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TEMPERATURE CONTROL NETWORK FOR THE INVESTIGATION OF NERVE CELLS

MIHÁLY VÉRÓ

Biological Research Institute of the Hungarian Academy of Sciences, Tihany, Hungary

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Action potentials representing the functioning of nerve cells are temperature dependent. The investigation and quantitative evaluation of this dependence can be greatly enhanced by a special preparation chamber with adjustable temperature in the range needed for the investigation.

Our intention was to investigate the parameters of nerve cell action potentials in the range between +7 and +33 °C (VADÁSZ and VÉRÓ, 1974). For this purpose, a temperature controlled chamber for preparation and a temperature adjusting device have been developed, suitable for adjusting four different temperatures quickly and accurately. The unit was developed for the electrophysiological investigation of nerve cells, and accordingly signals are taken from intracellular glass electrodes. Investigation has been performed at +7, +14, +22 and +33 °C.

The temperature of the chamber for preparation has been adjusted by using a Peltier element (KLEIN and WALZ, 1967). The rapid attainment of the selected temperature is assured by applying alternately cooling and heating operating modes. The reliable switching of low voltages and relatively high currents is performed by thyristors, driven by temperature sensing thermistors with the aid of a comparator circuit.

The block diagram of the temperature control device is shown in *Fig. 1* The investigated substance is placed in a plexiglass chamber comprising a disc with side illumination. The temperature controlled metallic plate is isolated at the bottom of the chamber. The plate temperature is sensed by a thermistor, and the thyristors of the switching circuit are controlled by this thermistor (MÜLLER and RUPPRECHT, 1965). The cooling and heating operation is switched on by alternating the current flow through the Peltier element. Cooling of the Peltier element is accomplished by a brass block, with water flow for better efficiency. The cooling water supplies also the cooling of the power supply power transistors, so even after 24-hours operation, the transistor temperature will not exeeed 80 °C. A control lamp, driven by a membrane type water pressure gauge, indicates low flow rate or no cooling water. Similar control lamps serve to indicate the heating and cooling cycle of the switching unit and the corresponding current supply of the Peltier element. A second

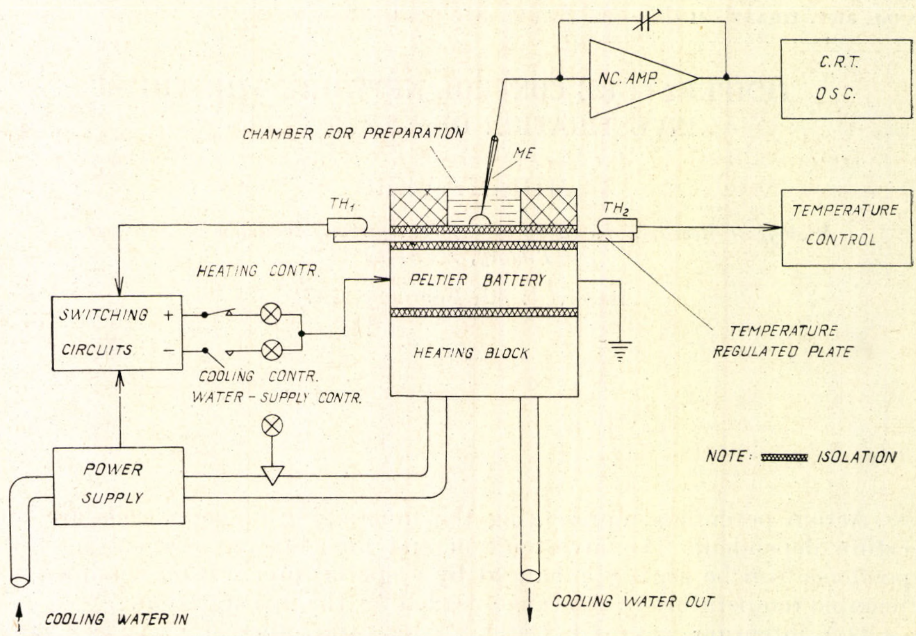

Fig. 1. Block diagram of the temperature control equipment

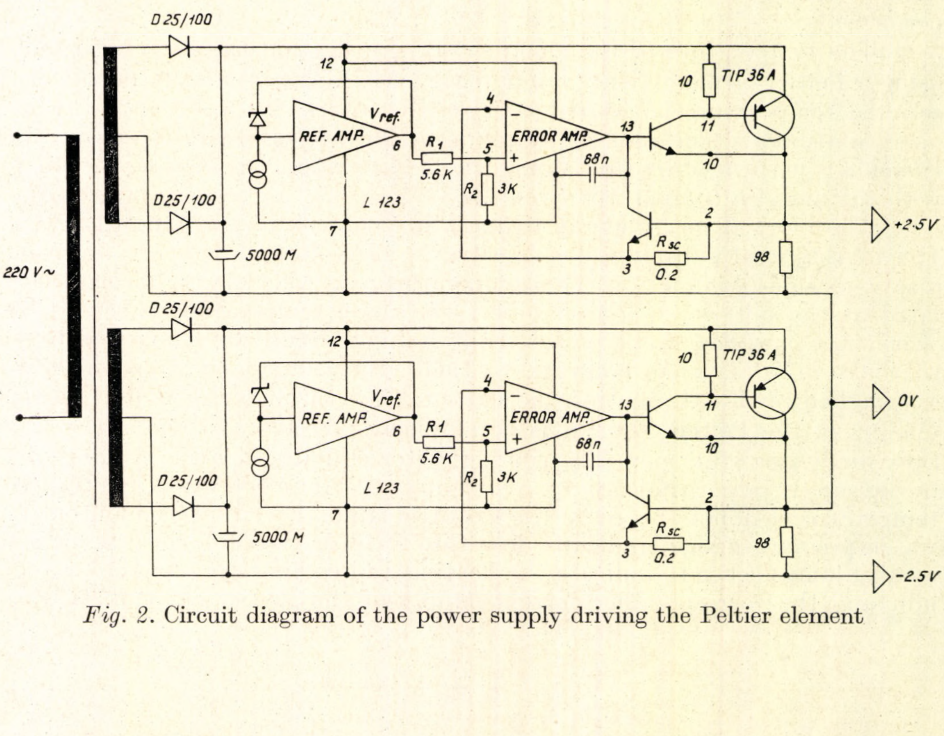

Fig. 2. Circuit diagram of the power supply driving the Peltier element

thermistor near the substance serves for temperature control of the substance by an external digital voltmeter.

The investigation of temperature dependence by means of microelectrodes required the solution of special circuit problems. The required accuracy of temperature and the adjustment speed could only be met by placing the Peltier element directly under the chamber of preparation. At the same time, the high impedance of the microelectrodes used for signal connection required a power supply ripple not more than 1 mV. Taking into account the relatively high current values, IC-type voltage regulators have been applied, with sensing and control circuits made up from high gain operational amplifiers, assuring good evaluation of the investigated signals (VÉRÓ, 1973).

The circuit diagram of the thyristors and of the power supply for the Peltier element is shown in *Fig. 2*. The mains transformer has two identical center-tapped secondary windings. After full-wave rectification and filtering, type L 123 voltage regulators receive +12 volts. The voltage regulators supply ±2.5 volts DC at 4 amperes for the thyristors and for the Peltier element. The L. 123 IC's are operated as positive voltage regulators, and their output voltages are set by resistors R1 and R2 according to the following relation:

$$V_{out} = V_{ref} \frac{R_2}{R_1 + R_2}$$

where,

$$V_{ref} = 7.15\,\text{V (min 6.8 V, max 7.5 V)}$$

From the resistance values pertaining to the normal L 123 output voltages, R_1 or R_2 may be approximated by extrapolation; so if R_1 is known, then

$$R_2 = \frac{R_1 V_{out}}{V_{ref} - V_{out}}$$

or if R_2 is known, then

$$R_1 = \frac{R_2 (V_{ref} - V_{out})}{V_{out}}$$

Owing to the high current demand, TIP 36A external transistors are applied as series regulators, and a current sensing limiter is used against load short circuit effects. This is effected by a transistor in the L 123 IC voltage regulator in the case when a correct valued R_{sc} resistor is connected between the base and emitter electrodes. The resistance value is calculated from the following relation:

$$I_{limit} = \frac{V_{sense}}{R_{sc}}, \text{ so } R_{sc} = \frac{V_{sense}}{I_{limit}}$$

where, V_{sense} is the V_{BE} voltage of the operating current limiter transistor (this is 0.7 volts with good approximation).

The compensating capacitance of the voltage regulator determining the frequency response has been experimentally selected as 68 nF which proved to be optimal regarding output noise.

The cooling and heating operation of the Peltier element is accomplished by the switching circuit shown in *Fig. 3.* A TG10 type glass thermistor, having

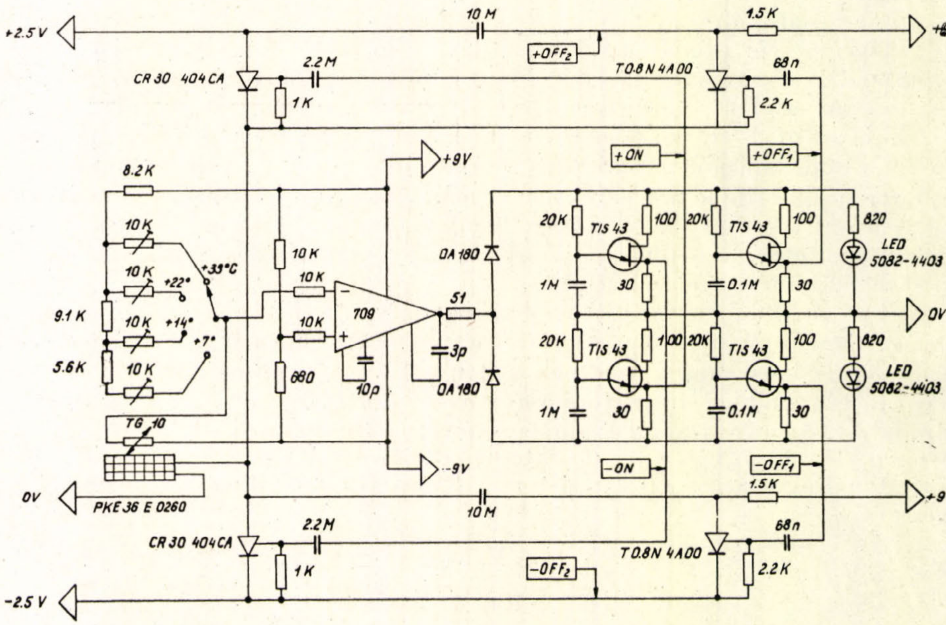

Fig. 3. Switching circuit serving for cooling and heating operation

a resistance of 1.5 kiloohms at 20 °C, is placed to the substance. If this resistance changes, a comparator circuit utilizing a μA 709 operating amplifier effects the cooling or heating operating mode of the Peltier element by switching on or off the corresponding thyristors. A positive or negative supply voltage appears at the output of the comparator, depending on whether the thermistor circuit voltage is lower or higher than the reference voltage. This supply voltage operates unijunction transistor pulse generators. On each positive or negative supply voltage appearance, two identical pulse generator pairs will operate. There is a 1 : 10 ratio between frequencies of the two generators within each pulse generator pair. Thus, following the supply voltage appearance, the higher frequency OFF pulses will first drive the thyristor which has been previously conducting, and ten OFF signals will effect a reliable "switching off" action. After this, the first ON signal will reach the driving electrode of the thyristor which was non-conducting and will make it conducting. Should the comparator output be switched over to the other supply voltage due temperature sensing thermistor control, then the other two pulse generators will operate, switching off the conducting thyristor and switching on the non-conducting thyristor (Granieri, 1972; Kleinman and Sherig, 1972).

The thyristors are operated by a primitive pulse reaching the gate electrode. Switching off is accomplished by reverse biasing: a charged capacitance is connected on the conducting thyristor by a low power thyristor (McNulty, 1972). The CR 30 404 CA high current thyristor driving waveforms during the cooling and heating periods are shown in *Fig. 4.*

The cooling or heating operating mode is indicated by front panel LED indicators connected to the comparator output. Polarity sensitive LED

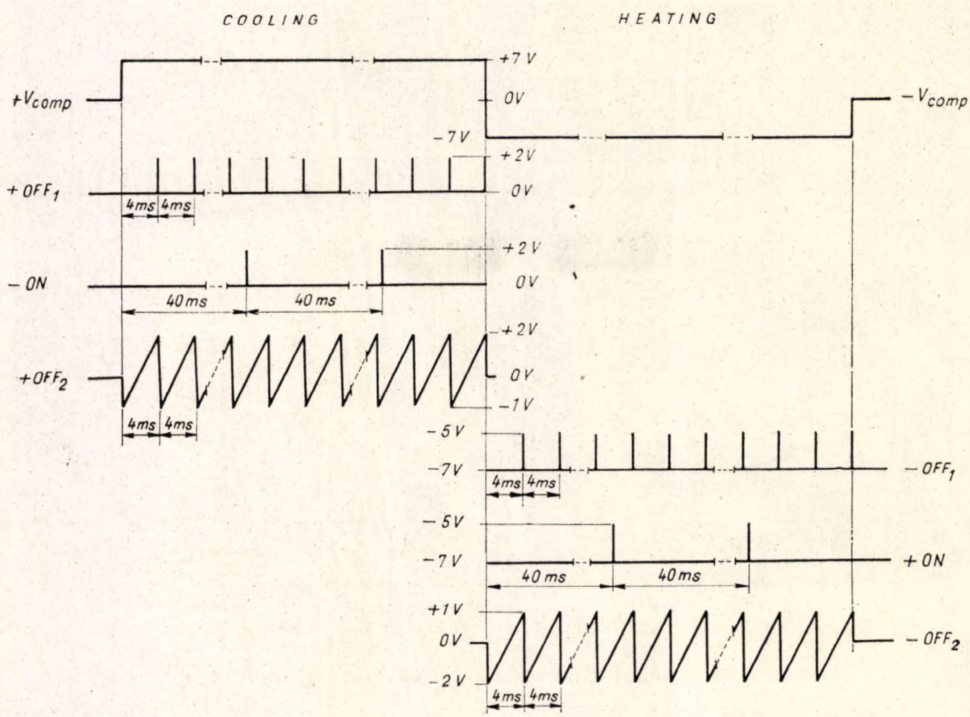

Fig. 4. Waveforms of signals driving the switching thyristors

indicators are also applied for indicating the conducting mode of the thyristors. This type of switching circuit has high reliability and theoretically infinite lifetime as no moving parts are contained.

Temperature is adjusted by a Siemens PKE 36 E 0260 solid-state Peltier element with 36 cells, having the following parameters:

operating voltage	3.5 volts
operating current	8 amperes
maximum cooling power	22 W (at T = 0 °C)
maximum operating temperature	80 °C
ohmic resistance	380 ohms
dimensions	53 × 28 × 7 mm

The chamber for preparation has a diameter of 20 mm, a depth of 10 mm and is housed together with the cooling block in a screening cylinder of 83 mm diameter and 150 mm height. A photograph of the cooling block and of the electronic equipment is shown in *Fig. 5.* The latter comprises the power supply, the switching unit and the water flow sensor, and is housed in a case having dimensions of 200 × 192 × 168 mm.

The heating and cooling times needed to reach different temperatures have been measured with the built temperature control equipment. Measurement results are shown in *Fig. 6*. The temperature was measured by a mercury thermometer placed in the chamber holding the liquid. The temperature accuracy proved to be ±0.2 °C.

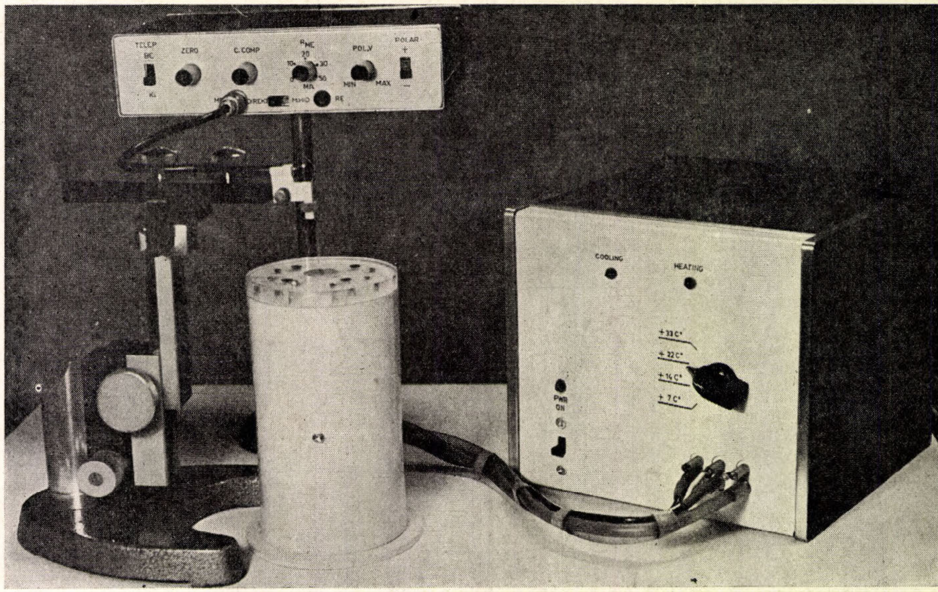

Fig. 5. Photograph of the temperature control electronic equipment

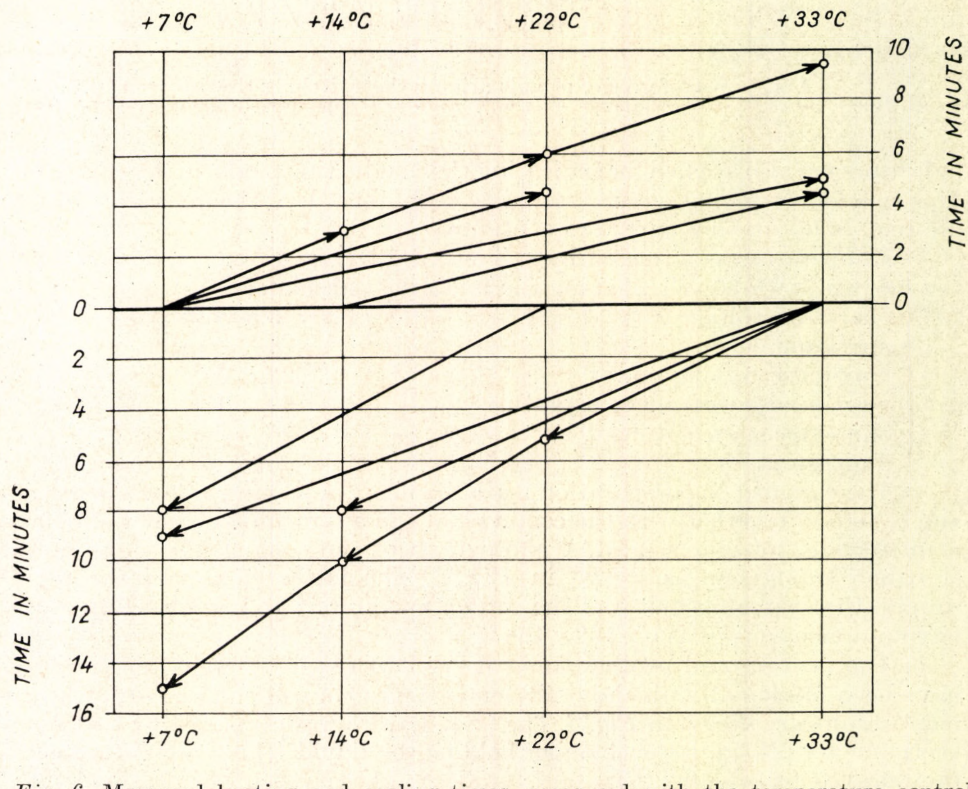

Fig. 6. Measured heating and cooling times, measured with the temperature control equipment

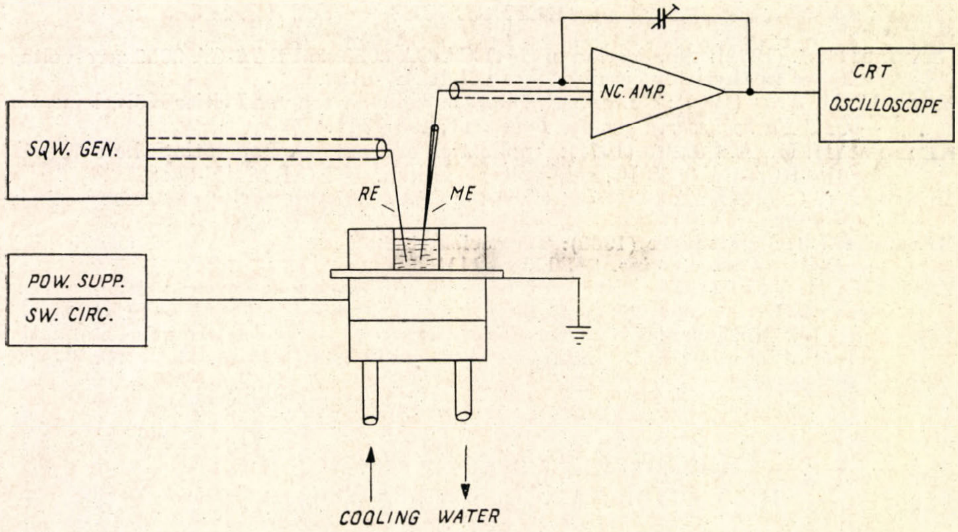

Fig. 7. Measurement set-up for determining interfering signals of the temperature control equipment

Interference due to the switching apparatus has been investigated by the arrangement shown in *Fig. 7*. According to our measurements using a 20 megohms glass electrode, the interference due to 50 Hz mains voltage and thyristor switching voltage was less than 1 mV. Practical investigations on substances clearly showed that the low level of interference allows the data processing of action potentials, and the temperature control system used is well adapted for rapid investigations.

Summary

The chamber for preparation intended for the investigation of nerve cell temperature is suitable for rapid adjustment of temperatures of +7, +14, +22 and +33 °C. The temperature values are adjusted by a Peltier element operating alternately in cooling and heating operating modes, and switching is accomplished by thyristors. The Peltier element is supplied by IC type voltage regulators. Thyristor switching is effected by pulse generators driven by a comparator circuit with thermistor input.

Circuit and construction details, operating speed, accuracy data and an interference investigation method are discussed in the paper. The equipment is also suitable for continuous temperature control of liquid baths containing other small biological objects.

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HŐMÉRSÉKLET SZABÁLYOZÓ ÁRAMKÖR IDEGSEJTEK MŰKÖDÉSÉNEK VIZSGÁLATÁHOZ

Véró Mihály

Összefoglalás

Az idegsejtek hőmérséklet függő vizsgálatához készült preparátumtartó +7 °C, +14 °C, +22 °C és +33 °C hőmérséklet értékek gyors beállítására alkalmas. A vizsgálatokhoz szükséges hőmérséklet értékek beállítása Peltier elemmel történik. A Peltier elem váltakozó hűtő-fűtő üzemmódban dolgozik és az átkapcsolás tirisztorokkal van megoldva. A Peltier elem áramellátását integrált áramkörös feszültség regulátorok biztosítják. A tirisztorok kapcsolását termisztor bemenetű komparátor áramkörrel vezérelt impulzusgenerátorok látják el.

A dolgozat részletesen ismerteti az alkalmazott áramköri és konstrukciós megoldásokat, a hőmérséklet szabályozó működési sebességére és pontosságára vonatkozó adatokat, valamint az alkalmazásnál fellépő zavarójelek vizsgálatának módszerét és eredményeit.

A berendezés alkalmas más, kisméretű biológiai objektum fürdőfolyadékának hőmérsékletszabályozására is.