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(54) **Ignition system**

(57) An ignition system for an engine is described consisting of a dual primary single secondary ignition coil for establishment of a continuous extended arc across a pair of electrodes, in which the primary coils have winding

ratios relative to the secondary that are closely matched. A method of producing electrical arcs making use of such a dual primary single secondary ignition coil is also described.

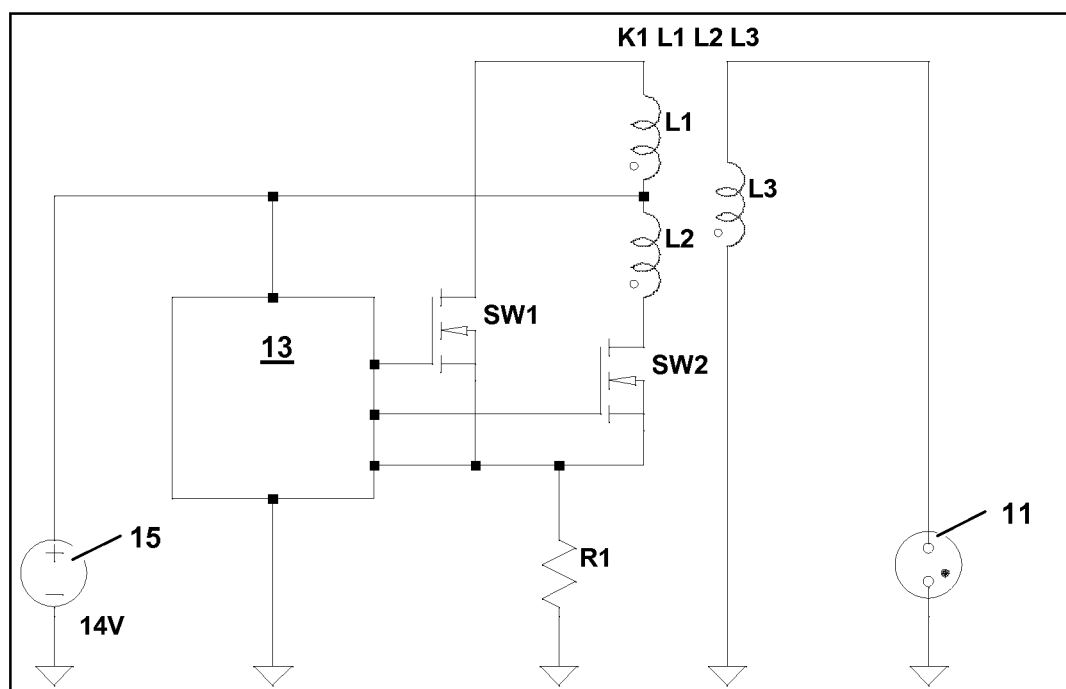


Figure 1

Description

Technical field

[0001] The present invention relates to an ignition system and particularly, but not exclusively, to an AC ignition system having two primary coils.

Background of the invention

[0002] The automotive industries have developed gasoline engines that use very lean air-fuel mixtures, that is, having a higher air component, to reduce fuel consumption and emissions. Common combustion principles are either homogeneous lean mixtures or stratified direct injection. To get a safe ignition it is necessary to have a high energy ignition source.

[0003] Prior art solutions are generally large, high energy, single spark ignition coils, which have a limited spark duration and energy output. To overcome this limitation and also to reduce the size of the ignition system multi-charge Ignition systems have been developed. Multi-charge systems produce a fast sequence of individual sparks, so that the output is a long quasi-continuous spark. Multi-charge ignition methods have the disadvantage that the spark is interrupted during the recharge periods which has negative effects, particularly noticeable when high turbulences are present in the combustion chamber. For example this can lead to misfire, resulting in higher fuel consumption and higher emissions.

[0004] AC Ignition systems do not interrupt the spark while recharging the coil but traditionally have been very complex and typically need an extra DC-DC converter, increasing complexity and cost.

[0005] Furthermore, AC Ignition systems having two primary coils and a single secondary coil are known, such as the system shown in US 5,886,476. US 5,886,476 discloses an AC ignition system having a dual primary ignition coil in which each respective primary winding of the ignition coil is independently energized to establish magnetic fields of opposite polarity. A single secondary winding of the ignition coil is inductively coupled to the primary windings and has opposite ends connected across a pair of electrodes.

[0006] The first primary winding is first energized and deenergized to induce a breakdown voltage across the pair of electrodes and create an electrical arc thereacross. The second primary winding is next energized subsequent to the deenergization of the first primary winding and thereafter deenergized to maintain an electrical arc across the pair of electrodes. The first primary winding to be energized has a relatively lower turns ratio to the secondary than the second primary winding to be energized. The turns ratio is kept low enough to avoid ignition on make. The arc is amplified by discharge of the second primary winding. This asymmetric arrangement militates against further cycling as it is not practical to reenergize

the first primary winding whilst the second primary winding is deenergized.

Summary of the invention

[0007] According to a first aspect of the present invention there is provided an ignition system for an engine comprising:

- 5 a pair of gapped electrodes;
- a secondary winding having a pair of output terminals coupled to the gapped electrodes;
- a first primary winding inductively coupled to the secondary winding;
- 15 a second primary winding inductively coupled to the secondary winding;
- the primary windings being so wound that a first winding ratio of the first primary winding to the secondary winding and a second winding ratio of the second primary winding to the secondary winding are closely matched; and
- 20 a circuit arrangement enabled to sequentially and repeatedly energize and deenergize the first primary winding to establish a first electrical arc across the gapped electrodes and energize and deenergize the second primary winding to establish a second electrical arc across the gapped electrodes.

[0008] The present invention provides a centre-tapped dual primary ignition coil in which each respective primary winding is independently energized to establish magnetic fields of opposite polarity. A single secondary winding is inductively coupled to the primary windings and has opposite ends coupled to a pair of electrodes.

- 35 **[0009]** Two switching devices alternately switch the center tapped primary. This flows current in different directions relative to the magnetic circuit. The first discharge creates a high voltage pulse to break down the spark gap. The following charge cycle drives alternate current through the secondary. A first one of the primary windings is first energized and deenergized to induce a breakdown voltage across the pair of electrodes and create an electrical arc thereacross. The second one of the primary windings is next energized subsequent to the deenergization of the first primary winding and thereafter deenergized to create an electrical arc across the pair of electrodes. The deenergization of the second primary winding preferably occurs prior to the extinguishment of the first primary winding induced arc to increase output energy.

- 50 **[0010]** In contrast to the prior art system exemplified by US 5,886,476 the first winding ratio of the first primary winding to the secondary winding and the second winding ratio of the second primary winding to the secondary winding are relatively closely matched to produce a system that is sufficiently symmetrical in practice that it becomes realistic to reenergize the first primary winding whilst the second primary winding is deenergized and

thus becomes possible to successively and indefinitely cycle between an arc generated by the first primary winding and an arc generated by the second primary winding. As long as the transformed voltage is greater than the spark gap "burn" voltage the discharge will be continuous. The discharge will transfer energy directly from primary to secondary as the secondary coil is shorted in a continuously cycled manner.

[0011] The ignition system produces a real continuous spark with adjustable energy and length. It requires only a small ignition coil and a few electronic parts. There may be a reduced requirement for high voltage components on the secondary side. The system may allow integration of diagnostic functions like ion current sensing.

[0012] The first and second primary windings are wound to define respective first and second winding ratios, being in each case the ratio of the number of turns on the secondary to the number of turns on the primary. In accordance with the invention, the first and second winding ratios are more closely matched than in the prior art, to give a more symmetrical arrangement. It is necessary for the invention that the arrangement approximates sufficiently closely to the symmetrical condition that it becomes practical to reenergize the first primary winding whilst the second primary winding is deenergized and thus alternate continuously. For example in the present invention a first winding ratio and a second winding ratio differ from one another by no more than a ratio of 3:2, more preferably by no more than 10%, and more preferably yet being substantially identical.

[0013] This requires a closer balance than that in US5886476 where in the specified embodiment the two primaries have substantially different winding ratios as it is a requirement that the coil that is charged first has a low enough turns ratio to prevent ignition on make. In a preferred mode of operation of the present invention, as discussed below, the make voltage concern is handled instead by having a faster charge time and higher primary current.

[0014] The winding ratios of the secondary winding to the first and second primary windings are also preferably relatively high. Preferably, the first and second winding ratios are at least 200 and more preferably at least 300 and in many instances at least 500. It is desirable to generate a secondary voltage of at least 6 kV. This can be achieved by making use of a high primary voltage, but at the penalty of additional components such as a DC-DC convertor and high voltage capacitor as will be familiar. In a preferred mode of operation of the present invention, as discussed below, this is achieved instead by using a high winding ratio and high primary current. An unstepped primary voltage, for example a standard vehicular 13V, may be used with an appropriate winding ratio to generate a secondary voltage of at least 6 kV.

[0015] Preferably, first and second primary windings may be wound on an axially extending magnetic core in familiar manner. In a particularly preferred geometry both primary windings may be wound directly on adjacent por-

tions of the magnetic core such that the primary windings are axially adjacent. Alternatively the primary windings may be coaxially wound as respectively inner and outer primary windings about an axially extending magnetic core. In such an arrangement the outer primary winding is disposed about the inner primary winding. Both of the primary windings may be wound in the same or opposite directions.

[0016] The ignition coil comprises a secondary winding that is inductively coupled to each of the primary windings. Preferably the ignition coil is disposed about the primary windings, for example coaxially therewith about an axial magnetic core.

[0017] Each of the windings may be wound as single or multiple winding layers about a magnetic core. The material choices for winding and core are not specifically pertinent to the invention, which relates rather to the particular structure of the two primary coils, and in particular to the at least relatively close matching of their turns ratios with respect to the secondary coil.

[0018] To enable a preferred mode of operation the circuit arrangement is preferably enabled to energize and deenergize successively and cyclically the first and second primary windings to produce a continuous arc discharge, for example in that the circuit arrangement is enabled to effect deenergization of a subsequently-energized primary winding prior to the extinguishment of an arc induced in a previously-energized primary winding. In this preferred mode of operation for continuous arc discharge it will be understood that references to the generation of a first electrical arc and a second electrical arc should be interpreted in this context as relating to the generation of successive electrical arcs by successively energized primary windings in such manner as to produce a continuous arc in operation.

[0019] To enable this preferred mode of operation the circuit arrangement is preferably enabled to produce a continuous spark via a plurality of successive and cyclical energization/deenergizations of a primary coil, in particular via at least three such cycles.

[0020] According to a second aspect of the present invention there is provided a method of producing electrical arcs across a pair of gapped electrodes coupled to opposite ends of a secondary winding of an ignition coil, comprising the steps:

energizing a first primary winding of the ignition coil inductively coupled to the secondary winding of the ignition coil;

reenergizing the first primary winding establish a first electrical arc across the pair of gapped electrodes; subsequent to the interruption of the energization of the first primary winding, energizing a second primary winding of the ignition coil inductively coupled to the secondary winding of the ignition coil; and deenergizing the second primary winding to establish a second electrical arc across the pair of gapped electrodes;

wherein the first primary winding and second primary winding are so wound about the ignition coil that a first winding ratio of the first primary winding to the secondary winding and a second winding ratio of a second primary winding to the secondary winding are closely matched, for example differing from one another by no more than a ratio of 3:2, more preferably by no more than 10%, and more preferably yet being substantially identical.

[0021] Preferably the method comprises:

energizing the first primary winding to produce a magnetic field of a first magnetic polarity;
deenergizing the first primary winding to induce voltage of a first voltage polarity across the pair of gapped electrodes resulting in a first arc of a first arc polarity across the pair of gapped electrodes;
energizing the second primary winding to produce a magnetic field of a second magnetic polarity opposite the first magnetic polarity; and,
deenergizing the second primary winding to induce voltage of a second voltage polarity opposite the first voltage polarity across the pair of gapped electrodes resulting in a second arc of a second arc polarity across the pair of gapped electrodes opposite the first arc polarity.

[0022] Preferably the method comprises successively and cyclically energizing and deenergizing the first and second primary windings to produce a continuous arc discharge, for example in that a subsequently-energized primary winding in deenergized prior to the extinguishment of an arc induced in a previously-energized primary winding.

[0023] This is made practical in that first winding ratio of the first primary winding to the secondary winding and the second winding ratio of the second primary winding to the secondary winding are relatively closely matched to produce a system that is sufficiently symmetrical to reenergize the first primary winding whilst the second primary winding is deenergized. It thus becomes possible to successively and indefinitely cycle between an arc generated by the first primary winding and an arc generated by the second primary winding. Preferably, the method comprises successively and cyclically energizing and deenergizing the respective primary windings a plurality of times, and more preferably at least three times.

[0024] In accordance with the invention, the first and second winding ratios are more closely matched than in the prior art as defined above. The first primary winding in particular is likely to have a significantly higher winding ratio. It may be desirable in such configuration to achieve faster charge times, for example to avoid ignition on make. Preferably therefore the method comprises the generation of a higher primary current than in some prior art systems. Preferably the method comprises the generation of a primary current of at least 20A, more preferably at least 30A and for example 30-40A. Preferably, the method additionally comprises the generation of a

first pulse having an energy of least 40mJ.

[0025] Suitable operational parameters necessary to achieve these objectives with a given ignition apparatus and system will readily be determinable by the skilled person.

Brief description of the drawings

[0026] The invention will now be described in an embodiment by way of example with reference to figures 1 to 3 of the accompanying drawings in which:

Figure 1 is an electrical schematic illustration of an ignition apparatus in accord with the present invention;

Figures 2 and 3 a to d illustrate certain characteristic signals at various points in a use cycle for the exemplary apparatus as illustrated in Figure 1.

Description of the preferred embodiments

[0027] With reference now to figure 1 a dual primary winding ignition coil is illustrated in electrical schematic as part of a one sided ignition apparatus servicing a single set of gapped electrodes in a spark plug 11 such as might be associated with a single combustion cylinder of an internal combustion engine (not shown).

[0028] The ignition system uses a fast charging ignition coil to generate the required high AC voltage L1, L2, L3 wound on a common core K1. The two coil ends of the first and second primary coils L1, L2 are alternately switched to a common ground such as a chassis ground of an automobile by electrical switches SW1, SW2. The two first and second primary coils are wound to have approximately the same winding ratios relative to the secondary winding L3. The secondary to primary winding ratio is kept high, and in the embodiment is around 500.

[0029] In the present embodiment for extended burn applications, it is assumed that the low-voltage end of the secondary winding L3 is coupled directly to a common ground or chassis ground of an automobile in conventional fashion. In application to plasma induced misfire detection, the low-voltage end could be, for example, coupled to ground through a tuned resonant network adapted to detect the presence of certain frequency content in the secondary winding indicative of combustion in the cylinder. In either application, the high-voltage end of the secondary ignition coil L3 is coupled to one electrode of a gapped pair of electrodes in a spark plug 11 through conventional means. The other electrode of the spark plug 11 is also coupled to a common ground, conventionally by way of threaded engagement of the spark plug to the engine block.

[0030] As earlier mentioned the primary windings of the dual primary ignition coil may be wound in the same or opposite directions about a primary core. In the illustration of figure 2 it is assumed that the two primary windings L1 and L2 are wound in the same direction.

[0031] To alternate the primary current a coil with centre tap is used. The centre tap of the primary coil is connected to a common energizing potential which in the present embodiment is assumed to correspond to conventional automotive system voltage in a nominal 12V automotive electrical system and is in the figure the positive voltage of battery 15. Such centre tap together with the assumed same direction winding pattern produces the desired opposite magnetic polarity through the magnetic circuit. Typically, the common energizing potential of the battery is coupled by way of an operator manipulated ignition switch which is hot in conventional start and run positions.

[0032] The charge current can be supervised by an electronic control circuit 13 that controls the state of the switches SW1, SW2. Also, the secondary current and / or primary voltage can be used to control the system to get the best performance (not shown in figure 2). The control circuit 13 is for example responsive to electronic spark timing (EST) signals to selectively couple the primary windings L1 and L2 to system ground through switches SW1 and SW2 respectively.

[0033] EST signals provide a conventional ignition timing control information from, for example, a conventional microprocessor engine control unit responsive to well known engine parameters for controlling engine functions including, in addition to ignition functions, engine fuelling, exhaust emissions and diagnostics. EST signals are well understood to set dwell duration and spark timing relative to cylinder stroke angle. Such microprocessor based controllers are also conventionally integrated with electronic transmission control functions to complete an integrated approach to powertrain control. Alternatively, some of the functions including ignition timing may be off-loaded from the central engine controller and incorporated into the ignition module. In such a latter case, the EST signals, as well as other ignition control signals, particularly cylinder selection signals where appropriate, would be implemented by the separate ignition module.

[0034] In operation, the control circuit 15 is operative, in accordance with a preferred embodiment having the objective of providing an extended continuous high-energy arc across the gapped electrode, to sequentially force primary current through the first primary winding L1 in accordance with the predetermined dwell time and to interrupt the current there through to cause initiation of a first arc across the gapped electrodes. At a predetermined point subsequent to the interruption of current through the first primary winding L1, current is forced through the second primary winding L2. After a predetermined dwell and prior to expiration of the first combustion arc, the current through the second primary winding L2 is interrupted to cause initiation of a second combustion arc of opposite polarity to the first combustion arc. An important feature of the presently described continuous burn embodiment is that the first combustion arc is not extinguished prior to the initiation of the second combustion arc thereby providing continuous uninterrupted

introduction of energy into the burn process. In a preferred mode of operation the control circuit 15 is operative to cycle repeatedly between successive energization of the first primary winding L1 and the second primary winding L2 to generate a continuous combustion arc. Preferably, the cycling operation is repeated a plurality of times, for example at least three times.

[0035] In operation, the control circuit 15 is operative, in accordance with a preferred embodiment to sequentially force a higher primary current than has been the case in some prior art dual primary single secondary systems. Preferably a primary current of at least 20A, more preferably at least 30A, is applied. This can produce reduced coil charge times. primary current of at least 20A, more preferably at least 30A and for example 30-40A. As a result of the turns ratio of the transformer a high AC ignition voltage is generated in the secondary coil L3 even at standard vehicle common voltages such as 14V. It becomes possible in the embodiment to dispense with the apparatus used in conventional systems to generate higher primary voltages, such as a DC-DC converter, high voltage capacitor etc.

[0036] Preferably, the system is operative to generate a higher energy first pulse for example having an energy of at least 40mJ. This is an important operational safeguard, as the general principle of operation of the invention in AC mode is likely to require input voltage toward full battery capacity. At low battery voltages the system may not be able to sustain AC operation, and therefore it is useful for starts or "limp home" conditions that the first pulse is sufficient to initiate combustion.

[0037] The various traces of Figures 2 and 3a to d may be referred to in appreciating the description of the circuit of figure 1 and its operation.

[0038] As described above operation comprise energizing a first primary winding L1 of the ignition coil inductively coupled to the secondary winding L3 of the ignition coil; deenergizing the first primary winding L1 to establish a first electrical arc across the gapped electrodes at the spark plug 11; subsequently to the interruption of the energization of the first primary winding, energizing a second primary winding L2 of the ignition coil inductively coupled to the secondary winding L3 of the ignition coil; and deenergizing the second primary winding to establish a second electrical arc across the pair of gapped electrodes; and preferably successively cycling in a continuous arcing mode.

[0039] Figure 2 illustrates basic traces for this successive cycling as the ends of the centre tapped primary are alternately switched to ground. In figure 2 the traces respectively represent:

- 1: Ignition on EST Signal at 10V / division on the graph;
- 2: Primary Current (I_{primary}) at 20A / div;
- 3: Secondary Voltage (U_{spark}) at 2kV / div;
- 4: Secondary Current ($I_{\text{secondary}}$) at 100mA / div;

with a common time axis scale of $500\mu\text{s} / \text{div}$.

[0040] The first trace thus illustrates a typical EST Signal and the second to fourth traces the characteristic response of the ignition coil to the EST signal along a common horizontal time axis. As can be seen the invention practiced in accordance with the embodiment described provides increasing primary current (trace 2) through the first primary winding L1 to a target I_{primary} of 20A. This produces an induced secondary voltage U_{spark} (trace 3). The rapid charge time in the initial phase is such as to avoid spark on make. Upon interruption of the current through the first primary winding L1, the secondary voltage polarity reverses and exceeds the breakdown voltage (see trace 3) causing the initiation of a combustion arc. Secondary current is illustrated by the trace of $I_{\text{secondary}}$ (trace 4). In the example a primary current peak of around 20A produces a secondary current peak of around 100mA.

[0041] The required gap voltage is dependent on the in-cylinder environment. The air flow at the gap (U) will stretch the arc and result in very high plasma voltages. This usually occurs at higher RPM. Required voltages to 3 to 4kV are expected. An AC system should operate in the glow phase. Arc phase is more efficient due to lower cathode drop and yields a lower gap requirement. V_{plasma} is also lower since it is inversely proportional to gap current. Arc phase typically occurs at current levels of 100mA or higher. "hot spots" of thermionic emissions are molten material. This is a significant driver of plug erosion and the main reason OEMs typically require peak secondary currents < 100-120mA.

[0042] In order to avoid excessive plug erosion an AC system should target 50-100mA secondary current levels.

[0043] Figure 2 illustrates the use of a relatively high primary current, in the example 20A. This produces a relatively rapid charge time in the primary coil. The result is an alternating high voltage at the secondary coil. The arrangement can simplify the secondary side in particular allowing dispensing with additional diodes etc. An advantage of the system illustrated in Figure 2 is that there is a direct energy flow from primary to the secondary at the recharging cycles of the primaries. (see the nonlinear ramps of the primary current signal during recharge).

[0044] Figure 3 illustrates further traces during operation in a range of operational conditions. In each case the nominal common voltage is 14V, load is variable spark gap (gap ca. 20 mm) and coil is a DC KE coil with modified primary and secondary winding. The traces respectively represent:

- 1: EST (10V/Div)
- 2: I_{primary} (20A/Div)
- 3: U_{spark} (2kV/Div)
- 4: $I_{\text{secondary}}$ (100mA/Div)

[0045] Figure 3a illustrates primary current controlled operation with 20A primary current trip with out air flow

on spark gap and Figure 3b illustrates primary current controlled operation with 30A primary current trip with out air flow on spark gap.

[0046] Figure 3c illustrates primary current controlled operation with 20A primary current trip and moderate air flow on spark gap and Figure 3d illustrates primary current controlled operation with 20A primary current trip and strong air flow on spark gap. In this mode it can be seen that as gap voltage required builds to exceed available transformed voltage the spark is extinguished. If extinguished the switch off of the primary will produce a high voltage pulse to re-establish the discharge.

15 Claims

1. An ignition system for an engine comprising:

a pair of gapped electrodes (11);
 a secondary winding (L3) having a pair of output terminals coupled to the gapped electrodes;
 a first primary winding (L1) inductively coupled to the secondary winding (L3);
 a second primary winding (L2) inductively coupled to the secondary winding;
 the primary windings being so wound that a first winding ratio of the first primary winding to the secondary winding and a second winding ratio of a second primary winding to the secondary winding are closely matched; and
 a circuit arrangement (13) enabled to sequentially energize and deenergize the first primary winding to establish a first electrical arc across the gapped electrodes and energize and deenergize the second primary winding to establish a second electrical arc across the gapped electrodes (11).

2. An ignition system as claimed in claim 1 wherein the first winding ratio and the second winding ratio differ by no more than a ratio of 3:2.

3. An ignition system as claimed in claim 2 wherein the first winding ratio and the second winding ratio are substantially identical.

4. An ignition system as claimed in any preceding claim wherein the first and second primary winding ratios being in each case the ratio of the number of turns on the secondary to the number of turns on the primary are at least 200.

5. An ignition system as claimed in any preceding claim wherein the first and second primary windings (L1, L2) are wound on adjacent portions of an axially extending magnetic core such that the primary windings are axially adjacent.

6. An ignition system as claimed in any preceding claim wherein the circuit arrangement (13) is enabled to energize and deenergize successively and cyclically the first and second primary windings to produce a continuous arc discharge.

7. An ignition system as claimed in any preceding claim wherein the circuit arrangement (13) is enabled to effect deenergization of the second primary winding prior to the extinguishment of the first primary winding induced arc.

8. A method of producing electrical arcs across a pair of gapped electrodes (11) coupled to opposite ends of a secondary winding (L3) of an ignition coil, comprising the steps:

energizing a first primary winding (L1) of the ignition coil inductively coupled to the secondary winding (L3) of the ignition coil;

deenergizing the first primary winding (L1) to establish a first electrical arc across the pair of gapped electrodes;

subsequent to the interruption of the energization of the first primary winding, energizing a second primary winding (L2) of the ignition coil inductively coupled to the secondary winding (L3) of the ignition coil; and

deenergizing the second primary winding (L2) to establish a second electrical arc across the pair of gapped electrodes;

wherein the first primary winding and second primary winding are so wound about the ignition coil that a first winding ratio of the first primary winding to the secondary winding and a second winding ratio of a second primary winding to the secondary winding are closely matched.

9. A method of producing electrical arcs as claimed in claim 8 wherein the method comprises:

energizing the first primary winding (L1) to produce a magnetic field of a first magnetic polarity; deenergizing the first primary winding to induce voltage of a first voltage polarity across the pair of gapped electrodes resulting in a first arc of a first arc polarity across the pair of gapped electrodes (11);

energizing the second primary winding (L2) to produce a magnetic field of a second magnetic polarity opposite the first magnetic polarity; and deenergizing the second primary winding to induce voltage of a second voltage polarity opposite the first voltage polarity across the pair of gapped electrodes resulting in a second arc of a second arc polarity across the pair of gapped

electrodes opposite the first arc polarity.

10. A method of producing electrical arcs as claimed in one of claims 8 to 9 wherein the method comprises cyclically energizing and deenergizing the first and second primary windings (L1, L2) to produce a continuous arc discharge.

11. A method of producing electrical arcs as claimed in claim 10 wherein the method comprises cyclically energizing and deenergizing the first and second primary windings (L1, L2) through a plurality of cycles.

12. A method of producing electrical arcs as claimed in one of claims 8 to 11 wherein the method comprises deenergizing a subsequently-energized primary winding prior to the extinguishment of an arc induced in a previously-energized primary winding.

13. A method of producing electrical arcs as claimed in one of claims 8 to 12 wherein the method comprises the generation of a primary current of at least 20A.

14. A method of producing electrical arcs as claimed in one of claims 8 to 13 wherein the method comprises the generation of a first pulse having an energy of at least 40mJ.

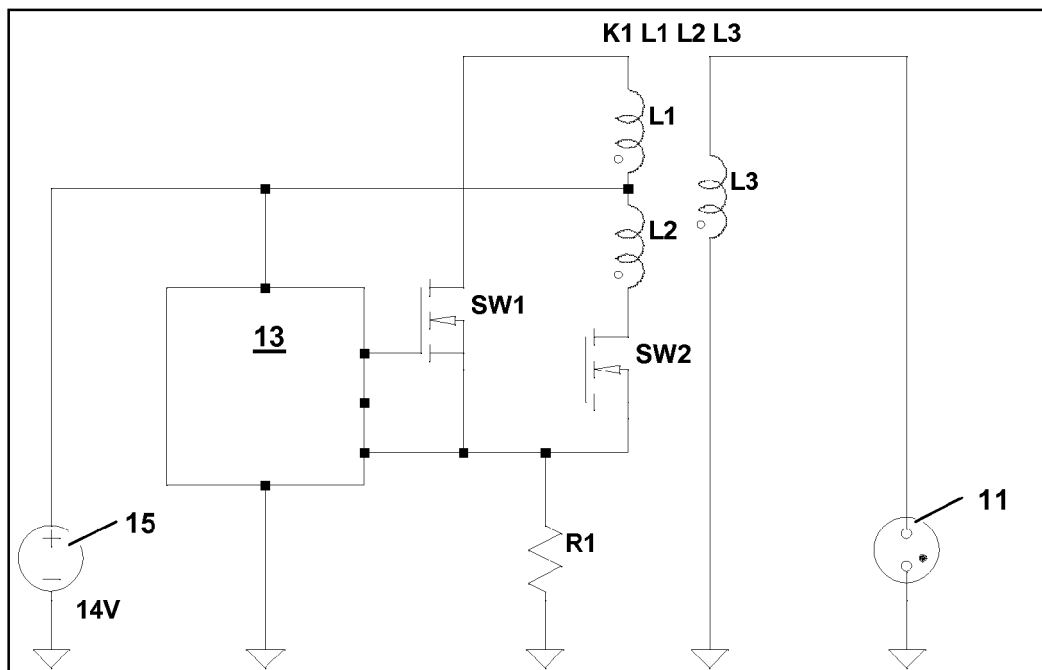


Figure 1

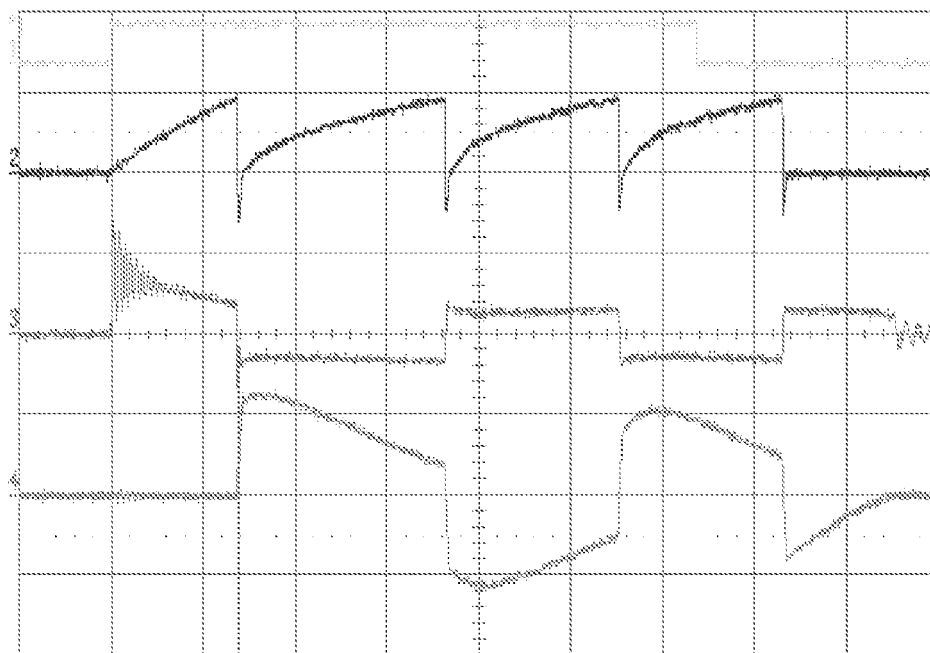


Figure 2

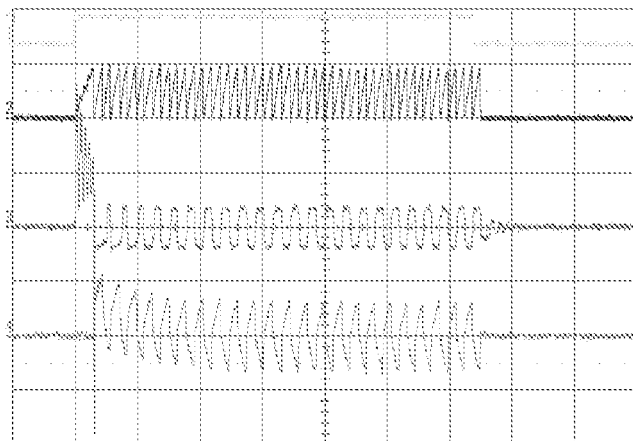


Figure 3a

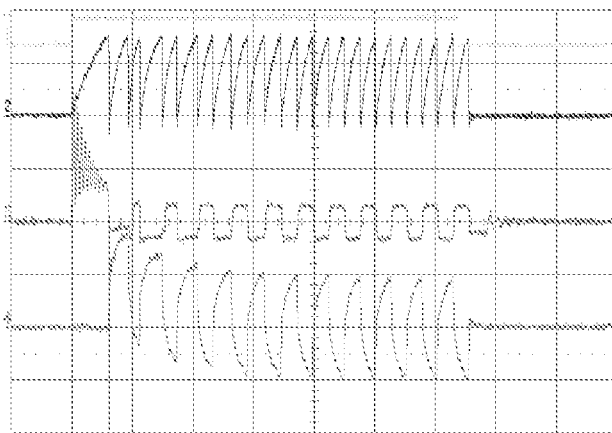


Figure 3b

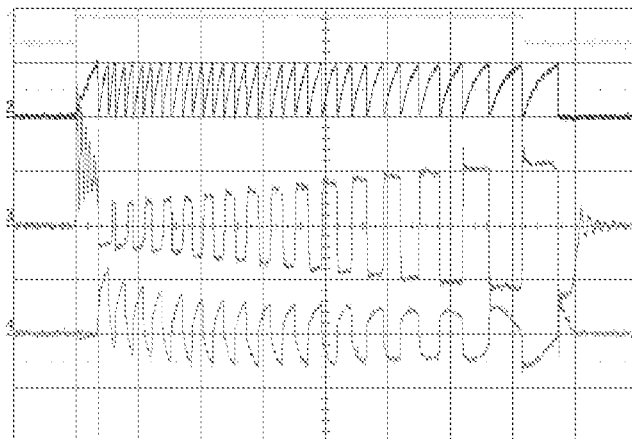


Figure 3c



Figure 3d



EUROPEAN SEARCH REPORT

Application Number
EP 08 15 9548

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 4 998 526 A (GOKHALE KALYAN P [US]) 12 March 1991 (1991-03-12) * column 2, line 17 - line 32 * * column 3, line 24 - column 4, line 25 * * column 4, line 46 - line 63 * * figures 1-5 *	1-3,5-14	INV. F02P15/10 F02P3/04
X	US 4 702 221 A (TOKURA NORIHITO [JP] ET AL) 27 October 1987 (1987-10-27) * column 3, line 54 - line 58 * * column 4, line 46 - line 49 * * column 6, line 41 * * figures *	1-14	
X	US 3 758 821 A (CANUP R) 11 September 1973 (1973-09-11) * column 4, line 3 - line 9 * * column 4, line 39 - line 62 * * figures *	1-12	
X	US 4 381 757 A (MORINO SEIJI [JP] ET AL) 3 May 1983 (1983-05-03) * column 2, line 63 - line 65 * * column 3, line 15 - column 4, line 60 * * figures 2-5,7-9 *	1-4,6	TECHNICAL FIELDS SEARCHED (IPC) F02P H01F
A	US 4 392 473 A (TSUTSUI MITSUKUNI [JP] ET AL) 12 July 1983 (1983-07-12) * figures 1,3 *	5	
A	EP 0 763 759 A (SUMITOMO ELECTRIC INDUSTRIES [JP]; SUMIDEN OPCOM LTD [JP]) 19 March 1997 (1997-03-19) * column 12, line 13 - line 36 * * figures 3,4,8,9,13 *	1-12	
		-/--	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 5 December 2008	Examiner 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 O : non-written disclosure P : intermediate document T : theory or principle underlying the invention 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			

 1
EPO FORM 1503 03.82 (P04C01)



EUROPEAN SEARCH REPORT

Application Number
EP 08 15 9548

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 6 550 463 B1 (SCHMOLLA WILFRIED [DE]) 22 April 2003 (2003-04-22) * figures 3,5,6 *	1,5,8	
D,A	US 5 886 476 A (SKINNER ALBERT ANTHONY [US] ET AL) 23 March 1999 (1999-03-23) * the whole document *	1-14	
			TECHNICAL FIELDS SEARCHED (IPC)
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 5 December 2008	Examiner Ulivieri, Enrico
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