USE OF THE POTENTIALOSCOPE TO DETECT WEAK BIOELECTRICAL SIGNALS BY THE COHERENT STORAGE METHOD

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An apparatus used to distinguish weak bioelectrical signals from noise of biological and instrument origin, working on the coherent storage principle is described. A cathode-ray tube with storage of discharges (the LN-8 potentialoscope) is used as the memory.

Specialized computers, such as the CAT-400, ART-1000, ATAC-20, ANOPS-1, neiron, and so on, are used at the present time for the analysis of bioelectrical signals. One of the problems most frequently tackled by these computers is the detection of weak bioelectrical signals and the averaging of evoked responses by the coherent storage method [3]. However, extensive use of specialized computers is limited because of their complexity and high cost. This, in turn, has placed difficulties in the way of using specialized computers directly in the course of the experiment, so that the subsequent tactics of the experiment could be determined on the basis of its results.

The development of small analog analyzers for use directly during an experiment is thus an urgent problem. A special cathode-ray tube known as a potentialoscope [4] can be used for this purpose. This tube can store information for a long time and it can therefore be used as an operative memory.

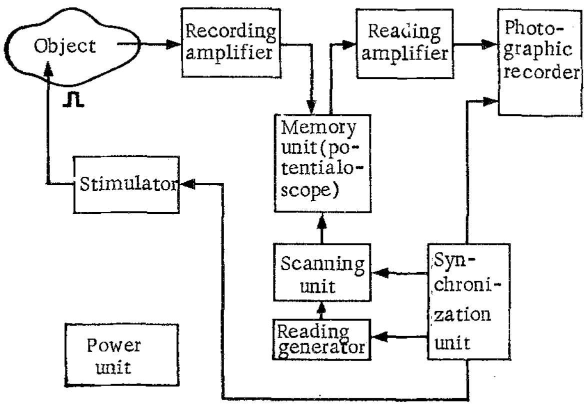

Fig. 1. Functional block diagram of instrument. Explanation in text.

The potentialoscope consists of a system of electrodes designed to form an electron beam and to control its sweep, a signal plate covered with a thin layer of dielectric (target), and a barrier grid. If a variable potential is applied to the signal plate and the electron beam is simultaneously turned, the potential of each area of the target will be determined by the magnitude of the potential of the signal plate at the time of passage of the electron beam through that area. As a result, a "potential relief" is formed on the target and this may last for some time [5]. The barrier grid reduces the mutual effects of neighboring areas of the target on each other and thus prevents obliteration of the potential relief to be recorded.

If the potentialoscope is operating to record the current passing through the load resistance, other

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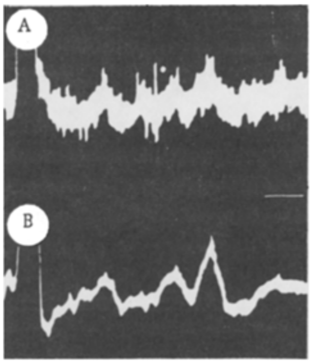

Fig. 2. Component axion potential of slow-conducting fibers of the cat's tibial nerve before (A) and after (B) averaging. Distance between stimulating and recording electrodes 82 mm. Calibration: 5 μV (for A), 20 msec (for A and B).

conditions being equal, the potential of the area of the target exposed at that moment to irradiation by the electron beam will be determined, i.e., the magnitude of potential recorded on that area of the target will be determined.

In the instrument developed by the authors the LN-8 potentialoscope is used. Investigations [2] have shown that the LN-8 tube, if working under suitable conditions, provides a linear relationship between the signals recorded and read during a change in amplitude of the recorded signals within the range from 10 to 60 V. This property means that distortion-free reproduction of the amplitude characteristics of test signals can be obtained within wide limits.

The functional block diagram of the apparatus is shown in Fig. 1. Potentials recorded from nerves, the brain, or muscles pass through the recording amplifier to the signal plate of the potentialoscope. The electron beam is triggered along the horizontal axis by the scanning unit synchronously with the pulse from a stimulator applied to the test object. Responses to one stimulus are arranged in each line. After sweeping a line the beam moves on to the next line. Provided that coherence is observed, the responses in the lines lie consecutively and a potential relief is formed on the target, consisting of a function of three variables: the amplitudes of the biopotentials (the magnitude of the potential on each area of the target, the Z axis), the time from the moment of stimulation (the X axis), and the line number (the Y axis). During reading, a sinusoidal voltage (the reading voltage) is applied to the vertical deflecting plates of the potentialoscope, the frequency of which is greater than the transmission band of the reading amplifier. The electron beam, spread by this voltage in a vertical direction over the whole target, passes once over the target in the direction of the time axis at a speed equal to the scanning speed during recording. If the frequency of the reading voltage is high enough, the electron beam will pass relatively quickly over the target in a transverse direction, carrying out algebraic summation of the values of the potentials in the lines consecutively in each discrete vertical line [1]. Statistically probable bioelectrical signals are thus revealed during counting on the load resistance as an averaged response recorded photographically from the oscilloscope. Noise, as a random process, is converted in accordance with the law of its distribution at the output of the instrument either into zero or into a constant component of the output signal.

The component of the action potential of C-fibers recorded from the intact (with its membranes in situ) trunk of the tibial nerve, recorded directly after the amplifier (Fig. 2A) and after averaging of 150 responses by the potentialoscope (Fig. 2B) is shown in Fig. 2. On record A the initial signal to noise ratio can be estimated as approximately 1:3, while on record B, after averaging, as 4:1. Consequently, as a result of averaging the signal to noise ratio was increased by 12 times. The experimental results demonstrate that the increase in the signal to noise ratio obtained by the use of this instrument obeys the $\sqrt{n}$ law, where n is the number of responses averaged. If weaker signals must be found, the number of averaged responses can be increased by increasing the capacity of the memory of the instrument by using two or more potentialoscopes.

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