

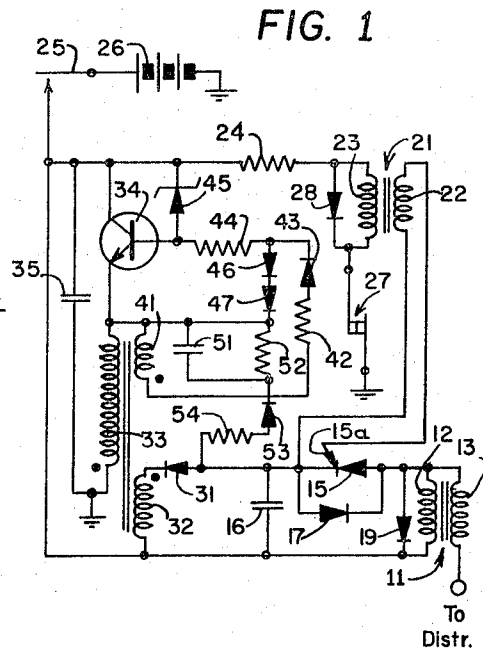
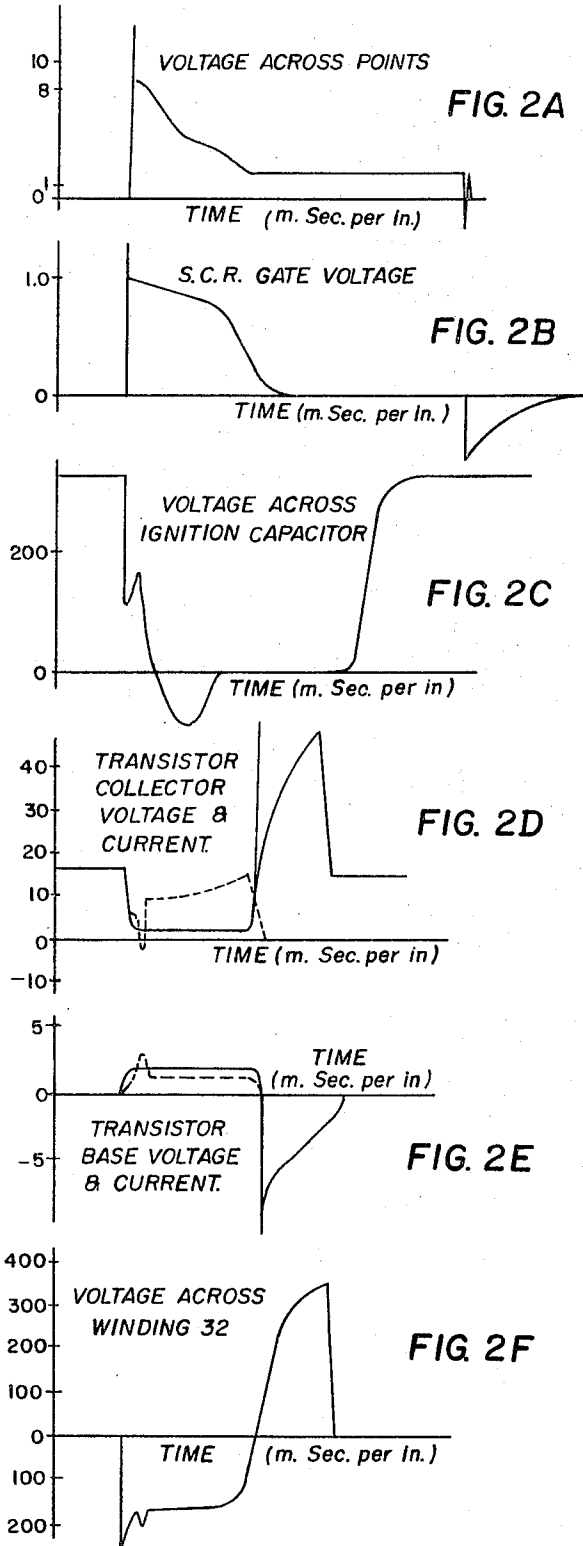
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A. G. HUFTON
ELECTRONIC APPARATUS

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2 Sheets-Sheet 1



Inventor
By Arthur G. Hufton
Mueller and Aichele
Attys.

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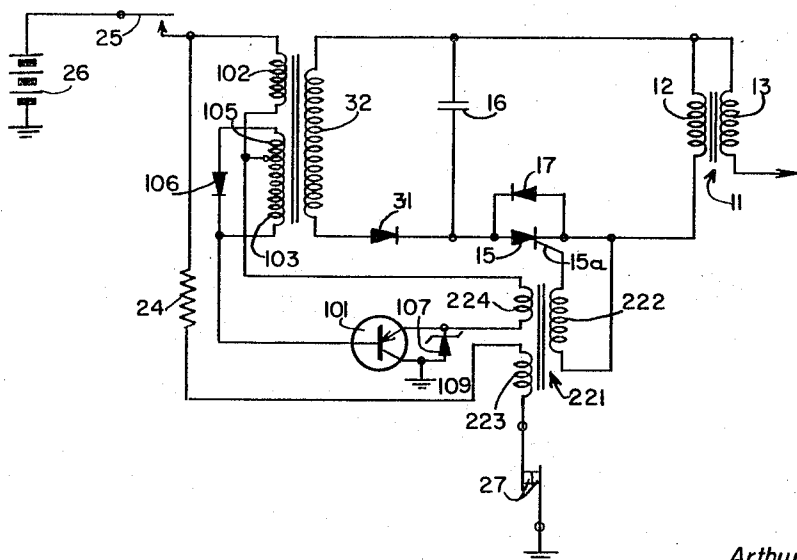
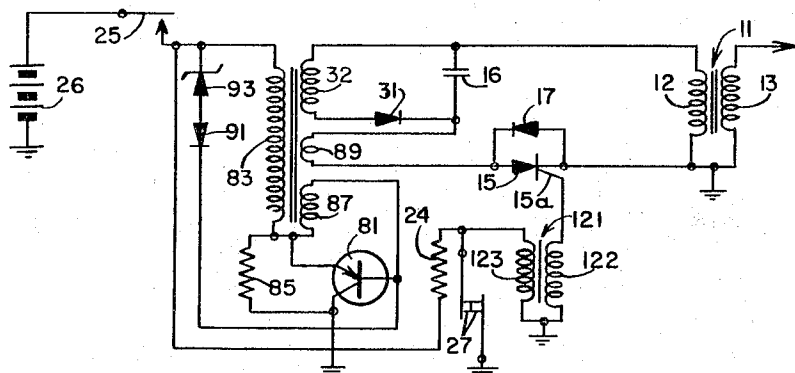
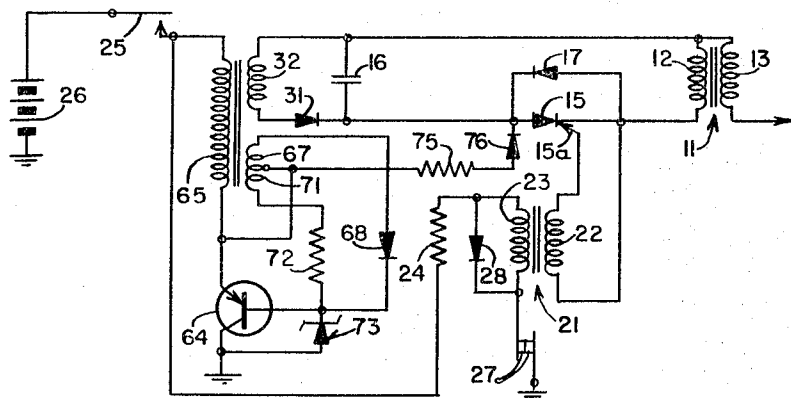
A. G. HUFTON

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2 Sheets-Sheet 2



Inventor
Arthur G. Hufton
By *Mueller and Richele*

Attys.

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ELECTRONIC APPARATUS

Arthur G. Hufton, Villa Park, Ill., assignor to Motorola, Inc., Franklin Park, Ill., a corporation of Illinois

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2

This invention relates to ignition systems for internal combustion engines, and more particularly to an improved ignition system of the capacitor discharge type.

Capacitor discharge ignition systems, that is, those systems which utilize a capacitor for intermittently discharging and causing current flow through an ignition coil, have been proposed over a long period of time. Such systems have been recognized as theoretically superior to other types of ignition systems but, as a practical matter, capacitor discharge systems have not been satisfactory. Many of the capacitor discharge systems proposed to date are complex and require excessive amounts of power for their operation. Often such systems fail to produce adequate voltage at low or high speeds and are unstable over variations in temperature and supply voltage.

Accordingly, it is an object of this invention to provide an improved, low cost ignition system for an internal combustion engine.

Another object of the invention is to provide a capacitor discharge ignition system which provides adequate firing voltages at low and high speeds, while utilizing a minimum of power.

Still another object of the invention is to provide a capacitor discharge ignition system which is stable and provides sufficient charge voltage to the storage capacitor over variations in source voltage and temperature.

A feature of the invention is the provision, in a capacitor discharge ignition system, of a charging circuit for the ignition capacitor which includes a saturable oscillator operative to provide a single charging pulse to the ignition capacitor upon the application of a triggering pulse to the oscillator.

Another feature of the invention is the provision, in a capacitor discharge ignition system, of a charging circuit for the ignition capacitor including a regenerative oscillator and means for initiating the operation thereof in synchronism with the internal combustion engine, and wherein the oscillator is coupled to a transformer which is saturable to cut off the oscillator after a single oscillation.

Still another feature of the invention is the provision, in a capacitor discharge ignition system, of a switch and a first winding coupled in series across a source of direct current, and a second winding coupled to the switch for controlling the operation thereof, and the further provision of a third winding coupled to the ignition capacitor for charging the same, with the second and third windings being inductively coupled to the first winding to form a transformer which is saturable after a period of time such that the capacitor is charged by a single pulse between firings.

In the drawings:

FIG. 1 is a schematic diagram of an ignition system constructed in accordance with the invention;

FIGS. 2A through 2F are curves illustrating characteristics of the ignition system of FIG. 1; and

FIGS. 3 through 5 are schematic diagrams of alternative embodiments of the invention.

The ignition system of the invention includes a firing circuit having an ignition capacitor and a switch for discharging the capacitor in synchronism with the engine to produce firing pulses. A charging circuit is coupled to the ignition capacitor for charging the capacitor between discharges. The charging circuit includes a saturable oscil-

lator operative to provide a single charging pulse to the ignition capacitor upon the application of a triggering pulse to the oscillator. A winding is coupled to the oscillator and is responsive to discharge of the ignition capacitor to apply a triggering pulse to the oscillator and initiate operation of the oscillator to recharge the ignition capacitor.

Referring now more particularly to FIG. 1, the ignition system shown therein is capable of use with either positive or negative ground systems. The ignition system includes an ignition coil 11 having a primary winding 12 and a secondary winding 13. Secondary winding 13 may be coupled to the center post of a distributor as is well known in the art. A semiconductor controlled rectifier 15 is connected in series with an ignition capacitor 16 across primary winding 12 of ignition coil 11. An oppositely poled diode 17 is connected across semiconductor controlled rectifier 15 to protect the rectifier from backswing voltages produced in the ignition coil 11. A diode 19 is connected across primary winding 12 and serves to reduce the amplitude of current reversals in the ignition coil secondary winding 13. This reduces the amount of electromagnetic radiation produced by the ignition coil and results in a corresponding reduction in radio interference noise.

Semiconductor controlled rectifier 15 is triggered in synchronism with the internal combustion engine by pulses applied to the gate 15a of rectifier 15. These pulses are coupled to gate 15a by means of a transformer 21 having a secondary winding 22 coupled between gate 15a and the cathode of rectifier 15. Transformer 21 has a primary winding 23 which is connected through resistor 24 and ignition switch 25 to a source of D.C. potential, storage battery 26. The opposite end of primary winding 23 is connected to ground by intermittently openable breaker points 27. Breaker points 27 may be the well known mechanical type breaker points synchronized with engine operation. Pulses may also be produced in secondary winding 22 by other means, within the scope of this invention, in order to synchronize the firing of semiconductor controlled rectifier 15 with the internal combustion engine. A diode 28 is connected across primary winding 23 of transformer 21 to damp out reverse transients.

When capacitor 16 is charged to the desired firing potential and controlled rectifier 15 is fired by a pulse applied to gate 15a, capacitor 16 will discharge through primary winding 12 of ignition coil 11. This produces a high voltage pulse in secondary winding 13 which is applied to the distributor for firing the fuel in the cylinders of the internal combustion engine. The voltage across the points 27 is shown in FIG. 2A. When the points open, the voltage thereacross will rise to a high value due to the inductance of primary winding 23. This voltage will then slowly decline to a steady state value, after which it will drop to zero upon closure of points 27. As may be seen from FIG. 2B, the initial spike of voltage across points 27 is coupled through transformer 21 to gate 15a. Transformer 21 is a step down transformer and the voltage on gate 15a first peaks to fire the semiconductor controlled rectifier 15, and then declines to a zero value, dropping to a small negative value upon enclosure of the points. Transients which could possibly fire semiconductor controlled rectifier 15 at the wrong time are damped out by diode 28.

For low power dissipation and maximum stability, it has been found advantageous to charge capacitor 16 by a single pulse stepped up to a high voltage. The charging circuit for capacitor 16 includes a diode 31 which is connected in series with capacitor 16 across a winding 32. Winding 32 is inductively coupled to a primary winding

3

33. Primary winding 33 is connected in series with the emitter and collector of transistor 34 and ignition switch 25 across the battery 26. A capacitor 35 is connected across transistor 34 and winding 33. It will be noted that transistor 34 is of the NPN type.

The circuit for controlling the conduction of transistor 34 will now be described. A winding 41 which is inductively coupled to winding 33 and winding 32, connects the emitter of transistor 34 through resistor 42 and diode 43 and resistor 44 to the base of transistor 34. A zener diode 45 connects the base and collector portions of transistor 34 for protective purposes. The base portion of transistor 34 is also connected to its emitter portion through resistor 44 and a pair of diodes 46 and 47 which provide a base to emitter bypass for limiting the base drive voltage. A capacitor 51, in parallel with a resistor 52, and series diode 53 and resistor 54 connect the emitter of transistor 34 to capacitor 16. This is for initiating operation of the system when the ignition switch 25 is first closed and when no charge is on capacitor 16, and will be described subsequently.

The operation of the circuit to charge capacitor 16 is initiated immediately subsequent to the firing of capacitor 16 through ignition coil 11. When capacitor 16 discharges, the inductance of the ignition primary 12 causes capacitor 16 to charge up in the reverse direction, that is, with the top part going positive and the lower part going negative. This places a voltage across winding 32 which is reflected in winding 41 such that the lower end of winding 41 goes positive and the upper end negative. The voltage across winding 41 is thereby impressed across the base and emitter of transistor 34, initiating conduction of the transistor. As the transistor conducts, current begins to flow in winding 33 and this increasing current continues to develop a voltage across winding 41 to maintain transistor 34 conductive. The transformer and associated circuitry are designed to saturate after a given length of time, which length of time is less than the time between firings of the semiconductor controlled rectifier 15. When the transformer saturates, no current is changing in winding 33 and, accordingly, transistor 34 is cut off. Cut off of current in winding 33 produces a collapsing field and the reverse voltage produced by this collapsing field in winding 32 is used to charge capacitor 16 for the next firing pulse.

The operation of the circuit with respect to time, as just described, may be observed from FIGS. 2C through 2F. FIG. 2C represents the voltage across capacitor 16. In FIG. 2D, the solid line represents the collector to emitter voltage of transistor 34, and the dotted line represents the collector current. It will be noted that in FIG. 2D there is a very large and sharp voltage spike 57 produced by winding 33 at saturation. This voltage spike is produced due to stray voltage charge and is extremely high and so fast that it is not reflected to any appreciable degree in any of the other windings of the transformer. The later voltage pulse, as a result of the collapsing fields in the core and windings, is shown by the broader spike 58 just to the right of the spike 57. In FIG. 2E, the solid line represents the base to emitter voltage on transistor 34 and the dotted line represents the base to emitter current. FIG. 2F shows the voltage across the winding 32. From these curves it will be seen that high voltage charging of capacitor 16 is obtained with a minimum of power drain.

As previously mentioned, capacitor 51, resistors 52 and 54, and diode 53 are for the purpose of initiating transistor conduction when ignition switch 25 is first closed and there is no charge on capacitor 16. When semiconductor controlled rectifier 15 is caused to conduct by pulses in transformer 21, current from the battery flows through diode 53 and winding 33, limited by resistors 52 and 54. The current flow in winding 33 induces a voltage in winding 41, causing forward biasing of transistor 34 and further increase in winding 33 current. Ultimately, the current in winding 33 is limited by the circuit resistance and

4

the oscillator is saturated. At this point, where current rate of increase is fastest and the voltage across the transistor 34 drops to a low level, the semiconductor controlled rectifier 15 is turned off because of insufficient current through resistor 52 to maintain conduction. After this initiation, subsequent conductions will take place at a given signal as previously described. This first conduction period serves to charge capacitor 16, and the system will then operate according to the description in the previous paragraph, without the need for resistors 52 and 54 and diode 53.

An operative ignition system in accordance with FIG. 1 has been constructed utilizing components of the following values:

- 15 Transistor 34—N.P.N. silicon transistor, Motorola 2N3448
- Controlled rectifier 15—Silicon controlled rectifier, Motorola 1304-6
- Diode 43—Silicon diode, Motorola SR-390, 1/4 watt, PIV 200 v.
- 20 Diode 31—Silicon diode, Motorola 1N4004, 1/4 watt, PIV 1000 v.
- Diode 17—Silicon diode, Motorola 1N4004, 1/4 watt, PIV 1000 v.
- Diode 53—Silicon diode, Motorola 1N4004, 1/4 watt, PIV 1000 v.
- 25 Diode 46—Silicon diode, Motorola SR-390, 1/4 watt, PIV 200 v.
- Diode 47—Silicon diode, Motorola SR-390, 1/4 watt, PIV 200 v.
- 30 Diode 28—Silicon diode, Motorola SR-390, 1/4 watt, PIV 200 v.
- Zener diode 45—Zener diode, Motorola SZ-1200, 56 volts, 1/4 watt
- Capacitor 16—1.0 microfarads, 400 v. D.C.
- 35 Capacitor 35—100 microfarads, 20 v. D.C.
- Capacitor 51—0.25 microfarads, 50 v. D.C.
- Resistor 24—20 ohms, 15 watt
- Resistor 52—4.7K ohms, 0.5 watt
- 40 Resistor 44—0.5 ohms, 1.0 watt
- Resistor 42—6.8 ohms, 5.0 watt
- Resistor 54—56.0 ohms, 0.5 watt

An alternative circuit configuration in accordance with the invention is shown in FIG. 3 and is for use with a negative ground system. The firing circuit for ignition coil 11 is substantially the same as that shown in FIG. 1, and accordingly identical numbering of the components is used. In addition, trigger transformer 21 is connected to the gate 15a of semiconductor controlled rectifier 15 in the same manner as in FIG. 1 and like numbering of this circuitry is therefore utilized.

The circuit for charging the ignition capacitor 16 is somewhat different from that shown in FIG. 1 and will now be described. A PNP transistor 64 series connects winding 65 across the source of potential through the ignition switch 25. A winding 67 is connected across the emitter and base portions of transistor 64 through a diode 68. A further winding 71 is connected across the emitter and base portions of transistor 64 through resistor 72. As shown in the drawing, windings 67 and 71 are part of the same inductive coil but it will be noted that the effect is the connection of oppositely wound coils across the base and emitter portions of transistor 64. A zener diode 73 is connected across the base and collector portions of transistor 64 for protective purposes. A resistor 75 and a diode 76 are connected in series from the emitter of transistor 64 to the juncture between capacitor 16 and semiconductor controlled rectifier 50.

When ignition switch 25 is first closed and the operation of the ignition system is to begin, the opening of breaker points 27 will render semiconductor controlled rectifier 15 conductive. At this time current will flow through winding 65 and diode 76, limited by resistor 75. The current in winding 65 is increasing and induces a voltage in winding 71 causing forward biasing of transistor

5

6

64. Winding 67 and diode 68 act to offset the forward bias in winding 71 to limit current through transistor 64. Ultimately, the current in winding 65 stops increasing due to saturation and the transistor is cut off. Just prior to cut off, current rate of increase is fastest and the voltage across transistor 64 drops to a low level. Thus, the semiconductor controlled rectifier 15 is turned off because of insufficient current through resistor 75 to maintain conduction. When transformer 64 is turned off, the collapsing field between inductively coupled windings 65 and 32 places a high voltage charge on capacitor 16. The system is now ready for normal operation.

In normal operation of the system, subsequent to first initiating the charging of capacitor 16, the resistor 75 and the diode 76 are no longer necessary, although they will have a slight effect. When points 27 open and semiconductor controlled rectifier 15 is rendered conductive, capacitor 16 discharges through ignition coil 11 to produce the firing pulse. After discharge of capacitor 16, a reverse voltage appears across winding 32. This voltage is reflected in winding 71 to forward bias transistor 64. When this reverse voltage dies out, the increasing current through winding 65 maintains the voltage in winding 71 in a proper direction to forward bias transistor 64.

In FIG. 4, those components having functions identical with the functions of the components in FIGS. 1 and 3 have been given identical numbers. It will be noted, therefore, that the firing circuit for capacitor 16 in FIG. 4 is substantially the same as that for the other figures, except for one modification which will be subsequently described. The trigger transformer for the semiconductor controlled rectifier 15, on the other hand, has its primary winding 123 connected in parallel with the breaker points 27. Secondary winding 122 of transformer 121 is connected between the gate 15a of the semiconductor controlled rectifier 15 and ground. The emitter-collector path of transistor 81 is connected in series with winding 83 across the battery 26 through ignition switch 25. A resistor 85 is connected across the emitter to collector path of transistor 81 and is of a relatively high value. A winding 87 is connected from the emitter to the base of transistor 81. A trigger winding 89 is connected in series with ignition capacitor 16 and semiconductor controlled rectifier 15. Windings 32, 89, 87 and 83 are all inductively coupled. A diode 91 and a zener diode 93 are connected across winding 83 and transistor 81 to protect the transistor from reverse transients in winding 83.

The operation of the circuit of FIG. 4 begins when ignition switch 25 is closed, thus causing a current flow through winding 83 and resistor 85. The current in winding 83 induces a current in winding 87 which forward biases transistor 81 and causes a rapid increase of current in winding 83, continuing the forward bias of transistor 81. This current build-up continues until saturation, at which time transistor 81 is cut off. The reverse voltage appearing across winding 32 is utilized to charge capacitor 16, as in the previous systems. When breaker points 27 open, causing a pulse on the gate 15a of semiconductor controlled rectifier 15, capacitor 16 discharges through the controlled rectifier 15 and the ignition coil 11, producing a high voltage ignition pulse. At the same time, discharge of the capacitor 16 through trigger winding 89 causes a voltage to be reflected in winding 87 which forward biases transistor 81 momentarily. This results in current flow through winding 83 which is transformed through winding 87 to maintain the forward bias on transistor 81 until the charging circuit saturates once more.

In FIG. 5, a still further embodiment of the invention is shown. Trigger transformer 221 includes a winding 223 series connected with the breaker points and limiting resistor 24. Transformer 21 also includes a secondary winding 222 which is connected between the gate 15a and the cathode of semiconductor controlled rectifier 15. Transformer 221 further includes winding 224. A

transistor 101 connects winding 224 in series with a further winding 102 through ignition switch 225 across the storage battery 26. A winding 103 is connected in series from the juncture between winding 102 and 224 to the base portion of transistor 101. Winding 103 and a further winding 105 comprise a single coil and the winding 105 thereof is connected from the juncture between windings 102 and 224 through a diode 106 to the base portion of transistor 101. Winding 102 and diode 106 serve as a current limiter on transistor 101 by opposing the forward bias placed thereon by the voltage across winding 103. The voltage across winding 103 is produced by reflection from the increasing current through winding 102.

When capacitor 16 is not charged, conduction of transistor 101 is initiated by the voltage produced in winding 224 when the breaker points 27 open. Once capacitor 16 is charged, the reverse voltage on winding 32 after discharge of capacitor 16 will induce a voltage in winding 103 sufficient to begin conduction of transistor 101 and winding 224 is no longer necessary to system operation. An ignition system constructed in accordance with the invention provides superior ignition performance and only draws current as required to give a substantially constant output over the entire engine speed range. The current drain at ordinary engine speeds is very low and the transistor utilized for switching operates at lower temperatures than continuous oscillator type systems. The system utilizes relatively few components for a lower cost and greater reliability. It may therefore be seen that the invention provides an improved low cost ignition system for internal combustion engines which provides adequate firing voltage at high speeds while utilizing a minimum of power, and which is stable and provides sufficient charge voltage to the storage capacitor over variations in source voltage and temperature.

I claim:

1. An ignition system of the capacitor discharge type, for an internal combustion engine, including in combination, a firing circuit including an ignition capacitor and means for discharging the same in synchronism with the engine to produce firing pulses, charging means coupled to said ignition capacitor for charging the same between discharges, said charging means including saturable oscillator means operative to provide a single charging pulse to said ignition capacitor upon the application of a trigger pulse to said oscillator means, and means coupling the ignition capacitor to said oscillator means so that the reverse voltage developed across said ignition capacitor is applied as a trigger pulse to said oscillator means to initiate operation of said oscillator means to recharge said ignition capacitor.

2. An ignition system of the capacitor discharge type, for an internal combustion engine, including in combination, a firing circuit including an ignition capacitor and a semi-conductor controlled rectifier connected in series with said ignition capacitor for discharging the same in synchronism with the engine to produce firing pulses, charging means coupled to said ignition capacitor for charging the same between discharges, said charging means including saturable oscillator means operative to provide a single charging pulse to said ignition capacitor upon the application of a trigger pulse to said oscillator means, and means coupled to said ignition capacitor and said oscillator means and responsive to discharge of said ignition capacitor to develop a reverse voltage across said ignition capacitor and to apply the same as a trigger pulse to said oscillator means to initiate operation of said oscillator means to recharge said ignition capacitor.

3. An ignition system of the capacitor discharge type, for an internal combustion engine, including in combination, a firing circuit including an ignition capacitor and means for discharging the same in synchronism with the engine to produce firing pulses, charging means coupled to said ignition capacitor for charging the same, said

charging means including oscillator means operative upon the application of a trigger pulse thereto, said oscillator means having transformer means saturable to cut off said oscillator means after a single oscillation to provide a single charging pulse to said ignition capacitor, and means coupling said ignition capacitor to said transformer means and applying the reverse voltage across said ignition capacitor following discharge thereof as a trigger pulse to said oscillator means to initiate operation of said oscillator means to recharge said ignition capacitor.

4. An ignition system for an internal combustion engine, including in combination, an ignition coil for providing high voltage firing pulses to the engine, an intermittently closable firing switch synchronized with the engine, an ignition capacitor connected in series with said firing switch across said ignition coil, a transistor having base, emitter and collector portions, first winding means connected in series with said emitter and collector portions of said transistor for connection across a source of direct current, second winding means connected in series between said base and emitter portions of said transistor, said second winding means being inductively coupled to said first winding means and being responsive to increasing current in said first winding means to bias said transistor into conduction, third winding means inductively coupled to said first and second winding means, rectifier means connected in series with said ignition capacitor across said third winding means for charging said capacitor, discharge of said ignition capacitor through said ignition coil upon closure of said firing switch causing the development of a reverse voltage across said ignition capacitor, said third winding means being responsive to the reverse voltage to induce a potential in said second winding means to forward bias said transistor and cause conduction thereof, said first winding means being constructed to saturate during a period of time after said transistor begins conduction which is less than the period of time between closures of said firing switch, said ignition capacitor being charged by said third winding means when said transformer saturates, whereby said ignition capacitor is charged by a single pulse of high voltage between discharges.

5. The combination of claim 4 including means for connecting said first winding means and said firing switch in series across the source of direct current to provide a current path through said first winding means for initiating conduction of said transistor.

6. The combination of claim 4 including fourth winding means connected in series with said ignition capacitor and said firing switch and inductively coupled to said second winding means to initiate conduction of said transistor when said firing switch closes.

7. The combination of claim 4 including transformer means connected to said firing switch for controlling the same, and fourth winding means connected in series with said second winding means and inductively coupled to said transformer means for rendering said transistor conductive when said firing switch closes.

8. The combination of claim 4 including a diode connected across said ignition coil for reducing the amplitude of current reversals therein.

9. An ignition system for an internal combustion engine, including in combination, an ignition coil for providing high voltage firing pulses to the engine, an intermittently closable firing switch synchronized with the engine, an ignition capacitor connected in series with said firing switch across said ignition coil, a transistor having base, emitter and collector portions, first winding means connected in series with said emitter and collector portions of said transistor for connection across a source of direct current, second winding means connected in series between said base and emitter portions of said transistor, said second winding means being inductively coupled to said first winding means and being responsive to increasing current in said first winding means to bias said tran-

sistor into conduction, inductive means coupled between said emitter and base portions of said transistor to limit bias current therebetween, third winding means inductively coupled to said first and second winding means, rectifier means connected in series with said ignition capacitor across said third winding means for charging said capacitor, said third winding means being responsive to discharge of said ignition capacitor through said ignition coil upon closure of said firing switch to induce a potential in said second winding means to forward bias said transistor and initiate conduction of same, said first winding means being constructed to saturate during a period of time after said transistor begins conduction which is less than the period of time between closures of said firing switch, said ignition capacitor being charged by said third winding means when said transformer saturates, whereby said ignition capacitor is charged by a single pulse of high voltage between discharges.

10. An ignition system for an internal combustion engine, including in combination, an ignition coil for providing high voltage firing pulses to the engine, an intermittently closable firing switch synchronized with the engine, an ignition capacitor connected in series with said firing switch across said ignition coil, a transistor having base, emitter and collector portions, first winding means connected in series with said emitter and collector portions of said transistor for connection across a source of direct current, second winding means connected in series between said base and emitter portions of said transistor, said second winding means being inductively coupled to said first winding means and being responsive to increasing current in said first winding means to bias said transistor into conduction, third winding means inductively coupled to said first and second winding means, rectifier means connected in series with said ignition capacitor across said third winding means for charging said capacitor, said third winding means being responsive to discharge of said ignition capacitor through said ignition coil upon closure of said firing switch to induce a potential in said second winding means to forward bias said transistor and cause conduction thereof, fourth winding means inductively coupled to said first winding means, said fourth winding means being connected between said emitter and base portions of said transistor and wound oppositely of said second winding means to limit emitter to base current, said first winding means being constructed to saturate during a period of time after said transistor begins conduction which is less than the period of time between closures of said firing switch, said ignition capacitor being charged by said third winding means when said transformer saturates, whereby said ignition capacitor is charged by a single pulse of high voltage between discharges.

11. An ignition system for an internal combustion engine including in combination, an ignition coil for providing high voltage firing pulses to the engine, an intermittently closable firing switch synchronized with the engine, an ignition capacitor connected in series with said firing switch across said ignition coil, means for connecting the junction between said ignition capacitor and said ignition coil to a source of direct current, an NPN transistor having base, emitter and collector portions, a transformer having a primary and first and second secondary windings, means for connecting said primary winding in series with said emitter and collector portions of said transistors across a source of direct current, means connecting said first secondary winding across said base and emitter portions of said transistor, serially connected resistance means and first rectifier means connected from the junction between said ignition capacitor and said firing switch to the junction between said emitter portion and said primary winding, to provide current in said primary winding when said firing switch closes for initiating conduction of said transistor, second rectifier means connecting said ignition capacitor across said second sec-

ondary winding for charging said capacitor, current limiting means connected between said base and emitter portions of said transistor and forming a base-to-emitter bypass for limiting bias current in said transistor, said second secondary winding and said first secondary winding being wound in a relation to cause said second secondary winding to reflect a voltage in said first secondary winding for biasing said transistor into conduction when said ignition capacitor discharges through said ignition coil upon closure of said firing switch, said transformer being saturable a period of time after said transistor begins conduction which is less than the period of time between closures of said firing switch, said ignition capacitor being charged by said second secondary winding when said transformer saturates, whereby said ignition capac-

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itor is discharged by a single pulse of high voltage between discharges.

References Cited by the Examiner

UNITED STATES PATENTS

3,032,684	5/1962	Kuykendall	-----	123—148	X
3,032,685	5/1962	Loomis	-----	123—148	X
3,051,870	8/1962	Kirk.			
3,263,124	7/1966	Stuermer.			
3,271,593	9/1966	De Vilbiss.			

MARK NEWMAN, *Primary Examiner.*

LAURENCE M. GOODRIDGE, *Examiner.*