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Jitter investigation in dual channel simultaneous sampling measurement methods

***Abstract**. Dual channel simultaneous sampling measurement methods of power, phase angle or impedance are highly affected by the jitter of the A/D converter. Thus it is necessary to determine the jitter in the validation procedure of a particular measurement method. The article concerns the Authors' research continuation, this time based on extended measurement setup for detailed jitter analysis, with two independent signal sources and A/D converter circuits.*

***Streszczenie.** W dwukanałowych pomiarach próbkujących duży wpływ na wynik pomiaru mocy, kąta fazowego, czy impedancji, może wywierać szum fazowy (jitter) przetwornika A/C. Oszacowanie wartości tego szumu jest niezbędnym krokiem przy walidacji wybranej metody pomiarowej. W artykule przedstawiono wyniki kontynuowanych przez Autorów badań, w których tym razem, w celu przeprowadzenia analizy wykorzystano dwa niezależne źródła sygnałów i dwa układy przetworników A/C (**Analiza szumu fazowego w dwukanałowych układach pomiarowych**).*

Keywords: dual channel analog-digital conversion, jitter, phase noise.
Słowa kluczowe: dwukanałowe przetwarzanie analogowo-cyfrowe, jitter, szum fazowy.

Introduction

Dual channel sampling measurement methods for evaluating such parameters as power, phase angle or impedance are highly affected by the jitter of the A/D converters. Thus it is necessary to determine the jitter in the validation procedure of a particular measurement method using chosen set of A/D converters or data acquisition card (DAQ). The methods of the jitter measurement and the authors' view on the jitter taxonomy are closely connected with the results based on continued research carried out in the past years [3,4].

The considered methods

Due to the fact that the measurement process for jitter estimation is disturbed by the complex phenomena it is necessary to perform and repeat entire procedure for different measurement topologies (Fig. 1). It should be noted that total jitter is the root-sum-square (rss) value of the generator output jitter and the digitizer jitter (rss value of the aperture jitter and the sampling clock jitter). That is why two different sine wave function generators and two independent A/D couples were used. This is very helpful in the analysis process for distinguishing different jitter factors.

The two methods involving the double-beat technique and based on a dual-channel system were investigated by authors:

1) the cycle to cycle method, according to [1],
2) the undersampling method, according to [2].

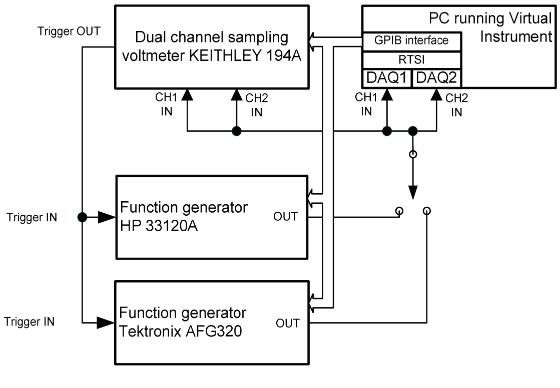

Fig. 1. Measurement setup for jitter estimation purpose

Both methods require coherent sampling and extensive set dozens of signal cycles for averaging. The double-beat technique is formed by the following operation - once the acquisition of all samples is complete, the succeeding period is subtracted from the its predecessor, point wise. Such results are obtained from repeated measurements for internal triggering and averaging. This action eliminates systematic errors such as differential non linearities and quantization noise. Non-coherent noises are quadratically added.

The measurement can be performed independently for different function generators as well as for different A/D converters. The dual channel sampling voltmeter Keithley 194A and a pair of National Instruments 6251M data acquisition cards are used. The measurement system is all controlled by a PC with a dedicated "virtual instrument" application (beside a slight necessary change in signal routing concerning generator outputs, which is not done by the software because of the expected additional noise, and pursuit of the shortest and the simplest circuit).

A single acquiring iteration starts from parameters setting for the voltmeter and generator used in measurement circuit (Fig. 1). Trigger mode of the voltmeter is programmed to wait for GET command on the GPIB bus. As it appears, the voltmeter in turn, triggers (Trigger OUT line in te Fig. 1) generators action and by itself starts the two channel simultaneous acquisition of the input signal, connected in parallel to the both inputs of the device. After that acquired data buffer is sent to the personal computer and saved to the mass storage, which ends a single iteration. Analogous procedure is performed with a use of data acquisition cards.

The measurements were repeated in series, for the narrow number of samples possible to acquire in a single iteration and on the other side, the demand for relatively extensive data set.

Data processing of the acquired signal, namely determining the period to period and channel to channel differences was calculated in Matlab and Excel environments.

The results of the consecutive subtractions in both above methods are the amplitudes of noise Δv which are equal to the jitter Δt modulated by the slew rate of the input signals [3]:

$$\Delta v = \frac{dv}{dt}\Delta t \tag{1}$$

Input signal:

$$v(t) = V_m \sin\left(2\pi f_{in} t + \varphi\right) \tag{2}$$

After differentiation

$$\Delta v = 2\pi f_{in} V_m \cos\left(2\pi f_{in} t + \varphi\right) \Delta t \tag{3}$$

After relabeling *Δt* as *J* (jitter) and rearranging the factors, one gets

$$J_{RMS} = \frac{(\Delta v)_{RMS}}{2\pi f_{in} V_m} \tag{4}$$

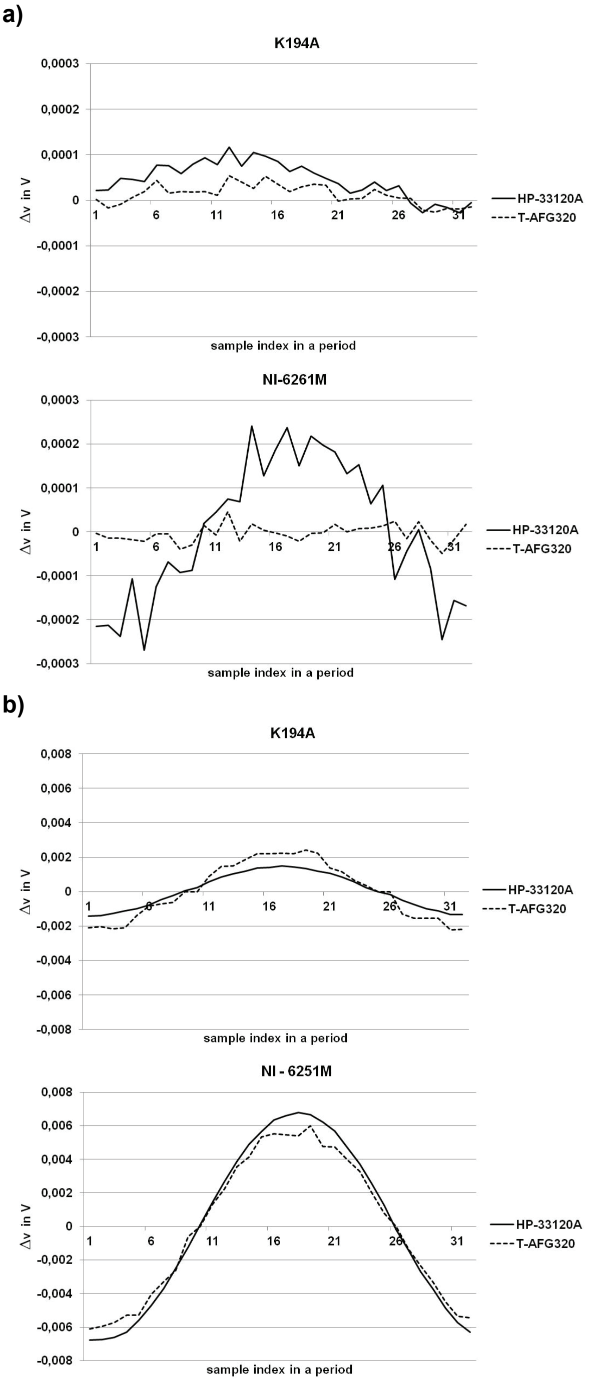

Fig. 2. Typical example of data provided by the double-beat technique - the mean value of the differential voltage *Δv* averaged for both channels in function of sample index (number of samples equals 32, signal frequency 312.5 Hz, amplitude of input signal 3.1 V)) for two cases: cycle-to-cycle method (a) and undersampling method (b)

Differential voltage Δ*v* depends only on jitter components. Consequently, equation (4) allows for simple determination of the total jitter at any input signal frequency.

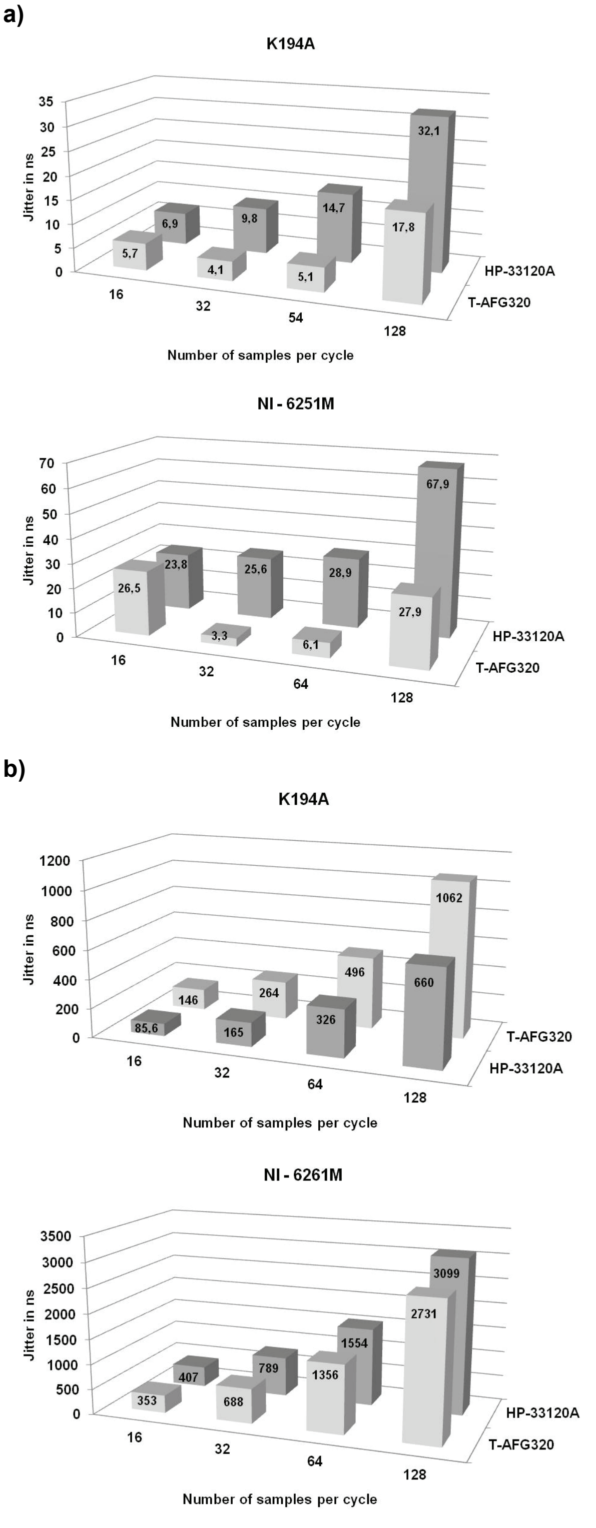

Fig. 3. Jitter estimated for cycle-to-cycle method (a) and undersampling method (b) - averaged for both channels (RMS value)

Discussion of the results

The investigation at constant input signal amplitude (3.1V) and constant resolution (16 bit, 100 μV) and variable number of samples per cycle at constant sine wave input frequency 312.5 Hz is presented. The analysis was performed in the time-domain. The results for a single set of the difference voltage Δv, that were investigated, served as the most representative for selecting the correct number of samples in a cycle, are presented in the Figure 2.

Differences between channels are almost the same for both methods. They can be averaged and reach about 0.5 mV (RMS).

The jitter obtained for two methods under investigation are shown in the Figure 3. The values of the jitter suggest the presence of considerable systematic difference between the two methods.

If one compare these graphs it becomes obvious that jitter values obtained in the undersampling method are approximately from ten to a few hundred times greater than in the cycle to cycle method. And it is regardless of input waveform frequency selection or number of samples per a cycle. Observed growth have multiplicative property, so it is systematic suitability of jitter phenomenon. The long term jitter fundamentally must be greater than the cycle to cycle jitter because it is made of the same components. The matter is how much greater ? This growth illustrates the basic fact that undersampling methods have fundamental limitations with respect to their ability to process wide dynamic range signals. Estimating jitter and omitting precise definition of phenomena being actually measured can lead to misunderstanding [5].

Measuring rms jitter less than 10 ns at input signal frequency 312.5 Hz is difficult, simply because of unwanted jitter which may appear on the input signal or the A/D converter sampling clock, or layout-induced noise. Different noise sources and jitter become indistinguishable at this level (see Fig. 2a, e.g. NI-6251M and T-AFG320). Obtaining reliable results when aperture jitter is demanded requires sine wave frequency sources with extremely low jitter, as well as detailed attention to the layout, signal routing, grounding, and decoupling. Finally one could take the amplitude jitter down to the least significant bit level and extract a little bit more resolution on the jitter measurement.

Conclusions

The paper has presented an experimental results for the total jitter which describes quantitatively the process by which noise sources of all types convert to jitter.

Short term jitter obtained by cycle to cycle method can be more effective when selecting proper number of samples per a cycle in sampling methods respecting the Shannon-Nyquist criterion. However, the long term jitter yields more stable basis to compare jitter sources impact on different A/D converters. When undersampling methods are concerned the long term jitter should be used first.

Continuation the Authors' research in the field of jitter analysis required more complicated measurement setup as compared to the previous published results [3,4]. Authors expected the process of jitter factorisation and differentiation to be easier with the possibility of using two different sources (generators) and A/D converters circuits (high speed sampling voltmeter and DAQ cards).

The obtained results have not given the clear prescription, so far, to the jitter components estimation. This may be caused that some simplifications were assumed, for example: temperature and humidity independence and the instant of measurement independency (allocated in different time of natural day resulting in different impact of environmental, industrial disturbances). Performing measurements, e.g. at night, results in the lower level of acquired noise provided by lower human activity. Each measurement device is disturbed by parasitic phenomena. This includes the electronic noise, but also any external event that affects the measured phenomenon (temperature and humidity, mentioned above). It is often possible to reduce the noise by controlling the environment.

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