Nov. 12, 1940. J. C. WILSON 2,221,015

PERIODIC WAVE GENERATOR

Filed Feb. 16, 1939

FIG. 1.

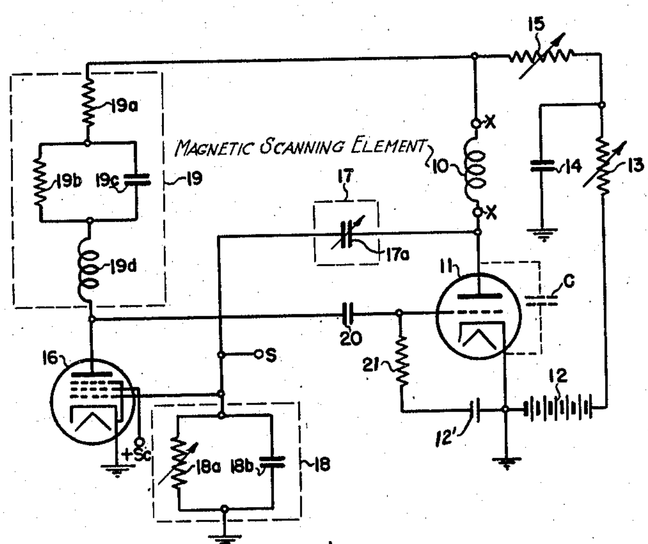
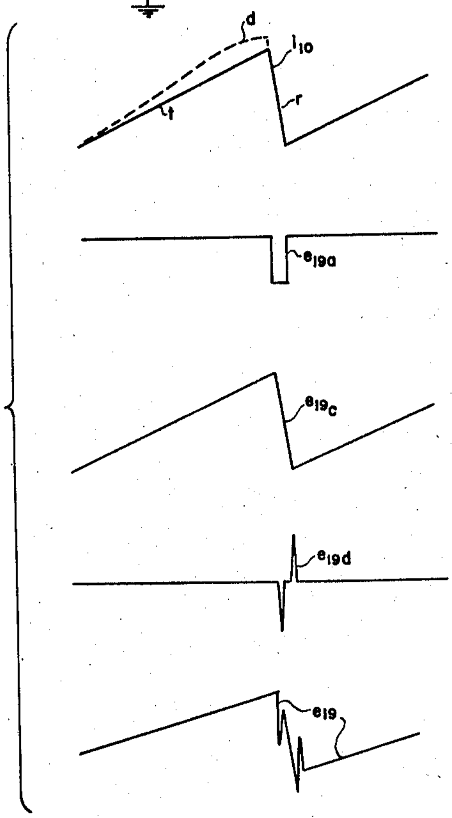


FIG. 2.



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Patented Nov. 12, 1940

2,221,015

UNITED STATES PATENT OFFICE

2,221,015

PERIODIC WAVE GENERATOR

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Application February 16, 1939, Serial No. 256,663

6 Claims. (Cl. 250—36)

This invention relates to periodic wave generators and, while of general application, it is especially useful in the development of scanning fields of saw-tooth wave form in television systems.

Periodic waves having complex wave forms, such as saw-tooth and related forms, are useful for various purposes. In television systems, for example, at both transmitters and receivers, electrostatic or electromagnetic fields of saw-tooth wave forms are utilized in scanning systems to deflect a beam, such as the cathode ray in a cathode-ray tube system, focused upon a target so as to cause the beam to scan successive fields or series of parallel lines on the target. These fields are produced by applying periodic waves of the desired wave form to field-producing elements.

In general, it is required that generators of the type described be capable of developing waves of the precise desired wave form, in a television system of a form suitable to effect accurate linearity of trace and rapid retrace of the scanning beam. Moreover, it is highly desirable that these generators be readily adjustable for controlling separately the frequency and amplitude of the developed waves. Further characteristics essential to such generators are simplicity of construction and dependability in operation.

It is an object of the present invention, therefore, to provide an improved generator for developing a periodic wave of complex wave form, such as a saw-tooth or related form.

It is a further object of the invention to provide a generator having one or more of the desirable characteristics and features referred to above.

In accordance with the present invention, there is provided a periodic wave generator which comprises a series circuit including inductance means, a normally highly conductive conductance-controlling device and a source of operating voltage. The effective impedance of this circuit comprises substantially only inductance but also contains incidental undesired impedances of other types. There is also provided means responsive to an electrical condition of the series circuit and including auxiliary impedance means having values related in a predetermined manner to those of the undesired impedances for developing a control wave having a plurality of predetermined wave form components. The control wave is utilized by suitable means to so control the conductance-controlling device as periodically and substantially to reduce its conductivity for only a small fraction of each cycle, thereby to develop a current of saw-tooth wave form through the inductance means. Preferably, means are also provided for controlling the source of operating voltage to adjust the amplitude of the periodic wave developed by the generator independently of other characteristics thereof. Suitable means are also preferably provided for controlling the operation of the control-wave-developing means to adjust the frequency of the control wave, thereby to adjust the period of the generated wave independently of other characteristics thereof.

In a preferred embodiment of the invention, auxiliary means responsive to the operating conditions in the series circuit may be provided for developing a control effect. The effect is applied by suitable means to the conductance-controlling device to aid in maintaining at least a portion of the wave form of the generated periodic wave substantially linear.

The term "normally highly conductive" as applied to a vacuum tube or like conductance-controlling device in this application, is used to refer to the characteristic of such conductance-controlling device by which, in its static condition and not energized by a fluctuating signal, it is highly conductive and requires some signal component to render it nonconductive or of low conductivity.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims. In the accompanying drawing, Fig. 1 is a circuit diagram of a periodic wave generator embodying the present invention, while Fig. 2 is a group of curves illustrating the wave forms of various waves developed in the generator of Fig. 1.

Referring now more particularly to Fig. 1 of the drawing, the generator illustrated comprises inductance element **10**, which may be a magnetic scanning element of a television scanning system through which it is desired to produce a current of saw-tooth wave form, as shown, or any suitable portion of a load circuit. The inductance element **10** is included in a main series circuit with a conductance-controlling device, preferably a vacuum tube **11**, which may be a triode, as shown, or a multigrid tube, and a source of operating voltage. The source of voltage includes a battery **12** or other suitable voltage supply means together with an adjustable series resistor 13 and a by-pass shunt condenser 14 of large value. To aid in controlling the linearity of the wave developed by the generator, an adjustable resistor 15 of small value is also included in the series circuit. With this arrangement the effective series resistance of the series circuit at the operating frequency is of a very low value. The effective impedance of the series circuit comprises substantially only the reactance of the inductance element 10, but incidentally includes undesired impedances of other types as will be presently more fully explained.

For the purpose of developing a control wave for the generator, there is provided means responsive to an electrical condition of the series circuit and comprising a feed-back or reversing vacuum tube 16 of the pentode type. The input circuit of the tube 16 is connected across the load circuit of tube 11 by way of a coupling impedance 17, which may comprise an adjustable condenser 17*a*, and an impedance 18 which may include an adjustable leak resistor 18*a* shunted by a condenser 18*b*.

A complex load impedance 19 for the tube 16 is connected between its anode and its source of operating potential, which may be the same as that of the tube 11, as shown. This impedance may include, for example, a resistor 19*a*, a parallel-connected resistor 19*b* and condenser 19*c*, and an inductance element 19*d*, connected in series in the order named. The control grid of the tube 11 is effectively connected across the load impedance 19 by way of a suitable coupling condenser 20 and leak resistor 21. A negative-bias potential is applied to the control grid of the tube 11 by way of the resistor 21 from a suitable source, for example, the battery 12′, while screen potential for tube 16 may be provided from a suitable source indicated at +Sc. The impedance values of the elements of the impedance 19, are related in a predetermined manner to the impedances of the main series circuit so that the control wave developed by the tube 16 is of the proper wave form so to control the tube 11 as periodically to reduce its conductivity to a very low value for a small portion of each cycle, thereby to develop a current wave through the inductance element 10 of saw-tooth wave form. Suitable equivalent circuit arrangements may, of course, be substituted for the impedances 15, 17, 18, and 19. For the purpose of synchronizing the operation of the generator, a synchronizing signal may be applied to the control grid of the tube 16 from a terminal S.

The operation of the generator embodying the present invention, as just described, may be considered as starting at a point where the conductivity of the tube 11 has just been established. Current rises through the winding 10 and the internal resistance of the tube 11. This current rise produces a voltage across the tube 11 and the resultant drop in its anode potential is applied by way of the impedances 17 and 18 to the control grid of the tube 16. The tube 16 is thus cut off during this portion of the cycle of operation, which corresponds to the trace period of the generated periodic current wave through the inductance element 10 which is illustrated by the curve i_{10} of Fig. 2, the trace portion being indicated at *t*.

After a certain period, the rate of rise of current through the winding 10 begins to decrease, due to anode saturation of the tube 11 or to curvature of its mutual-conductance characteristic if a pentode or tetrode type of tube is employed, so that anode potential of tube 11, applied to the control grid of tube 16, increases positively. The latter tube begins to pass current, developing a voltage across its load circuit and the resultant drop in its anode potential is applied by way of condenser 20 and resistor 21 to the control grid of tube 11, serving still further to reduce the current through this tube. Since this action is highly regenerative, the anode current of the tube 11 is rapidly reduced to a low value. The period of this rapid drop in anode current of the tube 11 through the inductance element 10 corresponds to the retrace period of the generated current wave, which is indicated at *r* on the curve i_{10} of Fig. 2. The grid of the tube 11 remains negative, maintaining the conductivity of this tube at a low value, only during the short retrace period just described, after which the grid returns to its normal bias as determined by battery 12′ so that the current again begins to rise through the inductance element 10 and tube 11 and the cycle begins de novo.

During the retrace period, the condenser 17*a* is charged by the flow of grid current of tube 16 and such current as flows through resistor 18*a* and condenser 18*b*. At the end of the retrace period, which is the termination of the positive pulse from tube 11, the charge on condenser 17*a* is, in part, transferred to condenser 18*b* and changes to opposite polarity, that is, with its upper terminal, connected to the grid of tube 16, negative. The rate of change of the potential on the grid of tube 16 during the following trace period is then determined by the time constant of R and C representing, respectively, the values of the resistor 18*a* and condenser 18*b*. This rate of change of grid potential, in turn, determines the periodicity of the control wave developed by tube 11 and, hence, the frequency of the current wave through the inductance 10. Thus, after the first cycle, the periodicity of the generator is controlled by the time constant of the impedance 18, or by the application of synchronizing pulses, and is independent of the saturation characteristics of tube 11. The periodicity of the generated wave thus may be readily adjusted, independently of the other characteristics thereof, by adjustment of the resistor 18*a*. Moreover, by the application of a synchronizing wave to the control grid of the tube 16, so that synchronizing pulses are applied positively thereto just prior to the time that the tube 16 would commence to conduct, the generator may be readily synchronized. It is to be noted that during the normal operation of the generator, while the leading edge of a synchronizing pulse applied to the tube 16 determines the start of the retrace period, the reaching of cutoff by the tube 11, effecting a negative pulse on the grid of the tube 16, determines the beginning of the trace period. Moreover, the condenser 17*a* which couples the output circuit of the tube 11 to the input circuit of the tube 16 functions, in conjunction with the complex grid impedance 18, to differentiate the negative pulses so that the amplitudes of the pulses as applied to the control grid of tube 16 are effectively increased.

The amplitude of the generated wave may be readily controlled and its linearity maintained by means of the arrangement for applying the operating voltage to the tubes 11 and 16, including the elements 13 and 14. These elements are so proportioned as to have a time constant which is very large compared to the period of the generated wave, thereby ensuring a steady potential at the upper end of the resistor 13 throughout a cycle of operation; that is, condenser 14 bypasses the alternating components of the total battery current drawn by tubes 11 and 16. Since the rate of rise in current through the winding 10 is substantially equal to E/L, where L is the inductance of element 10 and E the effective operating potential, the wave form of the current through the winding 10 is substantially linear and adjustment of the operating voltage, by adjustment of the resistor 13, serves to adjust the amplitude of the wave developed by the generator independently of other characteristics thereof, particularly its wave form and periodicity. This circuit is essentially different from various generators of the relaxation type heretofore devised, wherein an adjustable resistor is included in series with the inductance element through which it is desired to produce a saw-tooth current wave in order to adjust the periodicity of the generated wave, since such resistors always cause the wave form of the current to be decidedly exponential in addition to affecting its periodicity.

However, even in the series circuit of the generator of the present invention, there are undesired incidental impedances of other types. In order, therefore, to procure a current of the desired wave form through the inductance 10, the values of elements 19*a*, 19*b*, 19*c*, and 19*d* of the impedance 19 are related in a predetermined manner to those of the various incidental series circuit impedances.

If a current of saw-tooth wave form is to flow through inductance 10, considering it as a pure inductance, and if tube 11 had no internal resistance, a voltage wave of rectangular-pulse form, such as shown by curve 19*a* of Fig. 2, would appear thereacross and it would only be necessary to apply a similar pulse voltage wave to the control grid of tube 11. However, the tube 11 does have appreciable internal resistance and the current therethrough follows approximately the wave form of its input voltage. Further, the incidental undesired impedances in the anode circuit of the tube 11 include not only this resistance of the tube 11 itself but also its shunt capacitance, indicated by the dotted-line condenser C in Fig. 1, as well as the inherent resistance and capacitance of the winding itself. By proper transformation of circuit constants, this main series circuit can be reduced to a simple electrical equivalent of resistance and capacitance in parallel with inductance 10.

Since the flow of a current wave of saw-tooth wave form through the inductance 10 results in a voltage wave of rectangular-pulse wave form thereacross and, since this voltage appears also across the equivalent parallel incidental resistance and capacitance, there results a current of rectangular-pulse wave form through the incidental resistance and a current of double-pulse wave form through the incidental capacitance. The total output current wave of tube 11, therefore, is a complex current wave which is the resultant of the rectangular-pulse, the saw-tooth, and the double-pulse wave form current components. It is essential, therefore, that the control voltage wave applied to the grid of the tube 11, which is developed across the load circuit of the tube 16, be of a corresponding complex wave form and include components corresponding with each of these wave form components. The elements 19*a*, 19*b*, 19*c*, and 19*d* of the complex impedance 19, therefore, are so proportioned relative to the undesired incidental impedances of the main series circuit that such a control wave is developed across the impedance 19. In general, the impedance of the unit 19 is the inverse of that of the equivalent parallel-impedance circuit; that is, in the impedance unit 19 there are included impedance elements corresponding to impedance elements of the equivalent parallel-impedance circuit and so related thereto that the product of the resultant impedances of the two circuits is a constant with respect to frequency. This relation requires that each reactance in the one circuit be represented by a reactance in the other circuit of opposite type and changed in position from shunt to series or vice versa, and the resistance of the one circuit be represented by a conductance and similarly changed in position.

More particularly, the control voltage wave includes first, a primary saw-tooth wave form component, such as is illustrated by the curve e_{19c} of Fig. 2, which produces the desired saw-tooth current wave in the main series circuit including inductance 10. This wave is developed across or derived from the pulse current through condenser 19*c*. To compensate for the resistive components of the main series circuit, that is, to develop a rectangular-pulse current wave through the undesired equivalent parallel resistance, a rectangular-pulse voltage wave form component, such as illustrated by the curve e_{19a} of Fig. 2, is derived from the pulse current through resistor 19*a*. For compensating for the capacitance components of the main series circuit, that is, to develop a double-pulse current through the equivalent parallel capacitance, a voltage component of oppositely-poled double-pulse wave form, such as is illustrated by the curve e_{19d}, is derived from the pulse current through inductance element 19*d*. The composite control voltage wave developed across the impedance 19 is thus of the complex wave form generally illustrated by the curve e_{19} of Fig. 2 and includes the rectangular-pulse, the saw-tooth, and the oppositely-poled double-pulse wave form components, each so related to, or corresponding to, an impedance of the main series circuit that the effects of the undesired parallel equivalent impedance components thereof are compensated and a current of pure saw-tooth wave form is caused to pass through the inductance 10.

The above explanation presupposes that the tube 11 has an infinite internal resistance, that is, no internal conductance. However, the internal resistance of this tube is a finite quantity and its internal series conductance is appreciable and must also be compensated. For this purpose the parallel resistor 19*b* is included in the circuit 19 and constitutes the negative reciprocal of the series conductance of the tube 11, serving to so modify the control wave as to compensate for this undesired internal conductance of the tube.

In certain cases where the compensation is inexact, due to the decrease in the rate of rise of current through the inductance 10 during the latter part of the trace portion of the cycle, the linearity of the current wave tends to be distorted during the trace period. To compensate for this distortion, the negative feed-back resistor 15 is provided. This resistor is adjusted to a suitable relatively small value so that its impedance is not comparable with that of the inductance 10 and, therefore, it does not contribute significantly to the curvature of the current rise therethrough. However, during this current rise a voltage is developed across the resistor 15 and is applied, together with that developed across the impedance 19, to the control grid of the tube 11 and is of such polarity that it constitutes a negative feedback; that is, it introduces degeneration which tends to cancel the distortion caused by the decrease in the rate of current rise through the winding 10 in a conventional manner. While this causes the total amplitude of the generated wave to be less than it otherwise would be, it improves its linearity more than in proportion to this reduction in amplitude. Thus, the dotted portion of the curve i_{10} of Fig. 2 shows the wave form which the current through the winding 10 would have in the absence of the resistor 15, the distorted portion being indicated at *d*.

While the inductance 10, disposed between the terminals indicated at X—X in the drawing, may, as stated, constitute a scanning element of a television scanning system, it will be appreciated that the currents and voltages developed by the generator may be utilized in various other manners. For example, scanning elements may be inductively coupled to the winding 10, or the rectangular-pulse voltage appearing across this element or the saw-tooth voltage appearing across the tube 11 may be readily utilized.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A periodic wave generator comprising, a series circuit including inductance means, a normally highly conductive conductance-controlling device and a source of operating voltage, the effective impedance of said circuit comprising substantially only inductance but incidental undesired impedances of other types, means responsive to an electrical condition of said circuit and including auxiliary impedance means having values related in a predetermined manner to said undesired impedances for developing a control wave having a plurality of predetermined wave form components, means for utilizing said control wave to so control said device as periodically substantially to reduce its conductivity for only a small fraction of each cycle, thereby to develop a current of saw-tooth wave form through said inductance means, means for adjusting said source to adjust the amplitude of said operating voltage thereby to adjust the amplitude of the generated periodic wave independently of other characteristics thereof, and means for adjusting said control-wave-developing means to adjust the frequency of said control wave thereby to adjust the period of the generated wave independently of other characteristics thereof.

2. A periodic wave generator comprising, a series circuit including inductance means, a normally highly conductive conductance-controlling device and a source of operating voltage including an adjustable resistor and a condenser in parallel, having a time constant very large compared to the period of the generated wave, the effective impedance of said series circuit comprising substantially only inductance, means responsive to an electrical condition of said circuit for developing a control wave, means for utilizing said control wave so to control said device as periodically substantially to reduce its conductivity for only a small fraction of each cycle, thereby to develop current of saw-tooth wave form through said inductance means, and means for adjusting said voltage-source resistor to adjust the amplitude of said operating voltage, thereby to adjust the amplitude of said current wave independently of other characteristics thereof.

3. A periodic wave generator comprising, a series circuit including inductance means, a normally highly conductive conductance-controlling device and a source of operating voltage, the effective impedance of said series circuit comprising substantially only inductance, means responsive to an electrical condition of said circuit for developing a control wave, means having a unidirectional transconductance for so applying said control wave to said device as periodically substantially to reduce its conductivity for only a small fraction of each cycle, thereby to develop current of saw-tooth wave form through said inductance means, and means for adjusting the time constant of said control-wave-developing means to adjust the period of the generated periodic wave independently of other characteristics thereof.

4. A periodic wave generator comprising, a series circuit including inductance means, a normally highly conductive conductance-controlling device and a source of operating voltage, the effective impedance of said series circuit comprising substantially only inductance, a control circuit comprising a vacuum-tube repeater having an adjustable time-constant input circuit and an output circuit for developing a control wave, means for deriving a voltage from said series circuit and applying it to said input circuit, means coupling said output circuit to said device for applying said control wave thereto so to control said device as periodically substantially to reduce its conductivity for only a small fraction of each cycle, thereby to develop a current of saw-tooth wave form through said inductance means, and means for adjusting the time constant of said input circuit to adjust the frequency of said control wave, thereby to adjust the period of the generated periodic wave independently of other characteristics thereof.

5. A periodic wave generator comprising, a series circuit including inductance means, a normally highly conductive conductance-controlling device and a source of operating voltage, the effective impedance of said series circuit comprising substantially only inductance, a control circuit comprising a vacuum-tube repeater having an input circuit including an adjustable grid-leak resistor shunted by a condenser and an output circuit for developing a control wave, means for deriving a voltage from said series circuit and applying it to said input circuit, means coupling said output circuit to said controlling device for applying said control wave thereto so to control said device as periodically substantially to reduce its conductivity for only a small fraction of each cycle, thereby to develop a current of saw-tooth wave form through said inductance means, and means for adjusting said input circuit resistor to adjust the frequency of said control wave, thereby to adjust the period of the generated periodic

wave independently of other characteristics thereof.

6. A periodic wave generator comprising, a series circuit including inductance means, a normally highly conductive conductance-controlling device and a source of operating voltage, the effective impedance of said circuit comprising substantially only inductance, means responsive to an electrical condition of said circuit for developing a control wave, means for utilizing said control wave so to control said device as periodically substantially to reduce its conductivity for only a small fraction of each cycle, thereby to develop a current of saw-tooth wave form through said inductance means, and means for adjusting the amplitude of said operating voltage to adjust the amplitude of said current wave independently of other characteristics thereof.

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