

March 13, 1951

F. E. BRYAN ET AL
ELECTRONIC CONTROL DEVICE

2,545,257

Filed April 26, 1948

2 Sheets-Sheet 1

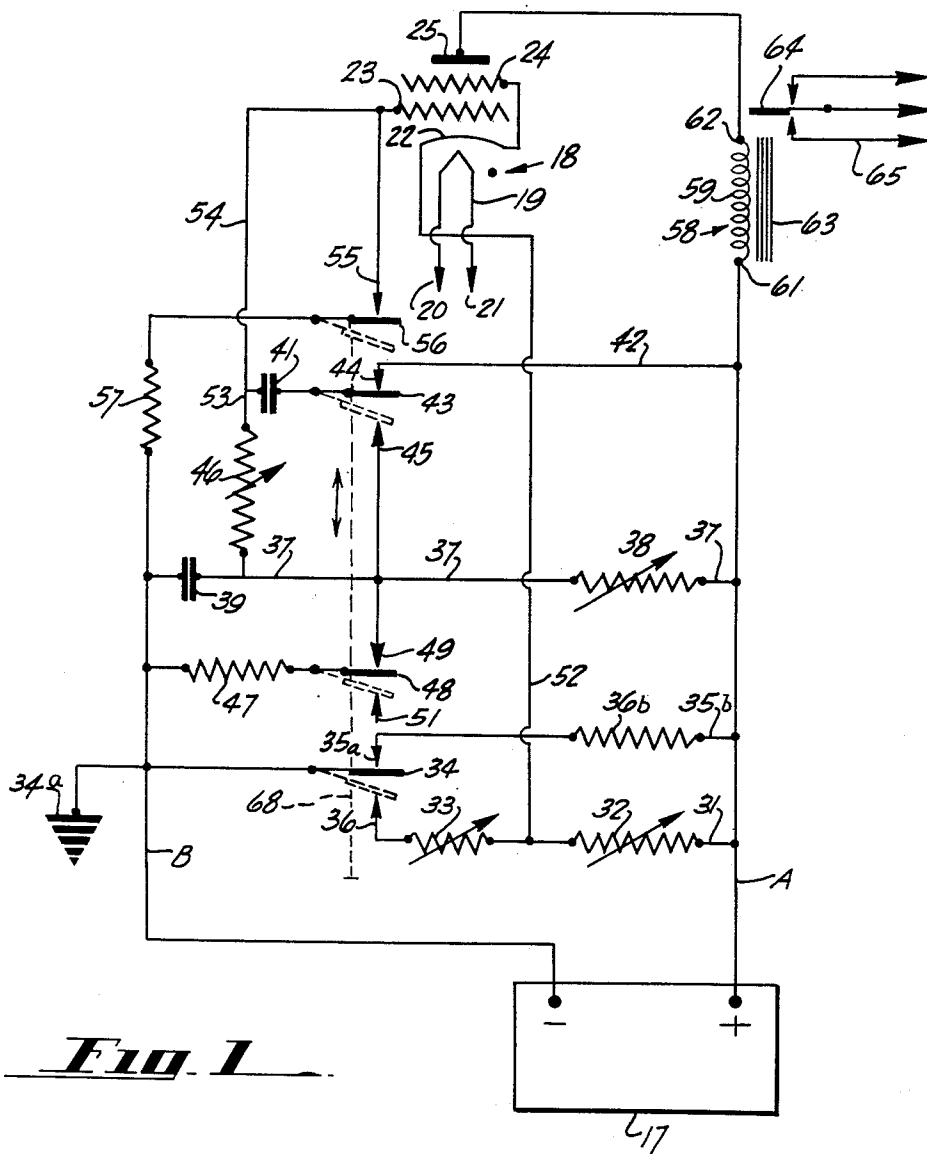


Fig. 1

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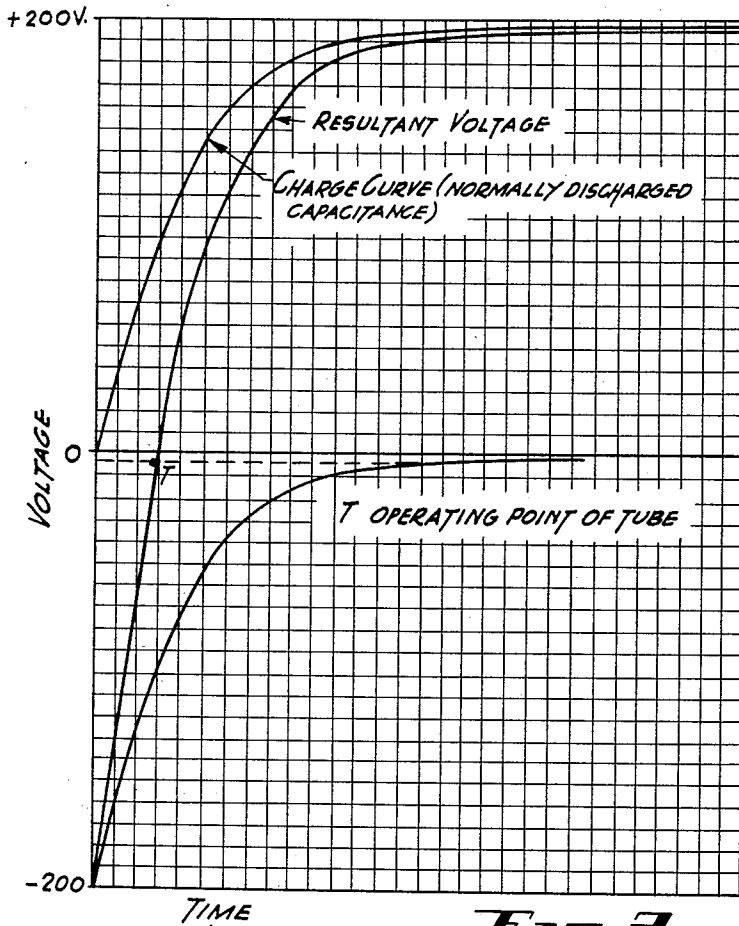


Fig. 2

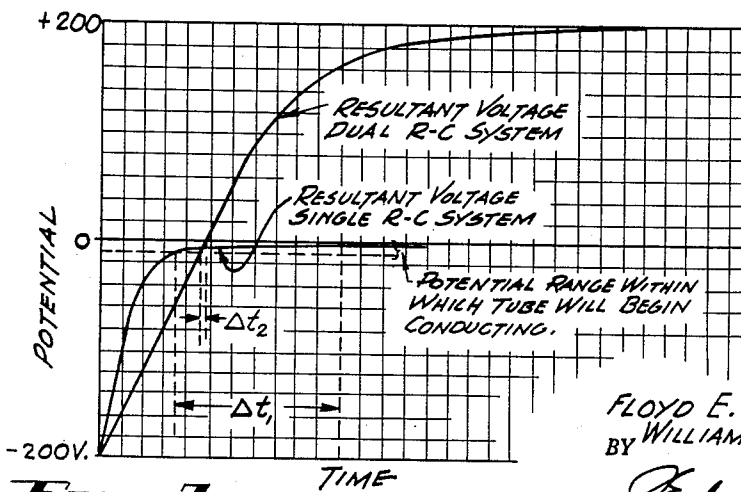


Fig. 3

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2,545,257

ELECTRONIC CONTROL DEVICE

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Application April 26, 1948, Serial No. 23,294

10 Claims. (Cl. 250—27)

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This invention relates to electronic timers and particularly to novel triggering means and circuit arrangements for controlling the firing of the electronic means of the timer. The invention is well adapted for service in controlling the timed periods of operation of associated mechanically or electrically actuated apparatus and will herein be described in such connection, but merely by way of exemplification. For, as will hereinafter become manifest, the invention is applicable to effect the control of the operation of an electronic tube for substantially any desired purpose. Also, as will become apparent, the invention is not limited to the nature and use of the energy emitted from the tube but resides in the novel timing instrumentality and the means for effecting the timed operation of this timing instrumentality.

Although electronic devices, such as cycle counters, have hitherto been adapted to perform timing operations of the present general nature, as by arranging them to operate a control relay after counting a predetermined number of oscillations of known frequency, the requisite timing accuracy can be achieved with such expedients only by employing a prohibitively large number of electronic tubes and other equipment.

The present timer operates with enhanced precision under all service conditions likely to be encountered, yet is of extreme simplicity, incorporating only one electronic tube and requiring but a relatively simple triggering circuit therefor.

The triggering circuit includes dual resistor-condenser units adapted to respectively discharge and charge concurrently. The R.-C. units are connected to the control electrode of the electronic unit and apply thereto a potential consisting of the algebraic sum of the two exponentially changing potentials therefrom. This potential may, if desired, be combined with a fixed potential bias. Because of the combined effects of the two R.-C. currents, the rate of change of the control electrode voltage is rendered sufficiently rapid to nullify any accuracy-reducing extraneous effects, such as those due to fluctuating supply voltage, etc. That is to say, as compared to the shallow slope voltage vs. time curve of the prior art, the voltage vs. time curve of this invention has a quite steep slope, so that the firing-period of the present tube subtends but a small segment of the time-abscissa. During this extremely minute, substantially infinitesimal period of time, the segment of the voltage ordinate subtended by the steeply sloped arc of the voltage curve is even more minute than the time-segment. The effect of voltage-fluctuations is hence minimized and substantially nullified. Hence, despite its relative simplicity, the invention, by virtue of its acceleration of the rate of change of the control voltage in the electronic element, effects the timed actuation of the automatically actuatable associ-

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ated device with substantially constant accuracy. The accuracy percentage of the device is better than plus or minus one per cent of the desired time interval, even under the most extreme conditions encountered in field service.

Essentially the device incorporating the invention comprises a source of electrical energy; an electro-mechanical energy transducer adapted to directly actuate the automatically actuatable device associated with the present apparatus; an electronic unit, including an anode and a control electrode and a cathode; and a novel triggering circuit for effecting firing of said electronic unit at a predetermined, substantially constant time interval following initiation.

The aforementioned electro-mechanical transducer is connected on one side to the positive terminal of the power source and on the other to the anode of the electronic unit. In its presently preferred form, the triggering circuit essentially includes a quadruple pole, double throw initiating switch; a capacitance connected to the control electrode, and, in the standby position of said switch, also connected across said energy source by the then-closed contacts of the fourth and third decks, from the bottom, of said switch, enabling it to be fully charged, preferably through a current limiting resistor. The triggering circuit also includes, extending across said energy source, a conductor path including a high ohmage resistor and a second capacitance. This capacitance, in the standby condition, is inactive, being shunted through the normally closed contact of the second deck of the switch by the low-value resistor. A connection extends from said conductor path by way of another resistor to the first said capacitance and to the control electrode, the second said capacitance being also connected to the negative leg of said energy source and to the junction of the aforesaid resistors. This second said capacitance is also connected to the contact of the third deck that is now open, and to the normally closed contact of the second deck of said switch, whereby to maintain the second said capacitance discharged. The triggering circuit also includes a conductor path extending from the positive leg of the energy source to the normally open contact of the first deck of the switch. This conductor path may also include two voltage-dividing resistors, the junction of which is connected to the cathode.

Thus, before actuation of the initiating switch, the control electrode is connected to the negative source-leg and the cathode is connected to the positive leg through a suitable resistor, the other resistor being, in this condition of the switch, in an inactive condition. The anode is connected through the electro-mechanical transducer to the positive leg of the energy source. The heater element of the electronic unit is connected to a

source of electrical energy and if a shield or screen grid is employed, it is suitably tied to the cathode. The first said capacitance, being connected across the legs of the energy source through the normally closed contacts of the third and fourth switch decks, has its charged polarity so arranged that the negative terminal of the first-said capacitance remains connected to the control electrode and its positive terminal remains connected through the third deck of the switch to the positive terminal of the energy source, and hence in effect is connected to the cathode. The second-said capacitance is in a substantially discharged condition, being connected directly to the negative leg of the energy source on one side, and on the other side is connected through the contacts of the second switch deck to a point at essentially the same potential.

The timed interval of operation of the electronic timing device is started by operating the aforesaid initiating switch, thus connecting the cathode biasing resistors in series across said energy source and constituting them a voltage divider which supplies the cathode with sufficient bias potential to prevent premature firing of the electronic unit. The charged first-said capacitance is then connected in parallel with, and discharged through, its discharge resistor via the now closed contact of the third deck of the switch. The initially uncharged second-said capacitance and the high ohmage resistor are now connected in series across the energy source. The second-said capacitance hence becomes charged.

Thus, the control electrode receives, by virtue of the combined effects of the discharging first-said capacitance and the concurrently charging second-said capacitance, a potential relative to said cathode that is the algebraic sum of the potential across the parallel combination of the first-said capacitance with its discharge resistor together with the potential across the second-said capacitance, the two being combinable, if desired, with the potential at the juncture of the cathode biasing resistors. That is, the potential applied to the control electrode consists of the sum of two exponential changes in potential which may, if desired, be combined with a fixed bias. The resulting control grid potential commences from the full supply voltage negative and progresses asymptotically towards the full supply potential positive.

When the high negative voltage applied to the control electrode falls to a point which will allow the electronic unit to conduct, or fire, the transducer is actuated, thus terminating the time interval. The point in the control voltage change at which this conduction starts is substantially that existing at the instant of change of the polarity of the control voltage.

Because of these two additive and cumulative voltage changes, the rate of change of the control voltage is rendered extremely rapid, thus nullifying most extraneous effects, such as those due to variations in tube manufacture, fluctuating supply voltage, and operating temperatures, which would normally be present in electronic tubes and their applied potentials. By virtue of this nullification, the timing operation of the device is rendered substantially constant under all service conditions likely to be encountered.

The now preferred, or service, embodiment of these concepts, together with a graphic summary of its operation, is illustrated in the accompanying drawings, but it is to be understood that this illustrative form includes many ramifications and

refinements in addition to the aforescribed essentials and that the invention may be embodied in other constructional forms than the one shown.

In these drawings:

Figure 1 is a diagrammatic view of the service form of the invention, showing the components of the timer and their circuit arrangements;

Figure 2 is a graph illustrating the operation of the present dual R.-C. circuit in providing the improved control of the electronic tube, and

Figure 3 is a graph comparing the variation, Δt_1 , of the controlled time interval of the conventional R.-C. timer system with the variation, Δt_2 , of the controlled time interval incident to the present invention.

The illustrated device includes, as shown in Figure 1, a suitable source 17 of D. C. potential, connected to the legs A and B of a control circuit later described, the latter circuit in turn being connected to an electronic tube-unit 13 including a heater 19 connected either to the source 17 of D. C. potential or to some suitable source of A. C. potential. The electronic unit also includes heater leads 20 and 21, a cathode 22, a control grid 23, a shield or screen grid 24, and a plate or anode 25.

The positive leg A is rendered connectible to the negative leg by means of a conductor path 31 including a resistor 32 in series with another resistor 33. Both these resistors may be variable if desired. A switch 34 having contacts 35a and 36 and constituting the lowermost deck of a quadruple-pole, double throw gang switch, operable as later described, is interposed in the conductor path to connect other components of the device, later described. The negative terminal may also be grounded as at 34a.

Another conductor path 35b, including a fixed resistor 36b, connects the positive leg, above the aforesaid path, to the contact 35a, for a purpose later described.

The positive leg is also connected to the negative leg by a conductor path 37, including a variable high ohmage resistor 38 and a normally inactive, or substantially discharged, capacitance 39. Another conductor path 42 connects a capacitance 41 to the positive leg through a switch 43 and the normally closed contact 44. These contacts, together with normally open contact 45, form the third deck, from the bottom, of said quadruple pole double throw gang switch. The second terminal of the capacitance 41 is connected to the juncture of the aforementioned resistor 38 and capacitance 39 through a resistor 46, which may be of the variable type and employed as later explained.

The same junction point is normally connected to the negative leg B of the energy source through a switch 48, a normally closed contact 49 and a resistor 47. The above switch 48 and contact 49 together with a stop-contact 51 form the second deck of the aforementioned quadruple deck switch.

A conductor path 52 extends from between the resistors 32 and 33 to the cathode 22 of the electronic unit and thence to the shield of screen grid 24 thereof. The control grid 23 of the unit is connected to the junction 53 that the condenser 41 makes with its discharge resistor 46, by means of a conductor path 54. The control grid is also in the inactive position, connected to the negative leg of the energy source through the normally closed contact 55 and switch 56. The above contact 55 and switch 56 together with a

stop contact 56a form the fourth deck of the aforementioned quadruple pole switch.

An electro-mechanical transducer 58 is provided for operating the timed device, and comprises an actuating coil 59, one side 61 of which is connected to the positive leg of the energy source, and the other side 62 of which is connected to the anode of the discharge unit. The transducer is shown as a relay operating, through its core 63, a switch 64 connected to any desired electrical device through leads 65. It is to be understood, however, that the coil may operate any desired mechanical device through suitable armatures, linkages or the like.

An electro-magnetic initiating circuit of conventional type, not shown but including a single-pole, single-throw switch and a solenoid associated with a link 68, is provided to actuate by means of the link 68, the aforementioned quadruple pole, double throw gang switch, comprising switches 34, 48, 43 and 56, in such a manner as to simultaneously actuate all the switches into their dotted line positions when the initiating switch is closed.

In the "stand by" condition of the device, with the initiating switch open and the gang switches 34, 48, 43 and 56 in the full line positions of Figure 1, the circuits are such that control electrode 23 is connected to the negative leg of the energy source and the cathode 22 is connected through resistor 32 to the positive leg of the energy source. The tube is thereby rendered non-conductive. The condenser 41 is connected across the energy source through the normally closed contacts of the third and fourth decks, 43 and 56, of the initiating switch and is thus charged to the full source potential, with its polarity so arranged that the negative terminal of the condenser 41 remains connected to the control electrode 23.

Condenser 39 has one side permanently connected to the negative terminal of the energy source, and to the small value resistor 47 and in the inactive condition of the device, the other side is connected through the elements 46, 54 and 55 to the normally closed contact 56 of the fourth deck, from the bottom, of the initiating gang switch. Condenser 39 is, therefore, in the stand-by condition of the device, maintained substantially discharged.

When it is desired to effect actuation of the automatically operable electrical or mechanical device associated with the transducer at the end of a predetermined time interval the initiating switch is closed. This switch operates the quadruple pole gang switch altering the tube control circuit in a manner to effect delayed triggering of the energy transducer 58. The control circuit is altered as follows, by closing the switch: the series-connected resistors 32 and 33 are connected through switch 34, across the legs of the energy supply to form a voltage-divider, thus furnishing the cathode 22 with a bias potential sufficient to prevent premature firing of the discharge unit. The charged condenser 41 is connected in parallel with its discharge resistor 45 through the switch arm 43 and contact 45, while the initially shunted and discharged condenser 39 and the resistor 38 are connected in series across the energy source.

Thus, from the concurrently discharging and charging condensers 41 and 39, respectively, the control grid 23 receives a potential relative to the cathode that comprises, as shown in Figure 2, the algebraic sum of the potentials across the condenser 41 and the condenser 39 combined with

the aforementioned bias potential. The exponential change commences, as shown in Figure 2, at the full supply voltage negative and progresses asymptotically toward the full supply voltage positive.

When the potential to the control electrode relative to the cathode reaches a predetermined value, the tube will fire, as shown in Figure 2. The firing will occur when the exponentially changing voltage on the control grid reaches a positive potential approximately equal to the aforementioned cathode bias potential or at point T, in Figure 2. The time interval elapsing between the closing of the initiating switch and the firing of the discharge unit may be made to vary by varying the values at which the resistors 32, 33, 38 and 46 are set, and can thus be altered as desired.

The firing of the electronic tube allows current to flow from the anode 25 through the actuating coil of the transducer 58, thus operating the electro-mechanical transducer which in turn actuates the load circuits 64-65.

As shown qualitatively in Figure 3, the possible limit of variation, Δt_2 , of the controlled time interval of the present timer consequent upon extraneous influences such as the variation in firing potential of the tube, is quite small as compared to that, Δt_1 , of the conventional single R.-C. system. Among other reasons, this fact results from the extremely rapid change of voltage provided by the present system, as shown by the steep slope of the present resultant voltage curve within the tube-firing potential range. This curve, in the firing-potential range, subtends a segment, Δt_2 , on the time-abscissa which is substantially infinitesimally small, whereas the segment, Δt_1 , subtended by the shallow slope of the curve of the conventional R.-C. system in the tube-firing potential range is relatively large.

The predetermined substantially constant and controllable delay between the initiating action and the operation of the energy transducer can, of course, be employed in many ways. For example, the device may be employed to close a pair of contacts in a circuit for opening or closing a bomb-bay door one second after the closing of the initiating switch. These contacts may be held closed by another similar timing circuit for one half second then the device automatically resets itself so that the cycle can be repeated after a rest period of several seconds.

The embodiment illustrated and described is that which is primarily adapted for operating a bomb-bay door as specified and hence includes several elements not absolutely essential to the performance of the basic timing function of the invention. If desired, instead of the discharge unit consisting of a gas filled, hot-cathode tetrode, it may consist of either a hot or cold cathode triode, omitting the screen grid 24. The conductor path 35 and resistor 36 may also be omitted without materially affecting the operation of the device, as may the biasing resistor 32. Resistors 47 and 57, provided chiefly to prevent arcing at the contacts 49 and 55, may be also omitted.

We claim:

1. A control system for stabilizing the firing of an electronic-tube having a cathode connected to an energy source and a control-electrode, comprising: resistor-capacitance means normally chargedly connected to said source and operatively associated with means enabling it to be alternatively dischargeably energy-flow communicat-

ed with said control electrode; other resistor-capacitance means normally connected in short circuit to said source in substantially discharged condition and operatively associated with means enabling it to be alternatively chargeably connected to the source and to the first-said means and said control-electrode; and independent control-initiating means for simultaneously establishing said alternative flow-paths, thereby to concurrently discharge the first-said means and charge the second-said means and apply the algebraic sum of their changing potentials to said control-electrode, whereby to effect on the control electrode of said tube a rate of potential change sufficiently rapid to nullify extraneous effects on said tube.

2. An electronic timer, comprising: an electrical-energy source; an electro-mechanical energy transducer connected at the one side to said source; an electronic-unit having a control grid, a source-biased cathode, and an anode connected to the other side of said transducer; a circuit-arrangement connected across said source and to said grid for triggering said electronic unit; and initiating means for actuating said triggering circuit; said triggering circuit including a first capacitor normally connected to the energy source in charged condition, the negative element thereof being dischargeably connected to said grid; a second capacitor normally connected in short-circuit to said source and connected to the first capacitor and to said grid; switch-means operatively interposed in said circuits and arranged and organized therewith in a pattern such as to effectuate discharge of the first capacitor and charge of the second capacitor, with the element thereof that is connected to said grid accumulating a positive charge, and to enable application of the algebraic sum of the oppositely changing potentials of said capacitors to said grid; said switch-means being operably connected to said initiating means for operation thereby, so as to effect concurrent discharging and charging of the respective capacitances in said dual R. C. circuit and to concurrently apply the potentials therefrom to said grid as a control voltage changing sufficiently rapidly to nullify accuracy-reducing extraneous electrical effects on said electronic-unit and render its operation substantially constant.

3. An electronic timer, comprising: a source of electrical energy; an electronic unit adapted to be energized thereby and including a control grid; an electro-mechanical transducer connected at the one side to the anode of said unit, and connected at the other side to said source, and operatively associated with a device to be operated thereby at a predetermined time interval after the initiation of the timer; a first capacitor normally connected to the energy source in charged condition, the negative element thereof being dischargeably connected to said grid; a second capacitor normally connected in short-circuit to said source and connected to the first-said capacitor and to said grid; independent control-initiating means operatively interposed in said circuits and organized therewith to effectuate discharge of the first capacitor and charge of the second capacitor with the element thereof that is connected to said grid accumulating a positive charge, and to enable application of the algebraic sum of the oppositely changing potentials of said capacitors to said grid, said resistor-condenser units being variable to vary the potentials supplied from said con-

densers to said control electrode, whereby to enable variation of the predetermined time interval of firing of said electronic unit and thereby vary the time interval of operation of said transducer.

4. In an electronic timer connectible to an energy source and including an energy-transducer connected at the one side of its actuating member to the positive source-leg; and an electron-generating unit having a control electrode and an anode energizingly connected to the other side of said actuating member, the timer also including an independent timer-initiating circuit; a triggering circuit for said generating unit and comprising, in combination a quadruple-pole, double-throw initiating switch, connected to said initiating circuit for automatic actuation thereby and having its decks interposed in said triggering circuit between said source and said generating unit; a capacitance connected to said control electrode and initially chargedly connected across said energy source; a conductor path for connecting the legs of said energy source, said path including a high-ohmage resistor and a second capacitance connected to the negative source-leg; a connection, including a resistor, extending from said conductor path to the first-said capacitance and to said control electrode; the second said capacitance being normally connected to the junction of the aforesaid resistors and also being connected to the now open contact of the third deck from the bottom of said switch and to the normally closed contact of the second deck from the bottom of said switch, whereby to maintain same substantially discharged; a conductor-path extending from the positive source-leg to the normally open contact of the bottom deck of said switch, said path including two voltage-proportioning resistors; and a connection extending from the mid-point of said path to said cathode; whereby switch operation effects series-connection of said voltage-proportioning resistors across said energy source so as to apply a premature-firing preventing potential to the cathode while connecting the first-said capacitance and its resistor in discharging-parallel, and concurrently effects series charging-connection of the second-said capacitance and its high-ohmage resistor across the energy source, thereby to apply to said control electrode, a firing and transducer-actuating potential that effects a voltage change on the control grid of the electronic unit sufficiently rapid to nullify accuracy-reducing extraneous effects on the timer.

5. An electronic timing device, comprising: a source of electrical energy; an electrical energy transducer having the one side of its actuating winding connected to the positive leg of said energy source; an electronic discharge unit including an anode connected to the other side of said actuating winding and having a control electrode and a cathode; and a triggering circuit for effecting firing of said unit to actuate said transducer at a predetermined, substantially constant time interval following initiation; said triggering circuit including: a multi-deck actuating switch having at least a middle-deck, an upper deck and a lower deck; a capacitance normally connected at its positive side across said energy source via the middle deck of said switch so as to be charged to full source potential and having its negative side connected to said control electrode; a conductor path connected across said energy source and including a primary resistor; a connection from said path to the nega-

tive side of said capacitance and including another resistor; another capacitance connected to the negative terminal of said energy source and to the junction of said resistor paths and to the normally open contact of the middle deck and the normally closed contact of the lower deck, of said switch; whereby normally to discharge the second said capacitance; a conductor path extending from the positive side of said energy source to the normally open contact of the upper deck of said switch and including a cathode-biasing resistor and a control electrode-biasing resistor; whereby actuation of said switch connects said cathode biasing resistor and said control electrode biasing resistor in series across said energy source, thereby to provide the cathode with a potential sufficient to prevent premature firing and whereby said actuation connects the first-said charged capacitance in parallel with its discharge resistor, connects the first said capacitance and said primary resistor in series across said energy source, and connects said control electrode to the algebraic sum of the potential across the parallel combination of the first-said capacitance and its resistor, together with the potential across said control electrode biasing resistor, so as to effect firing of said electronic discharge unit at the end of a predetermined substantially constant time interval occurring at the instant of change of the polarity of said control electrode.

6. A control system for an electronic tube having a cathode connected to a source of electrical energy and a control grid, including: a dual R. C. circuit, one of said R. C. circuits being directly connected to said grid and initially having its terminals chargingly connected across said source, and the other of said R. C. circuits being initially shunted as to said source and normally short circuited as to the energy source and connected to the control-grid; means for shifting one of the terminals of the first-said R. C. circuit so as to effect discharge thereof; and simultaneously effective means for chargingly connecting the second-said component to said source; whereby to effect substantially constantly accurate control of the firing of said tube.

7. The method of controlling the firing of an electronic-unit connected to an electrical energy source and having a cathode, an anode and a control electrode, comprising: deriving from said energy source a substantial negative potential and applying same to said electrode; diminishing said negative potential and concurrently deriving an increasing positive potential from said source and applying it to said electrode to thereon meet the oppositely quantitatively changing positive potential, these two oppositely changing potentials combining algebraically to effect an increase in their rate of potential change at the firing point of said electronic unit to render the rate of potential change in said electronic unit so rapid as to nullify extraneous influences in said unit and thereby stabilize the time-factor of said unit.

8. The method of controlling the firing of an electronic-unit having a cathode, an anode and a control electrode, comprising: producing a substantial negative potential and applying same to said electrode; decreasing said negative potential and concurrently producing an increasing positive potential and applying it to said electrode to thereon meet the oppositely quantitatively changing positive potential, these two

oppositely changing potentials combining algebraically to effect an increase in their rate of potential change at the firing point of said electronic unit to render the rate of potential change in said electronic unit sufficiently rapid to nullify extraneous influences in said unit and thereby stabilize the time-factor of said unit.

9. A control system for stabilizing the firing of an electronic tube having an energized cathode and an energizable control grid, comprising: a first capacitor normally connected to the energy source in charged condition, the negative element thereof being dischargeably connected to said grid; a second capacitor normally connected in short-circuit to said source and connected to the first-said capacitor and to said grid; independent control-initiating means operatively interposed in said circuits and organized therewith to effectuate discharge of the first capacitor and charge of the second capacitor, with the element thereof that is connected to said grid accumulating a positive charge, and to enable application of the algebraic sum of the oppositely changing potentials of said capacitors to said grid; whereby to effect on said control grid a rate of potential change sufficiently rapid to nullify the effect of extraneous influences on said tube and thus render its firing rate constant.

10. An electronically timed automatic device, comprising: a source of electrical energy; an electronic unit adapted to be energized thereby and including an anode and a control grid; an electro-mechanical transducer connected to the anode of said unit and operatively associated with said device to operate same at a predetermined time interval after the initiation of the timer; a first resistor-condenser unit, including a discharge circuit, normally connected in said energy circuit to be charged thereby; means for flow-connecting said resistor-condenser unit to said discharge circuit to remove a control voltage from the control grid of said electronic unit; a second resistor-condenser unit normally connected in short-circuit with said energy source; means flow-connecting said second unit to said source to effectuate charging thereof; means connecting said second unit to said control grid to apply a control potential to said grid concurrently with the aforementioned discharge thereto; and initiating means operatively interposed in said circuits and organized therewith to effectuate discharge of the first capacitor and charge of the second capacitor and to enable application of the algebraic sum of the oppositely changing potentials of said capacitors to said grid, thereby to effect firing of said tube when the exponential changes in the potentials from said capacitors reach predetermined values, whereby to effect operation of said transducer and said automatic device at a substantially constant time interval.

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