Ensuring System Accuracy Throughout the Years

Introduction

In this 21st century environment, we change gadgets every year and expect them to work correctly, even if they don't last all that long. They usually only survive until the next revision comes out, but that seems to be acceptable to most people. In contrast, there are many applications, such as field sensors, that demand high accuracy over a long period of time. A quick replacement for these devices would usually be unreasonable, and many times, impossible.

Within the hostile environment of a field sensor, a key device in the electrical systems that monitor and measure oil, gas, pressure and/or temperature is the seemingly insignificant voltage reference. The role of the voltage reference in these systems is to be the analog gatekeeper by maintaining an absolute point of reference for all measurements and calculations. This can be quite a challenge given the extreme operating conditions experienced by these systems (Figure 1).

Figure 1. High Mountain Weather Station

In this article, we will address not only the impact of two critical environmental variables, relative humidity (RH) and long-term drift (LTD) over time, but on the voltage reference gatekeeper and a winning solution that makes these variables a "non-issue".

The Voltage Reference Gatekeeper

At its root, system accuracy depends on voltage reference devices. For instance, the system's analog and digital converters use reference voltages to produce their digital results where the voltage reference value is an integral part of the output digital word (Figure 2).

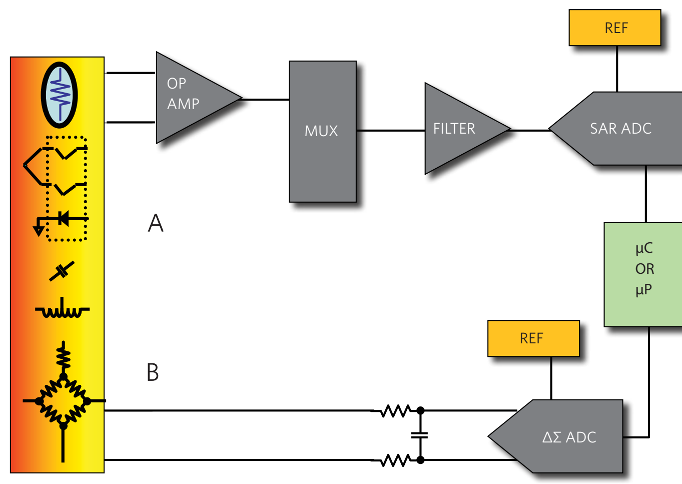

Figure 2. The SAR ADC Signal Path (A) and ΔΣ ADC Signal Path (B) Both Require Voltage References (REF) in the Circuit

In Figure 2, the left column shows a few of the more popular sensors. These signals can proceed through the (A) path, which finishes with the successive-approximation, analog-to-digital converter (SAR ADC) or the (B) path which finishes with a delta-sigma analog-to-digital converter (ΔΣ ADC). Both converters require a precision voltage reference (REF) to complete their conversion.

In signal path (A) with the SAR ADC and in signal path (B) with the ΔΣ ADC, the converter's LSB size is equal to:

$$LSB = \frac{V_{ref}}{2^N} \qquad \text{(Eq. 1)}$$

where LSB = Least Significant Bit

V_{ref} = Voltage reference voltage

N = Number of ADC bits

From Equation 1, it is clear that the voltage reference has a direct influence on the accuracy of the converter's system.

Humidity and Drift vs. Time

In field sensor applications, the electronics can experience large humidity excursions over time. As an example, the RH at the Mount Everest base camp can range from a maximum of 98% down to 20% throughout the year. This is equivalent to an RH delta of 78%. With systems in this environment, it is essential to guarantee equipment accuracy.

The pathway to this guarantee is to utilize the most stable voltage reference. By reviewing the voltage reference alone, one can predict the stability of the system over time.

Plastic Voltage Reference Performance

The following humidity chamber test results show the voltage accuracy of two groups of powered voltage references with RH, drift and elapsed time as variables.

Figure 3 shows the environmental conditions during a humidity chamber test. The grey line shows a relatively steady temperature at approximately +26.5°C and the blue line shows the RH over time. The chamber humidity changes from 45% to 28% starting at approximately the 600-hour mark.

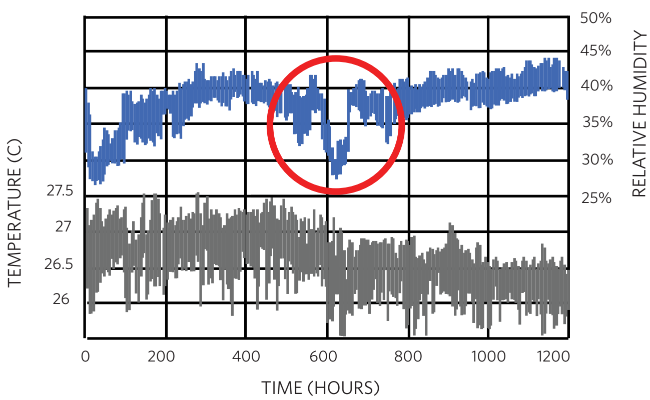

Figure 3. Chamber Relative Humidity Swings Between 28% and 45%

Figure 4 shows the accuracy variation of the first group of voltage references under test.

Humidity susceptibility is the absolute value of the degree of the voltage reference's accuracy change to the applied RH change. The calculated humidity susceptibility is equal to the delta change in accuracy divided by the delta change in RH.

For the test group in Figure 4, the variation in accuracy is approximately 13ppm during the 600 to 700-hour timeframe, which can be calculated as 13ppm/17% = 0.765ppm/%.

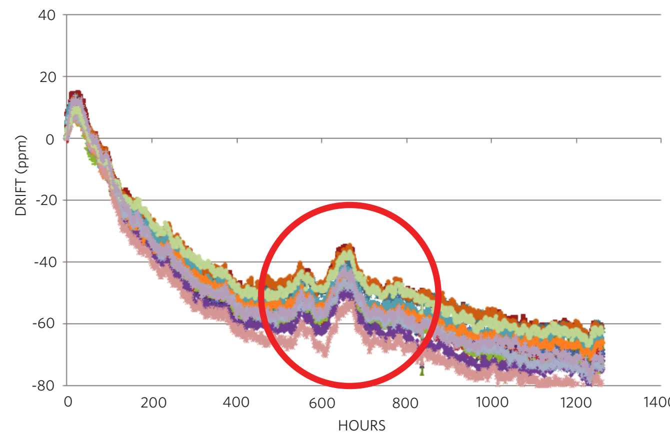

Figure 4. Sixteen SOT23 plastic MAX6070 Test Results a Voltage References in Plastic Package

Once the RH returns to 45%, the voltage reference accuracy continues to follow the original drift error tendency to decrease over time.

The total change at 1300 hours is approximately 75ppm. Over this period, the average accuracy change is approximately 75ppm/1300 hours = 5.8% (ppm/hour).

In this environment, the 24-bit converter and 2.5V reference will have a full-scale error during the humidity excursion of ~109 LSB.

This test illustrates the impact of a 17% RH delta. At Mount Everest's base there is an annual 78% RH delta. Under the Mount Everest base conditions, the RH changes would cause a full-scale error of ~500 LSB.

Ceramic Performance

Figure 5 shows the accuracy variation of the second group of references in a hermitically sealed ceramic package tested under the same conditions.

There appears to be a slight variation in accuracy during the 600 to 700-hour timeframe, but nothing significant. For this test group, the humidity susceptibility is extremely small. In other words, for every 1% change in RH, the effect on the voltage reference accuracy will be very small.

Once the RH returns to 45%, the voltage reference accuracy continues to be unwavering. There is basically no change over the entire 1300 hours. This level of low drift is highly desirable for many different systems that need to run longer than 10 or 15 years.

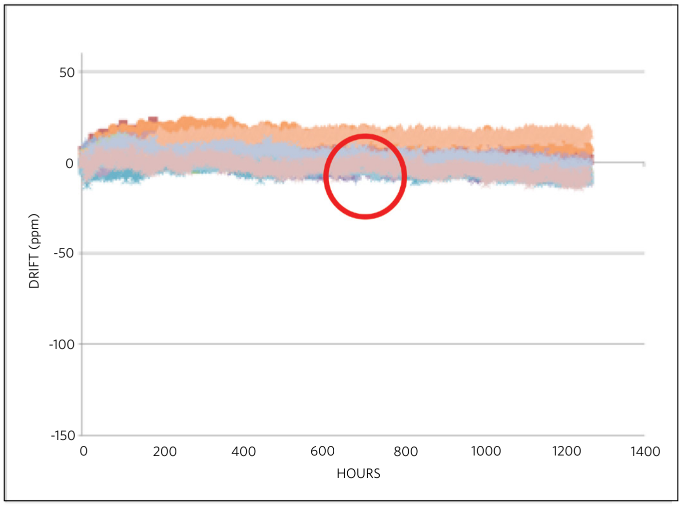

Figure 5. Sixteen MAX6079 voltage reference test Results for a voltage reverence in Ceramic Packages

Accuracy with Ceramic

The voltage reference in a hermetically sealed ceramic package option offers a high-accuracy solution that is appropriate for field sensor applications. The high-accuracy factors manifest themselves in terms of accuracy, long-term stability, and extremely low humidity susceptibility.

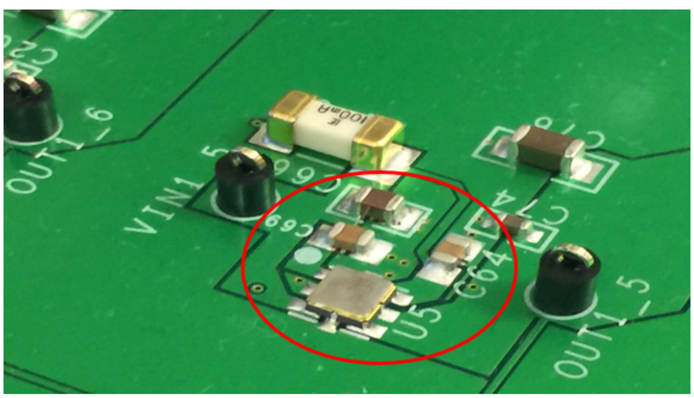

Figure 6. Voltage Reference (U5) in a Ceramic Package

The ceramic voltage reference (Figure 6) serves the purpose of being dependable, even when exposed to RH over long periods of time. The hermeticity of the ceramic package creates the perfect humidity shield with an excellent temperature coefficient (6ppm/°C, 25ppm/°C), low noise ($5\mu V_{RMS}$, $64\mu V_{RMS}$), high accuracy (±0.04%, 0.1%), and low supply current (200µA, ~70µA) specifications.

Winning Specifications

Field sensor applications demand high accuracy over long periods of time. Pressure and temperature measurement systems typically exist in environments that require reliable voltage references to sustain measurement consistency.

Voltage references in these application systems must meet tight specifications to maintain an absolute point of reference for all measurements and calculations. Tests prove that hermetically sealed ceramic packages perform with excellent humidity susceptibility and negligible long-term drift, two variables that make them an excellent choice for applications that require high accuracy over a long period of time.

Glossary

RH: Relative humidity

SAR ADC: Successive-approximation, analog-to-digital converter

ΔΣ ADC: Delta-sigma analog-to-digital converter

REF: Series voltage reference

LSB: Least significant bit

Learn more:

MAX6079 Low-Noise Precision Ceramic Voltage Reference

MAX6070 Low-Noise, High-Precision Series Voltage Reference

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