Yu. V. Shabatura, Sc. (Eng.), Assist. Prof., I. N. Shtelmakh, M. Yu. Shabatura

MEASURING CHANNELS BASED ON NEW PRINCIPLES OF MEASURING INFORMATION CONVERSION

The paper considers processes of measuring data formation regarding measured values of various physical nature. New principles of measuring conversions realization, their mathematical support as well as structures of corresponding measuring channels are suggested.

***Key words**: measuring channel, pulse signal, pulse duration, length of pulse signal envelope.*

Intensive development of scientific research, creation of engineering systems and application of new technologies require corresponding growth of indices of metrological and operation characteristics of information – measuring systems (IMS), intended for solution of problems dealing with measuring and control of magnitudes of numerous physical values.

Rapid progress in the sphere of computing and micro processing technologies has led to creation of the base needed for realization of radical changes in the concepts of IMS construction on the whole, and in the domain of obtaining, processing, storage and presentation of measuring information in particular. The result of this process became practically complete transformation of the engineering solutions in the sphere of measuring technologies: from various, separate, non – compatible measuring devices to highly integrated, multichannel automatic measuring systems, able to operate applying global computer networks.

Analysis of recent research and public

Proceeding from the analysis performed of the known publications [1,2,3] it should be noted that along with general increase of IMS performance certain problems emerge in this process among other things the main reason was the lag of technologies of measuring information formation regarding magnitudes of physical values from the possibilities of processing, storage presentation and transfer of measuring information technologies. Thus, the problem of elaboration of new principles the technologies of measuring information obtaining will be based, is very actual from scientific point of view and useful for practical application.

Problem set – up

Carry out the investigation of measuring channels, which operate on the basis of presentation of measuring of measuring information in the form of values of pulse signals duration or the length of their envelope. Elaborate mathematical and metrological support needed for the process the transformation of measuring information presentation form. The given process is performed by means of carrying out values, of measured physical quantities, expressed by the signals of corresponding nature into change of duration values or the length of pulse electric signals envelope, which are the carries of measured information in modern IMS.

Measuring channels based on application of new forms of measuring information presentation

Nowadays application in modern IMS of electric signals as basic carrier of information is generally accepted practice. In the structure of the IMS measuring channels, in the section from initial measuring converters to along – to – digital converters, electric signal provides transmission of measuring information, concentrated in values of its parameters. Conventionally, transmission of measuring information as a result of voltage or current amplitude variation is widely used. In this case measuring channel has structure shown in Fig 1.

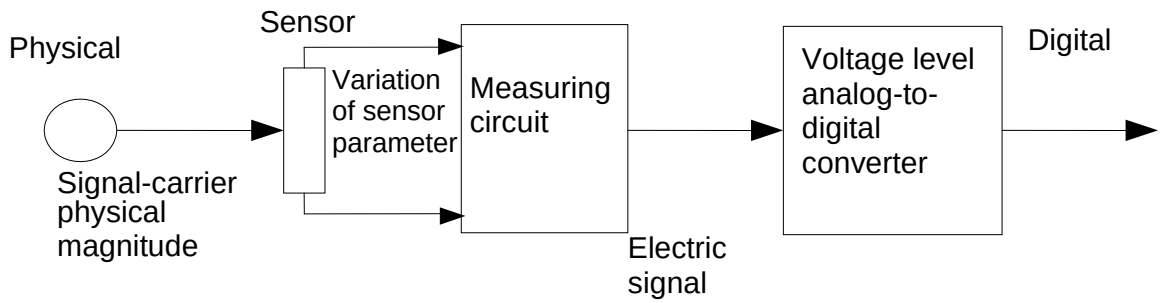


Fig 1. Structure of measuring channel based on the principle of conversion of measured physical values in the values of electrical signal amplitude

Main advantage of such measuring channel is available engineering and metrological support at the same time such channel has certain disadvantages. Main disadvantage is limited accuracy of measurements , sensitivity to the influence of noise and considerable energy consumption.

Other structures of measuring channels are known [1,2,3] where the information regarding the value of measured physical magnitudes is presented by means of changes of other parameters of electric , such as phase and frequency. These structures also have drawbacks.

Phase change requires high stable reference signal, and usage of frequency requires the application of complex technical equipment and is accompanied by increased energy consumption is achieved in IMS, operating in pulse mode. It should be noted, that application of known methods of formation of measuring information in such mode is not efficient. That is why, new methods of conversion of measuring information, suggested in works [4,5] together with pulse mode of measuring channels operation allow to obtain considerable improvement of both metrological and operation characteristics of IMS.

The essence of suggested principles is to use the presentation f measuring information in the form of change of special form pulse signals duration, which is defined at the set level, as well as in the form of change of pulse signals envelope length.

Transition from the necessity to measure the amplitude to measurement of time intervals allows to increase drastically the resolution of measurements (application of serially manufactured time-digital converters (IDC) of the firm Acam Mess Electronic GmbH provides measurement of pulse duration with the accuracy up to 14 psec, that in measurement range corresponds to the resolution of 30 bits) and usage of envelope length measurement, in spite of certain complexity of technical realization, allows to take into account complex character of large quantity of physical values and potentially can linearize square character of interaction of physical influence of measured values on changes of sensors parameters.

Generalized structure showing the suggested principles of carrying out measuring transformations is shown in Fig 2.

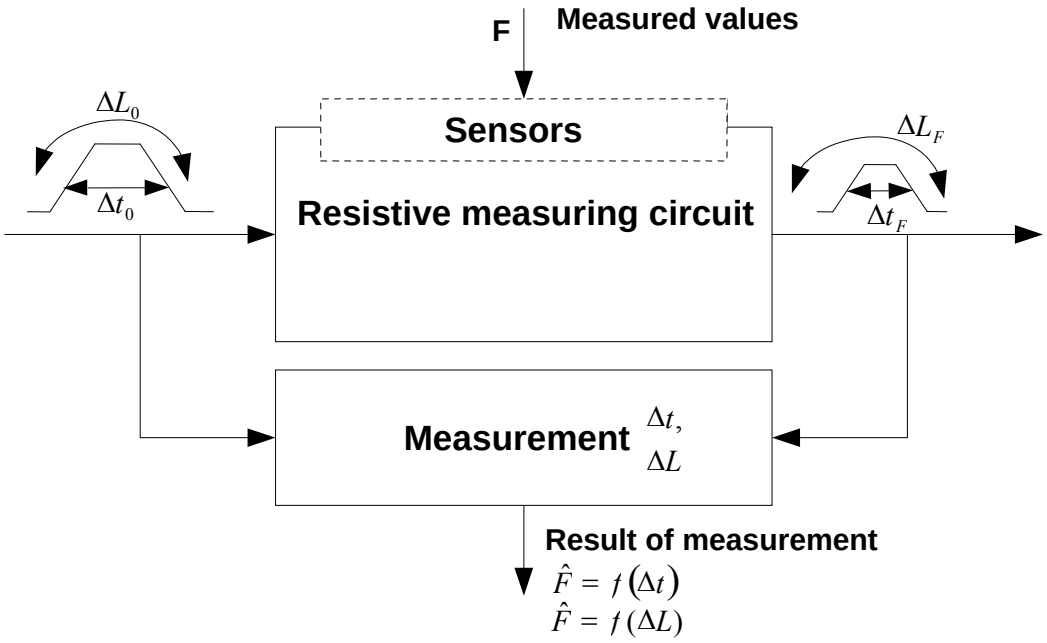


Fig 2. Structural diagram of measurements performed in accordance with suggested principles.

In accordance with the suggested structure the role of modulator of the duration or envelope length of pulse signal of special form is performed by resistive measuring circuit. This is due to the fact while passing of pulse signal in such circuit non – linear distortions of the given signal form does not take place. That is why from mathematical point of view simulation problem is correct and allows to obtain analytical solution for all forms of signals, described by analytical solutions and differential in the areas of their existence, functions. Possible types of mathematical models intended for description of elaborated measuring transformations are shown in classification Table 1.

Table 1

Models classification Table

Verbal form of measuring converter $S/\Delta T$ та $S/\Delta L$	Mathematical form of functional conversion $\Delta T(t) = M[S(t)],\ \Delta L(t) = W[S(t)]$
Linear, single-parametric, stationary	$T(t) = kS(t),\ L(t) = kS(t)$ k- const
Linear, single-parametric, non-stationary	$T(t) = kS(t),\ L(t) = kS(t)$ k- var
Linear, single-parametric, with delay	$T(t) = k(t-\tau)S(\tau)d\tau,\ L(t) = k(t-\tau)S(\tau)d\tau$
Non-linear, single-parametric	$T(t) = f[S(\tau)],\ L(t) = f[S(\tau)]$
Non-linear, single-parametric, with delay	$T(t) = k(t,\tau,S(\tau))S(\tau),\ L(t) = k(t,\tau,S(\tau))S(\tau)$
Linear, multiparametric	$T(t) = KS(t),\ L(t) = KS(t)$ K-vector-clm. (n×1)
Linear, multiparametric, with delay	$T(t) = K(t-\tau)S(\tau)d\tau,\ L(t) = K(t-\tau)S(\tau)d\tau$
Non-linear, multiparametric	$T(t) = F[S(t)],\ L(t) = F[S(t)]$
Non-linear, multiparametric, with delay	$T(t) = K[t,\tau,S(\tau)]S(\tau)d\tau,$ $L(t) = K[t,\tau,S(\tau)]S(\tau)d\tau$

As a result of research performed mathematical models of pulse signals (PS) and types of functional depending of their duration on amplitude changes they obtain in measuring circuit as well as type of sensitivity function of obtained dependences in Table 2.

Table 2

Mathematical models of pulse signals of measuring conversions and sensitivity functions

№ п/п	Type of the form	Mathematical model of PS	Function of dependence of Δt on PS amplitude	Sensitivity function of obtained dependence
1	Saw-tooth	$\begin{cases} U(t) = U_{\max}\dfrac{t}{t_i}; \forall t \in [0, t_i] \\ U(t) = 0; 0 > t > t_i \end{cases}$	$\Delta t = t_i\left(1 - \dfrac{L}{U_m}\right)$	$S_m = \dfrac{\partial \Delta t}{\partial U_m} = \dfrac{t_i L}{U_m^2}$
2	Triangular (symmetric)	$U(t) = \dfrac{U_m}{t_в}(t - 2(t - t_в)1(t - t_в) + (t - t_i)1(t - t_i))$	$\Delta t = 2\Delta t_{имп.} = 2t_в\left(1 - \dfrac{L}{U_m}\right)$	$S_m = \dfrac{\partial \Delta t}{\partial U_m} = 2\dfrac{t_в L}{U_m^2}$
3	Trapezoidal	$U(t) = k \cdot t - k \cdot (t - t_{f1}) \cdot 1(t - t_{f1}) - c \cdot (t - t_{f2}) \cdot 1(t - t_{f2}) + c \cdot (t - t_i) \cdot 1(t - t_i)$ (general)	$\Delta t = (t_{f1} + t_{f2})\left(1 - \dfrac{L}{U_m}\right) + t_{f2} - t_{f1}$ (symmetrical)	$S_m = \dfrac{\partial \Delta t}{\partial U_m} = \dfrac{L}{U_m^2}(t_{f1} + t_{f2})$
4	Bell	$U(t) = U_m e^{\frac{-(t - t_v)^2}{2a^2}}$	$\Delta t = 2a\sqrt{2\ln\left(\dfrac{U_m}{L}\right)}$	$S_m = \dfrac{\partial \Delta t}{\partial U_m} = \dfrac{a\sqrt{2}}{U_m\sqrt{\ln\left(\dfrac{U_m}{L}\right)}}$
5	Exponential form of the fronts	$U(t) = U_m e^{-g\lvert t_0 - t\rvert}$	$\Delta t = \dfrac{2}{g}\ln\left(\dfrac{U_m}{L}\right)$	$S_m = \dfrac{\partial \Delta t}{\partial U_m} = \dfrac{2}{gU_m}$
6	Hyperbolic of the fronts	$\begin{cases} U(t) = U_m \dfrac{b}{\lvert t - t_0\rvert} \\ U(t) \le U_{\max} \forall t \in [0; +\infty] \end{cases}$	$\Delta t = \dfrac{2bU_m}{L}$	$S_m = \dfrac{\partial \Delta t}{\partial U_m} = \dfrac{2b}{L} = const$

Similar researches were conducted for finding out of dependences of change of length circumflex impulsive signals, and also for determination of sensitiveness of such changes. The results of the conducted researches are reflected in Table 3.

The convenience of practical application of suggested principles of carrying out of such measuring transformations is that they can be performed on the basis of already known potentiometric and bridge measuring circuits. This allows without the special expenses to modernize any measuring systems, that will result in the substantial improvement of their metrology and operating descriptions.

The examples of possible variants of functional systems of elaborated measuring channels using data presentation in the form of changes of special form pulse signals duration while using potentiometer and bridge resistive measuring circuits shown in Fig 3.

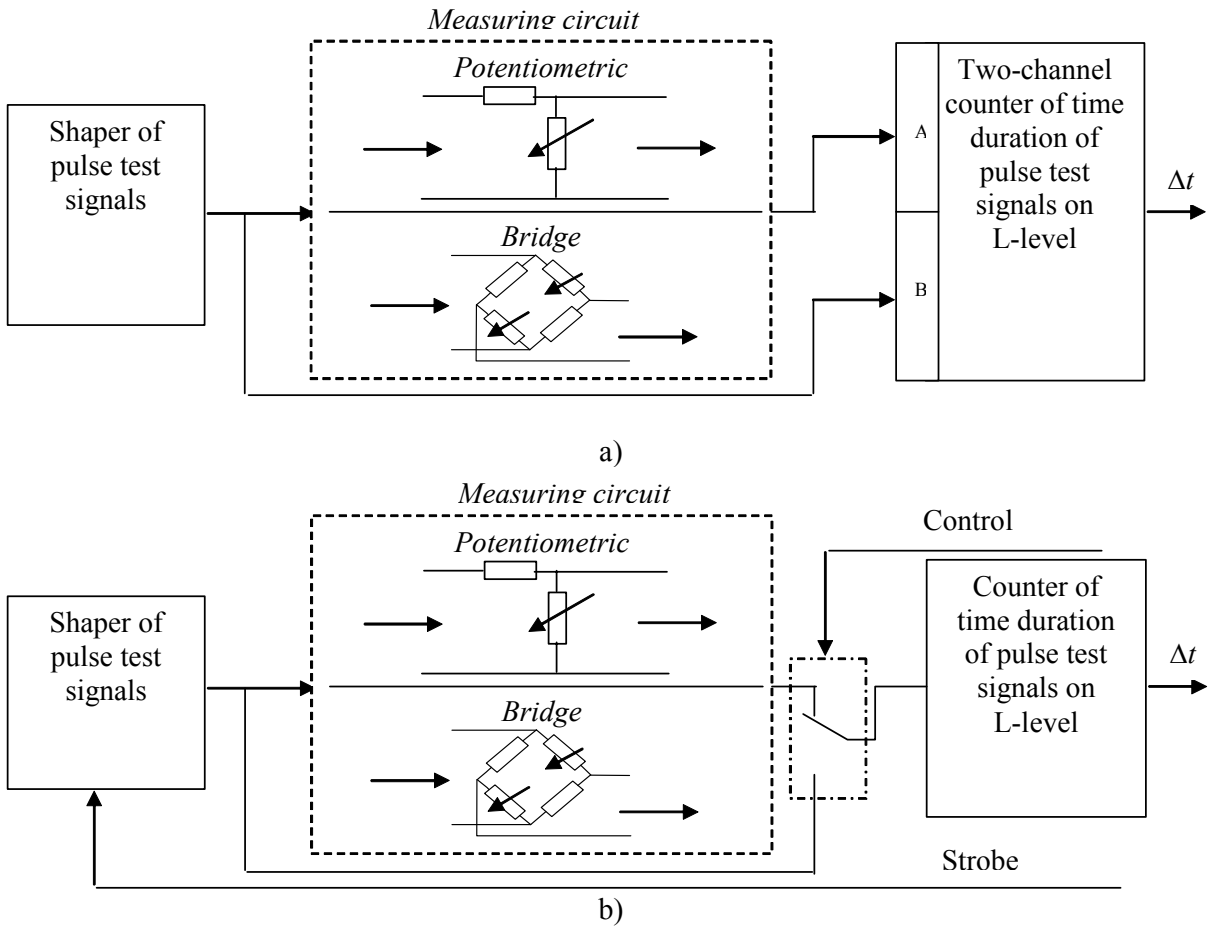
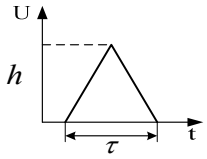
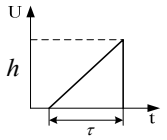
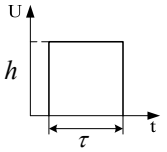
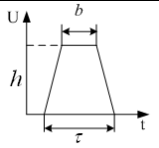
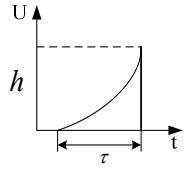


Fig 3. Functional diagram of measuring channel with a)single-cycle; b)double-cycle measuring modes

Table3

Idialized forms of pulse signals model of measuring transformations, sensitivity function.

Signal form	$L = f(h, \tau)$	$s = \partial L / \partial h$
	$L = 2 \cdot \sqrt{\left(\frac{\tau}{2}\right)^2 + h^2}$	$s = \frac{4h}{\sqrt{\tau^2 + 4h^2}}$
	$L = h + \sqrt{h^2 + \tau^2}$	$s = 1 + \frac{h}{\sqrt{h^2 + \tau^2}}$
	$L = 2 \cdot h + \tau$	$s = 2$

	$L = 2 \cdot \sqrt{h^2 + \left(\frac{\tau - b}{2}\right)^2} + b$	$s = 4\frac{h}{\sqrt{4h^2 + \tau^2 - 2tb + b^2}}$
	$L = 0{,}3662684 +$ $+1{,}9999117h$ Model of close approximation	$s = 0{,}3662684$

Unlike already known and widely used technologies of measuring information, which are based on measuring of amplitude, phases or frequencies, the offered principles of transformation of measuring information allow while using in measuring channels to obtain a number of important advantages. In particular: accuracy of measurements is considerably increased, noise immunity is improved, due to the fact, that measuring channels operate in pulse mode, and measuring process itself is carried out in time period, corresponding to the length of measuring pulse. Besides, due to passing to the pulse-mode of work, which can be taken to measuring in the mode of single-pulse, energy consumption is considerably reduced.

Formally considered principle of transformation of values of measured physical magnitudes in duration of certain pulse signal reflects realization of discrete presentation of analog signal $s(t) \in S(t)$ within the limits of current time variation $t \in T$ as a sequence of time axis coordinates $\{\Delta T_i, i = 0,1,2,..., N_k\}$, by the values of which it is possible to get the estimation $\overset{*}{s}(t) \in \overset{*}{S}(t)$ of initial value of measured physical magnitude. Such presentation and reverse restoration can be written as:

$$(\Delta T_0, \Delta T_1, \Delta T_2, ..., \Delta T_{N_k}) = \Im(s(t)); t \in T,$$

$$\overset{*}{s}(t) = \Re(\Delta T_0^*, \Delta T_1^*, \Delta T_2^*, ..., \Delta T_{N_k}^*); t \in T,$$

where $\Im$ - presentation operator; R – restoration operator; ΔT_i^* - results of time interval measurements, according to which, restoration of measured physical magnitude value is performed. Potentially such technology used for obtaining measuring informationallows to provide the accuracy of measurement of physical values, close the accuracy of time measurement.

Conclusions

The given paper considers new principles elaborated for measuring information conversion. The suggested principle of measuring information conversion based on usage of the method of time duration modulation of pulse signals allows to increase considerably, as compared with other knows approaches, measurements accuracy, reduce energy consumption of measuring channels and increase the term of measuring facilities operation.

In measuring channels, using the principle of measuring information conversion, based on modulation of pulse signal envelope length, there exists the possibility to take into consideration complex character of measured physical values, as well as, use, as sensors, primary measuring converters with reactive parameters and linearize square character of interaction of physical impacts of measured values on the changes of sensors parameters.

REFERENCES

1. Новоселов О. Н. Основы теории и расчета информационно-измерительных систем / О. Н. Новоселов, А. Ф. Фомин. – М. : Машиностроение, 2-е изд., 1991. – 336 с.

2. Асадов Х. Г. Синтез одного подкласса ИИС по принципу уменьшения размерности / Х. Г. Асадов // Измерительная техника. – 2001. – № 3. – С. 14 – 16.

3. Аналогова мікросхемотехніка вимірювальних та сенсорних пристроїв / [Вуйцік В., Голяка Р., Каліта В. та ін.]; за ред. З. Готри. – Львів: Видавн. „Львівська політехніка", 1999. – 364 с.

4. Шабатура Ю. В. Основи теорії і практики інтервальних вимірювань / Шабатура Ю. В. – Вінниця : УНІВЕРСУМ–Вінниця, 2003. – 167 с.

5. Шабатура Ю. В. Структурно-математичні основи синтезу інформаційно-вимірювальних систем з часовим поданням інформації / Ю. В. Шабатура // Вимірювальна техніка та метрологія. – 2006. – № 66. – С. 164–173.

Shabatura Yuriy – Doctor of Sc.(Eng.), Professor of the Chair of metrology and industrial automatics.

Shtelmakh Igor – Post Graduate of the Chair of metrology and industrial automatics.

Shabatura Maksim – student.

Vinnytsia National Technical University.