Dec. 11, 1951 L. H. ERICKSON 2,578,525

ELECTRONIC CONTROL

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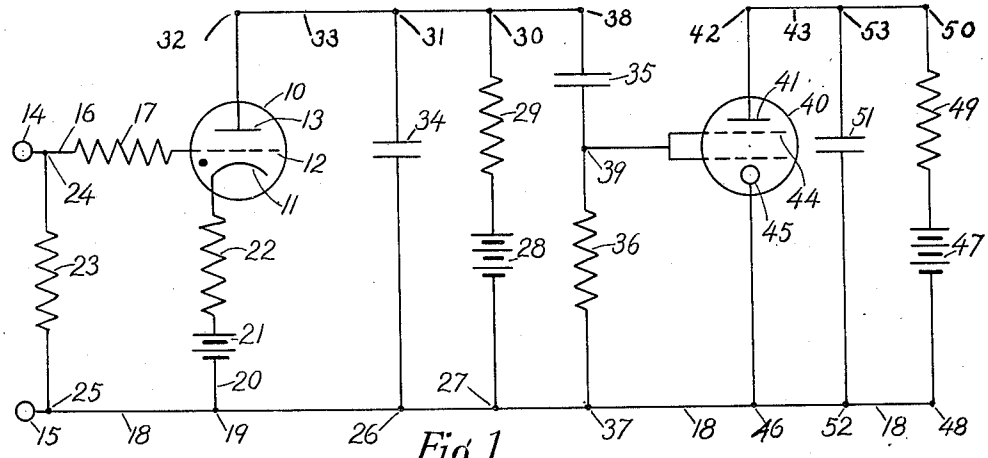

Fig. 1

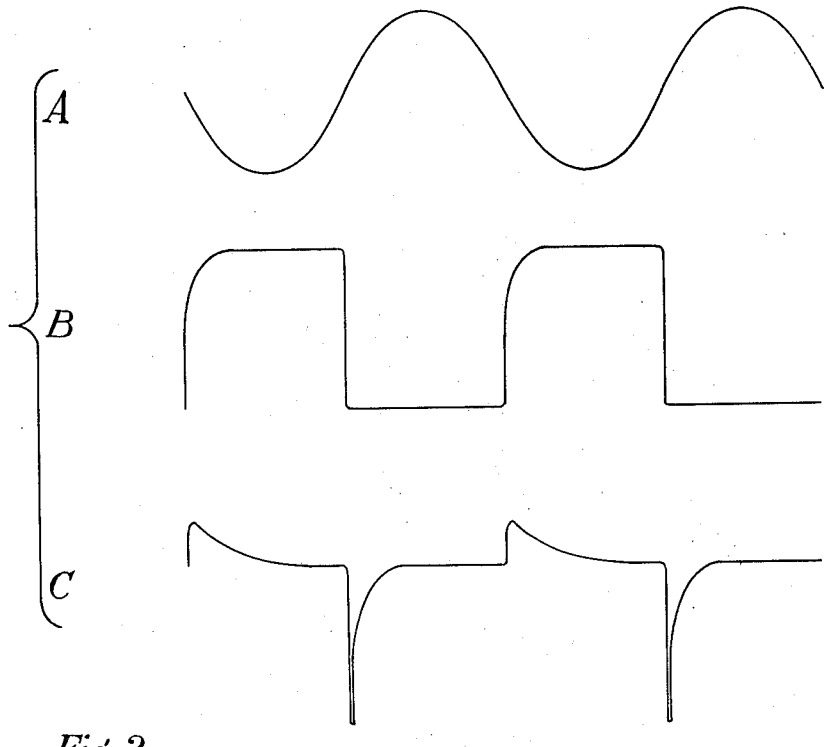

Fig. 2

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ELECTRONIC CONTROL

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5 Claims. (Cl. 250—27)

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This invention relates to electric circuits embodying a hot-cathode, gas-filled, grid-controlled electronic tube, of a type commonly known as a thyratron, and has an object to provide a new and improved circuit operable synchronously to manifest, in voltage output, cyclic characteristics of signals impressed upon the thyratron grid.

A further object of the invention is to provide a new and improved electric circuit arranged automatically to initiate and interrupt current flow through a thyratron in said circuit in synchronism with cyclic characteristics of signals impressed upon the thyratron grid.

A further object of the invention is to provide a new and improved electric circuit, including a thyratron, operative effectively to amplify, and synchronously manifest in voltage output, cyclic characteristics of weak signals impressed upon the thyratron grid.

A further object of the invention is to provide an improved arrangement and association of means in an electric circuit operable synchronously to manifest cyclic characteristics of relatively weak signals impressed upon the grid of a thyratron included in said circuit as voltage output characteristics, and preferably abruptly accentuated voltage characteristics, effective for the actuation and control of associated apparatus.

A further object of the invention is to provide an improved operative association of means in an electric circuit including a thyratron, for responsively conditioning thyratron current flow relative to and for synchronized control between the limits of signal-derived potential variations impressed upon the thyratron grid.

Another object of the present invention is the provision of a new and improved control circuit including a thyratron so constructed and arranged that large plate voltage variations are obtained and controlled by very small variations of the grid voltage.

A further object of the invention is to provide an improved operative association of means for firing a stroboscopic discharge lamp in synchronism with cyclic characteristics of an electric signal.

With the foregoing and other objects in view, my invention consists in the coordinations, relationships and sequential reactions constituting a novel arrangement and operative association of electric means and devices constituting a circuit, as hereinafter set fourth, pointed out in my claims, and illustrated by the accompanying drawings, in which:

Fig. 1 is a schematic diagram of an electric circuit arranged to give practical effect to the

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principles of the invention as applied to the firing of a stroboscopic discharge lamp.

Fig. 2 exhibits conventional voltage curves representing simultaneous potential variations at three separate points in the circuit of Fig. 1.

In certain operations, such as the testing of rotating bodies for unbalance, a vibratory characteristic indicative of the condition under exploration is developed in a manner which permits of its translation into correspondingly varying electric signals available for actuation of appropriate apparatus in indicating, recording or spotting synchronism with the orbital eccentricities of the source. Means and methods for the translation of vibratory phenomena into synchronous electric signals are old and well known, and in and of themselves constitute no part of the instant invention, the following disclosure being premised upon the existence, however generated or derived, of a characteristically varying electric signal which may be availed of as a control factor in the new arrangement of apparatus, the novelty of the instant invention hence residing in the particular operative association of means hereinafter described for the attainment of a desired result, rather than in the broad concept of such attainment.

As one of a number of current conducting electronic devices susceptible of some operative control by means of potential variations in signal input, a type of hot-cathode, gas-filled, grid-controlled tube commonly known and hereinafter referred to as a thyratron has certain functional properties, particularly its characteristic "trigger" action, which distinguish it as especially desirable for the synchronous manifestation of relatively weak signal characteristics in magnified and operatively-available form. Unfortunately, the properties of thyratrons, as heretofore associated and availed of in electric circuits, have negatived adoption of such types in situations where it is desired to initiate and also arrest current flow in response to signal potential variations, since a peculiar attribute of the thyratron is the persistence of current flow through its cathode-anode circuit, once the tube has fired in response to the slight shift of grid potential effective for such initiation of conduction, such persistence of current flow being of an order to render the grid incapable, in a practical sense, of interrupting it when once established, so that the output of the circuit is not susceptible of control by variations within the limits of practically utilizable signals.

It has now been determined that the desirable performance characteristics of a thyratron may be availed of without impairment in a circuit

arrangement which conditions the tube for interruption as well as initiation of current flow therethrough in response to cyclic characteristics inherent in a periodic signal impressed upon the thyratron grid, the voltage output of such circuit manifesting the signal periodicity in abruptly accentuated form effective for the actuation and control of associated devices and apparatus.

In the diagram of Fig. 1, a thyratron 10, having a cathode 11, grid 12 and anode 13, is conventionally shown in a circuit wherethrough the novel principles of the invention are made practically evident.

Input terminals 14 and 15 are connected with a source of periodic signal variations to be impressed upon the thyratron grid, terminal 14 connecting with said grid through conductor 16 and resistor 17, and terminal 15 connecting with bus conductor 18 and thence, through point 19 and conductor 20, with cathode 11. A source of potential 21, or a cathode bias resistor 22, or both, may be provided in the circuit intermediate point 19 and cathode 11, to bias the cathode; and a resistor 23 may be connected across conductors 16 and 18 at points 24 and 25.

Cathode 11 connects, through points 19, 26 and 27, with the negative side of a source of potential 28, the positive side whereof connects, through resistor 29, and through points 30, 31 and 32 on positive conductor 33, with the thyratron anode, thus completing the cathode-anode circuit.

Condenser 34 bridges conductors 18 and 33, being connected with the former at 26 and the latter at 31, in parallel with thyratron 10, thus being susceptible of being charged by supply source 28; the capacity of condenser 34 is of very low value (about .00005 mf.), so that in the charging thereof by supply source 28 through resistor 29 the time constant is short relative to a half-cycle of the signal voltage impressed upon grid 12, but is appreciable.

For the purposes of the invention, resistor 29 is selected to have a resistance sufficiently high that, when thyratron 10 is conducting, the current passed by thyratron 10 is limited to an amount susceptible of interruption by an increase in the negative potential of grid 12 within the signal-derived limits of grid potential variation; when thyratron 10 is nonconducting, the potentials across thyratron 10 and across condenser 34 are essentially equal to the potential across supply source 28, and of an order to fire thyratron 10 in response to a decrease in the negative potential of grid 12 within the signal-derived limits of grid potential variation.

Condenser 35 bridges conductors 18 and 33, being connected, through resistor 36, with conductor 18 at 37, and with conductor 33 at 38, thus being susceptible of being charged by supply source 28; the capacity of condenser 35 is of low value (about .001 mf.), so that in the charging thereof by supply source 28, connected through resistors 29 and 36, the time constant is short relative to a half-cycle of the signal voltage impressed upon grid 12, but is appreciable. Values are so chosen that the discharging time constant of condenser 35 is greater than that of condenser 34, but short relative to a half-cycle of the signal voltage impressed upon grid 12. A suitable connection is provided at point 39, intermediate resistor 36 and condenser 35, for furnishing voltage output to any suitable associated apparatus.

Thus, with the pertinent supply potential, grid bias, resistor and condenser values properly selected and suitably proportioned, preferably so that thyratron 10 fires at approximately the zero potential point of signal-derived grid potential variation, the operation of the circuit shown and thus far described may be illustrated as follows:

To follow a cycle of operation, let us choose an instant at which the thyratron is passing no current, and assume that the thyratron grid is biased to a negative potential just sufficient to prevent, independently of signal voltage, the firing of the thyratron, and that condensers 34 and 35 have been charged by supply source 28. Point 32 will at this instant be at a positive potential equal to the supply voltage, and point 39 will be at zero potential by reason of its connection to bus conductor 18 through resistor 36. Let us assume that at this instant the signal voltage applied to grid 12 through input terminals 14 and 15 is becoming more positive; as the net grid potential (the algebraic sum of the grid bias derived from supply source 21 and the signal voltage) reaches a critical value, thyratron 10 fires, condensers 34 and 35 discharge, there is a surge of current to and through point 32 to the thyratron anode, and the potential of point 32 suddenly drops. At this point it may be noted that there is no appreciable resistance intermediate condenser 34 and thyratron 10 to prolong the discharge of said condenser; however, in the case of condenser 35 there is such resistance, consisting of resistor 36, providing a time constant for the discharge of condenser 35 greater than exists in respect of condenser 34.

The discharge of condenser 35 occasions a current flow from point 39 toward the condenser, thus producing a sharp potential drop at point 39; however, by reason of the connection of point 39 with conductor 18 through resistor 36, the former potential of point 39 is restored very quickly in accordance with the time constant of the circuit. This momentary potential drop at point 39 may be utilized to actuate associated apparatus, as hereinafter mentioned.

After condensers 34 and 35 have discharged as aforesaid, a minute current continues to flow from supply 28 through thyratron 10, but is limited by resistance 29 to a low value; during such current flow the voltage across the thyratron and condenser 34 remains low.

As the signal voltage passes from positive to negative, it increases the negative potential of the thyratron grid, and this, coupled with the low anode voltage obtaining when the tube is conducting, results in the interruption of current flow through the thyratron, whereupon condenser 34 is charged to its former positive potential by supply source 28 at a rate dependent upon the time constant of the circuit including resistors 29 and 36, occasioning a current flow from condenser 35 toward resistor 36, thus producing a sharp potential rise at point 39 (which is less in degree than the potential drop produced upon discharge of condenser 35 as hereinbefore mentioned); however, by reason of the connection of point 39 with conductor 18 through resistor 36, the normal potential of point 39 is restored shortly in accordance with the time constant of the circuit. The apparatus is thus conditioned for the commencement of a new cycle.

The values of condensers 34 and 35 are so chosen that they recharge as aforesaid during the period between successive firings of the thyratron, hence at the instant the signal voltage reaches the value at which firing is desired, the

voltage across the thyratron is fixed and definite, and near the critical value.

It will be apparent that the capacitance 34 in parallel with the cathode-anode circuit makes the thyratron responsive to lesser signal variations than would otherwise be the case, and renders the apparatus more stable and precise in respect to the time of firing; and that the improved circuit is automatically operative, in response to a periodic signal input, to maintain the thyratron in conducting condition during the more positive approximately half-portion of each signal cycle, to maintain the thyratron in nonconducting condition during the more negative approximately half-portion of the signal cycle, and to synchronously manifest the periodicity of the signal as current and voltage variations in the cathode-anode circuit.

The value of capacitance should be very low, as heretofore indicated, and its value is critical, in order that the grid control both the starting and stopping of current flow through the tube. Its value depends upon the particular tube used and the capacitance between plate and ground and should be just below the value that will produce oscillations in the tube when the grid voltage is positive.

The cathode-anode circuit voltage variations above described are graphically exemplified in curve B of Fig. 2, which is an oscilloscope trace of potentials at point 32 of the circuit, plotted along the same time axis as and for comparison with a simultaneous oscilloscope trace of the signal input voltage variations at point 24 of the grid circuit and exemplified by curve A. The signal voltage develops as a periodic, sinusoidal curve, swinging between greater and lesser values, to shift the thyratron from nonconducting to conducting condition as curve A moves from greater to lesser negative value, and to shift the thyratron from conducting to nonconducting condition as the curve moves from lesser to greater negative values, the signal voltage periodicity being consequently and correspondingly manifested at point 32 in the cathode-anode circuit as a curve shifting between greater and lesser positive values and characterized by a prompt rise to and sustained maintenance of high potential when and while current flow through the thyratron is interrupted, with sudden drop to and sustained maintenance of low potential when and while current flow through the thyratron is established and maintained, the abrupt drop of curve B occurring when the thyratron fires.

From the foregoing description of the operation of the circuit, and a consideration of the variations of potential exhibited by curves A and B of Fig. 2, it is obvious that, when the thyratron is nonconducting, a relatively high potential is maintained across the thyratron, and that this potential is very slightly less than necessary to overcome the normal grid potential deriving from the grid bias supplied by source 21 through resistors 22 and 17, so that a very slight diminution of the normal grid bias, deriving from the signal, will operate to fire the thyratron. It is likewise obvious that when the thyratron is conducting, a relatively low potential is maintained across the tube, and that the values of this potential, and of the resulting current flow through the tube, are very slightly more than necessary to overcome the normal grid potential deriving from the grid bias supplied by source 21, so that a very slight increase of the normal grid bias, deriving from the signal, results in the interruption of the current through the thyratron.

In an embodiment of the invention constructed as disclosed herein and with the circuit parameters given hereafter, a voltage variation of about 285 volts in the plate voltage of the thyratron was obtained with a sinusoidal input voltage of about 0.2 volt R. M. S. to the grid 12.

The potential variations of point 39 in the thyratron cathode-anode circuit are graphically exemplified in curve C of Fig. 2, said curve being an oscilloscope trace taken in synchronism with curves A and B of said figure. Inspection of curve C shows a normal zero potential at point 39, interrupted by sharp negative peaks of considerable amplitude, coincident in time with the firing of the thyratron, and lesser, broader positive peaks coincident with interruption of conduction through the thyratron. From this curve it is apparent that the circuit including condenser 35 and resistor 36 operates as a voltage peaking or differentiating circuit.

The sharply defined potential drop exemplified in curve C in synchronism with a cyclic characteristic of the input signal is conveniently available and may be readily used for energization or activation of associated means and devices in correlation with the signal characteristic, a practical application being the firing of a stroboscopic discharge lamp by means of and in synchronism with a signal derived from the unbalance of rotating bodies.

Such an arrangement in operative relation with the circuits and devices hereinabove described is shown in Fig. 1. A stroboscopic discharge lamp, or equivalent device, is indicated as consisting of a tube 40, having an anode 41 connecting at point 42 with a supply conductor 43; said tube has a double grid 44 connecting with point 39 in the cathode-anode circuit of thyratron 10, and has a cold cathode 45 connecting with conductor 18 at point 46. A suitable source of potential 47 has its negative side connected with conductor 18 at point 48; its positive side connects, through resistor 49 and point 50 with conductor 43 and therethrough with anode 41, thus completing the cathode-anode circuit of stroboscopic discharge lamp 40.

A condenser 51 bridges conductors 18 and 43, being connected with the former at point 52 and the latter at point 53, and is hence susceptible of being charged to the potential of source 47 when there is no current flow through stroboscopic discharge lamp 40, and to discharge through said stroboscopic discharge lamp in the firing thereof. For firing control of said stroboscopic discharge lamp, the grid 44 thereof connects, as above stated, with point 39, the potential of which varies in the manner hereinbefore described in connection with the operation of thyratron 10; hence the firing of stroboscopic discharge lamp 40 is controlled by the voltage output of the circuit deriving from signal variations impressed upon the grid of thyratron 10. Thus, with stroboscopic discharge lamp 40 connected as shown and described, when the potential at point 39 abruptly drops as shown in curve C of Fig. 2, the stroboscopic discharge lamp fires, condenser 51 discharging therethrough, resulting in a flash of light of very brief duration; condenser 51 is thereupon recharged by source 47 through resistor 49, at a rate dependent upon the time constant of the circuit, the time of charging being low as compared with a half cycle of the signal input impressed upon the grid of

thyratron 10, and the stroboscopic discharge lamp is again in condition to fire in response to a sharp negative peak of potential at point 39. The characteristics and values of the elements involved may be so chosen that the stroboscopic discharge lamp fires only in response to a sharp peak of potential variation (herein illustrated as negative), but will not fire in response to variations in the opposite direction as exemplified by curve C of Fig. 2.

From the foregoing it will be apparent that, as one of the practical exemplifications of the principles of the invention, the circuit may be utilized to fire a stroboscopic discharge lamp at a precisely determined point in the cycle of signal variations deriving from the rotation of an unbalanced body, thus producing a stroboscopic effect whereby proper visual observation of such body may be made to determine the point in the orbit of rotation at which the signal variation is made manifest.

As an example of an operative assembly of elements suitable for the practical utilization of the invention, I set forth below a table of values and identifications of elements shown in Figure 1, the reference numeral of the elements being followed by their respective values or designations. To-wit:

10, tube known as 2051
17, 250,000 ohms
21, 2.35 volts
22, resistances may be substantially zero, but in some cases as high as 2000 ohms may be used.
23, 500,000 ohms
28, 300 volts
29, 2 megohms
34, .00005 microfarad
35, .001 microfarad
36, 500,000 ohms
43, tube known as 631–P1.
47, 300 volts
49, 5000 ohms
51, 4 microfarads

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. An apparatus for providing large output voltage pulsations in synchronized response to a much smaller alternating input signal, comprising a thyratron having an anode, a cathode, and a control grid, the thyratron having a predetermined zero signal breakdown voltage and a predetermined zero signal minimum discharge current; a voltage supply developing less voltage than the zero signal breakdown voltage; an output circuit including an output resistor connecting the voltage supply in series with the anode-cathode discharge path of the thyratron, the resistor being large enough to limit the thyratron discharge current to a value less than the zero signal minimum discharge current; and an input circuit to impress the alternating input signal between the grid and the cathode, the more positive portion of the input signal initiating the discharge in the thyratron and the more negative portion extinguishing the discharge.

2. An apparatus to provide a pulsating output signal at the same frequency as a much smaller alternating input signal having a known minimum periodicity, comprising a thyratron having an anode, a cathode, and a control grid, the thyratron having a predetermined zero signal breakdown voltage and a predetermined zero signal minimum discharge current; a voltage supply developing less voltage than the zero signal breakdown voltage; an output circuit including a capacitor, a discharging circuit connecting the capacitor across the anode and the cathode, the capacitor being so small that the discharging circuit is nonoscillatory, and a charging circuit including an output resistor in series with the voltage supply connecting the latter across the capacitor, the charging time constant of the resistor and capacitor being much smaller than the minimum half-period of the input signal, and the resistor being large enough to limit the thyratron discharge current to a value less than the minimum zero signal discharge current; and an input circuit to impress the alternating input signal between the grid and the cathode, the more positive portion of the input signal initiating the discharge in the thyratron and the more negative portion extinguishing the discharge.

3. An apparatus to provide a pulsating output signal at the same frequency as a much smaller alternating input signal having known minimum periodicity, comprising a thyratron having an anode, a cathode, and a control grid; an input circuit to impress the input signal between the control grid and the cathode, the input circuit including grid biasing means to predetermine a zero signal breakdown voltage and a zero signal minimum discharge current for the thyratron; a voltage supply developing less voltage than the zero signal breakdown voltage; and an output circuit including a capacitor, a discharging circuit connecting the capacitor across the anode and the cathode, the capacitor being so small that the discharging circuit is nonoscillatory, and a charging circuit including an output resistor in series with the voltage supply connecting the latter across the capacitor, the charging time constant of the resistor and capacitor being much smaller than the minimum half-period of the input signal, and the resistor being large enough to limit the thyratron discharge current to a value less than the minimum zero signal discharge current; the positive portion of the input signal thereby initiating the discharge and the discharge being maintained until it is extinguished by the negative portion of the input signal.

4. An apparatus for providing large extremely brief output pulsations at the frequency of a much smaller alternating input signal having known minimum periodicity, comprising a thyratron having an anode, a cathode, and a control grid, the thyratron having a predetermined zero signal breakdown voltage and a predetermined zero signal minimum discharge current; a voltage supply providing less voltage than the zero signal breakdown voltage; a first output circuit including a capacitor, a discharging circuit connecting the capacitor across the anode and the cathode, the capacitor being so small that the discharging circuit is nonoscillatory, and a charging circuit including an output resistor in series with the voltage supply connecting the latter across the capacitor, the charging time constant of the resistor and capacitor being much smaller than the minimum half-period of the input signal, and the resistor being large enough to limit the thyratron discharge current to a value less than the minimum zero signal discharge current; and a pulse sharpening output circuit connected in parallel with the first capacitor and including a second capacitor and a second resistor in series, the time constant of the second named output circuit be-

ing much less than the minimum half-period of the input signal and the second resistor being so large that the second output circuit is nonoscillatory; and an input circuit to impress the alternating input signal between the grid and the cathode, the more positive portion of the input signal initiating an arc discharge in the thyratron to produce a brief output pulsation across the second resistor, and the discharge being maintained until it is extinguished by the more negative portion of the input signal.

5. An apparatus to provide a pulsating output signal at the same frequency as a much smaller alternating input signal having a known minimum periodicity, comprising a thyratron having an anode, a cathode, and a control grid, the thyratron having a predetermined zero signal breakdown voltage and a predetermined zero signal minimum discharge current; a voltage supply developing less voltage than the zero signal breakdown voltage; an output circuit including a small capacitor, a discharging circuit connecting the capacitor across the anode and the cathode, the capacitor having a small value of about 50 micromicrofarads so that the discharging circuit is nonoscillatory, and a charging circuit including an output resistor in series with the voltage supply connecting the latter across the capacitor, the charging time constant of the resistor and capacitor being much smaller than the minimum half-period of the input signal, and the resistor being large enough to limit the thyratron discharge current to a value less than the minimum zero signal discharge current; and an input circuit to impress the alternating input signal between the grid and the cathode, the more positive portion of the input signal initiating the discharge in the thyratron and the more negative portion extinguishing the discharge.

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