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3,424,944

ELECTRONIC IGNITION SYSTEM USING MULTIPLE THYRISTORS

Filed Nov. 9, 1966

Sheet 1 of 2

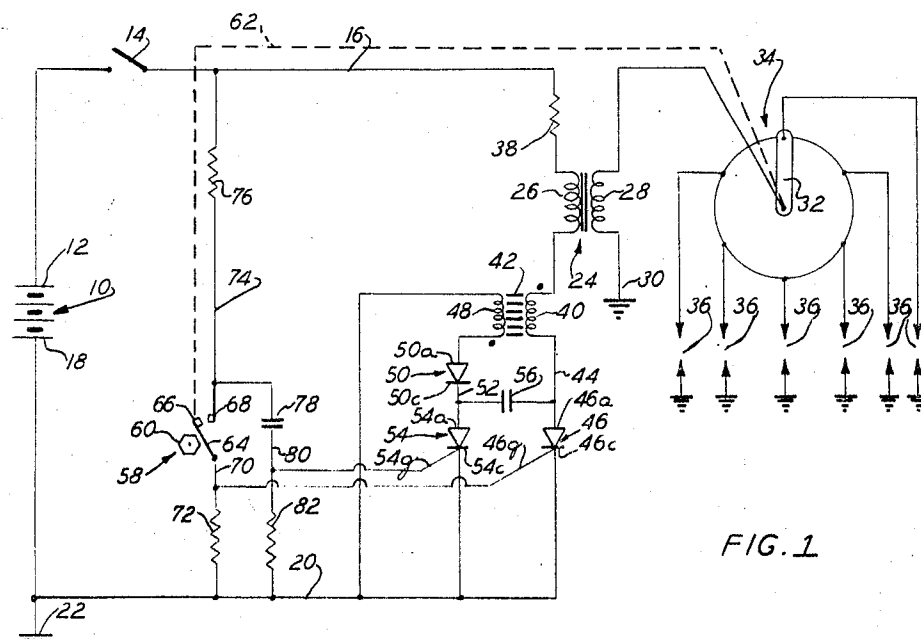


FIG. 1

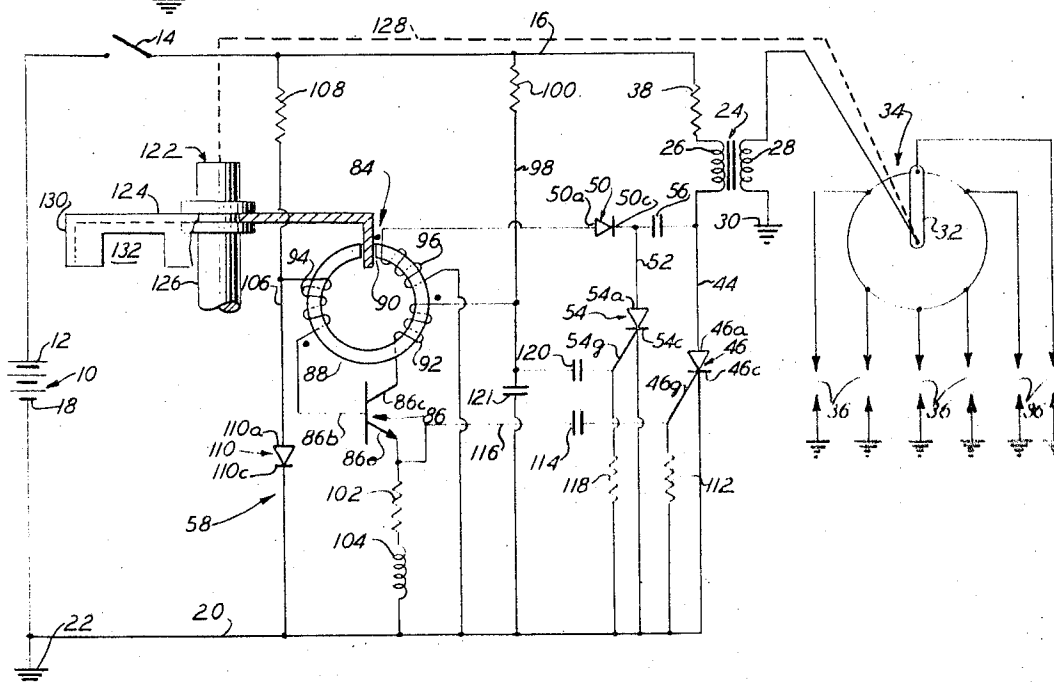


FIG. 2

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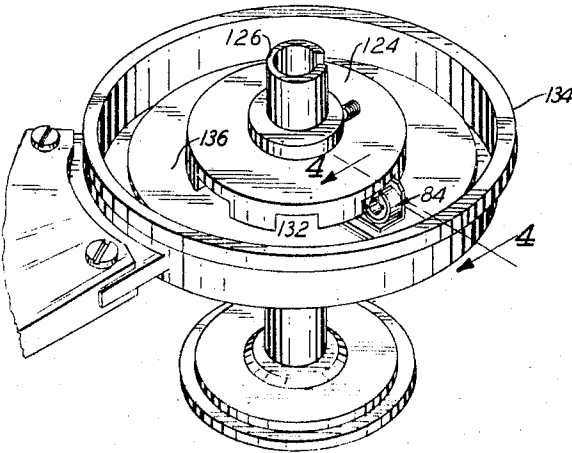


FIG. 3

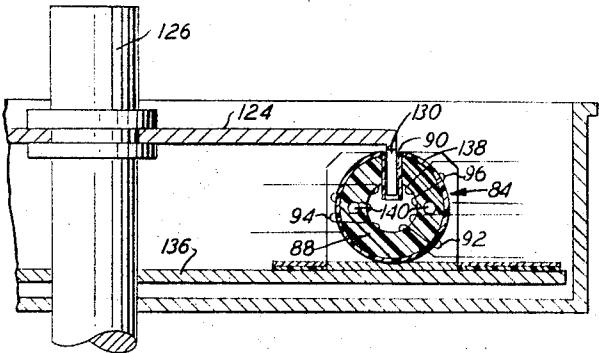


FIG. 4

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ELECTRONIC IGNITION SYSTEM USING MULTIPLE THYRISTORS

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8 Claims

Int. Cl. H05b 37/02, 41/36

This invention provides an electronic ignition system for an internal combustion engine in which a first thyristor controls current flow through an ignition coil primary winding and a second thyristor turns off precipitously the first thyristor in timed relationship to the engine. The ignition system can be made inexpensively from rugged components suitable for use in engine compartments and maintains initial accuracy throughout its long service-free life.

Most present day ignition systems for internal combustion engines use breaker points to control directly the electrical current through the ignition coil primary winding. The sudden change in current occurring when the breaker points open induces voltage in the coil secondary winding that is distributed to the appropriate spark plug. The average life of the breaker points is held to about 10,000 miles of vehicle operation by the high amounts of current and its highly inductive nature. Electronic ignition systems in which the breaker points control electronic switching devices that in turn control the current through the coil primary have been used on a limited scale along with a few more recent breakerless electronic systems. High costs and the delicate nature of the components in these electronic systems combined with the harsh engine compartment environment prevent widespread commercial acceptance of these prior art systems.

This invention provides an electronic ignition system made almost entirely of rugged, inexpensive components. Relative to many prior art systems, the number of components also is reduced, thereby decreasing even further the initial investment. The ruggedness of the components insures excellent service-free accuracy lasting in many cases throughout the life of the basic engine components.

In an ignition system of this invention having a source of electrical energy and a coil with a primary winding and a secondary winding, a first thyristor is connected in series with the coil primary winding, a second thyristor has its cathode coupled to the cathode of the first thyristor, and a capacitor couples the anodes of the thyristors. A transformer has its primary winding in series with the coil primary winding and its secondary winding connected to the capacitor. A two-stage trigger actuable by rotating parts of the engine turns on the first thyristor during one stage. Current begins in the coil primary winding and the transformer primary winding, inducing a charge on the capacitor from the latter.

When the trigger switches to its second stage, the second thyristor turns on to discharge the capacitor through the first thyristor in a direction that turns off the first thyristor precipitously, thereby abruptly halting the flow of current through the coil primary winding. Voltage thereby in the coil secondary winding is applied to an appropriate spark plug. The trigger then returns to its first stage and the above cycle repeats itself.

Details of construction and operation along with other advantages of this ignition system are presented below in connection with the drawings in which:

FIGURE 1 is a schematic diagram of an ignition system of this invention using breaker points as the trigger;

FIGURE 2 is a schematic diagram of a breakerless ignition system of this invention using an oscillator con-

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trolled by a rotating vane as the trigger and as a charging means for the capacitor;

FIGURE 3 is a perspective view of the rotating vane used in the trigger of the FIGURE 2 schematic; and

FIGURE 4 is a cross-sectional view along line 4-4 of FIGURE 3 showing additional structural details of the rotating vane and a feedback transformer used in the oscillator.

Construction of FIGURE 1

A battery serving as the source of energy is represented generally by the numeral 10 in FIGURE 1. Battery 10 has a positive terminal 12 connected through an ignition switch 14 to a positive buss lead 16. The negative terminal 18 of battery 10 is connected to negative buss lead 20 and to ground at 22. Battery 10 typically produces a no load potential of about 12 volts.

An ignition coil 24 having a primary winding 26 and a secondary winding 28 has one side of secondary winding 28 connected to ground at 30. The other side of secondary winding 28 is connected to the rotating arm 32 of a distributor assembly 34. Arm 32 sequentially connects one of a plurality of spark pulgs 36 to secondary winding 28.

One side of coil primary winding 26 is connected through a resistor 38 to buss lead 16. The other side of coil primary winding 26 is connected to the dotted terminal of the primary winding 40 of a saturable core transformer 42. A lead 44 connects the undotted terminal of winding 40 with the anode 46a of a silicon controlled rectifier 46, the first thyristor. Cathode 46c of rectifier 46 is connected to buss lead 20.

Secondary winding 48 of transformer 42 has its undotted terminal connected to lead 20 and its dotted terminal connected to the anode 50a of a diode 50. A lead 52 connects cathode 50c of diode 50 with anode 54a of a silicon controlled rectifier 54, the second thyristor. Cathode 54c of rectifier 54 is connected to lead 20. A capacitor 56 has one side connected to lead 44 and the other side connected to lead 52 so capacitor 56 couples anode 46a with anode 54a.

A trigger indicated generally by the numeral 58 comprises a cam 60 rotated through conventional gearing by the engine. Dotted line 62 represents the conventional mechanical connection between cam 60 and arm 32. An arm 64 having a contact 66 at one end is movable by cam 60 so contact 66 moves into and out of touch with an adjacent contact 68. A lead 70 connects arm 64 with one side of a resistor 72 that has its other side connected to lead 20.

Contact 68 is connected to a lead 74 that is connected through a resistor 76 to lead 16. A capacitor 78 has one side connected to lead 74 and its other side connected to a lead 80 that is connected through a resistor 82 to lead 20. Gate 46g of controlled rectifier 46 is connected to lead 70 and gate 54g of controlled rectifier 54 is connected to lead 80.

Operation of FIGURE 1

Windings 40 and 48 are arranged in transformer 42 so current into a dotted terminal of a winding induces current going out of a dotted terminal of the other winding.

Assume that ignition switch 14 is closed and the engine is turned over so cam 60 moves contact 66 into touch with contact 68. The positive voltage in lead 70 is applied to gate 46g, thereby turning on controlled rectifier 46. Conventional current begins in resistor 38, coil primary winding 26, transformer primary winding 40, and controlled rectifier 46. This current is low initially because of the self-inductance of winding 26 but eventually the current increases to a value limited by resistor 38, typically about one ohm.

The current through winding 40 induces a current at the dotted terminal of winding 48 that is applied through diode 50 to the side of capacitor 56 connected with lead 52. A typical primary winding 40 has 10 turns of 16 AWG wire, and a typical secondary winding 48 has 100 turns of 30 AWG wire. Diode 50 can be No. 1N1564 and a useful capacitor 56 is one having a rating of 0.5 microfarad at 150 volts. Current continues into capacitor 56 until transformer core 42 saturates. Transformer 42 is saturable so the charge built up on capacitor 56 is constant regardless of engine speed. Ordinarily, capacitor 56 attains a charge of about 120 volts.

Continued turning of cam 60 eventually separates contact 66 from contact 68. Resistors 72 and 76 typically are about 50 ohms each, respectively, when a 12 volt battery is being used, so the amount of current broken by contacts 66 and 68 is very low. As contacts 66 and 68 separate, the voltage in lead 74 rises rapidly to battery terminal voltage and the voltage in lead 70 drops rapidly to ground potential. The increased voltage in lead 74 produces a positive pulse that is applied through capacitor 78 to lead 80 and to gate 54g of controlled rectifier 54. This pulse turns on controlled rectifier 54 and the charge built up on capacitor 56 is applied through controlled rectifier 54 to the cathode 46c of controlled rectifier 46, thereby turning off controlled rectifier 46. The collapsing field in coil 24 produces a secondary voltage in secondary winding 28 that fires the appropriate spark plug 36. Current in winding 26 reverses its direction momentarily so electron current now passes into the dotted terminal of winding 40, thereby resetting the saturable core of transformer 42.

Subsequently, cam 60 moves contact 66 into touch again with contact 68. The potential of lead 80 falls while the potential in lead 70 rises to some positive value that is applied to gate 46g, thereby turning on rectifier 46 to begin again current through resistor 38, winding 26, winding 40, and rectifier 46.

Construction of FIGURES 2, 3 and 4

Numerals introduced in FIGURE 1 are used to designate the same components in FIGURE 2. In addition, the connection of components numbered 10 through 38 is the same in the FIGURE 2 circuit as the FIGURE 1 circuit and will not be repeated here. In FIGURE 2, lead 44 connects coil primary winding 26 directly to anode 46a of controlled rectifier 46. Cathode 46c is connected to buss lead 20. Capacitor 56 is connected between lead 44 and lead 52 that connects with anode 54a of controlled rectifier 54. Cathode 54c of rectifier 54 is connected to buss lead 20.

Trigger 58 in the FIGURE 2 circuit comprises an electronic oscillator made up of a transformer 84 and a transistor 86. Transformer 84 has a substantially circular core 88 that has a gap 90 therein. A primary winding 92, secondary winding 94, and tertiary winding 96 are wound on core 88.

A lead 98 is connected through a resistor 100 to lead 16. The dotted terminal of primary winding 92 is connected to lead 98 and the undotted terminal of winding 92 is connected to the collector 86c of transistor 86. Emitter 86e connects with a resistor 102 that is connected through an inductor 104 to buss lead 20.

Secondary winding 94 has its dotted terminal connected to base 86b of transistor 86. The undotted terminal of winding 94 is connected to a lead 106 that is connected through a resistor 108 to lead 16 and to the anode 110a of a diode 110. The cathode 110c of diode 110 is connected to lead 20. Diode 110 preferably has a relatively high capacitance so it constitutes a low AC impedance from lead 106 to lead 20.

Tertiary winding 96 has its undotted terminal connected to lead 20 and its dotted terminal connected to the anode 50a of diode 50. Cathode 50c of diode 50 is

connected to lead 52 and is thereby connected both to capacitor 56 and anode 54a.

Gate 46g of controlled rectifier 46 is connected through a resistor 112 to lead 20 and through a capacitor 114 to a lead 116 that connects with emitter 86e. Gate 54g of rectifier 54 is connected through a resistor 118 with lead 20 and through a capacitor 120 with lead 98. A capacitor 121 connects lead 98 with lead 20.

A timing device 122 comprises a cup-shaped vane 124 mounted on a shaft 126. Shaft 126 is driven by conventional means from the engine camshaft (not shown) and dotted line 128 represents a mechanical connection between shaft 126 and arm 32. Vane 124 has a web 130 made of a diamagnetic material such as brass and containing a plurality of cutouts 132, only one of which is shown in FIGURE 2. Web 130 moves through gap 90 when vane 124 is rotated by shaft 126. As shown in FIGURES 3 and 4, vane 124 rotates in a bowl-shaped housing 134. Transformer 84 is mounted on a plate 136 located near the floor of housing 134 in a position where web 130 passes through gap 90. Windings 92, 94 and 96 are wound on core 88. Core 88 is mounted in a shield 138 and is held in place by conventional fasteners 140. Core 88 ordinarily is made of ferrite. If desired, plate 136 can comprise a printed circuit board and the other components of the circuit can be mounted on the circuit board within housing 134.

Operation of FIGURES 2, 3 and 4

Transistor 86 is of the NPN type, a typical useful transistor being No. 2N3053. When ignition switch 14 is closed, positive voltage is applied through resistor 100, lead 98 and winding 92 to collector 86c and through resistor 108 and winding 94 to base 86b. Resistors 100 and 108 typically are about 100 and 1000 ohms, respectively. Diode 110, typically No. 1N4001, and resistor 108 bias transistor 86 slightly into conduction. The bias, however, is insufficient to sustain oscillation while the diamagnetic material of web 130 is in gap 90. Such bias is desirable because it ensures sufficient transistor gain to sustain oscillation when an additional voltage increment is induced in secondary winding 94.

When a cutout 132 moves into gap 90, feedback occurs from primary winding 92 to secondary winding 94 to induce additional positive voltage on base 86b. Typically, gap 90 is about 0.055 inch, winding 92 is 10 turns of 30 AWG wire, and winding 94 is 12 turns of 30 AWG wire. The additional voltage increases the forward bias on base 86b sufficiently so transistor 86 increases conduction. The conduction increases current through winding 92 which in turn increases the induced voltage at base 86b to further increase conduction of transistor 86. Transistor 86 continues to increase its conduction until it saturates.

At saturation, the increase in current through winding 92 stops and the induced increment of voltage at base 86b disappears. Base 86b suddenly becomes negative with respect to emitter 86e, and the current through transistor 86 falls rapidly to a very low value.

The falling current through winding 92 induces a negative voltage at base 86b that keeps transistor 86 off until the negative voltage is dissipated. At this point, conduction of transistor 86 begins again and the above cycle is repeated in an oscillatory manner as long as a cutout 132 is in gap 90. Oscillation frequency is determined primarily by the inductance of winding 92 and is at least several kilocycles per second, preferably ranging as high as several megacycles per second. During oscillation, when current through transistor 86 falls, current through resistor 100 passes into capacitor 121 which is selected so the current through resistor 100 is substantially constant. Thus, the voltage in lead 98 is constant during oscillation. A typical value for capacitor 121 is 0.1 microfarad at 25 volts.

The voltage at emitter 86e and in lead 116 rises when transistor 86 is conducting and falls when transistor 86

is turned off, thereby oscillating along with transistor 86. When oscillation begins, a pulse applied through capacitor 114 to gate 46g turns on controlled rectifier 46. Resistor 112 typically is about 1000 ohms and capacitor 114 typically is about 0.01 microfarad at 10 volts. Rectifier 46 then conducts current through resistor 38 and coil primary winding 26. Gate 54g of controlled rectifier 54 is negative or zero and rectifier 54 is off during oscillation. Resistor 118 typically is about 5000 ohms and capacitor 120 typically is about 0.1 microfarad at 10 volts.

Current through winding 92 during oscillation induces current in winding 96 passing out of the dotted terminal. This induced current is applied through diode 50 to capacitor 56. Since rectifier 54 is off, this current builds up a voltage on capacitor 56. When current through winding 92 decreases during oscillation, diode 50 blocks the negative voltage induced at the dotted terminal of winding 96 from capacitor 56.

As the diamagnetic material of web 130 moves into gap 90, the gain of transformer 84 declines until the induced voltage in winding 94 falls below the level necessary to sustain oscillation. The presence of web 130 in gap 90 also decreases the self-inductance of winding 92 which increases the oscillation frequency. This increased frequency in turn increases the inductance of inductor 104 which typically is about 0.01 microhenry, thereby increasing the impedance provided by inductor 104. Preferably, transistor 86 is selected so its gain decreases significantly with the increase in frequency resulting from the changed self-inductance of winding 92.

The decreasing gain of transformer 84 and transistor 86 plus the increased impedance offered by inductor 104 operate in cascade to stop oscillation precipitously. Current through resistor 100 drops suddenly, thereby raising the voltage in lead 98 and applying a positive pulse through capacitor 120 to gate 54g. This pulse turns on rectifier 54.

Rectifier 54 then applies the positive potential built up on capacitor 56 to cathode 46c of rectifier 46. Since the voltage disappeared from gate 46g when oscillation ceased, the positive potential of capacitor 56 turns off rectifier 46 rapidly. Current through coil primary winding 26 drops rapidly, thereby inducing voltage in coil secondary winding 28 that fires a spark plug 36.

Subsequently, another cutout 132 moves into gap 90 and oscillation begins again in transistor 86. Gate 46g again becomes positive turning on controlled rectifier 46.

If desired, a capacitor can be connected in parallel with diode 110 to decrease further the AC impedance between secondary winding 94 and ground. Vane 124 can have a planar or some other shape and can be made of paramagnetic or ferromagnetic material. The oscillator can be designed so no oscillation takes place when a cutout 132 is in gap 90, and movement of the material of web 130 into gap 90 begins oscillation. Transformer core 88 can be split into two C-shaped portions facing each other across dual gaps to increase the change in feedback when web 130 moves between the portions. Note that transformer 88 performs the dual functions of providing feedback for the oscillator and charging capacitor 56.

Silicon controlled rectifiers are preferred as thyristors 46 and 54 because their ruggedness enables them to function accurately in an engine compartment for long periods of time. The amount of current broken by contact points 66 and 68 can be as low as 0.1 ampere so the life of breaker points made from commercially available materials is extended to the life of the basic engine

components. Service life of the breakerless system of FIGURE 2 is even longer.

What is claimed is:

1. In an ignition system for an internal combustion engine having a source of electrical energy and a coil with a primary winding and a secondary winding, means for inducing an ignition voltage at the coil secondary winding comprising

a first thyristor in series with the coil primary winding, a second thyristor having its cathode coupled to the cathode of said first thyristor, a capacitor coupling the anodes of said first and second thyristors,

a two-stage trigger means actuatable by rotating parts of said engine, said trigger means turning on said first thyristor when in one of the stages, transformer means for charging said capacitor when said first thyristor is on, and

circuitry for turning said second thyristor on when said trigger means switches to its other stage, said second thyristor discharging said capacitor through said thyristors to turn said first thyristor off rapidly.

2. The ignition system of claim 1 in which thyristors are silicon controlled rectifiers and the trigger means comprises

an oscillator connected across said source of electrical energy, said transformer means being coupled to oscillation from said oscillator.

3. The ignition system of claim 2 in which the oscillator comprises a transistor and the transformer means provides a feedback connection from the output circuit to the input circuit of said transistor.

4. The ignition system of claim 3 in which the transformer means comprises a core having a gap therein and said trigger means comprises a web moving through the gap of said core to start and stop oscillation.

5. The ignition system of claim 4 in which the web is a diamagnetic material.

6. The ignition system of claim 1 in which said thyristors are silicon controlled rectifiers, the trigger means comprises breaker points connected across said source of energy and movable into and out of touch with each other, and the transformer means comprises a saturable transformer.

7. The ignition system of claim 6 in which the saturable transformer has its primary winding in series with the coil primary winding and said first silicon controlled rectifier.

8. The ignition system of claim 7 in which the transformer secondary winding is connected through a diode to said capacitor.

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