United States Patent [19]

Adams

[11] **3,814,950**

[45] **June 4, 1974**

[54] **TIMING CIRCUIT**

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[22] Filed: **Dec. 8, 1972**

[21] Appl. No.: **313,405**

[52] **U.S. Cl.** ..... **307/141,** 317/142 R
[51] **Int. Cl.** **H01h 7/00,** H01h 43/00
[58] **Field of Search** ..... 317/151, 142 R, 141; 328/210; 307/106; 315/234, 168

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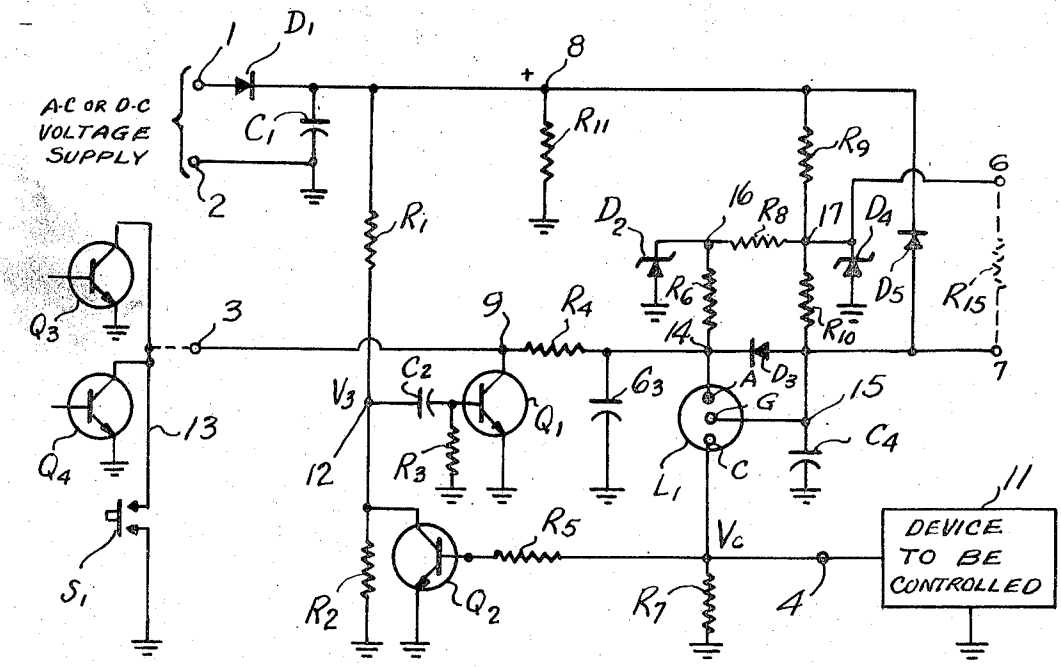
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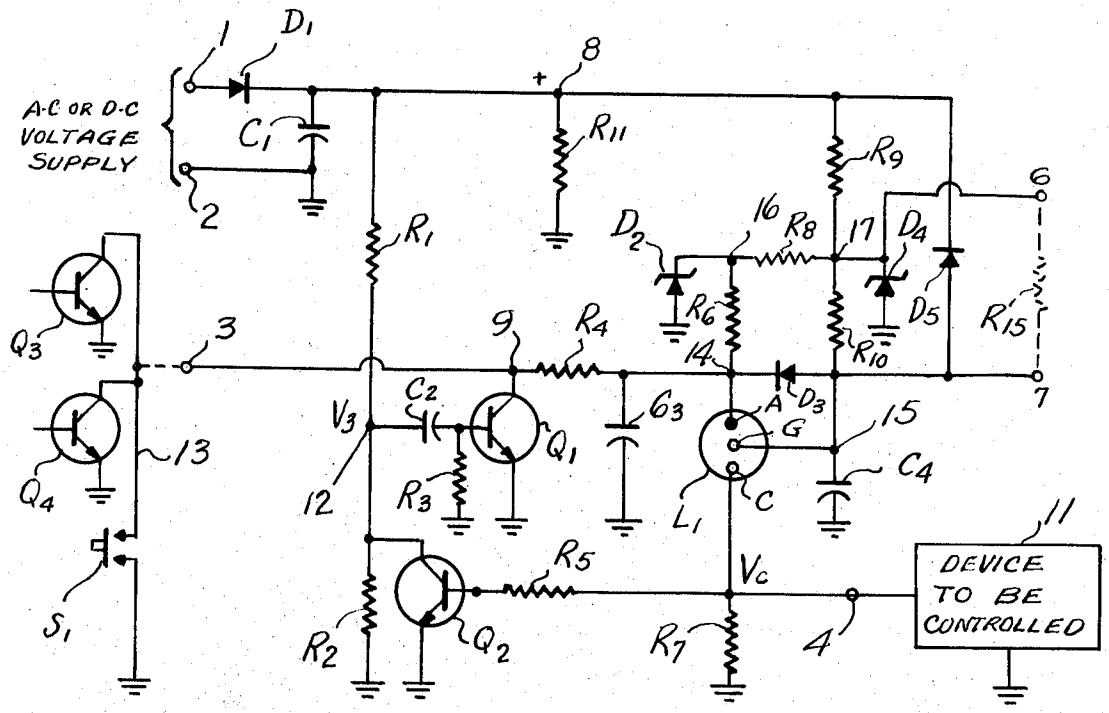
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[57] **ABSTRACT**

An electronic timing circuit that utilizes a three-element glow discharge lamp and operates from either alternating current or direct current power sources to provide a direct current control voltage upon completion of a desired timing interval, for example, when the power source is interrupted for more than a predetermined period of time and is then restored. A predetermined time delay is provided before the direct current control voltage is removed following removal of the power source. Another time delay is provided before the direct current control voltage returns following restoration of the power source. The circuit includes independently operable reset means which can be operated either locally and manually or by a remotely operated electronic circuit arrangement.

10 Claims, 1 Drawing Figure




A-C OR D-C VOLTAGE SUPPLY
1
2
D1
C1
8
+
R11
R9
6
R1
D2
16
R8
17
D4
D5
R15
Q3
3
9
R4
14
R6
R10
7
A
D3
G
15
C2
V3
Q1
63
C4
Q4
13
12
R3
C
L1
11
DEVICE TO BE CONTROLLED
R5
Vc
S1
R2
Q2
R7
4

TIMING CIRCUIT

This invention relates to electronic timing circuits and more particularly to a timing circuit for use between a supply source and a device to be controlled for providing a time delay between the application of the power source and the actuation of said device and similarly to provide another time delay between the removal of the power source voltage and the deenergization of the device.

A main object of the invention is to provide a novel and improved timing circuit for use between a source of electrical power and a device to be operated thereby, the circuit having high stability, being immune to noise, providing accurate timing, being operable satisfactorily with wide input voltage variations, providing visual indications of completed timing intervals, being adaptable for remote programming of the timing intervals or for remote reset control and operating automatically to safely restore power to a device to be controlled after a power supply interruption.

A further object of the invention is to provide an improved electronic timing circuit utilizing a three-element glow discharge lamp both as a working circuit element and as an indicating means to provide visual indications of completed timing intervals, the improved circuit having highly accurate timing characteristics and providing dependable operation over long periods of time.

A still further object of the invention is to provide an improved timing circuit which provides automatic resetting of the time interval whenever the line source is removed for more than a predetermined period of time and is then subsequently restored.

A still further object of the invention is to provide an improved timing circuit which provides resetting of its time interval by transistor switch action but is also adapted to provide resetting by mechanical switch action.

A still further object of the invention is to provide an improved timing circuit which generates a square wave DC output voltage after completion of a timing interval, the control voltage being quickly terminable by reset means provided in the circuit.

A still further object of the invention is to provide an improved electronic timing circuit having multiple input resetting controls of its timing interval.

A still further object of the invention is to provide an improved electronic timing circuit adapted to provide remote programming of its timing interval.

A still further object of the invention is to provide an improved electronic timing circuit which is not susceptible to line voltage source conditions of various types such as line voltage "flicker" but which is rapidly responsive to other line voltage conditions, such as substantial voltage deterioration or power stoppage.

Further objects and advantages of the invention will become apparent from the following description and claims, and from the accompanying drawing wherein the single figure represents a typical circuit diagram embodying the present invention.

Prior art devices such as that disclosed in U.S. Pat. No. 3,657,603 to William M. Adams disclose the need for a timing circuit which is stable with respect to wide source voltage variations and which can be reset by either transistor or mechanical switches. The present invention aims to accomplish the desired purposes by

employing the stable characteristics of gas filled glow lamps. The stability of the two-element gas filled glow lamp is well known. The addition of a third element provides additional control for ionization of such a glow lamp. Glow lamps normally operate at very low current values and require certain biasing voltage limitations. In a three-element glow lamp, one of such limitations is that the voltage level between two elements, commonly known as the "anode" and "gate" must not exceed a certain level to avoid unwanted ionization. The circuit of the present invention includes means to efficiently regulate such voltage levels.

Referring to the drawing, **11** generally designates a device to be operated or controlled from a pair of supply terminals **1** and **2**, which may be connected to a suitable source of alternating current or direct current. The device **11** may be any suitable known apparatus for controlling equipment to be energized from the power supply terminals through suitable circuits, not shown, the device **11** being connected in a well known manner so as to open and close the circuits. Thus, as a typical example, the device **11** may comprise a control relay or relay circuit connected so as to control the energization and deenergization of a load device or load circuit adapted to be energized from the power supply.

The device to be controlled, namely, the device **11**, is activated by the present of a control voltage V_c across the input terminals of said device **11**. Thus, the device **11** drops out when the control voltage V_c is removed.

As shown in the figure, the power supply voltage, which may be either alternating current or direct current, is applied at the terminals **1** and **2**, the terminal **2** being grounded. A diode D_1 is connected between the terminal **1** and a terminal **8**, and a filter capacitor C_1 is connected between terminal **8** and the grounded power terminal **2**. Thus, when alternating current is applied at the terminals **1** and **2**, the supply current will be rectified by the diode D_1 and filtered by the capacitor C_1, providing a positive DC voltage at the point **8**. If a direct current power supply is employed, when the positive supply wire is connected to the terminal **1** and the negative supply wire is connected to the terminal **2**, diode D_1 will pass the current, again providing a positive voltage at the terminal **8**. If the negative supply wire is connected to the terminal **1**, the diode D_1 will not conduct, and therefore this diode serves as a reverse polarity protective device.

Connected in series between the terminal **8** and the ground are resistors R_1 and R_2, forming a voltage divider network. Thus, when the above-mentioned positive DC voltage appears at the terminal **8**, a voltage V_3 appears at the junction **12** of resistors R_1 and R_2. Junction **12** is connected through a capacitor C_2 to the base of a transistor Q_1, and a resistor R_3 is connected between said base and ground. Thus, the capacitor C_2, the resistor R_3 and parallel input resistance of Q_1 form a RC coupling network whereby the voltage V_3 is applied to the base of the transistor Q_1 when the aforesaid positive DC voltage initially appears at the terminal **8**, causing the transistor Q_1 to become momentarily forward biased and therefore momentarily to be conductive from its collector terminal **9** through its emitter to ground.

A capacitor C_3 is connected from ground through a current limiting resistor R_4 to the collector terminal **9** so that the resistor R_4 limits the collector current of

transistor Q_1 when the capacitor C_3 is allowed to discharge through transistor Q_1, namely, when said transistor is conductive.

It will be further seen from the drawing that the transistor terminal **9** is connected to a terminal **3.** Grounding of this terminal will also cause the capacitor C_3 to discharge through the current-limiting resistor R_4. Terminal **3** may be connected to a conductor **13** which in turn may be at times connected to ground by use of a manually operated switch S_1 or alternatively, may be grounded by the conduction of transistors Q_3 or Q_4 connected in parallel between conductor **13** and ground. Transistors Q_3 and Q_4 represent typical electronic switch devices which may be remotely controlled or which may be programmed to become conductive at selected times in accordance with the requirements for control of the device **11.**

A transistor Q_2 is connected across the resistor R_2, and the base of transistor Q_2 is connected through a resistor R_5 to the control voltage terminal **4.** Designated at L_1 is a gas filled three-element glow discharge lamp having the anode A, the cathode C and the gate electrode G. The three-element glow discharge tube may be of any suitable commercial type, for example, may be similar to type 120 TG-27-2, manufactured by Signalite, Inc., a Division of General Instrument Corp., Neptune, N.J. A characteristic of this type of glow discharge lamp is that when sufficient voltage is applied between any two terminals, ionization of the gas therein will occur, resulting in increased current flow through the lamp's ionized gas and associated biasing circuits. As shown in the drawing, the anode terminal A is connected at **14** to the junction between capacitor C_3 and resistor R_4. The cathode C is connected to the control voltage terminal **4** and the gate electrode G is connected to a terminal **15.** A capacitor C_4 is connected between terminal **15** and ground.

As will be presently explained, normally, the voltage applied to the anode terminal A is set to a level less than the ionization potential for the anode to cathode circuit, but more than the maintaining potential for this circuit. The gate electrode G may then be utilized to control ionization of the gas in the lamp L_1. This control may be in the form of a slowly increasing voltage, which when of a suitable level, causes the gate-to-cathode circuit to ionize, which in turn, causes the anode-to-cathode circuit current to increase quickly at the time of ionization. Ionization of the lamp L_1 will be maintained until such time that the voltage on the anode A is lowered below its maintaining voltage value.

The cathode C is connected through a ground return terminating resistor R_7 to ground. The anode element A is connected to a zener-regulating voltage terminal **16** through a resistor R_6. Capacitor C_3, connected to terminal **14,** forms a RC circuit that charges when the circuit is first energized or the grounding functions at terminals **3** and **9** are removed. This reduces the voltage appearing on terminal A of the lamp L_1 to below the ionization potential for the anode-to-gate and anode-to-cathode circuits of L_1 for a period of time as determined by the circuit values of primarily C_3, R_6 and the zener voltage of D_2. This prevents the premature ionization of the lamp L_1, between elements A to G, until the charge on capacitor C_4 is of such value to cause the effective voltage between these elements to be less than the ionization potential for the anode-to-gate circuit. The gate electrode G is connected to the junction **15** of a RC circuit comprising a resistor R_{10} and the capacitor C_4. The resistor R_{10} is connected between the gate electrode terminal **15** and a zener-regulated voltage junction terminal **17.** The zener-regulated voltage at the junction **16** is regulated by a zener diode D_2, whereas the voltage at the junction **17** is regulated by another zener diode D_4. As shown, the respective zener diodes D_2 and D_4 are connected between the terminals **16** and ground, and **17** and ground, respectively. Terminal **17** is connected to the positive voltage terminal **8** through a resistor R_9. A resistor R_8 is connected between the zener-regulated voltage terminals **16** and **17.** A diode D_3 is connected between the terminals **14** and **15.** Another diode D_5 is connected between the positive voltage terminal **8** and the junction terminal **15.** A bleeder resistor R_{11} is connected between the positive voltage terminal **8** and ground.

The zener regulation by the diodes D_2 and D_4, or other equivalent voltage regulating devices which may be substituted therefor, stabilizes the bias voltages for the lamp L_1 which would otherwise vary due to source voltage variations at terminals **1** and **2.**

It will be noted that when the capacitor C_3 discharges to a voltage somewhat below the voltage level (charge) of capacitor C_4, for example, a few tenths of a volt below this voltage level, the diode D_3 becomes conductive and also causes capacitor C_4 to discharge rapidly through the resistor R_4 and a low resistance circuit which may comprise either transistor Q_1 (when conductive) or a grounding circuit from terminal **3,** namely, whichever circuit is conductive to ground from the collector terminal **9.** A sustained ground at terminal **3** will prevent capacitors C_3 and C_4 from charging.

When the circuit is energized by power applied at the terminals **1** and **2,** the resetting action by the conduction of transistor Q_1 previously described occurs. Provided that reset terminal **3** is not at or near ground level, capacitor C_3 will commence charging to a value determined by the voltage rating of zener diode D_2 and at a rate determined primarily by the parameters of the RC circuit comprising resistor R_6 and capacitor C_3. The voltage appearing on the anode terminal A of lamp L_1 with respect to time is therefore temporarily held below the ionization voltage level of the anode-to-gate circuit. Capacitor C_4 continues to charge at a predetermined rate determined primarily by the effective series resistance of resistor R_{10} toward a level equal to the regulated voltage provided by the zener diode D_4.

A parallel resistor R_{15} may be connected in parallel with the resistor R_{10} at terminals **6** and **7,** for example, to lower the effective circuit value of the resistance in the charging circuit for purposes of remote programming or timing control.

When the voltage on the charging capacitor C_4 reaches a value corresponding to the ionization level for the gate-to-cathode circuit of the lamp L_1, the lamp will completely ionize and conduct and will provide a visual indication of this condition. The increased ionization current passing through the resistor R_7 will result in an increased direct current voltage drop across this resistor which will provide a continuous DC square wave control voltage V_c at the terminal **4** until lamp L_1 is deionized. Transistor Q_2 will then become forwardly biased and will conduct, reducing the voltage drop across resistor R_2 to approximately **0.** Capacitor C_2 will then discharge to a new lower voltage level. Under

these conditions, the circuit can be considered as "timed-out," and the normal output control voltage V_c would be present at terminal 4 for control or actuation of the device 11 or other electronic devices or electrical circuits to be controlled.

Resistor R_6 limits the sustained ionization current of lamp L_1 and therefore allows the current through lamp L_1 and the cathode circuit of lamp L_1 to be controlled. Also, since the intensity of the visible light of lamp L_1 is a function of this ionization current, the brilliance and life expectancy of lamp L_1 may be controlled by selection of a desired value of resistor R_6.

As above-mentioned, the terminals 6 and 7 are provided to permit various values of resistance R_{15} to be connected in parallel with the resistor R_{10}. Connection of such a resistor across the terminals 6 and 7 lowers the total resistance of the RC circuit including the resistor R_{10} and the capacitor C_4, which will cause capacitor C_4 to charge more rapidly and will cause lamp L_1 to ionize more quickly, since it more quickly brings the gate electrode to ionizing potential. Resistor R_{15} may be of any suitable type, and may comprise a variable resistance, a resistance-selecting arrangement including a switch and respective resistors which may be connected thereby to the terminal 6 and 7 or may comprise conventional semi-conductor devices or circuits that exhibit resistor characteristics.

Resistor R_{11} is connected as a conventional bleeder resistor, to cause capacitor C_1 to discharge at a rate in accordance with the time constant of the RC circuit defined by capacitor C_1 and resistor R_{11}, whenever the source of voltage is removed from the terminals 1 and 2. Thus, the discharge rate of capacitor C_1 can be controlled by selecting a suitable value for resistor R_{11}. The energy stored in the capacitor C_1 will cause the lamp L_1 to remain ionized for a predetermined period of time following removal of the source voltage from the terminals 1 and 2. This effects a delayed deionization of lamp L_1 and therefore extends the period of time that the control voltage V_c is present at the terminal 4. This delay time is controlled by the selection of the appropriate values of the resistor R_{11} and capacitor C_1. After the removal of the source voltage from the terminals 1 and 2, the lamp L_1 becomes deionized when the voltage applied to the anode terminal A of lamp L_1 falls below the necessary maintaining voltage level. Visual indication of the "off" condition will occur at this time by the deionization of the lamp L_1.

Whenever the voltage at the point 8 falls a few tenths of a volt below the voltage across capacitor C_4, diode D_5 becomes forward biased (conductive). This causes capacitor C_4 to discharge through the relatively lower resistance path provided by diode D_5 and the resistor R_{11}, as well as certain of the other components. Thus, a delay period is required for capacitor C_4 to charge whenever a permissible charge condition for capacitor C_4 is subsequently allowed.

Diode D_3 also becomes forward biased (conductive) whenever the anode voltage at the terminal A of lamp L_1 falls a few tenths of a volt below the voltage across the capacitor C_4. Capacitor C_4 will then discharge through resistor R_4 and either the collector-to-emitter circuit of transistor Q_1 (when conductive) or through any low resistance device or element connected to terminal 3 and certain of the other circuit components. This similarly requires the programmed delay period for the capacitor C_4 to charge whenever a permissible charge condition for capacitor C_4 is subsequently allowed.

Whenever a relatively low resistance path to ground is applied to the terminal 3, this causes the voltage at the anode terminal A of lamp L_1 to drop below the maintaining voltage level and therefore deionizes lamp L_1. Deionization of lamp L_1 removes the control voltage V_c normally available at the terminal 4, as well as the forward bias normally applied to the base of the transistor Q_2. The removal of forward bias from transistor Q_2 causes it to become non-conducting and to place the resistor R_2 in circuit with the resistor R_1, thus increasing the voltage V_3 at the junction 12. This causes the transistor Q_1 to become forward biased (conducting) for a period of time in accordance with the time constant of the RC circuit defined by capacitor C_2 and the parallel resistance value of resistor R_3 and the input resistance of transistor Q_1. This provides a feedback arrangement that enhances the discharging of capacitor C_4 through the momentary low resistance path provided by the collector-to-emitter circuit of transistor Q_1.

It will thus be seen that in normal operation, when terminal 3 is grounded, either by actuating the manual switch device L_1 or by turning on either of the transistors Q_3 or Q_4, the maintaining voltage is removed from the anode terminal A of lamp L_1 causing the lamp to become deionized and thus remove the control voltage V_c from the output terminal 4. This discharges the capacitor C_4 in the manner above-described. When the low resistance path-to-ground is removed subsequently from the terminal 3, the maintaining voltage will be reapplied to the anode terminal A of lamp L_1, but the lamp will not ionize until the capacitor C_4 has charged to the required triggering voltage necessary at terminal G. Thus, a time delay is provided to restore the control voltage V_c at the terminal 4 after the reset terminal 3 becomes ungrounded. Similarly, this time delay is also required when power is reapplied to the terminals 1 and 2 after removal thereof. Thus, when the power supply at the terminals 1 and 2 is cut off for a period longer than that required for capacitor C_1 to discharge sufficiently to drop the voltage at the anode terminal A below the maintaining level, the lamp L_1 will become extinguished and remove the control voltage V_c from the output terminal 4. This control voltage will remain at terminal 4 if the power supply interruption is less than this required time.

After removal of the control voltage V_c, as above described, when the supply voltage is again applied to the terminals 1 and 2, the control voltage V_c will not return until capacitor C_4 has charged sufficiently to provide the required triggering voltage at the gate electrode G. The lamp L_1 becomes illuminated (ionized) upon such triggering, and simultaneously the control voltage V_c returns to the output terminal 4. The illumination of the lamp L_1 thus provides an indication of the presence of the control voltage V_c at terminal 4.

Many useful applications of the above-described timing circuit will become apparent to those skilled in the art. The flexibility provided by the DC output control voltage, remotely controlled "on-delay" programming, remotely controlled "muting," and "resetting," the high degree of immunity to noise, the programmable "off-delay" (when the source power is removed), the quick "off" switching (when muted or reset), the visual indication of the "timed-out" condition, and the accu-

rate timing with wide variations of input line source voltage and quick resetting of the timing elements allows for a broad range of timing control applications. One example would be to limit the time for restoration of power to an electrical or electronic device or system following the remote sensing and subsequent muting of this timing circuit. Another example would be to control a semi-conductor type circuit to invert the "on delay" functions, that is, to cause a circuit system or device to become energized during the timing-out period and deenergized during the timed-out period.

While a specific embodiment of an improved timing circuit has been disclosed in the foregoing description, it will be understood that various modifications within the spirit of the invention may occur to those skilled in the art. Therefore, it is intended that no limitations be placed on the invention except as defined by the scope of the appended claims.

What is claimed is:

1. A timing circuit comprising a gaseous glow discharge lamp having an anode, a cathode and a trigger electrode, an energizing circuit including a source of direct current connected to said anode and cathode and including a terminating impedance across which a device-controlling voltage is developed when the lamp is ionized, means to provide a maintaining voltage across said anode and cathode sufficient to maintain ionization, a triggering circuit branch connected to said energizing circuit and including a resistor and capacitor in series, means connecting the junction of said resistor and capacitor to the triggering electrode, said triggering circuit branch developing a triggering voltage at said triggering electrode after a predetermined period of charging of said capacitor sufficient to cause ionization of the lamp, a diode connected between said junction and said anode, and a second capacitor connected between said anode and a portion of the energizing circuit to sustain said maintaining voltage for a second predetermined period of time when the source of current is removed.

2. The timing circuit of claim **1**, and a controlled rapid-discharge circuit branch connected across said second capacitor to at times rapidly remove said device-controlling voltage.

3. The timing circuit of claim **2**, and wherein said controlled circuit branch includes a manually operated switch.

4. The timing circuit of claim **2**, and wherein said controlled circuit branch includes an electronic switch device.

5. The timing circuit of claim **2**, and wherein said energizing circuit is provided with a pair of input terminals and a series-connected rectifier at one terminal, and a filter capacitor connected between the output of the rectifier and the other terminal.

6. The timing circuit of claim **2**, and respective zener-controlled voltage stabilizing means connected to said anode and to said triggering circuit branch.

7. The timing circuit of claim **2**, and wherein said energizing circuit includes a voltage-divider branch, a transistor connected across said second capacitor, switch means normally shunting a portion of the voltage-divider branch, means to open said switch means responsive to deionization of the lamp, and means to render said transistor conductive responsive to opening said switch means, whereby to enhance the discharging of the first-named capacitor through said diode when the lamp becomes deionized.

8. The timing circuit of claim **7**, and wherein said means to render said transistor conductive comprises circuit means connecting the base of said transistor to said voltage-divider branch.

9. The timing circuit of claim **8**, and wherein said circuit means connecting the base of said transistor to said voltage-divider branch comprises a series capacitor and a discharge resistor connected across the base and emitter of the transistor.

10. The timing circuit of claim **8**, and wherein said switch means comprises a second transistor connected across said portion of the voltage-divider branch, and circuit means connecting the device-controlling voltage terminal of the terminating impedance to the base of said second transistor so as to remove forward bias from said last-named base when the device-controlling voltage is removed.

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