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INCREASING IMMUNITY TO NOISE AND INDUSTRIAL INTERFERENCE OF HIGHLY SENSITIVE MEASURING CHANNELS OF THE SENSOR SYSTEMS

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The article discusses the new construction principles of the highly sensitive and high-speed electronic channels for sensor measuring systems with parallel-sequential conversion of the dynamic informative signals of direct or alternating current in wide ranges of its amplitude and frequency. The possibilities of improving suppression of noise and the interferences on industrial power frequency with several methods of processing the obtained data shown analytically and experimentally. A prototype of a unified basic module of the measuring channel described, intended for the implementation of information-measuring systems for various purposes; its main characteristics are given. References 7, figures 14, table 1.

Key words: signal conversion, measuring channel, sensor systems, sensitivity, interference.

Introduction. An important requirement for the electronic channels of accurate measuring systems with sensors is the combination of high sensitivity and selectivity with respect to the informative parameter of the input signal with a sufficient conversion rate, which should correspond to the informative part of its frequency spectrum. This is because the relative changes in the informative parameters of accurate and stable sensors are limited, as a rule, by a few percent of the value of the test signal, which, in turn, is subject to amplitude limitations. At the same time, controlled processes are often dynamic and have a wide range of values, and external and internal noise interference, as well as power frequency interferences with frequencies of 50 (60) Hz, are superimposed on the informative signal. Additional requirements are the need to obtain data in real time, the simplicity of the equipment, reducing its energy consumption.

The solution to such problems is relevant in the development of monitoring and automatic control systems in industry and infrastructure, for environmental research, biotechnology and medical diagnostics. The specified conditions for performing measurements require high productivity and noise immunity of the secondary measuring conversion of the informative parameters of the sensors.

The content of this work is to study the possibilities of increasing the sensitivity and real resolution of the measuring channel for impedance sensors when high measurement rates are required under conditions of significant levels of the power frequency interference and noise. Objective: to assess the sensitivity and noise immunity of the prototype of the developed unified measuring channel for sensor systems that work with weak informative signals in conditions of limited measurement time with different variants of the primary data processing algorithms.

Applied methods and means. The metrological perfection of a sensory measuring instrument evaluate besides sensitivity, selectivity and conversion rate also by a whole range of other characteristics. First of all, these are functional capabilities - ability to implement some set of measurement methods of various physical quantities with various types of the impedance sensors. Among them is also noise immunity, which determined by the error of the averaged measurement results due to deviations of the zero offset, non-linearity and steepness of the channel conversion characteristics from the nominal values under the influence of various interference. Important parameters are the range and relative discreteness of measurements (number of scale divisions of the device), the level of test signals on the sensor. Achieving a

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higher level of each of the characteristics (moreover, several at the same time) is important for the development of measuring technology and therefore is the subject of many studies. However, each improvement in performance is associated with certain costs; therefore, the realities of the practical application of the created devices require a balance of their technical and economic indicators to achieve economic feasibility and competitiveness of measuring instruments.

A promising way for measuring electrical and other physical quantities is using impedance sensors (capacitive, resistive, inductive, as well as having a complex nature of impedance), which supply by AC test signals [1]. Secondary converters of their output signals based on direct conversion methods (ammeter - voltmeter, etc.), measurement methods using AC bridges, as well as on combined methods [2 – 5]. The using of a sinusoidal alternating current reduces errors from unstable parameters of the measuring circuits, allow optimizing the operating mode of the sensors (including taking into account the type of interference) and improve the noise immunity of the channel. With such measurements, useful information is contained both in the amplitude and in the phase of the signals, what increases their information content. Effective extraction of this information can be done by correlation methods, which can simply be implemented using synchronous detectors.

The measuring channel realizes the informative signals conversion in the measuring-information system, so it is the interface between the object of measurement and digital means of data collection and processing. The examples of devices that meet the trends of them development are given in [6 – 9]. However, the existing solutions do not allow unifying the measuring channel for a wide range of tasks, in particular, in cases of weak informative signals, limited measurement time, strong industrial influences.

On these principles, the Institute of Electrodynamics of NAS of Ukraine developed and successfully applied unified basic measuring channels for solving complex problems, which ensure economic efficiency of devices while meeting high requirements simultaneously for several of the above-mentioned characteristics. In these devices, the test signal and reference signals of synchronous detectors are generated by a digital-to-analog generator of quasi-sinusoidal voltage, and the informative signal is converted by a phase-selective micro-voltmeter based on a highly sensitive (“multi-slope”) integrating ADC with a key synchronous detector at its input [10, 11].

As a rule, during the operation of the ADC, only part of the input signal energy it use to extract information. The remaining energy is lost during the comparison of the extracted signal with the reference and in the processing of the comparison data. More effective is using parallel-serial conversion of the sensor signals using several ADCs. The instruments, based on this principle allow increasing the sensitivity and speed of measurements for solving important problems in the fields of biomedical measurements and technical diagnostics [12, 13].

The measuring channel, which considered in [12], use three 18-bit integrating ADCs of the MAX-132 type in the various measurement mode at a speed of 100 samples per second. Some important characteristics of such channel evaluated. The possibility of a deep suppression of power frequency interferences (50 or 60 Hz) by averaging two adjacent samples obtained from each ADC shown and experimentally confirmed. In [13], measurement methods for monitoring the parameters of moving objects under high interference consider when the interaction time of the measurement object with the sensor is limited.

In fig. 1 shows the structure of a signal conversion unit of a base measurement channel with three ADCs. The sensor S is included in the measuring circuit of the secondary converter ST, to which a sinusoidal test signals TS supplied from the GTS generator. The amplitude TS is determined by the stable output voltage of the reference voltage source SRV. The TS frequency chose optimal for the applied sensor and the method of obtaining an informative signal. GTS clocking perform by TI pulses from the MC microcontroller. To perform frequency and phase selection of the quadrature components of informative signal U_X from the ST output, the circuit contains a key synchronous detector SD, which is supplied the reference RS signal from the GTS generator (rectangular meander signal, common mode or quadrature to TS). This allows us to distinguish two components (Re and Im) of the informative sensor signal (for this type ADC at frequencies above 50 Hz). At lower frequencies, the RS reference signal of the synchronous detector fixed in one of two

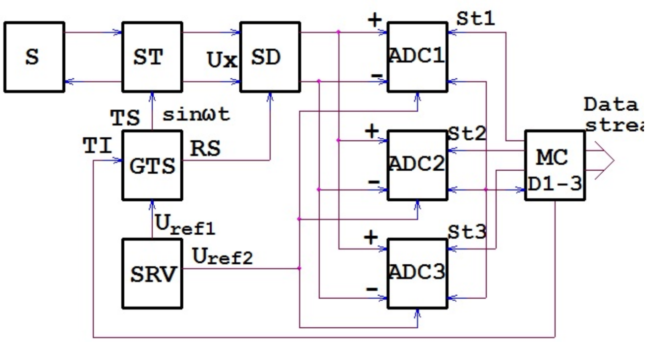


Fig. 1

possible states depending on polarity the constant bias of the input signal.

The SD output signal is converted to digital code in parallel by three integrating (multi-slope) ADC1, 2, 3. The conversion start in each of these ADCs is performed sequentially (cyclically), after the end of the integration phase in the ADC, which was launched earlier. The duration of this phase for this type of ADC is 1/3 of the conversion cycle duration (10 ms), therefore, the integration of the informative signal is performed continuously, with duration of each samples of 3.3 ms. The frequency of data output (U_X samples) by the conversion unit is also 3.3 ms. This sampling speed allows you to select and analyze signals with a frequency spectrum up to 150 Hz using samples of their averaged values with that intervals. To bind the received data stream to real time or to processes in the monitoring object, synchronization of the ADC conversion cycles start is possible by an external signal, which can connect to the microcontroller [13].

Fig. 2 shows the timing diagrams of the functioning of the measuring channel at a clock frequency of about 200 kHz (the conversion cycle in this case is 10 ms, which corresponds to a power network frequency of 50 Hz). The first line marks the moments when the controller issued commands to start conversion cycles. The second, third, and fourth lines show the arrangement of the integration phases in the first, second, and third ADCs, respectively. The following lines show the moments of data output for different methods of their processing.

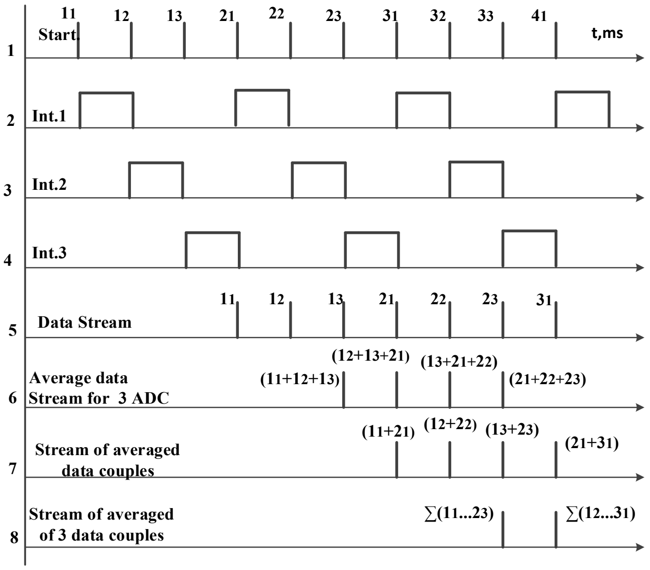


Fig. 2

Depending on the requirements for the measuring channel, different use of the received data stream is possible. Separate registration of all samples (line 5) gives the maximum measurement speed (300 samples per second), but the minimum noise immunity of the channel. Averaging the samples of three ADCs per conversion cycle narrows the noise band at a measurement speed of 10 ms, but without suppressing power frequency (50 Hz) interferences (line 6). Pairwise averaging of adjacent samples from each of the ADCs also makes it possible to narrow the noise band of the channel and additionally suppress power frequency interferences, but the establishment of measurement results after changes in the sensor signal occurs after approximately 16 ms (line 7). Averaging the samples of three ADCs for two adjacent conversion cycles provides the most suppression of the indicated interference and minimal noise bandwidth (line 8). The frequency of data output remains the same in all cases, but the response time of the channel to a step change in signal changes. In the latter case, it is 20 – 30 ms.

The study of power frequency interference suppression with changes of its frequency. For maximum suppression of the interferences with power frequency, the interval between adjacent integrations of each ADC should be exactly equal to half the voltage period in the power network. We can achieve this by appropriate selection of the clock frequency of the ADC and the moments of issuing commands for performing measurement cycles, taking into account the algorithm of the ADC. However, in real conditions, the voltage frequency in the network varies within a few tenths of Hz.

Let us determine the dependence of the suppression degree of network interference on the difference between the real frequency of the voltage in the network and its nominal value of 50 Hz using the method of averaging pairs of ADC samples following at intervals of 10 ms. The instantaneous values ΔU_I of the residual interference signal can be represented by the following expression:

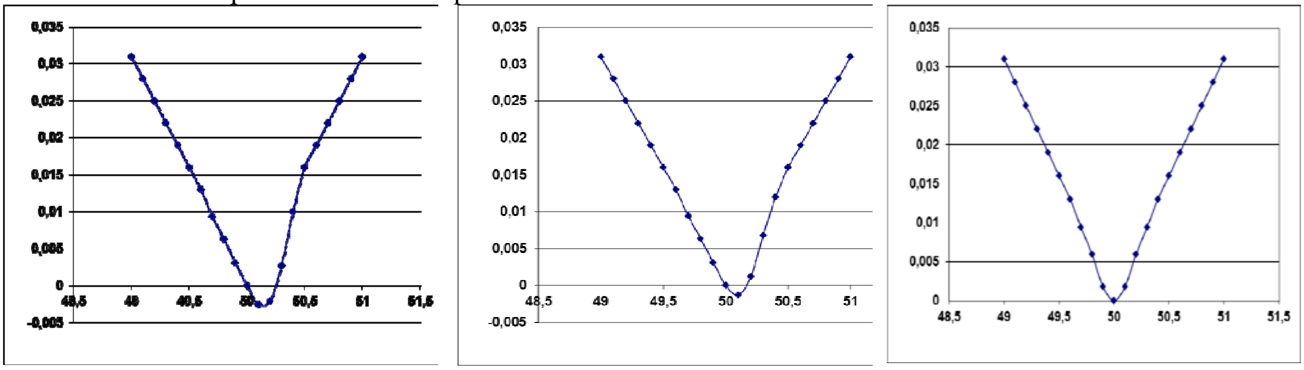
$$\Delta U_I = \frac{U_I \sin(2\pi f_I (t + \Delta t) + \varphi) + U_I \sin(2\pi f_I t + \varphi)}{2}, \tag{1}$$

were: U_I and f_I are the amplitude and frequency of the interference on the channel output; t is the time; Δt is the interval between samples (10 ms); φ is the phase of the interference.

We performed the numerical (computer) simulation of the power frequency interference suppression by using the MATHCAD package to visualize the studied dependence. The amplitude of the interference we assumed unity. The arrays of 50 values we calculated by expression (1) for interference frequency from 49 to 51 Hz and for different phases of the interference. For each array of data, the maximum and average relative values of the residual interference level were determined. The maximum values characterize the error of a single sampling under registration of relatively rapidly changing values. Average values characterize the measurement error of static values, when there is the possibility of averaging the results.

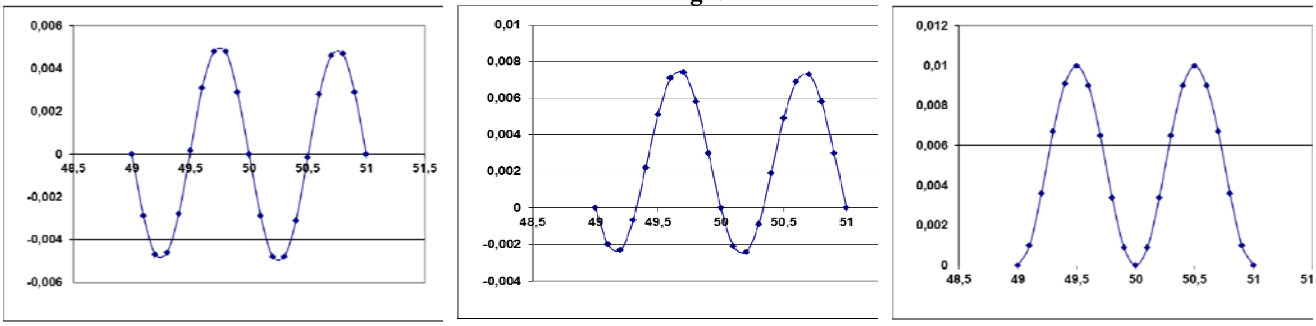
Fig. 3 shows graphs of the dependences of the maximum relative values ΔU_I of the residual interference on the network frequency (in Hz) at phase values φ equal to 0° (a), 30° (*b*), 90° (*c*). As can be seen in the graphs, the dependence of the maximum values of the residual interference amplitudes on the frequency (0.031) is practically independent of the phase of interference. Differences are observed only at frequencies of 50.1 Hz and 50.2 Hz, however, they are insignificant.

Fig. 4 shows graphs of the dependences of the average relative values of residual interference on the network frequency for values of φ equal to 0° (*a*), 30° (*b*), 90° (*c*). The maxima of the average values significantly depend on the phase of the interference. The maximum values (of 0.01) take place for interference with a phase of 90° at frequencies of 49.5 Hz and 50.5 Hz.



a ***b*** ***c***

Fig. 3



a ***b*** ***c***

Fig. 4

When the integrating ADC using in the measuring channel, it sample the signal not at one point, but on the certain interval of the sinusoidal voltage of the network interference. When using ADC MAX-132 manufactured by MAXIM, the minimum integration time is about 3.33 ms with a measurement cycle time of 10 ms. In this case, expression (1) takes the following form:

$$\Delta U_I = \frac{U_I}{2}\cdot\frac{\int\limits_{t}^{t+\Delta t/3}\sin(2\pi f_I t+\varphi)dt+\int\limits_{t+\Delta t}^{t+4\Delta t/3}\sin(2\pi f_I t+\varphi)dt}{\Delta t/3}. \qquad (2)$$

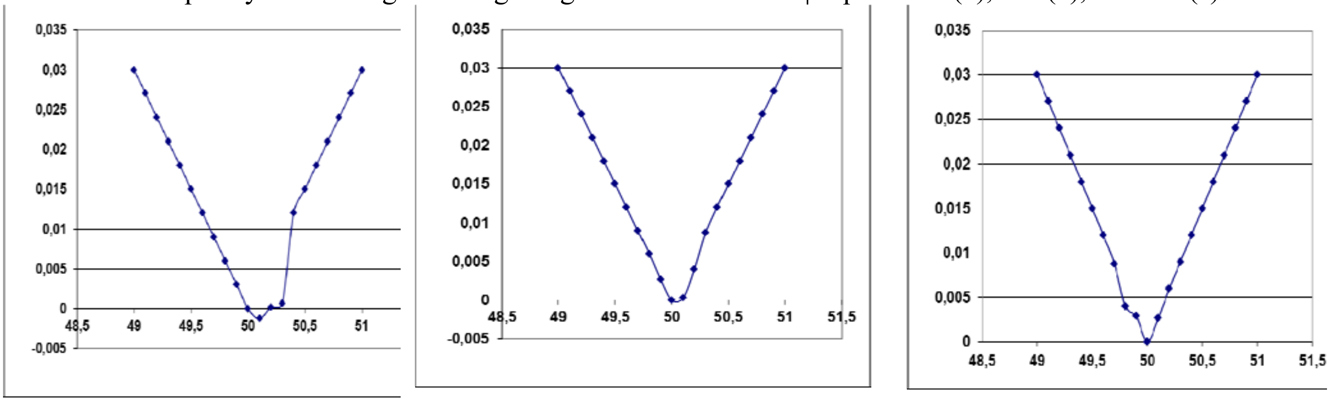
After integration, we obtain an expression for the measurement result:

$$\Delta U_I = \frac{U_I}{2}\cdot\frac{\cos(2\pi f_I t+\varphi)-\cos(2\pi f_I(t+\Delta t/3)+\varphi)+\cos(2\pi f_I(t+\Delta t)+\varphi)}{2\pi f_I\Delta t/3}-\frac{\cos(2\pi f_I(t+4\Delta t/3)+\varphi)}{2\pi f_I\Delta t/3}. \qquad (3)$$

Fig. 5 shows graphs of the dependences of the maximum relative values of the residual interference on the frequency of the power network when using one integrating ADC for values of φ equal to 0° (*a*), 30° (*b*), 90° (*c*).

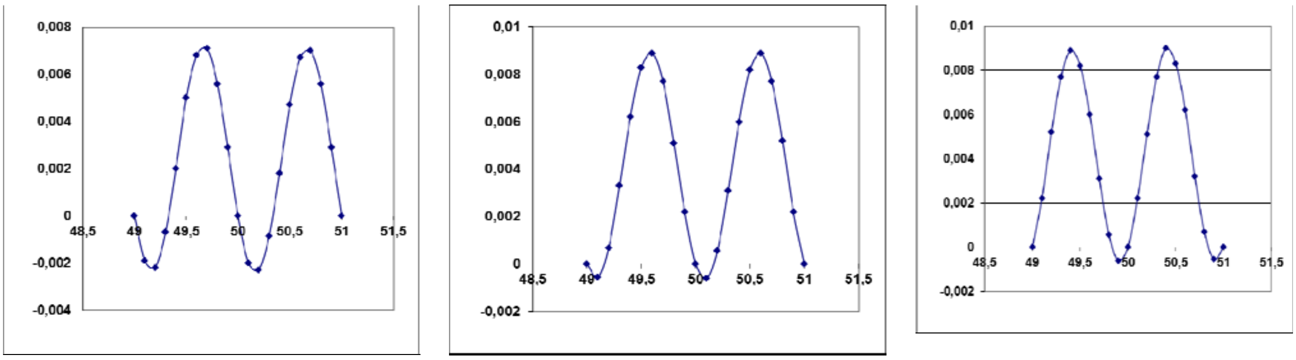
Similar to the case of measuring the instantaneous values of the signals, the maximum values of the residual interference are practically independent of the phase of the interference. The chart maxima occur at the extreme frequencies of the range and are 0.03, i.e. practically do not differ from the maxima determined for the previous case.

Fig. 6 shows graphs of the dependences of the average relative values of the residual interference on the interference frequency when using one integrating ADC for values of φ equal to 0° (*a*), 30° (*b*), and 90° (*c*).



a ***b*** ***c***

Fig. 5



a ***b*** ***c***

Fig. 6

We can see from the graphs in Fig. 6, that the maxima of the average relative values of interference are practically independent of the phase of the interference. The maximum values at the level of 0.009 are observed near the frequencies of 49.5 Hz and 50.5 Hz. In parallel-serial processing of signals using three ADCs, their integration intervals are shifted by Δt/3. If we take (3) as an expression for the residual signal at the output of the 1st ADC (ΔUP), then the expressions for the residual signals of the 2nd and 3rd ADCs will look like:

$$\Delta U_{I2}=\frac{U_I}{2}\cdot\frac{\cos(2\pi f_I(t+\Delta t/3)+\varphi)-\cos(2\pi f_I(t+2\Delta t/3)+\varphi)+\cos(2\pi f_I(t+4\Delta t/3)+\varphi)}{2\pi f_I\Delta t/3}-$$

$$-\frac{\cos(2\pi f_I(t+5\Delta t/3)+\varphi)}{2\pi f_I\Delta t/3}. \qquad (4)$$

$$\Delta U_{I3}=\frac{U_I}{2}\cdot\frac{\cos(2\pi f_I(t+2\Delta t/3)+\varphi)-\cos(2\pi f_I(t+\Delta t)+\varphi)+\cos(2\pi f_I(t+5\Delta t/3)+\varphi)}{2\pi f_I\Delta t/3}-$$

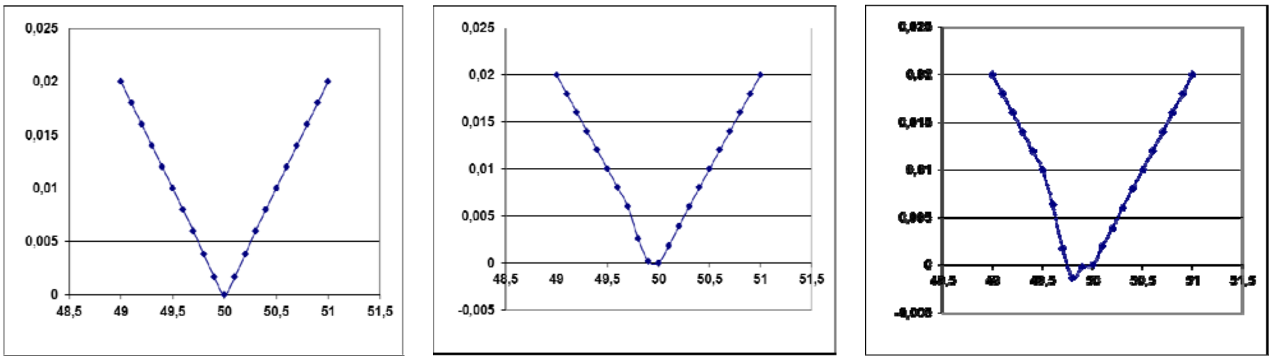
$$-\frac{\cos(2\pi f_I(t+2\Delta t)+\varphi)}{2\pi f_I\Delta t/3}. \qquad (5)$$

Fig. 7 shows graphs of the dependences of the maximum relative values of the residual interference on frequency when using three integrating ADCs for values of φ equal to 0° (*a*), 30° (*b*), and 90° (*c*).

The graphs on fig. 7 practically repeat the graphs in fig. 5, except that all values are 1.5 times smaller. We can explain this by the effect of averaging three samples.

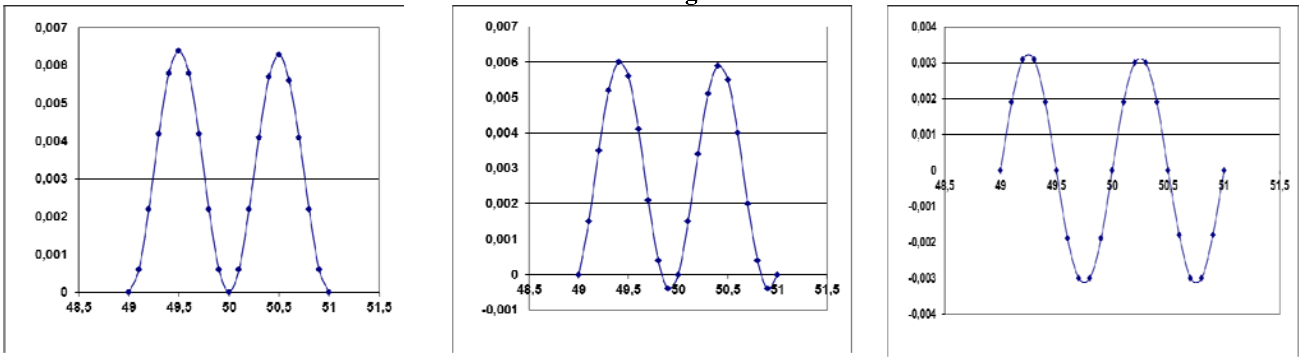
Fig. 8 shows graphs of the dependences of the average relative values of residual interference on the frequency when using three integrating ADCs for values of φ equal to 0° (*a*), 30° (*b*), 90° (*c*).

We can see from the graphs in fig. 8, the maxima of the average values of the interference substantially depend on the phase of the interference. The maximum value of 0.0065 has residual interference with a phase of 0° at frequencies of 49.5 Hz and 50.5 Hz.



a *b* *c*

Fig. 7



a *b* *c*

Fig. 8

Table contains data on the degree of suppression of power frequency interferences with the largest changes in the frequency of the power network (49 Hz and 51 Hz) for the three cases considered. From this table it follows that the effectiveness of the first two measurement methods is almost the same, and the third method is more than 1.5 times effective for suppression of network interference. We can achieve suppression of power frequency interferences up to 300 – 500 times in the range of normal variations of the network frequency (± 0.2 Hz) in the latter case.

Measurement Method	Interference Suppression Factors (times)	
	Averaging two adjacent samples.	Averaging over 50 periods of interference.
Instantaneous measurement	32	100
One integrating ADC	33	111
Three ADCs with parallel-serial conversion	50	153

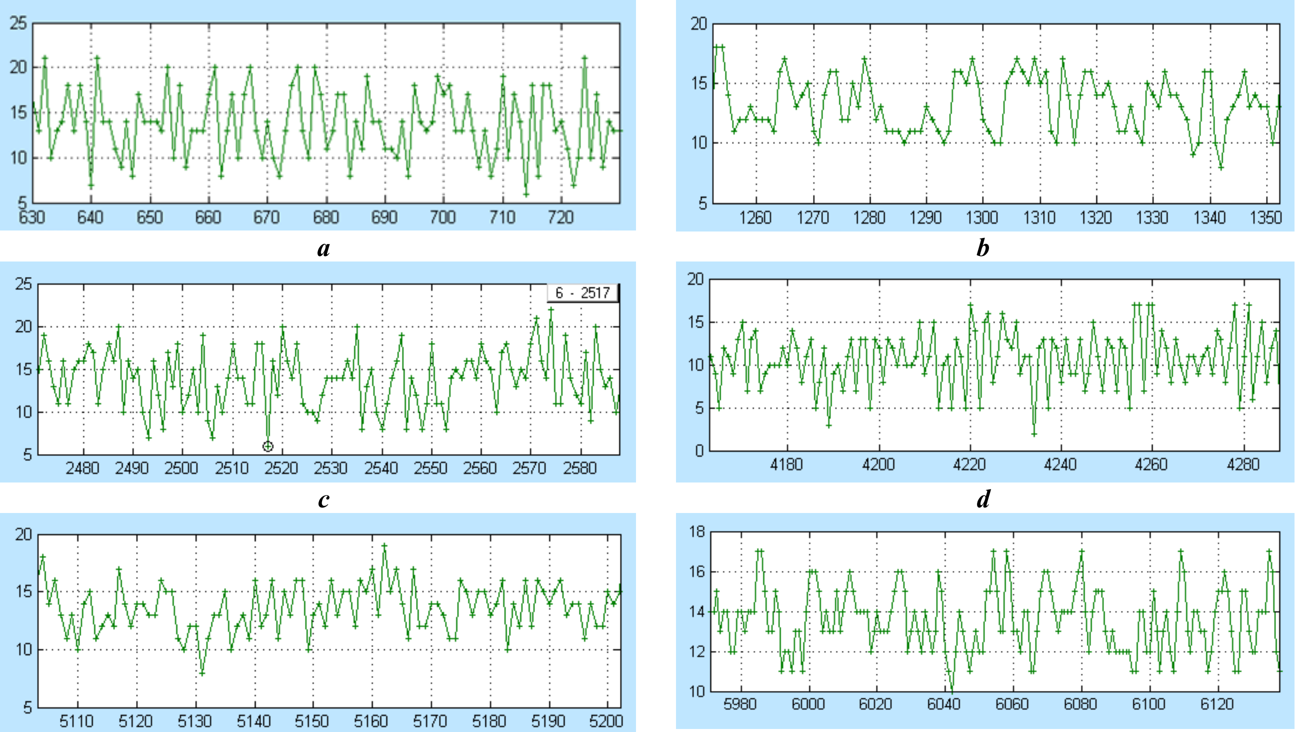
Experimental studies of the characteristics of the basic measuring channel. The structure and principle of operation of the measuring unit with parallel-serial conversion of informative signals described above were the basis for the prototype of the unified basic measuring module MXP-6, which is being developed at the Institute of Electrodynamics of NAS of Ukraine. The instrument intended for precision measurements in a wide frequency range (0 – 1 MHz) of voltage, current, parameters of electrical impedance, as well as various non-electrical quantities using sensors in information systems of technological and biomedical purposes.

The experimental complex for studying the potential metrological characteristics of the measuring cannel consists of an MXP-6 module and a computer connected via a USB interface. In addition to the elements shown in Fig. 1, the MXP-6 base module contains power supplies, interface block, a precision divider for the test voltage based on the AD7945 multiplying DAC, signal switches, a control keyboard, and an alphanumeric display. The secondary converter ST (or the measuring circuit, if the sensor is missing) is a replaceable unit that adapts the base module to a specific task. In our case, the adder of the informative signal and interference on the operational amplifier with voltage dividers at the corresponding inputs, which allow you to change the signal amplitudes and interference from 0 to 0.5 V, serves as such a block. The informative signal is simulated by normalizing the voltage TS from the GTS generator. An interference voltage with a frequency of 50 Hz we obtained from the voltage of the power network through a transformer. The frequency of the test signal set by selecting the clock frequency TI. To study the conversion characteristics in the entire dynamic range of the measuring channel (± 0.5 V), this unit also contains the generator of the adjustable, linearly varying voltage.

The MC controller program carries out the control of the signal conversion process in the base module, the primary digital processing of the received data (including averaging) and the transfer of measurement results to the computer. The computer application program performs general control of the measurement process (setting modes, issuing commands, receiving data, accumulating them, recording and graphical presentation).

Fig. 9 – 14 show graphically the data obtained on an experimental setup with various combinations of an informative signal and power frequency interference for the measurement modes described above. On the horizontal axis, the one unit of the scale is 3.33 ms (fig. 9, *c*, *d* and fig. 13) or 10 ms (other fig.); along the vertical axis, the one unit of the scale corresponds to 2 μV.

Figure 9 shows the data obtained in the absence of an informative signal and interference: 9, *a* – using one ADC without averaging the results; 9, *b* – with averaging of pairs of results of one ADC for two adjacent cycles; 9, *c* is the total data stream of three ADCs without averaging the results; 9, *d* – the total data stream of three ADCs with averaging the pairs of results of each ADC in two adjacent cycles; 9, *e* is the total data stream of three ADCs with averaging the results for one conversion cycle; 9, *f* - the total data stream of three ADCs with averaging with averaging of all results obtained in two adjacent cycles. The presented graphs characterize the random additive error of the measuring channel, which the action of internal noise causes.



a ***b***

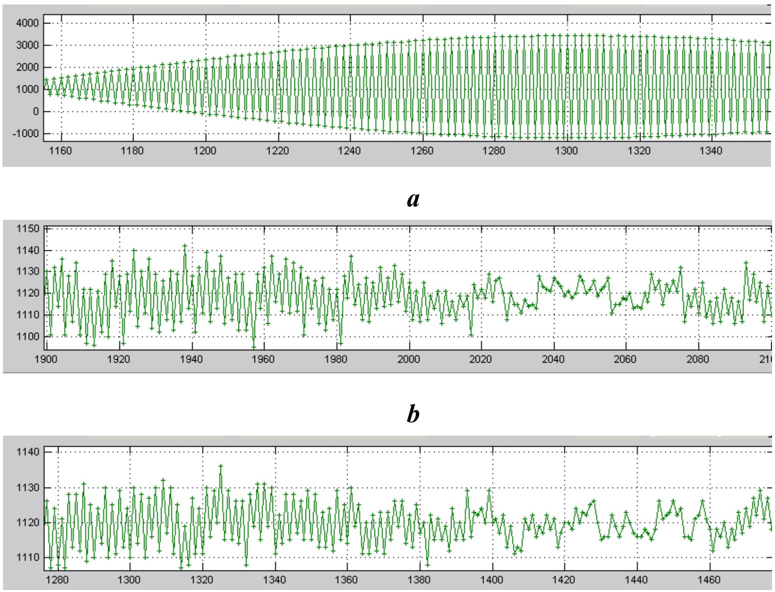
c ***d***

e ***f***

Fig. 9

Figure 10 shows the interference conversion data with a frequency of 50 Hz and an amplitude of 5 mV: 10, *a* – using one ADC without averaging the results; 10, *b* – with averaging of the pairs of results of one ADC for two adjacent cycles; 10, *c* – with averaging the results of the conversion of three ADCs for two adjacent cycles. The vibrations of the samples of interference are due to the difference in the frequencies of the voltage in the power network and the conversion cycles of the ADC (in this case, about 0.15 Hz).

Figure 11 shows the waveforms of the simulated an informative signal with a frequency of 4 Hz and an amplitude of 100 μV and 20 μV: 11, *a* – without the presence of the power frequency interference, using one ADC without averaging the results; 11, *b* – without the presence of the power frequency interference, with averaging the results of the conversions of three ADCs in two adjacent cycles; 11, *c* – in the presence of the power frequency interference with an amplitude of 5 mV and with averaging of the pairs of results of one ADC for two adjacent cycles; 11, *d* – in the presence of the power frequency interference with an amplitude of 5 mV and with averaging the results of the conversion of three ADCs in two adjacent cycles.



a

b

c

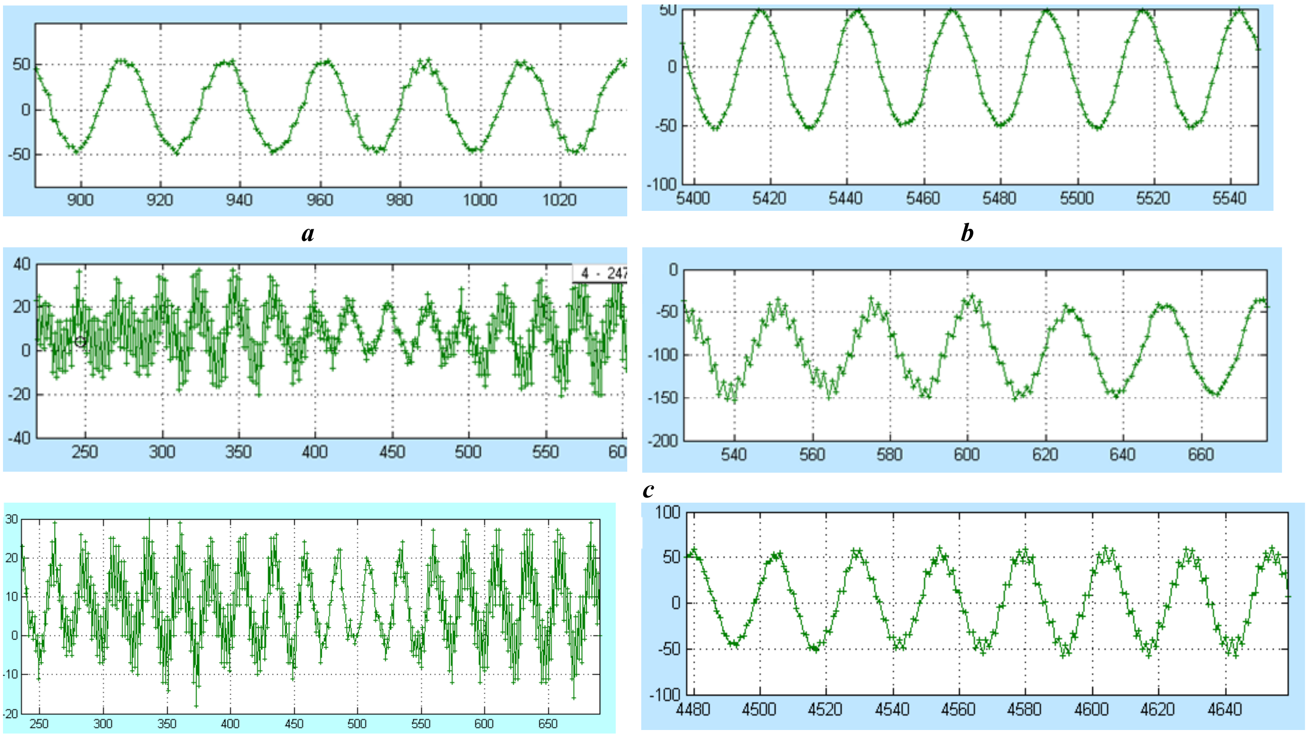
Fig. 10

Analysis of the experimental studies results. The purpose of the analysis is to assess the compliance of the experimental results with the above initial assumptions and the results of computer modeling.

Fig. 9 show a 1.4-fold decrease in sample variations (pic-to-pic) due to pairwise averaging of the results of each ADC in adjacent conversion cycles, and decrease of no less than 1.5 times due to averaging the results of three ADCs per cycle transformations. The variance of the samples decreases even more significantly. Due to both of these operations, more than twofold decrease in random error and increasing in the resolution of the measuring channel we have achieved in comparison with devices where one ADC is used. A triple increase in the sampling frequency achieved without a significant change in resolution.

Fig. 10 show real suppression of power frequency interference by 150 and 300 times for 2 modes of the channel operation within normal deviations (± 0.2 Hz) of voltage frequency in a power network, which is in good agreement with the data obtained by computer simulation of the developed measurement method.

Fig. 11, *a*, *b* show the possibility of significant improving the quality of selection of a weak dynamic signal using the developed device. On the fig. 12, *c*, *d* demonstrate the possibility of assured detecting an informative signal of 20 μV and measuring with error about 10% of the signal of 100 μV against the background of suppressed power frequency interference with an initial value of 5 mV.



a

b

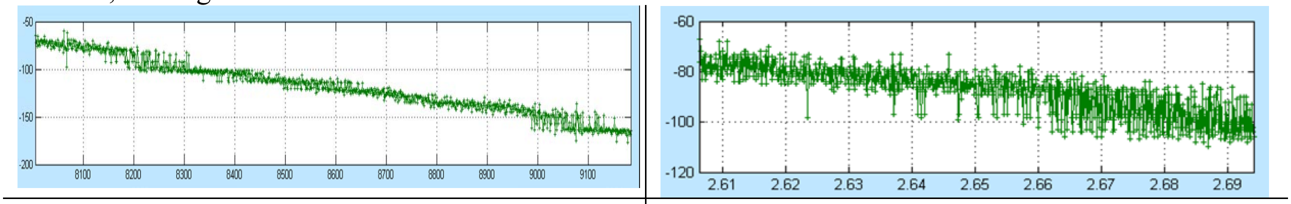
c

d

Fig. 11

To obtain stable and reliable measurement results using the integrating "multi-slope" ADC MAX-

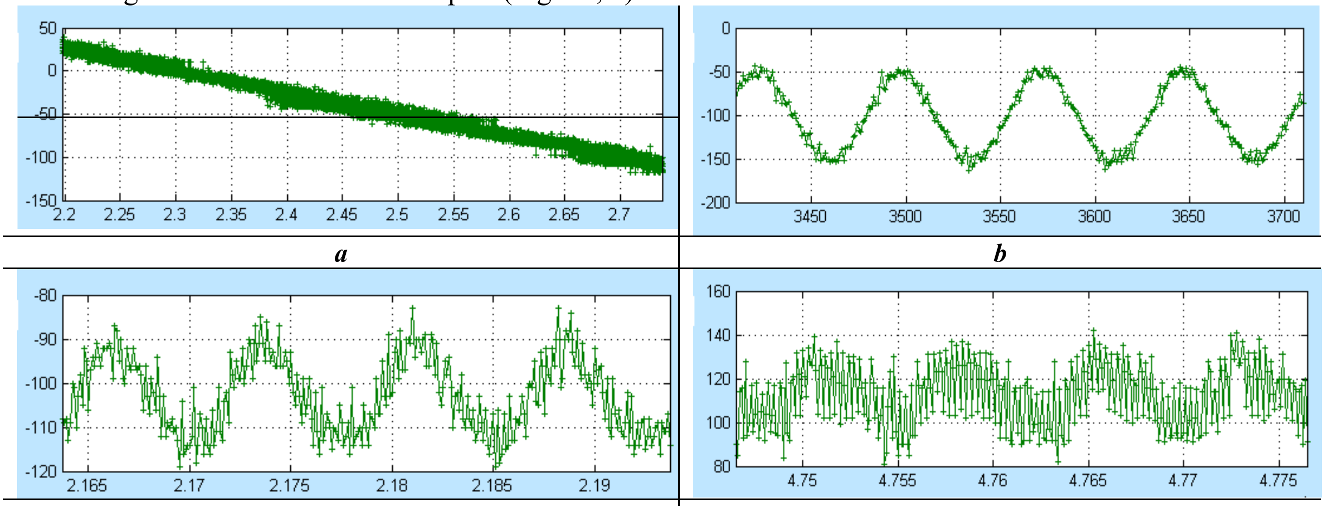
132, it is necessary to take into account some features of the conversion characteristics of this device that we studied earlier [10, 11]. The most essential question for achievement of good linearity of the conversion characteristic and sensitivity of devices is the presence on this characteristic of areas with increased dispersion of samples due to single or continuous jumps of the conversion results by values up to 10 – 20 units of scale. The most noticeable of these areas have length of about 20 units of discreteness and it repeats over the entire characteristic with an interval of about 64 units (fig. 12, *a*, *b*). When scanning such areas with averaging of significant number of measurement results, the stairs on the obtained characteristic (about 10 units) are formed that represent the special differential nonlinearity. If we do not perform averaging of a significant number of results, as in our case, we have at all points of such areas increasing of the random error. As we assume, the reason for this dispersion is the instability of fixing the values in the lower bits of the ADC, starting with the thirteenth under the influence of internal noise.



a ***b***

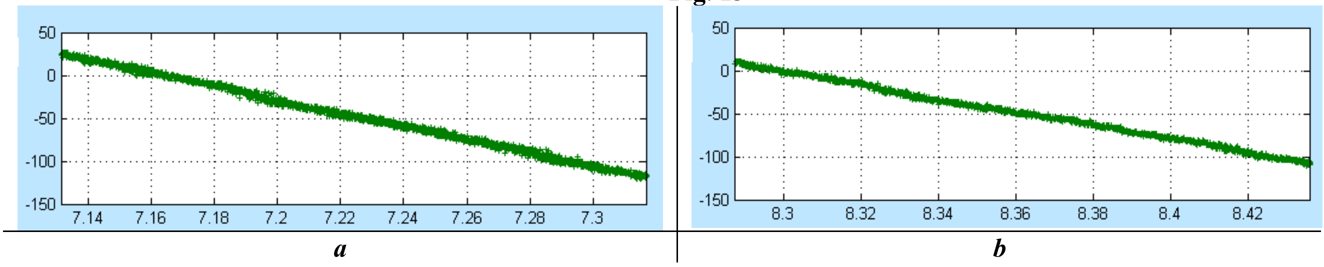
Fig. 12

Fig. 13, *a* show a part of the characteristic of the developed basic measuring channel with three ADCs in the mode of 300 samples per second. In fig. 13, *b*, *c* shown the oscillograms of a sinusoidal signal with amplitude of 100 and 20 µV, obtained with its help. In this case, the areas with increased dispersion of the three ADCs are shifted relative to each other and the deviations of the results from the average values are within ± (0.002 – 0.003) %. However, in some cases, such areas can overlap each other, which lead to increasing in the variance of the samples (Fig. 13, *d*).



c ***d***

Fig. 13



a ***b***

Fig. 14

With particularly high requirements for the measurement speed and resolution of the device, such overlays we can eliminate by a small adjustment of the ADC zero offset. In the operating modes of the developed measuring channel with averaging the results of three ADCs, the problem of increasing the dispersion of samples the problem is practically absent. Fig. 14 show areas of its characteristics similar to that shown in fig. 13, *a*. Diagram “a” corresponds to the mode of averaging the results of three ADCs in one conversion cycle, and diagram “b” corresponds to averaging of the results of two such cycles. In the first case, the random error (resolution of the channel) does not exceed ± 0.002% of the full scale (± 260 000 discrete units) at the measurement speed of 100 samples per second, and in the second case, it does not exceed ± 0.001% at the measurement speed of 50 samples in second.

Conclusion. Using the proposed parallel-serial signal conversion using several integrating ADCs allows you to more fully use the information, which it carry, and thereby to increase the measuring speed of channel (multiply of the number of ADCs) or its resolution with respect to random interference.

The method of the power frequency interference suppressing by averaging samples of an informative signal with an interval of 10 ms. allows to reduce the amplitude of such interference up to 300 times in the range of power frequency variations ± 0.2 Hz.

The developed structure and operation algorithm of the signal conversion unit provide for the implementation of several measurement modes and methods for processing the obtained results, which allows optimizing in the conditions of the problem being solved the speed of measuring and noise in the measuring channel and increase suppressing of the influence of the electric network.

The developed unified basic module for sensor systems, in which such a conversion perform, allows determining the parameters of DC and AC signals in the range of ± 0.5 V at a real resolution of up to 5 – 10 μV by the voltage at the output of the measuring circuit. The maximum measurement speed of this device is 300 samples per second (with minimal resolution 10 – 20 μV and without suppression of power frequency interference). In measurement modes with suppression of power frequency interference, the speed of outputting the results is 100 counts per second, and the time of complete establishment of data at the output of the device increases to 20 ms. The synchronization of sampling of an informative signal by external digital signal could be carried out.

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ПІДВИЩЕННЯ СТІЙКОСТІ ДО ДІЇ ШУМІВ І ІНДУСТРІАЛЬНИХ ЗАВАД ВИСОКОЧУТЛИВИХ ВИМІРЮВАЛЬНИХ КАНАЛІВ СЕНСОРНИХ СИСТЕМ

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В статті розглядаються нові принципи побудови високочутливого і швидкодіючого електронного каналу сенсорних вимірювальних систем з паралельно-послідовним перетворенням динамічного інформативного сигналу постійного або змінного струму в широких діапазонах його амплітуди і частоти. Аналітично та експериментально показані можливості поліпшення придушення шумів і завад силової мережі за декількох способах обробки отриманих даних. Описано прототип уніфікованого базового модуля вимірювального каналу, призначений задля реалізації інформаційно-вимірювальних систем різного призначення, наведені його основні характеристики. Бібл. 7, рис. 14, табл. 1.

Ключові слова*:* перетворення сигналів, вимірювальний канал, сенсорні системи, чутливість, завада.

ПОВЫШЕНИЕ УСТОЙЧИВОСТИ К ДЕЙСТВИЮ ШУМОВ И ИНДУСТРИАЛЬНЫХ ПОМЕХ ВЫСОКОЧУВСТВИТЕЛЬНЫХ ИЗМЕРИТЕЛЬНЫХ КАНАЛОВ СЕНСОРНЫХ СИСТЕМ

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В статье рассматриваются новые принципы построения высокочувствительного и быстродействующего электронного канала сенсорных измерительных систем с параллельно-последовательным преобразованием динамичного информативного сигнала постоянного или переменного тока в широких диапазонах его амплитуды и частоты. Аналитически и экспериментально показаны возможности улучшения подавления шумов и помех силовой сети при нескольких способах обработки полученных данных. Описан прототип унифицированного базового модуля измерительного канала, предназначенный для реализации информационно-измерительных систем различного назначения, приведены его основные характеристики. Библ. 7, рис. 14, табл. 1.

Ключевые слова: преобразование сигналов, измерительный канал, сенсорные системы, чувствительность, помеха.

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