

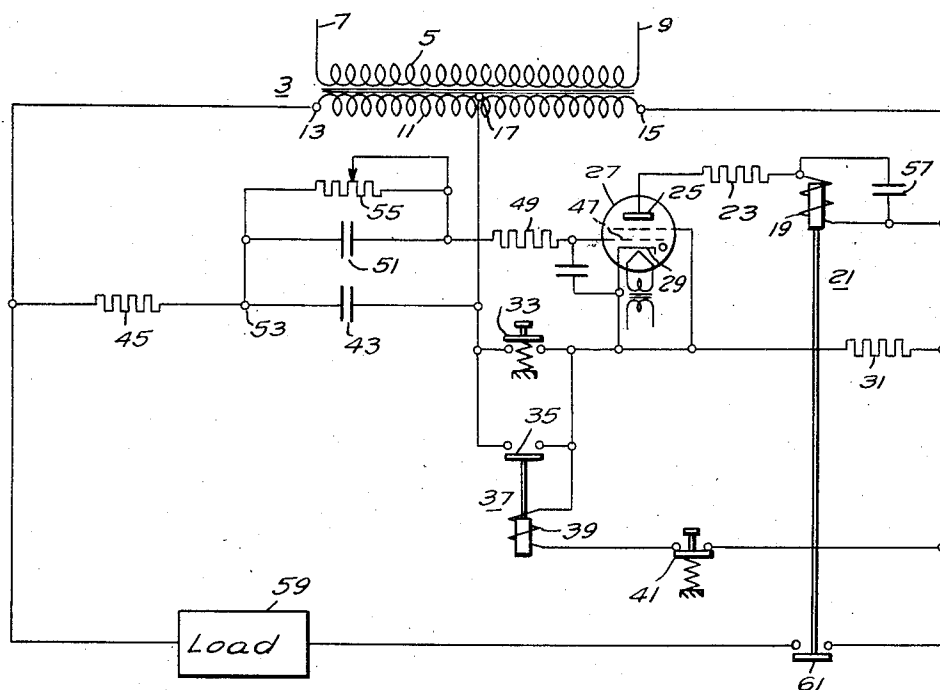
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TIMING CIRCUIT

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TIMING CIRCUIT

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This invention relates to an electronic timing circuit and it has particular relation to a timing circuit for use with an alternating voltage supply.

In resistance welding apparatus, an electronic timing circuit is frequently employed to time certain sequence operations. There are a number of different timing circuits now in use for this and various other purposes, which employ an electric valve which becomes conductive at the end of the timed interval. However, the prior circuits of which I am aware are either somewhat erratic in operation under certain circumstances or involve too many elements to be economically practical in many applications.

The more practical of the prior timing circuits have a connection between the control circuit of the valve and the alternating voltage source. As a result, surge voltages on the supply lines, as may be produced by the operation of other apparatus supplied therefrom, appear in the control circuit of the valve. Consequently, with a surge of the proper polarity, and sufficient magnitude, the valve may be rendered conductive by the surge regardless of the time, and the operation of the system may be seriously affected.

It is accordingly an object of my invention to provide a new and improved electronic timing circuit.

A further object of my invention is to provide a novel timing circuit of practical design in which variation in the timed interval because of surges in the supply voltage are substantially avoided.

Another object of my invention is to provide a novel timing circuit in which an electric valve is rendered conductive after an accurately measured time interval of a preselected length.

Still another object of my invention is to provide a timing circuit in which an electric valve is rendered conductive after an accurately measured time interval of a preselected length in which variation in the time interval because of surges in the supply voltage are substantially avoided.

The features of my invention which are considered novel are set forth with more particularity in the accompanying claims. The invention itself, however, together with the advantages and further objects thereof may be better understood from the following description of a specific embodiment when read in connection with the accompanying drawing, in which the single figure is a schematic circuit diagram of a preferred embodiment of my invention.

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As shown in the drawing, a supply transformer 3 has a primary winding 5 energized from a pair of alternating voltage supply lines 7 and 9 and a secondary winding 11 which is provided with a pair of end terminals 13 and 15 and an intermediate terminal 17. The right end terminal 15 of the secondary winding 11 is connected through the operating coil 19 of a relay 21 and a resistor 23 to the anode 25 of an electric valve 27 which is preferably of the arc-like type, such as a thyratron. The cathode 29 of the valve 27 is connected through a resistor 31 to the same end terminal 15 of the secondary winding 11. The cathode 29 is also connected to the intermediate terminal 17 of the secondary winding 11 through the normally open initiating switch 33. The initiating switch 33 is shunted by the normally open contact 35 of a hold-in relay 37, the operating coil 39 of which is connected between the cathode 29 and the right end terminal 15 of the secondary winding 11 through a normally closed stopping switch 41.

A first capacitor 43 and a resistor 45 are connected in series in the order named from the intermediate terminal 17 of the secondary winding 11 to the left end terminal 13. The control electrode 47 of the valve 27 is connected through a grid resistor 49 and a second capacitor 51 to a point 53 intermediate the first capacitor 43 and its associated resistor 45. An adjustable resistor 55, which may be calibrated in units of time within the range of operation for which the circuit is designed, is in shunt across the second capacitor 51.

Since the relay 21 is to be energized through the valve 27, a suitable capacitor 57 may be connected in shunt with the operating coil 19 to maintain the relay in its energized position in each negative half period of the alternating current following a positive half period in which the valve 27 is conductive. By a positive half period, it is meant a half period in which the anode of the valve 27 is positive with respect to the cathode.

A suitable load device 59 is connected between the end terminals 13 and 15 of the secondary winding 11 through the normally open contact 61 of the relay 21.

To operate the apparatus, the initiating switch 33 may be closed to start the timing interval. Prior to operation of the initiating switch 33, the second capacitor 51 is charged to a predetermined maximum value by the voltage appearing across the portion of the secondary winding 11 between the right end terminal 15 and the in-

intermediate terminal 17 plus the voltage appearing across the first capacitor 43. When the voltage on the secondary winding 11 is such that the left end terminal 13 is positive with respect to the right end terminal 15, current flows from the point 53 intermediate the first capacitor 43 and its associated resistor 45 through the second capacitor 51, the grid resistor 49, the control electrode 47 and cathode 29 of the valve 27 and, there through the resistor 31 to the right end terminal 15 of the secondary winding. Since the control electrode to cathode path within the valve 27 is in effect a rectifier, substantial current does not flow therethrough when the control electrode is negative with respect to the cathode. Consequently, while an alternating voltage appears across the first capacitor 43, the second capacitor 51 is charged to a preselected maximum value. The voltage across the first capacitor 43, of course, lags behind the voltage between the terminals 13 and 17, the amount of lag in a preferred arrangement being of the order of 80 degrees.

When the initiating switch 33 is closed, a circuit is completed through the operating coil 39 of the hold-in relay. As a result, the contact 35 of the relay is closed to provide a holding circuit about the initiating switch. Thus, a circuit from the cathode 29 to the intermediate terminal 17 of the secondary winding 11 is completed. When the circuit is thus completed from the cathode 29 to the intermediate terminal 17, further charging of the second capacitor 51 is prevented and cannot occur until the voltage on the second capacitor 51 is less than the voltage on the first capacitor 43 which, as later appears, does not occur until after the timing interval is over.

When the initiating switch 33 is closed, the first and second capacitors 43 and 51 are connected in series between the control electrode 47 and the cathode 29. The valve 27, of course, has such characteristics that a voltage more positive than a predetermined critical value must be impressed between the control electrode 47 and cathode 29 in a positive half period to render the valve conductive. In a typical and suitable valve such as an RCA-2050 thyatron, the critical voltage is of the order of minus 6 volts.

The voltage then appearing between the control electrode 47 and cathode 29 after the initiating switch 33 is closed is essentially the algebraic sum at any instant of the voltage on the second capacitor 51 and the voltage on the first capacitor 43. The charge on the second capacitor 51 is of such polarity as to tend to make the control electrode 47 highly negative with respect to the cathode 29. The alternating voltage on the first capacitor 43 while lagging behind that between terminals 13 and 17, leads, as applied between the control electrode and cathode, the anode to cathode voltage of the valve by approximately 80 degrees. However, the peak instantaneous value of the first capacitor voltage is considerably less than the charge on the second capacitor 51 when switch 33 is closed so the valve 27 is maintained non-conductive.

As the second capacitor 43 is no longer being charged after the initiating switch 33 is closed, it begins to discharge through the adjustable resistor 55 in shunt therewith at a rate preselected by the adjustment of the resistor. After a predetermined time interval as determined by the setting of resistor 55, the voltage on the second capacitor 51 is reduced to such an extent that the algebraic sum of the voltages of the first and

second capacitors become more positive than the critical value to render the valve 27 conductive. I prefer the amount of lead of the first capacitor voltage with respect to the anode to cathode voltage of the valve to be of the order of 80 degrees since the first capacitor voltage then reaches its peak value in a positive direction at approximately the same time in a period of the source voltage that the anode to cathode voltage of the valve becomes positive to permit the valve to be rendered conductive. Consequently, if the valve 27 is to be rendered conductive in a half-period, such action will occur at or near the beginning of the half-period.

When the valve 27 becomes conductive, current flows from the right end terminal 15 of the secondary winding 11 through the operating coil 19 of the relay 21, the resistor 23 the anode 25 and cathode 29 of the valve 27, the closed contact 35 of the hold-in relay 37 to the intermediate terminal 17. The relay 21 is thus energized to complete the circuit through the load 59 and since the valve 27 becomes conductive at or near the beginning of a half-period definite operation of the relay is assured.

Thereafter, the stopping switch 41 may be opened at will to deenergize the hold-in relay 37 and thereby cause the valve 27 to become non-conductive. As a result, the relay 21 is deenergized and the load circuit is opened. Reoperation of the timing circuit may be initiated by reclosing the initiating switch 33 after a short interval in which the second capacitor 51 is recharged.

It is apparent that the particular instant in a period of the first capacitor voltage at which the valve 27 becomes conductive depends upon the amount of phase displacement of the first capacitor voltage with respect to the anode to cathode voltage. Moreover, for any given phase displacement the valve always becomes conductive in successive operations at or near the same relative instant in a period of the first capacitor voltage, even with different time intervals within a practical range. Now the optimum condition for capacitor discharge timing requires that the end of the timing interval occurs when the voltage remaining across the discharging capacitor, in this case the second capacitor 51, is approximately 37% of its original value. The optimum condition may be shown in the following equations in which E_c is the capacitor voltage, t represents time, R represents the resistance of the discharge circuit, C is the capacity of the capacitor, and E_0 is the initial voltage on the capacitor. The voltage relations for a discharging capacitor may be expressed as

$$E_c = E_0 e^{-\frac{t}{RC}} \quad (1)$$

Then

$$\frac{dE_c}{dt} = -\frac{1}{RC} E_0 e^{-\frac{t}{RC}} \quad (2)$$

Now the optimum condition where an electric valve is to be rendered conductive through the discharge of a capacitor as illustrated is one in which the change in capacitor voltage with time is a maximum when the valve becomes conductive. This condition is found with the maximum value of Equation 2. Thus

$$\frac{d\left(\frac{dE_c}{dt}\right)}{d(RC)} = -E_0 e^{-\frac{t}{RC}} \left(\frac{t}{(RC)^3} - \frac{1}{(RC)^2} \right) \quad (3)$$

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To find the value of RC which causes

$$\frac{dE_c}{dt}$$

to be maximum we place Equation 3 equal to zero, and solve for RC. The solution is:

$$t=RC \quad (4)$$

Substituting Equation 4 in Equation 1, it appears that

$$E_c=E_0e^{-1} \quad (5)$$

or

$$E_c=.37E_0, \text{ approximately} \quad (6)$$

To obtain this optimum condition, it is then necessary that the instantaneous voltage on the first capacitor 43 at the instant in a period at which the valve 27 is to be rendered conductive, be approximately 37% of the original maximum charge on the second capacitor 51.

To avoid undesirable effects as a result of surges in the supply voltage, the relation between the first capacitor 43 and the resistor 45 is arranged, in accordance with my invention, to form, in effect, a filter for the surge voltages usually encountered. Thus, a surge in the supply voltage does not appear with substantial magnitude in the alternating voltage across the capacitor 43 so that undesirable effects on the operation of the valve 27 are substantially avoided. At the same time, the arrangement should be such that the voltage on the first capacitor 43 at an instant in a period thereof corresponding to the instant at which the valve is to become conductive is approximately 37% of the maximum charge on the second capacitor 51. To obtain these conditions, the resistor 45 and the capacitor are selected to form the filter with respect to the voltage surges. The position of the intermediate terminal 17 is selected to provide the desired voltage relation.

It is to be noted that the first capacitor 43 serves not only as a part of a filter for surge voltages but also provides an alternating voltage in the control circuit of the valve to insure positive operation and in addition enables the establishment of the optimum condition for capacitor discharge timing in operation of the valve throughout the entire range of time settings.

While I have shown and described a preferred embodiment of my invention, I am aware that many modifications thereof may be made without departing from the spirit of the invention. I do not intend, therefore, to limit my invention to the specific circuit disclosed.

I claim as my invention:

1. A timing circuit for use with a source of alternating voltage comprising an electric valve having an anode, a cathode and a control electrode, circuit means including an initiating device and effective upon operation of said initiating device for connecting said anode and cathode in a circuit with said source, a filter connected in a circuit energized from said source for filtering surges in said source voltage so that such surges do not appear in substantial magnitude in the alternating voltage across said filter, a capacitor connected in series with said filter from said control electrode to said cathode after operation of said initiating device, means effective only prior to operation of said initiating device to cause said capacitor to be charged to a predetermined maximum value, said valve having such characteristics as to become conductive after operation of said initiating device only when the control

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electrode to cathode voltage is more positive than a critical value which normally requires a charge on said capacitor no greater than a predetermined value less than said maximum value, and a discharge circuit including a second resistor in shunt with said capacitor to discharge it at a preselected rate following operation of said initiating device.

2. A timing circuit for use with a source of alternating voltage comprising an electric valve having an anode, a cathode and a control electrode, circuit means including an initiating device and effective upon operation of said initiating device for connecting said anode and cathode in a circuit with said source, a filter connected in a circuit energized from said source for filtering surges in said source voltage so that such surges do not appear in substantial magnitude in the alternating voltage across said filter, a capacitor connected in series with said filter from said control electrode to said cathode after operation of said initiating device, means effective only prior to operation of said initiating device to cause said capacitor to be charged to a predetermined maximum value, said valve having such characteristics as to become conductive after operation of said initiating device only when the control electrode to cathode voltage is more positive than a critical value which normally requires a charge on said capacitor no greater than a predetermined value less than said maximum value, and a discharge circuit including a second resistor in shunt with said capacitor to discharge it at a preselected rate following operation of said initiating device, whereby said valve becomes conductive after a preselected time interval at a predetermined instant in a period of the voltage on said element, said plurality of elements being arranged to provide a voltage on said one element displaced in phase relative to said source voltage and having an instantaneous value at said instant which is approximately 37% of said maximum value.

3. A timing circuit for use with a source of alternating voltage comprising an electric valve having an anode, a cathode and a control electrode, circuit means including an initiating device and effective upon operation of said initiating device for connecting said anode and cathode in a circuit with said source, a first capacitor and a first resistor connected in a circuit energized from said source and forming in effect a filter for surges in said source voltage so that such surges do not appear in substantial magnitude in the alternating voltage across said first capacitor, a second capacitor connected in series with said first capacitor from said control electrode to said cathode after operation of said initiating device, means effective only prior to operation of said initiating device to cause said second capacitor to be charged to a predetermined maximum value, said valve having such characteristics as to become conductive after operation of said initiating device when the control electrode to cathode voltage is more positive than a critical value which ordinarily requires a charge on said second capacitor no greater than a predetermined value less than said maximum value, and a discharge circuit including a second resistor in shunt with said second capacitor to discharge it at a preselected rate following operation of said initiating device.

4. A timing circuit for use with a source of alternating voltage comprising an electric valve having an anode, a cathode and a control elec-

trode, circuit means including an initiating device and effective upon operation of said initiating device for connecting said anode and cathode in a circuit with said source, a first capacitor and a first resistor connected in a circuit energized from said source and forming in effect a filter for surges in said source voltage so that such surges do not appear in substantial magnitude in the alternating voltage across said first capacitor, a second capacitor connected in series with said first capacitor from said control electrode to said cathode after operation of said initiating device, means effective only prior to operation of said initiating device to cause said second capacitor to be charged to a predetermined maximum value, said valve having such characteristics as to become conductive after operation of said initiating device when the control electrode to cathode voltage is more positive than a critical value which ordinarily requires a charge on said second capacitor no greater than a predetermined value less than said maximum value, and a discharge circuit including a second resistor in shunt with said second capacitor to discharge it at a preselected rate following operation of said initiating device, whereby said valve becomes conductive after a preselected time interval at a predetermined instant in a period of the voltage across said first capacitor, said first capacitor and first resistor being arranged to provide a voltage on said first capacitor having an instantaneous value at said instant which is approximately 37% of said maximum value.

5. A timing circuit comprising impedance means adapted to function as a source of alternating voltage and having a pair of end terminals and an intermediate terminal, an electric valve having an anode, a cathode and a control electrode, circuit means connecting said anode to one of said end terminals, a first resistor connected in a circuit from said cathode to said one end terminal, a first capacitor and a second resistor connected in series in the order named from said intermediate terminal to the other of said end terminals and having a time constant such that surges in said source voltage do not appear in substantial magnitude in the alternating voltage across said first capacitor, a second capacitor connected in circuit from said control electrode to a point intermediate said first capacitor and second resistor whereby said second capacitor is charged to a preselected maximum value, an initiating device operable to complete a circuit from said cathode to said intermediate terminal whereby further charging of said second capacitor is prevented and said first and second capacitors are connected in series from said control electrode to said cathode, said valve having such characteristics as to become conductive when the charge on said second capacitor is less than a predetermined critical value which is less than said maximum value, and a discharge circuit

including a third resistor in shunt with said second capacitor to discharge it at a preselected rate following operation of said initiating device.

6. A timing circuit for use with a source of alternating voltage comprising an electric valve having an anode, a cathode and a control electrode, circuit means including an initiating device and effective upon operation of said initiating device for connecting said anode and cathode in a circuit with said source, a filter connected in a circuit energized from said source for filtering surges in said source voltage so that such surges do not appear in substantial magnitude in the alternating voltage across said filter, a capacitor connected in series with said filter from said control electrode to said cathode after operation of said initiating device, means effective only prior to operation of said initiating device to cause said capacitor to be charged to a predetermined maximum value, said valve having such characteristics as to become conductive after operation of said initiating device only when the control electrode to cathode voltage is more positive than a critical value which normally requires a charge on said capacitor no greater than a predetermined value less than said maximum value, and a discharge circuit including a variable resistor in shunt with said capacitor to discharge it at a preselected rate following operation of said initiating device.

7. A timing circuit for use with a source of alternating voltage comprising an electric valve having an anode, a cathode and a control electrode, circuit means including an initiating device and effective upon operation of said initiating device for connecting said anode and cathode in a circuit with said source, a first capacitor and a first resistor connected in a circuit energized from said source and forming in effect a filter for surges in said source voltage so that such surges do not appear in substantial magnitude in the alternating voltage across said first capacitor, a second capacitor connected in series with said first capacitor from said control electrode to said cathode after operation of said initiating device, means effective only prior to operation of said initiating device to cause said second capacitor to be charged to a predetermined maximum value, said valve having such characteristics as to become conductive after operation of said initiating device when the control electrode to cathode voltage is more positive than a critical value which ordinarily requires a charge on said second capacitor no greater than a predetermined value less than said maximum value, and a discharge circuit including a variable resistor in shunt with said second capacitor to discharge it at a preselected rate following operation of said initiating device.

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No references cited.