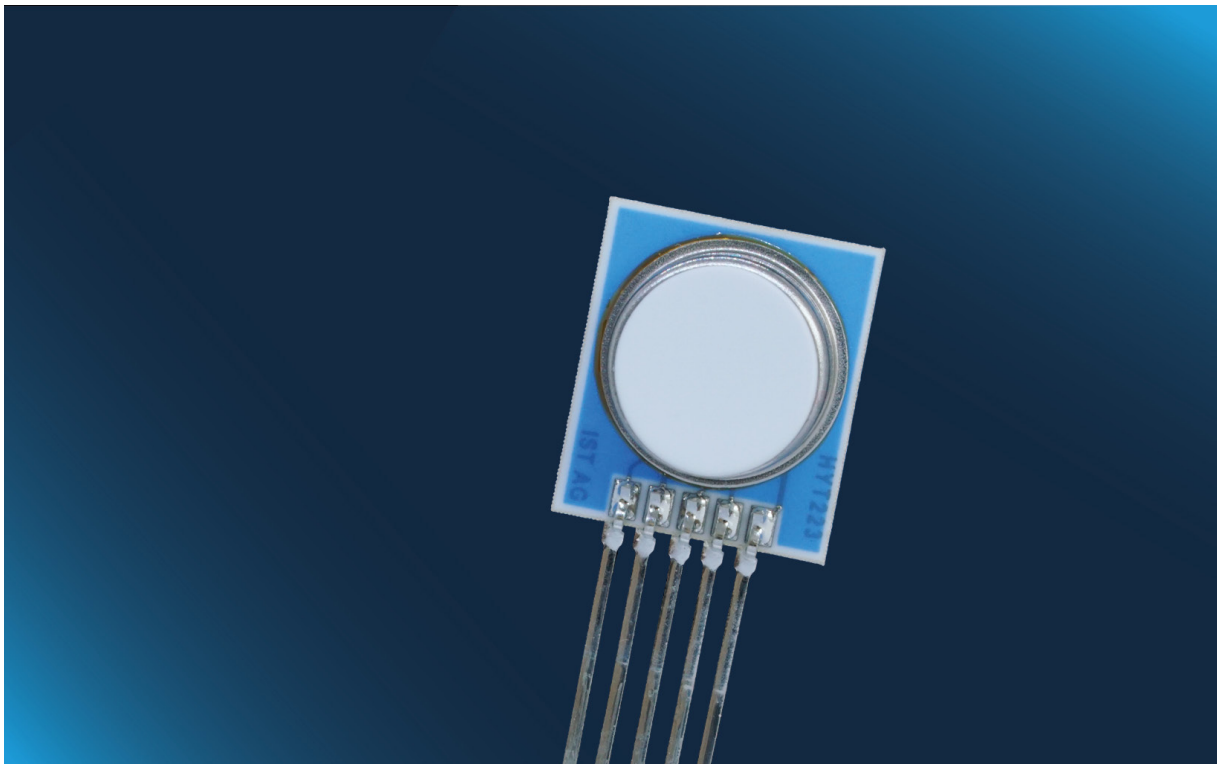


Application Note

Humidity module with integrated Heater

HYT 223





Application Note

Humidity module with integrated Heater

HYT 223

1. General benefits of the HYT-module family and HYT 223	3
1.1 Sensor construction	3
1.2 Benefits of the HYT 223	3
2. HYT 223	4
2.1 Accuracy/calibration	4
2.2 Custom specific versions	4
2.3 Heatable for drift correction	4
2.4 Typical areas of application	5
2.5 Mechanical dimensions	5
2.6 Pin assignment	5
3. Design recommendations	6
3.1 Mounting instructions	6
3.2 Coupling to environmental conditions	6
4. Application in condensing environment	7
5. Handling guidelines	7
5.1 Sensor pollution	7
5.2 Reconditioning procedure	8
5.3 Packaging	8
5.4 Handling	8
5.5 Sensor handling	8
5.6 Soldering of the sensor	9
5.7 Cleaning of the Sensor	9
5.8 Handling of the original blisters	9
6. I ² C Protocol description	10
6.1 I ² C Interface and timing	10
6.2 MR (measurement request)	11
6.3 DF (data fetch)	12
6.4 Scaling of measurement values	12
6.5 I ² C pull up resistor	14
7. I ² C address change	15
7.1 Step by step - I ² C address change	17
8. Micro heater	17
9. Additional documents	17



Application Note

Humidity module with integrated Heater

HYT 223

1. General benefits of the HYT-module family and HYT 223

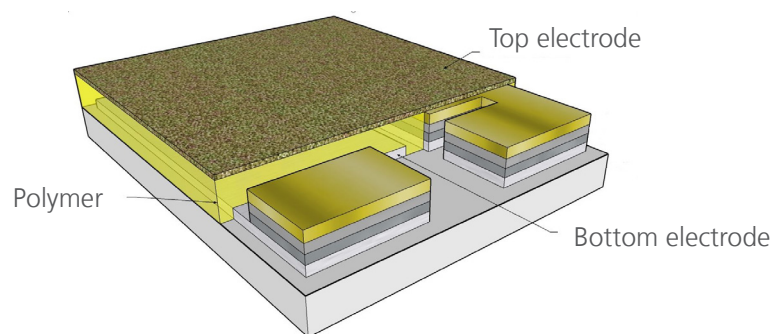
- Fast response time
- Stable at high humidity
- I²C protocol
- Low drift
- Low hysteresis
- Humidity and temperature sensor with excellent accuracy
- Easy integration, interchangeable without adjustments
- Different calibrations available with up to ± 0.5 %RH accuracy
- Customer specific versions
- Fully calibrated and temperature-compensated

IST AG's fully calibrated and temperature-compensated humidity modules are the best solution for the most demanding humidity applications.

The heart of any type of module is its capacitive polymer-based sensor element, which is fabricated with IST AG's cutting-edge thin film techniques. Its proprietary polymer and porous humidity-permeable cover layer enables excellent stability while maintaining the advantages of fast response times. The use of only first-class materials and the robust sensor design make the elements very stable in harsh conditions, such as high humidity and dew formation. With the SIL or pin-contacts, the modules can easily be integrated into various assemblies.

The signal processing integrated in the sensor completely processes the measured data and directly delivers the physical parameters of relative humidity and temperature over the I²C compatible interface as digital values. The precise calibration of every module against dewpoint ensures the outstanding accuracy of our humidity modules.

1.1 Sensor construction



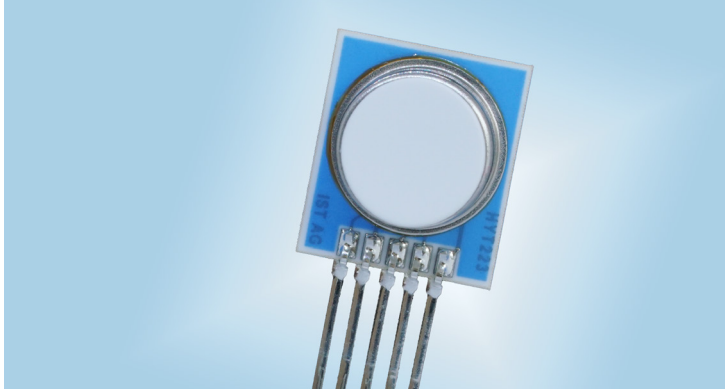
1.2 Benefits of the HYT 223

- Integrated Heater
- Allows for customized heating cycles to reduce drift/ correct drift in the application
- PTFE filter reduces drift
- Suitable for high humidity measurement
- Designed for applications with volatile organic compounds (VOC) present

With its SIL-contacts, it can easily be integrated into various assemblies. Like all representatives of the HYT family, the module is precisely calibrated and temperature compensated, directly delivering the relative humidity and temperature parameters.



2. HYT 223



Due to the very precise calibration of HYT as well as the pin contacts, the modules can easily be integrated and replaced in the assembly.

2.1 Accuracy/Calibration

	Humidity	Temperature
Accuracy	0 °C to 50 °C: ± 1.8 % RH at 0 - 90 % RH ± 3.0 % RH at 90-100 % RH	0 to 60 °C: ± 0.2 °C
Reproducibility	± 0.2 % RH	± 0.1 K
Resolution	0.03 % RH	+0.015 °C
Response time t63	< 10 s	< 10 s
Long-term drift:	0.5 % RH/a	< 0.05 K/a

For details see product data sheets.

2.2 Custom specific versions

Customized IST AG humidity modules feature extraordinary response times, high accuracies in condensing environments or low humidity conditions. Please contact us for custom specific versions, especially regarding custom specific calibrations.

2.3 Heatable for drift correction

HYT 223 contains a microheating structure which allows for thermal reconditioning. A reconditioning cycle is recommended in challenging atmospheres and conditions. Length and interval required depend on the application environment. A possible reconditioning setting is heating the module with 8 to 9 V and 700 mW power for 10 minutes every 24 hours.

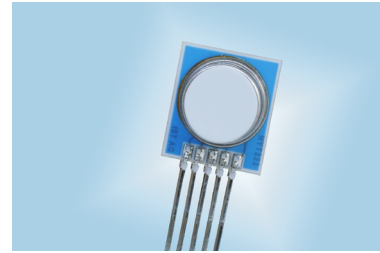
During reconditioning, the read-out values are not calibrated measurement data.

Note: more information in chapter 8

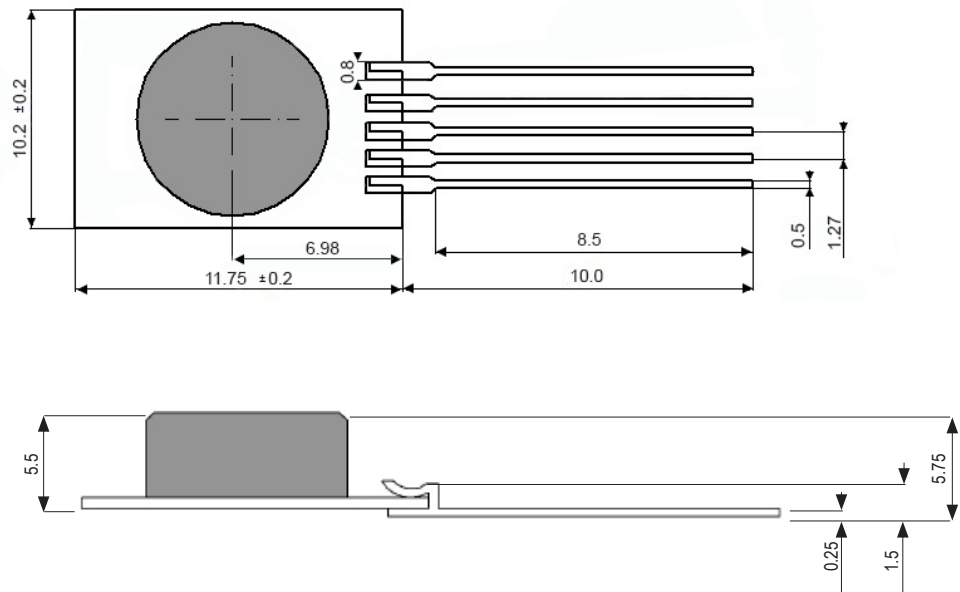


2.4 Typical Areas of Application

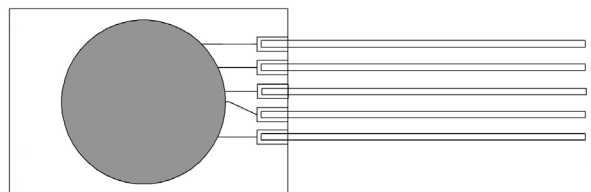
- Handheld measurement instruments
- Humidity transmitters
- Industrial applications
- Measuring technology
- HVAC
- HYT 223 is designed for applications with VOC contamination present



2.5 Mechanical Dimensions



2.6 Pin Assignment



1	2	3	4	5
SDA	GND	VDD	SCL	Heater

The GND connection is used for the humidity sensor as well as the heater.



3. Design Recommendations



3.1 Mounting Instructions

The media compatibility of the sensor, housing and sealing materials are to be checked and kept suitable as per the application. The housing and the assembly must be constructed so that it can withstand the application pressure multiplied by the factor of safety. In case of dynamic applications in the upper pressure range, an additional extra factor is to be taken into account for the material fatigue.



The assembly must be done stress-free. This should remain valid for the entire temperature range, considering the different coefficients of expansion between the sensor housing and the opening. The support from top may be provided only in the boundary area. The upper mounting ring must rest upon a flat surface.



3.2 Coupling to environmental conditions



In the assembly, the module should measure as close as possible to the real humidity and temperature value of the application. When designing an assembly/probe, please consider the following:



Heat sources: e.g. electronic components in the vicinity of the module can influence the temperature as well as the humidity measurement via heat conduction. Therefore, do not place possible heat sources near the module or make sure to thermally decouple critical components.

H₂O microclimate: Materials with large water absorption capacity in the vicinity of the humidity sensor element can cause a H₂O microclimate. In this case the relative humidity in the surrounding atmosphere of the element is not the same as in the conditions to be tested. This often results in wrong %RH readings. The exact value of maximal water absorption capacity of a material used in an assembly is extremely application dependent. To avoid false readings only use tested materials.

Filters/dead volume: Additional filters as well as dead volume in the assembly can increase the response time of the humidity measurement system.

UV-VIS radiation Protect the module in the assembly as good as possible from radiation, especially UV-VIS and heat radiation. Penetration of UV-VIS radiation damages the chemical structure of the humidity sensitive polymer and has therefore a large influence on the sensor performance.

Heat radiation Increasing the temperature in the materials around the temperature sensor, heat radiation can have an influence on the temperature measurement. Protect the module in the assembly as good as possible from radiation.

Thermal coupling to environmental conditions: A large thermal mass in direct contact with the module decreases the thermal response time of the assembly. If a fast temperature response time is important, decouple the module from the mass of the assembly.

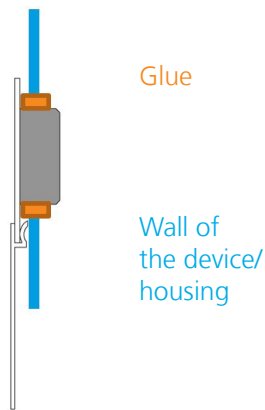


3.3 Suggestions for mounting

The following three suggestions are examples only and need to be adapted for the actual situation. There are many other possibilities that may fit better in other mounting situations.

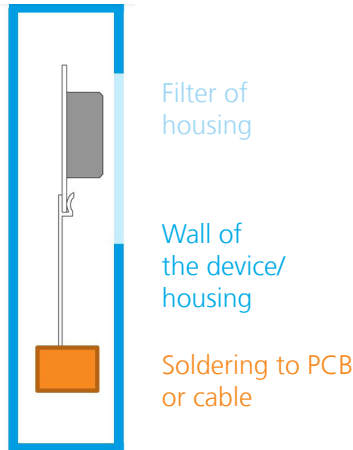
Suggestion 1

Glue HYT 223 into the opening of your device/housing. Please make sure the glue is not releasing VOC or blocking the filter.



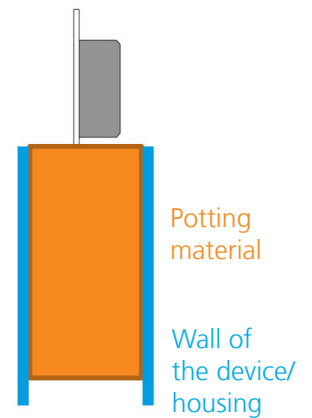
Suggestion 2

Solder the HYT 223 onto a PCB or cable which is fixed inside the housing. This is only possible if the housing contains a large filter.

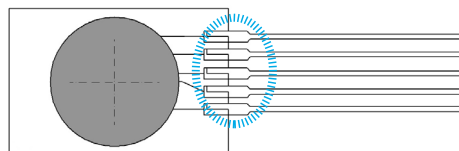


Suggestion 3

Potting after connecting the HYT 223 to a PCB or cable. Please pay attention that the potting material is not releasing VOC or blocking the filter.



4. Application in condensing environment



Area to be covered on the HYT 223 in the assembly for the application in condensing environment

For the application in condensing environment, the electronics must be protected by a suitable coating material which does not release polluting chemicals or produces a H₂O microclimate. The SIL contacts on both sides should be covered (see blue circle in the figure above).

Be careful not to touch or cover the filter during dispensing.



5. Handling guidelines

5.1 Sensor pollution

Gaseous chemicals such as volatile organic compounds (VOCs) are known to pollute the sensitive layer of the humidity sensor element. If such pollutants are present in the surrounding atmosphere of the sensor, they diffuse into the polymer where they occupy spaces reserved for water molecules. This process often results in lower humidity readings.

Sources of pollution can be materials that release chemicals such as:

- Plastics or other packaging materials, such as ESD Bags, cardboard boxes, foams etc.
- Potting compounds
- Adhesives
- Coatings
- Glues etc.

High concentrations of pollutants are known to occur in storage rooms and manufacturing floors especially where castings, glues, epoxies etc. are cured.

To avoid false readings please:

- Store the modules in the original sealed packaging material
- Only use tested or recommended packaging material
- The ESD bag must be hermetically sealed
- Eliminate VOCs during storage and manufacturing
- Ensure a clean surrounding atmosphere by fresh air supply and good ventilation. Keep the sensor in the recommended/tested packaging materials during longer storage times
- Use only tested materials in the sensor assembly

Although the HYT 223 is designed for applications in areas presence of VOC, we recommend storage in areas with no VOC present. For the heating cycles please refer to chapter 8.

5.2 Reconditioning procedure

Once the modules already read wrong humidity signals, the pollutants can be removed by evaporation in many cases. For reconditioning

- bake the sensors for 2-24 hours at 120°C.

It is possible that the modules read slightly too high values after reconditioning, then

- store the modules for 4-8 weeks in eurostat ESD bags (without desiccant) at 55 °C

HYT 223 is designed for reconditioning within the application (see chapter 8 for instructions). Nevertheless, reconditioning after storage (without heating cycles) is recommended.

5.3 Packaging

Due to the polluting effect of many plastics, only use tested or recommended packaging materials.

Recommendations:

ESD Bag

- ESD bag (eurostat 20-87x-xxxx, 20-771-xxxx) or
- W-Tech France MBB Aluminium bag: Total thickness 150µm ±10% Structure: ESD+PET (12µm) / PA (15µm) / AL (7µm) / ESD+LDPE (110µm)

Desiccant bag

- Desiccant bag DESI PAK (Clariant 25085627656)

Never use the ESD bags without desiccant bag (except reconditioning procedure)!

The bag with the desiccant and the modules must be sealed.



5.4 Handling

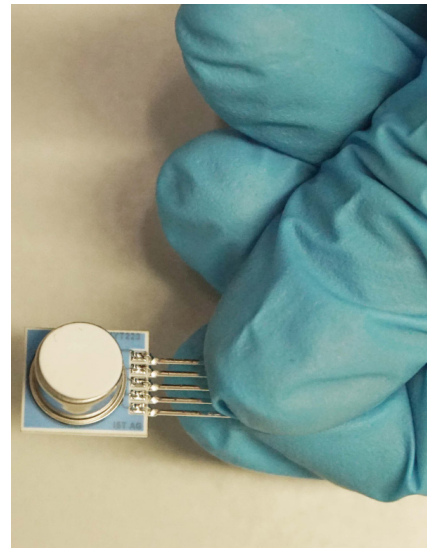
- Do not use metal tweezers to handle the modules
- Never handle the modules by hand without gloves
- Avoid mechanical stress, e.g. bending or touching the module with sharp objects
- Hold the module with plastic tweezers on the wires and side edges only

5.5 Sensor handling

Hold the sensor with plastic tweezers or with gloves on the wires only



Sensor held with plastic tweezers on the wires only



Sensor held with gloves on the wires only

5.6 Soldering of the sensor

During the soldering process it is recommended not to exceed temperatures of 200°C at the active sensor area. This can be achieved by hand soldering within 10 s at the end of the wires with a maximum temperature of 320 °C at the soldering iron. Avoid soldering flux residues caused by the soldering process or any other contaminants on the filter.

5.7 Cleaning of the sensor

The sensor must not be cleaned mechanically with cotton swabs.
It is possible to clean the sensor with oil-free and filtered clean air, e.g. to remove dust particles.



5.8 Handling of the original blisters

To avoid damages handle as follows:



1. Digital humidity sensors delivered in plastic blister



2. Open the plastic blister carefully



3. Remove the modules from the blister using plastic tweezers



4. Use plastic tweezers only to handle the module

Alternative: An alternative procedure is to hold the sensor gently by the metal cap wearing gloves to remove from the blister. Then change to plastic tweezers and hold the sensor by the SIL.

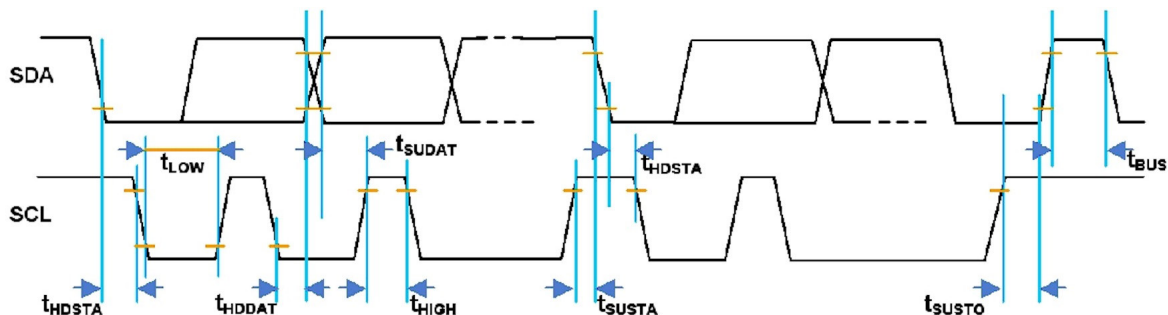




6. I²C Protocol description

6.1 I²C Interface and timing

For integration with a micro-controller, the humidity module has an I²C-compatible interface which supports both 100 kHz and 400 kHz bit rates. The I²C slave address is programmed by default on 0x28 and can be adjusted in the entire address range (0x00 to 0x7F). Hence, up to 126 humidity modules can be operated on a single I²C-Bus.

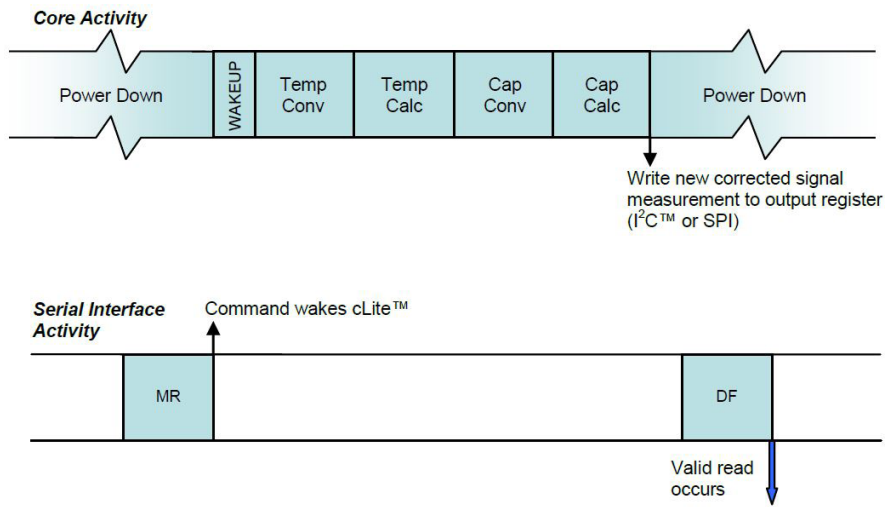


Parameter	Symbol	Min	Max	Unit
SCL clock frequency	fSCL	100	400	kHz
Start condition hold time relative to SCL edge	tHDSTA	0.1		µs
Minimum SCL clock low width 1	tLOW	0.6		µs
Minimum SCL clock high width 1	tHIGH	0.6		µs
Start condition setup time relative to SCL edge	tSUSTA	0.1		µs
Data hold time on SDA relative to SCL edge	tHDDAT	0		µs
Data setup time on SDA relative to SCL edge	tSUDAT	0.1		µs
Stop condition setup time on SCL	tSUSTO	0.1		µs
Bus free time between stop condition and start condition	tBUS	1		µs

There are two I²C commands for the user to access the humidity module:

Command	Description
‚Data Fetch‘ (DF)	Fetch the last measured value of Humidity / Temperature
‚Measuring Request‘ (MR)	Start a measuring cycle

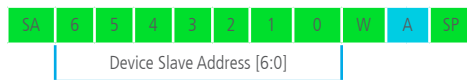
In the initial condition, the humidity module is in sleep mode to minimize the current consumption. A new measurement is carried out only after the command measuring request (MR) is received. Access to the status bits and measured values is made by the data fetch (DF) command. Valid data can be fetched only when a measurement cycle (ASIC conversion) is complete. User must wait for the measurement to complete before performing the DF. The status bit of the DF can be used to tell whether the data is valid or stale, but polling for the result must not be done before the time required for conversion has elapsed. The conversion time is between 60 and 100 milliseconds.



6.2 MR (Measurement Requests)

By a measurement request command, the sleep mode is terminated and the humidity module executes a measurement cycle. The measuring cycle begins with the temperature measurement, followed by humidity measurement, digital signal processing (linearizing, temperature compensation) and finally writes the processed measured values into the output register.

I²C MR - Measurement Request: Slave starts a measurement cycle



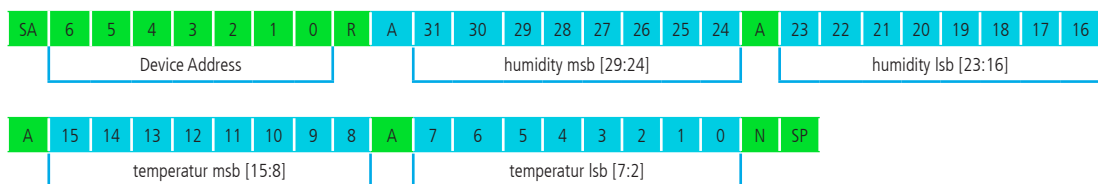
 Master	SA Start condition	A Acknowledge
 Slave (HYT)	W Write bit	N Not acknowledge
	R Read bit	SP Stop condition

6.3 DF (Data Fetch)

The data fetch command serves to read the output register. The DF command is sent by the master to the humidity module (slave) and begins with the 7 Bit slave address. The 8th bit is 1 (= read). The humidity module sends back an acknowledgement in case of correct addressing. The humidity and temperature value are encoded in two bytes each. If only the humidity value shall be read, the master can issue a stop condition after two bytes. The illustration below *PC DF - 2 Bytes: Slave returns only capacitance data to the master in 2 bytes* illustrates the transfer. The first two bits contain two status bit [31:30], which must be masked for the humidity value. The last two bit [1:0] are not used and must also be masked off.

In case of a failure, the slave issues not acknowledgement.

PC DF - 2 Bytes: Slave returns only capacitance data to the master in 2 bytes



 Master	SA Start condition	A Acknowledge
 Slave (HYT)	W Write bit	N Not acknowledge
	R Read bit	SP Stop condition



6.4 Scaling of measurement values

T_{raw} and RH_{raw} are the digital 16 bit values submitted by the sensor.

Humidity signal (2 bytes):

The first top bits are status bits with following relevance:

Bit 15: CMode Bit, if 1 – element is in command mode

Bit 14: Stale bit, if 1 – no new value has been created since the last reading.

To mask the 2 top status bits in a 16 bit value, it will be linked logically with 3FFF and AND. The remaining 14 bit represents the measured value. The masked value data now have to be scaled into physical measurement units:

Humidity values will be calculated as follows:

$$RH [\%] = (100 / (2^{14} - 1)) * RH_{raw}$$

0x0 complies with 0 %RH

0x3FFF complies with 100 %RH

$RH_{raw} = 0x0000$ to $0x3FFF$ (Hex) or 0 to 16383 (Dec)

Temperature signal (2 bytes):

The bits 15 to 2 represent the 14 bit measured value. Bit 1 and 0 are not used. The value data now have to be scaled into physical measurement units:

Temperature values will be calculated as follows:

$$T [^{\circ}C] = (165 / (2^{14} - 1)) * T_{raw} - 40$$

0x0 complies with -40 °C

0x3FFF complies with +125 °C

$T_{raw} = 0x0000$ to $0x3FFF$ (Hex) or 0 to 16383 (Dec)

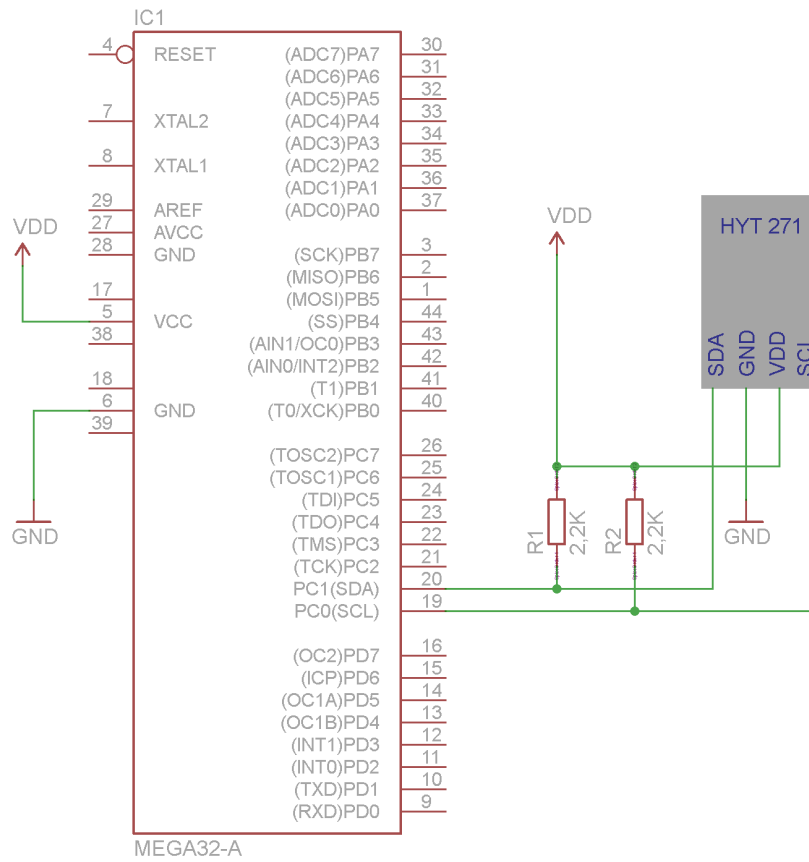
C-Code examples are available upon request.

Example:

	Byte 1	Byte 2	Byte 3	Byte 4
	31 dec	109 dec	96 dec	72 dec
bin	0001.1111	0110.1101	0110.0000	0100.1000
	Humidity 14 bit right-adjusted		Temperature 14 bit left-adjusted	
hex	1F6D		1812	
dec	8045 x 100/16383 =		6162 x 165/16383 - 40 =	
	49.1 %RH		22.06 °C	



6.5 I²C pull up resistor





7. I²C Address change

Code Examples can be found on our website, sort by „Software“ on: <https://www.ist-ag.com/en/downloads>

To change the I²C-address of the sensor module, the module must be switched into the Command-Mode. The switching is performed by sending the start-command-mode message over I²C-bus no later than 10 ms after Power-On reset. Each command-mode message is 4 byte long, like shown in table 1.

Table 1

S	6	5	4	3	2	1	0	W	A	7	6	5	4	3	2	1	0	A	7	6	5	4	3	2	1	0	A	7	6	5	4	3	2	1	0	A	P
S	0	1	0	1	0	0	0	0	A	C	C	C	C	C	C	C	C	A	D	D	D	D	D	D	D	D	A	D	D	D	D	D	D	D	D	A	P
Slave Address									Command Byte									Command Data [15:8]									Command Data [7:0]										

- Slave Address: 0x28 default value
- Command-Byte: 0xA0 start command-mode
- 0x1C read configurations parameter that includes the I²C-address
- 0x5C write configurations parameter that includes the I²C-address
- 0x80 end of command-mode, start normal-mode

At writing access both command data bytes contains the data, at reading access both data bytes must be set to 0x00. The response to the command-mode message can be read out by a Data-Fetch. The response time of the command-mode messages are 100 µs.

Table 2 shows the response to the start of the command-mode.

Table 2

S	6	5	4	3	2	1	0	R	A	7	6	5	4	3	2	1	0	N	P
S	0	1	0	1	0	0	0	0	A	S	S	D	D	D	D	R	R	N	P
Slave Address									Status			Diagnostics				Response			

- Status: 10_b command-mode
- 01_b stale
- Diagnostic: xxx1_b corrected EEPROM-error
- xx1x_b uncorrectable EEPROM-error
- x1xx_b RAM Parity error
- 1xxx_b configuration error
- Response: 00_b busy
- 01_b positive acknowledge
- 10_b negative acknowledge

Table 3 shows the response to the read out of the I²C-address.

Table 3

S	6	5	4	3	2	1	0	R	A	7	6	5	4	3	2	1	0	A	7	6	5	4	3	2	1	0	A	7	6	5	4	3	2	1	0	A	P
S	0	1	0	1	0	0	0	0	A	S	S	D	D	D	D	R	R	A	E	E	E	E	E	E	E	E	A	E	E	E	E	E	E	E	E	A	P
Slave Address									Status			Diagnostics				Response				EEPROM Data (15:8)									EEPROM Data (7:0)								



Status: see table 2
 Diagnostic: see table 2
 Response: see table 2
 EEPROM-Data: content of the memory

The response to the command byte 0x1C contains the I²C-address in bitposition 6:0, default value is 0101000b. The old I²C-address is valid until the module is in command-mode.

The following table shows a complete process of reading and writing back of the I²C-address.

Power – On Reset

S	0x50	A	0xA0	A	0x00	A	0x00	N	P	Start Command – Mode
S	0x51	A	0x81	N	P					Response (ACK)
S	0x50	A	0x1C	A	0x00	A	0x00	N	P	Read out Data Bytes with I ² C-address
S	0x51	A	0x81	A	Highbyte	A	Lowbyte	N	P	Response
Write the new address into the bits 6:0 of the lowbyte.										
S	0x50	A	0x5C	A	Highbyte	A	Lowbyte	N	P	Write back Data Bytes with I ² C-address
S	0x51	A	0x81	N	P					Response (ACK)
S	0x50	A	0x80	A	0x00	A	0x00	N	P	Start normaler mode

or alternatively Power – Off

The following table shows the I²C timing.

Command Byte	Third and Fourth Bytes	Description	Response Time ⁵⁵
8 Command Bits	16 Data Bits (Hex)		
00 _H to 1F _H	0000 _H	EEPROM Read of addresses 00 _H to 1F _H After this command has been sent and executed, a data fetch must be performed	100 µs
40 _H to 5F _H	YYYY _H (Y = data)	Write to EEPROM addresses 00 _H to 1F _H The 2 bytes of data will be written to the address specified in the 6 LSBs of the command byte	12 ms
80 _H	0000 _H	Start_NOM Ends Command Mode and transitions to Normal Operation Mode	Length of initial conversions depends on temperature and capacitance resolution settings and the capacitance „mult“ setting
A0 _H	0000 _H	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
B0 _H	0000 _H	Get revision Get the revision of the part. After this command has been sent and executed, a data fetch must be performed	100 µs



7.1 Step by Step - I²C Address Change

1. Power-on-reset
2. Within 10 ms, send command 0XA0 (start command mode) through I²C bus. The default 7 bit I²C address is 0x28. In I²C write mode, the bit "W" shall be 0

0x50	0xA0	0x00	0x00	Send Start-Command-Mode
0x51				Response fetch, the bit "R" is 1

If the response is not 0x81, then you did not enter the command mode successfully. If the sensor can be read out correctly, but entering command mode failed, please try to reduce your clock frequency to below 100kHz, and then repeat step 1) and 2).
3. First try to read the configuration parameters stored inside EEPROM. If entering command-mode is successful, the content can be read out successfully, otherwise start from step 1)

0x50	0X1C	0X00	0X00	Send read register 1C command. Register (1C) includes the I ² C address
0x51				Read out data bytes with I ² C address
4. If the response is not 0x81 0x00 0x28, then you did not read successfully
Change I²C address by sending the following command:

0x50	0x5C	0x00	0x31	Change I ² C address into 0x31
------	------	------	------	---

Repeat 3) to confirm whether the I²C address is successfully changed. If successful, the response is 0x81 0x00 and 0x31
5. Power-off, if 1), 2), 3) and 4) failed

8. Micro heater

HYT 223 contains a micro heater which allows for thermal reconditioning. In challenging atmospheres with VOC a reconditioning cycle is recommended. The intervals and duration depend on the application's environment. During reconditioning, the read-out values are not calibrated measurement data.

The heater and the sensor have different operation conditions which are listed in the table below.

	Humidity sensor	Heater
Operating voltage:	2.7 V to 5.5 V	8 - 9 V for regulated temperature
Operating voltage limit:	-0.3 V to 6 V	0 - 9 V
Current consumption:		< 250 mA
Current consumption (sleep):	< 1 μA	
Power consumption		< 720 mW
Resistance		~50 Ω

The GND connection of the heater is shared with the humidity sensor. For pin assignment please refer to chapter 2.6

Example for reconditioning setting:

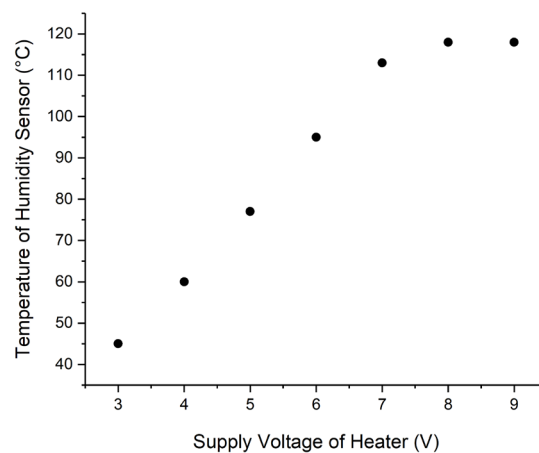
heat the module with 8 to 9 V and 700 mW power for 10 minutes every 24 hours.



The temperature regulation is set in a way that the humidity sensor reaches a maximum of 120° C. When this regulation is activated, withing the range of 8-9 V supply voltage, a constant temperature is reached.

If lower temperatures are needed, the supply voltage can be reduced. The temperature will no longer be regulated, but the heating can still be used. The exact temperature which is reached in your setup depends on the present gas flow and the mounting situation. For an estimation of the reached temperature at the humidity sensor please refer to the graph below.

The temperature reading of the modules does not give the temperature of the humidity sensor while heating. The temperature sensor is located at a slightly different position than the humidity sensor and the heater. Therefore, differences of up to 25 °C are completely normal while heating. Depending on the mounting situation and gas flow the difference in temperature can further increase during heating.



Temperature of the humidity sensor depending on the supply voltage of the heater while heating. These measurement points show the typical heating behaviour. The actual temperature depends on the mounting situation and gas flow.

9. Additional documents

Data sheet	Document name: DHHeatedHYT223_E
Software code examples:	https://www.ist-ag.com/en/downloads => Software

