Innovative Humidity-Sensor Module

Precise and long term stable humidity module with ASIC´s

by Martin Friedrich

Off late, humidity measurement has also found entry into mass produced items like ventilation units, household appliances or automotive applications. For such products, normally fully integrated and calibrated sub-systems are required, which can result into a favourable overall system price on a standard interface.

The innovative humidity module combines most modern thin film sensor technology with flexible signal processing of an ASIC to arrive at an optimum price performance ratio. The modules measure relative humidity and also temperature, based on which further climate related data can also be determined e.g. dew point or absolute humidity.

A large number of hygrometers available in the market are targeted towards the consumer segment. Typical mass produced items are weather stations, living room hygrometer and radio alarm clock. The humidity sensors for such products are not normally dew resistant and within a short time span, the measuring accuracy is often lost.

In the last few years, the demand has rapidly increased for high quality, precise and long-term stable humidity probes in the lower price segment, due to demand hike from the field of "automotives" and "white goods". The expected product life cycle in these sections is at least 10 years, and in this time span, the humidity probe must operate within the specification limits without the need for re-calibration, irrespective of the content of polluting materials in the environment. Despite these high requirements of product quality, the market price for the calibrated "Humidity sub-system" is so low that practically only products manufactured through automation or monolithic solutions stand a chance in the market. In addition, the calibration should also be done automatically in big batches, since calibration costs mainly decide the product price due to long stabilisation time required for a multi-point adjustment.

Sensor element

Sensor is the key component and certainly decides the performance of the complete system. A good signal to noise ratio and a high nominal capacitance of the sensor simplifies the evaluation circuit and improves stability.

Principally, all reproducible errors like linearity and temperature drift can be mathematically corrected. Non-reproducible errors such as drift due to dew formation, or changes in the polymer structure over a period of time (aging) cannot be compensated and these effects result into a permanent error.

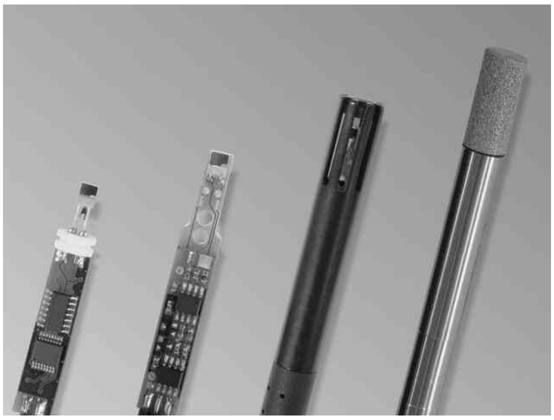

Fig 1: Humidity module as plug-in module or in housing with connection cable

In the last few years, various manufacturers of monolithic integrated solutions have not been able to make a dent in the automotive market, despite the attractive price. Reasons are as below:

- A limited humidity measuring range
- Limited operating temperature range on the higher side
- Inadequate long-term stability
- Lack of dew formation resistance
- Sensitive to light irradiation
- Poor signal to noise ratio
- Poor resistance against chemical contaminants
- Unfavourable mechanical adaptability
- No possibility to re-calibrate
- Special interfaces, no standard signal

As per present state of technology, monolithic integrated solutions are not suitable for industrial applications and high quality solutions are still not being considered with these components despite the new micro system technology.

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Among several options, the capacitive polymer humidity sensors are still superior for discrete assembly. Due to recent developments in layer construction and also introduction of innovative high performance polymer and high quality base substrate, such sensors are qualitatively much more stable than integrated monolithic solutions. Through optimised production methods and automated final inspection, such high quality sensor elements have also achieved a price range which is suitable for low cost applications in large quantities.

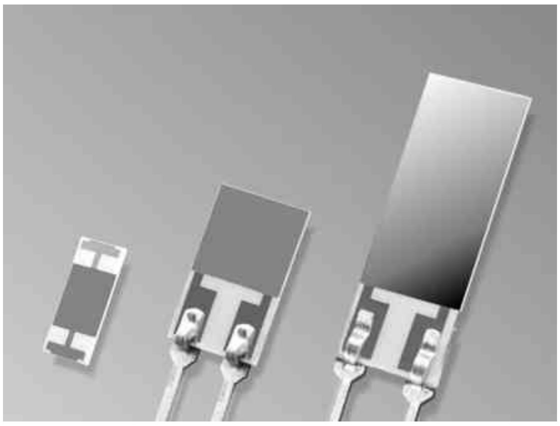

Fig 2: Size comparison between wired and SMD designs of capacitive polymer humidity sensor

The sensor elements are insensitive to large number of chemicals and solvents and also dew and temperature shock resistant. The application range covers the humidity temperature window up to 190°C at a maximum dew point of 80°C.

Especially important fact for cost reduction is that the sensor is available as an SMD-technology component conforming to RoHS, in order to save high labour cost of manual mounting. If one considers the fact that the temperature reaches around 250° at the point during SMD reflow soldering process, then the expectation is too high for the polymer in the sensor. Only modern polyimide based polymers can withstand such conditions without change in structure. Finally, one can conclude about its use in future applications due to the stability of sensors.

ASIC

The expected target price can be practically achieved only through an ASIC, to reduce the number of passive components as far as possible.

Polymer humidity sensor work with a nominal capacitance of approx. 120 pF and only 10 % increase. It means, that the capacitive converter should have resolution in the range of Femto-Farad.

All functions of humidity measuring system are integrated in the ASIC: In the front end, the capacitance of humidity sensor and resistance value of a PTC is converted into high resolution digital signal (14 bit). The downstream signal processing is done mathematically with the help of a micro-controller, integrated in the ASIC, which corrects the linearity error and also temperature drift of sensor element. The compensation algorithm is based on polynomials of third order, so that only the coefficients of correction function are stored in the integrated memory. The coefficient memory is comparatively small, so that a small chip surface is required, which further helps to reach a favourable system price.

The operating voltage of ASIC covers the entire range of 2.7 V to 36 V. The operating voltage beyond 5.5 V is also regulated with the integrated stabiliser and an external N-channel FET.

Another performance feature of the ASIC is the wide temperature range of -55 to 150°C, which is a pre-requisite for automotive applications. Extensive error detection algorithms are integrated in the ASIC to guarantee system security also under extreme working conditions. The chip has been certified and released for automotive applications.

Interface

The processed measured values are transmitted through one of the various type of interfaces. Practically all common µC interfaces are integrated in the ASIC:

The integrated D/A converter with 11 bit resolution has a built-in output amplifier which can produce both voltage signals (0..3/4/5 V) and current loop signals (4..20 mA). A ratiometric voltage output is also possible at the analog output with an operating voltage of 2.7 V to 5.5 V and alternatively absolute output voltage can also be obtained.

As far as digital interfaces are concerned, one I^2C-Interface, one SPI-interface and two PWM-outputs are supported. In addition, two optional switch outputs enable application as fixed point Hygrostat.

An ASIC-Variant with LIN-interface is under development.

Mechanical design

There are various type of requirements for housing and connection: normally a plastic housing is used in low cost applications, whereas for building instrumentation or industrial applications, stainless steel housings are required.

In most of the applications, the humidity probe is kept away from the controller; hence the electrical connection is done through a connecting lead.

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For many applications, filters are needed for improving the long-term stability. For applications in high humidity, special sealing arrangement is required for sensor head and the circuit casing must be moisture resistant.

Hence, during design of this new humidity module, these customer requirements have been taken into account and a flexible housing concept, to provide

housing items in "kit" form has been developed. All components, from protective cap to filter and up to the connection cable can be combined.

Of course, custom-made solutions can also be derived through a simple re-design of the standard variant. In addition, plug-in modules are also available without housing.

Calibration and reproducibility

The calibration of a humidity sensor module primarily determines its accuracy, the costs incurred and hence the price.

The calibration of sensor modules is done directly in gas flow in a so-called differential pressure humidity generator. Hence, better results are achieved with significantly shorter stabilisation time, than a static adjustment which is done by saturated salt solution. The procedure is based on vapour pressure saturation curve, and this is the primary method for exact determination of relative humidity. Moreover, the gas flow is measured at the exit with a dew point mirror: During calibration, double care is an absolute must, even if the product is for lower price segment.

The adjustment of module is done simultaneously by means of a multiplexer and in each lot, 128 modules are taken up for calibration with the help of a PC. The parameter set for correction-polynomial is transferred over a I^2C-interface and is loaded onto the EEPROM of ASIC.

The calibration software supports single point setting with statistical gain correction and also multipoint setting up to four calibration points. Accordingly, the result of correction function is either a straight line or a polynomial of second or third order.

The temperature compensation is done using statistical values, based on the typical design characteristics, represented by a mathematical model on which the exemplary specific calibration values are adapted.

Fig 3: Laboratory set-up of differential pressure humidity generators

Conclusion

Through development of innovative solutions, the product characteristics can be considerably improved and this can be done simultaneously with drastic reduction in system price.

Since functionality is based on a price optimised ASIC and software, the same hardware can be used for sensors from lower to medium price segment. The product differentiation is mainly based on the type of casing and the number of adjustment points considered during calibration.

With high integration density in the devices, automated production methods and calibration in large batch sizes, the labour cost component can be reduced so much that production is easily possible in Europe.

About the author

Martin Friedrich has been actively involved in the area of industrial instrumentation for over 15 years. His special contributions are development of physical and mathematical processes and algorithms for humidity measurement. He is managing director of the company HYGROSENS INSTRUMENTS GmbH situated in Löffingen.

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