



BY BONNIE BAKER



ADC voltage-reference errors impact full-scale conversions

SAR (successive-approximation-register) analog-to-digital references have more influence on conversion accuracy than you may initially think. **Figure 1** shows the transfer function of an ideal 3-bit ADC and the same converter with gain error. The transfer function of an ADC is equal to:

$$D_{\text{CODE}} = (V_{\text{IN}} - V_{\text{OS}}) \left(\frac{2^N}{V_{\text{REF}} - V_{\text{GE}}} \right),$$

where D_{CODE} is the digital-output code, V_{IN} is the input voltage to the converter, V_{OS} is the converter's offset voltage, V_{REF} is the reference voltage applied to the converter, N is the number of ADC bits or the ADC resolution, and V_{GE} is the combined ADC-gain error, reference-output-voltage error, and reference-voltage noise.

It is easy to see how the voltage reference's specified value affects the ADC's absolute accuracy. For high-resolution converters, the reference-offset error

is usually greater than the ADC-offset error, particularly over temperature. You will also notice from the transfer function that the reference errors have more influence on the converter results with higher input voltages.

You can reduce the ADC and reference-source errors with a ratiometric design. This scenario may require additional devices in the circuit or a processor/microcontroller-calibration algorithm. Remember that calibration algorithms require gain and offset characterization for each circuit.

The reference's noise error is a different matter. It affects the SNR (sig-

nal-to-noise ratio) and the THD (total harmonic distortion) of a conversion. The reference noise impacts the converter's SNR and THD at higher ADC input voltages (**Figure 2**).

If the converter lacks an internal buffer at the reference pin, you will notice incoming or outgoing current spikes. The converter uses these currents during the conversion cycle to charge internal capacitors. This knowledge may motivate you to insert a low-noise amplifier between the external reference and the ADC.

Don't try to test your ADC with an input voltage of 0V or ground. If you hope to see the effects of your voltage-reference source on your conversions, try to use a dc full-scale input and then a signal input that will help you look at the system's frequency response (**Reference 1**).**EDN**

REFERENCE

1 Oljaca, Miro and Bill Klein, "Improved Voltage Reference Circuits Maximize Converter Performance," Texas Instruments Webinar on Demand, www.techonline.com/learning/webinar/201307002.

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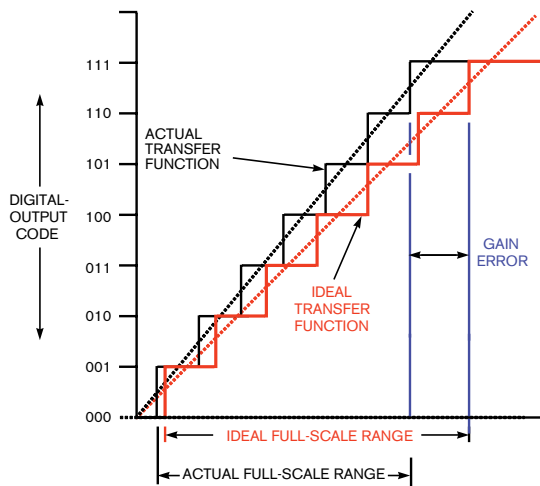


Figure 1 Gain error causes the transfer function of an ADC to rotate around the digital-input code of zero.

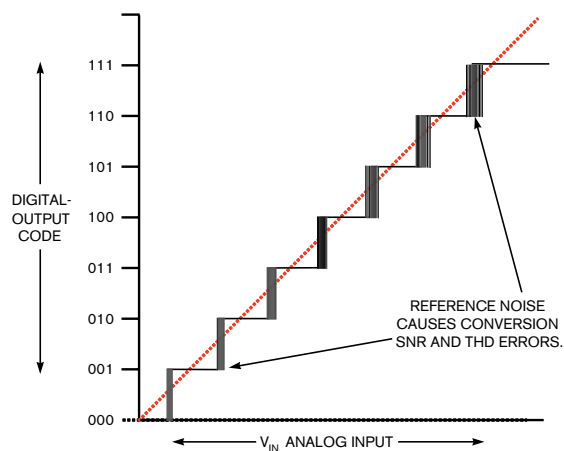


Figure 2 The voltage-reference noise of the ADC grows when output digital codes increase.