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Impedance Measuring Converters for Robotics and Automated Control Systems

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Annotation

The paper very briefly discusses the design of measuring impedance parameter converters and options for constructing transducers of this class based on a Wheatstone bridge. The possibility of improving the characteristics of converters by linearizing the output characteristics of the bridge and ensuring invariance to the specified types of non-informative parameters is shown.

Keywords: Impedance parameters; Parameter converters; Wheatstone bridge; Non-informative parameters; Converter invariance

Introduction

It is known that measuring converters of impedance parameters (TIP) are among the important blocks of robotic devices and automated control systems (ACS), since they are the primary sources of information due to connecting physical quantities of sensors (sensors, sensitive elements) to the input for converting output sensor signals in unified electrical quantities. Therefore, the effectiveness and quality of work of both robotic devices and ACS significantly depend on the properties and capabilities of the TIP, including the errors in converting the output signals of the sensors [1-8].

There are various methods of designing TIP with the necessary (desired) characteristics, among which the so-called structural-iterative method seems to be the most promising. It is considered in [3-7] and provides for the synthesis of TIP structures with the desired properties and capabilities based on the use of signal graphs. Thanks to this method, the author managed to build a number of TIP with improved characteristics, some of which will be discussed later. Their successful use in robotic devices and automated control systems is beyond doubt.

A Summary of The Design Process for Enhanced Performance Features

Since the main component of the TIP is the measuring circuit (MC), in the work, the improvement of the characteristics of the TIP is provided by improving the properties and capabilities of the IC, which is part of the TIP. Improving the performance of the TIP also depends on the correct choice of the initial MC used in the TIP. Based on the above, a four-shoulder bridge measuring circuit was chosen - the well-known Wheatstone bridge, shown in Figure 1a, and which, due to a number of its advantages, has been successfully used in TIP for a long time.

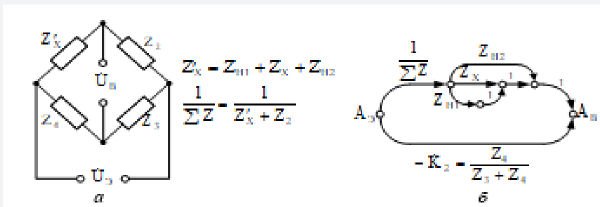

Figure 1: Wheatstone Bridge (a) and its model in the form of a signal graph (b).

However, this IC also has disadvantages, which include the nonlinearity of the output value UB on the informative parameter Z_X and the dependence of the same value on the uninformative parameters, which include the impedances of the connecting wires, electrodes and connections of the connection, indicated in Figure 1a as ZH_1 and ZH_2. The model of Wheatstone, presented in the form of a signal graph in Figure1b, reflects the selected parameters and shows a non-linear dependence of the output value of the graph AB on the parameter Z_X (also on the parameters ZH_1 and ZH_2). By introducing at least one feedback into the graph structure, linearization of the output characteristic of the Wheatstone bridge with respect to the sum of the parameters Z_X, ZH_1 and ZH_2 is provided. This only partially improves the accuracy of the Z_X conversion, since the significant effect of non-informative parameters on the conversion accuracy remains. To eliminate their influence on the accuracy of conversion and measurement of the informative parameter Z_X, additional structural transformations of the original graph shown in Figure1b are necessary. One of the options for eliminating the influence of ZH_1 and ZH_2 is the use of two additional connecting wires and corresponding signal transformations in the Wheatstone bridge, achieved on the basis of the structural-iterative method, and we can speak of the Wheatstone bridge that is linear and invariant to uninformative parameters. The converters constructed on the basis of a structurally modified MC have a linear output characteristic and invariance to non-informative parameters.

Construction of Linearized and Invariant TIP (Single-Channel and Multi-Channel) Invariance to Non-Informative Parameters

The TIP options that were implemented on the basis of the above, are presented as a single channel (Figure 2) and multichannel TIP (Figure 3), from which it can be seen that four-wire switching sensors are used in the TIP circuits. In these diagrams, the connecting wires of sensors with non-informative parameters are designated as Z_1, Z_2, and two additional connecting wires are designated as Z_3, Z_4. It is considered that the influence of the impedances of these connecting wires on the conversion accuracy can be neglected. From the single-channel TIP scheme, it is clear that the Wheatstone bridge is supplemented with the following components: $ДУ_1$, $ДУ_2$ differential amplifiers, C_1, C_2 adders with summation coefficients 1 over both inputs, П-repeater voltage. In, the output signal is linearly dependent on the informative signal Z_X and does not depend on non-informative parameters Z_1, Z_2. Using mathematical expressions, we show that the output signal of the TIP-UB is invariant to the non-informative parameters Z_1, Z_2.

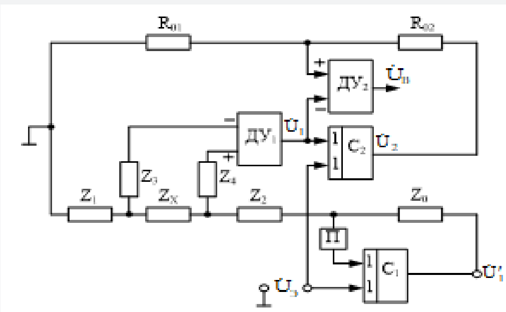

Figure 2: TIP with four-wire inclusions of the object of study.

It is easy to establish that the expression for the output voltage of the adder C_2 is:

$$U_1' = U_{Ý}\frac{Z_X + Z_1 + Z_2 + Z_0}{Z_0}$$

The expression for the output voltage $ДУ_1$, while neglecting the values of Z_3 and Z_4 in comparison with the values of the input resistance $ДУ_1$, has the form:

$$U_{Ý} = U\frac{Z_X}{Z_0}$$

Then at the output of the adder C_1 the voltage will be determined as:

$$U_{Ý} = U\frac{Z_X + Z_0}{Z_X}$$

The output voltage TIP is formed at the output of $ДУ_2$ and is determined by the expression:

$$U_B = \frac{U_{Ï} R_{01}}{(R_{01} + R_{02})} - U_1$$

After replacing the values of U1 and UП, the expression for UB will look like:

$$U_{Â} = U_{Ý}\frac{Z_X Y_0 - R_{01} G_{02}}{1 + R_{01} G_{02}}$$

where: $Y_0 = \frac{1}{Z_0}$ $G_{02} = \frac{1}{R_{02}}$

From (1) it is visible:

- output signal TIP - U_B linearly depends on the measured parameter Z_X;

- non-informative parameters Z_1, Z_2 do not affect the size of the output signal.

On the basis of a single-channel TIP, a multi-channel TIP was built, shown in Figure 3, from which it can be seen that the sensors with impedances ZX_1-ZX_P are connected to the TIP through multiplexers (M_1-M_3). It should be noted that the multichannel TIP scheme excludes not only the influence of the impedances of the connecting wires, but also the influence of the impedances of the keys of the multiplexers M_1-M_3.

In Figure 3, the same designations are used as in Figure 2, with the exception of the designation БИО, a block for intelligent processing of measurement results. For a significant expansion of the intellectual abilities of the converter БИО can be built on the basis of an artificial neural network.

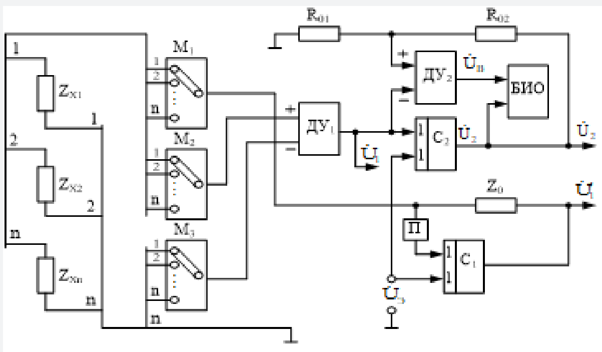

Figure 3: Multichannel invariant TIP.

Conclusion

The paper shows the effectiveness of the structural and iterative method for the case of designing PPI with the desired properties and capabilities. The high efficiency of the method is demonstrated by the example of designing TIP with linearized output characteristics and invariant to the parameters of the

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connecting wires, electrodes and contacts of the connection. Proposed two schemes TIP, with practical significance.

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