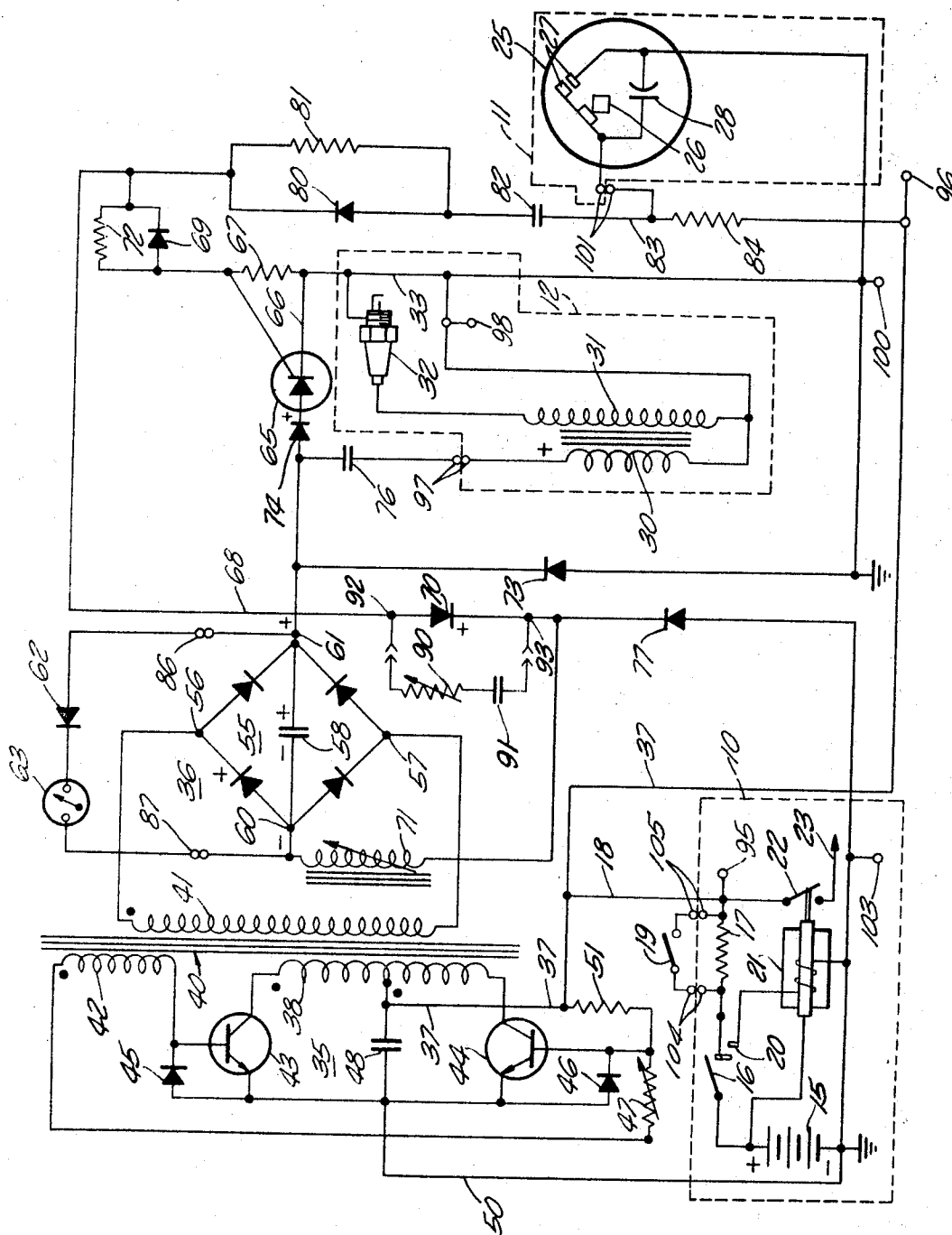


June 10, 1969

A. C. WEISS
CAPACITOR-DISCHARGE ELECTRONIC IGNITION SYSTEM AND A
METHOD FOR ADJUSTING THE CIRCUIT
Filed Sept. 6, 1966

3,448,732



AUGUST C. WEISS
INVENTOR.

WHANN & McMANIGAL
Attorneys for Applicant

By Robert M. McManigal

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**CAPACITOR-DISCHARGE ELECTRONIC IGNITION
SYSTEM AND A METHOD FOR ADJUSTING THE
CIRCUIT**

August C. Weiss, 11658 Harvard Drive,
Norwalk, Calif. 90650

Filed Sept. 6, 1966, Ser. No. 577,511

Int. Cl. F02p 3/06; H05b 41/36

U.S. Cl. 123—148

8 Claims

ABSTRACT OF THE DISCLOSURE

A battery powered capacitor discharge type of ignition system for a piston engine in which the storage capacitor is charged through a DC to DC power converter the output of which is fed to the storage capacitor through an inductance capacitance circuit. A switch means in series with the storage capacitor and primary of the ignition coil which form a discharge circuit is triggered by a pulse generated by a circuit powered from the battery and operated in synchronism with the breaker points.

This invention relates generally to ignition systems for internal combustion engines, and particularly relates to a solid state electronic ignition circuit for automotive engines.

Any ignition system for an automotive engine must be capable of delivering a high-voltage pulse capable of firing the spark plugs of the engine regardless of the engine speed. The engine speed usually varies over a very wide range from idling to the top speed. By way of example, the idle speed may be a few r.p.m. (revolutions per minute) while the top engine speed may be as high as 10,000 r.p.m. or greater. This, in turn, means that the ignition system whether electronic or not must be capable of cylinder, four-cycle engine.

It is accordingly an object of the present invention to provide an electronic ignition system capable of supply-furnishing the high-voltage pulses to the spark plugs at speeds up to 700 cycles per second or more for an eighting the spark plugs of an automotive engine with the required high-voltage pulses at all practical engine speeds, from idling to high speeds, and to increase the milage obtainable for a given amount of gasoline with a particular car.

Another object of the present invention is to provide an electronic ignition system of the capacitor-discharge type, so arranged as to give optimum performance throughout the operating range of the engine, that is, from a few r.p.m. to 10,000 r.p.m. or more.

A further object of the present invention is to provide an electronic ignition system of the type referred to which permits the balancing or tuning of an oscillatory circuit forming part of the ignition system to guarantee optimum performance of the system regardless of the particular type or make of car.

Still another object of the present invention is to provide a solid-state electronic ignition circuit of the type referred to which can be disposed in a unit to be connected by a cable with the remainder of an ignition system conventionally provided in an automobile without deteriorating the performance of the circuit at any operating frequency.

In accordance with the present invention there is provided an oscillatory circuit including a voltage converter and rectifier followed by a resonant circuit capable of discharging on demand a large charge storage capacitor to generate the required voltage peak in the ignition coil of the ignition system. The discharge of the large capacitor is triggered in response to the opening of the breaker points which in turn fires one of the plugs of the engine.

In other words, the firing is controlled in accordance with the speed of the engine, that is, the rate at which the various spark plugs of the engine are fired.

There is also provided an arrangement for balancing or tuning the resonant circuit of the ignition system by selectively connecting thereto a testing circuit to make sure that the electronic circuit will operate at optimum efficiency regardless of small variations of the components of the electronic circuit and of the ignition coil of the particular car involved.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, wherein;

The single figure is a circuit diagram of the electronic ignition system of the invention shown in connection with a portion of the standard ignition system of an automobile, the drawing indicating schematically the points to be connected by a cable and optionally by a switch.

Referring now to the drawing, there is illustrated an electronic circuit embodying the present invention and cooperating with a portion of the conventional ignition system of an automotive engine. The parts of the circuit showing components of the conventional automobile ignition system are shown in dotted boxes. Thus, dotted lines 10 enclose the car battery, the ignition switch, the starter relay and indicate the starter motor. Dotted lines 11 enclose the distributor with one set of points shown schematically, while dotted lines 12 enclose one of the spark plugs and the ignition coil.

Thus, within box 10 there is shown a battery 15 conventionally provided in any car which may have its negative terminal grounded as shown. This may, for example, be a 12 volt battery as has become conventional for late model automobiles. The positive terminal of the battery 15 is connected to the ignition switch 16 which in turn is connected through a ballast resistor 17 to the output line 18. The ignition switch may have an additional contact 20 which is operated for starting the engine to connect the relay 21 to the positive pole of the battery 15. The other end of the relay coil may be grounded as shown. Thus, energization of the starter relay 21 may close a switch 22, which connects the lead 18 carrying the positive voltage supply to the starter motor indicated by the line 23, thereby to start the engine. When the solenoid of the relay 21 is energized to start the starter motor, the ballast resistor 17, which is a necessary feature for conventional systems for cold weather starting, is bypassed so that the full battery voltage is supplied to the ignition coil. Switch 19, a set of contacts on the multiple switch that connects the cable to the automobile's electrical system, is provided in the unit to bypass ballast resistor 17, that is, ballast resistor 17 is paralleled, when the ignition key is returned to ignition "ON" after the engine is started. The bypass or parallel switch 19 is necessary in automobile ignition systems where the current drain is 5 amps or less, thus providing full battery supply to the unit during all speeds and driving conditions. Since switch 19 is an integral part of the electronic ignition unit, it is automatically disconnected as a bypass circuit and restores ballast resistor 17 into the automobile's electrical system when the master or multiple switch that connects the cable is switched to the car's original conventional system.

Within the dotted box 11 there is shown schematically at 25 the distributor which may include a cam 26 driven by the engine crank shaft and a pair of distributor points 27. An ignition capacitor 28 may be connected across the points 27 to minimize arcing. The dotted box 12 encloses a primary winding 30 and a secondary winding 31

forming together the ignition autotransformer. The secondary winding 31 is connected to the spark plug 32. One of the terminals of the spark plug 32 such as its base may be grounded as shown through the lead 33.

The electronic circuit of the present invention includes a voltage converter 35 for converting the DC (direct-current) battery voltage into a higher AC (alternating-current) voltage which may subsequently be rectified by a full-wave rectifier network 36. The voltage converter 35 is connected to the output lead 18, then through the closed bypass switch 19 which bypasses ballast resistor 17 and ignition switch 16 to the positive terminal of battery 15. The lead 18 connects through a lead 37 to the center point of the primary winding 38 of a converter transformer 40 having a secondary winding 41 and a control or feedback winding 42. The transformer 40 has a saturating core with a square hysteresis curve such as is available from a ferroxcube core. A pair of transistors 43 and 44 have their collectors connected to the terminals of the primary winding 38 while their emitters are tied together to ground through lead 50 and to respective anodes of a pair of diodes 45 and 46. The cathode of diode 45 is connected to one terminal of feedback winding 42 and to the base of transistor 43, while the other terminal of winding 42 is connected through an adjustable resistor 47 back to the cathode of the diode 46 and the base of the transistor 44.

A capacitor 48 may be connected between the center tap of primary winding 38 and the two emitters of the two transistors 43 and 44. Furthermore, a resistor 51 is connected between the center tap of the primary winding 38 and the base of transistor 44.

The capacitor 48 connected between the midpoint of the primary winding 38 and ground serves the purpose to suppress radio-frequency currents which may be generated in the electronic circuit of the invention and for preventing such radio-frequency currents from appearing in the electrical system of the car. It serves the additional purpose to smooth out the ripples or voltage variations of the battery 15 of the car which powers the transistors 43 and 44.

This voltage converter 35 operates in a conventional manner. The two transistors 43 and 44 are alternatively permitted to conduct and, hence, to cause a current flow through either one half or the other of the primary transformer 38. The two transistors are controlled through their bases in accordance with the voltages developed at the terminals of the feedback winding 42, which alternatively permits each transistor to conduct in a manner well known in the art.

As a result, a relatively high alternating voltage is developed across the secondary winding 41. This alternating voltage is rectified by the full-wave rectifier networks 36. This includes a rectifier bridge 55 having two terminals 56 and 57 connected directly across the secondary winding 41. A filter and smoothing capacitor 58 is connected across the other two terminals 60 and 61 which are the output terminals of the full-wave rectifier network 36. As indicated, a positive voltage appears at the point 61 and a negative voltage at the point 60. A diode rectifier 62 may have its anode connected to the point 61 in series with a DC voltmeter 63 having its other terminal connected to the point 60. The voltmeter 63 has a high internal resistance (300,000 ohms—300 volt full scale meter times 1000 ohms equals 300,000 ohms). Thus the 300,000 ohms serve the dual purpose of operating the DC voltmeter and regulating the power supply between the positive terminal 61 and the negative terminal 60 which is necessary to suppress voltage spikes at the full B-plus power supply level that may be damaging to the SCR and permits to observe continuously the actual DC voltage across the full-wave rectifier, which may be nominally of the order of 250 volts DC.

A controlled rectifier 65, such as a silicon-controlled rectifier has its anode connected to the cathode of diode 74 and the anode of diode 74 is connected to the point 61

carrying the positive output voltage of the high voltage source. The cathode is connected to a grounded lead 66 which, in turn, is connected through resistor 67, a diode 69 and a resistor 72 connected in parallel, lead 68, diode 70 and variable inductor 71 to the negative terminal 60 of the high voltage source provided by the rectifier network 36. The control electrode of the silicon-controlled rectifier 65 may be connected to the lead 68 through the resistor 72 and the diode 69 connected in parallel.

The positive output terminal 61 of the bridge rectifier may be grounded through a diode 73 having its cathode connected to point 61 and its anode grounded as shown. Further, a charge storage capacitor 76 which is periodically discharged by the controlled rectifier 65 and the reverse voltage blocking diode 74 is connected in series between the positive terminal of the primary winding 30 of the ignition coil and the positive terminal 61.

A diode 77 has its anode connected to ground while its cathode is connected directly to one terminal of the variable inductor 71. The junction point of resistor 72 and diode 69, connected in parallel and of diode 80 and resistor 81, connected in parallel is connected through lead 68 to diode 70 having its cathode connected to the cathode of the diode 77. Diode 80 and resistor 81 connected in parallel are, in turn connected to a control or signal generating capacitor 82. The capacitor 82, in turn, is connected to a lead 83 connected to the distributor 25. A resistor 84 may be connected between the lead 83 and the lead 37 which is returned to the center of the primary winding 38 and to the positive terminal of the battery via closed bypass switch 19 and closed ignition key 16.

The operation of the circuit illustrated in the drawing will now be explained.

When the ignition switch 16 is closed, the voltage of battery 15 is applied to the voltage converter 35 through ballast resistor 17, parallel or bypass switch 19, and lead 18. Also, as is conventional, the ignition switch may be further moved to connect contact 20 to the positive pole of battery 15, thereby to energize the starter relay 21 and the starter motor which is connected to the lead 23. When the starter motor is energized to turn the engine, ballast resistor 17 is automatically bypassed by the starter relay in the conventional operation, but ballast resistor 17 is bypassed or paralleled by switch 19 at all times when the capacitor-discharge electronic ignition system is in operation. When the original ignition system is used, ballast resistor 17 is restored to its original function in the circuit. In that case the ignition system of the invention receives the entire voltage of the battery 15. This promotes easier starting due to the heavy current drain on the battery 15 to drive the starter motor connected to the lead 23. Such an arrangement is particularly useful where the current drain through the ignition coil is 5 amperes or less.

The voltage converter 35 now operates in a conventional manner, that is, the transistor 43 and 44 are alternately energized to permit the flow of current from the center tap of the primary winding 38 through alternate portions thereof. The conduction of the transistor 43 and 44 is controlled by their bases through the feedback winding 42. Every time the base of one of the transistors becomes positive with respect to its emitter, the transistor conducts. The resistor 51 serves the purpose to control starting of the voltage converter. In other words, the voltage drop across the resistor 51 determines which of the two transistors begins to conduct initially.

The resistor 47 which is adjustable, is connected in series with the feedback winding 42. It may either be adjusted or else replaced by resistors of different resistance or by providing several resistors in parallel to apply the desired resistance. This permits to obtain maximum power output and smooth operation of the voltage converter at both the low and high frequency limits of the operating range. It also minimizes the occurrence of high current peaks which may otherwise occur at the extreme

portions of the operating cycle as the current through each transistor approaches a maximum.

As stated before, the transformer 40 has a core which saturates and has a substantially square wave hysteresis curve. This provides a better inversion action of the circuit and gives a smoother output voltage. The two diodes 45 and 46 prevent current flow in the conventional direction from the base to the emitter of each transistor. In other words, they prevent the bases from becoming negative because the emitters are grounded.

The voltage converter 35 is designed to have an operating frequency of approximately 8.5 kc. (kilocycles per second). It has been found that the output load may be shorted without damaging the circuit. After the short condition has been removed, the circuit automatically resumes operation.

The output voltage of the voltage converter is transformed up by the secondary winding 41, to which is connected a full-wave rectifier 36 operating in a conventional manner. The positive output voltage is obtained at the terminal 61 while a negative voltage is developed at the terminal 60. The output voltage is stored across the electrolytic capacitor 58 which, of course, filters out alternating current ripples and stores the electric charge to provide a smooth direct-current supply between the terminals 60 and 61. Since the full-wave rectifier network 36 including the rectifier bridge 55 is conventional, no further discussion is required.

Optionally, there may be connected a voltmeter 63 of high internal resistance (300,000 ohms) which serves the dual purpose of operating the DC voltmeter and smooths out and regulates the power supply, and diode 62 in series across the terminals 61 and 60 of the full-wave rectifier. This may be effected by a cable connected across the connection points indicated schematically at 86 and 87. The cable makes it possible, for example, to display the voltmeter 63 at the dashboard of the car. The diode 62 acts as a blocking diode and permits current to flow from terminal 61 to terminal 60 through the voltmeter 63. Thus, it permits only current flow in one direction through the voltmeter 63 and thus prevents current leakage to the anode of the silicon-controlled rectifier while it is conducting and in the overswing position. The voltmeter 63 permits to exhibit the output voltage of the full-wave rectifier and, hence, indicates whether the circuit is operating efficiently and properly while the electronic ignition system of the invention is operating.

The output voltage at the terminal 61, which may amount to 250 volts DC, now charges the charging capacitor 76 which, in turn, is connected to ground through the primary winding 30 of the ignition coil. The charging circuit across the charging capacitor 76 may be traced from ground through diode 77, choke coil 71 back to terminal 60 which, in turn, is connected through the filter capacitor 58 to terminal 61.

Thus, it will be noted that a resonant circuit is provided including capacitor 76, the primary winding 30 of the ignition coil and choke 71. As will be explained more fully hereinafter, this resonant circuit is preferably tuned to operate throughout the operating range of the automotive engine at which the charging capacitor 76 must be discharged into the primary winding 30 of the ignition coil to fire the spark plug 32 of the car. This frequency may be as high as 700 cycles per second, depending on the number of cylinders and, of course, on the highest number of revolutions of the engine.

The spark plug 32 is fired by suddenly discharging the capacitor 76 which, in turn, causes a voltage surge across the primary winding 30 of the ignition coil and a correspondingly higher voltage surge across the secondary ignition winding 31. This is effected by the controlled rectifier 65. The rectifier 65 is controlled by the operation of the distributor 25, that is, by the opening of the breaker points 27 thereof.

It should also be noted that the control or signal gen-

erating capacitor 82 is charged by the battery 15. This circuit can be traced from the positive pole of the battery 15 through the ignition switch 16, ballast resistor 17 and paralleled or bypass switch 19, leads 18, 37 and resistor 84 to the capacitor 82. The function of control capacitor 82 is to control the conduction of controlled rectifier 65 in accordance with the operation of the distributor, that is, in accordance with the engine speed. Thus, when the breaker points 27 of the distributor are closed, the capacitor 82 is discharged through ground through the breaker points 27 which, in turn, are grounded. The capacitor 28 across the breaker points, of course, serves the purpose to suppress sparks. The capacitor 28 furthermore forms a resonant circuit with the primary winding 30 when the points 27 of the distributor are open.

Also, resistor 84 is a dropping resistor and limits the current flow through the breaker points when the breaker points are closed. As soon as the breaker points open again, the capacitor 82 is charged again with the positive battery voltage through dropping resistor 84. This positive charging voltage provides a positive signal pulse which is conducted to the gate of the controlled rectifier 65 through diode 80 and resistor 72. This now permits the charge storage capacitor 76 to discharge directly to ground through the anode-cathode path of the controlled rectifier 65 and the reverse voltage blocking diode 74. The discharge circuit across the charge storage capacitor 76 is completed from ground back through the primary ignition winding 30. Further, another current path may be traced from ground through diode 77, choke coil 71 and back through the filter capacitor 58.

The voltage surge across the ignition coil 30, 31 is triggered by the opening of the breaker points 27 of the distributor 25. On the other hand, the resonant circuit referred to hereinbefore and including choke 71, primary ignition coil 30 and capacitors 58 and 76 should be tuned to have a resonant frequency sufficiently high so that the charge storage capacitor 76 may be discharged throughout the operating range of the engine to fire the spark plugs of the car.

Diode 73 aids in recharging capacitor 76 to approximately twice the regular B-plus voltage supply. This is, of course, due to the provision of the oscillatory circuit as previously explained. The diode 73 completes the oscillatory circuit while the capacitor 76 is subject to the voltage overswing during the reverse cycle. Reverse voltage blocking diode 74 prevents damage to silicon-controlled rectifier 65 when silicon-controlled rectifier 65 goes into the extreme negative voltage overswing position and, if at the same time the gate of the silicon-controlled rectifier is sufficiently negative, it will trigger the silicon-controlled rectifier into conduction in the reverse direction. In other words, placing diode 74 in series with silicon-controlled rectifier 65 prevents the negative half-cycles of the power supply from reaching the anode of silicon-controlled rectifier 65.

When the breaker points of the distributor 25 are open, control capacitor 82 is being charged to the 12 volt battery potential. At the instant the breaker points close, the control capacitor 82 is grounded therethrough. On the other hand the potential previously existing across the capacitor 82 must now be dissipated without triggering the controlled rectifier 65 into conduction again. To this end there is provided a relatively long time constant for capacitor 82 which includes resistor 81. It should be noted that the negative voltage now provided at the gate of the controlled rectifier through the resistor 67 also aids in preventing false triggering of the rectifier. This negative voltage at the gate of the silicon-controlled rectifier occurs when current is flowing through the resistor 67.

The resistor 72 limits current flow through the gate of the controlled rectifier 65. It also dampens voltage spikes. Further it smooths out the triggering pulse applied to the gate of the controlled rectifier. The diode 69

in conjunction with the diodes 70 and 77 and the two resistors 67 and 72 aids in providing a negative bias on the gate of the controlled rectifier sooner than could be applied solely through the resistor 72. This occurs again when a charging current flows from the positive terminal 61 to the charge storage capacitor 76. Diode 70 in its new location in the circuit, must be a "fast," high-conductance type diode such as 1N645 or 1N647. Diode 77 must be of the standard or avalanche type diode such as 5A4 or 1N2615 which are slower diodes with respect to the high-conductance diode. The functional change is made for this reason: when the capacitor 76 is in the extreme overswing voltage position and the voltage begins to reverse direction and the silicon-controlled rectifier 65 has stopped conducting, any current flowing through choke 71 to recharge capacitor 76 will first draw any positive electrons with respect to ground from the junction of resistor 72, diode 69, resistor 81, and diode 80, via the high-conductance (less resistance) type diode 70, thus positively clamping a negative bias voltage on the gate of the silicon-controlled rectifier 65, and any further current requirement to charge capacitor 76 will be drawn through the standard or avalanche type rectifier (higher resistance) diode 77. Therefore, this arrangement insures that the conduction of the controlled rectifier 65 ceases when the voltage of the storage capacitor 76 begins to overswing. In other words, this arrangement makes it possible for the voltage of the capacitor 76 to overswing and to reach a higher voltage than that developed by the full-wave rectifier.

As explained before, the diode 80 in conjunction with the resistors 81 and 72 conducts the control signal for the controlled rectifier 65 to the gate of the rectifier. This pulse, of course, is generated across the control capacitor 82.

As also mentioned before, the diode 73 is part of the circuit for recharging the charge storage capacitor 76 to a voltage which is approximately twice that of the voltage appearing across the terminals 60 and 61 of the rectifier. The inductance of the primary winding 30 of the ignition coil together with the capacitance of capacitor 76 forms an oscillatory circuit which, in turn, causes the voltage across the charge storage capacitor 76 to swing in a reverse direction. This reverse voltage, in turn, turns off the conduction of the controlled rectifier 65. The voltage across the storage capacitor 76 continues to swing in the opposite direction until the spark plug 32 is fired by the voltage developed across the secondary winding 31 of the ignition coil. This, of course, stops the overswing of the voltage across the capacitor 76. Now, the core of the ignition coil transformer 30, 31 begins to demagnetize. If there is any excess energy remaining as a negative voltage on the capacitor 76, it is fed back through the primary winding 30 and the bypass diode 73 to charge capacitor 76 in the forward direction. Hence, it will be seen that the diode 73 completes the inverse oscillation circuit of the resonant circuit during the time the voltage across the capacitor 76 overswings and reverses the cycle.

The diodes 70 and 77 are blocking diodes for the choke 71. It prevents leaking off to ground through capacitor 58 of the charge on capacitor 76 after the capacitor has been charged to approximately twice the voltage developed by the rectifier network 36. Also, it forms part of the resonant circuit as previously explained. Hence, the choke 71 alternately stores and releases electrical energy when the capacitor 76 is discharged and recharged.

Further, in accordance with the present invention, I have found that the resonant circuit including the choke 71 and the storage capacitor 76 must be tuned to an appropriate operating frequency. This assures optimum operation of the circuit regardless of the rate at which the spark plugs have to be fired. It has been mentioned before, that the voltage across the charging capacitor 76

is approximately twice that of the voltage supply. This is due to the overswing in voltage caused by the action of the resonant circuit coupled to the capacitor 76 and forming part thereof. Accordingly, in accordance with the present invention, a variable resistor 90 in series with a capacitor 91 may be removably connected across the diode 70 at the points 92 and 93.

This probe insertion circuit 90, 91, can now be used for tuning, thereby to permit optimum operation of the circuit and also to take care of variations of the circuit components particularly those forming part of the ignition system of the car such as the ignition system 12 and the like. While the probe insertion circuit 90, 91 is connected across the diode 70, the inductance of the choke 71 is adjusted. I have found that this can best be done by inserting pieces of insulation shim stock having different thicknesses until the proper amount of inductance in the circuit is achieved. The resistor 90 provided in the insertion circuit only serves the purpose to reduce or shut off the oscillation by adding resistance or impedance to the circuit. In other words, it simply reduces the oscillation in the circuit to the zero point.

It will, of course, be understood that after the circuit has been tuned or adjusted to optimum efficiency, the probe insertion circuit 90, 91 is removed again. Of course, it will be understood that when the circuit is adjusted, the inductive reactance of the choke 71 and the capacitive reactance of the capacitor 76 must be numerically equal in order to provide resonance at the desired frequency. Therefore, what is done when the choke 71 is adjusted is to make sure that the capacitive reactance equals the inductive reactance at the desired frequency after the circuit has been properly adjusted.

While it will be understood that the circuit specifications of the electronic ignition system of the invention may vary, according to the design for any particular application, the following specifications are included, by way of example only:

40	Battery:	
	15 -----	12 volts.
	Capacitors:	
	48 -----	250 microfarads.
	58 -----	12 microfarads.
	76 -----	2 microfarads.
45	82 -----	0.15 microfarad.
	91 -----	0.68 microfarad.
	Resistors:	
	47 -----	72 to 82 ohms.
	51 -----	15,000 ohms.
50	72 -----	7.5 ohms.
	67 -----	100 ohms.
	84 -----	50 ohms.
	81 -----	22,000 ohms.
	90 -----	50,000 ohms.
55	Diodes 45 and 46 -----	1N538 (silicon diode).
	The 4 diodes of full-wave	
	rectifier 55 -----	1N1693 (silicon rectifier).
	Diodes:	
	80 -----	1N647 (silicon diode).
60	73 -----	1N1695 (silicon rectifier).
	77 -----	1N2615 (avalanche diode).
	70 -----	1N645 (silicon diode).
	62 -----	1N647 (silicon diode).
	69 -----	1N647 (silicon diode).
65	Transistors 43 and 44 -----	2N2192A.
	Silicon - controlled rectifier	
	65 -----	C20D.
	Choke coil 71 -----	0.6 henry.
	Core of transformer 40 ---	2 ferroxcubes.
70		#206 F 440-3C5E.
	Diode 74 -----	GE-504A (avalanche type
		silicon rectifier).

It will be apparent that the electronic circuit of the present invention must be connected to the conventional

ignition system of a car. Thus, the electronic circuit of the invention preferably is disposed on a suitable terminal board with a socket for a four-conductor, shielded and jacketed cable so as to connect the electronic circuit to the ignition system of the car. This has been schematically indicated in the drawing. For example, the point 95 in the box 10 including the ignition switch 16 will be connected to the point 96 by the cable, thereby to connect the positive terminal of the car battery to the electronic circuit. The next conductor of the cable interconnects the points shown at 97, thus connecting one terminal of the charge storage capacitor 76 to the positive terminal of the primary winding 30 of the ignition coil. The next cable conductor interconnects the point 98 which is the lower terminal of the primary and secondary windings 30, 31 of the ignition coil to the point 100 which is the ground of the electronic circuit. This point, in turn, returns to the ground of the battery 15, that is, to the chassis of the car. Finally, the last cable connection is at the points indicated at 101 which interconnects the distributor 25 to the junction between control capacitor 82 and the resistor 84.

This four-conductor cable, which is well shielded and jacketed, may have a length of 3 to 4 feet depending on the arrangement of the car and the electronic circuit. In any case, the cable should be such that it will not interfere with the operation of the electronic circuit. It should be noted that in particular the cable carries the ground connection to the electronic circuitry between the points 98 and 100, the latter point being connected to the ground point 103 of the battery 15. One end of a special single, heavy-conductor wire connects to the "ON" side terminal of ignition switch 16 at connection 104 and the other end connects to the central terminal of a multiple pole, double-throw switch or solenoid (one set of the contacts being switch 19) in the unit. The electronic ignition system "ON" terminal of the multiple switch (the switch 19 contacts) is connected at connection 105 thus paralleling ballast resistor 17 and supplying 12 volts full battery supply to the unit at all times. Switch 19 on a multiple switch or solenoid is open when the unit is switched to conventional operation, restoring ballast resistor 17, thus preventing the coil from overheating and perhaps from starting a fire in the car. It will also be noted that the cable as shown at points 101 carries the control signal for the silicon-controlled rectifier 65. Nevertheless, the time delay and the distributed capacitance of the cable are such that the operation of the circuit is not affected.

I have also found it convenient to provide a switch in association with the four-conductor shielded cable which has just been discussed. By means of such a switch, the electronic circuit of the invention may be either connected or disconnected from the remainder of the car ignition system. In the latter case, the ignition system reverts to that originally provided for the car, that is, to a conventional and non-electronic ignition system. A further feature of the invention is the emergency run socket (which is attached to the unit and is easily removed), internally connected so as to be readily plugged into the cable socket which restores the ignition system to that originally provided for the car, thus permitting the removal of the unit for test or repair.

There has been provided an electronic ignition system capable of generating the high-voltage pulses required to fire the spark plugs of a late model car regardless of the engine speed. Since the voltage delivered to the spark plugs is high, regardless of the engine speed, a so-called hot spark is created which, in turn, means an appreciable savings in the consumption of gas. The electronic circuit is controlled by the opening of the breaker points of the distributor. Hence, the circuit is self-controlling, that is, it is under the direct control of the breaker points. But the breaker points and the control capacitor only receive the relatively low battery voltage. On the other hand, the circuit is so arranged that the charge storage

capacitor is ready to be discharged at a rate corresponding to the speed of operation of the engine. Furthermore, a resonant circuit is associated with the charge storage capacitor, thus substantially doubling the voltage across the storage capacitor by the overswing of the voltage created by the resonant circuit.

The invention and its attendant advantages will be understood from the foregoing description and it will be apparent that various changes may be made in the form, construction and arrangement of the parts of the invention without departing from the spirit and scope thereof or sacrificing its material advantages, the arrangement hereinbefore described being merely by way of example and I do not wish to be restricted to the specific form shown or uses mentioned except as defined in the accompanying claims, wherein various portions have been separated for clarity of reading and not for emphasis.

I claim:

1. An electronic ignition system comprising:
 - (a) a relatively low-voltage first direct-current source;
 - (b) means coupled to said first direct-current source for developing a relatively high voltage to provide a second direct-current source which has a low-voltage and a high voltage side;
 - (c) an ignition coil having a primary winding;
 - (d) a charge storage capacitor connected between said high voltage side of said second direct-current source and said primary winding;
 - (e) a choke coil connected between said low-voltage side of said second direct-current source and ground;
 - (f) a controllable discharge path for said charge storage capacitor including a controlled rectifier for substantially instantaneously discharging said capacitor and for creating a high voltage surge in said primary winding;
 - (g) a distributor having a plurality of points;
 - (h) means connecting said distributor points across said first direct current source; and
 - (i) a control capacitor connected between the control element of said controlled rectifier and said distributor points for rendering said controlled rectifier conductive when the points of said distributor open after having been closed, thereby to apply a low-voltage pulse to the control element of said controlled rectifier and to discharge said storage capacitor.
2. An ignition system as defined in claim 1 wherein a first diode is connected to the connection between said control element of said control rectifier and said distributor points, and the ground side of said choke coil.
3. An electric ignition system as defined in claim 2 wherein an adjustable resistor and a capacitor connected in series are selectively connectable across said diode for permitting adjustment of the inductance of said choke coil for optimum operation of said ignition system regardless of the speed of the engine.
4. An electric ignition system as defined in claim 1 wherein said control element of said controlled rectifier is connected to said control capacitor through a first resistor and a first diode in parallel, and a second resistor and a second diode in parallel.
5. An electronic ignition system as defined in claim 4 wherein a diode is connected between one terminal of said first direct-current source and the junction of said first and second resistors.
6. An electronic ignition system as defined in claim 1 wherein a diode is connected between the junction of said charge storage capacitor and said second direct-current source on the one hand and one terminal of said first direct-current source on the other hand.
7. An electronic ignition system as defined in claim 1 wherein a diode is connected between said choke coil and one terminal of said first direct-current source.
8. An ignition system as defined in claim 1 in which element (i) includes means operating through said choke coil for returning the voltage on said control element to

11

at least substantially zero voltage when said points are again closed.

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12

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⁵ LAURENCE M. GOODRIDGE, *Primary Examiner.*

U.S. Cl. X.R.

315—209

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,448,732 Dated June 10, 1969

Inventor(s) August C. Weiss

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 36, at the end of the line, add --furnishing the high-voltage pulses to the spark plugs at speeds up to 700 cycles per second or more for an eight- --.

Column 1, delete lines 40 and 41, which read "furnishing the high-voltage pulses to the spark plugs at speeds up to 700 cycles per second or more for an eight-".

Column 2, line 17, after "wherein", change the semicolon (;) to a colon (:).

Column 2, line 31, after "enclose", "he" should read --the--.

Column 3, line 26, "o fthe" should read --of the--.

Column 4, line 62, "conduits" should read --conducts--.

Column 7, lines 56 and 57, "circuitts" should read --circuits--.

SIGNED AND
SEALED
APR 28 1970

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents