United States Patent

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[54] **DUAL SPARK CAPACITOR DISCHARGE IGNITION SYSTEM**
4 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **123/148,** 315/209
[51] **Int. Cl.** **F02p 3/06**
[50] **Field of Search** 123/148E, 32E-1; 315/209, 218; 307/88.5

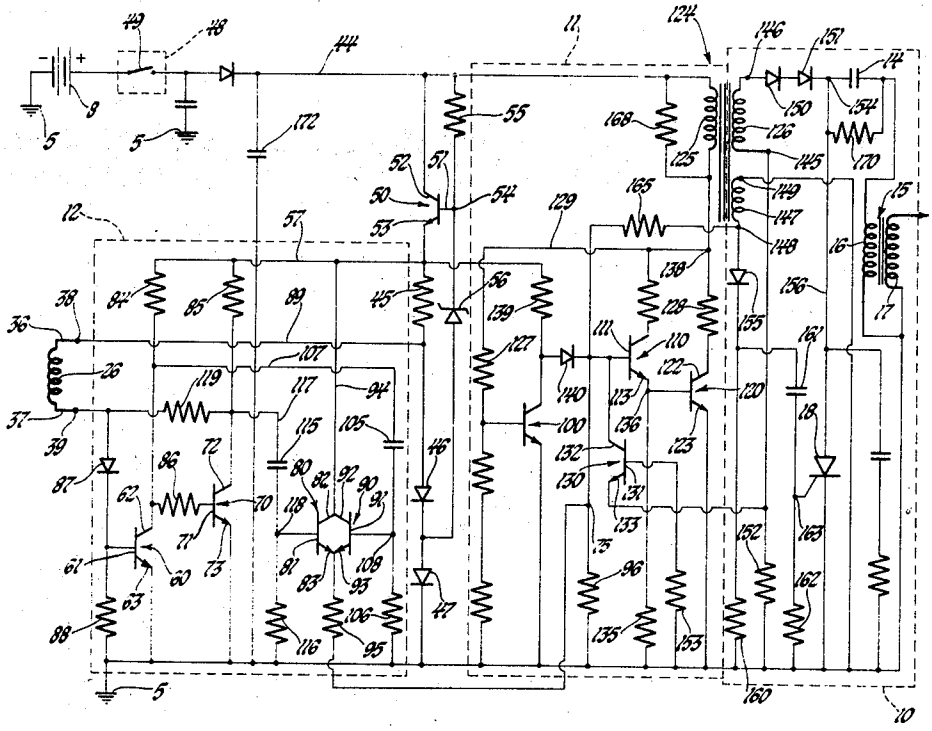
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ABSTRACT: A capacitor discharge ignition system which produces two sparks per cylinder per compression stroke in response to each half-cycle of alternating current ignition signals. The ignition signals are applied across the base-emitter electrodes of a first normally conducting transistor which is rendered nonconductive during a selected one-half-cycle of each ignition signal cycle. As the first transistor goes nonconductive, a second transistor is triggered conductive to maintain the first transistor in the nonconducting state and a first capacitor begins to charge from a direct current potential source through a series resistor. The charging current of this capacitor produces base-emitter and, consequently, collector-emitter current flow through a third transistor while the capacitor is charging. The collector-emitter current flow of this transistor produces a potential drop across an emitter resistor which is applied across the input terminals of an inverter circuit which produces the charging potential for the ignition capacitor and renders an ignition capacitor switch conductive to discharge the ignition capacitor through the primary winding of the ignition coil. With the other half-cycle of each alternating current ignition signal, the first transistor is rendered reconductive to extinguish the second transistor. As the second transistor goes nonconductive, another capacitor begins to charge through a series resistor. The charging current of this capacitor produces base-emitter and, consequently, collector-emitter current flow through a fourth transistor while the capacitor is charging. This collector-emitter current flow through the same emitter resistor, common to both the third and fourth transistors, produces a potential drop thereacross which is applied to the inverter circuit and the sequence of events is repeated as previously described.



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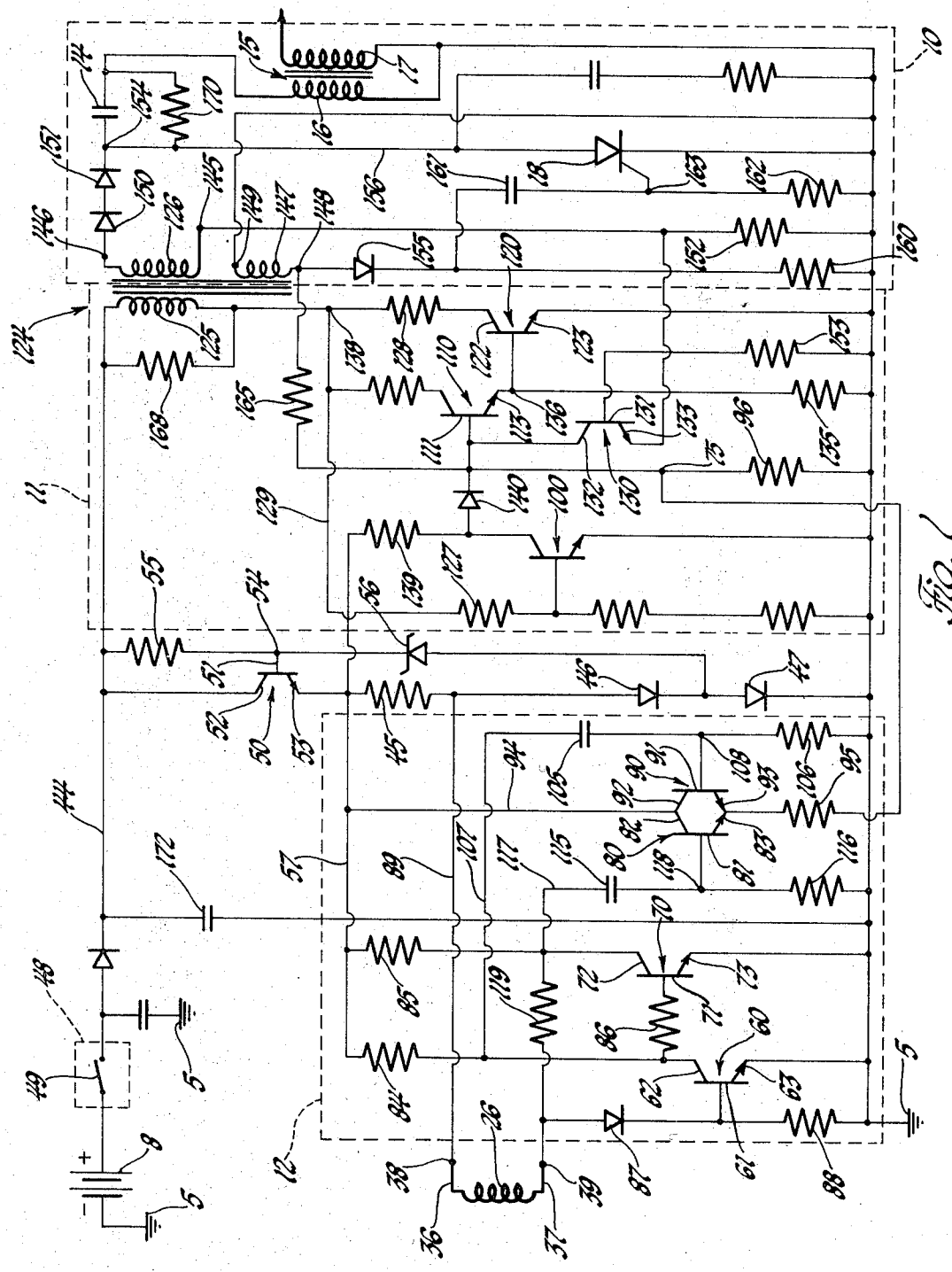


Fig. 1

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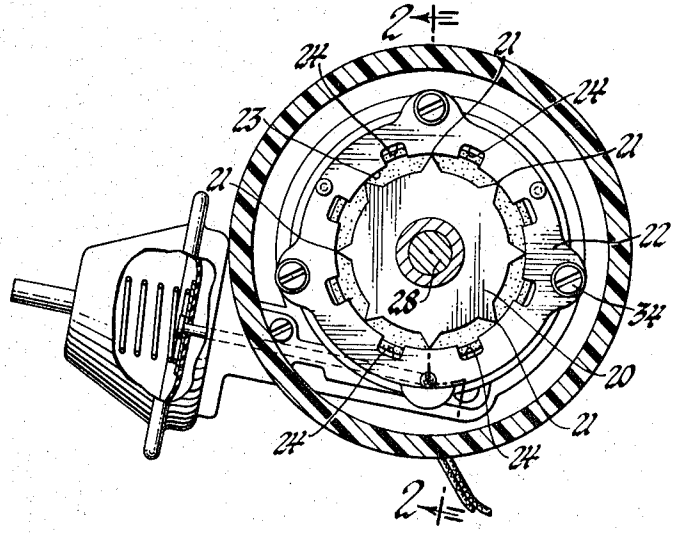


Fig. 3

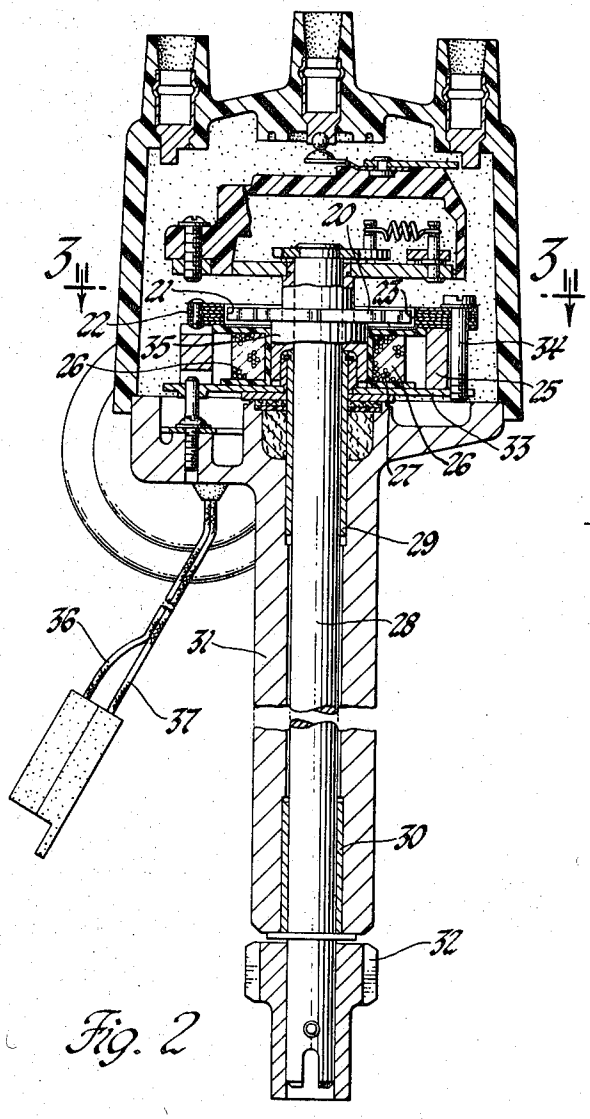


Fig. 2

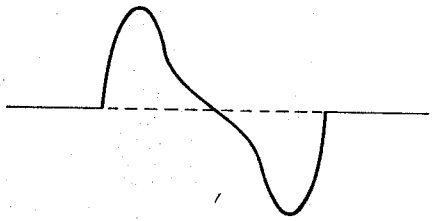


Fig. 4

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DUAL SPARK CAPACITOR DISCHARGE IGNITION SYSTEM

This invention is directed to a dual-spark capacitor discharge ignition system and, more specifically, to the circuit included therein which produces two like polarity output signal pulses in response to each alternating current input signal cycle.

It has been found that the fuel ignition spark produced by prior art capacitor discharge ignition systems is of an insufficient duration to provide adequate engine performance at intermediate and low engine speeds. Consequently, a capacitor discharge ignition system which provides two ignition sparks per cylinder per compression stroke to improve engine performance at these engine speeds is desirable.

It is, therefore, an object of this invention to provide an improved capacitor discharge ignition system.

It is another object of this invention to provide an improved circuit which will produce two like polarity output pulses in response to each alternating current input signal cycle.

It is another object of this invention to provide an improved capacitor discharge ignition system which produces two ignition sparks per cylinder per compression stroke.

It is a further object of this invention to provide a circuit which is responsive to each alternating current input ignition signal cycle to provide two like polarity output signals which are employed by associated converter and output stages of a capacitor discharge ignition system to supply two ignition sparks per cylinder per compression stroke.

In accordance with this invention, a dual-spark capacitor discharge ignition system is provided wherein a circuit responsive to each alternating current input ignition signal cycle to produce two like polarity output signals is employed in combination with a converter stage and an output stage to produce two ignition sparks per cylinder per compression stroke.

For a better understanding of the present invention, together with additional objects, advantages and features thereof, reference is made to the following description and accompanying drawings wherein:

FIG. 1 schematically sets forth the dual-spark capacitor discharge ignition system of this invention.

FIG. 2 is an elevation view, partially in cross section, of a magnetic-type distributor suitable for use with the capacitor discharge ignition system of this invention,

FIG. 3 is a section view of FIG. 2 taken along line 3–3 and looking in the direction of the arrows, and

FIG. 4 illustrates one cycle of the alternating current ignition signal potential waveform produced by the magnetic distributor of FIGS. 2 and 3.

As the point of reference or ground potential is the same point electrically throughout the system, it has been represented by the accepted schematic symbol and referenced by the numeral 5 in FIG. 1.

Corresponding elements of FIGS. 1, 2 and 3 have been given like characters of reference throughout these figures.

Referring to the figures, the capacitor discharge ignition system of this invention for use with internal combustion engines is shown to include an output stage set forth within dashed rectangle 10, having an ignition capacitor 14 and a charging circuit therefor, to be explained in detail later, the primary winding 16 of an ignition coil 15 which also has a secondary winding 17, and electrically operable ignition capacitor switch 18 for connecting the ignition capacitor 14 across the ignition coil primary winding 16, a converter circuit stage set forth within dashed rectangle 11, for producing the potential which provides the charge upon the ignition capacitor 14 in response to each input signal cycle having an input circuit and an output circuit across which the ignition capacitor charging circuit and the ignition capacitor switch are connected, a source of alternating current ignition signals produced in timed relationship with the internal combustion engine with which the ignition system is being used, FIGS. 2 and 3, and a circuit for producing two like polarity output signal pulses in response to each alternating current input signal cycle, set forth within dashed rectangle 12.

One example of a source of alternating current ignition signals which may be used with the ignition system circuit of this invention is set forth in FIGS. 2 and 3 as a magnetic-type distributor for producing alternating current ignition signals in timed relationship with the engine. Referring to FIG. 2, the magnetic type distributor includes a rotor member 20 of magnetic material rotated in timed relationship with the internal combustion engine with which the ignition system is being used having a pole tip corresponding to each engine cylinder, typically referenced at 21 in FIG. 3, a stationary pole piece 22 of magnetic material having a rotor accommodating bore 23 with a plurality of substantially rectangular notches 24, one for each engine cylinder, equally spaced about the circumference of the bore 23, a annular permanent magnet 25 and a pickup coil 26 would wound upon a spool 27 of an insulating material. For an eight cylinder engine, rotor member 20 has eight pole tips 21 and stationary pole piece 22 has eight notches 24, as best observed in FIG. 3. With engines of more or less cylinders, correspondingly more or less pole tips 21 and notches 24 would be required. Rotor member 20 is rotated in timed relationship with the engine with shaft 28, journaled in bearings 29 and 30 in tubular section 31, which is rotated by a gear 32 when the gear 32 is driven by a suitable meshing gear, not shown, in the internal combustion engine in a manner well known in the art.

Annular permanent magnet 25 is clamped between pole piece 22 and a timing plate 33 by a plurality of fasteners 34 which are threaded through suitable openings in timing plate 33. A magnetic circuit may be traced from the top end, as looking at FIG. 2, of permanent magnet 25, through stationary pole piece 22, across an airgap between stationary pole piece 22 and rotor 20, through rotor 20, a bushing member 35 and timing plate 33 to the opposite end of permanent magnet 25. With rotor member 20 being rotated by the engine, the reluctance of this magnetic circuit increases abruptly as a pole tip 21 of rotor 20 passes one edge of a notch 24 in stationary pole piece 22 in a direction toward the notch with a corresponding abrupt decrease of flux density therethrough. As the pole tip 21 passes the opposite edge of a notch 24, the reluctance of the magnetic circuit decreases abruptly with a corresponding increase in flux density through the magnetic circuit. These abrupt changes in flux density, as rotor 20 rotates, induce a series of alternating current potential signals in pickup coil 26, one cycle of which is illustrated in FIG. 4. For purposes of this specification and without intention or inference of a limitation thereto, the leading edge of this waveform will be assumed to be in a positive direction as is set forth in FIG. 4. The alternating current in ignition signals thus induced in pickup coil 26 may be conducted to external circuitry through external leas leads or wires 36 and 37.

A direct current potential source, which may be a conventional storage battery 8, is provided for supplying an operating potential. If desired, the potential of battery 8 may be regulated by a type NPN regulating transistor 50 and the associated circuitry to provide a substantially constant operating potential for the circuit which produces two output pulses in response to each alternating current input signal cycle. Collector electrode 52 and emitter electrode 53 of type NPN transistor 50 are connected across the positive and negative polarity terminals, respectively, of battery 8 through positive polarity line 44 and the series combination of resistor 45, diodes 46 and 47 and point of reference or ground potential 5, respectively, upon the closure of moveable contact 49 of switch 48 which may be one pole of a conventional automotive ignition switch. Upon the closure of switch 48, therefore, the collector-emitter electrodes of type NPN regulating transistor 50 are properly poled for collector-emitter current flow through transistor 50. Base electrode 51 of regulating transistor 50 is connected to junction 54 between resistor 55 and zener diode 56, connected in series across respective positive and negative polarity terminals of potential source 8 through positive polarity line 44 and diode 47 and point of reference or ground potential 5 upon the closure of movable contact 49 of switch 48.

The circuit for producing two like polarity output signal pulses in response to each alternating current input signal cycle includes an input circuit across which the input signals may be applied, which may be terminals **38** and **39** of any other of several electrical devices suitable for connection to external circuitry; first and second transistors, shown in FIG. **1** as type NPN transistors **60** and **70**, and each having two current-carrying electrodes connected in parallel across the direct current potential source and a control electrode with the control electrode of the second transistor **70** interconnected with one of the current-carrying electrodes of the first transistor **60** in such a manner that the second transistor **70** is conductive when the first transistor **60** is nonconductive and nonconductive when the first transistor **60** is conductive; circuitry for applying the alternating current input signals across the control electrode and a selected one of the current-carrying electrodes of the first transistor **60** for rendering transistor **60** nonconductive during a selected one-half cycle of each one of the alternating current input signal cycles and conductive during the other one-half cycle of each one of the alternating current input signal cycles; third and fourth transistors, shown in FIG. **1** to be type NPN transistors **80** and **90**, and each having two current-carrying electrodes connected in parallel across the direct current potential source and a control electrode; and output circuit across which the output signal pulses appear, which may be terminal **75** and point of reference or ground potential **5**; a first circuit interconnected with the control electrode and a selected one of the current-carrying electrodes of a selected one of transistors **80** and **90** and responsive to the first transistor **60** becoming nonconductive for rendering the selected one of transistors **80** and **90** conductive for a predetermined period of time for producing a first output signal across the output circuitry and a second circuit interconnected with the control electrode and a selected one of the current carrying electrodes of the other one of transistors **80** and **90** and responsive to transistor **70** becoming nonconductive for rendering the other one of transistors **80** and **90** conductive for a predetermined period of time for producing the second output signal across the output circuit.

The current-carrying electrodes, collector electrode **62** and emitter electrode **63**, of type NPN transistor **60** and the current carrying electrodes, collector electrode **72** and emitter electrode **73**, of type NPN transistor **70** are connected across the positive and negative polarity terminals, respectively, of direct current potential source **8** through respective series resistors **84** and **85**, regulated positive polarity potential line **57**, the emitter-collector electrodes of regulating transistor **50** and positive polarity line **44** and point of reference or ground potential **5**, respectively, upon the closure of movable contact **49** of switch **48**. Upon the closure of switch **49**, therefore, both these type NPN transistors are properly poled for collector-emitter conduction. If it should be elected not to regulate the potential of direct current potential source **8**, resistors **84** and **85** would be connected to positive polarity line **44**.

So that second transistor **70** is maintained nonconductive while first transistor **60** is conducting and is rendered conductive when transistor **60** goes nonconductive, the control electrode, base electrode **71** of transistor **70** is connected to the collector electrode **62** of transistor **60** through current limiting resistor **86**.

To apply the alternating current input signals across the control electrode and a selected one of the current-carrying electrodes of the first transistor **60**, pickup coil **26** may be connected across input terminals **38** and **39** through leads **36** and **37**, as schematically shown in FIG. **1**.

These signals are applied across base electrode **61** and emitter electrode **63** of transistor **60** through diode **87** and bias resistor **88** and lead **89**, series diodes **46** and **47** and point of reference or ground potential **5**.

The current-carrying electrodes, collector electrode **82** and emitter electrode **83** of type NPN transistor **80** and the current-carrying electrodes, collector electrode **92** and emitter electrode **93**, of type NPN transistor **90** are connected in parallel with each other and across the positive and negative polarity terminals, respectively, of direct current potential source **8** through lead **94**, regulated positive polarity potential line **57**, the emitter-collector electrodes of regulating transistor **50** and positive polarity line **44** and the series combination of emitter resistors **95** and **96** and point of reference or ground potential **5**, respectively, upon the closure of movable contact **49** of switch **48**. Upon the closure of switch **48**, both of these type NPN transistors are properly poled for collector-emitter conduction.

The first and second circuits interconnected with the control electrode and a selected one of the current-carrying electrodes of a selected one of the third and fourth transistors **80** and **90** and responsive to the first transistor **60** becoming nonconductive for rendering the selected one of the third and fourth transistors conductive for a predetermined period of time for producing a first output signal across the output circuitry may be respective R-C circuits connected across the current-carrying electrodes of respective transistors **60** and **70**. The series combination of capacitor **105** and resistor **106** is connected across the current-carrying electrodes of transistor **60** through lead **107** and point of reference or ground potential **5** and the series combination of capacitor **115** and resistor **116** is connected across the current-carrying electrodes of transistor **70** through lead **117** and point of reference or ground potential **5**.

The control electrode, base electrode **91**, of transistor **90** is connected to junction **108** between capacitor **105** and resistor **106** and the control electrode, base electrode **81**, of transistor **80** is connected to junction **118** between capacitor **115** and resistor **116**. With these connections, transistors **80** and **90** will be rendered conductive while respective capacitors **115** and **105** are charring when the corresponding respective transistors **60** and **70** are nonconductive.

With either one of transistors **80** or **90** conducting, an output signal appears across one common emitter resistor **96** which may be taken across output terminal **75** and point of reference or ground potential **5** and applied to external circuitry.

The current responsive converter circuit of this invention includes a converter transformer **124** having a primary winding **125** and a secondary output winding **126**, across which external utilization circuitry may be connected, a control resistor **128** and normally-not-conducting-type NPN transistor **120**, having collector electrode **122** and emitter electrode **123** connected in series with primary winding **125** of converter transformer **124** and the control resistor **128** across direct current potential source **8**, a trigger circuit for producing a trigger signal in response to each input signal pulse, shown in FIG. **1** as a normally-not-conducting-type NPN transistor **110** and the associated circuitry, a control circuit responsive to the potential drop across control resistors **128** for disenabling the trigger circuit when the potential drop thereacross has reached a predetermined magnitude, shown in FIG. **1** as normally-conducting-type NPN transistor **100** and the associated circuitry, and a circuit for applying the potential drop which appears across control resistor **128** to the control circuit, shown in the FIG. as lead **129** and resistor **127**.

Upon the closure of movable contact **49** of switch **48**, a circuit is established for base-emitter current flow through transistor **60** which may be traced from regulated positive polarity potential line **57**, through resistor **85**, resistor **119**, diode **87**, the base-emitter junction of transistor **60** and point of reference or ground potential **5**. Consequently, transistor **60** is normally conducting. With transistor **60** conducting, the base electrode **71** and emitter electrode **73** of transistor **70** are of substantially the same potential, consequently, transistor **70** is nonconductive, capacitor **105**, substantially short circuited by the collector-emitter electrodes of transistor **60**, remains substantially uncharged to interrupt the base-emitter circuit for transistor **90** which, consequently, is normally not conducting. With transistor **70** not conducting, capacitor **115** charges through a circuit which may be traced from regulated positive polarity potential line **57** through resistor **85**, line **117**,

capacitor 115, the base-emitter electrodes of transistor 80 and series resistors 95 and 96 to point of reference or ground potential 5. This base-emitter current flow through type NPN transistor 80 produces conducting through the collector-emitter electrodes of this device during the period of charge of capacitor 115. A circuit for base-emitter current flow through type NPN transistor 100 may be traced from positive polarity line 44 through the primary winding 125 of transformer 124, through resistor 127, the base-emitter electrodes of transistor 100 and point of reference or ground potential 5. Consequently, transistor 100 is normally conducting. With transistor 100 conducting, the base electrode 111 of type NPN transistor 110 is at substantially the same potential as emitter electrode 113 thereof, consequently, type NPN transistor 110 is nonconductive while transistor 100 is conducting. With transistor 110 nonconductive, the base-emitter circuit of type NPN transistor 120 is interrupted, consequently, transistor 120 is also nonconductive while transistor 100 is conducting.

Over the initial half-cycle of the alternating current input ignition signal, for purposes of this specification, that input terminal 38 is of a positive polarity with respect to input terminal 39. As this is not the correct polarity relationship to produce base-emitter current flow through a type NPN transistor, transistor 60 abruptly goes nonconductive.

As transistor 60 goes nonconductive, capacitor 105 begins to charge through a circuit which may be traced from regulated positive polarity line 57 through resistor 84, lead 107, capacitor 105, resistor 106 and point of reference or ground potential 5 and the potential of base electrode 71 of type NPN transistor 70 goes positive with respect to the emitter electrode 73 thereof, the correct polarity relationship to produce base-emitter current flow through a type NPN transistor. Consequently, transistor 70 conducts through the collector-emitter electrodes thereof to provide a discharge path for capacitor 115. Conducting transistor 70 also maintains transistor 60 nonconductive by reducing the potential across the base-emitter electrodes thereof to substantially zero.

The charging current of capacitor 105 produces a potential drop across series resistor 106 which is of a positive polarity at junction 108 with respect to point of reference or ground potential 5. As base electrode 91 of transistor 90 is connected to junction 108 and emitter electrode 93 thereof is connected to point of reference or ground potential 5 through series emitter resistors 95 and 96, the potential drop produced by capacitor 105 charging current through resistor 106 is applied across the base-emitter electrodes of transistor 90 in the correct polarity relationship to produce base-emitter current flow through this type NPN transistor. Consequently, when the potential drop across resistor 106 reaches a magnitude substantially equal to the breakdown potential of the base-emitter junction of the transistor selected as transistor 90, base-emitter current, and consequently, collector-emitter current flow through this device. When capacitor 105 has become charged after a predetermined period of time as determined by the time constant of the R-C circuit including capacitor 105 connected in series with the parallel combination of resistor 106 and series resistors 95 and 96, the circuit through which base-emitter current flows through transistor 90 is interrupted, consequently, this device goes nonconductive.

With transistor 90 conducting through the collector-emitter electrodes for the predetermined period of time as determined by the time constant of series connected capacitor 105 and resistor 106, current flows through the series emitter resistors 95 and 96. The potential drop across emitter resistor 96, as a result of this current flow, may be taken as an output signal pulse across output terminal 75 and point of reference or ground potential 5 and is of a positive polarity at output terminal 75 with respect to point of reference or ground potential 5.

Over the second half-cycle of the alternating current input ignition signal, input terminal 39 is of a positive polarity with respect to input terminal 38. As this is the correct polarity relationship to produce base-emitter current flow through a type NPN transistor, transistor 60 abruptly goes conductive.

As transistor 60 goes conductive, the conduction through the collector-emitter electrodes thereof establishes a discharge path for capacitor 105 and reduces the potential across the base-emitter electrodes of transistor 70 to substantially zero to extinguish transistor 70. As transistor 70 goes nonconductive, capacitor 115 begins to charge through a circuit which may be traced from regulated positive polarity line 57 through resistor 85, lead 117, capacitor 115, resistor 116 and point of reference or ground potential 5.

The charging current of capacitor 115 produces a potential drop across series resistor 116 which is of a positive polarity at junction 118 with respect to point of reference or ground potential 5. As base electrode 81 of transistor 80 is connected to junction 118 and emitter electrode 83 thereof is connected to point of reference or ground potential 5 through series emitter resistors 95 and 96, the potential drop produced by capacitor 115 charging current through resistor 116 is applied across the base-emitter electrodes of transistor 80 in the correct polarity relationship to produce base-emitter current flow through this type NPN transistor. Consequently, when the potential drop across resistor 116 reaches a magnitude substantially equal to the breakdown potential of the base-emitter junction of the transistor selected as a transistor 80, base-emitter current and, consequently, collector-emitter current flows through this device. When capacitor 115 has become charged after a predetermined period of time as determined by the time constant of the R-C circuit including capacitor 115 connected in series with the parallel combination of resistor 116 and series resistors 95 and 96, the circuit through which base-emitter current flows through transistor 80 is interrupted, consequently, this device goes nonconductive.

With transistor 80 conducting through the collector-emitter electrodes for the predetermined period of time as determined by the time constant of series connected capacitor 115 and resistor 116, current flows through the series emitter resistors 95 and 96. The potential drop across emitter resistor 96, as a result of this current flow, may be taken as an output signal pulse across output terminal 75 and point of reference or ground potential 5 and is of a positive polarity at output terminal 75 with respect to point of reference or ground potential 5. This is the second output pulse and is of the same polarity as the first output pulse.

The signal pulses produced by the circuitry just described appear across output terminal 75 and point of reference or ground potential 5, are of a positive polarity at output terminal 75 with respect to point of reference or ground potential 5 and are applied across the base-emitter electrodes of trigger transistor 110 in the correct potential polarity relationship to produce base-emitter current flow and, consequently, collector-emitter current flow through a type NPN transistor. Therefore, trigger transistor 110 is triggered conductive through the collector-emitter electrodes thereof upon the application of each input signal pulse across the base-emitter electrodes thereof.

Upon the triggering of trigger transistor 110 conductive, a circuit is established across direct current potential source 8 through the collector-emitter electrodes of trigger transistor 110 and series resistor 135. The resulting current flow through resistor 135 produces a trigger signal thereacross which is of a positive polarity at junction 136 with respect to point of references or ground potential 5. This trigger signal is applied across the base-emitter electrodes of switching transistor 120 and is of the correct polarity relationship to produce base-emitter current flow, and consequently, collector-emitter current flow through a type NPN transistor. Consequently, type NPN switching transistor 120 is triggered conductive through the collector-emitter electrodes by the trigger signals produced by the trigger circuit.

Conducting switching transistor 120 connects the positive polarity end, junction 138, of base bias circuit resistor 127 of control transistor 100 to point of reference or ground potential 5 through control resistor 128, a condition which results in a potential across junction 138 and point of reference or ground potential 5 which is of a positive polarity upon junc-

tion 138 with respect to point of reference or ground potential 5 and of a magnitude equal to the potential drop across control resistor 128 and the collector-emitter electrodes of switching transistor 120. Therefore, control resistor 128 is selected to have a resistance value which, upon the initial conduction of switching transistor 120, will result in a total potential drop, thereacross and the collector-emitter electrodes of switching transistor 120 of an insufficient magnitude to maintain base drive current through the base-emitter electrodes of control transistor 100, thereby extinguishing this device.

With control transistor 100 extinguished upon the initial conduction of switching transistor 120, a base drive circuit for maintaining base-emitter current flow through trigger transistor 110 is established through the series combination of resistor 139 and diode 140, the base-emitter electrodes of trigger transistor 110 and resistor 135 to maintain trigger transistor 110 and, consequently, switching transistor 120 conductive. Conducting switching transistor 120 establishes an energizing circuit for the series combination of primary winding 125 of converter transformer 124 and control resistor 128 across direct current potential source 8.

With the energizing circuit completed for primary winding 125 of converter transformer 124, energizing current which increases in magnitude, flows through primary winding 125 of converter transformer 124 and produces an increasing primary winding 125 magnetic field which induces a potential in secondary winding 126 thereof of a positive polarity at terminal 145 with respect to terminal 146, and a potential in switch winding 147 of a positive polarity at terminal 148 with respect to terminal 149. Blocking diodes 150 and 151 prevent the flow of current through secondary winding 126, consequently, the potential induced in secondary winding 126 is of no effect. The purpose of the potential induced in switch winding 147 will be explained in detail later in this specification.

As energizing current flow through primary winding 125 of converter transformer 124 and control resistor 128 continues to increase in magnitude, the potential upon junction 138 increases in magnitude. This positive polarity potential signal is applied across the base-emitter electrodes of control transistor 100 through resistor 127 and point of reference or ground potential 5 in the correct polarity relationship to produce base-emitter current flow through type NPN control transistor 100. When the potential drop across control resistor 128 reaches the predetermined magnitude. This signal produces base-emitter and, consequently, collector-emitter conduction through control transistor 100 to trigger this device conductive through the collector-emitter electrodes.

Conducting control transistor 100 diverts base current from trigger transistor 110 to extinguish this device. With trigger transistor 110 extinguished, the trigger signal appearing across resistor 135 is removed from across the base-emitter electrodes of switching transistor 120, consequently, switching transistor 120 extinguishes to interrupt the energizing circuit for primary winding 125 of converter transformer 124.

The resulting collapsing primary winding 125 magnetic field induces the ignition capacitor 14 charging potential in secondary winding 126 thereof, which is of a positive polarity at terminal 146 with respect to terminal 145, and a potential in switch winding 147, which is of a positive polarity at terminal 149 with respect to terminal 148. The ignition capacitor 14 charging potential induced in secondary winding 126 charges ignition capacitor 14 through a circuit which may be traced from terminal 146, through diodes 150 and 151, ignition capacitor 14, primary winding 16 of ignition coil 15, point of reference or ground potential 5 and the parallel combination of resistor 152 and the series connected resistor 153 and the base-emitter electrodes of transistor 130 to the other terminal 145 of secondary winding 126. Ignition capacitor 14 is now charged with an ignition potential with the plate thereof connected to junction 154 being of a positive polarity with respect to the other plate. Diode 155 prevents the flow of current through switch winding 147, consequently, the potential induced in switch winding 147 is of no effect.

The charge upon ignition capacitor 14 is applied across the anode-cathode electrodes of silicon-controlled rectifier ignition capacitor switch 18 through lead 156 and through the primary winding 16 of ignition coil 15 and point of reference or ground potential 5. As the polarity of the charge upon ignition capacitor 14 is positive upon the plate connected to junction 154, the polarity of the potential applied across the anode-cathode electrodes of silicon-controlled rectifier ignition capacitor switch 18 is positive upon the anode electrode and negative upon the cathode electrode.

The silicon-controlled rectifier is a semiconductor device having a control electrode, generally termed the gate electrode, and two current carrying electrodes, generally termed the anode and cathode electrodes, which is designed to normally block current flow in either direction. With the anode and cathode electrodes forward poled, anode positive and cathode negative, the silicon-controlled rectifier may be triggered to conduction upon the application to the control electrode, of a control potential signal of a polarity which is positive in respect to the potential present upon the cathode electrode and of sufficient magnitude to produce control electrode-cathode, or gate, current. In the conducting state, the silicon-controlled rectifier will conduct current in one direction and retains the ability to block current flow in the opposite direction. In the conducting state, therefore, the silicon-controlled rectifier functions as a conventional diode. Upon being triggered to conduction, however, the control electrode is no longer capable of affecting the device which will remain in the conducting state until either the anode-cathode circuit is interrupted or the polarity of the potential applied across the anode-cathode electrodes is reversed. Of these two alternatives, the reversal of the polarity of the potential across the anode-cathode electrodes thereof is perhaps the most satisfactory.

Upon the next input signal pulse across terminal 75 and point of reference or ground potential 5, the sequence of events just described is repeated. With the next initiation of conduction of switching transistor 120, the increasing primary winding 125 magnetic field produced as a result of increasing energizing current flow therethrough induces a potential in switch winding 147 of a positive polarity at terminal 148 with respect to terminal 149. This potential produces a current flow through a circuit which may be traced from terminal 148 through diode 155, the parallel combination of resistor 160 and series connected capacitor 161 and resistor 162 and point of reference or ground potential 5 to terminal 149. The capacitor 161 charging current flows through resistor 162 and produces a potential signal thereacross which is of a positive polarity at junction 163 with respect to point of reference or ground potential 5. This signal is applied across the gate-cathode electrodes of silicon-controlled rectifier ignition capacitor switch 18 in the proper polarity relationship to produce gate current through this device. As the charge on ignition capacitor 14 is applied across the anode-cathode electrodes of silicon-controlled rectifier ignition capacitor switch 18 in the correct anode-cathode polarity relationship, this device conducts through the anode-cathode electrodes thereof to connect ignition capacitor 14 across the ignition coil primary winding 16. Consequently, ignition capacitor 14 discharges rapidly through primary winding 16 of ignition coil 15 and the discharge current produces a magnetic field which induces a high firing potential in secondary winding 17. The firing potential is directed to the ignition coil terminal of a conventional automotive-type distributor, not shown.

With high engine speeds, the two pulses produced by the circuitry of dashed rectangle 12 may become so closely spaced that the second pulse occurs before ignition capacitor 14 has become completely charged. In this event, the second pulse will trigger silicon-controlled rectifier 18 conductive while ignition capacitor 14 is charging. That is, charging and discharging circuits for ignition capacitor 14 are established simultaneously. To prevent this undesirable situation, a pulse-canceling transistor 130 having the usual base 131, collector 132 and emitter 133 electrodes is provided. The collector

electrode 132 is connected to the junction between diode 140 and the base electrode of trigger transistor 110, the emitter electrode 133 is connected to terminal 145 of secondary winding 126 and the base electrode 131 is connected to point of reference or ground potential 5 through resistor 153. As ignition capacitor 14 charges, charging current flows through resistor 152 in a direction from point of reference or ground potential 5 toward terminal 145 of secondary winding 126. The potential drop produced by the charging current flow through resistor 152 places the emitter electrode 133 of pulse-canceling transistor 130 at a potential which is slightly less positive than the potential upon base electrode 131 thereof. Consequently, base-emitter current flows through pulse-canceling transistor 130 with each charge of ignition capacitor 14. Should a second pulse occur while ignition capacitor 14 is in the charging state, this pulse would be conducted through the collector-emitter electrodes of pulse-canceling transistor 130, which are connected in shunt with trigger transistor 110, consequently, the second pulse would be ineffective to trigger transistor 110 and, consequently, switching transistor 120 conductive at this time. As the terminal 149 of switch winding 147 is of a positive polarity with respect to terminal 148 thereof, resistor 165 is connected between terminal 148 and the collector electrode of pulse-canceling transistor 130 to provide an additional positive polarity potential upon collector electrode 132 of pulse-canceling transistor 130 to provide additional insurance that pulse-canceling transistor 130 will conduct with each second input pulse which is produced during the periods ignition capacitor 14 is charging.

With an open ignition coil secondary, the series L-C circuit comprising primary winding 16 of ignition coil 15 and ignition capacitor 14 produces a ringing action which charges ignition capacitor 14 in the reverse direction. Ignition capacitor 14 then discharges in the reverse direction through primary winding 16. The ring back of ignition capacitor 14 in a reverse direction extinguishes silicon-controlled rectifier 18.

Resistor 168 connected in parallel with ignition coil primary winding 125 rapidly dampens the oscillations through primary winding 125 while the ignition system is firing across a spark plug gap; resistor 170 is a "bleeder" resistor through which ignition capacitor 14 discharges when switch 49 is opened; and capacitor 172 is a filter.

Throughout the specification, specific transistor types, electrical polarities and circuit elements have been set forth. It is to be specifically understood, however, that alternate transistor types and compatible electrical polarities and alternate circuit elements possessing similar electrical characteristics may be substituted without departing from the spirit of the invention.

We claim:

1. In a capacitor discharge ignition system for use with internal combustion engines of the type including an output stage having at least an ignition capacitor and a charging circuit therefor, the primary winding of an ignition coil and an electrically operable ignition capacitor switch for connecting the ignition capacitor across the ignition coil primary winding and a converter circuit stage for producing the potential which provides the charge upon the ignition capacitor in response to each input signal cycle having an input circuit and an output circuit across which the ignition capacitor charging circuit and the ignition capacitor switch are connected, the means for producing two like polarity output signal pulses in response to each alternating current input signal cycle comprising in combination with a direct current potential source, a magnetic pulse generator including at least a rotor member of magnetic material rotated in timed relationship with the internal combustion engine with which the ignition system is being used having a pole tip corresponding to each engine cylinder, a stationary pole piece of magnetic material having a rotor-accommodating bore with a plurality of substantially rectangular notches, one for each engine cylinder, equally spaced about the circumference of the bore, a permanent magnet and a pickup coil for producing alternating current ignition signals in timed relationship with the engine:

first and second transistors each having two current-carrying electrodes and a control electrode:

means for connecting said current-carrying electrodes of both said transistors in parallel across said direct current potential source:

means for interconnecting said control electrode of said second transistor and one of said current-carrying electrodes of said first transistor in such a manner that said second transistor is conductive when said first transistor is nonconductive and is nonconductive when said first transistor is conductive;

means for applying said alternating current ignition signals across said control electrode and a selected one of said current-carrying electrodes of said first transistor for rendering said first transistor nonconductive during a selected one-half cycle of each one of said alternating current ignition signal cycles and conductive during the other one-half cycle of each one of said alternating current ignition signals;

first and second capacitors;

first and second resistors;

means for connecting the series combination of said first capacitor and said first resistor across said current-carrying electrodes of a selected one of said first and second transistors;

means for connecting the series combination of said second capacitor and said second resistor across said current-carrying electrodes of the other one of said first and second transistors;

third and fourth transistors each having two current-carrying electrodes and a control electrode;

means for connecting said current-carrying electrodes of said third and fourth transistors in parallel across said direct current potential source;

means for connecting said control electrode of a selected one of said third and fourth transistors to the junction between said first capacitor and said first resistor whereby said selected one of said third and fourth transistors is rendered conductive while said first capacitor charges when said selected one of said first and second transistors across the said current-carrying electrodes of which said series combination of said first capacitor and said first resistor is connected is nonconductive;

means for connecting said control electrode of the other one of said third and fourth transistors to the junction between said second capacitor and said second transistor whereby said other one of said third and fourth transistors is rendered conductive while said second capacitor charges when the other one of said first and second transistors across the current-carrying electrodes of which said series combination of said second capacitor and said second resistor is connected is nonconductive; and

at least one common resistor included in said means for connecting said current-carrying electrodes of said third and fourth transistors in parallel across said direct current potential source across which an output signal appears while either one of said third and fourth transistors is conducting.

2. A circuit for producing two like polarity output signal pulses in response to each alternating current input signal cycle comprising in combination with a direct current potential source:

first and second transistors each having two current-carrying electrodes connected in parallel across said direct current potential source and a control electrode;

means for interconnecting said control electrode of said second transistor and one of said current-carrying electrodes of said first transistor in such a manner that said second transistor is conductive when said first transistor is nonconductive and is nonconductive when said first transistor is conductive;

means for applying said alternating current input signals across said control electrode and a selected one of said

current-carrying electrodes of said first transistor for rendering said first transistor nonconductive during a selected one-half cycle of each one of said alternating current signal cycles and conductive during the other one-half cycle of each one of said alternating current signals;

third and fourth transistors each having two current-carrying electrodes connected in parallel across said source of direct current potential and a control electrode;

output circuit means;

first circuit means interconnected with said control electrode and a selected one of said current-carrying electrodes of a selected one of said third and fourth transistors and responsive to said first transistor becoming nonconductive for rendering said selected one of said third and fourth transistors conductive for a predetermined period of time for producing a first output signal across said output circuit means; and

second circuit means interconnected with said control electrode and a selected one of said current-carrying electrodes of the other one of said third and fourth transistors and responsive to said second transistor becoming nonconductive for rendering said other one of said third and fourth transistors conductive for a predetermined period of time for producing a second output signal across said output circuit means.

3. A circuit for producing two like polarity output signal pulses in response to each cycle of an alternating current input signal cycle comprising in combination with a direct current potential source;

first and second transistors each having two current-carrying electrodes connected in parallel across said direct current potential source and a control electrode;

means for interconnecting said control electrode of said second transistor and one of said current-carrying electrodes of said first transistor in such a manner that said second transistor is conductive when said first transistor is nonconductive and is nonconductive when said first transistor is conductive;

means for applying said alternating current input signals across said control electrode and a selected one of said current-carrying electrodes of said first transistor for rendering said first transistor nonconductive during a selected one-half cycle of each one of said alternating current signal cycles and conductive during the other one-half cycle of each one of said alternating current signals;

third and fourth transistors each having two current-carrying electrodes connected in parallel across said source of direct current potential and a control electrode;

output circuit means;

a first R-C circuit connected across said current-carrying electrodes of said first transistor and interconnected with said control electrode and a selected one of said current-carrying electrodes of a selected one of said third and fourth transistors for rendering said selected one of said third and fourth transistors conductive when said first transistor becomes nonconductive for a predetermined period of time for producing a first output signal across said output circuit means; and

a second R-C circuit connected across said current-carrying electrodes of said second transistor and interconnected with said control electrode and a selected one of said current-carrying electrodes of the other one of said third and fourth transistors for rendering said other one of said third and fourth transistors conductive when said second transistor becomes nonconductive for a predetermined period of time for producing a second output signal across said output circuit means.

4. A circuit for producing two like polarity output signal pulses in response to each cycle of an alternating current input signal cycle comprising in combination with a direct current potential source:

first and second transistors each having two current-carrying electrodes connected in parallel across said direct current potential source and a control electrode;

means for interconnecting said control electrode of said second transistor and one of said current-carrying electrodes of said first transistors in such a manner that said second transistor is conductive when said first transistor is nonconductive and is nonconductive when said first transistor is conductive;

means for applying said alternating current input signals across said control electrode and a selected one of said current-carrying electrodes of said first transistor for rendering said first transistor nonconductive during a selected one-half cycle of each one of said alternating current signal cycle and conductive during the other one-half cycle of each one of said alternating current signals;

first and second capacitors;

first and second resistors;

means for connecting the series combination of said first capacitor and said first resistor across said current-carrying electrodes of a selected one of said first and second transistors;

means for connecting the series combination of said second capacitor and said second resistor across said current-carrying electrodes of the other one of said first and second transistors;

third and fourth transistors each having two current-carrying electrodes and a control electrode;

means for connecting said current-carrying electrodes of said third and fourth transistors in parallel across said direct current potential source.

means for connecting said control electrode of a selected one of said third and fourth transistors to the junction between said first capacitor and said first resistor whereby said selected one of said third and fourth transistors is rendered conductive while said first capacitor charges when said selected one of said first and second transistors across the said current-carrying electrodes of which said series combination of said first capacitor and said first resistor is connected is nonconductive;

means for connecting said control electrode of the other one of said third and fourth transistors to the junction between said second capacitor and said second transistor whereby said other one of said third and fourth transistors is rendered conductive while said second capacitor charges when the other one of said first and second transistors across the current carrying electrodes of which said series combination of said second capacitor and said second resistor is connected is nonconductive; and

at least one common resistor included in said means for connecting said current carrying electrodes of said third and fourth transistors in parallel across said direct current potential source across which an output signal appears while either one of said third and fourth transistors is conducting.