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 APPARATUS FOR CONTROLLING THE OPERATION
 OF GAS-FILLED MODULATOR TUBES
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Fig. 1.

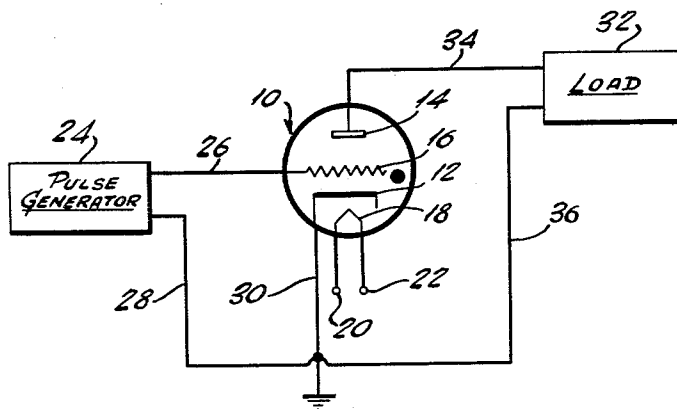
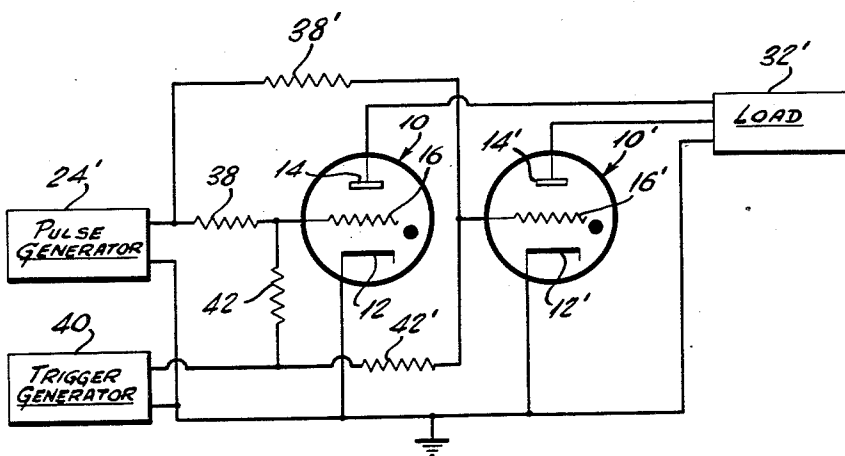


Fig. 2.



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APPARATUS FOR CONTROLLING THE OPERATION OF GAS-FILLED MODULATOR TUBES

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8 Claims. (Cl. 328—210)

This invention relates to thyatron control systems and more specifically to an improved method and apparatus for controlling the operation of thyatrons in order to attain precision operation of one or more tubes and insure stability of operation throughout the life of the tube.

Gas-filled grid-controlled thyatron rectifiers which are also referred to as soft tube modulators usually employ a heated cathode, a plate and a control grid as in the case of ordinary vacuum tubes. This tube differs, however, from the conventional vacuum tube in that the current flowing between the heated cathode and the plate jumps, for all practical purposes, from a zero value to a very high value with the application of a predetermined voltage on the grid of the tube. This action is brought about as a result of ionization of the gas within the tube carried by the application of a potential to the control grid. In the case of present thyatrons such as the 4C35, the firing pulse must be applied to the grid for durations of three to ten micro-seconds depending on the characteristics of the individual tube. Thus, in the case of one tube this grid or firing pulse must be applied for a duration of three micro-seconds before the plate current within the tube will rise to its maximum value. In another tube, the required firing pulse may be of the order of ten micro-seconds. This variation has not only limited the use of soft tube modulators in high-frequency circuits, but in applications requiring the synchronized firing of a plurality of tubes it was difficult, if not impossible, to fire them simultaneously or in other synchronized orders. In addition to the variation in this long time delay, grid-controlled gas tubes are found to have a rather rapid variation superimposed on the normal anode delay time discussed above so that a tube will not fire in precisely the same way each time a pulse is applied. This variation may be referred to as the "pulse-to-pulse jitter time" and of course seriously complicates synchronous and parallel operation of tubes.

One object of the invention is to overcome the problems encountered in the operation of thyatrons, and effect precision firing so that the firing of a given tube can be precisely determined and in addition a substantially uniform anode delay time can be secured for all tubes of a given type notwithstanding the inherent pulse-to-pulse jitter variations. Another object of the invention is an improved circuit for operating grid-controlled gas thyatrons that will effect in addition to precision control of the tubes very much faster and more uniform operation.

The above and other objects of the invention will become more apparent from the following description and accompanying drawing forming part of this application.

In the drawing:

Fig. 1 is a block diagram illustrating a circuit in accordance with the invention; and

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Fig. 2 illustrates the application of the circuit of Fig. 1 to the control of two or more tubes.

Broadly, this invention concerns an improved circuit and system for firing thyatrons to shorten the anode delay or firing time and to attain precision operation of circuits to be controlled thereby. In the drawing, a thyatron or soft tube modulator is denoted generally by the numeral 10 and includes a cathode 12, a plate 14, a grid 16 and a filament 18. The filament is normally heated by a suitable source of power connected to the terminals 20 and 22. Firing pulses for firing the tube may be generated by any suitable electronic equipment and is diagrammatically illustrated herein by the rectangle 24 which is connected by the leads 26 and 28 to the grid 16 and ground, respectively. For convenience the cathode 12 is also shown as connected to ground by means of the lead 30. The load, or that equipment, which is to be operated by the thyatron is denoted broadly by the rectangle 32 which is connected by leads 34 and 36 to the plate 14 and ground, respectively.

As is well known, the firing of a gas-controlled tube takes the form of a chain reaction which occurs after the potential applied to the grid has reached a value where plate current will begin to flow. At this point ionization begins to take place and it is normally completed in the order of three to ten micro-seconds. It has been found that this ionization or anode delay time can be materially reduced by arranging the pulse generator 24 to produce two successive pulses having predetermined characteristics for this purpose. The initial pulse applied to the grid 16 should preferably be of a value that does not permit the tube 10 to fire and is termed a pre-trigger pulse. This pulse functions to condition the tube for a second pulse that may follow the application of the first pulse by one or more micro-seconds. The second or firing pulse is preferably quite narrow and having a very fast rise time and an amplitude of the order of that required to fire the particular tube. With this system the firing of the thyatron is virtually coincident with the application of the second or firing pulse so that extremely high degrees in accuracy can be attained in controlling the precise time of firing of the tube.

This procedure is particularly useful in connection with the firing of two or more thyatrons simultaneously, in which case a circuit broadly illustrated in Fig. 2 may be employed. In this embodiment of the invention the thyatrons are denoted by the numerals 10 and 10'. Corresponding elements in each figure are denoted by like numerals with the numerals in Fig. 2 being primed. The pulse generator 24' in this form of the invention is connected to the grids 16 and 16' through series resistors 38 and 38' and is arranged to generate the first or pre-trigger pulse which conditions the thyatrons prior to the application of the trigger pulse. The trigger generator 40, which may be formed as part of the generator 24', applies the trigger pulse individually to the grids 16 and 16' through resistors 42 and 42' to effect substantially instantaneous firing of both tubes. While the precise circuits of the pulse generators 24, 24' and 40 are not shown, procedures for developing these pulses are so well known in the art that it was felt that their illustration and description would result in unnecessary complication of the application and therefore have been omitted.

The loads 32 and 32' which are controlled by the thyatrons have merely been shown diagrammatically since they may constitute any device that can be controlled by a thyatron, as for instance, pulsing of radar equipment employing the conventional magnetron oscil-

lator or the rectification of alternating current to provide controlled D.C. potentials and the like. Here again, the utilization of thyratrons for these purposes is so well known in the art that it is felt that any further showing would only serve to complicate rather than clarify the invention.

The method of effecting precision firing of thyratrons as described above reduces the pulse-to-pulse jitter to a negligible value and while insuring uniformity of operation of tubes and therefore facilitating the replacement thereof without disturbing the operation of the apparatus does not function to materially shorten the anode delay time as previously discussed. Shortening of this delay time may be accomplished, however, by the utilization of an improved force firing procedure wherein the pulse generator 24 of Fig. 1 is arranged to provide a pulse of extremely large magnitude and of such a nature that it will force ionization to take place within an extremely short time. In the case of the 4C35 thyatron, it has been found that by arranging the pulse generator 24 to produce a grid pulse of the order of 1,000 to 2,000 volts for a duration of .05 to .15 micro-second duration that the anode delay time of the thyatron can be reduced to the order of .05 micro-second as compared with the normal delay time of three to ten micro-seconds. The application of these high voltages to the grid of the thyatron has not been found to adversely affect the tube in any way, but on the other hand has actually resulted in attaining substantially uniform operation of the tube throughout its entire life. Moreover, the pulse-to-pulse jitter variation which heretofore constituted a serious problem in the utilization of tubes of this character is also reduced to a negligible value not measurable by methods heretofore used for this purpose. Actual tests have indicated that with the forced firing procedure as described above, variations between different tubes have been less than .01 micro-second, whereas, under normal conditions it is exceedingly difficult even with careful tube selection methods to maintain these variations within .25 micro-second.

In order to obtain the greatest precision in the firing of the thyratrons, the internal impedance of the pulse generators 24 and 49 in Figs. 1 and 2, respectively, should be relatively low as compared with the grid circuit impedance of the thyratrons. With conventional thyratrons, it is desirable to use pulse generators having internal impedances of 50 ohms or less.

It has been found that when a pulse generator having an impedance of 50 ohms is operated into the grid circuit of a thyatron having an impedance in excess of 500 ohms, the pulse will have a tendency to rise to almost double its nominal output. This will produce a somewhat faster rise on the leading edge of the pulse and thus, produce a short anode delay time and eliminate pulse-to-pulse jitter.

Where a pre-trigger pulse is applied as in Fig. 2, it is desirable that the internal impedance of the pre-trigger pulse source be fairly high, say, on the order of 1,000 ohms or more. However, the impedance of the trigger pulse source should be low and preferably on the order of 50 ohms for conventional thyratrons.

While two different systems have been described for attaining the objects of this invention, they both function to increase the rate of ionization of the gas within the tube in such a manner that the time of firing can be precisely controlled without adversely affecting the tube. Moreover, extremely high tube stability is obtained throughout its normal life.

While only certain embodiments of this invention have been illustrated and described, it is apparent that modifications, alterations and changes may be made without departing from the true scope and spirit thereof.

What is claimed is:

1. A pulse producing system comprising in combination first and second thyatron tubes each having at least

a cathode, a control electrode, and an anode, means coupling the cathodes of said tubes to a common terminal, means including a load coupled between said common terminal and the anodes of said tubes, a first pulse generator having a pair of output terminals, one of said terminals being coupled to said common terminal, first resistor means coupled between the other terminal of said first pulse generator and the control electrode of said first thyatron, second resistor means coupled between the other terminal of said first pulse generator and the control electrode of said second thyatron, a second pulse generator having a pair of output terminals, one of said terminals being coupled to said common terminal, third resistor means coupled between the other terminal of said second pulse generator and the control electrode of said first thyatron, and fourth resistor means coupled between the other terminal of said second pulse generator and the control electrode of said second thyatron, said first and second pulse generators producing coincident pulses for simultaneously firing said first and second thyatron tubes.

2. The pulse producing system as defined in claim 1 wherein the duration of the pulses from said first pulse generator is greater than the duration of the pulses from said second pulse generator.

3. The pulse producing system as defined in claim 1 wherein the magnitude of the pulses from said first pulse generator is insufficient to fire either of said first or second thyatron tubes.

4. A system for simultaneously firing a plurality of gas-filled tubes each having at least an anode, a cathode, and a control electrode, comprising in combination, load circuit means coupled to the anodes of said plurality of gas-filled tubes, a first pulse generating means coupled between each of the control electrodes of said tubes and the cathodes of said tubes, said first pulse generating means producing first recurrent positive pre-ionization pulses having a magnitude insufficient to cause any of said tubes to fire, and second pulse generating means coupled between each of the control electrodes of said tubes and the cathodes of said tubes, said second pulse generating means producing second recurrent positive trigger pulses having a magnitude larger than the magnitude of said first recurrent pulses for simultaneously firing said plurality of gas-filled tubes, said second recurrent trigger pulses occurring immediately following the application of said first recurrent pre-ionization pulses to the control electrodes of said tubes.

5. The system as defined by claim 4 wherein the duration of said first recurrent pre-ionization pulses produced by said first pulse generating means is longer than the duration of said second recurrent trigger pulses produced by said second pulse generating means.

6. A system for simultaneously firing a plurality of gas-filled tubes each having at least an anode, a cathode, and a control electrode comprising in combination, first means coupled to the control electrodes of said plurality of gas-filled tubes for supplying first recurrent positive pre-ionization pulses thereto having a magnitude insufficient to cause any of said tubes to conduct, and second means coupled to the control electrodes of said plurality of gas-filled tubes for supplying second recurrent positive trigger pulses thereto, said second recurrent trigger pulses having a duration less than the duration of said first recurrent pulses and occurring immediately following said first recurrent pulses.

7. A system for simultaneously firing a plurality of gas-filled tubes each having an input circuit and an output circuit comprising in combination, first means coupled to the input circuits of said plurality of gas-filled tubes for supplying first recurrent pre-ionization pulses thereto having a magnitude insufficient to cause any of said tubes to conduct, and second means coupled to the input circuits of said plurality of gas-filled tubes for supplying second recurrent trigger pulses thereto, said second re-

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current trigger pulses closely following the application of said first recurrent pre-ionization pulses to the input circuits of said gas-filled tubes.

8. The system for simultaneously firing a plurality of gas-filled tubes as defined by claim 7 further comprising a load means coupled to the output circuits of said plurality of gas-filled tubes. 5

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