Development of a calibrator for an impedance measuring transducer

O. D. Vasileva[1]

[1]Bauman Moscow State Technical University (BMSTU), 2-nd Bauman str., 5, Moscow, Russia

Contact: bizronmaziron@gmail.com

Introduction

Modern rheographs are able to measure the resistance of a bioobject in the range from 0 to 500 Ω with an accuracy of 5 mΩ. To establish the quantitative correspondence between the amplitude of change in the resistance of the bioobject under study and the value of the recorded voltage, there is a calibrator capable of generating reference signals of known shape and amplitude.

To date, there are several calibration tools for rheographs. These include the Diatest-4 functional generator and the voltage-resistance converter PNS-GF [2,3]. These calibrators are a set of fixed-value resistors $R_{ES1,2}$ =200 Ω and variable resistor R_{BO}, varying in the range from 0 to 500 Ω. However, when using a small electrode diameter a, the electrode-skin resistance has a wide enough spread and can reach 1.5 kΩ (1). In this range, the current source can change the amplitude of the output current, which negatively affects the accuracy of the measurement results.

It is necessary to perform calibration not only by changing the resistance of the bioobject, but also taking into account the different load in the current channel, that is, calibrate the current source and the impedance measuring transducer as a whole.

Materials and Methods

A calibrator was developed, the scheme of which is presented in Figure 1. Requirements for the calibrator being developed:

— range of resistance value of the measuring channel 0-500 Ω

— current resistance range 0-4.5 kΩ

To calibrate the measuring channel, one switch is needed to ensure that the resistance varies within the required range. Each switch has been matched with a number of precision resistors. The central resistor shown in Figure 1 serves as an analog potentiometer. This measuring channel is galvanically isolated from the main instrument and has control circuits.

The current calibration channels of the rheograph consist of two series-connected potentiometers assembled from precision resistors of fixed denomination, which in turn act as a chain with series-connected resistors with a variable value of resistance. Since the current channels are symmetrical, the current arms also provide synchronous switching.

The resistance range of the current channel is chosen based on formula 1 to find the contact resistance of the electrode-skin.

$$R = \frac{\rho}{2\pi a} \quad (1)$$

where ρ - the resistivity of the skin, a - the radius of the electrode. [1]

To calibrate a current source that operates with a load of up to 4.5 kΩ, it is necessary to implement a circuit of two series-connected variable resistors of 2.25 kΩ.

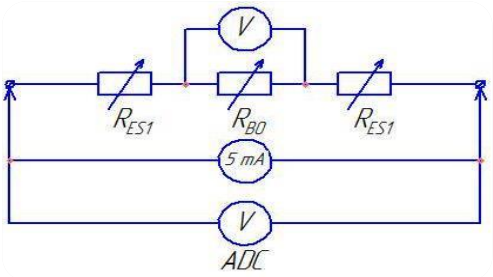

Figure 1: Calibrator circuit

The measurements were carried out by means of the developed individual calibration instrument of the rheograph. The calibrator is connected to the current channel of the rheograph. At the output, the current generator outputs a fixed value of 5 mA. The change in the resistance value simulates the changing resistivity of the bioobject. The values of the voltage value taken from the ADC built into the current source are recorded.

Results

Based on the measurements, a calibration curve was obtained, shown in Figure 2.

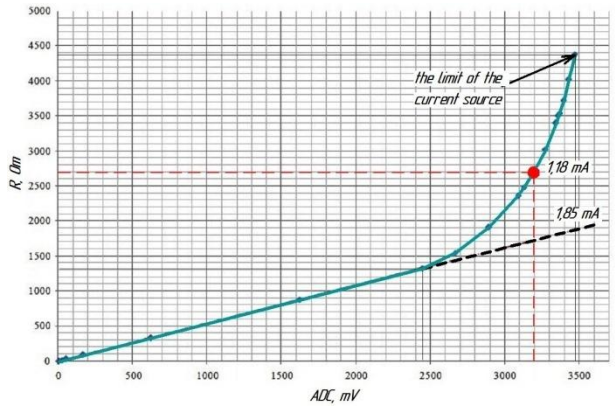

Figure 2: Calibration curve

The nonlinear dependence of resistance values (Y axis) and voltage values taken from the ADC (X axis) is revealed. So, with a load of 2700 Ω, the current in the circuit drops from 1.85 mA to 1.18 mA by 37.3%. It is caused by the fact that in real conditions the current source is not ideal.

The resulting calibration characteristic, shown in Figure 2, allows to extend the operating range of the current source from 1300 to 4350 Ω, which indicates an increase in the accuracy of R_{BO} measurements by the electrical impedance method.

The developed device provides calibration of the current channel of the rheograph. By comparing the reference signal with the detected value, it is possible to measure the amplitude of the rheogram directly in Ω. The next stage in the development is calibration of the measuring channel with subsequent correlation of the obtained values taken from the calibrator and the values taken from the rheograph.

References

[1] S. Grimnes and Ø. G. Martinsen, Bioimpedance and Bioelectricity Basics. 3rd edition. San Diego, CA: Academic Press, 2015, p. 143.
[2] Functional generator Diatest-4. Manual. Moscow, 2008.
[3] Voltage-resistance converters for the control of electrical medical products PNS-GF. Moscow: VNIIIMT, 2002.