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[54] **IGNITION ARRANGEMENT FOR INTERNAL COMBUSTION ENGINES**

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[51] **Int. Cl.**.......................... **F02p 3/06,** H05b 41/36

[58] **Field of Search** .... 123/148 E

[56] **References Cited**

UNITED STATES PATENTS

3,238,416	3/1966	Huntzinger	123/148 E
3,335,320	8/1967	Quinn	123/148 E
3,415,234	12/1968	Dammann	123/148 E
3,418,988	12/1968	Lewis et al.	123/148 E
3,487,822	1/1970	Hufton	123/148 E
3,575,153	4/1971	Hardin	123/148 E
3,502,955	3/1970	Minks	123/148 E
3,546,528	12/1970	Fisher	123/148 E

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Assistant Examiner—Cort Flint
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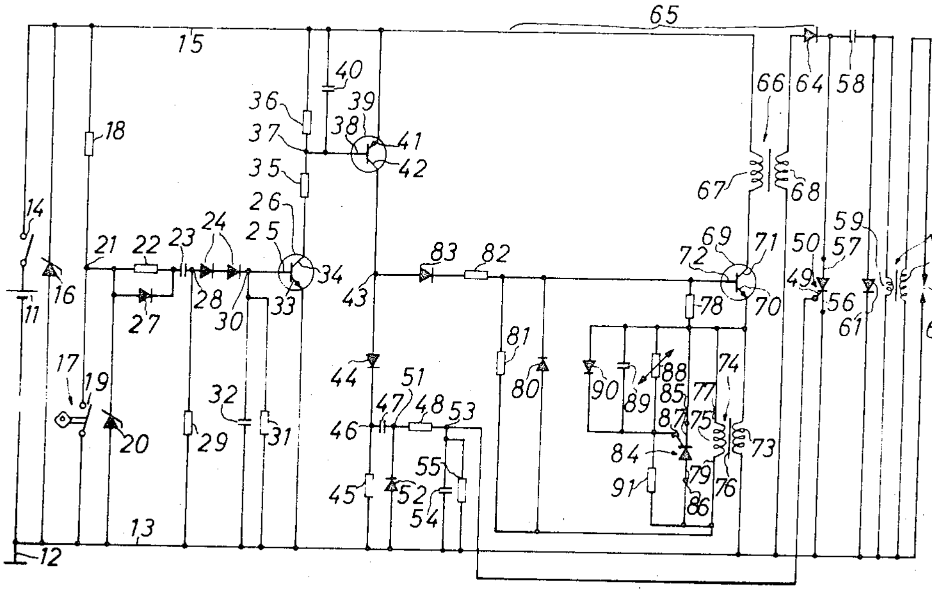
[57] **ABSTRACT**

An electronic ignition arrangement for internal combustion engines in which an ignition capacitor is connected to a charging circuit and a discharging circuit. A controlled electronic switch in the discharging circuit is connected in series with the primary winding of an ignition transformer which applies ignition pulses to the spark plugs. A signal generator coupled to the crankshaft of the engine operates the controlled electronic switch in the discharge circuit, synchronously with the engine. A charging transformer in the charging circuit has its primary winding interconnected with the primary winding of a control transformer, the secondary winding of which functions as a feedback winding. An auxiliary controlled electronic switch is connected in circuit with the primary winding of the charging transformer, and a limiting switch is connected to the primary winding of the control transformer.

33 Claims, 10 Drawing Figures



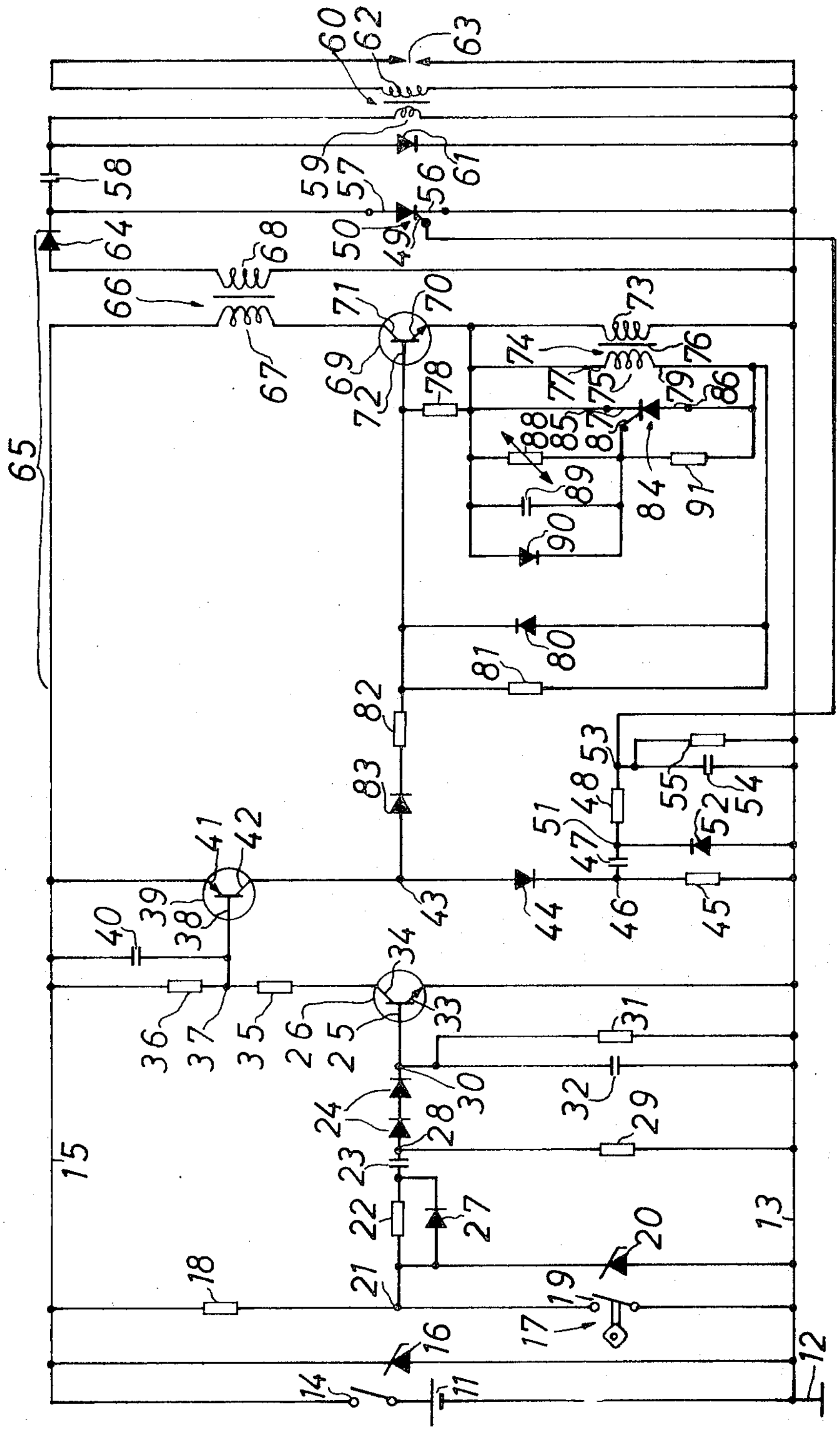


Fig. 1

Fig. 2

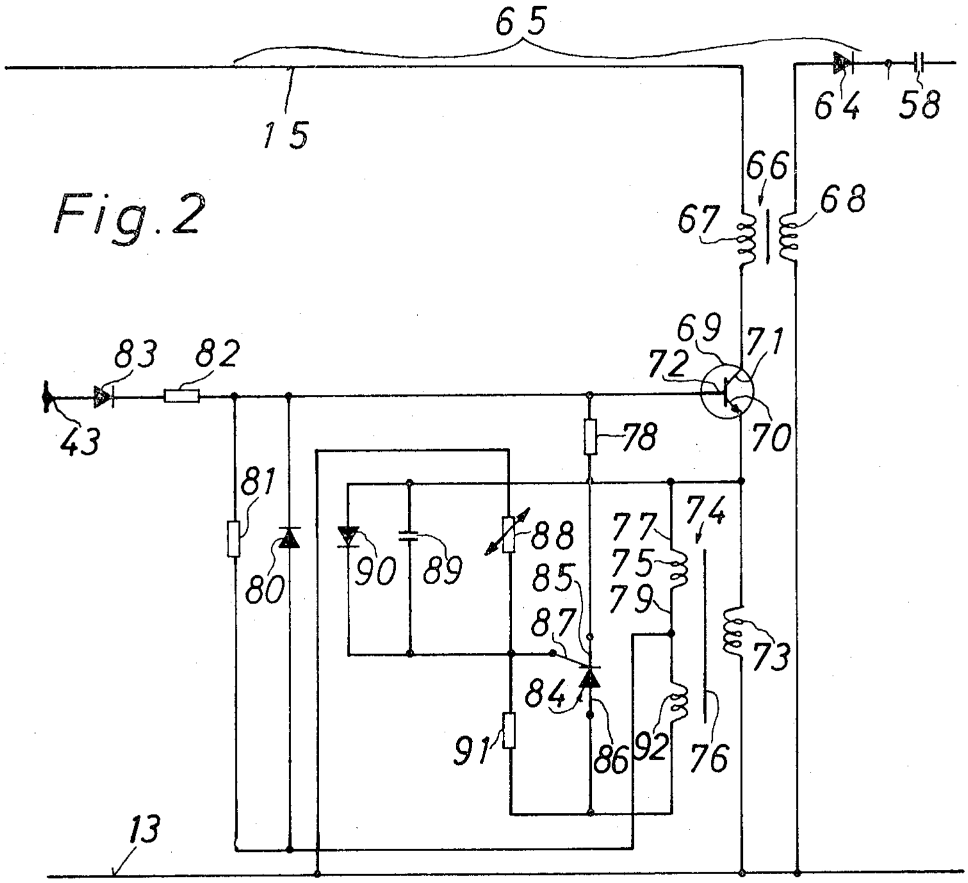

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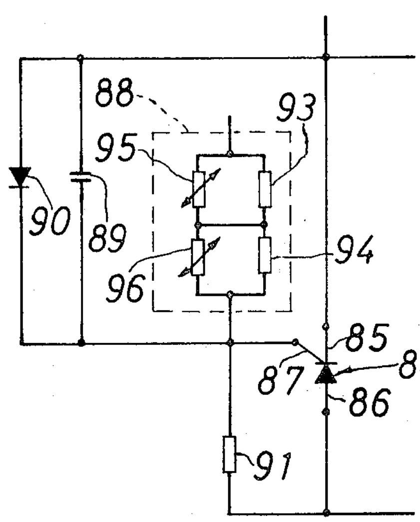
Fig. 3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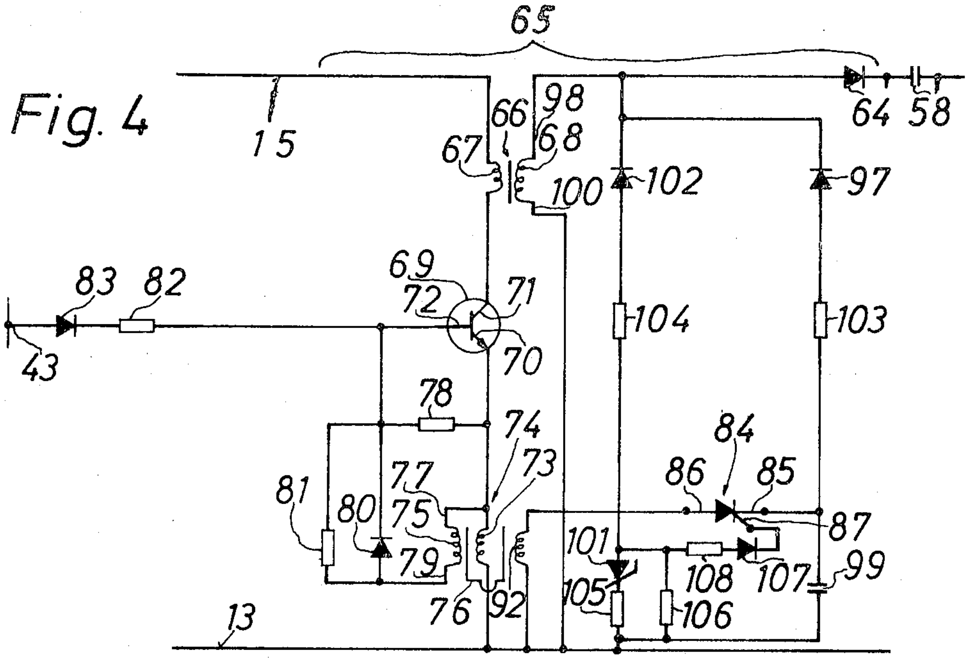
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Fig. 4

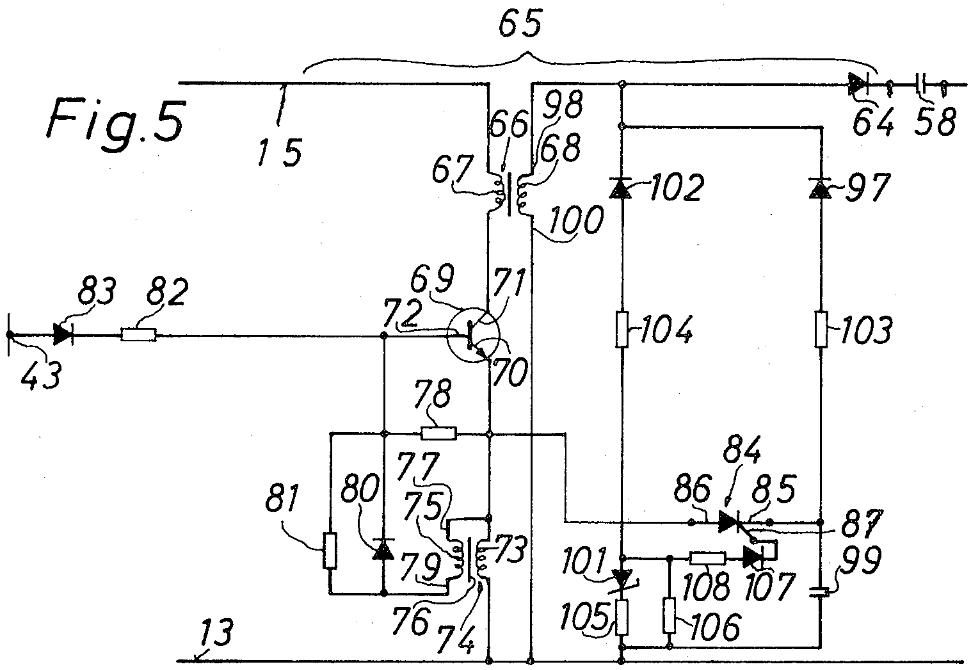
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Fig. 5

Fig. 6

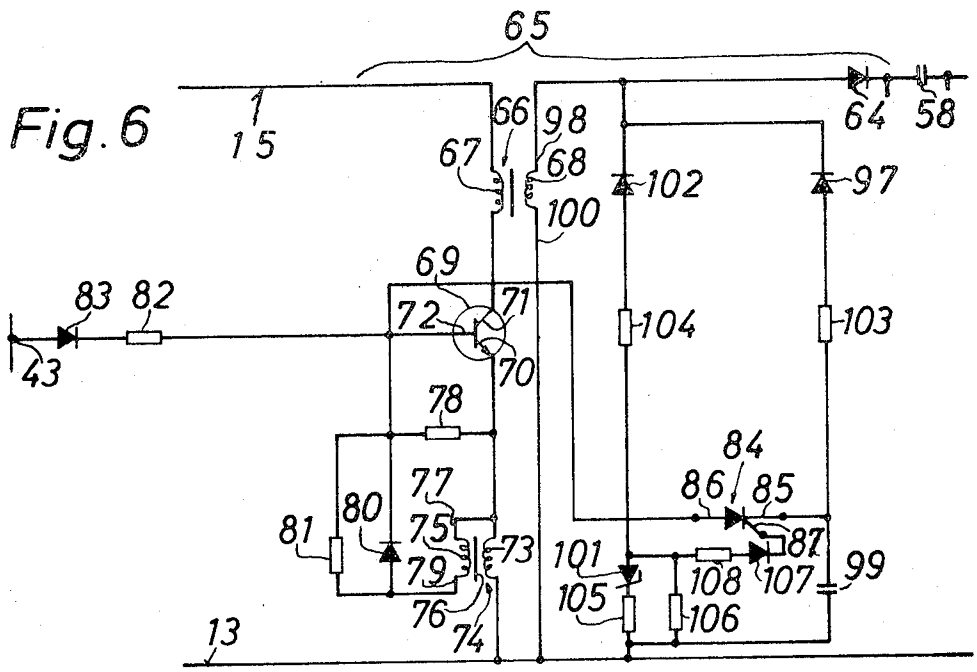
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Fig. 7

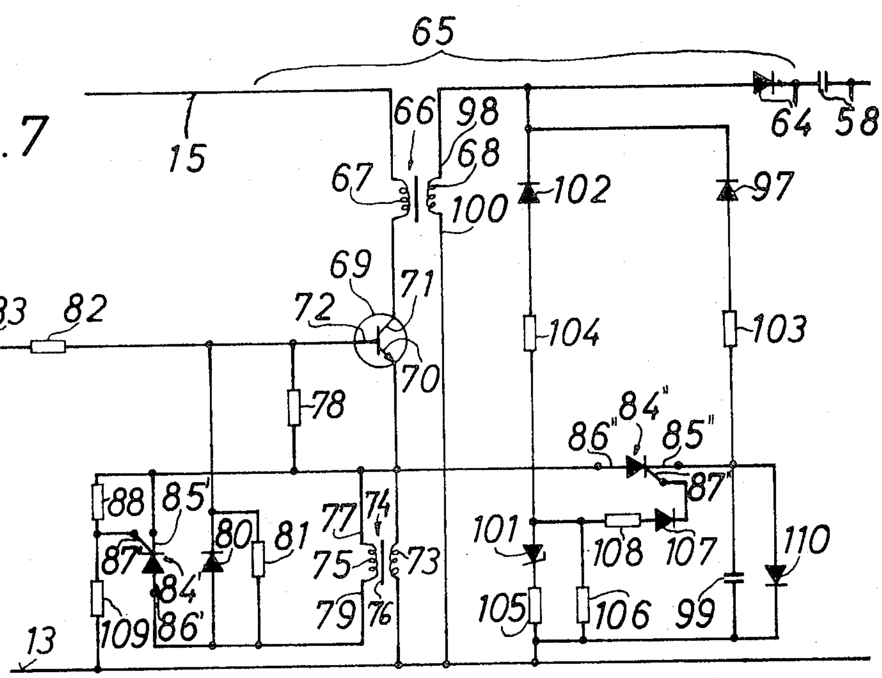
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Fig.8

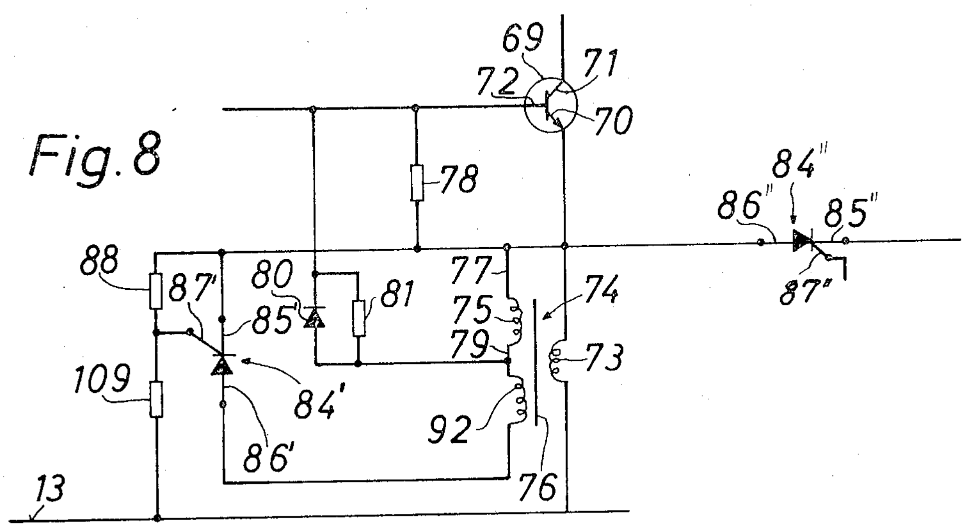
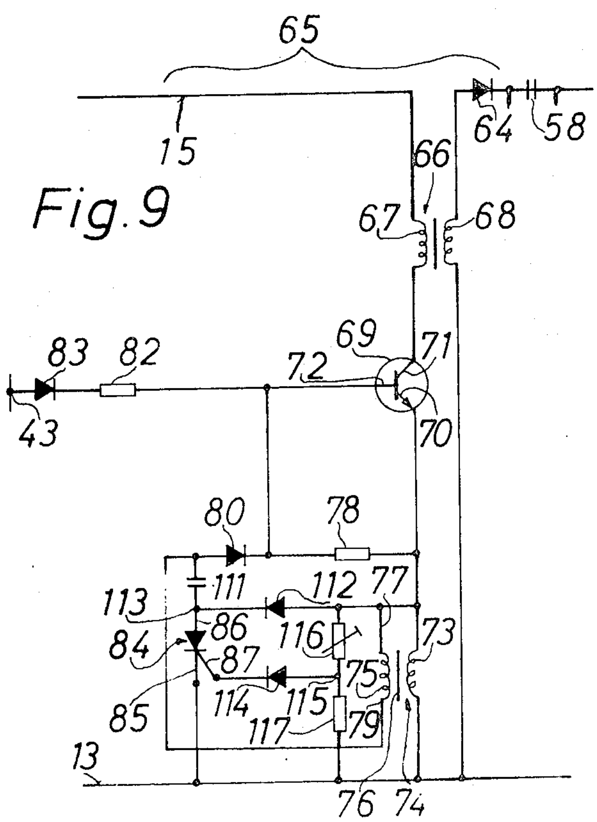


Fig.9



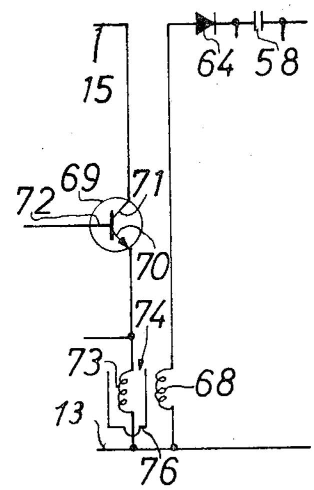


Fig.10

IGNITION ARRANGEMENT FOR INTERNAL COMBUSTION ENGINES

BACKGROUND OF THE INVENTION

The present invention relates to an ignition arrangement for internal combustion engines, in which an ignition capacitor is connected to a charging circuit as well as a discharging circuit. The discharging circuit includes a controllable electronic discharge switch connected in series with the primary winding of an ignition transformer. The secondary winding of this ignition transformer is connected to the spark plugs of the engine. The control electrode of the electronic discharge switch is subjected to signals from a signal generator operated by the engine. The charging circuit is, furthermore, constructed of a primary current circuit of a DC voltage converter, which is inductively coupled to a secondary circuit. This primary circuit of the DC voltage converter, is in turn connected to a voltage source. The primary winding of a control transformer is connected in series with the switching circuit path of a controllable electronic limiting switch whereas the control circuit of this limiting switch is connected to the secondary winding of the control transformer which serves as a feedback winding.

In the ignition arrangement of the preceding species, an igniton voltage pulse is obtained with relatively steep rising edge which produces sparking at the spark plugs even when the latter are severely soiled.

In an ignition arrangement of the preceding species, known in the art, a single signal from the signal generator is used to discharge the ignition capacitor and thereby produce a high voltage ignition pulse for the spark plug. At the same time, this same signal is also used for recharging the ignition capacitor for the subsequent ignition process. For the purpose of charging the ignition capacitor, the limiting switch becomes first switched to the conducting state, and this conducting state is maintained thereafter through current in the primary winding of the control transformer as well as in the feedback winding or secondary winding of this control transformer. The conducting state of the limiting switch, furthermore, is maintained until the core of the control transformer becomes saturated and the threshold level of the control path of the limiting switch is not reached by the voltage from the feedback winding connected to the control path or control circuit of the limiting switch. The primary circuit of the DC voltage converter becomes, thereby interrupted, and a charging current pulse is induced within the secondary winding for the purpose of charging the ignition capacitor for the next ignition process. By making use of the saturation of the core of the control transformer to switch the limiting switch, it is difficult to achieve an abrupt interruption of the primary circuit of the DC voltage converter. As a result, the charging voltage across the ignition capacitor does not have a satisfactory level in each case. In addition, difficulties are encountered in the precise control of the limiting switch.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an ignition arrangement of the preceding species, as set forth, in which the disadvantages associated with that species are avoided.

It is a further object of the present invention to provide an arrangement of the foregoing character which will provide ignition of spark plugs in an internal combustion engine, in a reliable manner.

Another object of the present invention is to provide an ignition arrangement which may be readily fabricated and economically maintained.

The objects of the present invention are achieved by providing an auxiliary current circuit inductively coupled to the primary circuit for charging the ignition capacitor. The auxiliary current circuit is connected with at least one controllable electronic auxiliary switch for switching the control circuit path of the switch by the feedback winding of the control transformer. The switching circuit path of a limiting switch is, furthermore, connected in series with the primary winding of the control transformer, and is used operatively in the non-conductive state.

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 drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a ciruit diagram of the ignition arrangement, in accordance with the present invention, and shows the applicable components as well as their interconnections;

FIGS. **2** to **10** are circuit diagrams of further embodiments of a DC voltage converter used in the ignition arrangement of FIG. **1**, in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawing, the ignition arrangement shown therein is used in conjunction with an internal combustion engine, not shown. The ignition arrangement is supplied with DC current from a low voltage source **11** which, for example, can be in the form of a 12 volt battery as used in motor vehicles. From the low voltage source **11**, a line **12** is taken as the negative voltage supply line **13** which is also connected to ground potential. A positive voltage supply line **15**, furthermore, is taken from the battery through an operating switch or ignition switch **14**. A zener diode **16** is provided across the negative voltage supply line **13** and a positive voltage supply line **15**, for the purpose of voltage stabilization. A series circuit including a signal emitter or generator **17** as well as the resistor **18**, is, furthermore, connected between the two voltage supply lines **13** and **15**. The signal emitter or generator **17** is connected to the negative voltage supply line **13** with one of its terminals, whereas one terminal of the resistor **18** is connected to the positive voltage supply line **15**. The signal generator or emitter **17** is coupled to the internal combustion engine, and is designed preferably in the form of a cam operated interrupting switch **19**. A zener diode **20** is connected across this interrupting switch **19** for the purpose of providing voltage stabilization features. The junction **21** of the Zener diode **20** and the switch **19**, is connected through a series circuit, to the base **25** of an npn transistor **26**. This series circuit connecting the junction with this base of the transistor 26, consists of a resistor 22 in series with a differentiating capacitor 23. Diodes 24, furthermore, are connected in series with the differentiating capacitor 23. A diode 27, furthermore, is connected in parallel with the resistor 22. A resistor 29 is connected between the junction of the capacitor 23 and diodes 24 (junction 28), and the negative voltage supply line 13. A further resistor 31 is connected between the junction 30 of the diodes 24 and base 25 of transistor 26, and the negative voltage supply line 13. A capacitor 32 is connected in parallel with the resistor 31. The emitter 33 of the transistor 26 is connected directly to the negative voltage supply line 13, whereas the collector 23 leads, through two voltage dividing resistors 35, 36, to the positive voltage supply line 15. The junction 37 between the two voltage dividing resistors 35, 36 is connected to the base 38 of a pnp transistor 39, as well as to one terminal of a capacitor 40. The other terminal of this capacitor 40 is connected to the positive voltage supply line 15.

The emitter 41 of the transistor 49 is connected directly to the positive voltage supply line 15, whereas the collector of this transistor 39 is connected to a control junction 43. The anode of a diode 44 is connected to this control junction 43, and the cathode of this diode 44 leads to the negative voltage supply line 13, through a resistor 45. The junction 46 between the diode 44 and resistor 45 leads, through a differentiating capacitor 47 and resistor 48, to the control gate or electrode 49 of an electronic controlled switch 50, which may be in the form of a semi-conductor controlled rectifier or thyristor. The cathode of a diode 52 is connected to the junction 51 between the capacitor 47 and resistor 48, whereas the anode of the diode 52 is connected to the negative voltage supply line 13. A capacitor 54, furthermore, is connected between the junction 53 between the resistor 48 and the gate 49 of the switch 50 and the negative voltage supply line 13. A resistor 55 is connected in parallel with the capacitor 54.

The switch 50 is used as a discharge switch for which a thyristor may be applied. This thyristor has as its gate the control electrode 49, the cathode 56, and anode 57. A capacitor 58 which functions as an ignition capacitor is connected between the anode 57 of the switch 50, and the anode of a diode 61 which is, in turn, connected in parallel with the primary winding 59 of a transformer 60. The latter functions as an ignition transformer which has a spark plug 63 across the secondary winding 62. The cathode of the diode 61 is connected to the negative voltage supply line 13. Accordingly, one terminal of the ignition capacitor 58 is connected to both the anode of the diode 61, as well as the primary winding 59 of the ignition transformer 60.

Charging current for the ignition capacitor 58 is provided through a diode 64 which functions as a rectifier within a DC voltage converter 65. The latter circuit includes a transformer 66 having a winding 68 which functions as the secondary winding of the transformer, connected to the anode of the diode 64. The primary winding of this transformer 66 is within the primary circuit of this DC voltage converter, and is designated as the primary winding 67.

A controllable electronic limiting switch 69 is, furthermore, provided in the form of preferably an npn transistor with emitter 70, collector 71 and base 72. The collector functions as the output electrode or terminal, whereas the base 72 functions as the control electrode or terminal. The emitter-collector path of the transistor 69 is connected in series with the primary winding 67 of the transformer 66, as well as in series with the primary winding 73 of a control transformer 74. The primary winding 67 of the transformer 66, furthermore, is connected between the collector 71 of the transistor 69 and the positive voltage supply line 15. The primary winding 73 of the control transformer 74, on the other hand, is connected between the emitter 70 of the transistor 69 and the negative voltage supply line 13.

The emitter 70 of the limiting switch or transistor 69 is connected to a feedback winding 75 which is inductively coupled to the primary winding 73 of the control transformer 74. The inductive coupling is provided through the core 76 of the transformer. A resistor 78 is connected between the base 72 of the transistor 69, and its emitter 70. The terminal 79 of one end of the winding 75 is connected to the anode of a diode 80, whereas the cathode of this diode 80 is connected directly to the base 72 of the transistor 69. A resistor 81 is connected across the diode 80 in a preferred design. A series circuit including a diode 83 and resistor 82 is, moreover, connected between the base of the transistor or limiting switch 69 and the circuit junction 43.

Within the DC converter 65 is an auxiliary electronic switch 84, referred to herein as a cut-off switch for switching the limiting switch 69 to the non-conducting state. In the preferred situation, the auxiliary switch 84 is in the form of a thyristor having its cathode functioning as the reference electrode 85. The anode of this thyristor 84 functions as the output terminal for electrode 86, whereas the gate of the thyristor functions as the control electrode 87. The emitter-collector path of the transistor 69, furthermore, is indirectly controlled, at the same time, by the control transformer 74. This results from the condition that when the thyristor 84 is in the conducting state, the voltage provided by the feedback winding 75 between the base and emitter of the transistor 69 may be reduced to a level which is below the threshold of the control path or base-emitter path of this transistor. The threshold in this case, is to be understood as that voltage level which is required to reliably switch the transistor 69 so that the emitter-collector path is in the conducting state.

The auxiliary current circuit including the feedback winding 75 in FIG. 1, is designed, furthermore, so that the terminal 77 of the winding 75 is connected directly to the cathode of the thyristor 84, while the terminal 79 of this winding 75 is connected to the anode of this thyristor 84. A resistor 88 is connected between the control electrode or gate 87 and the cathode 85 of the thyristor 84. From the viewpoint of stabilization this resistor 88 is preferably in the form of a temperature dependent resistor having a negative temperature coefficient. In a preferred design, it is desirable to connect a capacitor 89 across the resistor 88, and to also connect a diode 90 in parallel with this capacitor 89. A resistor 91 is, furthermore, provided between the control gate 87 of the auxiliary switch 84 and its anode 86.

In operation of the ignition arrangement of FIG. 1, the ignition arrangement is made operable for the internal combustion engine through the closure of the switch 14. During operation, the signal emitter or generator 17 provides a signal at the instant of ignition, and such a positive signal is obtained, in this case, through the opening of the interrupting switch 19. The resulting positive signal is transmitted, thereby, through the resistor 18, the diode 27, the differentiating capacitor 23, the diode 24, and is then applied to the base 25 of the transistor 26. As a result, the base 25 becomes positive relative to the emitter 33 to the extent that the emitter-collector path 33–34 of this transistor 26, becomes switched to the conductive state. The junction 37 of the voltage dividing resistors 35, 36 acquires thereby a potential so that the base 38 of the transistor 39 becomes negative in relation to the emitter 41 to the extent that the emitter-collector path 41–42 of this transistor 39 is also switched to the conducting state.

A positive step voltage appears, thereby, at the circuit junction 43, and this step voltage produces current flow through the diode 44 and resistor 45, with a resulting voltage drop across the resistor 45 charging current takes place through the differentiating capacitor 47 as well as the resistors 48 and 55, whereby the voltage drop across the resistor 55 causes the control gate 49 of the discharge switch 50 to become positive relative to the cathode 56, to the extent that the switch becomes conducting and cpacitor 58 discharges through switch 50 and also through the primary winding 59 of the ignition transformer 60. As a result, a high voltage pulse is induced in the secondary winding 62 of the ignition transformer 60, and a spark is thereby formed at the spark plug 63 for igniting the fuel-air mixture within the cylinder of the internal combustion engine.

The diode 61 provides for decay of the voltage oscillations at the ignition transformer 60. The capacitor 54 retains the disturbing oscillations away from the control electrode 49 of the discharge switch 50. The diode 52 makes it possible to obtain a rapid discharge of the differentiating capacitor 47. The capacitor 40 retains disturbing oscillations away from the base 38 of the transistor 39. Noise signals or voltages are, furthermore, conducted away from the base 25 of the transistor 26, by the capacitor 32. The resistor 31 serves to discharge the capacitor 32, and to set the base 25 of the transistor 26 to a predetermined potential. The resistor 29 is used for fixing the charging and discharging time interval of the differentiating capacitor 23. The transistors 26, 39 have their emitter-collector paths- 34–33, 41–42, respectively, conducting only until a predetermined quantity of electrical charge is stored within the differentiating capacitor 23. The discharge of this differentiating capacitor 23 results upon closure of the interrupting switch 19, through the resistors 22, 29. If the interrupting switch 19 chatters upon closure, then the step voltage cannot appear at the circuit junction 43, because the differentiating capacitor 23 is still charged and can, thereby not transmit a signal to the base 25 which is sufficiently large to switch the state of the emitter-collector path 33–34.

The brief rise in voltage appearing at the circuit junction 43 upon opening of the interrupting switch 19 at the instant of ignition, initiates the charging process for the ignition capacitor 58, simultaneously with the execution of the ignition process. This voltage rise is transmitted through the diode 83, as well as the resistor 82, to the control electrode 72 of the limiting switch 69. This causes the control electrode 72 to become positive in relation to the electrode 70, to the extent that the emitter-collector path 70–71 is transferred or switched to the conducting state. As a result, increasing current flows through the primary winding 67 of the charging transformer 66, as well as the primary winding 73 of the control transformer 74, in view of the inductive coupling of the primary winding 73 with the feedback winding 75. The induced voltage within the feedback 75 also increases thereby and produces, through the diode 80 as well as the resistor 81, a voltage drop across the resistor 78. After termination of the voltage rise at the circuit junction 43, this voltage drop across the resistor 78 maintains the transistor 69 in the conducting state. The induced voltage in the feedback winding 75 also prevails at the series circuit containing the resistor 88, and 91. Consequently, upon increase of this voltage, the voltage drop across the resistor 88 attains a value at which the threshold level of the switch 84 is exceeded and the switch with anode-cathode path 85–86 becomes conducting. The feedback winding 75 becomes, thereby, short-circuited, and the voltage applied to the control circuit path 70–72 of the switch 69 becomes reduced to the extent that this switch is transferred with the circuit path 70–71 to the non-conducting state. Upon interrupting of the primary circuit current of the DC voltage converter 65, a voltage pulse is induced within the secondary winding of the converter 65, which is designated as the secondary winding 68. This induced voltage pulse charges the ignition capacitor 58 through the rectifier 64, preparatory for the subsequent ignition process.

The diode 90 prevents that current in the wrong direction may be applied to the circuit path 85–87 of the switch 84. The capacitor 89 serves to maintain noise or disturbing voltage signals from this control circuit path 85-87. In the embodiment of FIG. 1, components 84, 88, 91, 89 and 90 constitute cut-off means including a cut-off switch means 84.

In the embodiments of FIGS. 2 to 10, components which are identical to those used in FIG. 1, are represented by the same reference numerals.

In the embodiment of FIG. 2, the resistor 88 is connected between the control gate 87 of the switch 84, and the negative voltage supply line 13. In this case, the voltage across the primary winding 73 of the control transformer 74 serves to switch, before it, the thyristor 84.

In the embodiment of FIG. 2, furthermore, the control transformer 74 is provided with an auxiliary winding 92. In this embodiment, the auxiliary winding 92 is connected between the terminal 79 of the feedback winding 75, and the terminal 86 of the thyristor or switch 84. With this arrangement, a sufficiently high anode voltage can be applied to the thyristor 84, without causing unnecessary power losses in the control circuit of the limiting switch 69.

In FIG. 3 it is shown that the resistor 88 may be arranged of two resistors 93 and 94 connected in series, with temperature dependent resistors 95 and 96 connected in parallel with the resistors 93 and 94, respectively. These temperature dependent resistors 95 and 96 have a negative temperature coefficient. With this design, it is possible to achieve satisfactory operation of the circuit, even upon severe temperature variations.

In the embodiment of FIG. 4, the secondary winding 68 of the DC voltage converter 65 is connected with the auxiliary current circuit in addition to the charging current circuit of the ignition capacitor 58. The auxiliary switch 84 is connected directly in the auxiliary current circuit, so that it has its cathode 85 connected, through a resistor 103 and diode 97, to the terminal 98 of the winding 68. At the same time, the cathode 85 of the switch 84 is connected, through a capacitor 99, to the negative voltage supply line 13. The other terminal 100 of the winding 68 is also connected to the negative voltage supply line 13. The gate 87 of the thyristor 84 leads, through a Zener diode 101, to the terminal 100 of the winding 68. The cathode of the diode 102 is connected to the terminal 98 of the winding 68, and the ignition capacitor 58 also leads to this terminal 98, through the diode 64. For optimum operation, it is desirable that the diode 97 is connected in series with the resistor 103, and that the diode 102 is connected with the resistor 104. The desired control potential at the electrode 87 of the thyristor 84 may be applied, when the Zener diode 101 is connected in series with a resistor 105. A resistor 106 is furthermore, connected in parallel with the series circuit of elements 101 and 105, in this preferred design. The gate 87 of the thyristor 84 is connected in series with the diode 107 and the resistor 108, so that the diode 107 passes only the proper current to the gate of the thyristor 84. The resistor 108 serves to limit the applied current to the gate 87. In this embodiment, the anode 86 of the thyristor 84 leads to the negative voltage supply line 13 through the winding 92, which has one terminal also connected to the terminal 100 of the winding 68.

In the embodiment of FIG. 4, the DC voltage converter 65 has the circuit path 70–71 of the limiting transistor switch 69, switched to the conducting state similar as in the arrangement of FIG. 1. Such switching action is accomplished through the opening of the interrupting switch 19 which causes a step voltage to appear at the circuit junction 43, which is applied to the control electrode of the switch 69, through the diode 83 as well as the resistor 82. The circuit path 70–71 of the transistor switch 69 is maintained further in the conducting state, as a result of the cooperation of the primary winding and the feedback winding 75 of the control transformer 74. This operation was described above in relation to the embodiment of FIG. 1. In this arrangement the current in the primary winding 67 of the transformer 66 increases also in addition to the current through the primary winding 73 of the control transformer 74, whereby a voltage is induced within the winding 68 which switches the rectifier 64 to the non-conducting state, whereas the diodes 97 as well as 102 become conductive. In view of the voltage across the winding 68, the capacitor 99 becomes charged, and this capacitor functions as a short-circuit until the voltage across it departs substantially from zero. A higher positive potential is applied to the electrode 85 of the switch 84 than to the gate 87. The potential at the control electrode 87 of the switch 84, is applied thereto by the circuit elements 101, 102, 104, 105, 106, 107, and 108. When the capacitor 99 has become charged to a predetermined quantity, the control gate 87 becomes positive relative to the electrode 85, to the extent that the circuit path 85–86 is switched to the conducting state. The resulting conducting path 85-86 of the switch 84 causes discharge of capacitor 99, through the auxiliary winding 92. As a result of the discharge current through the auxiliary winding 92, from the capacitor 99, the current in the primary winding 73 of the transformer 74 becomes reduced to the extent that the voltage applied to the control path 70–72 of the limiting transistor 69, by the feedback winding 75 drops below the threshold level. As a result, the circuit path 70–71 of this limiting transistor switch 69, is switched to the non-conducting state. In view of the interruption of the primary circuit current of the DC voltage converter 65, a charging voltage pulse is induced in the winding 68, which causes the diodes 97 and 102 to become blocked, whereas the rectifier 64 conducts. In this manner, the ignition capacitor 58 becomes charged for a subsequent ignition process. In accordance with the embodiment of FIG. 4, furthermore, an abrupt interruption of the primary circuit current of the DC converter 65 is also obtained in addition to the application of a charging voltage across the ignition capacitor 58, so that this charging voltage has substantially the same value at each ignition process.

The embodiment of FIG. 5 differs from that of FIG. 4 in the feature that the auxiliary winding 92 is omitted, and the electrode 86 of the thyristor 84 is directly connected to the terminal 70 of the limiting switch 69. In this case, the discharge current of the auxiliary capacitor 99 is directed so that the voltage applied to the control path 70–72 of the switch 69, by the feedback winding 75 is reduced below the threshold level.

The embodiment of FIG. 6 differs from that of FIG. 4 through the feature that the auxiliary winding 92 is also omitted and the electrode 86 of the thyristor 84 is directly connected to the control electrode of the limiting switch 69. In this case, the discharge current of the capacitor produces a voltage drop across the resistor 78, in addition to causing a reduction in the current through the primary winding 73 of the control transformer 74, when the circuit path 70–71 of the limiting switch 69 is conductive. This voltage drop across the resistor 78 opposes the voltage made available through the feedback winding 75. As a result of this arrangement, a rapid and reliable switching of the limiting switch 69 takes place.

In FIG. 7 two controllable electronic switches 84′ and 84″ are used in the form of preferably thyristors. The first switch 84′ is connected to the feedback winding 75, as in FIG. 1. The control electrode 87′ of the switch 84′ is, however, not connected to the electrode 86′, through the resistor 91. Instead, the control electrode 87′ is connected, through a resistor 109 to the negative voltage supply line 13. The capacitor 89 as well as the diodes 90 can be omitted in this embodiment. For the second auxiliary switch 84″, the charging winding 68 is connected as in the embodiment of FIG. 5, whereby a diode 110 is connected in parallel with the capacitor 99.

In the embodiment of FIG. 7 the charging of the capacitor 99 takes place similar to that described in relation to the embodiment of FIG. 4. When the capacitor 99 has become charged to a predetermined quantity, the control electrode 87″ also becomes positive here in relation to the electrode 85″, to the extent that the circuit path between the electrode 85″ and the electrode 86″ becomes switched to the conductive state. As a result, the capacitor 99 can discharge, on the one hand, through the negative voltage supply line 13, the primary winding 73 of the transformer 74 as well as the circuit path 85″–86″ of the second switch 84″. The capacitor can also discharge, on the other hand, through the negative voltage supply line 13, the resistor 109, the resistor 88, and the circuit path 85″–86″ of the second switch 84″. As a result of the voltage drop across the resistor 88, the control electrode 87′ of the first auxiliary switch 84′ becomes positive relative to the electrode 85', so that the circuit path 85'–86' becomes switched to the conducting state. With the circuit path 85'–86' in the conducting state, the feedback winding 75 becomes short-circuited. At the same time, the primary winding 73 of the control transformer 74 also becomes short-circuited, with the circuit path 85''–86'' in the conducting state. This short-circuiting of the primary winding 73 takes place through both the thyristor 84'' and the diode 110. With this circuit state, the limiting switch 69 receives no longer control voltage from the feedback winding 75, and the switch 69 is transferred, thereby to the non-conducting state so that the circuit path 70–71 is non-conducting. The interruption of the primary circuit current of the DC voltage converter 65 has here also an induced charging voltage pulse induced in the winding 68 for charging the ignition capacitor 58 through the rectifier 64, preparatory to a new ignition process.

The arrangement of FIG. 7 provides for a particularly stable charging voltage pulse and provides for reliable operation even with severe temperature variations.

The embodiment of FIG. 8 is a further development of the embodiment shown in FIG. 7. In this embodiment of FIG. 8, the control transformer 74 is again provided with the auxiliary winding 92, and the electrode 86' of the first auxiliary switch 84' is not directly connected with the feedback winding 75. Instead, the connection to the feedback winding 75 is made through the auxiliary winding 92.

In the embodiment of the DC voltage converter 65, in accordance with FIG. 9, the auxiliary switch 84 is used again only. The auxiliary circuit runs over a series circuit including a capacitor 111 and a diode 112. The circuit junction 113 of this capacitor 111 and diode 112 is connected to the anode 86 of the auxiliary switch 84. The cathode 85 of the switch 84 is connected to the negative voltage supply line 13, whereas the control gate of the switch 84 leads, through a diode 114, to the junction 115 of two voltage dividing resistors 116, 117. The voltage divider composed of these two resistors 115, 116, is connected between the anode of the diode 112 and the negative voltage supply line 13. The anode of the diode 112 is, in addition, connected to the terminal 77 of the feedback winding 75, as well as with the electrode or emitter 70 of the limiting switch or transistor 69. The capacitor 111 has one electrode connected to the terminal 79 of the feedback winding 75, and this capacitor electrode also leads to the control electrode or base 72 of the transistor 69, through the diode 80. A resistor 78 is connected between the emitter 70 and the base 72 of the transistor or limiting switch 69.

In the embodiment of the DC voltage converter 65, in accordance with FIG. 9, the circuit path 70–71 of the limiting switch 69 is switched to the conducting state in a manner similar to that described in relation to FIG. 1. Thus, the switching process takes place through the voltage rise or step voltage generated by the opening of the interrupting switch 19, and the resulting appearance of a potential at the circuit junction 43. The voltage is then transmitted from the circuit junction 43 to the base or control electrode 72, through the diode 83 and resistor 82. The circuit path 70–71 is held then further in the conducting state through the cooperative functioning of the primary winding 73 and the feedback winding 75 of the control transformer 74 – as described in relation to the embodiment of FIG. 1. Upon interruption of the primary circuit current of the DC converter 65, a step voltage appears in the feedback winding 75. This step voltage causes a negative potential to appear at the terminal of the capacitor 111 which is connected to the diode 80, in relation to the circuit junction 113. By switching on the primary circuit current of the DC voltage converter 65, the potential at the circuit junction 115 between the voltage dividing resistors 116, 117 becomes more positive, subsequent to the current rise in the primary winding 73 of the control transformer 74. As a result, the control electrode 87 becomes positive in relation to the electrode 85 to the extent that the circuit path 85–86 is switched to the conducting state. The capacitor 111 experiences thereby a voltage change which opposes the control voltage generated through the feedback winding 75 and the control path 70–72 so that the circuit path 70–71 of the limiting switch 69 is switched to the non-conducting state. Consequently, a charging voltage pulse is induced, thereby, in the charging winding 68. The circuit path 85–86 of the auxiliary switch 84 is as a result, also switched then to the non-conducting state, since the anode voltage drops below the required level. In the embodiment of FIG. 9 the auxiliary switch 84 can have its electrode 85 connected, in an advantageous manner, to the negative voltage supply line 19 which, in turn, is connected to ground potential.

FIG. 10 shows the circuitry through which a separate charging transformer 66 may be omitted in the embodiments of FIGS. 1 through 9. The charging winding 68 is, instead, provided for this purpose on the core 76 of the control transformer 74.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of ignition arrangements for internal combustion engines, differing from the types described above.

While the invention has been illustrated and described as embodied in ignition arrangements 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 various 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.

We claim:

1. An ignition arrangement for an internal combustion engine, comprising, in combination, at least one spark-producing unit; ignition transformer means comprising secondary winding means connected across said spark-producing unit and also comprising primary winding means; ignition capacitor means; charging transformer means comprising primary winding means and secondary winding means; a source of voltage; rectifier means; means connecting together said ignition capacitor means, said rectifier means and said secondary winding means of said charging transformer means to form a charging path for said ignition capacitor means; discharge switch means; means connecting

together said ignition capacitor means, said discharge switch means and said primary winding means of said ignition transformer means to form a discharge path for said ignition capacitor means; electronic switch means having a control input; means connecting said electronic switch means in series with said primary winding means of said charging transformer means and connecting said electronic switch means and said primary winding means of said charging transformer means to said voltage source for energization of said primary winding means of said charging transformer means when said electronic switch means is conductive; means synchronized with said engine and operative for rendering said discharge switch means conductive to effect discharging of said ignition capacitor means through said primary winding means of said ignition transformer means and for also rendering said electronic switch means conductive to initiate the flow of current through said primary winding means of said charging transformer means; feedback winding means connected to said control input of said electronic switch means and responsive to changes in flux produced by current flowing through said primary winding means of said charging transformer means and operative for applying to said control input at least part of a voltage generated across said feedback winding means in response to said changes in flux for maintaining said electronic switch means conductive after the latter has been rendered conductive; and cut-off means including cut-off switch means connected to said feedback winding means and automatically operative after build-up of current flow through said primary winding means of said charging transformer means for preventing continued generation across said feedback winding means of a voltage large enough to maintain said electronic switch means conductive, whereby to terminate the flow of current through said primary winding means of said charging transformer means and thereby generate across the secondary winding means of said charging transformer means a charging voltage resulting in charging of said ignition capacitor means.

2. An arrangement as defined in claim 1; and further including additional winding means connected in series with said primary winding means of said charging transformer means and forming together with said feedback winding means a control transformer means, said additional winding means constituting the primary winding means of said control transformer means and said feedback winding means constituting the secondary winding means of said control transformer means.

3. An arrangement as defined in claim 1, wherein said cut-off switch means is so connected to said feedback winding means that when conductive said cut-off switch means reduces the voltage applied by said feedback winding means to said control input of said electronic switch means to a voltage level lower than the requisite for maintaining said electronic switch means conductive.

4. An arrangement as defined in claim 1, wherein said cut-off switch means comprises an electronic switch element having a control input connected to said feedback winding means in such a manner that at least a portion of the voltage generated across said feedback winding means is applied to said control input of said electronic switch element for rendering said electronic switch element conductive when the voltage across said feedback winding means reaches a predetermined level, and wherein said electronic switch element is connected in parallel with said feedback winding means so as to short-circuit the latter when conductive.

5. An arrangement as defined in claim 1, wherein said electronic switch means comprises an electronic switch element having a reference electrode, a control electrode and an output electrode, and wherein said feedback winding means comprises a feedback winding, and further comprising a biasing resistor connected between said reference electrode and said control electrode, one terminal of said feedback winding being connected to said reference electrode, and wherein said feedback winding means includes a diode having one electrode connected to the other terminal of said feedback winding and having another electrode connected to said control electrode, said diode being so connected as to be conductive when said electronic switch element is conductive and carry at least a portion of the input current of said electronic switch element.

6. An arrangement as defined in claim 5, and further comprising a resistor connected in parallel with said diode.

7. An arrangement as defined in claim 1, wherein said electronic switch means comprises an electronic switch element having a control electrode, a reference electrode and an output electrode, and wherein said cut-off switch means comprises a switch element having a control electrode, a reference electrode and an output electrode, and wherein said feedback winding means comprises a feedback winding having one terminal connected to said reference electrode of said electronic switch means and having another terminal connected to said control electrode of said electronic switch means, and wherein said one terminal of said feedback winding is connected to said reference electrode of said cut-off switch means, and wherein said other terminal of said feedback winding is connected to said output electrode of said cut-off switch means.

8. An arrangement as defined in claim 7, and further comprising a resistor connected between the control electrode and the reference electrode of said cut-off switch means.

9. An arrangement as defined in claim 8, and further comprising a resistor connected between the control electrode and output electrode of said cut-off switch means, whereby the voltage across said feedback winding determines the voltage between the reference electrode and control electrode of said cut-off switch means.

10. An arrangement as defined in claim 8, and further comprising an additional winding connected in series with said primary winding means of said charging transformer means and forming together with said feedback winding a control transformer, said additional winding and said feedback winding respectively constituting the primary winding and secondary winding of said control transformer, wherein the resistor connected between the control electrode and reference electrode of said cut-off switch means is connected across said primary winding of said control transformer to form therewith a series circuit.

11. An arrangement as defined in claim 8, wherein said resistor is a negative-temperature coefficient resistor.

12. An arrangement as defined in claim 7, and further comprising a pair of series-connected resistors connected between the control electrode and reference electrode of said cut-off switch means and a pair of negative-temperature-coefficient resistors each connected in parallel with a respective one of said series-connected resistors.

13. An arrangement as defined in claim 8, and further comprising a capacitor connected between the control electrode and reference electrode of said cut-off switch means.

14. An arrangement as defined in claim 8, and further comprising a diode connected between the control electrode and reference electrode of said cut-off switch means and being so connected as to be reverse-biased when the voltage between the control electrode and reference electrode of said cut-off switch means has such a polarity such as to render said cut-off switch means conductive.

15. An arrangement as defined in claim 1, and further comprising auxiliary winding means also responsive to the flux produced by the current flowing through said primary winding means of said charging transformer means.

16. An arrangement as defined in claim 2, and further comprising auxiliary winding means responsive to the flux produced by current flowing through said primary winding means of said charging transformer means and constituting together with said feedback winding means said secondary winding means of said control transformer means.

17. An arrangement as defined in claim 15, wherein said electronic switch means and said cut-off switch means each comprises an electronic switch element having a control electrode, a reference electrode and an output electrode, and wherein said feedback winding means is connected between the control electrode and reference electrode of said electronic switch means for controlling the conductivity of the same, and wherein said auxiliary winding means is connected to said control electrode of said cut-off switch means for controlling the conductivity of the latter.

18. An arrangement as defined in claim 17, wherein said auxiliary winding means is connected between said output electrode of said cut-off switch means and the terminal of said feedback winding means to which said control input of said electronic switch means is connected.

19. An arrangement as defined in claim 1, wherein said secondary winding means of said charging transformer means comprises a secondary winding having two terminals, and further comprising a capacitor having one terminal connected to one terminal of said secondary winding, means connecting the other terminal of said capacitor to the other terminal of said secondary winding and including a first diode connected between said other terminals and having a forward-bias direction such that when the voltage generated across said secondary winding has a polarity not resulting in charging of said ignition capacitor means a charging current flows from said secondary winding through said capacitor to charge said capacitor, said cut-off switch means comprising an electronic switch element having a control electrode, a reference electrode and an output electrode, said reference electrode being connected to said other terminal of said capacitor, and further comprising means connecting said control electrode to said one terminal of said secondary winding and including a Zener diode, and means connecting said control electrode to said other terminal of said secondary winding and including a second diode connected to become reverse-biased when the voltage generated across said secondary winding has a polarity opposite to that resulting in charging of said ignition capacitor means, with said output electrode of said cut-off switch means being so connected as to render said electronic switch means non-conductive when said cut-off switch means becomes conductive.

20. An arrangement as defined in claim 19, wherein said means connecting said other terminal of said capacitor to said other terminal of said secondary winding further includes a resistor connected in series with said first diode.

21. An arrangement as defined in claim 19, wherein said means connecting said control electrode to said other terminal of said secondary winding further includes a resistor connected in series with said second diode.

22. An arrangement as defined in claim 19, wherein said means connecting said control electrode to said one terminal of said secondary winding further includes a series resistor connected in series with said Zener diode.

23. An arrangement as defined in claim 22, wherein said means connecting said control electrode to said one terminal of said secondary winding further includes a shunt resistor connected in parallel with the series combination of said Zener diode and said series resistor.

24. An arrangement as defined in claim 19, wherein said second diode and said Zener diode are connected together to carry Zener-diode current when the voltage generated across said secondary winding has a polarity opposite to that resulting in charging of said ignition capacitor means, and wherein said means connecting said control electrode to said one terminal of said secondary winding and also said means connecting said control electrode to said other terminal of said winding both include a coupling diode having one electrode connected to said control electrode and another electrode connected to one electrode of said Zener diode for applying to said control electrode a voltage dependent upon the magnitude of said Zener-diode current.

25. An arrangement as defined in claim 24, wherein said means connecting said control electrode to said one terminal of said secondary winding and also said means connecting said control electrode to said other terminal of said secondary winding further include a resistor connected in series with said coupling diode.

26. An arrangement as defined in claim 19, and further including an auxiliary winding connected between said output electrode of said cut-off switch means and said one terminal of said secondary winding and operative when said cut-off switch means becomes conductive for inducing in said feedback winding means a voltage such as to render said electronic switch means non-conductive.

27. An arrangement as defined in claim 19, wherein said electronic switch means comprises an electronic switch element having a control electrode, a reference electrode and an output electrode, and wherein said output electrode of said cut-off switch means is connected to said reference electrode of said electronic switch means.

28. An arrangement as defined in claim 19, wherein said electronic switch means comprises an electronic switch element having a control electrode, a reference electrode and an output electrode, and wherein said output electrode of said cut-off switch means is connected to said control electrode of said electronic switch means.

29. An arrangement as defined in claim 19, wherein said cut-off means includes a further cut-off switch means in addition to the first-mentioned cut-off switch means, said further cut-off switch means comprising a further electronic switch element having a control electrode, a reference electrode and an output electrode, said further electronic switch element being so connected to said feedback winding means as to prevent when conductive said feedback winding means from applying to the control input of said electronic switch means a control voltage sufficient to maintain the latter conductive, and further comprising a diode shunting said capacitor and connected with such polarity as to be reverse-biased when said capacitor is charged, and further including means connecting said one terminal of said capacitor to said control electrode of said further electronic switch element.

30. An arrangement as defined in claim 5, and further including an additional winding connected in series with said primary winding means of said charging transformer means, said additional winding and said feedback winding together forming a control transformer with said additional winding constituting the primary winding and said feedback winding constituting the secondary winding of said control transformer, and wherein said cut-off switch means comprises an electronic switch element having a control electrode, a reference electrode and an output electrode, said additional winding having one terminal connected to said reference electrode of said electronic switch means and another terminal connected to said reference electrode of said cut-off switch means, a capacitor connecting said output electrode of said cut-off switch means to said other terminal of said feedback winding, a diode connected between said outupt electrode of said cut-off switch means and said reference electrode of said electronic switch means with such a polarity as to be reverse-biased when said electronic switch means is conductive, a voltage divider connected across said additional winding and having a voltage divider tap, and means connecting said tap to said control electrode of said cut-off switch means.

31. An arrangement as defined in claim 30, wherein said means connecting said tap to said control electrode of said cut-off switch means comprises a diode having such a polarity as to be forward-biased when said electronic switch means is conductive.

32. An arrangement as defined in claim 1, wherein said cut-off switch means comprises a thyristor having an anode, a cathode and a gate, said anode and cathode being so connected to said feedback winding means as to prevent the same from applying to said control input of said electronic switch means a voltage sufficient to maintain the latter conductive when said thyristor is conductive, and means connected to said cathode and gate of said thyristor for rendering said thyristor conductive after build-up of current flow through said primary winding means of said charging transformer means.

33. An arrangement as defined in claim 1, wherein said electronic switch means comprises an npn-transistor having an emitter-collector path connected in series with said primary winding means of said charging transformer means, with the base and emitter of said transistor constituting said input of said electronic switch means.

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