INTERNAL COMBUSTION ENGINE IGNITION SYSTEM

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Fig. 2

Fig. 3

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ABSTRACT OF THE DISCLOSURE

An internal combustion engine ignition system of the type responsive to alternating current ignition signals produced in time relationship with the engine. The ignition coil primary winding, the collector-emitter electrodes of an ignition coil primary winding switching transistor and a control resistor are connected in series across the battery and forward base-emitter current is supplied to the switching transistor through the collector-emitter electrodes of a coil primary winding switching transistor and a control normally conducting control transistor. A trigger circuit is responsive to each selected half cycle of the alternating current ignition signals to establish a shunt circuit which shunts base-emitter current from the control transistor to extinguish this device and, consequently, the switching transistor whereby the switching transistor is operated conductive and not conductive in timed relationship with the engine. Another transistor, responsive to the potential developed across the control resistor, shunts base-emitter current from the control transistor to limit ignition coil primary winding energizing current to a predetermined magnitude and another transistor, also responsive to the control potential, establishes the electrical angle of each cycle of the alternating current ignition signals at which the control transistor conducts to determine the length of time energizing current flows through the ignition coil primary winding.

This invention relates to internal combustion engine ignition systems and, more particularly, to a solid state internal combustion engine ignition system which provides for the limiting of ignition coil primary winding energizing current to a predetermined magnitude and establishes the length of time energizing current flows through the ignition coil primary winding.

To provide an adequate ignition sparking potential to the spark plugs of an internal combustion engine, it is necessary that the ignition coil primary winding energizing current reach a predetermined magnitude. However, should the ignition coil primary winding energizing current reach a magnitude greater than is necessary to provide an adequate sparking potential or should the ignition coil primary winding energizing current flow through the ignition coil primary winding for a period of time longer than is necessary, a significant waste of battery power results.

It is, therefore, an object of the invention to provide an improved internal combustion engine ignition system.

It is another object of the invention to provide an improved solid state internal combustion engine ignition system.

It is an additional object of the invention to provide an improved solid state internal combustion engine igni-
determined magnitude for limiting the magnitude of energizing current flow through the current carrying electrodes of the automotive art having a primary winding 35, the collector-emitter electrodes of ignition coil primary winding switching transistor 10, control impedance element 14 and point of reference or ground potential 5 to the negative polarity terminal of battery 8. The circuit just described is the ignition coil primary winding energizing circuit through which the energizing current may flow through ignition coil primary winding 35 and control impedance element 14.

As with conventional automotive type ignition systems, the ignition coil primary winding energizing circuit is established to build up energizing current flow through a magnetic field and interrupted to collapse the magnetic field which induces a high ignition potential in secondary winding 36, in timed relationship with the engine. Consequently, circuitry responsive to alternate half-cycles of the alternating current signals is provided for operating ignition coil primary winding switching transistor 10 conductive and not conductive through the current carrying electrodes in timed relationship with the engine. This circuitry includes a normally conducting type NPN control transistor 20 having a control electrode, base electrode 21, and two current carrying electrodes 22 and emitter electrode 23, through which forward control electrode current is supplied to the ignition coil primary winding switching transistor 10 for producing conduction through the current carrying electrodes of switching transistor 10 to complete the ignition coil primary winding energizing circuit for the flow of ignition coil primary winding energizing current through the ignition coil primary winding 35 and the control impedance element 14. Forward control electrode current is supplied to type NPN control transistor 20 for conditioning control transistor 20 for conduction through the current carrying electrodes, collector electrode 22 and emitter electrode 23, through a circuit which may be traced from the positive polarity terminal of battery 8, through movable contact 25 and stationary contact 26 of switch 24, lead 27, ignition coil primary winding 35, the collector-emitter electrodes of ignition coil primary winding switching transistor 10, control impedance element 14 and point of reference or ground potential 5 to the negative polarity terminal of battery 8. The circuit just described is the ignition coil primary winding energizing circuit through which the energizing current may flow through ignition coil primary winding 35 and control impedance element 14.

FIG. 3.

Ignition coil 34 may be any one of the several conventional automotive type ignition coils well known in the automotive art. In the proceedings 35 and 36 in which the high sparking potential is induced upon the interruption of the energizing circuit of primary winding 35 in a manner to be explained later in this specification.

Without intention or inference of a limitation thereto, the ignition coil primary winding switching transistor 10 has been illustrated as a type NPN transistor having the usual current carrying electrodes, collector electrode 12 and emitter electrode 13, and a control electrode, base electrode 11. Control impedance element 14 has been illustrated in the drawing as a variable resistor. It is to be specifically understood, however, that any other suitable electrical impedance element which will provide a potential drop thereacross with current flow therethrough may be substituted therefor without departing from the spirit of the invention.

Upon the closure of movable contact 25 to stationary contact 26 of switch 24, which may be the movable contact and one of the stationary contacts of a conventional automotive type ignition switch well known in the automotive art, the ignition coil primary winding 35, the current carrying electrodes, collector electrode 12 and emitter electrode 13, and a control electrode, base electrode 11 of the type NPN control transistor 20, control impedance element 14 and point of reference or ground potential 5 to the negative polarity terminal of battery 8, through movable contact 25 and stationary contact 26 of switch 24, lead 27, ignition coil primary winding 35, the collector-emitter electrodes of ignition coil primary winding switching transistor 10, control impedance element 14 and point of reference or ground potential 5 to the negative polarity terminal of battery 8. As the potential of battery 8 is applied across the base-emitter electrodes of type NPN ignition coil primary winding switching transistor 10, control impedance element 14 and point of reference or ground potential 5 to the negative polarity terminal of battery 8, through movable contact 25 and stationary contact 26 of switch 24, lead 27, ignition coil primary winding 35, the collector-emitter electrodes of type NPN ignition coil primary winding switching transistor 10, control impedance element 14 and point of reference or ground potential 5 to the negative polarity terminal of battery 8, through movable contact 25 and stationary contact 26 of switch 24, lead 27, control impedance element 14 and point of reference or ground potential 5 to the negative polarity terminal of battery 8, through movable contact 25 and stationary contact 26 of switch 24, lead 27, ignition coil primary winding 35, the collector-emitter electrodes of ignition coil primary winding switching transistor 10, control impedance element 14 and point of reference or ground potential 5 to the negative polarity terminal of battery 8.
current flows through this device through the circuit just described. As the base-emitter current for ignition coil primary winding switching transistor 10 is supplied through the collector-emitter electrodes of control transistor 20, to trigger the ignition coil primary winding 5 switching transistor 10 conductive and not conductive through transistor 40 through which the forward control control current supplied to control transistor 20 may be shunted from control transistor 20 is provided and includes a device responsive to each selected half-cycle of the alternating current ignition signals for completing this circuit and to each other half-cycle of the alternating current ignition signals for interrupting this circuit whereby the ignition coil primary winding switching transistor 10 is triggered conductive and not conductive through the current carrying electrodes thereof in timed relationship with the engine. This shunt circuit includes the current carrying electrodes, collector electrode 32 and emitter electrode 33, of type NPN transistor 30 and resistor 44 connected in series across junction 45 and point of reference or ground potential 5. With movable contact 25 closed to stationary contact 26 of switch 24 and with no signal present in pickup coil 18, variable resistor 46 is adjusted until type NPN transistor 30 does not conduct through the current carrying electrodes, collector electrode 42 and emitter electrode 43. That is, the resistance of variable resistor 46 is increased until the potential appearing across junction 47 and point of reference or ground potential 5 is of an insufficient magnitude to break down the base-emitter junction of transistor 40, consequently, the forward base-emitter current which would be supplied to transistor 40 through variable resistor 46 and base resistor 48 is shunted from transistor 40 through diode 49, pickup coil 18, resistor 54 and emitter resistor 55 to point of reference or ground potential 5. With transistor 40 not conductive the potential of battery 8 is applied across the base-emitter electrodes of type NPN transistor 30 in the proper polarity relationship to produce base-emitter current through a type NPN transistor. Consequently, forward base-emitter current flows through type NPN transistor 30 through a circuit which may be traced from the positive polarity terminal of battery 8, through movable contact 25 and stationary contact 26 of switch 24, lead 27, resistor 48, variable resistor 46, base resistor 44, the base-emitter electrodes of type NPN transistor 40, resistor 44 and point of reference or ground potential 5 to the negative polarity terminal of battery 8. Upon the flow of base-emitter current through type NPN transistor 40, this device conducts through the collector-emitter electrodes thereof to establish a circuit through which forward base-emitter current is shunted around transistor 30 to extinguish transistor 30 which interrupts the shunt circuit through which base-emitter current is shunted away from control transistor 20. Upon the interruption of this shunt circuit, base-emitter current is supplied to control transistor 20, through a circuit previously described, to initiate collector-emitter current flow there through to establish the circuit, previously described, through which base-emitter current is supplied from the collector-emitter electrodes of type NPN transistor 10. The base-emitter current flow through ignition coil primary winding switching transistor 10 initiates collector-emitter current flow there through to establish the ignition coil primary winding energizing circuit, previously described, for the flow of energizing current through primary winding 35 and control impedance element 14. The build-up of energizing current through primary winding 35 produces a magnetic field in a manner well known in the art of transformers.

With each half cycle of the alternating current ignition signals during which the potential of terminal end 18a of pickup coil 18 is of the negative polarity with respect to terminal end 18b, diode 49 becomes forward poled to shunt base-emitter current from transistor 40 through the circuit previously described to point of reference or ground potential 5. With base-emitter current shunted away from transistor 40, this device extinguishes to interrupt the circuit through which base-emitter current is shunted around transistor 30. Transistor 30, consequently, conducts through the collector-emitter electrodes thereof to complete the shunt circuit through which base-emitter current is supplied from control transistor 20 to extinguish control transistor 20. With control transistor 20 extinguished, the circuit, previously described, through which base-emitter current is supplied to ignition coil primary winding switching transistor 10 is interrupted to extinguish this device, a condition which interrupts the ignition coil primary winding energizing circuit, previously described. Upon the interruption of the ignition coil primary winding energizing circuit, the magnetic field of ignition coil primary winding 35 collapses to induce a high ignition potential in ignition coil secondary winding 36 which is directed to the proper spark plug of the engine through a conventional distributor, not shown, in a manner well known in the automobile art. From this description, it is apparent that ignition coil primary switching transistor 10 is triggered conductive with each half-cycle of the alternating current ignition signal during which the potential of terminal end 18a of pickup coil 18 is of a positive polarity with respect to terminal end 18b and is triggered not conductive with each half-cycle of the alternating current ignition signal during which the potential of terminal end 18a of pickup coil 18 is of a negative polarity with respect to terminal end 18b.

The device included in the shunt circuit through which base-emitter electrode current is shunted away from control transistor 20 is, of course, transistor 30. Transistor 30 is responsive to alternate half-cycles of the alternating current signals during which the potential of terminal end 18a of pickup coil 18 is of a positive polarity with respect to terminal end 18b, diode 49 is reverse biased. Consequently, the potential appearing across junction 47 and point of reference or ground potential 5 is of increased magnitude and of a positive polarity upon junction 47. As this potential is applied across the base-emitter electrodes of type NPN transistor 40 in the proper polarity relationship to produce base-emitter current flow through a type NPN transistor, base-emitter current flows through transistor 40 through which the positive polarity terminal of battery 8, through movable contact 25 and stationary contact 26 of switch 24, lead 27, resistor 48, variable resistor 46, base resistor 44, the base-emitter electrodes of type NPN transistor 40, resistor 44 and point of reference or ground potential 5 to the negative polarity terminal of battery 8. Upon the flow of base-emitter current through type NPN transistor 40, this device conducts through the collector-emitter electrodes thereof to establish a circuit through which forward base-emitter current is shunted around transistor 30 to extinguish transistor 30 which interrupts the shunt circuit through which base-emitter current is shunted away from control transistor 20. Upon the interruption of this shunt circuit, base-emitter current is supplied to control transistor 20, through a circuit previously described, to initiate collector-emitter current flow there through to establish the circuit, previously described, through which base-emitter current is supplied from the collector-emitter electrodes of type NPN transistor 10. The base-emitter current flow through ignition coil primary winding switching transistor 10 initiates collector-emitter current flow there through to establish the ignition coil primary winding energizing circuit, previously described, for the flow of energizing current through primary winding 35 and control impedance element 14. The build-up of energizing current through primary winding 35 produces a magnetic field in a manner well known in the art of transformers.
current ignition signals for interrupting and establishing this shunt circuit whereby the ignition coil primary winding switching transistor is triggered conductive and not conductive through the current carrying electrodes thereof in timed relationship with the engine. Transistors 30 and 40 are connected in a trigger circuit configuration for the purpose of providing a sharp switching action with each half cycle of the alternating current ignition signal.

To limit the energizing current flowing through ignition coil primary winding 35 to a predetermined magnitude, a current limiting transistor, illustrated as type NPN transistor 50, having two current carrying electrodes, collector electrode 52 and emitter electrode 53, and a control electrode, base electrode 51, responsive to the control potential developed across control impedance element 14 of the magnitude produced by an ignition coil primary winding energizing current of a predetermined magnitude is provided. Base electrode 51 of current limiting transistor 50 is connected to junction 65 between the emitter electrode 13 of ignition coil primary winding switching transistor 10 and control impedance element 14 through a base resistor 66 and the collector- emitter electrodes of current limiting transistor 50 are connected across junction 45 between resistor 37 and base resistor 30 of potential 5 of reference or ground potential 5. Consequently, the control potential developed across control impedance element 14, of a positive polarity upon junction 65 with respect to point of reference or ground potential 5, is applied across the base-emitter electrodes of type NPN current limiting transistor 50 in the proper polarity relationship to produce base-emitter current flow through a type NPN transistor. The impedance value of control impedance element 14 is selected or adjusted to the value which, with the selected magnitude of energizing current flow through ignition coil primary winding 35, will establish a potential drop on the magnitude which will initiate base-emitter current flow through type NPN current limiting transistor 50 through a circuit which may be traced from the positive polarity terminal of battery 8, through movable contact 25 and stationary contact 26 of switch 24, lead 27, ignition coil primary winding 35, the collector-emitter electrodes of ignition coil primary winding switching transistor 10, base resistor 66, the base-emitter electrodes of current limiting transistor 50 and point of reference or ground potential 5 to the negative polarity terminal of battery 8. Consequently, when the flow of energizing current through ignition coil primary winding 35 has reached the predetermined magnitude, current limiting transistor 50 is triggered conductive through the collector-emitter electrodes thereof to establish another circuit, which may be traced from junction 45, through leads 67 and 68, the collector-emitter electrodes of current limiting transistor 50 and lead 69 to point of reference or ground potential 5, through which base-emitter current is shunted from control transistor 20 to reduce the degree of collector-emitter conduction through this device. With reduced collector-emitter conduction through control transistor 20, the magnitude of base-emitter current supplied to ignition coil primary winding switching transistor 10 is reduced, a condition which reduces the magnitude of collector-emitter current flow through this device which, of course, reduces the magnitude of energizing current flow through the energizing circuit for ignition coil primary winding 35, thus limiting the magnitude of energizing current flow therethrough to the predetermined magnitude.

A thermistor 75 may be connected across the base-emitter electrodes of current limiting transistor 50 for purposes of current compensation. Thermistor 75 compensates for Veb change versus temperature of transistor 50.

To determine the length of time ignition coil primary winding switching transistor is conductive through the current carrying electrodes during each alternating current ignition signal cycle, a circuit responsive to the control potential for establishing the electrical angle of each cycle of the alternating current ignition signals at which control transistor 20 conducts through the current carrying electrodes is provided. This circuit comprises type NPN transistor 60 and 70, each having two current carrying electrodes, respective collector electrodes 62 and 72 and respective emitter electrodes 63 and 73, and control electrode, respective base electrodes 61 and 71, capacitor 77 and the associated circuitry.

The base electrode 61 of transistor 60 is connected to junction 65 between the emitter electrode 13 of ignition coil primary winding switching transistor 10 and control impedance element 14 through base resistor 74 and base resistor 65. Consequently, the control potential developed across control impedance element 14 is applied across the base-emitter electrodes of transistor 60 in the proper polarity relationship to produce base-emitter current flow through a type NPN transistor. The base electrode 71 of transistor 70 is connected to junction 85 between resistors 86 and diode 87 through diode 88. The collector-emitter electrodes of transistor 60 are connected across junction 90 between the base electrode 71 of transistor 70 and capacitor 77 and point of reference or ground potential 5 of reference or ground potential 5. Transistor 70 and the collector-emitter electrodes of transistor 70 are connected across battery 8 through resistor 28, collector resistor 29 and emitter resistor 55.

As has been brought out earlier in this specification, control transistor 20 conducts through the collector-emitter electrodes to supply forward base-emitter current to ignition coil primary winding switching transistor 10 while transistor 40 is conductive through the collector-emitter electrodes and is not conductive through the collector-emitter electrodes thereof to interrupt the circuit through the forward biased base-emitter current supplied to ignition coil primary winding switching transistor 10 while transistor 40 is not conductive through the collector-emitter electrodes. Consequently, the electrical angle of each cycle of the alternating current ignition signals at which control transistor 20 conducts through the collector-emitter electrodes is determined by the electrical angle of each cycle of the alternating current ignition signals at which transistor 40 conducts through the collector-emitter electrodes.

Transistor 40 conducts through the collector-emitter electrodes thereof while the potential of the half cycles of the alternating current ignition signals is of a sufficient magnitude to reverse bias diode 49 and does not conduct through the collector-emitter electrodes thereof with the alternate half cycles of the alternating current ignition signals. The electrical angle of the half cycles of the alternating current ignition signals during which the potential of terminal end 18a of pick-up coil 18 is of a positive polarity with respect to terminal end 18b is of a sufficient magnitude to reverse bias diode 49. Consequently, this electrical angle may be controlled or selected or adjusted, or changed by inserting a source of bias potential for pick-up coil 18 in series with pick-up coil 18 and polarized to aid the ignition signals generated by pick-up coil 18 with the half cycles of the alternating current ignition signals during which terminal end 18a and 18b appears across pick-up coil 18 is of a sufficient magnitude to reverse bias diode 49. Consequently, this electrical angle may be controlled or selected or adjusted, or changed by inserting a source of bias potential for pick-up coil 18 in series with pick-up coil 18 and polarized to aid the ignition signals generated by pick-up coil 18 with the half cycles of the alternating current ignition signals during which terminal end 18a and 18b is of a positive polarity with respect to terminal end 18b and vice versa. To supply this bias potential type NPN transistor 70 connected in an emitter follower configuration is provided.
As the collector electrode 72 of transistor 70 is connected to the positive polarity terminal of battery 8 through collector resistor 95, resistor 28, lead 27, stationary contact 26 and switch 24 and the emitter electrode 73 is connected to the negative polarity terminal of battery 8 through emitter resistor 55 and point of reference or ground potential 5, the collector-emitter electrodes of transistor 70 are polarized for forward conduction therethrough. With transistor 70 conducting through the collector-emitter electrodes, the potential drop developed across emitter resistor 55 of a positive polarity upon junction 95 with respect to point of reference or ground potential 5 is the bias potential for pick-up coil 18, the greater the degree of collector-emitter conduction through transistor 70, the greater the magnitude of this bias potential. To establish the degree of collector-emitter conduction through transistor 70, capacitor 77 is connected across the base-emitter electrodes thereof. With the half cycles of the alternating current ignition signals during which the potential upon terminal end 18a of pick-up coil 18 is of a positive polarity with respect to terminal 18b, capacitor 77 charges through a circuit which may be traced from terminal end 18a of pick-up coil 18, through capacitor 96, resistor 86, diode 88, capacitor 77, point of reference or ground potential 5 and series resistors 55 and 54 to the opposite terminal end 18b. This charge upon capacitor 77 is of a positive polarity upon the plate thereof connected to junction 90 with respect to the opposite plate and is prevented from being drained off through resistor 86, capacitor 96 and pick-up coil 18 during the alternate half cycles of the alternating current ignition signals by diode 49 which is reverse biased thereby. As this potential is applied across the base-emitter electrodes of type NPN transistor 70 in the proper polarity relationship to produce base-emitter current flow through a type NPN transistor, the charge upon capacitor 77 produces base-emitter current flow through transistor 70 to initiate collector-emitter current flow therethrough which produces the bias potential across emitter resistor 55. The degree of collector-emitter conduction through transistor 70 is established by the magnitude of the charge upon capacitor 77, the greater the magnitude of this charge, the greater the degree of collector-emitter current and, consequently, the greater the degree of collector-emitter conduction through transistor 70. The bias potential developed across emitter resistor 55 is directly proportional to the degree of collector-emitter conduction through transistor 70.

The bias potential developed across emitter resistor 55 is in series with the series relationship with the potential of the half cycles of the alternating current ignition signals induced in pick-up coil 18 during which the potential of terminal end 18a of pick-up coil 18 is of a positive polarity with respect to terminal end 18b. Therefore, the sum of the bias potential magnitude and the ignition signal potential magnitude during these half cycles is the magnitude of reverse bias potential across diode 49. Diode 49 is reverse biased off by a reverse bias potential of a specific magnitude, therefore, the greater the magnitude of bias potential, the smaller the magnitude of the ignition signal potential required to reverse bias diode 49 and vice versa.

The control potential developed across control impedance element 14 is applied across the base-emitter electrodes of type NPN transistor 60 through base resistors 66 and 84 and point of reference or ground potential 5 and emitter resistor 92, respectively, in the proper polarity relationship to produce base-emitter current flow therefrom through a type NPN transistor. Should the ignition coil primary winding energizing current reach the predetermined magnitude, the control potential appearing across control impedance element 14 reaches the magnitude which will initiate base-emitter current flow through both type NPN transistors 50 and 60 to initiate collector-emitter current flow therethrough. The collector-emitter current flow through type NPN current limiting transistor 50, of course, drains base-emitter current from control transistor 20 to partially extinguish this device and, in turn, ignition coil primary winding switching transistor 10 in a manner previously explained. The collector-emitter current flow through transistor 60 drains a portion of the charge from capacitor 77 through resistor 91, the collector-emitter electrodes of transistor 60 and resistor 92 to point of reference or ground potential 5 to reduce the magnitude of charge thereon. The reduced magnitude of charge upon capacitor 77 reduces the degree of bias emitter current flow and, consequently, collector-emitter conduction through transistor 70 to reduce the magnitude of bias potential produced across emitter resistor 55. Therefore, a greater ignition signal potential magnitude of the half cycles of the alternating current ignition signals during which the potential of terminal end 18a of pick-up coil 18 is of a positive polarity with respect to terminal end 18b is required to reverse bias diode 49. As this required greater ignition signal potential magnitude is reached later during each cycle of the alternating current ignition signals, transistor 49 conducts through the collector-emitter electrodes later during each cycle and, consequently, ignition coil primary winding switching transistor 10 is operated conductive through the collector-emitter electrodes later during each cycle thereby reducing the length of time for the buildup of ignition coil primary winding energizing current. Should the ignition coil primary winding energizing current not reach the predetermined magnitude, transistor 60 would not conduct to drain away a portion of the charge upon capacitor 77. Therefore, this greater charge upon capacitor 77 increases base-emitter current flow and, consequently, collector-emitter conduction through type NPN transistor 70 to increase the magnitude of bias potential produced across emitter resistor 55. Therefore, a smaller ignition signal potential magnitude of the half cycles of the alternating current ignition signals during which the potential of terminal end 18a of pick-up coil 18 is of a positive polarity with respect to terminal end 18b is required to reverse bias diode 49. As this required smaller ignition signal potential magnitude is reached earlier during each cycle of the alternating current ignition signals, transistor 40 conducts through the collector-emitter electrodes earlier during each cycle and, consequently, ignition coil primary winding switching transistor 10 is operated conductive through the collector-emitter electrodes earlier during each cycle, thereby increasing the length of time for the buildup of ignition coil primary winding energizing current. This circuitry, of course, reaches a steady condition at which ignition coil primary winding switching transistor 10 conducts for a period of time just long enough for the ignition coil primary winding energizing current to build up to the predetermined magnitude.

To prevent spurious signals from triggering ignition coil primary winding switching transistor 10 conductive during those periods of time during which it should not conduct, a type NPN transistor 80 having two current carrying electrodes, collector electrode 82 and emitter electrode 83, and a control electrode, base electrode 81, may be employed. Base electrode 81 of transistor 80 is connected to the positive polarity terminal of battery 8 through base resistor 97, collector resistor 29, lead 27, stationary contact 26 and stationary contact 25 of switch 24 and emitter electrode 83 is connected to the negative polarity terminal of battery 8 through point of reference or ground potential 5. Therefore, the potential of battery 8 is applied across the base-emitter electrodes of type NPN transistor 80 in the proper polarity relationship to produce base-emitter current through a type NPN transistor. The collector-emitter electrodes of transistor 80 are connected across the base electrode 11 of ignition coil primary winding switching transistor 10 and point of reference or ground potential 5.

Ignition coil primary winding switching transistor 10 should conduct through the collector-emitter electrodes
while control transistor 20 is conducting through the collector-emitter electrodes and should not conduct through the collector-emitter electrodes while control transistor 20 is extinguished. With control transistor 20 conducting through the collector-emitter electrodes, forward base-emitter current is drained from transistor 80, consequently, this device is ineffective while control transistor 20 is conducting. With control transistor 20 extinguished, however, forward base-emitter current is supplied to transistor 80 in the proper polarity relationship to produce base-emitter current through and condition transistor 80 for collector-emitter current flow there through. Consequently, should any spurious or unwanted signal appear across the base-emitter electrodes of ignition coil primary winding switching transistor 10 of the proper polarity relationship to produce base-emitter current flow through a type NPN transistor, these signals would be shunted to point of reference or ground potential 5 through the collector-emitter electrodes of transistor 80.

In FIG. 1 of the drawing, the ignition coil primary winding switch is illustrated as a single type NPN transistor 10. It is to be specifically understood that transistor 10 may be transistors by two transistors connected in Darlington pair and connected as shown in FIG. 2, wherein like elements have been given like characters of reference, which sets forth that portion of the ignition system circuit of this invention involving the ignition coil primary winding transistors.

Diode 87 provides a low impedance discharge path for capacitor 96 during those half cycles of the ignition signals during which terminal end 18a of pick-up coil 18 is of a negative polarity, Zener diode 98 regulates the potential on the low end of resistor 28 and capacitor 99 represses any voltage transients which may appear at terminal 18b of pick-up coil 18.

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

While a preferred embodiment of the present invention has been shown and described, it will be obvious to those skilled in the art that various modifications and substitutions may be made without departing from the spirit of the invention which is to be limited only within the scope of the appended claims.

We claim:

1. An internal combustion engine ignition system comprising in combination with a source of alternating current ignition signals produced in timed relationship with the engine, a direct current potential source and an ignition coil having at least a primary winding, at least one ignition coil primary winding switching transistor having two current carrying electrodes and a control electrode, a control impedance element, means for connecting said ignition coil primary winding, said current carrying electrodes of said switching transistor and said control impedance element in series across said direct current potential source, means responsive to each cycle of said alternating current ignition signals for operating said switching transistor conductive and not conductive through said current carrying electrodes in timed relationship with said engine, first means responsive to the control potential developed across said control impedance element of the magnitude produced by an ignition coil primary winding energizing current of a predetermined magnitude for limiting the magnitude of energizing current flow through said current carrying electrodes during each alternating current ignition signal cycle.

2. An internal combustion engine ignition system comprising in combination with a source of alternating current ignition signals produced in timed relationship with the engine, a direct current potential source and an ignition coil having at least a primary winding, at least one ignition coil primary winding switching transistor having two current carrying electrodes and a control electrode, a control impedance element, means for connecting said ignition coil primary winding, said current carrying electrodes of said switching transistor and said control impedance element in series across said direct current potential source, means responsive to each cycle of said alternating current ignition signals for operating said switching transistor conductive and not conductive through said current carrying electrodes in timed relationship with said engine, first means responsive to the control potential developed across said control impedance element of the magnitude produced by an ignition coil primary winding energizing current of a predetermined magnitude for limiting the magnitude of energizing current flow through said current carrying electrodes during each alternating current ignition signal cycle.
through said current carrying electrodes of said ignition coil primary winding switching transistor is limited to the predetermined magnitude, and means responsive to said control potential for establishing the electrical angle of the cycle of said alternating current ignition signals at which said control transistor conducts through said current carrying electrodes.

4. An internal combustion engine ignition system comprising in combination with a source of alternating current ignition signals produced in timed relationship with the engine, said control potential source and an ignition coil having at least a primary winding, at least one ignition coil primary winding switching transistor having two current carrying electrodes, and a control electrode, a control impedance element, means for connecting said ignition coil primary winding, said current carrying electrodes of said switching transistor and said control impedance element in series across said direct current potential source, a control transistor having a control electrode and two current carrying electrodes, a first circuit through which forward control electrode current is supplied to said control transistor for conditioning said control potential source for said current carrying electrode current, and a second circuit including said current carrying electrodes of said control transistor through which forward control electrode current is supplied to said switching transistor for producing conduction through said current carrying electrodes of said switching transistor to complete an ignition coil primary winding energizing circuit for the flow of ignition coil primary winding energizing current through said ignition coil primary winding and said control impedance element, a third circuit through which said forward control electrode current is supplied to said control potential source for said current carrying electrode current, means for connecting said current carrying electrodes of said control transistor for extinguishing said control transistor, means included in said third circuit responsive to each selected half cycle of said alternating current ignition signals for completing said third circuit and to each other half cycle of said alternating current ignition signals for interrupting said third circuit whereby said ignition coil primary winding switching transistor is operated not conductive and conductive through said current carrying electrodes thereof in timed relationship with said engine, a current limiting transistor having a control electrode and two current carrying electrodes, means for connecting said current carrying electrodes of said current limiting transistor in shunt across said control electrode of said control transistor and the remainder of said first circuit, means for applying the control potential developed across said control impedance element of the magnitude produced by an ignition coil primary winding energizing current of a predetermined magnitude across said base-emitter electrodes of said current limiting transistor for producing conduction through said control-electrode electrodes to reduce the magnitude of base-emitter electrode current to said control transistor whereby the magnitude of energizing current flow through said collector-emitter electrodes of said ignition coil primary winding switching transistor is limited to the predetermined magnitude, and means responsive to said control potential for establishing the electrical angle of each said other half cycle of said alternating current ignition signals at which said third circuit is interrupted.

5. An internal combustion engine ignition system comprising in combination with a source of alternating current ignition signals produced in timed relationship with the engine, said control potential source and an ignition coil having at least a primary winding, at least one ignition coil primary winding switching transistor having collector-emitter electrodes and a base electrode, a control impedance element, means for connecting said ignition coil primary winding, said collector-emitter electrodes and said base electrode, said current carrying electrodes of said switching transistor and said control impedance element in series across said direct current potential source, a control transistor having a base electrode and collector-emitter electrodes, a first circuit through which forward base-emitter current is supplied to said control transistor for conditioning said control transistor for conduction through said collector-emitter electrodes, a second circuit including said base electrode of said control electrodes of said control transistor through which forward base-emitter current is supplied to said switching transistor for producing conduction through said collector-emitter electrodes of said switching transistor to complete an ignition coil primary winding energizing circuit for the flow of ignition coil primary winding energizing current through said ignition coil primary winding and said control impedance element, a third circuit through which said forward base-emitter current supplied to said control transistor may be shunted from said control transistor for extinguishing said control transistor, means included in said third circuit responsive to each selected half cycle of said alternating current ignition signals for completing said third circuit and to each other half cycle of said alternating current ignition signals for interrupting said third circuit whereby said ignition coil primary winding switching transistor is operated not conductive and conductive through said current carrying electrodes thereof in timed relationship with said engine, a current limiting transistor having a base electrode and collector-emitter electrodes, means for connecting said collector-emitter electrodes of said current limiting transistor in shunt across said base-emitter electrodes of said control transistor and the remainder of said first circuit, means for applying the control potential developed across said control impedance element of the magnitude produced by an ignition coil primary winding energizing current of a predetermined magnitude across said base-emitter electrodes of said current limiting transistor for producing conduction through said collector-emitter electrodes to reduce the magnitude of base-emitter electrode current to said control transistor whereby the magnitude of energizing current flow through said collector-emitter electrodes of said ignition coil primary winding switching transistor is limited to the predetermined magnitude, and means responsive to said control potential for establishing the electrical angle of each said other half cycle of said alternating current ignition signals at which said third circuit is interrupted.
connecting said current carrying electrodes of said second transistor across said control electrode of said control transistor and the junction between said second resistor and said current carrying electrodes of said first transistor and said second resistor, means for connecting said control electrode of said second transistor to the junction between said first resistor and one of said current carrying electrodes of said first transistor, a current limiting transistor having a control electrode and two current carrying electrodes, means for connecting said current carrying electrodes of said current limiting transistor in shunt across said control electrode of said control transistor and one polarity output terminal of said direct current potential source, means for connecting said control electrode of said current limiting transistor to the junction between said control electrode of said switching transistor and said control impedance element, a first diode, means for connecting said control electrode of said first transistor to one terminal end of said pickup coil through said first diode, first and second capacitors, a second diode, means for connecting said first resistor, said second diode and said second capacitor in series across the junction between said first diode and one terminal end of said pickup coil and one polarity output terminal of said direct current potential source in that order, third and fourth resistors, means for connecting the other terminal end of said pickup coil to the other polarity output terminal of said direct current potential source through said third and fourth resistors in series, a third transistor having two current carrying electrodes and a control electrode, means for connecting said current carrying electrodes of said third transistor across said direct current potential source through said fourth resistor, means for connecting said control electrode of said third transistor to the junction between said second diode and said second capacitor, a fourth transistor having two current carrying electrodes and a control electrode, means for connecting said current carrying electrodes of said fourth transistor across said second capacitor, and means for connecting said control electrode of said fourth transistor to the junction between one of said current carrying electrodes of said switching transistor and said control impedance element.

7. An internal combustion engine ignition system comprising in combination with a magnetic distributor of the type which produces alternating current ignition signals in a pickup coil in timed relationship with the engine a direct current potential source having positive and negative polarity output terminals and an ignition coil having at least a primary winding, said collector-emitter electrodes of said switching transistor and said control impedance element in series across said direct current potential source, a control transistor having a base electrode and collector-emitter electrodes, means for connecting said base-emitter electrodes across said direct current potential source, means for connecting said collector-emitter electrodes of said control transistor and said base-emitter electrodes of said switching transistor in series across said direct current potential source, first and second transistors each having collector-emitter electrodes and a base electrode, a control impedance element, means for connecting said first transistor across said base electrode of said control transistor and the junction between said emitter electrode of said first transistor and said second resistor, means for connecting said base electrode of said second transistor to the junction between said first resistor and said collector-emitter electrodes of said first transistor, a current limiting transistor having a control electrode and two current carrying electrodes, means for connecting said current carrying electrodes of said current limiting transistor in shunt across said base electrode of said control transistor and said negative polarity output terminal of said direct current potential source, means for connecting said base electrode of said current limiting transistor to the junction between said control electrode of said switching transistor and said control impedance element, a first diode, means for connecting said base electrode of said first transistor to one terminal end of said pickup coil through said first diode, first and second capacitors, a second diode, means for connecting said first capacitor, said second diode and said second capacitor in series across the junction between said first diode and one terminal end of said pickup coil and said negative polarity output terminal of said direct current potential source in that order, third and fourth resistors, means for connecting the other terminal end of said pickup coil to the other polarity output terminal of said direct current potential source through said third and fourth resistors in series, a third transistor having collector-emitter electrodes and a base electrode, means for connecting said collector-emitter electrodes of said third transistor across said direct current potential source through said fourth resistor, means for connecting said base electrode of said third transistor to the junction between said second diode and said second capacitor, a fourth transistor having collector-emitter electrodes and a base electrode, means for connecting said collector-emitter electrodes of said fourth transistor across said second capacitor, and means for connecting said base electrode of said fourth transistor to the junction between said collector electrode of said switching transistor and said control impedance element.

8. An internal combustion engine ignition system comprising in combination with a direct current potential source and an ignition coil having at least a primary winding, means for producing alternating current ignition potential signals in timed relationship with the engine, means responsive to selected polarity half cycles of said alternating current ignition potential signals for establishing an ignition coil primary winding energizing circuit across said direct current potential source when the potential of each of said selected half cycles reaches a predetermined magnitude and to the other half cycles of said alternating current ignition potential signals for abruptly interrupting said ignition coil primary winding energizing circuit, means for producing a bias potential, means for applying said bias potential to said alternating current ignition potential signals in an aiding relationship during those said selected half cycles, and means responsive to a predetermined magnitude of ignition coil primary winding energizing current for varying the magnitude of said bias potential in a direction which will result in the establishment of said ignition coil primary winding energizing circuit for a period of time just long enough for the ignition coil primary winding energizing current to reach said predetermined magnitude.

9. An internal combustion engine ignition system comprising in combination with a direct current potential source and an ignition coil having at least a primary winding, means for producing alternating current ignition potential signals in timed relationship with the engine, means responsive to selected polarity half cycles of said alternating current ignition potential signals for establishing an ignition coil primary winding energization circuit across said direct current potential source when the potential of each of said selected half cycles reaches a predetermined magnitude and to the other half cycles of said alternating current ignition potential signals for abruptly interrupting said ignition coil primary winding energization circuit, means for producing a bias potential, means for applying said bias potential to said alternating current ignition potential signals in an aiding relationship during those said selected half cycles, and means responsive to a predetermined magnitude for varying the magnitude of said bias potential in a direction which will result in the establishment of said ignition coil primary winding energization circuit for a period of time just long enough for the ignition coil primary winding energization current to reach said predetermined magnitude.
of ignition coil primary winding energizing current for limiting the magnitude of said energizing current to said predetermined magnitude, means for applying said bias potential to said alternating current ignition potential signals in an aiding relationship during those said selected half cycles, and means responsive to said predetermined magnitude of ignition coil primary winding energizing current for varying the magnitude of said bias potential in a direction which will result in the establishment of said ignition coil primary winding energizing circuit for a period of time just long enough for the ignition coil primary winding energizing current to reach said predetermined magnitude.

References Cited

UNITED STATES PATENTS
3,238,416 3/1966 Huntzinger et al. 315—209X

LAURENCE M. GOODRIDGE, Primary Examiner

U.S. Cl. X.R.
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,605,713 Dated September 20, 1971

Inventor(s) Paul D. Le Masters et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 15, "time" should read -- timed --; line 21, cancel "coil primary winding switching transistor and a control". Column 3, line 10, cancel "may", second occurrence. Column 6, line 55, "circuit" should read -- circuit --; line 62, "apparent" should read -- apparent --; line 68, after "half" insert -- a --. Column 9, line 49, "remitter" should read -- emitter --; Column 11, line 50, "ingition" should read -- ignition --. Column 13, line 55, after "said" insert -- current --. Column 16, line 45, "sad" should read -- said --.

Signed and sealed this 9th day of May 1972.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCALK
Commissioner of Patents