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When is good enough good enough?

If you are having difficulty making product-selection decisions in a consumer circuit, such as the temperature-sensor circuit in **Figure 1**, you can quickly solve this problem by choosing the absolute best performing parts for each socket. Is this statement true or false? Using this type of logic may give you a confident feeling that your circuit will work correctly the first time. However, following such logic goes only so far when you try to justify the cost-versus-performance factors of the products you are using.

In **Figure 1**, note that a 12-bit converter is at the end of the signal chain. So, are the highest performance analog products in front of the ADC appropriate? How do you determine which products are good enough for your system? Avoiding production-floor notifications or field failures may be your definition of "good enough."

Instead of choosing the best products, you can use the RSS (root-sum-square) algebraic approach. One criterion is to keep the signal within the dynamic range of the full-scale range of the ADC. The product characteristics that influence the extent of the dynamic range are the system's cumulative offset and gain errors.

As an example, assume that the maximum offset error of IC_1 and IC_2 is 0.5 mV. The offset error of the ADC is ±1 LSB or ±1.22 mV. (The full-scale range of the ADC is 5V.) The gain error of both the sensor cell and the IC_1 amplifier configuration depends on the ±1% maximum resistor tolerances as well as on a maximum sensor-resistor tolerance of ±2%. The ADC's contributed gain error is 0.098% or equals 4.9 mV maximum at full scale.

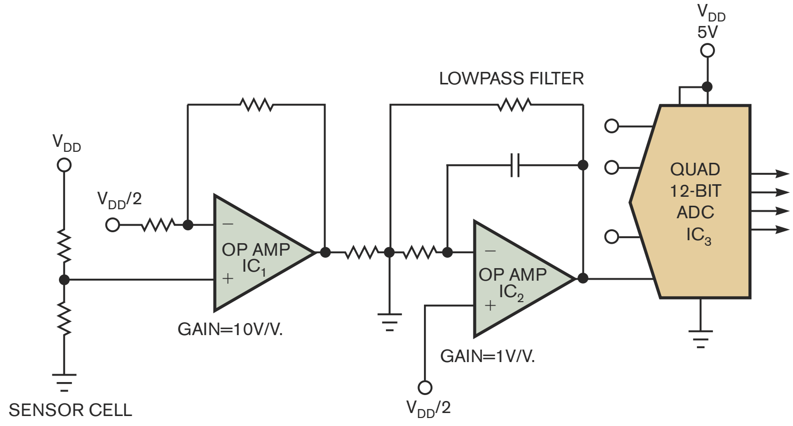

Figure 1 In this typical 12-bit temperature-sensing circuit for consumer applications, the gain of IC_1 is 10V/V, and the gain of IC_2 is 1V/V.

To determine the dynamic-range limitations of the circuit, if you combine all of these terms, you would calculate the combined RSS value of offset and gain, bringing these errors to the ADC's input. With the RSS formula, you take the square root of the sum of the squares of several terms that are statistically independent. You cannot use an RSS formula with entities that have correlated variations that are not statistically independent.

For instance, the worst-case sensor-resistive offset error would be ±94 mV×10V/V. The contribution of the amplifier-gain stage, IC_1, is ±500 μV×10, the filter-stage (IC_2) offset error is ±500 μV, and the ADC (IC_3) offset error is ±1.22 mV. The cumulative possible offset error at the ADC's input is $\sqrt{(\text{sensor}^2+IC_1^2+IC_2^2+IC_3^2)}=940$ mV. This calculation illustrates that the sensor cell contributes the most error with little impact from the amplifiers or the ADC. Using the same logic, you would use the RSS formula to determine gain-error contribution that limits the dynamic range from the four stages in this circuit.

So, during your first consumer-product-selection attempt, you can use RSS calculations. These calculations can assist you in making logical and economical product decisions. Once you take this first step, make sure you use the same evaluation technique in your manufacturing process to quantify the effects of the processes—such as solder reflow—that you impose on these devices and the end-of-life effects due to environmental exposures.**EDN**

REFERENCE

1 Sandler, Steven M, "A Comparison of Tolerance Analysis Methods," AEi Systems LLC, 1998, www.ema-eda.com/products/other/articles/Tolerance_Methods.pdf.

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