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TRANSISTORIZED SQUARE WAVE GENERATOR FOR BIOLOGICAL INVESTIGATIONS

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In experimental biology, properties of muscle and nervous cells and of different neuron pathways are investigated by using a square-wave generator capable of supplying a wide range of stimulating parameters.

In the past years according to some special requirement a solid state square wave generator has been developed which is well suited to stimulate muscle cells and neurons by microelectrodes and to investigate various neuron pathway characteristics by EEG electrodes.

The block-diagram of the square wave generator is shown in *Fig. 1.* The trigger signal of suitable frequency is supplied by the frequency control stage and is used to drive the delay control stage. Delayed by the value adjusted, the trigger reaches the pulse width control stage. The output square wave of the pulse width control is used to drive the output amplitude control stage which has a constant output impedance and supplies a square-wave having adjustable amplitude and polarity.

There are practical cases when single pulses with suitable parameters are required for the item under test. This is made possible by switching off the frequency control stage and triggering the square wave generator by a front panel push-button. In other cases, the frequency range of the generator may not be sufficient. A suitable external pulse generator can then be applied to trigger the stimulator, again switching off the frequency control stage.

The detailed circuit diagram of the square wave generator is shown in *Fig. 2.* The trigger signal with adjustable frequency is generated by a relaxation oscillator utilizing a unijunction transistor of type TIS43 (Texas). This

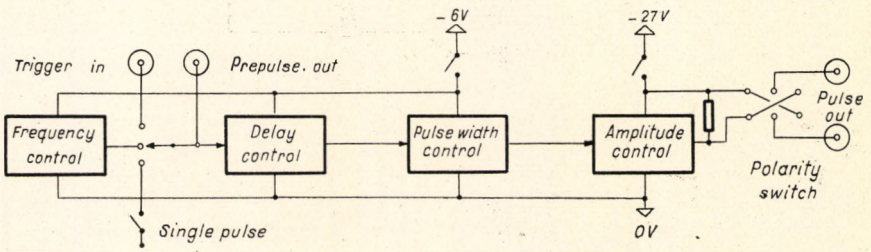

Fig. 1. Block diagram of the square wave generator

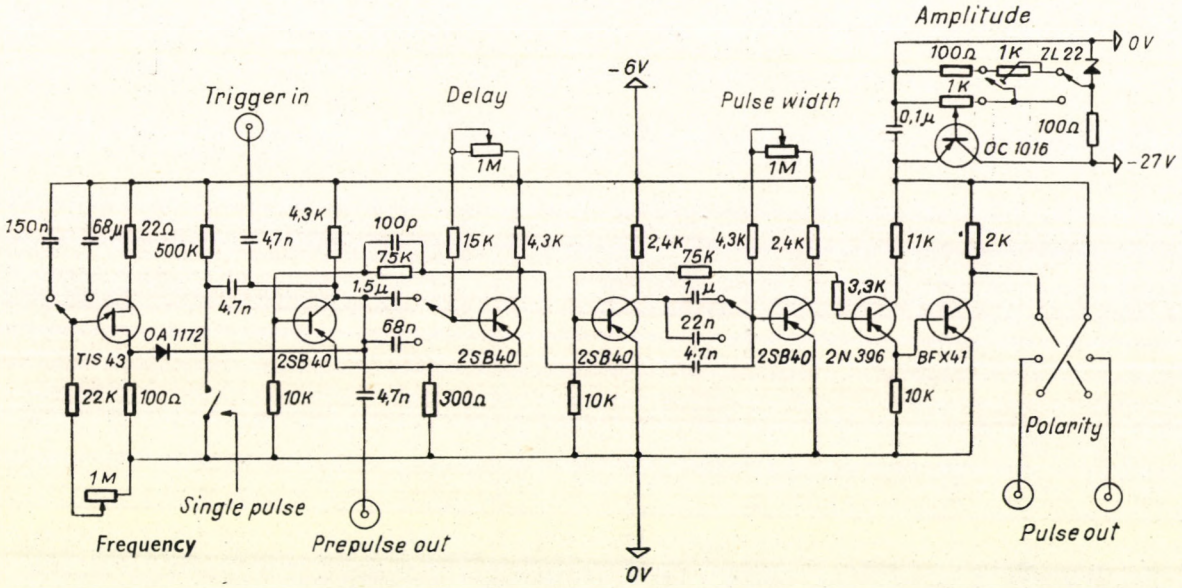

Fig. 2. Circuit diagram of the square wave generator

has more favourable properties than the conventional estable multivibrators (KAPOTA, 1967; YOUNG, 1967). This circuit is suitable for easy and sufficiently accurate generation of the low frequency trigger signal, with a relatively wide frequency coverage. It is convenient that only a single time constant has to be changed by the frequency range switch. With suitably chosen circuit element values, the frequency of oscillation will in practice not be dependent on supply voltage and temperature changes.

The oscillation frequency may be calculated by the following equation:

$$f = \frac{1}{RC \ln \frac{1}{1-\eta}}$$

In this equation, RC is the time constant, determined by the charging resistor and capacitor, and η is the internal voltage division ratio of the unijunction transistor. According to catalog data for the type TIS43, the value of η is between 0,55 and 0,82. In our case, $\eta = 0{,}74$ has been measured.

The required frequency range from 0,1 Hz to 210 Hz is covered by two ranges, the first reaching from 0,1 to 5 Hz, the second from 5 to 210 Hz. Thus appr. 1 : 50 and 1 : 40 frequency ratio is realized in one range.

The frequency control potentiometer has a switch which serves to make the frequency control stage inoperative when single pulses are needed.

The delayed trigger signal is generated by an emitter coupled monostable multivibrator as shown in *Fig. 2.* (JOYCE et al., 1963) which is driven by the output signal of the frequency control stage. Simultaneously with the input trigger signal, a prepulse is supplied to a front panel connector from the collector of the first transistor in the monostable multivibrator, in order to make possible the triggering of the oscilloscope sweep. The trigger signal at the second transistor collector in the multivibrator is delayed with respect to the prepulse by the amount adjusted by the delay control. The delay time of the circuit, taking into account the effect of the trigger signal coupling diode, may be calculated according to the following equation:

$$T = 0{,}405 \cdot RC$$

where R is the resistor and C is the capacitor determining the time constant.

The delay of the circuit is adjustable in two ranges from 0,7 to 600 msec. The first range covers 0,7 to 25 msec, the second covers 16— to 600 msec.

A front panel microswitch serves for the single pulse triggering of the monostable multivibrator. The positive trigger signal will change the state of the multivibrator, cutting off the second transistor current and switching the first transistor into the conducting quasi-stable state.

The pulse with a suitable width for driving the output stage is generated by a collector-vase couples monostable multivibrator as shown in *Fig. 2,* which in turn is driven by the output signal of the delay control stage. The pulse width of the circuit may be calculated from the following expression:

$$T = 0{,}693 \cdot RC$$

where R is the resistor and C is the capacitor determining the time constant.

The pulse width of the circuit is adjustable from 0,1 msec to 200 msec in two ranges. The first range covers 0,1 to 5 msec, the second range covers

3 to 200 msec. The pulse having a suitable width will appear on the multivibrator second transistor collector and will drive directly the amplitude control output stage which is also shown in *Fig. 2.*

In order to assure an appropriate rise-time of the stimulating square-wave signal, a type PNP silicon transistor having a short switching time is applied in the output stage (BFX41, Fairchild). The switching transistor is driven by an emitter follower stage. The switching transistor will be driven into saturation by the input square wave, and between pulses the transistor will not be conducting, the voltage drop on the collector resistance being determined by the cut-off current I_{CBO}. This has a value of 0,1 to 0,2 nA for the type BFX41, leaving a voltage level of 1 to 2 microvolts. This will not cause any trouble even with delicate EEG electrode configurations.

The output pulse amplitude is adjusted by changing the supply voltage (KRACH, 1969). The supply voltage change is brought about by a high current transistor of the type OC 1016 which satisfies the low output impedance requirements. A constant output impedance is assured by this circuit, independently from the stimulating pulse amplitude.

The stimulating pulse is DC coupled to the object under test. Depending on the nature of the test, a positive or negative ungrounded stimulation, and also a positive or negative stimulation with respect to ground potential may be chosen. The limits of the output waveform parameters are shown in *Fig. 3.*

The square-wave generator is battery operated in order to eliminate interference signals in microelectrode and EEG applications (LEWIS, 1967). The frequency control, delay control and pulse width control stages are supplied by a 6 V battery having a capacity of 500 mA/h. The output stage utilizes a 27 V battery with a capacity of 500 mA/h. In the cases when low level interfering signals can be tolerated, the square wave generator can also supplied by a mains operated power supply.

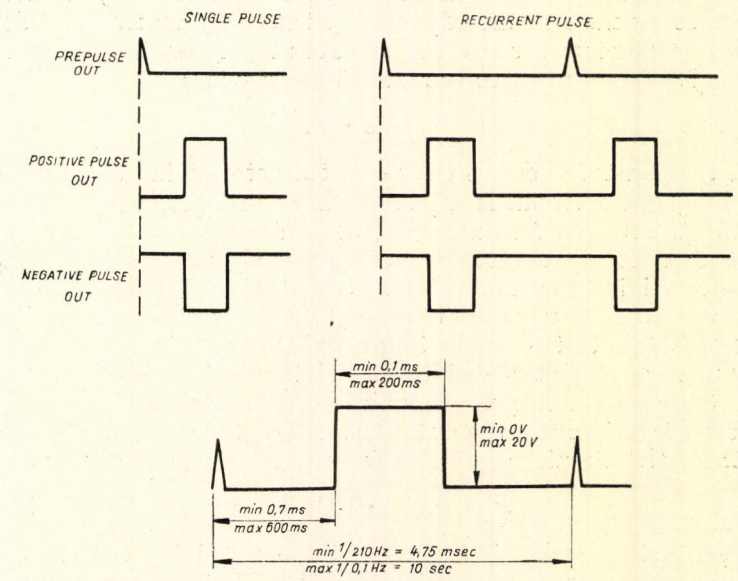

Fig. 3. Parameters of the stimulating signal

The more important technical data od the square wave generator are summarized in *Table I*.

TABLE I

Technical data of the square wave generator

Stimulating frequency	continuously adjustable in two ranges, 0.1 to 5 Hz and 5 to 210 Hz. Alternately, single pulses by push-button may be generated
Pulse width	continuously adjustable in two ranges, 0.1 to 5 msec and 3 to 200 msec
Pulse rise time	< 1 μsec
Pulse overshoot	1 mV at 20 volts pulse amplitude
Pulse amplitude	continuously adjustable in two ranges, 0 to 2 volts and 0 to 20 volts
Pulse polarity	positive or negative, ungrounded, or alternately, positive or negative with respect to ground
Output impedance	50 ohms
Delay of stimulating pulse with respect to pre-pulse	continuously adjustable in two ranges, 0.7 to 25 msec and 16 to 600 msec
Prepulse amplitude	5 volts
Prepulse polarity	positive with respect to ground
Prepulse rise time	100 μsec
Trigger required for external frequency control:	
amplitude	min. 2.5 volts
polarity	positive with respect to ground
rise time	100 μsec
Supply voltage	two batteries, 6 V 500 mA/h and 27 V 500 mA/h
Connector type	BNC (prepulse, ext. trigger and stimulator output)
Dimensions	$200 \times 192 \times 84$ mm

A photograph of the square wave generator as built in our laboratory is shown in *Fig. 4*. The four stages are independent subassemblies and are separately adjusted, complete with control potentiometers and scales. In this way, no circuit changes were required after the final assembly into the instrument

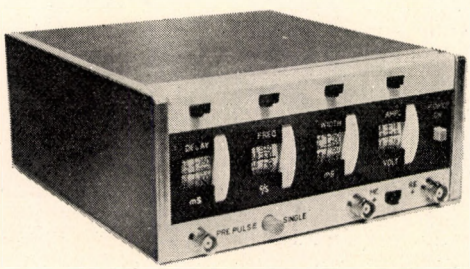

Fig. 4. Photograph of the square wave generator

cabinet, and the scale calibration procedure has been also simplified. Dimensions of the square wave generator as shown in Fig. 4 are 200 × 192 × 84 mm.

The square-wave generator has been successfully put to use in the following fields:

— stimulation threshold determination of biological objects,
— stimulation of neuron pathways by using bipolar electrodes,
— iontophoretic injection of defined substance quantities into nevre cells by micro-electrodes,
— investigation of cell membrane properties by the Voltage Clamp method.

Summary

A solid state stimulating device suitable for biological investigations is dealt with. Repetitive and single pulses are generated by the square-wave generator which also comprises a delay circuit.

The parameters of the stimulating signal are continuously adjustable in the following ranges: frequency, 0,1 to 210 Hz; delay, 0,7 to 600 msec; pulse width, 0,1 to 200 msec; amplitude, 0 to 20 volts. The output signal polarity may be selected, and the generator is capable of providing positive or negative bipolar signals ungrounded, and also positive or negative unipolar signals with respect to ground potential. Output impedance of the generator is constant, independently from the signal amplitude. The stimulator is battery operated in order to eliminate interference signals. A detailed circuit diagram and a *Table* of specifications data are given.

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TRANZISZTOROS NÉGYSZÖGGENERÁTOR BIOLÓGIAI VIZSGÁLATOKHOZ

Véró Mihály

Összefoglalás

A szerző biológiai vizsgálatokhoz készült félvezetős ingerlő készüléket ismertet. A négyszöggenerátor egyes és sorozat impulzusokat állít elő, és késleltető áramkört is tartalmaz.

A stimuláló jel frekvenciája 0,1 c/s-től 210 c/s-ig, késleltetése 0,7 ms-től 600 ms-ig, impulzusszélessége 0,1 ms-től 200 ms-ig és amplitúdója 0 V-tól 20 V-ig szabályozható folyamatosan. A kimenő jel polaritása átkapcsolható, így föld független pozitív vagy negatív bipoláris, illetve a földhöz képest pozitív vagy negatív unipoláris ingerjel előállítására alkalmas a készülék. A generátor kimenő impedanciája a jel amplitúdójától függetlenül állandó.

A négyszöggenerátor tápfeszültségét telepek szolgáltatják, ami a zavaró jelek szempontjából előnyös.

Az áramköri megoldásokat részletes kapcsolási rajz ismerteti és a generátor legfontosabb technikai adatai táblázatban vannak összefoglalva.