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TRANSISTORIZED IGNITION SYSTEM WITH A BISTABLE
ELECTROMAGNETIC SWITCH
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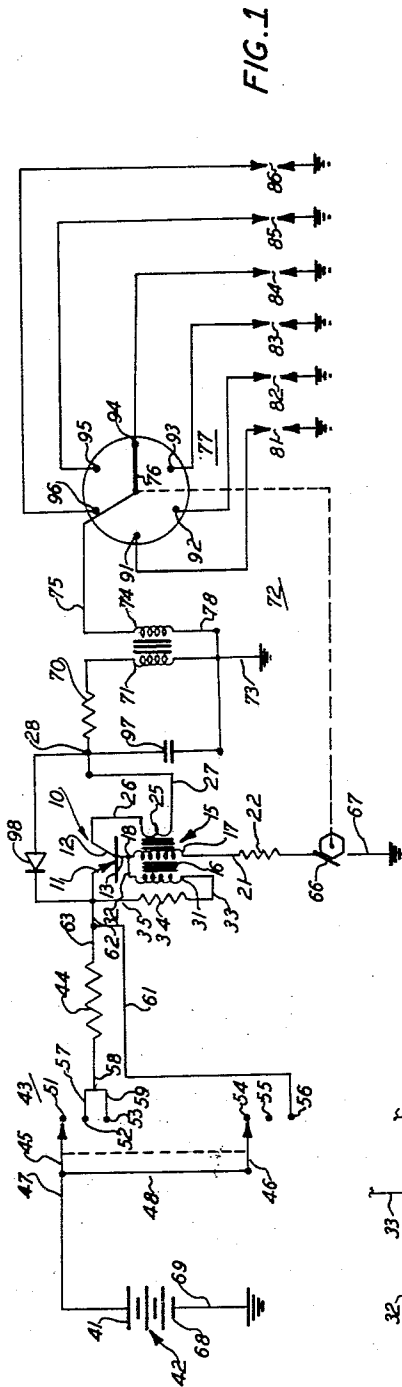


FIG. 1

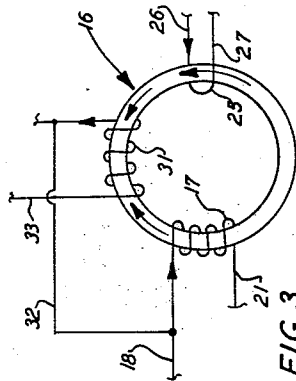


FIG. 3

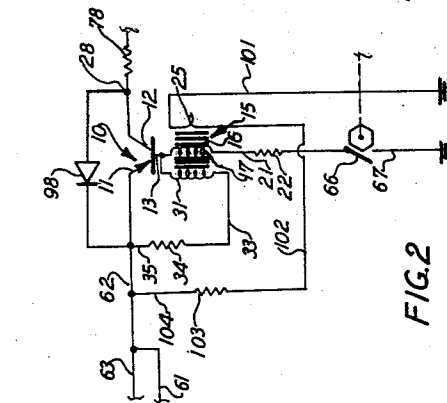


FIG. 2

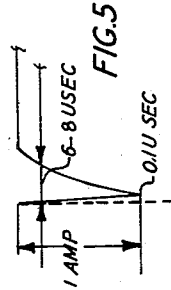


FIG. 5

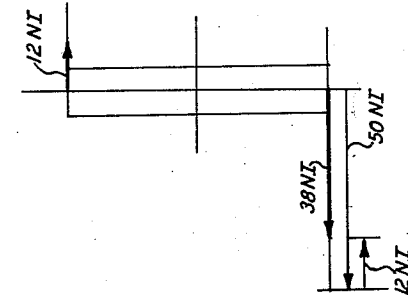


FIG. 4

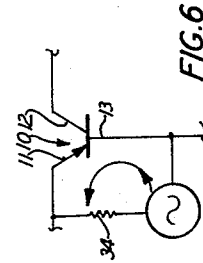


FIG. 6

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TRANSISTORIZED IGNITION SYSTEM WITH A BISTABLE ELECTROMAGNETIC SWITCH

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9 Claims. (Cl. 315-209)

This invention relates to an ignition system for an internal combustion engine and more particularly to a transistorized ignition system for an internal combustion engine.

In conventional internal combustion engine ignition systems, full battery voltage is applied across the primary winding of the ignition coil through a set of distributor breaker points. As a result, a heavy current flows in the primary winding and through the breaker points. When the breaker points are opened, arcing occurs across the points since current through the primary winding continues to flow because of the collapsing magnetic field of the ignition coil. This causes pitting and corrosion of the breaker points and experience shows that the breaker points have to be periodically replaced because of this pitting and corrosion.

The present invention provides an ignition system in which pitting and corrosion of the breaker points are substantially reduced. This is accomplished by employing a transistor circuit in which the primary of an ignition coil is positioned in the load circuit of the transistor and in which a pair of distributor breaker points are positioned in the base or control circuit of the transistor to alternately turn the transistor on and off. Thus, the breaker points switch only base or control circuit current which is substantially less than the primary current which must be switched by conventional ignition systems.

It is well known that the voltage induced in the secondary winding of an ignition coil is proportional to the time rate of change of the flux in the coil and that peak outputs occur when the magnetic field in the coil collapses due to change in primary current as the switching means in the primary circuit is opened. It follows, therefore, that high secondary winding outputs will occur if short switching times for the primary currents can be accomplished.

The present invention provides a circuit for reducing switching times in transistorized ignition systems by employing means that causes a reverse current to flow in the base-emitter circuit of the transistor when the distributor breaker points are opened. This reverse current causes the transistor to be rapidly cut off and it, therefore, rapidly interrupts current flow through the primary winding of the ignition coil. As a result, high secondary output voltages are obtained from the secondary winding of the ignition coil. The means referred to above may take the form of an electromagnetic switch including a core constructed of ferromagnetic material. This ferromagnetic core is magnetized in one direction when the transistor is in its conducting state. When the distributor breaker points are opened, the ferromagnetic core is switched from one direction of magnetization to the other direction of magnetization. An output winding is wound upon this ferromagnetic core and is connected to the base and to the emitter of the transistor. This output winding applies a pulse of electrical energy to the base of the transistor of a polarity opposite to the polarity of the bias applied to the base to cause the transistor to conduct thereby causing a pulse of reverse current to flow through the base and the emitter for a very short period of time. As a result, the transistor is rapidly switched from its conducting to its nonconducting state.

As will be more fully explained in the main body of

the specification, the transistorized ignition system of this invention will operate very well at low engine speeds such as occur during engine cranking conditions. This is brought about by the fact that the ferromagnetic core can be switched from one state of magnetization to the other state of magnetization even though the distributor breaker points are slow to open or may not open completely.

Although the invention was discussed above in relation to a pair of distributor breaker points being positioned in the base circuit of the transistor to periodically interrupt current flow therethrough, it is obvious that various other means for interrupting the base current may be employed. For example, a magnetic switch that includes a winding positioned in series with the base circuit and a multipole permanent magnet driven by the distributor and placed adjacent this winding may also be employed.

An object of the invention is the provision of a transistorized ignition system for an internal combustion engine.

Another object of the invention is the provision of a transistorized ignition system for an internal combustion engine in which the transistor is cut off very rapidly when it is desired to interrupt the current in the primary windings of ignition coil.

A further object of the invention is the provision of a transistorized ignition system for an internal combustion engine that will work very well and will provide proper ignition at low engine speeds.

Still another object of the invention is the provision of a transistorized ignition system for an internal combustion engine that includes means for causing a reverse current to flow in the base-emitter circuit of the transistor when it is desired to interrupt current in the primary winding of the ignition coil, thereby rapidly switching the transistor from its conducting to its nonconducting state.

Other objects and attendant advantages of the present invention will become more readily apparent as the specification is considered in connection with the accompanying drawings in which:

FIG. 1 is a circuit diagram of one embodiment of the invention;

FIG. 2 is a partial circuit diagram of another embodiment of the invention;

FIG. 3 is a wiring diagram of the ferromagnetic core employed in the embodiments shown in FIGS. 1 and 2;

FIG. 4 is a hysteresis loop of the ferromagnetic core shown in FIG. 3;

FIG. 5 is a plot of the pulse of reverse current that flows through the base-emitter circuit of the transistor, with the Y axis showing the magnitude of the current flow and the X axis being a time base in microseconds, and,

FIG. 6 is a schematic representation of the transistor during the time that reverse current flows in the base-emitter circuit of the transistor.

Referring now to the drawings in which like reference numerals designate like parts throughout the several views thereof, there is shown in FIG. 1 a transistorized ignition system that may be employed with an automotive vehicle internal combustion engine. This ignition system includes a transistor 10 having an emitter 11, a collector 12 and a base 13. For purposes which will be more fully developed later in the specification, the transistor 10 is preferably of the type that has a low breakdown voltage between the emitter and base when a reverse bias is applied between the emitter and base. A breakdown voltage in the range of 1 to 5 volts is satisfactory, and a diffused alloy power transistor having a graded or diffused base provides this characteristic.

An electromagnetic switch means 15 is connected in circuit with the transistor 10. This electromagnetic switch means includes a ferromagnetic core 16 constructed of a material having a square or rectangular type hysteresis loop and having a fast switching time. A "Deltamax" material which is a grain orientated 50 percent nickel-iron alloy having a rectangular hysteresis loop may be employed to construct the ferromagnetic core 16. A first input winding 17 is wound upon the core and has one end connected through a lead 18 to the base 13 of transistor 10. The other end of the first input winding 17 is connected by a lead 21 to a resistor 22. A second input winding 25 is wound upon the core 16 and is connected at one end through a lead 26 to the collector 12 of transistor 10. The other end of the second input winding 25 is connected through a lead 27 to a junction point 28. An output winding 31 is wound upon the core 16 and has one end connected to the base 13 of transistor 10 through a lead 32. The other end of the output winding 31 is connected through a lead 33 to a resistor 34. The resistor 34 is in turn connected to the emitter 11 of transistor 10 through a lead 35.

The emitter 11 of transistor 10 is connected to the positive terminal 41 of electrical storage battery 42 through an ignition switch 43 that includes a resistor 44. More specifically, the ignition switch includes a pair of movable ganged arms 45 and 46 that are connected to the positive terminal 41 of battery 42 through leads 47 and 48. The ignition switch 43 includes six contacts, designated by the numerals 51 through 56. The contact 52 is connected to resistor 44 through leads 57 and 58, while the contact 53 is connected to resistor 44 through lead 59 and lead 58. The contact 56 is connected to the emitter 11 of the transistor 10 through leads 61 and 62, while the resistor 44 is connected to the emitter 11 through a lead 63 and lead 62.

When the movable ganged arms 45 and 46 of ignition switch 43 are connected to contacts 51 and 54 respectively, the ignition switch is in the "off" position. When the arms 45 and 46 are in contact with the contacts 52 and 55 respectively, the ignition switch is in the "on" position and current is fed from the positive terminal of the battery 41 to the emitter 11 of transistor 10 through lead 47, movable arm 45, contact 52, lead 57, lead 58, resistor 44, lead 63 and lead 62. When the movable ganged arms 45 and 46 of ignition switch 43 are in contact with contacts 53 and 56 respectively, the ignition is in the "start" position and electrical energy is fed from the positive terminal 41 of the battery 42 to the emitter 11 of transistor 10 through lead 47, lead 48, movable arm 46, contact 56, lead 61 and lead 62. Thus, when the ignition switch is in the "start" position, the resistor 44 is bypassed so that more energy will be fed to the transistor 10 during starting operations than is fed to its during ordinary operating conditions.

As previously described, the resistor 22 is connected to the base 13 of transistor 10 through lead 21, input winding 17 and lead 18. The other end of the resistor 22 is connected to a current interrupting means that may conveniently take the form of a pair of distributor breaker points 66. This pair of distributor breaker points is also connected to ground through a lead 67. The lead 67 thus connects the distributor breaker points 66 to the negative terminal 68 of the storage battery 42 that is also grounded by a lead 69.

The junction point 28 of transistor 10 is connected to the primary winding 71 of an ignition coil 72 through a resistor 70. The other end of the primary winding 71 is grounded through a lead 73. The secondary winding 74 of the ignition coil 72 is connected through lead 75 with rotating arm 76 of distributor 77. The other end of the secondary winding 74 is grounded through a lead 78. The rotating arm 76 sequentially connects the secondary winding 74 of the ignition coil 72 with spark plugs 81 through 86 by means of distributor cap con-

tacts 91 through 96. The rotating arm 76 and the distributor breaker points 66 of the distributor 77 are operated in timed relationship so that the distributor breaker points 66 are opened when the rotating arm 76 comes into contact with any one of the distributor cap contacts.

A capacitor 97 is connected to the junction point 28 and to the lead 73 so that it is connected across the series combination of the primary winding 71 and the resistor 70. This capacitor functions to reduce the instantaneous wattage appearing across the transistor 10 when the transistor is switched from its conducting to its nonconducting state. A zener diode 98 is connected across the transistor between the emitter 11 and the junction point 28 to protect the transistor from voltages in excess of those at which it is designed to operate. This zener diode will have a breakdown voltage substantially equal to the voltage at which the transistor 10 is designed to operate. Voltages of a magnitude in excess of the peak voltage that the transistor can withstand may appear when the transistor is switched from its conducting to its nonconducting state due to the inductive kick from the primary winding 71 of ignition coil 72. When this occurs the zener diode 98 will break down and will provide a low resistance path in parallel with the collector and the emitter of the transistor.

FIG. 2 discloses another embodiment of the invention in which the second input winding 25 is connected across the terminals 41 and 68 of the electrical storage battery 42 rather than being connected in series with the emitter 12 of transistor 10 and the resistor 70 and primary winding 71 of the ignition coil 72. In FIG. 2, one end of the second input winding 25 is connected to ground through a lead 101 while the other end of the first input winding 25 is connected through a lead 102 to a resistor 103. The other end of the resistor 103 is connected through a lead 104 to the lead 62.

The emitter 11 and the collector 12 of the transistor 10 may properly be termed output terminals, while the base 13 and the emitter 11 may be termed input terminals. The emitter 11 in this sense is both an input terminal and an output terminal. The base 13 of the transistor 10 can also be termed a control electrode control terminal. the circuit interconnecting the collector and emitter may be properly denoted as an output or load circuit, while the circuit interconnecting the base and emitter may be properly termed an input or control circuit.

The ignition systems shown in FIGS. 1, 2 and 3, may employ the following components which are given by way of example only:

Transistor 10	2N1073B.
Core 16	An Arnold Engineering Deltamax core—3T8043D4. This core is constructed of a grain orientated 50 percent nickel-iron alloy having a rectangular hysteresis loop. It may be wound from a strip of this material having a thickness of .004 inch, and the core may have an inner diameter of 0.500 inch and an outer diameter of 0.625 inch.
First input winding 17	50 turns of copper wire.
Second input winding 25	1 turn of copper wire.
Output winding 31	10 turns of copper wire.
Resistor 22	8 ohms.
Resistor 34	5.6 ohms.
Resistor 44	0.33 ohm.
Resistor 70	0.43 ohm.
Primary winding 71 of ignition coil 72	100 turns of #17 copper wire.

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Secondary winding 74 of
ignition coil 72 ----- 26,000 turns of #38 copper
wire.
Storage battery 42 ----- A standard 12 volt automotive
vehicle storage battery.
Zener diode 98 ----- 1N3004A, having a break-
down voltage of 91 volts.
Resistor 103 ----- 1.00 ohm.

In operation of the ignition system shown in FIGS. 1 and 2, the operator of the automotive vehicle in which it has been installed, moves the ignition switch 43 to the "start" position in which the movable arms 45 and 46 are in engagement with contacts 53 and 56. After the internal combustion engine has started, the ignition switch is moved to the "on" position in which the movable arms 45 and 46 are positioned in engagement with the contacts 52 and 55. With the switch in the "start" position, the emitter 11 of the transistor 10 is directly connected to the positive terminal 41 of storage battery 42 through the ignition switch 43. With the ignition switch 43 in the "on" position, the emitter 11 will be connected to the positive terminal 41 of the storage battery 42 through the ignition switch 43 and the resistor 44. On the other hand, the base 13 is connected to the negative terminal 68 of storage battery 42 through the lead 18, first input winding 17, lead 21, resistor 22, distributor breaker points 66, lead 67 and lead 69. This will turn the transistor to its "on" position or conducting state when the distributor breaker contacts 66 are closed. As a result, base current will flow through the first input winding 17 positioned on core 16. The current that flows from the battery 42 through the transistor 10 to the primary winding 71 of the ignition coil 72 flows through the second input winding 25.

Under ordinary operating conditions, the base current traversing the winding 17 is approximately 1 ampere and since this winding comprises 50 turns, it will impress a magnetomotive force on the coil of 50 ampere turns. The current that normally flows from the transistor 10 to the primary winding 71 is on the order of 12 amps and since this winding comprises one turn, it will impress a magnetomotive force of approximately 12 ampere turns upon the core 16.

As can be seen by reference to FIG. 3, the first input winding 17 is wound to create a clockwise flux in the core and the second input winding 25 is wound to create a counterclockwise flux in the core. The resultant of these two magnetomotive forces is a magnetomotive force of approximately 38 ampere turns which creates a resultant flux in the core 16 in a clockwise direction. Referring to FIG. 4, this flux is designated as having a negative direction and the core described above, such as the Arnold 3T8043D4, is designed to saturate with magnetomotive force of approximately 6 ampere turns impressed upon it. It can be seen, therefore, that when current flows through both the first input winding 17 and the second input winding 25 that the core 16 is saturated in the negative direction.

During the time that the transistor is turned on, or is in its conducting state, as a result of the distributor contact points 66 being closed, the core 16 will be in a state of negative saturation. As a result, the impedance of the output winding 31 connected between the base 13 and the emitter 11 of transistor 10 will be substantially zero. The resistor 34, however, provides sufficient resistance between the emitter 11 and the base 13 of transistor 10 to maintain proper operating bias. When the breaker points 66 are opened, the current through the first input winding 17 is interrupted or substantially reduced to zero during normal operating conditions. The transistor 10 will, therefore, tend to be turned to its nonconducting state. It has, however, a large inductive element, primary winding 71 of ignition coil 72, connected in series with it. Current will continue to flow, therefore, through the transistor 10 for a short interval of time.

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This current also traverses the second input winding 25 and since it has a magnitude of approximately 12 amperes, it will switch the core from its negative state of saturation to its positive state of saturation in a very rapid switching action. As a result of the switching of the core, a voltage is induced in the output winding 31. This voltage is of a polarity to cause a reverse current to flow in the base-emitter circuit of the transistor. Since in normal operation of the transistor current flows from the emitter to the base, this reverse current flows from the base to the emitter. It can be appreciated that the polarity of the voltage applied to the base 13 by output winding 31 is opposite to the polarity of normal operating bias.

It has been found that the voltage induced in the output winding 31 as a result of the switching of the core 16 is approximately 5 volts. This is sufficient to cause a breakdown in the base to emitter junction of the transistor 10 and to cause a pulse of current through the base-emitter circuit including the winding 31 and the resistor 34 of a peak magnitude of approximately 1 ampere. Referring now to FIGS. 5 and 6, it can be seen that this current pulse has a very steep wave front. Tests have shown that the current reaches a maximum of approximately one ampere and approximately $\frac{1}{10}$ of a microsecond, and that it decays to approximately $\frac{1}{10}$ of an ampere in a range of from 6 to 8 microseconds after the core 16 has started to switch. As shown in FIG. 6, this current flows in a counterclockwise direction in the base-emitter circuit and thus it flows in a direction that is the reverse of ordinary current flow in the transistor when the transistor is in its conducting state.

This reverse current very rapidly switches the transistor 10 from its conducting to its nonconducting state since the peak value of this current is reached in approximately $\frac{1}{10}$ of a microsecond. It has been determined that the transistor can be turned off in the range of from 3 to 6 microseconds using the circuit of the present invention. This will provide high output voltages from the secondary winding 74 of the ignition coil 72 since the current through the primary winding 71 is rapidly cut off. When this current is cut off, the collapsing magnetic field of the primary winding 71 induces a high voltage in the secondary winding 74 which is applied to one of the spark plugs 31 through 86 by means of the rotating arm 76 and one of the distributor cap contacts 91 through 96. After this takes place, the distributor breaker points 66 will again close to complete the base or input circuit of transistor 10 and to bring the transistor 10 into conduction.

Referring now to FIG. 4, it can be appreciated that the core 16 is magnetized in a negative direction when the distributor breaker points 66 are closed and current is flowing in the first input winding 17. The negative direction of magnetization corresponds to a counterclockwise direction shown in FIG. 3. When the distributor breaker points 66 open, it will be apparent that the core 16 is switched to a positive direction of magnetization (corresponding to a clockwise direction in FIG. 3). When the distributor breaker points 66 open and the core 16 is switched from its negative to its positive state of magnetization, the output winding 31 provides a pulse of electrical energy having a polarity to drive a pulse of reverse current through the base-emitter circuit of the transistor. This rapidly switches the transistor 10 from its conducting to its nonconducting state. The core 16 will remain in a positive state of magnetization with a flux density at least equal to the remnant flux density of the core until the distributor breaker points 66 close. At this time, the base current will again flow through the first input winding 17 and the core 16 will be switched to its negative state of magnetization. The cycle described above is repeated periodically so that transistor 10 is alternately switched from its conducting state to its nonconducting state. Each time the transistor 10 is switched to its nonconducting state, the rotating arm 76 comes into contact with one of the distributor cap con-

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tacts 91 through 96 to supply a spark to one of the spark plugs 81 through 86.

The embodiment of the invention shown in FIG. 2 operates in substantially the same manner as the embodiment of FIG. 1 except that current continuously flows through the second input winding 25 by way of lead 104, resistor 103, lead 102 and lead 101. Thus, the core 16 is continually biased towards a direction of positive magnetization by the magnetomotive force developed by the current in the first input winding 25. When the distributor breaker points 66 are closed, current will flow in the first input winding 17, and this current will develop sufficient magnetomotive force to overcome the magnetomotive force developed by the current flowing in the second input winding 25, so that the core will be positioned in a state of negative magnetization. When the distributor breaker points 66 open, the core will be switched from its negative to its positive state of magnetization and will remain in the positive state of magnetization during the interval that the breaker points are open. When the breaker points are again closed, the core will then switch back to its negative state of magnetization. The currents flowing in the first input winding 17 and the second input winding 25 of the embodiment shown in FIG. 2 are substantially the same as those of the embodiment shown in FIG. 1. As a result, the output voltage of output winding 31 and the reverse current flowing through the base-emitter circuit of transistor 10 are substantially the same as those of the embodiment shown in FIG. 1.

In all of the embodiments of the invention, there is provided a very reliable transistorized ignition system in which breaker point life is substantially increased over conventional systems, since the breaker points need only switch the base current of the transistor rather than full primary current.

This system will work very well at low engine speeds such as encountered in engine cranking conditions. During low engine speeds, the breaker points 66 may be slow to open or will not open completely. In such a case, however, the core 16 of the ignition system will still switch from one state of magnetization to the other since as the breaker points 66 commence to open, the resistance of the base circuit will rise very rapidly and the current through the base circuit and the first input winding 17 will be substantially reduced. Since the core can be driven to saturation by a magnetomotive force of around 6 ampere-turns, it can be seen that the core will switch when the magnetomotive force impressed upon the core by the first input winding 17 falls to the neighborhood of 6 ampere turns. Thus, the system will operate efficiently even though the distributor breaker points are slow to open or even though the distributor breaker points fail to open completely.

The provision of the ferromagnetic core 16 with the very rapid switching time, in the neighborhood of a fraction of a microsecond, provides advantages over other types of feedback systems that derive a feedback pulse from a feedback winding coupled to the ignition coil itself. Such a feedback winding cannot apply a feedback pulse to the transistor at such a rapid rate since the maximum voltage output from such a feedback winding occurs only when the flux change in the ignition coil reaches a maximum. This may take a period of time of the order of several magnitudes larger than the time required to switch the ferromagnetic core 16. As previously stated, this rapid switching of the core 16 and hence the rapid turning off of the transistor 10 results in high secondary output voltages.

Although the invention is shown employing a p.n.p. type transistor, the invention is in no way limited to this type of transistor. It will be readily apparent to those skilled in the art how the circuit of the invention may be connected to employ other types of transistors, for example, a n.p.n. type transistor. Similarly, the invention may

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employ any type of ferromagnetic core that has a substantially rectangular hysteresis loop and that will switch very rapidly under low magnetomotive forces.

It will be understood that the 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. An ignition system for an internal combustion engine comprising, a spark plug, an ignition coil including a primary winding and a secondary winding, said secondary winding being connectable to said spark plug, a source of electrical energy, a transistor having an emitter, a collector and a base, said primary winding of said ignition coil, said source of electrical energy and said collector and emitter of said transistor being connected in series, means connecting said base of said transistor with said source of electrical energy for properly biasing said transistor, means connected in circuit with the base of said transistor for interrupting current flow through said base, a ferromagnetic core, means connected in circuit with said transistor and said source of electrical energy for switching said ferromagnetic core from one direction of magnetization to the other direction of magnetization in response to the interruption of current flow through said base, an output winding wound upon said ferromagnetic core and connected to said emitter and said base, said output winding being wound upon said ferromagnetic core in a direction to cause a current to flow through said emitter and base in a direction opposite to current flow through the base and the emitter when said transistor is in a conducting state whereby said transistor is brought rapidly to its nonconducting state.

2. An ignition system for an internal combustion engine comprising, a spark plug, an ignition coil including a primary winding and a secondary winding, said secondary winding being connectable to said spark plug, a source of electrical energy, a transistor having an emitter, a collector and a base, said primary winding of said ignition coil, said source of electrical energy and said collector and emitter of said transistor being connected in series, means connecting said base of said transistor with said source of electrical energy for properly biasing said transistor, means connected in circuit with said base of said transistor for interrupting current flow through said base, a ferromagnetic core having a substantially rectangular hysteresis loop, a first input winding wound upon said ferromagnetic core, said first input winding being connected in circuit with said base and with said means for interrupting current flow through said base whereby normal operating base current flows through said first input winding, a second input winding wound upon said ferromagnetic core, said second input winding being connected in circuit with said source of electrical energy, the magnetomotive force developed by the current in said first input winding being sufficient to magnetize the ferromagnetic core in one direction, the magnetomotive force developed by the current in the second input winding being sufficient to magnetize the ferromagnetic core in the other direction, the resultant magnetomotive force of said first input winding and said second input winding magnetizing said core in said one direction, said ferromagnetic core switching from one direction of magnetization to the said other direction of magnetization when said means interrupts current flow through said base and said first input winding, and an output winding connected to said emitter and to said base and wound upon said core in a direction to produce a current flow in said base and emitter in a direction opposite to the normal current flow through said base and emitter when said magnetic core is switched as a result of current being interrupted in said base and said first input winding, whereby said transistor is switched rapidly from its conducting to its nonconducting state.

3. In an ignition system for an internal combustion

engine the combination comprising a plurality of spark plugs, an ignition coil including a primary winding and a secondary winding, a distributor for sequentially connecting said secondary winding with said spark plugs, a source of electrical energy, a graded base transistor having an emitter, a collector and a base, said primary winding of said ignition coil being connected to said collector, said distributor including a pair of breaker points, said emitter being connected to said source of electrical energy and said base being connected to said source of electrical energy through said breaker points, a ferromagnetic core having a substantially rectangular hysteresis loop positioned adjacent said transistor, a first input winding positioned upon said core and connected in series with said base and said breaker points, a second input winding positioned upon said core and connected in series with said collector and the primary winding of said ignition coil, an output winding positioned upon said core and connected to said emitter and to said base, the resultant magnetomotive force of said first and second input windings being sufficient to magnetize the core in one direction, the magnetomotive force developed by said second input winding being sufficient to magnetize the core in the other direction whereby said core is switched from one state of magnetization to the other state of magnetization when said breaker points are opened, said output winding being wound upon said core in a direction to produce a current flow through said base and said emitter in a direction opposite to the normal current flow through said base and said emitter whereby said transistor is rapidly brought to its nonconducting state when said breaker points are opened.

4. In an ignition system for an automotive vehicle the combination comprising a plurality of spark plugs, an ignition coil including a primary winding and a secondary winding, a distributor for sequentially connecting said secondary winding with said spark plugs, a source of electrical energy, a transistor having input terminals and output terminals, an input circuit connected to said input terminals and an output circuit connected to said output terminals, said primary winding of said ignition coil being positioned in the output circuit of said transistor, said distributor including a pair of breaker points, said source of electrical energy and said pair of breaker points being connected in series and positioned in the input circuit of said transistor, and a bistable electromagnetic switch means positioned adjacent said transistor, said bistable electromagnetic switch means comprising a ferromagnetic core having a substantially rectangular hysteresis loop, a first input winding wound upon said ferromagnetic core and connected in the input circuit of said transistor and in series with said breaker points, a second input winding wound upon said core and connected in series with the primary winding of said ignition coil, the resultant magnetomotive force developed by said first and said second input windings being sufficient to magnetize the core in one direction, the magnetomotive force developed by said second input winding being sufficient to switch the core to its other direction of magnetization when current flow through said first input winding is interrupted due to the opening of said breaker points, and an output winding wound upon said core and connected in circuit with the input terminals of said transistor for causing a current to flow through said input terminals in a direction opposite to current flow through said input terminals during normal operation.

5. In an ignition system for an automotive vehicle the combination comprising a plurality of spark plugs, an ignition coil including a primary winding and a secondary winding, a distributor for sequentially connecting said secondary winding with said spark plugs, a source of electrical energy, a transistor including a collector, an emitter, and a base, said primary winding being connected in series with said collector, said emitter and said source of electrical energy, said base being connected to said

source of electrical energy for biasing said transistor to its conducting state so that current flows through said base to said source of electrical energy, a bistable ferromagnetic core, a first input winding wound upon said ferromagnetic core and connected in series with said base, a second input winding wound upon said core and connected in series with the primary winding of said ignition coil, the resultant magnetomotive force of said first and said second input windings being sufficient to magnetize said core in one direction when said transistor is in its conducting state, and means positioned in series with said base and said first input winding and driven by said distributor for interrupting current flow through said base and said first input winding, the current flow through said second input winding being sufficient to switch the ferromagnetic core to the other direction of magnetization, and an output winding connected to the emitter and the base of said transistor and wound upon said core in a direction to produce a current flow through said base and said emitter upon the change of direction of magnetization of said ferromagnetic core in a direction opposite to the current flow when said transistor is in a conducting state.

6. An ignition system for an internal combustion engine comprising, an electrical ignition means, an ignition coil including a primary and a secondary winding, said secondary winding being connected in circuit with said electrical ignition means, a source of electrical energy, a semiconductor device having input terminals and output terminals, an input circuit connected to said input terminals, said primary winding of said ignition coil being positioned in the output circuit of said semiconductor device, means operable by the internal combustion engine for periodically reducing current in the input circuit of said semiconductor device, a bistable electromagnetic switch, means positioned in the input circuit of said semiconductor device and coupled to said bistable electromagnetic switch for maintaining said bistable electromagnetic switch in one of its stable states by normal current flow through said input circuit of said semiconductor device when said semiconductor device is in its conducting state, means coupled to said bistable electromagnetic switch and said source of electrical energy for switching said bistable electromagnetic switch from its one stable state to its other stable state when current in the input circuit of said semiconductor device is reduced, and means coupled to said bistable electromagnetic switch and said input circuit of said semiconductor device for causing a current to flow through said input circuit of said semiconductor device when said bistable electromagnetic switch is switched from its one stable state to its other stable state in a direction opposite to the direction of current through said input circuit when said semiconductor device is in a conducting state.

7. An ignition system for an internal combustion engine comprising a source of electrical energy, an ignition coil including a primary and a secondary winding, a semiconductor device including an output circuit and an input circuit, said output circuit of said semiconductor device connected in circuit with said source of electrical energy and said primary winding of said ignition coil for controlling the energization of said ignition coil, an electrical ignition means, said electrical ignition means connected in circuit with said secondary winding, a bistable electromagnetic switch electrically coupled to said input circuit of said semiconductor device, means adapted to be operated by the internal combustion engine and coupled to the input circuit of said semiconductor device for periodically switching said semiconductor device to its nonconducting state, and circuit means coupled to said bistable electromagnetic switch and said last mentioned means for switching said bistable electromagnetic switch from one of its stable states to the other of its stable states as said semiconductor device is switched to its nonconducting state, and means coupled to said bistable elec-

tromagnetic switch and the input circuit of said semiconductor device for driving a current through said input circuit of said semiconductor device as said semiconductor device is switched to its nonconducting state in a direction opposite to the current flow through said input circuit when said semiconductor device is in a conducting state.

8. An ignition system for an internal combustion engine comprising, a source of electrical energy, an ignition coil including a primary and a secondary winding, a semiconductor device including an output circuit and an input circuit, said output circuit of said semiconductor device connected in circuit with said source of electrical energy and said primary winding of said ignition coil for controlling the energization of said ignition coil, an electrical ignition means, said electrical ignition means connected in circuit with said secondary winding, a bistable electromagnetic switch electrically coupled to said input circuit of said semiconductor device, means adapted to be operated by the internal combustion engine and coupled to the input circuit of said semiconductor device for periodically reducing current flow in the input circuit of said semiconductor device, circuit means coupled to said bistable electromagnetic switch and said last mentioned means for switching said bistable electromagnetic switch from one of its stable states to the other of its stable states as the current flow in said input circuit of said semiconductor device is reduced, and means coupled to said bistable electromagnetic switch and the input circuit of said semiconductor device for driving a current through said input circuit of said semiconductor device as said bistable electromagnetic switch is switched from said one stable state to said other stable state in a direction opposite to the current flow through said input circuit when said semiconductor device is in a conducting state whereby said semiconductor device is brought rapidly to its nonconducting state.

9. An ignition system for an internal combustion engine comprising, a source of electrical energy, an ignition coil including a primary and a secondary winding, a semiconductor device including an output circuit and an input circuit, said output circuit of said semiconductor device connected in circuit with said source of electrical energy and said primary winding of said ignition coil for controlling the energization of said ignition coil, an electrical ignition means, said electrical ignition means connected in circuit with said secondary winding, means connecting said input circuit of said semiconductor device with said source of electrical energy for causing said semiconductor device to conduct, means connected in circuit with said input circuit of said semiconductor device for reducing current flow in the input circuit of said semiconductor device, a ferromagnetic core, means connected in circuit with said semiconductor device and said source of electrical energy for switching said ferromagnetic core from one direction of magnetization to the other direction of magnetization in response to the reduction of current flow in said input circuit of said semiconductor device, an output winding wound on said ferromagnetic core and connected to the input circuit of said semiconductor device, said output winding being wound upon said ferromagnetic core in a direction to cause current flow through said input circuit of said semiconductor device in a direction opposite to current flow through said input circuit when said semiconductor device is in a conducting state whereby said semiconductor device is brought rapidly to a nonconducting state.

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