

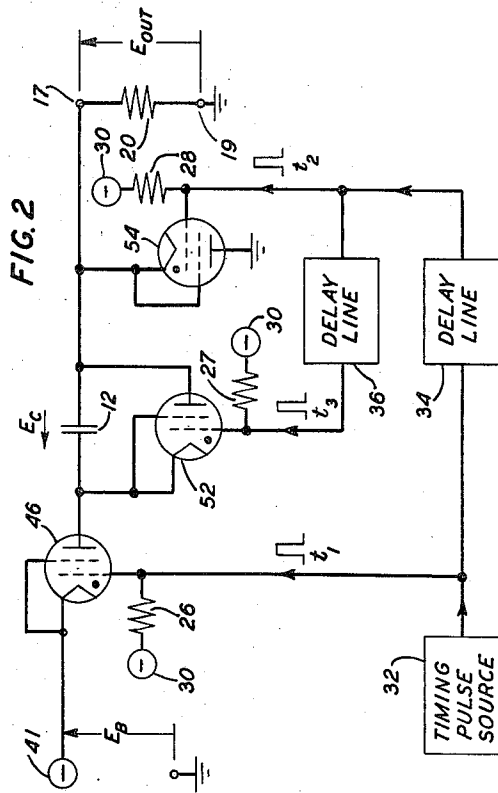
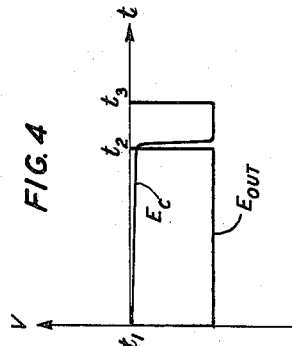
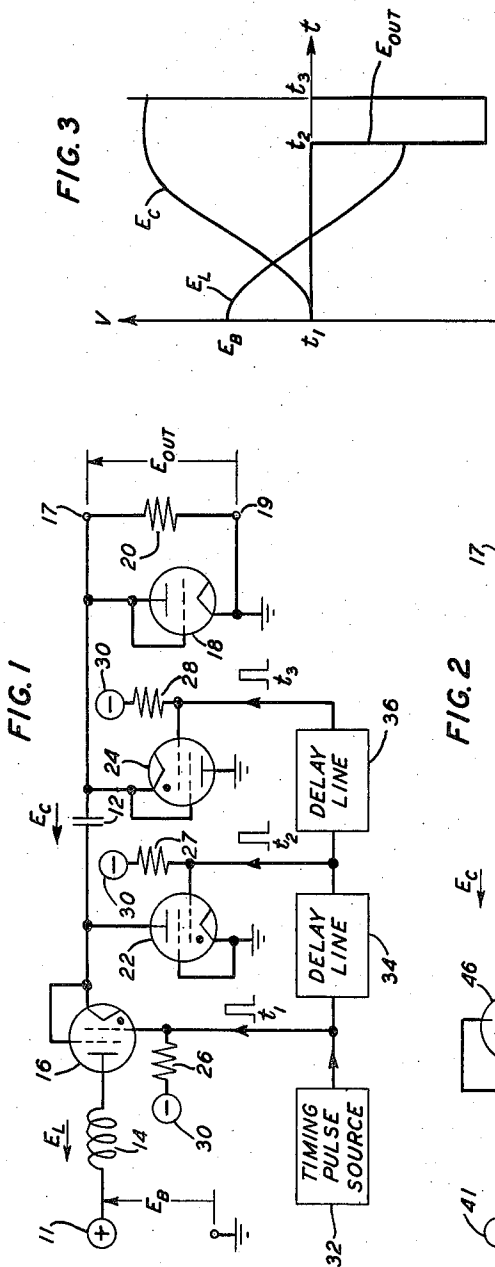
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PULSE GENERATOR

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PULSE GENERATOR

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This invention relates to pulse circuits and, more particularly, to pulse circuits employing gaseous electron discharge devices.

In a wide variety of electronic equipments, for both operating and testing purposes, there is a need for accurately timed pulse signals of precise duration and of substantial magnitude. This widespread need has given rise to a large number of different generators for such pulse signals. In a broad group of these generators, energy has been passed through one path for storage at a high level in a suitable reservoir. Thereafter, at a desired instant this stored energy is released through a different path. Conventionally, one of these paths includes a utilization apparatus, and the shift between storage and release circuit states marks the beginning and ending, though not necessarily in that order, of a desired pulse signal.

Advantageously in this type of apparatus, electron tubes have been employed as accurately timed switching devices for shifting storage energy between a charging path and a discharge path. Commonly, vacuum tubes may be so employed but with the limitation that, as the amplitude of the required pulse signal current rises, both the size and heating power requirements of the necessary vacuum tubes may go beyond that which is feasible for a particular application.

In such circumstances advantageous resort may be made to gaseous electron discharge devices which are exemplified by the well-known thyatron tube. In these discharge devices ionized gas within an envelope serves as a current carrier between cathode and anode electrodes. As is well known in the art, the initiation of such a current conducting ionized condition may be controlled by an auxiliary grid electrode. Thereafter, heavy current may be conducted by the ionized gas particles within the envelope without necessitating heavy thermionic electron emission by a cathode.

Utilization of such gaseous electron discharge devices in the past, however, has been limited to pulse signal generators in which the timing of one portion of the pulse signal, for example, the terminating portion, is of relative unimportance. This limitation has resulted from the fact that, once an appropriate conduction condition has been established within these gaseous devices, the electrostatic effect of auxiliary grids becomes insignificant compared to that of the current conducting ionized particles. Hence, termination of a current conducting electron discharge through such ionized devices becomes dependent upon external circuit phenomena almost entirely, and the discharge conduction current alone has, to a great extent, governed its own termination.

Accordingly, pulse generators of the prior art, on the one hand, have required overlarge vacuum tubes and associated power supplies or, on the other hand, have been objectionably inaccurate in either the beginning or the terminating portion of generated pulse wave signals. This latter inaccuracy has often led to a further objectionable delay in the generation of succeeding pulse signals.

It is a principal object of the present invention to generate accurately timed pulse signals of well-defined wave form, of substantial amplitude, and of rapid recurrence rate.

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It is a further object of the present invention to simplify and to reduce the cost of pulse generating structures.

In accordance with the present invention these and other objects are achieved with a structure in which two gas-filled electron discharge devices are arranged in serial connection with each other and with an energy storing reservoir. A control signal applied to one of these devices establishes heavy current conducting discharge conditions therein to initiate an abrupt change of substantial magnitude in an output signal. This control signal, applied at a later time, establishes a like discharge condition within the other device to accelerate the termination of the conducting discharge in both devices by their deionization and to terminate an output pulse signal by bypassing the parallel connected load circuit in which the output signal appears.

The control discharge devices are advantageously gaseous discharge devices having a control or starter electrode or grid to which the control signal is applied; a thyatron is an example of this type of device. Such devices enable the circuit to provide a large output signal. Circuits in accordance with our invention are so arranged that conduction in the control gaseous discharge devices is terminated by the breakdown of the last of the control devices, conduction in this last device automatically extinguishing the conduction in itself and in any other such devices in the circuit in a high conduction state at that time.

In one specific illustrative embodiment wherein the storage capacitor is priorly charged, as through a gaseous discharge device of the thyatron type, the circuit is arranged so that the first control device establishes a series circuit including itself, the storage capacitor, and the load to initiate the output pulse through the load. A second control device, upon conduction, bypasses the load and establishes a series path including itself, the storage capacitor, and the first device, to discharge the capacitor and in so doing to extinguish conduction both in itself and in the first device. Accordingly, the first and second control gaseous discharge devices are mutually poled for the flow of current in one direction through the series path including the intermediately connected storage condenser.

In a second illustrative embodiment the first device controls the charging of the storage capacitor and also determines the initiation of the output pulse. The second control gaseous discharge device terminates the output pulse by bypassing the output circuit, and a third gaseous discharge device connected in parallel with the storage condenser upon breakdown discharges the storage condenser and thereby automatically extinguishes the discharge in itself and in both the other control devices.

It is a feature of this invention that a pulse generator circuit for producing accurately timed large amplitude output pulses includes a pair of control discharge devices series connected with a storage capacitor for passage of current through this series path in a single direction. More specifically in accordance with our invention, the control discharge devices are gaseous discharge devices as of the thyatron type having a control or starter electrode.

It is another feature of our invention that the breakdown of one such control discharge device both discharges the storage capacitor and in so doing extinguishes or disables both itself and any other conducting control discharge device.

It is a further feature of one specific illustrative embodiment of our invention that the storage capacitor be charged independently of the two control gaseous discharge devices set forth above, the two devices being

connected so that upon conduction of the second to terminate the output pulse, both devices are initially conducting providing low impedance connections to ground in a series circuit from both plates of the storage capacitor and thereby providing both automatic discharge of the capacitor and extinction of the discharge in both control devices. Further in accordance with our invention, in this specific embodiment thereof the charging of the storage condenser may be controlled through another gaseous discharge device having an inductance connected in series therewith, conduction in this device being self-extinguishing on the charging of the storage condenser.

A complete understanding of this invention and of these and other features thereof may be gained from consideration of the following detailed description together with the accompanying drawing, in which:

FIG. 1 is a schematic diagram of an illustrative high power pulse generating system in accordance with one embodiment of the invention;

FIG. 2 is a schematic diagram of another illustrative high power pulse generating system in accordance with another embodiment of the invention; and

FIGS. 3 and 4 are wave forms of assistance in explaining the operations of the embodiments of the invention as shown in FIGS. 1 and 2, respectively.

Referring now more particularly to the drawing, in FIG. 1 there is shown a resonantly charged pulse generating circuit to which energy is supplied from a direct energy source 11 which may conveniently be any one of the many direct current power supplies known in the electronic art. Energy from this source serves to charge a storage element, the capacitor 12, through a serially connected charging inductor 14 and a variable impedance isolating element 16 which advantageously may be a high conductance electron discharge device such as a thyatron electron tube. Completing a serial circuit including the capacitor 12 and the energy source 11 is a rectifying device comprising a diode-connected triode electron tube 18, which is connected across a pair of output terminals 17 and 19 and is poled for conducting current in a low resistance direction consistent with the polarity of the source 11.

A load impedance 20 is connected in parallel with electron tube 18. This load impedance 20 is shown for convenience of illustration as a resistor. It may as well be any pulse utilization circuit as, for example, a radar magnetron pulsing circuit.

Two circuit controlling electron discharge devices 22 and 24 are connected in serial relation with the storage capacitor 12, each for conducting current flowing through that capacitor in a like direction. These discharge devices may advantageously also be thyatron tubes. In accordance with the above-noted serial connection these thyatron tubes are connected anode to cathode. Each has a direct connection of its shield grid to its cathode electrode to promote heavy current conduction. Thyatron 22 is further connected, as shown, in serial relation with the energy source 11, the inductor 14, and the isolating thyatron 16. The other circuit controlling discharge device, thyatron 24, is further connected in parallel with the load impedance 20.

As shown, the control grids of the three thyatrons 16, 22, and 24 are respectively connected through resistors 26, 27, and 28 to a source of Off-biasing potential 30. A timing pulse source 32, which may conveniently be a free-running blocking oscillator of the type well known in the art and which has a pulse repetition rate corresponding to the pulse repetition rate desired of the pulse generator circuit of FIG. 1, supplies enabling trigger pulses to the control grid electrodes of each of the thyatrons 16, 22, and 24.

Each trigger pulse is applied to the grid of a different one of these three tubes at a different time, which times are designated t_1 , t_2 , and t_3 in FIG. 3. The pulses are

supplied to the control grid of thyatron 16 by a direct connection, to the control grid of the thyatron 22 through a delay line 34, and to the control grid of the thyatron 24 through both the delay line 34 and an additional delay line 36. These delay lines may be any one of the many such delay lines well known in the art. They may, for example, be serially connected π sections of inductors and capacitors having values chosen to yield delay times corresponding to the intervals t_2-t_1 and t_3-t_2 . The magnitude of these intervals can best be considered together with a discussion of the operation of the pulse generator of FIG. 1 which may be understood more clearly by a consideration of the wave forms shown in FIG. 3.

Assuming the capacitor 12 to be initially discharged, the Off-biasing potential source 30 renders each of the thyatrons 16, 22, and 24 in a non-conducting, deionized state. The circuit stands in a quiescent state, and no signal appears across the load impedance 20; accordingly, as indicated in FIG. 3, the output signal voltage E_{out} is zero.

A positive pulse signal of suitable amplitude is generated by the timing pulse source 32 at a time designated t_1 . This positive pulse drives the control grid electrode of the isolating thyatron 16 to ionize the gas particles within that discharge device. Thus, an electrical circuit is completed through the electron tube 18, which acts to bypass the load impedance, the capacitor 12, the thyatron 16, and the inductor 14 to the energy source 11. At this instant t_1 , a voltage E_L appears across the inductor with a polarity as indicated by the arrow and in magnitude almost equal to and opposing the energy source potential E_B . This situation is shown in FIG. 3 at time t_1 by referring to the curve designated in this figure as E_L .

Immediately after the instant t_1 , the storage capacitor 12 potential E_c rises as the capacitor is charged through the electron tube 18. The inductor voltage E_L meanwhile decays sinusoidally to a negative value at the instant t_2 . The capacitor potential E_c correspondingly increases sinusoidally to a value substantially above the energy source potential at this same instant t_2 . Indeed, by well-known circuit analysis it may be shown that if the charging path, including the electron tube 18, the capacitor 12, the thyatron 16 and the inductor 14 are all of zero resistance, the capacitor voltage E_c rises to a value just twice the potential of the energy source 11. At this instant the thyatron 16 is deionized by the current through it reducing to zero, and the energy source 11 is thus isolated from the capacitor and its associated elements.

The time interval required for the capacitor 12 to rise to this maximum potential, that is, the interval t_2-t_1 , is given by half the period of the natural resonant frequency of the inductor 14 and the capacitor 12. Denoting the inductance and capacitance values of these two elements as L and C , respectively, it is readily apparent that in this preferred illustrative embodiment of the invention the time t_2-t_1 is given by the expression

$$t_2-t_1=\pi\sqrt{LC}$$

Accordingly, delay line 34 is constructed to delay pulse signals applied thereto from the pulse source 32 by just this interval t_2-t_1 as given above.

As shown in FIG. 1, a pulse signal delayed by delay line 34 is applied to the Off-biasing control electrode of the thyatron 22 at this advantageous instant t_2 ; the pulse may, however, be applied at any reasonable time thereafter as the capacitor tends to maintain its charge. The Off-biasing potential applied to this latter thyatron 22 by the biasing source 30 is thus overcome and the thyatron is enabled as an ionized current conducting condition is established. Ion supported discharge current now flows from the storage capacitor 12 through the low impedance path presented by this thyatron 22. Meanwhile

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the thyatron 16 is deionized and disabled by the equality of the capacitor potential E_c with the sum of the inductor potential E_L and the energy source potential E_B . Thus, the biasing potential source 30, acting through the resistor 26, re-establishes its Off-biasing control of the isolating thyatron 16. As the now isolated capacitor begins discharging through the thyatron 22, its potential drops and current tends to flow through the load resistor 20 to support the discharge in the thyatron 22. This discharge current in the load impedance 20 appears as a sharp negative-going pulse indicated by the heavy curve designated E_{out} in FIG. 3.

As the energy stored in the capacitor 12 decays at an exponentially decreasing rate, the output signal appearing across the load impedance 20 tends to have a substantial value for an indefinite period. This follows from the fact that the discharge thyatron tends to remain ionized as long as the capacitor is capable of supplying substantial current thereto.

In accordance with an aspect of our invention, the third thyatron 24 provides for the termination of the output signal. This third thyatron tube 24 is connected in serial relation with the discharge thyatron 22 and the storage capacitor 12 to provide a complete series path for the flow of the capacitor discharge current. This third thyatron is also, as shown, connected in parallel with the load impedance 20. At a desired pulse termination time t_3 , the pulse from the timing source 32 is applied through the delay lines 34 and 36 to overcome the Off-biasing potential supplied by the source 30 through the resistor 28. Thus, the third thyatron 24 is enabled and discharge current for the capacitor flows through the very low impedance path provided by the two ionized thyatrons 22 and 24. Immediately the thyatron 24 is ionized, the load impedance 20 is effectively short-circuited to terminate the output pulse and the capacitor is rapidly discharged through a near zero impedance path provided by the two ionized thyatrons 22 and 24. The capacitor being discharged rapidly, the ionizing potential for these thyatrons is rapidly removed and they both are returned to a nonconducting condition in expeditious fashion to await a repetition of the above-described operation to generate a new high current pulse in the load impedance 20.

Turning attention now to the pulse generator delineated in FIG. 2, there is seen another illustrative embodiment of the principles of the invention. In this embodiment, shown in FIG. 2, elements corresponding to those of FIG. 1 are correspondingly numbered.

In this generator a first gaseous electron discharge device 46, which may advantageously be a thyatron, is serially connected with the storage capacitor 12 and a load impedance 20. A second gaseous electron discharge device 54, again advantageously a thyatron, is connected in serial arrangement with the first discharge device 46 and the capacitor 12. This capacitor is of a value to have, in conjunction with the load impedance 20, a charging time constant which is large compared with the desired pulse signal duration. Still a third gaseous discharge device, thyatron 52, is connected in parallel with the storage capacitor and in serial relation with the first and second discharge devices 46 and 54.

A control grid electrode of each of these three thyatrons 46, 52, and 54 is connected through resistors 26, 27, and 28, respectively, to a source of Off-biasing potential 30. Energy source 41 is connected as shown with a polarity to supply energy to the capacitor 12 in a direction consistent with a high conductance condition of the serially connected discharge devices 46, 52, and 54. A timing pulse source 32 supplies intermittent positive enabling pulses to the control electrodes of the thyatrons 46, 52, and 54 at successive instants of time t_1 , t_2 , and t_3 by virtue of the operation of delay lines 34 and 36 as shown.

The operation of this embodiment of the invention can

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readily be understood with reference to the wave forms of FIG. 4. Upon generation of a timing pulse from the source 32 at a time t_1 , the Off-biasing potential applied to the thyatron 46 is overcome. Accordingly, this thyatron is conditioned for heavy discharge conduction and the capacitor 12 is charged by the energy source 41 through the load impedance 20 connected between a pair of output terminals 17 and 19. Accordingly, an output pulse signal E_{out} immediately appears across this load impedance. This output signal, as indicated in FIG. 4, has a value substantially corresponding to the potential E_B in view of the large capacitance of the capacitor 12 and the virtually zero impedance of the conducting thyatron 46.

At the instant t_2 , later than t_1 by an interval which is governed by the delay line 34, the second of the serially connected discharge devices, the thyatron 54, is driven into an ionized discharge condition by the arrival of the positive pulse from the source 32. This thyatron, by virtue of its parallel connection with the load impedance 20, acts to bypass the load impedance and to terminate the output pulse E_{out} . The capacitor 12 now is almost immediately charged to the full potential of the energy source 41 and the two discharge devices 46 and 54 are mutually driven by the heavy conduction of the second discharge device to a deionized condition.

At a still later instant t_3 , later than t_2 by an interval governed by the delay line 36, the pulse from the source 32 arrives at the control grid of the third thyatron 52 to condition this thyatron for discharge conduction. Hence, the energy stored in the capacitor 12 is dissipated rapidly and the pulse generator is restored to a quiescent condition awaiting the generation of a new enabling pulse from the source 32.

While specific illustrative embodiments of this invention have been described herein, it is, of course, to be understood that the above-described arrangements are merely illustrative of the application of the principles of the invention. Thus, numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. Pulse generating apparatus comprising a storage capacitor, electrical energy source means for charging said capacitor, a pair of terminals for connection of a load impedance, said capacitor, said source means, and said load impedance terminals being connected in serial arrangement, first and second gaseous discharge devices connected in serial arrangement for current conduction in a like circuit direction, said first discharge device being connected to one side of said capacitor and being poled for current conduction in a direction consistent with the polarity of said source, said second discharge device being connected to the other side of said capacitor and across said terminal pair, means for normally biasing said first and second discharge devices in a non-conducting condition, means for applying an enabling trigger signal to said first discharge device to establish a current conduction condition therein to alter the charge state of said capacitor through said load impedance, and means for thereafter applying said trigger signal to said second device for establishing a conduction condition therein for bypassing said load impedance terminals and for accelerating the re-establishment of a non-conducting condition in said first device.

2. A pulse generator which comprises an electrical energy storage element, first and second gaseous electron discharge devices, a distinct series circuit comprising said storage element and said first and second discharge devices being mutually poled for current conduction in a like circuit direction through said storage element, a load impedance, an energy source connected for charging said storage element with a polarity to drive current through at least one of said discharge devices, biasing means for

maintaining said discharge devices in a normally non-conducting condition, means for applying a trigger pulse signal to said first device for establishing a discharge condition therein for altering a current flow condition in said load impedance, and means for thereafter applying said trigger pulse signal to said second device to establish a discharge condition therein for accelerating the disestablishment of the discharge condition in said first device.

3. Apparatus as set forth in claim 2 wherein said first and second discharge devices are connected in parallel with said load impedance.

4. Apparatus for applying electrical energy from a source as an energy pulse to a load, said apparatus comprising a storage capacitor having one terminal connected to a first gaseous electron discharge device and the other terminal connected to a second gaseous electron discharge device, said first and second discharge devices being connected in shunt with the load, a distinct series circuit including said storage element and said first and second discharge devices mutually poled in a like direction, biasing means for maintaining said discharge devices in a normally deionized or nonconducting condition, means for applying an ionizing trigger signal to said first device for establishing a discharge condition therein to initiate a current pulse in the load, and means for thereafter applying said ionizing trigger signal to said second device for establishing a discharge condition therein to terminate the pulse in said load and to accelerate the disestablishment of the discharge conditions in said first and second devices.

5. In a pulse generator which comprises an electrical energy storage element, a load impedance, means including an energy source for charging said storage element, a first gaseous discharge device series connected between said charging means and said storage element, means for triggering said first gaseous discharge device to ini-

tiate said charging of said storage element, a second gaseous discharge device connected to said storage element so as to define a series path therewith and with said load impedance, and means for triggering said second discharge device for causing said storage element to supply a pulse to said load impedance, the improvement comprising means for terminating said pulse after a predetermined interval comprising a third gaseous discharge device connected to said storage element so as to define a series path therewith and with said second gaseous discharge device, said second and third gaseous discharge devices being mutually poled for current conduction through said storage element in a like circuit direction, and delay means for triggering said third gaseous discharge device a predetermined time interval after triggering of said second gaseous discharge device.

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