

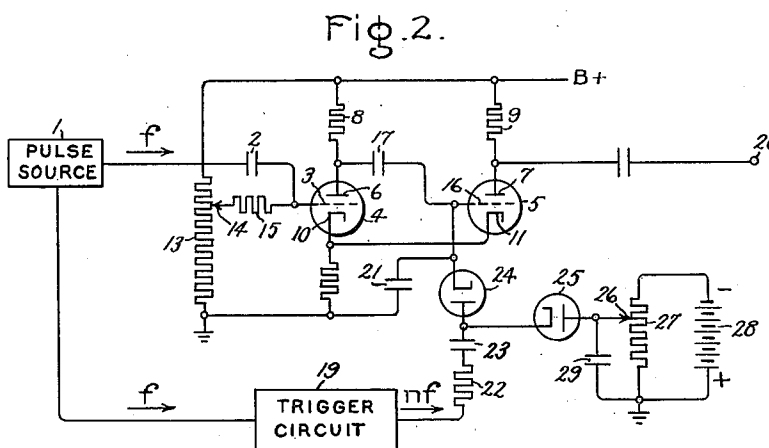
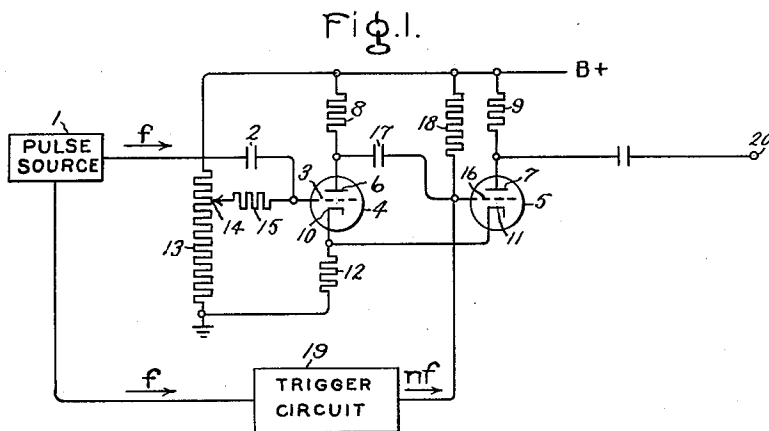
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R. E. MOE
PULSE DELAY CIRCUIT

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2 Sheets-Sheet 1



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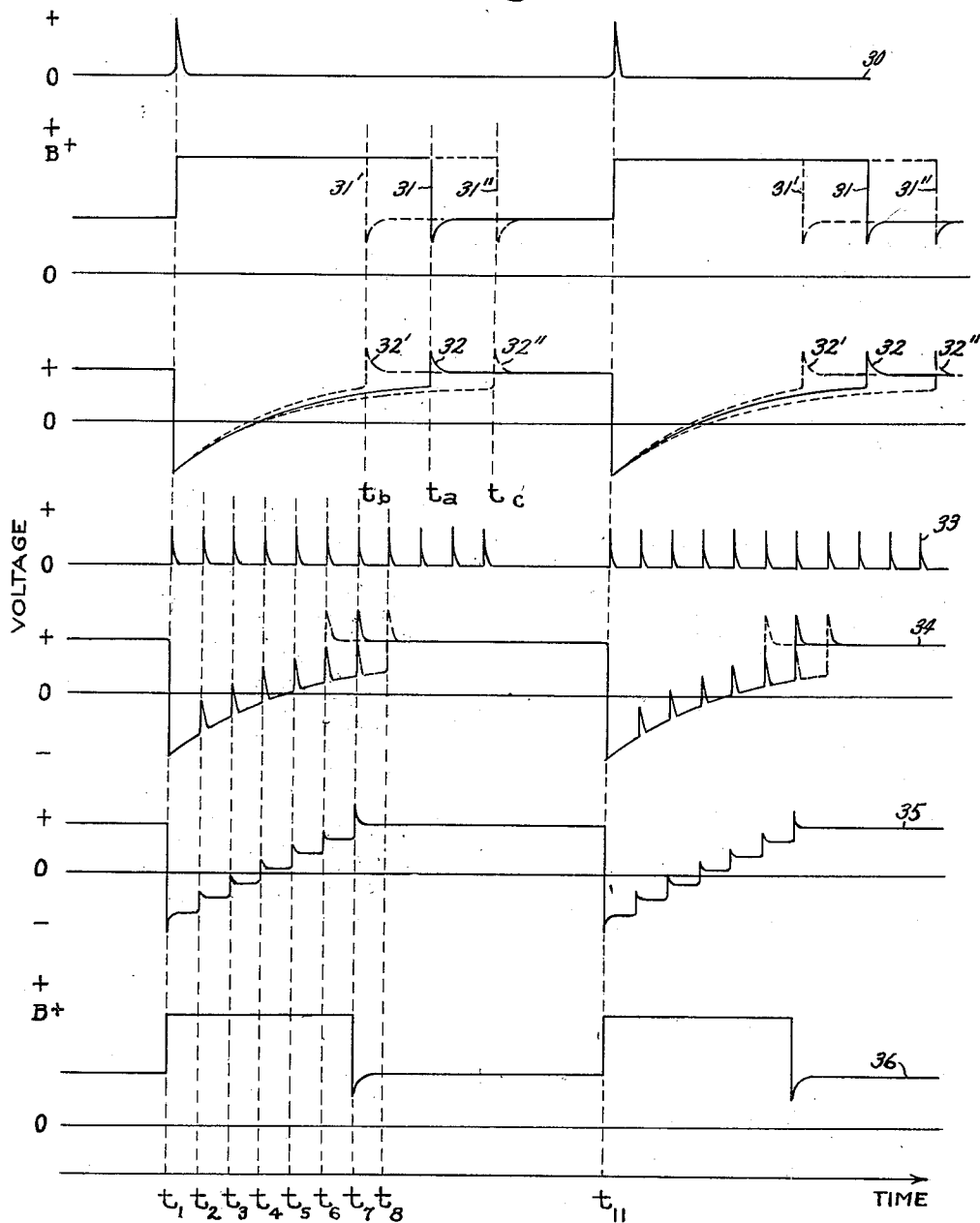
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Fig. 3.



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PULSE DELAY CIRCUIT

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5 Claims. (Cl. 250—27)

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This invention relates generally to electrical multivibrator circuits and more particularly to a circuit for accurately determining the time-duration of a voltage pulse.

An object of this invention is to provide an improved circuit for generating a rectangular pulse of voltage having a time-duration accurately determined as a multiple of the interval between repeated marking pulses.

Another object of this invention is to provide a circuit for generating a rectangular pulse whose time-duration is a sub-multiple of the period of an applied alternating current wave.

A further object of this invention is to provide a stable multivibrator circuit for generating a square wave upon the occurrence of a voltage pulse and for terminating the duration of said wave at a predetermined time after the occurrence of said pulse, said time being determined by an external circuit.

For further objects and advantages and for a better understanding of the invention, attention is now directed to the following description and accompanying drawings, and also to the appended claims, in which the features of the invention believed to be novel are more particularly pointed out.

In the drawings, Fig. 1 illustrates schematically a type of multivibrator circuit, known in the art as a cathode-coupled multivibrator; Fig. 2 illustrates schematically a cathode-coupled multivibrator with certain improvements embodying my invention; and Fig. 3 shows a series of curves illustrating, on a common time scale, voltage variations and wave forms occurring at various designated points in the circuit of Figs. 1 and 2.

Referring to Fig. 1, there is shown a source 1 adapted to supply pulses of voltage, through a capacitor 2, to the control electrode or grid 3, of an electron discharge device 4, which, in conjunction with another electron discharge device 5, constitutes a multivibrator circuit of the cathode-coupled type. The anodes 6 and 7 of devices 4 and 5 are connected through resistances 8 and 9 respectively to a source of operating potential indicated by B+. The cathodes 10 and 11 of both devices have a common connection to ground through a resistor 12. A potentiometer 13, connected between the source of operating potential B+ and ground, provides, at an adjustable tap 14, a positive bias potential for the grid 3 of device 4. The connection from grid 3 to tap 14 is made through a resistor 15 which has a sufficiently high resistance to prevent any substantial dissipation of pulse energy

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in the potentiometer. The anode 6 of device 4 is coupled to the grid 16 of device 5 through a capacitor 17, and a positive bias is applied to grid 16 through a resistor 18 providing a connection to the source of operating potential B+.

A trigger circuit 19 has an input terminal connected to source 1 and an output terminal connected to the grid 16 of device 5. The function of the trigger circuit is to provide, immediately after the occurrence of a pulse from the source 1, a series of pulses of predetermined shorter time-duration. Any of the multivibrator circuits known in the art and capable of providing a series of pulses, occurring at short time intervals immediately after the occurrence of an input pulse which is repeated at longer time intervals, may be used for the purpose. Such a circuit, for instance, is described in the publication "Principles of Radar" by the Radar School of the Massachusetts Institute of Technology, published by the McGraw-Hill Book Company of New York in 1946, and again in U. S. Patent No. 2,423,304—Fitch, issued July 1, 1947, and entitled "Pulse Producing Systems."

While I have not shown, in the curves of Fig. 3, any integral relationship between the repetition rate of the trigger circuit and that of the pulse source, it will be apparent that such could readily be the case. To obtain such an integral relationship, the trigger circuit 19 could be used as the basic circuit and the pulse source 1 operated therefrom. With such an arrangement, pulse source 1 may take the form of a counter circuit, and give, for example, one output pulse for every ten pulses supplied to it from the trigger circuit.

A description of the operation of the electrical multivibrator circuit of Fig. 1 will now be given, reference being made to the curves of Fig. 3. The multivibrator circuit comprising device 4 and 5 is of the type having one condition of stability in which device 4 is normally non-conducting and device 5 is normally conducting. This is due, in part, to the fact that the grid return of device 5 is made through resistor 18 to the positive source B+, whereas the grid return of device 4 is made to a source of less positive potential, as determined by the setting of tap 14 on potentiometer 13. Also, due to the common cathode connection through resistor 12, the current through device 5 serves to bias the cathode 10 of device 4 in a positive direction, thus producing a negative bias on grid 3 of that device, thereby rendering it completely non-conductive.

In operation, source 1 provides to the grid 3 of

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device 4, a series of pulses occurring at the relatively long time interval t_1 to t_{11} , as illustrated by curve 30 of Fig. 3. A positive pulse as grid 3 initiates a first pulse of current through device 4 causing a decrease in voltage at the anode 6, which is coupled back to grid 16 of device 5 as a negative increment of voltage. The negative increment of voltage at the grid of device 5 reduces the current through that device, thereby reducing the voltage drop across resistor 12 and further increasing the positive increment of voltage at the grid of device 4, over and above that originally supplied from the source 1. This further increase in the positive increment at the grid of device 4, in turn initiates another similar succession of changes, and thus a switching process occurs which proceeds very rapidly to the point where device 4 is conducting very heavily and device 5 has become completely non-conductive. The voltage at the anode 7 of device 5 is shown by curve 31 of Fig. 3, which illustrates a positive increment of voltage occurring at a time t_1 , and again at time t_{11} , as determined by the occurrence of pulses from source 1.

A negative increment of voltage, which is the inverse of the positive increment illustrated in curve 31, occurs at the anode 6 of device 4, and supplies, through coupling capacitor 17, a negative increment of voltage at the grid 16 of device 5. The charge coupled through capacitor 17 is dissipated or discharged through resistor 18 at a rate dependent upon the time-constant of the combination, as illustrated by curve 32 of Fig. 3. In normal course, device 4 remains conducting, and device 5 non-conducting, until the charge across capacitor 17 has decreased to the critical value where conduction through device 5 is just on the point of beginning. At that instant, a switching process in the reverse direction occurs, causing device 4 to become non-conducting and device 5 to become conducting. The positive increment of voltage at the anode of device 5 is thereby terminated, resulting in the generation of a square pulse of voltage, as illustrated by a curve 31 of Fig. 3.

The time-duration of the square pulse depends upon the magnitudes of capacitor 17 and resistor 18, and also upon the circuit constants of the associated elements and the operating voltages. The time-duration, as can be appreciated from an inspection of curve 32, is determined by the intersection of a sloping exponential curve with a certain horizontal voltage level and, accordingly, is not accurately and positively fixed. For instance, referring to Fig. 3, curves 31 and 32 represent respectively the anode output voltage, and the control electrode voltage of device 5 for a certain set of operating voltages and circuit constants. Curves 31' and 32' represent similar operating characteristics when capacitor 17 and resistor 18 have a slightly shorter time-constant, while curves 31'' and 32'' represent similar characteristics for a longer time constant. There is nothing in the circuit to accurately fix the occurrence of the reverse switching process, and the actual time duration of the anode output pulse may be anywhere within certain limits such as t_b to t_c in Fig. 3. Thus, any slight change in supply voltages or any drift in circuit constants due to temperature changes may shift the actual time t_a of the occurrence of the reverse switching process.

To provide a more definite fixation or determination of the time-duration of the rectangular output pulse, it has been customary heretofore

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to apply to the grid of device 5 a sharp pulse which will increase the voltage on the grid of device 5 to a value sufficient to initiate the reverse switching process. Thus, the function of the trigger circuit 19 is to provide a series of trigger pulses occurring at definite time intervals after the original input pulse. While the period between trigger pulses is normally an integral sub-multiple of the period between pulses from the source 1, there is no necessity that such be the case, and the trigger pulses may have any desired repetition rate. The output pulses from the circuit 19 are illustrated by curve 33 of Fig. 3. When these pulses are applied to the grid of device 5, they are superimposed on the exponential discharge curve and establish definite instants in time at which the switching action may occur, as illustrated by curve 34 of Fig. 3. For instance, the switching action would normally occur at time t_7 , and the time-duration of the rectangular output pulse of curve 31 would then be the interval t_1 to t_7 , which is equal to 6 of the periods of the trigger pulses from the circuit 19.

While the circuit which has been described provides results which are adequate for some applications, the circuit suffers from a considerable measure of instability, since it has been found in practice that the switching action may occur at the instants t_b to t_c , rather than at the instant t_7 . This is due to the fact that the timing pulses from the trigger circuit are superimposed on a gently curving exponential. Accordingly, there is not a great deal of difference in the absolute potential or voltage to which the grid of device 5 is raised by successive trigger pulses. The result is that the reverse switching action definitely occurs at an instant determined by one of the trigger pulses, but the number of the trigger pulse or in other words the particular individual pulse is not definitely and positively selected. Thus, referring to curve 34, the reverse switching occurs at time t_7 , but any slight disturbance or variation in circuit constants may make it occur at times t_b or t_c , and also may cause the switching instant to shift continuously back and forth from one to the other.

My invention resides particularly in an improvement in the circuit for applying the trigger pulses of curve 33 in a modified form to the grid of device 5, as illustrated in Fig. 2. Referring to Fig. 2 in which circuit elements performing the same function as in Fig. 1 bear the same numerals, the grid 16 of device 5 is no longer connected to the source of operating potential B+ through a resistor 18, but instead is connected to ground through a capacitor 21. The output terminal of the pulsing circuit 19 is now connected to the grid 16 of device 5 in series with a resistor 22, a capacitor 23, and a diode 24, which is connected to conduct current from capacitor 23 to grid 16. Another diode 25 is connected to conduct current from a point of potential, which is negative with respect to ground, to the junction of diode 24 and capacitor 23. The point of negative potential is provided by a tap 26 on a potentiometer 27, of which one terminal is grounded and the other terminal is connected to a source of negative potential provided by a battery 28. A capacitor 29 connected between ground and tap 26 provides a low impedance path for pulsating currents flowing through diode 25.

When a positive pulse of voltage is supplied to grid 3 of device 4 in the circuit of Fig. 2, the sequence of events is very similar to that occurring in the circuit of Fig. 1. Immediately upon

the occurrence of the pulse at times t_1 and t_{11} , as illustrated in curve 30, a switching action occurs which renders device 4 conducting and device 5 non-conducting. This results in a positive increment of voltage at the anode of device 5, as illustrated by curve 31, and also by curve 36, of Fig. 3. Simultaneously, a negative increment of voltage is produced at the grid 16 of device 5 through the coupling capacitor 9, as illustrated by the negative increment in curve 35 occurring at times t_1 and t_{11} . Trigger pulses, as illustrated in curve 33, are applied to the charging circuit comprising diode 24, from the trigger circuit 19. These pulses cause small increments of charge to flow through the diode 24, thereby incrementally raising the initial negative potential at grid 16 of device 5 toward zero. The voltage at grid 16, or in other words the charge developed across capacitors 17 or 21, increases in a series of small increments or steps, as illustrated by curve 35 of Fig. 3. For each pulse of voltage supplied from the trigger circuit, an increment of voltage appears at grid 16. The size or magnitude of this increment is dependent upon the ratio of the values of capacitors 23 and 17 and upon the ratio of resistance 22 to the anode resistance of device 4. The function of capacitor 21 is simply to stabilize the operation of the circuit, and its value may be approximately 10% of that of capacitor 17.

The voltage developed across capacitor 17 increases in a number of increments or steps until it reaches a value sufficient to initiate the reverse switching process and thereby determine the time-duration of the output pulse at terminal 20, as illustrated in curves 35 and 36. When the reverse switching process occurs at time t_7 , diode 25 conducts and restores, across capacitor 23, a reference voltage whose magnitude is dependent upon the setting of potentiometer 27. The length of time, or the number of pulses or steps, required to initiate the reverse switching process in the multivibrator is dependent upon both the setting of potentiometer 27, which determines the reference negative bias at grid 16 of device 5, and upon the setting of potentiometer 13, which determines the anode current of device 4 and, therefore, the magnitude of the negative pulse supplied to grid 16 of device 5 at the initiation of a switching process. In practice, either potentiometer 27 or potentiometer 13 is permanently set, and the other is varied to determine the length or time-duration of the rectangular output pulse.

In operation, the time-duration of the rectangular output pulse is always an exact multiple of the time between trigger pulses. With the circuit of my invention, the count or number of periods comprised within the time-duration of the rectangular pulses is definitely fixed. The operation remains stable because the number of trigger pulse periods contained within one rectangular output pulse is determined largely by the voltage divider action of potentiometer 13 which remains constant regardless of temperature drift. With my invention, the tendency of the switching process to shift in occurrence between adjacent pulses from the timing circuit is largely eliminated.

While a certain specific embodiment has been shown and described, it will, of course, be understood that various modifications may be made without departing from the invention. The appended claims are therefore intended to cover

any such modifications within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A system for generating a voltage pulse of predetermined time-duration after an initiating impulse, comprising a multivibrator, said multivibrator comprising time constant circuits providing said multivibrator with one condition of stability, means for applying said impulse to said multivibrator to disturb said condition of stability, means responsive to said impulse for generating a series of triggering pulses at predetermined time intervals after said occurrence, a unilateral charging circuit comprising said multivibrator time constant circuits responsive to said triggering pulses for generating a step voltage which increases by one step at a time for each of said triggering pulses, said multivibrator being responsive to a predetermined level of said step voltage for returning to said condition of stability.

2. A system for initiating an increment of voltage upon the occurrence of successive electrical impulses and for terminating said increment after a fixed number of equal time intervals beginning with said occurrences, comprising a multivibrator, said multivibrator comprising time constant circuits providing said multivibrator with one condition of stability, means for applying said impulses to said multivibrator to disturb said condition of stability and to cause an increment of voltage in said multivibrator upon the occurrence of said impulses, said voltage increment maintaining said multivibrator in said disturbed condition for a given interval, means responsive to said impulses for generating a series of triggering pulses at predetermined relatively short time-intervals after said occurrences, a unilateral charging circuit comprising said multivibrator time constant circuits responsive to said triggering pulses for generating a step voltage by the accumulation of a definite amount of charge in response to each one of said triggering impulses, said multivibrator responsive to a predetermined level of said step voltage for returning to said condition of stability and to terminate said increment before the expiration of said given interval.

3. A system for initiating an increment of voltage upon the occurrence of successive electrical impulses and for terminating said increment after a fixed number of equal time intervals beginning with said occurrences, comprising a multivibrator, said multivibrator comprising time constant circuits providing said multivibrator with one condition of stability, means for applying said impulses to said multivibrator to disturb said condition of stability and cause an increment of voltage in said multivibrator upon the occurrence of said impulses, said voltage increment maintaining said multivibrator in said disturbed condition for a given time interval, a trigger circuit responsive to each of said impulses for generating, a series of triggering pulses at time-intervals substantially less than said given interval, said trigger circuit having an output terminal connected in series with an impedance and a rectifier to said multivibrator, time constant circuits, said impedance rectifier and time constant circuits forming a storage circuit to produce a step voltage increasing by a small increment in response to each of said triggering pulses, and said multivibrator responsive to a predetermined level of said step voltage for returning

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to said condition of stability, thereby terminating said increment of voltage.

4. A pulse generating system comprising a source of initiating impulses, a pair of electron discharge devices each having an anode, a cathode and a control electrode, a common resistive connection from both said cathodes to a common point of fixed potential, separate resistive connections from said anodes to a point of positive potential with respect to said fixed potential, a voltage bias source, means to apply said bias to the control electrode of one of said devices to maintain said one device normally non-conducting, a capacitive connection from the anode of said one device to the control electrode of said other device, a connection from said impulse source to the control electrode of said one device to render said one device conducting and said other device non-conducting upon the occurrence of an initiating impulse, a trigger circuit connected to said source for generating, in synchronism with the occurrence of an initiating impulse, a series of triggering pulses at time intervals substantially less than the intervals between said initiating impulses, said trigger circuit having an output terminal connected in series with an impedance and a rectifier to the control electrode of said other device, said rectifier poled to produce at said control electrode a step voltage increasing by a small increment in response to the positive going portion of each of said triggering pulses, a second rectifier biased to a negative potential with respect to said fixed potential, said second rectifier connected to the junction of said first rectifier and impedance and poled to be conductive in response to the negative going portion of each triggering pulse, said step voltage being of a polarity to render said other device conducting after the attainment of a predetermined magnitude by step voltage.

5. A pulse generating system comprising a source of initiating impulses, a pair of electron discharge devices each having an anode, a cathode and a control electrode, a common resistive

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connection from both said cathodes to a common point of reference potential, separate resistive connections from said anodes to a point of positive potential with respect to said reference potential, a voltage bias source, means to apply said bias to the control electrode of one of said devices to maintain said one device normally conducting, a capacitive connection from the anode of said one device to the control electrode of said other device, a connection from said impulse source to the control electrode of said one device to render said one device conducting and said other device non-conducting upon the occurrence of an initiating impulse, a trigger circuit connected to said source for generating, in synchronism with the occurrence of an initiating impulse, a series of triggering pulses at time intervals substantially less than the intervals between said initiating impulses, said trigger circuit having an output terminal connected in series with an impedance and a first rectifier to the control electrode of said other device to produce thereat a step voltage increasing by a small amount in response to each of said triggering pulses, said first rectifier being poled to conduct on a positive going voltage, a second rectifier connected between the junction of said first rectifier with said impedance and a point of negative potential with respect to said reference potential, said second rectifier being poled to conduct on a negative going voltage.

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