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3,324,351

UNIT IMPULSE IGNITION SYSTEMS

Filed Feb. 19, 1964

2 Sheets-Sheet 1

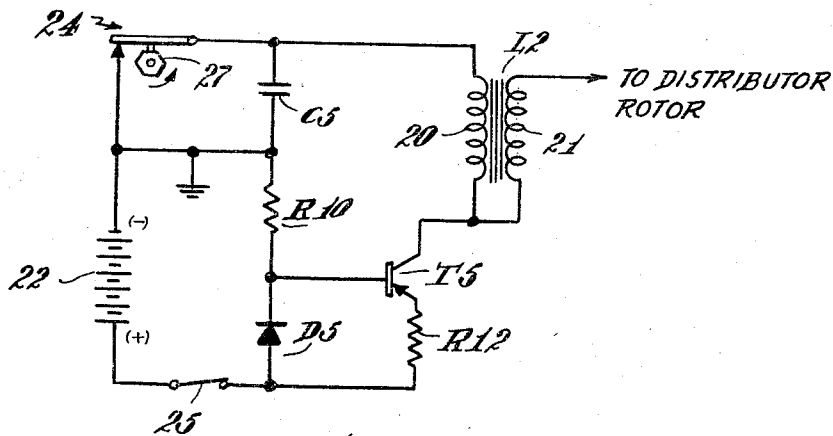


Fig. 1

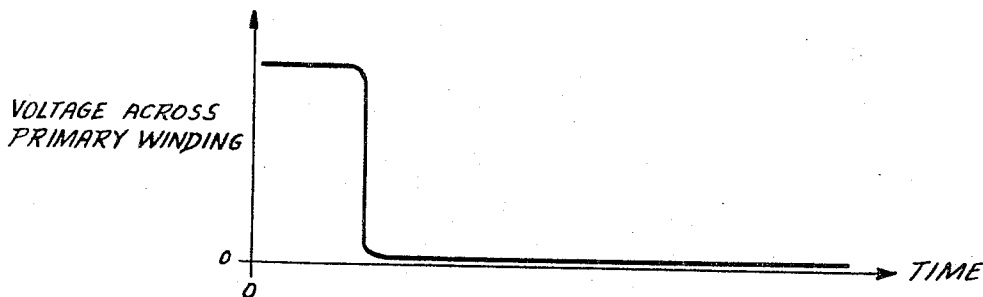


Fig. 2

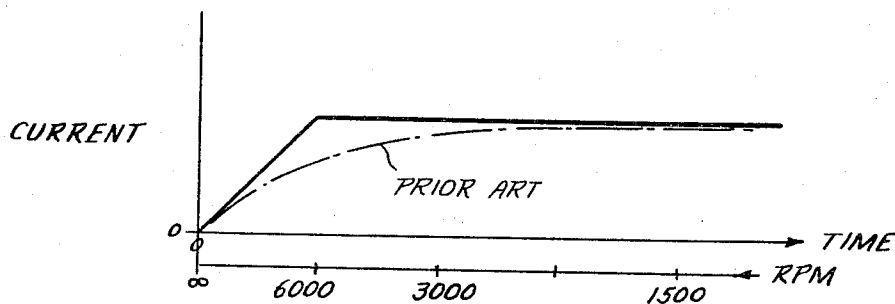


Fig. 3

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2 Sheets-Sheet 2

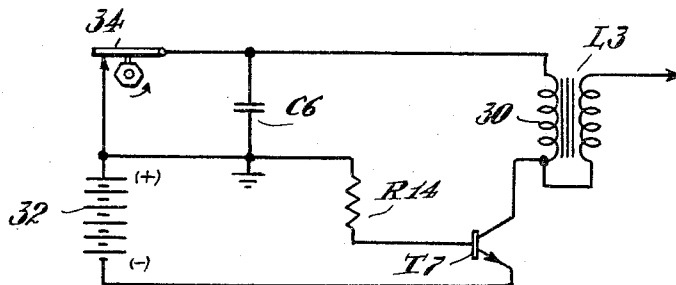


Fig. 4

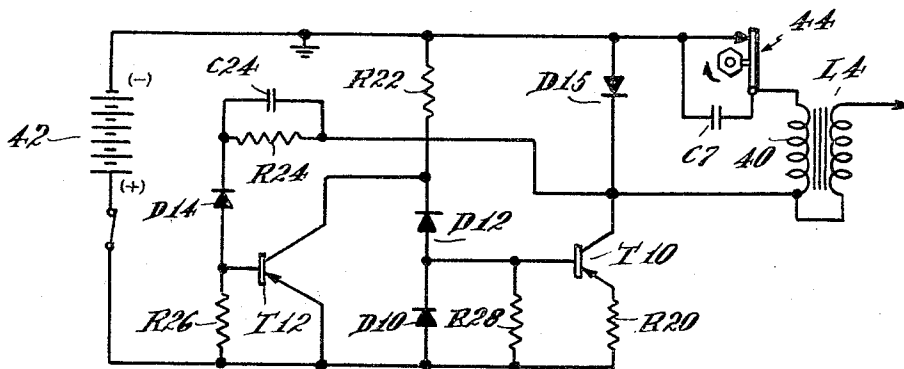


Fig. 5

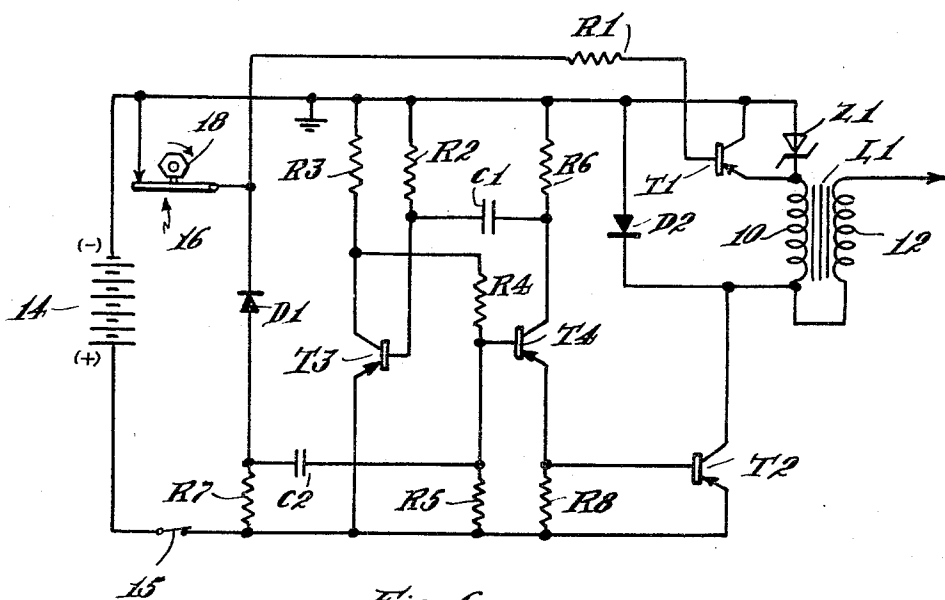


Fig. 6

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UNIT IMPULSE IGNITION SYSTEMS
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This invention relates to ignition systems for internal combustion engines and to inductive energy storage systems generally.

Most modern internal combustion engines are equipped with battery and spark coil ignition systems. The ignition coil has a low-voltage primary winding and a many-turned high voltage secondary winding. The coil develops the very high voltage necessary for proper ignition by a combination of inductive "kick" and transformer action. The primary winding is connected across the battery through a circuit which includes an ignition timing switch, commonly referred to as the ignition "points," and a series current limiting resistor. The series resistor may be a separate lumped resistance or may be a resistance distributed in the primary winding. The timing switch, usually incorporated into a distributor housing, is operated in synchronism with the engine, as by being driven from the valve-operating cam shaft.

When the points are closed, a current begins to flow through the primary winding, which current logarithmically approaches a limiting value determined by the series resistance. When the points open, an inductive kick is produced which typically develops more than a hundred volts across the points and tens of thousands of volts across the secondary winding. It should be understood that, all during the charging process, the source potential is divided in some proportion between the inductive reactance and the resistance in the primary circuit.

Conventional ignition systems as described above, possess three important disadvantages. Firstly, the inductive kick in the primary circuits causes appreciable burning of the distributor points despite the use of a small shunt condenser to limit the arcing. Secondly, at low speeds appreciable electric power is wasted in maintaining a heavy current through the primary circuit resistance after the inductively stored energy has already closely approached its maximum value. Thirdly, as engine speed increases, the primary current, which builds up according to its logarithmic characteristic, does not have time enough to closely approach its terminal value and thus the energy stored and hence the energy available for each spark falls off sharply. This latter problem is even more severe than the logarithmic characteristic of the charging pattern would indicate, since the energy stored in the inductance is proportional to the square of the current flowing in the primary winding.

Transistor ignition systems such as are now known in the art, have substantially solved the first problem by using a high power transistor switch or amplifier in the primary circuit. The transistor controls the heavy primary current and the points have only to handle a low level signal current. The transistor itself, since it is subjected to the inductive "kick" in place of the points, must typically be protected against over-voltage damage by a Zener diode.

The transistor ignition systems now available also typically attempt to alleviate the problem of reduced spark energy at higher speeds by employing ignition coils having a lower primary inductance, which are then charged to a higher current level. This expedient can be employed in these transistor systems since the higher current does not have to be switched by the points. This expedient does not, however, change the basic character of the problem, but only shifts upward the speed at which ignition energy fall-off becomes significant. This improvement in spark at

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high speed, however, is offset by a much higher demand for electrical power and an aggravation of the second enumerated problem, namely, the wasting of electric power in resistive dissipation at lower engine speeds.

Objects of the invention are to provide an electrical ignition system which provides an igniting impulse of uniform energy over a wide range of speeds, which does not waste electric power at low speeds, which produces a minimum of heat, which produces a hotter spark at high speeds than provided by conventional ignition systems, and which minimize burning of ignition-timing contact points.

Further objects are to provide such as ignition system in which the electric power consumed is a substantially linear function of engine speed.

In achieving these objects in an essentially conventional internal combustion engine ignition system having an ignition coil and a battery or other potential source associated therewith, the present invention contemplates apparatus which will apply the full source potential across the primary winding of the ignition coil until the current through the primary winding reaches a level such that sufficient energy is inductively stored in the coil to produce reliable ignition and which will then abruptly withdraw substantially the entire applied potential from the primary winding.

In certain preferred embodiments of the invention, current from the source is also stopped after sufficient energy is stored, and the release of the stored energy or inductive "kick" is delayed until the appropriate time by shunting the primary winding coil and the ignition timing switch means with a diode so as to provide a path or loop through which the primary winding current can persist or continue to flow after the current from the source has been cut off.

In one particular embodiment of the invention the full source potential is applied across the primary winding for a predetermined time interval, determined as by a one-shot multivibrator, appropriate for inducing the desired current level in the primary inductance.

For the purpose of illustration, presently preferred embodiments of the invention are shown in the accompanying drawings in which:

FIG. 1 is a schematic representation of a constant current ignition coil charging apparatus.

FIG. 2 is a graphical representative of the behavior of the voltage appearing across the primary winding in the apparatus of FIG. 1 during charging.

FIG. 3 is a graphical representation of charging current characteristics of the apparatus of FIG. 1 and of a conventional ignitional system.

FIG. 4 is a schematic representation of a modification of the apparatus of FIG. 1.

FIG. 5 is a schematic representation of a current sensing coil charging apparatus employing current loop energy storage.

FIG. 6 is a schematic representation of a timed coil charging apparatus also employing current loop energy storage.

An ignition impulse of uniform energy can be obtained over a wide range of engine speed with the relatively simple and inexpensive apparatus shown in FIG. 1. In this apparatus energy is inductively stored in the primary winding of an essentially conventional ignition coil by applying the full available source potential across the primary winding until the current passing therethrough reaches an appropriate value, and then abruptly withdrawing substantially the entire applied potential from the primary winding. The primary winding current, however, continues to flow from the source.

With reference to FIG. 1, L2 is an essentially conventional ignition coil having a primary winding 20 and a high-voltage secondary winding 21, one end of which is

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connected to one end of the primary winding and the other end of which is adapted for connection to a conventional distributor rotor in usual manner. The ignition apparatus is illustrated in association with a conventional negative-ground automotive electrical system including a twelve-volt storage battery 22, an ignition switch 25 and a set of ignition timing points 24. The points 24 are conventionally operated in synchronism with the internal combustion cycle of the engine by a six-lobed cam 27, there being one lobe on the cam for each cylinder of the engine. A conventional ignition condenser C5 shunts the points 24.

The primary winding 20 is connected across the potential source (the battery 22) by a circuit which includes, in series, the ignition timing points 24 and a high power germanium PNP switching transistor T5. The transistor T5 is connected in such a manner that it functions as a current-limiting or constant-current device. A silicon diode D5 is connected between the base of the transistor T5 and the positive terminal of the battery 22, the cathode of the diode being connected to the base of the transistor. Resistor R10, one end of which is grounded and the other end of which is connected to the base of the transistor T5, biases the diode D5 and the emitter-base junction of the transistor T5 in the forward direction. A resistor R12, in the emitter circuit of the transistor T5, provides a degeneration of its amplifying action. Since the forward voltage drop across the silicon diode D5 is about 0.5 volt and is thus larger than the emitter-base voltage drop (about 0.2 volt) in the germanium transistor T5 and is, in the circuit shown, relatively constant, a substantially constant voltage drive is provided for the transistor T5. Given such a voltage drive, the transistor T5 will conduct into saturation until the current in the emitter-collector circuit reaches such a level that the degenerative action of resistor R12 comes into effect and reduces the emitter-base voltage. At this point the collector circuit of the transistor T5 changes from a low impedance or saturated characteristic to a very high impedance or constant-current characteristic.

The operation of this circuit in cooperation with the ignition coil L2 is as follows. When the points 24 close, the transistor T5 is driven into saturation and substantially the entire battery voltage is applied across the primary winding 20. With the full source potential so applied, the current in the primary winding 20 rises linearly at a rate determined essentially solely by the battery voltage and the primary inductance of the coil. When the current in the primary circuit reaches the level at which the voltage drop across the resistor R12 becomes appreciable, the current level stops rising and assumes a constant level. Since the effective collector impedance at this point is high and since there is no reactive voltage developed in the primary 20, the voltage across the primary winding will drop abruptly from nearly the source potential to nearly zero and substantially the entire battery potential will appear across the transistor T5. The behavior with respect to time of the voltage appearing across the primary winding is shown graphically in FIG. 2. It should be noted that the interval over which the source potential appears across the primary winding 20 is predetermined by the value of the source potential, the current level to which the primary winding is to be charged, and the inductance of the primary winding.

Since the energy stored in the ignition coil L2 is uniform with uniform primary current, the energy available for each spark impulse will be the same at all engine speeds, provided only that there is sufficient time for the current in the primary to reach its full value with the full battery potential applied. The current charging characteristic with time of the primary winding 20 is shown in FIGURE 3. The behavior of the apparatus of FIG. 1 is represented by the solid line and, as may be seen, the current in the primary circuit rises linearly with time until the desired value is reached and then remains constant.

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For comparison purposes, the behavior of a conventional ignition system, having the same primary inductance but with the peak value of current determined by a series resistor, is shown by the broken line. A scale of corresponding engine speeds is shown below the time scale, engine speed being of course a reciprocal function of the charging time.

Up to that speed at which the coil's own primary inductance limits its charging, the two curves diverge with increasing engine speeds, the current in the conventional system falling off while that provided by the apparatus of FIG. 1 remains constant. At the inductance limited speed (6,000 r.p.m.), the separation between the two curves is quite marked, the current in the primary winding of the conventional system being only about 65 percent of that provided by the invention. The difference in energy values is, of course, even more marked since the energy available is proportional to the square of the primary current. The energy stored in the conventional system at this speed is in fact less than half of that provided by the apparatus of FIG. 1.

While the apparatus of FIG. 1 is thus seen to give markedly superior performance at higher engine speed it should be noted that the peak current drain is the same for both systems. The apparatus of FIG. 1 in general operation draws only slightly more power than the conventional system for the reason that its power consumption does not fall off as much at higher speeds as does that of a conventional system which uses resistive current limiting.

FIG. 4 illustrates apparatus similar to that shown in FIG. 1, except that it employs current drive for the series transistor. In this circuit the primary winding 30 of an ignition coil L3 is connected across battery 32 by a circuit which includes breaker points 34 and an NPN silicon power transistor T7. A conventional ignition condenser C6 shunts the points 34. Substantially constant current drive is provided through the base of the transistor by resistor R14. If the gain of the transistor T7 is relatively constant and its leakage is low, this circuit will operate in a manner very similar to the apparatus of FIG. 1. The full battery voltage will be applied across the primary winding 30 until the current in the primary circuit reaches a set value determined by the resistor R14 and the gain of the transistor T7, at which point substantially the entire battery voltage will appear across the transistor and the voltage applied across the primary winding 30 will abruptly drop to nearly zero. The necessary characteristics for the transistor T7 can be met by high quality silicon power transistor, although these are quite expensive. It should be noted that the system illustrated by FIG. 3 employs a positive ground, although a negative ground system can be straight-forwardly arranged if ignition timing points are provided in which neither contact is grounded. It should further be noted that the transistors shown in FIGS. 1 and 4 must be adequately heat-sinked since, once the coil is charged, substantial power is dissipated in the transistor.

According to another aspect of the invention, the dissipation of power in the series transistors used in the devices shown in FIGS. 1 and 3 can be substantially eliminated thereby providing a net power saving and reducing the strain on those transistors. The invention accomplishes this by providing means for turning the series transistor completely off when the desired current level in the coil is achieved, and by providing an alternate path through which current in the primary winding can continue flowing until the appropriate time for releasing the stored energy in the form of an inductive "kick."

A circuit providing these functions is shown in FIG. 5. In this circuit, the primary winding 40 of an ignition coil L4, is connected across battery 42 by a circuit which includes conventional ignition timing points 44 and a PNP germanium power transistor T-10. A conventional ignition condenser C7 shunts the points 44. If desired,

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a transistor switch can advantageously be substituted for the points 44, according to the various schemes taught in the prior art, so as to avoid burning of the points.

As in FIG. 1, a forward-biased silicon diode D-10 provides an essentially constant voltage drive to the base of transistor T10, and a resistor R20 determines, by degeneration, the current value to which the primary winding 40 will be charged. Current drive in the manner of FIG. 4 could be alternatively employed. The diode D10 and the emitter-base junction of the transmitter T10 are normally biased in the forward direction by current from the resistor R22, which also flows through a forward biased silicon diode D12 for a purpose discussed hereinafter. The collector of the power transistor T10 is connected, through current limiting resistor R24 and a forward biased silicon diode D14, to the base of a PNP germanium driver transistor T12.

When the points 44 first close the transistor T10 is saturated and substantially the full source voltage is applied across the primary winding 40. As very little voltage appears across the transistor T10, virtually no current drive is available to the base of the transistor T12 through resistor R24. The forward voltage drop across the silicon diode D14 is employed to insure that the transistor T12 can be completely cut off in this manner. A low voltage Zener diode could, of course, also be employed in place of diode D14. Resistor R26 shunts any small leakage currents.

When the current in the primary winding 40 approaches the desired level and the voltage across the transistor T10 abruptly increases in the manner described with reference to FIG. 1, drive current is applied to the base of transistor T12 through the resistor R24. The collector of transistor T12 is connected with the resistor R22 as its load so that, when the transistor T12 begins to conduct, drive current is diverted away from the base circuit of the transistor T10. The forward voltage drop across the silicon diode D12 is employed to insure that the transistor T10 can be completely cut off in this manner and resistor R28 shunts any leakage currents which might enable transistor T10 to remain partially conductive. A capacitor C24 bridging the resistor R24 speeds the switching in a manner which is conventional in trigger and multivibrator circuitry.

As it would be premature to have the spark impulse be released when the transistor T10 is cut off rather than when the points 44 open, a low forward resistance diode D15 is connected in shunting relation across the points 44 and the primary winding 40 so as to provide an alternate path for the current built up in the primary winding 40. The diode D15 is oriented so as to be reverse-biased and non-conducting when the battery voltage is being applied across the primary winding 40 and so as to be forward biased by the reactive voltage developed in the primary winding 40 when its external current supply is shut off. Thus, when the transistor T10 is cut off, current can continue to flow around a loop including the primary winding and thus the energy stored in the ignition coil can be retained until the points 44 open releasing an inductive "kick."

While the current in the primary winding 40 rises during the charging of the coil at a rate which is proportional to the source voltage, i.e., twelve volts, the current which persists after the turning off of transistor T10 will diminish only at a rate determined by the various small back voltages which are developed around the loop. These back voltages include the resistive voltage drop in the primary winding 40 and the voltage drop across the diode D15. To minimize the rate at which the persistent current is dissipated it is preferable that D15 be a germanium diode, rather than silicon because of the smaller barrier voltage involved. However, silicon diodes are more common in the high current ratings and may, in many cases, be entirely satisfactory if the interval over which the

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stored current must persist before the opening of the points 44 is not too long at idling speed.

Since the persisting current in the primary diminishes only slowly, the stored energy available for producing an ignition spark will remain relatively uniform over a fairly wide range of speeds even though the engine speed and the operational closed time for the points 44 vary over fairly wide ranges. Further, since virtually all of the electric power consumed is stored in the coil and then released as spark impulses, it will be apparent to those skilled in the art that the power consumed by this system is a substantially linear function of engine speed.

For starting an engine at low cranking speeds where the decay of the persistent current might be unacceptable, a switch, operable simultaneously with the starting motor, can be provided which disconnects the collector of transistor T12 from R22 and thus makes the operation of the device of FIG. 5 virtually identical with that of FIG. 1.

While the present invention is described herein with particular reference to the internal combustion engine ignition systems with which it is significantly useful, it will be apparent to those skilled in the art that the principles demonstrated in the illustrative embodiments are applicable to many situations in which energy is to be inductively stored and particularly so when energy is to be inductively stored for release at an indefinite later time. The claims appended hereto should be construed accordingly.

FIG. 6 illustrates an embodiment of the invention in which a predetermined quantity of energy is inductively stored into the primary winding of an ignition coil by applying the full source potential across the primary winding for a predetermined time interval. Since, under such conditions of constant applied potential the current in the primary winding will rise linearly with time and since the inductance of the primary winding is substantially constant, the time interval necessary to store the appropriate amount of energy is also constant. In operation the time interval is conveniently controlled by a one-shot multivibrator.

Referring to FIG. 6, L1 is an essentially conventional ignition coil having a primary winding 10 and a high-voltage secondary winding 12, one end of which is connected to one end of the primary winding and the other end of which is adapted for connection to a conventional distributor rotor in usual manner. The ignition apparatus is illustrated in association with a conventional automotive electrical system including a 12-volt battery 14, an ignition switch 15, and a set of ignition timing points 16. The points 16 are conventionally operated in synchronism with the internal combustion cycle of the engine by a six-lobed cam 18, there being one lobe on the cam for each cylinder in the engine. One end of the primary winding 10 is connected to ground through a PNP power-switching transistor T1. This transistor is connected in an emitter-follower configuration as is conventional in prior art transistorized ignition systems and is operated in synchronization with the timing points 16 by the connection of the base of the transistor to the ungrounded contact through current limiting resistor R1. As this transistor T1 is subjected to the inductive "kick" of the ignition coil, it is preferably protected against over-voltage damage by a high-power Zener diode Z1 which will become conductive if the peak voltage across the primary winding 10 approaches the maximum voltage rating of the transistor T1.

The other end of the primary winding 10 is connected to the positive terminal of the battery through a PNP power-switching transistor T2. Switching transistor T2 is periodically energized by an essentially conventional one-shot multivibrator, employing transistors T3 and T4, which in turn is triggered by the closing of the ignition timing points 16. It should be understood that transistors such as T2 are to be included within the term "switch" as

used herein although that term is intended also to include mechanical switches.

The connection and operation of the one-shot multivibrator is as follows. When the multivibrator is in its normal or "off" state, transistor T3 is biased into conduction by resistor R2. When T3 is conducting, current flows through its load resistor R3 and the voltage at the collector of T3 becomes positive with respect to ground. Transistor T4, which is driven from the collector circuit of transistor T3 through the resistive dividing network R4-R5, is thereby cut off and no current flows through its load resistor R6. In this "off" state, timing capacitor C1 is charged to a potential substantially equal to the source voltage.

The base of transistor T4 is connected to the ungrounded timing contact through coupling capacitor C2 and diode D1. The nominal voltage at the junction between capacitor C2 and diode D1, is maintained substantially at the positive source potential by bleeder resistor R7. When the timing points 16 close, thereby signaling the beginning of a charging period, the capacitor C2 passes a negative-going pulse which drives transistor T4 into conduction and triggers the multivibrator circuit into an "on" state. When T4 conducts, the voltage at its collector becomes more positive due to the current flowing in load resistor R6 and this positive-going pulse is coupled through capacitor C1 to the base of transistor T3 thereby cutting that transistor off. When T3 is cut off, the withdrawal of current from load resistor R3 causes the collector of transistor T3 to become more negative and additional drive current is supplied through R3 to the base of transistor T4. This drive is regenerative with the original negative-going pulse so that transistor T4 remains conductive so long as timing capacitor C1 is sufficiently charged to hold transistor T3 in a cutoff state. Gradually, however, current through R2 discharges the capacitor C1 so that transistor T3 is again permitted to become conductive and the multivibrator reverts to its original "off" state. As will be understood by those skilled in the art the time interval over which the multivibrator is in its "on" state is determined essentially by the relative values of resistor R2 and capacitor C1 and is relatively independent of the time interval over which the timing points 16 are closed. For the purposes of the invention, the "on" time of the multivibrator is made shorter than the operational closed time of the ignition timing points for the highest speed at which the internal combustion engine is to run.

The emitter of multivibrator transistor T4 is connected to the base of the power switching transistor T2 so that the transistor T2 will be turned on when the multivibrator is in its "on" state. The inductance of the primary winding 10 of the ignition coil L1 is chosen so that sufficient energy for a satisfactory spark will be inductively stored within the "on" time interval chosen when the full source potential is applied across the primary. The resistor R8 assures that the power switching transistor T2 will be turned completely off when the multivibrator is in its "off" state by shunting any leakage current.

As the turning off of the transistor T2 at the end of the multivibrator "on" period would otherwise cause an undesired and premature inductive "kick," the primary winding 10 and the power switching transistor T1 are shunted by a low forward-resistance diode D2 so as to form a sort of persistent current loop. This diode D2 is oriented so as to provide a path through which a current, induced in the primary winding 10 when both power switching transistors T1 and T2 were conductive, can continue flowing substantially uninterrupted through the primary winding during the varying interval between the turning off of transistor T2 and the opening of the ignition timing points 16, at which latter time the inductive kick is released developing a high voltage in the secondary winding 12 suitable for igniting an air-gas mixture.

While the current in the primary winding 10 rises dur-

ing the charging of the coil at a rate which is proportional to the source voltage, i.e. twelve volts, the current which persists after the turning off of transistor T2 will diminish only at a rate determined by the various small back voltages which are developed around the loop which includes the primary winding 10, transistor T1 and the diode D2. To minimize the rate at which the persistent current is dissipated it is again preferable that D2 be a germanium diode rather than silicon because of its smaller barrier voltage.

Since the persisting current diminishes only slowly after the multivibrator returns to its "off" state, the energy available for sparking will fairly constant over a wide range of engine speeds. On the other hand, since energy is taken into the coil only over a predetermined time interval for each spark impulse required, the power drain will be essentially proportional to engine speed and very little energy will be wasted.

For starting at low cranking speeds a switch, operable simultaneously with the starting motor, can be provided with a conventional, resistively limited source of current to the primary winding 10.

While the use of a persisting current loop is an advantageous method of delaying the release of inductively stored energy so that the uniform spark energy advantages provided by the devices shown in FIGS. 5 and 6 can be obtained in internal combustion engines having conventional timing means, the shunting diode which forms this loop can be omitted if the operating and timing of the "points" is modified so that ignition occurring a predetermined time after the closing of the ignition timing switch is at an appropriate time within the internal combustion cycle.

While particular embodiments have been described by way of illustration it should be understood that the present invention includes all modifications and equivalents falling within the scope of the appended claims.

I claim:

1. Apparatus for charging the primary winding of an ignition coil of an internal combustion engine having an associated electrical system including a potential source, one end of said primary winding being connectable to one side of said potential source through ignition timing switch means operable in synchronism with said engine, said charging apparatus comprising: means for connecting the other end of said primary winding to the other side of said source to apply the source potential across said primary winding for a predetermined time interval only after the closing of said timing switch means; and means shunting said primary winding and said timing switch means for permitting a current to flow through said coil after said interval but while said timing switch is closed.

2. Coil charging apparatus according to claim 1 in which the last said means is a semi-conductor diode.

3. An ignition system for internal combustion engines having an associated potential source comprising: an ignition coil having a primary winding; first switch means operable in synchronism with the engine for periodically connecting one end of said primary winding to one side of said source; a second switch means which closes substantially simultaneously with the closing of this first switch means and which opens a predetermined time interval thereafter for connecting the other end of said primary winding to the other side of said source, said interval being shorter than the operational closed time of said first switch means; and diode means connecting said other end of said primary winding to said one side of said source, the polarity of said diode means being such as to permit a current, induced in said coil by said source when both said switch means are closed, to continue flowing through the coil during the interval between the opening of said second switch means and the opening of said first switch means.

4. An ignition system for internal combustion engines having an associated potential source comprising: an ignition coil having a primary winding; first switch means operable in synchronism with the engine; a second switch means which opens a predetermined time interval after closing, the closing and opening of said second switch means both occurring within the operational interval between the closing and opening of said first switch means, the two said switch means and said primary winding being connected in series across said potential source; and diode means shunting said primary winding and said first switch means for permitting a current, induced in said coil when both said switch means are closed, to continue flowing during the interval between the opening of said second switch means and the opening of said first switch means.

5. An ignition system for internal combustion engines having an associated potential source comprising: an ignition coil having a primary winding; a set of ignition timing breaker points operable in synchronism with the engine; a first transistor; a second transistor; said transistors and said primary winding being connected in series across the potential source; means for turning each of said transistors on when said points close and for turning said first transistor off when said points open; means for turning said second transistor off a predetermined interval after the closing of said points, said interval being shorter than the operational closed time of said points; and diode means shunting said primary winding and said first transistor for permitting a current to continue to flow through said coil when said second transistor is turned off.

6. For use with an internal combustion engine ignition system which includes an electric potential source, an ignition coil having a primary winding and a set of ignition timing points operable in synchronism with the engine, an ignition impulse controlling system comprising: a first power transistor; means for switching said first power transistor on when said points are closed; a transistor one-shot multivibrator means arranged to be triggered to an "on" state upon the closing of said points and to revert to an "off" state a predetermined time interval thereafter, said interval being shorter than the operational closed time of the said points; a second power transistor arranged so as to be turned on when said multivibrator means is in an "on" state, said first and second power transistors and the primary winding of said coil being connected in series across said source; and diode means shunting said primary winding and said first power transistor, the polarity of said diode means being such as to permit a current, induced in said coil when both of said power transistors are on, to continue flowing through the coil during the interval between the return of said multivibrator means to an "off" state and the opening of said points.

7. For use with an internal combustion engine ignition system which includes an electric current source, an ignition coil having a primary winding, and a set of ignition timing breaker points operable in synchronism with the engine, an ignition impulse controlling system comprising: a first power transistor means for connecting one end of said primary winding to one side of said source when said points are closed; a two-transistor one-shot multivibrator means arranged to be triggered to an "on" state upon the closing of said points and to revert to an "off" state a predetermined interval thereafter, said interval being shorter than the operational closed time of said points; a second power transistor means, the base of which is connected to the emitter of that multivibrator means transistor which is conductive when said multivibrator is in an "on" state, for connecting the other end of said coil to the other side of said source; diode means shunting said primary winding and said first power transistor, said diode being oriented so as to be reverse biased when said power transistors are both on; and Zener diode

means for protecting said first power transistor from the inductive kick of said primary winding.

8. Apparatus for charging the primary winding of the ignition coil of an internal combustion engine having an associated electrical system including a potential source and timing switch means for periodically connecting one end of said primary winding to a first side of said potential source, said charging apparatus comprising: a power transistor; means for connecting the collector of said transistor to the other end of the primary winding; a current value determining resistor for connecting the emitter of said transistor to a second side of said potential source; and means for establishing a fixed, predetermined reference potential at the base of said transistor relative to said second side of said potential source, said means including a constant voltage reference device connecting the base of the transistor to said second side of said potential source and a resistor connecting the base of the transistor to said first side of said potential source; whereby said primary winding is charged to a current level determined by the value of said current value determining resistor in relation to the magnitude of said reference potential.

9. Apparatus for charging the primary winding of the ignition coil in an internal combustion engine having an associated negative-ground electrical system comprising: means including timing switch means operable in synchronism with the engine for connecting the negative terminal of the primary winding to ground; a PNP germanium power transistor; means for connecting the collector of said transistor to the positive terminal of the primary winding; a current-value-determining resistor for connecting the emitter of said transistor to a positive potential source in said electrical system; a silicon diode connecting the base of said transistor to said positive potential source, the cathode of said diode being connected to said base; and a resistor for connecting the base of said transistor to ground so as to forward-bias said silicon diode and the emitter-base junction of said germanium transistor.

10. An ignition system for an internal combustion engine comprising: an ignition coil having a primary winding; ignition timing switch means in series with said primary winding; and means in series with said winding and responsive to the level of current flow therethrough for applying a substantially constant source potential across said primary winding until the current through said primary winding reaches a predetermined value and then withdrawing the applied current independently of any further operation of said timing switch means; and a diode shunting said primary winding and said switch means for permitting a current to continue flowing through said coil after the applied current is withdrawn.

11. An ignition system for an internal combustion engine having an associated potential source comprising: an ignition coil having a primary winding; ignition timing switch means operable in synchronism with the engine; a second switch means connected in series with said primary winding and with said ignition timing switch means across said potential source; means, responsive to the magnitude of current flowing through said coil when both of said switch means are closed, for opening said second switch means when the current reaches a predetermined value; and diode means shunting said primary winding and said ignition timing switch means, said diode means being oriented so as to permit a current, induced in said coil from said source when both said switch means are closed, to continue flowing during the interval between the opening of said second switch means and the opening of the ignition timing switch means.

12. An ignition system for an internal combustion engine comprising: an ignition coil having a primary winding; ignition timing switch means operable in synchronism with said engine in series with said primary winding; a power switching transistor the emitter-collector circuit

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of which is in series with said primary winding and said timing switch; means for connecting a potential source across said series connected winding, switch means and transistor; means for driving said transistor to a predetermined current level; and means, responsive to the voltage of the collector of said transistor, for providing positive feed-back to said transistor so as to reduce the drive and cut off the transistor when the collector voltage rises, thereby accelerating the rise and cutting off of the transistor.

13. An ignition system for an internal combustion engine having an associated potential source comprising: an ignition coil having a primary winding; ignition timing switch means operable in synchronism with said engine in series with said primary winding; a power switching transistor the emitter-collector circuit of which is in series with said primary winding and said timing switch; means for connecting a potential source across said series connected winding, switch means and transistor; means for providing a predetermined current drive to the base of said transistor; means, responsive to the voltage of the collector of said transistor, for providing positive feed-back to the base of said transistor so as to reduce the current drive and cut off the transistor when the collector voltage rises, thereby accelerating the rise and cutting off of the transistor; and diode means bridging said primary winding and said ignition timing switch means for permitting current induced in said primary winding through said power transistor to continue flowing after said transistor is cut off until said ignition timing switch means is open.

14. An ignition system for an internal combustion engine comprising: an ignition coil having a primary winding; ignition timing switch means operable in synchronism with said engine in series with said primary winding; a power switching transistor the emitter-collector circuit of which is in series with said primary winding and said timing switch; means for connecting a potential source across said series connected winding, switch means and transistor; means for providing a predetermined voltage drive to the base of said transistor; a current value determining resistor in the emitter circuit of said transistor; means, responsive to the voltage of the collector of said transistor, for providing positive feed-back to the base of said transistor so as to remove the voltage drive and cut off the transistor when the collector voltage rises,

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thereby accelerating the rise and cutting off of the transistor; and diode means bridging said primary winding and said ignition timing switch means for permitting current induced in said primary winding through said power transistor to continue flowing after said transistor is cut off until said ignition timing switch means is open.

15. An ignition system for an internal combustion engine having an associated potential source comprising: an ignition coil having a primary winding; ignition timing switch means operable in synchronism with said engine in series with said primary winding; a power transistor, the collector of which is connected to said primary winding; means for connecting a potential source across the series connected winding, switch means and emitter-collector circuit of said power transistor; a driver transistor; means for direct current coupling the collector of said power transistor to the base of said driver transistor; means for direct current coupling the collector of said driver transistor to the base of said power transistor; a resistive load interconnecting the collector of said driver transistor with one end of said source; means for connecting the emitter of said driver transistor to the other end of said source; and diode means shunting said primary winding and said ignition timing switch means for permitting a current to continue to flow through said primary winding when said power transistor is cut off by regeneration between said transistors.

16. An ignition system according to claim 15 further comprising means providing a predetermined current drive to said power transistor.

17. An ignition system according to claim 15 further comprising a substantially constant voltage drive applied to the base of said power transistor and a current value determining resistor in the emitter circuit of said power transistor.

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