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SAW-TOOTH WAVE GENERATOR

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FIG. 1.

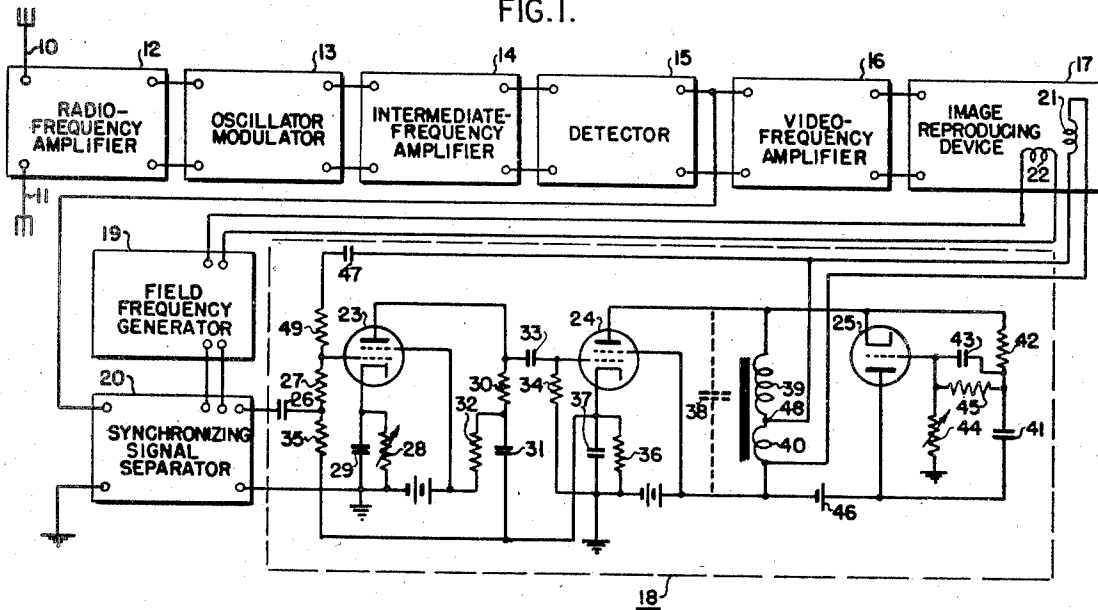
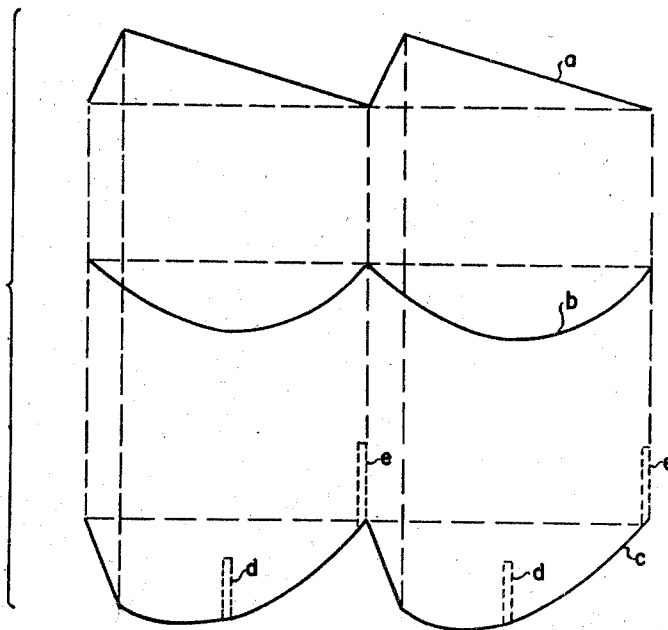


FIG. 2.



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## SAW-TOOTH WAVE GENERATOR

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Application October 25, 1939, Serial No. 301,103

8 Claims. (Cl. 250—36)

This invention relates to periodic wave generators and particularly to periodic saw-tooth wave generators for developing an output, the wave form of which has relatively long trace and relatively short retrace intervals. While the invention is of general utility, it is particularly useful as a scanning wave generator for a television signal receiver. The invention also is of particular utility in a periodic wave repeater adapted to be excited by periodic pulses, such as in a frequency divider where undesired other pulses may occur during the trace interval and only a certain periodic pulse is intended to control the excitation.

For some purposes, it is necessary to develop a current of saw-tooth wave form having relatively long trace and relatively short retrace intervals. In a television receiver of the type which utilizes a cathode-ray signal-reproducing tube with magnetic scanning, this current is delivered to a scanning inductor for deflection of the cathode-ray beam. Certain generators for providing such a saw-tooth current include an oscillator, the natural period of which is slightly greater than the period of the desired wave, together with a source of synchronizing signals for synchronizing the oscillator. A periodic wave generator of this type is disclosed in applicant's copending application Serial No. 256,033, filed February 13, 1939.

Periodic wave repeaters in such generators, adapted to be excited by periodic pulses, may have an undesirable characteristic in that undesired other pulses present with the desired pulses tend to affect the operation of the repeater and this particularly is true if they have an amplitude comparable with that of the desired pulses. For example, in submultiple-frequency generators or frequency dividers, such as those commonly used in the timing system of television transmitting apparatus, it often is desirable to effect synchronization by only particular ones of the pulses from a source of periodic synchronizing signals, it being particularly desirable that the apparatus be insensitive to the other pulses. A periodic wave repeater concerned with this problem is disclosed in applicant's copending application Serial No. 264,935, filed March 30, 1939.

It is often desirable in a saw-tooth wave generator that the period of the generated wave be critically determined and, therefore, stable in a free-running condition. Also, as pointed out above, it is usually desirable that the generator or oscillator be insensitive to undesired noise or synchronizing pulses other than the synchronizing pulse which occurs at the initiation of the retrace and thereupon trips the oscillator. The former desirable feature is present in an insufficient degree in the usual self-oscillating systems, while the latter feature is subject to improvement in the usual repeater systems in which periodic

synchronizing pulses are applied to an oscillator. It is known in the prior art how to desensitize a vacuum tube of the generator during the major part of a cycle to prevent disturbance by undesired pulses such as static or intermediate pulses occurring during the trace interval. The prior art includes arrangements for feeding back saw-tooth voltages for this purpose, but they are not completely satisfactory in some cases because their desensitizing action is maximum only at the beginning of the trace interval.

It is an object of the present invention, therefore, to provide an improved periodic wave generator for developing an output of saw-tooth wave form with relatively long and preferably linear trace intervals and relatively short retrace intervals, which overcomes one or more of the above-mentioned disadvantages of the arrangements of the prior art.

It is still a further object of the invention to provide an improved saw-tooth wave generator, the period of which is critically determined and therefore stable in a free-running condition.

It is another object of the invention to provide an improved periodic wave repeater or generator which is adapted to be excited or synchronized by periodic pulses applied thereto and which is insensitive to pulses other than the synchronizing pulse which determines the period of the generated wave.

In accordance with the invention, a periodic wave generator, for developing an output of saw-tooth wave form with relatively long trace and relatively short retrace intervals, broadly comprises an input circuit adapted to be connected to a source of periodic pulses synchronous with the desired output wave and incidentally subject to undesired other pulses, a vacuum-tube repeater coupled to said input circuit for developing said output wave, means for deriving from the periodic pulses a periodic wave, the form of which provides a maximum rate of change in one sense at the beginning of each trace interval and progressively varies to a maximum rate of change in the opposite sense at the end of each trace interval, and means for applying said periodic wave to said input circuit with such polarity that it does not reduce the effectiveness of said periodic pulses on said repeater but does reduce the effectiveness of said other pulses on said repeater. The derived wave preferably is a parabolic voltage wave which operates either to stabilize the running frequency of the generator or to protect it against interference over the major portion of its cycle, or both. The running frequency of the generator or oscillator is made more stable by causing the oscillator to trip itself more abruptly at the end of the trace interval.

In a preferred embodiment of the invention, the periodic wave generator includes integrating

means coupled to the input circuit for deriving a saw-tooth voltage from the periodic pulses, means including integrating means for deriving a saw-tooth output current from the periodic pulses, integrating means for deriving a parabolic voltage from the saw-tooth current, and means for applying both the saw-tooth and parabolic voltages to the input circuit with such polarity that they do not reduce the effectiveness of the periodic pulses on the first-named integrating means but do reduce the effectiveness of undesired other pulses on the first-named integrating means by a maximum amount during the initial portion of the trace interval.

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 drawing, Fig. 1 is a circuit diagram, partly schematic, of a complete modulated-carrier television-signal receiver embodying one form of the invention as a line-frequency scanning generator while Fig. 2 comprises graphs illustrating certain of the operating characteristics of the system of Fig. 1.

Referring now more particularly to the drawing, the system illustrated in Fig. 1 comprises a modulated-carrier television-signal receiver of the superheterodyne type including an antenna system 10, 11 connected to a radio-frequency amplifier 12 to which are connected in cascade, in the order named, an oscillator-modulator 13, an intermediate-frequency amplifier 14, a detector 15, a video-frequency amplifier 16, and an image-reproducing device 17. A line-frequency generator 18 and a field-frequency generator 19 are coupled to the output circuit of the detector 15 through a synchronizing-signal separator and processor 20, the line-frequency generator 18 being coupled to a line-scanning winding 21 of image-reproducing device 17 and the output of the field-frequency generator 19 being coupled to a field-scanning winding 22 of image-reproducing device 17 in a conventional manner. The stages or units 10-17, inclusive, 19, and 20 all may be of conventional well-known construction so that detailed illustrations and descriptions thereof are unnecessary herein.

Referring briefly, however, to the operation of the above-described system as a whole, television signals intercepted by antenna circuit 10, 11 are selected and amplified in radio-frequency amplifier 12 and coupled to the oscillator-modulator 13, wherein they are converted into intermediate-frequency signals which, in turn, are selectively amplified in the intermediate-frequency amplifier 14 and delivered to detector 15. The modulation components of the signals are derived by the detector 15 and are supplied to the video-frequency amplifier 16, wherein they are amplified and from which they are supplied in the usual manner to a brightness-control electrode of the image-reproducing device 17. The modulation components are also supplied to the synchronizing-control circuits of generators 18 and 19 through separator 20 which separates the line-frequency and field-frequency components from the video-signal components and from each other. The intensity of the scanning beam of the device 17 is modulated or controlled in accordance with the video-frequency voltages impressed upon its brightness-control electrode in the usual manner. Scanning waves are gener-

ated by the line-frequency and field-frequency generators 18 and 19, respectively, which are synchronized by the output of synchronizing-signal separator and processor 20 and applied to the scanning elements of the image-reproducing device to produce electric scanning fields, thereby to deflect the scanning beam in two directions normal to each other so as to trace a rectilinear scanning pattern on the screen and thereby reconstruct the transmitted image.

Referring now more particularly to the portion of Fig. 1 embodying the present invention, there is provided an improved periodic wave generator 18 for developing an output current of saw-tooth wave form with relatively long substantially linear trace and relatively short retrace intervals. The generator 18 is essentially an oscillator which can be synchronized with a relatively weak pulse of short duration derived from unit 20 at the beginning of the retrace interval. The generator 18 comprises an input vacuum tube 23, an output vacuum tube 24 and an efficiency triode 25. The tube 23 is utilized as a driver tube for deriving the required input wave form for controlling the output tube 24 and its control electrode is coupled to the synchronizing-signal separator and processor unit 20 through the generator input circuit comprising a blocking condenser 26 and leak resistor 27. The tube 23 is normally biased substantially to cutoff by an adjustable cathode-bias circuit comprising a resistor 28 shunted by a condenser 29, the time constant of which has a major influence on, and preferably is of the same order of magnitude as, the period of the generated wave.

In order to develop an input voltage of the required wave form for the tube 24, there is provided a wave-shaping circuit comprising a series-connected resistor 30 and condenser 31 connected in the anode circuit of tube 23. Condenser 31 is shunted by a resistor 32 to carry the unidirectional component of the space current of tube 23, that is, to charge the condenser 31 steadily during the trace intervals to produce a saw-tooth voltage component thereacross. The resultant voltage across resistor 30 and condenser 31 is applied to the control electrode of tube 24 by means of a coupling condenser 33 and a grid-leak resistor 34. Thus, the vacuum-tube repeater 24 is coupled through tube 23 to the generator input circuit comprising the condenser 26 and resistor 27.

The output tube 24 is preferably a high-mu tube and includes some means for suppressing secondary emission from its anode, a beam type of tube being assumed for this purpose in Fig. 1. A bias for the tube 24 is obtained by a cathode-bias resistor 36 shunted by a condenser 37 which, in the absence of the present invention, would be merely a by-pass condenser. The periodic voltage across condenser 37 is applied to the control electrode of the driver tube 23 by a circuit including the resistor 35 and the resistor 27 in series.

The anode circuits of the high-mu output tube 24 and the efficiency tube 25, preferably a low-mu tube, are coupled, as shown, with opposite polarities to the load circuit of the system. The common output circuit of tubes 24 and 25 includes a parallel-resonant circuit comprising shunt capacitance 38, shown in dotted lines for the reason that it may be comprised in whole or in part of the inherent capacitance of the circuit, and the load inductance of scanning coil 21, coupled into the tuned circuit by means of a step-down trans-

former comprising inductively-coupled primary and secondary windings 39 and 40, respectively, for converting the relatively small inductance of scanning coil 21 to the larger inductance required in the output circuit of the system. The effective inductance of the resonant output circuit of tubes 24 and 25 is thus that of the transformer windings 39 and 40 as measured with the scanning coil 21 connected across the winding 40.

A condenser 41 is connected in series with a resistor 42 directly across the load circuit, the voltage across resistor 42 being applied to the control electrode of the tube 25 through a condenser 43 and voltage-divider resistors 44 and 45. The initial grid bias on the inverted tube 25 is determined by the ratio of resistors 42, 44, and 45. An additional direct current source 46 may be needed in the plate circuit of the tube 25.

The generator 18 is provided with a feed-back circuit comprising a direct current blocking condenser 47 coupled between the common terminal 48 of the transformer windings 39 and 40 and the control electrode of tube 23 through a resistor 49. The values of resistors 27 and 35, which are coupled across the input circuit of tube 23 together with that of resistor 49, determine the relative amount of feedback and the coupling from the synchronizing separator unit 20 to the control electrode of tube 23. The scanning coil 21 is coupled to the transformer winding 40, as pointed out above, and suitable sources of unidirectional voltage are provided for tubes 23, 24, and 25, as indicated by the several batteries in Fig. 1 of the drawing.

In considering the operation of the periodic saw-tooth wave generator 18, neglecting for the moment the particular features of operation which characterize the present invention and assuming a fraction of the pulse voltage appearing across the load circuit is returned to the control electrode of driver tube 23 by feed-back path including condenser 47 and resistor 49, at the same time a pulse is received from unit 20, these components are sufficient to overcome the cutoff bias of tube 23 and the resultant pulse current which flows in the anode circuit of the tube 23 charges the cathode condenser 29. The subsequent discharging of the cathode condenser 29 through resistor 28 develops a saw-tooth voltage *a*, Fig. 2, in the cathode circuit of the driver tube 23. The output pulse current of the tube 23 develops a pulse voltage across resistor 30 and a saw-tooth voltage across condenser 31, the resultant of which is applied to the control electrode of the output tube 24 to develop an output current of saw-tooth plus pulse wave form. Thus, the condenser 31 and resistor 32 comprise integrating means coupled to the input circuit of tube 24 for deriving in the output circuit thereof a saw-tooth current from the periodic input pulses from unit 20, this saw-tooth current being synchronous both with the pulses applied to the input circuit of tube 23 and with the pulses developed in the output circuit thereof. The circuit constants are so proportioned that the pulse voltage applied to the control electrode of tube 24 is sufficient to drive the tube 24 to cutoff during the retrace interval. The saw-tooth component of current flowing in the cathode circuit of the tube 24 develops a parabolic voltage wave *b* across the cathode resistor 36 and condenser 37. At the beginning of the retrace interval, load inductance 21 is carrying maximum current which is diverted to flow through the capacitance 38 because that is the only remaining current

path, the high- $\mu$  tube 24 being biased beyond cutoff and the low- $\mu$  tube 25 being connected with opposite polarity so that it is nonconductive to this current. The energy of the current in inductance 21 is transferred to capacitance 38, the circuit completing a portion of a cycle of free oscillation and building up a reverse current in inductance 21 to a value nearly equal to its previous maximum value.

As the voltage across the load circuit reverses during the retrace interval, the low- $\mu$  tube 25 becomes conductive to carry the reverse current of load inductance 21 and thereby prevents the building up of a substantial reverse voltage across the load circuit and any substantial reverse charging of the capacitance 38. The output current of tube 25 commences to build up in value at the end of the retrace interval, that is, at the end of the pulse from tube 23 which operated the high- $\mu$  tube 24 beyond its cutoff point. The current then gradually rises in tube 24 during the succeeding trace interval, the rate of change of current in its output circuit being determined primarily by the wave form of the voltage on its control electrode, and at the same time the current gradually falls in tube 25 as the voltage across the load circuit reverses polarity as the current builds up in the load circuit. In addition, the voltage on control electrode of tube 25 derived from circuit 41, 42 keeps it near cutoff except during the positive pulse developed in the retrace interval.

By adjusting the value of resistor 28 the frequency of the generator may be changed substantially independently of its other characteristics. The amplitude of the saw-tooth output current of the generator may be controlled substantially independently of its other characteristics by adjusting the unidirectional voltages supplied to the tubes, preferably simultaneously.

The input circuit comprising the condenser 26 and resistor 27 is adapted to be connected to the source 20 of periodic pulses synchronous with the desired output wave and incidentally subject to excitation by undesired other pulses. The particular features of operation which characterize the present invention reside in deriving from selected ones of the periodic pulses supplied to the input circuit of the generator a periodic parabolic voltage, the wave form of which provides a maximum rate of change in one sense at the beginning of each trace interval, and progressively varies to a maximum rate of change in the opposite sense at the end of each trace interval, and applying such periodic voltage to the input circuit with such polarity that it does not reduce the effectiveness of the selected pulses but does reduce the effectiveness of pulses other than said selected pulses, which undesired other pulses may include undesired transients and may occur between said selected pulses. The current flowing in the cathode circuit of tube 24 has a saw-tooth component from which the condenser 37 derives a parabolic voltage *b* which appears across the cathode resistor 36 and the condenser 37. Thus, the condenser 37 and resistor 36 comprise integrating means for deriving a parabolic voltage from the saw-tooth current of tube 24 or, expressed in another way, comprise means for deriving from the periodic pulses of unit 20 a periodic wave the form of which provides a maximum rate of change in one sense at the beginning of each trace interval and progressively varies to a maximum rate of change in an opposite sense at the

end of each trace interval. The grid return of the input tube 23 includes the cathode-bias circuit of the output tube 24 so that the parabolic voltage *b* is applied negatively to the control electrode of tube 23. Since the parabolic voltage *b* has a maximum value during the middle portion of the trace interval, the tube 23 is thus immunized against the disturbing influences of equalizing pulses *d*, Fig. 2, or other undesired pulses or transients during the middle portion of the trace interval. Thus, the resistor 35 comprises means for applying the periodic parabolic wave to the input circuit comprising the condenser 26 and resistor 27 with such polarity that it does not reduce the effectiveness of selected periodic pulses from unit 20 on the vacuum-tube repeater 24 but does reduce the effectiveness of undesired other pulses on the repeater.

Since the time constant of resistor 28 and condenser 29 in the cathode circuit of the tube 23 is of the same order of magnitude as the period of the generator, the output pulse current of the tube 23 periodically charges the condenser 29 during the retrace interval, condenser 29 partially discharging through the resistor 28 during the trace interval. This produces a saw-tooth voltage component *a*. The condenser 29 and resistor 28 thus comprise integrating means coupled to the input circuit for deriving a saw-tooth voltage from the periodic input pulses from unit 20. The third curve *c* of Fig. 2 is the algebraic sum of the saw-tooth voltage *a* and parabolic voltage *b* and is the net voltage of the control electrode of the tube 23 relative to its cathode during free-running operation.

It is seen that the voltage wave *c* is effective to desensitize the tube 23 during the major part of the cycle. It has the greatest effect in the middle of the cycle when equalizing pulses *d* may appear in the synchronizing signal. It also desensitizes the system to noise or transient pulses during the major part of the cycle. This function is particularly useful in a frequency divider, where several pulses, such as *d* and *e*, may occur regularly during the trace period and only the pulse *e* is intended to trip the generator.

As pointed out above, the arrangements of the prior art for feeding back a saw-tooth voltage alone for this purpose are also inadequate to provide a stable free-running generator since the feed-back wave has a maximum slope only at the beginning of the trace period and a gradual slope at the end of the trace period when the generator must be tripped. The parabolic voltage wave *b* of the present invention is ideal for such purpose because it has a maximum slope just at the point where it is desired to trip the generator. Also, in the case of a driven generator, the slope of the feed-back wave is a maximum at the point at which the generator should be sensitive to the synchronizing pulse. There is no problem of resonating a tuned circuit or any other adjustment in order to develop the voltage wave *b* because it is derived from an aperiodic circuit including resistor 36 and condenser 37 and, therefore, is inherently in synchronism with the generator.

The dotted pulses *d* and *e*, as shown in Fig. 2 in connection with the voltage wave *c*, illustrate the behavior of the present system toward equalizing pulses *d* which occur in the middle of the cycle as well as toward the desired synchronizing pulses *e* which occur at the end of the cycle. The equalizing pulses *d* are prevented by

the feed-back wave *c* from effecting operation of the system.

Thus, the broad aspect of the invention involves developing a voltage wave which has a broad extreme value near the middle of the trace interval and progressively varies toward an opposite extreme value at the end of the trace interval, and utilizing said voltage wave to stabilize the free-running frequency of the saw-tooth wave generator and to desensitize it against disturbing pulses over the major part of the cycle. The free-running frequency of the periodic wave generator is made more stable by the generator being caused to trip itself more abruptly at the end of the trace interval in the absence of synchronizing pulses. By combining the parabolic wave with a saw-tooth wave, the generator is made less sensitive to disturbing pulses occurring during the initial portion of the trace period.

The following circuit constants are given as illustrative of values of circuit elements which may be utilized in the circuit of Fig. 1:

|                                             |                             |    |
|---------------------------------------------|-----------------------------|----|
| Inductance 21.....                          | 1 millihenry                | 25 |
| Tube 23.....                                | Type 6J5G                   |    |
| Tube 24.....                                | Type 6L6G                   |    |
| Tube 25.....                                | Type 45                     |    |
| Resistor 27.....                            | 50 kilohms                  |    |
| Condenser 29.....                           | 0.005 microfarad            | 30 |
| Resistor 30.....                            | 10 kilohms                  |    |
| Condenser 31.....                           | 750 micro-microfarads       |    |
| Resistor 32.....                            | 0.25 megohm                 |    |
| Condenser 33.....                           | 0.001 microfarad            |    |
| Resistor 35.....                            | 10 kilohms                  | 35 |
| Resistor 36.....                            | 370 ohms                    |    |
| Condenser 37.....                           | 0.1 microfarad              |    |
| Capacitance 38.....                         | About 100 micro-microfarads |    |
| Winding 39.....                             | 420 turns                   |    |
| Winding 40.....                             | 70 turns                    | 40 |
| Condenser 41.....                           | 150 micro-microfarads       |    |
| Resistor 42.....                            | 1 megohm                    |    |
| Condenser 43.....                           | 0.001 microfarad            |    |
| Resistor 44.....                            | 5 megohms                   |    |
| Resistor 45.....                            | 2 megohms                   | 45 |
| Source 46.....                              | 40 volts                    |    |
| Resistor 49.....                            | 0.1 megohm                  |    |
| Ratio of retrace period to line period..... | 0.12                        |    |
| Pulses from source 20.....                  | 10 volts positive           |    |

While the invention has been illustrated as applied only in the line-frequency generator of the receiver, it will be understood that the circuit of the field-frequency generator may also incorporate a circuit in accordance with the invention.

While there has been described what is at present considered to be the preferred embodiment 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 for developing an output of saw-tooth wave form with relatively long trace and relatively short retrace intervals comprising, an input circuit adapted to be connected to a source of periodic pulses synchronous with the desired output wave and incidentally subject to excitation by undesired other pulses, a vacuum-tube repeater coupled to said input circuit for developing said output wave, means for deriving from said periodic pulses a

periodic wave, the form of which provides a maximum rate of change in one sense at the beginning of each trace interval and progressively varies to a maximum rate of change in an opposite sense at the end of each trace interval, and means for applying said periodic wave to said input circuit with such polarity that it does not reduce the effectiveness of said periodic pulses on said repeater but does reduce the effectiveness of said other pulses on said repeater.

2. A periodic wave generator for developing an output of saw-tooth wave form with relatively long trace and relatively short retrace intervals comprising, an input circuit adapted to be connected to a source of periodic pulses synchronous with the desired output wave and incidentally subject to excitation by undesired other pulses, a vacuum-tube repeater coupled to said input circuit for developing said output wave, means for deriving from said periodic pulses a parabolic voltage, and means for applying said parabolic voltage to said input circuit with such polarity that it does not reduce the effectiveness of said periodic pulses on said repeater but does reduce the effectiveness of said other pulses on said repeater.

3. A periodic wave generator for developing an output of saw-tooth wave form with relatively long trace and relatively short retrace intervals comprising, an input circuit adapted to be connected to a source of periodic pulses synchronous with the desired output wave and incidentally subject to excitation by undesired other pulses, integrating means coupled to said input circuit for deriving a saw-tooth current from said periodic pulses, integrating means for deriving a parabolic voltage from said saw-tooth current, and means for applying said parabolic voltage to said input circuit with such polarity that it does not reduce the effectiveness of said periodic pulses on said first-named integrating means but does reduce the effectiveness of said other pulses on said first-named integrating means.

4. A periodic wave generator for developing an output current of saw-tooth wave form with relatively long trace and relatively short retrace intervals comprising, an input circuit adapted to be connected to a source of periodic pulses synchronous with the desired output current wave and incidentally subject to excitation by undesired other pulses, integrating means coupled to said input circuit for deriving said saw-tooth output current from said periodic pulses, integrating means for deriving a parabolic voltage from said saw-tooth output current, and means for applying said parabolic voltage to said input circuit with such polarity that it does not reduce the effectiveness of said periodic pulses on said first-named integrating means but does reduce the effectiveness of said other pulses on said first-named integrating means.

5. A periodic wave generator for developing an output of saw-tooth wave form with relatively long trace and relatively short retrace intervals comprising, a vacuum tube having a control electrode and an anode circuit, means for normally biasing said tube substantially to cut off, means for developing in said anode circuit periodic pulses of current synchronous with the desired output wave and incidentally tending to develop other pulses, integrating means for deriving a saw-tooth current from said periodic pulses, integrating means for deriving a parabolic

voltage from said saw-tooth current, and means for applying said parabolic voltage to said control electrode with such amplitude and polarity as to reinforce said cutoff bias primarily in the interval between said periodic current pulses in said anode circuit.

6. A periodic wave generator for developing an output of saw-tooth wave form with relatively long trace and relatively short retrace intervals comprising, an input circuit adapted to be connected to a source of periodic pulses synchronous with the desired output wave and incidentally subject to excitation by undesired other pulses, a load circuit, integrating means coupled to said input circuit and a vacuum tube repeater and an efficiency triode coupled to said load circuit with reverse polarity for deriving a saw-tooth current from said periodic pulses, integrating means for deriving a parabolic voltage from said saw-tooth current, and means for applying said parabolic voltage to said input circuit with such polarity that it does not reduce the effectiveness of said periodic pulses on said first-named integrating means but does reduce the effectiveness of said other pulses on said first-named integrating means.

7. A periodic wave generator for developing an output current of saw-tooth wave form with relatively long trace and relatively short retrace intervals comprising, an input vacuum tube having a control electrode and an anode circuit, means for normally biasing said tube substantially to cutoff, an output vacuum tube having a control electrode and a cathode circuit, means for developing in said anode circuit periodic pulses of current synchronous with the desired output current wave and incidentally tending to develop undesired other pulses, means including a condenser for coupling said anode circuit to said output tube control electrode for deriving from said periodic pulses a saw-tooth voltage for developing the desired saw-tooth current in said cathode circuit, a condenser in said cathode circuit for deriving from said saw-tooth current a parabolic voltage, and means for applying said parabolic voltage to said input tube control electrode with such amplitude and polarity as to reinforce said cutoff bias primarily in the interval between said periodic current pulses in said anode circuit.

8. A periodic wave generator for developing an output of saw-tooth wave form with relatively long trace and relatively short retrace intervals comprising, an input circuit adapted to be connected to a source of periodic pulses synchronous with the desired output wave and incidentally subject to excitation by undesired other pulses, integrating means coupled to said input circuit for deriving a saw-tooth voltage from said periodic pulses, means including integrating means for deriving a saw-tooth current from said periodic pulses, integrating means for deriving a parabolic voltage from said saw-tooth current, and means for applying both said saw-tooth and parabolic voltages to said input circuit with such relative polarities that they do not reduce the effectiveness of said periodic pulses on said first-named integrating means but do reduce the effectiveness of said other pulses on said first-named integrating means by a maximum amount during the initial portion of the trace interval.

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