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Experimental Studies of Signal Digitizing Based on Sine-wave Reference Crossings

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Introduction

As it has been shown before, digitizing of an analog signal can be based on detection of the time instants when crossings of this signal with a sine-wave reference waveform take place [1,2,3]. The obtained sequences of the timed crossing points then fully represent the respective input signal. This approach to signal digitizing, as well as electronic devices, performing digitizing in this way, are specific. Specific are also application options of these techniques. Basically they are well suited for multichannel data acquisition according to various scenarios. Time diagram illustrating the basic operational principle of Sine-wave Crossing (SWC) digitizing is givenin Fig. 1 and explained in the next section.

Digitizing Based on Sine-wave Crossings

To optimize designs of such data acquisition systems, it is essential to explore the processes determining the achievable performance quality of such data acquisition systems. It is already clear that to reveal full application potential of this type of digitizers, they have to be developed and made as an ASIC. That requires spending a lot of effort, time and financial resources. The experimental system, discussed in this paper, has been developed as a tool for obtaining the experimental data of the mentioned digitizers in varying conditions. Such a system has been built. It is described below and the first obtained results are presented in the following sections.

The most responsible device, in the structure of the considered digitizers, is the voltage comparator executing the operation of the signal and reference crossing instant detection. For that reason, the experimental studies have to be focused on disclosing the advantages and drawbacks of this digitizing technique. The structure of the experimental setup has been developed with this fact in mind. This system makes it possible to select and use various types of input signals and reference functions, to observe and measure essential parameters of the involved dominating processes. Description of this experimental system follows.

Before discussions of the developed experimental system, the operational principles of the specific signal Digitizers [1] to be investigated by using this system, have to be briefly explained.While detailed description of SWC digitizing is given in [2,3], let us explain just the basics of this approach to analog signal conversion into their digital counterparts. Time diagram, illustrating conversion of a signal $x(t)$ into the specific digital signal given as a sequence of time instants t_1, t_2, t_3, ...,is given in Fig. 1.
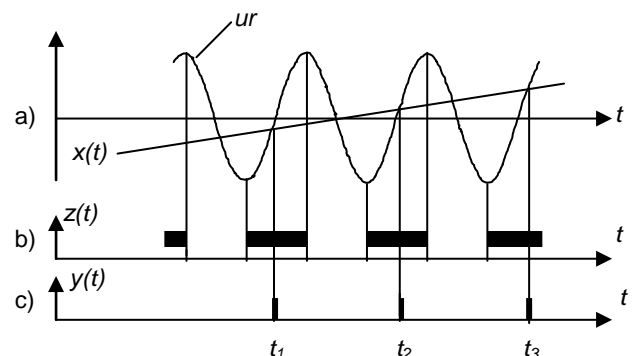
Fig. 1. Time diagram illustrating conversion of a signal $x(t)$ into a specific digital signal given as a sequence of crossing   time instants: a – crossings of the signal and the reference function; b – formed enabling function; c– output signal: sequence of crossing time instants

This specific digital representation of the continuous signal $x(t)$ by a sequence of time instants is obtained by comparing signal $x(t)$ with a sinusoidal reference function $u_r = A \sin 2\pi f_r t$ (Fig.1a) and forming short pulses $y(t)$ (Fig. 1c) positioned on the time axis so that their rising fronts coincide with the crossing instants as shown in Fig.1a and 1c. Only those crossing events that occur within time windows defined by the used enabling function $z(t)$ are taken into account at forming the pulse stream at the output. In the illustrated case, comparison of the signal with the reference function is enabled during the reference sine-wave rising half-periods.
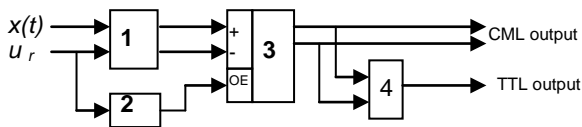
Fig. 2. Basic structure of the SWC digitizer

Basic structure (Fig. 2) of the investigated SWC digitizer contains unit 1 for input signal conditioning and zero adjustment, device 2, used for forming the enabling function, main comparator 3 that has an additional input OE for the enabling function, and the unit 4 serving for the output TTL signal forming. A converter, made on basis of an operational amplifier, transforms the reference sinusoids into cosine functions that are used inside the device 2 to form the enabling function in a simple way.

Specific implementations of the mentioned basic operations involved in SWC digitizing depend on the used electronic elements, therefore the configuration of the electronic circuits might be also slightly different. In this case, schematic diagram of circuits detecting the time instants of signal and reference crossings is as shown in Fig. 3.
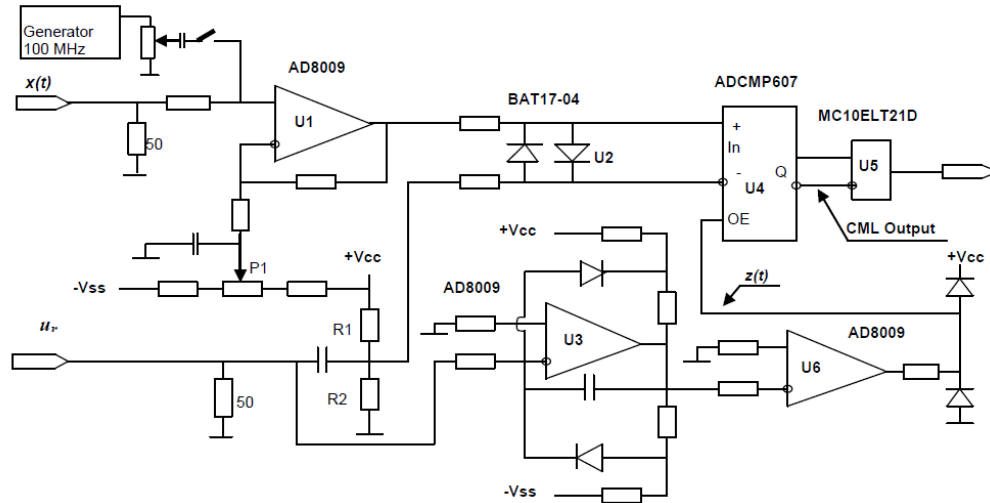

Fig. 3. Schematic diagram f of the SWC digitizer

Experimental set-up

The structure of the system built for experimental investigations of SWC digitizing is given in Fig. 4.

As can be seen from Fig. 4, the considered experimental system provide the input signal and the reference function to the SWC Digitizer placed at the core of the system and connect this core device to the needed test equipment and PC via USB interface. Clock generator, running at 100 MHz rate, is used also for activating the reference function generator at a variable frequency. A frequency divider with variable frequency reduction rate (set by choosing the needed value of the reduction rate *n*) is used for that. A number of test instruments is included into the system. While the use of the indicated test instruments is more or less clear, the device for recovery of the signal waveforms is performing of a well defined function in a less obvious way. This device actually is built on the basis of an ADC. The reference sine-wave is passed to the input of it and sampling of this input is carried out in the crossing time instants detected by the SWC Digitizer. The obtained estimates of the reference function, according to the definition, then are equal to the respective sample values of the signal waveform and this is how this waveform is reconstructed. Due has to be taken of correct balancing the delays in the path of the crossing instant transmission with the phase angle of the reference sine-wave at the input of this device reconstructing the digitized signal waveforms.
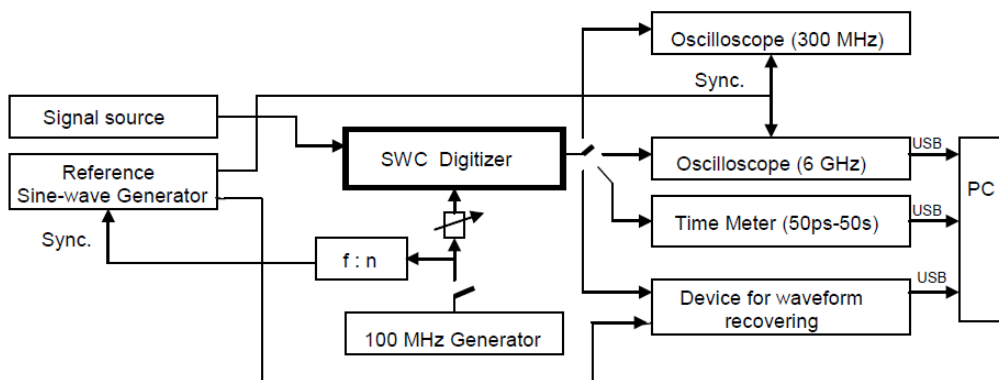

Fig. 4. Structure of the system built for experimental investigation of SWC digitizing

Experimental data acquisition

As this system has been made and activated only recently, the experience obtained so far from work with it is small. To illustrate operation of the discussed system, examples of some typical test and measurement results are given in Fig. 5,6 and in Table 1. Jittering of the detected crossing time instants is displayed in Fig. 5. These results have been obtained at experiments carried out under specific test conditions when the reference sine-wave was set at a low 100 kHz frequency and a constant voltage was put to the input of the tested SWC digitizer. Jitter values in the range of ± 2 ns were observed at the average value 733 ns. The measurement results obtained in case when using frequency 1 MHz are given in Table 1.
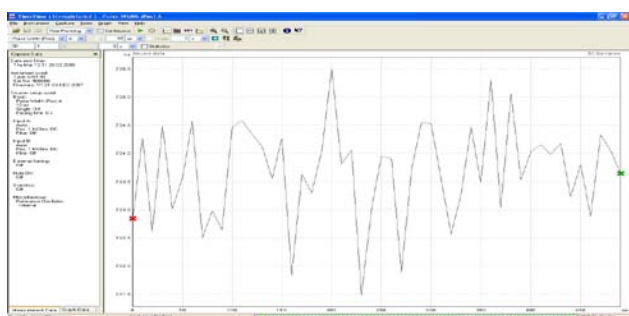
Fig. 5. Fluctuations of the detected crossing point instants under the specific test conditions

Table 1. Variation of crossing point estimates. Reference signal parameters: $f_r = 1$ MHz; $u_{r\,pp} = 520$ mV.

Reference level, mV	20,54	120,87	220,20	421,70
Estimated time intervals, nsec *)	25,54	78,26	120,85	206,21
	25,45	77,91	120,39	206,11
	24,78	78,41	120,96	205,79
	24,31	77,03	120,53	206,09
	24,50	77,93	120,59	205,9
	24,58	77,39	120,79	205,94
	25,33	77,79	120,29	205,86
	25,29	77,22	120,10	205,31
	25,16	78,25	120,39	205,72
	24,86	77,56	120,22	
Average value, nsec	24,98	77,77	120,51	205,85
Variation, %	$\pm 2,46$	$\pm 0,89$	$\pm 0,36$	$\pm 0,22$

*) – time intervals from enabling signal start points till signal crosspoints

Under the real conditions under which the SWC digitizer is normally exploited, the jitter of this kind of course is much smaller as the reference frequency usually is measured at least in MHz. Nevertheless attention has to be focused on this parameter as it directly impact the digitizing precision and many factors, including parasitic, impact the value of it. Indeed, whenever the reference voltage approaches the input signal, the involved comparator becomes very sensitive to the internal and external noise. The observed fluctuations reflect this impact of noise. It is important to discover the most essential noise sources and experiments of this type are carried out especially for this purpose. The results of them then are used for improving the design of the SWC digitizer. In particular, these experiments have led to the conclusion that quantizing of the time intervals, within the time periods when the comparator is enabled, could be useful for reduction of the discussed crossing instant variations. To perform experiments of this kind, an additional 100 MHz signal generator is included in the scheme of the experimental set-up. The diagrams, given in Fig. 6, reflect a signal and reference function crossing when the additional 100 MHz signal of small amplitude is used for emulation of the mentioned quantizing. Then crossing events are placed on a time grid with 10 ns wide steps.
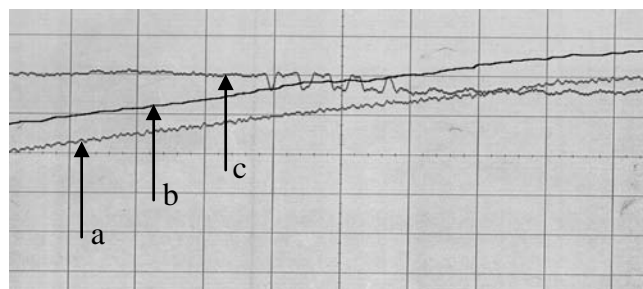
Fig. 6. Crosspoint of modulated input signal $x(t)$ and reference signal u_r: a – reference signal in the generator output; b – reference signal in the crosspoint; c – modulated input signal

Conclusions

A system for experimental testing and evaluation of the earlier suggested and described method and techniques for signal digitizing, based on detection of the time instants, when crossings of this signal with a reference sine-wave take place, has been developed, made and is discussed in this paper. This approach to signal digitizing, while rather specific, is well suited for applications in the area of multi-channel data acquisition according to various scenarios. The discussed experimental set-up is flexibly adaptable to the varying digitizing conditions so that it covers the needs of the planned experimental investigations. Some obtained test and measurement results are given to illustrate the capabilities and application potential of the developed system.

References

1. **Bilinskis I.** Digital Alias-free Signal Processing, Wiley, 2007.
2. **Bilinskis I., Sudars K.** Digital Representation of Analog Signals by Timed Sequences of Events // Electronics and Electrical Engineering. – Kaunas: Technologija, 2008. – No. 3(83). – P. 89–92.
3. **Bilinskis I., Sudars K.** Specifics of Constant Envelope Digital Signals // Electronics and Electrical Engineering. – Kaunas: Technologija, 2008. – No. 4(84). – P. 13–16.

I. Bilinskis, A. Skageris. Experimental Studies of Signal Digitizing Based on Sine-wave Reference Crossings // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 4(100). – P. 69–72.

A system for experimental testing and evaluation of the earlier suggested and described signal digitizing method and techniques, based on detection of the time instants when crossings of this signal with a reference sine-wave take place, has been developed, made and is discussed in this paper. This approach to signal digitizing, while rather specific, is well suited for applications in the area of multi-channel data acquisition according to various scenarios. The discussed experimental set-up is flexibly adaptable to the varying digitizing conditions so that it covers the needs of the planned experimental investigations. Ill. 6, bibl. 3, tabl. 1 (in English; abstracts in English, Russian and Lithuanian).

И. Билинский, А. Скагерис. Экспериментальные исследования дигитизации сигнала на базе пересечений с синусойдальным опорным сигналом // Электроника и электротехника. – Каунас: Технология, 2010. – № 4(100) – С. 69–72.

Разработана, изготовлена и рассматривается система для экспериментальной проверки и оценки ранее предложенного и описанного метода и техники дигитизации сигнала на базе обнаружения моментов времени пересечений этого сигнала с опорным синусойдальным сигналом. Данный специфический подход к дигитизации сигналов хорошо подходит для многоканальных систем сбора данных, используя различные сценарии..Данную экспериментальную систему можно гибко адаптировать для различных условий дигитизации и она предназначена для использования в планируемых экспериментальных исследованиях. Ил. 6, библ. 3, табл. 1 (на английском языке; рефераты на английском, русском и литовском яз.).

I. Bilinskis, A. Skageris. Sinusinio signalo skaitmeninimo tyrimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 4(100). – P. 69–72.

Pagaminta sistema, leidžianti eksperimentiškai patikrinti ir įvertinti anksčiau pasiūlytą ir aprašytą signalo skaitmeninimo metodą, remiantis šio signalo ir sukurto sinusinio signalo susikirtimo laiko momentų nustatymu. Šis signalo skaitmeninimo tyrimas yra specifinis. Toks principas labiausiai tinka daugiakanalėms duomenų sistemoms. Išanalizuotas ekeprimentinis tyrimas yra adaptyvus ir lankstus. Il. 6, bibl. 3, lent. 1 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).