HIGH-SENSITIVITY APPARATUS FOR TEMPERATURE RECORDING

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A description is given of a transistorized apparatus consisting of two identical channels, each of which is composed of balanced ac bridges (working frequency 10 kHz), narrow-band amplifiers with synchronous phase-sensitive detector, and a reference generator common to both channels. The apparatus can be used (in conjunction with automatic writers with sensitivity 10 mV/cm) to record fluctuations of temperature of the order of 0.005° or less.

Besides thermocouples, miniature semiconductor glass-insulated thermistors are now widely used to record the temperature of organs and tissues [4, 7, 8]. The use of thermistors is technically simpler than that of thermocouples, especially in investigations when the need arises for high-sensitivity recording, such as in studies of the brain temperature [9-11]. Several instruments for working with thermistors are described in the Soviet biological literature [1-3, 5, 6].

The portable two-channel apparatus suggested here for measurement of low variations of temperature can be used in conjunction with various dc automatic writers with a sensitivity of the order of 10 mV/cm.

This apparatus consists of two identical channels, each composed of balanced ac bridges, narrow-band amplifiers with phase-sensitive detectors, and a reference generator common to both channels. The whole apparatus is transistorized and has its own power supply.

The measuring bridge is fed from a special winding of the reference generator, taking into account the fact that the voltage on the thermistors must not exceed 70 mV, or otherwise the stability of work of the thermistors would be considerably impaired, and the thermistor would be heated to an amount commensurate with the value of the temperature recorded.

To prevent interference between the measuring bridge and amplifier, a matching emitter follower on transistors T_1 is introduced between them. Further amplification of the signal is achieved by a three-cascade amplifier on transistors T_2-T_4, which are spanned by loops of feedback, a change in the magnitude of which controls the sensitivity of the instrument. The final cascade of the amplifier is loaded on an output transformer, the primary winding of which is tuned in resonance with the frequency of the reference generator. The circuit of the secondary winding includes the phase-sensitive detector, the amplitude and polarity of the rectified voltage at the output of which depends on the phase of the measuring signal. The necessary conditions for working of the detector are provided by a supply of commutative voltage to the rectifier diodes from the reference generator, causing a synchronous change in conductance of the rectifier diodes and the appearance of a voltage at the output of the detector with an amplitude and polarity depending on the phase of the measuring signal.

The reference generator of the apparatus is based on a push–pull circuit, and silicon triodes T_5 and T_6 are used to increase its temperature stability. The transformer of the generator is built on a ferrite

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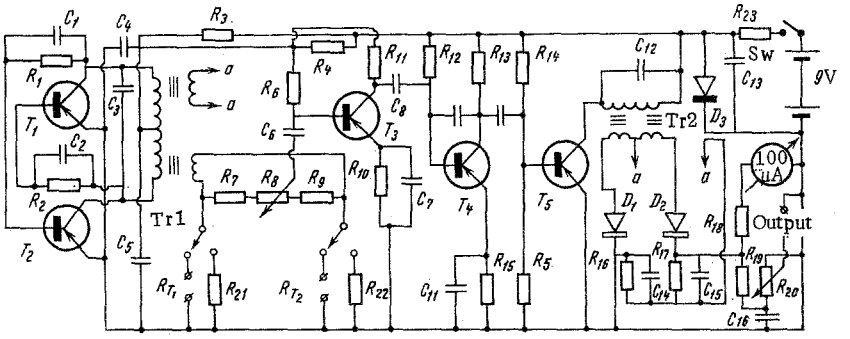

Fig. 1. Theoretical circuit of the apparatus. T_1-T_2-T_4, MP116; T_3, P27A; D_1-D_2, D105; D_3-D814A; C_1-C_2-C_3-C_6-C_{12}, 50,000 pF; C_4-C_5-C_7-C_{11}, 50 μF ×10V; C_6-C_8-C_{14}-C_{15}-C_{16}, 1.0 μF × 10 V; C_9, 4700 pF; R_1-R_2, 47 kΩ; R_3, 1 kΩ; R_4, 2.2 kΩ; R_5, 6.8 kΩ; R_6, 270 kΩ; R_7-R_9, 560 Ω; R_8, 1.1 kΩ; R_{10}, 360 Ω; R_{11}, 5.6 kΩ; R_{12}, 180 kΩ; R_{13}, 1.8 kΩ; R_{14}, 91 kΩ; R_{15}, 180 Ω; R_{16}-R_{17}, 8.2 kΩ; R_{18}, 680 Ω; R_{19}, 1.5 kΩ; R_{20}, 5.6 kΩ; R_{21}-R_{22}, 1 kΩ; R_{23}, 360 Ω.

Fig. 2. Record of cerebral cortical temperature of a rat.

toroidal core, which greatly reduces induction from the generator to the measuring circuit, and also reduces the size of the generator. In most electrophysiological instruments the frequency characteristic is limited to 2-3 kHz, and for this reason a working frequency of 10 kHz has been chosen for this instrument in order to avoid possible induction on other instruments. Otherwise the generator circuit has no special features in principle. The instrument has an in-built indicator system (M24 microammeter, 100-0-100 μA), used as an indicator of the supply voltage, and also for visual checking of bridge balance. The instrument is fed from two 9-V batteries, and the current consumption is 50 mA. The use of a narrow-band amplifier with synchronous phase-detection in conjunction with low-noise transistors has reduced the noise level of the amplifier to a value of the order of 10 μV; the use of a low alternating voltage for supplying the thermistor has also increased its stability and reduced noise. As a result, the zero drift of the whole instrument has been reduced to the level of 20 μV/h, and fluctuations of temperature of the order of 0.005° or less can be recorded reliably on the scale of type N-373 recording instruments.

If the two channels of the apparatus are used simultaneously, differential measurement and recording of temperatures from two thermistors can be carried out. The advantage of this method of measurement is that it does not require two thermistors with identical parameters. All that is necessary is to establish equal sensitivity of the two channels at the measured temperature and to connect the automatic writer in such a way that the difference between the readings of the two channels is recorded.

Recording the brain temperature by means of the instrument described here is not troubled with induction and the instrument is not sensitive to motor artefacts. This means that the temperature of any part of the brain can be recorded in freely moving animals in experiments of long duration.

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