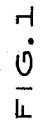


Filed Aug. 3, 1964

IGNITION SYSTEM

4 Sheets-Sheet 1



BY *John R. Faulkner*
Keith L. Zerschling
ATTORNEYS

Jan. 24, 1967

L. F. MIERAS

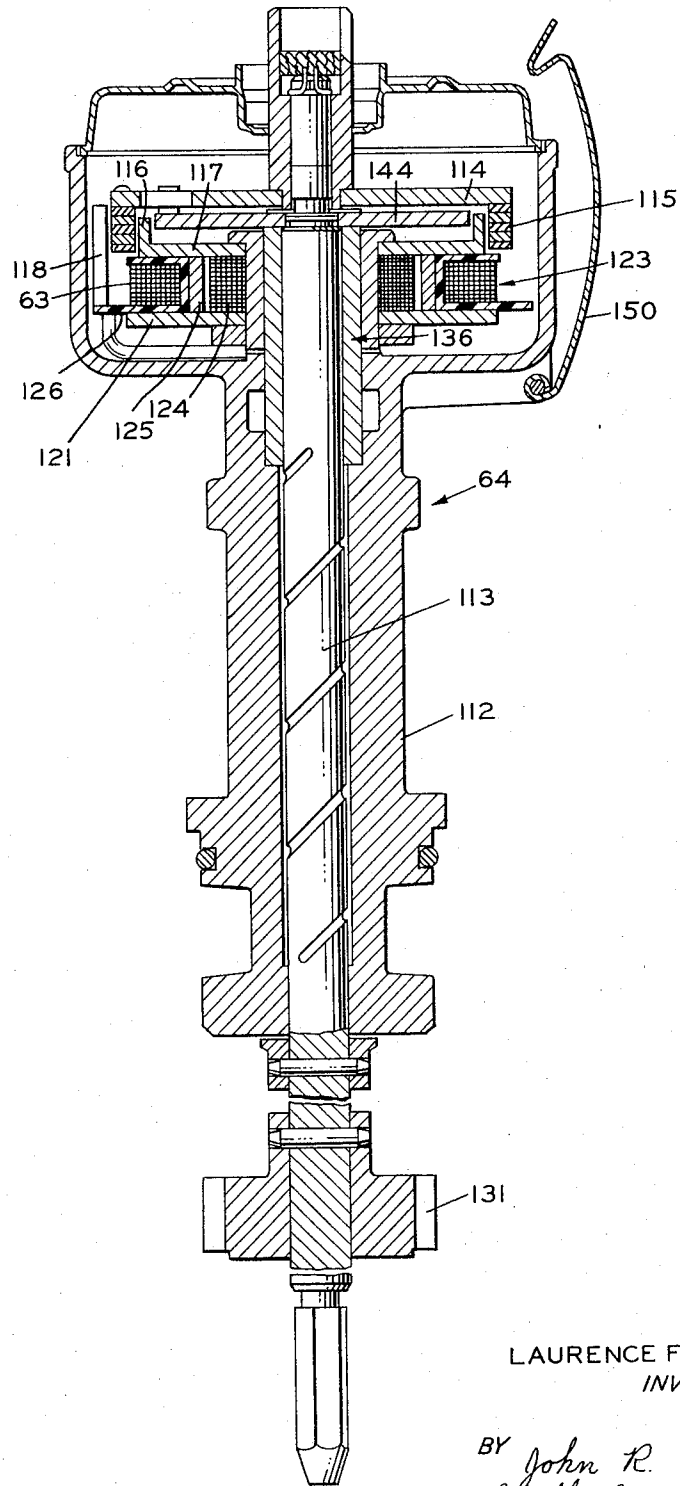
3,299,876

IGNITION SYSTEM

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FIG. 2

4 Sheets-Sheet 2



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IGNITION SYSTEM

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FIG. 3

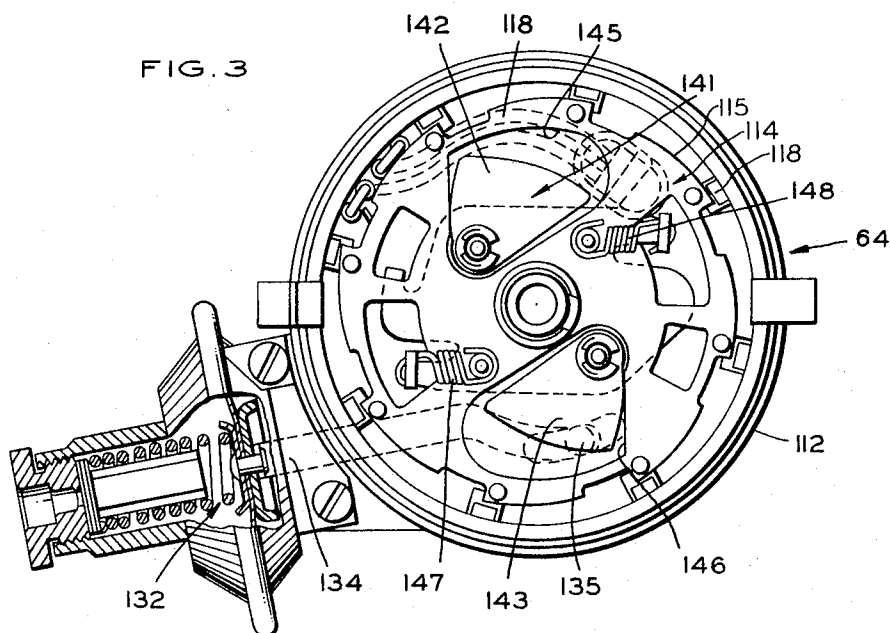
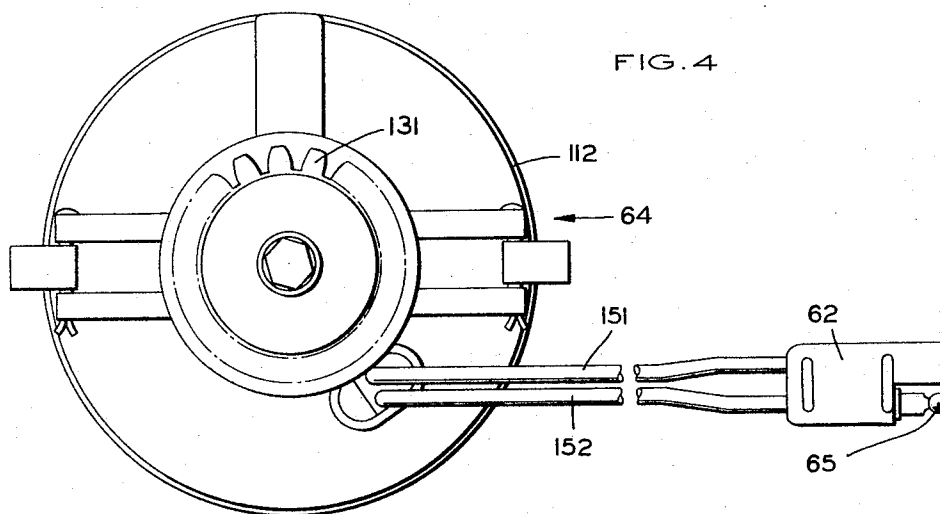


FIG. 4



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3,299,876

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FIG. 5

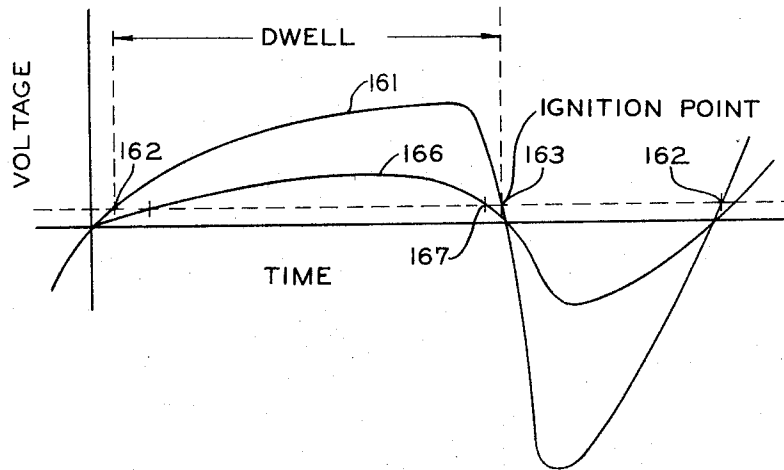
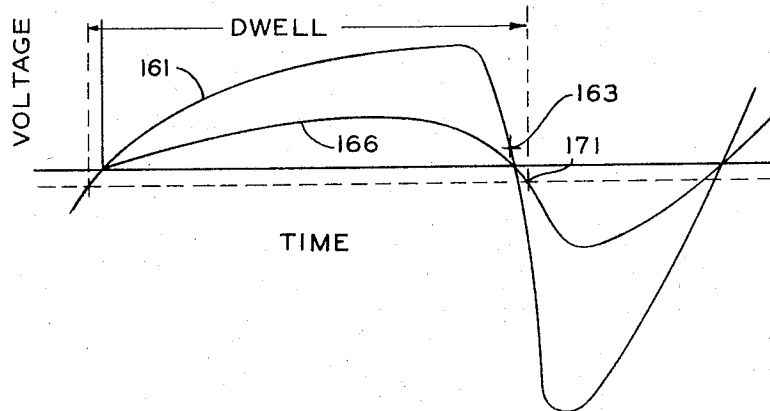


FIG. 6



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3,299,876

IGNITION SYSTEM

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Filed Aug. 3, 1964, Ser. No. 387,003

6 Claims. (Cl. 123-148)

This invention relates to a transistorized ignition system for an internal combustion engine and more particularly to such a transistorized ignition system which is controlled in timed synchronism with the operation of the engine by means of an electromechanical generator that produces an alternating current output.

In this system, a transistor is connected to control the flow of electrical energy from the battery or source of electrical energy of the vehicle through the primary winding of the ignition coil of the system. This transistor is normally biased by means of a biasing circuit into a steady state nonconducting state during normal running operations. The output of an electromechanical generator is applied to the biasing circuit for turning this transistor on during the dwell period of the ignition system thereby providing current flow through the primary winding of the ignition coil. The transistor is then turned off through the biasing circuit when the voltage generated by the electromechanical generator falls to a certain predetermined value determined by the bias placed on the biasing circuit. At this time, the transistor will turn off interrupting current flow through the primary winding of the ignition coil to provide high ignition voltages at the secondary winding of the ignition coil.

It can be appreciated that during cranking operations, the electromechanical generator will have a low voltage output. The voltage wave form is in the form of a modified sine wave so that the slope of the voltage wave form as it crosses the zero axis has a substantial negative value. If the ignition system is properly timed for running or high speed operation when high voltages are generated by the electromechanical generator during cranking or starting operations where low voltages are generated, the particular value of voltage at which the transistor turns off will be shifted toward the zero time axis since the slope of the voltage wave form decreases negatively as the voltage output from the electromechanical generator decreases. This will cause an advance in the firing of the spark plugs of the internal combustion engine over that experienced during normal running operations. This could cause some difficulty during starting when it is necessary that the spark not be advanced to any great extent in order to properly start the engine.

In order to obviate this difficulty, the present invention provides a means for rebiasing the transistor so that it is normally conducting during starting operations, or stated differently, it is biased to a steady state conducting state during starting operations. In the preferred embodiment of the invention, rebiasing of the circuit provides a system in which the transistor will be turned off when the wave form or the voltage output from the output winding of the electromechanical generator goes negative by a small amount with respect to the zero voltage axis of the wave form. Thus, when the wave form or the voltage output decreases in value and the slope of the voltage wave form where it crosses the zero axis decreases negatively, the point at which the transistor will turn off will be shifted away from the zero time axis thus retarding the firing of the spark plugs over that normally prevailing during standard running operations. This permits easy starting

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of the internal combustion engine with the transistorized ignition system of the invention.

An object of the invention is the provision of a transistorized ignition system for an internal combustion engine in which a transistor that normally is in a nonconducting state during normal operating conditions is rebiased to a conducting state during starting operations.

Another object of the invention is the provision of a transistorized ignition system employing an electromechanical generator for controlling the operation of the system in which the firing of the spark plugs will be retarded during starting operations over that which prevails during normal running operations.

A further object of the invention is the provision of a transistorized ignition system for an internal combustion engine that employs an electromechanical generator for control of the system that will be efficient during both starting and running operations.

Other objects and attendant advantages of the present invention may be more readily realized when the specification is considered in connection with the attached drawings, in which:

FIGURE 1 is a circuit diagram of the invention;

FIGURE 2 is a longitudinal cross sectional view of an electromechanical generator employed with the present invention;

FIGURE 3 is a top plan view of the electromechanical generator of FIGURE 2 with the cover removed and with portions thereof in section;

FIGURE 4 is a bottom plan view of the electromechanical generator of FIGURE 2;

FIGURE 5 is a curve showing the voltage output of the electromechanical generator of the invention during both running and starting conditions including the points of firing of the spark plugs, and

FIGURE 6 is a view similar to FIGURE 5, but showing the curve that exists in the firing of the spark plugs as the circuit operates during starting operations.

Referring now to the drawings in which like reference numerals designate like parts throughout the several views thereof, there is shown in FIGURE 1 the transistorized ignition system of the invention that includes an ignition coil 10 having a secondary winding 11. The secondary winding 11 is sequentially connected to spark plugs 12 through a distributor 13. The distributor 13 includes a rotating arm 14 for sequentially connecting the spark plugs 12 to the secondary winding 11 in synchronism with the operation of the engine in which the ignition system is mounted.

The primary winding 15 of the ignition coil 10 is energized from the source of electrical energy or storage battery 16 under the control of a transistor 17 that is connected in series with the primary winding 15 and the source of electrical energy 16. This is accomplished by connecting the positive terminal 21 of the source of electrical energy 16 to the emitter 22 of transistor 17 by means of lead 23, lead 24, movable arm 25 of ignition switch 26, contact 27 of this switch, lead 28, ballast resistor 29, lead 30, resistor 31 and lead 32. The collector 33 of the transistor 17 is connected to the primary winding 15 of ignition coil 10 through lead 34, winding 35 of a bistable electromagnetic switch 36, lead 37, lead 38 and resistor 41.

The control of transistor 17 is accomplished by means of a biasing circuit means 42 that includes a second transistor 43 having an emitter 44 connected to the base 45 of transistor 17 through diode 46. The collector 47 of transistor 43 is connected to ground through winding 48 of bistable electromagnetic switch 36 and a base current

limiting resistor 49. The emitter 22 and the base 45 of transistor 17 are interconnected through output winding 50 of bistable electromagnetic switch 36 and a resistor 51.

The base 52 of transistor 43 is connected to collector 53 of transistor 54 by means of lead 55. The lead 55 and the collector 53 of transistor 54 are connected to ground through a resistor 56. The emitter 57 of transistor 54 is connected to lead 32 through resistor 58.

The base 60 of transistor 54 is connected through lead 61 to one terminal 62 of the output winding 63 of an electromechanical generator 64. The other terminal 65 of the output winding 63 is connected to a junction 66 between resistor 67 and the cathode 68 of diode 69. The anode 71 of the diode 69 is connected to junction 72 and this junction in turn is connected to one terminal of resistor 73. The other terminal of the resistor 73 is connected to lead 30. A resistor 74 has one terminal connected to junction 72 and the other terminal connected to junction 75, while a resistor 76 has one terminal connected to junction 75 through lead 77 and the other terminal connected to the base 60 of transistor 54 by means of junction 78. The junction 78 is connected to lead 38 through a feedback resistor 81 and lead 82.

The ignition switch 26, in addition to having the movable arm 25, has a second movable arm 86 that moves in unison with the arm 25 and is connected to the positive terminal 21 of the source of electrical energy 16 through the lead 87 and the leads 24 and 23. As shown in the drawing, both movable arms 25 and 86 are in contact with off terminals 91 and 91' respectively. The ignition switch 26 is also provided with start terminals 92 and 92'.

The start terminal 92' is connected to relay winding 93 of starting relay 94 through lead 95. The starting relay 94 has a movable armature 96 normally biased to the open position but which will move into engagement with contacts 97 and 98 when relay winding 93 is energized. The contact 97 is directly connected to the positive terminal 21 of source of electrical energy 16 through lead 101 and lead 23. The other contact 98 of the starting relay 94 is connected to one terminal of starting motor 102 through a lead 103. The other terminal of the starting motor 102 is connected to ground through a lead 104.

A cold start relay 106 is provided that has a set of normally closed contacts 107 connected to armature 96 of the starting relay 94 and to lead 30. The winding 108 of the cold start relay 106 is connected to contact 98 of the starting relay 94 through lead 109. The other terminal of the winding 108 is connected to ground through a resistor 110. During cold weather starting operations, the terminal voltage of battery 16 will be low and thus when the starter relay 94 is energized during starting operations, the current flow through the winding 108 will be insufficient to open contacts 107. Ballast resistor 29 will, therefore, be shorted out of the series circuit that includes source of electrical energy 16, transistor 17 and primary winding 15 of coil 10. On the other hand, during starting operations at high temperatures, the terminal voltage of battery 16 will be sufficiently high that the current flow through winding 108 will be sufficient to open contacts 107. This keeps the ballast resistor in the circuit during high temperature starting to effectively limit the current through the transistor 17.

The junction 75 of the biasing circuit 42 is connected to the contact 98 of the starter relay 94 through a lead 111 thereby grounding the junction point 75 during normal running operations through the starter motor 102, by means of lead 111, contact 98 and lead 103.

The electromechanical generator 64 is shown in detail in FIGURES 2, 3 and 4. It includes a suitable housing 112 that is mounted in an internal combustion engine. The housing 112 may be a conventional distributor housing and may be mounted in the engine by any suitable means. A shaft 113 is rotatably mounted within the housing 112, and it has affixed thereto a rotor 114. The rotor 114 has a depending shaped flange 115 that extends

between an upstanding flange 116 on upper plate 117, and upstanding spaced teeth 118 on a lower plate 121. The upper plate and the lower plate 117 and 121 respectively, form part of the stator structure 123 of the electromechanical generator 64.

The stator structure 123 also includes an annular permanent magnet 124 positioned between the upper and lower plates 117 and 121 and a magnetic gate element 125 positioned between these two plate members. The winding 63 of the electromechanical generator 64 is positioned radially outwardly of the permanent magnet 124 and the magnetic gate element 125, and is enclosed within a plastic bobbin 126.

As the rotor or armature 114 is rotated, the reluctance of the magnetic paths between the upstanding teeth 118 and the upstanding flange 116 is varied in accordance with the shaping of the depending flange 115 of rotor 114, and this changes the amount of flux linked by the winding or coil 63. When the reluctance of the path between the teeth 118 and the upstanding flange 116 is at a maximum, as it is when the narrowest parts of flange 115 of rotor 114 are opposite teeth 118 of lower plate 121, most of the flux is shunted through the magnetic gate element 125. When the widest portions of the flange 115 of rotor 114 come into line with the teeth 118 on the lower flange 121, the reluctance between the teeth 118 and the flange 116 is substantially reduced. This changes the reluctance of the flux path, and an output voltage is generated in the winding or coil 63.

The depending flange 115 of the rotor 114 is shaped, as shown in FIGURE 3, and as the rotor 114 is rotated by the operation of the internal combustion engine, the voltage wave forms shown in FIGURES 5 and 6 will be produced. It can be appreciated that the rotor 114 may be rotated through the shaft 113 by having the gear 131 attached to shaft 113 engage a suitable rotating gear driven by the internal combustion engine, as done in conventional distributor systems.

As can best be seen by reference to FIGURE 3, standard vacuum advance means 132 may be employed to control the advance and retard of the ignition timing in accordance with engine load by connecting the arm 134 of the vacuum advance means to the lower plate 121 of the stator 123 through a pin 135 on the arm. This will cause the whole stator structure 123 to rotate about bearing 136 positioned in the housing 112.

A centrifugal advance means 141 of standard type may also be employed to advance or retard the ignition timing in accordance with engine speed. This comprises the standard centrifugal weights 142 and 143 that are mounted on plate 144 driven by the shaft 113. These weights fit into cam slots 145 and 146 in the rotor 114 and the rotor is biased to its normal position with respect to the armature shaft by means of springs 147 and 148. As the speed of the shaft 113, the plate 144 and the rotor 114 increases, the centrifugal weights 142 and 143 move the rotor 114 relative to the shaft 113 to thereby modify the ignition timing in accordance with the speed of the engine.

The shaft 113 receives a standard distributor rotor cap represented by the rotating arm 14 and the housing 112 receives a distributor cap that may be affixed to the housing by fastening means 150.

It can be seen by reference to FIGURE 4 that the coil 64 has output leads 151 and 152 that may be connected to the terminals 62 and 65 as described in relation to FIGURE 1.

The electromechanical generator 64 shown in FIGURES 2 through 4 was invented by Mr. Frank Skay and is shown and described more fully in a copending application Serial No. 403,264, filed October 12, 1964, in the name of Mr. Skay. No claim to the structure of this electromechanical generator is asserted in this application.

Referring back to FIGURE 1, there is shown a zener diode 153 connected across the transistor 17 as a protective device. The capacitor 154 connected between lead 38 and

ground is also a protective device to prevent the instantaneous wattage appearing across the transistor 17 from rising to undesirable levels. A capacitor 155 is connected between the lead 30 and ground to absorb high frequency transients that might come through the system to inadvertently trigger the transistorized ignition system.

Typical values that may be employed in the transistorized ignition system are given as follows by way of example only:

Resistor 73	-----ohms--	15
Resistor 74	-----do--	330
Resistor 67	-----do--	5,600
Resistor 81	-----do--	12,000
Resistor 76	-----do--	8,000
Resistor 56	-----do--	150
Resistor 31	-----do--	.015
Resistor 58	-----do--	1.5
Diode 69, milliwatts at 1 to 2 milliamps	-----	1N91-150
Transistor 54	-----	RCA2N2953
Transistor 43	-----	RCA2N301

The remaining components are given in my copending application Serial No. 170,055. This includes the transistor 17 and the values of the windings and other components that form the bistable electromagnetic switch 36.

In normal operation, when the internal combustion engine is running, the movable arms 25 and 36 of the ignition switch 26 are in engagement with the ignition contacts 27 and 27' of ignition switch 26 respectively. This connects the source of electrical energy 16 in series with the emitter 22 and collector 33 of transistor 17 and the primary winding 15 of ignition coil 10. At this time, and if it is assumed that the output winding 63 is not producing any output voltage, the transistor 54 is biased to a steady state conducting state. This is done by the connection of the emitter 57 of transistor 54 to the positive terminal 21 of the source of electrical energy 16 through the resistor 58, lead 32 and the circuit previously described.

The base 60 of this transistor is connected to ground or the negative terminal of the source of electrical energy 16 through resistor 76, lead 77, lead 111, contact 98 of starting relay 94, lead 103, the armature of the starting motor 102 and lead 104. The resistor 76 together with the resistor 81 may be thought of as a voltage divider with the base 60 of the transistor 54 connected to the junction of the voltage divider. As pointed out above the base 60 is connected to ground and hence the negative terminal of the source of electrical energy 16 through the resistor 76 of this voltage divider. It can be appreciated also that the base 60 is connected to the negative terminal of the source of electrical energy, or battery 16, through output winding 63 of the electromechanical generator 64 and the resistor 67 of the voltage divider comprised of resistor 67, diode 69 and the resistor 73. This provides the proper negative bias on the base 60 with respect to the emitter 57 to bias the transistor 54 into its conducting state. The current flow through the base circuit of this transistor, including the resistor 76 and the circuit previously described, will provide approximately a 0.4 volt negative voltage bias on the base 60 with respect to emitter 57.

With transistor 54 conducting, the transistor 43 will be in a nonconducting state, since the voltage drop across the transistor 54 is so small that the base current of transistor 43, flowing out of base 52, is zero. It can be appreciated that when transistor 43 is in a nonconducting state, transistor 17 will also be in a nonconducting state since no current can flow out of the base 45 of transistor 17.

In order to turn transistor 54 off and to turn transistors 43 and 17 on, it is necessary to overcome the negative bias on the base 60 of transistor 54, and this is done by means of the output voltage from the output winding 63 of the electromechanical generator 64. The output voltage wave form 161 appearing at the terminal 62 that is connected to the base 60 through lead 61 is shown in

FIGURE 5. The reference or zero voltage line of this figure is the voltage at the junction 78 and hence the voltage at the base 60 of transistor 54 when the generator 64 is not producing any output voltage. It is negative with respect to the emitter 57 of approximately 0.2 to 0.4 volt. The bias on the transistor 54 that must be overcome by this voltage wave form in order to turn the transistor 54 off is shown in the dotted line. In other words, the voltage output of the generator 64 must rise at junction 78 and base 60 of transistor 54 to 0.2 to 0.4 volt positive, as shown by the dotted line, in order to turn transistor 54 off. The voltage wave form 161 is the normal output voltage that occurs when the rotor 114 of the electromechanical generator 64 is driven at normal operating speeds.

When the voltage rises to the point 162 where the wave form 161 intersects the dotted line, the bias on base 60 of transistor 54 is overcome and the positive potential applied to the base 60 from the output winding 63 blocks current flow from the base thereby turning off transistor 54. This action permits current flow from the base 52 of transistor 43 thereby turning on both transistor 52 and transistor 17.

When the voltage appearing at the terminal 62 drops to the point of the cross 163, the base current from transistor 54 is no longer blocked and, therefore, this transistor will turn on and transistors 43 and 17 will turn off. During the dwell period that transistor 17 is conducting, the time between the two crosses, designated by the numerals 162 and 163, current flows from the source of electrical energy 16 through the emitter 22-collector 33 circuit of the transistor 17 and the primary winding 15 of the ignition coil 10. This current also flows through lead 34, winding 35 of bistable electromagnetic switch 36 and lead 37. When the point of the cross 163 is reached, the transistor 54 turns on and transistors 43 and 17 turn off. This interrupts current flow in the primary winding 15 of ignition coil 10 and ignition voltages are generated in the secondary winding 11.

The output voltage of the winding 63 appearing at terminal 62 then goes negative and after a time reverses and comes back to the same level that it was at the cross 162. At this time, the transistor 54 will again be turned off and transistors 43 and 17 will be turned on to initiate another ignition cycle.

The electromagnetic switch 36 and its action is identical to that described in my copending application Ser. No. 170,055 and it furnishes a means for rapidly switching the transistor 17 from a conducting to a nonconducting state at the time the voltage wave form 161 falls to the point 163.

It can be appreciated from an inspection of the values given of resistors 73 and 67 and the fact that the voltage drop across diode 69 is very small, that the voltage appearing at the junction 66 is only slightly below battery voltage as is the voltage appearing at the junction 78 during steady state conditions that prevail when electromechanical generator 64 is not producing an output voltage. Thus, for all practical purposes, the voltage wave forms shown in FIGURE 5 may be considered to be positive and negative with respect to the steady state voltage appearing at the junction 78 and hence at the base of transistor 60.

During very low speed operation that occurs during engine starting conditions, the voltage output of the winding 63 that appears at terminal 62 is shown by the wave form 166. The magnitude of the maximum voltage output of the voltage represented by this wave form is substantially reduced over that developed during normal running operations as represented by the wave form 161. The slope of the wave form 166 where it crosses the zero axis, in the region in which ignition voltages are generated by turning off transistor 17, therefore, decreases in a negative fashion from the slope of the curve 161. This would move the ignition point to the left to point 167 from the ignition point 163 that occurs during normal running

operations, resulting in an advance of the ignition timing during cranking operations. As a consequence, it may be difficult to start the internal combustion engine.

In order to provide proper ignition timing during starting operations, the transistor 54 is rebiased into a nonconducting state during starting or cranking operations. This is done through the starting relay 94. When the ignition switch 26 is positioned in the start position, the movable arm 86 engages contact 92' thereby energizing the winding 93 and moving armature 96 into engagement with contacts 97 and 98. This action connects the base 60 of transistor 54 with the positive terminal 21 of the source of electrical energy 16 through resistor 76, leads 77 and 111, contact 98, armature 96, contact 97 and leads 101 and 23.

With transistor 54 biased to its nonconducting state, as it will be since the emitter 57 is also connected to the positive terminal 21 of the source of electrical energy 16, transistors 43 and 17 are biased to their conducting states. It is necessary, therefore, to provide a negative voltage at the base 60 of transistor 54 in order to turn transistor 54 on and to turn transistors 43 and 17 off. It can be appreciated from an inspection of FIGURE 6 that this voltage level may be represented by the dashed line that may be a negative voltage value of somewhere in the neighborhood of from 0.2 to 0.4 volt.

With the contacts 107 of relay 106 closed, as they will be when the voltage of the battery 16 is below a predetermined value, the positive terminal 21 of battery 16 is connected to line 30 and hence the junction of resistors 31 and 73 through lead 23, lead 101, contact 97, armature 96, and closed contacts 107 of the relay 106. Therefore, prior to any current flow in the circuit or through the line 30, which will be the case at the time ignition switch 26 is moved to the start position since current cannot change instantaneously through the primary winding 15 of ignition coil 10, the voltage on the emitter 57 will be substantially battery voltage and the voltage at the base 60 as previously explained will be battery voltage. As a result, transistor 54 will be in a nonconducting state and as previously explained this will cause transistors 43 and 17 to turn to their conducting states. Current then will flow from line 30 which is at the potential of the positive terminal of battery 16, through resistor 31, the transistor 17, winding 35 of the bistable electromagnetic switch 36, lead 37, lead 38, resistor 41 and primary winding 15 of the ignition coil 17. This current which may be on the order of 10 amps. will cause a voltage drop of 0.15 volt across the resistor 31 that has a value of 0.015 ohm thereby applying a voltage to the emitter 57 of transistor 54 of 0.15 volt negative with respect to the positive terminal 21 of the battery 16.

The base 60 of the transistor 54 and junction 78 are, as previously stated, connected to the positive terminal 21 of battery 16 through the armature 96 and contacts 97 and 98 of relay 94, junction 75, lead 111, lead 77 and resistor 76. The base 60 and junction 78 are also connected to lead 38 through resistor 81 and lead 82. They are also connected to junction 66 through lead 61, winding 63 of generator 64 and lead 65.

The junction 66, it has been found, will be at approximately 0.165 volt below battery voltage due to the voltage drop across the 15 ohm resistor 73 and the diode 69. The junction 78 will also be at a slightly negative voltage at about this level due to current flow from junction 75, which is at battery voltage, through resistor 76, resistor 81 and lead 82 to the lead 38. This current flow is very small since resistor 76 is 8,000 ohms and resistor 81 is 12,000 ohms, and the lead 38 with the transistor 17 conducting is approximately 0.5 volt below battery voltage due to the voltage drop across the conducting transistor 17 and resistor 31. As a result, there will be substantially no bias voltage on the base 60 with respect to the emitter 57, or if there is any negative bias voltage it would

be so small that it would be insufficient to turn transistor 54 on.

In order to turn transistor 54 on and to turn transistors 43 and 17 off, which will result in the generation of ignition voltages in the secondary winding 11 of the ignition coil 10, it is necessary to apply a bias voltage of a negative value on the base of transistor 54 with respect to the emitter 57. This bias voltage, depending upon the transistor, should be somewhere in the neighborhood of 0.200 to 0.400 volt. As shown in FIGURE 6, this voltage is represented by the dashed line and during starting ignition voltages will be developed in the secondary winding 11 as a result of transistor 17 turning off by the action of transistor 54 turning on and transistor 43 turning off when the voltage waveform 166 in FIGURE 6 falls to a negative value of approximately 0.2 to 0.4 volt. As previously explained, the zero voltage line in FIGURES 5 and 6 is the voltage at the junction 78 or the base 60 of transistor 54.

The transistor 54 will again be switched to its nonconducting state and transistors 43 and 17 switched to their conducting state when the negative voltage waveform in FIGURE 6 again rises to the point where it crosses the dotted line. At this point the negative voltage on the base 60 of transistor 54 with respect to the emitter is insufficient to maintain transistor 54 in a conducting state. As a result, it turns off and transistors 43 and 17 turn on thereby again energizing the primary winding 11 of the ignition coil to commence another ignition cycle.

During starting operations it may be that the terminal voltage of the battery 16 is sufficiently high that current through the winding 108 of relay 106 is sufficient to open the normally closed contacts 107. This places the resistor 29 in series with the positive terminal 21 of the battery 16, the lead 30, resistor 31, the transistor 17, winding 35, resistor 41 and primary winding 15 of ignition coil 10. As brought out in copending application Ser. No. 387,002, the resistor 29 has a value of 0.33 ohm. Under these conditions with the resistor 29 in the circuit, when the ignition switch 26 is initially closed so that arm 25 is in contact with contact 92 and arm 86 is in contact with 92', there will be no current flow initially through the lead 30 or resistors 29 and 31 due to the inductance of the primary winding 15 of the ignition coil 10 that is in series with these two resistors. Similarly, there can be no current flow through resistors 76 and 81 because of the series connected inductance of the primary winding 15 nor can there be any current flow out of the base 60 of transistor 54 through the inductance of the winding 63 of the generator 64.

When the circuit is placed in start condition the initial conditions are such that the emitter 57 and the base 60 of transistor 54 will be at the same potential and the transistor 54 will be in its nonconducting state. As previously explained, this will place transistors 43 and 17 in their conducting states. When transistor 17 conducts there will be a voltage drop across the resistor 29 of approximately 3.3 volts because the current through this series circuit, including resistor 29, resistor 31, resistor 17 and primary winding 15 of ignition coil 10 will be approximately 10 amps. The junction, therefore, of resistors 31 and 73 will be approximately 3.3 volts below battery voltage.

The voltage at junction 75, however, will be the battery voltage and will be 3.3 volts higher than the junction of resistors 31 and 73. Current will, therefore, flow from junction 75 through resistor 74 and resistor 73 to the junction of resistors 73 and 31. Current will also flow from junction 75 through resistor 74, diode 69 and resistor 67 to ground. It has been determined that the voltage at junction 72 between resistor 73 and the diode 69 will be positive with respect to the junction of resistors 73 and 31 by approximately 0.12 volt and that the junction 66 that is tied to the junction 78 through the winding 63 of the generator 64 will be approximately at 0.15 volt

negative with respect to the junction of the resistors 31 and 72.

The potential difference between the junction 75 and the junction 66 will be approximately 3.45 volts since the junction 75 is at battery voltage and the junction 66 is negative by 0.15 volt with respect to the junction between resistors 31 and 73 and this junction is 3.3 volts negative with respect to the terminal voltage of the battery 16. It can be appreciated that a series circuit exists between the junction 75 and the junction 66 through lead 76, lead 77, resistor 76, junction 78, lead 61, winding 63 of generator 64 and winding 65. The resistor 76 has a value of 8,000 ohms while the resistance of the generator winding 63 is 150 ohms. It can be seen, therefore, that the voltage at the junction 78 and hence the voltage on the base 60 of transistor 54 is very close and just slightly positive with respect to the voltage at the junction 66.

As previously explained, the voltage at junction 66 is 0.15 volt negative with respect to the junctions 31 and 73 with 10 amps. flowing through resistor 31 and the junction 78 and hence base 60 are slightly positive with respect to junction 66. The voltage at the emitter 57 will also be approximately 0.15 volts below that of the junction of resistors 31 and 73. As a result, the voltage on the base 60 with respect to the emitter 57 may be slightly positive and it will be more positive than during the condition in which resistor 29 is not in the circuit.

Therefore, during starting conditions, the operation of the circuit is substantially the same whether resistor 29 is in or out of the circuit. The potential of base 60 of transistor 54 with respect to the emitter 57 will be slightly more positive when resistor 29 is in the circuit than it is when resistor 29 is out of the circuit. Therefore, when considering the operation in conjunction with FIGURE 6 the dotted lines shown there would be lower but not to such an extent that it would appreciably affect the timing of the ignition during starting operation. If anything, it will retard the occurring of ignition voltages somewhat more than when the resistor 29 is not in circuit since the cross 171 will be shifted a small amount to the right. This enhances the desired effect during starting, that of retardation of the generation of ignition voltages. It should be remembered in connection with FIGURE 6 that the base line for the voltage is the voltage appearing at the junction 78 and that when resistor 29 is in the circuit it will be approximately 3.5 volts below the terminal voltage of the battery and when resistor 29 is not in the circuit it will be approximately 0.16 volt below battery voltage.

Thus during starting operations with resistor 29 either in or out of the circuit, ignition voltages will be developed in the secondary winding 11 as the result of transistor 17 turning off, by the action of transistor 54 turning on and transistor 43 turning off when the voltage wave form 166 falls to the negative value of from 0.2 to 0.4 volt. Thus, at low voltage outputs that occur during cranking, the decrease in the negative slope of the wave form where it crosses the zero axis has the effect of retarding the ignition point or timing to the point 171. Rather than advancing the ignition point during the slow speeds that occur during cranking, the ignition timing is retarded and this permits normal starting of the engine.

Thus, during starting operations, the biasing circuit 42 is rebiased so that the ignition timing is retarded rather than being advanced and this aids in the starting of the internal combustion engine.

The use of the diode 69 and its purpose in the circuit is more fully described in my copending application Ser. No. 387,004, filed August 3, 1964.

Although the invention as disclosed uses transistors in its switching circuit arrangement, it is to be understood that other solid state or semiconductor devices could be employed within the scope of the invention.

Thus, the present invention provides a transistorized ignition system operated by an alternating current electro-mechanical generator that retards the spark timing during

starting operations thereby assuring easy starting of the internal combustion engine in which the ignition system is mounted.

It is to be understood that this invention is not to be limited to the exact construction shown and described but that various changes and modifications may be made without departing from the spirit and scope of the invention as defined in the appended claims.

I claim:

1. A transistorized ignition system for an internal combustion engine comprising, an ignition coil having a primary winding and a secondary winding, a plurality of spark plugs, a distributor operated in timed synchronism with the engine for sequentially connecting said secondary winding of said ignition coil with said spark plugs, a transistorized circuit coupled to said source of electrical energy and including a first transistor connected in series with said source of electrical energy and said primary winding of said ignition coil, a second transistor, means coupling said first and said second transistors for causing conduction of said first transistor when said second transistor is in a nonconducting state and for causing nonconduction of said first transistor when said second transistor is in a conducting state, a biasing means coupled to said source of electrical energy and said transistorized circuit for applying a bias to said second transistor of a polarity to cause said second transistor to be normally conducting and said first transistor to be normally nonconducting, an electrical generator operated in timed synchronism with the engine and having an output winding producing an alternating output voltage coupled to said second transistor, the alternating output voltage from said output winding switching said second transistor to a nonconducting state and said first transistor to a conducting state when the portion of the wave form of the opposite polarity to said bias reaches a magnitude equal to or greater than said bias and switching said second transistor to a conducting state and said first transistor to a nonconducting state when the magnitude of said portion of said wave form falls below the level of said bias, a starting circuit for said engine coupled to said source of electrical energy and to said transistorized circuit during engine starting operations for applying a bias to said second transistor of a polarity opposite to the polarity of said first mentioned bias whereby said second transistor will be normally conducting and said first transistor will be normally conducting during starting operations, the alternating output voltage from said output winding switching said second transistor to a conducting state and said first transistor to a nonconducting state when the portion of the wave form of opposite polarity to said last mentioned bias reaches a magnitude equal to or greater than said bias, whereby the ignition timing of said ignition system will be retarded during starting operations when low voltages are being generated in said output winding of said generator and the slope of the output voltage wave form decreases in the region of the magnitude of said bias voltage.

2. A transistorized ignition system for an internal combustion engine comprising, an ignition coil having a primary winding and a secondary winding, a plurality of spark plugs, a distributor operated in timed synchronism with the engine for sequentially connecting said secondary winding of said ignition coil with said spark plugs, a source of electrical energy, a transistorized circuit including a first transistor having an output circuit coupled to control the energization of said primary winding from said source of electrical energy and a control circuit, a second transistor having an output circuit and a control circuit, means coupled to the output circuit of said second transistor and the control circuit of said first transistor for causing said first transistor to be in a nonconducting state when said second transistor is in a conducting state and for causing said first transistor to be in a conducting state when said second transistor is in a nonconducting state, means coupled to said source of electrical

cal energy and said control circuit of said transistor for applying a bias voltage to the control circuit of said second transistor of a polarity to cause said second transistor to be normally conducting and said first transistor to be normally nonconducting, an electrical generating means operated in timed synchronism with the engine and distributor and coupled to said control circuit of said second transistor for generating an alternating voltage wave form having a substantial slope in the region where the wave form crosses a reference voltage axis, the magnitude of the generated voltage being substantially greater than the magnitude of the bias voltage applied to said control circuit of said second transistor, the alternating output voltage from said output winding switching said second transistor to a nonconducting state and said first transistor to a conducting state when the portion of the wave form of the opposite polarity to said bias reaches a magnitude equal to or greater than said bias and switching said second transistor to a conducting state and said first transistor to a nonconducting state when the magnitude of said portion of said wave form falls below the level of said bias, a starting circuit for said engine coupled to said source of electrical energy and to said control circuit of said second transistor during engine starting operations for applying a bias to said second transistor to cause said second transistor to be normally nonconducting and said first transistor to be normally conducting during starting operations, the alternating output voltage from said output winding switching said second transistor to a conducting state and said first transistor to a nonconducting state when the portion of the wave form of opposite polarity to said last mentioned bias reaches a magnitude equal to or greater than said bias, whereby the ignition timing of said ignition system will be retarded during starting operations when low voltages are being generated in said output winding of said generator and the slope of the output voltage wave form decreases in the region of the magnitude of said bias voltage and of said reference voltage axis.

3. A transistorized ignition system for an internal combustion engine comprising, an ignition coil including a primary and a secondary winding, a plurality of spark plugs, a distributor operated in timed synchronism with the engine for sequentially connecting said secondary winding of said ignition coil with said spark plugs, a source of electrical energy, a transistor having an emitter, a collector and a base, said emitter and collector being connected in series with said source of electrical energy and said primary winding of said ignition coil, an alternating current electromechanical generator having an output winding and a rotor, said rotor operated in synchronism with said distributor and the internal combustion engine, circuit means coupled to said source of electrical energy and to said base and including said output winding for causing said transistor to be switched to a nonconducting state when the positive portion of the output from said output winding falls to a selected level, a starting circuit for said internal combustion engine, said starting circuit including means coupled to said last mentioned means when said starting circuit is energized for causing said transistor to be switched to a nonconducting state when the negative portion of the output from said output winding falls below a predetermined value, whereby during engine starting operations the firing of said spark plugs will be retarded rather than advanced as a result of output from said electromechanical generator falling to low values of magnitude and the slope of the output decreasing negatively during engine starting operations.

4. In a transistorized ignition system for an internal combustion engine, the combination comprising, an ignition coil having a primary and a secondary winding, a plurality of spark plugs, a distributor operated in timed synchronism with the engine for sequentially coupling said spark plugs to said secondary winding of said ignition coil,

a source of electrical energy, a transistor having an emitter, a collector and a base, said emitter and collector connected in series with the primary winding of said ignition coil and said source of electrical energy, means coupling said source of electrical energy and said emitter and base of said transistor for normally biasing said transistor into its nonconducting state, means operated in synchronism with the engine and said distributor and coupled to said emitter and base of said transistor for periodically switching said transistor to its conducting state, a starting circuit for said transistorized ignition system adapted to be energized during starting of said internal combustion engine, said starting circuit including means coupling said source of electrical energy and said base and emitter of said transistor for biasing said transistor into a normally conducting state during starting operations, said means operated in synchronism with the engine and said distributor switching said transistor periodically to a nonconducting state during engine starting operations whereby the timing of the ignition system is retarded during starting operations.

5. An ignition system for an internal combustion engine comprising, an ignition coil including a primary and a secondary winding, a plurality of spark plugs, a distributor operated in timed synchronism with the engine for sequentially connecting said secondary winding of said ignition coil with said spark plugs, a source of electrical energy, a transistor having an output circuit and a control circuit, said output circuit connected in series with said primary winding of said ignition coil and source of electrical energy, means coupling said source of electrical energy and said control circuit for normally biasing said transistor into a steady state nonconducting state when said internal combustion engine is running, an electrical generator coupled to said control circuit and operated in timed synchronism with said engine and said distributor for periodically switching said transistor to its conducting state during normal running operations of said engine, a starting circuit for said ignition system, said starting circuit including means coupling said control circuit of said transistor and said source of electrical energy during engine starting operations for biasing said transistor to a normally conducting state during starting operations, the alternating energy output of said generator periodically switching said transistor to a nonconducting state during engine starting operations.

6. A transistorized ignition system for an internal combustion engine comprising, an ignition coil including a primary and a secondary winding, a plurality of spark plugs, a distributor operated in timed synchronism with the engine for sequentially connecting said secondary winding of said ignition coil with said spark plugs, a source of electrical energy, a first transistor having an emitter-collector circuit and a base, said emitter-collector circuit being connected in series with said source of electrical energy and said primary winding of said ignition coil, a control circuit coupled to the base of said first transistor and including a second transistor having an emitter-collector circuit and a base, circuit means coupling said emitter-collector circuit of said second transistor to said base of said first transistor for biasing said first transistor into a nonconducting state when said second transistor is in a conducting state, an alternating current generator including a stator having an output winding and a rotor operated in timed synchronism with the engine and said distributor, said output winding being connected to the base of said second transistor, a biasing means coupled to said source of electrical energy and to said base of said second transistor for normally biasing said second transistor to a conducting state by applying a negative bias to said base with respect to said emitter, the alternating current output of said output winding switching said second transistor to a nonconducting state and said first transistor to a conducting state when the positive portion of the output voltage wave form rises

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to a magnitude equal to the negative bias applied to the base of said second transistor and switching said second transistor to a conducting state and said first transistor to a nonconducting state when the positive portion of the alternating current wave form falls below the bias level 5 applied to the base of said second transistor, a starting circuit for said ignition system, said starting circuit including means for removing the negative bias of said base with respect to said emitter of said second transistor whereby said second transistor will be switched to a conducting state and said first transistor will be switched to a nonconducting state when the negative portion of the

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alternating current wave form from said output winding applies the requisite negative bias to said base.

References Cited by the Examiner

UNITED STATES PATENTS

2,898,392	8/1959	Jaeschke.	
3,060,346	10/1962	Sohner	123—148 X
3,184,640	5/1965	Jukes	123—148 X

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