May 17, 1966 R. C. BOWERS 3,251,351

ELECTRONIC IGNITION SYSTEM

Filed Oct. 14, 1963 2 Sheets-Sheet 1

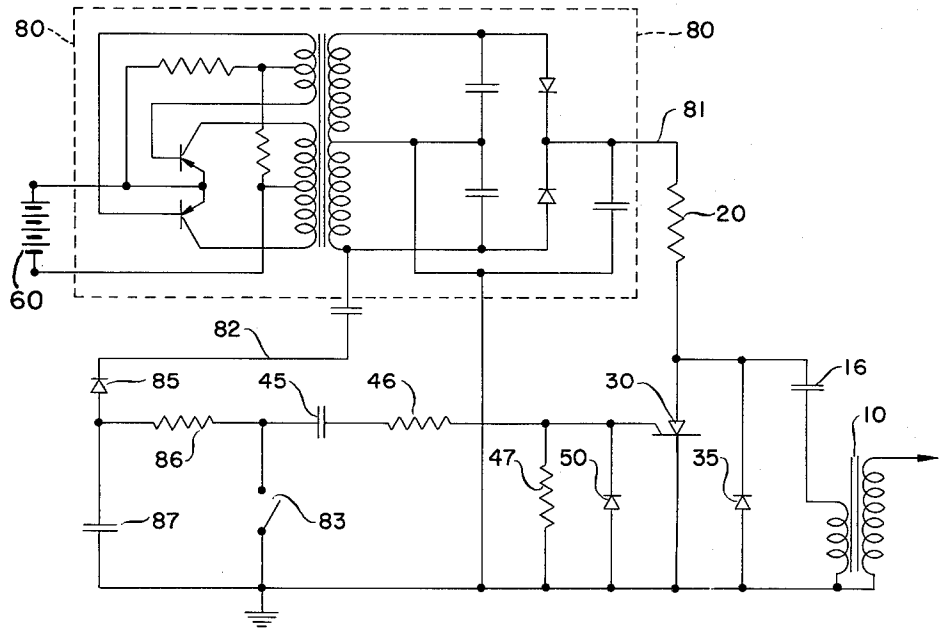


FIG. 3

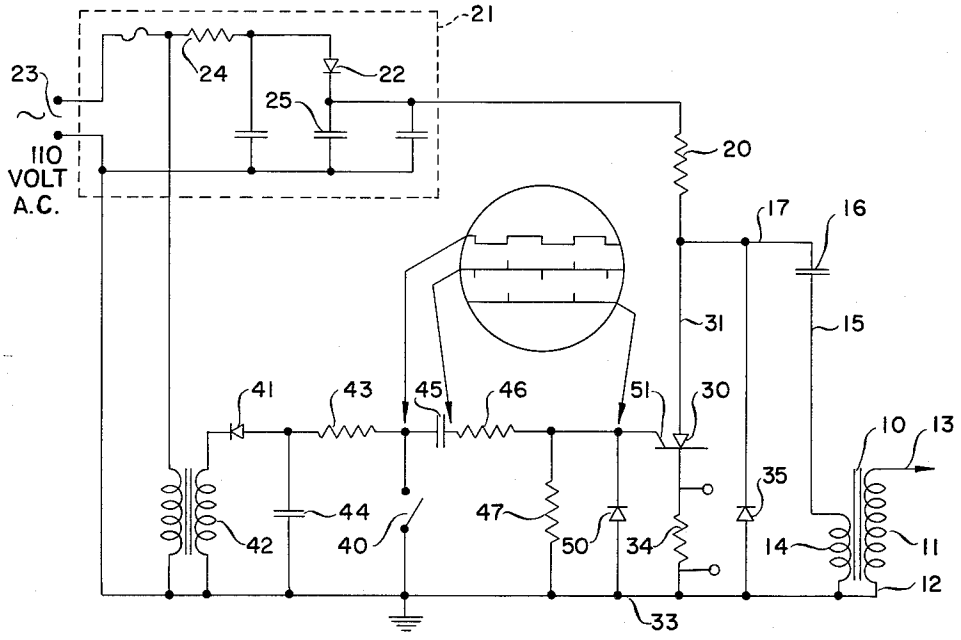


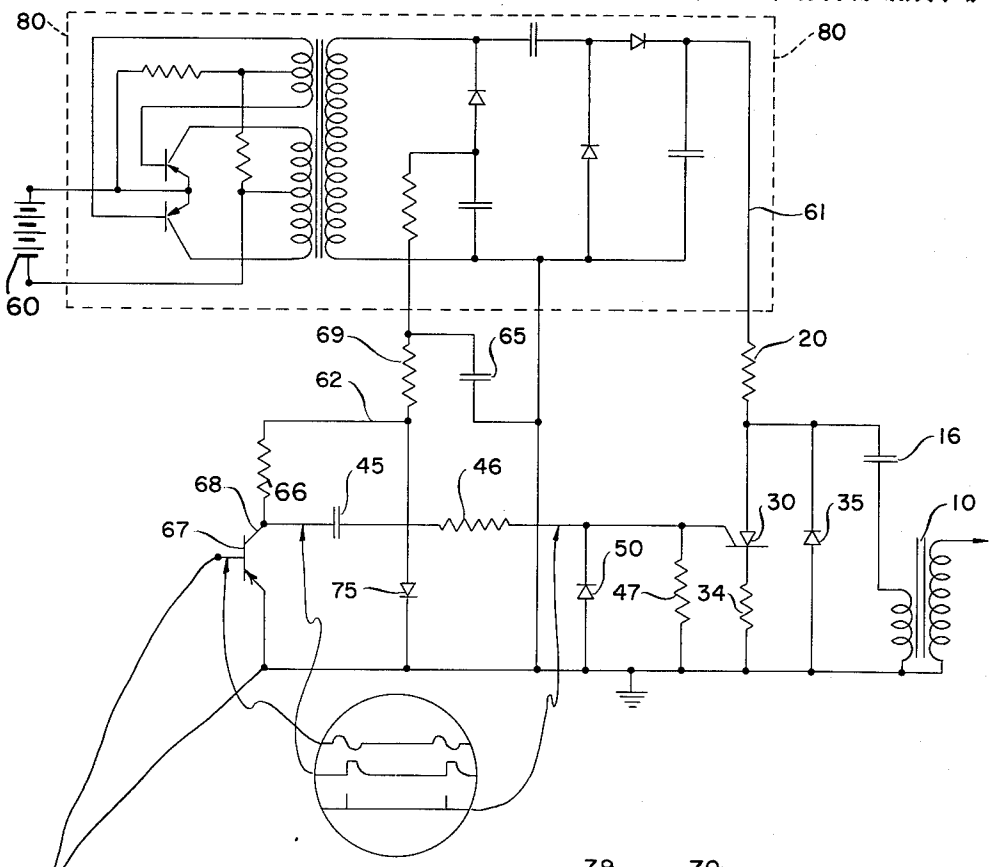
FIG. 1

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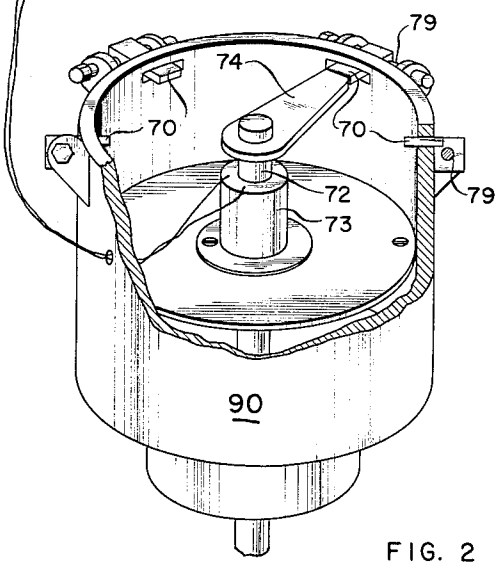


FIG. 2

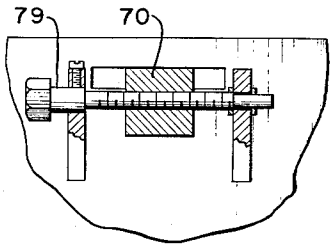


FIG. 4

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ELECTRONIC IGNITION SYSTEM

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This invention pertains to an ignition system for an internal combustion engine and more particularly to an electronic ignition system in which a silicon controlled rectifier is utilized to switch the high voltage to the primary of the ignition system coil.

The present day electronic ignition systems depend upon the use of transistors to increase the current supplied to the ignition coil by the engine driven breaker points. This results in a reduction of the current flow through the breaker points thus increasing their useful life. While this is a partial solution to the problem of supplying a high tension voltage to the spark plugs of an internal combustion engine it does not solve the complete problem. For example, transistors have internal heat losses which require that they be mounted on heat sinks to dissipate this heat especially in the case of an ignition system where the transistors are required to amplify relatively large electrical currents due to special low inductance coils.

The use of transistors has not eliminated all of the problems that arises with engine driven breaker points since transistors still require that the breaker points handle or transfer relatively large electrical currents. These electrical currents still cause some arcing at the breaker points and the resulting wear and malfunction of the breaker points. Also, to prevent damage to the transistors, a means must be provided to dissipate the heat produced by the transistors and limit the back electro-motive voltage produced when the voltage in the ignition coil decays. To limit the back electro-motive voltage, it has been the practice to use ignition coils having low inductance. While this reduces the back electro-motive voltage, it requires a greater number of turns on the secondary to produce the required secondary voltage.

Accordingly, it is the principal object of this invention to provide an ignition system wherein the breaker points are required to handle an electrical voltage having a relatively low current to switch a much larger voltage and current flow through the primary of the standard ignition coil.

A still further object of this invention is to use a silicon controlled rectifier as the main switching element of the system. The rectifier in turn being biased to an on condition by a pulse generated by the engine driven ignition points.

A still further object of this invention is to provide an ignition system for an internal combustion engine having a magnetic pickup driven by the engine, the signal from the magnetic pickup being used to control the operation of a silicon controlled rectifier, the silicon controlled rectifier in turn performing the switching function of the ignition system.

The above objects and advantages of this invention are achieved by providing an ignition system that utilizes a silicon controlled rectifier as a main switching element. A silicon controlled rectifier has similar characteristics to a gas filled thyratron vacuum tube in that the application of a relatively small voltage signal to the device will cause the device to trigger to a conducting stage. In the conducting stage, the device is capable of transferring or switching a large voltage and current signal. The rectifier is utilized to cause the alternate charging and discharging of a relatively large capacitor, the discharge of the capacitor being passed through the primary ignition coil to cause the generation of the high voltage electrical signal required for the operation of a spark plug. In one embodiment the signal for triggering the rectifier is generated by the engine ignition points, the ignition points being used to generate a series of square wave D.C. signals. The square wave signals are differentiated to provide a sharp positive and a sharp negative pulse with the positive pulse being aligned with the leading edge of the signal and the negative pulse with the trailing edge. The positive pulse is used to trigger the rectifier while the negative pulse is passed to ground by a suitable diode circuit. In a second embodiment the signal for triggering the rectifier is generated by a magnetic pickup wherein a single coil and magnetic pole piece is driven by the engine and a semifixed magnetic pole piece is provided for each cylinder of the engine.

The above objects and advantages of this invention will be more easily understood from the following detailed description of preferred embodiments when taken in conjunction with the attached drawings in which:

FIGURE 1 is a schematic circuit drawing of an ignition system for a single cylinder test engine;

FIGURE 2 is a schematic circuit drawing of a second embodiment of the ignition system of this invention for use on a multiple cylinder engine and showing the use of a magnetic pickup in place of the engine driven breaker points;

FIGURE 3 is a schematic circuit diagram of a third embodiment of this invention suitable for use on a multiple cylinder engine and using breaker points; and,

FIGURE 4 is a partial section of the pickup shown in FIGURE 2.

Referring now to FIGURE 1 there is shown in schematic form a circuit diagram for an ignition system suitable for a single cylinder test engine. This type of engine is normally used in laboratories to determine the octane number of motor fuels by a procedure that is referred to as the ASTM–D908 test procedure. This procedure accurately describes the procedural method for operating the test engine as well as various apparatus which must be used. More particularly, the procedure specifies that the ignition system must operate on the closing of the breaker points by the discharging of the capacitor through an ignition coil primary. Thus, the ignition coil functions as a transformer rather than as an induction coil as is the case in a normal automotive system. This procedure necessitates the switching of a high voltage and high current at the time of discharge of the capacitor to generate a sufficiently high voltage to cause discharge of the spark plug. The switching of these high voltage high peak current loads by the engine driven breaker points causes severe arcing and pitting of the points and thus introduces errors into the test procedure.

In FIGURE 1, the normal induction coil **10** of the ignition system has its secondary **11** grounded at one end **12** and coupled to supply a high tension voltage for the spark plug at the other end **13**. The primary of the coil **10** is grounded at one end and has its other end coupled by means of a lead **15** to a capacitor **16**. The coil **10** is a conventional ignition coil and is not modified for use in this invention. The capacitor **16** is used to store a sufficiently high charge to induce a voltage in the secondary **11** having sufficient magnitude to cause discharge of the spark plug. The capacitor **16** is charged through a resistor **20** coupled by means of a lead **17** to the capacitor **16**. The charging voltage is generated by a power supply **21** that is supplied with normal 60 cycle 110 volt A.C. power **23**. The A.C. power is rectified by means of a diode rectifier **22** with the rectified current being filtered

by means of an RC circuit formed by the resistance **24** and capacitance **25**.

The capacitor **16** is alternately charged and discharged by means of a silicon controlled rectifier **30**. The anode of the rectifier is coupled by means of a lead **31** to the lead **17** of the capacitor **16**. Similarly the cathode of the rectifier **30** is coupled to the ground bus **33** by means of a lead **32** having a limiting resistor **34** disposed therein. The negative voltage generated by the decay of the electrical current in the primary **14** of the coil **10** is shunted to ground by means of a diode **35** disposed in a parallel relationship with the primary **14** and the capacitor **16**.

The silicon controlled diode **30** is of the type that when supplied with a small positive pulse at its trigger or gate terminal **51** will break down and permit the conduction of a relatively large voltage and current. In this respect the rectifier is very similar to a gas filled thyratron tube. This type of rectifier is supplied by various commercial manufacturers of semi-conductor devices and the particular choice of rectifier will depend upon the particular service required of the igntion system. As is the case with all semi-conductor type devices the rectifier **30** must be operated near its maximum conditions yet must be protected from exceeding these conditions. The maximum voltage applied to the rectifier **30** is controlled by the power supply **21** and the peak current flow can be measured across a small resistance **34**, such as a 1 ohm resistor inserted for this purpose. Likewise, the diode **35** shunts the signal generated by the decay of the electrical current in the primary **14** directly to ground. Thus, the rectifier **51** is operated near its maximum conditions without danger of exceeding these conditions.

The positive pulses for triggering the rectifier **30** are generated by means of a set of engine driven breaker points **40**. The breaker points **40** are supplied with a low voltage direct current by means of a transformer **42** and a rectifier **41**. The transformer **42** is connected to the normal 60 cycle power supply **23**. The rectified A.C. power is filtered by means of an RC circuit consisting of a resistance **43** and a capacitance **44**. The rectified D.C. voltage supplied to the ignition points **40** should have a relatively low value, for example 9 volts. The closing of the breaker points **40** will generate a positive D.C. signal which is reduced to zero when the breaker points open. The D.C. signal generated by the breaker points will be a series of substantially square wave pulses. By differentiating the square wave pulses one can obtain a short positive pulse followed by a short negative pulse. The series coupled capacitor **45** and resistance **46** are used to differentiate the positive pulse. Since only a positive pulse is needed for triggering the rectifier **30** the negative pulse is shunted to ground by means of a diode **50** disposed in a parallel relationship with the cathode circuit of the rectifier **30**. In addition, a limiting resistor **47** is disposed in parallel with the cathode circuit. The value of the resistance **47** should be selected to limit the voltage appearing on the trigger terminal **51** of the rectifier **30** to a safe value.

When the system shown in FIGURE 1 is operated, the capacitor **16** will be initially charged. Then when the positive pulse is supplied to the rectifier **30** by the closing of the breaker points **40** the capacitor **16** will be discharged through the primary **14** of the induction coil **10**. This will induce a high voltage electrical current in the secondary **11** which voltage is of sufficient magnitude to cause a discharge to the spark plug connected to the secondary **11**. After the capacitor has discharged the rectifier **30** will cease to conduct since the positive pulse has been removed and capacitor has discharged to zero voltage. To insure that the rectifier **30** ceases to conduct, a portion of the negative pulse generated by the decay of the electrical signal in the primary **14** is used to extinguish the conduction of the rectifier **30**.

Referring now to FIGURE 2 there is shown a modified form of the ignition system shown in FIGURE 1 for use with a multiple cylinder engine. The main modification consists of the use of a magnetic pickup to generate the positive pulses used for triggering the rectifier **30** in place of the conventional breaker points **83** shown in FIGURE 3. In addition, the magnetic pole piece for each cylinder is provided with a means for adjusting the advance of the timing to permit tailoring the ignition timing or spark advance for each cylinder. The items in FIGURE 2 that have performed the same function and are identical with the items in FIGURE 1 have the same numerals. The battery **60** shown in FIGURE 2 is a conventional supply for supplying the high voltage direct current through power supply **80** for charging the capacitor **16** and low voltage direct current for the magnetic pickup shown pictorially with parts broken away. The power supply converts the normal six or twelve volt battery voltage to a high voltage at **61** for charging the capacitor **16** and a low voltage bias at **62** across dropping resistor **69** for the magnetic pickup. The lead **62** is coupled to one end of the coil **73** of the engine driven pickup unit **90** through a diode **75**. The lead **62** is also coupled to a load resistance **66** of the collector circuit of a transistor **67**. The base of the transistor **67** is coupled to the other lead of the coil **73** of the pickup. The pickup is actuated by a plurality of pole pieces **70** disposed on the periphery of a circle and a magnetic rod **72** and rotor **74** disposed with the center of the coil **73**. The rod **72** and rotor **74** should be formed of a material having a high magnetic permeability as, for example, iron. In addition, the cup-shaped member **90** should be formed of a magnetic material. Thus, when the rotor is moved radially past each of the pole pieces **70** it will cause a short alternating pulse to be generated in the coil **73**. This pulse is supplied across the base and emitter of the transistor **67** and causes the transistor **67** to conduct when the pulse starts to assume a negative value. The transistor **67** will amplify the pulse and produce a positive pulse of short duration on its collector **68**. The positive pulse on the collector **68** is supplied to the rectifier **30** through the differentiating circuit formed by capacitor **45** and resistance **46**. This positive pulse then triggers the rectifier **30** in the same manner as described above with reference to FIGURE 1.

The remainder of the circuit in FIGURE 2 is identical with the circuit shown in FIGURE 1. Thus, the arrangement shown in FIGURE 2 is suitable for a six-cylinder inline engine when the pole piece **72** is driven at one-half engine speed. Each of the magnetic pole pieces **70** is provided with a means for adjusting its radial position over a narrow range. A suitable means would be a micrometer screw **79** disposed to move the magnetic pole piece along a radial path. The distributor and remainder of the ignition system is not shown in FIGURE 2 since these are of conventional construction.

The circuit described above with relation to FIGURE 2 operates in the same manner as the circuit shown in FIGURE 1. As explained the circuit of FIGURE 2 utilizes a magnetic pickup in place of the breaker points shown in FIGURE 1. The magnetic pickup generates a small alternating signal which is converted to a sharp positive pulse by the combination of the amplifier **67** and the differentiating circuit. This positive pulse is then used to trigger the rectifier **30** to cause the discharge of the capacitor **16** and the resulting generation of the high tension signal required for discharging the spark plugs.

It should also be noted that the ignition circuit of FIGURE 2 causes the spark plug to discharge upon the actuation of the magnetic pickup by the rotor **74**. Thus, the capacitor **16** will have a sufficient time interval to recharge. Further, the micrometer screws **79** provide a means for individually tailoring the spark timing for each cylinder of the engine. Thus, each cylinder can have a different spark timing. It is well known that in any engine some cylinders are more prone to knock than others. By retarding the spark on the cylinders that are

prone to knock, several apparent octane numbers can be obtained without sacrificing engine performance.

Referring now to FIGURE 3 there is shown a modification of the circuit shown in FIGURE 2. More particularly, the circuit shown in FIGURE 3 utilizes engine driven breaker points **83** in place of the magnetic pickup. The power supply **80** of FIGURE 3 is similar to the power supply **80** of FIGURE 2. The power supply **80** supplies a high voltage at lead **81** for charging the capacitor **16** and a low voltage at lead **82** through a capacitor divider network for supplying low voltage for the breaker points **83**. The low voltage at the lead **82** is supplied to the engine breaker points **83** through a rectifying diode **85** and a filter circuit consisting of a resistance **86** and a capacitance **87**. The resistance **86** serves to drop a voltage to the level required for the breaker points. The breaker points **83** that are driven by the engine generate a square wave pulse in the same manner as described above with respect to FIGURE 1. This pulse is differentiated by the series RC circuit consisting of the capacitor **45** and resistance **46** in the same manner as described above with respect to FIGURE 1.

The circuit shown in FIGURE 3 operates in the same manner as described above with respect to FIGURE 1. As explained, the only modification is the use of an oscillator type power supply to convert the low voltage direct current battery source used on most internal combustion engines to the high voltage required for charging the capacitor **16**. In addition, the breaker points will open and close for each cylinder once every two revolutions in the case of a four-cycle engine. In addition, it should be noted that the ignition circuit of this invention is designed to produce a spark upon the closing or making of the breaker points and not the opening or break. This is opposite for most internal combustion engines ignition systems where the spark occurs upon the opening of the breaker points due to the decay of the field built up in the primary of the ignition coil. Accordingly, when the ignition system of this invention as shown in FIGURE 3 is used on an internal combustion engine it is necessary to advance the distributor or other means used for driving the breaker points approximately 25°.

The production of a spark upon the closing of the breaker points in FIGURE 3 or the actuation of the magnetic pickup in FIGURE 2 provides a longer time interval for charging the capacitor **16**. This insures that a high intensity spark will be produced regardless of engine speed. In normal automotive ignition systems, the dwell time of the breaker points is used to build up the field in the primary of the ignition coil. Upon the break of the breaker points the primary field collapses generating a high intensity voltage in the secondary. At high engine speeds the dwell time is not sufficient to allow the primary field to build up and thus the intensity of the secondary voltage is reduced. In contrast, once the capacitor **16** discharges in the system of the present invention it can immediately start to recharge and the charging time is not limited by the dwell time of any part of the system.

The power supply **80** is a standard D.C. to D.C. converter which is described in many transistor manuals. Basically the converter has two switching transistors which alternately supply a battery voltage across the center tapped primary of the transformer by switching on and off alternately. Initially a slight unbalance in the circuit will cause more current to flow through one transistor than the other so that a magnetic field will begin to build when the battery current is applied. The flux in the transformer core builds inducing a voltage into the small control winding connected to the respective bases of the transistors of the power supply with its center tap connected common to the emitters. This induced voltage drives one of the transistors quickly into saturation while the voltage across the other causes it to cut off. During this period, the flux in the coil will change to the constant rate determined by the voltage, number of turns and the core area until core saturation is reached. At this point, the current through the winding will increase sharply driving the core into deep saturation. The induced voltages in the windings drop sharply forcing the conducting transistor to cut off as the core saturation swings back toward its residual value, and induces a voltage of opposite polarity into the control winding connected to the base and the emitters of the respective transistors. Since this voltage is opposite in polarity, it will cause the other transistor to move quickly into saturation repeating the above cycle. Because of the center tap connection of the transistors to primary winding, the alternate conduction of the transistors induces opposite polarity voltages in the secondary of the transformer. By the foregoing switching action, a fairly high frequency A.C. square wave is generated in the secondary of the transformer which is subsequently rectified by diodes to provide higher voltage D.C., thus the name D.C. to D.C. converter.

I claim as my invention:

1. An electronic ignition system for internal combustion engines comprising:

an induction coil, the secondary of said induction coil supplying the high tension voltage and the primary of said induction coil having one terminal grounded;

a silicon controlled rectifier having an anode, a cathode and a gate terminal, said anode terminal being coupled in series with a capacitor and the other terminal of said primary, the cathode terminal being coupled to ground;

a diode, said diode being coupled in parallel with said series coupled capacitor and primary;

a source of direct current voltage, said source being coupled to said anode and said capacitor; and

a pulse circuit, said pulse circuit generating a short duration low voltage pulse in synchronism with desired firing of the internal combustion engine, said pulse circuit being coupled to the gate terminal of the silicon controlled rectifier.

2. The system of claim **1** wherein said pulse circuit consists of a set of contact breaker points driven by the engine generating a series of pulses and a differentiating circuit, said differentating circuit having a capacitor to differentiate the said pulses generated by the discharge of said capacitor.

3. The circuit of claim **1** wherein said pulse circuit consists of an inductive pickup, said pickup being disposed in an operable relation to said engine to generate an alternating signal as said engine rotates, an amplifier, said amplifier being coupled to said inductive pickup to generate a positive pulse when said alternating signal passes through a zero voltage.

4. An ignition system for internal combustion engines comprising:

an induction coil, the secondary of said induction coil supplying the high tension voltage and the primary of said induction coil having one terminal grounded;

a silicon controlled rectifier having an anode, a cathode and a gate terminal, said anode terminal being coupled in series with a capacitor and the other terminal of said primary, the cathode terminal being coupled to ground;

a diode, said diode being coupled in parallel with said series coupled capacitor and primary;

a source of direct current voltage having a high voltage potential, said source being coupled to said anode and said capacitor;

a pulse circuit, said pulse circuit comprising a magnetic pickup for each cylinder of the internal combustion engine, means driven by said engine for actuating said pickup to generate a pulse for each cylinder of the engine, circuit means coupled to said magnetic pickup to differentiate said pulses to provide short time duration pulses; and,

said pulse circuit being coupled to the gate terminal of the silicon controlled rectifier.

5. The system of claim 4 in which a means is provided for adjusting individually the timing position of each magnetic pickup.

6. An electronic capacitor discharge ignition system for internal combustion engines comprising:

an induction coil having a secondary to supply high tension voltage for spark plugs and a primary with one terminal grounded in the ignition system;

a silicon controlled rectifier having an anode, a cathode and a gate terminal with said cathode grounded in said ignition system;

a capacitor connected between said anode of said silicon controlled rectifier and the ungrounded terminal of said primary of said induction coil;

a direct current voltage source having one side grounded in said ignition system and one side coupled with said anode of said silicon controlled rectifier through a charging resistance;

a diode connected to said anode and having the other lead grounded in said ignition system to shunt reverse currents induced by the collapse of a magnetic field in said induction coil's primary to ground when the magnetic field collapses; and

circuit means connected between said gate terminal and said cathode of said silicon controlled rectifier to apply a gating pulse to said gate terminal in synchronism with the desired firing of the internal combustion engine.

7. An electronic capacitor discharge ignition system as defined in claim 6 wherein the direct current source includes a battery and a D.C. to D.C. converter for delivering higher than battery D.C. voltage to the anode to the silicon controlled rectifier and capacitor connected thereto.

8. An electronic capacitor discharge ignition system as defined in claim 7 wherein the circuit means connected between the gate terminal and the cathode is controlled by the internal combustion engine's breaker point.

References Cited by the Examiner

UNITED STATES PATENTS

2,811,672	10/1957	Gilbert	123—148
3,045,148	7/1962	McNulty et al.	123—148

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