United States Patent

[11] **3,629,598**

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[21] Appl. No. **71,714**
[22] Filed **Sept. 14, 1970**
[45] Patented **Dec. 21, 1971**
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[54] **ELECTRIC STARTING MOTOR LOCK-OUT SYSTEM**
10 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** .... **290/38 R,** 290/DIG. 4
[51] **Int. Cl.** **F02n 11/14**
[50] **Field of Search** .... 290/38 R, 38 C, DIG. 1, DIG. 4, 36, 37

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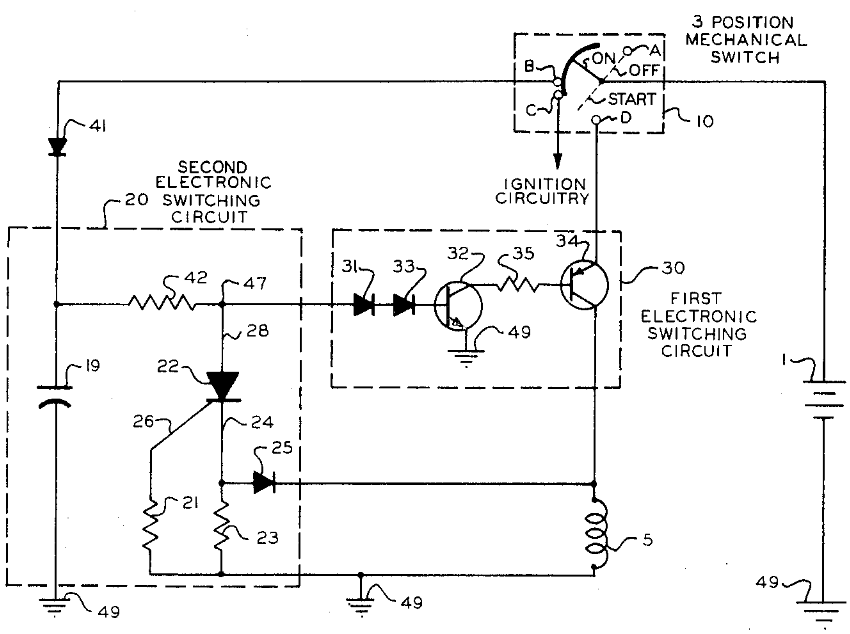
ABSTRACT: An electrical starting system for an internal combustion engine that includes solid-state control devices that are responsive to the voltage produced by the collapsing field of a starter solenoid when the starter is deenergized to prevent the reenergization of the starter solenoid until a manually operated ignition switch is moved to the off position for a predetermined time.



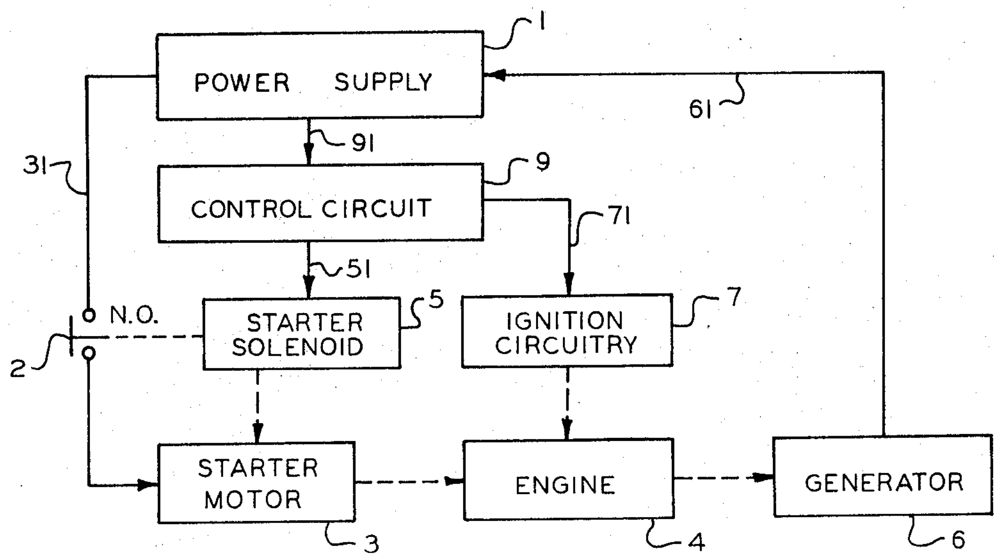


FIG. 1

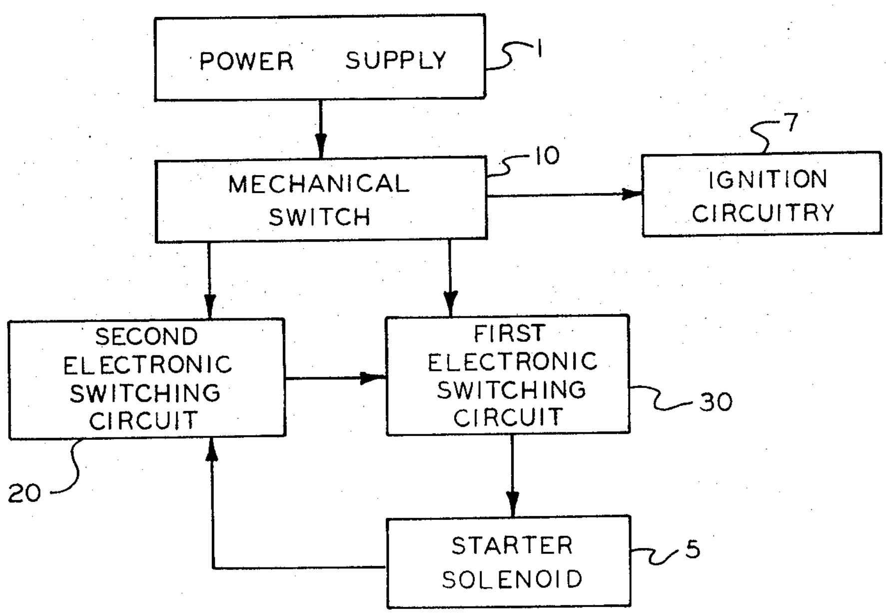


FIG. 2

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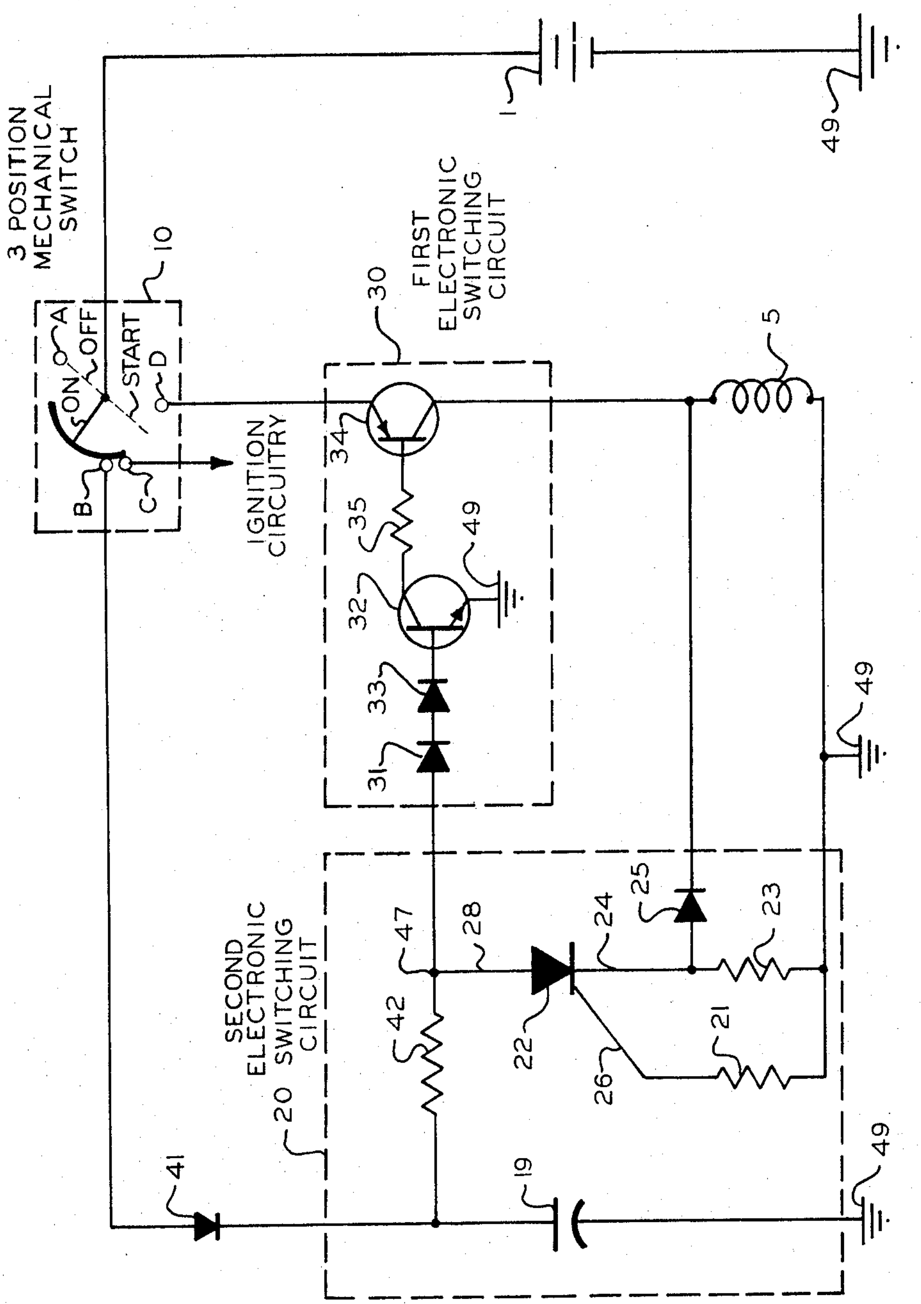

FIG. 3

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ELECTRIC STARTING MOTOR LOCK-OUT SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to an electric starting system for cranking an internal combustion engine of the type having a battery; a starter motor; a starter solenoid; and an ignition switch for connecting the battery to the starter solenoid, which when energized, couples the starter motor to the engine and connects the battery to the starter motor to crank the engine. The invention is particularly related to an improved electric starting system that prevents the starter motor from being energized when the engine or prime mover of a vehicle is in operation and/or when an unsuccessful attempt to start the engine has been made.

It has been a long standing problem to prevent the coupling of an electric starter motor to an internal combustion engine when only one of the aforementioned devices is operating so as to protect the engine, starter motor, and/or associated gears from damage. For instance, if the starter motor is operated while the engine is operating, elements of the starter assembly, and particularly the gears, may be damaged. Further, even if the engine is not operating and the electric motor is not coupled to the engine, damage could result to the motor, engine and/or gears if an attempt is made to restart the starter motor (and engage gears) while the starter motor is still rotating from a previous start attempt.

Up to the present time, starter system designs were directed at preventing the operation of the starter system while the engine was operating and were not directed to the restart problem. This is evidenced by prior art reliance upon control signals associated with the engine, e.g., oil pressure, generator output, and/or engine rotation. Therefore, prior art starter systems did not prevent energization of the starter under all undesirable operating conditions, nor did prior art control signals rely upon the electrical parameters of the solenoid which is the key electromechanical link in a starter control system.

SUMMARY OF THE INVENTION

To prevent energization of the starter motor under all undesirable conditions, especially under restart conditions, an electronic switching circuit capable of remembering an attempt to start the engine is used in combination with a manually operated ignition switch.

The electrical starting system is characterized by the fact that it remembers that the solenoid has been energized by sensing the voltage produced by the collapsing field of the starter solenoid when the starter solenoid is deenergized and prevents the reenergization of the starter solenoid until the ignition switch is moved to the off position for a predetermined time.

Accordingly, it is an object of this invention to prevent reenergization of the starter motor for internal combustion engines until the ignition switch is placed in the off position for a predetermined time.

Another object of this invention is to provide an electrical system for a motor vehicle which is operative to prevent actuation of the electrical cranking motor when the engine is running.

It is another object of this invention to provide an improved electric starting system for cranking an internal combustion engine.

It is a further object of this invention to provide an electric starting system with electronic switching circuitry that prevents the flow of current from a battery to an electric starting motor in response to a voltage produced by the collapsing field of a starter solenoid when the starter solenoid is deenergized.

It is still a further object of this invention to provide an electronic switching circuit that relies upon the voltage produced by the collapsing field of a coil for its control signal.

It is a still further object of this invention to provide a starter lockout system which is responsive to the starter electrical system components only and not with engine accessories or components.

The above and other objects and features of the invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings and claims which form a part of this specification.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of an internal combustion-engine-starting system.

FIG. 2 is a block diagram of an electrical control circuit for an internal combustion engine electric starting system.

FIG. 3 is a schematic diagram of a preferred embodiment of the control circuitry for an internal combustion engine electric starting system.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, FIG. 1 illustrates a system block diagram for an internal combustion engine electric starting system which utilizes the principles of the invention. The solid lines between blocks represent electrical interconnections while dotted lines represent mechanical interconnections and/or relationships between blocks. A power supply **1** supplies power to the starter solenoid **5** and ignition circuitry **7** through control circuit **9** and supplies power to the starter motor **3** through switch **2** which is operated by the starter solenoid **5**. The starter solenoid **5** also is operable to mechanically couple the starter motor **3** to the internal combustion engine **4** so that when electrical power is supplied to the starter motor **3** the engine is cranked. Once the engine is running it supplies sufficient power to operate a generator **6** which supplies energy to the power supply **1**. Generally, the power supply **1** is a battery which is recharged by the generator **6**.

FIG. 2 shows in greater detail the electrical block diagram for the engine-starting system. The power supply **1** is linked to the ignition circuitry **7** and starter solenoid **5** through a mechanical switch **10**. The mechanical switch **10** supplies power to a first electronic switching circuit **30** and a second electronic switching circuit **20**. The first electronic switching circuit **30** has an ON and OFF state which is controlled by the second electronic switching circuit **20** and the positioning of the mechanical switch **10**. When the first electronic switching circuit **30** is in the ON state, the starter solenoid **5** is energized. The second electronic switching circuit **20** has an ON and OFF state which is controlled by the deenergizing of the solenoid **5** and the positioning of the mechanical switch **10**. When the second electronic switching circuit **20** is ON the first electronic switching circuit **30** is OFF and when the second electronic switching circuit **20** is OFF the first electronic switching circuit **30** is ON. Therefore, if the second electronic switching circuit **20** is ON, the starter solenoid cannot be energized.

FIG. 3 illustrates how the first electronic switching circuit **30** and second electronic switching circuit **20** are energized, deenergized and reenergized in conjunction with the mechanical switch **10** to provide the application of power to the solenoid **5** only at the proper time. The mechanical switch **10** is a typical three position ignition switch having circuit contacts A, B, C and D. The mechanical switch **10** is shown in the ON position which connects the battery **1** to terminals B and C. In the starter position (dotted lines), the mechanical switch **10** connects the battery **1** to terminals B, C and D, while in the OFF position (dotted lines) the mechanical switch disconnects power completely from terminals B, C and D.

Connected to terminal D is the first electronic switching circuit **30** which is comprised of a first transistor **34**; a resistor **35**; a second transistor **32**; and a first and second diode **31** and **33**. The first transistor is preferably a PNP type with its emitter connected to terminal D and collector connected to one end of the starter solenoid **5**. The second transistor **32** is preferably an NPN type with its emitter connected to common **49**, its base connected to one of the series connected diodes **31** and **33**, and its collector connected to the base of the first transistor **34** through a resistor **35**.

Connected to terminal B through a blocking diode **41** is the second electronic switching circuit **20** which is comprised of resistors **21**, **23**, **42**; a capacitor **19**; a diode **25**; and a silicon-controlled rectifier (SCR) **22**. The second electronic switching circuit is in circuit relationship with the mechanical switch **10**, the first electronic switching circuit **30** and the solenoid **5**. The SCR **22** has its cathode **24** connected to one end of the solenoid coil **5** through a diode **25** and connected to the other end of the solenoid **5** through a resistor **23** (preferably 10 ohms). The gate **26** of the silicon-controlled rectifier **22** is also connected to the other end of the solenoid coil **5** through a resistor **21** which has a resistance at least 10 times as large as the resistance of resistor **23**. Capacitor **19** is connected to terminal B of the mechanical switch **10** through diode **41** which is arranged to block current from flowing back into the mechanical switch **10** upon discharge of the capacitor **19**. Resistor **42** is a current-limiting resistor sized to control the time required for capacitor **19** to discharge to ground **49** through SCR **22**. Preferably resistor **42** is at least about 100 times greater than resistor **23**.

Connected to terminal C is the ignition circuitry which is not shown.

OPERATION

Referring now to the drawings and more specifically to FIG. 3, the starter lockout control circuit operates as follows.

MECHANICAL SWITCH INITIALLY "ON"

Power is applied to terminals B and C.

A transient current charges capacitor **19** to the potential of battery **1** while a steady state current is established through the resistor **42**, the diodes **31**, **33**, and the base-emitter junction of transistor **32** to ground **49**. This establishes a voltage of about 2.0 volts from junction **47** to ground **49**.

SCR **22** OFF. No current flows through the SCR **22** because the voltage across the SCR **22** (anode **28** to cathode **24**) is less than the forward breakover voltage required to turn the SCR ON. The voltage at junction **47** to ground being approximately 2.0 volts. Therefore, no current flows through the SCR **22**, the resistors **21**, **23**, the diode **25**, or the solenoid **5** to ground **49**.

Transistor switch **32** in ON and transistor switch **34** is OFF because there is no battery power at terminal D. No current flows through the emitter-collector circuit of transistor **32**, the resistor **35**, the transistor **34**, or the solenoid **5**.

MECHANICAL SWITCH MOVED TO "START" POSITION

Power is applied to terminals B, C and D.

SCR **22** remains in the "OFF" state because the necessary forward breakover voltage required to turn the SCR "ON" is not present.

Transistor switch **32** is ON and transistor switch **34** is ON. The power applied to terminal D forward biases the emitter-base junction of transistor **34** thereby permitting transistor **34** to operate in its normal switching mode. Since the transistor **32** is ON a current (I_b) flows in the base circuit of transistor switch **34**. This turns the transistor switch **34** ON and permits current to flow through the solenoid coil **5** thus engaging and energizing the starter motor **3**. A diode **25** prevents the collector current from transistor **34** from flowing through resistor **23** to ground **49**.

MECHANICAL SWITCH RETURNED TO "ON" POSITION

Power removed from terminal D.

SCR **22** turned ON. The transient voltage produced by the collapsing field of the coil **5** when the power is abruptly removed causes a transient current to flow through resistor **23**, diode **25** and coil **5**. This transient current causes the cathode **24** of the SCR **22** to become more negative than the gate **26** creating a gate pulse which turns SCR **22** ON. (At anode-to-cathode voltages less than the breakover voltage, the SCR **22** can be switched ON by a small pulse, typically 1.5 volts and 30 milliampere, applied from gate **26** to cathode **24**.) Once the SCR **22** is turned on it continues to conduct until the anode current is interrupted or diverted by some external mans for about 20 microseconds.

Transistor switch **32** is OFF and transistor switch **34** is OFF. Since SCR **22** is ON the voltage drop from junction **47** to ground is 1.0 volts which is insufficient to forward bias the diodes **31**, **33** and turn transistor switch **32** ON. When transistor switch **32** is OFF no current can flow through the emitter-base junction of transistor switch **34**. Therefore, transistor switch **34** is OFF when transistor switch **32** is OFF.

MECHANICAL SWITCH RETURNED TO "START" POSITION

Transistor switch **32** and transistor switch **34** remain OFF.

SCR **22** remains ON. If the sequence of the mechanical switch **10** has been "ON"-"START"-"ON" returning the mechanical switch to the start position will not result in energization of the solenoid **5**. This is because transistor switch **34** is held in the OFF state by the conduction of SCR **22** which holds transistor **32** OFF preventing an emitter-base current from flowing through transistor switch **34** and turning transistor **32** ON.

MECHANICAL SWITCH TO "OFF" POSITION

Power is removed from terminals B, C and D.

SCR **22** remains ON until the discharge current from capacitor **19** through resistor **42** and SCR **22** just about decays to zero, whereupon SCR **22** is turned OFF. Therefore, capacitor **19** and resistor **42** are the predominant elements that determine how long the manual switch must remain in the OFF position before the SCR extinguishes automatically and the solenoid may be reenergized. Should the mechanical switch **10** be placed in the ON or START position before the SCR is turned OFF, the SCR will remain ON and prevent energization of the solenoid **5**. Preferably, the time the switch must remain in the OFF position is equal to or greater than the time required for the starter motor and/or gears to come to rest from a previous attempt to start the engine. Once the mechanical switch has been in the OFF position for the proper time interval, the starter solenoid can be reenergized and the engine cranked.

Having described the invention what is claimed is:

1. In combination with an electric starting system for cranking an internal combustion engine of the type having a battery; a starter motor; a starter solenoid; and a mechanical switch for connecting the battery in circuit relationship with the solenoid in a first position and disconnecting the battery from circuit relationship with said solenoid in a second position, said mechanical switch operating said starter solenoid which, when energized, couples the starter motor to the engine and connects the battery to the starter motor to crank the engine, wherein the improvement comprises
   switching means for preventing the flow of current to said solenoid in response to a voltage produced by the collapsing field of said solenoid when said solenoid is deenergized by the placing of said mechanical switch in said second position.

2. The combination as recited in claim **1** wherein said switching means comprises
   a first switching circuit having at least one transistor switch in circuit relationship with said mechanical switch, said battery, and said solenoid, said transistor having an ON state and on OFF state, said OFF state preventing the energization of said solenoid; and
   an SCR switching circuit in circuit relationship with said mechanical switch, said first switching circuit and said solenoid, said SCR having a cathode connected to one end of said solenoid through a diode and the other end of said solenoid through a resistor, and said SCR having a gate connected to said other end of said solenoid through

a resistor so that when said solenoid is deenergized and a transient voltage appears across said solenoid, said SCR conducts turning said transistor switch OFF whereby said solenoid cannot be energized.

3. The combination as recited in claim 1 wherein said switching means includes means for rendering said switching means conductive in response to movement of said mechanical switch into a third position.

4. The combination as recited in claim 2 wherein said switching means includes means for rendering said switching means conductive in response to movement of said mechanical switch into a third position.

5. In an electric starting system for cranking the engine of a motor vehicle, the combination comprising:

a storage battery;

an electric starting motor;

a solenoid for mechanically coupling said electric starting motor to said engine to crank said engine;

electronic switching means having semiconductors connected between said battery and said solenoid for controlling the energization of said solenoid;

a manually operable switch having an OFF, ON and START position; and

means for controlling the conduction of said semiconductors in response to the positioning of said manually operable switch and in response to a voltage produced by the collapsing field of said solenoid when the current to said solenoid is cut off.

6. An electric starting system for cranking an internal combustion engine which comprises:

a source of electric power;

an electric starting motor;

electromechanical means for mechanically coupling said electric starter motor to the engine, and for electrically connecting said electric power source to said electric starting motor to crank the engine, said electromechanical means including a solenoid;

switching means connected to said source of electric power, said switching means having a plurality of positions including a START position;

first circuit means for controlling the flow of current between said switching means and said solenoid, said first circuit means having an ON state which permits the passage of sufficient current to energize said electromechanical means and an OFF state preventing energization of said electromechanical means; and

second circuit means for controlling the state of said first circuit means, said second circuit means adapted to place said first circuit means in the OFF state in response to a voltage produced by the collapsing field of said solenoid when electric power is removed from said inductor, said second circuit means adapted to return said first circuit means to the ON state in response to the placing of said switching means in a preselected position for a predetermined time before returning said switching means to the START position whereby said electric starting motor cannot be energized until said mechanical switch is moved to a preselected position for a predetermined time.

7. An electric starting system as recited in claim 6 wherein said first circuit means for controlling the flow of current to said solenoid is a transistorized switch and said second circuit means for controlling the state of said transistorized switch is a silicon-controlled rectifier the cathode of which is in circuit relationship with said solenoid.

8. An electric starting system as recited in claim 6 wherein said second circuit means includes a resistance-capacitance network in circuit relationship with the anode of said silicon controlled rectifier and said mechanical switch.

9. An electric starting system as recited in claim 7 wherein said second circuit means includes a resistance-capacitance network in circuit relationship with the anode of said silicon-controlled rectifier and said mechanical switch.

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