A STIMULATOR GIVING STEPWISE INCREASING IMPULSES FOR ELECTROPHYSIOLOGICAL USE

K. N. Vikhoreva, R. A. Grigor'yan, and O. T. Lebedev

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Further progress in the field of investigation of the electrical phenomena of the central nervous system requires the application of electrical impulses of different forms as stimuli. One of the methods at present used for studying the accommodation properties of nerve tissue is the application of impulses of stepwise increasing amplitude and the subsequent comparison of their effects with the reaction to single rectangular impulses of the same amplitude and duration. The reason why the application of stepwise increasing impulses is preferable to the use of impulses increasing by a linear relationship is that stepwise changes in the amplitude of the stimulating impulse are essential. The more detailed study of these problems may shed light on the question of the peripheral coding in the sense organs.

As a first step in this direction, a special electronic stimulator is suggested, capable of generating stimuli both of stepwise increasing form and of rectangular form.

The impulse at the output of the apparatus contains 1-10 steps with a fine control of amplitude from 0 to 25 V. The duration of the steps can also be finely controlled from 0.2 to 2.0 msec. With automatic starting, impulses can be supplied in succession at intervals of 1-3 sec. The apparatus provides for independent control of the amplitude of the first step and an envelope increase in the step impulse from linear to exponential. The stimulator contains nine tubes in a bantam series. The power supply to the apparatus is: +250 V, 75 mA; –20 V, 5 mA; filament, 6.3 V, 4 A. A block scheme of the apparatus is given in Fig. 1.

Positive commutative impulses with an amplitude of about 20 V are supplied to the input of the stimulator. Through the cathode repeater CR_1, they are fed into a multivibrator MV and they cut out of the continuous series of impulses a "parcel" of impulses of negative polarity, which pass through the cathode repeater CR_2 to reach the storage system (SS). Because the trailing edge of the stepwise impulse obtained at the output is prolonged, these impulses arrive at the same time as commutative impulses from CR_3 to the electronic commutator (EC) for a sharp cutting off of the trailing edge. Through the inverting amplifier (IA) and the cathode repeater CR_4, with a low-ohmic output, the stimuli are applied to the object. To compare the effects of the action of stepwise and rectangular impulses, positive rectangular impulses may be applied through the final cascade of the stimulator to the same stimulating electrodes.

The theoretical circuit of the apparatus is shown in Fig. 2. The commutative rectangular impulses pass through the cathode repeater L_1 to the circuit L_2, L_3. The triode parts of these pentodes are used in the circuit of a multivibrator. To increase the stability of working and to prevent the influence of subsequent cascades on the shape of the generated impulse, these cascades are taken from the anode of L_2, where they arrive when commutative impulses reach the pentode grid. The frequency of the impulses is controlled by a double potentiometer in the circuit of the control grid of L_2, L_3. A group of impulses of negative polarity from the anode of L_2 reaches the storage circuit of the tube L_5 through the cathode repeater L_4. A stepwise increasing impulse with a decrement of considerable length is formed on the storage capacitance of 0.1 μF (in the cathode of L_5, the left diode). To obtain an equal increase in amplitude with a large number of steps (10 or more), the cathode repeater L_6 is used in the circuit, stabilizing the discharge current of the storage capacitance. A potentiometer of 5.6 kΩ in the cathode of L_4 is used to record the envelope increase of the stepwise impulse from linear to exponential.

Because of the strict demands made on the shape of the stepwise impulses, it was found advantageous to use secondary electronic commutation by means of a circuit on the tubes L_9 and L_{10} to obtain a steep cutting off of the trailing edge instead of the well known discharge circuits on thyratrons, blocking generators, transistors, and so on [1]. The stepwise impulses are fed through a cathode repeater L_7 to the control grid of L_9, and the commutative impulses through the cathode repeater L_8 to the pentode grids L_9 and L_{10}. A stepwise increasing impulse with a steeply cut off

Laboratory of Comparative Physiology of the Central Nervous System, I. M. Sechenov Institute of Evolutionary Physiology and Biochemistry, Academy of Sciences of the USSR, Leningrad. (Presented by Active Member of the Academy of Medical Sciences of the USSR, V. V. Parin.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 62, No. 8, pp. 119-121, August, 1966. Original article submitted December 1, 1964.

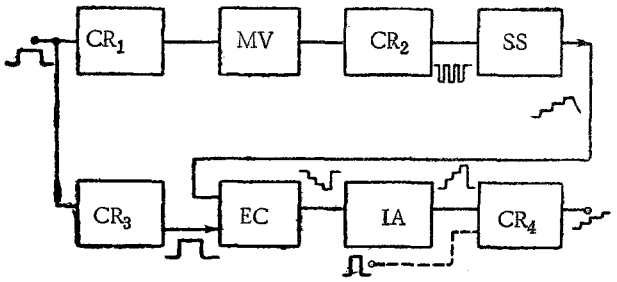
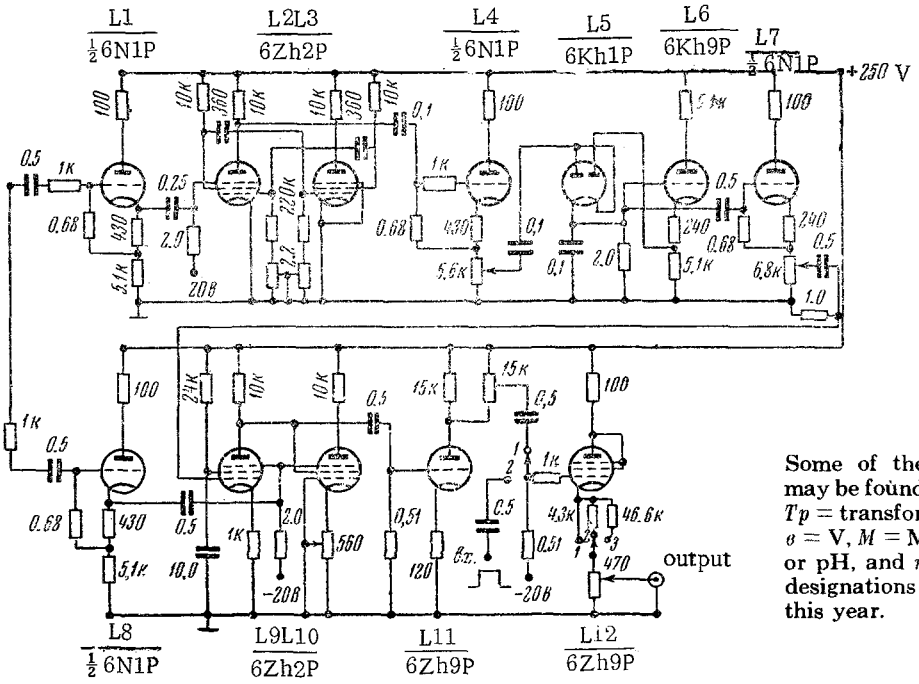


Fig. 1. Block scheme of apparatus.



Some of the following Russian abbreviations may be found in the figure: Л = tube, Д = diode, Тр = transformer, Др or др = choke, Вк = switch, в = V, М = MΩ, к = kΩ, мк = μF or μH, п = pF or pH, and н = nF or nH. For individual tube designations see Appendix to Issue No. 1 of this year.

Fig. 2. Theoretical circuit of the apparatus.

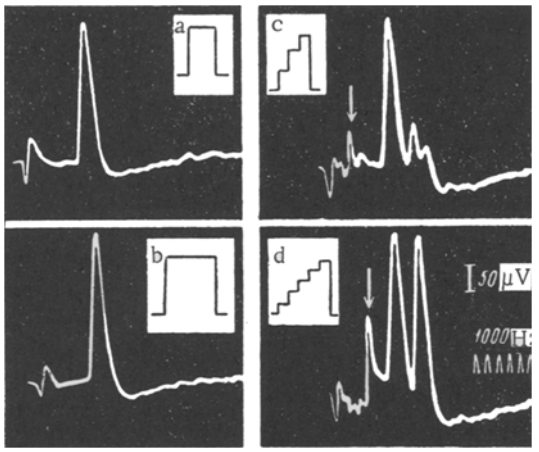


Fig. 3. Ventral root responses to application of rectangular (a,c) and stepwise increasing impulses (b,d) to muscular nerves of a cat (for explanation, see text).

trailing edge is formed on the anode charge of L_9. The necessary compensation of the commutative impulse is carried out by the cathode resistor of the tube L_{10}, so that the level of the first step only can be altered at the same time when the threshold strengths of the stimulus are being chosen.

From the secondary electronic commutation circuit, the stepwise impulses reach the output of the apparatus through a triode amplifier L_{11} and the low-ohmic output of the cathode repeater L_{12}. The rectangular impulses for comparing the effects of stimulation may also be applied to the imput of the final cascade. Synchronization of the driven sweep of the oscillograph is carried out by the leading edge of the commutative impulse through a capacitance of 200-1000 pF.

The stimulator was tested in experiments to record the action potentials in the ventral roots of the spinal cord of a cat during stimulation of the muscular nerves by rectangular and stepwise impulses of the same amplitude and duration. The results of these experiments are illustrated in Fig. 3, which clearly shows that an impulse consisting of three steps (0.5 V, 3 × 0.5 msec), applied additionally to monosynaptic excitation, is followed by the appearance of an asynchronous discharge (Fig. 3b), whereas an impulse of five steps (0.5 V, 5 × 0.5 msec) may produce a double monosynaptic peak (Fig. 3d).

LITERATURE CITED

1. E. I. Kramer, Electronics, 29, 192 (1956).