85°C/85% RH Accelerated Life Test Impact on Humidity Sensors

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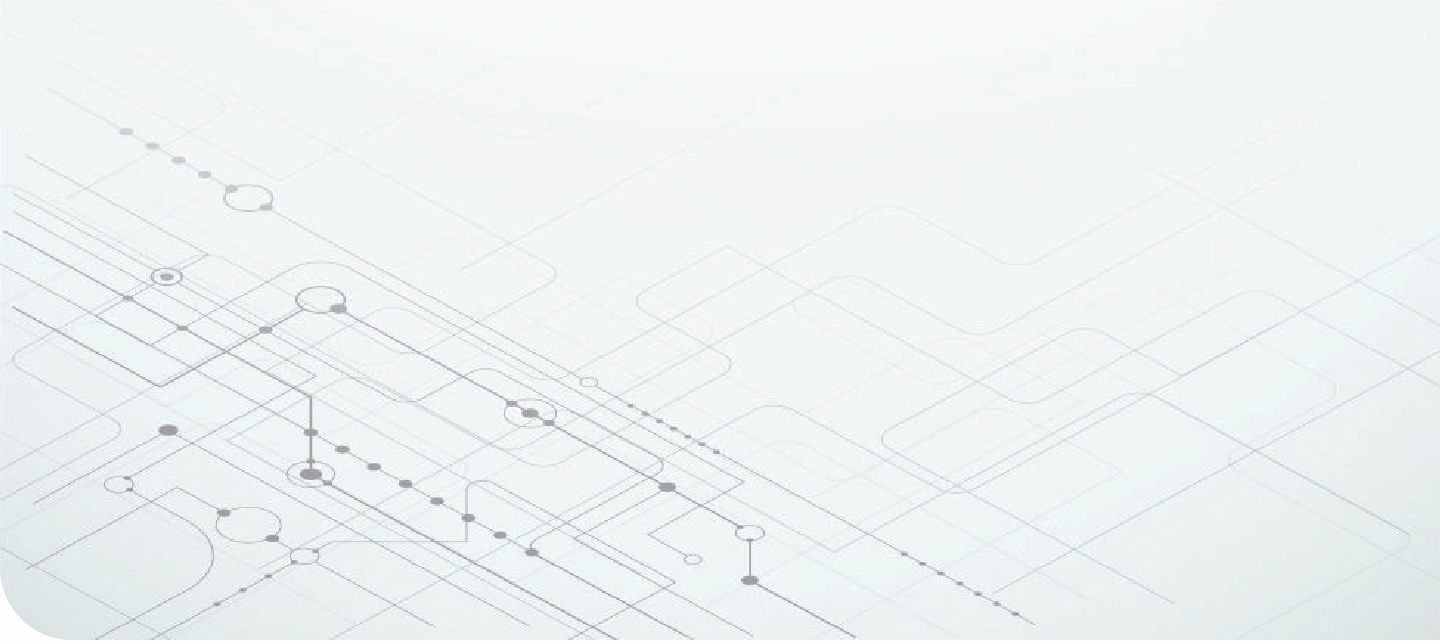

This white paper explores the 85°C/85% RH accelerated life test, its impact on RH sensors, and ultimately how to address conflicts when the same design needs both 85°C/85% tests and RH sensors.

Consumers expect their electronic systems to last for a specific period of time, either because they have historically, or because the manufacturer provided a specific lifetime warranty. Enabling a system to operate beyond these expectations gives consumers confidence in the product and its manufacturer, and can engender brand loyalty. In products such as heating, ventilation and air-conditioning systems or vehicles, consumers expect product lifetimes to extend beyond 10 years, a phenomenon that is ultimately putting pressure on system developers to ensure reliable designs – normally through extended testing.

The need for improved reliability of systems has also driven adoption of relative humidity (RH) sensors that provide information about the moisture content in the air. Moisture in the environment can create short circuits between electrical components, influence other components such as CO2 or pressure sensors, or can simply change the efficiency of systems designed to control air quality and temperature. The most common types of humidity sensors leverage a polymer to interact chemically with moisture in the air, and then quantify the moisture absorption based on a resistance or capacitance value. While these types of RH sensors are ultimately effective at the task of evaluating moisture content in a system, this chemical interaction with the environment leads to unique challenges compared to other components, especially when it comes to accelerated life testing.

Introduction to 85°C/85% relative humidity testing

Accelerated life tests, or tests that stress devices to accelerate fail mechanisms, help evaluate design behaviors during the electronic system development process, as illustrated in **Figure 1**. Accelerated life testing is important in products or systems that have long life cycles, because studying the behavior for the duration of that lifetime is not usually practical or feasible.

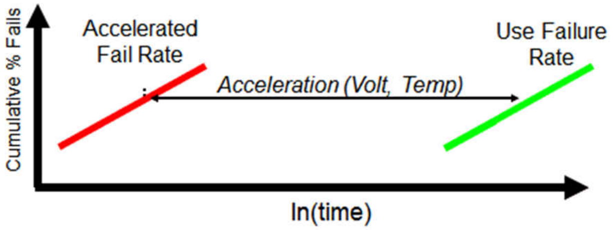

Figure 1. *Cumulative Percentage Fails in Time, Driven by the Acceleration of Factors such as Voltage or Temperature*

Two such tests – defined by Joint Electron Device Engineering Council (JEDEC) JESD22-A110 and JESD22-A101 standards, respectively – are the biased highly accelerated temperature and humidity stress test (BHAST) and the steady-state temperature humidity bias (THB) life test. These tests are known as 85°C/85% RH tests or 85/85 tests, meaning that the testing exceeds 85°C and 85% RH at the same time.

A BHAST requires 96 hours of electrical biasing while maintaining 130°C and 85% RH, in addition to a vapor pressure of 33.5 PSIA with the goal of accelerating corrosion within the device. In semiconductors, the BHAST test helps ensure that devices will continue operating electrically over extended product life cycles, despite exposure to humid environments, by accelerating the penetration of moisture into the package and die surface.

A THB life test is very similar, with the exclusion of pressure. The stress usually activates the same failure mechanism as a BHAST but with a lower acceleration factor; thus, units are subjected to a longer stress time of 1,000 hours at 85°C and 85% RH.

BHAST and THB tests can be equally useful in system testing. In a chip these accelerated life tests can simulate moisture ingress into a plastic package. In a full system the printed circuit board, connections and other materials can also be affected by humidity in the air over time. [KA1]

The difference between stress testing and overstress testing

Stress tests are vital to RH sensor reliability, as the results of a stress test can predict the longevity of a RH sensor under harsh environmental conditions; however, developers using humidity sensors in an application should consider the special **storage and handling guidelines.**

As shown in **Figure 2**, RH sensors have an open cavity that exposes a polymer to the air, enabling a chemical reaction with which it is possible to calculate the RH of the environment. Exposed polymers can be affected by extreme conditions (those exceeding data sheet specifications) including 85°C/85%, leading to shifts in RH measurements.

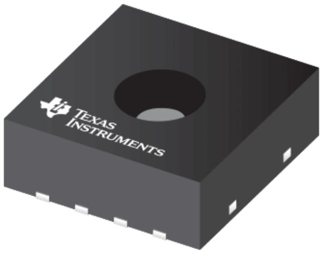

Figure 2. *HDC3020 Integrated Humidity and Temperature Sensor*

If the goal is to ensure that the system is still functionally operational, this testing may be OK – in fact, this is the expectation when running BHAST at the chip level. But, if data-sheet accuracy parameters need to remain within specifications after stress testing beyond data-sheet conditions, system developers may have a problem. A stress test of an RH sensor by definition involves selecting RH percentages and temperatures that can represent expected sensor performance in the field, even under harsh but realistic environmental conditions. Selecting RH percentages and temperatures that are beyond data-sheet specifications cannot serve as a reliable predictor of sensor performance in the field.

Figure 3 illustrates a meaningful approach to stressing a humidity sensor. The graph shows the **world record temperature for dew point** (35°C/95°F), which represents the largest known amount of moisture (100% RH) to have been held in the earth's air (42.0711 mmHg). 85°C and 85% RH would translate to a dew point of 81°C, which is far beyond what is possible in the Earth's atmosphere. Assuming constant air moisture, increasing the temperature enables a calculation of theoretical RH. For example, in **Figure 3**, at 85°C the RH is only 9.7%. Test points of temperature and RH exceeding those in **Figure 3** are overstressing the sensor and do not represent expected sensor performance in possible field stress scenarios, raising false alarms about sensor quality and performance.

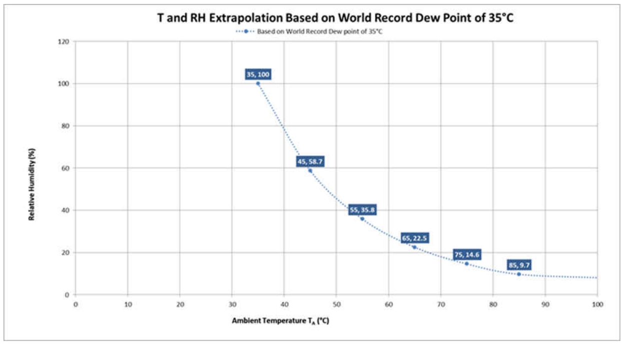

Figure 3. *Extrapolation of Temperature and RH Based on the World-Record Dew Point*

As the surface temperature increases, so does atmospheric humidity. Those wanting to account for global warming over time could use a guard band, as shown in **Figure 4**. The saturated vapor pressure increases approximately 7% per 1°C of warming.

Figure 4 shows a hypothetical dew-point extrapolation at 40°C and 50°C, in addition to the measured dew-point record of 35°C. Note that at 85°C, as well as other high temperatures, the RH is still very low.

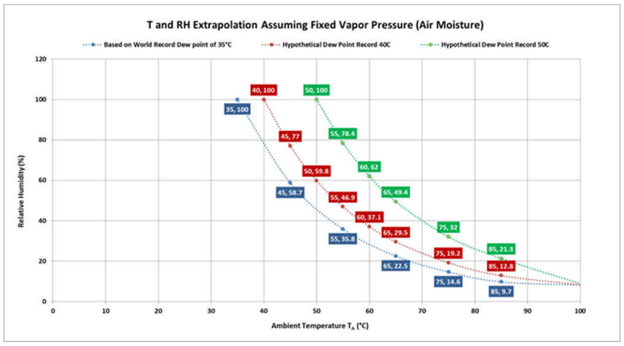

Figure 4. *Further Extrapolating Temperature and RH With a Guard Band to Account for Global Warming*

Enabling accelerated life testing in systems with a relative humidity sensor

Despite 85°C/85% being an overstress condition for polymer-based humidity sensors, it may still be required for some systems. Four approaches can be used if attempting to run 85°C/85% testing on a system involving a polymer-based RH sensor:

- Run the system test, but exclude the humidity sensor results – these devices functionally passed the silicon qualification (an example of these qualification tests can be found on the Texas Instruments quality and reliability page). You can populate humidity sensor results afterwords, or exclude them from evaluation.
- Understand and accept that 85°C/85% testing will lead to a shift in sensor accuracy – it is possible to characterize this shift in accuracy with testing, but do not consider accuracy results as a pass/fail criterion for the test, as lifetime operation within data-sheet recommended operating conditions will not lead to such results.
- Choose a humidity sensor specifically designed to minimize shifts after stress conditions – this includes the HDC3020 family of integrated humidity and temperature sensors.
- Attempt to recover sensor performance, after 85°C/85% testing, by leveraging the heater within the device to correct for errors caused by the overstress conditions.

Conclusion

System reliability requirements in automotive and industrial systems drove the development of accelerated life tests to enable early analysis of potential field failures. 85°C/85% accelerated life testing helps identify mechanical failures caused by corrosion that can develop as a result of exposure to humid conditions. The conditions of the 85°C/85% test exceed RH sensor recommended operating conditions and represent an overstress test that can lead to shifts in sensor accuracy. The shift from specification should not be concerning to system developers, as the conditions of the test are not possible given the current world-record dew point and atmospheric conditions.

Those who need to perform 85°C/85% tests for a specific application where an RH sensor is present should consider approaches to avoid stress to the sensor, accept the expected performance change, **select specialized devices** optimized for minimal accuracy shifts from stress, or be prepared to adjust for potential shifts with a ***HDC3 Silicon User's Guide*** or in software.

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