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[54] **OVERVOLTAGE AND ELECTRONIC RELAY CIRCUIT FOR CAPACITOR DISCHARGE IGNITION SYSTEMS**
9 Claims, 1 Drawing Fig.

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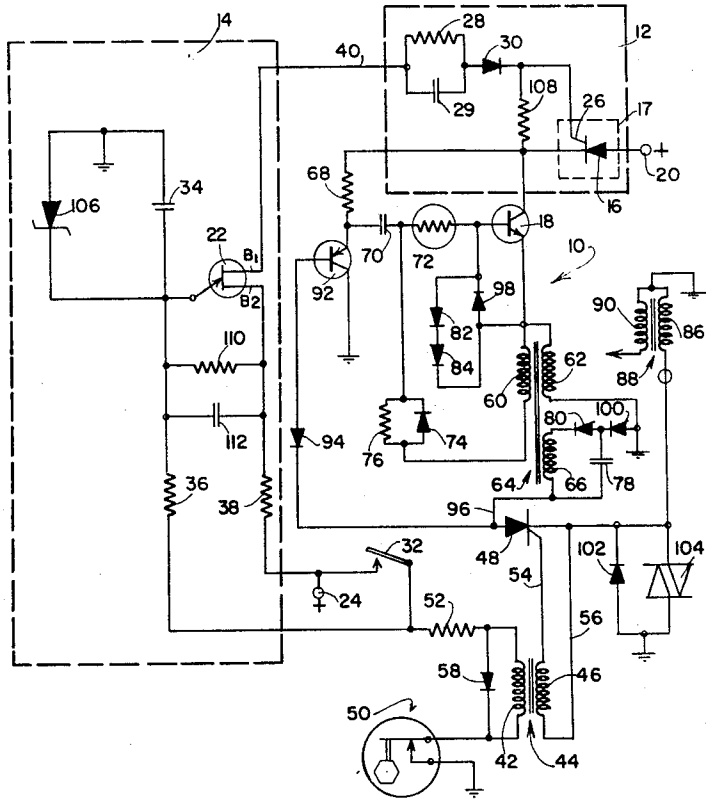
[56] **References Cited**

UNITED STATES PATENTS

3,253,163	5/1966	Konopa	123/148 E
3,318,296	5/1967	Hufton	123/148 E
3,335,320	8/1967	Quinn	123/148 E
3,395,686	8/1968	Minks	123/148 E
3,424,142	1/1969	Nilssen et al.	123/148 E
3,426,740	2/1969	Hufton et al.	123/148 E
3,433,208	3/1969	Dogadko et al.	123/148 E
3,502,955	3/1970	Minks	123/148 E
3,534,719	10/1970	Minks	123/148 E

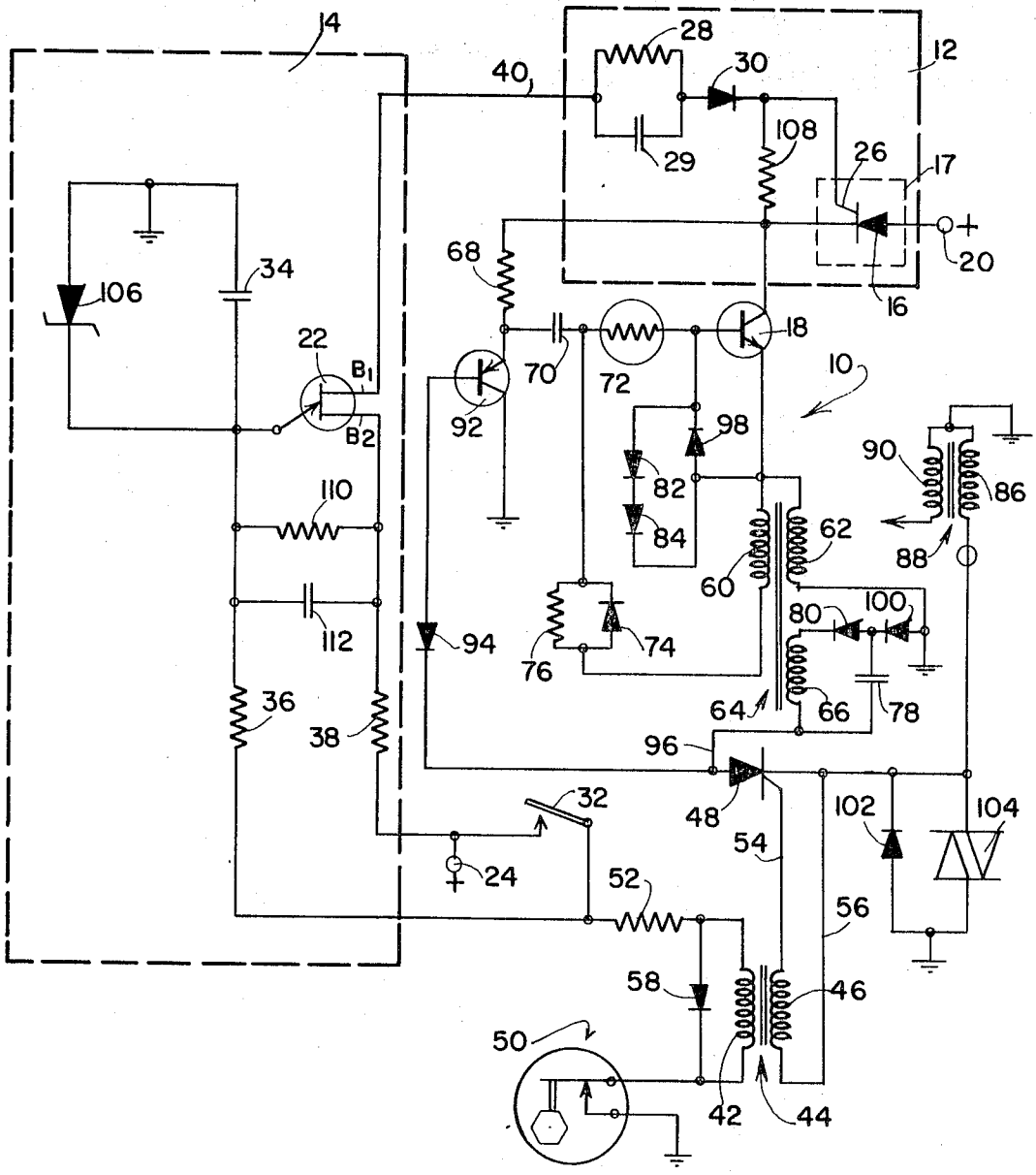
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ABSTRACT: An energy-pulsing circuit is provided for reestablishing a predetermined energy level within a storage capacitor after the energy therefrom has been applied to the ignition coil in response to external pulse signal information. A power-switching circuit is connected between the energy-pulsing circuit and an external power supply to block current flow to the energy-pulsing circuit during one instance, and to provide a current path to the energy-pulsing circuit during another instance. A synchronized oscillator is provided for controlling current flow through the power-switching circuit during desired periods of time, the oscillator circuit being synchronized with the external pulse signal information.



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ATTYS.

OVERVOLTAGE AND ELECTRONIC RELAY CIRCUIT FOR CAPACITOR DISCHARGE IGNITION SYSTEMS

BACKGROUND OF THE INVENTION

This invention relates generally to ignition systems of the type providing a high-voltage low-current energy pulse to the primary winding of an ignition coil, and more particularly to an improved capacitor discharge ignition system.

Capacitor discharge ignition systems, that is, systems which utilize a capacitor for intermittently discharging a relatively high-voltage energy pulse through an ignition coil, have found relatively widespread and popular use in connection with internal combustion engines. Such capacitor discharge ignition systems have several advantages over the conventional Kettering ignition systems. One of the advantages is that the power drain from the automobile battery is substantially reduced when using a capacitor discharge ignition system. Another advantage of capacitor discharge ignition systems is that a spark of higher voltage, i.e., higher fuel-igniting properties, can be generated more readily with a somewhat rundown storage battery connected thereto, than could otherwise be obtained by a conventional ignition system. Yet another advantage obtained from capacitor discharge ignition systems is that the spark potential generated at spaced-apart electrodes within a spark plug remains substantially constant over a much wider range of engine speeds than otherwise can be obtained from the conventional ignition systems.

Despite the advantages mentioned hereinabove, as well as others not mentioned, capacitor discharge ignition systems of the prior art are easily damaged whenever an overvoltage is applied to such systems. For example, if for some reason the connection to the automobile battery becomes loose or is removed while the engine is running, a high voltage, on the order of 30 volts or more, is supplied to the ignition circuit by the alternator which is driven by the engine. This high voltage, as compared to the usual 12 volts, is sufficient to Cdestroy some or all of the electronic components which go into forming the capacitor discharge ignition system. One attempt by the prior art to circumvent this serious problem is to provide a manually operated switch which, when actuated, will disconnect the capacitor discharge ignition system from the ignition coil of the car and reconnect the conventional ignition system. This at least allows the operator of the automobile to continue on his journey.

Still another serious problem of prior art capacitor discharge ignition systems is that of the residual alternator voltage which, when applied to the ignition switch, is sufficiently high to generate spark-producing potentials at the output of the ignition system even after the ignition switch of the automobile has been turned off, that is, switched to the open circuit condition.

SUMMARY OF THE INVENTION

It is therefore an object of this invention to provide an improved capacitor discharge ignition system which will not suffer adverse affects when an overvoltage is applied thereto. Another object of this invention is to provide a capacitor discharge ignition system which is rendered inoperative instantaneously and continuously upon the opening of the ignition switch of an automobile.

Briefly, the ignition system of the illustrated embodiment includes an energy storage capacitor, or any other suitable energy storage means, for receiving and storing a relatively high-voltage energy pulse. The stored energy is then synchronously discharged from the capacitor, as for example by means of opening the breaker points of an automobile, and applied to the primary winding of an ignition coil through a current control device such as a silicon-controlled rectifier. Preferably, the energy pulse as applied to the storage capacitor is developed in a secondary winding of a step-up transformer, the primary winding or windings thereof being connected to an energy-pulsing circuit such as a blocking oscillator. A trigger amplifier stage may be coupled to the secondary winding of the transformer to initiate conduction of a power-switching transistor which is connected in series with the primary winding of the transformer. Suitable regenerative feedback circuit means are provided between the output of the switching transistor and its base electrode to drive the transistor rapidly to a current saturated condition. Upon completion of the saturated condition of the power-switching transistor, a reverse voltage feedback will occur in one of the primary windings of the transformer to render the switching transistor nonconductive. Regardless of the time duration between spark discharges, the power-switching transistor remains nonconductive until the next spark discharge occurs whereupon the single swing-blocking oscillator formed by the transistor and its associated transformer will again deliver an energy pulse to the storage capacitor. Although the illustrated embodiment uses a single swing-blocking oscillator to apply energy pulses to the storage capacitor it will be understood that any suitable energy-pulsing circuit can be used.

Most advantageously, a power switching device, preferably a silicon-controlled rectifier, is connected in series with the blocking oscillator circuit and is rendered conductive by the output of a synchronized oscillator circuit connected thereto to apply operating potential to the blocking oscillator. The synchronized oscillator circuit preferably is a simple unijunction transistor oscillator of the relaxation oscillator type, but in accordance with this invention is operated to be synchronized by kickback pulses from a pulse-forming trigger transformer connected to a second silicon-controlled rectifier which controls discharge of the storage capacitor. The base electrodes of the unijunction transistor in the oscillator circuit are connected directly to an external battery while the emitter electrode thereof is connected to the battery potential through, for example, the ignition switch of an automobile. When the Cignition switch is opened to turn off the engine, also turning off the ignition system, the residual voltage developed at the alternator will appear at the ignition switch, this voltage being approximately 5 volts, while full battery potential remains on the base electrode of the unijunction transistor. This difference of potential between the base electrode and emitter electrode of the unijunction transistor renders it completely inoperative so that no further pulse signals are applied to the power-switching circuit thus, instantly and completely removing power from the blocking oscillator circuit to disable the ignition system.

A charging capacitor connected between the emitter electrode of the unijunction transistor and ground potential is shunted by a zener diode, or other suitable reference voltage device, which when rendered conductive offers a relatively low resistance. The reference potential of the zener diode is selected to be greater than the battery potential but less than the output voltage of a free-running alternator, i.e., an alternator not connected to a battery or voltage regulator circuit. When an overvoltage occurs because of the unconnected battery the zener diode will breakover to prevent charge from building up on the capacitor within the unijunction transistor oscillator. As the synchronized oscillator no longer operates, the power-switching circuit is rendered inoperative and the blocking oscillator circuit is completely disconnected from the battery potential.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Now referring to the drawing an ignition system designated generally by reference numeral **10** is alternately connected and disconnected from an external source of positive potential by means of a power-switching circuit **12** which, in turn, is controlled in response to output signals of a unijunction transistor oscillator **14** which operates as a trigger circuit. In the normal off condition of the ignition system **10**, no voltage is applied thereto because of the high resistance blocking condition of a silicon-controlled rectifier **16** connected between a power-switching transistor **18** of the ignition system **10** and a positive potential receiving terminal **20**. That is, no operating

potential is applied to ignition system 10 through the load electrodes of the silicon-controlled rectifier 16 when in its high resistance blocking condition.

The silicon controlled rectifier 16 may be mounted to a heat sink of any suitable configuration, and is here illustrated by the dotted area designated by reference numeral 17. A unijunction transistor 22 of the oscillator 14 has one base electrode B_2 thereof connected to a positive potential at a terminal 24 and the other base electrode B_1 thereof coupled Cto the gate electrode 26 of the silicon controlled rectifier 16 preferably through a parallel network comprising resistor 28 and capacitor 29 and a series diode 30. Operating potential is applied to the emitter electrode of unijunction transistor 22 through a switch 32, preferably this being the ignition switch of an automobile.

With the ignition system in the off condition capacitor 34 will charge rather slowly as compared to its charge rate during normal operation, this slow charge being accomplished through resistors 38 and 110. Therefore, when starting an engine the oscillator circuit 14 is in readiness to control the power-switching circuit 12 and apply operating potential to the energy-pulsing circuit 10. However, with switch 32 closed the capacitor 34 within the oscillator circuit 14 charges at a much faster rate through resistor 36 to the full, or substantially full, value of the plus potential at terminal 24. A resistor 38 is connected to base B_2 of the unijunction transistor 22 and is of a resistance value, together with, among other things, the resistance value of resistor 36 to set the circuit parameters of the oscillator 14 so that it will not oscillate until the voltage across capacitor 34 exceeds the positive potential applied to terminal 24. Therefore, even when the switch 32 is closed the oscillator 14 produces no output signal to render the power-switching circuit 12 operative so as to connect operating potential to the ignition system 10. However, only a slight increase in potential across capacitor 34 will be sufficient to render the unijunction transistor 22 conductive to deliver a pulse over line 40 into the gate electrode 26 of silicon-controlled rectifier 16 to render it conductive. The necessary additional voltage across capacitor 34 is obtained by a short kickback pulse across a primary winding 42 of a triggering transformer 44 which has its secondary winding 46 connected to the gate, cathode circuit of a silicon-controlled rectifier 48 which acts as a current control switching device for the ignition system 10.

A voltage-dropping resistor 108 is connected across the cathode gate junction of silicon controlled rectifier 16 to provide the necessary triggering voltage across these terminals for firing the silicon-controlled rectifier 16 in the prescribed and well-known manner. Also a resistor 110 and capacitor 112 are connected across the emitter base junction of unijunction transistor 22 of the oscillator 14 to act as a noise and/or transient voltage suppression filter to prevent spurious, undesired and uncontrolled firing of the unijunction transistor 22.

Upon closing of a mechanical breaker-point assembly 50 current will flow from the positive terminal 24 through the ignition switch 32, a current-limiting resistor 52 and the primary winding 42 of transformer 44. However, this initial current flow produces a negative potential at line 54 connected to the secondary winding 46 and will have no affect on the silicon controlled rectifier 48. Upon opening of the mechanical breaker-point assembly 50, current flow through the primary winding 42 is terminated and the magnetic field within the transformer 44 rapidly collapses to produce a positive polarity pulse in the line 54 and a negative polarity pulse in a line 56 which is connected to the cathode electrode of silicon-controlled rectifier 48. During the rapid collapse of this magnetic field a kickback voltage of reverse polarity is generated within the primary winding 42. A diode 58 is connected across the primary winding 42 substantially to reduce and dampen out the reverse kickback voltages. However, the diode 58 does not completely eliminate the kickback voltage and, in accordance with this invention, it is desired not to completely eliminate such kickback voltage as it is this kickback voltage which is applied to the capacitor 34 to energize the relaxation oscillator.

As mentioned hereinabove the charge on capacitor 34 is substantially that of applied potential at terminal 24 and, as such, is not sufficient to cause conduction of the unijunction transistor 22. However, the kickback voltage from primary winding 42, upon opening of the breaker-points 50, is delivered through resistors 52 and 36 and added to the charge on capacitor 34. The combined voltages on capacitor 34 are then sufficient to render unijunction transistor 22 highly conductive to produce an output pulse through line 40 which, in turn, will render the power-switching silicon-controlled rectifier 16 conductive. With silicon-controlled rectifier 16 now in its low-resistance condition the positive potential at terminal 20 is applied directly to the collector electrode of transistor 18 which, in turn, will deliver current to a pair of primary windings 60 and 62 of a voltage step-up transformer 64.

At the outset of the first cycle of operation of the ignition system 10 switching of the silicon-controlled rectifier 16 also allows sufficient current to flow through a resistor 68 and a coupling capacitor 70 through the base electrode of transistor 18 initially to render it only slightly conductive. A temperature compensating resistor 72 is connected between the capacitor 70 and the base electrode of transistor 18 to provide more stable operation of the ignition system 10. The initial slight current conduction of transistor 18 will produce current through the primary winding 62 which has the other end thereof connected to ground potential. However, as a result of transformer coupling between the primary windings 60 and 62 a regenerative feedb ack signal is applied to the base electrode of transistor 18 through a parallel network consisting of a diode 74 and a resistor 76. This regenerative feedback further increases the positive potential at the base electrode of transistor 18 to drive it to a higher degree of conduction. This action of increasing current conduction through transistor 18 continues at a relatively rapid rate until the transistor is completely saturated.

Also, during this portion of the operating cycle a stepped-up voltage is developed across the secondary winding 66 of transformer 64 to apply energy to a storage capacitor 78 in the form of a high voltage, preferably in the order of from about 100 to 300 volts. The secondary winding 66 together with storage capacitor 7 and a blocking diode 80 are connected in a series loop arrangement to provide substantially a closed loop connection for voltages of one polarity and an open loop connection for voltages of the opposite polarity, which opposite polarity voltages are then stored within the capacitor 78 and remain therein because of the reverse-biased condition of diode 80.

A pair of conventional diodes 82 and 84 are connected in series one with the other and connected across the base emitter junction of transistor 18. The diodes 82 and 84 provide a sufficiently low reference potential across the base emitter junction of transistor 18 to limit the current flow therethrough to within the rated value of the transistor. Upon reaching substantially complete saturation of transistor 18 the current flow through primary winding 62 no longer produces a varying magnetic field within the transformer 64 and the field collapses producing a self-induced voltage within the feedback winding 60 to apply a negative potential to the base electrode of transistor 18 thus, within a relatively short period of time, completely turning off the transistor. Transistor 18 will remain in its off condition until again pulsed by some external source. The single swing, blocking oscillator formed by transistor 18 can be considered an energy-pulsing circuit which applies energy, in pulse form, to charge the storage capacitor 78 during each cycle of operation of the ignition system 10.

Upon opening of the breaker points 50, a pulse will be delivered to the cathode gate circuit of silicon-controlled rectifier 48 which, in turn, forms current-controlled switch means rapidly to discharge the energy on capacitor 78 into a primary winding 86 of an ignition coil 88, the high-voltage

secondary winding 90 thereof being connected to the center post of an ignition distributor.

If desired, a triggering amplifier may be used with the single swing blocking oscillator formed by transistor 18 to apply the necessary reinitiation pulse to the transistor 18 for the next cycle of operation. This triggering amplifier is herein illustrated as a transistor 92 forming an emitter-follower circuit coupled to the capacitor 70. The base electrode of transistor 92 is connected to one end of a capacitor 78 via a diode 94 and a circuit line 96. When the silicon-controlled rectifier 48 is rendered conductive to discharge capacitor 78 into the primary winding 86, the potential across capacitor 78 and across the secondary winding 66 rapidly decreases substantially to zero. Thus, at this point in time a slight ringing current is generated between capacitor 78 and secondary winding 66 so that a short duration negative potential is sensed at circuit line 96. This negative potential serves not only to commutate the silicon-controlled rectifier 48 to an off condition but also serves to forward bias diode 94 which, in turn, will render transistor 92 conductive to apply a negative pulse to a capacitor 70 and therefrom to the base electrode of a transistor 18. However, shortly thereafter the potential on line 96 rapidly changes to zero or to a positive potential to reverse bias the diode 94 and render transistor 92 nonconductive. This action will produce a positive pulse through capacitor 70 which, in turn, will initiate operation of transistor 18 to deliver another energy pulse to the capacitor 78.

During the collapse of the magnetic field within transformer 64, and substantially immediately thereafter, a diode 98, which has its anode connected to the windings 60 and 62 and its cathode connected to the base electrode of transistor 18, substantially dampens any tendencies for sustained oscillations within the blocking oscillator circuit, as the diode 98 provides backswing limiting in such a fashion that the oscillator repetition rate and duty cycle are not materially affected. Also, a diode 100 is connected in series with diode 80 at the junction of capacitor 78 and provides a current path to ground potential for the secondary winding 66 during voltages of a given polarity thus dampening any ringing effect within the closed loop of winding 66, capacitor 78 and diode 80 after the capacitor 78 has been discharged. Connected in parallel with the primary winding 86 of the ignition coil 88 is a diode 102 connected in parallel with a bidirectional threshold switching device 104 or any other suitable voltage dependent resistor means which serves to prevent voltage breakdown of the diode 102 which dampens oscillation in the primary winding 86 after the high-voltage spark discharge has been created.

Most advantageously, overvoltage protection of the ignition system 10 is obtained by maintaining the power-switching, silicon-controlled rectifier 16 in its high-resistance current-blocking condition, i.e., its off condition, whenever a high voltage is applied to the terminal 20. The illustrated embodiment accomplishes this advantageous result by incorporating a reference voltage device, or threshold voltage device, in parallel with the capacitor 34 of the unijunction transistor oscillator circuit 14, here it being illustrated as a zener diode 106. Since the value of the applied potential at terminal 20 is the same as that applied to terminal 24, these connections being in all likelihood connected together at some distribution buss line within the automobile, the same voltage will be sensed at the power-switching, silicon-controlled rectifier 16 and the unijunctional transistor 22. However, the high voltage, if it occurs, either with switch 32 open or closed, is applied across capacitor 34 and is of sufficient value to cause conduction of the zener diode 106, which action will substantially instantaneously reduce the resistance of the zener diode 106, to discharge the capacitor 34 and maintain it in such discharged condition. The capacitor 34 while in the discharged condition cannot operate the unijunction transistor 22 in an oscillating fashion. Therefore, no trigger pulse will be applied to the gate electrode 26 of the power-switching silicon-controlled rectifier 16 and the power at terminal 20 is prevented from reaching transistors 18 and 92.

Accordingly, this invention provides means for controlling the application of power to an energy-pulsing circuit which, in turn, applies energy to charge the capacitor of a capacitor discharge ignition system. The controlling of the power applied to the energy-pulsing circuit is accomplished by means of an oscillator which produces control signals in synchronism with an external pulse-forming device, such as the breaker points of an automobile.

We claim:

1. An ignition system for generating a spark discharge between spaced-apart electrodes in synchronization with an external pulse signal, comprising in combination, an ignition coil having primary and secondary windings, said secondary winding being coupled to the spaced apart electrodes, energy storage means for receiving and storing electrical energy to be discharged into the primary winding of said ignition coil, current control switch means connected to said energy storage means to form a substantially instantaneous low-resistance current path from said energy storage means to the primary winding of said ignition coil to produce a spark discharge between the spaced-apart electrodes in response to the external pulse signal, an energy supply circuit coupled to said energy-storing means to apply electrical energy thereto after each discharge thereof by conduction of said current control switch means, a semiconductor power-switching device having load electrodes and a control electrode, one of said load electrodes connected in circuit with said energy supply circuit to apply power thereto and the other of said load electrodes arranged for connection to an external power source, trigger circuit means connected to the control electrode of said semiconductor power-switching device periodically to render said power-switching device conductive to effect a direct current connection of the external power source to the energy supply circuit after each transfer of energy from said energy storage means into the primary winding of the ignition coil, and a reference voltage device connected in circuit with said trigger circuit means to disable said trigger circuit means and maintain said semiconductor power switching device nonconductive to completely disconnect the external power source from said energy supply circuit when the voltage value of the external power source exceeds a predetermined level.

2. The ignition system of claim 1 including means coupling the external pulse signal to said trigger circuit means to operate said trigger circuit means in synchronism with said pulse signal information thereby controlling said semiconductor power switching device in a manner to effect direct current connection of an external power source to the energy supply circuit in response to said pulse signal information.

3. The ignition system of claim 1 wherein said trigger circuit means include first and second current paths, said first current path applying operating potential to said trigger circuit means and said second current path providing a control potential to said trigger circuit means, and said first current path arranged for direct connection to the external power source and said second current path arranged for connection to said external power source through switch means, and a reduction of voltage applied to said second current path substantially instantaneously disabling said trigger circuit means to terminate operation of the ignition system.

4. The ignition system of claim 1 wherein said semiconductor power switching device is a silicon-controlled rectifier having its load electrodes connected between the external power source and said energy supply circuit, and its control electrode coupled to said trigger circuit means for receiving output signals therefrom to render the silicon-controlled rectifier conductive in response thereto.

5. The ignition system of claim 4 further including a diode connected in series between said trigger circuit means and the gate electrode of said silicon-controlled rectifier, said diode being biased to allow control signals to flow from said oscillator means to said gate electrode and to block current flow in the opposite direction.

6. The oscillator circuit of claim 1 wherein said trigger circuit means includes a unijunction transistor having its base electrode forming a first current path to produce control signals therethrough and an emitter electrode connected to a second current path for applying a control potential thereto, and a capacitor connected between said emitter electrode and ground potential for receiving a charge from said external power source, and means coupling a synchronizing pulse from the external pulse signal to said capacitor to add with the charge thereon to rapidly raise the potential thereacross sufficiently to render said unijunction transistor operative to produce an output pulse therefrom in synchronization with said external pulse signal information.

7. The ignition system of claim 6 wherein said reference voltage device is a zener diode having a zener voltage value greater than the voltage value of the external power source, said zener diode being connected in circuit with said capacitor so that application of an increased voltage above its zener voltage value will render the zener diode conductive to disable said unijunction transistor, thereby preventing said power-switching means from connecting the external power source to said energy supply circuit.

8. The ignition system of claim 6 wherein said first current path to said unijunction transistor is delivered from a direct connection to the external power source, and said second current path for the control potential is delivered through an external switch means, and opening of said switch means causing a reduction in voltage applied to said second current path below said external power source but above zero volts, and the difference of potential between said external power source and the reduced voltage at said second current path acting substantially instantaneously to render said unijunction transistor inoperative to prevent further trigger pulses from being applied to said semiconductor power-switching device.

9. The ignition system of claim 1 wherein said semiconductor power-switching device is a silicon-controlled rectifier having its load electrodes connected between the external power source and said energy supply circuit, and its control electrode coupled to said trigger circuit means for receiving output signals therefrom to render the silicon-controlled rectifier conductive in response thereto, said trigger circuit means including a unijunction transistor having its base electrodes forming a first current path to produce trigger signals therethrough and an emitter electrode connected to a second current path for applying a control potential thereto, and a capacitor connected between said emitter electrode and ground potential for receiving a charge from said external power source, and means coupling a synchronizing pulse from the external pulse signal information to said capacitor to add with the charge thereon to rapidly raise the potential thereacross sufficient to render said unijunction transistor operative to produce an output trigger pulse therefrom in synchronization with said external pulse signal information: and said reference voltage device having a reference voltage value greater than the voltage value of the external power source, said reference voltage device being connected in circuit with said capacitor so that application of an increased voltage above its reference voltage value will render the reference voltage device conductive to disable said unijunction transistor thereby preventing said semiconductor power-switching means from connecting the external power source to said energy supply circuit when an overvoltage occurs; and said current path to said unijunction transistor is delivered from a direct connection to the external power source, and said second current path for the control potential is delivered through an external switch means, and opening of said switch means will cause a reduction in voltage applied to said second current path below said external power source but above zero volts, and the difference of potential between said external power source and the reduced voltage at said second current path acting substantially instantaneously to render said unijunction transistor inoperative to prevent further trigger pulses from being applied to said semiconductor power-switching device.

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