Quality improvement in measurement channel including of ADC under operation conditions

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Abstract-The possibility of using of the IEEE STD-1057 and STD-1241 standards for measurement channel features estimation in operation conditions is discussed. The standards concern the test methods and circuits for the devices containing ADC in laboratory conditions and cannot be simply applied in the instrument under operation conditions. Some remarks concerning the specificity of such conditions and range of applicability of standards are presented. The results of examining of selected test signal sources are discussed.

I. The IEEE standards for estimation of ADC features

On the present development of technology, the acquisition, processing and transmission of the digital data are easier than analog one. Thus, the request for the analog-to-digital converter (ADC) has appeared and still growing. In effect, the general using of ADC in number of devices makes it possible to convert the information among these separate two in nature groups of quantities, also in applications designed for use in measurement and control. ADC presents the interface enabling the displacement of information from a world of analog quantities to digital one.
The evolution of digital technology is stimulated by processes connected with the wide use of microprocessor devices and especially personal computers. It is rearranged on growth of request for the arrangements enabling the processing of information from analog form in the digital form – as additional endowment of computer or autonomous devices, from which the information can be sent with standard digital interface. In consequence, the problem of evaluation of quality of ADC converters becomes important, as well as the devices, the ADCs were applied. The standards elaborated by organization IEEE: STD-1057 and STD-1241 [1,2] have a key meaning in estimation of parameters of considered devices. The main aim of the mentioned standards is to establish the common surface for the exchange of information between producers and users of mentioned devices in the fields:

- terminology,
- testing methods,
- potential errors sources identification,
- device usable parameters.

In common practice, the standards constitute the base for the comparative estimation of parameters of devices including ADC. Both standards have many common references. They contain the basic terms in domain of terminology and symbols as well as the way of designation of the parameters used in ADC and connected with them digital devices features. The methods and testing circuits for estimation of recommended parameters are also proposed.
In different applications, the essentiality of several parameters related to ADC is varied. Tab.1 shows the exemplary domains of ADC applications set together with the critical parameters typically designated for respective application [1,2].
In Fig.1 the general configuration of ADC parameters testing system is shown. Depending on kind of the nominated parameter and applied estimation algorithm, as the test signal the sine wave, ramp or pulse/step signals are used. In selected cases, the other sources of test signals are additionally used, e.g. the combination of sine waveforms (multitone) or noise signal generators. As the reference signal source, the precise DAC converters controlled by test system are used. In acquisition block (Acquisition and data processing) collecting the output data from ADC, the designation of required parameters is achieved.

Table 1. The exemplary domains of ADC application and critical parameters.

Exemplary applications	Critical parameters	Exemplary applications	Critical parameters
Audio	SINAD, THD, IMD, Crosstalk	Video and television	INL, DNL, BW, THD, SINAD
Data transmission	SFDR, SINAD, INL, DNL, BW	Radars and sonars	SINAD, SFDR, INL, BW
Digital instruments	ENOB, BW, SINAD, INL, DNL, SFDR	Spectrum analyzers	SINAD, SFDR, BW, ENOB
Medical instruments	SFDR, SINAD, INL, BW	Telecommunication	SINAD, SFDR, THD, IMD
Automatic control	Monotonicity, stability	Monitoring	ENOB, SINAD

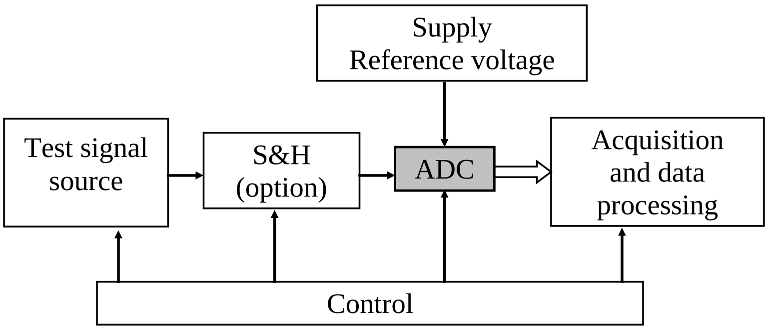

Figure 1. The general configuration of ADC parameters estimation testing system.

The ADC inclusive devices test methods can be classified considering the domain used for respective parameters designation. The classification contains the methods fulfilled in domain of amplitude, frequency and time [1,2,3,4].
The methods related to amplitude domain usually are connected with using of sine wave or ramp signal source as the test signal. The data processing algorithm, leading to the required parameter designation, is based on the statistical data analysis and enable the making of histogram of registered data as a result.
The methods related to frequency domain are usually based on use the sine wave or step signal as the test signal. The ADC output data are processed using Fourier transform. The required parameters are calculated on the basis of corresponding mathematical dependencies.
The pulse or step signals are usually used as the test signals for the test methods related to time domain. They are applied for designation such parameters as the time response for step, delay, settle time etc.
The potential instrument user is usually interested in limited number of parameters defined in standards and they are the subject of comparative analysis of the different devices features. The selection of the proper ADC test method, among recommended in standards, is done taking into consideration the necessary scope of information about the features of respective devices (Tab.1). The testing procedures are fulfilled in the especially arranged measurement station and they are very closely related to the certification (legalization) procedures commonly carried out for examination of all measurement instruments. The obtained values of investigated parameters testify to a quality of the examined device. According to measurement instrument, the quality of device means usually the accuracy of measurement results obtained with use of the instrument.
The certification procedures are carried out in laboratory conditions, but additionally the influences of external reference condition changes on the selected features of instrument are examined. The mentioned procedures are fulfilled usually selectively and in such form the effects of various influences are presented for user information.

II. The assessment of instrument features “on-line”

The test procedures accordingly to standards recommendations need to apply the test signal source, properly to the given ADC. The recommendations included in standards concern the procedures fulfilled in the laboratory conditions. The result of examination is designation of the value of coefficients characterizing the features of the given ADC set. Because of variety of designated coefficients, the miscellaneous test signal are proposed.
The instrument user for adequate accuracy estimation should to perform the multilateral analysis of the influencing factors and to evaluate on this base the uncertainty of results obtained during measurement process.
The above procedure has the purely hypothetical meaning because the practical measurements are fulfilled

accordingly to assumption of “the sufficient accuracy” of used instrument, based on the actuality of its certificates [5].

The operation conditions usually differ from the laboratory ones. These conditions influence as a rule on the conversion characteristics of measurement channel, especially on the stage of the data acquisition (the analog part of the measurement channel together with ADC). Uncontrolled changes of the various influences result in modification of many features of the channel under consideration. In measurement channel, the information is transmitted usually on the voltage level, so the influences related to its static conversion characteristics course seem to be most important.

The dynamic parameters of measurement channel (including ADC) are established while the instrument is designed, usually taking into account the indispensable dynamic reserve of its respective characteristics. The instrument designer does it mainly on the way of selection of the units and elements having the adequate dynamic features.

Accepting such assumption for measurement instrument and taking into account the accuracy of measurement result, the presence of various systematic disturbances with fluent intensity effects in the course of the conversion characteristics of all data acquisition unit (the analog part of measurement channel including ADC). Additionally, the presence of the random disturbances in operation condition, transmitted by various ways to the channel, influences the accuracy of obtained measurement results.

The research intended to apply of the standards’ recommendations for the estimation of selected features of the measurement channel, the measurement result correction and its uncertainty estimation are undertaken [6,7].

In Fig.2, the location of additional test procedures (graded blocks) location in relation to the standard configuration of the measurement channel is shown. The test signal S_t on the input of measurement channel enables to complete the digital file of data D_t, used for the estimation of actual characteristics of the channel. The digital data D_m gained during the conversion of measurement signal S_m are corrected taking into account the actual characteristics of the channel (D_k) and are processed according to the measurement function applied in the channel. On the base of the data acquired during test procedure and data processing algorithms, the uncertainty of measurement result is estimated. The graded blocks included in the measurement channel, excepting the “Test signal” block, are the software procedures. The “Test signal” block represents the test signal source.

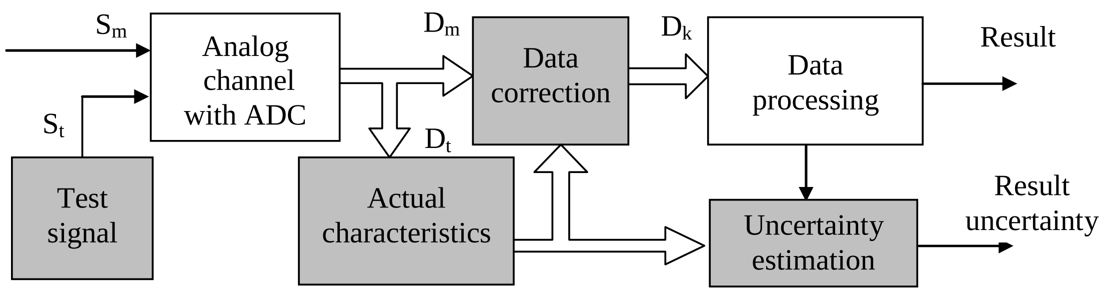

Figure 2. The location of test procedures in measurement channel.

The main problem to perform presented idea is how to arrange the adequate quality test signal source. A few configurations of signal sources were examined in test arrangement shown in Fig.3. The connections to the ports of PCI-730 board are presented.

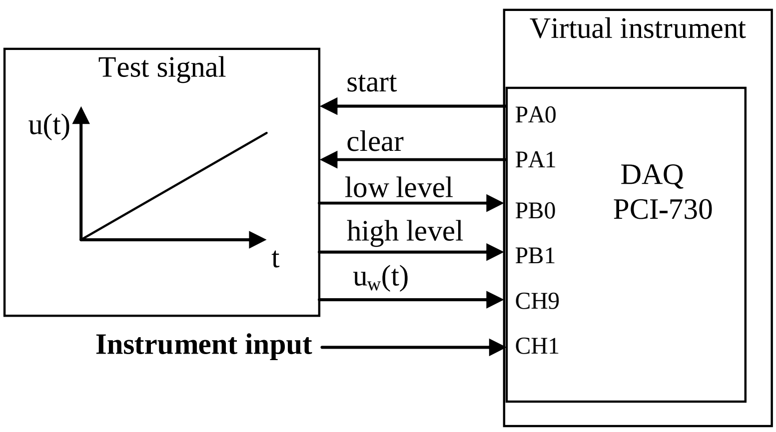

Figure 3. The circuitry configuration of virtual instrument with test signal source [5].

The data acquisition procedures are controlled by LabVIEW application. Selected parts of program are shown in Fig.4. The block diagram consists of the sequence of procedures enabling the control of work of devices included into source test arrangement.

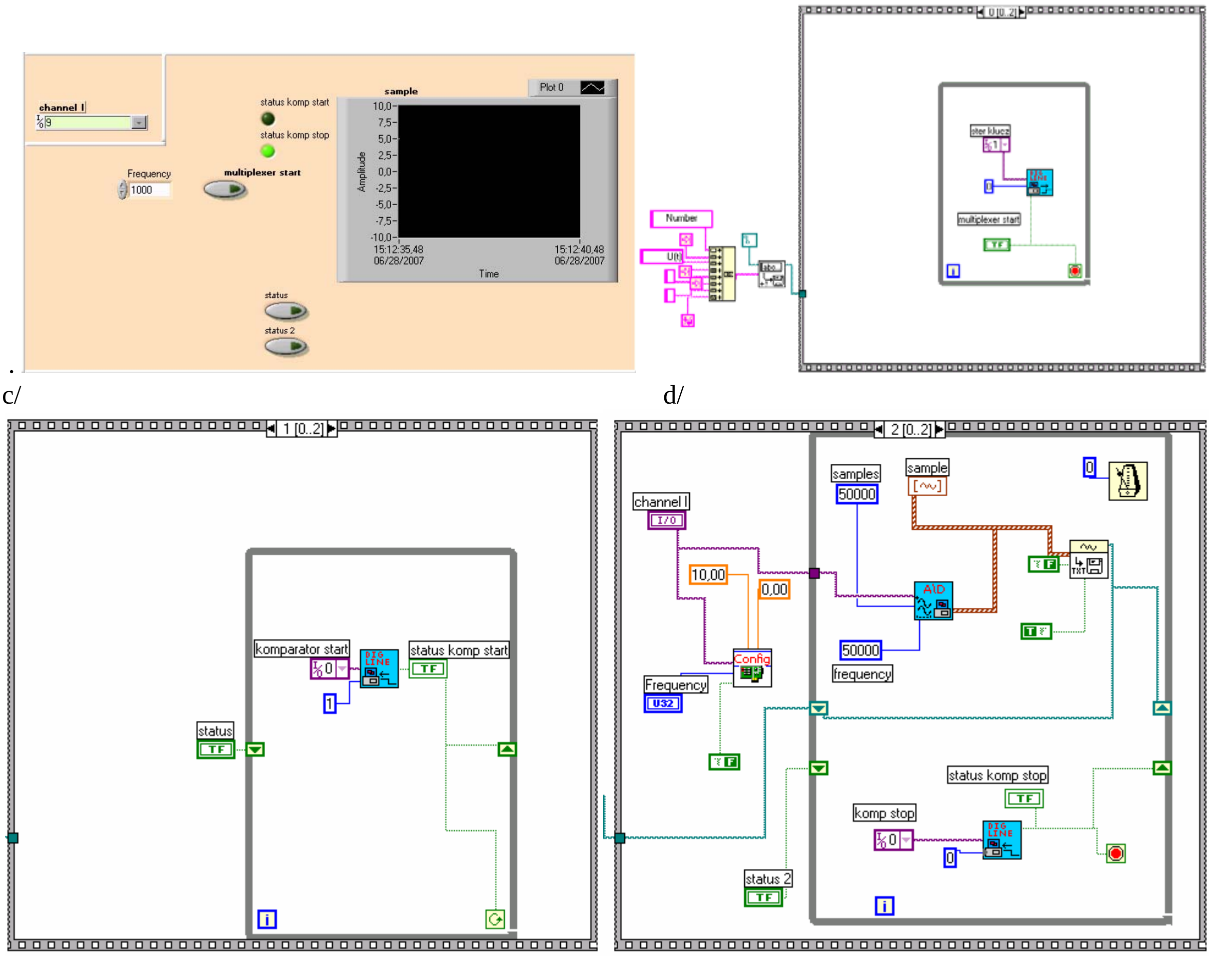

Figure 4. The front panel (a/) and sequence of block diagrams (b/, c/, d/) of LabVIEW application controlling the test arrangement and data acquisition for examination of test sources.

The ADC board input range was established on ±5 [V].

The subject of research were a few circuit configurations of the test sources. The examination results of some of them are shown in Fig.5. They have not passed the tests. The output signals have proved to be not enough linear.

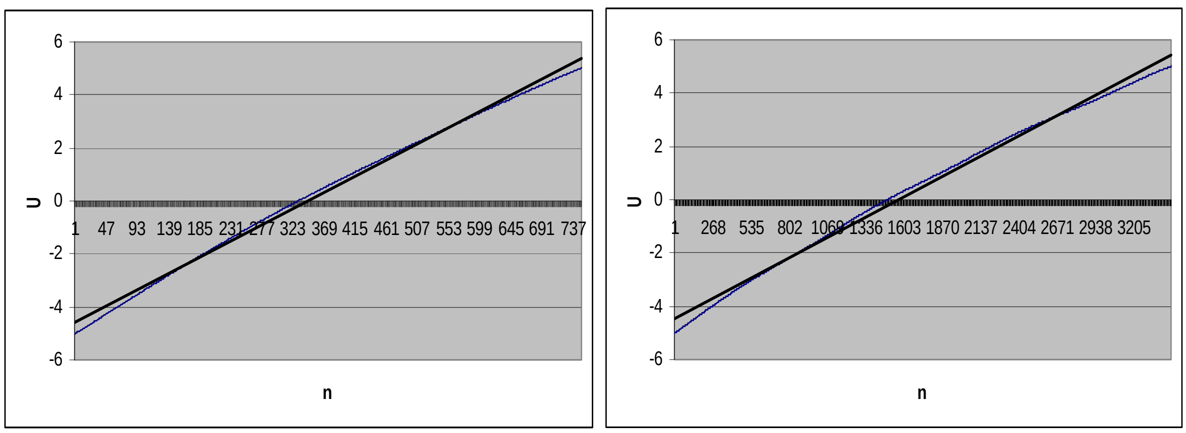

Figure 5. The exemplary courses of output signals of the negatively classified test signal sources (trend line of signal is added).

Finally, as a result of number of modifications, the test signal source configuration, providing desirable output signal, was elaborated. The signal provided from this source to virtual instrument is shown in Fig.6.a. The linearity of obtained course is satisfactory. As a reference, in Fig.6.b the course of acquired ramp signal from 33220A Agilent generator is shown.

a/ b/

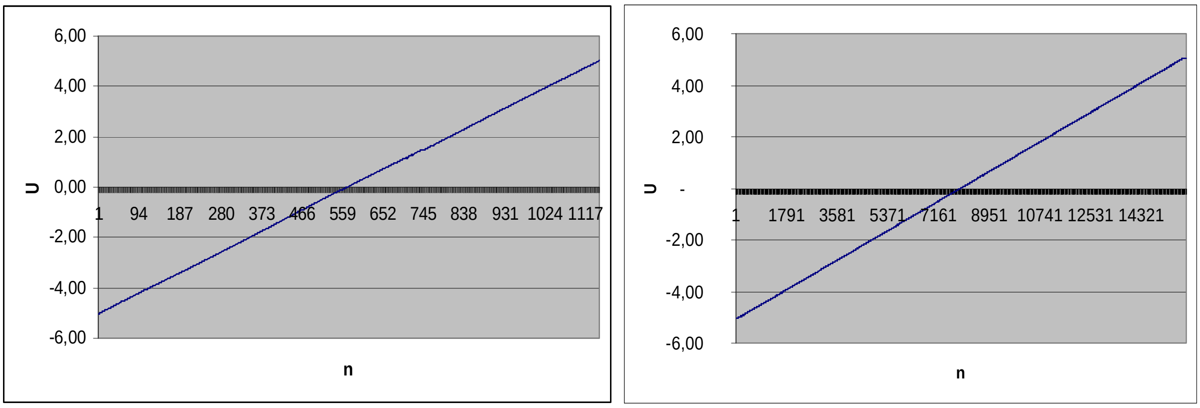

Figure 6. The PCI 730 acquired digital data as a result of analog-to-digital conversion of input signals: a/ tested pattern source, b/ ramp signal provided by 33220A Agilent generator.

The linearity of analyzed courses was estimated by calculating of the *r - Pearson* factor. It is the coefficient used to assess the linear dependence between two sets of data. Its value is calculated as in (1).

$$r = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}} \qquad (1)$$

where: $x, y, \bar{x}, \bar{y}$ – estimated data tables and their mean values, respectively.

The estimation was carried out for acquired data obtained by conversion of ADC input signals in accordance to linear approximation of considered courses (the reference data sets).

For examined source, the r-factor value is equal to 0,9999762, the r-factor for input pattern ramp signal provided by 33220A Agilent generator is equal to 0,9999998.

The values of r-factor for rejected sources were on the level of 0,995.

The standard deviation for the test signal calculated in relation to its linear approximation (trend line) is equal to 0,047 [V] and for reference Agilent generator signal is equal to 0,072 [V]. The value of standard deviation of signal from pattern generator is higher because of the nature of digitally synthetized output waveform. The root mean squared errors are equal 0,00173 [V] and 0,00058 [V], respectively. The considered ADC quantum value corresponding to 1 LSB is equal approximately to 0,0006 [V].

III. Conclusions

The IEEE standards concerning the estimation of ADC and related devices may be the reference for the investigation focused on the evaluation of measurement result in operation conditions. The recommendations of standards concern the methods of test and estimation of features of devices and channels containing the ADCs. They are used mainly for comparative assessment of the features of several devices. They have limited usability to on-line estimation of actual characteristics of measurement channel as well as the measurement result.

The examination of instrument in operation conditions needs to solve the problems of the test signal generating and providing it to the input of measurement channel as well as the data obtained on the ADC output further processing.

In the paper, the configuration of measurement channel additional circuits enabling on-line channel feature estimation and the result correction according to the actual operation conditions are proposed. Selected results connected with the examination of several sources configurations are shown.

The satisfactory results give the assumption to further research focused on the on-line measurement channel feature estimation.

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