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Dynamic Testing of ADC: A Review

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ABSTRACT

Analog to digital converters are Mixed signal devices. With the increasing popularity of these devices , it is important to get more faster and accurate device. Along with design, testing of ADC plays major role . Static and Dynamic methods are available for ADC testing. Ideal ADC itself has quantization error. A NonIdeal ADC consists many other errors like offset error, Gain error, DNL, INL,ENOB,SNR,THD,SINAD etc. In this paper various methods of dynamic testing of ADC are discussed.

Keywords : ADC,dynamic testing,non ideal ADC)

I. Introduction

ADC has wide applications in the modern electronic devices and system. ADC is a mixed signal device .It is an interface between the analog world and digital instruments. Therefore, characterizing the performance of ADC is an important concern [1].The most famous methods for dynamic testing of ADC are the code density histogram test and the Spectral analysis method. The histogram method is more sensitive to the (DNL), whereas the FFT test is more sensitive to integral Nonlinearities(INL).The DFT output spectrum contains the test signal ,a noise floor caused by quantization errors and harmonic distortion caused by INL[2]. An analog signal can has infinite possible voltage levels between any two values. But when it is converted into digital form it contains only limited possible codes depending upon resolution N, of the ADC (possible codes = 2^N).

II. ADC characterization

Conversion from analog to digital is two steps process. First step is to make the time discrete (Sampling) and the second step is to make the amplitude discrete (Quantization). An ideal ADC (Fig. -1) has a linear response throughout the input range .An ideal ADC is having Quantization Noise. A real life ADC model is shown in Fig.2. If the transfer characteristic of the ADC does not pass through the origin, it is said that ADC has an offset error and if the angle of the transfer characteristic of the ADC is not 45 degree then the ADC has gain error. If the transfer characteristic is not a straight line at all then the ADC has nonlinearity error. Gain error and offset error present in a practical ADC can be minimized but nonlinearity error cannot be reduced unless an ADC with low nonlinearity error is selected . In real life ADC, the real transition voltage will be different from the ideal ones. To express those differences several parameters are used.[3]

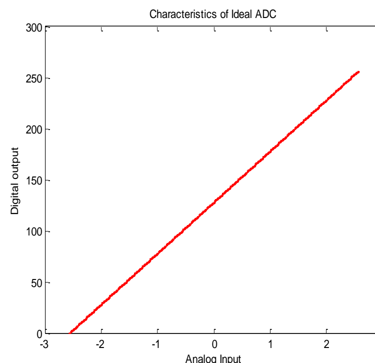

Fig. 1

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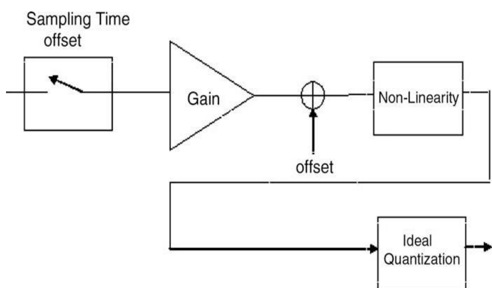

Fig 2 Real Life model of ADC[4]

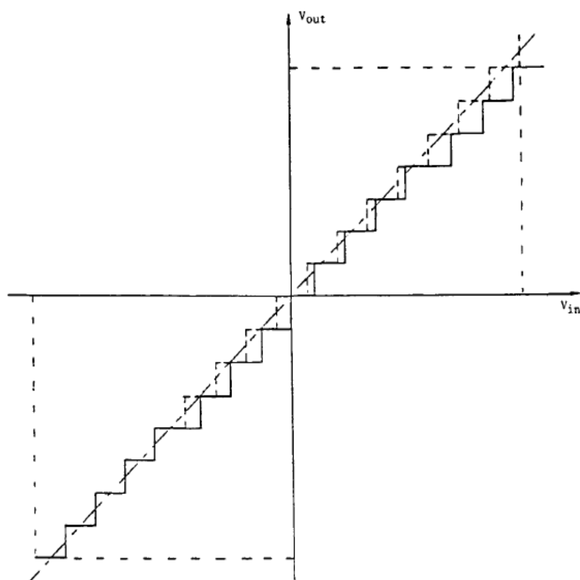

Fig 3

Characteristics of Non-Ideal ADC

Data Converters are typically characterized by static , time domain and frequency domain performance metrics. Offset Error, Gain error, DNL,INL ,monotonicity are the static parameters ,while signal to noise ratio, Delay, settling time ,SNDR,SFDR comes in the dynamic category.

III Histogram Method

The Histogram or output code density is the no. of times every individual code has occurred [5].

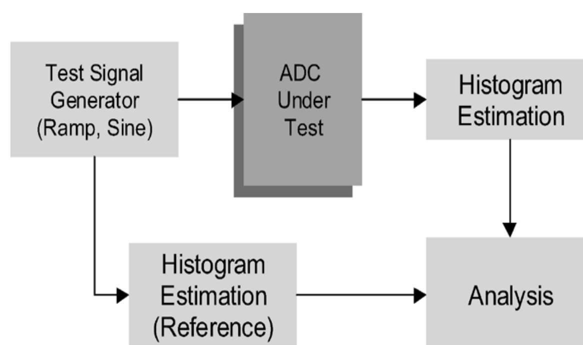

Fig. 4

Typical Histogram Scheme

It presents a method of extracting a stationary transfer function of the converter through the comparison of the pdf (probability density function) of the stimulus signal before and after the converter. Any output code density or histogram bin equal to 0 is a missing code. Differential Nonlinearity is the deviation from 1LSB of the range of input voltages that give the same output code. The no. of counts in the ith bin H(i) divided by the total no. of samples N_t is the width of the bin as a fraction of full scale. The ratio of bin width to the ideal bin width is the differential linearity and should be unity. Subtracting 1 LSB gives the differential nonlinearity in LSB.

$$DNL(i) = \frac{H(i)/N_t}{P(i)} - 1$$

Integral nonlinearity is the deviation of the transfer curve from ideal. By coupling a cumulative histogram, the cumulative bin widths are the transition levels. Once the transition is known, the ADC is characterized. Connect the input terminal of the ADC to the ground and accumulate a histogram only the bin for zero input should have count in it, any other count are caused by noise the ADC. By increasing the ADC conversion rate and comparing the desired properties such as linearity, Max. Conversion rate for a desired accuracy can be determined. By varying the input test frequency is a frequency response measurement. The drawback of the test is that it requires some hundred of samples per each code bin, and is therefore very time consuming, especially for high resolution ADC [6].

IV Sine wave curve fitting (Time domain analysis)

SF basically consists of generating a sine wave that best fits the data record acquired from an analog sine wave source. The best-fit sine wave is therefore

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considered to be the ideal input, the differences among the sample points and the fitted sine wave points, called residues, are assumed to include all the device non-idealities. Three and four parameter SF algorithms have been proposed and adopted. The 4 parameters SF algorithms can provide the amplitude, phase, frequency, and offset. In sine wave testing of ADCs these assumptions are far from being true. The quantization error is partly deterministic, and the sample values are strongly interdependent. This makes the sine fit worse than expected, and since small changes in the sine wave affect the residuals significantly, especially close to the peaks, ADC error analysis may become misleading. Processing of the residuals (e.g. the calculation of the effective number of bits, ENOB) can exhibit serious errors [6].

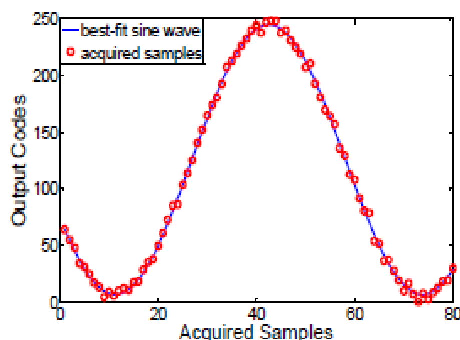

Fig. 5

Best fit Sine wave of acquired samples for an 8-bit ADC

V FFT Method (Frequency Domain analysis)

The discrete Fourier transform computed with a Fast Fourier transform algorithm can be used to measure the nonlinearity of ADC transfer function. The spectrum of the output will contain the input test signal ,quantization error harmonic and any distortion caused by integral nonlinearity[5]. It is possible with DFT to detect the repetition of the peaks in the DNL and the square waves in the INL .The DFT is applied to the INL and DNL[8]. Very less no. of samples are required as compared to the histogram method irrespective of the resolution of the ADC .Frequency domain analysis is much faster as compared to others. The FFT test is commonly employed to inspect the output spectrum of the ADC under test and derive figures of merit like SNR, THD, or effective bits. The frequency range and Resolution on the X-axis of the spectrum plot depend on the sampling rate and the size of the data record. The number of frequency points or lines in the power spectrum is N/2,where N is the number of signal points captured in the time domain. The first frequency line in the power spectrum always represents DC. The last frequency line can be found at fSAMPLE/2 - fSAMPLE/N. Frequency lines are spaced at even intervals of fSAMPLE/N, commonly referred to as a frequency bin or FFT bin.

Conclusion

In this paper different method of ADC testing has been reviewed. The main attraction of the FFT is that the results can be obtained instantly irrespective of the resolution of the ADC, while in the Histogram method time required for test may take several hours. Dynamic test methods are used to determine the Gain error, offset error, ENOB and frequency dependent errors like THD, SNR, and SFDR. Now a day's ADC plays an important role in the Electronics and communication field. By proper Testing of ADC, quality of ADC can be improved and error can be minimized. This may help the Manufacturer and circuit designer.

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