Calibrated, Precise Humidity Sensor With I²C Interface

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Although relative humidity is a frequently measured parameter, the long-term stable, precise measurement with a capacitive polymer sensor results into some expenses. First of all, the technological conversion of the series calibration is not simple. From the developer point of view, the most preferable one to use is the complete sensor system, duly calibrated and fitted with a digital interface, which can provide fully processed measured values.
In the following article, such a combined Humidity and Temperature sensor has been described, which offers an optimum overall performance at an outstanding price performance ratio based on a new solution concept.

Simple applications in the area of building technology, household appliances and also in the area of air-conditioning systems, it is necessary that stringent requirements are put forward for a humidity sensor. For example, from a customer point of view, even a room air-conditioner has to also perform reliably for period of 10 years. For many applications, apart from relative humidity, the temperature also needs to be measured in order to compute further humidity parameters like Dew point or the Absolute humidity. At the same time, there are also price restrictions to consider so that the sensor can be used in a new product design, especially if it is with respect to a secondary measurement parameter.

State of the art technology

Monolithic integrated solutions are available from different manufacturers, which could not manage to capture the industrial market despite an attractive price. Problems come up, especially in a narrow Humidity/Temperature measuring range, including poor accuracy, an unstable behaviour around the measuring range limits and an unsatisfactory chemical resistance against contaminants. Further problems are the often not declared dew formation resistance, inadequate long-term stability and also failure during load spikes. Some competitor's products show an excessive temperature drift or sensitivity to light radiation. Moreover, regarding the digital I²C protocol and interface, often all points do not correspond to the standard.

As per current state of the art technology, the monolithic integrated solutions are not suitable for professional, industrial applications and high quality solutions in the field of micro-system technology are not being seen so far.

Problem definition

From processing technology point of view, it is well known that certain manufacturing steps of a polymer sensor cannot be carried out so easily on one silicon substrate. The special manufacturing steps necessary for a polymer sensor are not compatible with the CMOS process, otherwise the already processed semiconductor structure would get damaged.

In the already available monolithic solutions, accordingly there is always a compromise, because of which the specific, optimised characteristics of the discrete, capacitive polymer sensors on ceramic substrates cannot be achieved. Problems come up particularly with respect to long term stability, chemical stability and accuracy in the higher range and very deep humidity.

A further aspect is that the complexity of manufacturing steps for the sensor layer construction increases the production risks and hence the overall throughput of wafers gets so much affected that the cost of production increases and the economic manufacturing becomes unfavourable.

Pic 1: View of the sensor in TO 39 housing

Solution

The conclusion derived from it is logical: The goal should be to manufacture the polymer sensor with

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proven technology and with optimum layer construction, but to drastically reduce the surface through innovative manufacturing processes.

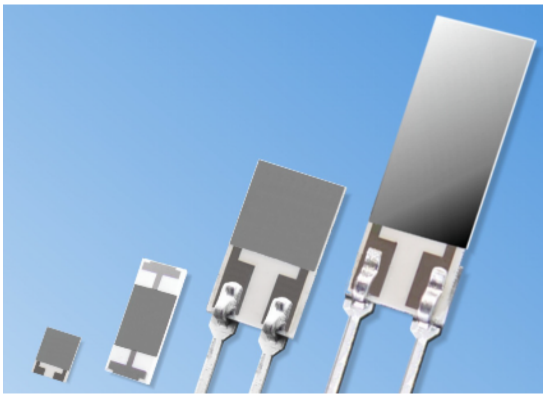
Such a miniaturised sensor is then combined with one matching ASIC, optimised as per the application, on a common carrier substrate. The connection technique is made economical with the help of standard technologies like printed thick layer substrate and wire bonding, and the connection to the target system over brazed SIL contact strips or standard TO sockets.

Such a solution offers the advantage of an optimum performance for the user over the entire application range - even at the lower range limit at around 0% rH and also at extreme high humidity and dew formation.

In addition, it also results in some positive side effects like lower manufacturing costs. Because of this, the individual components and ASIC as well as the sensor and carrier substrate can be tested before assembly. Hence, the throughput of the assembled micro-module becomes practically 100%. A substantial technological advantage for the user from this production process is the resulting optimum price performance ratio.

Optimised Polymer Sensor element

In the context of product development, the dimensions of applied polymer of the sensor element can be reduced to 2 x 2 mm. The used, modern high performance polymer on Polyamide base and the layer construction with the special implemented, porous shell electrode has been adopted from the design of the previous discrete solution. In the long run, the result achieved is that the sensor possesses the same outstanding characteristics with respect to chemical stability, dew formation resistance, long term stability, linearity and hysteresis, like the wired models which are well proven for years together.



Pic 2: Development history and size comparison

Functionality of the ASICs

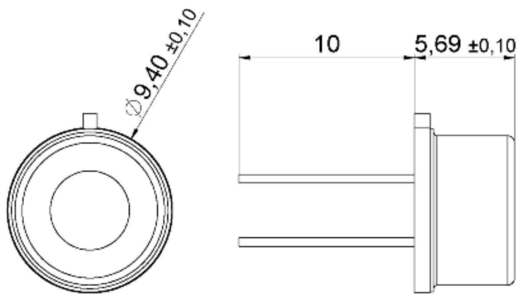
The applied ASIC carries out the entire signal processing of the physical parameters of humidity and temperature up to the stage of fully processed measured values, which are made available at the I²C compatible interface as digital values.

Hence, the temperature measurement takes place on-chip with high accuracy (better than 0.2 °C) and a resolution of 0.02 K.

The entire operating voltage range from 2.7 V to 5.5 V is supported. The average current consumption in the Standby mode is only around 1 µA and at measuring rate of 1 Hz, it is approximately 22 µA, making the sensor ideally suitable for battery-operated applications.

The ASIC consists of the internal module cap digital converter (14 bits), a polynomial signal processor, a coefficient memory for the calibrated values and the digital I²C-Interface.

The humidity measurement is similarly very accurate: The correction algorithms implemented in ASIC works by means of quadratic polynomials and ensures computational correction of offset, gain and linearity behaviour as well as the temperature drift. Hence, the application window is extremely wide from 0… 100% rH in the temperature range of -40… 125 °C with a maximum dew point of 80°C.



Pic 3: Dimensions

Construction and dimensions

The ASIC is mounted together with the polymer sensor element on a high quality, mechanically robust thick film ceramic carrier with dimensions of 5 x 5 mm. Due to the small thermal mass, a fast response behaviour is achieved. Both the sensor and the ASIC are bonded.

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HUMIDITY

FLOW

TEMPERATURE

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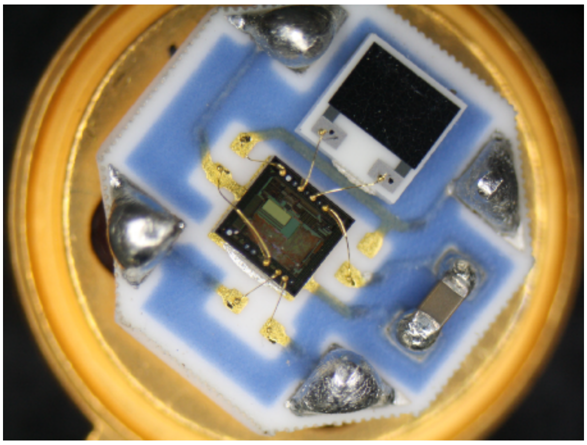
Up to the active layer of sensor element, the structure is environment resistant, protected with glass filled Globetop. SMD capacitors are integrated on the module, so that no further decoupling capacitors is needed.

The golden, solderable connection pins in the grid of 5.0 mm also accommodate commercial sockets, so that the humidity sensor can be termed as fully interchangeable, calibrated functional module.

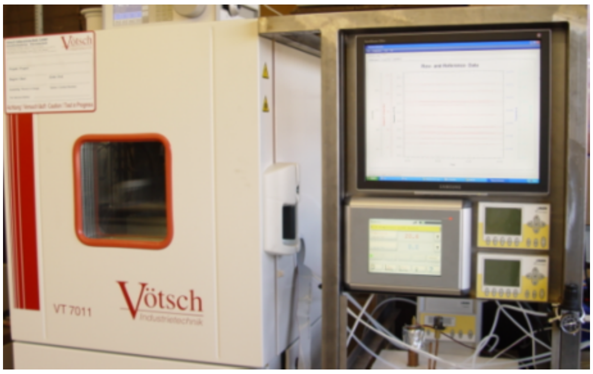
All materials are optimised for minimum water absorption, so that the microclimate in the environment is not disturbed. With the used materials, the application temperature range -40… 125 °C is well covered. All materials are RoHS conforming.



Pic 4: Construction and connection technique

Calibration

After manufacture, the module is precisely calibrated at 9 Humidity/Temperature points and also temperature compensated. It is not necessary to do any further adjustment or any further setting by the user. Both linearity error and temperature drift are already corrected computationally "On chip", because of which an outstanding accuracy is achieved over a wide range of application. The accuracy level of ±1.8 % rH and ±0.2 °C (at 20°C) exceeds all other available competitor's products available in the market. The application range is right from 0… 100% rH in the temperature range of – 40 … 125 °C.



Pic 5: Calibration unit

Digital I²C-Interface

At the I²C compatible interface, the fully processed physical dimensions of relative humidity and temperature are made available as numerical digital values. It is not necessary to do any further setting through the application software, which helps to save energy and system resources.

The digital interface fully corresponds to the I²C-Standard (up to 400 kHz clock rate) and can be used together with other I²C components connected at the same bus. In addition to the fixed allotted address, a second address can also be defined. Hence, simultaneous operation of up to 126 sensors is possible at the same I²C bus.

Areas of application

The innovative component is suitable for almost all meticulous applications in which the monolithic designs proved to be unsuitable and which were so far reserved for the discrete polymer sensors.

Building automation: The component covers the entire humidity measuring range from 0 to 100% rH and is dew formation resistant.

Domestic appliances: The component has been tested on the usual household chemicals used in kitchen and sanitary area (household cleaner, hair spray, etc.) and is long-term stable.

Drying technology: The high performance polymer has proved satisfactory in many industrial drying processes (tiles, insulating materials, metal chips, etc.).

Agriculture: The sensor is used successfully in agricultural drying plants (corn, grain, hop, wood). As protection from resin aerosols, a sinter filter is sufficient.

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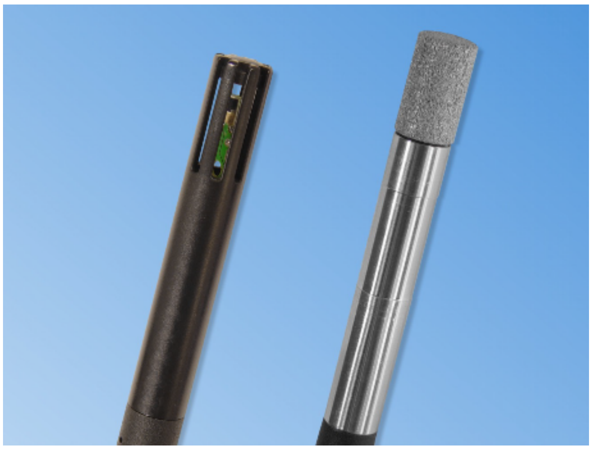
Compressed air systems: The sensor has been tested in plants up to 16 bar for the measurement of pressure dew point (cold and membrane dryer).

Medical technology: The sensor is sterilisable up to 130°C and 2 bar without getting a drift or failing due to such a hard treatment.

Project specific options

The ASIC has further characteristic features, which can be made available as a customised model (OEM):

- Instead of the digital I²C-Interface, an SPI-Interface is also possible. In this case, the connection is done through 5 Pins.
- The ASIC additionally also supports two quasi analog PDM outputs for temperature and relative humidity. Thus a quasi analogue output of the measured value is possible.
- Two optional switch outputs enable an additional usage as fixed point Hygrostat. A minimum and maximum value can be monitored independently as switch output.



Pic 6: Models in probe housing

Cost-Benefit Optimisation

By adapting to the qualitative requirements of the application and due to bulk manufacturing benefits, substantial saving potentials can be realized with large quantities. Custom low priced solutions can be manufactured on FR4 substrates.

Moreover, the geometry and mechanical dimensions of the module can be adapted to the customer requirements. Also designs with housing and with connection leads can be developed and manufactured as per the need of customer projects up to a complete humidity probe with connection leads.

Further cost optimization can be achieved as a result of reduction of the used calibration points in the case of alternative inclusion of statistical procedures. Under certain specifications, even an adjustment at only one humidity-temperature point may be required, with which a substantial shorter calibration time, and hence, a clear cost reduction may be achieved.

Conclusion

The HYT 939 and HYT 271 combine the advantages of a precise, capacitive humidity sensor with the high integration density and functionality of an ASIC.

The HYT 939 has a special TO39 housing while the HYT 271 package has SIL-connection pins with a pitch of 1.27 mm for compatibility with commercially available plug connectors.

The sensor is calibrated and delivers the processed measured values for temperature and relative humidity, which extremely simplifies the integration into systems.

In comparison to monolithic solutions, the high performance polymer of HYT 939 and HYT 271 offers an outstanding chemical resistance and excellent long term stability, even in critical operational areas and with high humidity. The sensor is dew formation resistant.

The bus based interface fully corresponds to the I²C standard up to 400 kHz clock frequency. Through addressing, up to 126 sensors can be operated in parallel at the same bus.

Because of the wide operating voltage range and small current consumption, the component is ideally suitable for battery operated applications.

In the context of customized projects, product characteristics can be adapted as per the application and system costs can be further optimised.

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