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MULTIVIBRATOR

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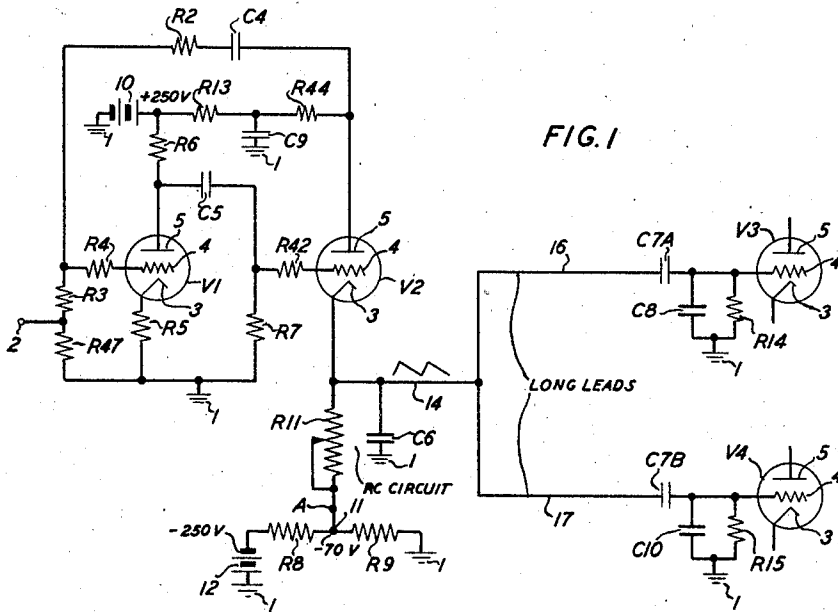


FIG. 1

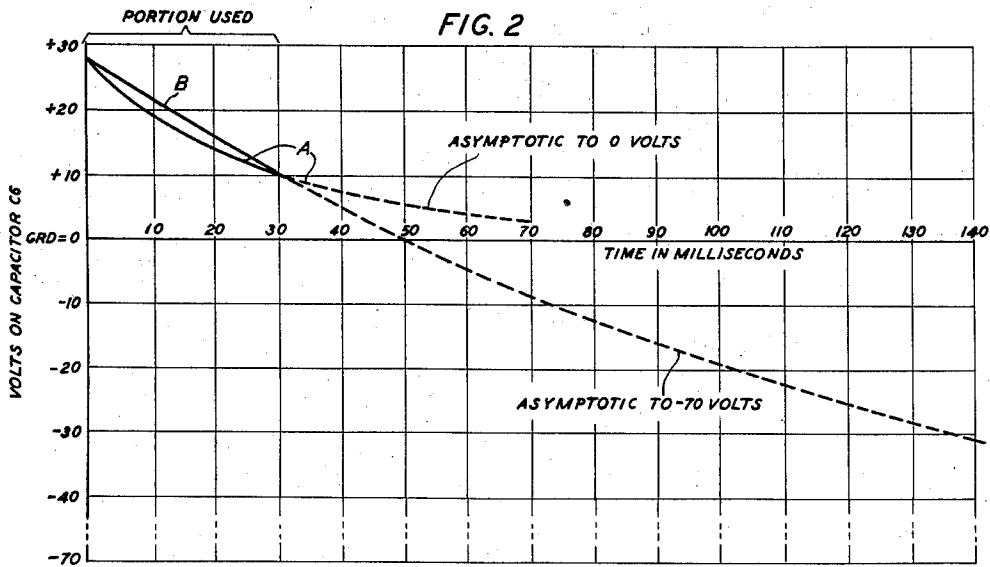


FIG. 2

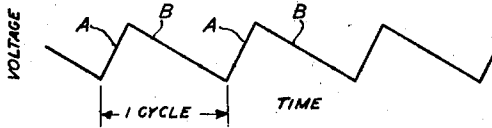


FIG. 3

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MULTIVIBRATOR

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6 Claims. (Cl. 250—36)

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This invention relates to electric oscillators of the multivibrator or relaxation oscillator type, and particularly to means for controlling the form of the saw-tooth wave voltage generated and produced by such oscillator apparatus.

One of the objects of this invention is to control the form of the voltage wave produced by an oscillator of the multivibrator type.

Another object of this invention is to provide a linear or nearly linear form for a saw-tooth wave voltage generated by an oscillator of the multivibrator type.

Another object of this invention is to reduce the effect upon the form of the saw-tooth wave of extraneous voltages that may be induced by stray fields in long lead lines associated with an oscillator of the multivibrator type.

Electric oscillators of the multivibrator type may be utilized to generate waves of the saw-tooth form and of other forms. Such waves may be utilized for controlling the sweep of a cathode-ray tube for example, and for other purposes. When a saw-tooth wave is used for controlling the timing action in a radio system for example, it is often desirable to have a linear form of wave for better control of the timing action. The linear form of the saw-tooth wave has a rate of change of voltage which is uniform with time, and accordingly, is useful in obtaining uniform time divisions in apparatus to be controlled, as in the sweep of an oscilloscope for example.

In accordance with this invention, the saw-tooth wave generated by a multivibrator may be rendered of linear or nearly linear form and also relatively free from the effects of extraneous voltages that may be induced in the lead lines of the output circuit by stray fields. For this purpose, a suitable negative bias potential may be utilized in connection with the condenser discharge circuit of the multivibrator in order to obtain a nearly linear discharge characteristic for the form of the saw-tooth wave voltage generated during the discharge of the condenser through its associated resistance. Also, an additional condenser or condensers connected in parallel circuit relation with the condenser of the discharge circuit and comprising a part of the capacitance thereof may be provided at the far end of the lead line for providing a low impedance to thereby reduce the effect of extraneous voltages that may be induced in the lead line by nearby stray fields. These two features may be utilized in combination or separately, the former to obtain the generated wave voltage of substantially linear form and the latter to pre-

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serve such linear wave form in its transmission to the load or work circuit.

For a clearer understanding of the nature of this invention and the additional advantages, features and objects thereof, reference is made to the following description taken in connection with the accompanying drawing, in which like reference characters represent like or similar parts and in which:

Fig. 1 is a circuit diagram of a multivibrator in accordance with this invention;

Fig. 2 is a graph illustrating the linear form of the voltage wave generated by the discharge of the RC circuit of Fig. 1; and

Fig. 3 is a graph illustrating the complete saw-tooth voltage wave generated by the multivibrator of Fig. 1.

Referring to the drawing, Fig. 1 is a circuit diagram of a self-oscillating multivibrator comprising two amplifier type vacuum tubes V1 and V2 each having a cathode 3, a grid or control electrode 4 and an anode or plate electrode 5. The two amplifier tubes V1 and V2 are resistance-capacitance coupled, the output of one tube being fed to the input of the other, and the frequency of oscillation being determined by the time constants of the resistances and capacitances of the circuit. The plate electrode 5 of the second tube V2 is connected with the grid electrode 4 of the first tube V1 by means of a capacitance C4, a resistance R2 and a resistance R4. The plate electrode 5 of the first tube V1 is connected with the grid electrode 4 of the second tube V2 by means of a condenser C5 and a grid resistance R42. The grid 4 of the tube V1 is connected to ground 1 through the resistance R4 and the series-connected resistances R3 and R47. If desired, a terminal 2 may be connected with a point intermediate the resistances R3 and R47 for the purpose of introducing a synchronizing voltage into the grid circuit 4 of the tube V1. The grid electrode 4 of the second tube V2 is connected with ground 1 through the grid resistance R42 and a resistance R7. The cathode 3 of the first tube V1 may be connected to ground 1 through a resistance R5. Any suitable filament and power supply source (not shown) may be used for heating the cathodes 3 of the tubes V1 and V2 and also of the output circuit tubes V3 and V4. A suitable power supply source 10 and associated anode resistances R6 and R13 and R44 may be provided for maintaining the anodes 5 of the tubes V1 and V2 at a positive potential with respect to ground 1.

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The cathode 3 of the second tube V2 is connected through a capacitor or condenser C6 to the ground 1, and through a variable resistance R11 to a tap point 11 on a voltage divider comprising the resistances R8 and R9. A source of negative bias potential 12 connected with the resistance R8 and the ground 1 supplies a potential at the tap 11 and also at point A in Fig. 1, which is negative with respect to the ground 1. The resistance R9 is grounded at its far end. Accordingly, current flowing through the voltage divider R8 and R9 produces at the tap 11, a negative potential with respect to the ground 1. The condenser C6 discharges through the resistances R9 and R11, and is charged from the tube V2. The saw-tooth wave generated appears on the lead wire 14 connected with the cathode 3 of the tube V2. A condenser C9 may be connected with and intermediate the plate resistances R13 and R44 in order to eliminate the effect of ripple from the plate power supply source 10 upon the saw-tooth wave generated at the output lead wire 14.

The saw-tooth wave voltage from the lead wire 14 may be supplied over one or more relatively long lead wires 16 and 17 to load or work circuits represented by the tubes V3 and V4 respectively, which may be for example electronic relays, or amplifiers. At the far ends of the long lead lines 16 and 17 and adjacent the tubes V3 and V4, condensers C8 and C10 respectively may be connected in parallel circuit relation with the condenser C6 and form part of the total capacitance of the RC circuit. Resistances R14 and R15 may be connected in parallel circuit relation with the condensers C8 and C10 respectively. The condensers C7A and C7B are large blocking condensers interposed in the long leads 16 and 17, respectively. The RC circuit capacitance, which may comprise the single condenser C6 or in addition other smaller condensers C8 and C10 connected in parallel circuit relation therewith, is included in the cathode circuit 3 of the tube V2 to develop the saw-tooth wave. The large resistances R14 and R15 associated with the condensers C8 and C10, respectively may be considered as being connected in parallel circuit relation with the principal resistance R11.

In a particular example for a multivibrator of about 26 cycles per second frequency, the values of the resistances and the capacitances chosen for use in the circuit of Fig. 1 were substantially as follows: R2=47,000 ohms, R3=510,000 ohms, R4=470,000 ohms, R5=2,700 ohms, R6=51,000 ohms, R7=1,000,000 ohms, R8=75,000 ohms, R9=30,000 ohms, R11=500,000 ohms, R13=2,200 ohms, R44=22,000 ohms, R42=470,000 ohms, R47=22,000 ohms, R14=1,000,000 ohms, R15=1,000,000 ohms; C4=.0051 microfarad, C5=.03 microfarad, C6=2.5 microfarads, C7A=1.0 microfarad, C7B=1.0 microfarad, C9=0.5 microfarad, C8=0.1 microfarad, C10=0.1 microfarad. The tubes V1, V2, V3 and V4 are, in the example given, conventional vacuum tubes, and the bias voltage supply sources 10 and 12 are provided to supply direct current potentials of +250 volts and -250 volts respectively.

The operation of the circuit is as follows: Start at a time when the tube V2 is blocked, and the tube V1 is conducting with its grid 4 at ground potential obtained through the resistances R3 and R47. At this time, the grid 4 of the tube V2 is at ground potential obtained through the resistance R7, and the cathode 3 is positive with respect to ground 1 and the grid 4 by the amount

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of the voltage across the condenser C6. This condition is keeping the tube V2 blocked. The condenser C6 slowly discharges through the resistance R11 approaching a voltage of -70 volts, the voltage between the resistances R8 and R9 with no current flow in the resistance R11 on its top plate. However, as soon as the condenser C6 has discharged enough to lose about 18 volts in the present example, the grid bias potential becomes low enough that the tube V2 starts conducting, thus causing its plate voltage to change in a negative direction. This negative change in voltage is passed to the grid 4 of the tube V1 by the RC coupling network consisting of the condenser C4 and the resistances R2, R3 and R47. The amount of voltage change is reduced because the resistances R2, R3 and R47 form a voltage divider as the grid 4 of the tube V1 is driven in a negative direction in potential, the current in the plate circuit of the tube V1 is reduced and the plate voltage changes in a positive direction. This change is passed to the grid 4 of the tube V2 by the RC coupling circuit comprising the resistance R7 and the condenser C5. This tends to increase the current in the plate circuit 5 of the tube V2, thus causing the plate 5 to become still more negative. Because of this regenerative action the current in the plate circuit of the tube V2 rises very quickly to a maximum value determined by the tube characteristics. Most of the plate current consists of the charging current of the condenser C6 although there is a small amount of current through the resistance R11.

The charging of the condenser C6 will continue until the plate current of the tube V2 is blocked by the following means. When the tube V2 started conducting, the grid 4 of the tube V1 was driven to cut-off by the RC coupling circuit consisting of the resistances R2, R3, R47 and the condenser C4. Now, even though there is a nearly constant voltage at the plate 5 of the tube V2 during the charging of the condenser C6, there will be a changing voltage across the condenser C4 because the plate of the condenser C4 which is connected to the resistance R2 will tend to assume ground potential. As soon as this plate of the condenser C4 approaches sufficiently near to the ground potential, the grid 4 of the tube V1 will no longer be at cut-off potential and the tube V1 will start conducting. Its plate 5 will become more negative, the grid 4 of the tube V2 will become more negative, the plate current in the tube V2 will be reduced, the plate voltage of the tube V2 will become more positive and its plate still more negative. Hence the action will quickly build up until the plate current of the tube V2 is cut off. While the tube V2 is cut off, the plate of the condenser C4 which is connected to the resistance R2 reaches ground potential, the tube V1 remains conducting with a grid bias equal to the voltage across the resistance R5 and the grid 4 of the tube V2 attains ground potential. The time constant of the condenser C5 and the resistance R7 is such that this network acts as a good low frequency coupling circuit. That is, the voltage change across the condenser C5 during the time the tube V2 is cut off is small. With the tube V2 cut off, the action described above repeats.

The tube V2 is blocked during most of the multivibrator cycle. But during the short period that the tube V2 is conducting, most of the plate-cathode current thereof flows through the capacitor C6 to ground 1, thereby rapidly charging the condenser C6. When the tube V2 is blocked, the condenser C6 discharges rather slowly through

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the resistances R9 and R11 due to the relatively high resistance of the resistor R11. The low voltage point A of the resistance R11 in Fig. 1 is carried to about -70 volts, in the example given, by means of the voltage divider R8 and R9 supplied from the -250 volt supply source 12. With this arrangement the condenser C6 loses only a relatively small part of the total charge during the discharge operation, but provides a full or substantial voltage drop for the saw-tooth wave at the lead line 14, the wave being practically linear as illustrated by the downwardly sloping portion B of the curves in Figs. 2 and 3.

In the conventional form of multivibrator circuit, the point labeled A in the cathode lead of the tube V2 in Fig. 1 would be connected to ground 1. Under that condition, the condenser C6 will discharge from a voltage which may be, for example, about 28 volts when the tube V2 is blocked, to about 10 volts for example, at which time the tube V2 starts conducting. This gives a swing of some 18 volts which represents

$$\frac{18}{28}$$

or 64 per cent of the starting voltage in RC circuit of the multivibrator. When the circuit is connected as shown in Fig. 1, the starting voltage on the cathode 3 of the tube V2 is still the same 28 volts and it still drops to the same 10 volts before the tube V2 starts to conduct. However, when the circuit is connected as shown in Fig. 1 where, instead of being grounded at the point A, a voltage of -70 volts for example is applied at the point A from the voltage source 12 through the resistance R8, there results a total starting voltage in the RC circuit of $70+28=98$ volts, which decreases by 18 volts in the example assumed. This results in a swing of 18 volts in 98 volts which represents

$$\frac{18}{98}$$

or 18 per cent of the starting voltage in the RC circuit of the multivibrator. The curve of voltage versus time of the condenser C6 discharging through the resistance R11 is nearly linear for about the first 20 per cent of its final or total voltage change, but is not nearly linear if some larger percentage voltage change is involved, as illustrated by the curves A and B in Fig. 2. Accordingly, by operating the discharge of the condenser C6 on only a relatively small part, such as less than about 20 per cent for example, of its total charge, a substantially linear form of wave is generated, as illustrated by the curve B in Figs. 2 and 3.

Fig. 2 is a graph illustrating typical curves of voltage versus time for a condenser such as the condenser C6 discharging through a resistance such as the resistances R9 and R11 in Fig. 1. In Fig. 2, the ordinates may represent the values of voltage on the cathode 3 of the tube V2 where the value of +28 volts illustrates the maximum voltage on the cathode 3 of the tube V2, where the value of +10 volts represents the cut-off voltage of the tube V2, where the value of 0 volt represents the potential at ground 1, and where the value of -70 volts represents the voltage applied at point A of Fig. 1 by the tap point 11 of the voltage divider R8, R9 and the source 12.

The curve A of Fig. 2 represents the non-linear form of voltage characteristic of the condenser

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C6 of Fig. 1 discharging through the resistance R11 of Fig. 1 that is obtained if and when the circuit is grounded at the point A of Fig. 1 and the resistance R11 is readjusted to obtain the same cycle time. The curve B of Fig. 2 represents the nearly linear form of voltage characteristic that may be obtained from the condenser C6 discharging through the resistances R9 and R11 of Fig. 1 when a negative bias voltage is applied at point A of Fig. 1 of suitable value to keep the discharge voltage change of the condenser C6 within about 20 per cent of its total voltage charge.

The data for the curves A and B of Fig. 2 were obtained using the well known formula for the voltage across a condenser discharging through a resistance:

$$V = E_0 e^{-\frac{t}{RC}}$$

where,

E_0 =voltage across the condenser at time zero

V =voltage across the condenser at time t

t =time after the discharge starts

R =resistance in series with the condenser

C =capacity of the condenser

$e=2.718$ (base of natural logarithms)

Fig. 3 is a graph illustrating a typical form for the saw-tooth wave generated by the multivibrator circuit of Fig. 1. The portion of the curve labeled B in Fig. 3 corresponds to the curve B in Fig. 2 and represents the form of the wave generated during the discharge of the condenser C6 through the resistors R9 and R11 in Fig. 1. The tube V2 is blocked during this part which is the greater part of the time cycle; but during the remainder or lesser part of the time cycle, the tube V2 is conducting and charges the condenser C6, as indicated by the upwardly sloping part A of the saw-tooth wave curve in Fig. 3.

It will be noted that the cathode circuit 3 of the tube V2 of the multivibrator in Fig. 1 is provided with a condenser C6 and parallel-connected resistances R9 and R11 which taken together form the RC circuit, and that one feature of this invention involves using a voltage divider for providing a negative bias potential in connection with the resistance and condenser of the RC discharge circuit in order to obtain a linear or nearly linear discharge voltage characteristic for the form of the saw-tooth wave voltage generated. This substantially linear voltage characteristic with time is illustrated by the downwardly sloping curve B in Figs. 2 and 3. Also, it will be noted that the substantially linear form of the saw-tooth wave as a whole may be preserved from interference in transmission over the associated lead line by means of another feature of this invention which involves the use of an additional but smaller condenser C8 or condensers C8 and C10 connected in parallel circuit relation with the condenser C6 and comprising a part of the total capacitance of the principal RC circuit, but disposed at the far end of the output lead line 16 or 17. This arrangement provides a low impedance and thereby reduces the effect of any extraneous voltages that may be induced in the long lead line 16 or 17 by stray fields.

Although this invention has been described and illustrated in relation to specific arrangements, it is to be understood that it is capable

of application in other organizations and is therefore not to be limited to the particular embodiments disclosed.

What is claimed is:

1. An oscillator for producing a saw-tooth wave form comprising a pair of electron discharge tubes each including a cathode, a control electrode and an anode, means including anode resistances for maintaining said anodes positive with respect to said cathodes, means including capacitances for connecting the anode of each of said tubes with the control electrode of the other of said tubes, means including resistances for connecting said control electrodes with one of said cathodes, means including another resistance for connecting the other of said cathodes with a source of direct current bias potential which is negative with respect to said one of said cathodes, and means including a condenser connected across said another cathode resistance, the value of said negative bias potential being related to a partial capacitance discharge value of said condenser and comprising means for obtaining a nearly linear discharge characteristic for the form of said saw-tooth wave when said condenser discharges through said another resistance.

2. A generator for producing a saw-tooth wave comprising a pair of electron discharge devices each including a cathode, a control electrode and an anode, means including anode resistances for maintaining said anodes positive with respect to ground, means including a series-connected capacitance and resistance for connecting the anode of each of said discharge devices with the control electrode of the other of said discharge devices, a pair of resistances, means for connecting one end of each of said pair of resistances to said control electrodes and the other ends of said pair of resistances to said ground, means including a series resistance for connecting said cathode of one of said discharge devices with said ground, means for connecting said cathode of said other of said pair of said discharge devices with said ground including a condenser connected between said last-mentioned cathode and said ground and including a cathode resistance connected at one of its ends with said last-mentioned cathode and at its other end with a grounded voltage divider at a point thereon where said voltage is negative with respect to said ground, means for supplying said point on said voltage divider with said negative voltage of a value that keeps the discharge voltage across said condenser within substantially 20 per cent of the total voltage charge applied to said condenser whereby a substantially linear wave form is generated by said condenser discharging through said last-mentioned cathode resistance.

3. A system in accordance with claim 2 and apparatus connected therewith comprising a saw-tooth wave output circuit connected with said last-mentioned cathode and said ground, said output circuit comprising a pair of parallel-connected circuits having relatively long leads whereby extraneous voltages may be undesirably induced by stray fields, each of said parallel-connected circuits including a series blocking condenser, a shunt resistance and a shunt condenser, each of said shunt condensers forming a part of the capacitance of said condenser connected with said last-mentioned cathode and each of said shunt condensers being made of values to provide a relatively low impedance at each of the remote ends of said leads whereby the

effect of said induced extraneous voltages on said saw-tooth wave in said leads is reduced

4. A system in accordance with claim 2 and apparatus connected therewith comprising a saw-tooth wave output circuit connected with said last-mentioned cathode and said ground, said output circuit comprising a pair of parallel-connected circuits having relatively long leads whereby extraneous voltages may be undesirably induced therein by stray fields, each of said parallel-connected circuits including a series-blocking condenser and a shunt condenser, each of said shunt condensers forming a part of the capacitance of said condenser connected with said last-mentioned cathode and each of said shunt condensers being made of values to provide a relatively low impedance at each of the remote ends of said leads whereby the effect of said induced extraneous voltages on said saw-tooth wave in said leads is reduced.

5. A generator for producing a saw-tooth wave comprising a pair of electron discharge devices each including a cathode, a control electrode and an anode, means including anode resistances for maintaining said anodes positive with respect to ground, means including a series-connected impedance for connecting the anode of each of said discharge devices with the control electrode of the other of said discharge devices, a pair of resistances, means for connecting one end of each of said pair of resistances to said control electrodes and the other ends of said pair of resistances to said ground, means including a series resistance for connecting said cathode of one of said discharge devices with said ground, means for connecting said cathode of said other of said pair of said discharge devices with said ground including a condenser connected between said last-mentioned cathode and said ground and including a cathode resistance connected at one of its ends with said last-mentioned cathode and at its other end with a grounded voltage divider at a point thereon where said voltage is negative with respect to said ground, means for supplying said point on said voltage divider with said negative voltage of a value that keeps the discharge voltage across said condenser within substantially 20 per cent of the total voltage charge applied to said condenser whereby a substantially linear wave form is generated by said condenser discharging through said last-mentioned cathode resistance, and output circuit means connected with said last-mentioned cathode and said ground.

6. A generator for producing a saw-tooth wave comprising a pair of electron discharge devices each including a cathode, a control electrode and an anode, means including anode resistances for maintaining said anodes positive with respect to ground, means including a series-connected impedance for connecting the anode of each of said discharge devices with the control electrode of the other of said discharge devices, a pair of resistances, means for connecting one end of each of said pair of resistances to said control electrodes and the other ends of said pair of resistances to said ground, means including a series resistance for connecting said cathode of one of said discharge devices with said ground, means for connecting said cathode of said other of said pair of said discharge devices with said ground including a condenser connected between said last-mentioned cathode and said ground and including a cathode resistance connected at one of its

ends with said last-mentioned cathode and at its other end with a grounded voltage divider at a point thereon where said voltage is negative with respect to said ground, means for supplying said point on said voltage divider with said negative voltage of a value that keeps the discharge voltage across said condenser substantially less than the total voltage charge applied to said condenser whereby a substantially linear wave form is generated by said condenser discharging through said last-mentioned cathode resistance, and output circuit means connected with said last-mentioned cathode and said ground.

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