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Lundy

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[54] **CAPACITIVE DISCHARGE IGNITION SYSTEM**

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[51] **Int. Cl.** **H02m 3/28**

[58] **Field of Search**..... 123/148 OC, 148 D; 321/2; 322/28

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[57] **ABSTRACT**

A capacitive discharge ignition system utilizing a silicone controlled rectifier to control the application of capacitively stored energy to the primary of an ignition coil. This energy, which is supplied by a DC-to-DC convertor network, is initially stored in a capacitor. The capacitor is then discharged through the primary ignition coil circuit at predetermined times under the control of the SCR. The SCR conduction state is positively controlled, allowing for multiple energy exchange cycles to occur if desired. The DC-to-DC convertor is turned off during the time that the SCR is conducting.

10 Claims, 3 Drawing Figures

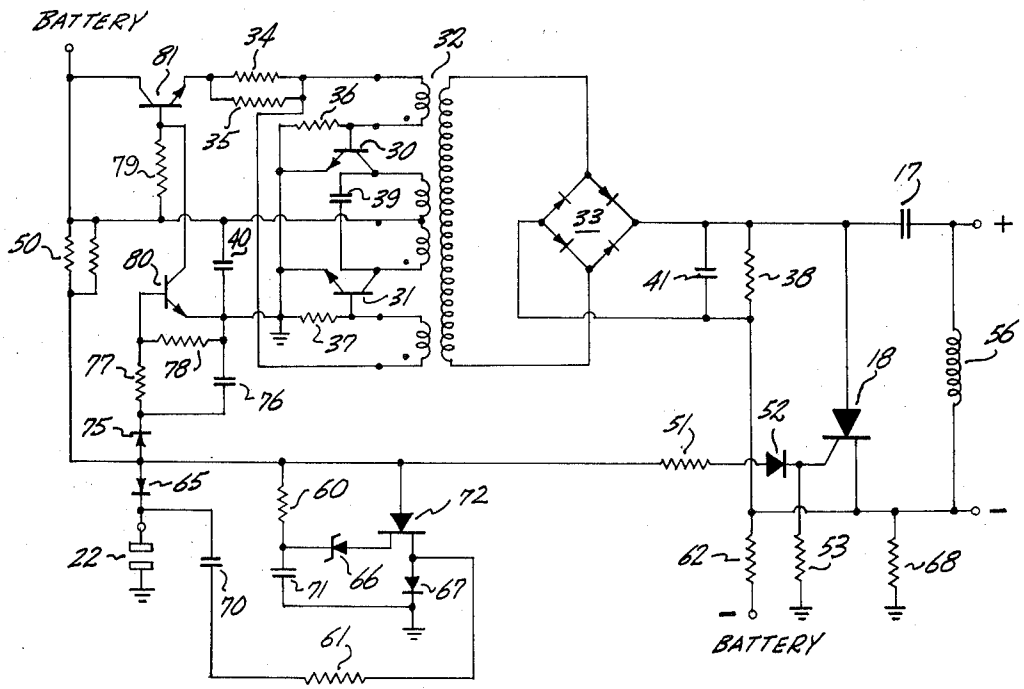


Fig. 1.

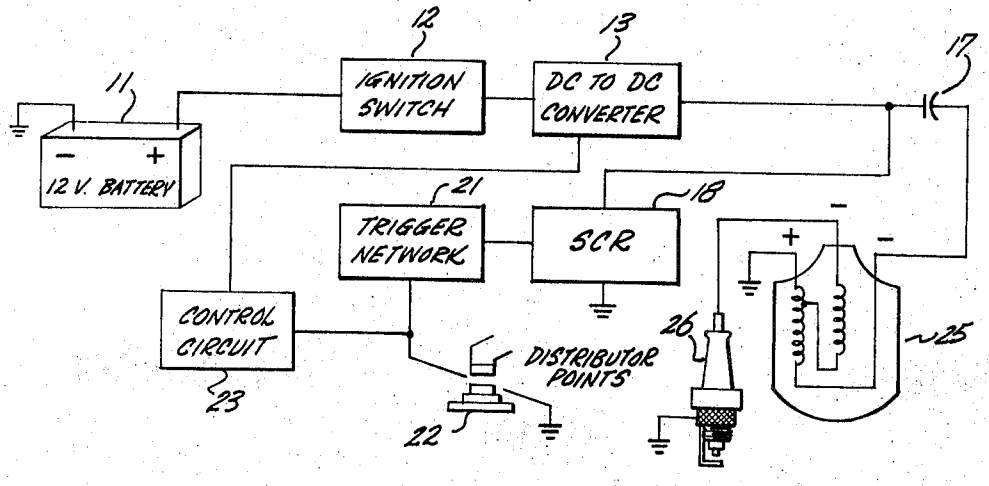
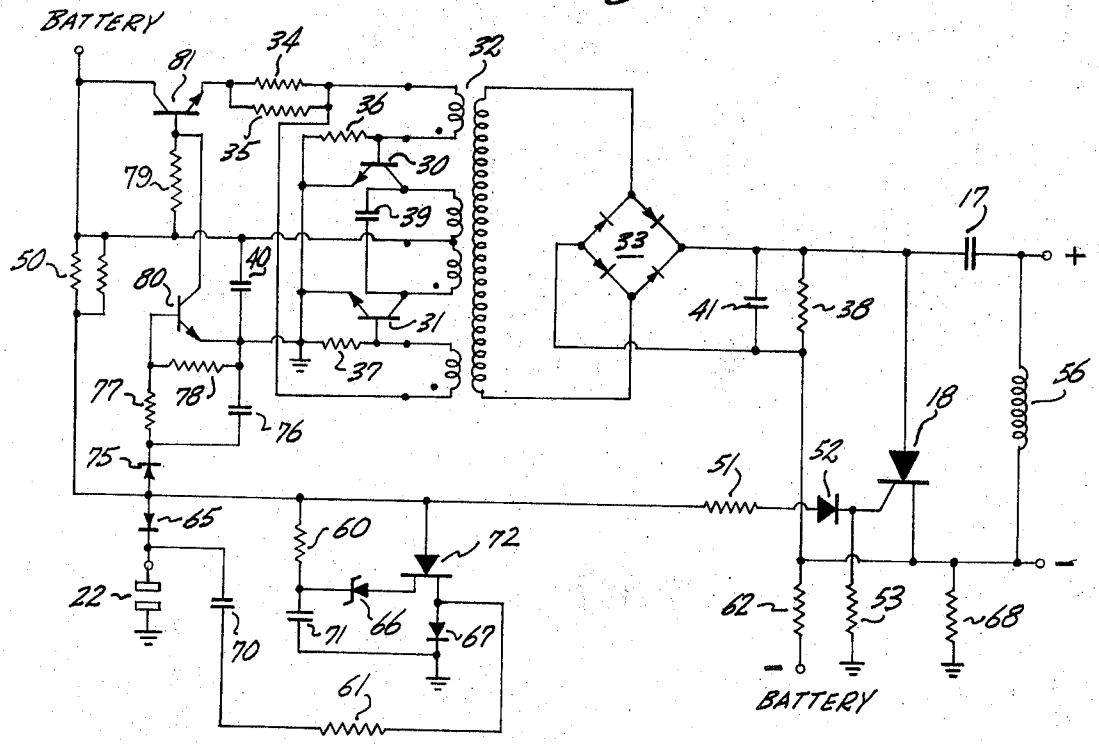

12
13
17
11
IGNITION SWITCH
DC TO DC CONVERTER
12 V. BATTERY
21
18
TRIGGER NETWORK
SCR
CONTROL CIRCUIT
23
DISTRIBUTOR POINTS
22
26
25

Fig. 2.


BATTERY
81
34
32
36
35
30
79
39
33
17
50
40
80
41
38
31
37
77
78
76
18
56
75
51
52
65
60
72
22
66
71
67
70
62
53
68
61
BATTERY

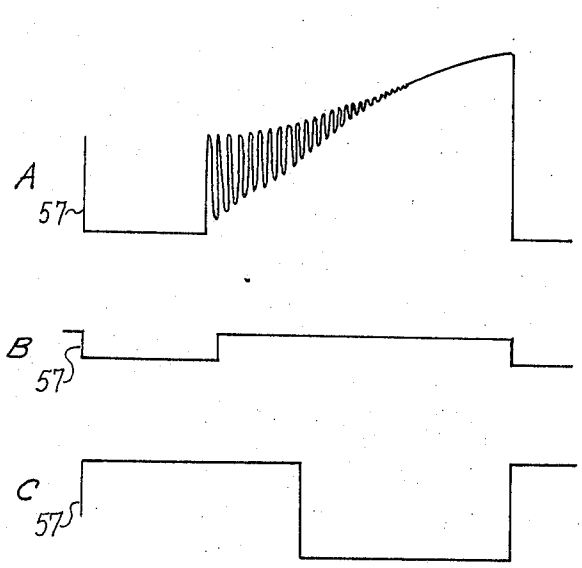


Fig. 3.

CAPACITIVE DISCHARGE IGNITION SYSTEM

BACKGROUND OF THE INVENTION

This invention relates primarily to the art of semiconductor ignition systems, and more specifically, to capacitive discharge ignition systems utilizing a silicone controlled rectifier to control the application of a capacitively stored voltage to the primary of an ignition coil.

The ignition system of an internal combustion engine plays a critical role in the proper operation of an engine, particularly in a modern, emission-controlled automobile. The iignition system must supply a large, properly timed, spark to the spark plugs to properly ignite the fuel/air mixture contained in the engine's combustion chambers. Until recently, nearly all ignition systems used the sequential opening and closing of mechanical distributor points to directly control the application of a battery voltage to the primary of an ignition coil having a high secondary-to-primary turns ratio. The resulting high voltage at the secondary of the coil was then applied to the spark plugs in a predetermined sequence to achieve a smooth running of the engine.

With the advent of semi-conductor devices, however, there has resulted a great deal of experimentation with respect to ignition systems, including oscillator-excited ignition systems, gate controlled ignition systems, piezoelectric ignition systems, and capacitive discharge ignition systems, to name some varieties currently being investigated as well as commercially used.

The capacitive discharge ignition system utilizing a silicone controlled rectifier is currently a popular and practical implementation of a semi-conductor ignition system. Present capacitive discharge systems, however, have significant operational disadvantages. In a typical prior art capacitive discharge system, the charging capacitor charges to a specified maximum value, independent of the dwell time of the distributor points. When the points open, a positive pulse is applied to the gate element of an SCR, turning the SCR on, and a single energy exchange then occurs between the primary of the ignition coil and the charging capacitor. The collapsing field of the primary of the ignition coil when the capacitor is completely discharged will then tend to establish a charge on the capacitor opposite to that of its original charge. The SCR is typically rendered non-conducting, or commutated, by a reverse potential, which is established by the reverse current in the circuit when the oppositely charged capacitor begins to discharge back through the primary of the coil. This reverse current is sufficient to commutate tbe SCR, and thus, one complete cycle of energy exchange between the capacitor and the coil typically occurs before the SCR becomes non-conducting. During the time that the SCR is conducting, the power converter which charges the capacitor is under a very heavy load, and does not produce a useful output for the operation of the ignition system. The battery, however, is still supplying the input to the power convertor, resulting in continued heat loss in the input section of the convertor.

Another significant disadvantage with present capacitive discharge systems utilizing distributor breaker points concerns the phenomenon of breaker point bounce, which may result in spurious triggering of the SCR and subsequent engine misfire.

Additionally, since the commutation of the SCR depends upon a reverse current sufficient to overcome the small forward current of the power convertor and reach a threshold reverse potential, a partial failure in the coil or the charging capacitor, or abnormalities in the coil load, may result in a failure of the SCR to commutate at all, ultimately resulting in complete engine failure and possible ignition burn-out.

In view of the above, it is an object of the present invention to provide a capacitive discharge ignition system wherein the operational state of the silicone controlled rectifier is controlled by means other than the energy stored in the primary of the coil.

It is another object of the present invention to provide a capacitive discharge ignition system wherein the entire power convertor circuit is turned off when the SCR is in a conducting state.

It is a further object of the present invention to provide a capacitive discharging system wherein more than one energy exchange cycle may take place between the charging capacitor and the primary of the coil during the distributor breaker point cycle.

It is a still further object of the present invention to eliminate or reduce the effect of breaker point bounce producing spurious triggering of the silicone controlled rectifier.

SUMMARY OF THE INVENTION

Briefly, in accordance with a preferred embodiment, the present invention includes a voltage supplying circuit, which converts a given low voltage generated by other components in the automobile to a significantly higher voltage; a series-circuit connected to the voltage supply circuit, including a charging capacitor, a discharge circuit for the capacitor, and the primary winding of the ignition coil; and a control circuit to control both the operation of the discharging circuit, and the voltage supply circuit such that the voltage supply circuit is turned off during the time that the discharging circuit is conducting, and such that a predetermined number of energy cycle exchanges may take place between the charging capacitor and the ignition coil during one ignition cycle.

DESCRIPTION OF THE DRAWINGS

A more thorough understanding of the invention may be obtained by a study of the following detailed description taken in connection with the accompanying drawings in which,

FIG. 1 is a block diagram of the capacitive discharge ignition system of the present invention.

FIG. 2 is a schematic diagram of the capacitive discharge ignition system of the present invention.

FIG. 3 is timing diagrams for the charging capacitor relative to the operational condition of the DC-to-DC convertor, and the distributor breaker point cycle.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, a nominal 12-volt voltage supply 11 for a standard automobile ignition system is shown with respect to a block diagram of the present invention. It should be understood, however, that although the present invention is disclosed in the context of an automobile ignition system, its principles are applicable in any system employing a semi-conductor control with capacitive discharge voltage circuit.

Furthermore, it should also be understood that if the system is utilized in an automobile ignition system, triggering sources other than breaker points, such as photochoppers or the like, may be utilized. In FIG. **1**, however the 12-volt voltage supply **11** is connected to a standard ignition switch **12** which is in turn connected to a standard DC—DC convertor **13**, which has a typical DC output of approximately 400 volts. This output is applied to a charging capacitor **17**, which is discharged periodically under the control of a silicone controlled rectifier **18**. The operating state of SCR **18** is in turn positively controlled by trigger network **21** and control circuit **23**.

The triggering sequence is initiated by tbe breaker points **22** in the distributor. Additionally, the breaker points initiate the operation of a control circuit **23** which in turn controls the operation of the DC-to-DC convertor **13**. CIrcuits **21** and **23** operate in conjunction to control the operational cycle of the entire ignition system.

Referrring to FIG. **3**, timing diagrams for several important portions of the ignition system are shown, and which will be referred to in the following paragraphs, as the description of the preferred embodiment proceeds. Diagram A is an idealized charging cycle of the capacitor **17**. Diagram B is the operational sequence of the DC-to-DC convertor, and Diagram C is the timing sequence for the opening and closing of the distributor points. Each of the timing sequences is referenced to the opening of the distributor points.

When the distributor points **22** open, and capacitor **17** is charged to a peak value, a positive gate current is established by the triggering network **21**, turning SCR **18** on, thus allowing the charging capacitor **17** to discharge through the primary of the auto transformer **25**, resulting in a high secondary voltage spike being applied to the electrodes of the spark plug **26**. At the same time, the control circuit **23** turns the DC-to-DC convertor entirely off, effectively isolating it from the rest of the circuit.

Several cycles of energy exchange then occur between the capacitor **17** and the primary of the ignition coil or auto transformer through the SCR **18**, which is held on by the trigger network **21**, in the forward direction, and a diode bridge circuit in the reverse direction. At some predetermined point in time, after a number of energy exchanges has occurred, independent of whether the breaker points **22** remain open, the trigger network **21**, in conjunction with the control circuit **23**, will commutate the SCR, thus interrupting the current flow to the transformer **25**. The trigger network **21** supplies a negative gate current to the SCR **18** in conjunction with a lack of forward current through the SCR, and commutation of the SCR occurs. When the SCR commutates, capacitor **17** will begin to charge again, because of the energy remaining in the system.

Sometime after the SCR **18** commutates, as determined by a timing circuit in control circuit **23**, control circuit **23** will turn the DC-to-DC convertor back on, and the capacitor **17** will once again charge to a peak value.

Referring to FIG. **2**, a schematic diagram of the present invention is shown. Transistors **30** and **31**, transformer **32**, diode bridge network **33**, resistors **34, 35, 36, 37, 38**, and capacitors **39, 40** and **41** comprise a DC-to-DC convertor. As explained above, this circuit converts ordinarily the nominal **12**-volt battery voltage to a high DC voltage, which is used to charge the capacitor **17** during a controlled interval. FIG. **3** shows an idealized charging curve of the capacitor **17** with respect to the timing sequence of the distributor points and the timing of the DC-to-DC convertor.

The ignition cycle begins when the points **22** open, the capacitor **17** at this time being charged to a peak value. A current will flow from the positive battery terminal through resistor **50**, resistor **51** and diode **52**, and will then divide between resistor **53** and the gate connection of the SCR **18**. This positive current turns the SCR on, placing it in the conducting state. Capacitor **17**, which had been charged to a peak value, now discharges through the SCR **18** and the primary winding of the coil **56**, which is connected as shown. As current flows through the primary winding **56** an expanding electromagnetic field is created around the winding, and the energy initially stored in the capacitor **17** is now stored in the electromagnetic field, less the energy dissipated in the spark plugs and through normal heat and other losses.

At some point, the capacitor **17** will become completely discharged, and the electromagnetic field around the coil will be at a maximum. The field will then begin to collapse and in turn will tend to reinforce the original current flow, thus charging the capacitor **17** in the opposite direction. The capacitor **17** will be charged to its maximum opposite or negative value when the field around the primary of the coil is at a minimum. The energy exchange then continues, as a reverse current through the coil **56** is established, which flows through the diode bridge **33** and tends to charge the capacitor **17** in the original, or positive direction. This continuous energy exchange would continue until the energy is depleted due to the natural dampening effect of energy losses in the circuit elements or until the SCR is commutated. During a predetermined number of these cycles, the SCR **18** is continuously conducting, provided with a positive gate current from the triggering circuit, also allowing conduction through the bridge diode consistent with the reverse current of energy exchange cycle.

The commutation of the SCR **18** is initiated, after a predetermined number of energy exchanges, by the triggering network **21**, comprising resistors **60, 61, 62, 51, 53**, diodes **65, 66, 67, 52**, capacitors **70, 71** and SCR **72**. When the points **22** open, resulting in a positive current flow to the SCR **18**, a positive current was also established in resistor **60**, which charges capacitor **71** toward the nominal voltage rating of zener diode **66**. When the charge on capacitor **71** exceeds the critical zener voltage, a positive current flow occurs at the gate of SCR **72**, turning SCR **72** on. When SCR **72** conducts, SCR **18** is deprived of positive gate current. The gate-to-cathode voltage of SCR **18** becomes effectively negative because of the small positive voltage at its cathode provided by the voltage divider of resistors **62** and **68**. Since the SCR **18** thus has an effective negative gate voltage, and since there is no forward current at this time through the SCR either by the DC-to-DC convertor **13** or C17, the SCR **18** commutates. At this point, the capacitor **17** begins to charge as shown in FIG. **3**, because of the remaining energy in the system.

The timing of the commutation depends on the RC time constant established by resistor **60** and capacitor

71. This RC time constant is chosen such that several high voltage spikes may be delivered to an engine combustion chamber during a single firing sequence. This positive control over the number of firing spikes allows for more complete combustion, as well as positive SCR 18 commutation, during each combustion cycle.

The opening of the contact point 22 also initiates the operation of the control circuit 23, which comprises resistors 77, 78, 79, transistors 80, 81, capacitor 76, and diode 75. A positive current flow is established by the opening of the points through diode 75, in turn charging capacitor 76, flowing through resistor 77, and then dividing between resistor 78 and the base of transistor 80. This heavy base current drives transistor 80 into saturation. This saturation condition in transistor 80 deprives transistor 81 of its positive base current, which results in transistor 81 turning off. Since transistor 81 is now off, the base current to transistors 30 and 31 through resistors 34 and 35 will also be blocked. The DC-to-DC convertor 13 is hence turned off. This is shown at point 57 in Diagram B of FIG. 3. By thus preventing current flow into the DC-to-DC convertor circuit when the SCR 18 is conducting, heat loss in the primary winding of the transformer 32 and transistors 30 and 31 is eliminated.

When the positive current flow through diode 75 is interrupted by the conduction of SCR 72, which is at the predetermined time of the commutation of SCR 18, as explained above, the DC-to-DC convertor will not immediately revert to an "on" condition. The DC-to-DC convertor remains off until time is allowed to assure that output SCR 18 has indeed commutated. This time is determined by the time constant of the discharged current of capacitor 76 flowing through resistor 77 and the base of transistor 80. When this current is low enough for transistor 80 to come out of saturation and turn off, the DC-to-DC convertor will then revert to an on condition. The capacitor 17 will then again charge to peak value, with a slight ripple caused by the DC--DC convertor, as shown in FIG. 3. When the points again open, the cycle of operation will be repeated.

Another feature of the invention concerns protection against the effect of point bounce, which refers to the condition in which the points 22, upon initial closing, will bounce slightly open again for a very brief period before closing for the rest of the normal cycle time. Point bounce is undesirable because it Is possible that the SCR 18 may immediately fire again. This would be, of course, a spurious triggering of the output SCR, and unless prevented, results in misfiring and inefficient operation of the engine. To prevent this, the commutation of the SCR 72 is delayed for a very short period of time. Energy is stored in capacitor 70 while the points are open to provide for this delay in the commutation of the SCR 72. When the points 22 initially close, capacitor 70 will start to discharge through SCR 72 and resistor 71, holding SCR 72 in a conducting state, which maintains the negative gate current for SCR 18 and prevents a possible false trigger. When the discharge curve in capacitor 70 drops below the forward threshold current of SCR 72, SCR 72 will commutate. At this point in time, points 22 have already closed, the time for point bounce is over, the DC-to-DC convertor 13 is in an on condition, the capacitor 17 is once again charging toward a peak value, and SCR 72 and 18 are both commutated. When the points 22 again open, at point 57 in FIG. 3, the cycle repeats, with the capacitor 17 immediately discharging through the SCR 18, the DC-to-DC convertor being turned off by the control circuit.

Although a preferred embodiment of the invention has been disclosed herein for purposes of illustration, it will be understood that various changes, modifications and substitutions may be incorporated in such embodiment without departing from the spirit of the invention as defined by the claims which follow:

What is claimed is:

1. An electronic ignition system, comprising:
means for storing energy, said storing means capable of being discharged;
circuit means having first and second operating conditions, said storing means receiving energy from said circuit means when said circuit means is in said first operating condition, said storing means receiving substantially no energy from said circuit means when said circuit means is in said second operating condition;
discharging means operative in a first condition to permit said storing means to discharge; and
means for controlling the condition of said circuit means such that said circuit means is in said second condition as long as said discharging means is in said first condition, said controlling means including first and second transistors connected such that said second transistors turns off when said first transistor is saturated, and means for saturating said first transistor as long as said discharging means is in said first condition, said second transistor thereby maintaining said circuit means in said second condition when turned off.

2. An apparatus of claim 1, wherein said storing means is a capacitor.

3. An apparatus of claim 1, wherein said circuit means includes a DC-to-DC convertor.

4. An apparatus of claim 1, wherein said discharging means is a first silicon-controlled rectifier.

5. An apparatus of claim 1, including ignition transformer means having a primary winding and a secondary winding, said primary winding being in series connection with said storing means and said discharging means.

6. An electronic ignition system, comprising:
means for storing energy, said storing means capable of being discharged;
circuit means operative to provide energy to said storing means;
discharging means operative when conductive to permit said storing means to discharge;
ignition transformer means having a primary winding and a secondary winding, said primary winding being in series connection with said storing means and said discharging means; and
means for controlling said discharging means, said controlling means periodically rendering said discharging means conductive for a sufficient time to permit more than one exchange of energy between said primary winding and said storing means.

7. An apparatus of claim 6, wherein said discharging means is a first silicon-controlled rectifier.

8. An apparatus of claim 6, wherein said means for controlling includes a second silicon-controlled rectifier, sald second silicon-controlled rectifier being connected to said discharging means such that upon con-

duction of said second silicon-controlled rectifier said discharging means becomes nonconductive.

9. An apparatus according to claim **8,** including a timer means initiated upon said discharging means becoming conductive for indicating a predetermined time therefrom, and means for rendering said second silicon-controlled rectifier conductive at said predetermined time.

10. An apparatus of claim **9,** wherein said timer means includes a resistor and a first capacitor, and wherein said means for rendering said second silicon-controlled rectifier conductive is a zener diode.

* * * * *