Using of Pulse Signal Sinx/x for DAC Testing

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Abstract- In this paper the qualities of short methods for testing dynamical parameters internal ADCs and DACs with impulses Multi-Tone and Sinx/x signal are analyzed. Practically examples are compared with standard Single-Tone Fourier Transform Test Method. This methods finds an application in the industry in less demanding economical short testing.

I. Introduction

Standardized methods for dynamic testing of ADCs and DACs are *Single Tone Fit Test* and *Discrete Fourier Transform Test* [1], [2]. Typical dynamic parameters DACs are *ENOB* (Effective Number of Bits), *THD* (Total Harmonic Distortion), *SNHR* (Signal to Non-harmonic Ratio), *SINAD* (Signal Noise and Distortion), *SFDR* (Spurious Free Dynamic Range), and *IMD* (Inter-modulation Distortion) for Double Tone Test. Stated methods are designated for precise measurement of ADC's parameters. However in technical praxis fast, simple, functional, short tests are demanded. DUT is tested in chosen frequency range using i.e. a frequency swept test or an exponential fit test [4], [5] Another approach is to test ADC using Multi-Tone signal with discreet frequency components or Sin*x*/*x* (Sinc) signal.

II. Testing with multi-tone signal

The Multi-Tone (MT) signal with discrete frequency components is defined by formula

$$u_{\mathrm{MT}} = \sum_{i=1}^{m} U_i \sin(\omega_i t) \tag{1}$$

where U_i and ω_i, i = 1,2,..m are amplitudes and frequencies of *m* spectral component.
For simplicity's sake all of the tones have zero phase shifts. In this case it is possible to compute the *SINAD* of the signal, which is generated by the ideal DAC.
Effective number of bits is given by equation

$$ENOB_{\mathrm{MT}} = \frac{SINAD_{\mathrm{MT}} - 4{,}77 + 20\log CF_{\mathrm{MT}}}{6{,}02}\,(bit) \tag{2}$$

Where CF_{MH} is a *Crest Factor* of this multi-tone signal

$$CT_{\mathrm{MT}} = \frac{\sum_{i=1}^{m} U_i}{\sqrt{\sum_{i=1}^{m} \frac{U_i^2}{2}}} \tag{3}$$

In Table I. is summarized the Crest Factors *CF*, depending of Signal Noise and Distortions Δ*SINAD* and Effective Number of Bits Δ*ENOB* for multi-tone test signals.

TABLE I. DEPENDING OF *SINAD* AND *ENOB* BY MULTI-TONE SIGNALS

	1 Tone	2 Tone	3 Tone	4 Tone
CF_{MH}	√2	2	√6	2√2
Δ*SINAD* (dB)	0	- 3.01	-4.8	- 6.02
Δ*ENOB* (bit)	0	- 0.5	-0.8	- 1.0

If the components has same amplitude $U_i = 1/2m$, then *Crest Factor* is equal to $\sqrt{2m}$.

III. Testing with sinc signal

The testing signal composed of two signals with same parameters only second period of the signal is inverted, see Fig.1.

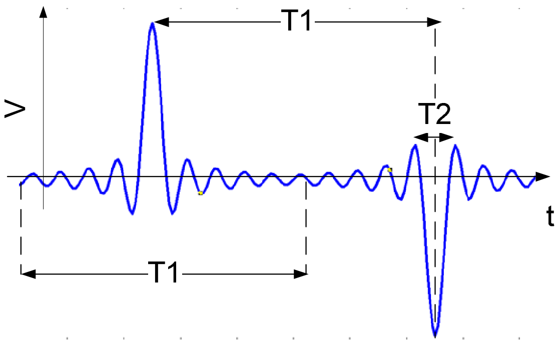

Fig. 1 Time plot of sinc signal

First period of the signal is described by next formula:

$$u(t) = H\left(t + \frac{T_1}{2}\right)\left(\frac{\sin\left(\frac{2\cdot\pi\cdot t}{T_2}\right)}{\frac{2\cdot\pi\cdot t}{T_2}}\right) - H\left(t - \frac{T_1}{2}\right)\left(\frac{\sin\left(\frac{2\cdot\pi\cdot t}{T_2}\right)}{\frac{2\cdot\pi\cdot t}{T_2}}\right),\ t \in \left\langle -\frac{T_1}{2}, \frac{T_1}{2}\right) \qquad (4)$$

,where *H* is *Heaviside function*, which chops the *sinc* function in time range < $-T_1/2, T_1/2$). Second period is inverted version of previous function.

Thus generated signal symmetrically covers the Full Scale of the DAC. Crest Factor (*CF*) can be computed from one period of our signal.

$$CF = \frac{Max[u(t)]}{RMS} = \frac{1}{\sqrt{\frac{1}{T_1}\int_{-T_1/2}^{T_1/2} u^2(t)dt}} \qquad (5)$$

Integral in equation (4) can be solved numerically. To reduce leakage in signal it is necessary to apply window to each period. Windowing also affect signal shape.

In Fig.2 to Fig.4 is presented time and spectral plots of reconstructed *sinc* signals from 16 bit DAC under test.

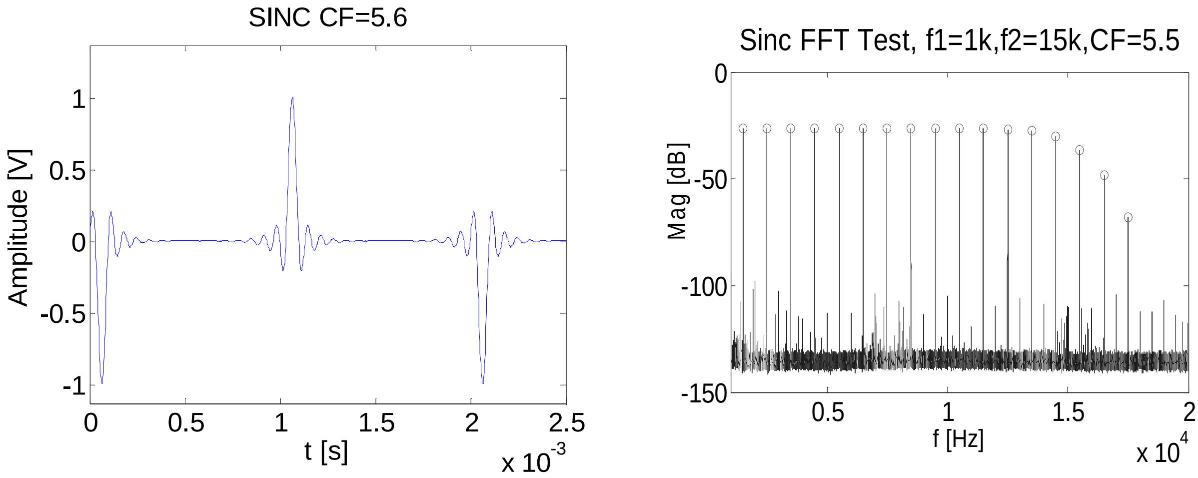

Fig. 2 Time plot of sinc signal – 17 Tones

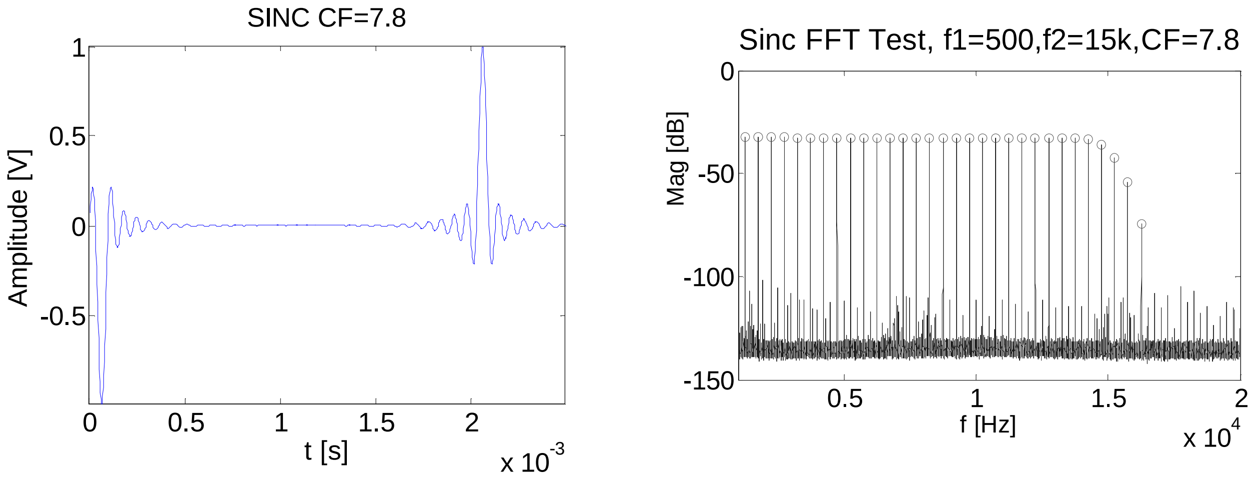

Fig. 3 Time plot of sinc signal - 31 Tones

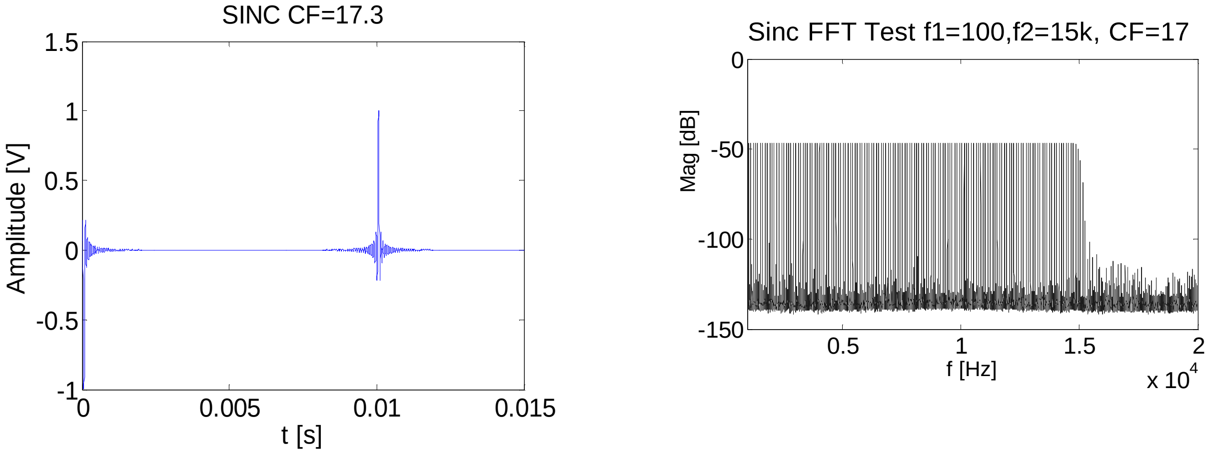

Fig. 4 Time plot of sinc signal - 143 Tones

IV. Test setup

The testing system was created for a purpose of a method evaluation. A 16 bit Multifunction Data Acqusition System NI PXIe-625 was chosen as DUT. For all experiments has been reconstructed signals with sampling frequency 1.048576 MS/s. The output signal from 16 bit DAC under test has been used by 24-bit digitizer NI PXI 5922 with sample frequency 15 MS/s. Whole system was controlled by PC with LabView. Acquired data were processed in program Matlab.

Firstly DUT was tested using *Single Tone* a *Multi-Tone* signal. Single Tone test proves that *ENOB* is practically flat function in frequency range 100 Hz -15 kHz. Therefore the *Multi-Tone* and *Sinc Tests* results can be directly compared with single tone test. Next table shows which frequencies were chosen for testing.

Secondly *Sinc Test* was arranged. An analysis of the signal was done *CF* was computed numerically and it was compared to real result. *CF* measured and *CF* computed are different, because a *Blackman-Harris window* was used to avoid leakage within signal. Then propriety parameters of the signal were chosen to cover maximum of the frequency range. Parameter $f_2 = 1/T_2$ affects *BW* of the signal. And $f_1 = 1/T_1$ affects number of spectral components. Both parameters affect *CF*.

V. Results

Results from *Sinc Test* and *Multi-Tone Test* are shown in Tab. I. Coherent sampling condition cannot be satisfied in this measurement; hence *Blackman-Harris window* 4. order was applied. Affect of this windows reflect column *CFc* in Tab. I. In comparison with *Single Tone* and *Multi-Tone Test*, in this case much more frequency components are easily generated. Only one parameter f_1 affects number of spectral components. Also in this case it is necessary to compensate an influence of the window and signal' itself *CF*.

Results of *ENOB* by *Single Tone*, *Multi-to*ne and *Sinc Tone Tests* in frequency range from 3357.87 kHz to 15987.41 kHz is practically identical, the differences is 0,2 LSB by nominal resolution 16 bit.

TABLE I. RESULTS FOR DISCRETE MULTI-TONE AND SINC TEST SIGNALS

Signal Ton	***CF***	***CFc***	***SINAD* (dB)**	***ENOB***	***SINADc* (dB)**	***ENOBc***
Single 3357.87 kHz	1.4	2.3	82.8	13.5	87.8	14.3
Single 7359.87 kHz	1.4	2.3	81.4	13.2	86.5	14.1
Single 9784.52 kHz	1.4	2.3	81.1	13.2	86.4	14.0
Single 15987.41 kHz	1.4	2.3	80.6	13.1	85.2	13.9
Dual 3357.87 kHz, 7359.87 kHz	2.0	3.3	79.4	12.9	87.4	14.2
Triple 3357.87 kHz, 7359.87 Hz, 9784.52 kHz	2.5	4.0	77.7	12.6	87.5	14.2
Quad 3357.87 kHz, 7359.87 kHz, 9784.52 kHz, 15987.41 kHz	2.8	4.6	76.6	12.4	87.6	14.3
Sinc – 17 Tones BW = 15 kHz	5.6	9.1	69.9	11.3	86.9	14.2
Sinc – 31 Tones BW = 15 kHz	7.8	12.8	67.7	10.9	87.7	14.3
Sinc – 143 Tones BW = 15 kHz	17.4	28.3	60.7	9.8	87.6	14.3

VI. Conclusion

After the correction - the results from *Multi-Tone* and *Sinc-Test* are comparable with results from *Single Tone Test*. As it was said, frequency characteristic of the *ENOB* can be considered as flat. Obtained *ENOB* from the *Multi-Tone* or *Sinc-Test* can be directly compared with *Single-Tone Test*. Otherwise the *ENOB* corresponds to the *average ENOB* in chosen frequency range. The differences between reference *Single-Tone* test and other methods are 0.2 LSB (16-bits nominal resolution). However those methods are designated for fast, run-time tests, for measuring tolerance error of the tested devices. So the possibility of using pulse signal was proven.

The advantage this methods is time reduction in wider frequency range without need of measuring their frequency characteristic. Therefore it is possible to suppose, that stated finds application in industry in less demanding economical short tests.

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