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Meyer et al.

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[54] **IGNITION CIRCUIT**

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[51] **Int. Cl.** **F02p 3/06,** F02p 3/02

[58] **Field of Search** .... 123/148 E; 315/209 T, 209 CD, 213, 222

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[57] **ABSTRACT**

An ignition circuit for combustion engines has an ignition transformer and an ignition spool, each having primary and secondary windings. The two secondary windings are series connected by means of a high voltage diode. Another high voltage diode bridges the first mentioned diode and the secondary of the ignition spool —both diodes being arranged to conduct current in the same direction. A sparkplug is connected between the free ends of the secondary winding.

7 Claims, 2 Drawing Figures

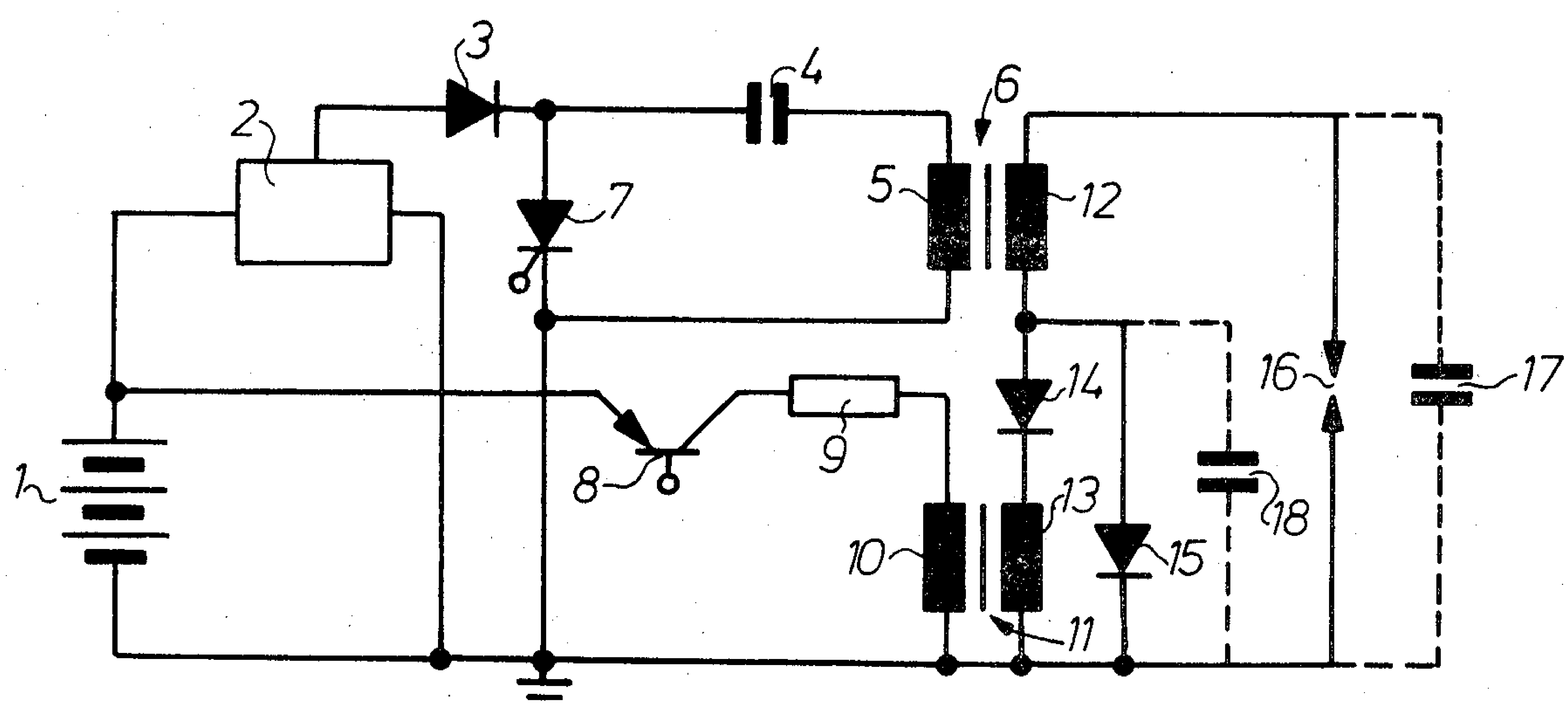

Fig. 1

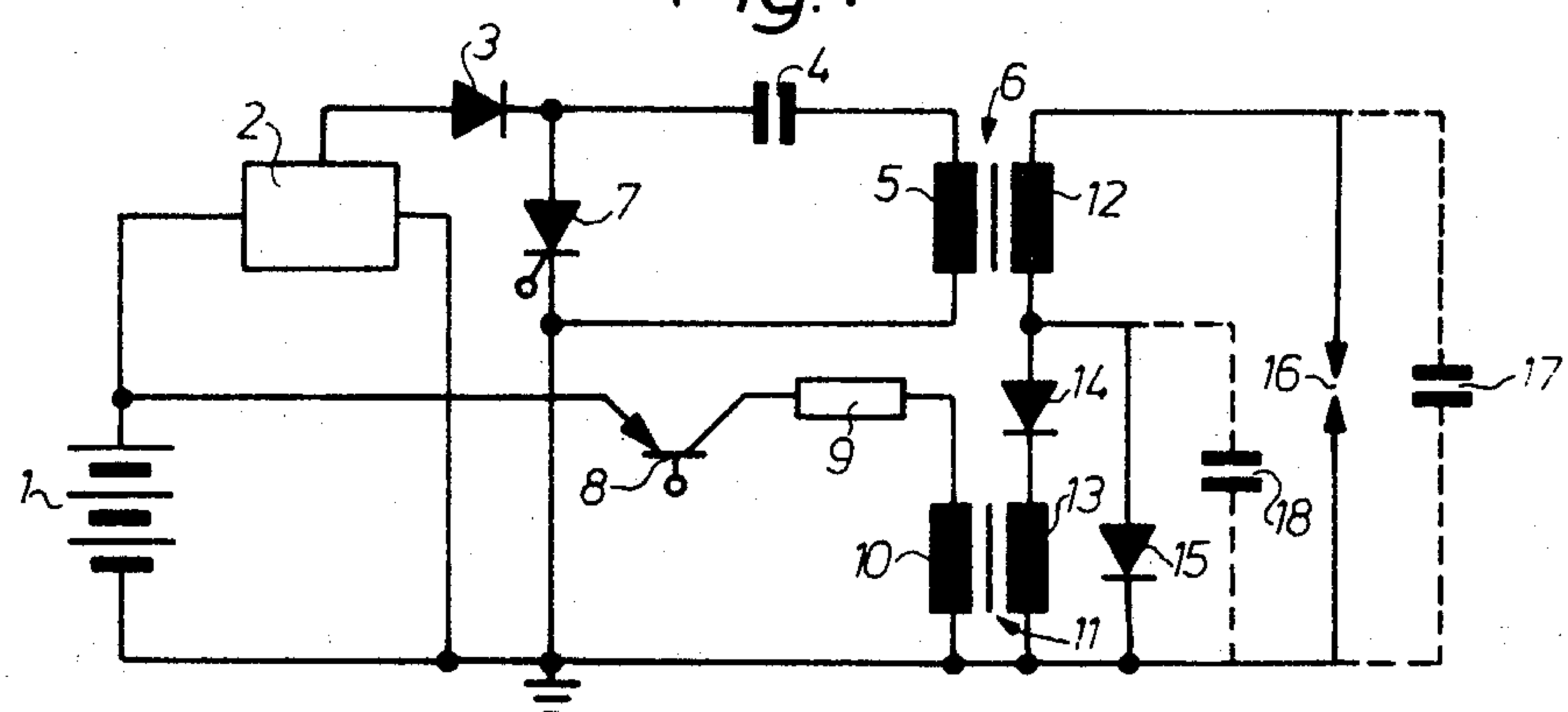
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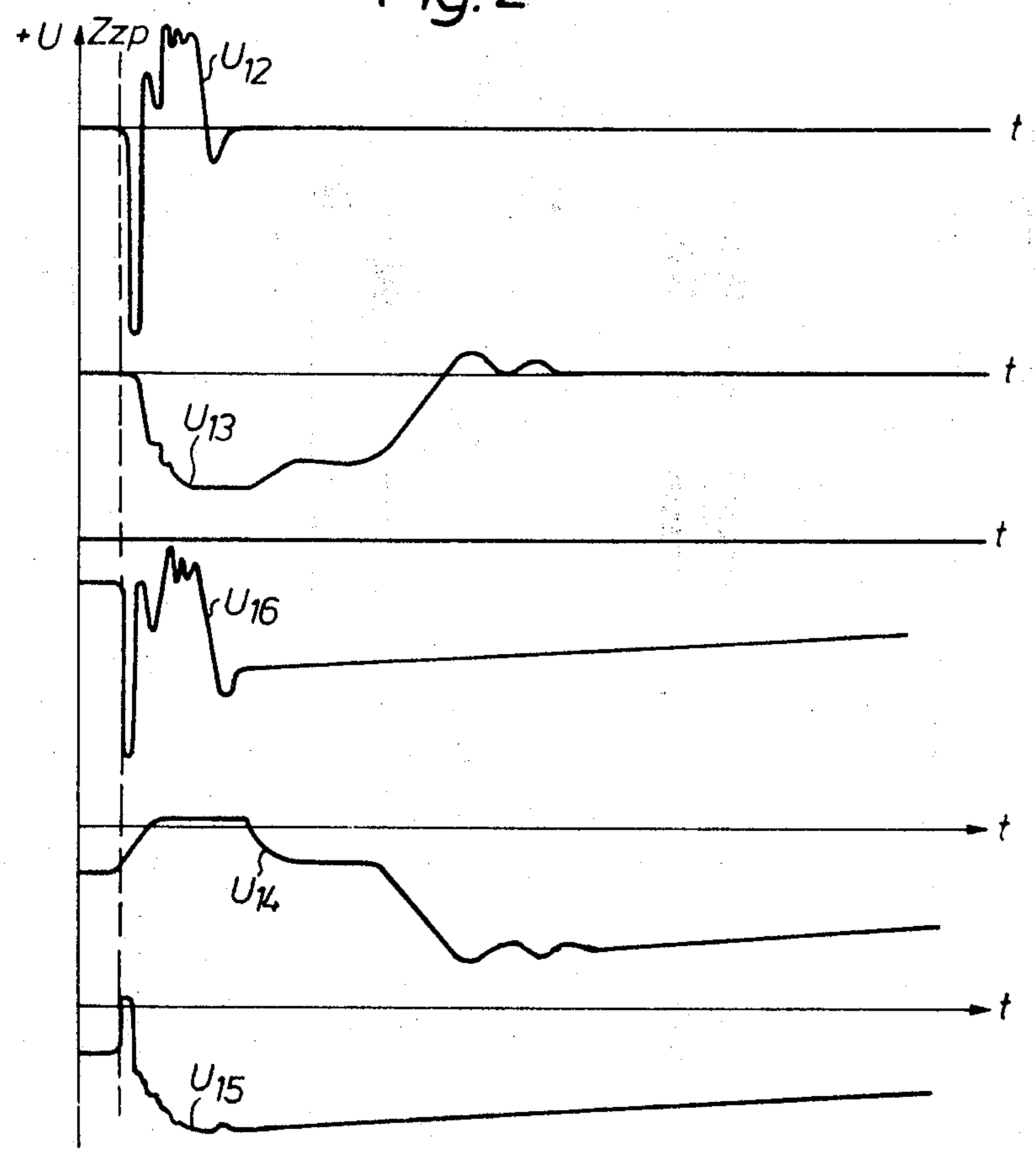
Fig. 2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IGNITION CIRCUIT

BACKGROUND OF THE INVENTION

This invention relates to ignition systems, and more particularly to an ignition system for an internal combustion engine having an ignition transformer and an ignition spool. A capacitor, acting as capacitive energy supply is connected to the primary winding of the ignition transformer. The ignition spool acts as an inductive energy supply —the secondary windings of the transformer and the spool being series connected by means of a voltage dependent switching element which decouples the two secondary windings.

Ignition systems of this type are already known wherein a battery supplied D.C. converter charges a capacitor which is connected to the primary winding of the ignition transformer. An ignition spool has its primary winding connected to an accumulator battery to establish a current therethrough. At the ignition time, the capacitor is discharged through the primary winding of the ignition transformer and simultaneously the current in the ignition spool in the primary winding thereof is interrupted. As a result of this, voltages are induced in the secondary windings of the ignition transformer as well as of the ignition spool, these voltages being directly or by means of an ignition distributor applied to the sparkplugs to generate an intensive or strong and adequately long ignition spark.

It is also known in such systems to minimize the mutual or reciprocable influence of the secondary windings on each other by means of a high-voltage diode. According to this known arrangement, the diode is interposed between the two secondary windings, each of the windings being parallel to each other as well as to the sparkplugs.

The above-described ignition systems have, however, serious disadvantages. Thus, the high voltages which the high voltage diodes are to block, usually in cases of ignition interruption or spark jump whereby a spark fails to develop across the sparkplug, exceeds the maximum desired no-load voltages of approximately 20 to 25 kilovolts on the secondary sides of the ignition transformer. These high voltages are produced as a result of the arrangement of the diodes in relation to the secondary windings. Thus, the secondary side of the ignition transformer has a stray capacitance which, in the absence of the spark, charges to the maximum no-load voltage induced in the secondary winding of the ignition transformer. As soon as the no-load voltage swings from the negative to the positive potential maximum there appears on the diode which isolates the two secondary windings a blocking voltage which is approximately double in magnitude of the no-load peak voltages appearing at the secondary winding of the ignition transformer. The application of such high voltages to the isolating diode frequently destroys the latter and accordingly causes the ignition system to fail.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an ignition system which does not possess the disadvantages known in the prior-art systems.

It is another object of the present invention to provide an ignition system of the above type which utilizes an ignition transformer and an ignition spool which can be reliably isolated from one another.

It is still another object of the present invention to provide an ignition system of the type under discussion which utilizes high-voltage diodes whose breakdown voltages are not exceeded.

It is a further object of the present invention to provide an ignition system which remedies the prior art deficiencies as well as increases the reliability of operation.

According to the present invention, an ignition system for internal combustion engines comprises, in combination, an ignition transformer having first primary and secondary windings. Capacitor means are provided for periodically discharging through said first primary winding. Ignition coil means are provided having second primary and second secondary windings, each of said windings having a first and a second end. Means are provided for periodically inducing a voltage in said second secondary winding substantially simultaneously with said periodic discharges. First voltage dependent switching means are provided which are connected to said second end of said first secondary winding to said first end of said second secondary winding. Second voltage dependent switching means are provided for bridging said first voltage dependent switching means and said second secondary winding. Sparkplug means are provided which are connected between said first end of said first secondary winding and said second end of said second secondary winding.

According to a presently preferred embodiment, at least one of said voltage dependent switching means comprises a diode. Advantageously, both voltage dependent switching means comprise diodes, both being arranged to condut current in the same direction.

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 DRAWING

FIG. 1 is a schematic of an ignition system in accordance with the present invention, showing both capacitive and inductive energy supply means; and

FIG. 2 are time plots of voltage curves across different elements in the high-voltage circuit of the ignition system illustrated in FIG. 1 during idling, during which no ignition spark takes place.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The ignition system is supplied by an accumulator battery **1**. Connected to the positive pole of the battery **1** is a D.C. converter **2** whose operation is well known. The output of the D.C. converter **2** is connected to an energy storing capacitor **4** over a diode **3**. The capacitor **4** is connected to one free end of the primary winding **5** of an ignition transformer **6** —the capacitor **4** and the primary winding **5** being series connected. The other free end of the primary winding **5** is connected to a ground reference potential point. Connected in parallel to the series connection of the capacitor **4** and the primary winding **5** is a thyristor **7** whose cathode is connected to ground while its anode is connected to a point between the diode **3** and the capacitor **4**. The positive pole of the battery 1 is further connected to the emitter of a transistor 8 whose collector is connected to one free end of the primary winding 10 over a resistor 9. The primary winding 10 forms part of ignition spool 11 which acts in the ignition system as an inductive energy supplying means, as will be described hereafter. The other end of the primary winding 10 is connected to the circuit ground. The secondary windings 12 and 13 of the ignition transformer 6 and of the ignition coil 11 respectively are connected in series to each other. Connecting the second end of the secondary winding 12 and the first end of the secondary winding 13 is a high-voltage diode 14. A second high-voltage diode 15 bridges the secondary winding 13 of the ignition spool 11 as well as the high-voltage diode 14. Both high-voltage diodes 14 and 15 are arranged to conduct current in the same direction, i.e., from the secondary winding 12 towards the circuit ground. To this end, the two anodes of the two high-voltage diodes are connected with one another. The second diode 15 has its cathode connected to the circuit ground. Between the first end of the winding 12 and the second end of the winding 13 is connected a sparkplug 16.

The stray or interwinding capacitance of the secondary windings 12 and 13 is represented by the equivalent lump capacitor 17 which acts between the first end of the winding 12 and the second end of the winding 13 and is shown connected between these two points by the dashed lines. As will be noted, the capacitor 17 acts as an equivalent capacitor connected parallel to the sparkplug 16. Also, since the second end of the primary winding 12 is not connected to the circuit ground, as is well known to be the case in present ignition systems, but is connected to the circuit ground over the secondary winding 13 of the ignition spool 11 as well as over the high-voltage diodes 14 and 15, there appears another stray capacitance during the operation of the ignition system between the secondary winding 12 and with the primary winding 5 of the ignition transformer 6, the latter having one of tis free ends connected to the circuit ground. The stray or interwinding capacitance between the windings 5 and 12 is represented by the lump capacitor 18 —shown to be connected between the second end of the secondary winding 12 and the circuit ground. This connection, in FIG. 1, is shown by means of the dashed line.

The operation of the ignition will now be described.

After the beginning of a cycle, when the ignition system is first turned on, the converter 2 charges the capacitor 4 over the diode 3 to a positive voltage of approximately 400 volts. The thyristor 7 is blocked at this time. Further, a current flows over the transistor 8 emitter-collector path through the resistor 9 to the primary winding 10 of the ignition spool 11. In the steady-state condition, the current flowing through the primary winding 10 is a D.C. current of substantially constant magnitude, although during the operation of the ignition system at high frequencies, the current flowing in the primary also includes exponential rising and falling portions representing the time constants of this primary circuit. In both cases, the flow of a current through the primary winding 10 establishes a strong magnetic field about this winding in accordance with well-known principles. At the ignition time, the thyristor 7 is made conductive by applying a voltage pulse to its control electrode in a well-known manner. The means for applying a control pulse to the control electrode is well known and does not form part of the present invention. Upon the application of the control pulse to the thyristor 7, the latter becomes conductive to thereby form a loop circuit consisting of the thyristor 7, the capacitor 4 and the primary windings 5. At this time, the capacitor 4 discharges through the thyristor 7 and a loop current flows through the primary winding 5 of the ignition transformer 6. The current surge in the primary winding 5 induces a high voltage pulse in the secondary winding 12 of the ignition transformer 6. The initial surge produces a negative voltage in the secondary winding 12 —the negative voltage being defined as one where the first end of the primary winding 12 is more negative than the second end thereof. Because the second end of the secondary winding 12, which is connected to the anode of the diode 15, is positive with respect to ground, the high-voltage diode 15 is made conductive and a current is caused to flow in the secondary winding 12, the diode 15 as well as in the sparkplug 16 and the capacitor 17 simultaneously. The strong or high magnitude voltage pulse thus caused to flow through the sparkplug 16 generates a strong spark, in accordance with well-known principles, even if the sparkplugs are fouled or covered with soot. When a spark is produced, during normal operation, the resistance across the sparkplugs 16 decreases substantially and the voltages developed across the capacitor 17 do not rise to dangerous levels. Simultaneously with the application of a control pulse to the thyristor 17, or slightly earlier or subsequently thereto, a control pulse is applied to the base of the transistor 8. In the case of the transistor 8, a PNP transistor, a positive pulse is applied thereto to block the normally conducting transistor to thereby interrupt the current which flows in the emitter-collector path thereof. Accordingly, the current flowing in the primary winding 10 will be interrupted. The magnetic field which was established about the ignition spool 11 collapses and a high voltage is induced in the secondary winding 13. The voltage induced in the secondary winding 13 is similarly a negative voltage, i.e., the first end of the winding 13 is more negative than the second end thereof, the latter end being connected to the circuit ground. Accordingly, the cathode of the diode 14 is placed at a substantially negative voltage and the latter diode is made conductive. At such time, a current is caused to flow in the secondary winding 12, the diode 14, the secondary winding 13 as well as in the parallel combination of the sparkplug 16 and the capacitor 17. This second current caused by the voltage induced in the secondary winding 13 is utilized to maintain the length of the spark across the spark gap for an adequately long time.

It now appears that it is expedient to supply the pulse to the base of the transistor 8 several microseconds prior to the application of the control pulse to the control electrode of the thyristor 7. In this manner, it is made certain that after the occurrence of the strong high-voltage pulse in the secondary winding 12 of the ignition transformer 6, the spark across the sparkplug 16 will continue without interruption after the spark has been initiated by the voltage induced in the secondary winding 12.

By such an arrangement of the diodes 14 and 15, the secondary winding 12 of the ignition transformer 6 still somewhat influences the secondary winding 13 of the ignition spool 11. However, this influence is insignificant since the secondary inductance of the ignition spool **11** is substantially greater than is that of the ignition transformer **6.** It will be noted, therefore, that whereas the diode **15** decouples the secondary winding **13** of the ignition spool **11** from the secondary winding **12** of the ignition transformer **6,** by bridging over the ignition spool **11** secondary side, the purpose of the high-voltage diode **14** is to prevent the interference of the build-up of the magnetic field about the primary winding **10** by the circuitry connected to the secondary winding **13.** Thus, when current is first made to flow to the primary winding **10** through the transistor **18,** a voltage will be induced in the secondary winding **13** which would be a positive voltage, i.e., the first ends of the secondary winding **13** will be positive with respect to its second end connected to ground. Accordingly, the diode **14** will be reversed biased and will be blocked. Because no current is permitted to flow in the secondary winding at this time, the secondary circuit of the ignition system will not interfere with the rapid buildup of the magnetic field about the primary winding.

FIG. **2** illustrates the voltages appearing across the various elements of the high-voltage circuit during idling. Thus, the voltage U_{12} appears across the secondary winding **12** of the ignition transformer **6,** the voltage U_{13} appears on the secondary winding **13** of the ignition spool **11,** the voltage U_{16} on the high-voltage lead of the sparkplug **16,** the voltage U_{14} on the high-voltage diode **14** and the voltage U_{15} on the high-voltage diode **15.**

The graph or plot illustrated in FIG. **2** will now be explained in terms of the operation of the ignition circuit illustrated in FIG. **1.** During the discharging of the capacitor **4,** there appears an abrupt and strong negative voltage pulse in the secondary winding **12** of the ignition transformer **6.** The voltage U_{12}, after reaching its maximum negative voltage, rapidly rises towards the positive range and passes through zero voltage and attains a substantially positive voltage.

After remaining positive for a short while, the voltage across the winding **12** goes slightly negative and finally goes towards zero voltage while remaining in the negative region. On the other hand, by interrupting the primary current circuit of the ignition spool **11,** a voltage U_{13} is induced across the secondary winding **13** which initially tends towards the negative region —the voltage slowly becoming more negative until it reaches a maximum value. The voltage U_{13} remains in the region of its maximum negative voltage for approximately several 100 microseconds and then gradually becomes more positive until it crosses the zero voltage level and tends towards zero by means of a damped oscillation in the positive voltage region. The voltage U_{16} appearing as the high-voltage contact of the sparkplug **16** exhibits the high negative voltage surge characteristic of the voltage U_{12} when the capacitor **4** is first discharged. During the negative half-wave of the secondary voltage U_{13} of the ignition coil **11,** the voltages U_{12} and U_{13} are superimposed and the capacitor **17** is charged to a negative voltage of approximately 20 kilovolts. As the curve for the voltage U_{16} shows, this voltage tends towards a zero voltage quite gradually —this being the result of the capacitor **17** discharing through the blocked diodes **14** and **15.** The curves illustrated in FIG. **2** illustrate the situation where the primary circuit of the ignition system operate in a normal manner but wherein the sparkplug **16,** for one reason or another, has failed to ignite. Therefore, as far as the circuit operation is concerned, the sparkplug **16** is effectively outside the circuit. It will therefore be noted that once the capacitor **17** has charged to a negative voltage, there does not exist any discharge path for the capacitor **17** except through the back biased diodes **14** and **16** —these diodes presenting high impedances to the capacitor **17** discharge circuit due to their nonconductive state.

The voltage U_{14} appearing on the high-voltage diode **14** corresponds to the voltage U_{16} prior to the ignition time. As soon as the negative voltage U_{13} appears on the secondary winding **13,** the diode **14** becomes conductive. As described above, a negative voltage across the secondary winding **13** causes the cathode of the diode **14** to be at a potential less negative than the circuit ground. Accordingly, the voltage U_{14} drops to its low forward conducting voltage. After the secondary voltage U_{13} has passed its region of maximum value, the voltage U_{14} appearing across the diode **14** again becomes negative. The diode **14** becomes non-conductive and the curve of the blocking voltage U_{14} becomes equal to the difference between the voltages U_{13} and U_{16}, i.e., (U_{16}–U_{13}). This different voltage is thereby maintained at a maximum of approximately 25 kilovolts. Thus, it will be noted that the diode U_{14} is protected from excessive reverse voltages by the expedient of connecting the secondary windings **12** and **13** in series by means of the diode **14** so that the voltage across the capacitor **17** or U_{16} is prevented from reaching the high levels known in the prior art by insuring that the voltages across the capacitor **17,** i.e., U_{16}, and the voltage appearing across the secondary winding **13** are of opposite phase so that there is a cancellation to some extent of voltages and only the difference in these voltages appears across the back biased diode **14.**

Also, the voltage U_{15} across the high-voltage diode **15** responds to the voltage U_{16} across the condenser **17** or across the sparkplug **16.** During the first negative halfwave of the voltage U_{12} across the secondary winding **12** of the ignition transformer **6,** the high-voltage diode **15** is in the conductive state. As described above, a negative voltage across the secondary winding **12** means that the second end of the winding **12** connected to the anode of the diode **14** is positive with respect to the circuit ground. Accordingly, the diode **15** becomes conductive and the voltage U_{15} thereacross drops to its low forward conducting voltage. The current flowing through the diode **15** charges the capacitor **17** to approximately 30 kilovolts. During the second positive half-wave of the voltage U_{12} and the secondary winding **12** the high voltage diode **15** is blocked. This is because the development of a positive voltage across the secondary winding **12** causes a voltage at the anode of the diode **15** which is more negative than the circuit ground potential. Thus, it results from these conditions that during this second voltage half-wave of the secondary winding **12,** the capacitors **17** and **18** are connected in series with each other and with the winding **12.** The capacitor **18** is now charged to some extent by the charge first developed across the capacitor **18** —the thus arranged series connected capacitors causing the voltage applied across the capacitor **17** to be voltage divided between itself and the capacitor **18.** This devision of voltage causes the voltages applied across either one of the capacitors **17** and **18** to be equal to approximately one-half the maximum obtainable voltage during ignition failure. Since the capacitor 18 is connected in parallel to the diode 15, it follows that the reverse voltage applied across the diode 15 will be limited to the voltage which develops across the capacitor 18 —this being limited to a value approximately of 25 kilovolts.

The objects of the invention are not limited to the specifically described circuit illustrated in FIG. 1. For example, the voltage diodes 14 can, e.g., also be selected to be a spark gap or a Zener diode which has a Zener voltage greater than approximately one kilovolt. The important feature of the elements connecting the secondary windings are that they be voltage sensitive switching elements which control the flow of current therethrough as well as through the secondary windings as a function of the voltages applied thereacross. The sensitivity may be to the amplitude, the phase or other characteristics of the voltages induced in the secondary windings. In all cases, with the primary winding of the transformer being connected with ground, the secondary winding of the ignition transformer is disconnected from the circuit ground by a first voltage sensitive switching element upon the open circuit voltage exceeding a predetermined amount and is disconnected from a secondary winding 13 by means of a second voltage sensitive switching element. In this manner, the capacitance between the primary winding and the secondary windings of the ignition transformers, namely capacitance 18, limits the value of the blocking voltage U_{15} to a value which is not dangerous to diode 15. Such voltage reducing action takes place when no-load voltage is exceeded, typically when the sparkplug 16 fails to ignite to produce a spark thereacross. By limiting the blocking voltages across the high voltage diodes, their safety is assured and continued reliable operation of the ignition system is obtained.

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 system differing from the types described above.

While the invention has been illustrated and described as embodied in an ignition system for an internal combustion engine utilizing both an ignition transformer, an ignition winding as well as high voltage isolating diodes, 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:

1. In an ignition system for internal combustion engine, a combination comprising an ignition transformer having first primary and first secondary windings; capacitor means for periodically discharging through said first primary winding; ignition coil means having second primary and second secondary windings, each of said windings having a first and a second end; means for periodically inducing a voltage in said second secondary winding substantially simultaneously with said periodic discharges; first voltage dependent switching means connecting said second end of said first secondary winding to said first end of said second secondary winding; second voltage dependent switching means bridging said first voltage dependent switching means and said second secondary winding; and spark plug means connected between said first end of said first secondary winding and said second end of said second secondary winding.

2. A combination as defined in claim 1, wherein at least one of said voltage dependent switching means comprises a diode.

3. A combination as defined in claim 1, wherein both said voltage dependent switching means comprise diodes, the latter diodes being arranged to conduct current in the same direction.

4. A combination as defined in claim 3, wherein the system has a ground reference potential point and wherein said diodes have anodes connected to each other, and the second diode has a cathode connected to said ground reference potential point.

5. A combination as defined in claim 1, wherein said first voltage dependent switching means comprises a zener diode.

6. A combination as defined in claim 1, wherein said first voltage dependent switching mean comprises a spark gap.

7. A combination as defined in claim 1, wherein said first voltage dependent switching means has a breakdown voltage of 1KV.

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