Dec. 24, 1946. R. C. HERGENROTHER 2,413,181

SIGNAL GENERATOR

Filed Feb. 9, 1944 2 Sheets-Sheet 1

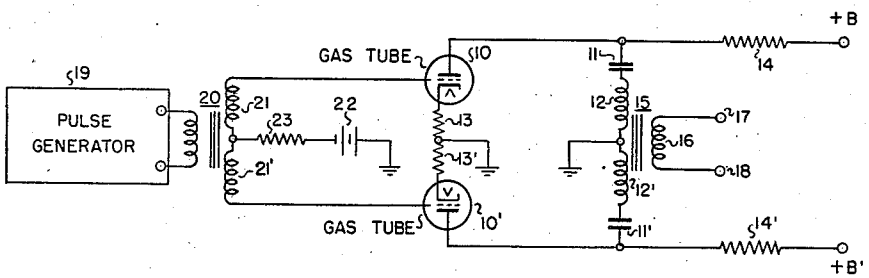

FIG.1

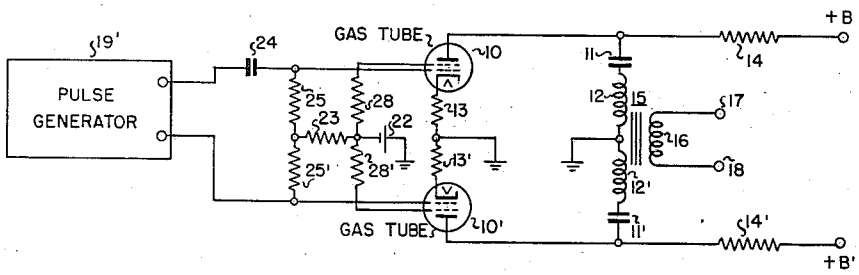

FIG.3

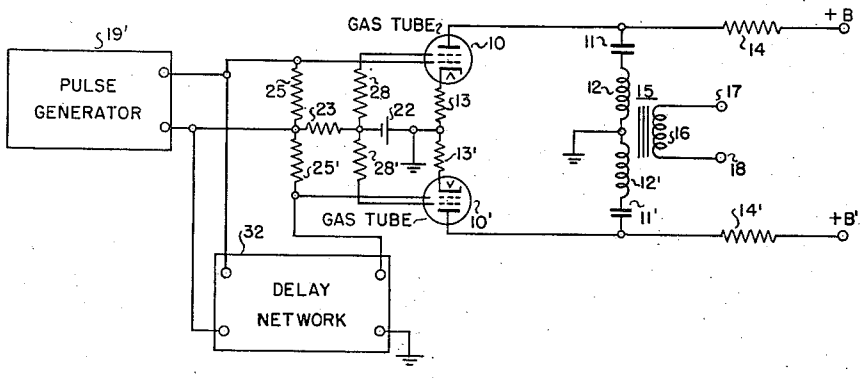

FIG.4

INVENTOR
RUDOLF C. HERGENROTHER
BY Harry C. Page.
ATTORNEY

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SIGNAL GENERATOR.

Filed Feb. 9, 1944 2 Sheets-Sheet 2

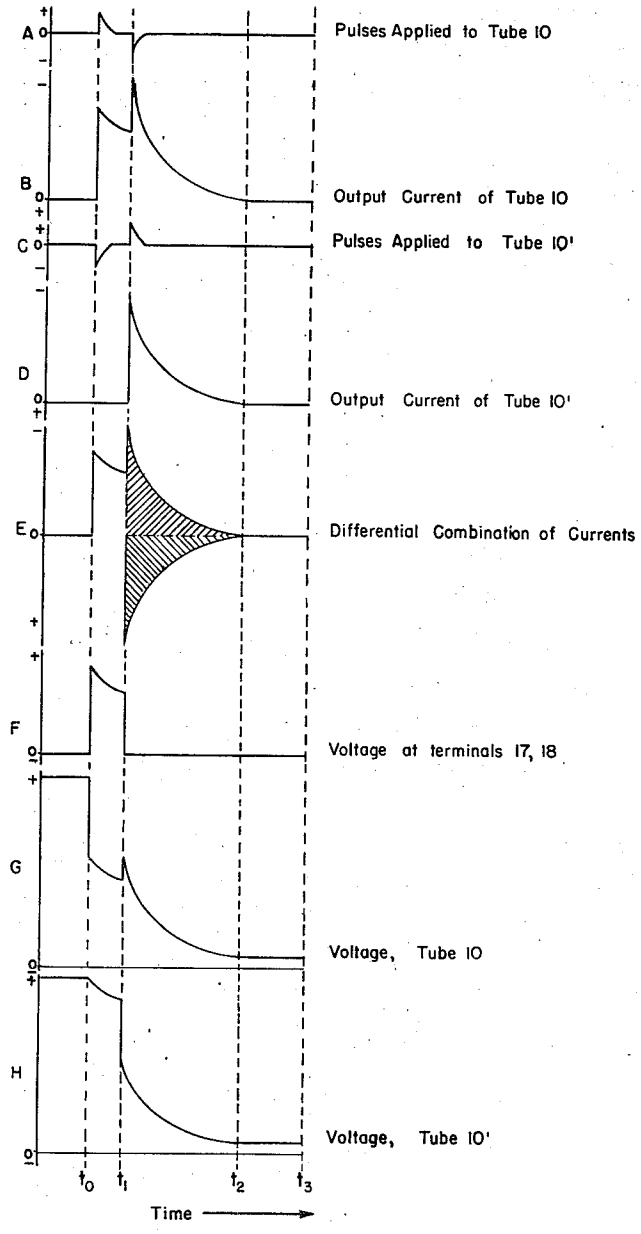

FIG. 2

INVENTOR
RUDOLF C. HERGENROTHER
BY Harry B. Page.
ATTORNEY

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SIGNAL GENERATOR

Rudolf C. Hergenrother, Beechhurst, N. Y., assignor, by mesne assignments, to Hazeltine Research, Inc., Chicago, Ill., a corporation of Illinois

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10 Claims. (Cl. 178—44)

1

The present invention relates to signal generators adapted to provide pulses of electrical energy and relates particularly to pulse generators of a type adapted to supply pulses having a relatively large energy content.

In pulse-wave generators of a type commonly employed in signal-transiating and control circuits it is customary to use high-vacuum electron tubes. Since high-vacuum electron tubes are high-impedance devices, the peak power output of generators utilizing this type of tube is generally limited by the peak voltage which may be applied to the tube. In order to avoid the disadvantages and limitations attendant upon the use of tubes of this type in a pulse generator, it has been proposed in accordance with one prior art arrangement to employ a low-impedance vapor-electric discharge device through which a condenser discharges into a load circuit. However, since such an arrangement has a discharge characteristic or decay curve of exponential form, it is necessary, when rectangular pulses are desired, to shape the output pulses into the desired form by additional circuit arrangements. Such arrangements generally depend upon more or less complicated wave-shaping networks. It has been found that such networks, while producing approximately rectangular pulses, are limited in the steepness of the sides of the pulse. It is therefore desirable to provide a pulse-wave generator which utilizes the superior power performance of the vapor-electric discharge device and which at the same time avoids the limitations of the prior art arrangements mentioned above.

It is an object of the present invention, therefore, to provide a new and improved pulse-signal generator which is free from one or more of the limitations and disadvantages of the prior art arrangements mentioned above.

It is an additional object of the invention to provide a pulse-wave generator which does not require the use of wave-shaping networks, such as limiting or clipping circuits, or ultimate dependence upon high-vacuum tubes.

It is another object of the invention to provide a simple, economical means for generating pulses of relatively high power.

It is a further object of the invention to provide an improved pulse-signal generator for generating pulses defined by relatively steep sides.

In accordance with the invention, a signal generator comprises means for developing a first signal of pulse wave form each pulse of which has a steep edge portion and an exponential portion. The generator also includes means for developing a second signal of pulse wave form each pulse of which has a smaller amplitude than each pulse of the first signal and has a corresponding steep edge portion and an exponential edge portion similar to, and coextensive in time with, at least a part of the first-mentioned exponential edge portion. The signal generator additionally includes means for differentially combining these signals to obtain a resultant signal of substantially rectangular-pulse wave form having substantially zero amplitude during this coextensive time.

2

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the accompanying drawings, Fig. 1 is a circuit diagram, partly schematic, of one embodiment of the present invention; Fig. 2 comprises a set of curves used in explaining the operation of the Fig. 1 embodiment; Fig. 3 is a circuit diagram, partly schematic, of a modified form of the invention; and Fig. 4 illustrates a further modified form of the invention.

Coming now to a detailed description of the invention, the embodiment illustrated in Fig. 1 comprises a signal generator including means for developing a first signal of pulse wave form each pulse of which has a steep edge portion and an exponential edge portion. This means comprises a vapor-electric discharge device or gaseous tube 10 and a condenser 11, included in the output circuit of the tube and adapted to be discharged through the tube. Also serially included with condenser 11 in the output circuit of tube 10 are an inductor 12 and a cathode resistor 13. Tube 10 is provided with a source of anode potential +B connected through a resistor 14 to its anode. The value of resistor 14 is so chosen that, following the discharge of condenser 11, the tube current is reduced below the threshold value for which the tube remains conducting.

The Fig. 1 embodiment also comprises means for developing a second signal of pulse wave form each pulse of which has a smaller amplitude than each pulse of the first signal and has a corresponding steep edge portion and an exponential edge portion similar to, and coextensive in time with, at least a part of the exponential edge portion of the signal developed by the first-described means. This means is generally similar to the first means described above and comprises a

vapor-electric discharge device or gaseous tube 10' and a condenser 11' included in the output circuit of tube 10' and adapted to be discharged through the tube. Elements of this means which are identical to elements of the first-mentioned means are represented by the same reference numerals primed. It should be noted, however, that the voltage of source +B is greater than that of source +B'.

The Fig. 1 embodiment also comprises means for differentially combining the signals developed by the two first-described means to produce a resultant signal having substantially zero amplitude during the above-mentioned coextensive time. This means comprises a transformer 15 which has a secondary winding 16, coupled to output terminals 17 and 18, and includes as primary windings the inductors 12 and 12'. The primary inductors are wound in the same sense and are grounded at their common terminal, the junction of resistors 13 and 13' also being grounded to complete the discharge paths of the tubes.

The Fig. 1 embodiment is provided with means for supplying first and second pulse signals of relatively small energy content having a predetermined interval therebetween for controlling the operation of the tubes 10 and 10' to provide the desired output signal. Specifically, the input circuits of tubes 10 and 10' are coupled with opposite polarity through inductors 21 and 21' of a transformer 20 to a common control-signal source 19. The control elements of the tubes are provided with an appropriate source of bias potential 22 which is connected through a grid-current limiting resistor 23 to the junction of inductors 21 and 21'. The source 19 of control signals comprises a generator of conventional design adapted to generate adjacent pulses of opposite polarity, which are spaced apart by a time interval equal to the desired output pulse duration.

Reference is made to the curves of Fig. 2 for a description of the operation of the Fig. 1 embodiment of the invention. It is assumed that a first control or triggering pulse from source 19, as represented by curve A, is applied to the transformer 20 and it will be seen that this pulse, being of positive polarity as applied to the control electrode of tube 10, causes tube 10 to become conductive. Thereafter the gas in tube 10 ionizes, the control electrode loses control, and condenser 11 starts to discharge through the tube at a high rate, as represented by curve B. Since this first "triggering" pulse is of negative polarity as applied to the control electrode of tube 10', no anode-current flow occurs therein due to this pulse.

During the interval between the first and second control pulses of curve A, condenser 11 continues to discharge exponentially. The second pulse of curve A, being of negative polarity as applied to the control electrode of tube 10, does not affect the discharge current thereof. However, this pulse, being of positive polarity as applied to the control electrode of tube 10', as represented by curve C, renders tube 10' conductive. Condenser 11' therefore discharges through tube 10' at a high rate, as represented by curve D. The flow of current through inductor 12' is effective to induce a voltage in inductor 12 and to decrease the impedance of inductor 12 due to the mutual coupling between these inductors. Therefore, the current through inductor 12 and the rate of discharge of condenser 11 increase at instant t_1, as indicated by curve B.

The circuits are so proportioned that tubes 10 and 10' develop signals having similar exponential portions following the time t_1, as represented by the curves B and D, respectively. The combined signal output of tubes 10 and 10' is illustrated by curve E and the shaded areas of the curve have equal and opposite effects on the voltage induced in secondary winding 16 so that the voltage at terminals 17 and 18 is substantially as represented by curve F. The voltage across tubes 10 and 10', respectively, is represented in curves G and H. At time t_2 condensers 11 and 11' have been discharged below the extinction potential and the tubes return to their initial high impedance after de-ionization has been completed. Following the time t_2 the condensers 11 and 11' are slowly charged from their respective source +B and +B' and, after they have been charged, the above-described cycle can be repeated.

The result of this cycle of operations is the generation of a signal of high energy content at output terminals 17, 18, this signal having sharp leading and trailing edges and substantially zero amplitude during the coextensive time of the discharge of condensers 11 and 11', and having a duration determined by the interval between the first and second of control pulses generated by source 19.

The embodiment illustrated in Fig. 3 is essentially similar to that shown in Fig. 1 and like circuit elements have identical reference numerals. The Fig. 3 embodiment also is suitable for the generation of signals of high energy content at a repetition rate determined by the repetition rate of the applied control signals. The Fig. 3 embodiment differs from that of Fig. 1 in that it comprises a pulse generator 19' of conventional design, adapted to generate rectangular pulses of small energy content, and means for differentiating these pulses to derive therefrom adjacent control pulses of opposite polarity. This means comprises a differentiating circuit including a condenser 24 and resistors 25 and 25' individually included in the input circuits of tubes 10 and 10', respectively, and having a common point connected to resistor 23. Pulse generator 19' has an output circuit connected to this differentiating circuit. Shielding electrodes are preferably provided in tubes 10 and 10' and are negatively biased by source 22 through resistors 26 and 26', respectively.

The operation of the Fig. 3 embodiment is generally similar to that of the Fig. 1 embodiment. However, in this case, a rectangular control pulse developed by generator 19' is differentiated by the circuit comprising condenser 24 and resistors 25 and 25' so that resultant triggering pulses, as represented by curves A and C, are derived at the initiation and termination of the control pulse and applied in opposite polarity to tubes 10 and 10', respectively. The remainder of the cycle of events occurring in the circuits following the application of the triggering pulses to tubes 10 and 10' is the same as that occurring in the Fig. 1 embodiment. In this embodiment, the duration of the output signal is determined by the interval between the leading and trailing edges of the control pulse.

The embodiment illustrated in Fig. 4 is essentially similar to that shown in Fig. 3 and like circuit elements have identical reference numerals. The embodiment of Fig. 4 differs from that of Fig. 3 in that the means for producing

the desired first and second triggering pulses comprises a pulse generator and a delay network instead of a pulse generator and differentiating circuit. Thus, this means comprises pulse generator 19' which has an output circuit connected across resistor 25 to the input circuit of tube 10 and a delay network 32 of conventional design. This network 32 has an input circuit connected to the output circuit of control-signal generator 19' and an output circuit connected across resistor 25' in the input circuit of tube 10'.

The operation of the Fig. 4 embodiment is generally similar to that of the Fig. 3 embodiment. However, the control pulse from generator 19' is applied directly to the input circuit of tube 10 and constitutes the triggering pulse for tube 10 and there is derived from the control pulse a delayed pulse which appears in the output circuit of network 32 and which is utilized as the triggering pulse applied to tube 10'. These triggering pulses may be of any desired shape, such as rectangular or triangular, and correspond in function to the first pulse illustrated in curve A and the second pulse illustrated in curve C. Following the application of these pulses to tubes 10 and 10', respectively, the operation of the embodiment of Fig. 4 is the same as that of the Fig. 3 embodiment. However, it will be noted that the width of the resultant pulse in the Fig. 4 arrangement is dependent upon the time delay of network 32 and is independent of the width of the control pulse supplied by unit 19'.

While it is not proposed to limit the invention to any specific circuit parameters, the following parameters have been found suitable in an arrangement in accordance with the Fig. 3 embodiment of the invention, when operating at a repetition rate of sixty pulses per second:

Source +B	volts	280
Source +B'	do	185
Resistors 25 and 25'	ohms	3000
Resistors 28, 28' and 23	do	1000
Resistors 13 and 13'	do	0.1
Resistors 14 and 14'	do	8000
Load resistance into which circuits are working (connected to terminals 17 and 18)	ohms	1860
Condenser 24	microfarad	0.0005
Condenser 11 and 11'	do	1
Tubes 10 and 10'	Type 2050 Thyratron	
Source 22	volts	15
Transformer 15	Primary 42 turns of No. 20 enameled wire, center tapped; secondary 240 turns of No. 30 enameled wire; core, Hipersil 046, shell type; coil, size 5/8" x 5/8" square, 15/16" long.	

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 signal generator comprising, means for developing a first signal of pulse wave form each pulse of which has a steep edge portion and an exponential edge portion, means for developing a second signal of pulse wave form each pulse of which has a smaller amplitude than said each pulse of said first signal and has a corresponding steep edge portion and an exponential edge portion similar to, and coextensive in time with, at least a part of said first-mentioned exponential edge portion, and means for differentially combining said signals to obtain a resultant signal of substantially rectangular-pulse wave form having substantially zero amplitude during said coextensive time.

2. A signal generator comprising, means including a control-electrode-controlled vapor-electric discharge device for developing a first signal of pulse wave form each pulse of which has a steep edge portion and an exponential edge portion, means including a control-electrode-controlled vapor-electric discharge device for developing a second signal of pulse wave form each pulse of which has a smaller amplitude than said each pulse of said first signal and has a corresponding steep edge portion and an exponential edge portion similar to, and coextensive in time with, at least a part of said first-mentioned exponential edge portion, and means for differentially combining said signals to obtain a resultant signal of substantially rectangular-pulse wave form having substantially zero amplitude during said coextensive time.

3. A signal generator comprising, means for developing a first signal of pulse wave form each pulse of which has a steep edge portion and an exponential edge portion, means for developing a second signal of pulse wave form each pulse of which has a smaller amplitude than said each pulse of said first signal and has a corresponding steep edge portion and an exponential edge portion similar to, and coextensive in time with, at least a part of said first-mentioned exponential edge portion, and means comprising a transformer having a primary winding in the output circuit of each of said first-mentioned means for differentially combining said signals to obtain a resultant signal of substantially rectangular-pulse wave form having substantially zero amplitude during said coextensive time.

4. A signal generator for developing a pulse of relatively large energy content comprising, means for supplying a control pulse of relatively small energy content, means for differentiating said pulse to obtain triggering pulses of opposite polarity at the initiation and termination of said pulse, means including a vapor-electric discharge device and responsive to the first of said triggering pulses for developing a first signal of pulse wave form each pulse of which has a steep edge portion and an exponential edge portion, means including a vapor-electric discharge device and responsive to the second of said triggering pulses for developing a second signal of pulse wave form each pulse of which has a smaller amplitude than said each pulse of said first signal and has a corresponding steep edge portion and an exponential edge portion similar to, and coextensive in time with, at least a part of said first-mentioned exponential edge portion, and means for differentially combining said signals to obtain a resultant signal of substantially rectangular-pulse wave-form having substantially zero amplitude during said coextensive time.

5. A signal generator for developing a pulse of relatively large energy content comprising, means for supplying first and second pulses of relatively small energy content, said pulses having a predetermined interval therebetween, means including a vapor-electric discharge device and responsive to the first of said pulses for develop-

ing a first signal of pulse wave form each pulse of which has a steep edge portion and an exponential edge portion, means including a vapor-electric discharge device and responsive to the second of said pulses for developing a second signal of pulse wave form each pulse of which has a smaller amplitude than said each pulse of said first signal and has a corresponding steep edge portion and an exponential edge portion similar to, and coextensive in time with, at least a part of said first-mentioned exponential edge portion, and means for differentially combining said signal to obtain a resultant signal of substantially rectangular-pulse wave form having substantially zero amplitude during said coextensive time and a duration determined by the interval between said first-named pulses.

6. A signal generator for developing a pulse of relatively large energy content comprising, means for developing a first control pulse of relatively small energy content, means independent of the duration of said first control pulse for deriving therefrom a second control pulse delayed by a predetermined time interval, means including a vapor-electric discharge device and responsive to said first control pulse for developing a first signal of pulse wave form each pulse of which has a steep edge portion and an exponential edge portion, means including a vapor-electric discharge device and responsive to the second of said control pulses for developing a second signal of pulse wave form each pulse of which has a smaller amplitude than said each pulse of said first signal and has a corresponding steep edge portion and an exponential edge portion similar to, and coextensive in time with, at least a part of said first-mentioned exponential edge portion, and means for differentially combining said signals to obtain a resultant signal of substantially rectangular-pulse wave form having substantially zero amplitude during said coextensive time and a duration independent of the duration of said first control pulse.

7. A signal generator for developing a pulse of relatively large energy content comprising, means for developing a pulse of relatively small energy content, said pulse having two sharply defined discontinuities, means responsive to the first of said discontinuities for developing a first signal of pulse wave form each pulse of which has a steep edge portion and an exponential edge portion, means responsive to the second of said discontinuities for developing a second signal of pulse wave form each pulse of which has a smaller amplitude than said each pulse of said first signal and has a corresponding steep edge portion and an exponential edge portion similar to, and coextensive in time with, at least a part of said first-mentioned exponential edge portion, and means for differentially combining said signals to obtain a resultant signal of substantially rectangular-pulse wave-form having substantially zero amplitude during said coextensive time.

8. A signal generator for developing a pulse of relatively large energy content comprising, means for developing a first control pulse of relatively small energy content, means for deriving from said first control pulse a second control pulse delayed by a predetermined time interval, means including a vapor-electric discharge device and responsive to said first control pulse for developing a first signal of pulse wave form each pulse of which has a steep edge portion and an exponential edge portion, means including a vapor-electric discharge device and responsive to said second control pulse for developing a second signal of pulse wave form each pulse of which has a smaller amplitude than said each pulse of said first signal and has a corresponding steep edge portion and an exponential edge portion similar to, and coextensive in time with, at least a part of said first-mentioned exponential edge portion, and means for differentially combining said signals to obtain a resultant signal of substantially rectangular-pulse wave form having substantially zero amplitude during said coextensive time and a duration determined by said predetermined time interval.

9. A signal generator for developing repeating pulses of relatively large energy content comprising, means for developing first and second triggering pulses of relatively small energy content at a predetermined repetition rate, means responsive to said first triggering pulse and including a vapor-electric discharge device having a condenser included in its output circuit for developing from each said first triggering pulse a first signal of pulse wave form each pulse of which has a steep edge portion and an exponential edge portion, means responsive to said second triggering pulse and including a vapor-electric discharge device having a condenser included in its output circuit for developing from each said second triggering pulse a second signal of pulse wave form each pulse of which has a smaller amplitude than said each pulse of said first signal and has a corresponding steep edge portion and a similar exponential edge portion coextensive in time with at least a part of a corresponding one of said first-mentioned exponential edge portions, means including a time-constant circuit for charging said first-mentioned condenser to a desired potential at said repetition rate, and means including a time-constant circuit for charging said second-mentioned condenser to a different potential at said repetition rate, said time-constant circuits being so proportioned that the magnitudes of said time-coextensive exponential edge portions are equal, and means for differentially combining said first and second signals to obtain resultant signals of substantially rectangular-pulse wave form having substantially zero amplitude during said coextensive times.

10. A signal generator comprising, means for developing a first signal of pulse wave form each pulse of which has an exponential edge portion at least a part of which is undesirable, means for developing a second signal of pulse wave form each pulse of which has a steep edge portion and an exponential edge portion of substantially the same amplitude and wave form as said part of said undesirable exponential edge portion of said first signal, and means for differentially combining said signals to obtain a resultant signal of pulse wave form each pulse of which has in point of time a steep edge portion corresponding to the steep edge portion of said each pulse of said second signal and substantially zero amplitude during the interval corresponding to the undesirable part of the exponential edge portion of said each pulse of said first signal.

RUDOLF C. HERGENROTHER.