A STIMULATOR GENERATING A SERIES OF PRESET PULSES

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Many types of neurons discharge in volleys. This means that cell discharges occur in series at measurable intervals with a more or less constant arrangement of the pulses in the series. Such "volley" activity is frequently encountered in neurons of both the efferent and the afferent pathways [1-3].

It would be interesting to check the hypothesis that a certain type of volley recorded in some division of the nervous system is related to the function of this division by experiments in which preparations are stimulated by volleys. In this article we will describe an electronic stimulator which makes such electrophysiological investigations possible.*

This stimulator generates series of square pulses whose amplitude and frequency vary during the series according to an arbitrary predetermined plan. The duration of the series (volley) can be set anywhere from 4 msec to 240 sec. The interval between pulses in the volley can be varied from 0.6 msec to 7.5 sec in eight overlapping ranges involving a factor of 8-20 each. The output amplitude of the pulses can be set between 30 and 150 V for low-resistance output and between 6 and 50 V for radiofrequency output. The stimulator can be triggered manually by a button or automatically at periods ranging from 1.7 to 80 sec by a built-in starting generator. The stimulator can also be triggered by external pulses, with a delay relative to the input pulse that can be set anywhere from 5 msec to 20 sec.

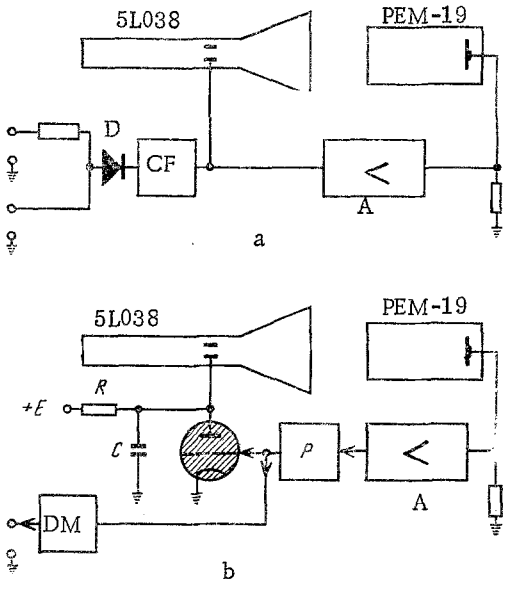

Fig. 1. Amplitude control system (a) and pulse generator (b). A) Direct-current amplifier; D) diode of pulse modulator; CF) cathode follower; P) relay element (Schmitt circuit); DM) driven multivibrator forming the pulse; R, C) resistor and capacitor in the sawtooth-voltage generator circuit.

The regulation of the pulse amplitude and intervals is accomplished by two formers made of opaque material placed between the screen of the cathode ray tube and the photocathode of a photomultiplier (PEM). The generator, common for both tubes, generates the horizontal sweep voltage. The duration of the sawtooth pulse of the sweep determines the duration of the volley of pulses generated by the stimulator. For any volley duration the pulse repetition frequency and pulse amplitude at any moment during the volley (e.g., at $\frac{1}{4}$ of the duration of the volley after its start) are determined only by the height of the formers at the corresponding point (in our example, at $\frac{1}{4}$ of the length from the start) of the sweep line. The number of pulses, of course, is different in a volley of different duration.

The pulse amplitude is fixed by a follow-up system (Fig. 1a) consisting of a PÉM, direct-current amplifier, and

*The author thanks B. I. Golyshev for help in producing the prototype instrument.

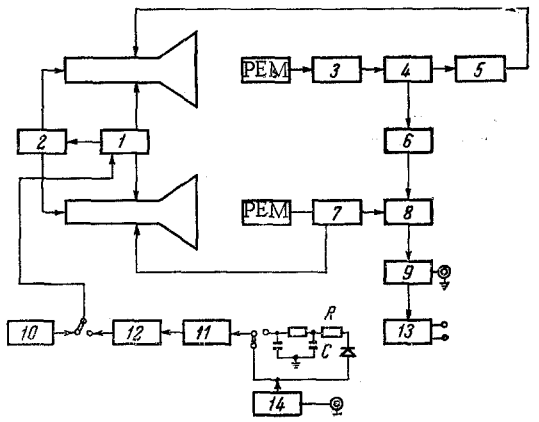

Fig. 2. Block diagram of instrument. 1) Sweep voltage generator; 2) intensifier circuit; 3) d-c amplifier; 4) relay element; 5) sawtooth voltage generator; 6) pulse former; 7) d-c amplifier; 8) modulator; 9) high-power output; 10) internal starting generator; 11) relay element; 12) start-delay circuit; 13) radio-frequency output; 14) starting amplifier.

cathode ray tube 5L038. The voltage from the PEM after boosting is fed to the vertically deflecting plates of the tube. An increase in the illumination of the photocathode of the PEM causes movement of the tube beam to the lower part of the screen (covered by the former). During horizontal movement under the action of the sweep voltage the beam remains at the edge of the former the entire time. The output voltage of the d-c amplifier is used for amplitude modulation of the pulses. Modulation is accomplished by a diode modulator consisting of a diode D and a cathode follower CF.

The pulse generator with present intervals between the pulses (Fig. 1b) consists of a PEM, d-c amplifier, a relay element, thyratron sawtooth-voltage generator and a driven multivibrator forming the pulse. The boosted voltage is fed from the PEM to the input of the relay element. If the illumination of the photocathode of the PEM is below the threshold value (the threshold is determined by the relay element), the thyratron is cut off. In this case the voltage at the capacitor rises and the tube beam moves upward (from the region covered by the former to the edge of the former). At the moment of the appearance of the beam from behind the edge of the former, the relay element fires the thyratron and the voltage across the capacitor drops to the thyratron extinction voltage. At the same time the relay element triggers the driven multivibrator, whose impulse is sent to the aforementioned modulator.

The output circuits of the stimulator make it possible to supply high-power pulses to the preparation from a low-resistance input (200 ohms). In addition, the instrument has a radio-frequency output which makes it possible, at a somewhat lower amplitude of the stimulating impulses, to appreciably reduce the pickup on the recording apparatus. For convenient operation of the instrument the output circuits are in a separate unit, which can be placed in the immediate vicinity of the preparation.

The block diagram of the instrument is shown in Fig. 2. The sawtooth sweep voltage generator is assembled on the basis of a phantastron circuit. Coarse and fine control of the sweep duration is provided. The sweep intensifier trigger (2) is fired from the sweep voltage generator (1). There are two possible regimes of internal triggering: one-time (by the button) and periodic (from the relaxation oscillator (10) of the thyratron). Starting of

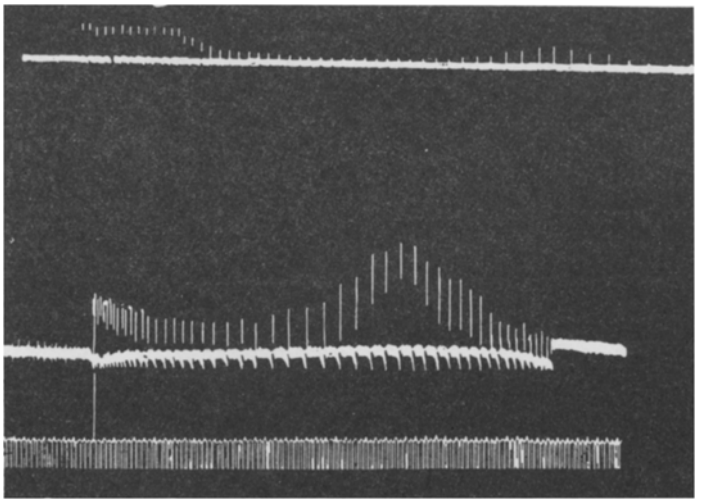

Fig. 3. Examples of pulse series.

the sweep by a pulse (volley) from an external source is also provided. External starting of the sweep is accomplished by a relay element (11) through a controlled delay circuit—phantastron (12).

The pulse generators consists of a PEM, a one-stage d-c amplifier (3), relay element (4) and a relaxation oscillator (5) on a thyratron. These stages are intercoupled galvanically. Such a connection of stages ensures reliable operation at the shortest intervals between pulses (isolated, random nonoperation of the thyratron does not stop the generation of pulses). The interval between pulses depends on the build-up rate of the sawtooth voltage of the relaxation oscillator (5) and the height of the former. A smooth change of the interval between pulses in the volley (within each of the eight ranges) is present by the height of the former. The range of the intervals between the generated pulses is changed by switching the capacitor in the relaxation oscillator (5). At the moment of igniting the thyratron, the relay element (4) triggers the pulse-former-driven multivibrator (6), the pulses from which go to the modulator (8). This modulator is a diode limiter, the reference voltage across which is fed from amplifier (7) through the cathode follower. Thus, the amplitude of the pulses at each instant is equal to the voltage across the output of amplifier (7) of the follow-up system. The d-c amplifier (7) in the follow-up system controlling the pulse amplitude consists of two tubes. D-813 silicon stabilitron tubes are used for the RC circuits (they are convenient in that they do not require special selection).

From the modulator the pulses go to the output circuits of the instrument: cathode follower (9) and radio-frequency output (13). The latter is a high-frequency generator (7 Mc) electronically coupled to a GU-50 tube.

The generator is modulated with respect to the screen grid by pulses from the cathode follower. The plate circuit of the GU-50 tube has a resonant high-frequency transformer. The rectified voltage from the secondary winding of this transformer is supplied to the preparation. The magnitude of the pulses at the terminals of the radio-frequency output is proportional (within 10%) to the magnitude of the modulating pulse. As has already been noted, the cathode follower and the radio-frequency output are situated in a separate, shielded unit.

The stimulator is powered from rectifiers located in a separate unit in order to cut dow pickup. The rectifier supplying the PEM is regulated.

The PEM and CRT are placed in a light-proof compartment of the main unit. The formers in special cassettes are inserted through a light-tight trapdoor in the cover of the main unit.

Examples of the pulse series being generated are shown in Fig. 3.

The instrument can be used for various electrophysiological investigations in any division of the nervous system. I. M. Rodionov, of the staff of the Institute of Biophysics of the Academy of Sciences of the USSR has carried out preliminary experiments on the stimulation of the peripheral sympathetic nervous system using the instrument described in this article. In these experiments the blood circulation and pressure were recorded in relation to stimulation.

A number of specific vasomotor reactions to various forms of stimulating volleys have been demonstrated.

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