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(54) **METHOD AND APPARATUS TO CONTROL AN IGNITION SYSTEM WITH TWO COILS FOR ONE SPARK PLUG**

VERFAHREN UND VORRICHTUNG ZUR STEUERUNG EINES ZÜNDSYSTEMS MIT ZWEI SPULEN FÜR EINE ZÜNDKERZE

PROCÉDÉ ET APPAREIL POUR COMMANDER UN SYSTÈME D'ALLUMAGE AVEC DEUX BOBINES POUR UNE BOUGIE

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EP 2 876 298 B1

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Description

Technical Field

[0001] The present invention relates to an ignition system and method of controlling spark plugs. It has particular but not exclusive application to systems which are adapted to provide a continuous spark, such as a multi-spark plug ignition system.

Background of the Invention

[0002] Ignition engines that use very lean air-fuel mixtures have been developed, that is, having a higher air composition to reduce fuel consumption and emissions. In order to provide a safe ignition it is necessary to have a high energy ignition source. Prior art systems generally use 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.

[0003] An improved multi-charge system is described in European patent application EP 2 325 476 A1 which discloses a multi-charge ignition system without these negative effects and, at least partly, producing a continuous ignition spark over a wide area of burn voltage, delivering an adjustable energy to the spark plug and providing with a burning time of the ignition fire that can be chosen freely.

[0004] A further interesting example of the prior art is the German publication DE 10 2012 106 207 B3, which discloses the preamble of the independent claims.

[0005] The system described above uses a step down converter stage to limit the maximum input current such as transistor switch and diode. However the step-down converter means that additional components are required. It is an object of the invention to provide a system and method of operation where there are a reduced number of components, thus providing a cheaper alternative system.

Summary of Invention

[0006] According to the invention, an ignition system as defined in claim 1 and a method of controlling an ignition system as defined in claim 3 are disclosed.

Brief Description of the Drawings

[0007] The invention will now be described by way of example and with reference to the following figures of which:

Figure 1 is a schematic diagram of a prior art ignition system.

Figure 2 is a diagram of prior art ignition system showing highlighting the stages of the circuitry.

Figure 3 illustrates the operation of the circuitry of figure 2.

Figure 4 is a schematic diagram of an ignition system according to one aspect of the invention.

Figure 5 illustrates the operation of the system of figure 4 according to one aspect.

[0008] Figure 1 shows the circuitry of a prior art coupled-multi-charge (CMC) ignition system for producing a continuous ignition spark over a wide area of burn voltage 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). The CMC system uses fast charging ignition coils (L1-L4), including primary windings, L1, L2 to generate the required high DC-voltage. The voltage and wound on a common core K1 forming a first transformer and secondary windings L3, L4 wound on another common core K2 are forming a second transformer. The two coil ends of the first and second primary 20 windings L1, L3 may be alternately switched to a common ground such as a chassis ground of an automobile by electrical switches Q1, Q2. These switches Q1, Q2 are preferably Insulated Gate Bipolar Transistors. Resistor R1 for measuring the primary current I_p that flows from the primary side is connected between the switches Q1, Q2 and ground, while resistor R2 (25) for measuring the secondary current I_s that flows from the secondary side is connected between the diodes D1, D2 and ground.

[0009] The low-voltage ends of the secondary windings L2, L4 may be coupled to a common ground or chassis ground of an automobile through high-voltage diodes D1, D2. The high-voltage ends of the secondary ignition windings L2, L4 are 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. The primary windings L1, L3 are 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. The charge current can be supervised by an electronic control circuit 13 that controls the state of the switches Q1, Q2. The control circuit 13 is for example responsive to engine spark timing (EST) signals, supplied by the ECU, to selectively couple the

primary windings L1 and L2 to system ground through switches Q1 and Q2 respectively controlled by signals lgbt1 and lgbt2, respectively. Measured primary current I_p and secondary current I_s are sent to control unit 13. Advantageously, the common energizing potential of the battery 15 is coupled by way of an ignition switch M1 to the primary windings L1, L3 at 20 the opposite end that the grounded one. Switch M1 is preferably a MOSFET transistor. A diode D3 or any other semiconductor switch (e.g. MOSFET) is coupled to transistor M1 so as to form a step-down converter. Control unit 13 is enabled to switch off switch M1 by means of a signal FET. The diode D3 or any other semiconductor switch will be switched on when M1 is off and vice versa.

[0010] In prior art operation, the control circuit 13 is operative to provide an extended continuous high-energy arc across the gapped electrodes. During a first step, switches M1, Q1 and Q2 are all switched on, so that the delivered energy of the power supply 15 is stored in the magnetic circuit of both transformers (T1, T2). During a second step, both primary windings are switched off at the same time by means of switches Q1 and Q2. On the secondary side of the transformers a high voltage is induced and an ignition spark is created through the gapped electrodes of the spark plug 11. During a third step, after a minimum burn time wherein both transformers (T1, T2) are delivering energy, switch Q1 is switched on and switch Q2 is switched off (or vice versa). That means that the first transformer (L1, L2) stores energy into its magnetic circuit while the second transformer (L3, L4) delivers energy to spark plug (or vice versa). During a fourth step, when the primary current I_p increases over a limit (I_{pmax}), the control unit detects it and switches transistor M1 off. The stored energy in the transformer (L1, L2 or L3, L4) that is switched on (Q1, or Q2) impels a current over diode D3 (step-down topology), so that the transformer cannot go into the magnetic saturation, its energy being limited. Preferably, transistor M1 will be permanently switched on and off to hold the energy in the transformer on a constant level. During a fifth step, just after the secondary current I_s falls short of a secondary current threshold level (I_{smin}) the switch Q1 is switched off and the switch Q2 is switched on (or vice versa). Then steps 3 to 5 will be iterated by sequentially switching on and off switches Q1 and Q2 as long as the control unit switches both switches Q1 and Q2 off.

[0011] Figure 2 shows a similar arrangement to figure 1 with similar reference numerals. The step down converter stage and two coil stages are outlined in broken lines 1, 2, 3 respectively. In addition the control unit has input means to determine the voltage at the secondary stages. The figure also shows the connectivity of the spark plug control unit with the engine control unit.

[0012] Figure 3a and b shows a plot of the primary and secondary currents against time respectively, during operation of the figure 2 system. The system of figure 2 is using a step-converter-stage to limit the maximum input current and with this the input power e.g. during the

Coupled-MultiCharge-Mode where the power is supplied alternately to the coils. When the primary current reaches the maximum primary current threshold, then the switch M1 is pulsed this way that the primary current remains on a constant level. Thus in summary, in the conventional CMC mode, the switches Q1 and Q2 are toggled, to provide continuous spark, and the down-converter function is to limit input current.

[0013] According to one embodiment of the invention, the step down converter is eliminated; in other words the switches M1 and D1 are eliminated, and the control of the ignition system implemented in a novel fashion, and in an example, control of the switches Q1 and Q2 are used also to limit the (maximum) input current.

[0014] Figure 4 shows a figure of the circuitry according to one example of the invention without the step-down converter stage. As can be seen it includes as in the figure 2 circuitry, two coil stages being entirely controlled by switches Q1 and Q2, the control being implemented by the control unit. As can be seen there are connections from the low side of the secondary coils to the control unit which can be used by the control unit to determine the voltages at the stages. However it is to be noted that according to simple embodiments these can be dispensed with. The low side of the secondary coils are connected to diodes D1 and D2 as before. In addition, a line connects the ground side of the diodes to the control unit so that the current in the secondary coils can be measured. According to one aspect, means to implement operation is based solely on selective switching of switches Q1 and Q2.

[0015] Figure 5a and 5b illustrate the methodology used in one embodiment to implement control of the system during the charge coupled mode. Figures 5a and b and shows the primary current and secondary current respectively in an ignition cycle.

[0016] Accordingly, when the primary current in the CMC phase reaches a maximum primary current threshold, both switches Q1 and Q2 are switched off for a period of time, typically between 100 and 200 microseconds. During this time the transformers are discharging their stored energy into the spark ignition and so as can be seen from the trace of the secondary current in figure 5b. By the implementation of this algorithm the magnetic circuit cannot go into magnetic saturation and will not end in a fast oscillating system. After expiry of said time period, normal operation of the circuitry in CMC mode is resumed; that is to say the switches Q1 and Q2 are toggled as before.

[0017] In an alternative example, which is not part of the invention, the switches Q1 and Q2 are switched off until the secondary current reaches a particular minimum secondary current threshold. Thus in this embodiment the secondary current is measured or estimated (e.g. by the control unit by e.g. the connections shown in figure 3) and compared with a threshold which may be stored in the control unit. This threshold may be signaled by the ECU and may be variable. After this, again, normal

operation of the circuitry in CMC mode is resumed; that is to say the switches Q1 and Q2 are toggled as before. In certain embodiments this secondary current threshold may be a set proportion (e.g. twice as much) of the typically adjusted threshold in standard CMC mode. In other embodiments the primary current may be measured/estimated and compared with a minimum threshold, which once reached, causes resumption in operation (i.e. toggling Q1 and Q2).

[0018] Thus in one aspect, there is means to determine e.g. in the charge coupled mode, when the primary current reaches a threshold, and dependent thereon selectively switching on/off one or more of said switches. The threshold value may be stored in the control unit. This may be variable depending on the operation and/or other parameters.

[0019] As can be seen in figure 4 there is a line which connects to the control unit which enables primary current to be measured. Alternatively this line may be omitted and, during the recharge-cycle it is possible to determine the primary current based on the previously measured secondary current level for the same coil stage. Together with the battery voltage, the gradient of the primary current is determined and then the primary current can be determined.

[0020] In a specific embodiment there is means to determine if the primary current in the charge coupled mode reaches a threshold value, and if so switching both switches Q1 and Q2 off for a pre-set time.

[0021] The primary current can be measured e.g. by providing a line from the primary coil stages to the control unit. Alternatively the primary current can be determined or estimated from the measured secondary current.

Claims

1. An ignition system including a spark plug control unit adapted to control at least two stages comprising a first transformer (T1) including a first primary winding (L1) inductively coupled to a first secondary winding (L2); a second transformer (T2) including a second primary winding (L3) inductively coupled to a second secondary winding (L4); said control unit enabled to simultaneously energize and deenergize primary windings (L1, L3) by simultaneously switching on and off two corresponding first and second

switches (Q1, Q2) to maintain a continuous ignition fire, wherein means to implement operation is based solely on selective switching of the first and second switches (Q1, Q2);

wherein during a Coupled-Multi Charge-Mode, the power is supplied alternately to the coils by toggling the first switch (Q1) with the second switch (Q2);

wherein the ignition system has means to measure a primary current and said spark plug con-

trol unit includes means to determine if the measured primary current in the Coupled-Multi Charge-Mode mode reaches a maximum primary current threshold value, and when the measured primary current in the Coupled-Multi Charge-Mode phase reaches said maximum primary current threshold value, both first and second switches (Q1) and (Q2) are simultaneously switched off for a period of time, and thereafter toggling first switch (Q1) with the second switch (Q2) is resumed;

characterised in that the period of time is a pre-set time.

2. An ignition system as claimed in claims 1, wherein said pre-set time is in the region of between 100 and 200 microseconds.
3. A method of controlling an ignition system, said system including a spark plug control unit adapted to control at least two stages comprising a first transformer (T1) including a first primary winding (L1) inductively coupled to a first secondary winding (L2); a second transformer (T2) including a second primary winding (L3) inductively coupled to a second secondary winding (L4); said control unit enabled to simultaneously energize and deenergize primary windings (L1, L3) by simultaneously switching on and off two corresponding first and second switches (Q1, Q2) to maintain a continuous ignition fire, based solely on selective switching of the first and second switches (Q1, Q2);

wherein during a Coupled-Multi Charge-Mode, the power is supplied alternately to the coils by toggling the first switch (Q1) with the second switch (Q2);

wherein the method includes measuring a primary current and determining if the measured primary current in the 2. Coupled-Multi Charge-Mode mode reaches a maximum primary threshold value, and when the measured primary current in the Coupled-Multi Charge-Mode phase reaches said maximum primary current threshold value, both first and second switches (Q1, Q2) are simultaneously switched off for a period of time, and thereafter normal toggling the first switch (Q1) with the second switch (Q2) is resumed;

characterised in that the period of time is a pre-set time.

4. A method as claimed in claims 3 wherein said pre-set time is in the region of between 100 and 200 microseconds.

Patentansprüche

1. Zündsystem umfassend eine Zündkerzensteuereinheit, die zur Steuerung von mindestens zwei Stufen ausgelegt ist, die einen ersten Transformator (T1) umfassend eine erste Primärwicklung (L1), die induktiv mit einer ersten Sekundärwicklung (L2) gekoppelt ist; einen zweiten Transformator (T2) umfassend eine zweite Primärwicklung (L3), die induktiv mit einer zweiten Sekundärwicklung (L4) gekoppelt ist, umfassen; wobei die Steuereinheit in der Lage ist, durch gleichzeitiges Ein- und Ausschalten von zwei entsprechenden ersten und zweiten Schaltern (Q1, Q2) die Primärwicklungen (L1, L3) gleichzeitig zu erregen und zu entregen, um eine kontinuierliche Zündflamme aufrechtzuerhalten,

wobei das Mittel zur Implementierung des Betriebs allein auf einem selektiven Schalten des ersten und zweiten Schalters (Q1, Q2) basiert; wobei während eines Coupled-Multi-Charge-Mode die Energie abwechselnd den Spulen durch Umschalten zwischen dem ersten Schalter (Q1) und dem zweiten Schalter (Q2) zugeführt wird; wobei das Zündsystem Mittel zur Messung eines Primärstroms aufweist und die Zündkerzensteuereinheit Mittel zur Bestimmung, ob der gemessene Primärstrom im Coupled-Multi-Charge-Mode-Modus einen maximalen Primärstromschwellwert erreicht, umfasst, und wenn der gemessene Primärstrom in der Coupled-Multi-Charge-Mode-Phase den maximalen Primärstromschwellwert erreicht, werden der erste und der zweite Schalter (Q1) und (Q2) gleichzeitig für einen Zeitraum ausgeschaltet, und danach wird das Umschalten zwischen dem ersten Schalter (Q1) und dem zweiten Schalter (Q2) wieder aufgenommen; **dadurch gekennzeichnet, dass** der Zeitraum eine voreingestellte Zeit ist.

2. Zündsystem nach Anspruch 1, wobei die voreingestellte Zeit im Bereich zwischen 100 und 200 Mikrosekunden liegt.
3. Verfahren zur Steuerung eines Zündsystems, wobei das System eine Zündkerzensteuereinheit umfasst, die zur Steuerung von mindestens zwei Stufen ausgelegt ist, die einen ersten Transformator (T1) umfassend eine erste Primärwicklung (L1), die induktiv mit einer ersten Sekundärwicklung (L2) gekoppelt ist; einen zweiten Transformator (T2) umfassend eine zweite Primärwicklung (L3), die induktiv mit einer zweiten Sekundärwicklung (L4) gekoppelt ist, umfassen; wobei die Steuereinheit in der Lage ist, durch gleichzeitiges Ein- und Ausschalten von zwei entsprechenden ersten und zweiten Schaltern

(Q1, Q2) die Primärwicklungen (L1, L3) gleichzeitig zu erregen und zu entregen, um eine kontinuierliche Zündflamme basierend allein auf einem selektiven Schalten des ersten und zweiten Schalters (Q1, Q2) aufrechtzuerhalten,

wobei während eines Coupled-Multi-Charge-Mode die Energie abwechselnd den Spulen durch Umschalten zwischen dem ersten Schalter (Q1) und dem zweiten Schalter (Q2) zugeführt wird;

wobei das Verfahren das Messen eines Primärstroms und das Bestimmen, ob der gemessene Primärstrom im Coupled-Multi-Charge-Mode-Modus einen maximalen Primärstromschwellwert erreicht, umfasst, und wenn der gemessene Primärstrom in der Coupled-Multi-Charge-Mode-Phase den maximalen Primärstromschwellwert erreicht, werden der erste und der zweite Schalter (Q1, Q2) gleichzeitig für einen Zeitraum ausgeschaltet, und danach wird das normale Umschalten zwischen dem ersten Schalter (Q1) und dem zweiten Schalter (Q2) wieder aufgenommen;

dadurch gekennzeichnet, dass der Zeitraum eine voreingestellte Zeit ist.

4. Verfahren nach Anspruch 3, wobei die voreingestellte Zeit im Bereich zwischen 100 und 200 Mikrosekunden liegt.

Revendications

1. Système d'allumage comprenant une unité de commande de bougie d'allumage conçue pour commander au moins deux étages comprenant un premier transformateur (T1) comprenant un premier enroulement primaire (L1) couplé par induction à un premier enroulement secondaire (L2) ; un second transformateur (T2) comprenant un second enroulement primaire (L3) couplé par induction à un second enroulement secondaire (L4) ; ladite unité de commande étant apte à mettre sous tension et mettre hors tension simultanément les enroulements primaires (L1, L3) par l'activation et la désactivation simultanée de deux premier et second commutateurs (Q1, Q2) correspondants afin de maintenir une explosion d'allumage continue,

dans lequel le moyen de mise en oeuvre du fonctionnement est basé uniquement sur la commutation sélective des premier et second commutateurs (Q1, Q2) ;

dans lequel pendant un mode de couplage à charge multiple, l'énergie est fournie en alternance aux bobines en basculant le premier commutateur (Q1) avec le second commutateur

(Q2) ;

dans lequel le système d'allumage comporte des moyens pour mesurer un courant primaire et ladite unité de commande de bougie d'allumage comporte des moyens pour déterminer si le courant primaire mesuré dans le mode de couplage à charge multiple atteint une valeur seuil de courant primaire maximale et lorsque le courant primaire mesuré dans la phase de mode de couplage à charge multiple atteint ladite valeur seuil de courant primaire maximale, les premier et second commutateurs (Q1) et (Q2) sont tous deux simultanément désactivés pendant une période de temps, et par la suite le basculement du premier commutateur (Q1) avec le second commutateur (Q2) reprend ;
caractérisé en ce que la période de temps est un temps prédéfini.

du premier commutateur (Q1) avec le second commutateur (Q2) reprend ;
caractérisé en ce que la période de temps est un temps prédéfini.

2. Système d'allumage selon la revendication 1, dans lequel ledit temps prédéfini se situe dans la région comprise entre 100 et 200 microsecondes. 20
3. Procédé de commande d'un système d'allumage, ledit système comprenant une unité de commande de bougie d'allumage conçue pour commander au moins deux étages comprenant un premier transformateur (T1) comprenant un premier enroulement primaire (L1) couplé par induction à un premier enroulement secondaire (L2) ; un second transformateur (T2) comprenant un second enroulement primaire (L3) couplé par induction à un second enroulement secondaire (L4) ; ladite unité de commande étant apte à mettre sous tension et mettre hors tension simultanément les enroulements primaires (L1, L3) par l'activation et la désactivation simultanée de deux premier et second commutateurs (Q1, Q2) correspondants pour maintenir une explosion d'allumage continue, basée uniquement sur la commutation sélective des premier et second commutateurs (Q1, Q2) ; 25 30 35 40

dans lequel pendant un mode de couplage à charge multiple, l'énergie est fournie en alternance aux bobines en basculant le premier commutateur (Q1) avec le second commutateur (Q2) ;
dans lequel le procédé comprend la mesure d'un courant primaire et la détermination si le courant primaire mesuré dans le mode de couplage à charge multiple atteint une valeur seuil primaire maximale, et lorsque le courant primaire mesuré dans la phase de couplage à charge multiple atteint ladite valeur seuil de courant primaire maximale, les premier et second commutateurs (Q1, Q2) sont tous deux simultanément désactivés pendant une période de temps, et par la suite le basculement normal 45 50 55

4. Procédé selon la revendication 3, dans lequel ledit temps prédéfini se situe dans la région comprise entre 100 et 200 microsecondes.

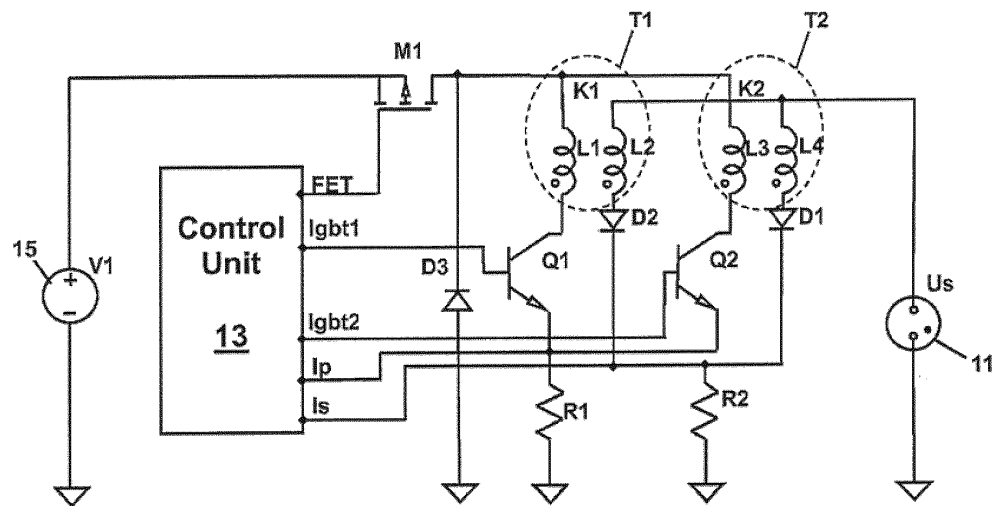


Figure 1

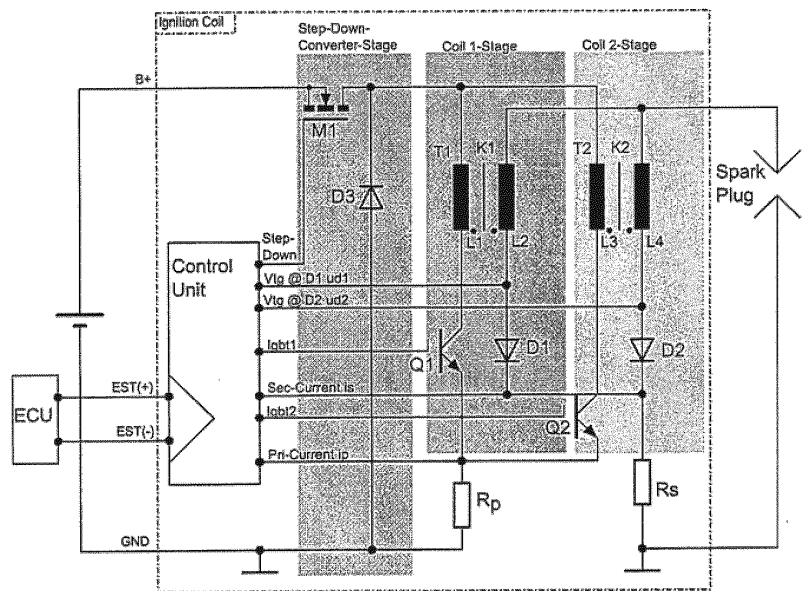


FIGURE 2

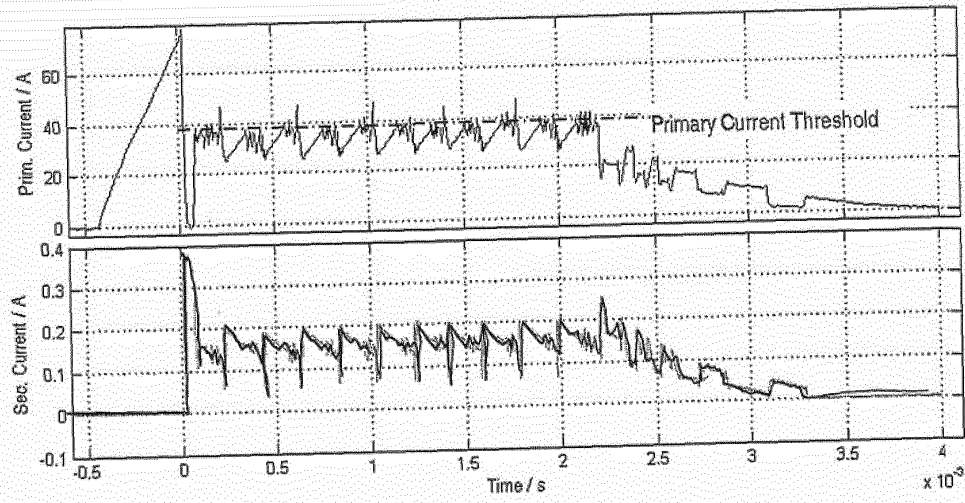


Figure 3

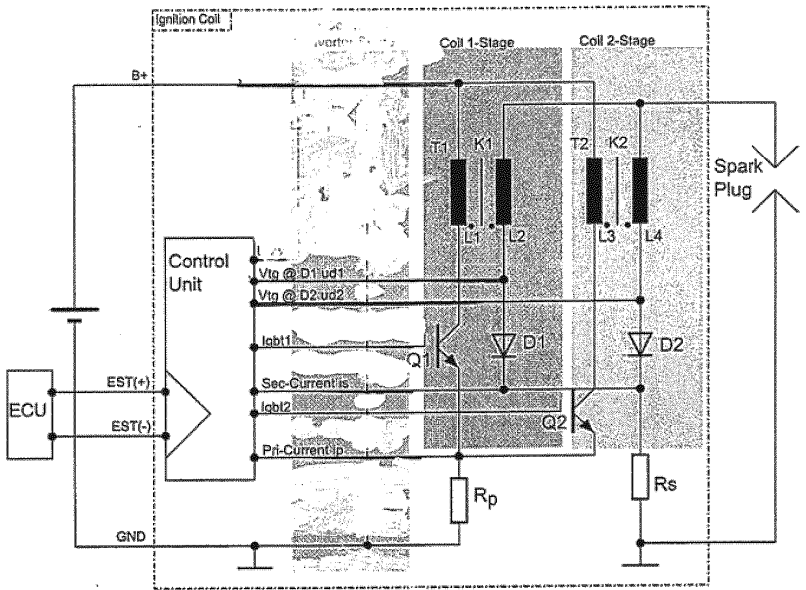


FIGURE 4

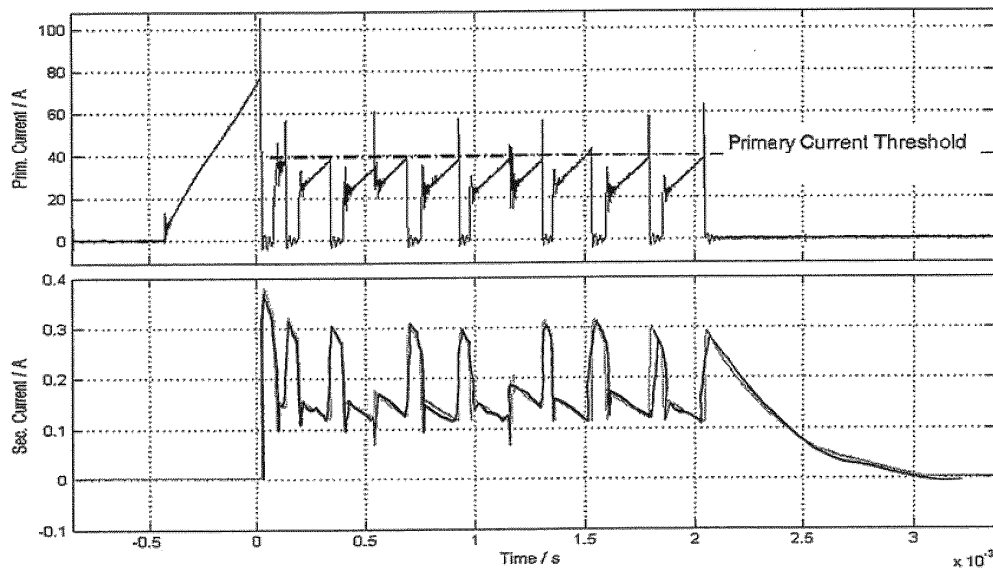


FIGURE 5

REFERENCES CITED IN THE DESCRIPTION

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