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A Simple Variable 'Square-Wave' Stimulator for Biological Work

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ABSTRACT. An instrument is described using two standard triode valves to produce impulses independently variable in intensity, duration, and frequency over the wide ranges called for in the excitation of nerve and muscle. The impulse wave-form is rectangular. Accurate and reliable operation has been maintained over a year's continuous routine use.

A number of precision stimulators recently described for biological work(1,2,3) suffer from the disadvantage that the duration in time of the shock cannot be independently varied with respect to the frequency of repetition. The excitation of living tissues depends on the intensity, duration, and frequency of the applied stimuli, and it is desirable to have a wide range of control over these three variables, both for animal experiments, and for nerve injury testing in man.

An elaborate instrument which fulfils these requirements has been described by Bauwens(4).

This article describes a simple instrument using readily obtainable standard components which has a very wide range of all three variables, and which has proved reliable over a period of a year's routine use in measuring strength-duration curves in human nerve and muscle. A quantitative stimulator is of the greatest value in examining cases of injury to these parts of the body. The wave-form of the stimulus is 'square', which has advantages in the differential excitation of certain tissues, and in respect of calibration and evaluation.

The basic circuit is the multivibrator, designed with small power valves in an asymmetric manner so that one valve provides the stimuli and the other the interval between stimuli, each being independently controlled by simple switching. The valves operate in one or other of two mutually exclusive conditions: one when the grid is highly negative and anode current cut off, and the other when the grid is at cathode potential, or slightly positive, and the anode current limited by the load-line and valve parameters. The valves draw current alternately, and the change-over is very rapid. These two points on the operating curves of the valves appear to be very constant throughout the life of the valve, as the original instrument has not altered in calibration by more than 2 per cent in its year of service.

No particular attention to components is necessary beyond the choice of first-grade condensers, and the circuit will operate with almost any valves or component values, provided the valve anode dissipation rating is not exceeded.

In order to obtain a low impedance source of stimuli, PX 4 valves are run at 70mA anode current, and provide a maximum voltage stimulus of over 100 V from a resistance of 1500 Ω; the resistance of the ordinary preparations to which electrodes are applied is such as to have a negligible effect on the calibration of the instrument.

The duration of the stimulus is given to a first approximation by the time constant of the grid condenser and resistance of V_1, and depends to a minor degree only upon other circuit values(5); the data given in Fig. 1 are approximately correct, but individual calibration is necessary with the aid of the oscillograph. Adjustment to a desired duration of stimulus is easily effected by supplementing or reducing the appropriate grid resistor. Similarly, the interval between stimuli depends primarily on the time constants of $C_{1-5} \times R_9$. The maximum value of C_1 must be kept as low as possible, as it has to recharge during the period of the stimulus through R_1 and the grid-cathode resistance of V_2; grid current flows during this period.

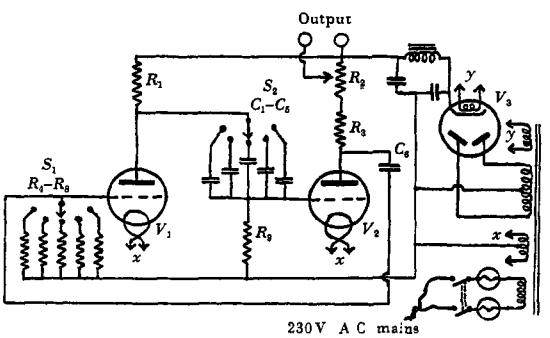

Fig. 1. Stimulator circuit

S_1, 5-way switch for control of stimulus duration:

R_4	1 MΩ,	1 W	Duration 100 m.sec.
R_5	100,000 Ω,	1 W	10
R_6	10,000 Ω,	1 W	1
R_7	1,000 Ω,	1 W	0·1
R_8	250 Ω,	1 W	0·025

S_2, 5-way switch for control of stimulus frequency:

C_1	0·1 mF, 750 V working	Frequency 1 per sec.
C_2	0·02	5
C_3	0·01	10
C_4	0·005	20
C_5	0·002	50

R_2, 1500 Ω, 15 W potentiometer for intensity control. Stimulus peak variable from 0 to 110 V:

R_1	3000 Ω, 20 W	C_6	0·1 mF, 750 V working
R_3	1500 Ω, 10 W	V_1, V_2	Osram PX4 valves
R_9	10 MΩ, ½ W		

Power supply 70mA at 400 V, smoothed.

This limitation necessitates a high value for R_9 if slow repetition rates are desired. If C_1 is too large, the shortest stimulus cannot be repeated at the slowest rate; this is of little consequence in animal experiment, but the ability to repeat stimuli at 1 sec. intervals is a great convenience in human nerve testing.

With the valves specified, the shortest stimulus which preserves the configuration of 'squareness' is of the order of 0·02 m.sec.; this might be reduced by better layout and the use of pentode power valves. The wave-form at various durations and frequencies is shown in Fig. 2, which also illustrates a convenient method of calibration of the intermediate duration

stimuli by arranging them to produce a radial deflexion on a circular time-base drawn by the 50 cyc./sec. mains.

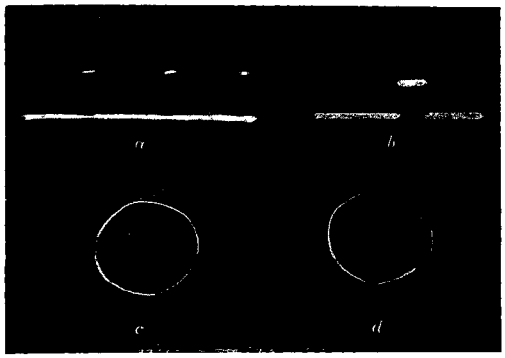

Fig. 2. Oscillograms of stimulator output. Recorded as potential wave-form across living load consisting of human arm with normal muscle-testing electrodes. (*a*) Stimuli of 1 m.sec. duration at 200 per sec. (*b*) Stimulus of 100 m sec. duration at 1 per sec. (*c*) Stimulus of 19·5 m.sec. calibrated as radial deflexion on 50 cyc./sec. time-base. (*d*) Stimulus of 2·8 m.sec. similarly demonstrated. Peak voltages: (*a*) 55 V; (*b*) 26 V; (*c*) and (*d*) 65 V.

Component values for the power pack are not given, as no unusual features appear; regulation is of no importance, as the valves draw similar anode currents and function alternately, resulting in a constant rectifier load; this is of practical interest in a high-output impulse generator. The stimulus characters are very little affected by minor fluctuations in power supply voltage.

No stimulus indicator has been specified, as this depends on the use to which the instrument may be put: both telephone earpiece and indicator neon bulb work satisfactorily at all except the shortest stimuli, and one of these or a time marker may be run off either of the valve anode loads provided sufficient series resistance is included not to shunt the anode resistors significantly. The expense and complication of a magic-eye cathode-ray valve has not been considered desirable.

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A Quenching Furnace Suitable for Small Specimens

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ABSTRACT. A furnace is described for the rapid quenching of small specimens, in lump or in powder form, from temperatures up to about 1000° C. The specimens are enclosed in small evacuated silica, pyrex, or soda-glass containers, according to the temperature quenched from, and these are mounted in holes bored in a steel block which is supported near the centre of the furnace. The arrangement is such that the temperature of the specimen during the annealing treatment, as recorded by a thermocouple, does not change before the specimen enters the quenching medium which is usually iced water. The quenching operation is completed in about 2 sec., and the temperature of the block enveloping the specimens does not alter appreciably during the operation.

The furnace which will be described in this note was designed especially for use with small specimens in lump or in powder form. With the procedure adopted very rapid quenching can be effected.

A sectional diagram of the furnace is shown in Fig. 1. The outer casing is not shown; it can be seen in the two photographs of the furnace in Fig. 2 and its outer dimensions are 11 in. × 11 in. × 21·5 in. The furnace consists of a silica tube *T*, 24 in. long, 2 in. internal bore, and 0·25 in. wall thickness, on which is wound Brightray wire, in turns 0·1 in. apart over a length of about 16 in., symmetrically about the centre of the tube. Both ends of the furnace tube protrude about an inch beyond the Uralite ends of the outer casing which is filled with magnesium oxide to provide thermal insulation. The ends of the furnace winding come to two terminals fixed to the top Uralite cover, the furnace being mounted in a vertical position on a tall stand, made of angle iron, which raises the bottom of the furnace casing about 30 in. above floor level.

A closely fitting Uralite cap is held by a spring against the bottom end of the silica tube and can be readily removed and displaced sideways by means of the handle *A* (Fig. 2). The Uralite cover over the top end of the tube carries the mechanism in which the specimens are mounted and by means of which they can be made to fall into the quenching medium. This part of the furnace can be seen in Fig. 2; in Fig. 2(*a*) the cover is seen in position and in Fig. 2 (*b*) it has been lifted above the furnace and slightly rotated from its position directly above the tube of the furnace in order that the parts attached to it may be seen more clearly.

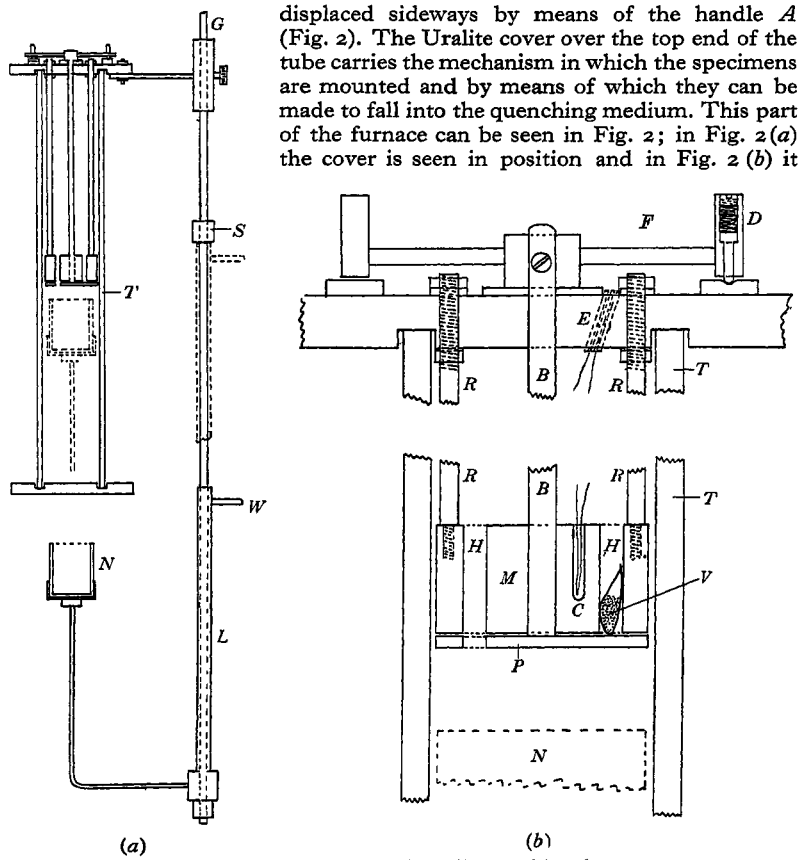

Fig. 1. Sectional diagram of small quenching furnace