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Analysis of Errors of the Measuring Converter Which Results from an Abrupt Change of Additive Errors of its Blocks

Aalysis of conversion equation and equations of errors of generalized block diagram of the measuring converter which uses iterative-integrating conversion method which results from errors of its blocks is described. Basic expressions for the calculation are listed for the case when the additive errors of the transfer functions of its blocks change abruptly in time.

Introduction. It is known that the measuring converters, which are used to creation information systems with high metrological parameters, need high accuracy. Achievement of high metrological parameters of the measuring converters is provided in various ways. Very often this goal is achieved using the measuring converter which uses iterative-integrating conversion method [1], which is a combination of integrating conversion methods and additive iterative error correction [2; 3]. Devices using this method are called iterative-integrating converters [1]. Many of iterative-integrating converters [2 – 7] possess high metrological parameters.

Generalized block diagram of such measuring converter, proposed by the author in Ref. [1], is shown in Figure.

The operation of the generalized block diagram is described, for example, in Ref. [1; 6 – 9].

The inputs values are X, $Z1$ and $Z2$, and the output value is Y. The block diagram contains the blocks that perform basic functions: integrator I, sample-and-hold device SH, switches SW1 and SW2, and auxiliary converters CV_X, CV_{Z1}, CV_{Z2}, CI_1, CI_2, CO_1, CO_2,.., CO_m, BC, inverter INV, adder ADD, having transfer coefficients, respectively, K_X, K_{Z1}, K_{Z2}, K_{CI1}, K_{CI2}, K_{CO1}, K_{CO2},.., K_{COm}, β, K_{INV}, K_{ADD}.

This article is devoted to the analysis of the generalized block diagram of the measuring converter which uses iterative-integrating conversion method and is a continuation of the analysis carried out by the author in his previous works [no. 1; 5 – 9].

Thus, in particular, analysis of the generalized block diagram of iterative-integrating converters and its conversion equation and errors for case when the input values X, $Z1$, $Z2$ and output value Y are constant values and for case where the input variable $X = X\ (t)$ is not a constant, while the input values $Z1$, $Z2$ and output value Y are constant and for case where the input variable $X = X\ (t)$ and output value $Y = Y\ (t)$ are not a constant, while the input values $Z1$, $Z2$ are constant was made by the author in [5; 7].

Problem statement. However, it seems expedient to perform an analysis of the measuring converter taking into account the imperfection of all its units.

Analysis of the errors of the measuring converter due of influence the imperfection of its blocks on its total static and dynamic errors, as well as on its dynamic properties for various particular embodiments of the measuring converter are considered in some of the author's previous publication.

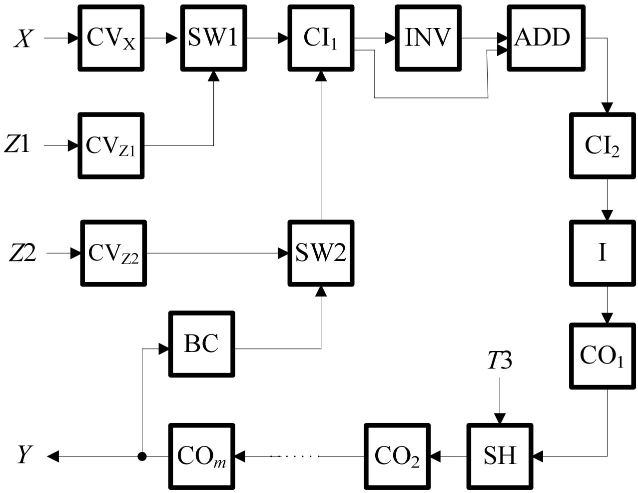


Figure. A generalized structural scheme of iteratively integrating converter

Analysis taking into account the imperfection of all blocks of the generalized block diagram of measurement converter is devoted this publication of the author.

It is possible to consider cases when the errors of the transfer functions of these blocks are constant in time (1), change abruptly (2) or change continuously (3).

Consider the second of the above cases.

Solution of the problem. Let us analyze the simplest case of combinations of input and output values: *X*, *Z*1, *Z*2, and *Y* are constant values, since the results of the analysis can easily be extended to all the other cases mentioned above. In this case, among all the converter blocks only switches SW1 and SW2, and inverter INV will be considered ideal, since the errors of these units can easily be taken into account by introducing them into the errors of other blocks.

So far we have assumed that the errors of the blocks are constant in time, which is to some extent an idealization. Since the various factors that cause errors are generally variable, it seems interesting to analyze the effect of block errors on the overall error in the event that these errors are variable. In this case, we will consider the change in those additive errors of blocks that do not contribute to the overall error in the steady state. These are the additive errors of blocks CO_1, SH, CO_2,.., CO_m.

Our analysis we divide in to two parts. At the first one, we consider the effect on the overall error of the measuring transducer of the abrupt change in the additive errors of the blocks SH, CO_2,.., CO_m.

And in the second part of the analysis, we will take into account the abrupt change in additive error of the block CO_1.

For each case, we will write the expressions for determining the output value of the converter before the time of the change (with an abrupt change) of the error – Y_0, after the end of the 1st conversion cycle – Y_1, after the second conversion cycle – Y_2 after the n-th conversion cycle – Y_n, the error of the transformation of the *n*th cycle due to the finiteness of the transformation time (dynamic error) – г_n, output value in the steady state – Y_∞. The derivation of the expressions for determining the values listed above is analogous to the derivation of equations (2.3), (2.4), (2.5), (2.7) and (2.6) in Ref. [1], and due to its simplicity, it will not be cited here.

Let us denote the jump of the output quantity, brought to the input of the measuring transducer through ΔY_{ADD}. Let us denote by ν_2 the relative time, that is, the ratio of the time from the beginning of the closure interval of switch SW2 to the time when the jump occurred to the duration of the closure interval of switch SW2.

The obtained expressions for the abrupt change in the additive errors of the blocks SH, CO_2,.., CO_m are summarized in Table 1.

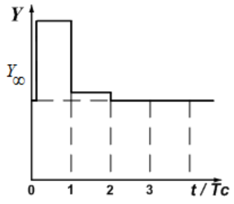
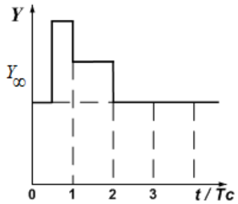
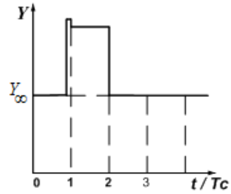
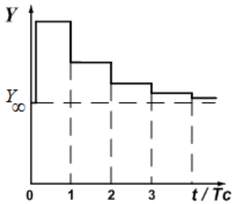
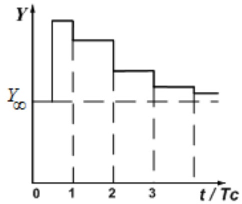
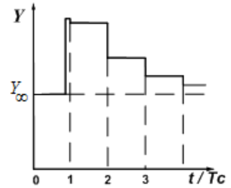
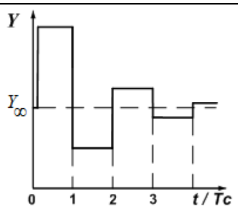
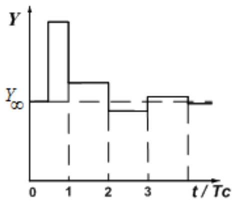
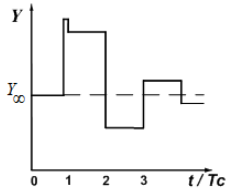
Table 1

The abrupt change in the additive errors of the blocks SH, CO_2,.., CO_m
$Y_0^{(a1)} = Y_\infty$ $Y_1^{(a1)} = Y_\infty + \Delta Y_{add} Q^*$ where $Q^* = 1 - Z2K_{Z2\text{B}} \prod_{i=1}^{l} K_i (1-\nu_2)$ $Y_2^{(a1)} = Y_\infty + \Delta Y_{add} Q^* Q$ where $Q = 1 - Z2K_{Z2\text{B}} \prod_{i=1}^{l} K_i$ $Y_\infty^{(a1)} = \lim_{n\to\infty} Y_n^{(a1)} = Y_\infty$ $\gamma_n^{(a1)} = \dfrac{Y_n^{(a1)} - Y_\infty}{Y_\infty} = -\Delta Y_{add} Q^* Q^{n-1}$

From the consideration of the equations given in Table 1 it follows that the abrupt change in the additive errors of the blocks SH, CO_2,.., CO_m leads to a "sudden" (of course, taking into account the inertia of the blocks) the jump in the output value of the measuring converter. After the end of the first conversion cycle (in which the jump occurred), the error is partially corrected, and the degree of this correction depends on how close the value of Q to zero and how soon after the start of the closure of the switch SW2, the above-mentioned jump occurred, that is, from the proximity to zero of the value of Q^*. In subsequent cycles, the error caused by the above jump is corrected iteratively, and the speed of the correction process and its nature depend on the value of Q. So, if $Q^* = 0$, the correction process will end in the first conversion cycle, and if $Q^* \neq 0$ and $Q = 0$, then the correction process will end in the second conversion cycle.

Table 2 is a graphical representation of the transient process of setting the output value of the measuring transducer after the above-mentioned jump for different magnitudes of the value of Q and for various instants of the appearance of a jump.

Table 2

	$\nu_2 = 0,1$	$\nu_2 = 0,5$	$\nu_2 = 0,9$
$Q = 0$			
$Q = 0,5$			
$Q = -0,5$			

Similar to the expressions in Table 1, Table 3 shows the expressions for the case of taking into account the abrupt change in the error of the block CO_1.

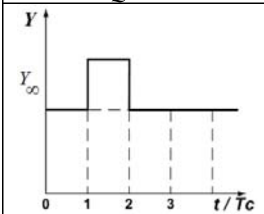
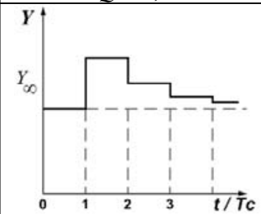
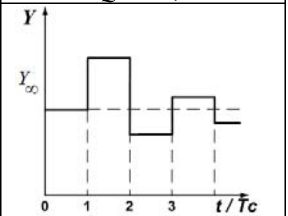
From the above expressions it follows that the abrupt change in the additive error of the block CO_1 is manifested in the form of a jump in the error of the output value of the measuring converter immediately after the end of the conversion cycle in which the jump of the additive error of the block CO_1 occurred. Then, in subsequent conversion cycles, this error is corrected iteratively. The nature and speed of this correction process (transient process of setting the output value of the measuring converter) does not depend on the time of the jump occurrence within the transformation cycle, but depends only on the value of Q. The condition for the maximum speed of the correction process (the condition of the finite duration of the transient process) is the equality $Q = 0$, at which the transition process ends in the next cycle. A graphical representation of this transition process for various values of Q is given in table.3.

Table 3

The abrupt change in the additive error of the block CO_1
$Y_0^{(a2)} = Y_\infty$ $Y_1^{(a2)} = Y_\infty + \Delta Y_{add}$ $Y_2^{(a2)} = Y_\infty + \Delta Y_{add} Q$ $Y_n^{(a2)} = Y_\infty + \Delta Y_{add} Q^{n-1}$ $\gamma_n^{(a2)} = \dfrac{Y_n^{(a2)} - Y_\infty}{Y_\infty} = \Delta Y_{add} Q^{n-1}$ $Y_\infty^{(a2)} = \lim\limits_{n \to \infty} Y_n^{(a2)} = Y_\infty$

From the above expressions it follows that the abrupt change in the additive error of the block CO_1 is manifested in the form of a jump in the error of the output value of the measuring converter immediately after the end of the conversion cycle in which the jump of the additive error of the block CO_1 occurred. Then, in subsequent conversion cycles, this error is corrected iteratively. The nature and speed of this correction process (transient process of setting the output value of the measuring converter) does not depend on the time of the jump occurrence within the transformation cycle, but depends only on the value of Q. The condition for the maximum speed of the correction process (the condition of the finite duration of the transition process) is the equality Q = 0, at which the transition process ends in the second conversion cycle. Graphic representation of this transient process for different values of Q is given in the table. 4.

Table. 4

$Q = 0$	$Q = 0{,}5$	$Q = -\,0{,}5$
		

Conclusion. 1. Abrupt change in the additive errors of the blocks SH, CO_2,.., CO_m leads to a "sudden" (of course, taking into account the inertia of the blocks) the jump in the output value of the measuring converter. After the end of the first conversion cycle (in which the jump occurred), the error is partially corrected, and the degree of this correction depends on how close the value of Q to zero and how soon after the start of the closure of the switch SW2, the above-mentioned jump occurred, that is, from the proximity to zero of the value of Q^*. In subsequent cycles, the error caused by the above jump is corrected iteratively, and the speed of the correction process and its nature depend on the value of Q.

2. Additive error of the block CO_1 is manifested in the form of a jump in the error of the output value of the measuring converter immediately after the end of the conversion cycle in which the jump of the additive error of the block CO_1 occurred. Then, in subsequent conversion cycles, this error is corrected iteratively. The nature and speed of this correction process (transient process of setting the output value of the measuring converter) does not depend on the time of the jump occurrence within the transformation cycle, but depends only on the value of Q. The condition for the maximum speed of the correction process (the condition of the finite duration of the transient process) is the equality $Q = 0$, at which the transient process ends in the nearest cycle.

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