April 15, 1947. O. D. ENGSTROM 2,418,825

RELAXATION OSCILLATOR

Filed Jan. 8, 1943 2 Sheets-Sheet 1

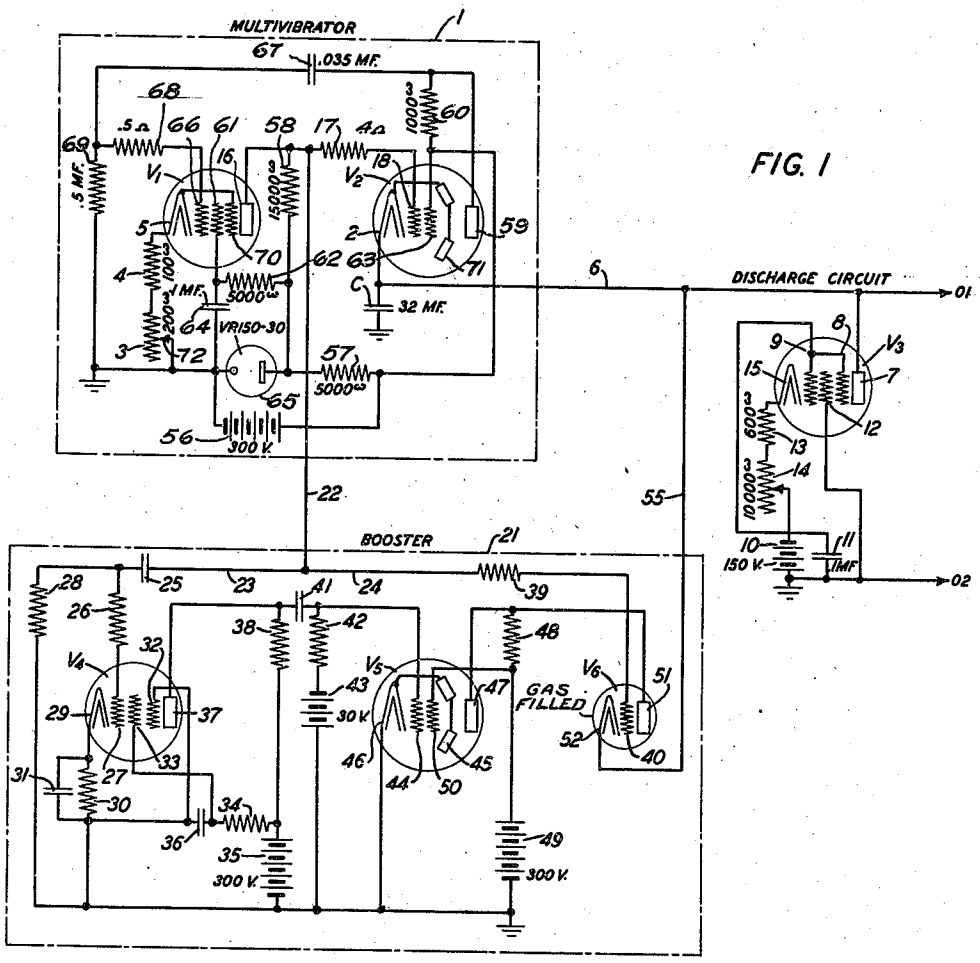


FIG. 1

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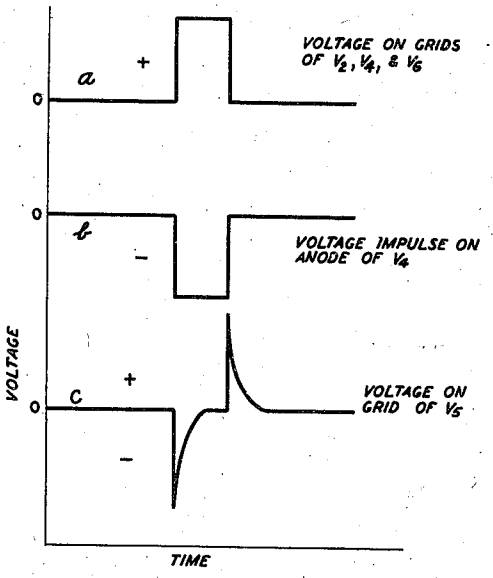
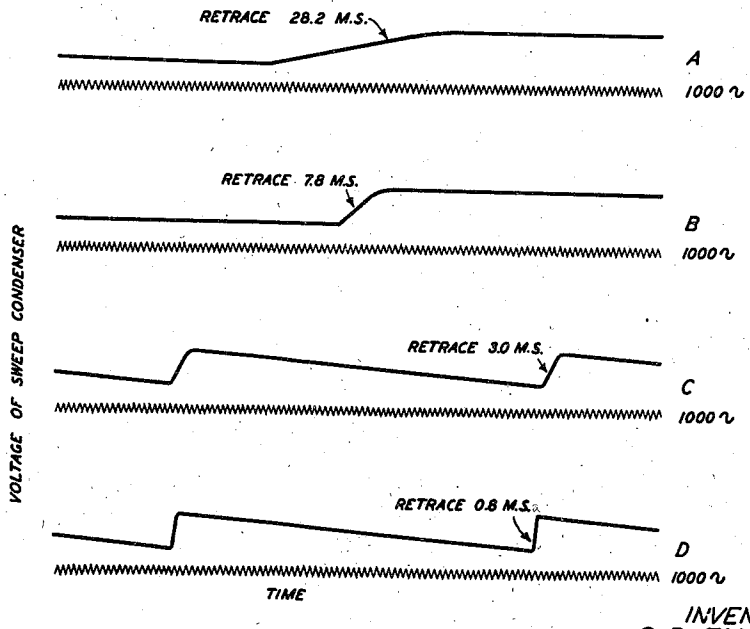


FIG. 2

FIG. 3



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RELAXATION OSCILLATOR

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5 Claims. (Cl. 250—36)

1

This invention relates to an improvement in relaxation oscillators of the type known as asymmetrical multivibrators.

Numerous circuits are known to the prior art. They serve as generators of saw-tooth voltage oscillations varying in frequency from several megacycles to a few hundredths of a cycle per second and the oscillating voltages so generated are used to control various phenomena, for example, the deflection of an electron beam in the cathode ray oscilloscope. The voltage wave form of an asymmetrical multivibrator as recorded on the oscillograph exhibits for each oscillation a relatively slow change in one direction between two extremes of voltage followed by a rapid change in the opposite direction between the same extremes. In United States Patent 1,934,322, granted November 7, 1933, to W. O. Osbon, there is disclosed a multivibrator circuit of which the asymmetry serves to confine the rapid change of voltage to a small fraction of the oscillation period. Osbon also discloses thermionic means to insure linearity with time of the relatively slow voltage change.

The interval of rapid voltage change, conveniently called the "retrace interval," is made by such circuits as that of Osbon adequately short in the case of higher frequency oscillations, but more is needed when extremely low oscillation frequencies are used. The problem solved in the present invention is to shorten this retrace interval to a substantially negligible time, even for a cycle ten seconds long. The solution is found in the use of a booster circuit to accelerate the charge of the sweep condenser of which the periodic voltage variation constitutes the saw-tooth wave, while leaving the condenser's rate of discharge to be regulated by the conductances of a thermionic discharge device.

It is therefore an object of the invention to provide an improved apparatus for the generation of saw-tooth voltage waves.

Another object of the invention is to provide a multivibrator circuit capable of generating saw-tooth voltage waves having one side of the wave relatively steeper than is possible with circuits previously known while sacrificing no advantage afforded by the disclosures of the prior art.

Another object of the invention is to provide a booster circuit cooperative with and controlled by a known form of multivibrator circuit to enable the latter to generate saw-tooth voltage waves in which the retrace interval is reduced to a substantially negligible fraction of the voltage cycle.

2

These objects are attained in a manner which will be clear from the following description of the invention read with reference to the accompanying drawings in which:

Fig. 1 is the complete circuit of the apparatus of the invention omitting unessential details;

Fig. 2 symbolically represents voltage pulses determinative of the operation of the booster circuit of Fig. 1; and

Fig. 3 exhibits oscillographic comparisons of the retrace intervals of the conventional multivibrator circuit and of the circuit of the invention.

In Fig. 1 numeral 1 indicates within the dash-dot line a multivibrator circuit the design of which is substantially conventional. Battery 56, the negative terminal of which is grounded supplies voltage to anode 16 of tube V1 through resistors 57 and 58 in series, and to anode 59 of tube V2 through resistor 60. From battery 56 voltage is also supplied to screen grid 61 of tube V1 through resistors 57 and 62 and directly to screen grid 63, tube V2. Condenser 64 is connected between ground and the junction of resistor 62 with grid 61. The voltage supplied through resistor 68 to anode 16 is maintained constant by voltage regulator tube 65, a VR150–30 as indicated in the figure. Anode 59 of tube V2 is joined to control grid 66 of tube V1 through condenser 67 in series with resistor 68, the junction of the two last named elements being grounded through resistor 69. In tube V1, cathode 5 and suppressor grid 70 are directly joined as are cathode 2 and deflector plates 71 in tube V2. Cathode 5 of tube V1 is grounded through fixed resistor 4 in series with the portion of potentiometer 3 selected by adjustment of tap 72. Included between ground and cathode 2 of tube V2 is condenser C of capacity approximately 32 microfarads as shown. Anode 16 of tube V1 and control grid 18 of tube V2 are connected through resistor 17. Conductor 22 leads from the junction of anode 16 with resistor 17 to the booster circuit later described, while conductor 6 leads from the junction of cathode 2 with condenser C to anode 7 of tube V3 of a discharge circuit later described in detail and to cathode 52 of gas-filled tube V6 forming a part of the booster circuit. Vacuum tubes V1 and V2 are amplifier and trigger tubes, a 6AC7 and a 6L6G, respectively, and they are alternately conducting as is usual in such circuits. Interaction of these tubes generates in a well-known way the periodic voltage of saw-tooth wave form across the terminals of condenser C connected between ground and cathode 2 of tube V2. The operation of amplifier tube V1 is sta-

bilized by cathode feedback derived from variable potentiometer 3 and fixed resistor 4 in series between ground and cathode 5 of tube V1. Numerical examples of the constituent elements are given in the appropriate places in the diagram of Fig. 1 whereby the circuit may be constructed. Details of cathode heater circuits are in every case omitted.

In the operation of the circuit of Fig. 1 tubes V1 and V2 are alternately conducting but for unequal time intervals. Trigger tube V2 conducts only during the interval of charge of condenser C and only during this interval does space current flow in tube V2. Tube V1 is conducting during the discharge of condenser C through the circuit of tube V3 later to be described. The retrace interval of the circuit which it is the object of the invention to shorten is the interval of charging condenser C. This condenser begins to discharge at the moment V2 ceases to be conductive and the discharge takes place through a constant current tube V3, preferably a pentode such as the 6AC7. The junction of one terminal of condenser C and cathode 2 is connected by conductor 6 to anode 7 of tube V3; the other terminal of condenser C is grounded. Conductor 6 is continued as shown to constitute output terminal 01 of the circuit. Suppressor grid 8 and control grid 9 of V3 are together connected to the negative terminal of 150 volt battery 10, the positive terminal of which is grouned. Battery 10 is shunted by by-pass condenser 11. Screen grid 12 of tube V3 is connected to ground and to the positive terminal of battery 10 and this connection is continued to become the other output terminal 02. In series between ground and cathode 15 of tube V3 are connected fixed resistor 13 and variable potentiometer 14. Discharge tube V3 with its associated elements forms actually a part of the multivibrator circuit. Solely for convenience in description, tube V3 and its accessories are shown in Fig. 1 outside the dot-dash line 1.

Under the circumstances indicated in the figure, tube V3 is continuously conducting. During the conducting interval for tube V2 condenser C varies in potential from 75 to 150 volts, approximately, at a rate determined by the constants of multivibrator 1 and this voltage rise is available across terminals 01, 02. When tube V2 ceases to conduct, condenser C discharges through the anode-cathode path of tube V3 at a slower rate determined by the setting of the potentiometer 14. This decreasing voltage in condenser C may likewise be impressed on a subsequent circuit connected to the output terminals.

If such a sequence of voltage variations is used, for example, to control the electron beam of the cathode ray oscilloscope the relatively slowly decreasing voltage in condenser C will furnish the sweep and the rapid recharge of that condenser the retrace. The frequency of the saw-tooth oscillation of the voltage of condenser C is determined by the setting of potentiometer 14 which fixes the interval of discharge together with the constants of multivibrator 1 which fixes the interval of recharge. For example, with 32 microfarads as the capacity of condenser C and suitable adjustment of potentiometer 14 the oscillations in voltage will have a frequency of .15 cycle per second. The voltage across terminals 01, 02 will require about 28 milliseconds to rise from 75 to 150 volts, declining to 75 volts in the ensuing 6.64 seconds. Changing the value of condenser C to 3.2 microfarads without change in

conductance of V3 will change the oscillation frequency to about 1.5 cycles per second with a retrace interval of some 3 milliseconds. These conditions of the conventional operation are shown in Fig. 3 where A and C are oscillographic records of retrace for the oscillations of frequencies .15 and 18 cycles per second, respectively. A thousand cycle timing wave is shown with each oscillogram. In the case of C, potentiometer 14 has been reset. In each case, the charge interval is fixed by the capacity of condenser C.

To reduce this charge interval in the ratio of three or four to one with the same oscillation frequency requires the addition of the booster circuit enclosed within the dash-dot line 21 of Fig. 1. Anode 16 of tube V1 is joined through .4 megohm resistor 17 to control grid 18 of tube V2. In the operation of multivibrator 1, at the moment tube V2 becomes conducting a positive voltage pulse approximately square-topped appears on grid 18 and on anode 16. The duration of this pulse is the charging interval of condenser C and the pulse ceases when C is charged to 150 volts.

This positive voltage pulse, represented by *a* in Fig. 2, is transferred by conductor 22 to the booster circuit 21 of Fig 1. Conductor 22 branches to control by way of conductors 23 and 24 tubes V4 and V6, respectively. Tube V4 may suitably be a 6AC7, V6 a gas triode such as the 884. Conductor 23 transmits positive pulse *a* of Fig. 2 through condenser 25 and resistor 26 to control grid 27 of tube V4. Resistor 28 joins to ground the junction of condenser 25 and resistor 26. Tube V4 is thus an amplifier resistance-capacity coupled to tube V1. In V4, cathode 29 is grounded through .1 megohm biasing resistor 30 by-passed by condenser 31; suppressor grid 32 is grounded; screen grid 33 is connected through resistor 34 to the positive terminal of 300 volt battery 35 of which the negative terminal is grounded. Grid 32 is directly grounded and capacitively coupled to grid 33 by condenser 36 and anode 37 is supplied through resistor 38 from battery 35. The circuit constants of booster 21 are later tabulated. Under these conditions, tube V4 is conducting and the positive pulse of anode 16 at V1 transferred to grid 27 of V4 is reversed with approximately unit gain in V4 to appear as a negative pulse at anode 37. This reversed pulse is shown at *b* in Fig 2. In this figure voltage and time scales are arbitrary and the diagrams are illustrative only.

At the same time that pulse *a* appears at grid 27 it also is transferred through resistor 39 to control grid 40 of tube V6. Reverse pulse *b* on anode 37 is differentiated by the circuit comprising condenser 41, resistance 42 and 30 volt battery 43 of which the positive terminal is grounded as shown in the figure. To the junction of condenser 41 and resistor 42 is connected control grid 44 of tube V5, suitably a 6L6G like tube V2. Deflector plates 45 and cathode 46 of V5 are together grounded while anode 47 is supplied through resistor 48 from 300 volt battery 49, which directly supplies screen grid 50. Battery 49 likewise supplies anode 51 of V6 in parallel with anode 47 of V5. Cathode 52 of V6 is connected through conductor 55 with conductor 6 leading to anode 7 of discharge tube V3 and output terminal 01.

The operation of the circuit above described is as follows:

Positive voltage pulse *a* of Fig. 2 appear on anode 16 of V1 and control grid 18 of V2 and is at once effective on control grid 27 of V4 and grid 40 of V6. The latter tube, V6, at once breaks down allowing the potential of 300 volt battery 49

to flow through resistor 48 to charge sweep condenser C. Condenser C already charged to 75 volts at once charges rapidly to a potential of 150 volts, at which potential tube V2 ceases to be conductive on the cessation of voltage pulse *a*. Under these circumstances the rise in potential of condenser C from 75 to 150 volts takes place with great rapidity.

It is of course requisite to annul the conductivity of V6 when condenser C has acquired the desired potential corresponding to cut-off of tube V2. This office is performed by the differentiating circuit of condenser 41 in series with resistor 42 and 30 volt biasing battery 43. The voltage and poling of battery 43 is such as to maintain tube V5 initially blocked.

Positive pulse *a*, reversed in V4 to appear as negative pulse *b* on anode 37, is differentiated by the circuit 41, 42 and appears on control grid 44 of V5 as a pulse represented by *c* in Fig. 2. Corresponding to the leading side of pulse *b* pulse *c* has a steep and nearly instantaneous negative peak. This peak drives V5 still further past cut-off but is elsewhere not felt, V5 being already blocked. At the moment the potential of condenser C has reached 150 volts and tube V2 blocks, the cessation of pulse *b* is represented in *c* by a steep positive peak. This nearly instantaneous positive peak more than overcomes the negative bias furnished by battery 43 and renders V5 suddenly conductive. The abrupt onset of conductance of V5 is accompanied by an equally abrupt drop in potential of anode 47 and of anode 51. By proper choice of circuit constants this drop of potential in anode 51 is made sufficient to extinguish tube V6. Condenser C is now charged to 150 volts, tube V2 is blocked and tube V1 begins to conduct as condenser C discharges to 75 volts through the discharge tube V3 at a rate determined by the setting of potentiometer 14.

Except for booster circuit 21 charging of condenser C would have been accomplished by the space current flowing in tube V2. When condenser C is of capacity 32 microfarads, this charging by the multivibrator circuit alone requires 28 milliseconds as shown in A of Fig. 3. Supercharging by the aid of booster circuit 21 reduces the required interval to 8 milliseconds as shown in B, Fig. 3. Fig. 3 shows also at C the 3 millisecond retrace time of multivibrator circuit 1 when condenser C has the capacity 3.2 microfarads. For this condition supercharging by circuit 21 reduced the retrace time to .8 millisecond as shown by D of Fig. 3.

Appropriate values of the multivibrator are indicated in Fig. 1 and are not identified by reference numerals further than necessary to an understanding of the cooperation of the multivibrator circuit and the booster circuit. For the latter suitable values of capacity and resistance are as follows:

Condensers:		Microfarads
25		0.25
31		40.
36		30.
41		0.002
Resistors:		
26	megohms	5
28	ohms	50,000
30	do	100,000
34	do	100,000
38	do	5,000
39	do	100,000
42	do	50,000
48	do	750

The values tabulated above are appropriate in the particular booster circuit 21 shown in Fig. 1 in which tubes V4, V5 and V6 are respectively a 6AC7, a 6L6G and an 884. If it is desired to use other tubes than those mentioned for V4 and V5 the corresponding circuit constants may be revised, it being only necessary to insure that the positive voltage pulse derived from anode 16 shall after reversal in V4 and differentiation by the circuit 41, 42 result in a negative pulse on anodes 47 and 51 sufficient to annul the conductance of V6. The temporary conductivity of tube V6, conferred by a first positive impulse directly received from anode 16 and annulled by a second biasing impulse indirectly occasioned by the first impulse, permits accelerated charge of sweep condenser C in the multivibrator circuit thereby accomplishing the object of the invention.

What is claimed is:

1. In a relaxation oscillator including a condenser, means including thermionic devices for alternately charging and discharging said condenser coupled with additional means including thermionic devices controlled by said first-mentioned means for accelerating the charging of said condenser.

2. In combination, means for the generation of electrical oscillations including a multivibrator circuit comprising a condenser, a discharge circuit for said condenser and a pair of thermionic vacuum tubes cooperating to generate a recurrent saw-tooth voltage across said condenser by the alternate charging and discharging thereof, and means including thermionic devices controlled by and cooperative with said multivibrator circuit to accelerate the charging of said condenser during each recurrence of said voltage.

3. In a relaxation oscillator, in combination, a multivibrator circuit comprising a condenser, a first and a second thermionic tube, a discharge circuit including a third thermionic tube in shunt with said condenser, each of said tubes having at least a cathode, a control grid and an anode, power supply for said tubes, coupling including resistance and capacity in series between the control grid of said first tube and the anode of said second tube and conductive coupling between the anode of said first tube and the control grid of said second tube, whereby said condenser is alternately charged and discharged between desired extremes of voltage, and an auxiliary circuit for accelerating the charging of said condenser comprising a fourth, a fifth and a sixth auxiliary thermionic tube, each of said auxiliary tubes having at least a cathode, a control grid and an anode, power supply for said auxiliary tubes, coupling including capacity and resistance in series between the anode of said first tube and the control grid of said fourth tube, conductive coupling between the anode of said first tube and the control grid of said sixth tube, a differentiating circuit coupling the anode of said fourth tube and the control grid of said fifth tube, conductive coupling between the anode of said fifth tube and the anode of said sixth tube, and conductive coupling between the cathode of said sixth tube and the cathode of said second tube.

4. For a multivibrator including a pair of thermionic tubes having each at least a cathode, a control grid and an anode cooperating to generate a recurrent voltage across a condenser in the cathode circuit of one of said tubes by the alternate charging and discharging of said condenser, an auxiliary circuit for accelerating the charging

of said condenser comprising a first, a second and a third auxiliary thermionic tube, each of said auxiliary tubes having at least a cathode, a control grid and an anode, conductive coupling between the control grid of said one tube in said multivibrator and the control grid of said third auxiliary tube, coupling including capacitance between the control grid of said one tube and the control grid of said first auxiliary tube, a differentiating circuit coupling the anode of said first auxiliary tube and the control grid of said second auxiliary tube, conductive coupling between the anode of said second auxiliary tube and the anode of said third auxiliary tube and conductive coupling between the cathode of said third auxiliary tube and the cathode of said one tube.

5. In combination, a multivibrator circuit including a condenser, in which recurrent saw-

tooth voltages are generated between the terminals of said condenser by alternate charging and discharging thereof, and an auxiliary circuit additional to said multivibrator circuit including thermionic devices controlled by said multivibrator circuit to accelerate the charging of said condenser.

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