Dec. 20, 1949 D. E. SUNSTEIN 2,492,018

SYNCHRONIZING SYSTEM FOR SAW TOOTH WAVE GENERATORS

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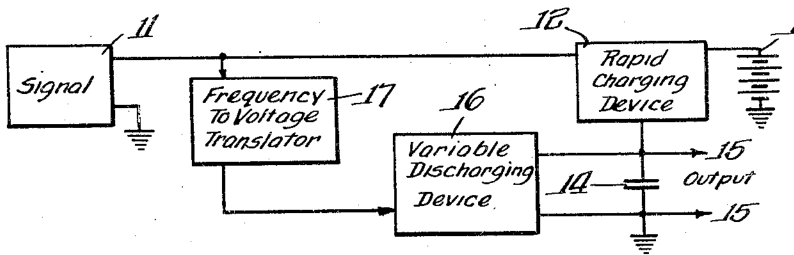

Fig. 1.

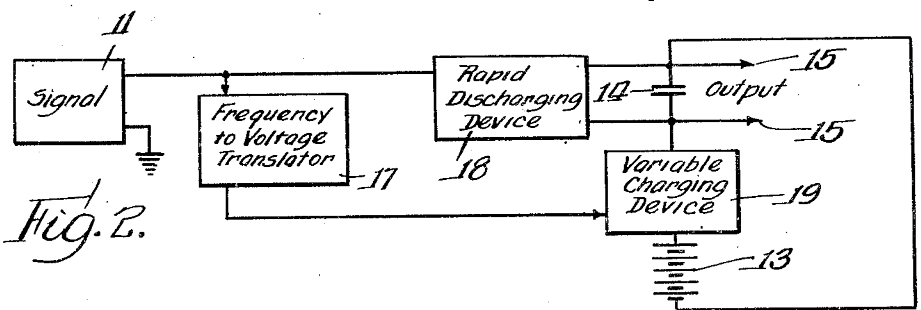

Fig. 2.

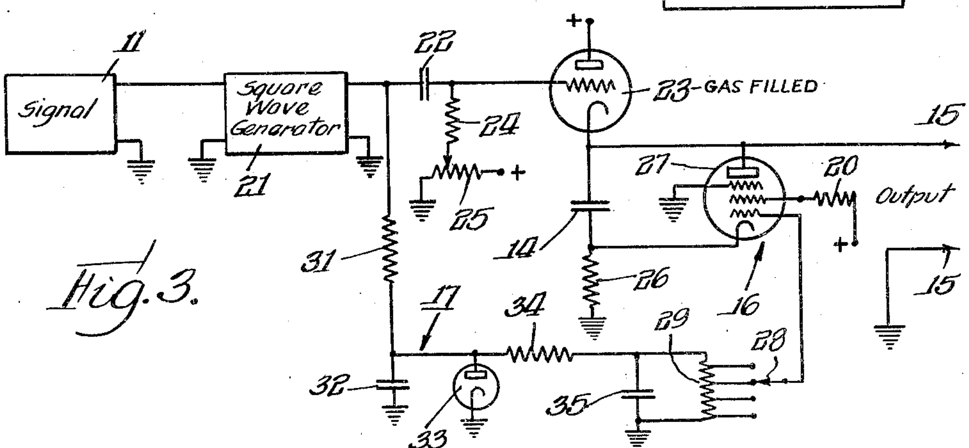

Fig. 3.

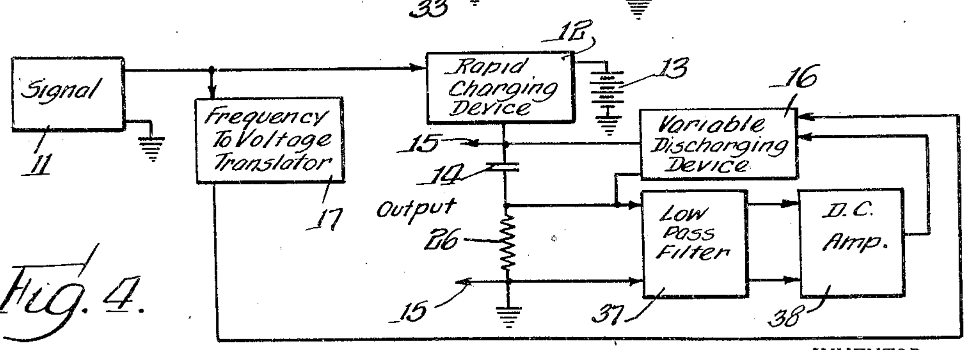

Fig. 4.

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Fig. 5.

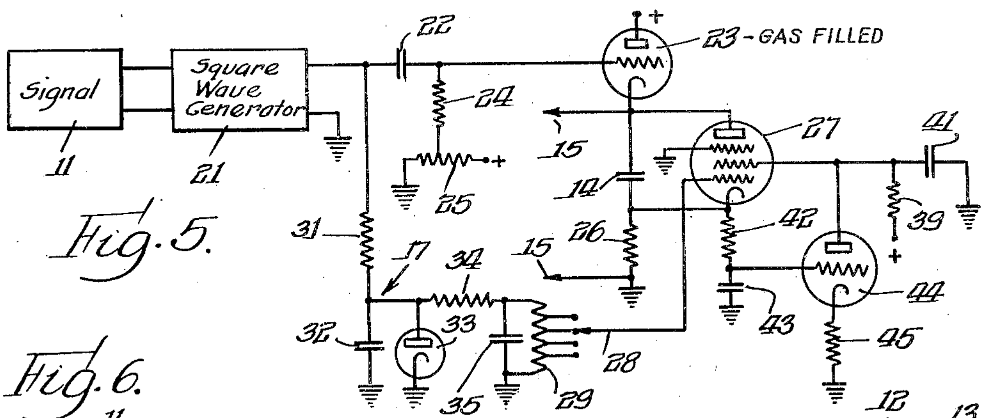


Fig. 6.

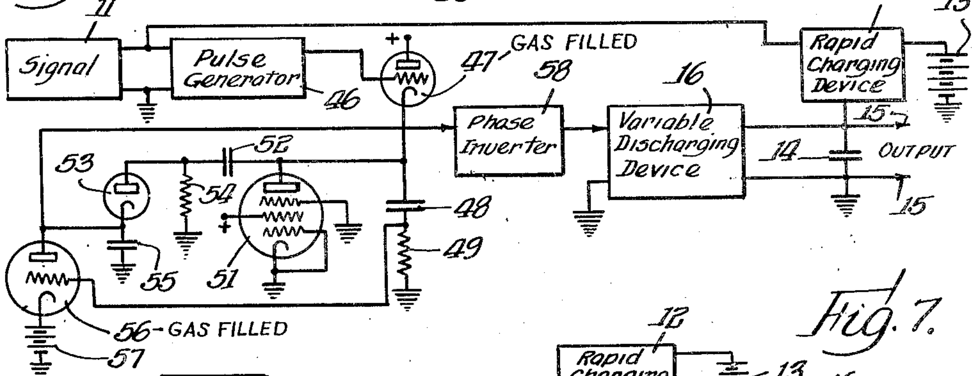


Fig. 7.

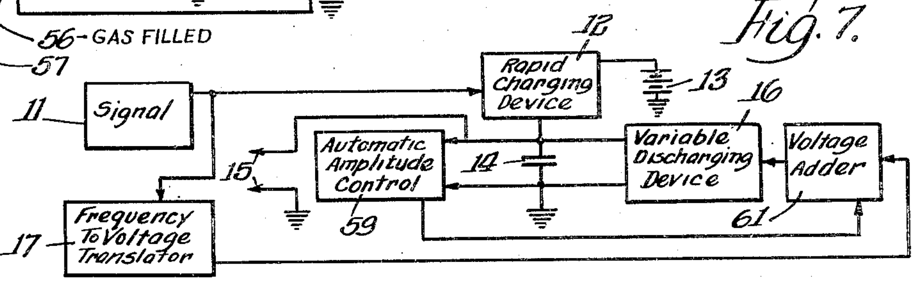
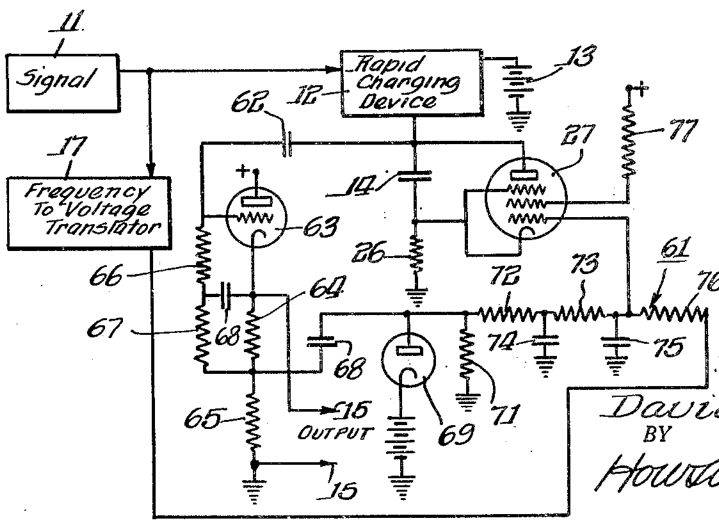


Fig. 8.



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Patented Dec. 20, 1949 2,492,018

UNITED STATES PATENT OFFICE

2,492,018

SYNCHRONIZING SYSTEM FOR SAW-TOOTH WAVE GENERATORS

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Application November 11, 1944, Serial No. 563,027

5 Claims. (Cl. 250—36)

The present invention relates to an automatically synchronized saw tooth generator and more particularly to such generator for use as a time axis generator or sweep control for an oscilloscope. For certain applications of the oscilloscope the saw tooth generator is of the type which is synchronized with another operation as in the case of television systems, vibration, acoustic, and speech investigations and studies. Where synchronization is to occur in response to a variable frequency input, generally it has been necessary to provide a number of manual controls to adjust the operation of the saw tooth generator. Considerable skill is required in adjusting such manual controls, which may be rather large in number, in order to provide the desired operation. It, therefore, would be desirable to provide a saw tooth generator which would be synchronized automatically to the variations in frequency of the initiating voltage, and which has a wide range of operation over the desired band of frequencies and which provides a saw tooth wave having an amplitude substantially independent of the frequency.

In accordance with the present invention a saw tooth generator is provided with a frequency-to-voltage translator responding to the control of input frequency which is used to control the rate of operation of an either variable discharging device or a variable charging device for an energy storage circuit. The frequency-to-voltage translator responds to the change in frequency to modify the operation of the charging or discharging device so that the saw tooth wave is maintained at substantially constant amplitude throughout the range of operation over a band of frequencies.

The frequency-to-voltage translator controls the rate of charging or discharging of the capacitor or energy storage circuit on the basis of several preceding cycles of the input control frequency. If it is desired to have an extremely rapid rate of response to the change of the rate of the input frequency, the frequency-to-voltage translator may be modified to measure the period of one previous cycle and to control the charging or discharging on that basis. Such an arrangement may also be combined with an automatic amplitude control responsive to the amplitude of the output of the saw tooth wave which in conjunction with the frequency-to-voltage translator operates to control the charging or discharging circuit for the capacitor.

It, therefore, is an object of the present invention to provide an improved timing axis generator for an oscilloscope which will provide an output wave or signal of substantially constant amplitude independently of the frequency of operation.

Another object of the present invention is to

provide an improved saw tooth generator which is automatically synchronized with a varying frequency control signal, such as speech, music, or the like.

Still another object of the present invention is to provide an improved circuit which may be used as a frequency divider.

Other and further objects of the present invention subsequently will become apparent from the following description taken in connection with the accompanying drawings in which

Figure 1 is a block diagram of one embodiment of the present invention;

Figure 2 is a block diagram of another embodiment of the present invention;

Figure 3 is the embodiment shown in Figure 1 illustrating certain circuit details;

Figure 4 is a block diagram of still another embodiment similar to that shown in Figure 1;

Figure 5 shows certain details of the embodiment of Figure 4;

Figure 6 is a diagram of an embodiment having a more rapid rate of response to frequency change;

Figure 7 is a block diagram of still another embodiment; and

Figure 8 is a diagram showing certain circuit details of the embodiment of Figure 7.

The block diagram in Figure 1 shows a source of signal energy 11 arranged to control the operation of a rapid charging device 12 having a suitable source of energy such as the battery 13. The rapid charging device supplies energy to an energy storage circuit in the form of a capacitor 14 which is connected to a pair of output terminals 15. The source of energy 13 and the capacitor 14 are each connected to ground. The capacitor 14 is discharged by a variable discharging device 16 the rate of operation of which is controlled by a frequency-to-voltage translator 17, receiving energy from the signal source 11. In this circuit arrangement the capacitor 14 is rapidly charged to a certain voltage value by the rapid charging device 12. Upon reaching this predetermined value the variable discharging device 16 reduces the charge across the capacitor 14 to a predetermined value in a certain time interval. The time interval is determined by the rate of operation of the variable discharging device 16 which is controlled by the frequency-to-voltage translator 17. The variable discharging device 16 preferably is of a type which discharges the capacitor at a constant rate for any given value of the rate of discharge as determined by the action of the frequency-to-voltage translator 17. When the capacitor 14 has been discharged or partially discharged the cycle is repeated. This operation produces a saw tooth output voltage across the terminals 15 having a steep or substantially perpendicular wave front followed by a substantially linear wave form to give one saw tooth impulse. For each constant frequency of the signal generator 11 the same type of wave is obtained at the output terminals.

Another method of obtaining a saw tooth wave is shown by the block diagram of Figure 2 where parts corresponding to those shown in Figure 1 have been given similar reference characters. The capacitor 14 is connected to a rapid discharging device 18 which rapidly dissipates the charge across the capacitor 14 so that the discharging portion of the saw tooth wave appearing across the terminals 15 is substantially perpendicular. The capacitor 14 is charged to a predetermined voltage value by a variable charging device 19 connected in series with the voltage source 13 so that the wave front of the saw tooth generated by the capacitor has a substantially constant slope for any constant frequency of the signal generator 11. The output wave obtained by block diagram in Figure 2 therefore is a reversal of the saw tooth wave obtained by the block diagram of Figure 1.

To illustrate the manner in which the block diagram of Figure 1 may be constructed there is shown in Figure 3 a signal generator 11 which is connected to a square wave generator 21 coupled through a blocking capacitor 22 to the grid of an electric valve 23. The electric valve 23 comprises a tube of the type having within its envelope a gas or an ionizable medium as is the case in "Thyratron" tubes. The gas tube 23 constitutes the tube used in the rapid charging device 12 and its anode is connected to the positive terminal of a suitable source of voltage such as a source of voltage 13 as shown in Figure 1. The grid of the gas tube 23 has a grid resistor 24 connected to an adjustable contact on a resistor 25 which is connected between ground and a suitable source of positive biasing voltage. The "Thyratron" 23 has its cathode connected to the capacitor 14 which in turn is provided with a current limiting resistor 26 having one terminal connected to ground. The circuit thus far described therefore constitutes a rapid charging circuit for the capacitor 14. The capacitor 14 is connected between the anode and cathode of a vacuum tube 27 which preferably is of the pentode type which has the characteristic of maintaining substantially constant anode current even though the voltage between the anode and cathode varies over a substantial range. The pentode 27 is used to discharge the capacitor 14, and the rate of operation of the pentode 27 is controlled in accordance with the voltage determined by the frequency-to-voltage translator 17 of Figure 1. The suppressor grid of the vacuum tube 27 is connected to ground. The screen grid of the vacuum tube 27 is connected to a suitable source of potential, preferably through an un-bypassed resistor 20. The control grid of the vacuum tube 27 is connected to a switch arm 28 adapted to contact a plurality of contact points each connected to different portions of a resistor 29. An integrating network comprising a resistor 31 and a capacitor 32 connected between ground and the square wave generator 21 integrates the output of the square wave generator to supply an integrated output to a diode rectifier 33 having its cathode grounded. The anode of the diode rectifier 33 therefore is connected between the common juncture of the resistor 31 and the capacitor 32. The diode rectifier 33 operates to form a unidirectional voltage bias across the capacitor 32, which is inversely proportional to the frequency supplied by the signal generator 11 at the synchronous input terminals of the square wave generator 21. The unidirectional voltage thus generated is filtered by a resistor 34 and a capacitor 35 to supply voltage to the voltage divider resistor 29. By movement of the switch arm 28, a certain portion of the direct current voltage is supplied to the control grid of the variable discharge tube 27. When the voltage supplied to the control grid of the vacuum tube 27 is a large portion of the voltage appearing across the resistor 29, a certain step-down ratio is obtained between the frequency of the signal generator 11 and the frequency of the saw tooth voltage appearing across the output terminals 15. Thus the arrangement in Figure 3 by operation of the switch 28 may be used as a frequency divider. The circuit elements associated with the diode 33 comprise the frequency-to-voltage translator 17 in the diagram of Figure 1. As the frequency of the signal voltage 11 changes, the direct current bias appearing across the capacitor 32 is changed so that the voltage supplied to the discharging vacuum tube 27 is changed therefore modifying the rate of discharge of the capacitor 14 so that the frequency of the output saw tooth wave appearing across the terminals 15 is rapidly brought into synchronism with the stabilized changed frequency of the signal generator 11.

In order to increase the range of operation of the system shown in Figures 1 and 3 certain modifications may be introduced as illustrated by the block diagram of Figure 4. In this arrangement the various parts have been given reference characters corresponding to the same parts in Figures 1 and 3 from which it will be seen that the output terminals 15 appear across the series circuit comprising the capacitor 14 and the current limiting resistor 26. The variable discharging device 16 is directly connected across the capacitor 14. The operation of the discharging device 16 is controlled by the difference between two signals. One of these signals is derived from the frequency-to-voltage translator 17, and the other signal is derived from the current limiting resistor 26. The second signal is proportional to the direct current component of current flowing through the variable discharge device 16. The voltage component appearing across the resistor 26 is supplied to a low pass filter 37 the output of which is connected to a direct current amplifier 38. The variable discharge 16 also receives a voltage component from the frequency-to-voltage translator 17 from which is subtracted the direct current component supplied by amplifier 38. This produces a current degeneration which insures a greater range of operation than is obtainable by the circuit arrangement of Figure 3 by overcoming any inherent nonlinearity between the rate of discharge of the vacuum tube 27 and the signal supplied from the frequency-to-voltage translator 17. Thus there is insured that the current drawn by the discharge tube 27 will bear a nearly linear relationship to the voltage supplied to its control grid over a very wide range of voltages supplied thereto, as contrasted to a relatively narrower range capable of being handled by the circuit arrangement in Figure 3.

One manner in which the modification of Figure 4 may be applied to the circuit arrangement shown in Figure 3 is illustrated in Figure 5. The adjustable contact 28 for the resistor 29 is connected to the control grid of the variable discharge tube 27. The screen grid is supplied from a suitable source of potential through a resistor 39 which is by-passed to ground by a capacitor 41. The voltage supplied to the screen grid of the vacuum tube 27 is modified by the direct current component obtained across the current limiting resistor 26 which is connected to a low-pass filter comprising a resistor 42 and a capacitor 43. The common juncture between the resistor 42 and the capacitor 43 is connected to a grid of a vacuum tube 44 having its anode connected to the screen grid of the vacuum tube 27. The cathode of the vacuum tube 44 is connected through a biasing resistor 45 to ground. The vacuum tube 44 operates as a direct current amplifier with the resistor 39 operating as a plate or load resistor for the vacuum tube 44. The alternating current components are by-passed by the capacitor 41. The voltage appearing at the anode of the vacuum tube 44 therefore is the voltage which is supplied to the screen grid of the vacuum tube 27. If it is assumed that the signal source 11 is increased in frequency, the integrator circuit including the resistor 31 and the capacitor 32 will cause the diode rectifier 33 to operate to reduce the negative bias applied to the grid of the variable discharge vacuum tube 27. This produces an increase in the rate of discharge of the capacitor and in the current flow through the tube 27 so that an increased voltage drop is produced across the current limiting resistor 26. This voltage drop across the resistor 26 is amplified by the direct current amplifying tube 44 to lower the screen grid voltage of the discharge tube 27 thereby tending to reduce the current drawn by that discharge tube. This tendency therefore tends to maintain more nearly linear the modified rate of discharge of the capacitor 14 for the changed signal frequency. The circuit therefore obviates the frequency range limitation obtained by the circuit arrangement in Figure 3 which has an inherent nonlinearity above a certain frequency range.

In the preceding arrangements shown in detail in Figures 3 and 5 the rate of discharge of the vacuum tube 27 was controlled in accordance with the average of several preceding cycles of energy obtained from the signal source. It, therefore, will be appreciated that there is a certain time delay between the change of frequency of the signal source and the time when the variabe discharge device reaches synchronism so as to produce a saw tooth wave of uniform amplitude in synchronism with the signal frequency. If it is desired to have an arrangement whereby the output wave responds very rapidly to any change of the frequency of the input wave, certain modifications may be made as are illustrated in Figure 6. A pulse generator 46 is arranged to be energized from the signal source 11; and the pulse generator, which preferably is of the type having an output wave of the peaked variety, supplies this wave to the grid of a "Thyratron" 47. The "Thyratron" 47 is connected, between the suitable source of anode potential and ground, in series with a capacitor 48 and a current limiting resistor 49. The peaked pulses of short duration impressed upon the grid of the "Thyratron" 47 produce ionization so as to bring about the charging of the capacitor 48 in synchronism with such pulses. The capacitor 48 is discharged at a substantially constant rate, either by a resistor or by a pentode vacuum tube 51 having its anode connected to the capacitor 48 and its cathode connected to ground. The pentode 51 has its suppressor grid connected to ground, its screen grid connected to a suitable source of potential, and its control grid is connected to the cathode. This produces a saw tooth wave which is fed through a coupling capacitor 52 to a diode vacuum tube 53. A resistor 54 is connected to the capacitor 52 so that the capacitor and resistor combination constitute a differentiating circuit which produces at the anode of the diode rectifier 53 a peaked wave having amplitude inversely proportional to the incoming frequency. This peaked wave supplied to the diode rectifier 53 is utilized to charge a capacitor 55. The capacitor 55, however, is so arranged as to have been discharged at the time that the capacitor 48 was being charged. This is obtained by a "Thyratron" 56 and a biasing source of voltage 57 connected in parallel with the capacitor 55. The control electrode or grid of the "Thyratron" 56 receives energy from the common juncture between the capacitor 48 and the current limiting resistor 49 so that the "Thyratron" 56 operates to discharge the capacitor 55 during each cycle or pulse corresponding to the frequency of the signal voltage 11. Since the capacitor 55 is arranged to be discharged once during each cycle, each succeeding charge is inversely proportional to the incoming frequency. The voltage appearing across the capacitor 55 therefore may be supplied to a phase inverter 58 so as to control the variable discharging device 16. The phase inverter 58, which may comprise a single stage amplifier, is provided in order to make the grid of the discharge tube of the variable discharging device 16 more negative as the input frequency of the signal generator 11 is decreased. Such an arrangement will control the bias of the variable discharging device 16 so as to adjust the rate of discharge to the incoming frequency within a time interval represented by one cycle of the incoming frequency, thus insuring rapid adjustment of the output frequency and amplitude appearing across the terminals 15 with respect to the change in frequency of the signal voltage 11.

While the systems heretofore described have the inherent characteristic of maintaining a constant amplitude saw tooth output independent of changes in the signal frequency, oversensitivity of frequency-to-voltage translator 17 or of variable discharging device 16 or of variable charging device 19 will cause the amplitude to fall off with an increase of frequency, and undersensitivity will have the opposite effect. Therefore, in some cases it may be desirable to introduce an action which has inherently the characteristic of tending to produce a slightly reduced amplitude of saw tooth wave with an increase in the operating frequency. Such an arrangement is illustrated in Figure 7 which in addition to the previous components illustrated by the block diagrams in Figures 1 and 2 utilizes an automatic amplitude control 59 arranged to be energized directly from the capacitor 14. A component derived from the automatic amplitude control 59 is combined with a component of voltage derived from the frequency-to-voltage translator 17 by a voltage adder 61. The voltage adder 61 is arranged to control the operation of the variable discharging device 16. The manner in which the automatic amplitude control serves to supply the voltage component is illustrated in Figure 8 where one terminal of the capacitor 14 is connected through a coupling capacitor 62 to the grid of a vacuum tube 63 which serves as an isolation stage. The cathode of the vacuum tube 63 is connected to one of the output terminals 15, the other output terminal 15 being connected to ground. A voltage divider comprising resistors 64 and 65 is connected between ground and the cathode of the vacuum tube 63. The grid of the vacuum tube 63 is connected to series resistors 66 and 67 having their common juncture by-passed by a capacitor 68 to the cathode of the vacuum tube 63. The other terminal of the resistor 67 is connected to the common juncture of the resistors 64 and 65. The resistor 66 corresponds to a grid resistor, and the resistor 67 and the capacitor 68 constitute a filter circuit. The isolation stage thus described operates to reduce any load on the capacitor 14 since it is desired to make such load negligible so as to maintain the discharge rate of the capacitor linear and controllable by tube 27. The isolation stage therefore permits the net resistive component of the impedance across the capacitor 14 to be kept at a relatively high value so that the size of the capacitor may be relatively small even at low frequencies.

The common juncture between the resistors 64 and 65 is capacitively coupled by a capacitor 68 to the anode of a diode rectifier 69. The anode of the diode rectifier is provided with a grounded resistor 71, and the voltage developed thereacross is supplied to a filter circuit comprising resistors 72 and 73 and by-pass capacitors 74 and 75. The output of the filter is connected to a resistor 76 which also receives the voltage component from the frequency-to-voltage translator 17. The juncture of resistors 73 and 76 is connected to the grid of discharge tube 27 so that the discharge tube 27 has its rate of discharge controlled by the sum of two voltage components so as to give the desired operational characteristic. Thus resistor 76 working with resistors 71, 72 and 73 constitute the voltage adder 61.

While for the purpose of describing and illustrating the present invention, certain specific embodiments have been shown in the drawings, it is to be understood that the invention is not to be limited thereby since such variations in the circuit arrangements and in the instrumentalities employed are contemplated as may be commensurate with the spirit and scope of the invention defined in the following claims.

This invention is hereby claimed as follows:

1. The combination comprising a source of unidirectional voltage, a capacitor, means for charging said capacitor from said source of voltage, means for discharging said capacitor, one of said means having a rapid rate of operation, the other of said means having a variable rate of operation, a source of signal voltage for controlling the operation of the first one of said means, means for deriving a first control voltage from said signal source, the amplitude of said control voltage depending upon the frequency of said signal, means for deriving a second control voltage from the current through either of said first two means, and means for applying both of said control voltages to the means having a variable rate of operation so as to control the latter.

2. The combination comprising a source of unidirectional current, a capacitor, means for charging said capacitor from said source of voltage, means for discharging said capacitor, one of said means having a rapid rate of operation, the other of said means having a rate of operation which may be varied, a sources of signal voltage for controlling the frequency of operation of one of said means, means responsive to the voltage difference appearing across said capacitor for producing a control voltage, means for deriving a second control voltage in accordance with the frequency of said signal voltage, and means for combining said control voltages for varying the rate of operation of said second means.

3. The combination comprising a source of unidirectional current, an energy storage circuit, means for charging said circuit from said source of voltage, means for discharging said circuit, one of said means having a rapid rate of operation, the other of said means having a rate of operation which may be varied, a source of signal voltage for controlling the frequency of operation of one of said means, means responsive to the voltage difference appearing across said circuit for producing a control voltage, means for driving a second control voltage in accordance with the frequency of said signal voltage, and means for combining said control voltages for varying the rate of operation of said second means.

4. The combination comprising a source of unidirectional voltage, an energy storage device, means for charging said device from said source of voltage, means for discharging said device, one of said means having a rapid rate of operation, the other of said means having a rate of operation which may be varied, a source of signal voltage for controlling the frequency of operation of the first one of said means, means for deriving a first control voltage from said signal source, the amplitude of said control voltage depending upon the frequency of said signal, means for deriving a second control voltage from the current through either of said first two means, and means for applying both of said control voltages to the means having a variable rate of operation so as to control the latter.

5. The combination comprising a signal source, a pulse generator energized from said source, a first capacitor, means for charging said capacitor in synchronism with the generated pulses, means for discharging said capacitor at a substantially constant rate, a second capacitor, means responsive to the voltage across said first capacitor for charging said second capacitor in inverse proportion to the frequency of said pulses, means for discharging said second capacitor during the occurrence of each pulse, and means for deriving an output voltage from across said second capacitor.

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