

July 18, 1967

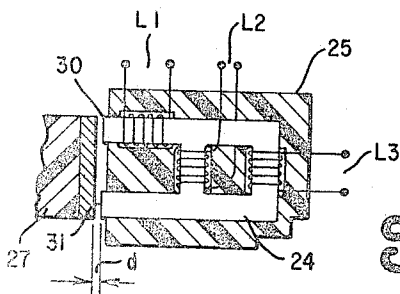
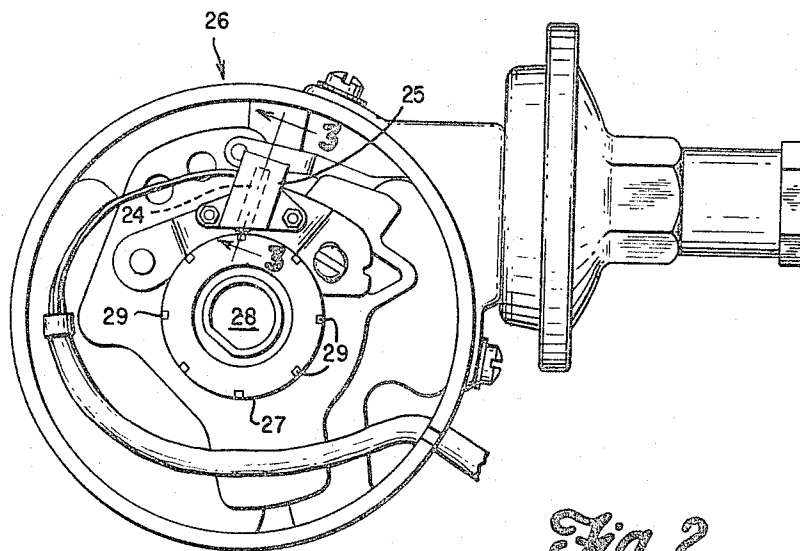
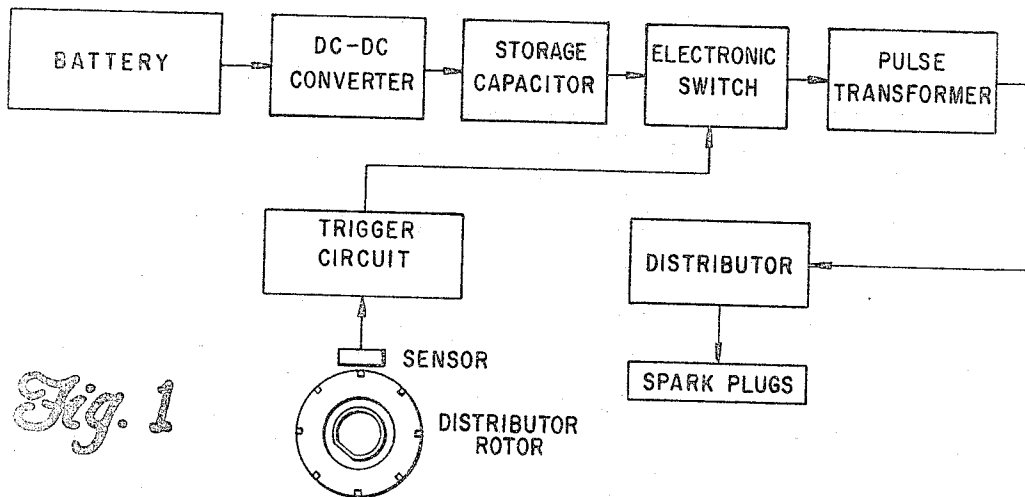
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3,331,986

CONTACTLESS IGNITION SYSTEM

Filed Nov. 16, 1964

5 Sheets-Sheet 1



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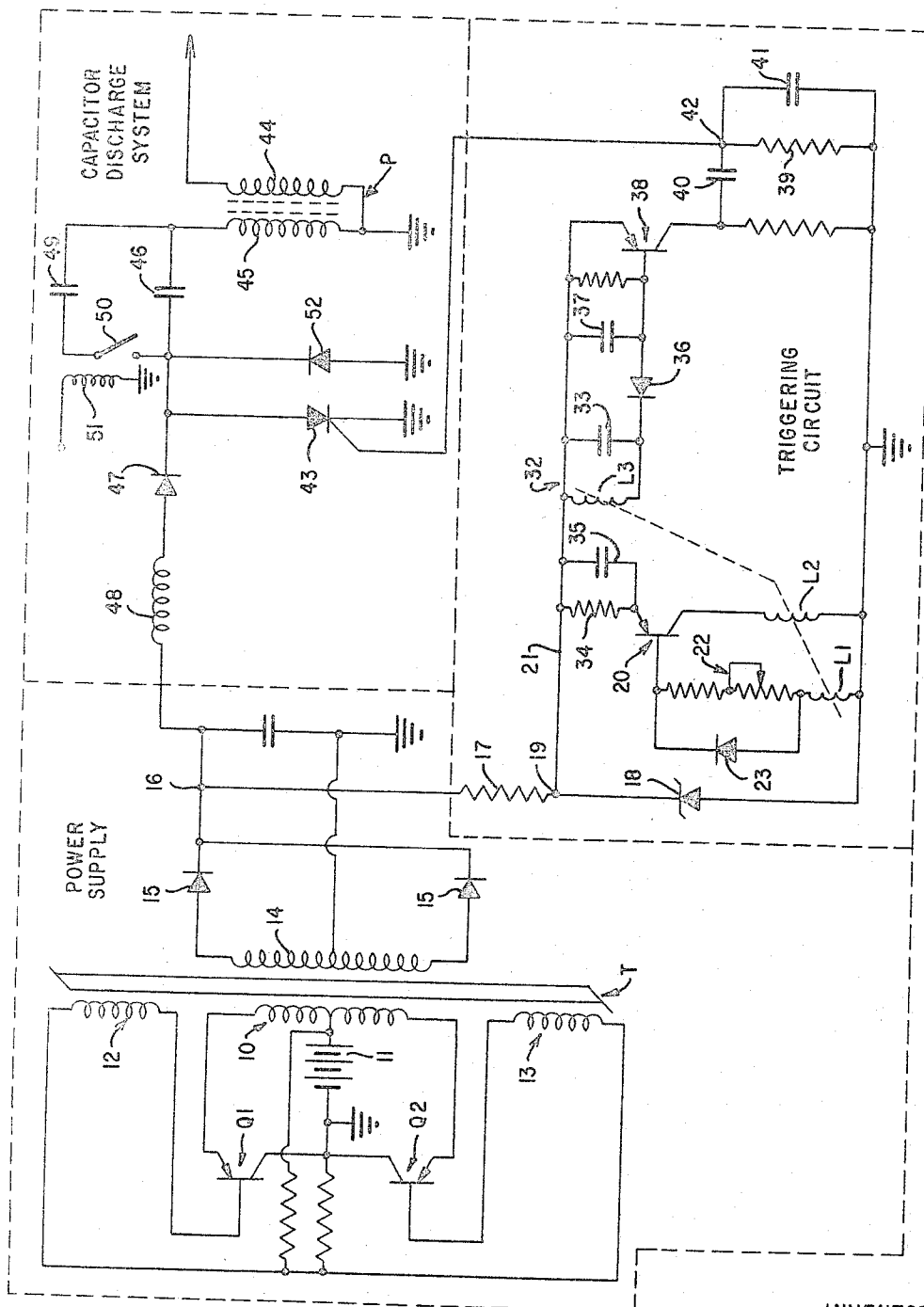
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3 Sheets-Sheet 2



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3 Sheets-Sheet 3

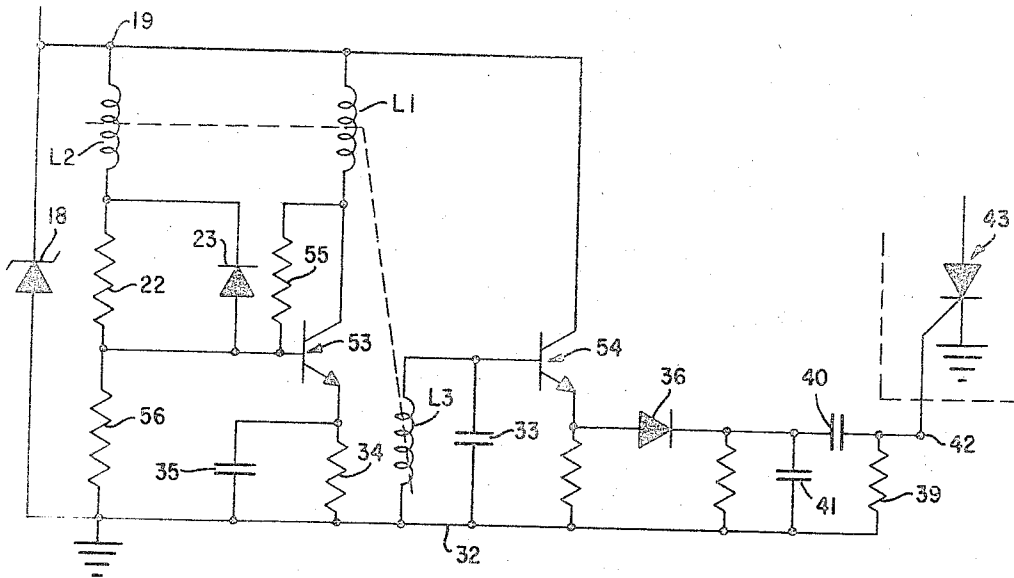


Fig. 5

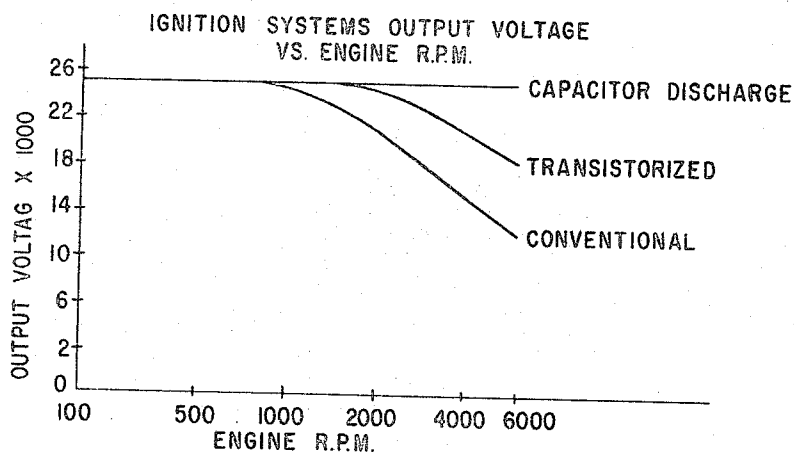


Fig. 6

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3,331,986

CONTACTLESS IGNITION SYSTEM

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7 Claims. (Cl. 317—200)

This invention relates to an ignition system for an internal combustion engine in which no mechanical breaker contacts or points are required and which is capable of delivering a uniformly high voltage to the spark plugs throughout a wide range of engine operating speeds. More specifically, this invention relates to a contactless ignition system for an internal combustion engine which includes a transistorized triggering circuit to control the flow of current to a capacitor discharge system and thence to a primary winding of a pulse transformer whose secondary is connected through the distributor to the spark plugs.

Conventional ignition systems now used with internal combustion engines in motor vehicles include a pair of breaker contacts or points which are opened and closed by a distributor cam mechanically driven by the engine. The breaker contacts control the current flow to the primary winding of an ignition coil where energy is stored and which induces a high voltage current in the coil secondary when the primary is discharged. The contacts are subjected to severe punishment due to mechanical and electrical forces imposed upon them. Such conventional ignition systems require periodic maintenance for several reasons. First, the points themselves are subject to wear due to mechanical erosion from rubbing against one another. Second, electrical erosion or pitting is caused by the inductive "kickback" voltage caused by interrupting the flow of current in the primary of the spark coil. Third, the contacting surfaces of the points are subject to being fouled or coated by films which may interfere with their function of completing the circuit to the coil primary. Also, the rubbing block, which rides against the distributor cam, is subject to wear from continual sliding contact against the cam.

In addition to the necessity for periodic maintenance of the contacts or points in a conventional ignition system, such systems present several inherent drawbacks which limit their efficiency, particularly in operation at high engine speed. At certain engine speeds, contact bounce is present due to mechanical resonance of the movable contact arm and its biasing spring. Also, at high engine speeds, the time necessary for the primary current to reach its maximum to fully charge the coil primary (depending upon the L/R time constant of the ignition coil) may be longer than the dwell time of the contact points (the time that the points are closed) and therefore the energy stored in the primary of the coil is decreased, thus decreasing the induced output of the secondary to the spark plugs.

Accordingly, it is an object of this invention to provide a contactless ignition system which eliminates the maintenance problems that are inherent in the conventional breaker-point systems.

It is another object of this invention to provide a contactless ignition system wherein energy from a power supply is stored in a capacitor prior to being released to the spark plugs and which is not subject to the problem of electrical erosion of the contacts due to inductive kickback voltage from an ignition coil.

It is a further object of this invention to provide a contactless ignition system which is capable of operating at a constant maximum output and high efficiency at any speed above zero to at least 6000 r.p.m.

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It is yet another object of this invention to provide a contactless ignition system which may be adapted for use within the physical confines of a conventional distributor of an internal combustion engine.

It is still a further object of this invention to provide a contactless ignition system with the advantages described above and which is rugged, maintenance free, and is capable of efficient operation throughout a wide range of environmental temperatures such as would be present under the hood of an automobile.

Other objects and advantages of this invention will be apparent from the following detailed description of a preferred embodiment thereof, reference being made to the accompanying drawings in which:

FIGURE 1 is a block diagram showing the essential parts of the contactless ignition system as they would be associated with a conventional distributor and spark plugs for an internal combustion engine;

FIGURE 2 is a plan view of a conventional distributor bowl and its associated vacuum advance, showing the location of certain elements of the contactless ignition system of this invention installed therein;

FIGURE 3 is a cross-sectional view, on an enlarged scale, taken along line 3—3 of FIGURE 2, showing the position of several fixed inductance coils in relation to a rotating ferrite core on the rotor, which elements comprise an important part of this invention;

FIGURE 4 is a circuit diagram of a preferred embodiment of the contactless ignition system of this invention including a power supply, a triggering circuit and a capacitor discharge circuit, with a pulse transformer as shown in the block diagram of FIG. 1;

FIGURE 5 is another embodiment of the triggering circuit shown in FIGURE 4; and

FIGURE 6 is a graphic comparison of the output voltage available to the spark plugs from a conventional distributor system, a transistorized distributor ignition system such as that disclosed in U.S. Patent 3,016,477, and the contactless ignition system of this invention.

Summary of the invention

As previously explained, the contactless ignition system of this invention is adaptable for use with a conventional distributor for an internal combustion engine.

The electronic package which is to be associated with the conventional distributor and spark plugs consists of three major electronic components: a power supply, a triggering circuit, and a capacitor discharge system, all of which are shown in FIGURE 4. The relationship of these three electronic components with a conventional distributor and spark plugs is schematically shown in the block diagram of FIGURE 1. The power supply, which is a DC to DC converter, supplies power from a battery to the triggering circuit and also the capacitor discharge system. The triggering circuit, parts of which are mechanically associated with the conventional distributor, supplies an electrical signal, which may be amplified in an amplifier shown in FIGURE 1 if necessary, to the capacitor discharge system which, in turn, supplies a signal to the primary of a pulse transformer. This signal to the primary of the pulse transformer induces a high voltage in the secondary of the pulse transformer which is then directed to the appropriate spark plug by the conventional distributor.

The source of the triggering signal within the triggering circuit is an astable blocking oscillator which employs a positive collector-to-base feedback to achieve regeneration. The regenerative feedback circuit includes inductive reactances which vary in value in accordance with the position of a rotating ferrite I core which is driven at a speed proportional to the engine speed by the distributor. The components of the astable oscillator are so selected

that its output, as determined by the variable inductive reactance in the feedback circuit, consists of timed output pulses which are detected by an AM detector, amplified by a triggering transistor, and thence act as a triggering impulse to fire a solid state controlled rectifier in the capacitor discharge system. A capacitor in the discharge system stores energy from the power supply and periodically releases this energy to the primary of a pulse transformer when the controlled rectifier fires. The voltage induced in the secondary is directed by the distributor to a spark plug in a conventional manner. The operation of these components is described in detail below.

Power supply

In the preferred embodiment of the power supply shown in FIGURE 4, a two transistor, push-pull type oscillator is operably connected to the primary 10 of a power transformer T. The transistors Q1 and Q2 are powered by a conventional automotive-type twelve volt battery 11 and are base connected to regenerative feedback coils 12 and 13, respectively. Oscillations in the primary 10 of the transformer T induce a high voltage alternating current in the secondary 14 of the transformer T which is full wave rectified by diodes 15. In this preferred embodiment, the ratio of the windings of the primary 10 and secondary 14 of the transformer T is such that the twelve volts supplied from the battery 11 is increased to 150 volts, after full wave rectification, at the junction 16.

From this junction 16, power is supplied to the triggering circuit through a dropping resistor 17 and a zener diode 18. The resistor 17 and zener diode 18 keep the voltage at junction 19 at a constant twelve volts over a range of fluctuations in battery voltage due to change in environmental temperatures, state of charge or other causes. It is to be understood that the power supply previously described may be readily adapted to operate with a six volt battery or other source by varying the turns ratio of the transformer T, etc.

The triggering circuit

The triggering circuit includes an astable blocking oscillator comprising a PNP transistor 20 with its emitter-collector circuit connected across the line 21 to ground. The transistor 20 employs a positive collector-to-base feedback through inductive coils L1 and L2 and an adjustable resistor 22 and a diode 23. The adjustable resistor 22 constitutes a means for manually adjusting the frequency of the astable oscillator but is not necessary to its basic mode of operation. The diode 23 provides an alternate feedback path when coils L1 and L2 are coupled as will be explained below.

Referring to FIGURES 2 and 3, inductance coils L1 and L2 are wound upon a fixed "A-core" 24 as shown in FIGURE 3. A third inductance coil L3, is also wound upon the A-core as shown in FIGURE 3 and is connected in the triggering circuit as shown in FIGURE 4. This coil disposition on the common A-core is indicated by the dashed line in FIG. 4. The ferrite A-core 24 is preferably encased in a nonmagnetic housing 25 which is fixed within a conventional distributor 26 in place of conventional points as shown in FIGURE 2. A nonmagnetic ring 27 is secured to the distributor shaft 28 for rotation therewith in place of the conventional cam. A plurality of ferrite bars or "I-cores" 29 are equally spaced around and recessed within the periphery of the ring 27, as shown in FIGURE 2. The housing 25, containing the A-core 24 and inductive coils L1 and L2 and L3, is positioned within the distributor such that the legs 30 and 31 of the A-core 24 are closely adjacent the outer periphery of the ring 27 and the I-cores 29. Rotation of the ring 27 by the distributor shaft 28 will pass each of the I-cores 29 closely adjacent the legs 30 and 31 of the A-core 24 to effectively close the air gap therebetween.

The mutual inductance between coils L1 and L2, which are magnetically coupled to one another on the A-core 24, is changed each time an I-core 29 effectively closes the air

gap between the legs 30 and 31 of the A-core 24. Utilizing this change, the output of the PNP transistor 20 is controlled by changes in the total inductive reactance in the coils L1 and L2 and the alternate current path through the diode 23 which shunts the adjustable resistor 22.

The legs 30 and 31 of the A-core 24 are spaced approximately .015 inch from the periphery of the ring 27 and the I-cores 29 so that, contrary to conventional ignition systems employing breaker points, there is no contact or frictional engagement between the ring 27 and I-cores 29 with the legs 30 and 31 of the A-core 24. Therefore, once the housing 25 holding the A-core 24 has been positioned within the distributor 26 as shown in FIGURE 2, there is no need for further adjustment because the parts are not in contact and therefore are not subject to wear. This distance of .015 inch between the legs 30 and 31 of the A-core 24 and the I-cores 29, indicated by reference numeral *d* in FIGURE 3, is small enough so that the reluctance of the air gap is substantially less than the reluctance of the larger air gap between the legs 30 and 31 of the A-core 24 when in an uncoupled state.

The astable blocking oscillator is operated as follows: the PNP transistor 20 is biased so that current starts to flow through the emitter-to-base circuit and through inductive coil L1 and the emitter-to-collector circuit through inductive coil L2. As the base current through L1 increases, the collector current through L2 increases. This changing current in the collector circuit through inductive coil L2 causes a changing flux in the A-core 24 and thus induces a voltage in inductive coil L1 in the base circuit of a polarity which increases the flow of current through the base circuit. Regeneration continues until the transistor 20 saturates at which time the rate of change in the flux in the A-core 24 drops to zero. The induced voltage in the inductive coil L1 consequently becomes zero and, because the DC bias is insufficient to keep the A-core 24 saturated, the flux therein begins to decrease. This negative rate of change of the flux in the A-core 24 consequently induces a voltage of opposite polarity in the inductive coil L1 which further reduces the flow of current through the inductive coil L1 and starts degeneration in the system. This condition continues until the PNP transistor 20 shuts off. The applied DC bias across the emitter-to-collector circuit again starts the regenerative cycle previously described and increased current through the inductive coil L2 again induces a positive voltage in the inductive coil L1, etc.

As previously described, operation of the astable blocking oscillator which includes the PNP transistor 20 is affected by the position of the I-cores 29 which are rotated by the distributor 27 in and out of alignment with the legs 30 and 31 of the A-core 24. The operation of the PNP transistor 20 is essentially the same for both the "coupled" and the "uncoupled" states. However, alignment of an I-core 29 with the A-core 24 changes the mutual inductance between the inductive coils L1 and L2 in the control circuit for the PNP transistor 20 and therefore changes the frequency and amplitude of the oscillations from the emitter of the PNP transistor 20. Furthermore, when the induced voltage in the inductive coil L1 is sufficiently high during its coupled state, the conduction threshold of the diode 23 is exceeded and the diode 23 conducts and effectively shunts the adjustable resistor 22 to increase the degenerative current.

The variable output from the transistor 20 is utilized by the triggering circuit in a parallel resonant network 32 consisting of an inductance coil L3 and a capacitor 33 operably connected to the collector of the PNP transistor 20, as shown in FIG. 4. The parallel resonant network 32 is tuned to the output frequency of the astable blocking oscillator when the legs 30 and 31 of the A-core 24 are aligned with one of the I-cores 29 on the distributor ring 27. For example, if the PNP transistor 20, when the I-cores 29 and the legs 30 and 31 of the A-core 24 are uncoupled, is oscillating at a frequency of 30 kc., the parallel

resonant network 32 connected to the emitter of the PNP transistor 20 acts as an external load to keep the output of the PNP transistor 20 (the amplitude of the oscillations) at a relatively low value. However, when the legs 30 and 31 of the A-core 24 are coupled with an I-core 29, the frequency of the oscillations of the PNP transistor 20 changes to a value which has been preselected as the tuned frequency of the parallel resonant network 32 and, therefore, the effect of the impedance of the parallel resonant network 32 upon the PNP transistor 20 drops to practically zero. Removal of this impedance increases the amplitude of the output of the PNP transistor 20 until the A-core 24 is again uncoupled from one of the I-cores 29 by reason of the physical movement of the I-core 29 as the distributor shaft 28 rotates and the impedance of the parallel resonant network 32 is no longer negligible.

A resistor 34 is connected in series with the emitter-to-collector circuit of the PNP transistor 20 to adjust the operating DC bias and a capacitor 35 is provided to remove the degenerative effect of the resistor 34 upon the output of the PNP transistor 20.

An AM detector including a diode 36 and a capacitor 37 acts as a peak rectifier to detect the signal from the PNP transistor 20 and this signal is impressed upon the base of a switching transistor 38. The switching transistor 38 has a square wave output depending on the envelope of the oscillatory voltage of the blocking oscillator. The square wave output of the switching transistor 38 is then differentiated by the network consisting of a resistor 39 and capacitors 40 and 41 so that the signal at the junction 42 consists of sharp pulses which correspond in time to the alignment of the A-core 24 with one of the I-cores 29. This signal is utilized to trigger a controlled rectifier 43, preferably an SCR, whose intermittent firing provides a current in a circuit operably connected with a pulse transformer P. The oscillator output depends on whether its windings are coupled or uncoupled with the "T" cores so that the rotational velocity of the distributor rotor does not affect the systems output.

The capacitor discharge system

The secondary 44 of the pulse transformer P is connected through the distributor 26 to the spark plugs, as schematically indicated in FIGURE 1. The primary 45 of the pulse transformer P is connected in the discharge circuit of the SCR 43 with a storage capacitor 46. The storage capacitor 46 is connected to the junction 16 of the full wave rectifier of the power supply through a diode 47 and a coil 48 which functions as a voltage doubler. In the preferred embodiment described herein, the 150-volt rectified signal at the junction 16 is doubled to 300 volts by the coil 48 and is applied to one side of the storage capacitor 16. The diode 47 prevents leakage from the storage capacitor 46 back to the power supply.

If desired, a second storage capacitor 49 may be connected in parallel with the storage capacitor 46 through a normally open switch 50 operated by a solenoid winding 51. The second storage capacitor 49, when the switch 50 is closed, increases the energy stored in the firing circuit of the SCR 43 during periods when additional energy may be required in the primary 45 of the pulse transformer P, such as when the automobile engine is turned slowly at starting. The solenoid winding 51 is operably connected to the battery 11 through a manually operated switch (not shown) such as an ignition key in the automobile such that the normally open switch 50 is closed by the solenoid 51 when the automobile is started and is again opened after the engine has commenced firing.

The SCR 43 is so biased that it is normally off, or in a nonconducting state, until the signal from the triggering circuit is applied at its gate. During periods of nonconduction, the storage capacitor 46 (and the capacitor 49 during starting) builds up a charge which, when the SCR 43 is triggered by the differentiated pulse from the triggering circuit, discharges through the SCR 43 and the

primary 45 of the pulse transformer P. Thus, when the SCR 43 conducts, the current flowing in the primary 45 of the pulse transformer P induces a high voltage in the secondary 44 of the pulse transformer P which is directed by the distributor 26 to the spark plugs. A diode 52 connected in parallel with the SCR 43 clamps the kickback voltage in the primary 45 of the pulse transformer P and eliminates the requirement for a high reverse voltage specification for the SCR 43.

It will be clear that the timing of the spark voltage in the secondary 44 of the pulse transformer P corresponds to the firing of the SCR 43 which is, in turn, gate controlled by the differentiated signal from the triggering circuit. As previously explained, the signal from the triggering circuit is a modulated and differentiated form of the oscillations from the oscillatory circuit including PNP transistor 20. These oscillations, as previously explained, are controlled in amplitude by the changing mutual inductance between inductive coils L1 and L2 which, in turn, is varied in accordance with the position of the I-cores 29 rotated by the distributor 26 in relation to the legs 30 and 31 of the fixed A-core 24. Because the speed of the distributor 26 is directly proportional to the engine speed, the output of PNP transistor 20 and thus the timing of the spark voltage in the secondary 44 of the pulse transformer P is controlled in proportion to the engine speed. Thus, the system as described produces a spark at the plugs in a manner similar to a conventional ignition system so that conventional centrifugal or vacuum actuated mechanisms for controlling ignition timing (spark advance or retard) will operate in a similar manner with the contactless ignition system of this invention.

In the modification of the triggering system, shown in FIGURE 5, the twelve volts from the power supply is applied across a NPN transistor 53 whose output is again operably connected, through the parallel resonant network 32, to the base of a second transistor 54. The output of the transistor 54 is detected and differentiated by the AM detector and differentiating circuits as before and is again fed to the gate of the SCR 43 in the capacitor discharge system, as shown in FIGURE 5. In this second embodiment, the output of the blocking oscillator which includes the NPN transistor 53 is also controlled by the varying mutual inductance of the inductive coils L1 and L2 which are wound on the A-core 24 shown in FIGURE 3 and whose mutual inductance is controlled by the position of the I-cores 29 which are rotated by the distributor 26. In the circuit of the NPN transistor 53, a resistor 55 connected in the collector-to-base circuit provides negative feedback for gain stabilization. A resistor 56 is connected in the base to ground circuit to provide bias stabilization at high temperatures.

It is to be understood that the particular voltages, frequencies, and parameters of the components of the above-described embodiments are used for illustrative purposes only and that various changes may be made without departing from the concept of this invention. For instance, it has been found that through use of a high oscillator frequency, for example 300 kc., and a sensitive detector circuit, the entire system is relatively insensitive to variations of the gap d between the I-cores 29 and the legs 30 and 31 of the A-core 24. This is an important advantage due to the fact that a certain amount of shaft play in the distributor 26 is inherent. It has been found that variation of the gap d from 0.010 to 0.025 inch produces less than a one degree change in timing of the spark from the secondary 44 of the pulse transformer P. It has further been found that when a coupled frequency of 100 kc. is used, the maximum delay in the timing of the spark from the secondary 44 of the pulse transformer 43 is only 1.7° at an engine speed of 6000 r.p.m. Because the amount of delay is a direct function of the coupled frequency, increased coupled frequencies will reduce the degrees of timing retard proportionally. At engine speeds as high as 6000 r.p.m., conventional distributors have

considerable difficulty with contact bounce. As previously explained, the contactless system of this invention is free of such disadvantages.

Another advantage inherent in the present system is the elimination of the conventional coil now utilized in conventional ignition systems. In a conventional system, the spark energy available to the secondary of the coil must be stored in the primary of the coil. Energy stored in a coil is equal to $\frac{1}{2}Li^2$, where L is the primary inductance and i is the primary current. Conventional systems become inefficient at high engine speeds because the time required to fully charge the primary may be longer than the distributor dwell time as previously explained, and secondly because the required primary turns to secondary turns ratio of a conventional ignition coil results in a large secondary inductance which creates a relatively large kickback voltage.

A transistorized ignition system, such as that disclosed in U.S. Patent 3,016,477, makes use of the same principle of energy storage as a conventional system but, because the maximum current that the transistor can switch is larger than that switched by the contacts in the conventional system, the primary inductance or L in the above formula can be reduced. However, the peak inverse voltage of commercially available transistors is limited to about 100 volts and to reduce the kickback voltage to accommodate a commercially available transistor, the primary to secondary turns ratio of the coil must be higher which then results in a larger secondary inductance and slower rise time in the secondary. Thus, a transistorized ignition system, while an improvement over the conventional system, is subject to decrease in secondary voltage output at high speeds.

However, with the capacitor discharge system coupled with the triggering circuit of this invention, the energy for ignition is stored in the capacitor 46 (and the capacitor 49 during starting). Since the energy is not stored in the inductive primary of the coil as it is in the conventional and transistorized systems, the pulse transformer P may be made physically smaller than a conventional coil and the secondary will accordingly have a relatively small inductance and a fast rise time. Ideally, the pulse transformer P should have a zero inductive reactance in the primary and secondary and would be an ideal transformer which performs only the function of increasing the voltage in the primary to the level required for spark ignition, without introducing any losses or time delay. While such a theoretical transformer is impossible, a well designed pulse transformer will cause only a fraction of a microsecond delay and will therefore be capable of providing a uniform fast rise time voltage output to the sparkplugs, such as 25 kv. in the preferred embodiments described, even at high engine speeds. FIGURE 6 graphically shows the output voltage available to the spark plugs plotted against engine r.p.m. for conventional, transistorized and the contactless capacitor discharge systems. Because the output voltage in the capacitor discharge contactless system of this invention does not fall off at speeds below 6000 r.p.m., this system is ideally suited for high speed operation and has the ability to fire fouled plugs throughout a wider range of engine operation than conventional systems.

Various modifications of the above-described preferred embodiment of the invention will be apparent to those skilled in the art and it is understood that such modification can be made without departing from the scope of the invention, if within the spirit and tenor of the accompanying claims.

What we claim is:

1. An ignition system for an internal combustion engine, comprising in combination, a power supply, at least one spark discharge device, an energy storage device for storing electrical energy from said power supply, and a triggering means for causing the timed intermittent discharge of energy from said energy storage device to said

spark discharge device, said triggering means comprising a controlled oscillator operably connected to said power supply and to said energy storage device, said oscillator including a transistor having a control electrode, a pair of magnetically coupled coils operably connected to said control electrode, a timing disc driven by said engine and having equally spaced portions of effective high permeability separated by areas of effective low permeability whereby rotation of said disc will serially pass said portions of effective high permeability past said pair of coils to cause programmed variations in their magnetic coupling whereby said programmed variations in said magnetic coupling cause programmed variations in the output frequency of said oscillator, means operatively connected to said oscillator and responsive to said programmed variations in output frequency to vary the amplitude of said output during successive periods in timed proportion to engine speed, and means to detect said successive periods of output and effective to produce timed voltage pulses at a frequency proportional to engine speed, said detector means operatively connected to said energy storage device to cause said intermittent discharge of energy from said energy storage device to said spark device in timed proportion to engine speed.

2. The ignition system of claim 1 wherein said detector means includes an AM detector and a differentiating network operably connected to said oscillator whereby the variations of said oscillator output are detected and differentiated to produce a signal having sharp voltage variations in timed proportion to engine speed.

3. An ignition system for an internal combustion engine, comprising, in combination, a power supply, at least one spark discharge device, an energy storage device for storing electrical energy from said power supply, and a triggering means for causing the timed intermittent discharge of energy from said energy storage device to said spark discharge device, said triggering means comprising a controlled oscillator operably connected to said power supply and to said energy storage device, said oscillator including a transistor having a control electrode, a pair of magnetically coupled coils operably connected to said control electrode in a feedback loop, a voltage responsive means in said feedback loop effective to establish two levels of regeneration in response to oscillator output, a timing disc driven by said engine and having equally spaced portions of effective high permeability separated by areas of effective low permeability whereby rotation of said disc will serially pass said portions of effective high permeability past said pair of coils to cause programmed variations in their magnetic coupling whereby said programmed variations in magnetic coupling cause programmed variations in the output of said oscillator, and means to detect said programmed variations in the output of said oscillator and effective to produce timed voltage pulses at a frequency proportional to engine speed, said detector means operatively connected to said energy storage device to cause said intermittent discharge of energy from said energy storage device to said spark device in timed proportion to engine speed.

4. The ignition system of claim 3 wherein said feedback loop includes a resistor with said voltage responsive means connected in parallel thereto whereby conduction by said voltage responsive means effectively shunts said resistor.

5. The ignition system of claim 3 wherein said voltage responsive means is a diode.

6. An ignition system for an internal combustion engine, comprising in combination, a power supply, at least one spark discharge device, an energy storage device for storing electrical energy from said power supply, and a triggering means for causing the timed intermittent discharge of energy from said energy storage device to said spark discharge device, said triggering means comprising a controlled oscillator operably connected to said power supply, said oscillator including a transistor

having a control electrode, variable inductive reactance elements operatively connected to said control electrode and means driven in timed proportion to engine speed to cause variations in said inductive reactance whereby programmed variations in said reactance cause pro- 5
grammed variations in the output of said oscillator, regenerative circuit means operatively connected to said oscillator, said regenerative circuit means responsive to oscil- 10
lator variations to further augment the response of oscillator output to said programmed variations, and means to detect said programmed variations and to pro-
duce timed voltage pulses at a frequency proportional to the speed of engine, said detector means operatively connected to said energy storage device to cause said intermittent discharge of energy from said energy storage 15
device to said spark device in timed proportion to engine speed.

7. An ignition system for an internal combustion engine, comprising, in combination,

- (1) a direct current power supply including a D.C. 20
to D.C. converter for converting a low voltage source to a higher voltage direct current supply,
- (2) at least one spark discharge device,
- (3) an energy storage device operably connected to said power supply for storing electrical energy from 25
said power supply,
- (4) a controlled rectifier having (a) an anode-cathode circuit connected between said energy storage device and said spark discharge device to provide a discharge path therethrough for energy stored in said 30
energy storage device, and (b) a gate electrode operably connected to a
- (5) trigger circuit for causing said controlled rectifier to periodically conduct in timed proportion to engine speed to periodically discharge energy from said 35
energy storage device to said spark discharge device

in timed proportion to engine speed, said trigger circuit comprising

- (a) a solid state oscillator circuit operably connected to said power supply,
- (b) a pair of magnetically coupled coils operably connected to a control electrode of a transistor in said solid state oscillator,
- (c) a timing disc driven by said engine and having spaced apart portions of effective high permeability separated by areas of effective low permeability whereby rotation of said disc will serially cause variations in the magnetic coupling between said coils to cause programmed variations in the output frequency of said oscillator,
- (d) means operatively connected to the output of said oscillator and responsive to said programmed variations in output frequency to vary the amplitude of the output in timed proportion to engine speed,
- (e) means for detecting said programmed periods of output and for producing periodic sharp voltage variations in timed proportion to engine speed, and
- (f) means for applying said periodic voltage variations to said gate of said controlled rectifier to periodically fire said controlled rectifier in timed proportion to engine speed.

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