A high-frequency continuous-wave ignition system for internal combustion engines. It employs a unidirectional magnetic circuit in a square-wave oscillator. Starting and stopping the oscillator is controlled by a winding coupled to the magnetic circuit. A circuit including this control winding has a full-wave AC short-circuit connection for stopping the oscillator between sparking intervals. However, a predetermined half-wave path in the short circuit has a greater impedance than the other half-wave path. This acts so that the magnetic circuit is always set in a given state as the oscillator is stopped. As a result it ensures instant starting of the oscillator at the beginning of each sparking interval.
HIGH-FREQUENCY CONTINUOUS-WAVE IGNITION SYSTEM

CROSS-REFERENCES TO RELATED APPLICATIONS

This application relates to the subject matter disclosed in my co-pending application Ser. No. 209,060, filed Dec. 17, 1971, entitled “Controlled Spark-Duration Ignition System”.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention concerns ignition systems in general, and more specifically relates to an ignition system for internal combustion engines. It is particularly concerned with a high-frequency continuous-wave type of spark-generation system.

2. Description of the Prior Art

Hereinafter, there have been a number of different arrangements that proposed to generate a series of continuous spark-generation signals. However, it has been found difficult to apply such systems to internal combustion engines generally, and particularly to reciprocating type engines. A principal difficulty apparently has been the problem of reliability in instantaneously starting an oscillator that develops this type of ignition signals.

Such difficulty has been substantially overcome by various systems developed by this applicant. However, in particular situations it has been found that there is still a need for providing the assurance of proper magnetic state in the magnetic circuit of an oscillator that is employed in such ignition systems.

Consequently, it is an object of this invention to provide an improvement that relates to an ignition system which employs a full-wave loading circuit to stop the oscillator.

SUMMARY OF THE INVENTION

Briefly, this invention relates to a combination with a controlled-spark-duration ignition system for an engine. The said system has a high-frequency continuous-wave oscillator, including a transformer having a high-voltage output winding. The system also has first circuit means for connecting said output winding to a sparking circuit, and an oscillator-control winding on said transformer for starting and stopping the oscillator. It also has second circuit means for applying a DC bias current to said control winding when said oscillator is not oscillating, and means controlled by said engine crank angle for cutting off said DC bias current at the beginning of each spark-duration interval. It also has third circuit means which comprises an AC low-impedance short-circuit path connected in shunt with said DC bias source, for stopping said oscillator at the end of each spark-duration interval. In connection with the foregoing combination, the improvement comprises means incorporated with said AC path for increasing the impedance for a predetermined one of the half-cycles of AC current flow sufficiently to retard without stopping said oscillator. The arrangement is such that the magnetic state of the core of said transformer will always be set so as to insure instantaneous starting of the oscillator thereafter.

Again briefly, the invention relates to a combination with a controlled-spark-duration ignition system for an engine. The said system has a high-frequency continuous-wave oscillator including a transformer having a high-voltage output winding. The system also has first circuit means for connecting said output winding to a sparking circuit, and an oscillator-control winding on said transformer for starting and stopping oscillation. It also has second circuit means for applying a DC bias current to said control winding when said oscillator is not oscillating, and means controlled by said engine crank angle for cutting off said DC bias at the beginning of each spark-duration interval. The system also has an AC pass diode bridge connected in shunt with said DC bias current source for stopping said oscillator at the end of each said spark-duration interval. In connection with the foregoing combination, the improvement comprises a resistor connected in a predetermined arm of said diode bridge for increasing the impedance for a predetermined one of the half-cycles of AC current flow sufficiently to retard without stopping said oscillator, whereby when the oscillator is stopped on the succeeding half-cycle, the magnetic state of the core of said transformer will always be set so as to insure instantaneous starting of said oscillator. The improvement also comprises fourth circuit means for permanently connecting said oscillator to a power source, and an ignition switch and a relay controlled by said ignition switch. Finally, the improvement also comprises fifth circuit means connected to said relay for short-circuiting said control winding when said ignition switch is off.

BRIEF DESCRIPTION OF THE DRAWING

The foregoing and other benefits of the invention will be more fully set forth below in connection with the best mode contemplated by the inventor of carrying out the invention, and in connection with which there are illustrations provided in the drawing wherein:

The FIGURE of drawing is a schematic circuit diagram illustrating an ignition system which incorporates the invention therein.

DESCRIPTION OF THE PREFERRED EMBODIMENT

It may be noted that a basic ignition system to which this invention applies, includes a full-wave short-circuit path connected to the control winding of a spark-generating oscillator. Such an ignition system has been shown and described in the above-noted co-pending application.

It is also pertinent to observe that some similar ignition systems using the same basic oscillator to generate spark signals, have been disclosed using only a half-wave short-circuit path to stop the oscillator at the end of each sparking interval, e.g., see my co-pending application Ser. No. 257,952, filed May 30, 1972, entitled “High Frequency Type Ignition System”. However, where the power requirements are especially great, it has been found that the oscillator may continue to oscillate in spite of such half-wave loading. Therefore, the full-wave loading circuit was developed to overcome that situation.

A difficulty was discovered in that the full-wave loading arrangement tends to create a random situation for the magnetic state of the transformer as the oscillation stops. This means that the oscillator would stop in a random manner with the magnetic state of the core so located on the hysteresis curve thereof that it would not provide instantaneous starting of the oscillator when
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called for. Furthermore, this was so even though a DC magnetic bias was employed, because of the magnitude of the AC currents involved. However, it was discovered that an element could be provided in the full-wave loading circuit such that the stopping of the oscillator would always be on a given half-cycle. In this manner the transformer core would always be set in the proper state for insuring positive instantaneous starting thereafter.

Referring to the FIGURE of the drawing, it will be observed that there is an oscillator 11 that includes a pair of transistors 12 and 13. These transistors are connected with the collector electrodes joined to the ends of a center-tapped winding 14. The winding 14 is the primary energy-input winding of a transformer 17. The transformer has a secondary, or output winding 18 that is connected to the high-voltage distributor of an internal combustion engine, as indicated by the caption.

In addition, the oscillator 11 includes a feedback winding 19 which has the ends thereof connected to the base electrodes of transistors 12 and 13. Also, there are a pair of diodes 22 and 23 that are connected between the base electrode and ground of each of the transistors 12 and 13, respectively. Finally, there is a control winding 26 that acts to control the starting and stopping of the oscillator 11. This is accomplished by loading the magnetic circuit of the oscillator sufficiently to reduce the feedback enough to stop the oscillator. As already indicated above, such action has been described in considerable detail in one or more of my co-pending applications.

The ignition system is energized by a battery 31 which has one side grounded as illustrated, and the other side connected via a circuit connection 32 to the center tap on transformer 14. There is a capacitor 35 connected between circuit connection 32 and ground for by-passing radio-frequency energies.

Also connected to the ungrounded side of battery 31, there is a circuit connection 38 to both of the "run" and "start" contacts of an ignition switch 39. The switch 39 has the common contactor connected to a circuit connection 42 which goes to one end of a relay winding 43 that has the other end thereof grounded. The winding is part of a relay 44 which has normally closed contacts 54 controlled by the winding 43. Consequently, when the winding 43 is energized, the switch contacts 45 will be open. This relay is provided in order to have the positive short-circuiting of the control winding 26 whenever ignition switch 39 is turned off.

Under normal operating conditions when the engine is running, control winding 26 is under the control of a spark-timing circuit. For example, there might be breaker points (not shown), or a circuit to control the state of conduction of a transistor 50. The latter circuit (not shown) would be controlled by other types of engine-timed elements such as light-sensitive devices or magnetic pick-up elements, or the like. Such arrangements have been shown and described in detail in various of my co-pending applications.

When the transistor 50 is conducting, it is comparable to breaker points that are closed, and so the control winding 26 is short-circuit which will stop the oscillator 11. Such short-circuit path includes a full-wave loading circuit that includes a diode bridge 51 with four diodes 54, 55, 56 and 57 therein. The diagonal point on bridge 51 between 54 and 57 is connected via a con-

ector 60 to one end of the control winding 26. The other end of winding 26 is connected via a circuit connection 61 to another circuit connection 62 that leads to the connection point 63. One side of a Zener diode 66 is connected to the point 63, while the other side thereof is connected via a circuit connection 67 to the opposite diagonal of bridge 51. The remaining diagonal points of bridge 51 include a diagonal point 70 that is connected to ground as illustrated, and its opposite diagonal point 71. The latter is connected via a circuit connection 72 to the collector electrode of the transistor 50.

The DC voltage supply from battery 31 is connected to control winding 26 when the oscillator is stopped, so that a DC bias current applies a magnetic bias to the core of transformer 17. The circuit for completing such DC current flow may be traced from the circuit connection 42 (described above) over another circuit connection 75 to a resistor 76 and then via a diode 77 to the circuit point 63. From there, the circuit continues over the circuit connection 62 and the circuit connection 61 to one end of the winding 26. The other end of winding 26 is connected to ground via the circuit connection 60, diode 54, bridge diagonal point 71, connection 72, and transistor 50 (now conducting). From ground, of course, the circuit is completed via ground connection of the battery 31.

As has been indicated above, the system of this invention concerns a full-wave oscillator-stopping arrangement to stop the oscillation at the end of each spark-signal-generating interval. At the same time it acts to insure that the magnetic state of the core of transformer 17 is properly set. In order to do this, there is included in the bridge 51 a resistor 80 that is in series with the diode 57 in one arm of the bridge 51. The ohmic value of resistor 80 is determined so as to permit sufficient current flow for partially loading the magnetic circuit of the oscillator, but not enough to stop the oscillation on that half-cycle. Then, the next half-cycle of oscillation will completely load the oscillator and stop the oscillation so that the state of the magnetic core will always be set in a desired manner. This means that at the beginning of each spark interval, the oscillator 11 will start instantaneously upon deenergization (i.e., cut-off) of transistor 50.

It may be noted that the relay 44 is provided in order to ensure no oscillation by oscillator 11 when the ignition switch is turned off. This is necessary because the oscillator is permanently connected for receiving the DC potential from battery 31. Such permanent connection permits the use of a conventional ignition switch while, otherwise, the amount of power required by the oscillator would necessitate a special heavy-duty switch. The short-circuiting of control winding 26 is removed whenever the ignition switch is turned on, for either starting or running, by having the contacts 45 open whenever the relay winding 43 is energized.

The operation of a major feature of this invention may be clarified by tracing the circuit and describing the action, or current flow as the oscillator is stopped at the end of each spark-duration interval. Thus, whenever the spark-duration interval is to be terminated by energizing of transistor 50, there will be a direct circuit connection through the transistor. If, at that instant, the AC signal induced in control winding 26 is causing a downward flow of current therethrough, the current flow may be traced as follows. Beginning at the lower
end (as viewed in the drawing) winding 26 and continuing via connection 60, diode 54 of the bridge 51, point 71, and connection 72 to the transistor 50. Then, the circuit is completed via ground connection and the diagonal point 70 of the bridge 51 via diode 56 and circuit connection 67 to the Zener diode 66. It continues via Zener diode 66 and via point 63, connections 62 and 61 to the other side of the winding 26. In addition, there is a parallel path beginning at the ground connection that goes via the battery 31 and continues over connection 38, the ignition switch 39, connections 42 and 75 to the resistor 76. Then via the resistor 76 and the diode 77 to the circuit point 63 where it joins the other circuit back to winding 26. That short-circuit path will cause control winding 26 to load the oscillator sufficiently to stop oscillation.

On the other hand, if the transistor 50 becomes conducting during the other half-cycle so that current flow induced in control winding 26 is in the opposite direction, the path of flow will be as follows. Beginning at the top of winding 26 and going via connections 61 and 62 to the point 63, it then continues via Zener diode 66 (breakdown voltage is exceeded) and circuit connection 67 to the diode 55. From there it continues via diagonal point 71 and circuit connection 72 to the transistor 50 and to the ground circuit. From the ground connection it continues back to the other diagonal point 70 of the bridge 51, and then it flows through resistor 80 and diode 57 to circuit connection 60 which leads back to the other side of winding 26.

It will be noted that the latter circuit includes the resistor 80 which is designated to have only sufficient impedance for partially loading the oscillator without completely stopping same. Consequently, when the next half-cycle of the oscillator takes place, it will induce the opposite direction of current flow in winding 26 and the reverse path of flow (described above) will be connected. This connection makes a complete short circuit and it will stop the oscillator on that half-cycle. Thus, the resistor 80 ensures the proper setting of the magnetic state of the core of transformer 17 whenever the oscillator is stopped. This means that starting of the oscillator will always be positive and instantaneous and at the beginning of each spark-duration interval. This is particularly important at high engine speeds where only a few cycles of oscillation will be involved, and a delayed initiation of the spark would be especially detrimental.

While the invention has been described above in considerable detail and in accordance with the applicable statutes, this is not to be taken as in any way limiting the invention but merely as being descriptive thereof.

I claim:

1. In combination with a controlled-spark-duration ignition system for an engine, said system having a high-frequency continuous-wave oscillator including a transformer having a high-voltage output winding, first circuit means for connecting said output winding to a sparking circuit, an oscillator-control winding on said transformer for starting and stopping oscillation, second circuit means for applying a DC bias current to said control winding when said oscillator is not oscillating, means controlled by said engine crank angle for cutting off said DC bias at the beginning of each spark-duration interval, and third circuit means comprising an AC low-impedance short-circuit path connected in shunt with said DC bias current source for stopping said oscillator at the end of each said spark-duration interval,

the improvement comprising means incorporated with said AC path for increasing the impedance on a predetermined one of the half-cycles of AC current sufficiently to retard without stopping said oscillator whereby the magnetic state of the core of said transformer will always be set so as to insure instantaneous starting of said oscillator.

2. The invention according to claim 1, wherein said third circuit means comprises a diode bridge, and wherein said impedance-increasing means comprises an additional impedance in a predetermined arm of said diode bridge.

3. The invention according to claim 2, wherein said additional impedance comprises a resistor.

4. The invention according to claim 3, wherein said improvement also comprises fourth circuit means for permanently connecting said oscillator to a power source, an ignition switch, a relay controlled by said ignition switch, and fifth circuit means connected to said relay for short-circuiting said control winding when said ignition switch is off.

5. In combination with a controlled-spark-duration ignition system for an engine, said system having a high-frequency continuous-wave oscillator including a transformer having a high-voltage output winding, first circuit means for connecting said output winding to a sparking circuit, an oscillator-control winding on said transformer for starting and stopping oscillation, second circuit means for applying a DC bias current to said control winding when said oscillator is not oscillating, means controlled by said engine crank angle for cutting off said DC bias at the beginning of each spark-duration interval, and an AC pass diode bridge connected in shunt with said DC bias current source for stopping said oscillator at the end of each said spark-duration interval,

the improvement comprising a resistor in a predetermined arm of said diode bridge for increasing the impedance on a predetermined one of the half-cycles of AC current flow sufficiently to retard without stopping said oscillator whereby when the oscillator is stopped on the succeeding half-cycle, the magnetic state of the core of said transformer will always be set so as to insure instantaneous starting of said oscillator,

fourth circuit means for permanently connecting said oscillator to a power source, an ignition switch, a relay controlled by said ignition switch, and fifth circuit means connected to said relay for short-circuiting said control winding when said ignition switch is off.

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