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IGNITION SYSTEM USING PUSH-PULL TRANSFORMER

Abstract

An ignition system for an internal combustion system has a power source for passing a DC voltage, a push-pull isolating transformer connected to the power source so as to increase the voltage from the power source and convert the DC voltage to AC voltage, a high-voltage transformer having a primary winding connected to an output of the push-pull isolating transformer, and a spark plug connected to a secondary winding of the high-voltage transformer. The high-voltage transformer increases the voltage from the push-pull isolating transformer to a voltage that fires the spark plug.

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Background/Summary

FIELD OF THE INVENTION

[0001] The present invention relates to internal combustion engines. More particularly, the present invention the relates to an electrical ignition apparatus that are used for the igniting of fuel within the internal combustion engines. The present invention also relates to ignition systems that apply an AC voltage for the ignition of the spark plug. Additionally, the present invention relates to ignition systems that utilize a push-pull transformer in combination with a pair of transistors so as to provide for AC power to the spark plug.

BACKGROUND OF THE INVENTION

[0002] Most internal combustion engines have some type of an ignition circuit to generate a spark in the cylinder. The spark causes combustion of the fuel in the cylinder to drive the piston and the attached crankshaft. Typically, the engine includes a plurality of permanent mount magnets mounted on the flywheel of the engine and a charge coil mounted on the engine housing in the vicinity of the flywheel. As the flywheel rotates, the magnets pass the charge coil. A voltage is thereby generated on the charge coil and this voltage is used to charge a high-voltage capacitor. The high-voltage charge on the capacitor is released to the ignition coil by way of a triggering circuit so as to cause a high-voltage, short-duration electrical spark across the spark gap of the spark plug and ignite the fuel in the cylinder. This type of ignition is called a capacitive discharge ignition.

[0003] Typically, the engine control module provides an electronic spark timing pulse which is used to command a given spark event for a given engine cylinder. This electronic spark timing pulse is commanded for a given amount of time to charge the primary coil to the desired current or energy. The electronic spark timing pulse duration is often referred to as “dwell-time” or charging time for a given coil and engine operating condition. As an example, during cold starting conditions, when the engine is cold, and the battery voltage is low, the electronic spark timing control signal for a given cylinder may have an extended pulse duration to fully charge the coil to generate the necessary energy in the primary coil. This energy is then transferred to the secondary coil that is connected to the spark plug output. Likewise, during hot engine conditions and nominal battery power, the electronic spark timing pulse can be commanded to have a shorter duration to fully charge the primary coil to a given energy level. Thus, a given electronic spark timing pulse for commanding a given coil operation will vary the dwell time, or charging time, depending on several engine sensor inputs and desired engine operating conditions.

[0004] Typically, current ignition systems use the electronic spark timing pulse to command a semiconductor power switch device which is connected to the primary coil and allows the coil to reach a targeted primary current. When the semiconductor power device is switched off, the stored energy in the primary coil is then transferred to the secondary coil. Based on the clamping voltage of the power semiconductor switch, and the turns ratio of the primary to secondary windings, an available voltage of approximately 40,000 volts can be provided to the spark plug output. Therefore, the high-voltage spark event is commanded by the falling edge of an electronic spark timing pulse. This translates to a command “turn-off” of the semiconductor power device and energy is then transferred to the spark plug with an exponential voltage decay. Typically, one spark event occurs for each electronic spark timing cycle for a given engine cylinder. This method of control has been employed by numerous engine control module designs used to command DC ignition systems for many years and has become the general method of firing a given spark plug used in an internal combustion engine.

[0005] The design of standard reciprocating internal combustion engines which use spark plugs and induction coils to initiate combustion have, for years, utilized combustion chamber shapes and spark plug placements which are heavily influenced by the need to reliably initiate combustion using a single short-duration spark of relatively low intensity that is timed to fire off of the falling edge of the given electronic spark timing pulse.

[0006] In recent years, however, increased emphasis has been placed on fuel efficiency, completeness of combustion, exhaust cleanliness, and reduced variability in cycle-to-cycle combustion. This emphasis has meant that the shape of the combustion chamber must be modified and the ratio of the fuel-air mixture changed. In some cases, a procedure has been used which deliberately introduces strong turbulence or a rotary flow to the fuel-air mixture at the area where

the spark plug electrodes are placed. This often causes an interruption or blowing out of the arc. This places increasing demands on the effectiveness of the combustion initiation process.
[0007] Referring to FIG. **1**, there is shown the ignition system in accordance with the prior art. This ignition system is illustrated, in particular, in association with U.S. Pat. No. 10,385,819 issued on Aug. 20, 2019 to Marshall Electric Corp., the present applicant. In FIG. **1**, there is shown an ignition system **10** that has a transformer **12** that is directly connected to the spark plug **14**. Similarly, a transformer **16** is directly connected to the spark plug **18**. An electrical line **20** will extend from the engine control module **22** to the transformer **12**. Another line **24** will extend from the engine control module **22** to the transformer **16**. As such, the engine control module **22** (including the electronic spark timing circuit) can provide the necessary timing signals to the transformers **12** and **16** for the firing of the spark plugs **14** and **18**, respectively. Each of the transformers **12** and **16** can be an ignition coil.
[0008] The transformer **12** can include a sensor line **26** extending back to the engine control module **22**. As such, the engine control module **22** can receive suitable signals from the transformers **12** and **16** as to the operating conditions of the spark plugs **14** and **18** for proper monitoring of the output current and output voltage of the secondary winding. By providing this information, the engine control module **22** can be suitably programmed to optimize the firing of the spark plugs **14** and **18** in relation to items such as engine temperature and fuel consumption. The transformer **16** also includes a sensor line **28** extending back to the engine control module **22**. An automotive battery **30** is connected by line **32** so as to provide power to the engine control module **22**. The battery **30** is configured so as to supply at least eight volts to the engine control module **22**.
[0009] As can be seen in FIG. **1**, the firing of each of the spark plugs **12** and **16** is carried out directly on the spark plugs. The engine control module **22** can be a microprocessor which is programmed with the necessary information for the optimization of the firing of each of the spark plugs. The control module **22** can receive inputs from the crankshaft or from the engine as to the specific time at which the firing of the combustion chamber of each of the spark plugs **14** and **18** is necessary. Since each of the transformers **12** and **16** is located directly on the spark plugs **14** and **18**, respectively, and since they operate at low frequencies, radio interference with the automobile is effectively avoided.
[0010] FIG. **2** shows a configuration of the spark plug **14**. Spark plug **14** includes an anode **32** and a cathode **34** (the “electrodes”). This is a unique small-gap spark plug in which the distance between the electrodes is between 0.6 millimeters and 0.8 millimeters. This type of spark plug is manufactured by Pyrotek Enterprises, Inc. and is the subject of U.S. Pat. No. 6,495,948 of Dec. 17, 2002.
[0011] FIG. **3** is a plan view showing the configuration of the anode **32** in relation to the cathode **34** of the spark plug **14** as shown in FIG. **2**. Initially, it can be seen that the anode **32** is located in the center of the spark plug **14**. The cathode **34** is horseshoe-shaped and extends around at least a portion of the periphery of the anode **32**. In U.S. Pat. No. 6,495,948, this type of spark plug **14** is referred to as a “box” plug. This box plug uses an electrode that is substantially in the shape of a square or a horseshoe that appears to encircle the spark plug's center electrode (when viewed from above). The box does not fully encircle the spark plug's center electrode since there is a gap defined between the upper round end surface of the center electrode and the plane in which the downwardly-directed lower surfaces of the split prong members lie.
[0012] The electrode includes a pair of end prongs which initially diverge but then converge. The end prongs include segments of substantially equal length. Two of the segments would be considered as diverging elements and the other segments would be considered as converging segments. An elbow is considered as connecting the diverging segment of a particular segment to the corresponding converging segment. The ground electrode would be considered to have three (vertixes), a main vertex **40** and a pair of elbow inner vertices **41**.
[0013] FIG. **4** is an electrical schematic from the teachings of U.S. Pat. No. 10,385,819. In

particular, unlike the present invention, the schematic shown in FIG. **4** includes both a booster circuit and a multi-strike circuit.

[0014] FIG. **4** is a schematic diagram showing the electronic control system **50**, the power boost circuit **52**, the multi-strike circuit **54** and the delay circuit **56** of the prior art system. Initially, the electronic spark timing pulse is received at terminal **51**. The spark timing pulse is transmitted along line **52**. A blocking diode combination **54** is provided so as to block current from returning back along line **52** to the electronic spark timing pulse. Line **52** will extend to a boost oscillator timing IC **56**. The boost oscillator timing IC **56** will provide for the isolation of the signal and the timing of the signal. For example, if it is desired to set the logic high of the waveform for one-hundred milliseconds, then the boost oscillator timer IC can be set for such period of time. As such, this will create the necessary timing for the electronic spark timing pulse. The boost oscillator timer IC ultimately creates the waveform **42** which, in turn, will provide the necessary signal for the firing of the spark plugs in the manner shown by waveform **34**. The boost oscillator timer IC is connected to the gate driver **58**. Gate driver **58** is configured so as to alternately fire the field effect transistors **60** and **62**. When the field effect transistors **60** and **62** are fired, the timing pulse can be transmitted to the spark plug or to the transformer **64**. Ultimately, it is important that the gate driver **58** provide a fifty percent on/off duty cycle for each of the field effect transistors **60** and **62**. As such, the field effect transistors **60** and **62** will never be on the same time. The field effect transistors **60** and **62** need to go on-and-off so as to avoid magnetic balancing issues on core saturation. This arrangement keeps the circuit sample, but effective. As will be described hereinafter, the power for the firing of the spark plugs is transmitted by the driver circuit by introducing the power to the field effect transistors **60** and **62**.

[0015] In FIG. **4**, a booster circuit **52** is provided so as to optimally store the power that is provided to the electronic spark timing circuit **60** so as to fire the respective spark plugs. The battery **30** is connected to the line **32** of the booster circuit **52**. A diode **72** is provided on line **32** so as to prevent return current and voltage to the battery **30**. The power from the battery **30** goes to a boost regulator so as to fix the voltage being transmitted to the inductor **78**. Inductor **78** is a passive electronic component that stores energy in the form of a magnetic field. A diode **80** is provided on line **82** so as to block return current flowing to keep the charge on the capacitor **82**. An input capacitor **84** is placed on line **86**. Similarly, the output capacitor **84** serves to hold the charge as transmitted from the inductor **78**. Ultimately, the output capacitor can be charged to twenty-eight volts. As a result, regardless of the firing of the respective spark plugs **14** and **18** by the electronic spark timing circuit **50** of the present invention, the capacitor **82** will continue to be charged during the process. As such, when the battery is low, the capacitor will continue to be charged. The lack of charge on the battery **30** will not change the waveform **34** in any way. All of the power for the firing of the spark plugs is a result of the charging of the capacitor **82**. Fundamentally, if the engine speed is high, the battery **30** will be fully charged. This will meet the requirements for producing the waveform **34**. If the battery is low and the car is idling, the charge in the battery will be low. However, the power required for the firing of the spark plugs as a virtue of the waveform **34** will be less. Since the capacitor **82** is continuously charged by the boost circuit **52** of the present invention, the present invention avoids the need for any charging time for the ignition coils or the transformers. The power is continuously available.

[0016] A field effect transistor **83** is cooperative between the capacitor **82** and the inductor **78**. As such, this will effectively control the charging of capacitor **82** from the energy stored in the inductor **78**.

[0017] The output **84** of the booster circuit **52** will be connected to the center tap of field effect transistors **60** and **62** in the electronic spark timing circuit **50**. Output **86** is connected to ground. Field effect transistor **83** serves to control the charge inductor and the timer control. The field effect transistor **88** operates in combination with the gate driver IC **90** and with a boost oscillator IC **56**. The boost oscillator IC **56** sets the frequency of the signal passing as the output **84**. This would be typically 50,000 Hz. However, the boost oscillator **56** could be set so as to change the firing pattern during the waveform. It can be used so as to create a multi-strike waveform or a multi-burst waveform, as will be described hereinafter. A Zener diode **94** is located on feedback loop **96** so as to set the target voltage for the circuit **70**.

[0018] The electronic spark timing signal **51** is also transmitted along line **52** to the multi-strike timer **100**. Multi-strike timer **100** is a boost timer oscillator. This multi-strike oscillator **100** has a terminal connected to a terminal of the gate driver IC **58**. As such, the multi-strike IC **100** can be controlled so as to set multiple strikes in a pulse from the electronic spark timing circuit. The multi-strike pulse can be fired continuously after the falling edge of the waveform. The multi-strike IC **100** can, in the preferred embodiment the present invention, set pulses of between 1 millisecond and 2 milliseconds. When multi-strikes are used during the firing of the spark plug, this can tend to create a more complete and cleaner combustion. Furthermore, it can also serve to reduce fuel requirements. The multi-strike oscillator **100** can create multiple strikes during the time period between the falling edge and the rising edge of the waveform. This period of time will be between ten milliseconds and fifty milliseconds. The oscillator in the multi-strike IC **100** transmits a signal to the gate driver **58** for action in conjunction with the field effect transistors **60** and **62**.

[0019] The delay circuit **56** can be used in conjunction with the multi-strike circuit **54** and the electronic spark timing circuit **50**. The delay circuit **56** has a timer delay IC **102** that is cooperative with the electronic spark timing signal **51**. It can be seen that line **52** transmits the signal to the timer delay IC **102**. Timer delay IC **102** is connected to a terminal of the multi-strike IC **100**. In particular, the timer delay IC will be a NOR gate circuit. The NOR gate is a logic gate which gives a positive output only when both inputs are negative. NOR gates are so-called “universal gates” that can be combined to form any other types of logic gate. As such, this NOR gate circuit can be used in connection with the electronic spark timing pulse so as to control and fix a delay of the pulse. For example, the timer delay IC **102** can be set so as to begin the spark-driving pulse at a time after the falling edge of the waveform. Alternatively, it can be set so as to create a delay between firing pulses during the period between the falling edge and the rising edge of the waveform. Various other configurations of delay can be implemented through the use of the delay circuit **56**. Additionally, the delay circuit can be combined with the multi-strike circuit **54** so as to create delay associated with the multi-strike firing of the spark plug.

[0020] The schematic of FIG. **4** has an extremely large number of components. So as to enhance the reliability of the ignition system, it was felt necessary to reduce the number of components in order to provide a durable, accurate and fuel efficient system.

[0021] The circuit shown in FIG. **4** of U.S. Pat. No. 10,385,819 is made up of two parts. This is the DC voltage boost circuit and the basic circuit which provides the main frequency and the basic circuit. The basic circuit provides the main frequency, the twelve volt battery, the power source, the arc duration, and the EST signal which tells the circuit when the spark. It was found that the boost circuit does not deliver the required output voltage. The DC boost voltage is required to boost the twelve volts of the battery to approximately forty volts DC. The circuit involves a large capacitor (of 680 microfarads) that turns the twelve volts on-and-off through inductor at a high-frequency supply and then is turned off-and-on with a MOSFET.

[0022] The required forty volts AC then goes through a push-pull circuit that feeds the primary of the high-frequency transformer. The problems with the boost circuit in this patent are that the capacitor in the circuit must be much larger in order to store energy necessary to deliver the necessary spark voltage and current to the spark gap of the spark plug. The capacitor does not stand up well at the under-hood temperatures. As such, failures could occur. Additionally, the boost circuit cannot be run at a high enough frequency to deliver adequate energy to the capacitor.

[0023] In the past, various patents have issued with respect to such ignition systems. For example, U.S. Pat. No. 5,806,504, issued on Sep. 15, 1998 to French et al., teaches an ignition circuit for an internal combustion engine in which the ignition circuit includes a transformer having a secondary winding for generating a spark and having first and second primary windings. A capacitor is connected to the first primary winding to provide a high-energy capacitive discharge voltage to the transformer. A voltage regulator is connected to the secondary primary winding for generating an alternating current voltage. A control circuit is connected to the capacitor and to the voltage generator for providing control signals to discharge the high-energy capacitive discharge voltage to the first primary winding and for providing control signals to the voltage generator so as to generate an alternating current voltage.

[0024] U.S. Pat. No. 4,998,526, issued on Mar. 12, 1991 to K. P. Gokhae, teaches an alternating current ignition system. The system applies alternating current to the electrodes of a spark plug to maintain an arc at the electrodes for a desired period of time. The amplitude of the arc current can be varied. The alternating current is developed by a DC-to-AC inverter that includes a transformer that has a center-primary and a secondary that is connected to the spark plug. An arc is initiated at the spark plug by discharging a capacitor to one of the winding portions at the center-primary. Alternatively, the energy stored in an inductor may be supplied to a primary winding portion to initiate an arc. The ignition system is powered by a controlled current source that receives input power from a source of direct voltage, such as a battery on the motor vehicle.

[0025] In each of these prior art patents, the devices used dual mechanisms in which a high-energy discharges were supplemented with a low-energy extending mechanism. The method of extending the arc, however, presents problems to the end-user. First, the mechanism is, by nature, electronically complex in that multiple control mechanisms must be present either in the form of two separate arc mechanisms. Secondly, no method is presented for automatically sustaining the arc under a condition of repeated interruptions. Additionally, these mechanisms do not necessarily provide for a single functional-block unit of low mass and small size which contains all of the necessary functions within.

[0026] U.S. Pat. No. 6,135,099, issued on Oct. 24, 2000 to T. Marrs, discloses an ignition system for an internal combustion engine that comprises a transformer means having a primary winding adapted to be connected to a power supply and having a secondary winding adapted be connected to a spark plug. The transformer serves to produce an output from the secondary winding having a frequency of between 1 kHz and 100 kHz and a voltage of at least 20 kV. A controller is connected to the transformer so as to activate and deactivate the output of the transformer means relative to the combustion cycle. The transformer serves to produce the output having an alternating current with a high-voltage sine wave reaching at least 20 kV. A voltage regulator is connected to the power supply into the transformer so as to provide a constant DC voltage input to the transformer. The transformer produces power of constant wattage from the output of the secondary winding during the activation by the controller. The controller is connected to the transformer so as to allow the transformer to produce an arc of controllable duration across the electrode of the spark plug. This duration can be between 0.5 milliseconds and 4 milliseconds. A battery is connected the primary winding of the transformer. The battery produces a variable voltage of between 5 and 15 volts.

[0027] For example, U.S. Pat. No. 5,806,504, issued on Sep. 15, 1998 to French et al., teaches an ignition circuit for an internal combustion engine in which the ignition circuit includes a transformer having a secondary winding for generating a spark and having first and second primary windings. A capacitor is connected to the first primary winding to provide a high-energy capacitive discharge voltage to the transformer. A voltage regulator is connected to the secondary primary winding for generating an alternating current voltage. A control circuit is connected to the capacitor and to the voltage generator for providing control signals to discharge the high-energy capacitive discharge voltage to the first primary winding and for providing control signals to the voltage generator so as to generate an alternating current voltage.

[0028] U.S. Pat. No. 4,998,526, issued on Mar. 12, 1991 to K. P. Gokhae, teaches an alternating current ignition system. The system applies alternating current to the electrodes of a spark plug to maintain an arc at the electrodes for a desired period of time. The amplitude of the arc current can be varied. The alternating current is developed by a DC-to-AC inverter that includes a transformer that has a center-primary and a secondary that is connected to the spark plug. An arc is initiated at the spark plug by discharging a capacitor to one of the winding portions at the center-primary. Alternatively, the energy stored in an inductor may be supplied to a primary winding portion to initiate an arc. The ignition system is powered by a controlled current source that receives input power from a source of direct voltage, such as a battery on the motor vehicle.

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[0030] It is an object of the present invention to provide an ignition system that is has improved fuel efficiency.

[0031] It is another object of the present invention to provide an ignition system that has a longer arc duration.

[0032] It is another object of the present invention to provide an ignition system that fires at a lower voltage.

[0033] It is another object of the present invention to provide an ignition system that has a cool operation.

[0034] It is another object of the present invention to provide an ignition coil that produces reduced emissions.

[0035] It is another object of the present invention to provide an ignition system that increases the horsepower of the engine.

[0036] It is another object of the present invention to provide an ignition system that offers a more complete burning of the fuel.

[0037] It is another object of the present invention to provide an ignition system that produces no misfires.

[0038] It is a further object of the present invention provided in the ignition system that does not require a DC voltage boost.

[0039] It is still another object of the present invention to provide it ignition system that has increased durability.

[0040] It is still a further object of the present invention provided ignition system that is simplified electronics.

[0041] These and other objects and advantages of the present invention will become apparent from a reading of the attached specification and appended claims.

BRIEF SUMMARY OF THE INVENTION

[0042] The present invention is an ignition system for an internal combustion engine that comprises a power source for passing a DC voltage, a push-pull isolating transformer connected to the power source, a high-voltage transformer having a primary winding connected to an output of the push-

pull isolating transformer, and a spark plug connected to a secondary winding of the high-voltage transformer. The push-pull isolating transformer increases the voltage from the power source and converts the DC voltage to AC voltage. The high-voltage transformer increases the voltage from the push-pull isolating transformer.
[0043] In the present invention, the power source will be an automotive battery. In the preferred embodiment of the present invention, the power source is an automotive battery. The DC voltage of this power source is twelve volts DC.
[0044] The push-pull isolating transformer has a primary winding and a secondary winding. The primary winding of the push-pull isolating transformer is connected to a pair of transistors. The pair of transistors pass energy to the primary winding of the push-pull isolating transformer during alternating half-cycles. The primary winding of the push-pull isolating transformer is center tapped. Each of the transistors has a diode interposed between the transistor and the primary winding. The push-pull isolating transformer increases twelve volts DC from the power source to forty volts AC at ninety kilohertz. The secondary winding of the push-pull isolating transformer is connected to the high-voltage transformer.
[0045] The high-voltage transformer increases of voltage from the push-pull isolating transformer to thirty-five kilovolts so as to pass the thirty-five kilovolts to the spark plug.
[0046] The spark plug has a secondary spark plug gap between a electrodes thereof of between 0.6 millimeters and 0.8 millimeters. One of the electrodes of the spark plug is in a center thereof. The other electrodes is horseshoe-shaped and at least partially extends around an outer diameter of the anode.
[0047] In comparison with the prior art, the DC voltage boost circuit is replaced by small push-pull isolating transformer that increases the twelve volts DC to forty volts AC at ninety kilohertz. The output of the push-pull transformer is connected to the primary winding of the high-voltage transformer. The primary of the high-voltage transformer is six turns without any center tap. This improves the durability and simplifies the component construction. The present invention also reduces the small components required in the DC voltage boost circuit.
[0048] The large gap spark plug is replaced by a small gap (0.6 millimeters to 0.8 millimeters) spark plug. This reduces the voltage required at the spark plug. As a result, heat and energy required are reduced. The present system can be set with a ninety kilohertz frequency to reduce the capacitive load on the high-voltage secondary.
[0049] The dwell table from the engine can be used to adjust the arc duration of the spark plug according to the RPM of the engine. As the RPM increases, the arc duration needs to decrease.
[0050] With reference to U.S. Pat. No. 10,385,819, the present invention replaces the boost circuit with a small transformer and also turns the twelve volts DC into AC current before it enters the small transformer. The small transformer is then steps up the twelve volts AC to forty volts AC. This can then be delivered to the high-voltage transformer.
[0051] This foregoing Section is intended to describe, with particularity, the preferred embodiments of the present invention. It is understood that modifications to this preferred embodiment can be made within the scope of the present claims. As such, this Section should not to be construed, in any way, as limiting of the broad scope of the present invention. The present invention should only be limited by the following claims and their legal equivalents.

Description

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS
[0052] FIG. **1** is a block diagram showing an ignition system including the controller and the spark plugs to which the ignition system of the present invention is applied.
[0053] FIG. **2** is a plan view of a small-gap spark plug is used in the present invention.

[0054] FIG. **3** is a plan view showing the electrodes of the small-gap spark plug of FIG. **2** of the prior art.
[0055] FIG. **4** is an electrical schematic of a prior art ignition system of the present Applicant.
[0056] FIG. **5** is a schematic showing a schematic of ignition system used in the present invention.
[0057] FIG. **6** is a isolated schematic showing the push-pull isolating transformer as used in conjunction with the high-voltage transformer of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0058] Referring to FIG. **5**, there is a schematic of the ignition system **100** of the present invention. Initially, the electronic spark timing pulse is received at terminal **151**. The spark timing pulse is transmitted along line **152**. A blocking diode combination **154** is provided so as to block current from returning back along line **152** to the electronic spark timing pulse. Line **152** will extend to an oscillator timing IC **156**. This oscillating timing IC **156** will provide for the isolation of the signal in the timing of the signal. For example, if it is desired to set the logic high of the waveform for one-hundred milliseconds, the oscillator timer IC **156** can be set for such a period of time. As such, this will create the necessary timing for the electronic spark timing pulse. The oscillator timing IC **156** ultimately creates the waveform to provide the necessary signal for the firing of the spark plugs. The oscillator timer IC **156** is connected to a gate driver **158**.
[0059] Gate driver **158** is configured so as to alternately fire the transistors **160** and **162**. When the transistors **160** and **162** are fired, the timing pulse can be transmitted to the spark plug or to the transformer **164**. In particular, the timing pulse is transmitted to the primary winding of the transformer **164**. Ultimately, it is important that the gate driver **158** provide a 50% on/off duty cycle for each of the transistors **160** and **162**. As such, the transistors **160** and **162** will never be “on” at the same time. The transistors **160** and **162** need to go on-and-off so as to avoid magnetic balancing issues on core saturation. This arrangement keeps the circuit simple, but effective. The power for the firing of the spark plugs is transmitted by the driver circuit for introducing the power to the transistors **160** and **162**.
[0060] The gate driver **158** and the transistors **160** and **162** will be part of the push-pull isolating transformer as shown at **200** in FIG. **6**. As can be seen, the first transistor **202** will be connected to a terminal **204** of the gate driver **158**. Similarly, the transistor **206** will be connected to another terminal **208** of the gate driver **158**. As such, the gate driver **158** (as shown in FIG. **5**) is able to provide an alternating duty cycle for each of the transformers **202** and **206**. Power supply **151** will extend to a center tap **210** of a primary winding **212** of transformer **214**. Line **216** extends to each of the transistors **202** and **206** so as to supply thereto. Ultimately, the transistors **202** and **206** operate in an one-half-cycle on-and-on mode so as to pass twelve volts DC from the power supply **151** as forty volts to the transformer **214**. The secondary **218** of the transformer **214** can be connected to a high-voltage transformer (such as shown and known in the prior art) so as to boost the forty volts AC at ninety kilohertz so as to fire the spark plugs at thirty-five kilovolts.
[0061] A diode **220** will act on the input and output of the transistor **202** so as to avoid voltage spikes to the transformer **214**. Similarly, another diode **222** is cooperative with the second transformer **206** so as to avoid voltage spikes to the transformer **218**.
[0062] The push-pull isolating transformer circuit **200**, shown in FIG. **6**, utilizes the center-tapped transformer **214** to use both top and bottom half-cycles from the transistors **202** and **206**. The schematic shown in FIG. **6** shows the push-pull converter in which the push-pull converter utilizes the center-tapped primary **212** of the transformer **214** for the primary winding. The primary winding **212** is controlled by the transistors **202** and **206**. The transistors allow them to conduct during each half-cycle so that the output is receiving voltage directly through one of the transistors at all times. This means that the efficiency of the configuration is approximately 90%. This allows the overall size for the power supply to be smaller for comparables power supply whose efficiency is 75% to 80%.
[0063] As shown in FIGS. **5** and **6**, the DC voltage boost circuit (as shown in FIG. **4**) has replaced

by the small push-pull isolating transformer **200** (as shown in FIG. **6**). This increases the twelve volts DC to forty volts AC at ninety kilohertz. The output of the push-pull transformer is connected to the primary winding of a high-voltage transformer. The primary of the high-voltage transformer will be six turns without any center tap.
[0064] The configuration of the present invention improves the durability and replaces the component count. The MOSFETS of the prior art shown in FIG. **4**, are replaced by the push-pull isolating transformer. It also replaces all the other small components required in the DC voltage boost circuit of FIG. **4**.
[0065] The standard large-gap spark plug is replaced by a small gap spark plug. This gap is between 0.6 millimeters to 0.8 millimeters. This small gap reduces the voltage required at the spark plug. It also reduces the heat and energy required. It is important to use such a small gap spark plug (as was shown in FIGS. **2** and **3** herein), so as to work properly with the present invention, to achieve the advantages of the present invention, and to cooperate properly with the push-pull isolating transformer.
[0066] The output of the transformers is set to ninety kilohertz in order to reduce the capacity of load on the high-voltage secondary. A dwell table from the engine can be used to adjust the arc duration of the spark according to the RPM of the engine. As the RPM increases, the arc duration needs to decrease.
[0067] The foregoing disclosure and description of the invention is illustrative and explanatory thereof. Various changes in the details of the illustrated construction can be made is the scope of the present invention without departing from the true spirit of the invention. The present invention should only be limited by the following claims and their legal equivalents.

Claims

1. An ignition system for an internal combustion engine, the ignition system comprising: a power source for passing a DC voltage; a push-pull isolating transformer connected to the power source, said push-pull isolating transformer increasing the voltage from said power source and converting the DC voltage to AC voltage; a high-voltage transformer having a primary winding connected to an output of said push-pull isolating transformer, said high-voltage transformer for increasing the increased voltage from said push-pull isolating transformer; and a spark plug connected to a secondary winding of said high-voltage transformer.
2. The ignition system of claim 1, said power source being an automotive battery.
3. The ignition system of claim 2, the DC voltage of said power source being twelve volts DC.
4. The ignition system of claim 1, said push-pull isolating transformer having a primary winding and a secondary winding, the primary winding of said push-pull isolating transformer being connected to a pair of transistors.
5. The ignition system of claim 4, wherein the pair of transistors passes energy to the primary winding of said push-pull isolating transformer during alternating half-cycles respectively.
6. The ignition system of claim 4, each of the primary windings of said push-pull isolating transformer being center tapped.
7. The ignition system of claim 4, each of the pair of transistors having a diode connected between the transistor and the primary winding.
8. The ignition system of claim 4, said push-pull isolating transformer increasing a twelve volts DC from said power source to forty volts AC at ninety kilohertz, the secondary winding being connected to said high-voltage transformer.
9. The ignition system of claim 1, that high-voltage transformer increasing the voltage from said push-pull isolating transformer to thirty-five kilovolts so as to pass the thirty-five kilovolts to said spark plug.
10. The ignition system of claim 1, said spark plug having a spark plug gap between cathode

electrodes thereof of between 0.6 millimeters and 0.8 millimeters.

11. The ignition system of claim 10, one of the electrodes of said spark plug being in a center thereof, another electrode of the electrodes of said spark plug having a horseshoe shape and at least partially extending around an outer diameter of the one of the electrodes.

12. An ignition system for an internal combustion engine, the ignition system comprising: a power source for passing the DC voltage; a push-pull isolating transformer connected to the power source, said push-pull isolating transformer increasing the voltage from said power source and converting the DC voltage to AC voltage; a high-voltage transformer having a primary winding connected to an output of said push-pull isolating transformer, said high-voltage transformer for increasing the increased voltage from said push-pull isolating transformer; and a spark plug connected to a secondary winding of said high-voltage transformer, the spark plug having a spark plug gap between electrodes thereof of between 0.6 millimeters and 0.8 millimeters.

13. The ignition system of claim 12, one of the electrodes of said spark plug being in a center thereof, another of the electrodes of said spark plug being horseshoe-shaped and at least partially extending around an outer diameter of the one of the electrodes.

14. The ignition system of claim 12, said push-pull isolating transformer having a primary winding and a secondary winding, the primary winding of said push-pull isolating transformer being connected to a pair of transistors, the pair of transistors passing energy to the primary winding of said push-pull isolating transformer during alternating half-cycles, respectively.

15. An ignition system for an internal combustion engine, the ignition system comprising: a power source for passing a DC voltage; a push-pull isolating transformer connected to the power source, said push-pull isolating transformer increasing the voltage from the power source and converting the DC voltage to AC voltage; a high-voltage transformer for AC voltage, said push-pull isolating transformer having a primary winding and a secondary winding, the primary winding of said push-pull isolating transformer being connected to a pair of transistors, the pair of transistors passing energy to the primary winding of said push-pull isolating transformer during alternating half-cycles respectively; and a spark plug connected to a secondary winding of said high-voltage transformer.

16. The ignition system of claim **17**, said spark plug having a spark plug gap between electrodes thereof of between 0.6 millimeters and 0.8 millimeters.

17. The ignition system of claim **19**, one of the electrodes of said spark plug being in a center thereof, another of the electrodes being horseshoe-shaped and at least partially extending around an outer diameter of the one of the electrodes.