United States Patent [19]

Myers

[11] **3,709,206**

[45] **Jan. 9, 1973**

[54] **REGULATED IGNITION SYSTEM**

[75] Inventor: **Richard Stanley Myers**, Branchburg, N.J.

[73] Assignee: **RCA Corporation**

[22] Filed: **July 8, 1971**

[21] Appl. No.: **160,808**

[52] **U.S. Cl.** ....**123/148 E,** 315/209 T

[51] **Int. Cl.** **F02p 3/02**

[58] **Field of Search**.................123/148 E; 315/209 T

[56] **References Cited**

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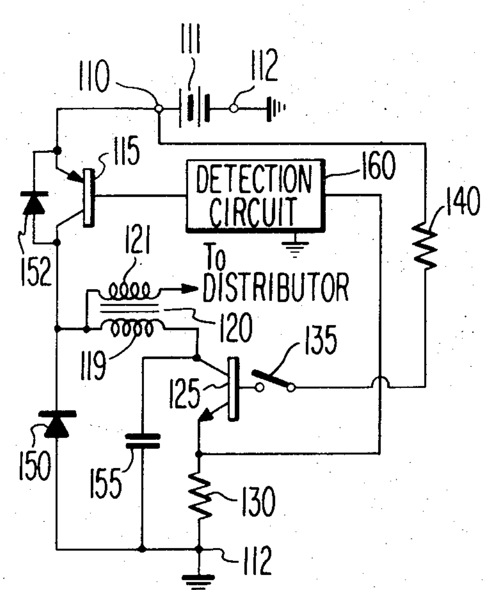
Primary Examiner—Laurence M. Goodridge
Assistant Examiner—Cort Flint
Attorney—Edward J. Norton

[57] **ABSTRACT**

Disclosed is an ignition system for an internal combustion engine wherein a regulating transistor regulates the energy stored in the primary winding of an ignition coil. A spark control transistor is responsive to the operation of the engine to cause the energy stored in the primary winding to induce a high voltage in the secondary winding of the coil which in turn is used to provide a high energy spark to the spark plugs via the distributor.

11 Claims, 5 Drawing Figures



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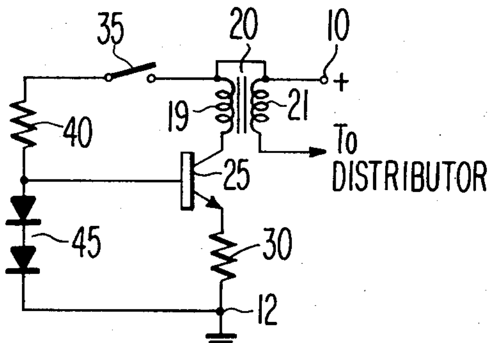


(PRIOR ART)

Fig. 1a.

Fig. 1b.

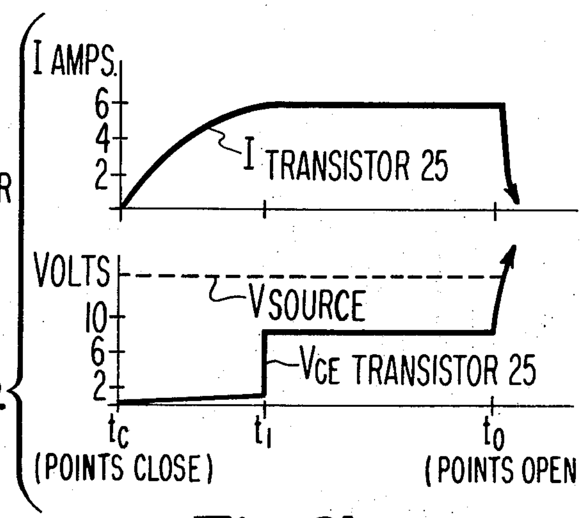


Fig. 2b.

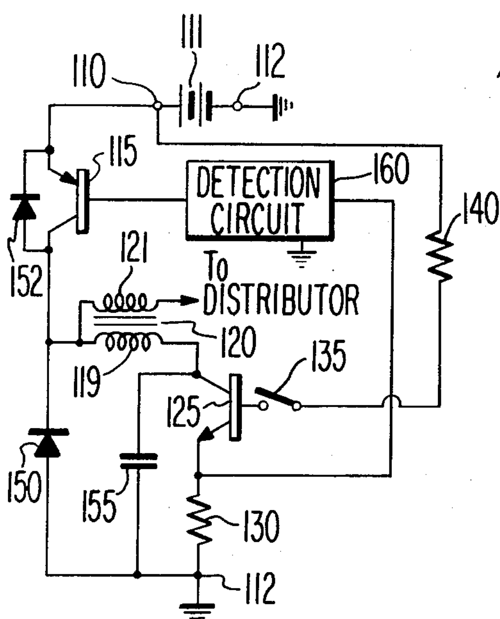


Fig. 2a.

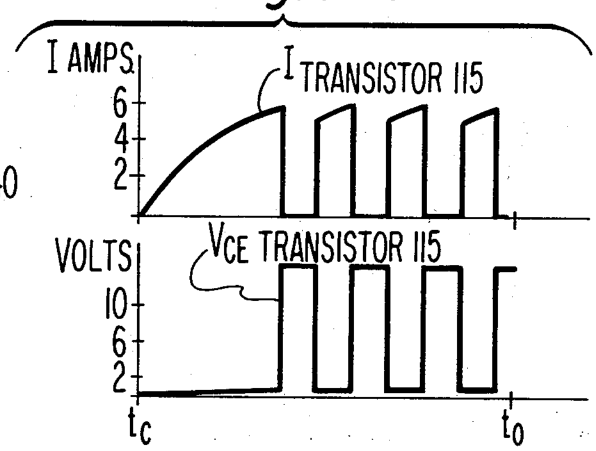
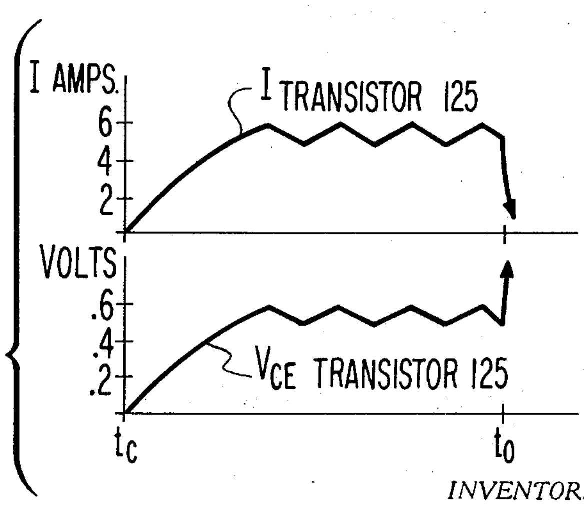


Fig. 2c.



INVENTOR.
Richard S. Myers
BY Herbert L. Jacobson
ATTORNEY

REGULATED IGNITION SYSTEM

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

In conventional transistorized ignition circuits the collector-to-emitter path of a switching transistor is placed in series with a ballast resistor and the primary winding of a coil across a direct current source such as a battery. A set of ignition points, which open and close in timed relationship with the engine operation, is used to provide base current to the switching transistor. When the points are closed the transistor is switched into conduction and the primary winding is charged with energy as a function of the current flowing in the series circuit; such current being a function of the impedance of the circuit and the battery voltage. When the points open the transistor is switched off and the energy stored in the primary winding induces a high voltage in the secondary winding of the coil which provides the necessary spark to the spark plugs via the distributor. During engine startup, when it is particularly desirable to obtain a high energy spark for the coil, the voltage output of the battery is greatly reduced due to the current drawn by the starting motor and other accessories. In addition, the condition of the battery and/or the temperature of the ambient are further factors which may reduce the available voltage during startup. To compensate for the reduced battery voltage, the ballast resistor is generally shorted out during startup to maximize current through the primary winding. During normal running operation (and more important during stall conditions where the points remain closed), when the battery voltage is substantially greater than during startup, i.e., in the order of 12 volts, the ballast resistor is required in the circuit to limit the current through the series circuit. Although such systems have been used with apparent success, this approach has several limitations: viz., the ballast resistor dissipates a significant amount of power during normal operation and, as a result, its power rating causes it to be expensive; it does not provide more than a two position adjustment of the circuit resistance and cannot compensate for the entire range of battery voltages experienced; it provides good starting characteristics at the expense of high speed engine performance; and it subjects the switching transistor to higher than necessary currents if the starter sticks or if higher voltage than normal booster batteries are used for cold engine starting.

The desirability of providing an ignition circuit wherein the ballast resistor is eliminated was early recognized. One such circuit is disclosed in U.S. Pat. No. 3,340,861, assigned to the same assignee as this application, wherein a switching transistor in series with the primary winding of an ignition coil is initially operated at saturation to initiate current therethrough, which current thereafter is limited to a desired level regardless of battery voltage and independent of the time the ignition points are closed and the transistor is conducting. Although this circuit has proven technically successful the nature of its operation, which will be discussed in more detail infra, can involve the use of an expensive high power transistor.

A regulated ignition for an internal combustion engine, in accordance with the present invention, comprises an ignition coil having a primary winding and a secondary winding; a regulating transistor and a spark control transistor each having emitter, collector and base electrodes; a pair of terminals adapted for connection to a direct current source; means connecting said primary winding and the emitter-to-collector paths of said transistors in series circuit between said terminals; means responsive to the energy stored in said primary winding for switching said regulating transistor into conduction when said energy falls below a predetermined level; means for switching said spark control transistor into conduction in timed relationship with the operation of said engine; and means for preventing the energy stored in said primary winding from inducing a voltage in said secondary winding of sufficient magnitude to provide an ignition spark when said spark control transistor is conducting and said regulating transistor is off.

The present invention will be more readily understood upon reading the present specification in conjunction with the accompanying drawing wherein:

FIG. **1***a* is a circuit diagram of a transistorized ignition system without a ballast resistor in accordance with the prior art;

FIG. **1***b* is a graphical representation of the current and voltage conditions within the circuit represented in FIG. **1***a;*

FIG. **2***a* is a circuit diagram of a transistorized ignition system without a ballast resistor in accordance with the present invention; and

FIGS. **2***b* and **2***c* are graphical representations of the current and voltage conditions within the circuit represented in FIG. **2***b*.

With reference to FIG. **1***a*, the positive terminal **10** of a direct current source (not shown) is connected through the primary winding **19** of an ignition coil **20**, the collector-to-emitter path of an NPN transistor **25**, and a small emitter resistor **30**, to the negative terminal **12** of the dc source. One terminal of the secondary winding **21** of the coil **20** is connected to terminal **10** and the remaining terminal of the secondary winding **21** is connected to the distributor. Terminal **10** is further connected through a set of ignition points **35** and a resistor **40** to the base of transistor **25**. A pair of diodes **45** are connected in series between the base of transistor **25** and terminal **12**; the diodes **45** being poled to conduct current in the same direction, with respect to terminal **12**, as the collector-to-emitter path of transistor **25**.

In operation, when the points **35** are open no base current is provided to transistor **25** and the transistor is in its non-conducting state. When the points close the transistor **25** initially goes into saturation (i.e. the voltage across the collector-to-emitter path of transistor **25** is less than 1 volt) and current begins to flow in the series circuit comprising primary winding **19**, transistor **25** and resistor **30**, as shown in FIG. **1***b*. It will be seen that the maximum current through transistor **25** is limited by the voltage across its base and emitter electrodes which in turn is determined by the voltage drop across diodes **45** less the voltage drop across resistor **30**. As the current through the series circuit increases the voltage drop across resistor **30** increases thereby serving to limit the current through the transistor **25** and consequently through the primary winding **19** of the coil **20**. When this occurs (i.e. at time t_1 in FIG. 1*b*) transistor **25** comes out of saturation and operates in the active region causing the voltage drop across its collector-to-emitter path to increase significantly (i.e. in the order of 8 volts). A typical circuit as shown in FIG. 1*a*, when designed for use in an automobile, would draw a primary winding current of approximately 6 amps at a normal battery operating voltage of 14 volts. Since the resistance of the emitter resistor **30** is negligible relative to the internal resistance of the primary winding **19**, transistor **25** will carry approximately 6 amps with a collector-to-emitter voltage of approximately 8 volts. Assuming an average dwell rate of 66 percent (i.e. dwell rate equals the percentage of the interval between sparks when the points are closed) transistor **25** would have to dissipate an average of 32 watts. In the event of engine stall (i.e. dwell equal to 100 percent) dissipation could be in the order of 50 watts if the engine were to stall with the points closed.

Turning now to a description of the circuit shown in FIG. 2*a*, the positive terminal **110** of a direct current source, such as an automobile battery **111**, is connected through the emitter-to-collector path of a PNP transistor **115**, the primary winding **119** of an ignition coil **120**, the collector-to-emitter path of an NPN transistor **125**, and a small emitter resistor **130**, to the negative terminal **112** of the dc source **111**. One terminal of the secondary winding **121** of coil **120** is connected to the collector of transistor **115** and the remaining terminal of the secondary winding **121** is connected to the distributor. A set of ignition points **135**, which open and close in timed relationship with the operation of the engine, are connected in series with a resistor **140** between the base of transistor **125** and terminal **110** of dc source **111**. It will be seen that the negative terminal **112** of dc source **111** has been referenced to ground potential as is usually the case in practice. A first diode **150** is connected in series with primary winding **119**, the collector-to-emitter path of transistor **125** and resistor **130**; diode **150** is poled so that a current loop is formed by the series circuit comprising diode **150**, winding **119**, transistor **125** and resistor **130**. A second diode **152** is connected between the emitter and collector electrodes of transistor **115**; diode **152** being poled to conduct current in a direction opposite to the conduction path of said transistor. It will be seen that diodes **150** and **152** provide conduction paths of opposite polarity relative to the primary winding **119** of coil **120**. A tuning condenser **155** is shown connected between the collector of transistor **125** and terminal **112**. Condenser **155** together with winding **119** form a tuned circuit which limits the voltage across transistor **125** when ignition points **135** are opened. It will be understood that the tuning condenser **155** may be located in a number of places other than as shown. For example, it could be placed directly across winding **119**. A threshold detection circuit **160** is shown, in generalized form, connected between the base of transistor **115** and the emitter of transistor **125**. The detection circuit **160** provides base current to transistor **115** whenever the voltage across resistor **130** falls below a first value with respect to ground and may be of any standard design. For example, detection circuit **160** may comprise a Schmitt trigger coupled to an amplifying stage which serves to amplify the output signal of the Schmitt trigger before applying it to the base of transistor **115**. When the potential across resistor **130** rises above a second value with respect to ground the detection circuit **160** provides no base current to transistor **115**.

Referring now to the operation of the circuit shown in FIG. 2*a*, with the ignition points **135** closed, base current is provided to transistor **125**. Since no current is flowing initially in the circuit, the potential across resistor **130** is zero and base current is also provided to transistor **115** via detection circuit **160**. Accordingly, both transistors are switched into saturation and current begins to flow through the series circuit comprising dc source **111**, transistor **115**, winding **119**, transistor **125** and resistor **130** as a function of the time constant of the circuit. It should be kept in mind that the time constant of the series circuit is determined primarily by the impedance of primary winding **119**, since the combined resistance of transistor **115**, transistor **125**, and resistor **130** are negligible relative to the internal resistance of winding **119**.

As the current through the coil builds up the potential across resistor **130** increases and, when it attains a predetermined level, the detection circuit **160** responds by cutting off the supply of base current to transistor **115** causing it to turn off. With transistor **115** off and transistor **125** on (i.e. the ignition points **135** still closed) the energy stored in the primary winding **119** sustains current flow through the series circuit including winding **119**, transistor **125**, resistor **130** and diode **150**. As the energy stored in the coil is dissipated due to the lossy nature of the circuit, the current decreases resulting in a decrease in the potential across resistor **130**. When the current decreases sufficiently, the drop in potential across resistor **130** is detected by detection circuit **160** which responds by providing base current to transistor **115** causing it to turn on and recharge the coil to its desired energy level. Accordingly, it will be seen that transistor **115** serves to regulate the energy stored in the primary winding **119** of the ignition coil **120**, within desired limits, when the ignition points **135** are closed. The presence of diode **150**, which completes the current loop including winding **119**, transistor **125** and resistor **130**, provides a relatively low impedance path for the current to circulate thereby preventing the energy stored in winding **119** from inducing a voltage in winding **121** sufficient to provide an ignition spark. It should also be noted that when transistor **115** is not conducting, the coil **120** is effectively disconnected from the dc source **110**.

When the ignition points **135** open base current is removed from transistor **125** causing it to turn off at which point the energy stored in winding **119** induces a high voltage in secondary winding **121** which in turn provides the necessary ignition spark to the spark plugs via the distributor. Accordingly, it will be seen that whereas transistor **115** operates as a regulating transistor, transistor **125** operates as a spark control transistor.

Bearing the foregoing description in mind, reference is made to FIGS. 2*b* and 2*c* which graphically represent the current and voltage conditions of regulating transistor **115** and spark control transistor **125**, respectively.

Referring first to FIG. 2*b*, it will be seen that when the points close (i.e. at time equal t_c) the current through transistor **115** rises as a function of the time constant of the circuit to a level of approximately 6 amperes. During this time the transistor is in saturation and the voltage drop across its emitter-to-collector path is very small (i.e. in the order 0.6 volts). When the current attains 6 amps the voltage across resistor **130** causes detection circuit **160** to discontinue the supply of base current to transistor **115** causing it to turn off. When transistor **115** turns off its emitter-to-collector voltage rises to a level equal to the battery voltage plus the forward bias voltage across diode **150** (i.e. approximately 14.7 volts) and the current flowing through it drops to zero. When the current circulating through the series circuit comprising winding **119**, transistor **125**, resistor **130** and diode **150** drops to approximately 5 amperes, transistor **115** is again switched into saturation causing its emitter-to-collector voltage to once again become approximately 0.6 volts. This action is repeated until such time as the points open (i.e. at time equal t_o). It will be seen that the maximum power dissipated by regulating transistor **115** is approximately 3.6 watts (i.e. 6 amps × 0.6 volts). The actual average power dissipated is considerably less, however, due to the dwell rate and the factor that the average current and average voltage are actually less than the peak values.

Referring now to FIG. 2*c*, it will be seen that when the ignition points close (t_c) the current through transistor **125** also begins to rise to a level of approximately 6 amperes. When transistor **115** turns off however, transistor **125** remains in saturations although the current flowing through it begins to drop toward 5 amps. During this time the voltage across its collector-to-emitter terminals varies from 0.6–0.5 volts. When the current through resistor **130** drops to approximately 5 amperes detection circuit **160** causes transistor **115** to turn on and the current through transistor **125** climbs again toward 6 amperes. Since the current through transistor **125** is the same as the current through the primary winding of the ignition coil it will be seen that the current through the coil (and consequently the energy stored in the coil) is regulated (after an initial charging period) between 5 and 6 amperes. Moreover, it will be seen that the maximum power dissipated by spark control transistor **125** is also approximately 3.6 watts.

Accordingly, there has been disclosed a regulated ignition system for an internal combustion engine which provides the required spark voltage at both low and high battery voltages without necessitating the use of high power consuming components as required by the prior art.

What is claimed is:

1. A regulated ignition system for an internal combustion engine of the type having an ignition coil having a primary winding and a secondary winding, comprising

a regulating transistor and a spark control transistor each having emitter, collector and base electrodes;

a pair of terminals adapted for connection to a direct current source;

means connecting said primary winding and the emitter-to-collector paths of said transistors in series circuit between said terminals;

means responsive to the energy stored in said primary winding for switching said regulating transistor into conduction when said energy falls below a predetermined level;

means for switching said spark control transistor into conduction in timed relationship with the operation of said engine; and

means for preventing the energy stored in said primary winding from inducing a voltage in said secondary winding of sufficient magnitude to provide an ignition spark when said spark control transistor is conducting and said regulating transistor is off.

2. The invention as defined in claim **1** wherein said means for switching said regulating transistor comprises a threshold detection circuit coupled between the base of said regulating transistor and a point in said series circuit, the potential at said point with respect to a point of reference potential being indicative of the energy stored in said primary winding, said detection circuit providing base current to switch said regulating transistor into conduction when the potential at said point drops below a predetermined value.

3. The invention as defined in claim **2** wherein said detection circuit further responds to the potential at said point to switch said regulating transistor off when the potential at said point rises above a second predetermined value.

4. The invention as defined in claim **1** wherein said means for preventing said primary winding from inducing a voltage in said secondary winding of sufficient magnitude to provide an ignition spark when said spark control transistor is conducting and said regulating transistor is off comprises a diode connected in series with said primary winding and the emitter-to-collector path of said spark control transistor, said diode poled to conduct current in the same direction as said emitter-to-collector path of said spark control transistor within the series circuit comprising said spark control transistor, said diode and said primary winding.

5. The invention as defined in claim **1** further comprising a tuning condenser connected in circuit with said primary winding to limit the voltage across said spark control transistor when said spark control transistor is in a non-conducting state.

6. A regulated ignition system for an internal combustion engine comprising:

an ignition coil having a primary winding and a secondary winding;

a regulating transistor of a first conductivity type having emitter, collector and base electrodes;

a spark control transistor of opposite conductivity type having emitter, collector and base electrodes;

a direct current source;

means connecting said direct current source, said regulating transistor, said primary winding and said spark control transistor in series circuit in the order named,

means for switching said regulating transistor into a conducting state when the current flowing through said primary winding is below a first value and for switching said regulating transistor into a non-conducting state when said current is above a second value,

whereby said direct current source is effectively disconnected from said primary winding when said regulating transistor is in said nonconducting state;

means for switching said spark control transistor into conduction in timed relationship with the operation of said engine; and

means for preventing said primary winding from inducing a voltage in said secondary winding of sufficient magnitude to provide an ignition spark when said spark control transistor is conducting and said regulating transistor is not conducting.

7. The invention as defined in claim **6** wherein said prevention means comprises a diode connected in series with said primary winding and the emitter-to-collector path of said spark control transistor, said diode poled to conduct current in the same direction as said emitter-to-collector path of said spark control transistor within the series circuit comprising said spark control transistor, said diode and said primary winding.

8. The invention as defined in claim **7** wherein said regulating transistor is a PNP transistor and said spark control transistor is an NPN transistor, said primary winding being connected between the collectors of said transistors.

9. The invention as defined in claim **6** further comprising a sensing resistor connected in said series circuit, said regulating transistor switching means being responsive to the voltage across said resistor.

10. The invention as defined in claim **6** wherein said means for switching said spark control transistor into conduction comprises a set of ignition points which provide base current to said spark control transistor in timed relationship with the operation of said engine.

11. The invention as defined in claim **10** further comprising a tuning condenser connected in circuit with said primary winding to limit the voltage across said spark control transistor when said ignition points are open.

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Disclaimer

3,709,206.—*Richard Stanley Myers*, Branchburg, N.J. REGULATED IGNITION SYSTEM. Patent dated Jan. 9, 1973. Disclaimer filed Jan. 10, 1977, by the assignee, *RCA Corporation*.

Hereby enters this disclaimer to all claims of said patent.

[*Official Gazette September 30, 1980.*]