Aug. 10, 1965 LE ROY E. DILGER 3,200,291

IGNITION SYSTEM

Filed Jan. 23, 1961 2 Sheets-Sheet 1

FIG. 1

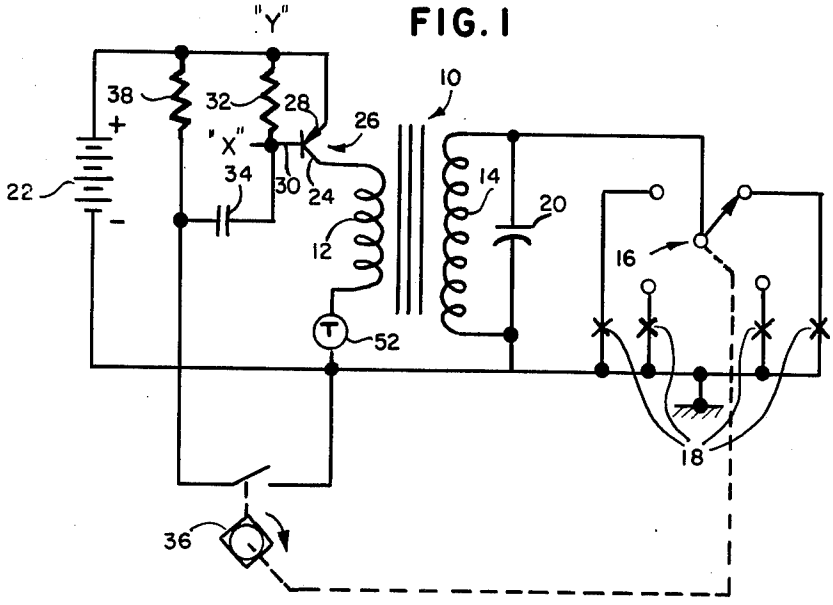
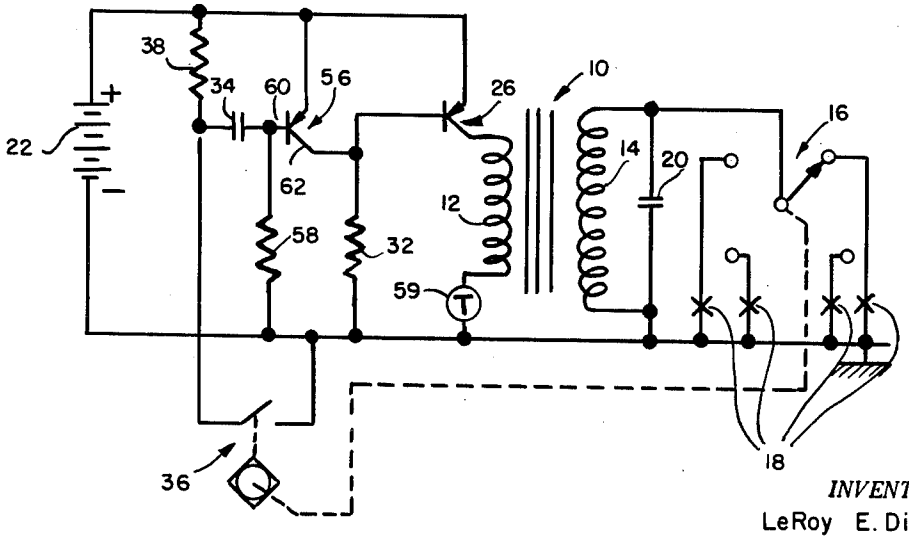


FIG. 2



INVENTOR.
LeRoy E. Dilger
BY John W. Michael
Attorney

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IGNITION SYSTEM

Filed Jan. 23, 1961 2 Sheets-Sheet 2

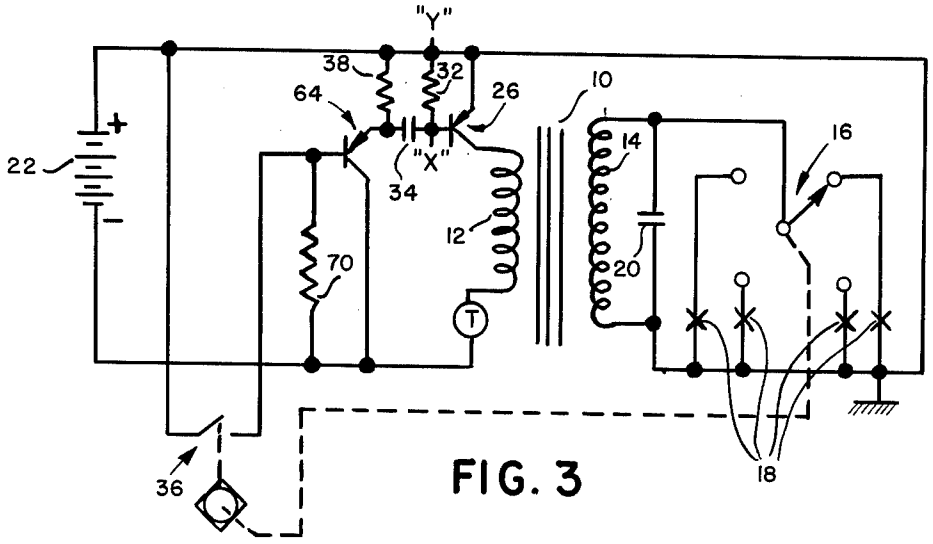

FIG. 3

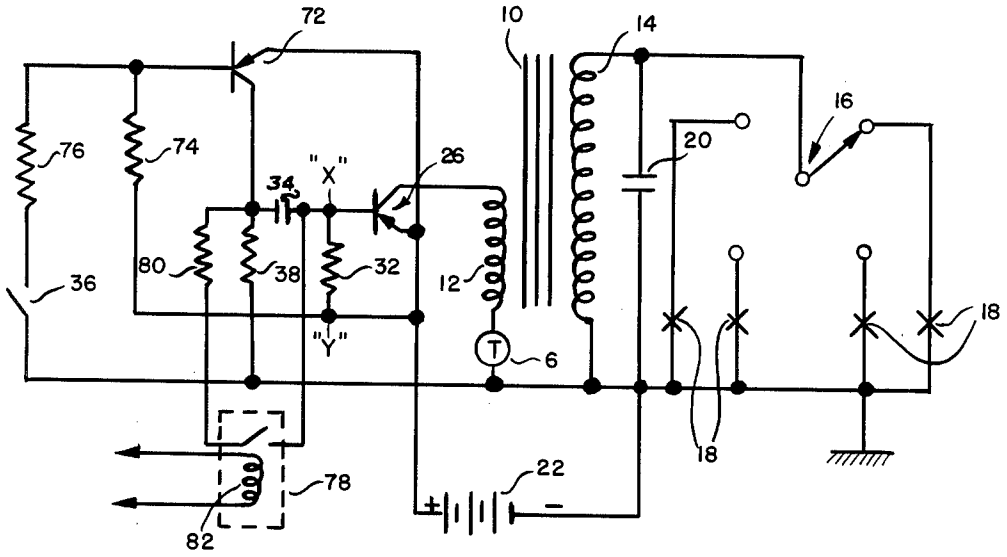

FIG. 5

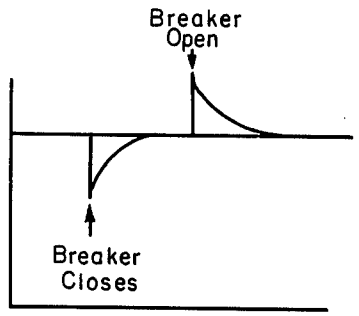

FIG. 4

INVENTOR.
LeRoy E. Dilger

BY John W. Michael

Attorney

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IGNITION SYSTEM

Le Roy E. Dilger, Milwaukee, Wis., assignor to Globe-Union Inc., Milwaukee, Wis., a corporation of Delaware

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20 Claims. (Cl. 315—205)

This invention relates to transistorized ignition systems for internal combustion engines.

Battery operated ignition systems used with internal combustion engines store the energy for ignition in the magnetic field of an ignition coil. This energy is proportional to the product of the amperes of current flowing through and the number of turns of wire in the coil. With the upper limit of current fixed at about six amperes, it becomes necessary to have considerable inductance (a large number of turns) in the coil in order to store sufficient energy for ignition. The time that it takes for the current in the coil to reach full value is proportional to the inductance of the coil. Thus, it can be seen that the more turns there are in the coil, the longer the time it will take for the primary current to reach full value. At high speed, with multi-cylinder engines, the primary coil current reaches only a fraction of its full value and available ignition power is reduced proportionately.

Considerable power is also wasted at low engine speed because the primary current must be maintained at full level ready for the time of ignition. With the times for ignition widely spaced, as they are at low engine speed, much power is wasted in the form of heat which causes bluing of the breaker contacts and deterioration of the coil insulation. Breaker contact life is further shortened because the contacts must break a current of 4 to 6 amperes flowing in the high-inductance primary of the ignition coil. The arc caused by the rapid decay of current in the ignition coil results in severe erosion of the breaker contacts and deterioration of ignition performance.

The primary object of the present invention is to provide an ignition system in which the full value of the ignition power is available at high engine speeds and not wasted at low engine speeds.

Another object of this invention is to provide an ignition system in which the circuit breaker will have lessened erosion and longer life.

A further object is to increase the thermal content of the spark across the spark gap.

Another object is to provide an ignition system which has high instantaneous currents in the ignition coil primary.

Still another object is to provide an ignition system having more precise switching at high engine speeds and greater operating life.

A still further object is to provide a more efficient ignition system by drawing heavy current only during the actual ignition pulse.

Still another object is to provide an ignition system with substantially constant energy for each spark throughout the entire engine speed range.

A final object is to increase the energy at the plugs when starting the engine.

These objects are accomplished by the circuitry of this invention. A low inductance step-up transformer, that is, one having a small number of turns in its primary and its secondary, increases the voltage to a level suitable for ignition by means of the well known principles of induction. A transistor is used to control the current through the primary of the step-up transformer with a differentiating circuit connected to the base of the transistor to decrease current flow exponentially from a maximum to a minimum. Due to the low inductance of the primary coil and the high momentary current flow from the transistor, a voltage will be induced immediately in the secondary coil at a sufficiently high level to produce a spark suitable for proper ignition. For starting, a shunt circuit is used to bypass the differentiating circuit and cause the transistor to deliver more power until the engine starts, thus providing a more intense spark to start the engine.

Other objects and advantages will be pointed out in, or be apparent from, the specification and claims, as will obvious modifications of the embodiments shown in the drawings, in which:

FIG. 1 is a circuit diagram of an ignition system which will fire when the circuit breaker is closed;

FIG. 2 is a circuit diagram of a modified ignition system that fires when the circuit breaker is opened;

FIG. 3 is a variation of FIG. 1 arranged for firing when the circuit breaker opens and the positive side of the battery is grounded;

FIG. 4 is a drawing of the waveform which appears across "X," "Y" in FIG. 1; and

FIG. 5 is a circuit diagram of a modified ignition system which includes a shunt circuit for starting.

The ignition systems shown in the drawings each include a low inductance type step-up transformer **10** having a primary winding **12** and a secondary winding **14** connected to a distributor **16** which routes the current pulse induced in the secondary winding to sparking devices **18**. Because of the relatively small number of turns in the primary winding, the inductance of the transformer is low and current flow through the primary winding will reach a maximum almost instantly inducing a voltage in the secondary winding which will initially charge capacitor **20** until the voltage is sufficient to bridge the natural gap in the distributor, at which time the capacitor will discharge across the sparking devices. This build up of voltage in the capacitor increases the thermal content of the spark by consolidating the energy available and giving it up in an extremely short time. The instantaneous power dissipated in the spark is much greater than that normally dissipated in conventional systems.

The primary winding **12** of the transformer is connected to the negative terminal of battery **22** and to collector **24** of transistor **26**. Emitter **28** is connected to the positive terminal of the battery. The base **30** of the transistor is connected to a differentiating circuit which includes a first resistor **32**, a capacitor **34** and a circuit breaker **36** serially connected across the battery. A second resistor **38** is connected in parallel with resistor **32** and capacitor **34**. Considering the operation of the differentiating circuit only with reference to the voltage waveform (FIG. 4) between point "X" and point "Y," it can be seen that with the circuit breaker open, the circuit is quiescent. At the precise instant that the circuit breaker is closed, the entire voltage drop will appear across resistor **32** due to the charging of capacitor **34**. Point "X" will be negative with respect to point "Y." The capacitor will accumulate a charge at an exponential rate and the voltage across resistor **32** will drop at an exponential rate until the total supply voltage appears across capacitor **34**. When the circuit breaker is opened, the capacitor will discharge through resistor **38** and resistor **32** in series. The voltage across resistor **32** will rise instantly to a value determined by the ratio of the two resistances. The voltage at point "X" will then be positive with respect to point "Y." The capacitor will discharge at an exponential rate and the voltage across resistor **32** will drop to zero at an exponential rate.

Referring now to FIG. 1, it can be seen that resistance **32** forms the input circuit for transistor **26** with point "X" at base **30** and point "Y" at emitter **28**. Transistor **26** operates at cut-off (no collector current flowing) by virtue of having the base connected to the positive side of the battery through resistor **32**. The sharp negative swing of voltage at point "X," when circuit breaker **36** closes,

makes the base of the transistor negative with respect to the emitter and the transistor conducts heavily with its collector current passing through the primary of the transformer. Typical values of collector current are from 30 to 50 amperes compared to a maximum of six amperes in conventional systems. The sudden current passing through the transformer primary winding causes a voltage to be induced immediately across the secondary winding due to the low inductance of the transformer. The voltage from the secondary winding charges capacitor **20** until the voltage in the seocndary circuit reaches a value sufficient to bridge the normal gap of the distributor and then discharges across the spark plug. The distributor, operating in synchronism with the circuit breaker and the engine, will route the voltage to the proper spark plug. This arrangement makes it possible to enhance the thermal content of the spark by consolidating the energy available at the seocndary winding and giving it up in an extremely short time. The instantaneous power dissipated in the spark is much greater than that dissipated in conventional systems.

After the initial sharp turn-on pulse, the voltage applied to the base of the transistor will decay at an exponential rate (FIG. 4) and quickly returns the transistor to the cut-off condition. Thus it can be seen that the transistor carries current for only a very brief instant and there is no unnecessary dissipation. The positive pulse occuring when the breaker **36** opens only drives the transistor further into the cut-off region. An ammeter **52** inserted in the position shown or as indicated in dotted lines will indicate increasing current with increasing speed and can be calibrated in terms of speed so that it may function as a tachometer.

Where a system is required which will fire the circuit breaker opens (FIG. 2), a phase inversion amplifier is inserted between capacitor **34** and resistor **32** in order to use the positive pulse of the differentiating circuit for firing. The amplifier includes a second transistor **56** and a resistor **58** as shown in FIG. 2. The base **60** of the transistor is connected to the negative terminal of battery **22** through resistor **58** in order to bias the transistor to its full conduction. The collector **62** of the transistor is connected through resistor **32** to the battery to cause a voltage drop across resistor **32** that is very nearly equal to the supply voltage. This voltage drop has a positive polarity at the collector end of resistance **32** which is connected directly to the base of transistor **26** and holds transistor **26** at collector current cut-off.

Capacitor **34** is charged by the battery when the circuit breaker is opened. When the circuit breaker is closed, the capacitor will discharge through resistance **58**. This increases momentarily the negative polarity of the base of transistor **56**. Since transistor **56** is fully conducting as the result of the fixed negative bias, it cannot be made more conductive by the negative pulse resulting from the closure of breaker **4**. As a result there is no net change in the rest of the circuit.

At the precise instant that the circuit breaker opens, capacitor **34** will start to charge. The charging current is drawn through resistor **58** and resistor **38**. At that precise instant of opening, a positive voltage of a value determined by the resistance of resistors **38** and **58** and also the base circuit resistance of transistor **56**, appears at the base of transistor **56**. This positive pulse momentarily drives transistor **56** into collector current cut-off. The collector of transistor **56** and the base of transistor **26** will be brought toward the potential of the negative supply terminal. The negative potential at the base of transistor **26** drives it into full conduction and the remainder of the circuit functions as in FIG. 1. As the capacitor continues to charge, the positive voltage across resistor **58** decays to zero and the circuit returns to its initial quiescent condition. An ammeter **59** can also be connected to this circuit to act as a tachometer as described above.

The circuit shown in FIG. 3 is for use with electrical systems having the positive battery terminal grounded to the chassis of the engine and is designed to fire when the circuit breaker opens. The circuit is similar to the circuit described in FIG. 1 except that transistor **64** is used as the circuit breaker and circuit breaker **36** is used to control the conductivity of the transistor **64**. When circuit breaker **36** is closed, transistor **64** is biased to cut-off. Its base is returned directly to the positive battery terminal through the circuit breaker. Transistor **26** is at cut-off with its base returned to the positive battery terminal through resistor **32**. Capacitor **34** has no charge because the emitter of transistor **64** is also connected to the battery positive terminal through resistor **32**.

At the precise instant that the circuit breaker opens, transistor **64** goes into full conduction because its base circuit is now returned to the negative terminal of the battery through resistor **70**. Capacitor **34** charges through the transistor **64** and resistor **32**. The charging current causes a negative voltage to a appear at point "X" which drives transistor **24** into full conduction. As the charge on the capacitor approaches full charge, the voltage drop across resistor **32** falls to zero and the action of the remainder of the circuit is the same as that described above. Closing the circuit breaker shifts transistor **64** back to the cut-off condition. Capacitor **34** discharges through resistor **38** and resistor **32** creating a positive pulse at point "X" which only drives transistor **24** further into collector current shut-off.

The circuit shown in FIG. 5 is for use in ignition systems having the negative battery terminal grounded and is designed to fire when the circuit breaker opens. The transformer secondary winding **14** functions as above with the current induced in the secondary winding charging capacitor **20** until the voltage in the secondary circuit is sufficient to bridge the normal gap of distributor **16** causing a spark across the sparking devices **18**.

Transistor **72** is used as a switch to control the charging of capacitor **34**. With circuit breaker **36** closed, transistor **72** is biased to full conduction by virtue of the voltage appearing at the junction of resistors **74** and **76** serially connected across battery **22**. These resistors from a voltage divider across the battery when the circuit breaker is closed and the voltage at their junction is selected to cause full conduction of the transistor. At full conduction there is very little voltage drop across transistor **72**, therefore, the left side of capacitor **34** is, in effect, connected to the positive battery terminal. The right side of the capacitor is also returned to the positive terminal of the battery. Since both sides of the capacitor are returned to the positive side of the battery, the capacitor has no charge.

At the instant circuit breaker **36** opens, transistor **72** is biased to cut-off because its base is now returned to the positive battery terminal through resistor **74**. With transistor **72** at cut-off, capacitor **34** is now effectively in series with resistors **38** and **32** across battery **22**. The capacitor draws a heavy charging current that is at a maximum when the contacts open and decays to zero before they close again. The charging current across resistor **32** causes a voltage drop across resistor **32** of such polarity as to drive transistor **26** into full conduction. When the voltage again falls low enough during the exponential decay, transistor **26** will return to collector current cut-off. The abrupt turn-on of transistor **26** causes full current flow through primary winding **12** which induces the ignition voltage in the secondary winding.

When the circuit breaker again closes, capacitor **34** discharges through transistor **72** collector-emitter circuit and resistor **32**. The discharge of capacitor **34** causes a voltage drop across resistor **32** of a polarity at the base of transistor **26** to drive it to collector current cut-off.

Because of the drain on the battery while driving the starting motor, the energy at the plugs will be at a minimum during starting. To increase the energy available

during starting, resistor 80 and solenoid switch 82 are serially connected across capacitor 34. Coil 84 of the solenoid switch is connected to the coil terminal of the starter relay to close the switch when the starter relay is energized. This biases transistor 26 into conduction during the entire period that the circuit breaker 36 is open for each firing interval. This permits more energy to be delivered to the plugs than would be the case if during such period the transistor cut-off the flow exponentially as in normal operation. De-energizing of the starter relay allows switch 82 to open and the circuit operates normally.

Although but a few embodiments of the present invention have been illustrated and described, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit of the invention or from the scope of the appended claims.

I claim:

1. An ignition system for an internal combustion engine having a number of spark plugs comprising, a low inductance transformer having a primary winding and a secondary winding, a unidirectional voltage power supply, a transistor having its emitter connected to the positive terminal of the power supply and its collector to one end of the primary winding, the other end of the primary winding being connected to the negative terminal of the power supply, differentiating circuit means connected across the power supply and without any impedance component interposed directly to the base of the transistor to provide an initially high bias current to the base of the transistor which decreases exponentially, and voltage distribution means connected to the secondary winding to distribute the voltage induced in the secondary winding by the current flow in the primary winding to the spark plugs.

2. An ignition system according to claim 1 wherein said differentiating circuit means includes circuit breaker means so that the transistor is conductive only when the circuit breaker is closed.

3. An ignition system according to claim 2 including phase inversion circuit means connected between the differentiating circuit means and the base of the transistor so that the transistor is conductive when the circuit breaker is opened.

4. An ignition system according to claim 3 including a second transistor means controlled by the circuit breaker so that the first transistor is controlled by the second transistor.

5. An ignition system for an internal combustion engine having a number of spark plugs comprising, a low inductance transformer having a primary winding and a secondary winding, a unidirectional voltage power supply, a transistor having its emitter connected to the positive terminal of the power supply and its collector to one end of the primary winding, the other end of the primary winding being connected to the negative terminal of the power supply, circuit means including a capacitor connected across the power supply and without any impedance component interposed directly to the base of the transistor to provide an initially high bias current to the base of the transistor which decreases exponentially, said circuit means including a circuit breaker to control the charging of the capacitor, said transistor being conductive only when the capacitor is charging, and voltage distribution means connected to the secondary winding to distribute the voltage induced in the secondary winding by the current flowing from the primary winding to the spark plugs.

6. An ignition system according to claim 5 wherein said circuit means includes a first resistance member connected in series with the capacitor and a second resistance member connected in parallel with the first resistance member and the capacitor.

7. An ignition system according to claim 6 wherein the breaker means and distribution means are timed so that when the distribution means is positioned to energize a spark plug the breaker means will be closed.

8. An ignition system according to claim 7 including an ammeter connected between the negative terminal of the power supply and the primary winding to indicate the engine speed in relation to current rise through the winding.

9. An ignition system for an internal combustion engine having a number of spark plugs comprising, a transformer having a primary winding and a secondary winding, a unidirectional voltage power supply, a first transistor having its emitter connected to the positive terminal of the power supply and its collector to one end of the primary winding, the other end of the primary winding being connected to the negative terminal of the battery, differentiating circuit means including a circuit breaker connected across the power supply, a phase inversion amplifier connected across the power supply including a second transistor having its base connected to the differentiating circuit and its collector connected to the base of the first transistor, said second transistor being operative when the circuit breaker is closed to drive the first transistor to collector current cut-off, said differentiating circuit driving the second transistor momentarily to collect current cut-off when the circuit breaker is opened, allowing the first transistor to momentarily operate at full conductance, and voltage distribution means connected to the secondary winding to distribute the voltage induced in the secondary winding by the current flow in the primary winding to the spark plugs.

10. An ignition system according to claim 9 wherein the circuit breaker and distribution means are timed so that circuit breaker is open only when the distribution means is positioned to energize a spark plug.

11. An ignition system for an internal combustion engine having a number of spark plugs comprising, a low inductance transformer having a primary winding of a few turns and a secondary winding, a unidirectional voltage power supply, a first transistor having its emitter connected to the positive terminal of the power supply and its collector to one end of the primary winding, the other end of the winding being connected to the negative terminal of the power supply, differentiating circuit means including a first and second resistor and a capacitor connected across the power supply and to the base of the transistor, a transistorized circuit means connected in series with the differentiating circuit and a circuit breaker connected to control the energization of the transistorized circuit means whereby the first transistor is conductive only when the transistorized circuit means is conductive, and voltage distribution means including a capacitor connected across the secondary winding to energize one of the spark plugs when the secondary voltage reaches a predetermined level.

12. An ignition system according to claim 11 wherein the circuit breaker and distribution means are timed so that circuit breaker is opened only when the distribution means is positioned to energize a spark plug.

13. An ignition system for an internal combustion engine having a number of spark plugs comprising, a low inductance transformer having a primary winding and a secondary winding, a unidirectional voltage power supply, a first transistor having its emitter connected to the positive terminal of the power supply and its collector to one end of the primary winding, the other end of the winding being connected to the negative terminal of the power supply, differentiating circuit means including a resistance and a capacitance connected across the power supply and without any impedance component interposed directly to the base of the transistor, circuit breaker means for controlling energization of the differentiating circuit to momentarily drive the transistor to full conductance when the circuit breaker is open, and voltage distribution means connected across the secondary winding to energize one of the spark plugs when the secondary voltage reaches a predetermined level.

14. An ignition system according to claim 13 wherein

said circuit breaker means includes a second transistor connected to control the differentiating circuit whereby said differentiating circuit is operative to drive the first transistor momentarily to full conductance when the second transistor is non-conductive.

15. An ignition system according to claim 14 including a shunt circuit having a solenoid switch connecting the second transistor to the first transistor whereby said first transistor is fully conductive during the periods when the circuit breaker is open and the solenoid switch is closed.

16. An ignition system for an internal combustion engine having a spark plug comprising, a low inductance transformer having a primary winding and a secondary winding connected to the spark plug, a unidirectional voltage power supply, a transistor having its emitter connected to the positive terminal of the power supply and its collector connected to one end of the primary winding, the other end of the primary winding being connected to the negative terminal of the power supply, impedance circuit means connected across the power supply and without any impedance component interposed directly to the base of the transistor to control current conduction through the transistor, circuit breaker means connected to the circuit impedance means so that the impedance means allows an initially high current to flow through the transistor, said current decreasing exponentially to a low value, and a capacitive means connected across the secondary winding to enhance the thermal content of the spark by discharging across the spark plug when the voltage in the secondary reaches a predetermined level.

17. An ignition system according to claim 16 wherein said impedance circuit includes a first resistance and a capacitance serially connected to the circuit breaker means with the base of the transistor being connected to the junction of the resistance and capacitance and a second resistance connection in parallel with the serially connected first resistance and capacitance.

18. An ignition system according to claim 17 wherein the circuit breaker means includes a second transistor having its emitter connected to the junction of the second resistor and the capacitor and its collector to the negative terminal of the power source, said first transistor being conductive when the second transistor is non-conductive.

19. An ignition system according to claim 16 wherein said impedance circuit includes a first resistance, a capacitance and a second resistance serially connected across the battery with the base of the first transistor connected to the junction of the capacitor with the first resistor, said circuit breaker means including a second transistor having its emitter connected to the positive terminal of the battery and its collector to the junction of the capacitor with the second resistor, and a voltage divider circuit connected across the power supply end to the base of the second transistor whereby current flowing across the voltage divider will cause the second transistor to conduct, causing the impedance circuit to bias the first transistor to conduct current fully momentarily.

20. An ignition system according to claim 19 including a shunt circuit for the capacitor to allow the first transistor to conduct fully during the entire time that the second transistor is not conducting.

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GEORGE N. WESTBY, *Primary Examiner.*

RALPH G. NILSON, *Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,200,291 August 10, 1965

Le Roy E. Dilger

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 7, line 37, for "connection" read -- connected --.

Signed and sealed this 1st day of February 1966.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents