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(54) **Multi-charge ignition system**

(57) An ignition system and method of multicharge ignition are presented.

The system comprisies an ignition coil (16) having primary (18) and secondary (20) windings and a control unit (30) configured to operate charging and discharging phases of the ignition coil (16) by actuation of a switching device (22) in order to create a first spark followed by a plurality of subsequent sparks at prescribed timings ($t_{s1}...t_{s4}$). The control unit (30) is further configured to, during a respective spark-interval (T_{si}), monitor the energy level in the secondary winding (20) and stop the discharge phase and operate a charging phase, at the moment when the remaining time until the next prescribed timing (t_{si}) corresponds to the time required to charge the primary winding (18) to a prescribed energy level (I_{P-tgt}).

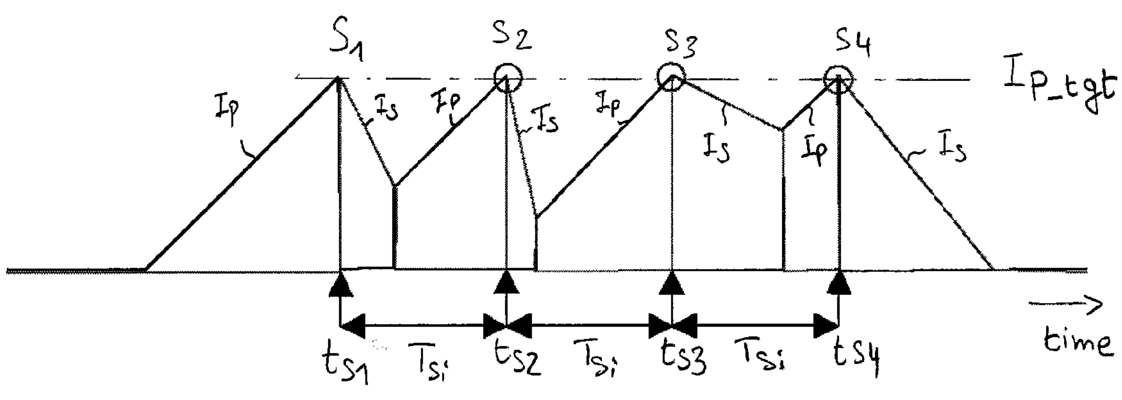

FIG. 2

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Description

FIELD OF THE INVENTION

[0001] The present invention generally relates to the control of ignition in an internal combustion engine, and more particularly to the production of repetitive sparks for ignition of the combustion mixture.

BACKGROUND OF THE INVENTION

[0002] Multi- charge ignition systems are designed to generate multiple spark events during a combustion event. Such ignition systems provide a sequence of (preferably fast) spark breakdowns to ensure ignition of a combustible air/ fuel mixture introduced in a cylinder of an internal combustion engine. According to the multi-charge ignition strategy, a series of sparks is provided to increase the probability of combustion of the air/ fuel mixture by extending the time and total energy available for ignition.

[0003] Typically, an ignition coil undergoes an initial charge (i.e., initial dwell) wherein a primary current is established in a primary winding of the ignition coil/ transformer. The initial dwell is immediately followed by an initial discharge of the ignition coil wherein a secondary current in a secondary winding thereof discharges through a spark plug to generate a first spark. Subsequent recharge phases (i.e., subsequent dwell periods) follow, accompanied by respective discharge phases (i.e., spark events) . The number of sparks produced is generally determined by a predetermined operating strategy (e.g., a fixed number of sparks, or, the greatest number of sparks that can be initiated before the end of a predetermined angle of engine rotation or a predetermined fixed time) .

[0004] Two control principles have been developed for multi-charge ignition systems: (1) time control and (2) current control.

[0005] In a time-controlled multi-charge ignition systems, the period of time allowed for the discharge of the coil-i.e. spark event-and burn before the next recharge and the period of time allowed for the next recharge is determined solely based on time. This means in practice that a prescribed time interval is set between two consecutive sparks for a given combustion cycle, generally implying pre-defined discharge and charge time-periods. A known shortcoming of time-controlled multi-charge is the variability of the level of energy in the primary winding during a recharge phase. Indeed, since the discharge rate depends on the combustion conditions, the discharge level of the ignition coil is variable. Accordingly, when combustion requirements increase, the recharge dwell/phase may not switch at a high enough primary winding current to compensate for the previous spark discharge and result in less efficient combustion. Conversely, when the combustion requirements decrease, the recharge dwell may switch current at a too high level.

[0006] Current- controlled systems, on the other hand, detect the energy that is taken away from the coil during a discharge event and replace this energy to an exactly defined level during the following recharge event before it fires again. The value (or level) of the primary current is used as a measure of the coil energy. In contrast to time- controlled systems the charge state of the current controlled ignition coils is always known. As mentioned above, varying conditions in the combustion chamber can lead to a more or less emptied coil during sparking. Conventional time- controlled systems cannot determine the varying coil charge state. To avoid a highly discharged coil, in current- controlled systems the secondary current can also be measured and the spark can be interrupted when the secondary current drops below a certain given threshold.

[0007] US 6,378,513 describes such a current-controlled multi-charge ignition system, which permits minimising or eliminating the variability in the amount of energy delivered to the combustion chamber. It comprises a control circuit configured to generate an ignition control signal so as to repetitively interrupt the primary current, creating pulses of secondary current to produce a plurality of sparks at the spark plug. A sensing circuit is designed to determine the level of the current in both the primary winding and the secondary winding; this allows controlling the amount of energy that is stored in the ignition coil and delivered to the combustion chamber, respectively.

[0008] Current- controlled multi- charge systems are thus generally considered superior to time controlled system, as they allow for a precise control of the charging level, although at variable timings. For certain engine operating conditions it is however desirable to know with precision the spark timing for improved performances.

OBJECT OF THE INVENTION

[0009] Hence, there is a need for an improved system for providing multi- charge ignition to an internal combustion engine that allows producing a fast sequence of sparks with short burn time and does not comprise the above- described shortcomings.

[0010] This object is achieved by an ignition system as claimed in claim 1.

SUMMARY OF THE INVENTION

[0011] The present invention concerns a multi-charge ignition system for an internal combustion engine comprising: an ignition coil having a primary winding and a secondary winding typically coupled to a pair of gapped electrodes at a spark plug; a power supply for supplying power to said primary winding; and a switching device for allowing or interrupting the flow of primary current through the primary winding.

[0012] A control unit is configured to operate charging and discharging phases of the ignition coil by actuation of the switching device in order to create a first spark followed by a plurality of subsequent sparks at prescribed timings (i.e. pre-defined, fixed timings).

[0013] It shall be appreciated that the control unit is further configured to, during a respective spark-interval, monitor the energy level in the secondary winding and stop the discharge phase and operate a subsequent charging phase, at the moment when the remaining time until the next prescribed timing corresponds to the time required for charging the primary winding to a prescribed energy level.

[0014] The present invention hence provides a multi-charge ignition system that is timely controlled, i.e. sparks are delivered at known, pre-set timings, and that also allows controlling the energy level stored in the ignition coil. This is possible since the charging characteristic of the primary winding is fairly predictable, contrary to the rate of ignition coil discharge. As it is known, the greater the discharge of the secondary winding, the greater the energy to be charged in the primary winding to return to the same energy level. In other words, the time required to charge the primary to a desired energy level depends on the energy level in the secondary and on the charge characteristic of the primary winding.

[0015] According to the present invention, the control unit switches from discharge to recharge mode when it is determined that the time remaining until the next prescribed timing (respectively until the next spark) corresponds to the time required to charge the coil to the desired energy level, in view of the actual discharge state of the ignition coil. In such control the primary energy reaches the target level at the moment of the next spark, which further avoids overcharging.

[0016] Such control is achieved with the help of an energy threshold function defining a discharge energy level in function of time, which is designed in consideration of the charging characteristic of the ignition coil. In a practical implementation, this energy threshold function may be used to determine a variable secondary threshold (preferably expressed as a current threshold) that is compared to the energy level (also preferably a current level) remaining in the coil during a discharge phase.

[0017] Accordingly, in a preferred embodiment, the secondary current flowing through the secondary winding is monitored and the discharge phase is terminated when the measured secondary current equals or drops below the value of the variable secondary current threshold at the corresponding time.

[0018] The time dependence of the energy threshold function, respectively of the variable secondary current threshold, may be configured in function of the time elapsed since the last prescribed spark-timing or the time remaining until the next prescribed spark-timing.

[0019] As it will be understood by those skilled in the art, the time required for charging the ignition coil depends on the target primary current and the charge characteristic, itself affected by the coil temperature and supply voltage (battery or alternate power source coupled to the ignition coil). Accordingly, the energy threshold function, respectively the variable secondary (current) threshold, is configured to be dependent on one or more of these parameters. A further parameter that is preferably taken into account for implementation is the time between two consecutive sparks (i.e. spark-interval).

[0020] In practice, the function energy threshold function may be embodied as mathematical expressions and/or tables. Preferably, a set of tables is used that define the variable secondary current threshold as a function either of the time elapsed since the last prescribed spark-timing or the time remaining until the next prescribed spark-timing. The various tables are provided for different configurations of at least one of the following: target primary current of the charge phase for the next spark; power supply voltage; ignition coil temperature; spark interval.

[0021] Generally, the spark- interval may be constant for a combustion cycle, but dependent on engine operating conditions (e.g. speed and load) . However, the interval between two consecutive pre- scribed spark timings may be programmed to be variable.

[0022] Furthermore, the target primary current for a spark may be constant for a combustion cycle. Alternatively, a target primary current may assigned to each spark of a combustion cycle, which allows using two or more target primary current values.

[0023] These and other embodiments of the present invention are recited in the appended dependent claims.

[0024] According to another aspect, the invention concerns a method for providing multi-charge ignition to an internal combustion engine as claimed in claim 9.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1: is a current vs. time graph illustrating the operating principle underlying the present invention;

FIGS. 2 and 3: are exemplary diagrams illustrating the primary and secondary currents during a multi-charge ignition event with constant spark interval that is controlled in accordance with a preferred embodiment of the present invention; and

FIG. 4: is a principle diagram of a current-controlled multicharge ignition system configured for implementing a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

[0026] The present invention proposes a multi-charge ignition system and method that provides a time-controlled spark generation and is also capable of controlling the energy level in the ignition coil so that a prescribed charge level is available for each spark.

[0027] As it is known in the art, the rate of discharge of the secondary winding of an ignition coil (or transformer) depends on the condition of the combustion in the corresponding combustion chamber, mainly on the pressure distribution, the temperature and the air - fuel mixture. As it is also known, the more stored energy is discharged from the ignition coil, the larger the amount of energy is to be replaced until the next firing. Put in another away, the length of the recharge phase to bring the primary current to a target level is a function of the secondary current level at the time the discharge phase is terminated.

[0028] In conventional time controlled ignition, spark timings or spark intervals are pre-defined, as well as the duration of the charge and discharge periods of the ignition coil. Due to the variability of the discharge, the duration of the next charge/dwell of the primary coil may in certain cases be too short to reach the same energy level as for the previous spark. Alternatively, the fixed dwell period may be too long, whereby excess energy is stored in the primary winding, which is undesirable.

[0029] Whereas the discharge rate on the secondary side is not predictable, the charging characteristic of the primary winding is fairly predictable. This means that one may relatively accurately calculate the time required to store a certain amount of energy in the ignition coil.

[0030] The invention takes advantage of this predictable charging characteristic of the primary coil to switch from a discharge phase to a charging phase. During the discharge phase in a spark-interval, the secondary current in the secondary winding is monitored and the discharge is stopped-and the primary charging then started- at the moment when the remaining time until the next prescribed spark timing corresponds to the time required for charging the primary winding to the target primary current I_{P_tgt}.

[0031] The present control principle is illustrated in Fig. 1, where time t_{s1} corresponds to the pre-defined, fixed time of the first spark and time t_{s2} corresponds to the pre-defined, fixed time of the second spark. The spark-interval, i.e. the time period separating the two consecutive, prescribed spark timings and is noted T_{si}.

[0032] Curves 6_a to 6_i represent different discharge currents in the secondary winding, which depend on the combustion conditions. As can be seen, different discharge rates may exist over a given time period, and the ignition coil may be more or less discharged.

[0033] Curve 8, in turn, represents the predictable charging characteristic (or charging rate) of the primary winding. The graph of Fig.1 hence readily shows the dependence between the ignition coil discharge level (indicated by the secondary current) and the predictable time required to charge the ignition coil (with predictable charge characteristic) to a target primary current.

[0034] In practice, a control unit of the ignition system preferably measures the secondary current and compares it to a time dependent, variable secondary current threshold, which is designed in consideration of the primary charging characteristic. As it will be understood, the variable secondary current threshold is typically also function of the target primary current $\mathbf{I_{P\_tgt}}$.

[0035] As it appears from Fig.1, the greater the discharge state, the longer the re-charge phase to bring the coil to a same energy level. Thanks to the variable secondary current threshold used in the present method, the discharge of the coil can be terminated at the time required to bring the coil to a desired energy level for the next spark.

[0036] Fig.4 illustrates an ignition system 10 for an internal combustion engine (not shown) designed to operate the present multi-charge ignition principle. The engine is of the type having a rotating crankshaft to which are connected a plurality of pistons disposed in respective cylinders in a manner understood to those skilled in the art. Engine may be of the type having a direct ignition system for initiating combustion.

[0037] The ignition system 10 includes an ignition coil 16 (or transformer) comprising primary winding 18 and secondary winding 20, a switch 22, a spark plug 24 comprising a pair of gapped electrode 26, 28, primary and secondary sensing circuits comprising a resistor R1 and R2 respectively, and an ignition Control Unit 30. In addition, system 10 may include a diode D1, avoiding a so-called spark- on- make, which is a spark that occurs at switch on (i.e. closing) of switch 22 during the initial charge (dwell) of the coil due to secondary voltage being induced by the turns ratio of the transformer.

[0038] Ignition coil 16 is configured to function as a selectively controllable step-up transformer. One end, such as the high side end, of primary winding 18 is connected to a supply voltage provided by a power supply, such as a vehicle battery 32. Supply voltage may nominally be approximately 12 to 14 volts. A second end of primary winding 18, opposite the high side end, is connected to switch 22. A first end of secondary winding 20, namely the high side end, is coupled to spark plug 24. A second end of secondary winding 20 opposite the high end, namely the low side end, is connected to a ground node through diode D1 and sensing resistor R2. The Diode D1 is optional and can also be placed on the high side end. Primary winding 18 and secondary winding 20 are matched in a predetermined manner known in the art. In the present embodiment, one ignition coil 16 is provided per plug 24.

[0039] Switch 22 is provided to selectively connect primary winding 18 to ground, in accordance with a control voltage SCS applied by control unit 30. Such a connection to ground, as is known generally in the art, will cause a primary current I_P to flow through primary winding 18. Switch 22 is illustrated in Fig. 4 as an insulated gate bipolar transistor (IGBT); however, it should be understood that switch 22 may comprise additional and/or alternative conventional components known to those of ordinary skill in the art to perform such switching operation.

[0040] Coil 16 and switch 22, together, define the means for selectively storing energy, preferably in a predetermined amount, and thereafter transferring the stored energy to spark plug 24.

[0041] Spark plug 24 is disposed in the engine with its firing face in a combustion chamber thereof, and is configured to produce a spark across the gap between its electrodes 26, 28. The spark, as is generally understood by those of ordinary skill in the art, is provided to ignite an air and fuel mixture introduced into the cylinder. During the spark, the secondary current I_S flows across the gap through plug 24 through secondary winding 20 and hence to ground by way of diode D1 and resistor R2.

[0042] Control circuit 30 is configured generally to perform time-controlled multi-charge ignition on the basis of the above-explained principle. As it is known in the art, the conditions for the first spark of the multi-charge ignition cycle is conventionally given by an engine control unit, such as a powertrain control module (PCM) (not shown), in the form of a ignition control signal EST (engine spark timing). The received EST signal conventionally defines the initial charging time (e.g., duration), and the relative timing (e.g., relative to cylinder top dead center) of when the initial, first spark is to occur. Under such a configuration, the control circuit 30 is designed to drive switch 22 in accordance with the received ignition control signal EST, but is further configured to thereafter generate the drive signals to switch 22 required for subsequent recharge/discharge phases of ignition coil 16. It may be noted that control circuit 30 may alternately be configured to determine the EST signal by itself.

[0043] Secondary current sensing circuit comprising sensing resistor R2 is illustrated as being coupled to secondary winding 20 and is configured to generate a secondary voltage signal, designated V_S. The secondary voltage signal V_S is representative of the level of secondary current I_S in secondary winding 20. Similarly, the primary current sensing circuit, which is optional, comprises sensing resistor R1 and the level of current I_P through the primary winding is indicated by the voltage V_P across sensing resistor R1.

[0044] Time- controlled multi- charge ignition implies generating a first spark and at least one subsequent spark at prescribed timings, i.e. fixed and predefined timing, so that the spark occurs at known timings. The ignition is generally performed in accordance with an ignition window. To create the sparks, charging and discharging phases are cyclically operated. The procedure starts with an initial charging phase (or dwell), e.g. triggered by the EST signal coinciding with a rising edge of an ignition window signal, which is followed by first discharge phase. During a charging/ dwell phase the control unit closes switch 22 to charge the primary coil.

[0045] The discharge phase starts at a prescribed timing (spark timing), with the interruption of the current in the primary to simultaneously induce a voltage in the secondary winding and create a spark. In the illustrated embodiment, this is done by discontinuing the signal SCS to switch 22. This action interrupts the primary current Ip and establishes a secondary voltage at secondary winding 20, which causes spark plug 24 to produce a spark across gap 30, whereby secondary current I_S flows and energy is discharged from the coil.

[0046] In the present time- controlled system, the timing of the sparks is known (pre- defined), and hence the start of each discharge phase. However, the duration of the discharge phases and corresponding recharges is not pre- defined. The switching from discharge to charge is operated at a timing appropriate to bring the primary winding to a desired energy level, respectively primary current, in consideration of the discharge in the secondary. As a result, discharge and recharge phases have a variable duration, but sparks are generated at fixed timings and at controlled energy.

[0047] As mentioned above, variable secondary current threshold can be used to trigger the new charging phase. In practice, the variable secondary current threshold may be implemented as a time dependent function stored in a memory as tables (or maps) with values for the secondary current threshold in function of time. The time dependence may be expressed as the time elapsed since the beginning of the discharge phase (hence since last prescribed timing) or as the time remaining until the next prescribed timing. As it has been understood, the basis for constructing this table is the charge characteristic of the primary winding, which is determined by the coil internal construction. In a first approximation, the charge characteristic for a given ignition coil is preferably dependent on the supply voltage (e.g. battery voltage) and ignition coil temperature. Furthermore, the charge duration depends on the target primary current. Accordingly, a set of tables of the secondary current threshold are preferably stored, for different combinations of supply voltages, temperature, target primary current I_{P_tgt} and spark-intervals. Instead of tables one may employ mathematical expression and algorithms to determine the secondary current threshold in function of time and for said parameters affecting the charge duration.

[0048] The secondary current I_S is thus periodically measured and compared to the variable secondary current threshold. As soon as the measured current Is equals, or drops below, the actual value of the variable secondary current threshold, the discharge phase is stopped and a new recharge phase initiated. The current in the primary winding will then be at the desired level $\mathbf{I_{P\_tgt}}$ at the prescribed time for the next spark.

[0049] The present control principle will now be explained on the basis of Figs.2 and 3. In Fig.2, the ignition coil undergoes a first charging phase to bring the primary current at I_{P_tgt} at the timing of the first spark t_{s1} to create a first spark S_1. Three secondary spark events S_2, S_3, S_4 are shown, which occur at prescribed timings t_{s2}, t_{s3} and t_{s4}. The spark interval T_{si} between two consecutive sparks S_n, S_{n+1} is constant (not variable).

[0050] The charge characteristic being predictable, the start of the first charging phase is determined so that

I_{P_tgt} is reached at the prescribed timing of first spark. At the first prescribed spark timing, the first discharge phase is triggered with the discontinuation of the primary current, causing a spark breakdown to be generated at the spark plug and the discharge of the secondary winding. During the first discharge phase the secondary current I_S is monitored and compared to the variable secondary current threshold. The discharge phase stops when the secondary current Is drops below the variable secondary current threshold, and a charge phase is initiated. Again, the variable secondary current threshold is time dependent and designed (on the basis of the coil charge characteristic) so that when Is crosses (equals or drops below) the threshold, the time remaining until the next prescribed timing corresponds to the time required to charge the primary winding to a desired energy level. In the exemple of Fig.2, the same target primary current I_{P_tgt} is used for each spark. As can be seen, by monitoring the discharge current in the secondary winding it is possible to bring the primary to the target level I_{P_tgt} when stopping at the appropriate timing, in consideration of the charge characteristic. In Fig.2, the predictable charge characteristic of the primary winding is characterized by the constant slope of the primary current trace.

[0051] Fig.3 also shows a multi-charge cycle with 4 sparks occurring at prescribed timings $t_{s1}...t_{s4}$ with a constant spark interval T_{si}. Here however the target primary current I_{P_tgt1} for the first spark S_1 is greater than the recharge primary current level I_{P_tgt2}.

[0052] As can be seen, the present control principle allows performing time-controlled multi-charge ignition by providing sparks at controlled timings, while ensuring a known and controlled energy level in the ignition coil.

[0053] The present control principle can be easily implemented. The pre-set information, like for any time controlled ignition system, are: the number of sparks and their timing (or the spark interval). The first timing and first charge duration are preferably set by the EST signal. To perform the present method, the target primary current is further pre-defined as well as a set of tables for the variable secondary current threshold. In general, the spark-interval is constant within one combustion cycle, although one could operate with varying pre-defined spark-interval (which would then require additional tables for for the variable secondary current threshold). As regards the target primary current, a single value may be used for within one combustion chamber, or one may assign a predefined target primary level to each individual spark event.

[0054] As it will be understood, the spark-timing, spark interval and target primary current are said to be predefined in the sense that they are input value in the charge or discharge phases. But these parameters need not be all pre-defined at the beginning of an ignition event, they can also be evaluated during a combustion event, in as much as they are pre-defined with regard to the operating phase in which they are used. For example, the spark intervals or timing may be constant, or determined based on engine operating parameters. Similarly, the target primary current to be reached at the end of a charge phase may be fixedly defined (mapped) or e.g. expressed as a function of discharge current of the preceding discharge.

Claims

1. An ignition system for an internal combustion engine comprising:

   an ignition coil (16) having a primary winding (18) and a secondary winding (20);
   a power supply (32) for supplying power to said primary winding (18);
   a switching device (22) for allowing or interrupting the flow of primary current (I_P) through said primary winding at controlled timings;
   a control unit (30) configured to operate charging and discharging phases of said ignition coil (16) by actuation of said switching device (22) in order to create a first spark followed by a plurality of subsequent sparks at prescribed timings ($t_{s1}...t_{s4}$)
   characterized in that the control unit (30) is further configured to, during a respective spark-interval (T_{si}), monitor the energy level in the secondary winding (20) and stop the discharge phase and operate a charging phase, at the moment when the remaining time until the next prescribed timing (t_{si}) corresponds to the time required to charge the primary winding (18) to a prescribed energy level (I_{P-tgt}).

2. The ignition system according to claim 1, wherein the energy level in said secondary winding is compared to a time-dependent variable secondary threshold depending, preferably a variable secondary current threshold.

3. The ignition system according to claim 2, wherein monitoring said energy level in said secondary winding comprises monitoring the secondary current flowing therethrough; and the discharge phase is terminated when the measured secondary current equals or drops below said variable secondary current threshold.

4. The ignition system according to claim 2 or 3, wherein said variable secondary current threshold is designed in consideration of the charging characteristic of the primary winding.

5. The ignition system according to claim 3 or 4, wherein said variable secondary current threshold is dependent on:

   - the time elapsed since the last prescribed

spark-timing or the time remaining until the next prescribed spark-timing;
- the target primary current of the charge phase for the next spark;
- and preferably further dependent on at least one of the voltage of said power supply, the ignition coil temperature, the spark-interval.

6. The ignition system according to any one of the preceding claims, wherein the spark-interval is substantially constant for a combustion cycle.

7. The ignition system according to any one of the preceding claims, wherein the target primary current for a spark is constant for a combustion cycle; or a target primary current is assigned to each spark of a combustion cycle.

8. The ignition system according to any one of the preceding claims, wherein the charge and discharge phases are cyclically continued in accordance with an ignition window of a combustion cycle.

9. A method for providing multi-charge ignition to an internal combustion engine, wherein charging and discharge phases of an ignition coil are operated by actuation of a switching device in order to create a first spark followed by a plurality of subsequent sparks at prescribed timings, **characterized in that** during a discharge phase the energy level in the secondary winding is monitored and the switch to the next charging phase is operated, at the moment when the remaining time until the next prescribed timing corresponds to the time required to charge the primary winding to a prescribed energy level.

10. The method according to claim 9, wherein the switching moment is determined with an energy threshold function defining a discharge energy level in function of time, which is designed in consideration of the charging characteristic of ignition coil.

11. The method according to claim 10, wherein during a discharge phase, the switching is operated when the measured energy level in the coil reaches or drops below the actual value of said energy threshold function.

12. The method according to claim 10 or 11, wherein said energy threshold function is dependent on at least one of:

- the time elapsed since the last prescribed spark-timing or the time remaining until the next prescribed spark-timing;
- the target primary current of the charge phase for the next spark;
- the voltage of said power supply;
- the ignition coil temperature; and
- the spark-interval.

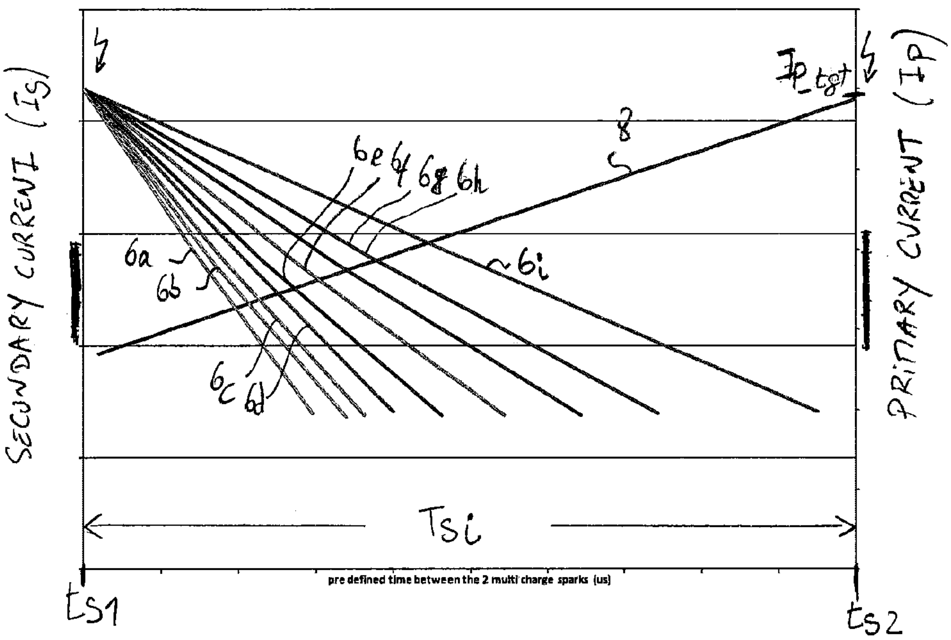

FIG. 1

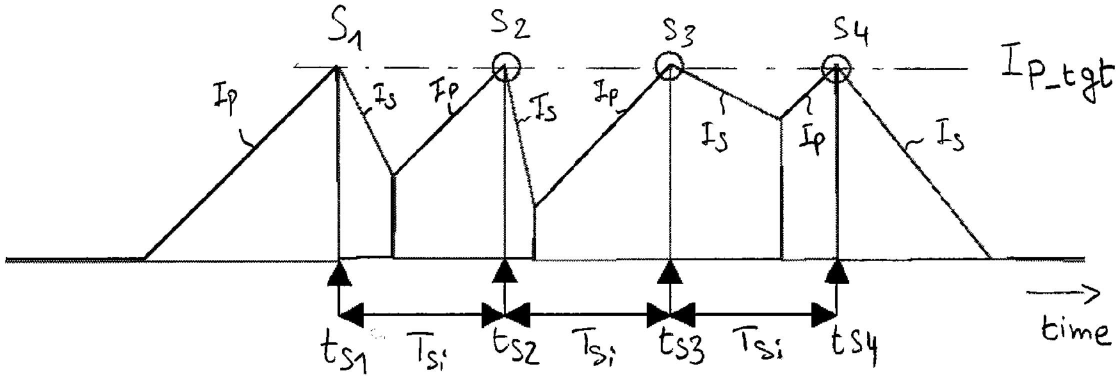

FIG. 2

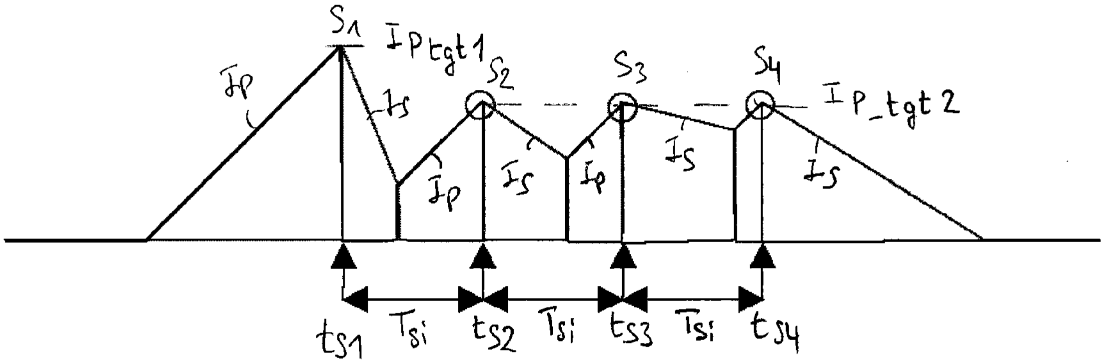

FIG. 3

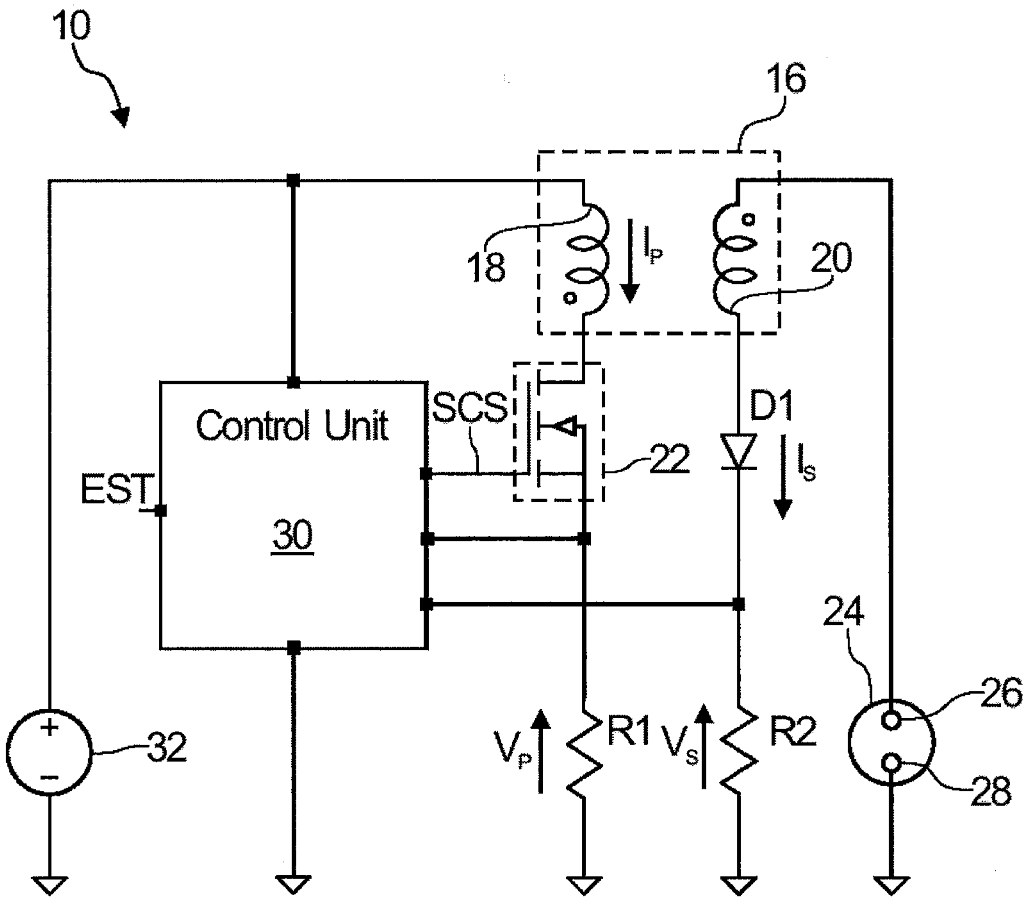
10
16
18
I_P
20
Control Unit
30
SCS
D1
22
I_S
EST
24
26
+
–
32
V_P
R1
V_S
R2
28

FIG. 4

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 12 16 4128

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 6 186 130 B1 (SKINNER ALBERT ANTHONY [US] ET AL) 13 February 2001 (2001-02-13) * column 3, line 51 - column 4, line 31; figures * * column 5, line 6 - column 6, line 37 *	1-12	INV. F02P3/08 F02P15/08
X A	US 2003/089355 A1 (VOGEL MANFRED [DE] ET AL) 15 May 2003 (2003-05-15) * paragraph [0016] - paragraph [0017]; figures * * paragraph [0021] *	1-4,6-11 5,12	
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X	DE 10 2007 034399 A1 (DAIMLER AG [DE]) 29 January 2009 (2009-01-29) * paragraph [0021] - paragraph [0023]; figures *	1-4,6-11	TECHNICAL FIELDS SEARCHED (IPC) F02P
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The present search report has been drawn up for all claims

3

Place of search	Date of completion of the search	Examiner
Munich	21 September 2012	Ulivieri, Enrico

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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