



# Advanced Humidity Sensor-Design and Sensor-Solutions

Humidity measurement is nowadays crucial for most applications in the industry. The application range for humidity sensing is manifold: Industrial process control, food storage & refrigeration, test & measurement, home & building, medical & healthcare, automotive, are only a few examples where humidity measurement and control plays a vital role in our lives.

## Humidity Measurement Applications

Often, humidity needs to be carefully balanced. Imagine breathing air controllers in a medical environment (anesthesia), where only small variations in relative humidity content of the breathing air would result in nausea of the patient or even unfavorably impacts the anesthetic result.

Production of building materials often requires that a certain humidity profile is being followed carefully over time. Comparable small deviations could result in deterioration of material quality (yield) or reduced throughput (material embrittlement).

Certain applications have to avoid humidity at all, like high power transformers (dry insulation and cooling oil), or high power switches (inert gas humidity), while other applications have to maintain a certain minimum level of humidity like cheese factories.

The most critical tasks in humidity measurement are stable detection of proper humidity level at acceptable response time. Coverage of the full measurement range from 0 to 100 % rH thus is mandatory. Needless to say that detection linearity and response time should remain unchanged, even if operated under elevated conditions over years. Table 1 shows a compilation of critical requirements for humidity sensors versus different market environments.



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		Application																
		Automotive	Enerav / Transformer oil / High	Medical	Building Automation	Paper & Wood	Building Materials	Food Processing	Storage & Refrigeration	Cloth dryers	IT & Computing	Agriculture / Pta stable /	Heating Ventilation Air-	Test & Measurement	Snowmaking	Weather Forecasting	IST - P14 Sensor Series	IST - MK33 Sensor Series
Humidity Level	Remark																	
Very dry	Humidity warning																	
Dry	Drying																	
Medium	Humidity control																	
Humid	Humidifying																	
Very humid	Humidity guarantee																	
Response Time $t_{63}$ for 50 → 0 %rH																		
Less than 1 sec	Fast Air Stream																	
1-5 sec.	Fast Fan																	
5-10 sec.	Ventilated																	
10-30 sec.	Convection																	
More than 30sec.	Air Diffusion																	

Table 1: Humidity Sensor Markets Per Requirement

Temperature and environmental aspects of the individual application have significant impact to sensor lifetime requirements. Often, humidity sensors show their weaknesses if it comes to high or low temperatures, to temperature cycling or to elevated chemical sustainability. Table 2 shows the environmental requirements of the markets above.



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		Application													
Temperature Range	Remark	Automotive	Energy / Transformer oil / Medical	Building Automation	Paper & Wood	Building Materials	Food Processing	Storage & Refrigeration	Cloth drivers	IT & Computing	Agriculture / Pig stable / Heating Ventilation Air-Test & Measurement	Snowmaking	Weather Forecasting	IST - P14 Sensor Series	IST - MK33 Sensor Series
-80 deg C. ... -50 deg C	Upper atmosphere														
-50 deg C.... -25 deg C	Deep Freeze														
-25 deg C. 0 deg C	Winter														
0 deg C. 60 deg C	Normal														
60 deg C ...85 deg C	Elevated														
85 deg C ...100 deg C	Boiling														
100... deg C ... 125 deg C	Electronics limit														
125 deg C. 150 deg C	Extreme Dissipation														
150 deg C. 190 deg C	Active Heated														
Chemical compatibility															
Etching fluids & Reactive Gases	p.ex. H2SO4														
Weak Reactive Gases	p.ex. ETO, CF4														
Salts fog															
Strong solvents	p.ex. Acetone														
Solvents & Tap Water	p.ex. Hot Motor Oil														
Gaseous Agents	p.ex. NH3														
Alcohol & Inert Gases	p.ex. N2														

Table 2: Environmental Requirements per Sensor Market



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# Measurement Principles



While the humidity sensor market is comparably old, it has taken a long time for the industry to get away from the classic measurement principle of shear strain measurement.

Originally, this principle was used within mechanical devices measuring the well-known elongation properties of female hair under the influence of humidity.

Still today, this principle is used within highly integrated sensor modules, which try to calibrate out the inherent measurement errors due to ageing, drift and surface adhesion problems, by very sophisticated algorithms. These algorithms are using extensive expert data bases allowing to forecast the ageing process of the shear strain mass. This works for a certain period of time where these devices get rid of the drift automatically. Unfortunately the drift of the shear strain parameters is not very homogeneous in between production lots, and the lab-based acquisition of the required datasets is very time consuming. More critical is the fact that the shear strain properties of these materials show a rather unpredictable hysteresis over temperature (due to micro cracks in the surface adhesion zone) which makes the correction datasets void only after a few thermal cycles. However, with significant calibration efforts, it is possible to achieve simulation models that minimize the drift. Therefore, rapid temperature cycling is important in order to assess typical lifetime behavior of critical sensor parameters.

Other sensors are based upon the change in electrical resistivity of certain materials, observed under humidity intake from the surrounding air. This principle however suffers from extremely nonlinear transfer functions (namely exponential), significant hysteresis between high and low humidity (memory effects) and accompanying long-term drift. These sensors are thus often used in applications where information is needed like humidity (yes/no) and accuracy is not required (toys etc). The inherent drift makes their use difficult for any measurement application.

Electrolytic based sensors suffer less from the restrictions above but show instead a significant temperature dependent response time and are very susceptible for high humidity.

All these sensor types fail under dewing or even immersion into water.



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# Modern Capacitive Sensor Design



Today's state of the art humidity measurement sensors are all based upon polymeric capacitive principle which are produced only by a couple of companies.

The important success factors are high temperature range substrates (temperature shock resistance down to liquid nitrogen and up to boiling motor oil) in combination with a significant sensor surface area (more than 2 sq mm, in order to cut down bulk drift effects) and the use of drift free, heavy-duty polymers (for good chemical resistance)

For all polymers, as a rule of thumb, the chemical ruggedness is strongly coupled with the relative capability of humidity intake. The more humidity the polymer can soak, the steeper its transfer function will be, but then a higher susceptibility for chemical agents can be observed. Thus it is important to focus on polymers with a comparable flat transfer function in order to get a significant ruggedness against chemical agents.

## Market Success Factors

For a company with market leadership it is important to produce only capacitive humidity sensors of the 4<sup>th</sup> generation: this means absolute technology leadership in the fields of thin film technology and polymer design. Using state-of-the-art clean room technologies for deposition and structuring in combination with latest heavy-duty polymers and noble metals, it is possible today to produce thin film hybrids, geared to withstand even harshest environmental conditions in humidity measurement applications. Most customers in Agriculture, Food & Beverages, Industrial & Building Automation, Avionics, and Automobile industry value a long operating life and a reduced cost of ownership, as in-field replacement of sensors often is costly and may become a lengthy procedure. Instead of focusing to a steeper transfer function at cost of chemical reliability and sensor drift, it is important for the market leader to clearly target those customers with elevated reliability demands.

Even after direct immersion into most chemical agents, thin film humidity sensors from IST show negligible impact to their transfer function, whereas competitive products often already show complete sensor breakdown or at least fall short to their drift specification. Needless to say, that a quality house is in a position to provide the customers with outstanding variety of terminal configurations, to be extended even further in the future.



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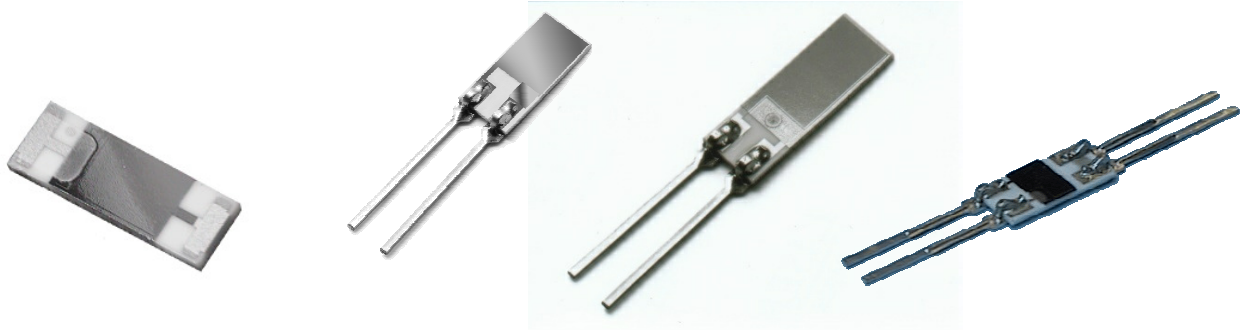


Fig. 1 Typical high volume humidity sensor designs from IST

From table 1 and 2 it can be seen that IST humidity sensors fulfill the technical requirements of a wide application range. They have been tested towards extreme environmental conditions as rapid temperature cycling towards  $-195\text{ }^{\circ}\text{C}$  up to  $+160\text{ }^{\circ}\text{C}$ , their resistance to aggressive agents and atmospheres is outstanding and in most applications outperforming competition.

Wire terminals of various length, SIL, DIL-pin-outs, as well as various SMD layouts for fully automated pick & place handlers cut down design-in times, a benefit for the R&D team, as well as granting high throughput with automated production lines. Custom designs with short lead times, e.g. with integration of other sensor and heater elements to one chip for better thermal coupling or with design of complete sensor arrays and subsystems, are other features we may offer you to offer advanced solutions for your applications.



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# Summary and Conclusion



The humidity sensors from IST AG, Switzerland fulfill the requirements above in an outstanding manner. The sensor family covers all, the mass-market applications as well as the high precision sensor applications. High volume production with stringent quality assurance and closed loop in-process control help to achieve an excellent performance to cost ratio and minimize cost of ownership over the full product life. The recently introduced analog modules (LinPicco™ series) present another contribution to customers, who have no own in-house electronic development and require a readymade plug and play device which can be easily connected to existing valve controllers or display equipment in a very cost effective manner.



Frank Dittrich works for IST AG Switzerland as Business Director Humidity Sensors. After studying physics, he acquired his experience in R&D at Siemens and Epcos, from 1985 till 1990. Since then, he worked in marketing and sales at major international electronics manufacturers, where he successfully managed several business fields in sensorics, telecom, test & measurement, and chip manufacturing.



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