



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
01.09.2010 Bulletin 2010/35

(51) Int Cl.:
F02P 19/02^(2006.01)

(21) Application number: **09100156.0**

(22) Date of filing: **27.02.2009**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA RS

(71) Applicant: **Robert Bosch GmbH**
70442 Stuttgart (DE)

(72) Inventor: **Moritz, Rainer**
70794, Filderstadt (DE)

(54) **A glow plug controller for vehicles**

(57) The invention relates to a glow plug controller (10) and a method to operate a plurality of glow plugs (20, 21, 22, 23) such a way that the glow plugs (20, 21, 22, 23) generate lower EMI levels. The glow plug controller (10) receives a set of engine parameters (18) and generates PWM signals (31, 32, 33, and 34) to control each of the glow plugs (20, 21, 22, and 23). When the PWM signals (31, 32, 33, and 34) have more than 50%

duty cycle, spikes appear in the current waveform whenever three or more of the PWM signals (31, 32, 33, 34) have on periods. This results in EMI. To reduce the peak level of the energy which represents the EMI, jitter is added to the PWM signals by varying the frequency of the PWM signals. The jitter in the PWM signals will spread the energy in the spikes over a range of frequency components, bringing down the peak level of the energy, thereby reducing the peak EMI level.

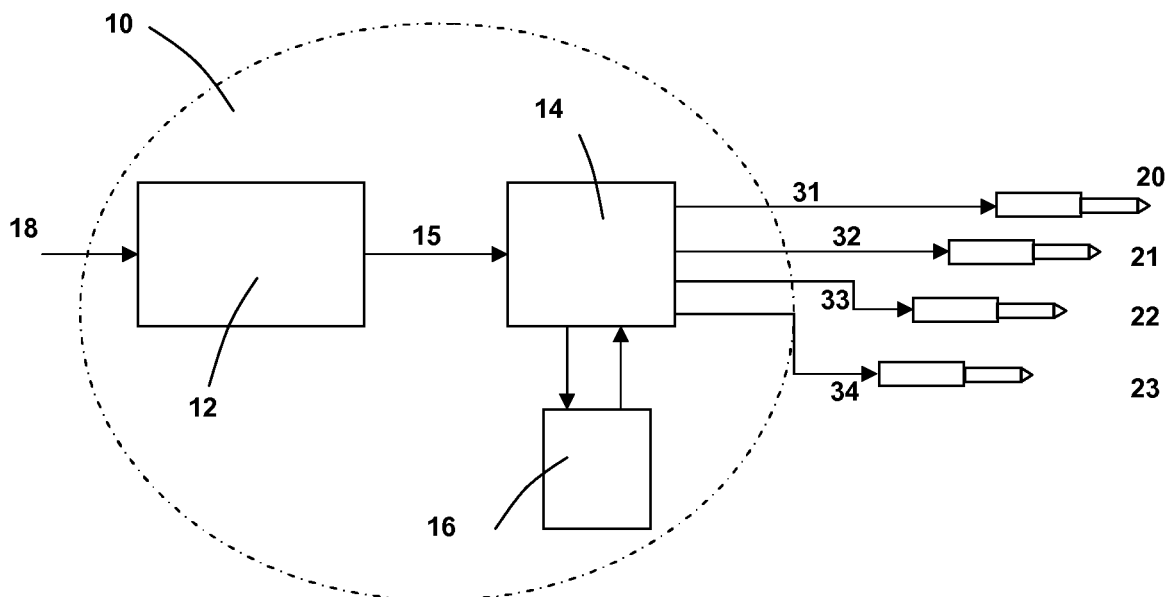


Fig. 1

Description

State of the Art

[0001] The invention relates to a glow plug controller for a combustion engine. The US 6, 009, 369 A1 discloses a glow plug controller with improved functionality and diagnostics.

Advantages of the invention

[0002] The glow plug controller and the method of controlling the glow plug controller, with the features of the independent patent claims have the below advantages:

[0003] Introducing offsets in the PWM frequency, results in spreading the energy contained in the spikes appearing on the power lines of the glow plugs, bringing down the peak energy level in a measuring window and hence bringing down the peak level of the Electro Magnetic Interference (EMI) in the measuring window. The reduced EMI from the glow plugs will improve the smooth operation of the glow plugs and also ensure safe operations with other electronic devices in the proximity.

[0004] Further improvements and/or advantages are realised by the features of the dependent patent claims.

[0005] The glow plug controller uses a known PWM generator which generates a plurality of PWM signals which are sequential in time.

[0006] The jitter generator used to vary the frequency of the PWM signals uses a pre-stored table containing the offsets for the PWM frequencies which is simple.

Brief description of the drawings

[0007] The embodiments of the invention are shown in the drawing and are described in detail in the description.

Figure 1 Shows schematic of a glow plug controller

Figure 2 Shows the graphs of the PWM signals and the current signal for PWM signals with 50% duty cycles

Figure 3 Shows the graphs of the PWM signals and the current signal for PWM signals which have more than 50% duty cycles

Figure 4 Shows the current and energy graphs

Figure 5 Shows the PWM signals, current and energy graphs with jitter

Description of the embodiments

[0008] Shown in Figure 1 is a glow plug controller 10 receiving engine parameters 18 and delivering PWM signals 31 to 34 to glow plugs 20 to 23 respectively. The

glow plug controller 10 further comprises a computation means 12, a sequencing means 14 and a jitter generator 16. The number of PWM signals and the glow plugs may vary depending upon the engine requirements.

[0009] The computation means 12 receives the engine parameters 18 such as engine temperature, ambient air temperature and pressure, fuel quantity to be injected, intake mass air flow, exhaust gas characteristics, exhaust gas recirculation characteristics etc. to calculate the effective voltage and the timing information 15 for each of the PWM signals 31 to 34. The effective voltage and the timing information 15 are supplied to the sequencing means 14.

[0010] The sequencing means 14 receives the effective voltage and the timing information 15 and using the same, generates a plurality of PWM signals 31, 32, 33 and 34 which are delivered to the glow plugs.

[0011] The PWM signals 31, 32, 33 and 34 are continuous in time and have a frequency F. Each of the PWM signals 31, 32, 33 and 34 comprise PWM pulses of time duration T which is $1/F$. The time duration T includes both on time and off time of the PWM pulse.

[0012] The jitter generator 16 when activated by the sequencing means 14 generates different offsets for the time duration T of the PWM signals. Different offsets are added to T in positive and negative directions, keeping the original T at the centre. For example if the original T of the PWM signal is 40 millisecond, different offsets are added to it to generate modified T, for example, of durations 37 msec, 38 msec, 39 msec, 40 msec, 41 msec, 42 msec and 43 msec. The original T is kept at the centre and other values are at equal steps to its left and right sides. The jitter generator may compute the offsets dynamically or it may contain a pre-computed table containing the different time durations of the PWM signals for different conditions. To generate PWM pulses of varying time durations, the frequency of the PWM signal is varied so that the rising edge of the PWM pulses keep shifting in both directions. The movement of the rising edges of the PWM pulses is like adding jitter to the original PWM signal. This jitter reduces the peak energy measured in a window on the power lines thereby reducing the Electro Magnetic Interference EMI. The working of the invention is explained in detail in subsequent paragraphs.

[0013] The glow plugs 20 to 23 get energised when the PWM signals have high level and get de-energised when the PWM signals have low level. The glow plugs 20 to 23 get heated up when they are energized and help in igniting the fuel injected into the combustion chambers which are not shown.

[0014] The glow plugs and the glow plug controllers are already known as state of the art. Glow plugs are used to bring the engine temperatures to an operating level where the air and fuel mixture ignites easily on compression, in the diesel combustion engines. Diesel engines are substantially different from the standard spark ignition internal combustion engines. The diesel engine

does not have a sparking device such as a standard spark plug. Fuel is ignited when fuel and hot compressed air are mixed in the engine cylinders. For this ignition to occur efficiently, the engine must be brought to a temperature at or above a given minimum operating temperature because a cold diesel engine will not achieve ignition.

[0015] Glow plugs are used as heaters to heat the diesel engine prior to initial start up. These glow plugs serve to bring the diesel engine to an efficient operating temperature before the engine is started. Ideally glow plugs will rapidly bring a diesel engine to a desired starting temperature. After the engine has started, the glow plugs operate for sufficiently long time to maintain desired engine temperature until engine self-heating reaches an efficient sustainable point. The glow plugs also enable the engine to run smoothly during an initial period and minimize emissions. Once an engine can sustain its operating temperature, the glow plug is turned off.

[0016] The glow plugs are also used in different engine running conditions to help the ignition of the air fuel mixture or to bring the temperature of the exhaust gases to a predefined value, for example, when the engine needs to run in re-generation mode where the soot in the exhaust pipe needs to be burnt.

[0017] The temperature of the glow plugs is controlled by controlling the voltage supplied to the glow plugs and also the duration of the voltage supplied to the glow plugs. The computation of the timing requirements is normally done by a glow plug controller based on the engine parameters. The glow plugs are supplied with power from the battery of the vehicle.

[0018] The computation means 12 in Fig. 1 receives the engine parameters 18 and based on the engine parameters 18, the computation means computes the temperature requirements of the glow plugs and also the timing information. The temperature requirement of the glow plugs is then converted into the effective voltage required for each of the glow plugs to attain the required temperature. The computed effective voltage values and the timing information are supplied to the sequencing means 14. Based on the effective voltage required for each of the glow plugs and the timing information, the sequencing means generates a PWM signal for each of the glow plugs.

[0019] Figure 2 shows the PWM signals generated by conventional state of the art glow plug controllers. The PWM signals shown in the graphs 2A, 2B, 2C and 2D are generated by the sequencing means 14, the X axis of the graphs representing the time t and the Y axis representing the voltage V . Each of the PWM signals 2A, 2B, 2C and 2D control one of the glow plugs 20 to 23. Here as an example the duty cycles of the PWM signals are taken as 50%. The PWM signals are sequential, i.e. at t_1 the on period of the first PWM starts. At t_2 , the on period of first PWM signal ends and the on period of second PWM starts. At t_3 , the on period of second PWM signal ends and the on period of third PWM signal starts. At t_4 , the on period of third PWM signal ends and the on

period of fourth PWM signal starts. The cycle keeps repeating as long as the glow plugs are operational. Four glow plugs are shown only as an example but the number of glow plugs may vary based on the engine.

[0020] The graph 2E shows the current waveform as observed on the power lines supplying power to the glow plugs for the above case where the duty cycles of the PWM signals are 50%. From t_1 to t_2 , only glow plug 20 is on, from t_2 to t_3 only glow plug 21 is on. So from t_1 to t_3 the current is constant at a level I_1 . From t_3 onwards, at any given time two glow plugs are on. So the current drawn is twice, i.e. I_2 , constantly.

[0021] Figure 3 shows the PWM signals generated by conventional state of the art glow plug controllers where the PWM signals have more than 50% duty cycle. For such cases the current drawn will not be constant as there will be overlap of on-periods of different PWM signals at different time slots.

[0022] The graph 3A, 3B, 3C and 3D are similar to the graphs in Fig. 2, the only difference being the duty cycles of PWM signals in Fig.3 are more than 50%. The graph 3E shows the current waveform as observed on the lines supplying power to the glow plugs for the above case where the duty cycles of the PWM signals are more than 50%. Here from t_1 to t_3 current remains at I_1 , from t_3 to t_5 current is at I_2 , at t_5 a small spike appears for a small duration where the current is at I_3 because three glow plugs have on periods. Similarly at t_7 , for a small duration of the time the current is at level I_3 . The cycle repeats as long as the glow plugs are operational.

[0023] The measurement of current in a measuring window W is shown in graph 3E. The part is blown in the figure 4 graph 4A.

[0024] Fig. 4 graph 4A shows the measurement of current in the measuring window W where the spike appears, the X axis representing the time t and the Y axis representing the current I .

[0025] The graph 4B shows the energy representation of the graph 4A. During the window a peak level in the energy is observed which corresponds to the spike in the current. The peak energy also represents the Electro Magnetic Interference caused by the glow plug during the measuring window as the EMI is directly proportional to the energy.

[0026] All the electronic devices which cause EMI need to adhere to safety standards wherein the EMI caused by them should be below a limit, the limit being prescribed by the governing authorities, for safe operations of the electronic devices in proximity of each other. So each electronic device undergoes an EMI test before it is declared as fit for use.

[0027] The glow plugs also cause the EMI because of rapid changes in the current drawn by them from the power supply of the vehicle when the spikes occur. So the glow plugs undergo the EMI test before they are declared safe for use.

[0028] Here the invention proposes a method to reduce the peak level of the EMI by varying the frequency

of the PWM signals.

[0029] In Fig. 5 the graph 5A shows a normal PWM signal where the frequency of the PWM signal is constant, the X axis representing the time and the Y axis representing the voltage. The frequency of the PWM signal is F and the time duration of one PWM pulse is T, the T being 1/F.

[0030] The graph 5B shows the PWM signal wherein the T of the PWM pulse is varied by varying the frequency F of the PWM signal. The frequency is varied by adding small steps of positive and negative offsets to the frequency F as explained earlier. The resulting PWM signal is shown with dotted lines in graph 5B.

[0031] The variation of the frequency of the PWM signals is achieved using the jitter generator 16. The jitter generator 16 has a table where different values of T are stored for different frequencies for the PWM signals. The jitter generator 16 when activated provides to the sequencing means, the offsets to be used for the PWM signals based on the current frequency of the PWM signals and also based on engine parameters. The jitter generator may also calculate the offsets in real time.

[0032] The graph 5C shows the current in the window 'W' where a spike is observed because of the overlap of on periods of different glow plugs. The position of the spike keeps shifting to left and right because of the variation in frequency of PWM signals.

[0033] The graph 5D shows energy analysis of the graph 5C. Because of the variations in the frequency of PWM signals, the energy contained in the spike gets distributed over a wide range of frequency components, in the measuring window W. The distribution of the energy results in reduction of peak energy level when the frequency of the PWM signal is varied. The reduction of peak energy in the window W will directly reduce the peak EMI level as the EMI is directly proportional to the energy.

[0034] Using the invention, the glow plugs have a reduced EMI level in a given measuring window and may easily meet the safety standards set for EMI tests for the glow plugs.

[0035] In the embodiment described above, the glow plug controller has its own microcontroller and has computation means. In another embodiment, the glow plug controller can be realised in an engine control unit which controls the engine.

[0036] While at least one exemplary embodiment has been presented in the foregoing description, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing the exemplary embodiment, it should be understood that various changes can be made in the function and arrangement of the elements without departing from the scope of the invention.

Claims

1. A glow plug controller (10) for vehicles, the said glow plug controller adapted to receive engine parameters (18) to generate at least one PWM signal (31, 32, 33, 34) deliverable to at least one glow plug (20, 21, 22, 23), the said glow plug controller (10) **characterised by** a jitter generator (16) adapted to vary the frequency of the PWM signals (31, 32, 33, 34) by introducing an offset in the frequency.
2. A glow plug controller (10) according to claim 1 wherein the glow plugs (20, 21, 22, 23) receive power from the battery through power lines.
3. A glow plug controller (10) according to claim 1 wherein the on periods of the PWM signals (31, 32, 33, 34) are in a sequential order with respect to time.
4. A glow plug controller (10) according to claim 1 wherein the on periods of the PWM signals overlap with each other based on the duty cycles of the PWM signals.
5. A glow plug controller (10) according to claims 1, 2, 3 and 4 wherein the overlaps of the on periods of the PWM signals cause spikes in the current on the power lines.
6. A glow plug controller (10) according to claim 1 and 5 wherein the jitter generator (16) introduces a jitter in the frequency of the PWM signals (31, 32, 33, 34) by varying the frequency of the PWM signals (31, 32, 33, 34) thereby causing a distribution of energy contained in the spikes, bringing down the peak energy level in a measuring window around the spikes.
7. A glow plug controller (10) according to claim 1 is a part of an engine control unit.
8. A method to operate a glow plug controller (10), the said method comprising the steps:
 - receiving engine parameters (18)
 - generating at least one PWM signal (31) for at least one glow plug (20) in dependence of the engine parameters (18)
 - adding a jitter to the PWM signals (31, 32, 33, 34) by varying the frequency used to generate PWM signals (31, 32, 33, 34) whenever spikes appear in the current measurement in a measuring window, thereby reducing the peak level of the energy in the measuring window.

**Amended claims in accordance with Rule 137(2)
EPC.**

1. A glow plug controller (10) for vehicles, the said glow plug controller adapted to receive engine parameters (18) to generate a set of PWM signals (31, 32, 33, 34) deliverable to a set of glow plugs (20, 21, 22, 23) respectively, the said glow plug controller (10) **characterised by** a jitter generator (16) adapted to vary the frequency of the PWM signals (31, 32, 33, 34) by introducing an offset in the frequency when the on periods of PWM signals overlap. 5

2. A glow plug controller (10) according to claim 1 wherein the glow plugs (20, 21, 22, 23) receive power from the battery through power lines. 10

3. A glow plug controller (10) according to claim 1 wherein the on periods of the PWM signals overlap with each other based on the duty cycles of the PWM signals. 20

4. A glow plug controller (10) according to claims 1, 2, 3 and 4 wherein the overlaps of the on periods of the PWM signals cause spikes in the current on the power lines. 25

5. A glow plug controller (10) according to claim 1 and 5 wherein the jitter generator (16) introduces a jitter in the frequency of the PWM signals (31, 32, 33, 34) by varying the frequency of the PWM signals (31, 32, 33, 34) thereby causing a distribution of energy contained in the spikes, bringing down the peak energy level in a measuring window around the spikes. 30
35

6. A glow plug controller (10) according to claim 1 is a part of an engine control unit.

7. A method to operate a glow plug controller (10), the said method comprising the steps: 40
 - receiving engine parameters (18)
 - generating a set of PWM signal (31, 32, 33, 34) for a set of glow plugs (20, 21, 22, 23) in dependence of the engine parameters (18) 45
 - adding a jitter to the PWM signals (31, 32, 33, 34) by varying the frequency used to generate PWM signals (31, 32, 33, 34) whenever spikes appear in the current measurement in a measuring window, thereby reducing the peak level of the energy in the measuring window. 50

55

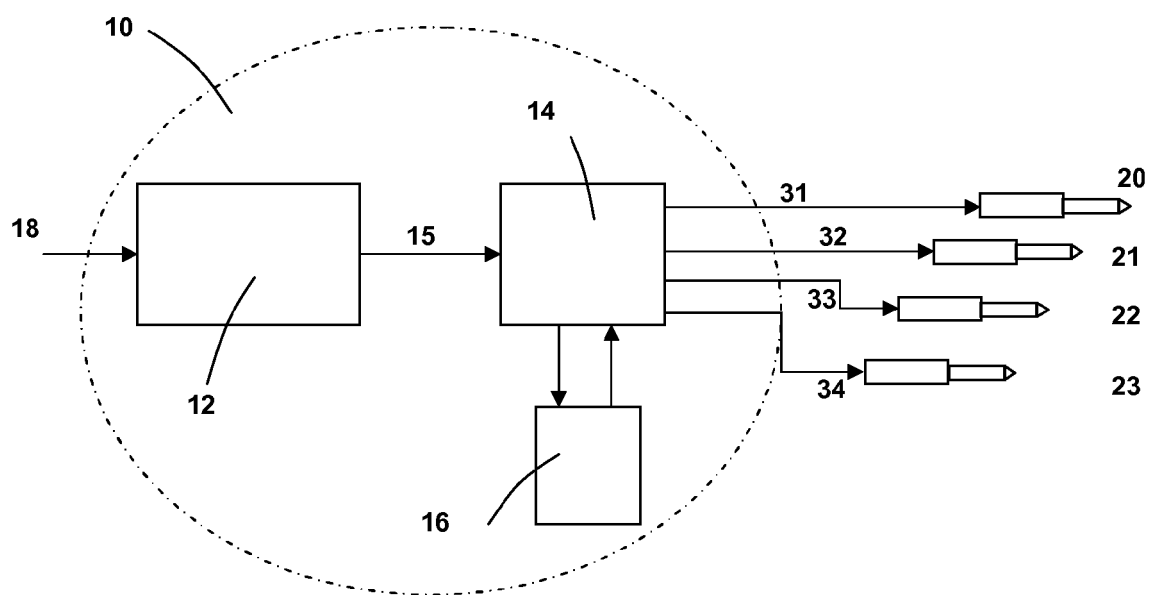


Fig. 1

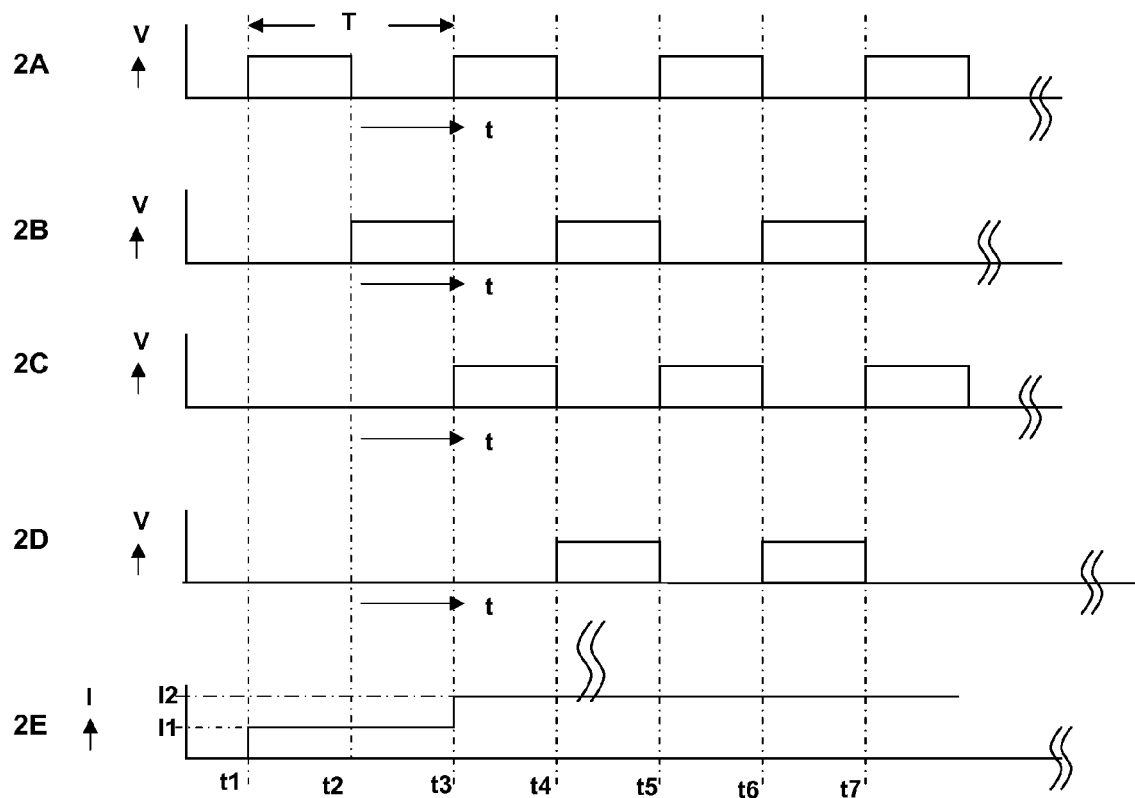


Fig. 2

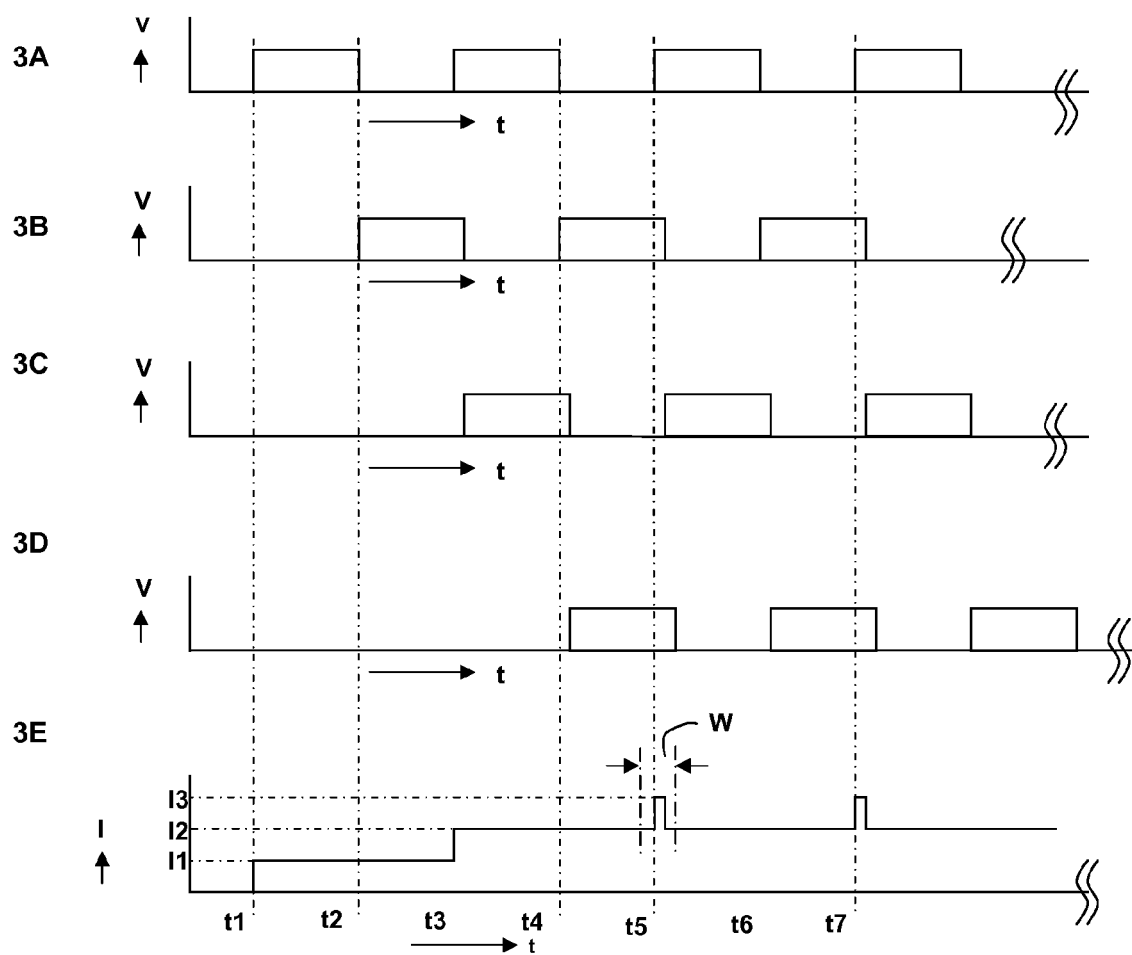


Fig. 3

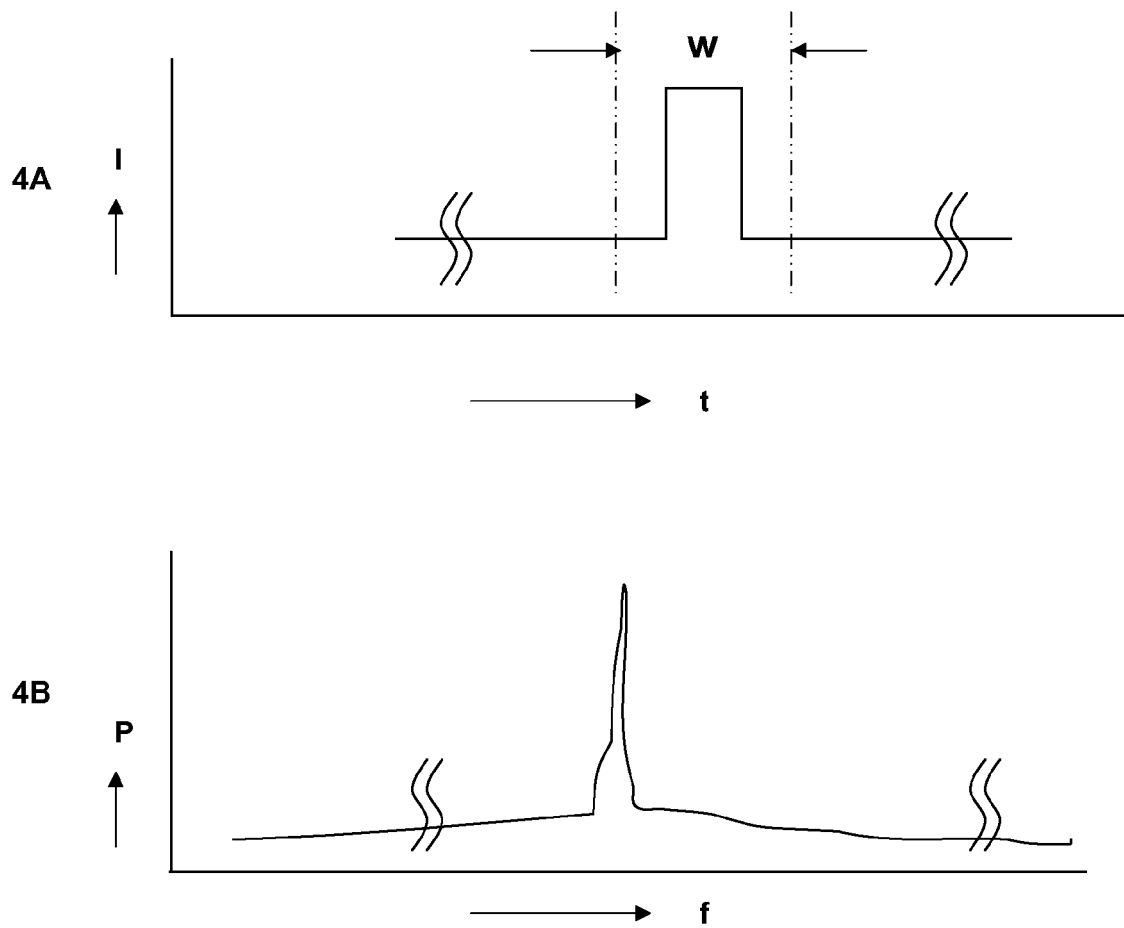


Fig. 4

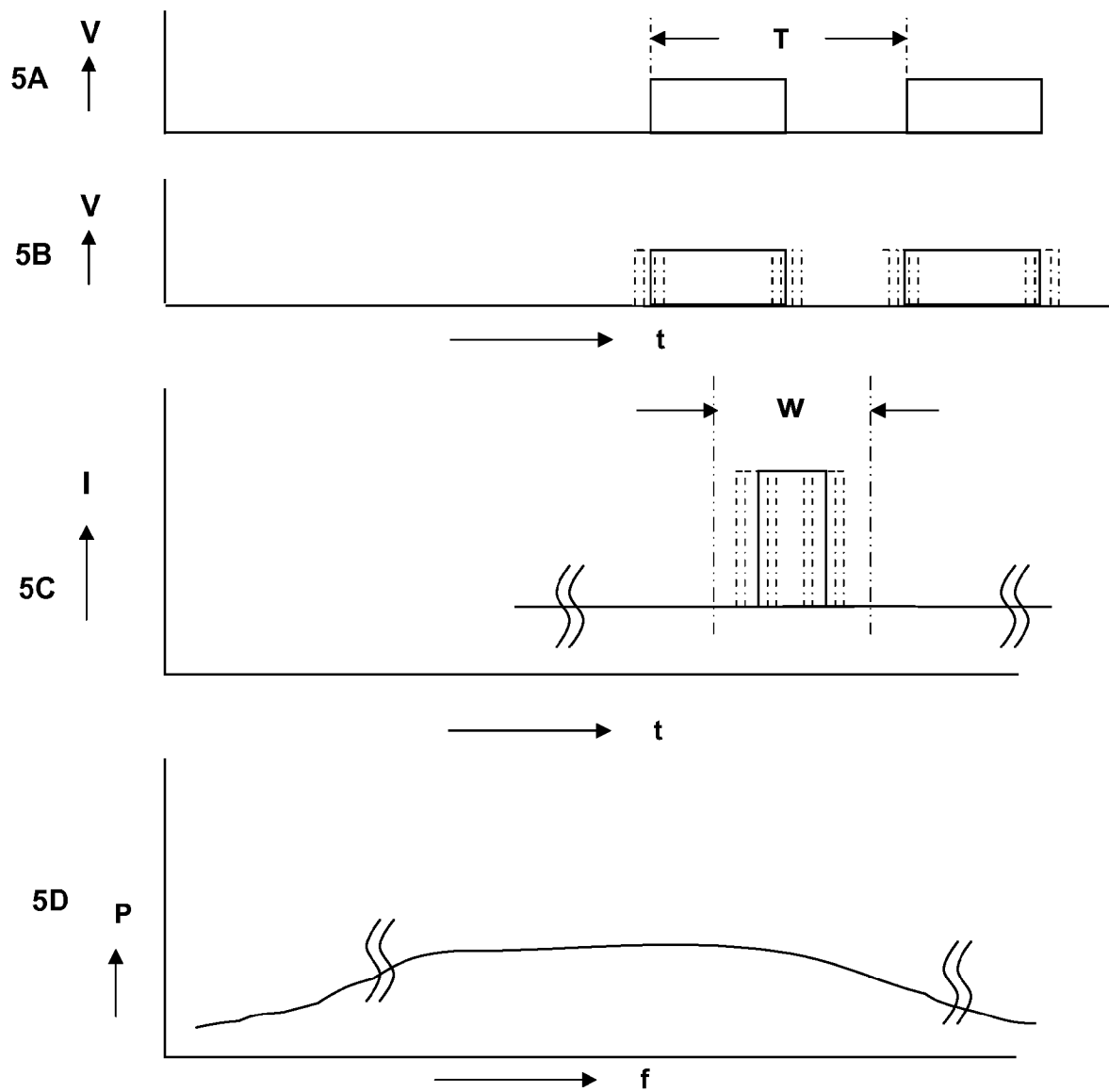


Fig. 5



EUROPEAN SEARCH REPORT

Application Number
EP 09 10 0156

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	DE 10 2006 010083 A1 (BERU AG [DE]) 6 June 2007 (2007-06-06) * paragraphs [0011] - [0013] * -----	1-8	INV. F02P19/02
X	WO 2006/009523 A (COSYLAB D O O [SI]; SIMONCIC URBAN [SI]; GOLOB DAMJAN [SI]; KOVACIC RO) 26 January 2006 (2006-01-26) * page 2, lines 16-18 * * page 2, line 31 - page 3, line 1 * * page 3, lines 4,5 * -----	1-5,7	
X	WO 2008/110143 A (BERU AG [DE]; EHLERT RALF [DE]) 18 September 2008 (2008-09-18) * figure 1 * * page 2, paragraph 2 - page 3, paragraph 2 * * page 4, paragraph 1 * * page 5, paragraph 1 * -----	1-8	
A	US 6 164 258 A (PETROVICH PAUL A [US] ET AL) 26 December 2000 (2000-12-26) * the whole document *		TECHNICAL FIELDS SEARCHED (IPC)
A	US 3 916 329 A (HEKIMIAN NORRIS C ET AL) 28 October 1975 (1975-10-28) * the whole document * -----		F02P F02D
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 29 July 2009	Examiner Parmentier, Hélène
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			

 4
EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 09 10 0156

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

29-07-2009

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102006010083 A1	06-06-2007	NONE	
WO 2006009523 A	26-01-2006	EP 1787022 A1 SI 21858 A	23-05-2007 28-02-2006
WO 2008110143 A	18-09-2008	NONE	
US 6164258 A	26-12-2000	NONE	
US 3916329 A	28-10-1975	NONE	

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 6009369 A1 [0001]