CHECKING A/D CONVERTER LINEARITY
Without a Precision Reference. Statistical Technique Finds Missing Codes Quickly

by Dr. D. Philip Burton

The linearity of an analog-to-digital converter is usually measured by calibrating the ADC against a d/a converter that is at least 2 bits more accurate than the device under test.[1] For example, a 10-bit ADC should be calibrated against (at least) a 12-bit converter. However, a precision DAC may not always be available for the purpose of calibration; even if one is available, it may be difficult to instrument a measuring circuit with the necessary accuracy. The technique described here (which has been described elsewhere[2,3]) provides a simple way of measuring the linearity of a/d converters without using a precision dc reference signal.

Figure 1 shows the basic circuit. A waveform generator feeds a free-running low-frequency waveform into the ADC, which is connected to perform repeated conversions. The results of each conversion are fed into the microcomputer, which makes a record of the number of times each binary code appears in the output of the ADC. In this way, based on the number of "hits", a probability-density function can be built up for each of the 2^n binary codes.

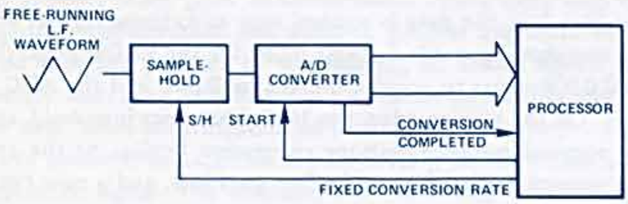

Figure 1. Basic scheme for statistical linearity testing.

If a perfect a/d converter is used, and if a large number of samples are taken, the number of hits for all binary codes should correspond to the number expected for probability-density function of the input signal. In practice, it is necessary to restrict the number of samples so as to keep the calibration time fairly short; this, of course, introduces statistical errors due to finite sample size.

Generally, it is acceptable to run a calibration until the maximum number of hits for any given code reaches about 50. Then, the number of hits for each code may be displayed as a bar chart or in the form of an analog plot as shown in Figure 2. An a/d converter with missing codes will show up by having no hits at those codes. Since a complete listing and analysis of the desired probability-density function is time-consuming, it is perhaps better to use the microcomputer to scan through the results and output only the following information:

1) Mean number of hits

2) The three highest hits and the values for eight places each side of those codes

3) The three lowest hits and the values for eight places each side of those codes.

Clearly, if each code has had several hits, there are no missing codes, and the converter is probably performing with the required accuracy.

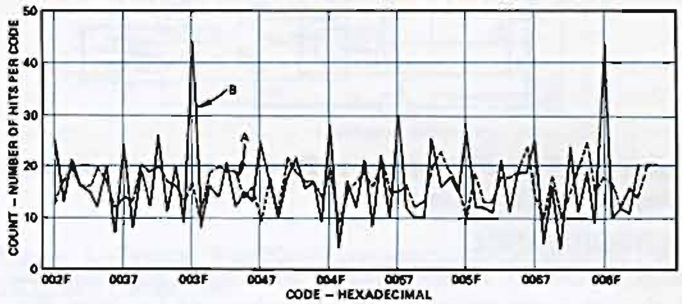

Figure 2. A portion of the probability density function of two different a/d converters sampling a triangular wave.

The input signal can be any signal whose p.d.f. is known; sinusoids, filtered noise, and triangular waves have been suggested. For most ADC's with conversion times of 5μs or more, the triangular wave is the best choice, since its p.d.f. is a horizontal line; this makes analysis of the results relatively easy. It is best to use a triangular wave which has extreme values just outside of the a/d converter's range. This will guarantee coverage of the full range but will produce undue concentrations of hits at the all-0's and all-1's binary codes; these extreme values may be discounted.

In Figure 2, the results show a portion of the pattern for two AD571 10-bit ADC's connected to the same input signal and being activated at the same time (Figure 3). Both converters are within the 10-bit accuracy specifications, but converter B has a greater degree of nonlinearity and shows a distinct preference for binary codes ending with the hexadecimal value "F". Note that the two values either side of the enhanced value are depleted, since some of the hits which should have occurred in these regions have been shifted into the enhanced region.

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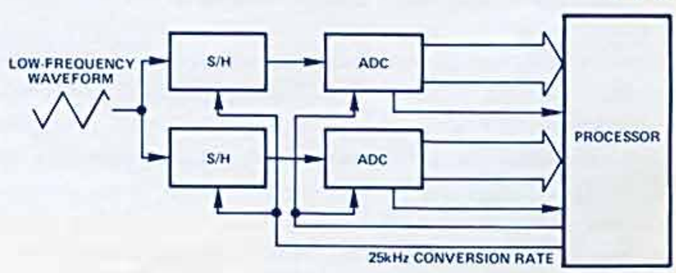

Figure 3. The basic scheme used to obtain the plot of Figure 2.

[1] *Analog-Digital Conversion Notes*, D. H. Sheingold, ed., pages 211-215, 1977, Analog Devices, Inc., Box 796 Norwood, Mass. 02062, $5.95

[2] O. J. Downing, P. T. Johnson, "A Method for the Assessment of the Performance of High-Speed Analogue/Digital Converters." *Electronics Letters*, 13th April 1978, Vol. 14, No. 8, pp. 238-240

[3] G. Pretzl, "Dynamic Testing of High-Speed A/D Converters," *IEEE Journal of Solid-State Circuits*, Vol. SC-13, No. 3, June, 1978, pp. 368-370