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VARIABLE FREQUENCY STIMULATOR

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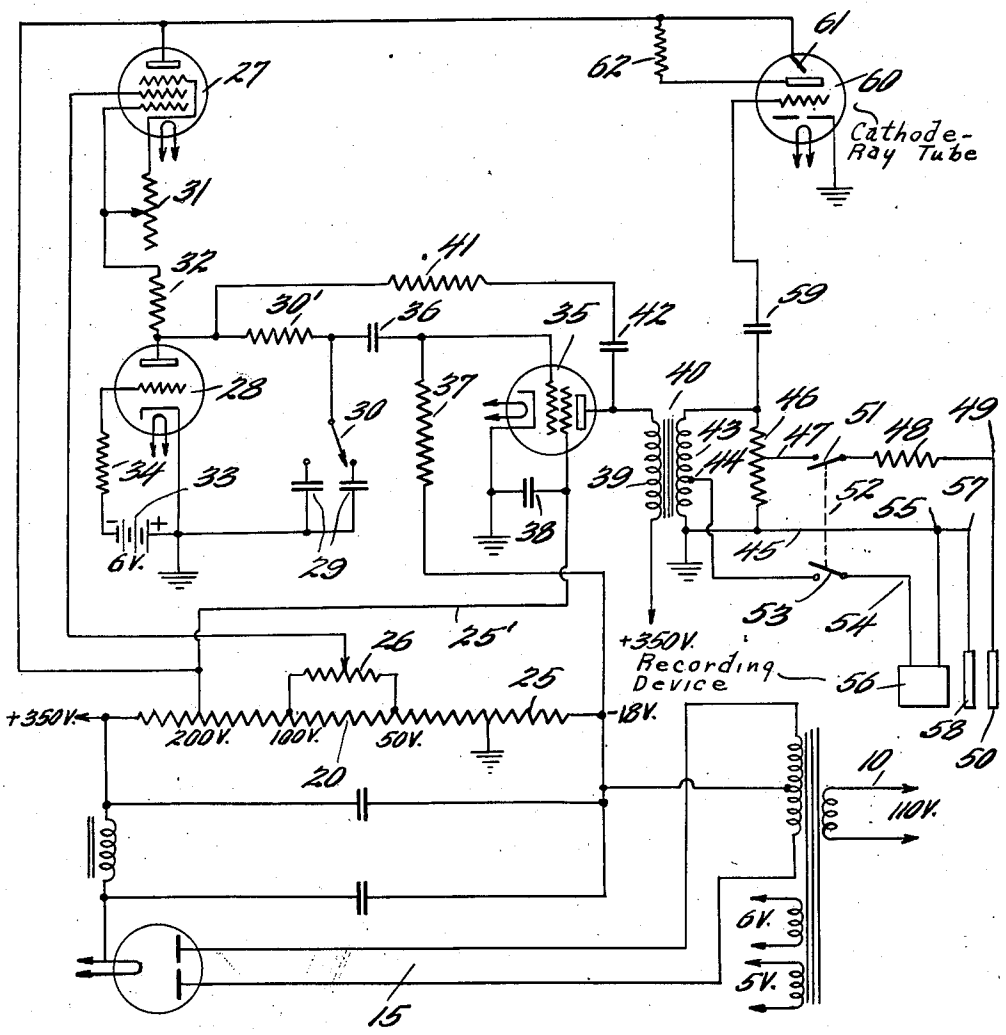

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VARIABLE FREQUENCY STIMULATOR

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5 Claims. (Cl. 128—422)

This invention relates to a variable frequency stimulator.

The principal object of the invention is to provide a device for automatically and rhythmically stimulating biological nerve, muscle or nerve-muscle preparations. It may also be used to stimulate the nerves and muscles of humans; for example, in the treatment of diseases or disorders. It is particularly well adapted for use as a stimulator both for research and for routine student use in physiological and pharmacological laboratories and in other branches of biological activity and study.

A further object of the invention is to provide a device which automatically supplies variable frequencies of stimulation ranging from approximately 1 stimulus every 6 seconds to an upper limit of about 10,000 stimuli per second. A corollary of this feature is the fact that the time interval between any two successive stimuli at a given frequency within the operating range is absolutely constant.

A still further object is to provide not only variable frequencies of stimulation, but also to provide independent and variable control of the intensity of the stimuli through all values between the limits of zero and maximum.

Another important object of the invention is the provision of means connected in the circuit for operating a synchronous recording device which may be made to indicate both visibly and audibly, as well as to record, the exact moment of application of and the exact frequency of the stimuli.

A further object of the invention is the provision of means for interrupting the stimulating electrode and recording circuits while maintaining operation of the visual indicating device in order that adjustments of frequency and intensity of the stimuli may be made prior to their application, if desired.

A still further feature is the fact that the intensity of the stimulating current does not vary with change of frequency of the stimulus but, when desired, can be varied, as mentioned above, by adjusting the intensity control.

Another feature of the invention resides in the production of an ideal type of stimulation which consists of a succession of pure unidirectional and instantaneous currents, there being no current flow in the intervals.

Still other objects and advantages of the device will become apparent in considering the following specification and drawing, in which the single figure is a schematic circuit diagram of one, and the preferred, embodiment of the invention.

Current is supplied to the circuit either directly from a direct current source or, if an alternating current source such as at **10** is used, the same is converted, through a conventional rectifier filter system **15**, to direct current.

The rectified and filtered current is fed to a 20,200 ohm voltage divider **20** which is connected across the output of the rectifier-filter system and the desired voltages are tapped off. The voltage divider is grounded 200 ohms from the negative end to provide a C bias **25** for the beam tetrode hereinafter explained.

Shunted across approximately a 50 and a 100 volt tap on the voltage divider is a 10,000 ohm potentiometer **26**, the purpose of which is to control the screen potential of a variable mu current limiting pentode tube **27**, a function of which is to act as a constant current resistor connected in the plate circuit of a hot cathode grid glow tube **28**. The resistance of this current limiting tube **27** in conjunction with one of two fixed condensers **29** having respective capacities of 0.5 and 0.01 microfarad, either one of which can be selected by a switch **30**, is shunted across the grid glow tube **28** in series with a 500 ohm resistor **30'** from the anode to the cathode to cause this tube to function as a relaxation oscillator, the frequency of which is controlled within the limits of the selected condenser by varying either the screen potential or the control grid bias of the current limiting pentode **27** by potentiometer **26** or variable resistor **31**, or both.

The control grid bias of the current limiting pentode **27** is controlled by a 3 megohm variable resistor **31** connected in series with the cathode of the current limiting tube **27**, the movable contact arm of which connects on the one hand to the control grid of the current limiting pentode **27** and on the other hand through a 50,000 ohm fixed resistor **32** to the anode of the hot cathode grid glow tube **28**.

The grid of the grid glow tube is maintained at a constant negative potential of 6 volts by a C battery **33** acting through a 75,000 ohm resistor **34**. By this means thus far described, complete and uniform variation of frequency is obtainable, ranging from one impulse every six seconds to in the vicinity of 5,000 impulses per second.

The source of voltage is applied to the anode or plate of the grid glow tube through the current limiting pentode **27** which acts as a constant current resistor to charge the selected condenser **29** which is connected between the cath-

ode and anode of the grid glow tube. When the potential applied to the anode reaches the striking or ionization potential, the tube conducts and the condenser is discharged. At all voltages below the striking potential the tube fails to conduct and this allows the potential to build up in the condenser until the striking voltage is reached, the value of which is determined by the negative potential applied to the grid. The discharge of the condenser lowers the anode potential of the grid glow tube below the extinction voltage. This allows the grid to regain control and stops the conduction through the tube. A new charge must be built up in the condenser before another discharge can occur. The rate at which the charge in the condenser is built up is determined by the capacity of the condenser and by the resistance of the current limiting pentode, which is controlled by the positive potential of the screen grid and the negative potential of the control grid. The function of the 500 ohm resistor **30'** is to prevent excessive peak current from flowing through the grid glow tube.

The provision of two frequency controls **26** and **31**, rather than one, affords greater latitude in the range of the frequencies developed, due to the fact that the current flowing through a pentode tube is a function both of the screen voltage and of the control grid voltage. In effect the screen voltage control **26** serves as a vernier adjustment for the resistance of the variable mu pentode tube **27**.

The impulses originating in the oscillator circuit just described are applied to the control grid of a beam power tetrode **35** through a one microfarad coupling condenser **36**, the grid of which tetrode tube receives a negative bias of approximately minus 10 to minus 20 volts through a one megohm grid leak resistor **37** which is connected to the negative tap of the voltage divider **20**.

The screen of the beam tube is maintained at a positive voltage of approximately 200 volts by conductor **25'** connected to a suitable tap on the voltage divider. A one microfarad by-pass condenser **38** is connected between the screen and the cathode which is grounded.

Connected in series between the anode of the beam tube **35** and the high potential end of the voltage divider is the primary coil **39** of a 2700 ohm output transformer **40**.

Between the anode of the beam tetrode **35** and the anode of the grid glow tube **28** is connected a one megohm resistor **41** in series with a 0.015 fixed condenser **42**, which furnishes inverse or negative feed back and stabilizes the circuit.

Every time the grid glow tube **28** conducts, the grid of the grid glow amplifier tube is excited through the one microfarad coupling condenser **36**. This causes the plate current to vary accordingly and results in an induced current in the secondary coil **43** of the transformer, which in turn furnishes the stimulating current and the current which operates a recording device and an indicator tube, to be subsequently described, all of which operations are synchronous.

The secondary of the output transformer has a total impedance of 500 ohms and is tapped as at **44** at an impedance of 2 ohms, there being a common negative lead **45** which is grounded.

The wave form of the output of the secondary coil of the transformer, as tested by an oscilloscope, is a series of almost perfectly straight parallel vertical lines of equal amplitude and of perfectly regular and even spacing. Of course, the usual reference line connects the vertical lines at the bottom.

The peak voltage is constant and substantially independent of frequency.

Connected across the 500 ohm terminal and the negative terminal of the secondary coil of the transformer is a 5,000 ohm potentiometer **46** having a movable arm **47**, which arm is connected through one pole **51** of a double pole single throw switch **52** to one end of a 1000 ohm resistor **48**. The other end of the resistor **48** is connected to a binding post **49** which furnishes current for a stimulating electrode **50**. The two ohm tap **44** of the secondary coil **43** of the output transformer is adapted to be connected through the second pole **53** of switch **52** to binding post **54**, which in conjunction with a second binding post **55** connected to the common negative **45** of the secondary of the output transformer, supplies the operating current for the recording device **56**, one form of which may be what is known as a signal magnet. However, any recording device having a two ohm impedance, such as a loud speaker, is within the purview of this invention. The common negative in conjunction with another binding post **57** is connected to the second electrode **58** which, in conjunction with electrode **50**, forms a pair of stimulating electrodes.

Connected to the high potential end of the secondary coil **43** is one plate of a condenser **59** of approximately .000001 microfarad, the other plate of which is connected to the grid of a cathode ray tuning indicator tube **60**. The target **61** of the tuning indicator is connected to a 200 volt source, preferably on the voltage divider **20**. A one megohm resistor **62** is connected between the target and the ray control electrode. The cathode is grounded.

It will thus be seen that by providing a double pole single throw switch **52** in the circuit between the transformer secondary and the two sets of electrodes, the circuits to the electrodes may be opened while the proper or desired frequency is being selected in the oscillating circuit through the several adjustments provided. After the electrodes have been applied to the object being stimulated, the switch **52** may be closed and the impulses will forthwith be directly imparted to the object through the electrodes, and a synchronous current will simultaneously operate the recording device **56**. The intensity of the impulses may be readily adjusted by the variable resistance **46** shunted across the high potential winding of the secondary coil of the transformer and the negative lead **45**.

Particularly in instances where the device is being used for laboratory experiment or classroom demonstration, the stimulating electrodes are suitably connected to the tissue or object being investigated, such as a muscle, and the signal magnet of the recording device is connected to a conventional stylus which in turn is set up to mark on any suitable device such as a smoked cylinder, whereby, when the single throw double pole switch **52** is closed, stimuli will be applied to the tissue or object and the signal magnet of the recording device will be caused to function and will impart markings to the smoked cylinder, thereby indicating the exact instant of application of each stimulus and the interval between successive stimuli. In this connection there will also be a stylus connected to the moving end of the muscle being stimulated, whereby a wave denoting both the frequency and ampli-

tude of the contractions developed in the muscle as a result of receiving the impulses from the stimulating electrodes are also recorded on the smoked cylinder and may be referred to the marks on the cylinder made by the signal magnet.

The foregoing is a description of our invention and the manner in which it functions. This description, however, is only to be considered as illustrative and not restrictive in any sense, since it is recognized that the invention has wider applications than those referred to in the foregoing and it is intended that this invention shall encompass all equivalent elements and circuits which will perform similar results coming within the spirit of this invention.

Having thus described our invention, what we claim is:

1. A variable frequency stimulator comprising a source of direct current, a variable oscillator circuit comprising a current limiting tube connected between said current source and a relaxation oscillator tube, an electron amplifying tube, an output transformer, said amplifying tube being coupled to the output of said oscillator tube, the primary coil of said transformer being connected in series between the anode of said amplifier tube and said voltage source, a resistor and condenser connected in series with each other and in series between the anodes of the amplifier and oscillator tubes to act as a negative feed back in the circuit to stabilize the same, and a pair of applicator electrodes connected to the secondary coil of said transformer.

2. A variable frequency stimulator comprising a source of direct current voltage, a variable oscillator circuit comprising a current limiting tube connected between said current source and a relaxation oscillator tube, an electron amplifying tube having a grid, an output transformer, said amplifying tube grid being coupled to the output of said oscillator tube, the primary coil of said transformer being connected in series between the anode of said amplifier tube and said voltage source, a resistor and condenser connected in series with each other and in series between the anodes of the amplifier and oscillator tubes to act as a negative feed back in the circuit to stabilize the same, and a pair of applicator electrodes connected to the secondary coil of said transformer, and a cathode ray indicator connected to the high potential end of said secondary coil to indicate the frequency of the current discharge through the applicator electrodes.

3. A variable frequency stimulator comprising a source of direct circuit voltage, a variable oscillator circuit comprising a current limiting tube connected between said current source and a relaxation oscillator tube, an electron amplifying tube having a grid, an output transformer, said amplifying tube grid being coupled to the output of said oscillator tube, the primary coil of said transformer being connected in series between the anode of said amplifier tube and said voltage source, a resistor and condenser connected in series with each other and in series between the anodes of the amplifier and oscillator tubes to act as a negative feed back in the circuit to stabilize the same, and a pair of applicator electrodes connected to the secondary coil of said transformer, a cathode ray indicator connected to the high potential end of said secondary coil to indicate the frequency of the current discharge through the applicator electrodes and a switch connected in the circuit of the positive electrode whereby the switch may be opened to permit adjustment of the frequency of the impulses, as indicated by said cathode ray indicator following which the switch may be closed, and impulses are then discharged from said electrode.

4. A variable frequency stimulator comprising a voltage source, a variable oscillator circuit connected thereto, an amplifier tube having a grid, which is coupled to the output end of said oscillator circuit, an output transformer having its primary coil connected in series with the anode of said amplifier tube and said voltage source, a pair of applicator electrodes connected to the secondary coil of said transformer, a cathode ray indicator tube connected to the high potential end of said secondary coil to indicate the frequency of the current discharge through the applicator electrode, a lead tapped off said secondary of the transformer near the negative end, said lead being operatively connected to a magnet of an indicating device, said applicator electrodes being respectively positive and negative, the lead to said negative electrode also being connected to said magnet and a single pole double throw switch connected in the circuit of the leads to the positive applicator electrode and the magnet whereby the switch may be opened to permit the adjustment of the frequency of the impulses as indicated by said cathode ray indicator following which the switch may be closed to permit the impulses to be discharged through the applicator electrodes and also actuate said magnet of the indicating device.

5. A variable frequency stimulator comprising a voltage source, a variable oscillator circuit connected thereto, an amplifier tube having a grid, which is coupled to the output end of said oscillator circuit, an output transformer having its primary coil connected in series with the anode of said amplifier tube and said voltage source, a pair of applicator electrodes connected to the secondary coil of said transformer, a cathode ray indicator tube connected to the high potential end of said secondary coil to indicate the frequency of the current discharge through the applicator electrodes, a lead tapped off said secondary of the transformer near the low potential end to provide an impedance match with that of an indicating device, said lead being operatively connected to a magnet operating said indicating device, said applicator electrodes being respectively positive and negative, the lead to said negative electrode also being connected to said magnet, a single pole double throw switch connected in the circuit of the leads to the positive applicator electrode and the magnet whereby the switch may be opened to permit the adjustment of the frequency of the impulses following which the switch may be closed to permit the impulses to be discharged through the applicator electrodes and also actuate said magnet of the indicating device and a variable potentiometer having a movable arm connected across the ends of the secondary winding of the transformer, said movable arm being connected to one stimulating electrode, the other electrode being connected to the low potential tap of said secondary coil, whereby the intensity of the stimulating impulses may be readily varied.

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