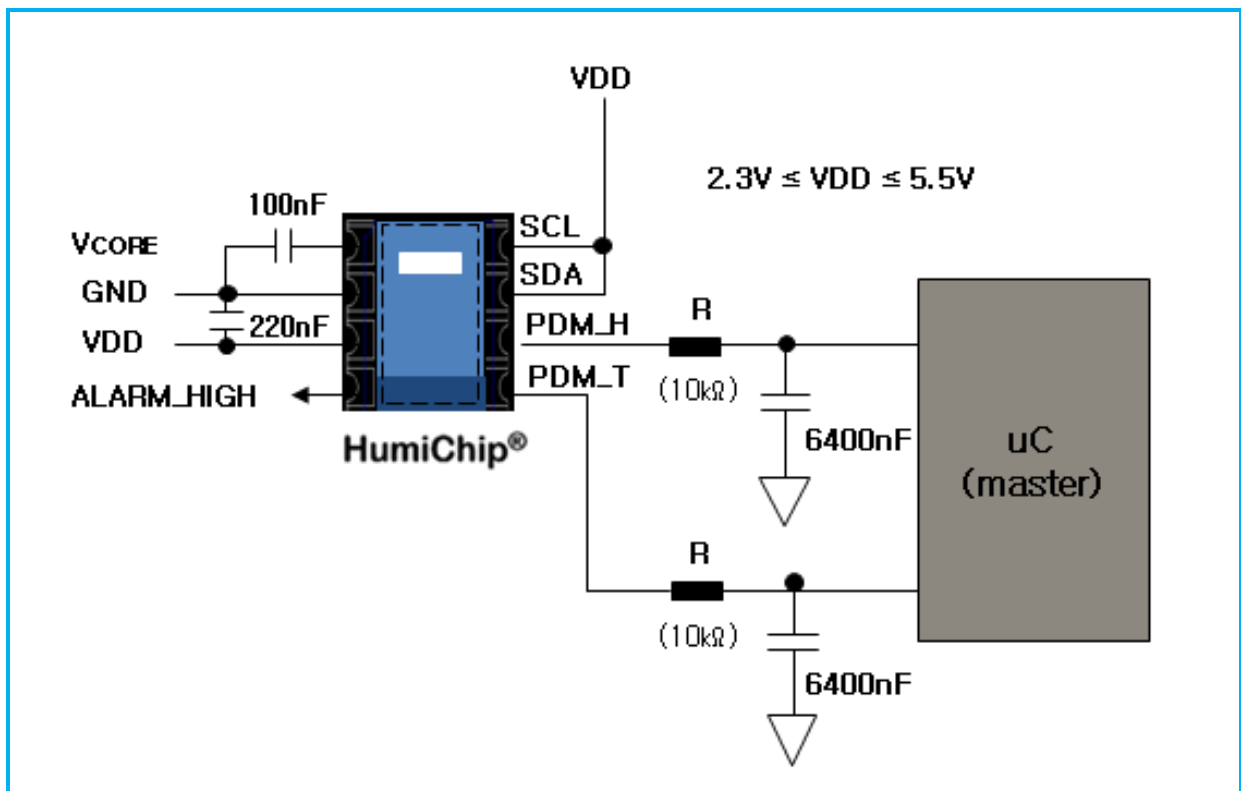
3. Electrical Specification

3.1 Absolute Maximum Rating

Table 3.1. shows the Absolute Maximum Ratings for HumiChip. 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 HumiChip 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 ±100mA or (up to +8V / down to -4V) relative to VSS/VSSA. The internal module pin VCORE 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.

Table 3.1   **Absolute Maximum Rating**

PARAMETER	SYMBOL	MIN	MAX	Unit
Supply Voltage (V_{DD})	V_{DD}	-0.3	6.0	V
Supply Voltage at I/O pads	V_{IO}	-0.3	$V_{DD}+0.3$	V
Storage Temperature Range	T_{STOR}	-55	150	°C
Junction Temperature	T_j	-55	150	°C

Table 3.2   **Recommended Operating Conditions**

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 Vcore and Gnd	C_{VCORE}		100		nF
Pull-up on SDA and SCL	R_{PU}	1	2.2		kΩ

Table 3.3   **Electrical Characteristics Specifications**

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
SUPPLY						
Supply Current (varies with update rate and output 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 to 85°C		0.6	1	µA
		-40 to 125°C		1	3	µA
PDM Output						
Voltage Range	V_{PDM_Range}	3V±10%, 3.3V±10%, 5V±10%	10		90	%V_{SUPPLY}
PDM Frequency	f_{PDM}			f_{SYS}/8		KHz
Filter Settling Time[1]	t_{SETT}	0% to 90% LPFilter 10kΩ/400nF			9.2	ms
Ripple[1]	V_{RIPP}	0% to 90% LPFilter 10kΩ/400nF			1.0	mV/V
PDM Additional Error (Including Ratiometricity Error)	E_{PDM}	-40 to 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 settings	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 3.4 **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	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	10.0
5.5	20.0	20.0	20.0	20.0	20.0	20.0

Table 3.5 **Output Low Drive Strength**

Output Low 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

4. Communicating with HumiChip®

4.1 Power–On Sequence

On system power-on reset (POR), the **HumiChip®** wakes as an I**2**C 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㎳ if Fast Startup bit is not set in EEPROM (Factory Setting) or for 3㎳ if fast startup bit is set in EEPROM (see **Figure 4.1**). If the **HumiChip®** receives the Start_CM command during the command window, it enters and remains in Command Mode.

Command Mode is primarily used for initializing **HumiChip®**.

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

4.2   I^{2}C Features and Timing

The HumiChip® uses I^{2}C-compatible communication protocol with support for 20kHz to 400kHz bit rates. The I^{2}C 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 I^{2}C 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 4.1   **Power-On Sequence with Fast Start-up Bit Set in EEPROM**
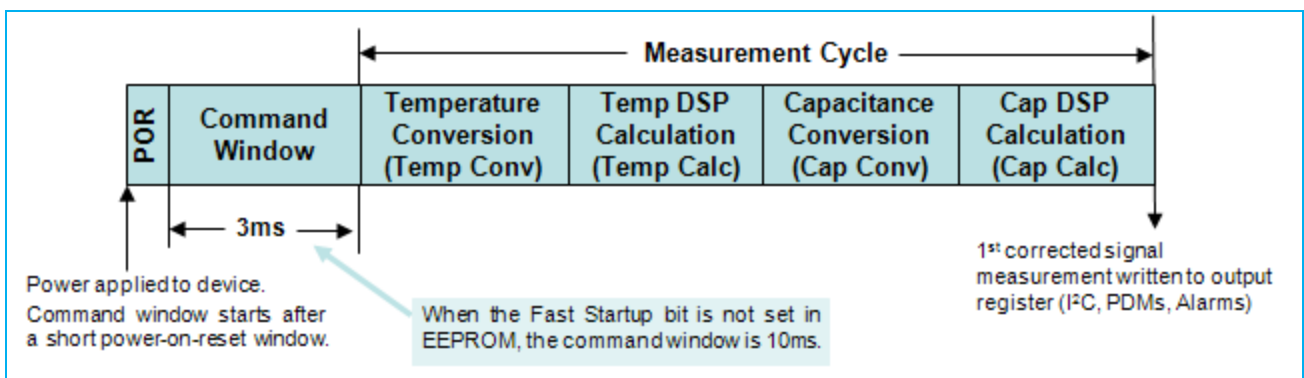
Figure 4.2   **I^{2}C Timing Diagram**
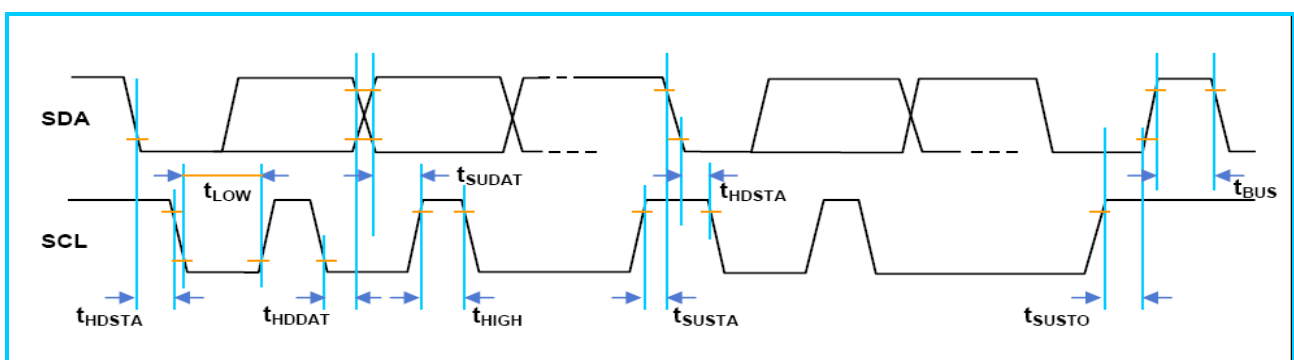
Table 4.1   **I^{2}C Parameters**

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS
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 on 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 **HumiChip®** can be programmed to operate in either Sleep Mode or Update Mode. The measurement mode is selected with the Measurement_Mode bit in the **HumiChip®** Config

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**

Register word. In Sleep Mode, the part waits for commands from the master before taking measurements (see **section 4.3.2**).

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
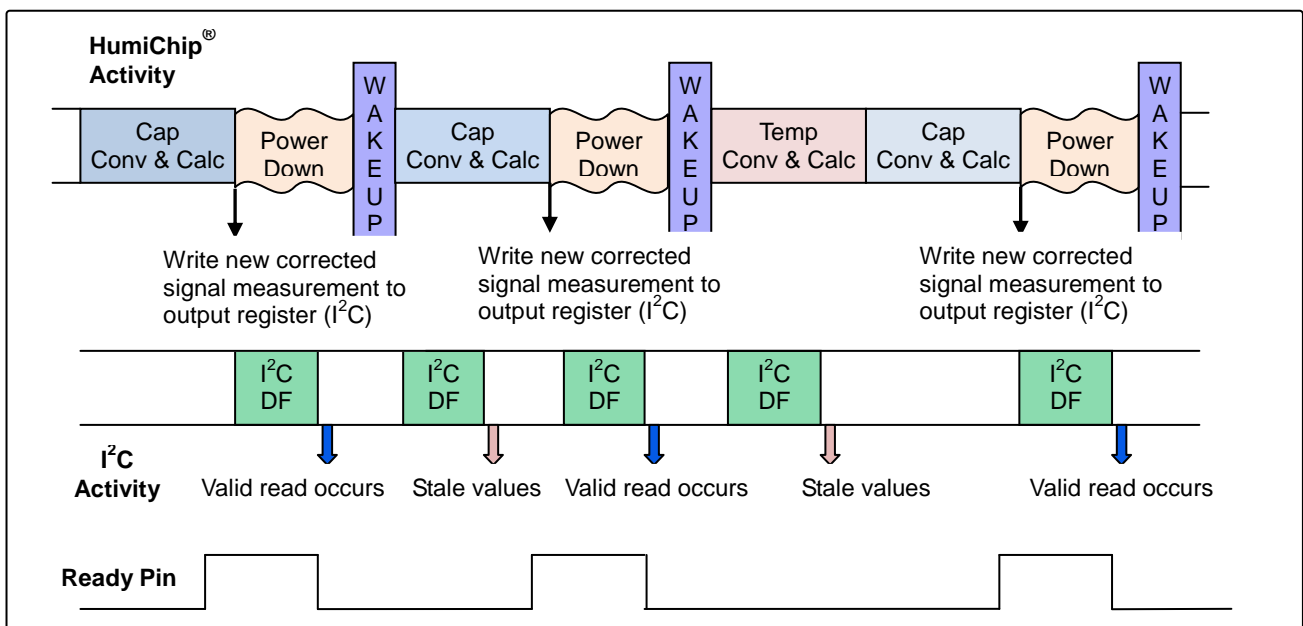
4.3.2 Data Fetch in Sleep Mode

In Sleep Mode, the **HumiChip® core** will only perform conversions when **HumiChip®** receives a Measurement Request command (MR); otherwise, the **HumiChip®** 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

HumiChip® from power down. After **HumiChip®** wakes up, a measurement cycle is performed consisting of both a temperature and a capacitance conversion followed by the **HumiChip® Core** correction calculations.

At the end of a measurement cycle, the digital output register and Alarms will be updated before powering down. An I^{2}C data fetch (DF) is performed during the power-down period to fetch the data from the output register. In I^{2}C 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   I^{2}C Data Fetching in Sleep Mode

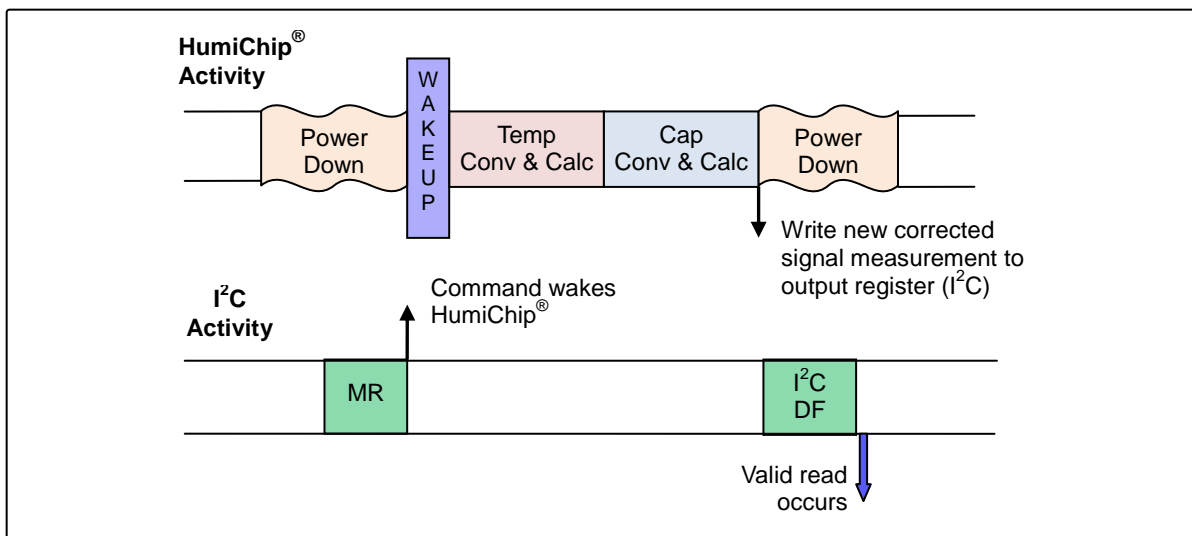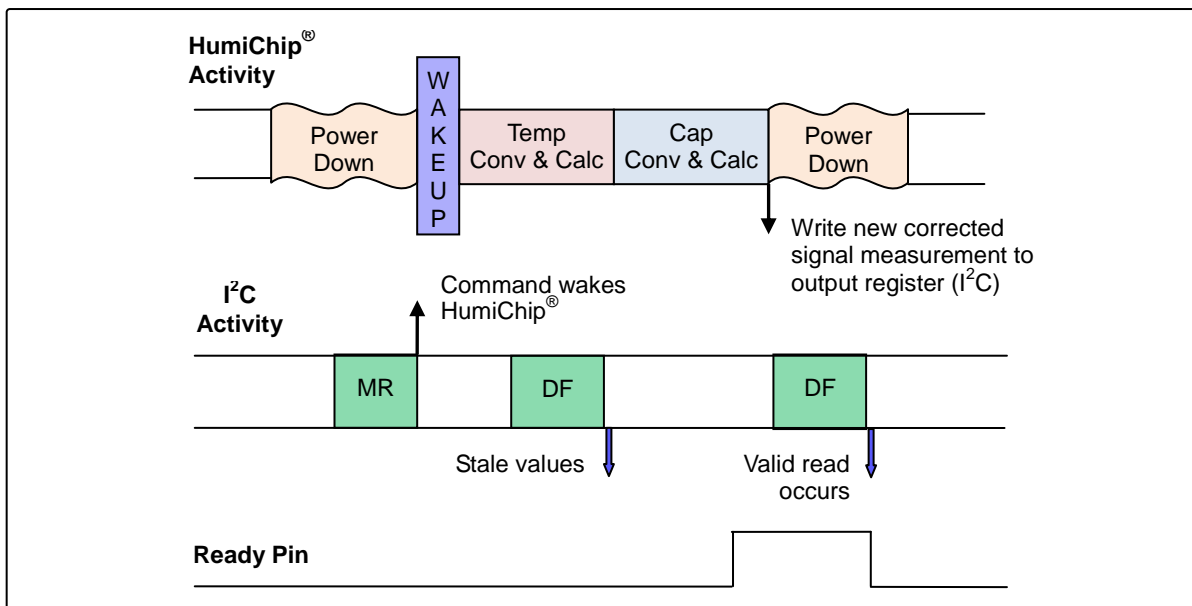In Sleep Mode, I2C are used to request a measurement with a MR command and to fetch data from the digital output register using a Data Fetch (DF) command (see **section 4.7** for details on the MR command).

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). 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.

4.4 Status Bits

Status bits (the two MSBs of the fetched high data byte, see **Table 4.2**) are provided in I^2C but not in PDM. The status bits are used to indicate the current state of the fetched data.

Table 4.2 Status Bits

Status Bits(I^2C)	PDM Output	Definition
00B	Clipped normal output	Valid data: Data that has not been fetched since the last measurement cycle.
01B	Not applicable	Stale data: Data that has already been fetched since the last measurement cycle.
10B	Not applicable	Command Mode: The **HumiChip®** is in Command Mode.
11B	Not used	Not used

4.5 I^2C Commands

As detailed in **Table 4.3**, there are two types of commands which allow the user to interface with the **HumiChip®** in the I^2C.

Table 4.3 I^2C Command Bits

Type	Description	Communication Supported	Reference Sections
Data Fetch (DF)	Used to fetch data in any digital mode	I^2C	Section 4.6
Measurement Request (MR)	Used to start measurements in Sleep Mode	I^2C	Section 4.7

4.6 Data Fetch (DF)

The Data Fetch (DF) command is used to fetch data in any digital output mode.

An I^2C Data Fetch command starts with the 7-bit slave address and the 8th bit = 1 (READ).

The **HumiChip®** as the slave sends an acknowledgement (ACK) indicating success.

The number of data bytes returned by the **HumiChip®** 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.

Figure 4.3   I²C Measurement Packet Reads

I^2C DF – 2 Bytes: Slave returns only humidity (RH) data to the master in 2 bytes.

| S | 6 | 5 | 4 | 3 | 2 | 1 | 0 | R | A | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | A | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | N | S |

Device Slave Address [6:0]   RH Data [13:8]   RH Data [7:0]

Wait for Slave ACK   Master ACK   Master ACK   Master NACK

| S | 6 | 5 | 4 | 3 | 2 | 1 | 0 | R | A | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | A | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | A | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | N | S |

Device Slave Address [6:0]   RH Data [13:8]   RH Data [7:0]   Temp. Data [13:6]

| **S** Start Condition | **S** Stop Condition | **A** Acknowledge (ACK) | **N** Not Acknowledge (NACK) | **R** Read/Write (Read = 1) |
| **2** Slave Address Bit (Example: Bit 2) | | **2** Command or Data Bit (Example: Bit 2) | | Status Bit |

I^2C DF – 4 Bytes: Slave returns 2 RH data and 2 Temperature data to the master.

Wait for Slave ACK   Master ACK   Master ACK   Master ACK   Master NACK

| S | 6 | 5 | 4 | 3 | 2 | 1 | 0 | R | A | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | A | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | A | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | A | 5 | 4 | 3 | 2 | 1 | 0 | | | N | S |

Device Slave Address [6:0]   RH Data [13:8]   RH Data [7:0]   Temp. Data [13:6]   Temp. Data [5:0]

| **S** Start Condition | **S** Stop Condition | **A** Acknowledge (ACK) | **N** Not Acknowledge (NACK) | **R** Read/Write (Read = 1) |
| **2** Slave Address Bit (Example: Bit 2) | | **2** Command or Data Bit (Example: Bit 2) | Status Bit | Bits should masked off and ignored |

Humidity & Temperature Conversion Formula	
Humidity Output (%RH)	$\left(\text{RH\_High}[5:0] \times 256 + \text{RH\_Low}[7:0] \right) / 2^{14} \times 100$
Temperature Output (°C)	$\left(\text{Temp\_High}[7:0] \times 64 + \text{Temp\_Low}[7:2] / 4 \right) / 2^{14} \times 165 - 40$

4.7 Measurement Request (MR)

A measurement request (MR) is a Sleep-Mode-only command sent by the master to wake up the **HumiChip®** and start a new measurement cycle in I^2C.

The I^2C 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 I^2C.

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 I^2C MR function can also be accomplished by sending "don't care" data after the address instead of immediately sending a stop bit.

Figure 4.4 I^2C Measurement Request
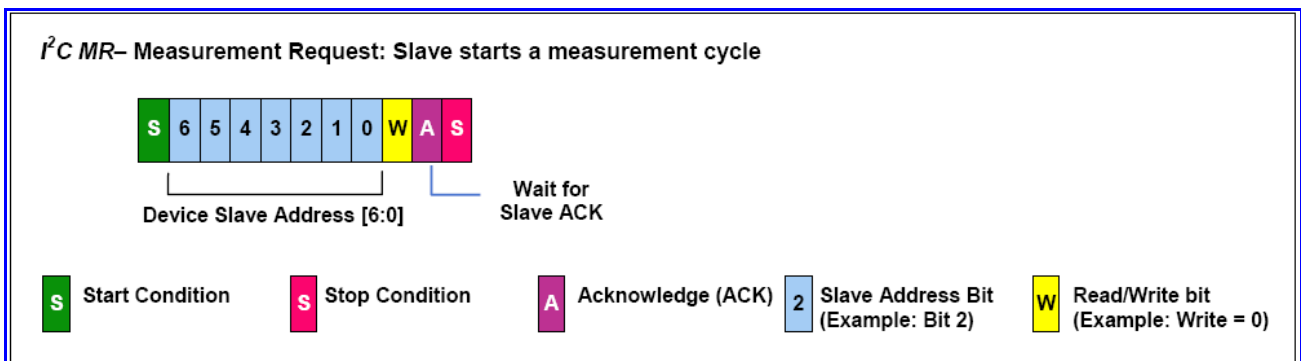
4.8 Ready Pin

A rise on the Ready pin indicates that new data is ready to be fetched from the I^2C 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 **Note:** If two high alarms or two low alarms are

Ready_Open_Drain bit in EEPROM word Cust_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 pull-up resistor to connect all the parts in a bus format.

4.9 Command Mode

Command Mode commands are only supported for the I^2C 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
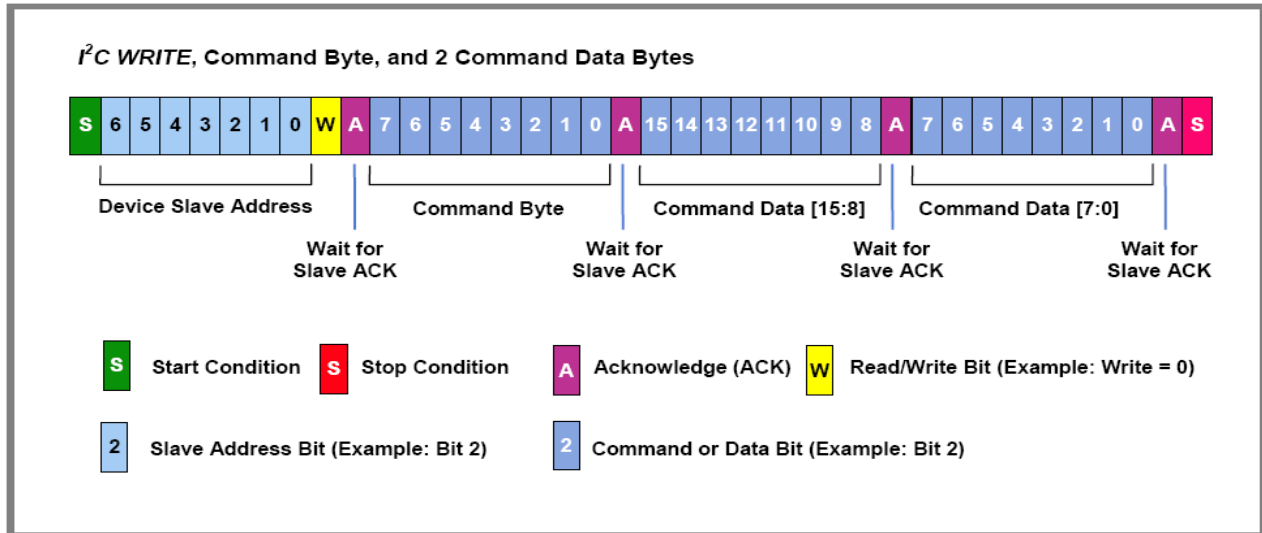
4.10 Command Encodings

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.

Table 4.4 Command List and Encodings

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.	100µs
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.	12ms
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.	100µs

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 I^{2}C 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 the 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**)

Table 4.5   **Response Bits**

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 4.6   **Command Diagnostic Bits**

Bit Position	Name	Description
2	Corrected EEPROM Error	A corrected EEPROM error occurred in execution of the last command.
3	Uncorrectable EEPROM Error	An uncorrectable EEPROM error occurred in execution of the last command.
4	RAM Parity Error	A RAM parity error occurred during a microcontroller instruction in the execution of the last command.
5	Configuration Error	An EEPROM or RAM parity error occurred in the initial loading of the configuration registers.

Figure 4.6 **Command Mode Data Fetch**
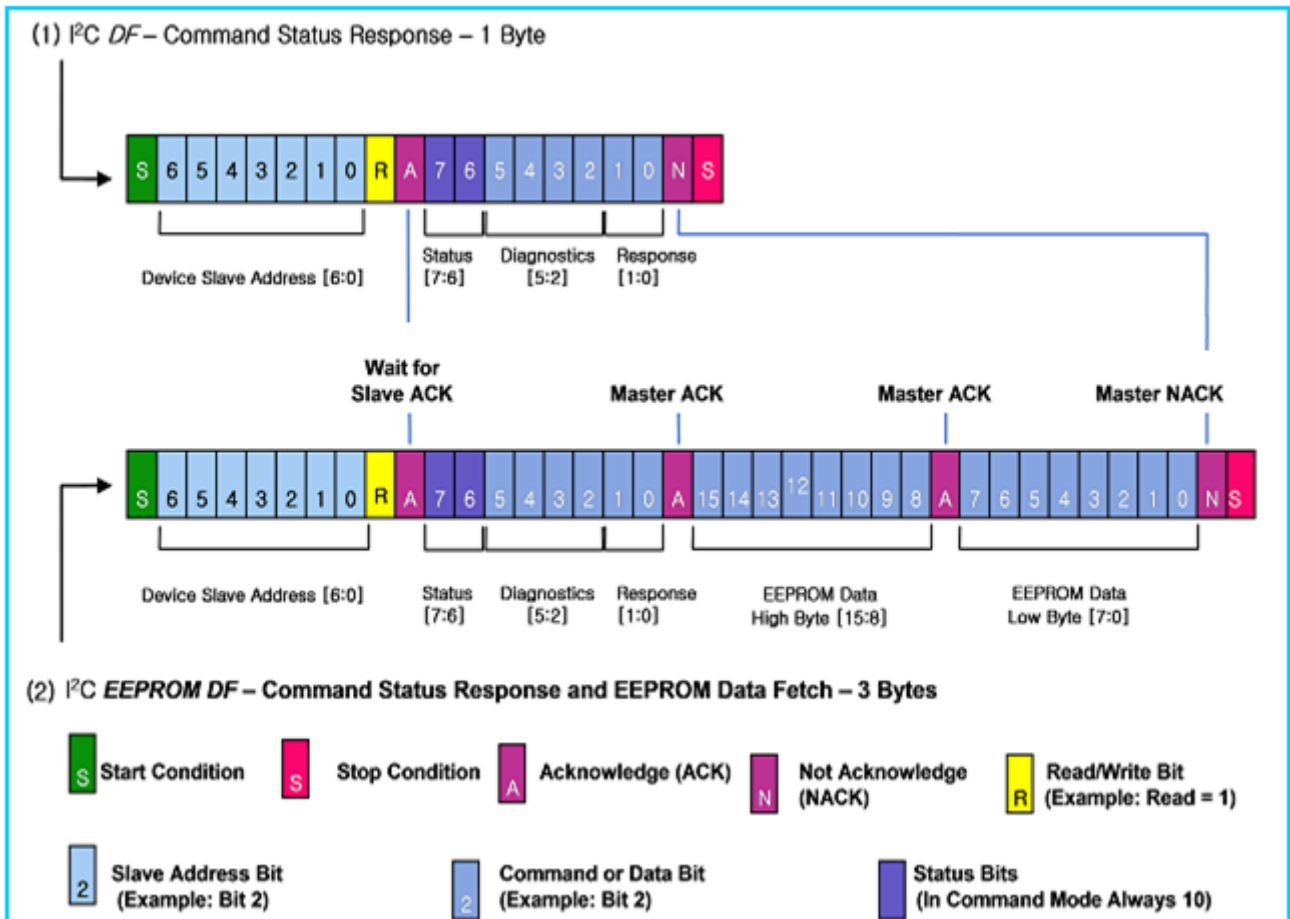
4.12 EEPROM

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 **HumiChip®** 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 I^{2}C interface. When programming the EEPROM, an internal charge pump voltage is used; therefore a high voltage supply is not needed.

Table 4.7 **EEPROM Word Assignments**

EEPROM Word	Bit Range	IC Default	Name	Description and Notes
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

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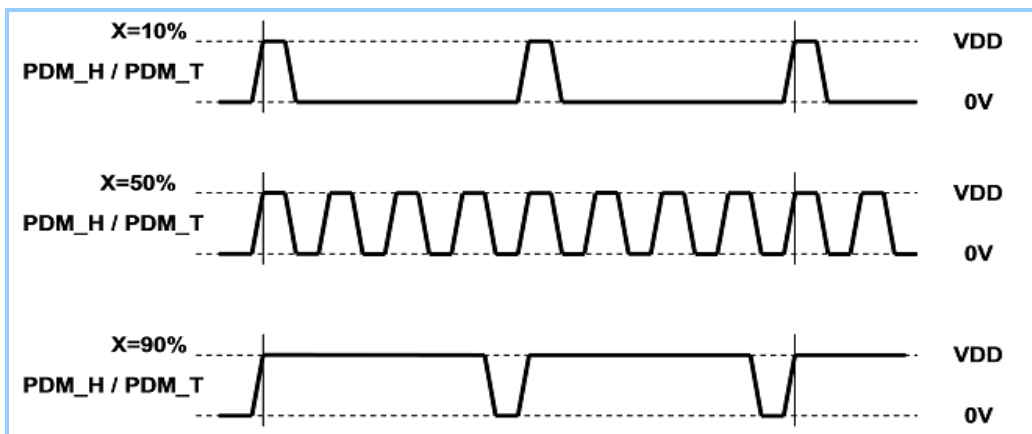
The PDM frequency is 231.25kH±15% (i.e., the oscillator frequency 1.85㎒±15% divided by 8). Both PDMs output 14-bit values for Humidity and Temperature.

In PDM Mode, **HumiChip**® 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 $\geq$ 10kΩ.

Table 5.1   **Low Pass Filter Example for R=10㏀**

Filter Capcitance (nF)	PDM_H / PDM_T		Desired Analog Output Resolution
	Vpp Ripple (mV/V)	0 to 90% settling time (ms)	
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($\text{k}\Omega$) * C(nF)]

Or the setting time **t**$_{\text{SETT}}$ for a 0% to 90% setting can be calculated as

t$_{\text{SETT}}$ (ms) = 0.0023 * R($\text{k}\Omega$) * C(nF)

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[$^\circ$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 pre-programmed 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 **HumiChip®** 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 **HumiChip®** can be connected together with a single pull-up resistance so that one can detect an alarm on any device with a single wire.

6.5   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)

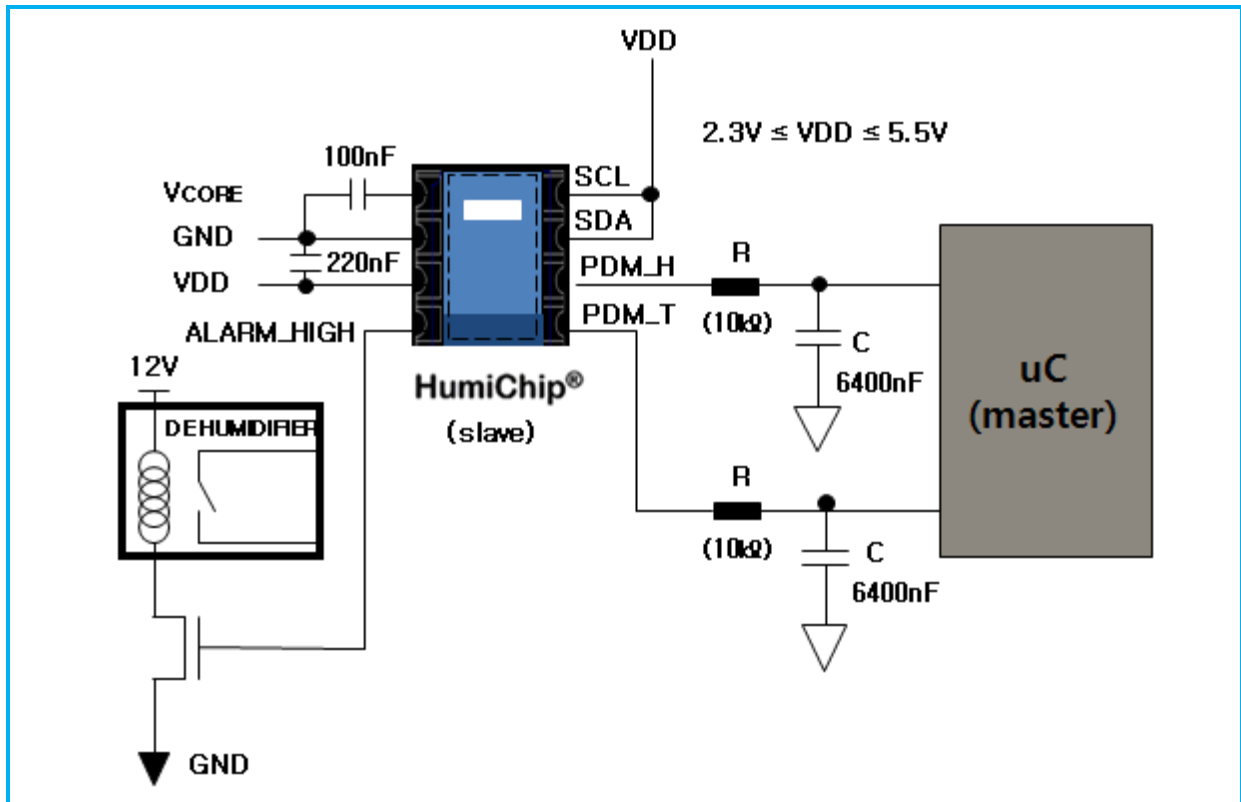**HumiChip®PDM:** **1 Alarms / Humidity Output** (Optional)

Figure 6.2 Bang-Bang Humidity Control (High Voltage Application)

HumiChip® I2C : **2 Alarms / Humidity Output** (Optional)

HumiChip® also can be directly installed to a device without MCU interface when only a switch on/off function is required at desired humidity level. (*e.g.* Bathroom Vent Fan, Humidifiers, Dehumidifiers)
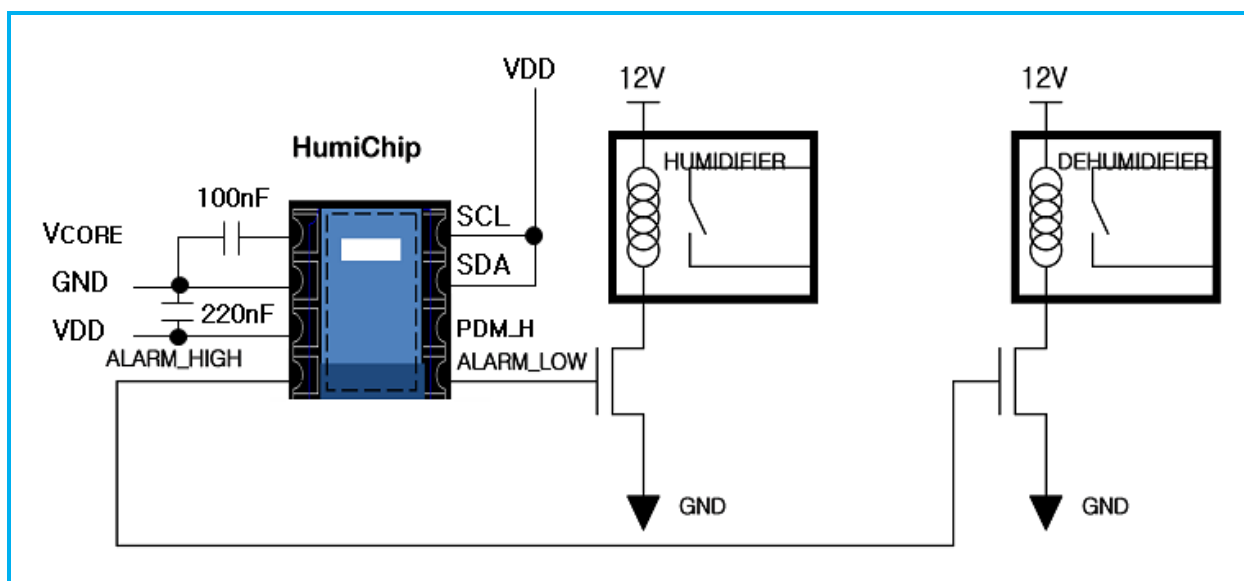
Figure 6.3 LED control with Alarm function

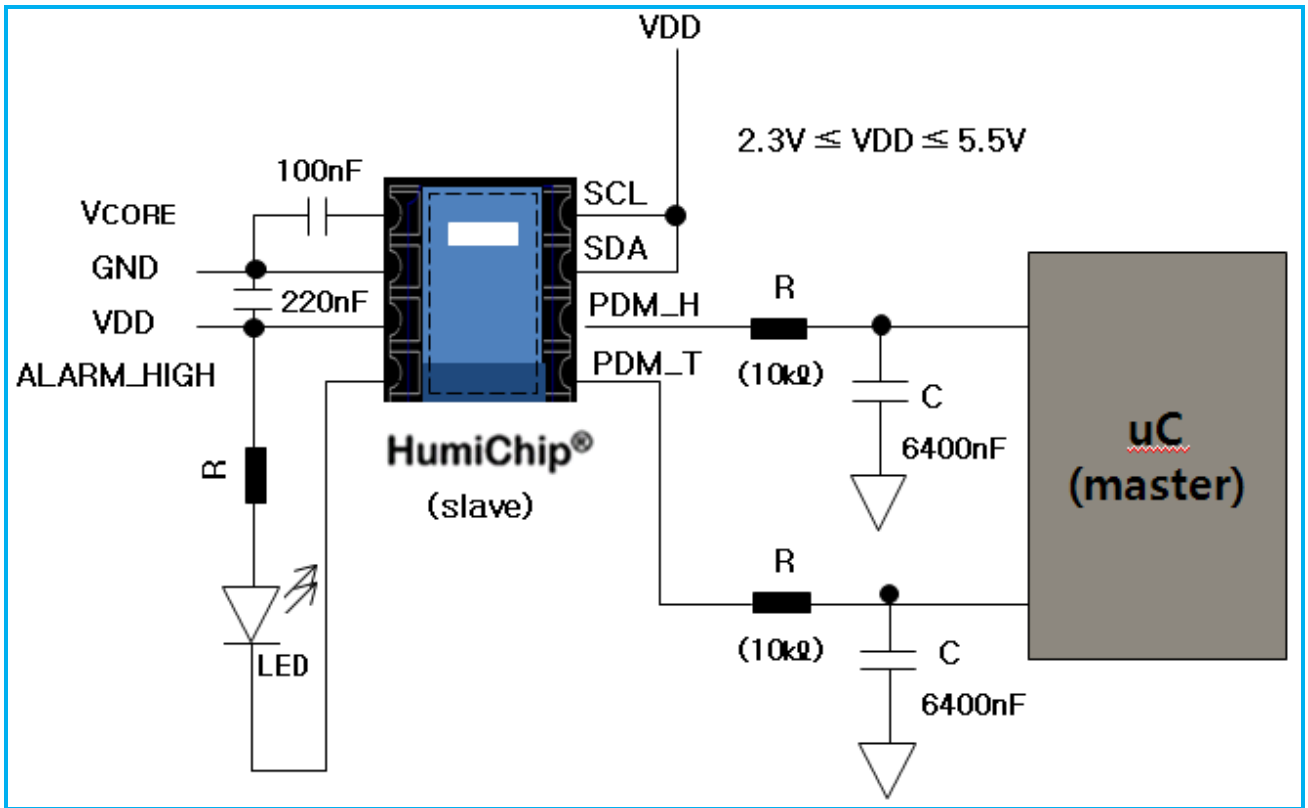HumiChip® PDM: 1 Alarms / Humidity Output (Optional)
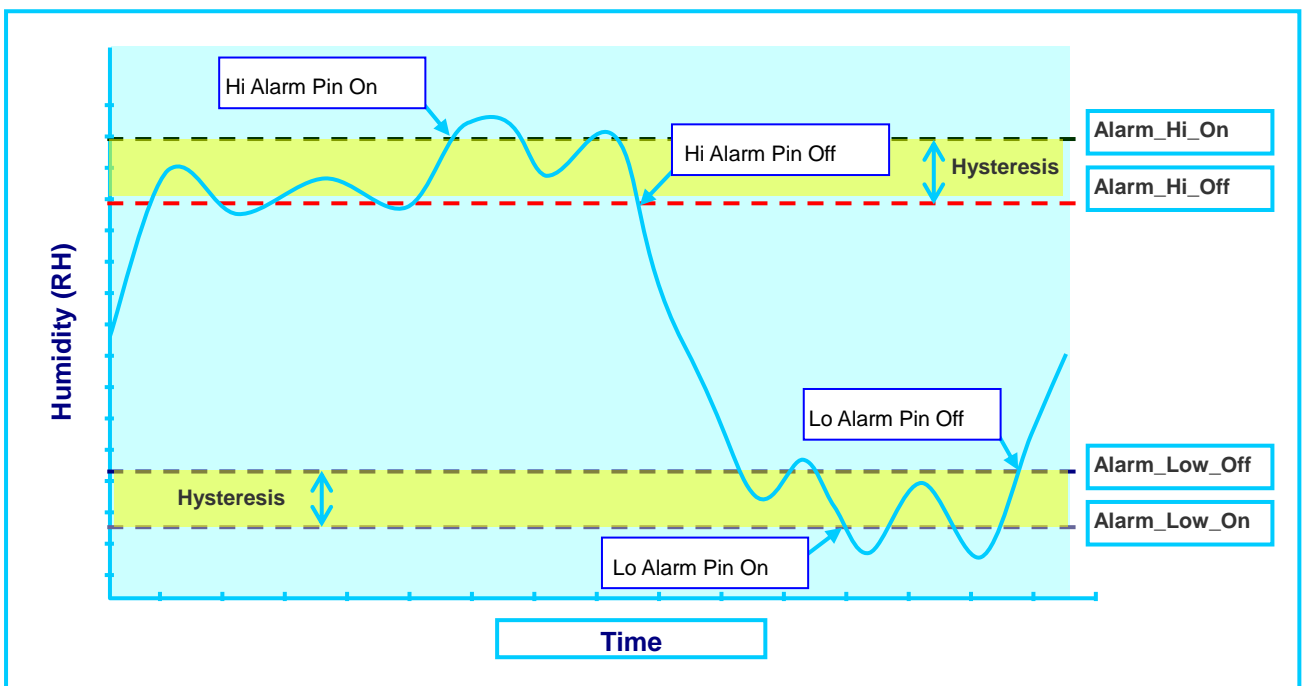

Figure 6.4 Example of Alarm Function
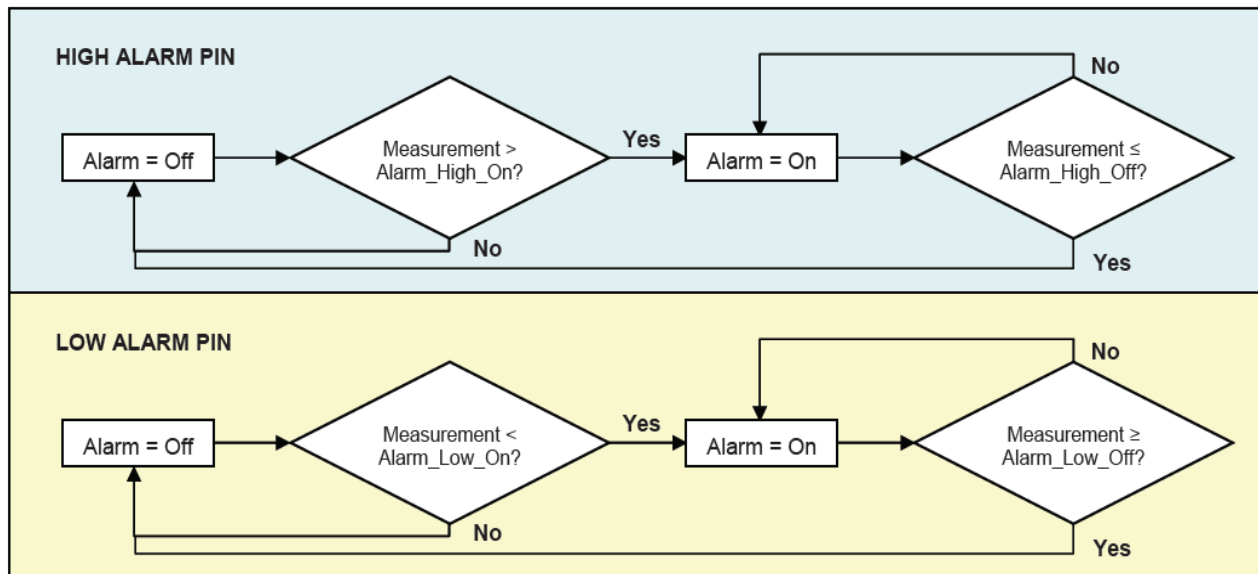
<center>**Figure 6.5   Alarm Output Flow Chart**</center>
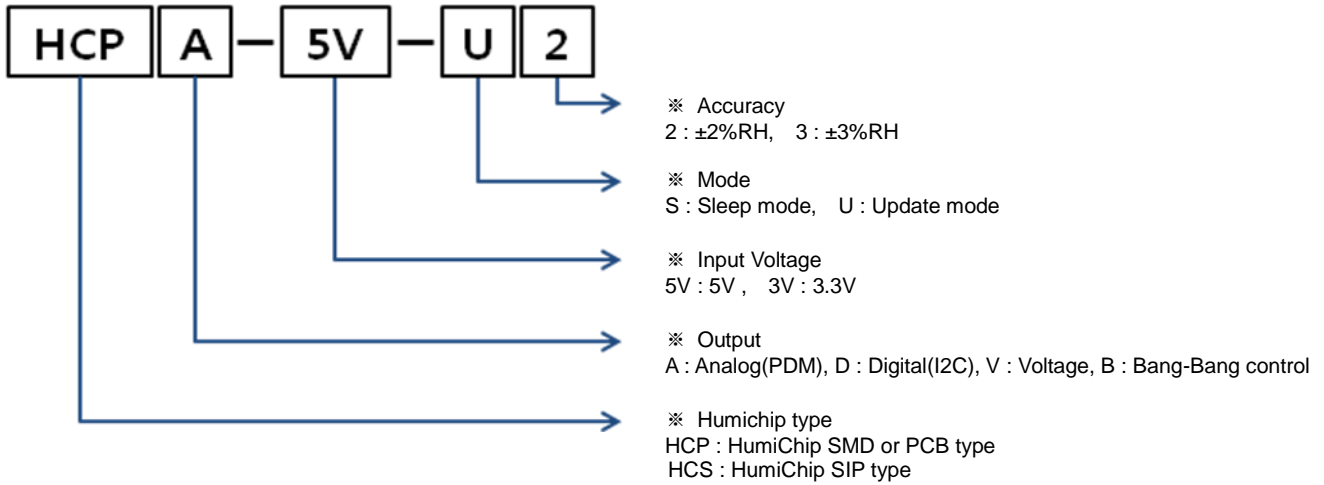

Table 6.1   Cust_Config Bit Assignments

Bit Range	IC Default	Name	Description and Notes
6:0	0101000	Device_ID	I^2C slave address
8:7	00	Alarm_Low_Cfg	Configure the Alarm_Low output pin: <table><tr><td>Bits</td><td>Description</td></tr><tr><td>7</td><td>Alarm Polarity: 0 = Active High 1 = Active Low</td></tr><tr><td>8</td><td>Output Configuration: 0 = Full push-pull 1 = Open drain</td></tr></table>
10:9	00	Alarm_High_Cfg	Configure the Alarm_High output pin: <table><tr><td>Bits</td><td>Description</td></tr><tr><td>9</td><td>Alarm Polarity: 0 = Active High 1 = Active Low</td></tr><tr><td>10</td><td>Output Configuration: 0 = Full push-pull 1 = Open drain</td></tr></table>
*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 7.1

HumiChip Part Number List


```
HCP  A — 5V — U  2
```

※ Accuracy
2 : ±2%RH,　3 : ±3%RH

※ Mode
S : Sleep mode,　U : Update mode

※ Input Voltage
5V : 5V ,　3V : 3.3V

※ Output
A : Analog(PDM), D : Digital(I2C), V : Voltage, B : Bang-Bang control

※ Humichip type
HCP : HumiChip SMD or PCB type
HCS : HumiChip SIP type

Items	Series	Output	Operating Voltage(V)	Mode	Accuracy(%RH)	Part Number
Humi A	HCP (SMD)	PDM (Analog)	5	Update	±2	HCPA-5V-U2
			5	Update	±3	HCPA-5V-U3
			3.3	Update	±2	HCPA-3V-U2
			3.3	Update	±3	HCPA-3V-U3
Humi D	HCP (SMD)	I2C (Digital)	5	Update	±2	HCPD-5V-U2
			5	Update	±3	HCPD-5V-U3
			3.3	Update	±2	HCPD-3V-U2
			3.3	Update	±3	HCPD-3V-U3
			5	Sleep	±2	HCPD-5V-S2
			5	Sleep	±3	HCPD-5V-S3
			3.3	Sleep	±2	HCPD-3V-S2
			3.3	Sleep	±3	HCPD-3V-S3

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