STOCHASTIC TEST METHOD APPLICATION FOR 16-BIT REFERENCE ADC DEVICE

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Abstract *– Stochastic methods for ADC (analogue-to-digital converter) tests have been developed to enable testing of precise AD converters that are difficult to test by standard methods using deterministic signal. A transportable high stable reference AD device was designed and realised for a comparison of systems for testing a dynamic quality of ADCs or AD modules using mainly those standard (deterministic) test methods. However, the stochastic test methods require different conditions and test arrangement due to large number of samples that has to be acquired during the stochastic test. This article shows results of the test and their comparison with standard tests performed on the same ADC.*

Keywords: stochastic test signal, ADC testing

1. Stochastic Testing of AD Converters

High-linearity and/or high-resolution AD converters that are difficult to test by standard methods using deterministic signal [1] can be tested by means of stochastic test methods [4]. Histogram test can use various input signals and principally allows use noise as the input signal. To overcome difficulties related to generation of large-scale uniformly distributed stochastic signal, a method based on superposition of Gaussian noises with equidistantly spaced DC shifts has been proposed [3] and theoretical analysis has been provided there.

Each particular testing signal is Gaussian noise with probability density function (p.d.f.) $f_G(\mu,\sigma)$ where μ is the mean value and σ means standard deviation. It is easy to show that

$$\lim_{\Delta\to 0}\left[\left(\sum_{k=-\infty}^{\infty} f_G(\mu + k.\Delta,\sigma)\right) - \frac{1}{\Delta}\right] = 0\,,\quad k \text{ integer} \tag{1}$$

Independently on the value of μ and σ. In other words, the superposition of Gaussian distributed noises with the equidistantly spaced DC values by step Δ is for suitably small values of Δ an excellent approximation of uniformly distributed signal (see Fig. 1). Measurement is provided for each Gaussian noise separately but histograms are cumulated. Theoretical analysis of such signal has been provided in [3]. The sensitivity of resulting probability density function to the variances in DC positions of Gaussian sub-signals, to variations of their power (r.m.s. value) and the border error was described there. It is important to know that from that analysis follows that testing signal that can be used to test high-resolution ADCs can be built in this way. Moreover, it is useful to note that in the case that particular Gaussian stochastic signals are generated by DAC, the used DAC should provide better accuracy than only the relevant portion of tested ADC. It means it is not necessary to compare the linearity of the full scales of tested ADC and testing DAC.

The following formula should be used to calculate the necessary amount of samples to achieve a required accuracy:

$$k = m \cdot \frac{a^2}{\varepsilon^2} \tag{2}$$

where k is number of required samples, m is number of code words of the tested ADC, $a = 1{,}96$ for 5% confidence level of DNL evaluation and ε is the statistical error of DNL evaluation (5% in our case).

The practical applicability of this method has been verified by comparison of results obtained by this method and by standard histogram test using deterministic (ramp) testing signal for an internal ADC of digitising oscilloscope [3].

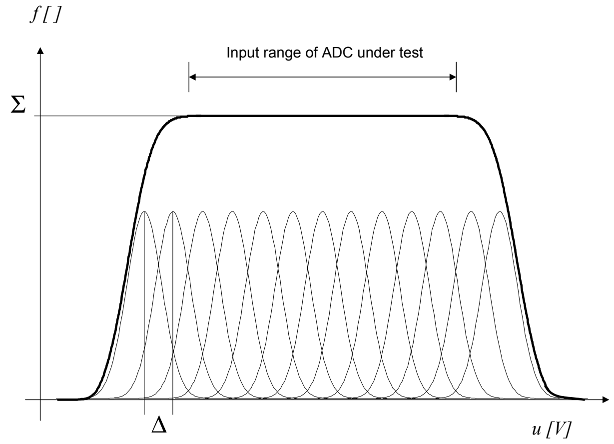

Fig. 1. Basic principle of Stepp-Gauss Test

2. Transportable Reference ADC Device

To assess the real precision of ADC testing systems and to compare advantages and disadvantages of applied methods, a transportable high stability reference AD device was designed and realised in the Dept. of Measurement of FEE - CTU in Prague in 2000-2003 [2]. Its usability was confirmed during the first comparative measurements among the Laboratoire de micro-électronique IXL - University Bordeaux, the laboratory of Institute of Microelectronics and Mechatronics Systems Ilmenau, and the ADC T&M Laboratory of the Dept. of Measurement of FEE CTU in Prague. In current development stage, it can host the following AD ICs:

- 14-bits cascade ADC AD9240; 10 MSa/s;
- 16-bits sigma delta ADC AD7723; 1,2 MSa/s;
- 16-bits successive approximation ADC AD976A; 200 kSa/s.

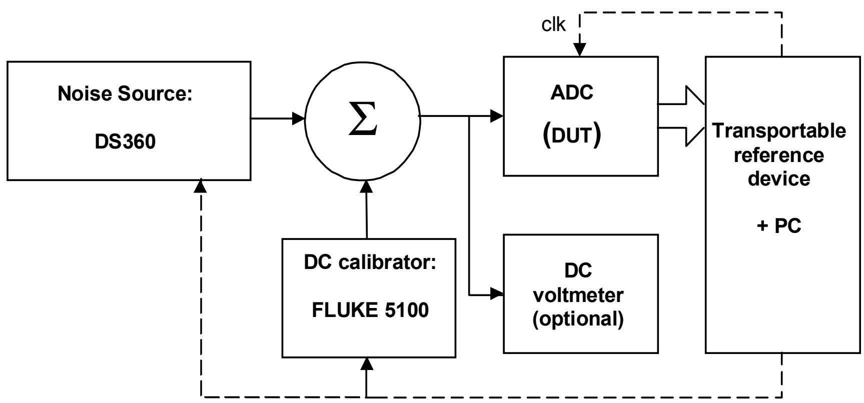

Fig. 2 Step-Gauss Stochastic Test Arrangement

In our case, the last IC (AD976A) has been tested.

3. Test Method – Design and Results

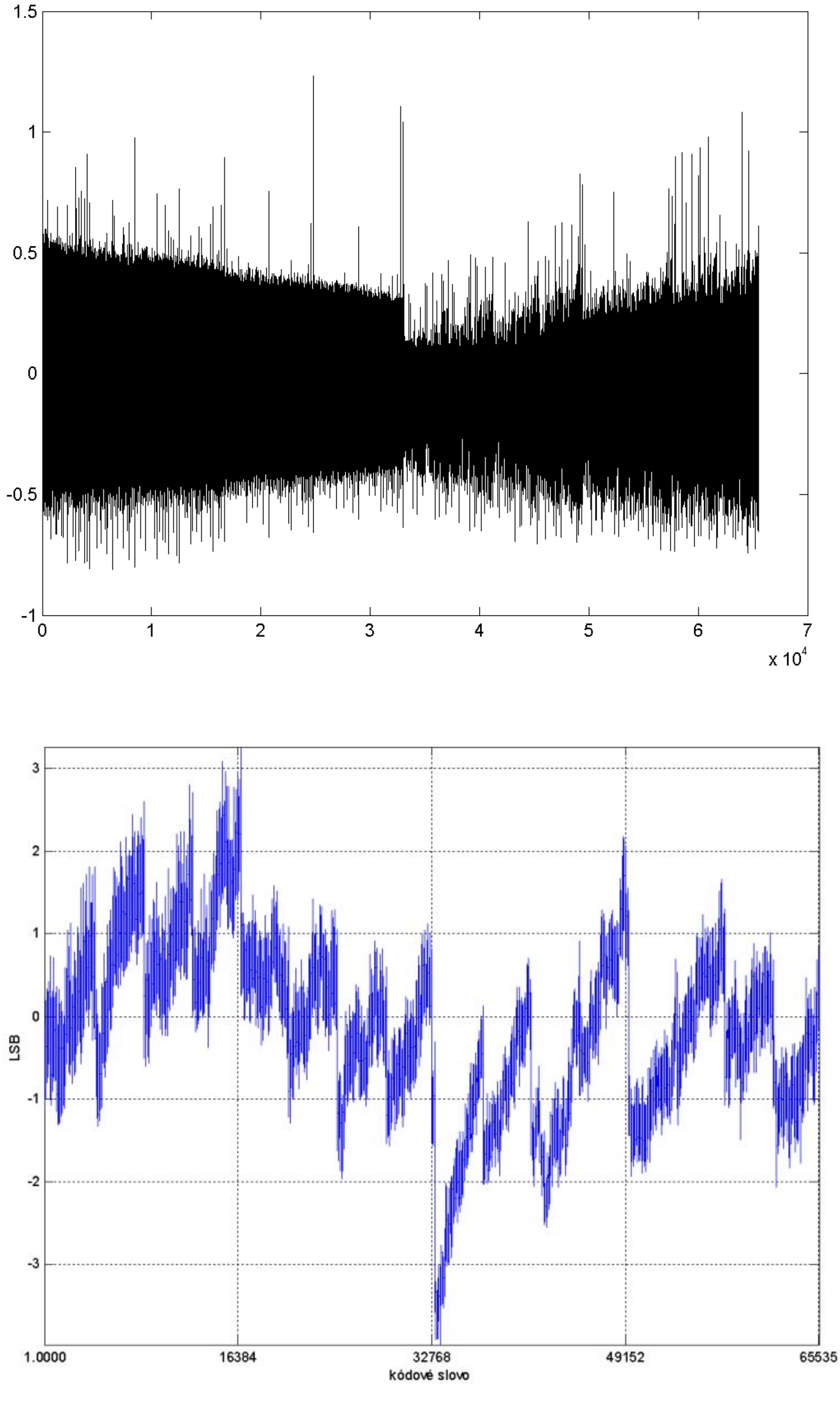

Fig. 3 Differential (DNL, upper picture) and Integral Non-linearity (INL, lower picture) of the tested AD976A [LSB]. Step-Gauss stochastic test method used

The following measuring equipment was used: Stanford Research signal generator DS360 as the noise generator and Fluke 5100B as a DC voltage source. Low-cost op-amp TL081 served as a summing amplifier.

According [3], 10^8 samples are necessary for Step Gauss test of 16-bits ADC to achieve 5% confidence level of DNL (Differential Non-linearity) evaluation and the same statistical error of DNL evaluation. Due to nature of Step Gauss test, this amount of samples has been split into 44 blocks with different DC offsets of test Gauss signal. The measured DNL and INL (Integral Non-linearity) are depicted in Fig. 3.

The Effective Number of Bits (ENOB) evaluated according to [3] is 14.11 bits. Using Sine-fit method, one gets 13.8 bits @50 kHz and 14.1 bits @50 kHz using FFT test [2].

The result differences between different tests fit easily into uncertainty interval. However, they confirmed well known rule that sine-fit test provides lower ENOB due to the fact that also input and internal noise are considered, while for long-record-based FFT test and for all histogram-based methods those types of noise are filtered out.

Conclusion

The applicability of Step-Gauss stochastic test method has been confirmed on 16 bit, 200 kSa/s successively approximating ADC housed in portable reference device. It enables to perform comparative measurements even for stochastic tests, however, it is necessary to carefully design the test conditions to balance the requirements for high number of samples necessary for stochastic tests and limited data transfer capability of the device. The results enable to test various ADC test systems in different locations on the same portable test reference converter by stochastic methods.

Acknowledgements

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References

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