Dec. 10, 1946. J. W. WHITELEY 2,412,485

SAW TOOTH VOLTAGE GENERATOR

Filed Feb. 5, 1943

FIG. 1

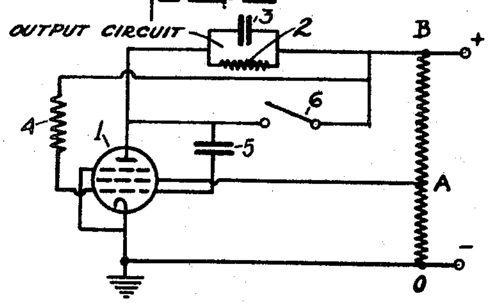


FIG. 2

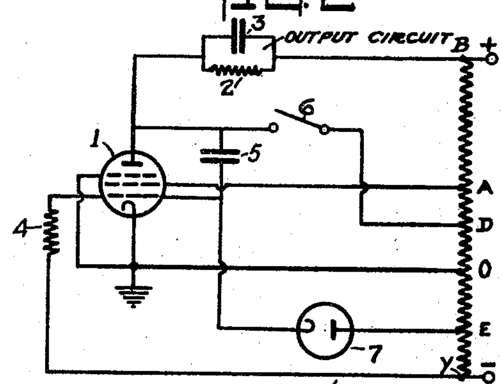


FIG. 3

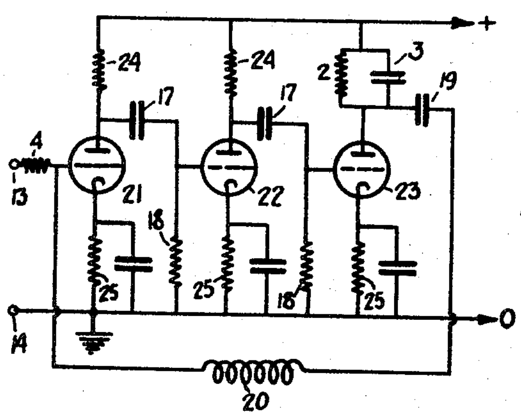


FIG. 4

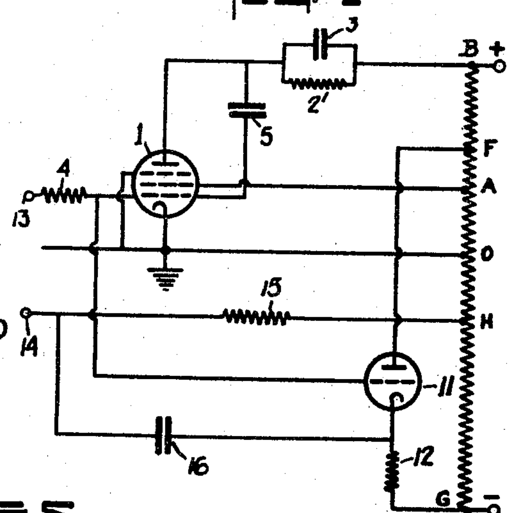
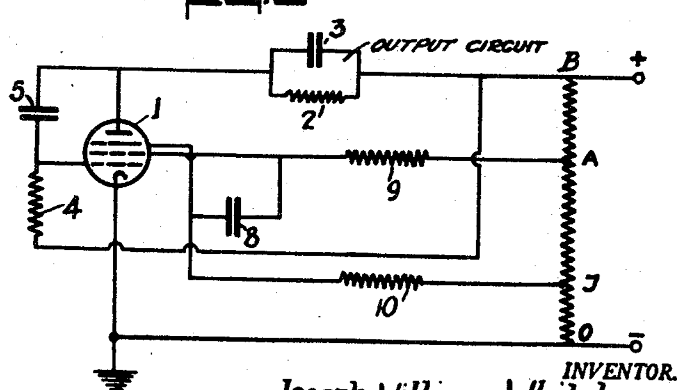


FIG. 5



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SAW-TOOTH VOLTAGE GENERATOR

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8 Claims. (Cl. 250—36)

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This invention relates to electric circuits in which either, (*a*) the instantaneous rate of change of output voltage is substantially proportional to an applied voltage, or (*b*) the instantaneous output voltage is substantially proportional to the rate of change of an applied voltage. Circuits of type (*a*) will be denoted "integrating circuits" and circuits of type (*b*) will be denoted "differentiating circuits."

The apparatus according to the invention for these purposes comprises a thermionic valve amplifier and a feed-back path whereby the output voltage of said amplifier is fed back through a time-constant network in degenerative sense into the input circuit of said amplifier.

If the circuit is required to integrate, the time-constant network in the feed-back path will be of the differentiating type. On the other hand, if the circuit is required to differentiate, the time-constant network in the feed-back path will be of the integrating type.

The invention is particularly applicable to the special purpose which consists in the integration, for limited periods, of constant voltages; this is to say, the production of voltages which vary substantially linearly with time. Circuits for this purpose are commonly known as "linear saw-tooth time-base voltage generators," or "linear saw-tooth voltage sweep generators."

A substantially linear saw-tooth voltage sweep generator according to a preferred form of the invention comprises a thermionic valve, an anode load connected between the anode and a point of highly positive fixed potential, a resistance connected between the control grid and a point of constant potential remote from cathode potential, a condenser connected betwen anode and control grid. and means to establish an initial potential difference across said condenser widely different from the potential difference which is ultimately obtained if said means are rendered inoperative.

In the accompanying drawing, each figure is a circuit diagram of an embodiment of the invention. Figures 1 and 2 represent single-valve time-base circuits requiring external means for producing flyback; Figure 3 represents a general differentiating circuit; Figure 4 represents a general integrating circuit; and Figure 5 shows a single-valve saw-tooth time-base circuit which can be adjusted to be self-running.

The generator represented in Figure 1 is shown as employing a pentode valve 1, and having its suppressor and screen grids conventionally connected respectively to cathode and to a point of positive fixed potential which is indicated by letter A on a potentiometer or other voltage source. An anode load, shown as comprising resistance 2 in parallel with capacitance 3, is conventionally connected between the anode and a point of highly positive fixed potential, indicated at B. The output voltage is developed across this anode load, which may, if desired, consist only of the circuit across which the generated time-base voltage is to be applied. Thus the capacitance 3 may comprise the deflector plate capacitance of a cathode ray tube plus the stray anode capacitance of valve 1.

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A resistance 4 is connected between the control grid and a point of positive constant potential, preferably of high value. This point and point B may conveniently be the same point as shown in the drawing. If the anode current supply to point B is derived from an alternating source through a conventional rectifier and smoothing system, it is desirable that additional means be employed to maintain constant the potential of point B.

Between the anode and the control grid, a condenser 5 is connected, which together with resistance 4 forms a time-constant network through which the voltage developed across the anode load is fed back in degenerative sense to the control grid. The voltage developed across resistance 4, which is thus applied in the grid circuit, is nearly constant and is slightly greater than the opposing positive constant voltage existing between point B and cathode; and the resultant grid-cathode potential difference is relatively small.

During the sweep cycle, voltage across condenser 5 will tend to fall, at a nearly constant rate, until a low limiting value is reached. Means must be provided to establish an initial voltage across condenser 5 widely different from that value. Means indicated by switch 6 are provided for this purpose. When this switching means is closed, the upper plate of condenser 5 and the lower plate of capacitance 3 are directly connected to a point of high positive fixed potential which may conveniently be the same as point B as shown in the drawing. The potential of the lower plate of condenser 5 is prevented from rising above approximately that of the cathode, by grid current flowing in valve 1. Condenser 5 is thus given a high initial charge by closing switch 6.

When switch 6 is opened, the potential difference between anode and grid is momentarily maintained by condenser 5. The potentials of both will change abruptly, and equally, to a condition of temporary equilibrium determined by the anode load, the resistance 4, and the valve characteristic. The control grid voltage must assume a value within the grid base, in order to avoid cutting off anode current entirely. It is therefore evident that the abrupt change in anode and grid potentials will be a slight fall, smaller than the grid base of the valve. The anode potential will therefore still be high, and it follows that the actual value of control grid potential established will be near the negative end of the grid base.

Condenser 5 will now discharge steadily through resistance 4 and through the valve 1. The anode current and grid voltage will be related throughout this discharge according to the characteristics of the valve. The anode potential will sweep downwards, varying substantially linearly with time, while the control grid potential sweeps upwards within the grid base of the valve.

The discharge may be continued until the control grid voltage approaches close to the value at which grid current will begin to flow. The anode potential will then have fallen to within a few volts of cathode potential. By re-closing and re-opening switch 6, the cycle may be repeated.

The generator represented in Figure 2 is generally similar to that in Figure 1 but has the resistance 4 connected between the control grid and a point of negative constant potential, preferably of highly negative value, which is indicated at Y. The voltages across condenser 5 will tend to increase at a substantially constant rate towards a high value, and the initial voltage which it is necessary to establish is therefore low. Consequently, switch 6 is arranged to connect the upper plate of condenser 5 to a point of low positive fixed potential, which is indicated at D. Assuming that condenser 5 has a high voltage charge at the time when switch 6 is closed, with the upper plate positive relative to the lower, it cannot be discharged by grid current in valve 1. In this figure, therefore, a unidirectional path, shown as a diode 7, is provided from a point of small negative fixed potential, indicated at E, to the lower plate of condenser 5, and the potential of this plate is thus prevented from falling substantially below the potential of this point E. Preferably this potential should be slightly more negative than the cut-off potential of the control grid of valve 1.

By closing switch 6, therefore, condenser 5 is discharged to a voltage approximately equal to the voltage between the points D and E. This voltage may be only a few volts greater than the grid base of the valve 1.

When switch 6 is opened, the potentials of both plates of condenser 5 will rise abruptly until a condition of temporary equilibrium is reached, determined by the anode load, the resistance 4, and the valve characteristic. The anode potential at this instant is low and therefore the grid potential will be only slightly below cathode potential.

Condenser 5 will now steadily charge through resistance 4 and through the anode load. The anode potential will sweep upwards, varying substantially linearly with time, while the control grid potential sweeps downwards within the grid base of the valve.

The discharge may be continued until the control grid voltage approaches close to the value at which anode current is cut off. By re-closing and re-opening switch 6 the cycle may be repeated.

In the arrangement of Figure 2, the anode load resistance 2 must be sufficiently low to pass the anode current for valve 1 together with the charging current for condenser 5. In Figure 1, on the other hand, the anode load resistance 2 may be raised to a very high value, because the anode current can be supplied by condenser 5.

In the embodiments of the invention represented by Figures 1 and 2, it is desirable that the following conditions shall be observed in order that the rate of change of anode potential shall be as constant as possible during the sweep period:

(1) The valve should have a high amplification factor,

(2) The valve should have a high mutual conductance (this condition requires inter alia that the control grid potential shall not become so far negative as to approach closely to anode current cut-off),

(3) The control grid potential should not become so far positive that grid current flows,

(4) The resistance 2 of the anode load should be high,

(5) The anode load capacitance 3 should not be excessively large in comparison with the capacitance 5,

(6) The potential to which resistance R_4 is connected should be remote from cathode potential. This potential should furthermore be held as constant as possible relative to cathode.

The following component values are suitable as an example of a circuit according to Figure 1. The pentode valve may have an amplification factor of 2,000 and a mutual conductance of 2 milliamps per volt. The point B may be at 250 volts positive to cathode. Resistance 4 may have a value of 100,000 ohms, while the capacitance 5 may be varied between 0.0001 and 0.1 microfarad. With such a circuit the output voltage is substantially linear, even when the anode load resistance 2 is as low as 100,000 ohms and the capacitance 3 of the anode load is several times the value of condenser 5. The sweep amplitude, which is determined by the interval between successive operations of switch 6, may be of the order of 240 volts when the applied voltage, as above stated, is 250 volts.

The rate of change of anode potential may be adjusted:

(1) By adjusting the said potential,

(2) By adjusting the value of resistance 4,

(3) By adjusting the value of condenser 5.

In the general differentiating circuit represented in Figure 3, the signal to be differentiated is applied between terminals 13 and 14, the latter of which is connected directly to the point of fixed zero potential, normally earth, indicated at 0.

In this circuit, in order to increase the amplification factor, and thus obtain a higher degree of accuracy in the differentiation, a multi-valve amplifier is shown.

The terminal 13 is connected through resistance 4 to the control grid of valve 21. The grid circuit of valve 21 should be substantially purely resistive. If the internal impedance of the signal source connected between terminals 13 and 14 is not substantially purely resistive, additional resistance may be added in series therewith. Resistance 4 represents the resistive component of the internal impedance plus any such additional resistance, and thus forms the resistive arm of the feed-back time-constant network.

The valves 21 and 22 are arranged as ordinary amplifiers with anode load resistors 24 and conventional couplings comprising large blocking condensers 17 and grid leaks 18. Valves 21, 22 and 23 have conventional self-biassing networks 25.

The output load, represented as in previous figures as resistance 2 in parallel with capacitance 3, is connected in the anode circuit of the last valve 23. The output voltage developed across this anode load is fed back through a large blocking condenser 19 and then through an integrating time-constant network comprising inductance 20 in series with said resistance 4 in the input circuit.

Pentode valves may be substituted for the triode valves 21, 22, 23, if desired.

If an integrating circuit is required instead of a differentiating circuit, this may be achieved by substituting a differentiating time-constant network for the integrating time-constant network. For example, a condenser giving, in conjunction with resistance 4, a suitable time-constant, may be substituted for inductance 20, and then blocking condenser 19 is unnecessary.

The general integrating circuit represented by Figure 4 includes double compensation. The valve 1, here shown as a pentode, is provided with a feed-back time-constant network comprising the condenser 5 and the resistance 4. The potential difference across the resistance 4 is applied to the grid of the pentode, in series with the applied potential difference which is to be integrated and which is introduced between the input terminals 13, 14. The terminal 14 is connected to a point H of fixed negative supply potential through a high resistance 15, so as to provide a suitable grid bias potential at the grid of valve 1. Furthermore, the terminal 14 is connected through a large blocking condenser 16 to the cathode of a cathode follower triode 11 so that the variations of potential across the cathode load 12 are reproduced at terminal 14. The grid of the cathode follower triode is connected to the grid of the pentode 1. The function of the cathode follower in this arrangement is to provide, at terminal 14, variations of potential which are nearly equal to the variations of potential which appear at the grid of the pentode 1, so that the potential difference across resistance 4 is very nearly equal to the potential difference applied between terminals 13 and 14. Under these circumstances, the current flowing through resistance 4 is nearly proportional to the applied potential difference and the variation of potential difference across condenser 5 is nearly proportional to the integral, with respect to time, of the applied potential difference.

Pentode 1 is provided with an anode load, comprising resistance 2 and capacitance 3, across which is developed an output potential variation substantially proportional to the time integral of the applied potential.

If there is difficulty in giving a sufficiently long time-constant to the coupling 15, 16, a battery may be substituted for the condenser 16.

If an inductance, in series with a large blocking condenser, be substituted for condenser 5, the potential variations across the anode load impedance 2, 3, will be substantially proportional to the rate of change of the potential applied between terminals 13 and 14.

The generator represented in Figure 5 is generally similar to that of Figure 1 but has internal means for re-establishing a basic initial potential difference across condenser 5 at the completion of each voltage sweep. In Figure 5 this is effected by cutting off, or nearly cutting off, the anode current of valve 1. The resulting rise of anode potential is accompanied by the charging of condenser 5 through the anode load resistance 2 and by grid current.

The interruption of anode current is effected by an arrangement similar to that employed in a transitron oscillator. The screen and suppressor grids are directly coupled together by condenser 8. Impedance 9 is connected between the screen grid and a point A of appropriate high positive fixed potential. Impedance 10 is connected between the suppressor grid and a point J of appropriate low positive or negative potential. A sharp fall of the potentials of the screen and suppressor grids is desired at the end of each voltage sweep, followed by a sharp rise to initiate the next sweep. To achieve this, the impedance between these grids and earth, offered to alternating currents, should be substantially resistive. The impedances 9 and 10 are both shown as resistors.

By appropriate choice of the bias potential applied to the suppressor grid through impedance 10, the circuit may be arranged to operate continuously, and so to provide a saw-tooth potential waveform across the anode load 2, 3. Alternatively, the circuit may be arranged to remain quiescent until the arrival of a synchronising or tripping pulse, after which the anode potential will fall steadily to a minimum and then return rapidly to the original level. In the latter case the circuit functions as a single-stroke time-base generator. In either case, synchronising pulses may, for example, be applied to the suppressor grid through a condenser.

If the circuit of Figure 1 or Figure 2 is required to produce a succession of sweeps, the switch 6 may take the practical form of a mechanically driven commutator, or of an electrical discharge circuit employing a gas discharge triode or one or more high vacuum valves. Such a discharge circuit may be designed to be self-operating when the anode reaches a predetermined potential, so that a self-running time-base generator is obtained. Alternatively, it may be designed to operate in response to a signal to produce a single sweep, or in response to a succession of synchronising signals to produce a succession of sweeps.

Although the valve 1 is shown in each of the figures as a pentode, it may be preferred in some arrangements according to the invention that a high-gain triode be employed.

I claim:

1. In a sweep voltage generator, a vacuum tube amplifier comprising at least a cathode, an anode, a first control grid near said cathode, a second control grid near said anode and a screen grid interposed between said first and second control grids, input and output circuits including an anode load impedance and means to provide a relatively high steady positive bias potential upon said first control grid, to cause the anode potential to decrease from an initial high value to a low limit value, a feedback interconnecting said output and input circuits and including a condenser and a resistance in series to produce a potential upon said first grid during the sweep of the anode potential varying in accordance with the rate of change of the anode potential and being nearly

equal to and applied in opposition to said grid bias potential, a condenser connected between said screen grid and said second control grid, a resistive load impedance connected to said screen grid and designed to produce a sudden high negative potential upon said second control grid at the completion of the anode sweep whereby to raise the anode potential to its initial value.

2. A sweep voltage generator comprising an electron discharge tube having at least a cathode, an anode, a control grid, a screen grid, and a suppressor grid, an output load connected between said anode and cathode, an input circuit for said tube comprising a resistance having one end connected to said control grid and having its opposite end connected to a point of relatively high fixed positive potential remote from the range of grid operating potential for said tube to act as a voltage amplifier, a condenser connected between said control grid and a point of said output load, means for periodically interrupting the anode current of said tube comprising a further condenser connected between said screen grid and said suppressor grid, a resistance connected between said screen grid and a point of relatively high fixed potential and a further resistance connected between said suppressor grid and a point of relatively low fixed potential.

3. A sweep voltage producing means comprising a vacuum tube having a cathode, a grid and an anode, a source of direct current potential, means for connecting the negative terminal of said source to said cathode, means for connecting the positive terminal of said source through a resistance and condenser in parallel to said anode to normally bias said anode to a potential below the potential of said positive terminal, a further condenser connected between said anode and said grid, a further resistance connecting said grid with the positive terminal of said source, and means for momentarily raising the potential of said anode to the potential of the positive terminal of said source.

4. A sweep voltage producing means comprising a vacuum tube having a cathode, a grid, and an anode, a source of direct current potential, means for connecting the negative terminal of said source to said cathode, means for connecting the positive terminal of said source through a resistance and condenser in parallel to said anode to bias said anode to a normal potential below the potential of the positive terminal of said source, a further condenser connected between said anode and said grid, a further resistance connecting said grid with the positive terminal of said source, and means for momentarily short-circuiting said first-mentioned resistance.

5. A sweep voltage producing means comprising a vacuum tube having a cathode, a grid, and an anode, a source of direct current potential, means for connecting the negative terminal of said source to said cathode, means for connecting the positive terminal of said source through a resistance and condenser in parallel to said anode to bias said anode to a normal potential below the potential of the positive terminal of said source, a further condenser connected between said anode and said grid, a further resistance connecting said grid with the positive terminal of said source, and means for momentarily interrupting the electron current within said tube to said anode.

6. A sweep voltage producing means comprising a vacuum tube having a cathode, a grid and an anode, a source of direct current potential, means for connecting the negative terminal of said source to said cathode, means for connecting said anode through a resistance and condenser in parallel to a positive potential point of said source with respect to said cathode to bias said anode to a normal potential below said positive potential point, a further condenser connected between said grid and a point of said resistance below said positive potential point, means for connecting said grid through a further resistance to a positive potential point of said source with respect to said cathode, and means for momentarily raising the potential of said anode to a value above said normal potential.

7. A sweep voltage producing means comprising a vacuum tube having a cathode, a grid and an anode, a source of direct current potential, means for connecting the negative terminal of said source to said cathode, a condenser connected between said anode and said grid, means for connecting said anode through a resistance and a further condenser in parallel to a positive potential point of said source with respect to said cathode to bias said anode to a normal potential below said positive potential point, said further condenser having a capacity of an order not excessively large in comparison with the capacity of said first condenser, means for connecting said grid through a further resistance to a positive potential point of said source with respect to said cathode, and further means for momentarily raising the potential of said anode to a value above said normal potential.

8. A sweep voltage producing means comprising a vacuum tube having a cathode, a control grid, a screen grid, a suppressor grid, and an anode, a source of direct current potential, means for connecting the negative terminal of said source to said cathode, means for connecting said suppressor grid to said cathode, further means for connecting the screen grid to a point of positive potential of said source with respect to said cathode, a condenser connected between said anode and said control grid, means for connecting said anode through a resistance and a further condenser in parallel to a positive potential point of said source with respect to said cathode to bias said anode to a normal potential below said positive potential point, means for connecting said control grid through a further resistance to a point of positive potential of said source with respect to said cathode, and means for momentarily raising the potential of said anode to a value above said normal potential.

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