# Measuring and correcting wideband ADC non-linearity

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# Measuring and correcting wideband ADC non-linearity

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In order **to measure** amplitude non-linearity characteristic ,the measured amplitude probability distribution function (APDF) of the ADC output is compared with the ideal distribution and the differences used to calculate integral non-linearity error (INL)

If the INL characteristic is known the inverse of this can be included in a look-up table to **correct** the ADC output

Conventionally, the test signal is a pure sine wave test signal as its ideal APDF is known exactly. However, the accuracy of this method is limited by the practical problem of generating a pure sine wave and also as it's a single frequency, a wideband measurement requires a longer test time.

For wideband testing, random noise is an alternative to the sine wave test signal. Unfortunately, a much larger number of samples is required for this method to achieve a given confidence level. This is due mainly to the need to be sure that they fit a Normal distribution with sufficient accuracy. The approach reported in the literature has been to fit a Chebyshev polynomial to the INL result. However, results measured using noise do not correlate well with those of sine wave tests.

A new approach to testing is described that makes use of a periodic signal derived from pseudo random binary sequences . Its periodicity and better defined APDF offers the potential for a smaller number of samples with increased accuracy in measuring INL.

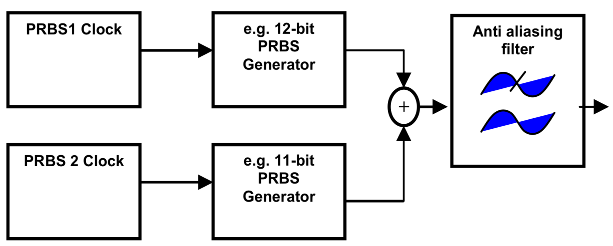


Fig. 1 Wideband test signal generator

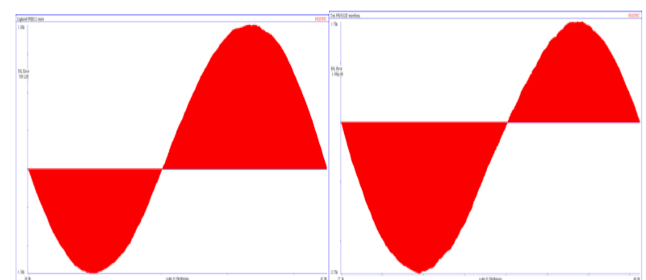

FIGURE 2 APDF 'error' of test signal FIGURE 3 APDF 'error' of Normal distribution

## ADPF error model for this wideband test signal

**F(x) = a0 + a1cos(xω) + b1sin(xω) + a2cos(2xω) + b2sin(2xω)+ a3cos(3xω) + b3sin(3xω) +a4cos(4xω) + b4sin(4xω) +a5cos(5xω) + b5sin(5xω)**

| Coefficient | $a_0$ | $a_1$ | $b_1$ | $a_2$ | $b_2$ | $a_3$ | $b_3$ | $a_4$ | $b_4$ | $a_5$ | $b_5$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Result of fit | -162.4 | 1266 | 963.8 | -574.1 | 1337 | 393.8 | -540.9 | -206.6 | 179.4 | 79.31 | -47.8 |
| Harmonic Ratios | | | | $-2a_1$ | $7b_1$ | $-1.25a_2$ | $-3b_2$ | $-2a_3$ | $-3b_3$ | $-3a_4$ | $-3b_4$ |

TABLE 1 Best fit Fourier Coefficient values

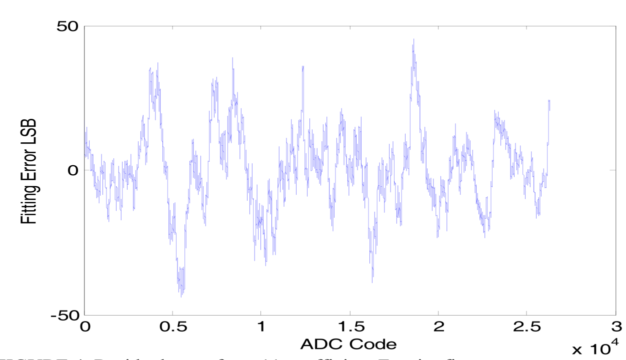


FIGURE 4 Residual error from 11 coefficient Fourier fit

## Results of applying this APDF error model

The non-linearity of an ADC was simulated by assuming that it could be modelled by a third order polynomial where the values of the coefficients are a = 0, b = 1, c = 0.01, d = 0.01.

$$Y(t)=a + bx(t)+cx(t)^2+dx(t)^3$$

ADC non-linearity function

The test signal was applied to this model and the distortion signal separated from the original test signal by using two synchronised comb filters. As these comb filters remove only the test signal this distortion signal has the same APDF as would have been obtained by subtracting the APDF of the test signal from the distorted test signal. This is equivalent to calculating the integral non-linearity error. Next, the APDF 'error' of this linearity error signal was calculated using a uniform distribution as the reference.

When the cubic term was set to zero the APDF shown in Figure 5 was produced. By comparing this with Figure 2 it can be seen that the quadratic term has produced an APDF with even symmetry. If the APDF of the undistorted test signal can be approximated using the results in Table 1 then a comparison of both APDFs could enable the quadratic coefficient 'c' to be determined with a precision close to 13 bits.

In contrast, when the quadratic term is set to zero the APDF becomes asymmetrical and is depicted in Figure 6. Curve fitting of these error functions is a method of obtaining the value of the coefficients of Y(t). All the modelling and simulations were undertaken using our WinSATS software in combination with Matlab and Labview

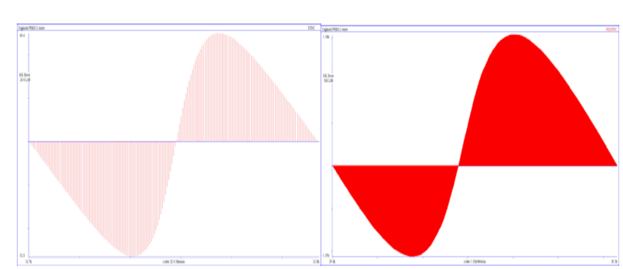

FIGURE 5 Quadratic FIGURE 6 Cubic

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