

Sept. 20, 1971

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3,605,714

CONTACTLESS IGNITION SYSTEM

Filed June 11, 1969

2 Sheets-Sheet 1

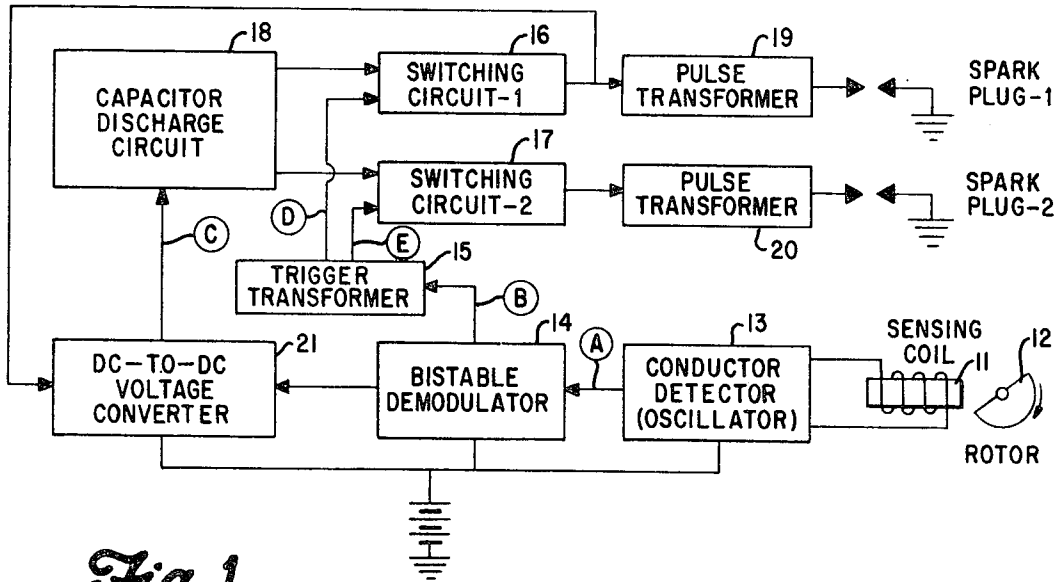


Fig. 1

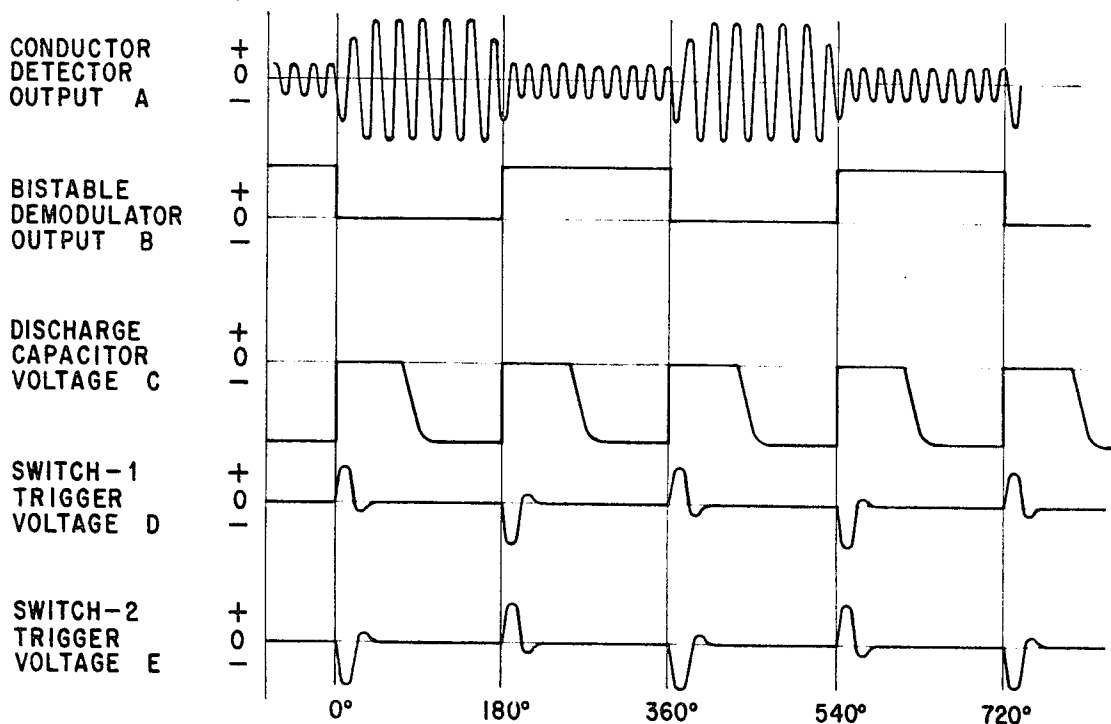


Fig. 2

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2 Sheets-Sheet 2

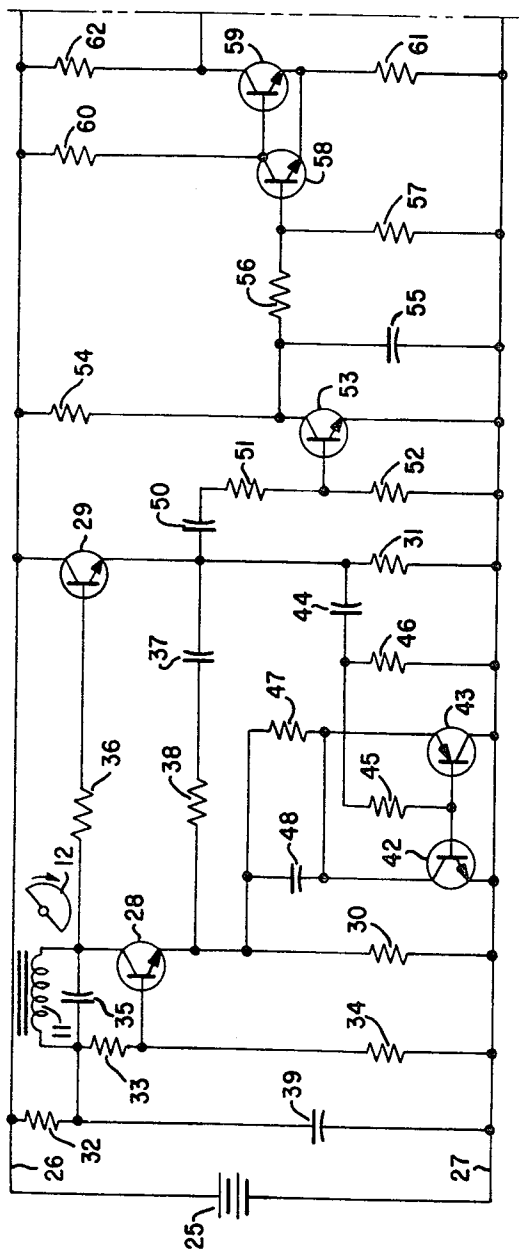


Fig. 3a

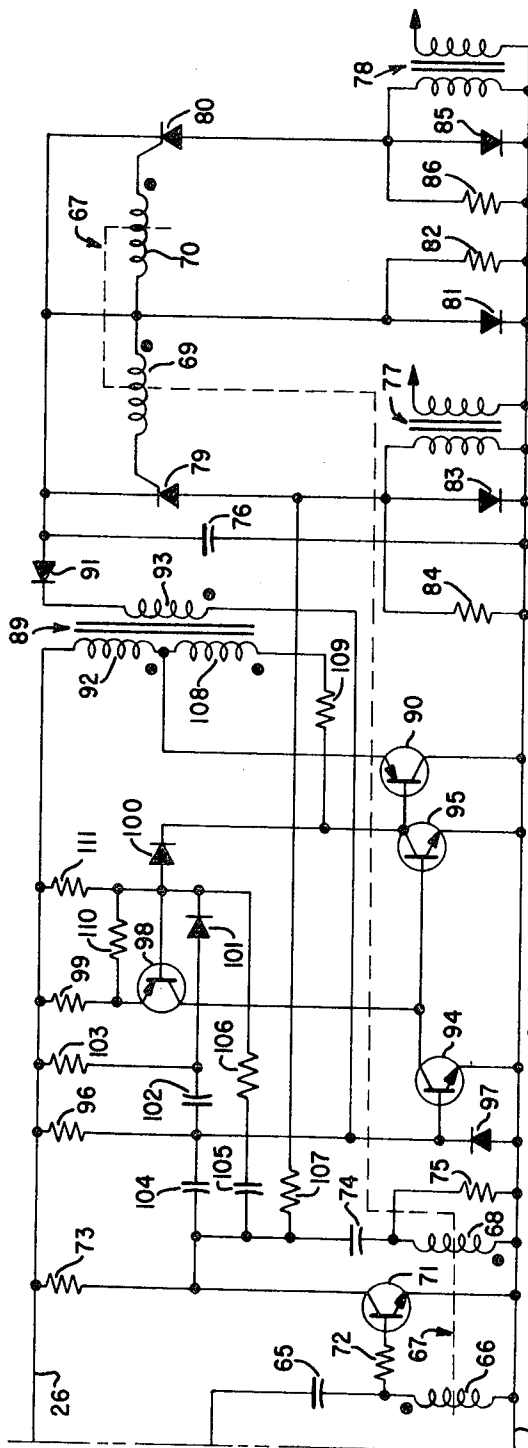


Fig. 3b

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CONTACTLESS IGNITION SYSTEM

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Filed June 11, 1969, Ser. No. 832,217

Int. Cl. F02p 3/02

U.S. Cl. 123—148E

7 Claims

ABSTRACT OF THE DISCLOSURE

An ignition system for alternately firing two spark plugs in an internal combustion engine. A rotor is used to modulate the output signal of an oscillator, which in turn triggers a bistable demodulator to produce a square wave synchronized with the engine. The square wave is used to alternately fire two silicon controlled rectifiers for alternately discharging a storage capacitor through the primary windings of two ignition transformers, eliminating the need for a high voltage distributor. A charging circuit is triggered to recharge the capacitor each time it is discharged. The maximum rate at which the charging circuit can operate is limited, thereby acting as a governor to limit maximum engine speed.

BACKGROUND OF THE INVENTION

This invention relates to an ignition system for internal combustion engines having at least two spark plugs which are alternately fired and in which no mechanical breaker contacts or points are required for synchronizing the firing with the rotating engine.

Conventional ignition systems for internal combustion engines typically include a pair of mechanical breaker contacts or points which control the current flow to a primary winding of an ignition coil where energy is stored, which, upon release, induces a high voltage current in a secondary winding of the ignition coil which is then directed to the spark plugs through a rotating switch commonly called a distributor. Inherent disadvantages in a mechanical breaker system are the mechanical and electrical erosive forces which cause the points to wear out or to pit due to the inductive "kick back" voltage from the primary of the ignition coil. Also, the points may become fouled or coated by films which interfere with their function of making and breaking the electrical circuit. These problems are further aggravated when the engine is used for marine purposes where the breaker points are subjected to moisture and corrosive forces. Another inherent problem present in mechanical breaker point systems is the presence of contact bounce due to mechanical resonance of the moving parts at high engine speeds. Likewise, electrical erosion and wear and a high degree of susceptibility to environmental conditions cause the conventional high voltage distributor to be a problem.

SUMMARY OF THE INVENTION

The instant invention is directed to a solid state ignition system for alternately firing at least two spark plugs in an internal combustion engine. A sensing coil is mounted on the engine adjacent to a rotor having electrically conductive and non-conductive portions. The sensing coil is effective to amplitude modulate the output of an oscillator between alternately high and low levels as the engine alternately drives the non-conductive and conductive portions of the rotor past the sensing coil. A bistable demodulator is triggered by the amplitude modulated output of the oscillator to produce a square wave which is synchronized with the engine. The square wave output of the bistable demodulator is applied to the primary winding

of a trigger transformer for alternately firing first and second silicon controlled rectifiers. A storage capacitor is connected in a first closed series circuit with the first silicon controlled rectifier and the primary winding of a first ignition coil and in a second closed series circuit with the second silicon controlled rectifier and the primary winding of a second ignition coil. The secondary windings of the ignition coils are connected to fire different spark plugs without the use of a high voltage distributor.

When the square wave output of the bistable demodulator changes from a first voltage to a second voltage, the trigger transformer applies a positive triggering signal to the control electrode of one of the silicon controlled rectifiers, thereby discharging the storage capacitor through the primary winding of one of the ignition coils. Again, when the bistable demodulator output changes from the second voltage back to the first voltage, a trigger transformer applies a positive trigger signal to the control electrode of the other silicon controlled rectifier, thereby discharging the storage capacitor through the primary winding of the other ignition transformer. A DC-to-DC regulated voltage converter is provided to charge the storage capacitor. The voltage converter is triggered to recharge the storage capacitor each time one of the silicon controlled rectifiers is triggered to discharge the capacitor. The maximum operating rate of the voltage converter is selectively limited, thereby fixing a maximum speed for the internal combustion engine.

Accordingly, it is the primary object of this invention to provide an improved contactless distributorless ignition system for alternately firing two spark plugs in an internal combustion engine.

It is a further object of this invention to provide an improved method of limiting the maximum operating speed of an internal combustion engine.

Further objects and advantages of the invention will become apparent from the following detailed description, reference being made to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing the essential components of the contactless ignition system of this invention, and schematically showing the functional relationships therein;

FIG. 2 graphically indicates the wave forms which appear at various indicated points in the block diagram of FIG. 1; and

FIG. 3 consisting of FIGS. 3a and 3b, is a detailed schematic circuit diagram of a contactless distributorless ignition system constructed in accordance with the instant invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1 and 2, a block diagram of the contactless ignition system is shown along with the voltage wave forms at selected points in the block diagram. A sensing coil 11 is mounted adjacent to a rotor 12 which is driven in timed synchronism with the crankshaft of an internal combustion engine (not shown) in which at least two spark plugs are mounted. The sensing coil 11 is connected to amplitude modulate the output of an oscillator 13. The rotor 12 is shown as a semi-circular conductor mounted to rotate on a shaft, although other rotor configurations may be used in which alternately conductive and non-conductive portions will be driven past the sensing coil 11. As shown in graph A of FIG. 2, the oscillator will have an oscillatory output with a controlled low amplitude when the sensing coil 11 senses the presence of the conductive portion of the rotor 12 and will have a higher voltage oscillatory output when the sensing

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coil 11 does not sense the presence of the conductive portion of the rotor 12. A bistable demodulator 14 having a time constant greater than the oscillatory period of the oscillator 13 and insensitive to the controlled low amplitude output is triggered by the amplitude modulated output of the oscillator 13 to generate a square wave which will be synchronized with the engine driven rotor 12, as seen in graph B of FIG. 2. The square wave output of the bistable demodulator 14 is then coupled to the primary winding of a trigger transformer 15.

The high voltage for alternately firing the two spark plugs is produced when the trigger transformer 15 alternately energizes a first switching circuit 16 and a second switching circuit 17 to alternately discharge energy stored in a capacitor discharge circuit 18 to a pulse transformer 19 and a pulse transformer 20. A DC-to-DC regulated voltage converter 21 is triggered to recharge the capacitor discharge circuit 18 in response to the alternate operation of the switching circuits 16 and 17. The voltage at the capacitor for several cycles is shown in graph C of FIG. 2. The DC-to-DC regulated voltage converter 21 is designed to have a predetermined maximum operating rate to limit the maximum speed of the internal combustion engine. This is particularly advantageous in marine engines where the load imposed by the water may be suddenly removed.

Referring now to FIG. 3, a detailed schematic circuit diagram of the improved contactless ignition system is shown. A battery 25 or other suitable D.C. power source is connected to supply a voltage between a positive line 26 and a negative line 27 for operating the ignition system. The oscillator 13 basically comprises a pair of NPN transistors 28 and 29 connected across the lines 26 and 27, with the emitter of the transistor 28 connected through a resistor 30 to the line 27 and the emitter of the transistor 29 connected through a resistor 31 to the line 27. Bias voltage is applied from the collector to the base of the transistor 28 by a voltage divider including two resistors 33 and 34 connected in series. The collector circuit of the transistor 28 includes a parallel tuned resonant LC circuit comprising a capacitor 35 and the sensing coil 11. The base of the transistor 29 is connected through a current limiting resistor 36 to the collector of the transistor 28 and the emitter of the transistor 29 is connected through a series capacitor 37 and resistor 38 to the emitter of the transistor 28 to form an in-phase feedback circuit with the transistor 29 operating as an emitter follower and the transistor 28 operating in essentially a common base configuration. A capacitor 39 is connected to provide a low impedance A.C. path from the common connection between the resistor 32, the resistor 33 and the LC circuit to the line 27.

If nothing more is added, the oscillator, including the transistors 28 and 29, can oscillate at the resonant frequency of the parallel tuned LC circuit including the sensing coil 11 and the capacitor 35, whenever the Q (the ratio of the stored energy to the dissipated energy) of the LC circuit is such that the closed loop gain of the oscillator is equal to or larger than unity. When the rotor 12 is positioned such that no conductors are within the magnetic field of the sensing coil 11, the Q of the LC circuit is such that the closed loop gain of the oscillator is equal to or larger than unity. When, on the other hand, the rotor 12 is positioned such that a conductive portion of the rotor 12 is adjacent to the sensing coil 11, the Q of the LC circuit is such that the closed loop gain of the oscillator is less than unity and the oscillator will not oscillate. With this arrangement, the oscillator depends on random disturbances for starting when the conductive portion of the rotor 12 moves away from the magnetic field of the sensing coil 11.

The capacitor discharge portion of the ignition system is triggered in response to the envelope of the oscillations. If the oscillator is dependent upon random disturbances for starting, the relationship between rotor posi-

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tion and oscillator amplitude will be less precise for increasing amplitude than for decreasing amplitude. Therefore, a supplementary feedback system, including a NPN transistor 42 and a PNP transistor 43, is connected in parallel with the normal feedback loop to prevent the oscillator output from decreasing below a predetermined minimum value and thereby eliminate the dependency upon random disturbances for ignition timing information when the oscillator output is increasing. With the supplementary feedback system, the rotor 12 will amplitude modulate the oscillator output between maximum and minimum levels as shown in graph A of FIG. 2. The demodulator is set so switching takes place at a level above the minimum and below the maximum oscillator amplitude.

The supplementary feedback system is connected in parallel with the feedback path which includes the series capacitor 37 and resistor 38 between the oscillator transistors 28 and 29. The oscillator output at the emitter of the transistor 29 is applied through a capacitor 44 and a series resistor 45 to the bases of the transistors 42 and 43. A resistor 46 is connected from between the capacitor 44 and the resistor 45 to the negative line 27. The emitter of the NPN transistor 42 and the collector of the PNP transistor 43 are connected to the negative line 27, while the collector of the transistor 42 and the emitter of the transistor 43 are connected together through a parallel connected D.C. bias resistor 47 and A.C. coupling capacitor 48 to the emitter of the transistor 28.

The bases of the transistors 42 and 43 are driven by an A.C. signal without a D.C. component, supplied through the capacitor 44 from the oscillator output. A.C. voltages which appear across the transistors 42 and 43 are applied through the capacitor 48 to the emitter of the transistor 28 along with the normal positive feedback signal through the capacitor 37 and the series resistor 38. If the PNP transistor 43 were alone, it would conduct for negative half cycles of the oscillator output. The A.C. component of the voltage across the transistor 43 would be in phase with the oscillator output, and the supplementary feedback system would increase the total feedback. Similarly, if the NPN transistor 42 were alone, the transistor 42 would produce an out-of-phase feedback signal. When the oscillator output amplitude is above a minimum design level, the voltage across the transistors 42 and 43 is very low, and there is essentially no supplementary feedback. When the oscillator output amplitude is below the design level, the reduced base drive through the capacitor 44 allows the D.C. voltage across the transistors 42 and 43 to increase. The D.C. voltage at the emitter of the PNP transistor 43 adds to the base drive for the transistor 43, while the base drive for the transistor 42 is unaffected by the D.C. level at the emitter of transistor 43. The resulting unbalance gives a large net in-phase feedback signal whenever the oscillator amplitude decreases to a level where the NPN transistor 42 is not saturated. The emitter-base junction of the NPN transistor 42 acts as a reference element and prevents the oscillator amplitude from going below this level. Therefore, as the rotor 12 turns, the oscillator amplitude varies between a maximum level determined by the supply voltage as applied on the line 26 and a minimum level determined by the supplementary feedback network independently of the supply voltage.

The output of the oscillator, taken at the emitter of the transistor 29, is applied through a capacitor 50 and a voltage divider including a resistor 51 and a resistor 52 to the base of a transistor 53. The transistor 53 detects, inverts, amplifies, and clips the oscillator output signal. The collector of the transistor 53 is connected through a resistor 54 to the positive line 26 while the emitter is connected to the ground line 27. The minimum oscillator output amplitude, as determined by the emitter-base characteristics of the transistor 42, varies with tempera-

ture in the same way as the amplitude required to bias the transistor 53 on. Therefore, very little attenuation of the oscillator output is needed to keep the transistor 53 off whenever the oscillator output is at its controlled minimum level. When the oscillator output is high, the transistor 53 is driven into saturation during positive half cycles, and a capacitor 55, connected from the collector of the transistor 53 to the ground line 27, keeps the collector voltage low during negative half cycles. The resulting voltage across the transistor 53 has approximately a rectangular wave form, related inversely to the oscillator output envelope and corresponding to the shape of the rotor 12.

The voltage appearing across the transistor 53 is applied to the bistable demodulator 14 through a voltage divider comprising a pair of series connected resistors 56 and 57. The bistable demodulator 14 is essentially a pair of NPN transistors 58 and 59 connected as a Schmitt trigger. The collector of the transistor 58 is connected through a resistor 60 to the positive line 26, while the base is connected through the resistor 57 to the ground line 27 and the emitter is connected in common with the emitter of the transistor 59 and through a resistor 61 to the ground line 27. The collector of the transistor 59 is connected through a resistor 62 to the positive line 26 and the base of the transistor 59 is driven from the collector of the transistor 58. The resistors 56 and 57 are selected such that the required voltage across the capacitor 55 and the transistor 53 for switching the transistor 58 will be between the ripple voltage appearing on the capacitor 55 when the transistor 53 is conducting and the lowest anticipated supply voltage appearing on the capacitor 55 when the transistor 53 is cut off. When the transistor 53 is cut off, the transistor 58 will conduct and the transistor 59 will be cut off. When the transistor 53 starts conducting, the transistors 58 and 59 will rapidly change states. The resistor 61 is connected to the emitters of the transistors 58 and 59 to provide positive feedback which decreases the switching time and makes the circuit insensitive to small changes in the voltage across the transistor 53.

A capacitor 65 and a primary winding 66 of a trigger transformer 67 are connected in series from the collector of the transistor 59 to the ground line 27. The trigger transformer 67 includes a second primary winding 68 (the primary windings 66 and 68 may be a single, center tapped winding with the center tap connected to the ground line 27) and a pair of secondary windings 69 and 70. (The windings 66, 68, 69, and 70 of the trigger transformer 67 are shown connected by a dashed line.) The secondary windings 69 and 70 may also be a single center tapped winding. When the transistor 59 is cut off, the capacitor 65 will be charged through the resistor 62 and the trigger transformer primary winding 66 to approximately the supply voltage. When the transistor 69 conducts, the capacitor 65 will be rapidly discharged through the primary winding 66 to produce a first trigger signal.

The base of an NPN transistor 71 is connected through a resistor 72 to the junction between the capacitor 65 and the primary winding 66. The collector of the transistor 71 is connected through a resistor 73 to the positive line 26 and the emitter is connected to the ground line 27. A capacitor 74 is connected in series with the second trigger transformer primary winding 68 and a parallel resistor 75 between the collector of the transistor 71 and the ground line 27. The capacitor 74 will be charged to approximately the supply voltage on the line 26 when the transistor 71 is cut off. When the transistor 59 is off and the capacitor 65 starts charging, the impedance of the primary winding 66 is large and the transistor 71 is switched on. The capacitor 74 is then rapidly discharged through the transistor 71 and the primary winding 68 to produce a second trigger signal. The polarities of the two primary windings 66 and 68 are such that the discharge

of the capacitor 74 through the primary winding 68 provides a positive feedback in the primary winding 66 to help saturate the transistor 71, with the base resistor 72 preventing the emitter-base junction of the transistor 71 from limiting the primary winding voltages.

The first and second trigger signals, produced by discharging the capacitor 65 through the trigger transformer primary 66 and by discharging the capacitor 74 through the trigger transformer primary winding 68, respectively, are used to alternately trigger the discharge of energy stored in a capacitor 76 through the primary of a first ignition transformer 77 and the primary of a second ignition transformer 78. The anode and cathode of a first silicon controlled rectifier 79 are connected in a closed series circuit with the capacitor 76 and the primary of the first ignition transformer 77. The anode and cathode of a second silicon controlled rectifier 80 and the primary of the second ignition transformer 78 are connected in a second closed series circuit with the capacitor 76, with the cathodes of the two silicon controlled rectifiers 79 and 80 connected together. The secondary winding 69 of the trigger transformer 67 is connected between the control electrode and the cathode of the silicon controlled rectifier 79 and the second winding 70 is connected between the control electrode and the cathode of the silicon controlled rectifier 80. The polarities of the primary and secondary windings 66, 68, 69, and 70 of the trigger transformer 67 are such that, when the capacitor 65 is discharged through the primary winding 66, a positive pulse is applied to the control electrode of the silicon controlled rectifier 79, triggering the silicon controlled rectifier 79 to discharge energy stored in the capacitor 76 through the primary of the ignition transformer 77 and to thereby produce a high secondary voltage for firing a first spark plug (not shown). A negative pulse is simultaneously applied to the control electrode of the silicon controlled rectifier 80. This negative pulse prevents triggering the silicon controlled rectifier 80. Similarly, the winding polarities are such that when the capacitor 74 is discharged through the primary winding 68, a positive trigger pulse is applied to the control electrode of the silicon controlled rectifier 80 and a negative pulse is applied to the control electrode of the silicon controlled rectifier 79. When the silicon controlled rectifier 80 is triggered, energy stored in the capacitor 76 is discharged through the primary of the ignition transformer 78, providing a high secondary voltage for firing a second spark plug (not shown). A diode 81 and a resistor 82 are placed in parallel with the capacitor 76, a diode 83 and a resistor 84 are placed in parallel with the primary of the ignition transformer 77, and a diode 85 and a resistor 86 are placed in parallel with the primary winding of the ignition transformer 78. The diodes 81, 83 and 85 and the resistors 82, 84 and 86 protect the silicon controlled rectifiers 79 and 80 from reverse voltages, prevent reverse charging of the capacitor 76, and provide discharge paths if the ignition transformers 77 and 78 are disconnected or open.

Each time the capacitor 76 is discharged to fire a spark plug, the DC-to-DC regulated voltage converter 21 is simultaneously triggered to recharge the capacitor 76. The converter 21 basically comprises a power transformer 89, a current switching transistor 90, a charging diode 91, and a control circuit for the switching transistor 90. A primary winding 92 of the power transformer 89 and the switching transistor 90 are connected in series across the power lines 26 and 27. When the converter 21 is triggered, the control circuitry turns on the current switching transistor 90 for a period of time inversely proportional to and dependent upon the unregulated voltage of the battery 25. The transistor 90 is switched off after a predetermined quantity of energy is stored in the transformer 89. The collapsing magnetic field in the transformer 89 produces a voltage across the secondary winding 93 of the transformer 89 which charges the capacitor 76 through the

charging diode 91. The charging diode 91 prevents the capacitor 76 from charging while energy is being stored in the transformer 89 and from discharging through the secondary winding 93 while the capacitor 76 is waiting to be discharged through one of the silicon controlled rectifiers.

The control circuit for the switching transistor 90 generally comprises a modified monostable multivibrator including a normally conducting transistor 94 and a normally non-conducting transistor 95. The base of the transistor 94 is connected through a resistor 96 to the positive line 26 and through a reverse biased diode 97 to the ground line 27. The emitters of the transistors 94 and 95 are connected to the ground line 27. The collector of the transistor 94 and the base of the transistor 95 are connected together and are connected through a normally non-conducting transistor 98 and a resistor 99 to the positive line 26. The collector of the transistor 95 is connected to the base of the current switching transistor 90 and is also connected through a series connected diode 100, a diode 101 and a capacitor 102 to the base of the transistor 94. A resistor 103 is connected from the positive line 26 to a common point between the capacitor 102 and the diode 101.

When the multivibrator is in the stable state, the transistor 94 is held on by current flowing through the resistor 96, the transistor 95 is held off, and the capacitor 102 is charged through the resistor 103 to approximately the voltage of the battery 25. To start the converter 21, a negative trigger pulse is applied through a capacitor 104 to the base of the conducting transistor 94 and through a series connected capacitor 105 and resistor 106 to the base of the non-conducting transistor 98. This negative trigger pulse is applied from the anode of the silicon controlled rectifier 79 through a resistor 107, when the silicon controlled rectifier 79 is fired. When the silicon controlled rectifier 80 is fired, the negative trigger pulse is taken from the collector of the transistor 71. At least one of the negative trigger pulses must be independent of the firing of the silicon controlled rectifiers to permit initial starting of the converter 21.

When a negative pulse is applied through the capacitor 104 to the base of the transistor 94, the transistor 94 momentarily loses base current and turns off. The negative pulse through the capacitor 105 simultaneously turns on the transistor 98. Current flow through the resistor 99 and the conducting transistor 98 turns the transistor 95 on, discharging the previously charged capacitor 102 through the diodes 101 and 100 and the conducting transistor 95. While the transistor 95 remains on, the transistor 98 is held on by base current through the diode 100. As the capacitor 102 discharges, the voltage at the base of the transistor 94 is set at a level that is below ground by the forward voltage drop of the diode 97. Also, while the transistor 95 is conducting, the voltage of the battery 25 is applied to timing components including the resistor 96 and the capacitor 102. Current through the resistor 96 gradually increases the voltage at the base of the transistor 94 from its initial negative value to a positive value sufficient to turn the transistor 94 back on, returning the system to its stable state.

As previously stated, the time interval during which the current switching transistor 90 conducts after the converter 21 is triggered is inversely proportional to the unregulated voltage of the battery 25. This time interval will be accurate if the voltage change on the capacitor 102 is small compared to the voltage applied by the battery 25. When the change in the capacitor 102 voltage is small, the product of the applied voltage and the time increment is approximately equal to a constant. In the instant circuit, the voltage change on the capacitor 102 is equal to the forward voltage drop of the diode 97 plus the forward base-to-emitter voltage of the transistor 94, which is sufficiently small that acceptable regulation can be maintained with a supply voltage as low as four volts.

The current switching transistor 90 is connected to

the output of the multivibrator such that the transistor 90 conducts whenever the transistor 95 is conducting. A winding 108 on the transformer 89 along with a series resistor 109 is connected to raise the base voltage of the transistor 90 slightly above the emitter voltage when the emitter-to-collector voltage is high, to minimize leakage through the transistor 90. The series resistor 109 limits the winding current to avoid excessive losses. Therefore, it can be seen that the transistor 90 becomes conductive in response to a trigger pulse generated either when the transistor 71 is turned on or when the silicon controlled rectifier 79 is fired. The transistor 90 remains conductive for a period of time inversely proportional to the voltage applied by the battery 25, allowing the current to build up in the primary winding 92 of the transformer 89 to a regulated maximum. When the transistor 90 is switched off by the multivibrator returning to its stable state, the collapsing magnetic field in the transformer 89 produces a high voltage across the secondary winding 93 which charges the capacitor 76.

To avoid abnormal component stresses resulting from excessive current in the primary winding 92 of the power transformer 89, a recycle rate limiter prevents the converter 21 from responding to a trigger pulse while current flows from the secondary winding 93 to the capacitor 76. This may be accomplished by connecting the secondary winding 93 to ground through the base-emitter junction of the transistor 94, so that the transistor 94 cannot turn off while there is secondary current flow. If the rotor 12 is turned faster than the maximum recycle rate at which the converter 21 will operate, the converter 21 will ignore enough trigger pulses to keep its maximum operating rate at a safe level. Just above the maximum recycle rate, the converter 21 responds only to alternate trigger pulses and the capacitor 76 will be charged for the firing of only one of the silicon controlled rectifiers 79 and 80. Operation under these conditions will not harm either the ignition system or the engine. The recycle rate limiter may be modified by connecting the secondary winding 93 directly to the negative line 27 and then providing an RC time delay circuit to prevent recycling the converter 21 while there is current flow in the secondary winding 93.

If there is a decrease in the voltage applied by the battery 25 while the ignition system is operating, current will flow through the capacitor 102 away from the base of the transistor 94, which could give a false starting signal. To prevent the converter from starting, the transistor 98 normally blocks the path through which base current flows to the transistor 95. The opposite change in supply voltage would tend to trigger the transistor 98, but any change in supply voltage will be ignored by either the transistor 94 or the transistor 98 and will not start the converter 21. After the start of a normal cycle, the transistor 98 is held on by current flow through the diode 100 and the transistor 95, so that normal operation is unaffected. A resistor 110, connected between the emitter and the base of the transistor 98, prevents the system from operating at undesirably low voltages. The base of the transistor 98 is also connected to the converter input through the series resistor 106 and capacitor 105 and to the supply voltage line 26 through a resistor 111. The diode 100 isolates the transistor 98 from the transformer 89. Although the diode 100 and the diode 101 have similar functions, separate diodes are used so that the capacitor 102 does not slow recovery of the transistor 98.

While the discussion has been limited to engines having two spark plugs, the same system can be used to fire more spark plugs so long as they are fired in two alternate sets. For example, a four-cylinder four-stroke-cycle engine can often be made to operate with only two alternate spark plug firing voltages, applied to two spark plugs at a time.

What we claim is:

1. An ignition system for alternately firing two spark plugs in an internal combustion engine, comprising, in

combination: means for generating a substantially square wave having a frequency proportional to the engine speed, said square wave alternating between first and second voltages, a storage capacitor, means for charging said storage capacitor, first and second switches, first and second ignition transformers, each of said ignition transformers having a primary winding and a secondary winding, means for connecting said secondary windings of said transformers across different ones of such spark plugs, means connecting said capacitor, said first switch and said primary winding of said first transformer in a closed series circuit, means connecting said capacitor, said second switch and said primary winding of said second transformer in a closed series circuit, means for energizing said first switch in response to said square wave changing from the second voltage to the first voltage whereby said capacitor is discharged through said primary winding of said first transformer to produce a high secondary voltage, and means for energizing said second switch in response to said square wave changing from the first voltage to the second voltage whereby said capacitor is discharged through said primary winding of said second transformer to produce a high secondary voltage.

2. An ignition system for alternately firing two spark plugs in an internal combustion engine, as defined in claim 1, wherein said means for charging said storage capacitor is triggered to re-charge said capacitor each time one of said first and second switches is energized to discharge said capacitor.

3. An ignition system for alternately firing two spark plugs in an internal combustion engine, as defined in claim 2, and including means for limiting the maximum repetitive rate at which said means for charging said capacitor can be triggered to re-charge said capacitor, whereby the maximum speed of the internal combustion engine is limited.

4. An ignition system for alternately firing two spark plugs in an internal combustion engine, as defined in claim 1, wherein said first and second switches are silicon controlled rectifiers having anode, cathode and control electrodes, said anode and cathode of said first silicon controlled rectifier being connected in series with said capacitor and said primary winding of said first transformer, said anode and cathode of said second silicon controlled rectifier being connected in series with said capacitor and said primary winding of said second transformer, said means for energizing said first switch includes a trigger transformer connected to apply a triggering signal to said control electrode of said first silicon controlled rectifier, and said means for energizing said second switch includes a trigger transformer connected to apply a triggering signal to said control electrode of said second silicon controlled rectifier.

5. An ignition system for alternately firing two spark plugs in an internal combustion engine comprising, in combination: means for generating a substantially square wave having a frequency proportional to the engine speed, said square wave alternating between first and second voltages, a storage capacitor, means for charging said storage capacitor, first and second electronic switches,

said switches having anode, cathode and control electrodes, first and second ignition transformers, said transformers having primary and secondary windings, means for connecting said secondary windings of said ignition transformers across different ones of such spark plugs, means connecting said capacitor, said anode and cathode of said first switch and said primary winding of said first transformer in a closed series circuit, means connecting said capacitor, said anode and cathode of said second switch and said primary winding of said second transformer in a closed series circuit, said cathodes of said switches being connected together, a trigger transformer having a primary winding and a center tapped secondary winding, means connecting said center tap to said cathodes of said switches, means connecting one end of said center tapped secondary winding to said control electrode of said first switch, means connecting the other end of said center tapped secondary winding to said control electrode of said second switch, and means for coupling said square wave to the primary winding of said trigger transformer whereby, when said square wave changes from the second voltage to the first voltage, a positive triggering signal is applied to the control electrode of said first switch to discharge said capacitor through the primary winding of said first transformer and, when said square wave changes from the first voltage to the second voltage, a positive triggering signal is applied to the control electrode of said second switch to discharge said capacitor through the primary winding of said second transformer.

6. An ignition system for alternately firing two spark plugs in an internal combustion engine, as defined in claim 5, wherein said means for charging said storage capacitor is triggered to deliver a regulated charge to said capacitor each time said capacitor is discharged, and including means for limiting the maximum speed of the internal combustion engine by limiting the maximum rate at which said charging means can be triggered.

7. An ignition system for alternately firing two spark plugs in an internal combustion engine, as defined in claim 5, wherein said means for generating a square wave having a frequency proportional to the engine speed comprises: an oscillator, means for amplitude modulating the output of said oscillator in synchronism with the engine, the modulated output of said oscillator alternating between predetermined high and low levels, and a bistable demodulator, said demodulator having a square wave output when triggered by the amplitude modulated output of said oscillator.

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LAURENCE M. GOODRIDGE, Primary Examiner

U.S. Cl. X.R.

315—209