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SYNTHESIS OF THE STRUCTURE OF A MULTI-CHANNEL DATA-MEASUREMENT SYSTEM

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СИНТЕЗ СТРУКТУРЫ МНОГОКАНАЛЬНОЙ ИНФОРМАЦИОННО-ИЗМЕРИТЕЛЬНОЙ СИСТЕМЫ

Abstract. The paper considers an approach to synthesizing the structure of a multi-channel data-measurement system. The information and measurement system is a complete metrological product and is designed to receive measurement information from primary temperature transmitters operating on different physical principles. The four channels of the data-measurement system have a contact and non-contact method for measuring temperature. A method for synthesizing the structure of measuring channels of the system is proposed. The General essence of the proposed approach is to consistently select the elements of the measuring channel of the system, taking into account the requirements of the field of operation, metrological requirements, as well as design and technological requirements. Thus, the resulting structural model of the data-measurement system meets the basic requirements, such as multi – channel measurement of a physical quantity-temperature, direct communication with the measured object, automatic control and processing of measurement information. An information model of the system is proposed that allows evaluating the nature of the information process when measuring several homogeneous physical quantities in a multi-channel data-measurement system.

Keywords: data-measurement system, model, structure, measuring channel, temperature, synthesis method.

Аннотация. Рассматривается подход к синтезу структуры многоканальной информационно-измерительной системы. Информационно-измерительная система представляет собой законченное метрологическое изделие и предназначена для получения измерительной информации от первичных измерительных преобразователей температуры, работающих на разных физических принципах. В четырех каналах информационно-измерительной системы реализованы контактный и бесконтактный способ измерения температуры. Предложена методика синтеза структуры измерительных каналов системы. Общая суть предложенного подхода заключается в последовательном выборе элементов измерительного канала системы с учетом требований области эксплуатации, метрологических требований, а также конструкторско-технологических требований. Таким образом, получаемая структурная модель информационно-измерительной системы отвечает основным требованиям, таким как многоканальное измерение физической величины – температуры, непосредственная связь с измеряемым объектом, автоматическое управление и обработка измерительной информации. Предложена информационная модель системы, позволяющая провести оценку характера информационного процесса при измерении нескольких однородных физических величин в многоканальной информационно-измерительной системе.

Ключевые слова: информационно-измерительная система, модель, структура, измерительный канал, температура, методика синтеза.

Introduction. Problem statement

New scientific and technical tasks in the field of design and technological design also set new goals in the field of creating measuring instruments. Thus, by increasing the accuracy of measurements, increasing the number of functions performed and the productivity of measurement operations, a new level of measurement technology is achieved. In modern conditions, for many measurements carried out during design and technological design, not just measuring devices are needed, but full-fledged data-measurement systems. One of these tasks is to measure the temperature in various nodes of the designed radio-electronic equipment. As the design practice proves, it is extremely inefficient to use simple temperature meters – analog or digital thermometers-in a real device. In conditions when it is necessary to take a complete picture of the thermal field both on the surface of the device and inside, and at the same time repeat the experiment many times under different boundary and initial conditions, a deep automation of the measurement process is required.

The use of a data-measurement system makes it possible to solve this problem as efficiently as possible. A modern data-measurement system that meets the requirements of the methodology for building data-measurement and control systems is a prominent representative of complex technical systems. This is proved by the fact that any data-measurement system is nothing more than a symbiosis of measurement tools and a set of technical tools, the combination of which provides a solution to a specific measurement problem [1]. At the same time, the integration of all components of the data-measurement system should be carried out according to the system principle, i.e. all components of the data-measurement system should have constructive and functional autonomy. The latter is provided by the presence of a computing device in the data-measurement system. Taking into account this characteristic feature of the data-measurement system, we will proceed to the development of its structural scheme.

Research aim and problems

Based on the methodology for building data and measurement systems, develop a block diagram and information model of a multi-channel data-measurement system designed to measure temperature in both contact and non-contact ways.

Development of a block diagram and information models

The methodology for constructing a data-measurement system implies that the main purpose of an arbitrary data-measurement systems is to receive from the object and deliver to the consumer the necessary amount of information with a given accuracy and level of adequacy, i.e. with specified and controlled quality indicators [1]. The analysis has shown that the modern data-measurement systems can be represented as a set of tools, including hardware and software, mathematical and metrological support (fig. 1).

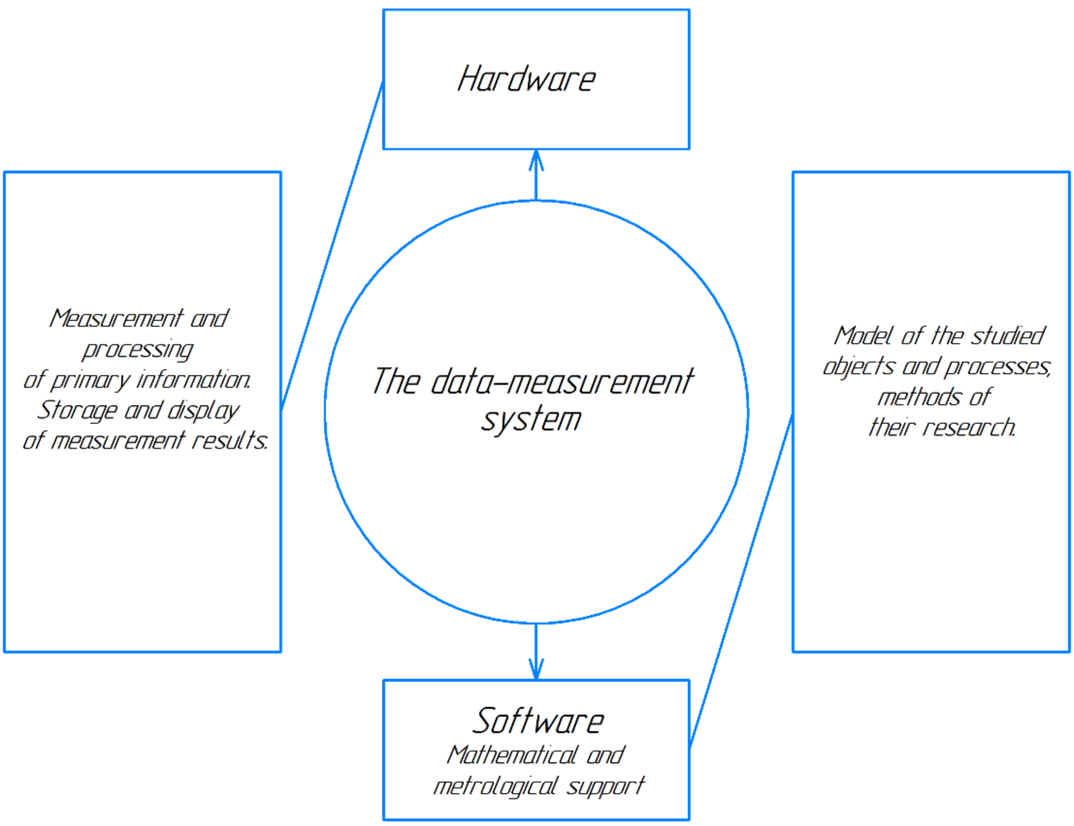

Fig. 1. Simplified data-measurement system composition

Hardware and software use primary measuring transducers to measure the desired parameter. Then the measurement results are processed, stored, and displayed. The software is designed to monitor the operation of hardware subsystems.

The basic structure for the system under development is the model of the data-measurement system proposed in [2].

The model presents only subsystems that perform separate independent functions. The source of messages is the object under study and primary measuring transducers that form an analog electrical signal λ(*t*). This signal is called a message. The message representation subsystem provides temporary channel separation (time sampling), then each discrete value is quantized by its level and encoded. The discrete value is called the message coordinate, and their sequence from different measurement channels is combined into a common stream, i.e. it is grouped for subsequent transmission. The message transmission subsystem provides noise-tolerant encoding and message delivery to the subsystem where digital processing is performed.

Abnormal values of measurement results, primarily associated with distortions of the highest bits of the code word, as well as the time and address parts of words when transmitting compressed data, are rejected in the digital processing subsystem. This subsystem is responsible for restoring the original signal with an acceptable error, as well as for calculating the desired characteristics of the message and object.

Mathematical and metrological support, using models of the studied objects and processes based on algorithms for their research, allows you to determine the desired parameters with a given accuracy.

Simplified, the block diagram of the data-measurement system looks as shown in the fig. 2.

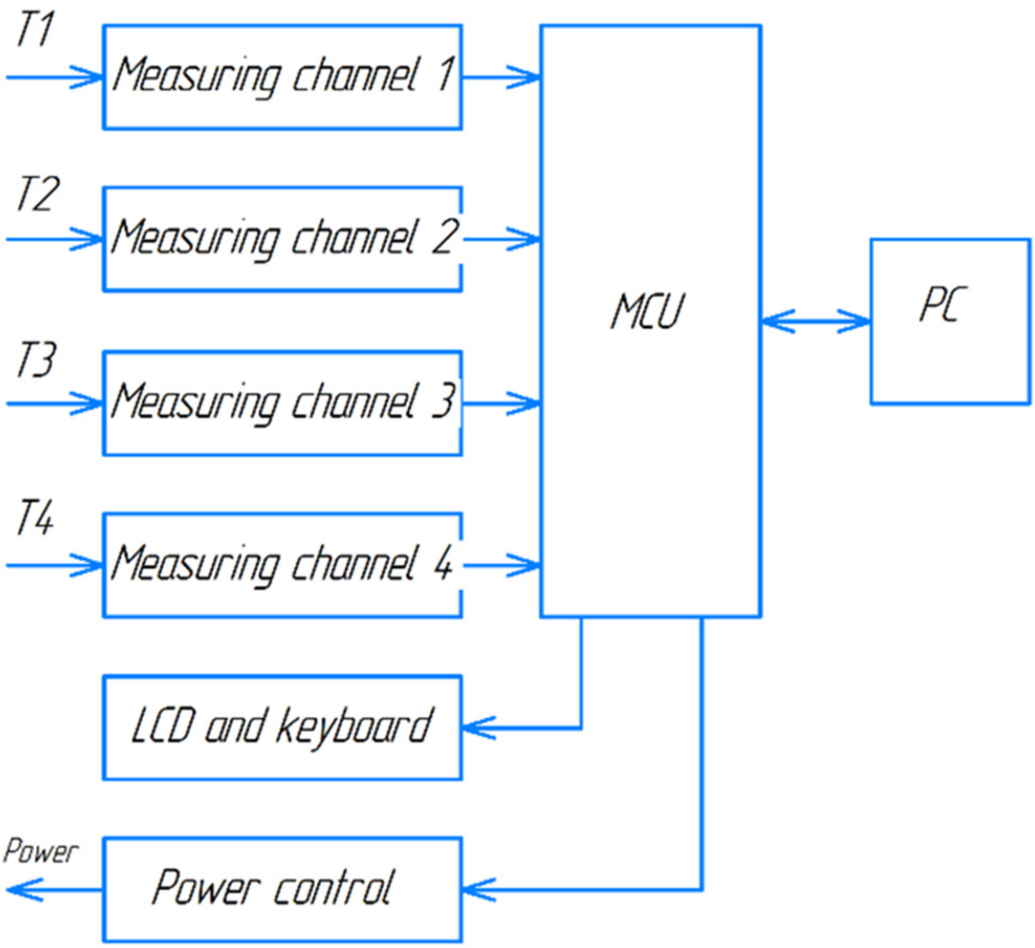

Fig. 2. The simplified diagram of the multi-channel measuring system

By enlarging the generalized scheme of an information and measurement system designed for measuring temperature both by contact and non-contact methods, we distinguish its components in more detail. As a result, we get the structure of the multi-channel data-measuring system shown in fig. 3.

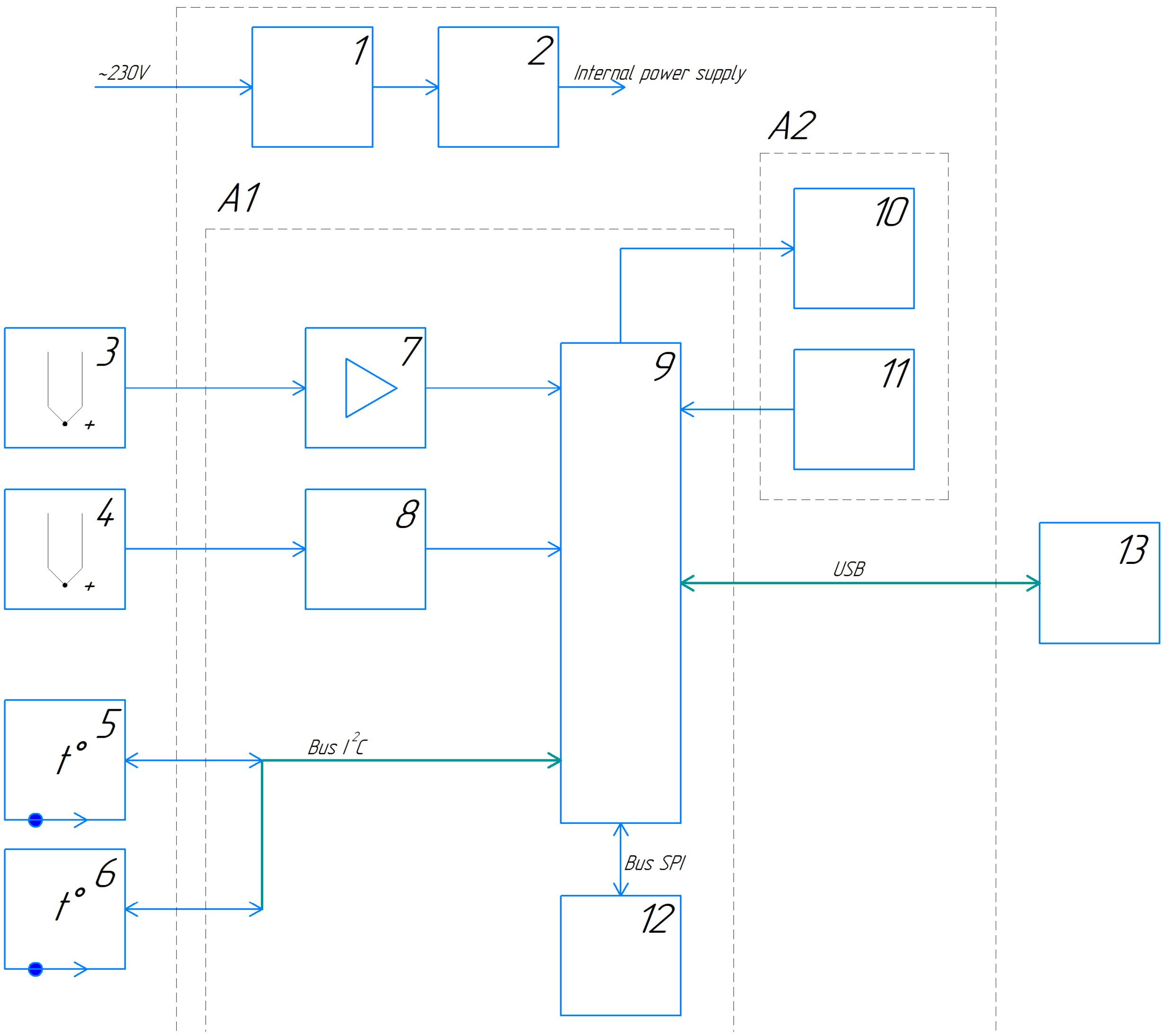

Fig. 3. Enlarged block diagram:
1 – AC/DC converter; *2* – DC power supply; *3* – analog thermocouple; *4* – digital contact temperature sensor; *5*, *6* – contactless temperature meters; *7* – thermocouple signal Amplifier; *8* – digital interface; *9* – central computing device; *10* – indicator device; *11* – keyboard; *12* – non-volatile memory device; *13* – PC

All the above components of the information and measurement system are divided into two functional modules. Measurement functions and functions for processing measurement information are assigned to module A1 (data collection and processing module). Local control and display the operation mode of the information and measurement system is provided by the blocks included in the A2 module (local control and display module).

As a result of further decomposition of the structure of the information and measurement system, we obtain a more detailed structural diagram of the designed system (fig. 4).

This detail allows you to more clearly assess the functional features of the designed system and, later, during the implementation of the system, go to the solution of fundamental, circuit issues. Block 1 is a switch or multiplexer (MUX1) that switches data about the object's temperature field from two contactless temperature meters based on a microcontroller (MCU) signal. Only one-meter signal is present at the MUX1 output at any given time. Block two converts data about the temperature field of the object, taking into account the resolution, into a digital code, which is fed to block 9. the Latter is a switchable signal delay line with the ability to adjust the delay time.

Block 6 converts the thermo EMF of the thermocouple to a voltage ΔU for further amplification. This voltage is amplified by a specialized amplifier with an adjustable gain-block 8. Then the voltage increased to the desired level passes another conversion-sampling in an analog-to-digital converter (block 10).

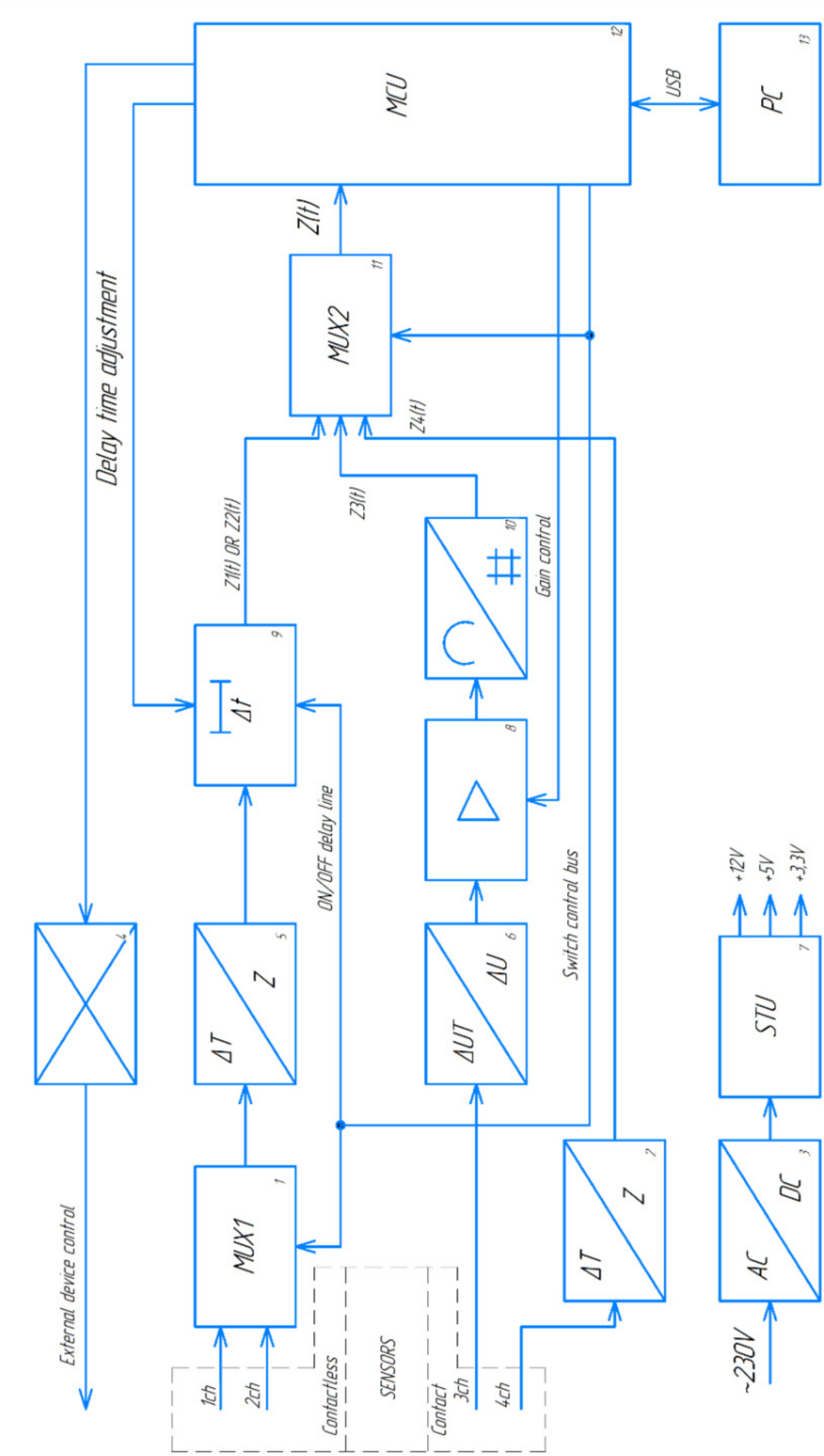

Fig. 4. The diagram of the multi-channel measuring system

Block 7 performs direct conversion of the temperature ΔT of the object under study, obtained by contact method, to the digital code *Z*. This code is sent to the switch OR MUX2 multiplexer-block 11. The remaining two MUX2 inputs are fed a digital code from one of the contactless temperature meters and a digitized thermocouple temperature value. Synchronization of MUX1 and MUX2 is provided by the MCU so that each of the four measurement channels is polled 20 times per second. This creates a complete picture of the temperature distribution of the object under study.

Block 4 is an executive device designed to control the state of the object under study.

Based on the obtained block diagram of a multi-channel data-measurement system, we will develop its information model. Based on the main measurement goals set out in [3], the developed system allows finding the temperature values of the object under study by direct measurements. In this case, the information model for measuring independent input values of temperature has the form:

$$Z = \{[Z_1],[Z_2],[Z_3],[Z_4]\},$$

where Z_1 – the temperature value obtained during non-contact measurement in the first measuring channel; Z_2 – the temperature value obtained by non-contact measurement in the second measuring channel; Z_3 – the temperature value obtained by contact measurement in the third measuring channel; Z_4 – the temperature value obtained by contact measurement in the fourth measuring channel.

If it is not possible to measure the temperature separately, for example, the object under study has a relatively small size or the shape of the object surface does not allow independent measurements, the model becomes:

$$Z_G = \left(Z_{q1}, Z_{q2}, Z_{q3}, Z_{q4}\right).$$

The block diagram also allows you to study thermal processes in dynamics, such as the heating rate, cooling rate, etc. In this case, the model looks like:

$$Z(t) = Z_1(t_1), Z_2(t_2), Z_3(t_3), Z_4(t_4),$$

the condition must be met:

$$t_1 = t_2 = t_3 = t_4 .$$

It follows from the condition that all measurement channels must be synchronized. Taking into account the inertia of temperature processes [4], [5], this problem requires a separate circuit solution.

Thus, the complete information model for the developed block diagram has the form:

$$\left\{\begin{aligned} & Z = \{[Z_1],[Z_2],[Z_3],[Z_4]\}, \\ & Z_G = \left(Z_{q1}, Z_{q2}, Z_{q3}, Z_{q4}\right), \\ & Z(t) = Z_1(t_1), Z_2(t_2), Z_3(t_3), Z_4(t_4). \end{aligned}\right\}.$$

Conclusion

Simulation modeling of the developed structural scheme showed the adequacy of the obtained data on the state of the temperature field of the object under study. Analysis of the simulation results and their comparison with known developments [6], [7] and [8] that are similar in purpose, but have a number of functional disadvantages, proves the advantages of the developed structural scheme. Meanwhile, it should be noted that when implementing the proposed structure, one of the most difficult tasks is to synchronize the survey of information channels, which will require the use of a sufficiently fast computing device. Thus, the developed block diagram of the data-measurement system meets the basic requirements, such as multichannel measurement of a physical quantity-temperature, direct communication with the measured object, automatic control and processing of measurement information. An information model of the system is proposed that allows evaluating the nature of the information process when measuring several homogeneous physical quantities in a multi-channel data-measurement system.

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