IGNITION SYSTEM FOR AN INTERNAL COMBUSTION ENGINE

Inventors: Diedrich Steinberg, Stuttgart; Winfried Jahnke, Ludwigsburg; Helmut Roth, Stuttgart; Walter Ruf, Munchingen; Ulrich Steinbrenner, Stuttgart; Hans Linstedt, Reutlingen, all of Germany

Assignee: Robert Bosch GmbH, Stuttgart, Germany

Filed: July 19, 1972

Appl. No.: 273,185

Foreign Application Priority Data
July 24, 1971 Germany.......................... 2137204

U.S. Cl........................... 123/148 E, 123/148 S

Int. Cl........................... F02p 1/00

Field of Search.......................... 123/148 E

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Primary Examiner—Charles J. Myhre
Assistant Examiner—Ronald B. Cox
Attorney, Agent, or Firm—Michael S. Striker

ABSTRACT

An ignition system has a switching transistor having an emitter-collector path connected in series with the primary winding of an ignition coil. The latter series combination is connected between voltage supply leads. A driver circuit has a control electrode and controls the conductive state of the switching transistor. An ignition breaker switch has alternating open and closed intervals in response to rotation of the engine. The breaker switch may have the undesirable property that it closes momentarily during the open interval shortly after opening of the breaker switch. A signal control circuit is connected to the ignition breaker switch and to the control electrode to make the emitter-collector path of the switching transistor conductive when the breaker switch is closed and to make it nonconductive when the breaker switch is open. An energy storage element, either the primary winding itself or a capacitor, stores energy prior to the closing of the breaker switch during an open interval of said switch, and the stored energy is used to maintain the control electrode at a potential to maintain the transistor path open irrespective of the closing of the breaker switch during an open interval of the same.

41 Claims, 5 Drawing Figures
IGNITION SYSTEM FOR AN INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

The present invention relates to ignition systems, and particularly to an ignition system for an internal combustion engine which generates sparks in response to opening and closing of the ignition breaker switch whose quality is not deteriorated by the momentary closing of the breaker switch during an open interval thereof.

Ignition systems already known which have an ignition coil having a primary and a secondary winding. In such systems, the secondary winding is typically connected to at least one spark plug whereas the primary winding is connected in series with a switching element. The switching element may consist of a switching transistor whose emitter-collector is connected in series with the primary winding. A control circuit is provided with such ignition systems which is connected to the base of the switching transistor and which causes the transistor to become conductive when the ignition breaker switch is closed and is caused to become non-conductive when the breaker switch is open. In this manner, whenever the breaker switch is closed, current is permitted to flow through the primary winding whereas whenever the breaker switch is open, such current flow is inhibited.

In ignition systems of the above type, the current passing through the ignition breaker switch is relatively small so as not to have an adverse effect on the operation of the engine due to the burning out of the switch contacts. The utilization of small currents in the breaker switch largely removes this danger.

However, the systems of the type described above have disadvantages. Thus, although the breaker switch is designed to open and close in response to rotation of a rotary element of the internal combustion engine, the switch does not always properly open. Thus, due to almost unavoidable clearances and the manufacturing tolerances in such switches, the resulting play often causes the switch to close momentarily for a short period of time subsequent to opening in the open interval, after which the switch reopens and stays open for the remainder of the open interval. Such action of the switch not only causes heavy loading of the switching transistor, but also has an adverse effect on the quality of the spark produced in the secondary winding and may result in missing of ignitions in some of the cylinders to thereby result in inefficient and rough operation of the engine.

SUMMARY OF THE INVENTION:

Accordingly, it is an object of the present invention to provide an ignition system for an internal combustion engine which does not have the disadvantages of the systems known in the prior art.

It is another object of the present invention to provide an ignition system which is simple in construction and economical to manufacture.

It is still another object of the present invention to provide an ignition system of the type under discussion wherein the sparks generated are not deteriorated by the closing action of the breaker switch during an open interval thereof.

It is a further object of the present invention to provide an ignition system which does not produce loading in the transistor connected in series with the primary winding due to momentary closings of the breaker switch during an open interval thereof.

With the above objects in view, the present invention is for an ignition system for an internal combustion engine having a rotary element. The combination comprises an ignition coil with primary and secondary windings. An ignition breaker switch is provided which respectively opens and closes for alternating first and second intervals determined by said rotary element of the engine and which may exhibit a tendency to close during said first intervals. Switching means are provided which are connected in series with the primary windings, said switching means being arranged to open to thereby block current flow in the primary winding and to close to thereby permit current to flow through the primary winding. First circuit means are provided which are connected between the ignition breaker switch and said switching means to open the latter when the ignition breaker switch opens and to close said switching means when the ignition breaker switch closes. Second circuit means are provided which are connected to said first circuit means for maintaining said switching means open irrespective of closing of said ignition breaker switch during at least portions of said first intervals.

According to one embodiment of the present invention, said second circuit means cooperates with the primary winding, the latter acting as an energy storing element. In this case, the primary winding stores energy prior to a closing of the breaker switch during said portions of said first intervals. Part of the stored energy cooperates with said second circuit means to maintain said switching means open irrespective of closing of said ignition breaker switch during said portion of said first intervals. In accordance with another embodiment, said second circuit means includes capacitor means which store energy prior to closing of said ignition breaker switch during said portions of said first intervals to maintain said switching means open during said portions of said first intervals.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic of an ignition system in accordance with the present invention, wherein the primary winding of the ignition coil is used as an energy storing element;

FIG. 2 is a schematic of a second embodiment of the invention as shown in FIG. 1;

FIG. 3 is a schematic of a third embodiment of the invention as shown in FIG. 1, wherein a storage capacitor is added to cooperate with the primary winding;

FIG. 4 is a schematic of an ignition system in accordance with the present invention, wherein a capacitor is utilized to store energy; energy; and

FIG. 5 is a schematic of another embodiment of the invention as shown in FIG. 4.
DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the Figures, wherein similar reference numerals have been utilized for the same parts throughout, and first referring to FIG. 1, an ignition system 10 in accordance with the present invention is shown to have an ignition coil 11 which has a secondary coil 12. The secondary coil 12 is connected at one of its terminals to one of its terminals to one of the terminals of a spark plug 13. Ignition coil 11 also has a primary winding 14 which is connected to an n-p-n switching transistor 15. The specific construction of the ignition coil 11 is well known and does not form part of the present invention. Although the secondary winding 12 has been shown to be connected to only one spark plug 13, it is understood that, if an internal combustion engine has more than one cylinder, the secondary winding 12 may be connected to all the spark plugs by means of a conventional distributor (not shown). With such a distributor arrangement, successive voltages induced in the secondary winding 12 can be sequentially applied to the spark plugs in a predetermined order.

The transistor 15 has an emitter 16 and a collector 17 which forms an emitter-collector path which is connected in series with primary winding 14.

Continuing to first describe the conventional details of the ignition system, an ignition breaker switch is indicated by the reference numeral 18. The breaker switch cooperates with a rotary element (not shown) in the combustion engine in a well-known manner so as to open and close said switch in dependence on the position of the rotary element. Particularly, the breaker switch 18 opens and closes alternately. The times when the breaker switch 18 is open will be referred to as the open interval and when the breaker switch 18 is closed will be referred to as the closed interval. Ideally, the open and closed intervals are sharply defined so that the state of the breaker switch 18 is solely defined by the position of the rotary element. Thus, for continuous rotation of the rotary element in one direction, the breaker switch opens at a predetermined position of the rotary element and remains opened until the rotary element has reached a second position. At such time, the breaker switch 18 closes and remains closed until a third position of the rotary element has been reached. Upon reaching the fourth predetermined position, the breaker switch 18 opens once again. However, as described above in connection with the background of the invention, these breaker switches do not always operate in such an ideal fashion. The imperfect action is partly attributable to the play in said switches caused by clearances and manufacturing tolerances. For this reason, such switches often have a tendency to open improperly. Thus, once the breaker switch 18 opens, it will often close again at least momentarily during said first intervals. More commonly, such breaker switches close shortly after initial opening, after which the switch opens once again and remains open for the remainder of the open interval.

The ignition system 10 is connectable to a battery 19 whose negative terminal, in the embodiments to be described is connectable to the circuit ground 20. A voltage supply lead 21 is connected to the ground 20 and provides said potential to the ignition system 10. A single pole, single throw switch 22 is connected between the positive pole of the battery 19 and a positive voltage supply lead 23.

The ignition circuit is controlled by the breaker switch 18 electrode 24 whose potential is controlled by the breaker switch 18 as will presently be described. Each of the embodiments to be described has an electrode 24, the potential thereof being effective for actuating a switching transistor in series with primary winding. As will be presently described, each of the embodiments can be functionally broken down into two circuits. The first circuit is generally connected between the ignition breaker switch 18 and the switching transistor 15 (or 68 in FIGS. 4 and 5) to open the latter when the ignition breaker switch opens and to close the switching transistor 15 when the ignition breaker switch closes. Thus, the first circuit serves the function of opening and closing the switching transistor 15 under ideal operating conditions of the breaker switch.

The second circuit, which will be identified for each of the embodiments that follow, is connected to the first circuit and is so arranged that it maintains the switching transistor 15 open irrespective of closing of the ignition breaker switch 18 during at least portions of the open intervals. The first circuit can be further broken down into two sub-circuits which are readily identifiable in all of the embodiments. Thus, the first circuit includes a driving circuit which is connected to the switching transistor 15 and is connected to the control electrode 24. The potential applied to the control electrode 24 determines whether the driving circuit opens or closes the switching transistor 15. Secondly, the first circuit includes a control circuit which is connected to the breaker switch 18 and to the control electrode 24 for generating signals during the open and closed intervals of the breaker switch. Thus, it is seen that the control electrode 24 functionally divides the first circuit into the two latter sub-circuits just described, the control circuit controlling the potential of the control electrode 24 as a function of the condition of the breaker switch 18, while the driving circuit responding to the potential at the electrode 24 to thereby control the operation of the switching transistor 15.

The switching transistor 15 has a base 25 which is connected to the driving circuit described above, and presently to be defined. By applying suitable voltages to the base 25 in relation to the emitter 16, the switching transistor 15 can be open or closed to thereby make the emitter-collector path 16-17 conductive or non-conductive. Since the switching transistor 15 is connected in series with the primary winding 14, the current flow to the latter is dependent on the conductive state of the switching transistor 15. Thus, when the switching transistor 15 is conductive, current can flow from the positive lead 23 to the primary winding 14, to the emitter-collector path 16, 17, and to the ground lead 21. However, when the switching transistor is non-conductive, current through the primary winding 14 is inhibited, except as will presently be described.

Referring to FIG. 1, the control circuit, referred to above, for regulating the voltage at the control electrode 24 as a function of the open-closed conditions of the breaker switch 18, consists of a control resistor 26 connected between the positive lead 23 and the control electrode 24 and a resistor 27 between the control electrode 24 and one terminal of the breaker switch 18, the other terminal of the latter being connected to the ground lead 21. The resistances 26 and
3,854,466

27 comprise a voltage divider whose tap point is connected to the control electrode 24. While the voltage divider is always connected to the positive lead 23 through the control resistor 26, it is connectable to the ground leaf 21 only through closing of the breaker switch 18. The control resistor 26 serves as a voltage dropping element to thereby apply a potential difference between the positive lead 23 and the control electrode 24 when current flows through the control resistance 26 as will presently be described. It is essential that the control element 26 be a resistor as shown but can be any element which exhibits a voltage drop upon the passage of current therethrough, e.g., a diode (not shown) having its cathode connected to the positive voltage lead 23 and its anode connected to the control electrode 24 to thereby conduct current from the latter to the former. In the event, if a diode is used, it may be desirable to connect a shunt capacitance thereacross (not shown).

The values of the resistors 26 and 27 are so selected that a relatively small voltage is developed across the resistor 26 when the breaker switch 18 is closed. Since the voltage developed across the resistor 26 is applied across an emitter-base of a transistor, to be described, for the purpose of forward biasing or cutting off the same, the voltage to be developed across the resistor 26 will typically be approximately 0.7 to 1 volts. With a battery voltage of 12 volts, for example, the ratio of the resistances of the resistor 27 to the resistor 26 is greater than 10:1. Thus, with this arrangement of the control circuit, the resistance of resistor 26 is much smaller than the resistance of resistor 27.

The primary winding 14 is connected in series with the emitter-collector path 16, 17 of the switching transistor 15 to form a tap point 28. As described above, when the switching transistor 15 is conductive, current flows through the primary winding 14. In the embodiment under discussion, the primary winding 14 utilizes as an energy storage element which cooperates with the secondary circuit described above to maintain the switching transistor 15 open or non-conductive during the open intervals of the breaker switch 18 irrespective of closing of the breaker switch 18 during said open intervals. To achieve these desired results, the second circuit comprises a discharge conductor path 28a connected to the tap 28. The discharge conductor 28a is connected to a resistor 29 which serves to limit the current flowing through the following series connected diode 30, the latter being connected to the control electrode 24 and to the tap points formed by the resistors 26 and 27. Thus, the second circuit in this instance comprises the discharge conductor 28a, the limiting resistor 29 and the diode 30. This second circuit is connected to the tap point 28 and permits current flow from the primary winding 14 when the switching transistor 15 is placed in its non-conductive state. The diode 30 is arranged with its cathode connected to the control electrode 24 and its anode connected to the limiting resistance 29 as shown to thereby permit current flow from the tap point 28 towards the control electrode 24. Such current flow, presently to be more fully described, is generated by the stored energy in the primary winding 14.

The control electrode 24 is connected to the base 31 of a npn coupling transistor 32 which forms a part of the driving circuit mentioned above. The coupling transistor 32 has its emitter 33 connected to the positive lead 23 and its collector 34 connected to a voltage divider which comprises series connected resistors 35 and 36. The voltage divider has a tap point 37 which is connected to the base 25 of the switching transistor 15. Thus, the driving circuit in this instance comprises the coupling transistor 32 and the resistors 35 and 36. The resistor 36 is also connected to the ground lead 21 so that the voltage divider 35, 36 as well as the series connected emitter-collector path 33, 34 are connected between the positive lead 23 and the negative lead 21.

The operation of the embodiment illustrated in FIG. 1 will now be described. Examining first the closed intervals of the breaker switch 18, the closing of the switch 18 places the terminal of the resistor 27 connected thereto at the ground potential. This places the voltage divider 26, 27 across the battery 19 to thereby apply a preselected voltage to the control electrode 24, as described above. Thus, the base 31 of the coupling transistor 32 is made more negative than the emitter of said transistor to thereby cause the latter to become conductive. Emitter-base current flows through the control electrode 24, the resistor 27 and the closed breaker switch 18 to the ground lead 21. It should be noted in this connection, that if a diode were to be utilized in place of the resistor 26, as suggested above, the same emitter-base current would flow to permit the coupling transistor 32 to become conductive in the same manner. When the emitter-collector path 33, 34 becomes conductive, a current flows through the resistors 35 and 36 forming the voltage divider, and a positive potential with respect to the ground is applied to the base 25 by virtue of this connection with the tap point 37. The resistors 35 and 36 are so selected that a sufficiently positive voltage is applied to the base 25 with respect to the ground potential which exist at the emitter 16 to cause the emitter-collector path 16, 17 of the switching transistor 15 to become conductive. In the embodiment under discussion, the current flowing through the primary winding 14 at said times, namely during the closed intervals of the breaker switch 18, decreases magnetic energy to be stored in the primary winding 14. In the driving circuit the coupling transistor 32 and the voltage divider, comprising the resistances 35 and 36, are so arranged and the values of the latter are so selected so that the switching transistor 15 becomes highly conductive to present a virtual short circuit between the tap 28 and the ground lead 21. Thus, during the times when the switching transistor 15 is so heavily conducting, hardly any current is diverted into the discharge conductor path 28a.

First assuming ideal operation of the breaker switch 18, it can therefore be assumed that the second circuit comprising of the discharge conductor 28a, the limiting resistor 29 and the diode 30 are not connected in the circuit. Now, when the breaker switch 18 opens, emitter-base current flowing through the emitter-base path 33, 34 is prevented and the coupling transistor 32 becomes non-conductive. With no current flowing through the emitter-collector path 33, 34, the voltage at the tap 37 of the voltage divider 35, 36 is the same as the ground potential and the base of switching transistor 15 is thereby placed at the same potential as the emitter 16. By thus removing the positive biasing voltage from the base 25, the switching transistor becomes non-conductive and the field which has been built up around the primary winding 14 begins to collapse to the drop in current in the latter. An induced voltage in the
3,854,466

1. Secondary winding 12 is thereby generated in accordance with well-known principles, the turn ratio between the primary and secondary windings being so selected that a sufficiently high voltage is attained which will be effective to produce a spark across the spark plug 13.

The effect of a non-ideal breaker switch 18 will now be considered. As described above, such a switch will not open exactly during the ignition time but will momentarily close thereafter and thereafter open again and remain open for the balance of the open interval. As described above, when no precautions are taken to compensate for such disturbances, there is a strong loading of the switching transistor 15 and may result in ignition failure or missing. However, with the provision of the second circuit, namely the diode 30 and the limiting resistor 29, such disturbances are eliminated. In the closed period of the breaker switch 18 the first circuit operates as described above. Now when the breaker switch 18 opens for the first time after the closed interval, the emitter-collector path 16-17 of the switching transistor 15 is interrupted as is the current flowing through the primary winding 14. However, it is known that currents flowing in inductors resist abrupt changes and the current, due to the storage of the magnetic field about the coil, tend to maintain the current flow. The current flowing in the primary winding 14 initially flows from the positive supply lead 23 through the primary winding 14 and through the emitter-collector path 16-17. However, now that the emitter-collector 16-17 is closed, the current is permitted to flow through the second circuit namely the discharge conductor 28a, the limiting resistor 29, the diode 30 and the resistor 26 and back to the primary winding 14 to thereby form a closed loop. As noted above, the resistor 26 is selected so that when the current flowing in the latter loop flows therethrough, the voltage developed across the resistor 26 is sufficient to maintain the emitter-base junction of the transistor 32 in the non-conductive state. Otherwise, the voltage across the resistor 26 and the loop is controlled by the value of the resistor 29. The resistor 29 is selected so that an appropriate cut-off voltage may be developed across the transistor 32 emitter-base junction but to prevent a substantial portion of the current originally flowing through the primary winding 14 to be diverted into the second circuit. In this manner, the change in current effected as a result of the turning off of the switching transistor 15 is still considerable and therefore a sufficient voltage may be developed in the secondary winding 12 to create a spark across a spark plug 13. Now, when the breaker switch momentarily closes after initial opening the base 31 of the transistor 32 is made somewhat more negative by the voltage division action of the resistors 26 and 27. However, the resistors 26 and 27 are so selected so that, with the loop current above described, the voltage developed across the resistor 26 is still sufficiently positive at the base 31 in relation to the emitter 33 so that the transistor 32 remains non-conductive. Therefore even with a momentary closing of the breaker switch 18, the coupling transistor 32 remains in its non-conductive condition, just as though the breaker switch 18 had never closed. The time constant of the loop comprising the primary winding 14, the limiting resistor 29, the diode 30, and the resistor 26 is so selected that the magnetic field discharges in the manner described for a long enough period after initial opening of the breaker switch 18 to include all the anticipated times during the open interval during which the breaker switch may momentarily close. In this manner, the momentary closings of the breaker switch 18 are masked out at the input to the driving circuit so that insofar as the switching transistor 15 is concerned it is only turned on and off as it would be by an ideal breaker switch 18. As soon as the stored energy has been anticipated, the current through the loop, and particularly the resistor 26 ceases to flow, and, by the time that the normal closing interval arrives, the coupling transistor 32 is susceptible to be made conductive once again by the closing of the breaker switch 18 as described above. The closing of the breaker switch 18 will at this time again build up the magnetic field around the primary winding 14, which field will be utilized in conjunction with the second circuit to compensate for the imperfect, actual operation of the breaker switch.

The diode 30 is provided in the loop so that during the conductive state of the emitter-collector path 16-17, no unnecessary current flows through the second circuit but all the current flowing into the collector 17 is primary winding 14 current.

Four more embodiments of the present invention will now be described. Insofar as similar elements used in FIG. 1 appear in the subsequent embodiments and serve similar functions, these will be designated by the same reference numerals and will not be described in detail insofar as their operation is concerned.

Referring to FIG. 2, the control circuit of the first circuit has somewhat been modified, as to be described. The driving circuit of the first circuit, comprising the transistor 32 and the resistors 35 and 36, is identical with that in FIG. 1. However, the second circuit comprising the limiting resistor 29 and the diode 30 in FIG. 1 has been deleted and a new circuit has been substituted therefor. Now, the diode 48 is connected between the two resistors 26 and 27 making up the voltage divider of FIG. 1. Connected to the tap point 28 is a Zener diode 39 connected in series with a limiting resistor 29, these series connected elements being connected to the base 47 of a transistor 44. The emitter 45 of this transistor is connected to the negative supply lead 21 while the collector of the transistor 44 is connected to the base 42 of a transistor 39 through a resistor 43. The emitter 40 of the transistor 39 is connected to the positive supply lead 23 while the collector of this transistor is connected to a tap point formed by the connection between the resistor 27 and the diode 48. The control electrode 24 of the driving circuit is now connected between a tap point which is formed by the connection of the resistor 26 with the anode of the diode 48. The transistor 39 is selected to be a pnp transistor while the transistor 44 is an npn transistor.

The operation of the embodiment shown in FIG. 2 will now be described. The closing of the breaker switch 18 at the beginning of a normal closed interval causes the cathode of the diode 48 to be more negative than the anode thereof. Consequently, the diode 48 is made conductive and the control electrode 24 is made more negative, as in the embodiment shown in FIG. 1. Consequently, the coupling transistor 32 as well as the switching transistor 15 are made conductive, as already described. When the switching transistor 15, however, is conductive, the tap point 28 is brought to a potential very nearly that of the ground or the potential at the negative supply lead 21. Whatever small positive po-
potential exists at the collector 17, appears across the Zener diode 38 which is not, however, great enough to break down the latter. Consequently, the voltage at the base 47 of the transistor 44 is substantially at the ground potential and equal to the potential of the emitter 45. Thus, the transistor 44 is in the non-conductive state and no current flows in the collector 46 of transistor 44 or in the base 42 of the transistor 39. The emitter-collector path 40-41 of the transistor 39 is thus non-conductive, and, for all practical purposes, the second circuit is not present.

Now, when the breaker switch 18 is initially opened the switching transistor 15 becomes non-conductive and the energy stored in the primary winding 14 is diverted into the discharge collector 28a. The emitter-collector path 16-17 no longer shorts the tap point 28 to the negative lead 21, the voltage at the tap point 28 becoming sufficiently positive so that the Zener diode 38 breaks down and maintains its Zener voltage there across. The balance of the positive voltage at the tap point 28 is applied to the base 47 of the transistor 44 which is sufficiently positive with respect to the emitter 45 potential, that the emitter-collector path 45-46 of the transistor 44 becomes conductive. This causes a base current to flow in the base 42 of the transistor 39 and the latter transistor similarly becomes conductive. The resistor 43 is selected so that sufficient base current can flow in the base 42 in order that the transistor 39 becomes highly conductive and creates a substantial short circuit between the positive lead 23 and the cathode of the diode 48. In fact, the cathode of the diode 48 is thereby maintained at a potential nearly equal to that of the positive supply leads 23 and this is substantially independent of whether the breaker switch 18 is opened or closed. Thus, the control electrode 24 is maintained at its positive potential as long as energy from the primary winding 14 maintains the transistors 44 and 39 in their conductive states. During this time the control electrode 24 is maintained at a sufficiently positive level so that the closing of the breaker switch 18 momentarily after opening does not bring the control electrode 24 to sufficiently negative voltage which can cause the driving transistor 32 to become conductive. The provision of the diode 48 between the electrode 24 and the conducting collector 41 is to insure that the somewhat more negative collector 41 relative to the lead 23 cannot make the control electrode 24 sufficiently negative to make the transistor 32 conductive. Thus, any difference in potential between the collector 41 and the emitter 40 appears across the diode 48. In this manner, the voltage of the control electrode 24 is almost identical with the voltage at the emitter 33. The resistor 43 serves to limit the current flowing in the emitter-base path 40-42 to thereby prevent the transistor 39 from becoming damaged or destroyed. It should be noted, that except for the short interval following initial opening of the breaker switch 18 when the stored energy in the primary winding 14 is being discharged, the embodiment shown in Fig. 2 operates similarly to the embodiment shown in Fig. 1 in respect to the normal opening and closing intervals.

As soon as the energy in the primary winding 14 has been dissipated, the voltage across the Zener diode 38 falls below the Zener voltage or threshold voltage thereof and insufficient base currents flow into the base 47. Thus, the transistor 44 becomes non-conductive and base current in base 42 ceases to flow to thereby make the transistor 39 similarly non-conductive. The circuit is now in its initial condition described above and is ready for another closing of the breaker switch 18 to thereby reestablish a magnetic field about the primary winding 14.

The ignition circuit illustrated in Fig. 3 has been somewhat modified in that the control circuit comprising the resistors 26 and 27 of Figs. 1 and 2 has been replaced by the resistor 26 which is now directly connected to the breaker switch 18. A diode 49 is connected to the tap point formed by the connection of the two latter elements. The cathode of the diode 49 is connected to a limiting resistor 57 which in turn is connected to the control electrode 24. The driving circuit of the first circuit now merely consists of a driving transistor 52 whose collector 55 is connected to the positive supply lead 23 through a collector resistor 54. The base 56 forms the control electrode 24 and the emitter 53 is connected to the negative supply lead 21. The base 25 of the switching transistor 15 is directly connected to the collector 55 of the driving transistor 52. The second circuit in the present embodiment comprises a resistor 29 connected to the tap point 28 which is connected in series with a resistor 50, the latter also being connected to the negative supply lead 21. A storage capacitor 51 is connected in parallel with the resistor 50. The tap point formed by the connection between the resistor 29 and 50 is connected to the cathode of the diode 49. The diode 49 is arranged so that its anode is connected to the breaker switch 18 and its cathode is connected to the junction between the resistors 29 and 50 so that a current flow from the junction is blocked from flowing through the diode 49 but instead must flow through the resistor 57. The driving transistor 52 is an npn coupling transistor.

Examine first the normally closed condition of the breaker switch 18, the anode of the diode 49 is placed at the potential of the negative supply lead 21 and is thereby made non-conductive. Since the capacitor 51 is originally discharged, the voltage applied between the cathode of the diode 49 and the resistor 57 is substantially equal to the ground potential of the circuit, this voltage being applied to the base 56 or the control electrode 24 to thereby maintain the emitter-collector path 53-55 of the driving transistor 52 in the non-conductive state. With the transistor 52 non-conductive, the collector 55 thereof is substantially more positive than the emitter 16 of the switching transistor 15, so that the latter transistor becomes conductive by virtue of its base 25 being connected to the collector 55. Consequently, the emitter-collector path 16-17 of the switching transistor 15 becomes highly conductive and becomes saturated to thereby present an almost perfect short circuit between the tap point 28 and the negative supply lead 21. Under this condition, the voltage across the capacitor 51 cannot build to any substantial positive value so that the voltage transmitted to the control electrode 24 remains to be sufficiently negative to thereby maintain the transistor 52 non-conductive.

However, as soon as the breaker switch 18 opens, the anode of the diode 49 becomes positive with respect to its cathode by virtue of the former being connected to the positive supply lead 23 through the resistor 26. Thus, a current flows from the positive supply lead 23, the resistor 26, the diode 49, the resistor 57, the control electrode 24 and the base emitter path 56-53 of the
transistor 52 to the negative supply lead 21. In this manner, the emitter-collector path 53-55 becomes conductive and the base 25 of the transistor 15 drops substantially in a negative direction. This makes the emitter-collector path 16-17 non-conductive and the current initially flowing in the primary winding 14 is at least partially diverted into the discharge conductor or branch-off lead 28a. The discharge loop in the embodiment in FIG. 3 is as follows: The branch-off lead 28a, the resistor 29, the resistor 50, the battery 19, the switch 22 and the primary winding 14. Upon initial opening of the switch 18, the discharge current begins to flow in the last-mentioned loop. The resistors 29 and 50 are so selected so that the discharge current develops a sufficiently high positive voltage across the resistor 50 so that this voltage applied between the diode 49 and the resistor 57 will be of sufficiently high positive magnitude to maintain the transistor 52 in its conducting state. Thus, should the breaker switch 18 momentarily close, the transistor 52 will nevertheless remain conductive as long as the junction points between the resistors 29 and 50 is of a sufficiently high positive magnitude to restrict voltage. To somewhat prolong this effect, the capacitor 51 is connected in parallel with resistor 50 so that some of the current flowing through the resistor 29 is utilized to charge the capacitor 51 to a positive level at its upper plate. Now, when the transistor 52 is in its conductive state, such conductive state is maintained by the discharge current from the capacitor 51 into the control electrode 24 and the base emitter junction 56-53 of the transistor 52. Of course, as soon as the discharge current through the primary winding 14 has ceased to flow and as soon as the capacitor 51 has become discharged, the junction point between the resistors 29 and 50 is again at the ground potential and therefore the transistor 52 now remains conductive but due to the open condition of the switch 18 as described above. The closing of the breaker switch at this time, with the junction point between the resistors 29 and 50 at the ground potential, would cause the transistor 52 to become non-conductive to thereby again turn the switching transistor 15 on and cause a current to flow through the primary winding 14 to reestablish a field thereabout. By selecting the value of the capacitor 51 and the resistors 29, 50 and 57, the time constant of the second circuit may be selected so that the momentary closing of the breaker switch 18 can be compensated for within a range of time after initial opening.

The blocking diode 49 is provided to prevent a rapid discharge of the capacitor 51 by a closing of the breaker switch 18. Thus, whenever the capacitor 51 has a voltage thereacross the breaker switch 18 closes, the blocking diode 49 automatically becomes non-conductive and the rapid discharge of the capacitor is thereby prevented.

In connection with the embodiments 1-3 above, the second circuit has been connected to the primary winding 14, the latter providing the energy which has been stored during the closed condition of the breaker switch 18 to prevent the closing of the switching transistor during momentary closing of the breaker switch after a normal opening thereof. In the two embodiments that follow, a separate energy-storing element is utilized for the purpose of storing energy when the breaker switch 18 is closed during the normally closed interval and this stored energy is utilized for the purposes described above. Referring first to FIG. 4, the control circuit of the first circuit here consists of a resistor 26 which is connected between the positive supply lead 23 and the breaker switch 18. The tap point between the resistor 26 and the switch 18 is connected to the control electrode 24 through two resistors 57 and 60 which are connected in series with one another. The driving circuit of the first circuit comprises a npn transistor 52 whose base 56 comprises the control electrode 24. The emitter 53 of the transistor 52 is connected to the negative supply lead 21 while its collector 55 is connected to the positive supply lead 23 through a collector-resistor 54. A second driving transistor 63 has its base 62 connected to the collector 55 of the transistor 52 through a limiting resistor 62. The emitter 64 of the transistor 63 is connected to the negative supply lead 21 while the collector 65 thereof is connected to the positive supply lead 23 through a set of series connected resistors 66 and 67 forming a tap point 70. Here, the switching transistor 68 has a base 69 connected to the tap point 70 of the voltage divider while its emitter-collector path 71-72 is respectively connected between the positive supply lead 23 and the primary winding 14. The second circuit in this embodiment comprises a diode 59 connected in parallel with the resistor 60 in a direction to conduct current from the resistor 26 towards the resistor 57. Also, the second circuit consists of a storage capacitor 58 which is connected between the cathode of the diode 59 and the negative supply lead 21. As illustrated in FIG. 4, the transistors 52 and 63 are selected to be of the npn type while the switching transistor 68 is selected to be of the pnp type.

The operation of the embodiment shown in FIG. 4 will now be described. During normal initial closing of the breaker switch 18, the tap point between the resistor 26 and the breaker switch 18 is placed at ground potential so that the control electrode 24 is not sufficiently positive to cause the transistor 52 become conductive. With the transistor 52 non-conductive, the collector 55 thereof is sufficiently positive in relation to the emitter 64 of the transistor 63, that the latter transistor becomes conductive and a current flows from the positive supply lead 23 through the resistors 66 and 67 through the emitter-collector path 65-64 towards the negative supply lead 21. The current flowing through this voltage divider develops a voltage at the tap point 70 which is sufficiently negative in relation to the emitter 71 of the transistor 68 so that the latter transistor becomes conductive and current flows through the emitter-collector path 71-72 into the primary winding 14 where energy is stored as described above.

When the breaker switch 18 initially opens during its open interval, the junction point between the resistor 26 and breaker switch 18 becomes highly positive so that the diode 59 becomes conductive in a forward direction and a current flows therethrough to both provide a base current in the base 56 as well as to provide a charging current to charge the capacitor 58. Thus, when the breaker switch opens, the transistor 52 becomes conductive and its collector 55 drops sharply in the negative direction to a point where it is no longer sufficiently positive in relation to the emitter 64 of the transistor 63 so that the negative element 65, 67 maintain the conductive state of the latter. With the transistor 52 turned off, the current originally flowing through the resistors 66 and 67 ceases and the voltage at the tap point 70 rises sharply.
towards the voltage of the positive supply lead 23. The rise in voltage at the tap point 70 no longer places the base 69 at a voltage sufficiently negative with respect to the emitter 71 of the transistor 68 to maintain the latter in a conductive state and the transistor becomes non-conductive. In accordance with the operation described above, such an abrupt change in current in the primary winding 14 causes a very high induced voltage in the secondary winding 12 to thereby produce a spark across the sparkplug 13. As long as the breaker switch 18 remains open, current continues to flow from the positive supply lead 23, the resistor 26, the diode 59 into the storage capacitor 58 to charge the same. The current flowing through the diode 59 also produces the base current for the transistor 52 as described above. Should the breaker switch 18 now momentarily close after initial opening, the anode of the diode 59 is placed at the ground potential while its cathode is at the potential developed across the capacitor 58. Therefore, the diode 59 becomes non-conductive. However, the capacitor 58 has sufficient charge stored thereon so that it may continue to supply a base current through the resistor 57 to the transistor 52 to maintain the same in a conductive state in spite of a momentary closing of the switch 18. The time during which the transistor 52 can be so maintained conductive when the switch 18 is closed is determined by the time constant of the capacitor 58 and the resistors 57 and 60. It will be noted that the operation of the embodiments in FIG. 4 is somewhat different than that discussed previously in relation to the embodiments of FIGS. 1-3. Thus, in the earlier embodiments, the energy stored for purposes of compensating for momentary closings of the breaker switch 18 was the same energy stored during a normal closing of the switch 18. In the embodiment of FIG. 4, however, the energy stored for this purpose is not stored during the normal closing of the breaker switch 18 but is rather stored during the short initial opening interval of the breaker switch 18 prior to the undesired momentary closing thereof.

In the circuits of FIG. 4, the discharge resistor 60 is so chosen that the storage capacitor 58 after the closing of the breaker switch 18 discharges the latter in a relatively short period of time during the normal closing interval of the switch. However, the discharge current is made small enough so that the capacitor 60 does not fully discharge during the anticipated time intervals during which the breaker switch 18 is contemplated to momentarily close after a normal opening of the switch. In this manner, the storage capacitor 58 acts as a source of voltage during the critical time intervals when the breaker switch 18 may close to maintain the control electrode 24 potential the same as it would be were the breaker switch 18 to remain continuously open. The diode 59 is selected to conduct current in the direction described above to thereby permit a quick charging of the storage capacitor 58 while preventing an equally rapid discharging thereof when the switch 18 closes.

The ignition system illustrated in FIG. 5 differs from the previous embodiments in that the driving circuit has been totally eliminated from the first circuit. Here the control circuit of the first circuit, similarly to that in FIG. 2, consists of a pair of resistors 26 and 27 connected in series with each other to form a voltage divider between the positive supply lead 23 and the breaker switch 18. A diode 48 is connected between the resistors 26 and 27, the resistor 26 and the anode of the diode 48 forming a tap point which is connected to the control electrode 24. A storage means similar to that in FIG. 4 is utilized here and this consists of the storage capacitor 58. The second circuit in this embodiment is similar to that described in connection with FIG. 2 except that the second circuit is not dependent here upon energy storage from the primary winding 14 but rather from the energy stored in the capacitor 58. Thus, the second circuit here comprises a transistor 39 whose emitter is connected to the positive supply lead 23 and its collector is connected to the cathode of the diode 48. The base 42 of the transistor 39 is connected to the collector 46 of the transistor 44. The transistor 39 is a pnp transistor while the transistor 44 is an npn transistor. The emitter 45 of the transistor 44 is connected to the negative supply lead 21 while its base 47 is connected to the storage capacitor 58 through a limiting resistor 73. As in FIG. 4, the storage capacitor 58 is connected to a source of current by means of a diode 59 and a parallel connected resistor 60. In this case, the diode 59 and resistor 60 are connected between the storage capacitor 58 and the cathode of the diode 48.

The operation of the embodiment illustrated in FIG. 5 will now be described. It will be assumed that the capacitor 58 is initially discharged so that the base 47 of the transistor 44 is substantially at the same potential as its emitter so that the transistor 44 is in a non-conductive state. This, as will be described, also causes the transistor 39 to be non-conductive. With the breaker switch 18 closed, the series connected resistors 26 and 27 as well as the diode 48 are placed across the positive and negative supply leads 23 and 21 respectively so that a current flows from the former to the latter. In this state, the diode 48 is conductive and a voltage is developed across the resistor 26 which is sufficiently high to apply to the control electrode 24 or the base 69 a sufficiently high negative voltage in relation to that appearing at the emitter 71 of the switching transistor 68 so that the latter becomes conductive and a collector current flows through the collector 72 into the primary winding 14. Energy is stored in the primary winding 14 during the normally closed interval of the breaker switch 18.

When the breaker switch opens, assuming that the second circuit were not provided, the current flow in the resistor 26 is interrupted so that the control electrode 24 attains the positive potential present as the positive supply lead to thereby equalize the voltages at the emitter 71 and the base 69 whereby the switching transistor 68 is made non-conductive. Therewith, the current flow in the primary winding 14 is interrupted and a high voltage is induced in the secondary winding 12 to thereby generate a spark across the spark gap 13.

Were a second circuit not be provided, a momentary closing of the breaker switch 18 after initial opening would produce a closing of the emitter-collector path 71-72. This would result in the disadvantages discussed above. However, with the second circuit provided as shown, the opening of the breaker switch 18 raises the potential of the anode of the diode 59 sufficiently to make the same conductive and a current flows through the positive supply lead 23, through the resistor 26, diode 48, the diode 59 to the storage capacitor 58. The current flowing through the diode 59 charges the ca-
capacitor 58 as well as provides a base current which flows through the resistor 73 into the base 47 to
thereby turn the transistor 44 on or to make the emit-
tter-collector path 45-46 conductive. Since the transis-
tor 39 is of the npn type and the transistor 44 is of the
npn type, current flow in the collector 46 forms a base
current in the base 42 which is effective to make the
transistor 39 similarly conductive. When the emitter-
collector path 40-41 of the transistor 39 becomes con-
ductive, it presents a virtual short circuit between the
positive supply lead 23 and the anode of the diode 59
to thereby place the latter at such a high positive poten-
tial that a momentary closing of the breaker switch 18
does not bring the cathode of the diode 48 to a suffi-
ciently negative voltage to turn the latter diode on. As
long as the diode 48 remains in its non-conductive
state, no current can flow through the resistor 26 and
the transistor 68 remains non-conductive. As in the em-
bodyment shown in FIG. 4, the time during which
momentary closings of the breaker switch 18 can be
masked is a function of the time constant of the capaci-
tor 58 as well as the resistors 60 and 27. Now, when the
breaker switch 18 momentarily closes after initial
opening, the anode of the diode 59 is placed at a more
negative potential than its cathode so that it becomes
non-conductive. However, the charge on the capacitor
58 is still sufficiently positive to continually supply a
base current to the base 47 of the transistor 44. As long
as this occurs, the transistor 39 remains conductive and
the switching transistor 68 is prevented from turning
on. Ultimately, when the breaker switch 18 opens
again, the capacitor 58 discharges through the resistors
27 and 60. When this occurs, the base 47 is substi-
tially at the same potential as the emitter 45 so that the
transistor 44 becomes non-conductive and thereby the
transistor 39 similarly becomes non-conductive. Under
these conditions, the cathode of the diode 48 drops to-
wards the negative potential and becomes conductive
whereby the control electrode 24 becomes more nega-
tive in respect to the emitter 71 and the switching tran-
sistor 68 can once again conduct.

It will be understood that each of the elements de-
scribed above, or two or more together, may also find
a useful application in other types of control circuit dif-
ferring from the types described above.

While the invention has been illustrated and de-
scribed as embodied in ignition systems for internal
combustion engines, it is not intended to be limited to
the details shown, since various modifications and
structural changes may be made without departing in
any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully
reveal the gist of the present invention that others can
by applying current knowledge readily adapt it for vari-
ous applications without omitting features that, from
the standpoint of prior art, fairly constitute essential
characteristics of the generic or specific aspects of this
invention and, therefore, such adaptations should and
are intended to be comprehended within the meaning
and range of equivalence of the following claims.

What is claimed as new and desired to be protected
by Letters Patent is set forth in the appended claims:

1. In an ignition system for an internal combustion
engine of the type including an ignition transformer
comprised of a primary winding and a secondary wind-
ing and spark producing means connected across said
secondary winding, in combination therewith, a rotary
element driven by and rotating in synchronism with the
engine; an ignition breaker switch coupled to said ro-
tary element and arranged to be open during first time
intervals corresponding to first predetermined ranges
of angular positions of said rotary element and to be
closed during second time intervals alternating with
said first time intervals and corresponding to second
predetermined ranges of angular positions of said ro-
tary element; switching means connected in the current
path of said primary winding and operative when open
for preventing flow of current through said primary
winding through such current path and operative when
closed for permitting flow of current through said pri-
mary winding through such current path; first circuit
means connected between said ignition breaker switch
and said switching means and normally operative for
causingsaidswitchingmeans to open when said
breaker switch opens and for causing said switching
means to close when said breaker switch closes; and
second circuit means connected to said first circuit
means and operative if due to faulty operation said
breaker switch briefly closes during one of said first
time intervals for maintaining said switching means
open despite such brief closing of said breaker switch.

2. A combination as defined in claim 1, wherein said
first circuit means comprises driving means connected
to said switching means and having a control electrode;
and signal control means connected to said breaker
switch and to said control electrode for generating sig-
nals during said first and second intervals in response
to opening and closing of said breaker switch at said
control electrode which causes said driving means to
correspondingly open and close said switching means.

3. A combination as defined in claim 2, wherein said
second circuit means is connected to said control elec-
trode and is arranged to maintain said driving means in
a condition wherein the latter prevents said switching
means from closing during at least portions of said first
intervals.

4. A combination as defined in claim 3, wherein said
first circuit means further comprises first and second
leads each connectable to a respective pole of a source
of electrical energy, connected primary winding and
switching means being connected in series between
said first and second leads, said ignition breaker switch
having two terminals one of which is connected to one
of said leads and the other terminal of which is con-
ected to said control electrode.

5. A combination as defined in claim 4, wherein said
one of said leads to which said one terminal is con-
ected constitutes said second lead, and wherein said
first circuit means further comprises first resistance
means connected between said first lead and said other
terminal of said ignition breaker switch.

6. A combination as defined in claim 5, wherein said
first circuit means further comprises second resistance
means connected between said first resistance means
and said other terminal of said ignition breaker switch,
said first and second resistance means forming a tap
point connected to said control electrode.

7. A combination as defined in claim 5, wherein said
series connected primary winding and switching means
form a tap point, said tap point being connected to said
other terminal of said ignition breaker switch.
8. A combination as defined in claim 7, further comprising capacitor means connected between said tap point and one of said first and second leads.

9. A combination as defined in claim 8, wherein said capacitor means is connected between said tap point and said second lead.

10. A combination as defined in claim 4, wherein said first circuit means comprises capacitor means for storing electrical energy when said ignition breaker switch is open during said first intervals, said capacitor means being arranged to discharge said electrical energy during said at least portions of said first intervals to thereby apply a maintaining signal to said control electrode for maintaining said switching means open during said portions of said first intervals.

11. A combination as defined in claim 4, wherein said second circuit means includes a discharge conductor lead connecting the tap point between said series connected primary winding and switching means with said control electrode.

12. A combination as defined in claim 11, wherein said second circuit means further comprises a resistance connected between said discharge conductor lead and said control electrode.

13. A combination as defined in claim 12, wherein said second circuit means further comprises a voltage reference means connected in series with said resistance and said discharge conductor lead.

14. A combination as defined in claim 13, wherein said voltage reference means comprises a Zener diode.

15. A combination as defined in claim 12, wherein said second circuit means further comprises diode means connected in series with said resistance and said discharge conductor lead.

16. A combination as defined in claim 11, wherein said one lead constitutes said second lead, and wherein said first circuit means comprises first resistance means connected between said first lead and said other terminal of said ignition breaker switch, and said discharge conductor lead being connected to said other terminal.

17. A combination as defined in claim 6, said second circuit means further comprises a switch connected between said first lead and said tap point, said switch being actuable during said portions of said first intervals to maintain said switching means open irrespective of closing of said ignition breaker switch during said portions.

18. A combination as defined in claim 17, wherein said switch comprises a switching transistor having its emitter-collector path connected between said first lead and said tap point, and having its base actuated during said portions of said first intervals to close said path to thereby maintain said switching means open during said interval portions.

19. A combination as defined in claim 6, further comprising diode means connected between said first and second resistance means arranged to conduct current from the former to the latter.

20. A combination as defined in claim 18, wherein said second circuit means further comprises a control transistor having its emitter-collector path connected between the base of said switching transistor and said second lead, and having a base actuable during said portions of said first intervals, to thereby close said switching transistor emitter-collector path.

21. A combination as defined in claim 20, wherein second circuit means includes a discharge conductor lead connecting the tap point between said series connected primary winding and switching means with said control electrode, said discharge conductor being connected to the base of said control transistor.

22. A combination as defined in claim 5, further comprising diode means connected between said other terminal of said ignition breaker means and the junction of said primary winding and said switching means.

23. A combination as defined in claim 22, wherein said diode means comprises a diode arranged to conduct current which flows from said first lead through said first resistance means during said portions of said intervals, said diode also being connected to said control electrode.

24. A combination as defined in claim 23, wherein said second circuit means further comprises first and second resistors connected in series with one another, said series connected resistors being connected in parallel to said switching means.

25. A combination as defined in claim 24, wherein said first and second resistors form a tap point, said second circuit means further comprising capacitor means connected between said tap point and said second lead, said tap point also being connected between said diode and said control electrode.

26. A combination as defined in claim 5, wherein said second circuit means further comprises diode means connected between said other terminal and said control electrode; and capacitor means connected between said control electrode and said second lead.

27. A combination as defined in claim 26, wherein said diode means comprises a diode arranged to conduct current in a direction from said first resistance means towards said control electrode.

28. A combination as defined in claim 26, further including resistor means connected in parallel with said diode means.

29. A combination as defined in claim 26, further including second resistance means connected between said other terminal and said diode means.

30. A combination as defined in claim 26, wherein said second circuit means further includes a transistor having its base connected to said diode means and its emitter-collector path connected between said second lead and said control electrode.

31. A combination as defined in claim 30, further comprising a resistance connected between said diode means and the base of said transistor.

32. A combination as defined in claim 4, wherein said driving means comprises a transistor having its emitter-collector path connected between said first and second leads, and having its base connected to said control electrode, said transistor being connected to said switching means for controlling the open and closed states of the latter.

33. A combination as defined in claim 4, wherein said switching means comprises a transistor having its emitter-collector path connected in series with said primary winding and having its base directly connected to said control electrode.

34. A combination as defined in claim 4, wherein said driving means comprises a transistor having its emitter-collector path connected between said first and second leads; said signal control means comprising first and
second resistance means connected in series with each other and with said breaker switch between said first and second leads to form a tap, said tap being connected to the base of said transistor, said transistor being connected to said switching means for controlling the open and closed states of the latter.

35. A combination as defined in claim 34, further comprising diode means connected between said first and second resistance means, the base of said transistor being connected to a tap point formed by said diode means and one of said resistance means.

36. A combination as defined in claim 35, wherein said first resistance means is connected to said first lead, said second resistance is connected to said second lead, and the base of said transistor is connected to a tap point formed by said first resistance means and said diode means.

37. A combination as defined in claim 4, wherein said driving means comprises a transistor having its emitter-collector path connected between said first and second leads; said signal control means comprising first resistance means connected in series to said breaker switch to form a tap, the latter series combination being connected between said first and second leads, the base of said transistor being connected to said tap.

38. A combination as defined in claim 37, further comprising diode means connected between the said base and said tap.

39. A combination as defined in claim 38, wherein said diode means comprise a diode arranged to conduct current from said tap to said base.

40. A combination as defined in claim 38, further comprising resistance means connected between said diode means and said base.

41. In an ignition system for an internal combustion engine of the type including an ignition transformer comprised of a primary winding and a secondary winding and spark producing means connected across said secondary winding, in combination therewith, a rotary element driven by and rotating in synchronism with the engine; an ignition breaker switch coupled to said rotary element and arranged to be open during first time intervals corresponding to first predetermined ranges of angular positions of said rotary element and to be closed during second time intervals alternating with said first time intervals and corresponding to second predetermined ranges of angular positions of said rotary element; switching means connected in the current path of said primary winding and operative when open for preventing flow of current through said primary winding through such current path and operative when closed for permitting flow of current through said primary winding through such current path; first circuit means connected between said ignition breaker switch and said switching means and normally operative for causing said switching means to open when said breaker switch opens for causing said switching means to close when said breaker switch closes, and wherein said primary winding constitutes an energy storing element which stores energy during said second intervals; and second circuit means operative for utilizing at least part of the energy stored in said primary winding for maintaining said switching means open during brief closing of said breaker switch in the event that due to faulty operation said breaker switch briefly closes during one of said first time intervals, and wherein said switching means includes an electronic switch element having a current path connected in said current path of said primary winding and having a control electrode connected to and controlled by said first circuit means.