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Bruijning et al.

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[54] **MULTI-PULSE CAPACITOR DISCHARGE IGNITION SYSTEM**

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Related U.S. Application Data

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[30] **Foreign Application Priority Data**

Apr. 26, 1967 Netherlands 6705849

[52] **U.S. Cl... 315/209 SC,** 123/148 E, 315/209 CD

[51] **Int. Cl.** **F02p 3/08,** F02p 5/14

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

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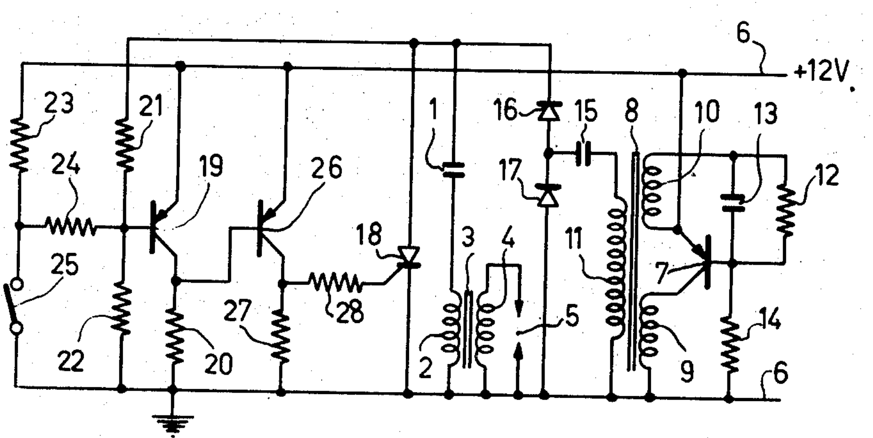
[57] **ABSTRACT**

An electric ignition system for an automobile engine includes a capacitor and a SCR in series with the primary winding of a high voltage transfer. The SCR is triggered by means of an AND gate to which a recurrent control signal synchronized with the engine and a voltage derived from the capacitor voltage are applied. During each control signal, a plurality of high voltage pulses are generated by the repeated charge and discharge of the capacitor through the SCR and transformer.

18 Claims, 5 Drawing Figures



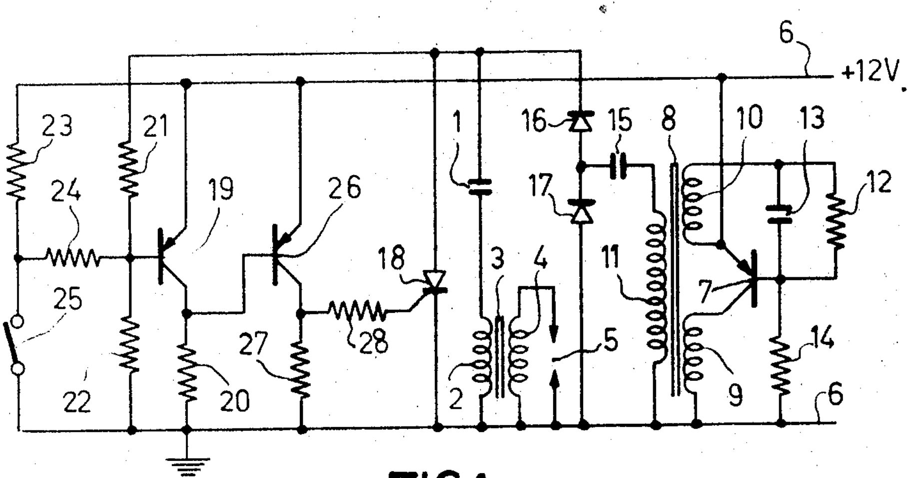


FIG.1

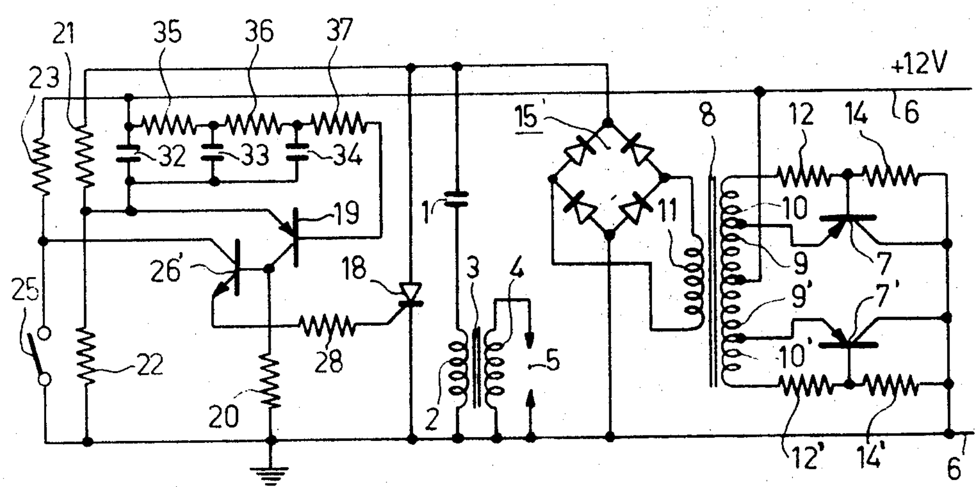


FIG.2

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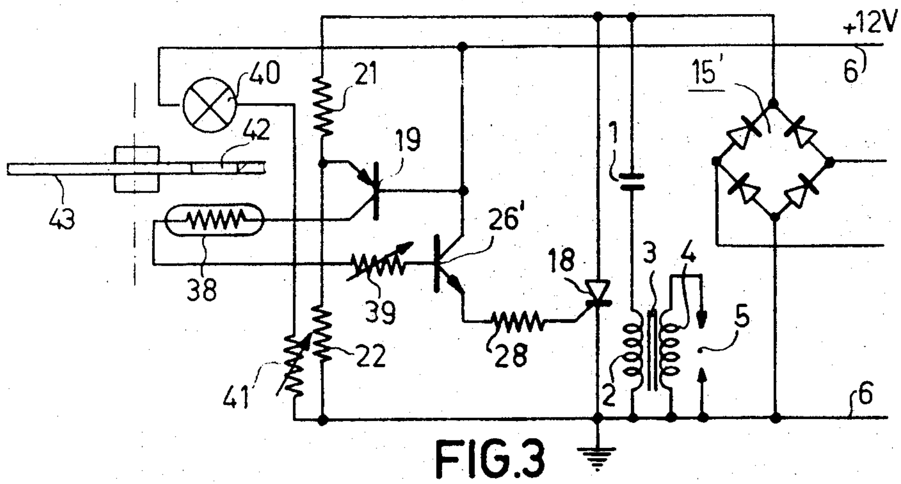

FIG.3

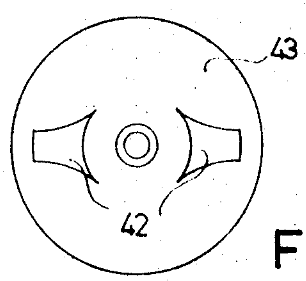

FIG.4

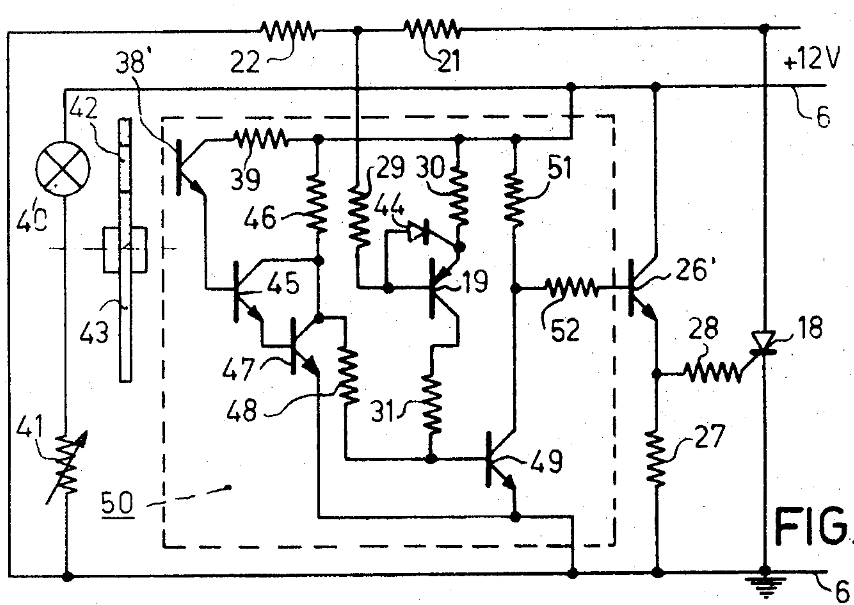

FIG.5

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MULTI-PULSE CAPACITOR DISCHARGE IGNITION SYSTEM

This application is a continuation of application Ser. No. 722,850, filed Apr. 22, 1968.

The present invention relates to an apparatus for producing high-voltage pulses, especially for producing sparks at a spark plug of an internal combustion engine. The invention particularly relates to an apparatus of the type known, for example, from U.S. Pat. No. 3,051,870, including a capacitor connected in series with the primary winding of a step-up high-voltage transformer across the secondary winding of which at least one spark plug may be connected. The apparatus also includes a voltage source by which said capacitor is charged, a controlled rectifier through which the capacitor is discharged through the primary winding of the high-voltage transformer, and a control circuit for causing the controlled rectifier to conduct.

In an internal combustion engine, especially a spark-ignition engine provided with an apparatus of the above defined type or of one of most of the other known types, starting difficulties frequently occur. These are usually due to a weak storage battery, for example, due to its age. When the engine is driven by an electric starter-motor energized by the battery, the battery voltage drops excessively and hence the driving torque developed by the starter-motor is too weak to bring the internal combustion engine up to a sufficient starting speed. These poor starting conditions are aggravated by the fact that, owing to the abnormally low battery voltage, the ignition spark also is weak and of short duration if the same battery is used for feeding the starter-motor and the ignition-apparatus.

With the known ignition-apparatuses, combustion frequently is far from complete so that the efficiency of the engine is reduced and the toxicity of its exhaust gases is increased. In the towns, the air is increasingly contaminated by exhaust gases, so that this toxicity must be combated with all available means. On the other hand, internal combustion engines of ever higher speeds and ever higher compression ratios continuously require better ignition apparatuses.

It is an object of the invention to provide an improved and yet simple apparatus of the above defined type.

The apparatus in accordance with the invention is characterized in that the control circuit includes an and-gate to which a recurrent control signal and a voltage derived from the voltage across the capacitor are applied, so that, during the application of the control signal, the controlled rectifier is repeatedly rendered conductive when the voltage across the capacitor reaches a predetermined value. Consequently, for example, when an internal-combustion engine is running slowly or is being started, and owing also to the comparatively long duration of the control signals, a train of high-voltage pulses and a corresponding train of ignition sparks are produced during each control signal.

It should be noted that the use of a train of high-voltage pulses for igniting the combustible gas mixture in a combustion chamber of a spark-ignition internal-combustion engine is known, inter alia from Belgian Pat. specification No. 509,801. The apparatus in accordance with the invention, however, is very simple and effective.

The invention will now be described more fully with reference to the accompanying diagrammatic drawings, in which:

FIG. **1** is the circuit diagram of a first embodiment of the apparatus in accordance with the invention,

FIG. **2** is the circuit diagram of a second embodiment,

FIG. **3** is the circuit diagram of a third embodiment,

FIG. **4** shows a detail of this third embodiment, and

FIG. **5** is the circuit diagram of a modification of the third embodiment.

The first embodiment shown diagrammatically in FIG. **1** includes a capacitor **1** connected in series with the primary winding **2** of a step-up high-voltage transformer **3.** Across a secondary winding **4** of the transformer a spark plug **5** can be connected, for example, through a distributor, not shown. The system further includes a voltage source constituted by a source **6** of a low direct voltage in the form of a 12 volt battery and by a converter in the form of a blocking oscillator including a transistor **7** and a transformer which comprises a core **8** made of a square-loop ferromagnetic material, a primary winding **9** connected in the collector circuit of the transistor **7,** a feedback winding **10** connected in the base-emitter circuit of this transistor and a high voltage secondary winding **11.** The emitter of the transistor **7,** which is of the p-n-p type, is connected to the positive terminal of the source **6,** its base is connected to its emitter through the series combination of a feedback capacitor **13** shunted by a resistor **12** and the winding **10** and to the negative terminal of the source **6** through a biasing resistor **14.** Its collector is connected to this negative terminal through the winding **9.** One end of the secondary winding **11** is connected to ground and to the negative terminal of the source **6,** and the other end is connected to a full-wave rectifier in voltage-doubling connection which comprises a coupling capacitor **15** and two rectifier elements **16** and **17.** The rectifier elements **16** and **17** are connected in series and in the same pass direction across the series combination of the capacitor **1** and the winding **2,** and the capacitor **15** is connected between the nongrounded terminal of the winding **11** and the junction of the rectifier elements **16** and **17.** Both windings **2** and **4** of the transformer **3** are connected to ground at one end, and the electrode of the capacitor **1** which is not connected to the winding **2** is positively charged to a voltage of, say, 400 volts through the rectifier **15, 16, 17.**

The apparatus further includes a controlled rectifier in the form of a semiconductor controlled rectifier or thyristor **18** through which the capacitor **1** is discharged through the primary winding **2,** and a control circuit for rendering the controlled rectifier **18** conducting.

The control circuit includes a p-n-p transistor **19** which acts as an and-gate. The emitter of this transistor is directly connected to the positive terminal of the source **6,** its collector is connected to ground through a load resistor **20** and its base is connected to the tapping of a voltage divider which comprises resistors **21** and **22** connected across the capacitor **1.** A second voltage divider comprising resistors **23** and **24** is connected between the base of the transistor **19** and the positive terminal of the source **6,** and its tapping is connected to ground through a switch **25,** for example, the contact breaker of a spark-ignition internal-combustion engine having at least one combustion chamber which is provided with the spark plug **5**. The control circuit further includes a p-n-p amplifying transistor **26**. The base of this transistor is connected to the collector of the transistor **19**, its emitter is directly connected to the positive terminal of the source **6** and its collector is connected to ground through a load resistor **27** and to the control electrode of the thyristor **18** through a resistor **28**.

The resistors **21, 22, 23** and **24** have values such that the transistor **19** is highly conducting as long as the switch **25** is closed, even if the capacitor **1** is fully charged. Under these conditions the transistor **26** is cut off and supplies no forward current to the control electrode of the thyristor **18**, so that this thyristor also remains cut off. When a control signal is produced by the circuit of the switch **25** being broken, the transistor **19** compares the voltage of the source **6** applied to its emitter with the voltage across the resistor **22** applied to its base and derived from the voltage across the capacitor **1**. If the latter voltage exceeds a predetermined value, the transistor **19** is cut off. The transistor **26** becomes highly conducting and, through the resistor **28**, part of its collector current flows to the control electrode of the thyristor **18**, rendering the latter conducting. The capacitor **1** now discharges through the thyristor **18** and the winding **2**, the current pulse through this winding produces a high-voltage pulse across the secondary winding **4** and causes a spark discharge to take place between the electrodes of the spark plug **5**.

Owing to the capacitor **1** being discharged, the voltage at the base of the transistor **19** again becomes negative with respect to the voltage at its emitter, even if the contact of the switch **25** is still open. Hence, this transistor begins to conduct again and cuts off the transistor **26**, enabling the thyristor **18** to be extinguished again at the next passage through zero of its main current.

Owing to the secondary winding **11** of the converter transformer being completely short-circuited by the thyristor **18** via the rectifier **15, 16, 17**, the converter including the transistor **7** substantially stops oscillating until the thyristor **18** is again rendered non-conducting.

As soon as the thyristor has again become non-conducting, the converter including the transistor **7** starts oscillating strongly, and the capacitor **1** is thus charged again through the rectifier **15, 16, 17**. At the instant at which the voltage across this capacitor again reaches the predetermined value, the transistor **19** is again cut off unless the contact of the switch **25** has been closed in the meantime. If this is not the case, the transistor **26** and hence the thyristor **18** become conductive again, the capacitor **1** again discharges through the thyristor and the winding **2** and the apparatus produces a second spark between the electrodes of the spark plug **5**, and so on.

Thus, each time the contact of the switch **25** is broken the system produces a train of high-voltage pulses and a corresponding train of sparks, these trains being interrupted only by the contact of the switch **25** being closed again. The time interval between two successive pulses is determined by the capacitance of the capacitor **1**, by the internal resistance of the source of charging voltage comprising the source **6**, the converter **7 – 14** and the rectifier **15 – 17**, by the predetermined voltage across the capacitor **1**, which is determined by the resistors **21, 22, 23** and **24**, and by the transformation ratio of the converter with the rectifier.

When the thyristor **18** is conducting, the capacitor **1** together with the inductance of the winding **2** forms a resonant circuit closed for both directions of current flow; for currents in the reverse direction of the thyristor **18** it is closed through the rectifier elements **16** and **17**. This closed circuit is strongly excited by the discharge of the capacitor **1** through the thyristor **18** and oscillates with damped oscillations at its resonant frequency. If a half-cycle of this oscillation is sufficiently longer than the recovery time of the thyristor **18**, say, 20 microseconds, the latter is cut off after a full oscillation cycle. If this half-cycle is shorter than the recovery time of the thyristor, for example, is equal to 10 microseconds (frequency of oscillation 50 kc/s), the thyristor remains conducting in its forward direction until the oscillation amplitude has decreased to such an extent that the forward current through the thyristor **18** can no longer maintain it in the conductive state.

When the full-wave rectifier **15–17** is replaced by a half-wave rectifier, for example, by omitting the capacitor **15** and the rectifier element **17** and connecting the winding **11** to the anode of the rectifier element **16**, the capacitor **1** together with the winding **2** form, for one direction of current flow, a resonant circuit having a comparatively high natural frequency and closed through the thyristor **18** and, for the other direction of current flow, a resonant circuit having a lower natural frequency and closed through the rectifier **16** and the winding **11**. Hence, the second and any further even-numbered half-cycles are of longer duration and lower amplitude than the first and any further odd-numbered half-cycles of the oscillation.

According to another modification, not shown in the drawings, the winding **2** may be shunted by a diode which would have its cathode connected to ground and would suppress the even-numbered half-cycles of the oscillation across the winding **2**, so that each pulse produced is limited to only about the first quarter-cycle of the resonant circuit **1, 2**.

The shape, the duration, the nature (of one polarity or of alternating polarities) and the mutual time intervals of the high-voltage pulses may thus be acted upon at will. It should be noted that if the converter **7 – 14** were to continue oscillating and supplying a charging current to the capacitor **1** during the pulses, the thyristor **18** could not be so readily extinguished and, under certain conditions, would not extinguish at all. These conditions obtain when the charging current supplied by the converter **7 – 14** through the rectifier **15 – 17** forms a sufficient holding current for the thyristor used. By ensuring that the converter **7 – 14** cannot oscillate when the thyristor **18** conducts, the thyristor **18** is prevented from being maintained in the conducting condition by the rectified alternating current supplied by the converter **7 – 14** through the rectifier **15 – 17**. This also results in slightly shortening the high-voltage pulses produced, by suppressing a useless low-amplitude end portion or "tail," and also in reducing the dissipation in the element **7** of the converter **7 – 14** and the mean value of the current supplied by the source **6** of low direct voltage.

Especially for starting a cold engine, the described train of ignition sparks has proved more effective than a single continuous spark of the same duration. Combustion is accelerated and is more complete, the exhaust gases contain less carbon monoxide and less carbon is deposited in the exhaust and in the engine, especially on the electrodes of the spark plugs.

The second embodiment shown in FIG. **2** is equipped with a balanced converter including two transistors **7** and **7'**. The transformer **8 – 11** has a primary winding **9, 10, 9', 10'**, which also acts as a feedback winding and is provided with a centre tapping connected to the positive terminal of the source **6.** The ends of the winding are connected to the bases of the transistors **7** and **7'** through biasing resistors **12** and **12'**, respectively, the emitters of said transistors being connected to intermediate taps on this winding. The transformer **8 – 11** has a high transformation ratio and its secondary winding **11** is connected to the input terminals of a rectifier bridge **15'**. The control circuit includes a delay circuit comprising capacitors **32, 33, 34** and resistors **35, 36, 37** which determines, or at least limits, the duration of each pulse produced by a discharge of the capacitor **1.** This network is connected between the emitter and the base of the transistor **19** so that the capacitors **32, 33, 34** are charged to the difference between the voltage across the resistor **22** of the voltage divider **21, 22** and the voltage of the supply source **6.** The emitter of the transistor **19** is connected to the tapping on the voltage divider **21, 22** and its base is connected to the positive terminal of the supply source **6** through the resistors **35, 36, 37** of the delay network. Therefore, the transistor **19** becomes conductive when the said voltage difference is positive and exceeds its base emitter threshold. The collector current flows through the resistor **20** and the resulting voltage across this resistor biases the base of a second transistor **26'** of the n-p-n type in the forward direction.

The collector of the transistor **26'** is connected to the negative terminal of the supply source **6** through a switch, for example, a contact breaker **25**, and its emitter is connected to the control electrode of the thyristor **18** through a resistor **28.** Consequently, the transistor **26'** can supply a forward current to this control electrode only if the transistor **19** is conducting and the contact of the switch **25** is broken. When these two conditions are simultaneously satisfied the thyristor **18** becomes conducting and the capacitor **1** discharges through this thyristor **18** and the winding **2.** The resulting reduction of the potential of the emitter of the transistor **19** is delayed by the network **32 – 37,** so that a reduction of the voltage across the capacitor **1** does not immediately cut off the transistors **19** and **26'**. As a result the thyristor **18** is also maintained conducting, even after interruptions of its anode current of a duration longer than its recovery time. The duration of the forward current supplied to its control electrode is thus limited by the time constant of the network **32 – 37,** provided the contact of the switch **25** remains broken during this time. During the time determined by this time constant, a train of high-voltage pulses may be produced across the secondary winding **4,** for example, in the form of pulses of damped oscillations of a comparitively low frequency, for example, 20 kc/s, of the circuit **1,2** which is alternately closed through a thyristor **18** and through the rectifier **15'**.

A practical embodiment of the apparatus of FIG. **1** included a balanced converter as shown in FIG. **2.** The following components were used:

Transistors 7 and 7'	Philips type ASZ 18,
Transistors 19 and 26	Philips type BC 186,
Rectifier 15'	Philips type BY 123,
Thyristor 18	Philips type BTY 91,
Capacitor 1	1 μF,
Resistors 12 and 12'	5 ohms each,
Resistors 14 and 14'	270 ohms each,
Resistor 20	22 kilo-ohms,
Resistor 21	180 kilo-ohms,
Resistor 22	5.6 kilo-ohms,
Resistor 23	27 ohms,
Resistor 24	4.7 kilo-ohms,
Resistor 27	1 kilo-ohm,
Resistor 28	220 ohms,
Transformer 8–11	12 volts →400 volts,
Transformer 2–4	normal ignition coil.

The control signal may be produced by various means other than a switch or contact breaker, for example, by a permanent magnet displacable relative to a coil or a Hall generator.

In the third embodiment, part of which is shown in FIG. **3,** this signal is transmitted as a sudden large variation of a photosensitive resistor. The transistors **19** and **26'** are connected in the manner shown in FIG. **2,** with the exception that the base of the transistor **19** is directly connected to the positive terminal of the supply source **6,** the delay network **32 – 37** being omitted, and that the collector resistor **20** of this transistor is also omitted and replaced by a photosensitive resistor or LDR **38** connected in series with a variable resistor **39** between the collector of the transistor **19** and the base of the transistor **26'**. An electric incandescent lamp **40** is fed from the source **6** through a variable resistor **41.** It is arranged so as to be capable of illuminating the LDR **38** through an aperture **42** in a screening member **43.**

As shown in FIG. **4,** the screening member **43** is a disc having two apertures **42.** The disc may be driven by the crankshaft of a two-cylinder four-stroke spark-ignition internal-combustion engine together with the rotor of the distributor thereof.

As in the second embodiment shown in FIG. **2,** the transistor **19** compares a proportional part of the charge voltage of the capacitor **1** with the voltage of the supply source **6** and conducts only if the capacitor voltage exceeds a predetermined value. The collector circuit of this transistor includes the control electrode cathode path of the thyristor **18,** the resistor **28,** the base emitter path of the transistor **26'** and, in addition, the variable resistor **39** and the LDR-**38.** So long as the latter is not illuminated its resistance is so high that only a negligibly small collector current can flow to the base of the transistor **26'** so that the emitter current of this transistor is not sufficient to render the thyristor **18** conducting. Consequently, the thyristor becomes conducting only when, the capacitor **1** being sufficiently charged, the LDR **38** is illuminated by the lamp **40.**

The duration of the train of high-voltage pulses produced is equal to the time during which the LDR **38** is sufficiently illuminated to cause the transistor **26'** to supply a sufficient forward current to the control electrode of the thyristor **18.**

As shown in FIG. **4,** the apertures or slots **42** of the screening member **43** have a gradually varying width, so that a gradually increasing and decreasing part of the light emitted by the lamp **40** illuminates the LDR **38.** On the other hand, the sensitivity threshold of the control circuit can be varied by means of the variable resistor **39** and/or the brightness of the lamp **40** can be varied by means of the variable resistor **41.** The duration of the train of high-voltage pulses and/or the starting instant of this train relative to the position of the screening member **43** can thus be controlled. In an ignition apparatus for a spark-ignition internal-combustion engine, this control can be automatically performed, for example, by varying the value of the resistor **41** under the control of data supplied by a gas-chromatograph and/or a tachometer-generator. A transistor can thereby obviously be used as the variable resistor. U.S. Pat. No. 3,361,123 (R. Kasama et al.) describes an ignition system in which the internal resistance of a transistor is varied as a function of engine speed to provide an automatic ignition advance capability. This automatic control is a very useful and desirable property because the composition and the pressure of the combustible gas mixture in a spark-ignition internal-combustion engine vary very strongly, whereas the most complete combustion possible is always desired or even required, incomplete combustion giving rise to strong corrosion of the spark plug electrodes, which again results in a still poorer combustion. An indispensable means for counteracting such incomplete combustion is a permanently operating automatic adjustment of the instant of ignition and of the duration of the ignition spark or train of ignition sparks. U.S. Pat. No. 3,314,407 (A. Schneider) provides background information for the invention and further illustrates the state of the art by describing a control system in which a parameter of an internal combustion engine is used to vary an electrical characteristic of an engine control system or the like. Bosch et al. discloses a fuel injection system for an internal combustion engine in which the airflow in the engine intake manifold influences the amount of fuel injection via a heated negative temperature coefficient resistor placed in the manifold and electrically connected in a transistor control circuit. Bosch et al also shows a centrifugal device coupled to the engine shaft and mechanically coupled to the arm of a variable resistor connected in the same transistor control circuit whereby the engine speed is made a factor in the control arrangement. The engine parameter control principles disclosed in the foregoing U.S. patents may be utilized in the embodiment of FIG. 3 of the invention.

In the modification shown in FIG. **5,** the transistor **19** forms part of an integrated circuit **50** which also comprises base, emitter and collector resistors **29, 30** and **31** for this transistor, a protection diode **44,** connected with the opposite polarity in parallel with its base emitter path, a phototransistor **38'** which replaces the LDR **38** of FIG. **3,** and three additional n-p-n amplifying transistors **46, 47** and **49** in grounded emitter connection with thin collector resistors **46** and **51** respectively, and coupling resistors **48** and **52** respectively. By using such an integrated circuit having only four connecting leads, namely two for the supply, one for the input and one for the output, the entire apparatus is reduced to very small dimensions, whilst its production is rendered very simple and hence cheap.

What is claimed is:

1. An apparatus for producing high-voltage pulses for a spark plug of an internal-combustion engine comprising, a capacitor connected in series with the primary winding of a step-up high-voltage transformer across the secondary winding of which at least one spark plug is connected, a voltage supply source including means by which said capacitor is charged to a predetermined voltage level sufficient to produce a spark discharge, a controlled rectifier through which the capacitor is discharged through the primary winding of the high-voltage transformer, and a control circuit for causing the controlled rectifier to become conductive including an and-gate to which a recurrent control signal synchronized with the engine rotation and a voltage derived from the voltage across the capacitor are applied so that the controlled rectifier is repeatedly rendered conductive when the voltage across the capacitor reaches said predetermined level and the control signal is simultaneously applied to the and-gate.

2. An apparatus as claimed in claim **1** wherein the control circuit includes a transistor between the emitter and base electrodes of which a voltage is applied that is the difference between a proportional part of the voltage across the capacitor and a reference voltage proportional to the voltage of the supply source with the control signal present, so that the repetition frequency of the high-voltage pulses produced is substantially independent of the voltage of the supply source.

3. An apparatus as claimed in claim **1** in which the series combination of the capacitor and the primary winding of the high-voltage transformer is shunted by the series combination of two rectifier elements so that when the controlled rectifier conducts the first mentioned series combination forms a resonant circuit closed for currents of both directions, characterized in that the capacitance of the capacitor and the inductance effective across the primary winding of the high-voltage transformer are chosen so that one half-cycle of the natural oscillation of the resonant circuit is shorter than the recovery time of the controlled rectifier, so that each high-voltage pulse produced is an oscillation pulse extending over more than one oscillation cycle of said resonant circuit.

4. An apparatus as claimed in claim **1** wherein the control signal is produced by the illumination of a photosensitive element through a slot formed in a screening member driven by the engine, characterized in that the width of this slot varies gradually, and means for varying the intensity of the source of light used for illuminating the photosensitive element and/or the sensitivity of said photosensitive element under control of the respective values of one or more operational parameters of the engine.

5. An apparatus as claimed in claim **4,** further comprising means for varying the intensity of the light source and/or the sensitivity of the photosensitive element under control of a gas chromatograph.

6. An electric ignition system for an engine having one or more spark plugs comprising, a source of voltage, a transformer having a primary winding and a secondary winding coupled to a spark plug, a capacitor connected in series with said primary winding across the voltage source, means including said voltage source for charging the capacitor to a predetermined value sufficient to produce a spark discharge, a discharge circuit for said capacitor including a controlled rectifier connected in series with the capacitor and primary winding, and a control circuit coupled to the control electrode of the controlled rectifier so as to initiate current flow therein comprising, a gate circuit having an output coupled to said control electrode and an input, means controlled by the engine for generating a recurrent control signal that varies as a function of the engine speed, means for deriving a voltage proportional to the capacitor voltage, means coupling said signal generating means and said voltage deriving means to the input of said gate circuit whereby the gate circuit supplies a current initiating pulse to said control electrode when the control signal is present at the gate input and the capacitor voltage reaches said predetermined value.

7. A system as claimed in claim **6** wherein the electrical parameters of the transformer and capacitor are chosen so that a charge-discharge cycle of the capacitor is substantially shorter than the recurrence gating period of said control signal for low engine operating speeds whereby the capacitor is charged and discharged at least twice during each recurrence period of the control signal thereby to develop a plurality of spark discharge pulses across said spark plug during each recurrence gating period.

8. A system as claimed in claim **7** wherein said gate circuit includes an electronic switch having one input coupled to said signal generating means and said voltage deriving means and a second input coupled to a source of reference voltage of a value chosen so that said electronic switch passes a control pulse to said control electrode each time said predetermined capacitor voltage is developed and the control signal is present at the input.

9. A system as claimed in claim **6** wherein said voltage source comprises a DC-AC converter including electric oscillating means having an output circuit coupled to said capacitor and controlled rectifier via a rectifier circuit so that oscillations therein are inhibited during at least a part of the period said controlled rectifier is conductive.

10. A system as claimed in claim **6** wherein said control signal generating means comprises a contact breaker operated in synchronism with the engine.

11. A system as claimed in claim **6** wherein said control signal generating means comprises a photosensitive element connected in the input of said gate circuit, a source of light spaced from said photosensitive element, and an opaque member having a slot therein positioned between said light source and photosensitive element and rotatable in synchronism with the engine.

12. A system as claimed in claim **11** further comprising means for varying the intensity of the light emitted by said light source as a function of the engine speed.

13. A system as claimed in claim **6** wherein said gate circuit comprises a transistor having a base electrode and an emitter electrode which together form the input thereof, and means for applying a reference voltage proportional to the voltage of the voltage source to one of said electrodes and said capacitor proportional voltage to the other of said transistor electrodes, the capacitor voltage being determined by the voltage of said voltage source.

14. A system as claimed in claim **6** wherein said voltage deriving means comprises a first voltage divider connected across said capacitor and to the input of the gate circuit and a second voltage divider connected across the voltage source and to the input of the gate circuit, and wherein said control signal generating means includes switching means synchronized to the engine shaft rotation and coupled to said first and second voltage dividers so as to alter the voltage distribution thereacross as a function of the condition of the switching means.

15. A system as claimed in claim **6** wherein said control signal generating means comprises a photosensitive element conncted in the input of said gate circuit, a source of light spaced from said photosensitive element, an opaque screening member having a slot therein positioned between said light source and photosensitive element and rotatable in synchronism with the engine, and means for varying the intensity of the light emitted by said light source in a manner so as to control the instant of ignition of the spark discharge.

16. A system as claimed in claim **6** wherein said control circuit further comprises a time delay network coupled to the input of the gate circuit and arranged to maintain the flow of said current pulse to said control electrode subsequent to the discharge of the capacitor and for a time period determined by the time constant thereof.

17. A system as claimed in claim **15** wherein the width of the slot in the screening member varies gradually.

18. A system as claimed in claim **6** wherein said control signal generating means comprises a photosensitive element connected in the input of said gate circuit, a source of light spaced from said photosensitive element, an opaque screening member having a slot therein positioned between said light source and photosensitive element and rotatable in synchronism with the engine, the width of said slot varying gradually with its radial distance from the axis of rotation of the screening member, and means for varying the intensity of the light emitted by said light source as a function of the engine speed.

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