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[54] **CAPACITIVE DISCHARGE IGNITION SYSTEM**

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[51] **Int. Cl.** **F02p 3/06**

[58] **Field of Search** 123/148

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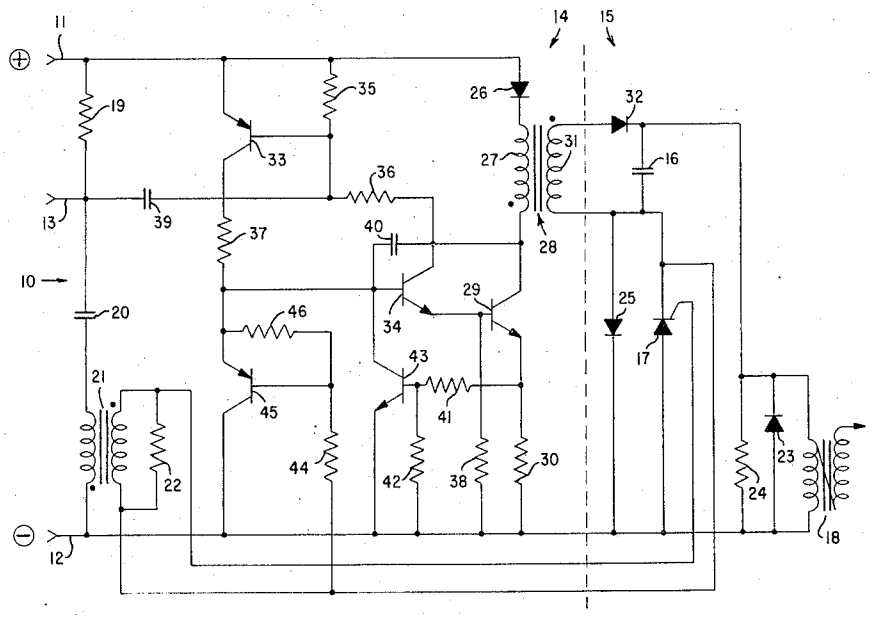
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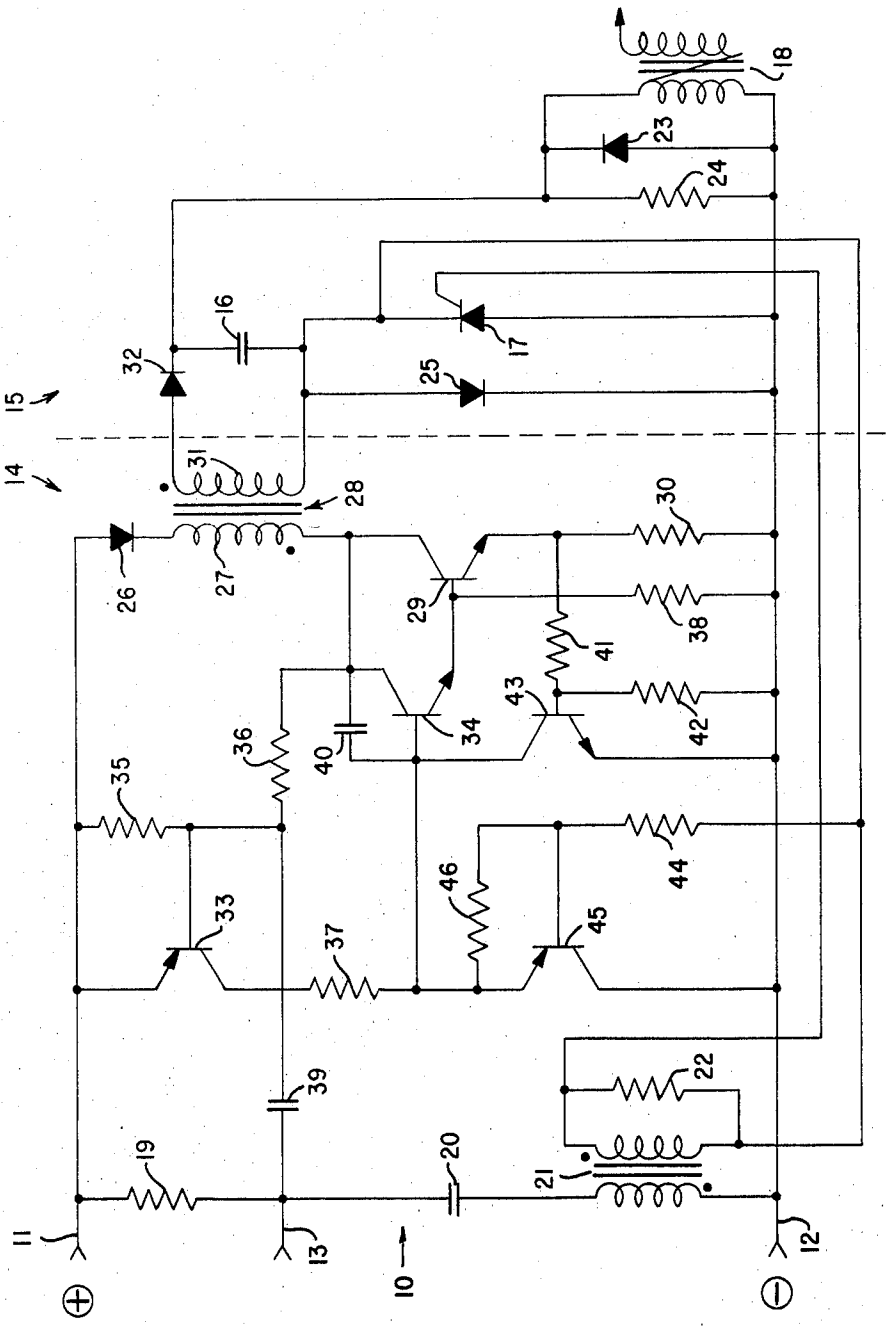
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[57] **ABSTRACT**

An improved capacitor discharge ignition system for internal combustion engines. By regulating the peak primary current in a voltage step-up transformer for a DC-to-DC converter, a regulated quantity of energy is stored in the core of the transformer. The stored energy is used to charge a storage capacitor to a predetermined voltage. The charged capacitor is discharged through the primary winding of an ignition coil for generating a high voltage to fire a spark plug.

4 Claims, 1 Drawing Figure




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CAPACITIVE DISCHARGE IGNITION SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to electronic ignition systems and more particularly to an improved capacitive discharge ignition system in which a regulated quantity of energy is stored in the core of a transformer for charging a storage capacitor to a predetermined voltage.

Ignition systems for automobile engines and similar internal combustion engines are generally either of an inductive discharge type or of a capacitive discharge type. Capacitive discharge ignition systems usually outperform inductive discharge systems by providing a more uniformly high output voltage over a wide engine speed range. In a capacitive discharge ignition system, a battery is connected to charge a storage capacitor. An electronic switch such as a silicon controlled rectifier is triggered in synchronism with the engine to discharge the capacitor through the primary winding of an ignition coil, thereby establishing a high voltage across the ignition coil secondary winding for firing a spark plug. The electronic switch can be triggered by any conventional means, such as breaker points, a magnetic pickup or an optical pickup.

Capacitor discharge ignition systems are often provided with a DC-to-DC converter for charging the storage capacitor to a voltage considerably higher than the battery voltage. When used, the converters are sometimes designed to regulate the voltage to which the capacitor is charged. However, circuits of prior art DC-to-DC voltage converters used in capacitor discharge ignition systems typically have been one of the least reliable portions of the ignition system and, when such converters are provided with voltage regulating capabilities, they have been relatively expensive to build. When an ignition system is designed with regulating capabilities, it has the advantage of eliminating the need for a ballast resistor and a bypass switch to increase the voltage during starting or engine cranking when the battery is at low voltage due to the high cranking load.

SUMMARY OF THE INVENTION

According to the present invention, a capacitive discharge ignition system is provided with an improved, highly reliable regulating DC-to-DC converter for periodically charging a storage capacitor to a substantially constant voltage above an applied battery voltage. The converter includes a voltage step-up transformer for charging the storage capacitor to a voltage level several times higher than the relatively low battery voltage. Voltage regulation is achieved by limiting the current in the transformer primary winding to a predetermined maximum level, regardless of the value of the applied voltage within a predetermined voltage range. The transformer primary winding is connected across the battery in series with the input and output electrodes of a switching transistor and a current sensing resistor. The transistor is caused to conduct in response to each trigger pulse from a conventional pulse generator on the engine. As the current increases in the transformer primary winding, the current through the resistor is used as a control signal for limiting the maximum current passing through the transistor and, hence, through the primary winding. When the current ceases to increase, the transistor is switched to a nonconducting state and the collapsing magnetic field in the transformer core establishes a secondary voltage for charging the capacitor. By limiting the maximum current through the series connected transformer winding, transistor and current sensing resistor, the transistor is protected from possible damage due to either a high voltage from the battery or a high current caused by a short in the transformer primary winding. A circuit is also provided to protect the capacitor from accumulating a dangerously high charge in the event that the capacitor is not discharged.

Accordingly, it is a primary object of the invention to provide an improved capacitive discharge ignition system for internal combustion engines.

Another object of the invention is to provide an improved ignition system capable of operating over a wide range of input voltages.

Still another object of the invention is to provide an improved regulating DC-to-DC voltage converter for charging a storage capacitor in a capacitive discharge ignition system.

Other objects and advantages of the invention will become apparent from the following detailed description of a preferred embodiment, with reference being made to the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The single FIGURE shows a schematic circuit diagram for a capacitive discharge ignition system constructed in accordance with the principles of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Turning now to the single FIGURE, a capacitive discharge ignition system is shown embodying the principles of the present invention and is generally designed by the reference numeral **10.** The ignition system **10** has a positive terminal **11** and a negative terminal **12** for connection to a suitable power source, such as a battery in a vehicle in which the ignition system **10** is used. The various components for the system **10** may be selected to provide a substantially constant output over a wide range of voltages, for example, from 6 volts to 35 volts. The ignition system **10** also has an input terminal **13** for receiving trigger pulses timed in synchronism with the operation of an internal combustion engine (not shown) with which the ignition system **10** is used. The trigger pulses applied on the input **13** may come from any conventional pulse source, such as breaker points driven by a cam on the engine, a magnetic pickup associated with either a disk with attached magnets or a toothed disk driven by the engine, or an optical pickup associated with a toothed or slotted disk driven by the engine. Pulse generating devices of these types are well known in the prior art and will not be covered in detail herein.

The capacitive discharge ignition system **10** generally consists of a DC-to-DC voltage converter **14** and a conventional capacitive discharge circuit **15.** The capacitive discharge circuit **15** includes a storage capacitor **16,** a switch such as a silicon controlled rectifier **17,** and an ignition coil **18.** The capacitor **16,** the controlled rectifier **17** and the ignition coil **18** are connected to form a closed series circuit. When the controlled rectifier **17** is triggered, a charge on the capacitor **16** is discharged through the primary winding of the coil **18,** thereby establishing a high voltage across the

secondary winding of the coil **18** for firing a spark plug on the engine.

Triggering of the controlled rectifier **17** is achieved by a negative pulse applied on the input **13** and a circuit including a resistor **19**, a capacitor **20** and a trigger transformer **21**. The capacitor **20** is charged through the resistor **19**. A negative pulse on the trigger input **13** discharges the capacitor **20** through the primary winding of the transformer **21** to trigger the silicon controlled rectifier **17** in synchronization with the internal combustion engine. A resistor **22** is connected as a load across the secondary of the transformer **21** to prevent multiple triggering of the controlled rectifier caused by the circuit oscillating.

When the controlled rectifier **17** is triggered, the charge on the capacitor **16** is discharged through the primary winding of the coil **18** to establish the high ignition voltage across the secondary winding of the coil **18**. A diode **23** is connected in parallel with the primary winding of the ignition coil **18** to prevent energy stored in the core of the coil from establishing a reverse emf across the coil primary winding which would charge the capacitor **16**. A resistor **24** is also connected in parallel with the diode **23** and a diode **25** is connected between the capacitor **16** and the negative terminal **12**. The diode **25** and resistor **24** will also discharge any negative charge on the capacitor **16** and the diode **25** will protect the controlled rectifier **17** from a reverse voltage.

Each pulse on the trigger input **13** also activates the regulated DC-to-DC voltage converter **14** for recharging the capacitor **16** immediately after it is discharged to the ignition coil **18**. A diode **26**, the primary winding **27** of a voltage step-up transformer **28**, a power transistor **29** or similar controlled conduction device and a current sensing resistor **30** are connected in series between the positive terminal **11** and the negative terminal **12**. The secondary winding **31** of the transformer **28** is connected through a diode **32** to charge the capacitor **16**. The transistor **29** is initially switched to a conducting state in response to a pulse on the trigger input **13** from the engine. Current then builds up in the primary winding **27** of the transformer **28** to a predetermined level to store a regulated quantity of energy in the core of the transformer **28**, at which time the transistor **29** is turned off. The collapsing magnetic field in the transformer **28** establishes a predetermined high voltage across the secondary winding **31** for charging the capacitor **16** through the diode **32**. The diode **26** merely serves as a safety device to prevent reverse currents from flowing through the series circuits if, for example, the polarity of a battery connected to the terminals **11** and **12** is accidentally reversed.

A transistor **33** and a transistor **34** are connected with the transistor **29** for forming a monostable switch. The emitter of the transistor **33** is connected to the positive terminal **11**. The base of the transistor **33** is connected through a resistor **35** to the positive terminal **11** and through a resistor **36** to the collectors of the transistors **34** and **29**. The collector of the transistor **33** is connected through a resistor **37** to the base of the transistor **34**. The emitter of the transistor **34** is connected for driving the base of the transistor **29** and also through a bias resistor **38** to the negative terminal **12**. The transistors **34** and **29** are arranged in what is known as a Darlington connection with the transistor **34** driving the power transistor **29**.

The trigger input **13** from the engine is connected through a capacitor **39** to the base of the transistor **33** for starting the converter **14**. A negative pulse on the trigger input **13** drives the transistor **33** into saturation, in turn driving the driver transistor **34** and the power transistor **29** into conduction. Current will then increase in the series connected primary winding **27** of the transformer **28**, the transistor **29** and the resistor **30** to a maximum level determined by the total resistance of the series circuit. As the current approaches a constant value, the voltage across the primary winding of the transformer **28** will approach a minimum level determined by the resistance of the primary winding of the transformer **28**. This voltage is insufficient to maintain the transistor **33** in saturation. At this point, currents through the transistors **33**, **34** and **29** decrease. With a decrease in current, a reversed emf is established across the primary winding of the transformer **28**, causing the transistors **29** and **34** to stop conduction. A capacitor **40** is connected between the interconnected collectors of the transistors **29** and **34** and the base of the transistor **34** to suppress a positive voltage transient at the collector of the transistor **29** when the transistor **29** switches off. The value of the capacitor **40** is chosen to improve the switching of the transistor **29** by reducing the maximum collector voltage without greatly increasing the switching time.

Regulation of the energy stored in the core of the transformer **28** is achieved by controlling the conduction of the transistor **29** when the current reaches a predetermined maximum level. A voltage will appear across the current sensing resistor **30** which is substantially proportional to the current flowing through the primary winding **27** and the transistor **29**. A voltage divider consisting of a pair of resistors **41** and **42** is connected across the current sensing resistor **30**. The common junction between the resistors **41** and **42** is connected to the control electrode or base of a transistor **43**. The collector of the transistor **43** is connected to the base of the driver transistor **34** and the emitter is connected to the negative terminal **12** to shunt a portion of the current flowing through the resistor **37** to drive the base of the driver transistor **34**. When the current through the primary winding **27** of the transformer **28** approaches the predetermined maximum level, the portion of the voltage across the current sensing resistor **30** which is applied by the resistors **41** and **42** to the base of the transistor **43** reaches a value equivalent to the base-emitter turn-on voltage of the transistor **43**. At this point, the transistor **43** begins to conduct, shunting a part of the current to the base of the driver transistor **34** to the negative terminal **12**. Through this arrangement, conduction by the transistor **29** is limited as the predetermined maximum permissible primary winding current is approached. At this point, the voltage across the primary winding **27** approaches a minimum and the transistor **33** switches the transistors **34** and **29** to nonconducting states. The magnetic energy stored within the core of the transformer **28** then collapses to establish a regulated high secondary voltage which charges the capacitor **16**.

In some cases, it could be possible for the converter **14** to cycle even though the capacitor **16** has not been discharged by triggering the controlled rectifier **17**. A voltage transient, for example, might be sufficient to cycle the converter **14** without triggering the controlled rectifier **17** or a faulty component could prevent dis-

charging the capacitor **16.** An over-voltage circuit is provided to protect the capacitor **16,** the diode **32** and the controlled rectifier **17** against possible damage caused by over-charging the capacitor **16.** As previously stated, one side of the capacitor **16** is connected through the resistor **24** to the negative terminal **12.** The other side of the capacitor **16** is connected through a resistor **44** to the base of a transistor **45.** A bias resistor **46** is also connected between the base and emitter of the transistor **45.** The emitter of the transistor **45** is connected to the base of the driver transistor **34** and the collector is connected to the negative terminal **12** for shunting the base drive for the transistor **34** in the event that the voltage on the capacitor **16** exceeds a maximum permissible limit. The amount of base current available to the transistor **45** for over-voltage protection is dependent upon the ohmic value of the resistor **44** and the magnitude of the voltage on the storage capacitor **16.** The value of the resistor **44** is a compromise. It must be large enough to keep the storage capacitor **16** from discharging too rapidly between converter cycles, yet it must be small enough to provide sufficient base drive for the transistor **45** when the supply voltage between the terminals **11** and **12** is at a maximum design value, for example, 35 volts on a system designed to regulate between 6 volts and 35 volts. At this time, the amount of base current available for the driver transistor **34** will be at its highest and, therefore, the drive requirement for the transistor **45** will also be at its highest. From this, it can be seen that the amount of voltage allowed to accumulate across the storage capacitor **16** when the controlled rectifier **17** fails to fire is dependent upon the supply voltage between the terminals **11** and **12.**

If the controlled rectifier **17** should fail to fire, the over-voltage protection circuit would at first shut the converter **14** completely off. Then, as the voltage across the storage capacitor **16** decays, a point will be reached where the transistor **45,** though still conducting current, can no longer keep the converter **14** from cycling. Although the converter **14** can now be cycled, most of the base drive for the driver transistor **34** is still being shunted to the negative terminal by the transistor **45.** The power transistor **29** is allowed to conduct only a small amount of current through the primary winding **27** of the transformer **28.** A small amount of voltage will appear across the secondary winding of the transformer **28** to increase the charge on the storage capacitor **16,** again shuting down the converter **14.** This on-off action will continue as long as the controlled rectifier **17** fails to fire or while for any other reason the capacitor **16** is not discharged. The voltage across the transistor **45** levels off at a value determined by the resistor **44** and the supply voltage between the terminals **11** and **12.**

Accordingly, it will be apparent that the above-described preferred embodiment of the capacitive discharge ignition system **10** includes a regulated converter **14** for charging a storage capacitor **16** to a predetermined level independent of the supply voltage between the input terminals **11** and **12** and also includes means for protecting the capacitive discharge circuit **15** from an over-voltage condition which could possibly damage components such as the capacitor **16** and the controlled rectifier **17.** Furthermore, the system **10** will have a uniformly high output at engine cranking when the voltage across the terminals **11** and **12** is near the design minimum without the use of a ballast resistor and a bypass switch. The regulating circuit which limits the current in the primary winding **27** will also protect the transistor **29** from high currents resulting from either a short in the primary winding **27** or a high voltage across the terminals **11** and **12.** It will be appreciated that various changes and modifications may be made in the above-described ignition system **10** without departing from the spirit and the scope of the claimed invention.

What I claim is:

1. A capacitive discharge ignition system for use with an internal combustion engine having a power source and means for producing timed pulses for triggering the ignition system comprising, in combination, a storage capacitor, a voltage step-up transformer having primary and secondary windings mounted on a core, a controlled conduction device having input, output and control electrodes, means connecting said primary winding, said input electrode and said output electrode in series, means for connecting said series connected transformer and controlled conduction device to the power source, means connected to said control electrode responsive to each trigger pulse for switching said controlled conduction device to a conducting state whereby current flows from the power source through said primary winding and said controlled conduction device to store energy in said transformer core, first means connected to said control electrode responsive to an increasing current flow through said series primary winding and controlled conduction device for increasing the impedance of said controlled conduction device to limit current flow through said controlled conduction device to a predetermined maximum level whereby the total energy stored in said core is regulated, second means responsive to the voltage across said primary winding dropping to a predetermined minimum as the current through said primary winding increases to said predetermined maximum level for switching said controlled conduction device to a non-conducting state whereby a collapsing magnetic field in said core establishes a predetermined high voltage across said secondary winding, means for charging said capacitor with such secondary voltage, means responsive to each trigger pulse for discharging said capacitor, and means responsive to the discharge of said capacitor for generating a high voltage for firing a spark plug.

2. A capacitive discharge ignition system, as set forth in claim **1,** wherein said means for limiting current flow through said controlled conduction device includes a resistor, means connecting said resistor in series with said primary winding and said input and output electrodes whereby a voltage is established across said resistor substantially proportional to the current flow through said primary winding, and means responsive to such voltage across said resistor reaching a predetermined level for limiting conduction of said controlled conduction device whereby the maximum current through said primary winding is regulated.

3. A capacitive discharge ignition system, as set forth in claim **2,** and including means responsive to the voltage across said capacitor exceeding a predetermined level for inhibiting switching said controlled conduction device to a conducting state whereby the maximum charge on said capacitor is limited if said discharging means fails.

4. A capacitive discharge ignition system, as set forth in claim 1, and including means responsive to the voltage across said capacitor exceeding a predetermined level for inhibiting switching said controlled conduction device to a conducting state whereby the maximum charge on said capacitor is limited if said discharging means fails.

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