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[54] **ELECTRONIC CONTROL APPARATUS**
7 Claims, 2 Drawing Figs.

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[51] **Int. Cl.** **F02p 3/00**
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ABSTRACT: An electronic control apparatus applicable to a number of different actuatable structures of the type requiring a predetermined voltage level or current flow wherein the apparatus utilizes a decoding means having a plurality of current-carrying elements which are arranged in a manner so as to require simultaneous actuation in order to provide a desired enabling voltage or current flow for the structure with which the apparatus is connected. The apparatus is especially adapted for use as a lock for a system having an ignition coil for energy transfer between the windings of the coil can be effected only if the elements of the decoding means are simultaneously actuated.

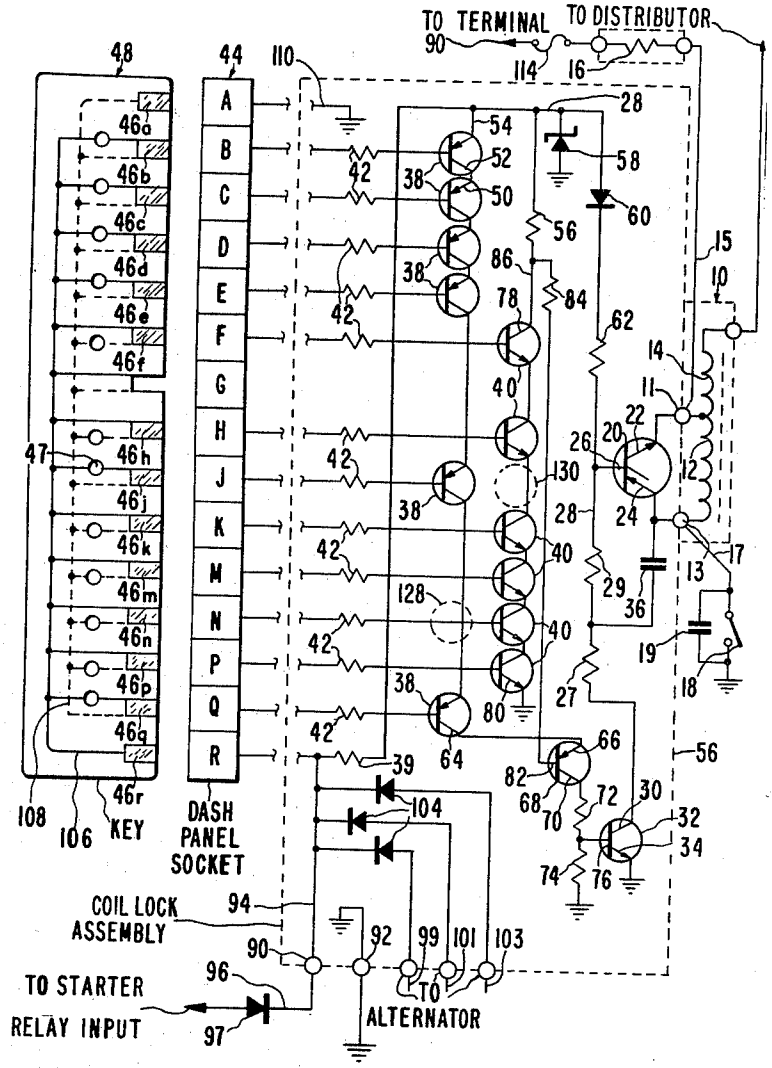
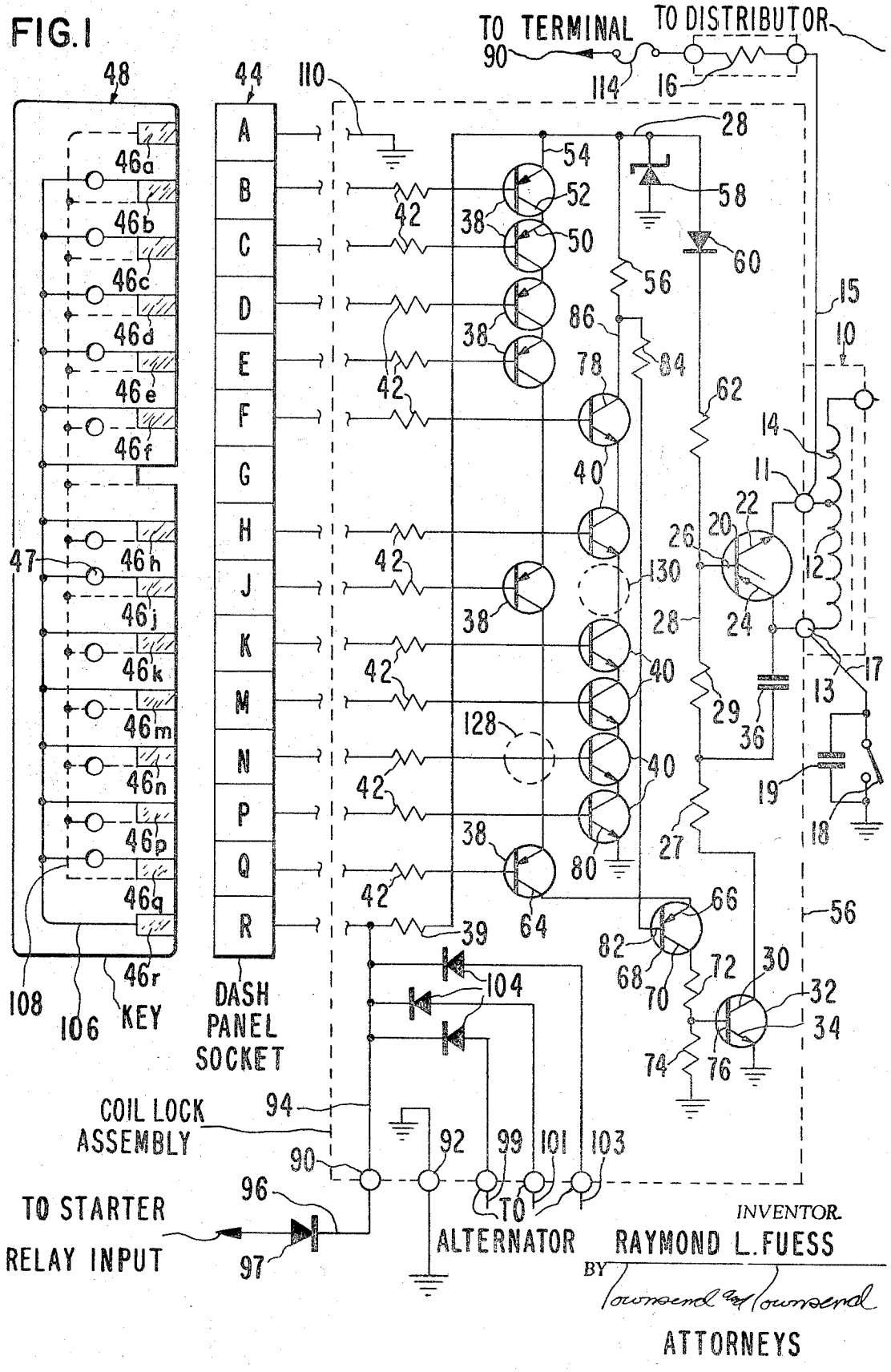


FIG. 1



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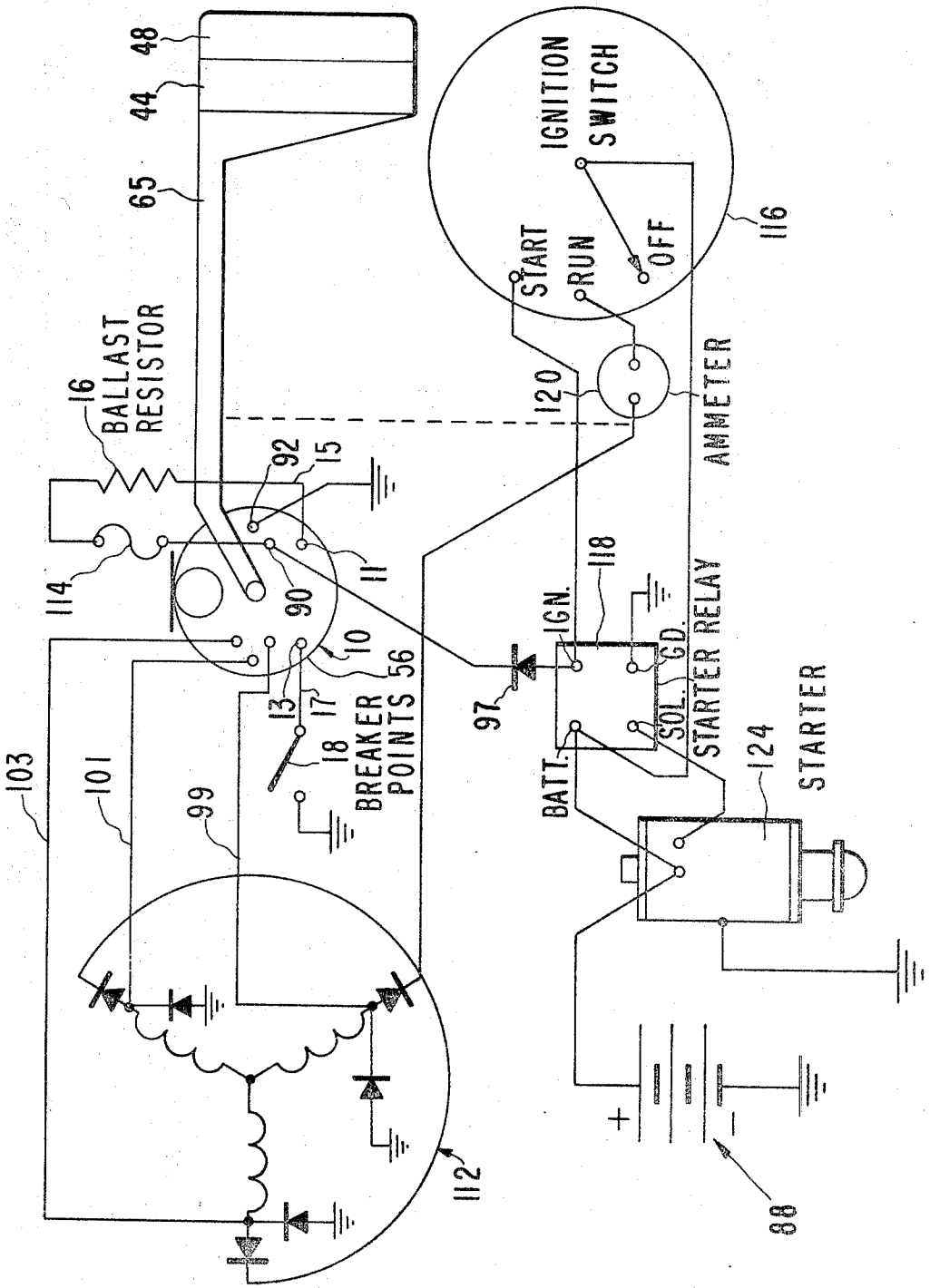


FIG. 2

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ELECTRONIC CONTROL APPARATUS

This invention relates to improvements in electronic control apparatus and, more particularly, to an electronic control apparatus utilizing direct current logic and being programmable in accordance with a preselected code.

While the present invention is suitable for a wide variety of different applications, it is especially suitable for use as an ignition lock for an internal combustion engine of a vehicle or the like. The advantages achieved by the use of the invention is that the lock can be constructed in accordance with a preselected code which is one of a relatively large number of codes from which an individual can choose. Thus, the teachings of the invention provide a structure which renders extremely difficult any theft of the property safeguarded by the apparatus when the latter is used as a lock.

Since the invention can be clearly understood when applied to the control of an ignition system, the following description, with reference to the accompanying drawings, will be made based upon an ignition system for a conventional ignition coil in combination with breaker points operated from the cam shaft of a vehicle or the like.

Among the advantages of the invention is that it may be operated by a key remote from the circuitry which provides the actuating or voltage current signals. The invention uses AND and NAND logic preferably and the key for operating the apparatus can only be duplicated by extensive trial and error so as to discourage any "would be"thief. If the invention is used with the ignition system of a vehicle, the key must be removed to stop the engine, thus providing a security measure not capable of being achieved with conventional ignition keys. Wiring cannot be rearranged or cut to defeat the purposes of the lock. An alternative power source cannot be utilized to operate the circuitry.

The primary object of this invention is, therefore, to provide an improved electronic control apparatus of simplified construction and capable of utilizing digital logic as well as providing useful voltage or current signals levels for use as enabling means for permitting the actuation of any one of a number of different actuatable power structures.

Another object of this invention is to provide apparatus of the type described wherein the apparatus has programmable decoding means and an actuating member or key selected from a relatively large number of constructions for actuating the decoding means to provide useful voltage and current signals, whereby the apparatus is suitable for use as an electronic lock capable of giving an "enable" or "disable" command.

A further object of this invention is to provide control apparatus of the type described wherein the apparatus is capable of controlling the energy transfer between the windings of an ignition or other impulse-operated coil so that the apparatus can provide an additional safeguard against vehicle thefts as well as to permit a simplified, programmed device for an ignition which discourages the keeping of the ignition key in the vehicle during periods of nonuse.

Other objects of this invention will become apparent as the following specification progresses.

In the drawings:

FIG. 1 is a schematic view of the apparatus when the same is used with an ignition coil or an ignition system; and

FIG. 2 is an electrical schematic of the ignition system showing the wiring between the various components of the system.

To illustrate the teachings of the present invention, the control apparatus forming the subject matter of this invention will be hereinafter described with respect to the control of an ignition system for an internal combustion engine wherein the ignition system for an internal combustion engine wherein the ignition system has an ignition coil **10** for generating a voltage and thereby an electrical current in the secondary winding **14** of the coil to create a spark for the various spark plugs of the engine according to the firing order of a distributor (not shown). The coil has a primary winding **12** inductively coupled with secondary winding **14**, the primary winding **12** being

in series with a ballast resistor **16** and a switch **18** defining the breaker points of the ignition system. Resistor **16** is connected to terminals **90** through fuse **114** and switch **18** is connected to the negative battery terminal as represented by the electrical ground symbol.

The improvement of this invention is directed to a means for controlling the flow of current in a particular circuit and thereby the voltage level at a particular location so that this voltage level can be used to enable or disable the current flow through a circuit element connected to primary winding **12** to thereby either permitting transfer of energy between the windings of the coil or dissipating this energy in the circuit element, i.e., no energy transfer between the coil windings. In particular, the invention will be described with respect to controlling the forward and reverse bias voltage on the gate **26** of a silicon controlled rectifier or SCR **20** whose anode **22** and cathode **24** are connected in parallel with primary winding **12** as shown in FIG. 1. Gate **26** is coupled by resistors **29** and **27** to the collector terminal **30** of an NPN transistor **32** whose emitter **34** is connected to ground. Resistors **27**, **29** and **62** are in series with each other and these resistors form a voltage divider for gate **26** to assure that the reverse bias voltage across the gate **26** and anode **22** is not above the specified maximum value for the SCR used when transistor **32** is conductive. Resistor **29** thus serves to limit the current to gate **26** of SCR **20**. A diode **60** is also in series with resistors **27**, **29** and **62** and serves to effectively disconnect gate **26** from power lead **28** when transistor **32** is nonconductive and when a capacitor **36** connected to one end of primary winding **12** receives an actuation pulse from primary winding **12**, capacitor **36** also being coupled to the junction of resistors **27** and **29**. As a secondary function, resistors **27**, **29** and **62** limit the current flow through transistor **32** when the latter is conductive.

As will hereinafter be set forth, gate **26** of SCR **20** will be reverse biased when transistor **32** is conducting to inhibit current flow through SCR **20**, whereby opening of switch **18** to cause the collapse of the magnetic field of the coil will cause a voltage to be induced into the secondary winding, resulting in a current flow therethrough and thereby a spark discharge at one of the spark plugs of the engine. On the other hand, if transistor **32** is nonconducting, gate **26** will be forward biased by the discharge of primary winding **12** through capacitor **36**. This forward bias will be great enough to permit SCR **20** to "fire" and conduct and thereby allows the energy stored in the coil to be dissipated, when switch **18** is opened, through the resistance of primary winding **12** and SCR **20** rather than being inductively transferred to the secondary winding.

When transistor **32** is nonconductive and as switch **18** closes, gate **26** of SCR **20** is, in essence, "floating" since diode **60** and collector **30** are open. If switch **18** is then opened, the voltage at terminal **13** of primary winding **12** rises rapidly from the initial voltage level of the positive terminal of the battery until the charging current through capacitor **36**, resistor **29**, gate **26**, anode **22** and the other terminal **11** of primary winding **12** causes SCR **20** to "fire." When this occurs, the voltage at terminal **13** immediately swings back to a positive voltage somewhat higher than that of the positive terminal of the battery and capacitor **36** discharges at a rate determined by resistor **29**. Primary winding **12** then discharges its energy, at a rate determined by its resistance, through SCR **20** until the current flow decays to less than a specified "holding value" at which time SCR **20** returns to its normal "open" state. The time constant represented by the parameters of resistor **29** and capacitor **36** is very much less than the R/L time constant of primary winding **12** so that there is no forward bias voltage on gate **26** when the current through SCR **20** decays to the aforesaid "holding value."

The control means for controlling the bias voltage on the base of transistor **32** includes a first bank of PNP transistors **38** and a second bank of NPN transistors **40**, each of these transistors having a current-limiting resistor **42** connected to the base terminal thereof. The resistors are in parallel with each other and are connected to respective terminals of a key-

receiving connector broadly denoted by the numeral 44 and having terminals denoted by A through R. These terminals are adapted to make electrical contact with respect to certain terminals 46 on a key 48 capable of being inserted into connector 44, the function of which is to actuate the control means, when properly constructed, so as to cause transistor 32 to be conducting and thereby allow an induced voltage in secondary winding 14 each time switch 18 is opened.

Transistors 38 are cascaded so that the emitter terminal of one transistor is connected to the collector terminal of the next adjacent transistor. This is shown in FIG. 1, for instance, wherein the emitter terminal 50 of one transistor 38 is connected to the collector terminal 52 of the preceding transistor, the emitter 54 of the transistor 38 corresponding to terminal B being connected to a current-limiting resistor 56, to a Zener diode 58, and to lead 28. The Zener diode is connected to ground and serves to maintain the voltage on lead 28 essentially constant. Lead 28 also connects emitter 54 with a resistor 39.

The transistor 38 corresponding to terminal Q of connector 44 has its collector terminal 64 connected to emitter 66 of PNP transistor 68 whose collector 70 is connected to a pair of resistors 72 and 74 in series, resistor 74 being connected to ground. The base 76 of transistor 32 is connected to the junction between resistors 72 and 74, emitter 34 of transistor 32 being connected to ground. The second bank of transistors 40 are cascaded in the manner similar to that of transistor 38, the collector 78 of the transistor corresponding to terminal F of collector 44 being connected by lead 86 through resistor 56 to lead 28. The emitter of the last-mentioned transistor 40 being connected to the collector of the transistor 40 corresponding to terminal H and so on, emitter 80 of the transistor 40 corresponding to terminal P of collector 44 being connected to ground. The base 82 of transistor 68 is connected to a resistor 84 which is, in turn, connected to lead 86 connecting collector 78 with resistor 56.

Power is supplied through lead 96 to terminal 90 and fuse 114 during starting operation by a starter relay connected to terminal 90 through a diode 97. Terminal 90 is connected by lead 94 to terminal R of connector 44 and also to resistor 39. To connect the output of an alternator or generator to the circuit, the output leads 99, 101 and 103 are connected through diodes 104 to lead 94.

Key 48 has a lead or conductor bar 108 (far side) connecting terminal A of connector 44 to the terminals 46 which are to be connected to those terminals of connector 44 coupled to transistors 38. For purposes of illustration, terminals 46*b*, 46*c*, 46*d*, 46*e*, 46*j* and 46*q* are provided on key 48 to contact terminals B, C, D, E, J and Q. Thus, these last-mentioned terminals and thereby the base terminals of corresponding transistors 38 are connected to terminal A and thereby to ground when key 48 is coupled to connector 44. In a similar manner, lead or conductor bar 106 (front side) connects terminal 46*r* to terminals 46*f*, 46*h*, 46*k*, 46*m*, 46*n* and 46*p*. Terminal R is connected to the positive side of the starter relay or alternator rectifier output so that the terminals F, H, K, M, N and P and thereby the base terminals of corresponding transistors 40 are placed at positive supply potential.

The control circuitry described above may be connected by cable to the engine or vehicle with which coil 10 is associated. For purposes of illustration, the elements of the invention are shown in an electrical schematic form in FIG. 2 wherein cable 65, connector 44 and key 48 are remotely located relative to lock assembly 56. Breaker point switch 18 is connected to the negative terminal of lock assembly 56 and the three-phase output of alternator 112 is connected by lead 99, 101 and 103 to the respective rectifier terminals of lock assembly 56.

Ballast resistor 16 is connected by means of fuse 114 to the positive supply terminal 90 of lock assembly 56. A conventional ignition switch 116 operated remotely from coil 10 is connected to the starter relay 118 and an ammeter 120. Ignition switch 116 and the combination of connector 44 and key 48 cooperate to cause actuation and continued operation of the ignition system. In the absence of one of these components or revision of any wires, the ignition system cannot operate. Starter 124 is connected to relay 118 and to battery 88.

Alternator 112 for use with this system is slightly modified with respect to a conventional alternator in that the three-phase output thereof is connected from within the alternator. A key feature of the alternator connection is that the circuitry of the invention are powered from the alternator alone and are only powered from the battery during starter operation. This feature makes it possible to pull key 48 and stop the engine immediately. Moreover, it is possible to use the invention with an older model electrical system using a DC generator. In such a case, leads 99, 101 and 103 would be connected together and to the output terminal of the generator.

The circuit components are preferably attached to an etched circuit board molded in plastic in a form to fit on the tower end of a conventional ignition coil. Alternately, the circuit board can be molded integrally with the coil on any coil structure. If separately attached, the circuit assembly is preferably secured by tubular screws with a round or conical head and a "one-way" driving recess used to attach the circuit board to the coil terminals 11 and 13 and the wire connections 15 and 17 to the coil. The coil may be secured to the engine block with a padlock for additional security.

Key 48 is preferably made from a plastic sheet laminated on both sides with suitable conducting material, such as copper or the like. The key is preferably cut to approximately the size of a credit card and both sides are etched to form terminals 46 and conductors 106 and 108 connected to these terminals. This can be accomplished by making in one side of the key the high voltage side and the other side of the key the low voltage or ground side. Connector 44 accomplishes the function of interconnecting both sides of key 48.

Key 48 is made as a blank with all terminals 46 connected on both sides by conductor bars to conductor bars 106 and 108. Each conductor bar for each key face for a terminal 46 and has a drill target 47 in its center and encoding is accomplished by drilling a hole in the key at the target location. This results in an "open" connection since it severs only that conductor bar. The holes are shown in FIG. 1, wherein the bases of the PNP transistors are connected to conductor bar 108 and the bases of the NPN transistors are connected to conductor bar 106 when key 48 is inserted into connector 44.

Key 48 is also mechanically coded by means of a slot, such as the slot corresponding to the G terminal of connector 44. A tab is provided in connector 44 for insertion in the slot, thereby preventing keys with slots in other locations from being inserted in connector 44.

There are a large number of different ways in which the lock assembly 56 can be encoded and the encoding of the lock assembly will be determined by the transistor arrangement in two transistor banks. There is a fixed number of transistors, for instance, six PNP and six NPN transistors as shown in FIG. 1. Each of the transistor input positions can terminate in either a PNP or NPN transistor but not both. The coding possibilities are accomplished on the etched circuit board by making both transistor positions share the same base terminal connection and by installing a "short" at the collector to emitter etched board terminations on the unused transistor bank. Thus, position 128 (FIG. 1) provides an alternate possibility for locating a PNP transistor, replacing an existing transistor 40 in connector position N. Similarly, position 130 aligned with the NPN transistors provides another location for an alternate NPN transistor to provide a different coding arrangement, replacing a transistor 38 in the connector position J.

To change this arrangement, circuit board for the circuitry of this invention will be provided with alternate positions or locations 128 (shown in dashed lines) for rearranging the type of PNP transistors 38 or NPN transistors 40 for each command line. In the example shown, there are 12 transistors of which there are *n* PNP transistors and 12-*n* NPN transistors. Only one of the two possible positions is used for each transistor.

In operation, connector **44** is coupled to the transistor banks through resistors **42** and starter relay input is connected to terminals **90** with terminal **92** grounded. The alternator three phase output is connected by leads **99**, **101** and **103** through diodes **104** to terminal R and ignition coil **10** is coupled to SCR **20**. It is assumed that key **48** is properly encoded so that negative voltages will be applied to transistors **38** whereas positive voltages will be applied to transistors **40** when the key is coupled to connector **44**. The connector may be suitably formed so that it has a recess to receive the key.

When the key is out of the connector, transistors **38** and **40** are nonconducting so that transistor **32** is nonconducting. This is because base **76** of transistor **32** is at ground potential so that the transistor is off but not back biased. In this case, capacitor **36** coupled to gate **26** charges whenever switch **18** opens. This charging of the capacitor forward biases gate **26** of SCR **20** so that when the switch **18** opens, SCR **20**, which is conducting because of the forward bias on gate **26**, provides a closed circuit with the primary winding allowing the energy of the collapsing magnetic field to be dissipated through the resistance of the primary winding and SCR **20**. There will be a low induced voltage in the secondary winding so that there will be insufficient voltage produced to cause a spark to be discharged at the terminal of a corresponding spark plug.

Without the presence of key **48** in connector **44**, the engine associated with ignition coil **10** cannot be started or operated. It will be necessary to provide the proper reverse bias on SCR **20** before such operation can be started and continued.

If the key with the proper terminals thereon is inserted in connector **44**, negative or ground voltages are applied to the base terminals of transistors **38** and positive potentials are applied to the base terminals of transistors **40**. The transistors are then forward biased and since they are connected to power lead **63**, they become conducting. Since transistors **40** are conducting, this provides a forward bias on transistor **68** which becomes conductive because transistors **38** are conducting. This causes base **76** of transistor **32** to be forward biased since it will then be at a potential above ground due to resistor **74**.

When transistor **32** conducts, this places a relatively low bias voltage on gate **26** of SCR **20**, rendering the SCR nonconducting so long as transistor **32** conducts. Thus, a voltage will be induced in the secondary winding **14** when breaker **18** opens since there is no closed circuit path for dissipating the energy of the collapsing magnetic field.

Since the displayed circuit assumes addition of the control to an existing vehicle, ignition switch **116** will be closed when key **48** is inserted in connector **44**. The existing ignition key may be modified to make it impossible to remove from the ignition switch.

While the invention has been shown for use as controlling the energy transfer between windings of an ignition coil, it is clear that the invention can be used for other purposes as well. It can be used where a bias voltage is needed or where a particular current flow is necessary. In essence, transistor **32** operates as a gate to permit or prohibit operable structure.

The circuitry of the present invention can be considered an enabling or a disabling device in the sense that it allows or enables an event to occur or prohibits such event from occurring, in the latter case it disables a particular system. When applied to the foregoing apparatus, it enables the primary winding **12** to transfer its energy to the secondary winding to thereby induce a voltage in the latter. Thus, when transistor **32** is conductive, the combination of SCR **20** and primary winding **12** is in the enabling state. However, such combination may or may not have been actuated. When the combination is actuated (when breaker switch **18** opens), coil **10** goes through its firing operation as if SCR **20** did not exist. If transistor **32** is nonconductive, the combination or SCR **20** and primary winding **12** is disabled. When this occurs, and before the started sequence advances to a firing point, gate **26** of SCR **20** has a voltage approximately equal to that of lead **28** due to leakage so that SCR **20**, up to that time, will have done nothing. When breaker switch **18** opens, the SCR and the coil form a closed circuit to cause the stored energy of the coil to be absorbed in the circuit rather than transferred inductively to the secondary winding. Thus, the energy is diverted from the second winding and dissipated in the form of heat.

In summary, the coding input actuates transistors **38** and **40** which, in turn, actuate transistor **68**, the latter, in turn, actuates transistor **32** and this transistor enables the primary winding **12**. Moreover, capacitor **36** provides a control member for SCR **20** when transistor **32** is nonconductive in that the capacitor, being responsive to the rate of voltage rise across coil **10**, becomes charged when switch **18** is opened to thereby provide the forward bias voltage for SCR **20** sufficient to cause it to "fire" and thereby be conductive. When transistor **32** is conductive, capacitor **36** is also conductive but it does not bias the gate of SCR **20** sufficiently to overcome the reverse bias or "enabling voltage" caused by the conductive state of transistor **32**.

The circuit of the invention shown in FIG. **1** has built-in safeguards to prevent tampering with the circuit so as to bypass the same. For instance, the transistor **32** and diode **60** can be selected to withstand a voltage of three times or more than the normal supply voltage and to exhibit a small enough leakage current in the case of diode **60** or a small enough open state leakage current in the case of the transistor **32** so that either the transistor **32** will absorb most of the positive voltage impressed on terminal **11** (if lead **96** is removed from terminal **90**) or diode **60** will absorb most of the supply voltage (if terminal **92** is disconnected from ground and terminal **90** is grounded). This feature is possible due to relative high leakage current of reverse bias gate-anode junctions of available SCR's. The function of this protection is to prevent an intruder from connecting a higher voltage source to fuse **114**, disconnecting wire **17** from the breaker, and manually grounding the disconnected wire to attempt to destroy the SCR **20** by "burning" the relatively sensitive gate **26** open by excessive applied reverse voltage and thereby permit unauthorized operation of the ignition coil after reconnection.

I claim:

1. In combination: an inductive member; a silicon controlled rectifier device having a gate and adapted to be placed in an enabled state when a reverse bias voltage is applied to the gate, said device being normally in a disabled state and being connected to said inductive member to provide closed electrical current path therefor when the device is in said disabled state; a normally nonconductive, current-carrying member having means responsive to a predetermined electrical signal independent of the current through the device for rendering the current-carrying member conductive, said current-carrying member being coupled to the gate of said device for providing the reverse bias voltage therefor when the current-carrying member is conductive; means coupled with said gate for applying a forward bias voltage to the gate when said current-carrying member is nonconductive to thereby place said device in said disabled state; decoding means having a plurality of actuatable, current-carrying elements for generating said signal when the elements are simultaneously actuated; means connecting said decoding means to said signal responsive means of said current-carrying member, whereby the latter becomes conductive when said signal is generated; and means coupled to said elements for simultaneously actuating the same.

2. Control apparatus as set forth in claim **1**, wherein said current-carrying member comprises a transistor, means including a voltage divider for connecting the transistor to said device, said voltage divider providing said enabling voltage when said transistor is conductive.

3. Control apparatus as set forth in claim **1** wherein said decoding means includes a connector having a plurality of terminals, a group of PNP transistors, a number of NPN transistors, and a power source having a positive terminal and a negative terminal, the base of each of said transistors being connected to a respective terminal of said connector, said ac-

tuating means including a key for coupling each terminal of the connector to a respective terminal of the power source.

4. In combination: an inductive member; a silicon controlled rectifier device having a gate and adapted to be placed in an enabled state when a reverse bias voltage is applied to the gate, said device being normally in a disabled state and being connected to said inductive member to provide closed electrical current path therefor when the device is in said disabled state; a normally nonconductive, current-carrying member having means responsive to a predetermined electrical signal independent of the current through the device for rendering the current-carrying member conductive, said current-carrying member being coupled to the gate of said device for providing the reverse bias voltage therefor when the current-carrying member is conductive; a capacitor coupled with said gate and with said inductive member for applying a forward bias voltage to the gate when said current-carrying member is nonconductive to thereby place said device in said disabled state; decoding means having a plurality of actuable, current-carrying elements for generating said signal when the elements are simultaneously actuated; means connecting said decoding means to said signal responsive means of said current-carrying member, whereby the latter becomes conductive when said signal is generated; and means coupled to said elements for simultaneously actuating the same.

5. The combination as set forth in claim 4 wherein said inductive member has a pair of ends, said device having a pair of terminals connected to respective ends of the inductive member, said capacitor being connected to one end of the inductive member and to the gate of said device.

6. The combination as set forth in claim 5, wherein said current-carrying member includes a transistor having a base defining said signal responsive means.

7. The combination as set forth in claim 5, wherein said current-carrying member comprises a transistor having a collector, and wherein is included a power source, and means connecting said collector to said power source.