



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
**07.06.2017 Bulletin 2017/23**

(51) Int Cl.:  
**F02D 41/14** (2006.01) **F02D 35/02** (2006.01)  
**F02D 41/40** (2006.01) **F02D 41/00** (2006.01)  
**F02D 37/02** (2006.01)

(21) Application number: **15197693.3**

(22) Date of filing: **03.12.2015**

(84) Designated Contracting States:  
**AL 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 RS SE SI SK SM TR**  
 Designated Extension States:  
**BA ME**  
 Designated Validation States:  
**MA MD**

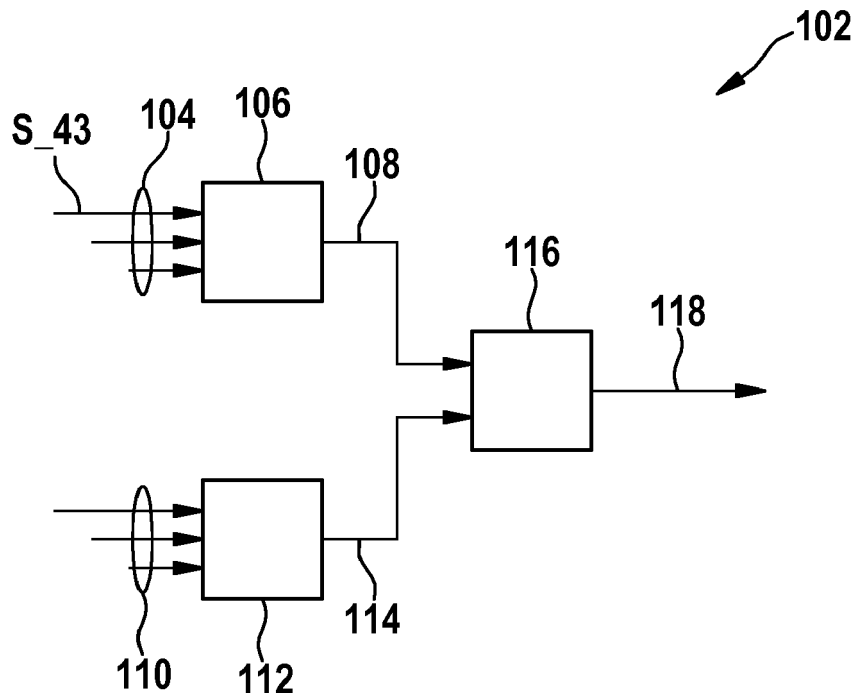
(71) Applicant: **ROBERT BOSCH GMBH**  
**70442 Stuttgart (DE)**

(72) Inventors:  
 • **Mannal, Soenke**  
**70026 Modugno (Bari) (IT)**  
 • **Saracino, Roberto**  
**73026 Melendugno (LE) (IT)**

(54) **METHOD TO OPERATE A COMBUSTION ENGINE**

(57) It is proposed a method to operate a combustion engine of a motor vehicle. It is determined a pressure (S<sub>43</sub>) inside a combustion chamber of the combustion

engine. An exhaust pollutant emission of the combustion engine is limited in dependence on the pressure (S<sub>43</sub>).



**Fig. 2**

## Description

### State of the art

**[0001]** The invention is related to a method to operate a combustion engine according to the preamble of claim 1.

**[0002]** Methods to affect the exhaust pollutant emissions of combustion engines for motor vehicles are well known. Moreover, model-based methods to determine an emission of pollutants are known.

**[0003]** EP 1 398 483 A2 proposes a method for controlling an internal combustion engine with reduced emission of pollutants. It is proposed to compare an emission, which is measured in the exhaust gas of the combustion engine with a desired value. In dependence on the comparison it is corrected a value having influence on the combustion in the combustion engine.

**[0004]** However, current trends from legislation side concerning pollutant emissions from passenger cars and light duty vehicles enforce the monitoring, both in the homologation phase and during the lifetime, over tailpipe emissions and fuel consumption. Moreover, these requirements have to be fulfilled under real world driving conditions. Emission testing procedures with portable measurement systems are defined, to be performed on the vehicles to be homologated on real roads, taking into account among other things the speed/load profile of the vehicle and well as the traffic conditions, etc.

### Summary

**[0005]** In view of the prior art, it is an object of the disclosure to provide a method to operate a combustion engine according to claim 1 which avoids the disadvantages of the prior art. Further embodiments are disclosed in the dependent claims and in the following description of embodiments.

**[0006]** It is determined a pressure inside a combustion chamber of the combustion engine and an exhaust pollutant emission of the combustion engine is limited in dependence on the pressure. The pressure inside the combustion chamber advantageously follows the actual combustion process which has a huge impact on the exhaust pollutant emission. Therefore, emission testing procedures in real world driving conditions according to future emission legislation standards can be passed by the proposed limiting. Therefore the method provides that the conditions under which the vehicle emission tests are performed are controllable. This leads to a guaranteed maximum level of exhaust pollutant emission while minimizing the impact on costs and calibration efforts to achieve these targets.

**[0007]** In an advantageous embodiment the method comprises: determining an exhaust pollutant emission estimate, determining an exhaust pollutant emission parameter, and determining an operating parameter for operating the combustion engine in dependence on the ex-

haust pollutant emission estimate and in dependence on the exhaust pollutant emission parameter. It is provided an operating parameter for operating the combustion engine which takes into account the actual pollutant emission produced and therefore provides an immediate action to limit the actual pollutant emission level.

**[0008]** In an advantageous embodiment the exhaust pollutant emission estimate is determined in dependence on the pressure inside the combustion chamber. The exhaust pollutant emission estimate is therefore provided with an adequate accuracy to determine the actual exhaust pollutant emission level of the combustion engine.

**[0009]** In an advantageous embodiment the exhaust pollutant emission parameter is a threshold value and the method comprises limiting the exhaust pollutant emission of the combustion engine when the exhaust pollutant emission estimate traverses the exhaust pollutant emission parameter. Therefore it is provided a cost-effective exhaust pollution control method reducing effort regarding implementation and application. Moreover, execution and operational safety is ensured by less complex operations.

**[0010]** In an advantageous embodiment the exhaust pollutant emission parameter is a set-point value and the method comprises: determining a deviation in dependence on a comparison of the exhaust pollutant emission estimate and the exhaust pollutant emission parameter, and controlling an operating parameter of the combustion engine in dependence on the deviation. This method provides an effective limitation of the exhaust pollutant emission.

### Brief description of the figures

#### **[0011]**

Figure 1 shows a schematic depiction of a combustion engine; and

Figures 2 and 3 each show a schematic block diagram.

### Description of the embodiments

**[0012]** Figure 1 shows a schematic depiction of a combustion engine 10 of a motor vehicle. The combustion engine 10 is operated according to a direct injection scheme, wherein fuel is injected directly into a combustion chamber 14 of the combustion engine 10 according to an Otto cycle method or a Diesel method or a further method. According to the Otto cycle method a mixture of air and fuel is ignited by means of a spark plug 16. If the combustion engine 10 is a diesel combustion engine the spark plug 16 is not part of the combustion engine 10.

**[0013]** Each combustion chamber 14 is sealed by a movable piston 18 and is supplied by an intake air system 50 with air. After an air-fuel mixture is burned in the combustion chamber, the burned charge of the combustion

chamber 14 will be exhausted by an exhaust system 60. The exchange of charge is controlled by charge cycle valves 24, 26, which are actuated by actors 28, 30 synchronous to the movement of the piston 18. The actors 28, 30 are cams of one or more camshafts, which are driven synchronously to the movement of the piston 18. By means of an exhaust gas recirculation system 70 exhaust gases can be fed back to the combustion chamber 14 in order to reduce nitrogen oxide emissions, NOx emissions, or further exhaust pollutant emissions of the combustion engine 10.

**[0014]** The exhaust system 60 may comprise further components for exhaust gas treatment. Furthermore, the exhaust system 60 may comprise a NOx sensor 36 and a lambda sensor 37. The combustion engine 10 is operated by a control unit 38 which receives signals S from the respective sensors, for example a signal S\_36 from the NOx sensor 36, a signal S\_37 from the lambda sensor 37, a signal S\_40 of a revolution speed sensor 40, a signal S\_42 from an accelerator pedal sensor 42, a signal S\_43 from a pressure sensor 43 and further signals like an ambient temperature, a combustion engine temperature, intake air temperature, etc. The pressure sensor 43 measures a pressure inside the combustion chamber 14 and provides this pressure as the signal S\_43. In dependence on these signals S or at least a part of these signals S the control unit 38 determines an operating parameter S\_12 for the injector 12, if applicable an operating parameter S\_16 for the spark plug 16, an operating parameter S\_34 for an exhaust-gas recirculation valve 34 and if applicable signals for further actuators being part of the combustion engine 10. The control unit 38 comprises a digital processing entity on which a computer program is executable.

**[0015]** The intake air system 50 and the exhaust system 60 and further related components like the exhaust-gas recirculation valve 34 may be referred together as an air system. Further operating parameters regarding the air system comprise at least one of a rate of air passing through the exhaust-gas recirculation valve 34, a boost pressure in the intake manifold, a swirl rate. The injectors 12 and the related components like a fuel pump are referred to as an injection system. Further operating parameters regarding the injection system comprise at least one of an injections pattern, injections timing, a quantity of injections, a fuel mass, and a fuel pressure.

**[0016]** Figure 2 shows a schematic block diagram 102 to operate the combustion engine 10. A plurality of signals 104 inter alia the pressure inside the combustion chamber 14 in form of the signal S\_43 is applied to a block 106. The block 106 comprises a model-based determination of an exhaust pollutant emission estimate 108. The exhaust pollutant emission estimate 108 comprises for example a NOx concentration and/or a soot concentration.

**[0017]** A plurality of signals 110 are applied to a block 112, which determines an exhaust pollutant emission parameter 114 in form of a threshold value. The plurality of

signals 110 may comprise one or more of the following: engine speed, engine load, engine operating mode in form of a conventional mode or a regeneration of exhaust gas mode, further environmental conditions like air temperature, etc. Based on these signals 110 in an application calibration step of the combustion engine 10 an operating map may be determined for determining the threshold value in dependence on the signals 110. Therefore, the block 112 may be in its simplest form the operating map. Of course, further logic or arithmetic operations may be included in the block 112.

**[0018]** A block 116 compares the exhaust pollutant emission estimate 108 with the exhaust pollutant parameter 114. If the exhaust pollutant emission estimate 108 remains below the exhaust pollutant emission parameter 114 the block 114 is in a normal operation mode and does not limit the exhaust pollutant emission. If the exhaust pollutant emission estimate 108 traverses the exhaust pollutant emission parameter 114 in the normal operation mode the block 114 enters a limiting mode and limits the exhaust pollutant emission of the combustion engine 10 in dependence on the pressure S\_43 by adapting operating parameters of the combustion engine 10 exemplified by an operating parameter 118.

**[0019]** Figure 3 shows a schematic block diagram 120 to operate the combustion engine 10. A plurality of signals 122 is applied to a block 124, which determines an exhaust pollutant parameter 126 in form of a set-point value. The signals 122 may be equal to the signals 110. A deviation 128 is determined by subtracting the exhaust pollutant parameter 126 from the exhaust pollutant estimate 108 at a summing point 130. A controller 132 determines the operating parameters of the combustion engine 10 exemplified by an operating parameter 134. It is therefore provided a closed control loop.

**[0020]** To achieve a limiting of the exhaust pollutant emission of the combustion engine 10 the operating parameter 118, 134 may comprise one or more of the plurality of operating parameters as outlined to figure 1 above.

**[0021]** In an embodiment the operating parameter 118, 134 may comprise the operating parameter S\_34 for an exhaust-gas recirculation valve 34. In the embodiment of figure 2, the exhaust-gas recirculation valve 34 may open to increase the exhaust-gas recirculation rate if the threshold is reached or passed.

**[0022]** The exhaust pollutant emission estimate 108 for example, a value for a NOx emission is compared to a threshold value defined as a function of the operating conditions of the combustion engine 10 like speed, load, engine temperature, or further measured or calculated environmental conditions. When reaching or passing the threshold an exhaust gas recirculation rate is increased by appropriately operating the exhaust-gas recirculation valve 34. In case of a turbo system the intake boost pressure is increased. The maximum exhaust-gas recirculation rate is limited for the respective combustion engine 10 for several reasons like an unacceptable fuel con-

sumption increase, an unstable combustion, a limitation of fresh air admission of the air system, or a turbo system especially the respective compressor reaching an unstable operating condition talked.

[0023] To further reduce NOx emissions a combustion timing may be retarded with respect to the top dead center by retarding the diesel fuel injection timing or the spark plug timing depending on the type of combustion engine 10. In this case a compromise between NOx reduction and combustion stability / fuel consumption penalty has to be found because excessive retarding of the combustion timing leads to similar detrimental effects on the combustion engine 10. Moreover trade-offs exist between NOx emission and soot emission as they are counteracting. For example if NOx emissions increase soot emissions decrease. Therefore, the combustion engine 10 has to be operated according to a multi-parameter optimization taking into account NOx emissions and further pollutant emissions. In a further operating mode the torque/load of the combustion engine is reduced in dependence on an increasing exhaust pollutant emission estimate 108. Especially considering NOx and/or soot emissions, they both increase when the combustion engine operates in a higher load-operating region. This limitation of the load or torque in order to limit tailpipe NOx and/or soot emissions can be accomplished by limiting the load/torque for a defined time window when the exhaust pollutant emission estimate 108 crosses a respective threshold.

[0024] If a time-integral value of the exhaust pollutant emission estimate 108 crosses a respective threshold over a defined time window, the load/torque of the combustion engine 10 is reduced. Furthermore, a respective threshold value for the above time-integral value of the exhaust pollutant emission estimate 108 can be calculated as a function of the actual driving profile, for example taking into account the behavior of the driver (aggressive, mild, medium) and/or traffic conditions (urban, rural, highway) and/or an altitude profile (popular, downhill, flat). In order to limit the integral emission over the observed time window it is also possible that the integral emissions limitation strategy as outlined above includes the limitation of the maximum torque furnished by the engine.

[0025] A person of skill in the art would readily recognize that steps of various above-described methods can be performed by programmed computers. Herein, some embodiments are also intended to cover program storage devices, e.g., digital data storage media, which are machine or computer readable and encode machine-executable or computer-executable programs of instructions, wherein said instructions perform some or all of the steps of said above-described methods. The program storage devices may be, e.g., digital memories, magnetic storage media such as a magnetic disks and magnetic tapes, hard drives, or optically readable digital data storage media. The embodiments are also intended to cover computers in the form of the control unit 38 programmed

to perform said steps of the above-described methods.

[0026] The description and drawings merely illustrate the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within its scope. Furthermore, all examples recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof.

[0027] It should be appreciated by those skilled in the art that any block diagrams herein represent conceptual views of illustrative circuitry embodying the principles of the invention. Similarly, it will be appreciated that any flow charts, flow diagrams, state transition diagrams, pseudo code, and the like represent various processes, which may be substantially represented in computer readable medium and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

## 30 Claims

1. A method to operate a combustion engine (10) of a motor vehicle,  
**characterized in**
  - determining a pressure (S\_43) inside a combustion chamber (14) of the combustion engine (10);
  - limiting of an exhaust pollutant emission of the combustion engine (10) in dependence on the pressure (S\_43).
2. The method according to claim 1, wherein the limiting of the exhaust pollutant emission comprises:
  - determining an exhaust pollutant emission estimate (108);
  - determining an exhaust pollutant emission parameter (114; 126);
  - determining an operating parameter (118; 134) for operating the combustion engine (10) in dependence on the exhaust pollutant emission estimate (108) and in dependence on the exhaust pollutant emission parameter (114; 126).
3. The method according to claim 2, where the exhaust pollutant emission estimate (108) is determined in dependence on the pressure (S\_43) inside the com-

bustion chamber (14).

4. The method according to claim 2 or 3, wherein the exhaust pollutant emission parameter (114) is a threshold value; and the method comprises: 5
- limiting the exhaust pollutant emission of the combustion engine (10) when the exhaust pollutant emission estimate (108) traverses the exhaust pollutant emission parameter (114). 10
5. The method according to claim 2 or 3, wherein the exhaust pollutant emission parameter (126) is a set-point value; and the method comprises: 15
- determining a deviation (128) in dependence on a comparison of the exhaust pollutant emission estimate (108) and the exhaust pollutant emission parameter (126);
  - determining an operating parameter (134) of the combustion engine (10) in dependence on the deviation (128). 20
6. The method according to one of the preceding claims, wherein the exhaust pollutant emission estimate (108) is a NO<sub>x</sub> concentration and/or a soot concentration, and wherein the exhaust pollutant emission estimate (108) is determined model-based. 25
7. The method according to one of the preceding claims, wherein an injector (12) is operated in dependence on the operating parameter (S\_12) and/or a spark plug (16) is operated in dependence on the operating parameter (S\_16), and/or an exhaust-gas recirculation valve (34) is operated in dependence on the operating parameter (S\_34). 30 35
8. A computer program product for a digital processing entity, which is configured to execute the method according to one of the preceding claims. 40
9. A control unit (38) for operating a combustion engine (10) of a motor vehicle, which comprises a digital processing entity, on which the computer program product according to claim 8 is executable. 45
10. A storage device for a control unit (38) according to claim 9, on which the computer program product according to claim 8 is stored. 50

55

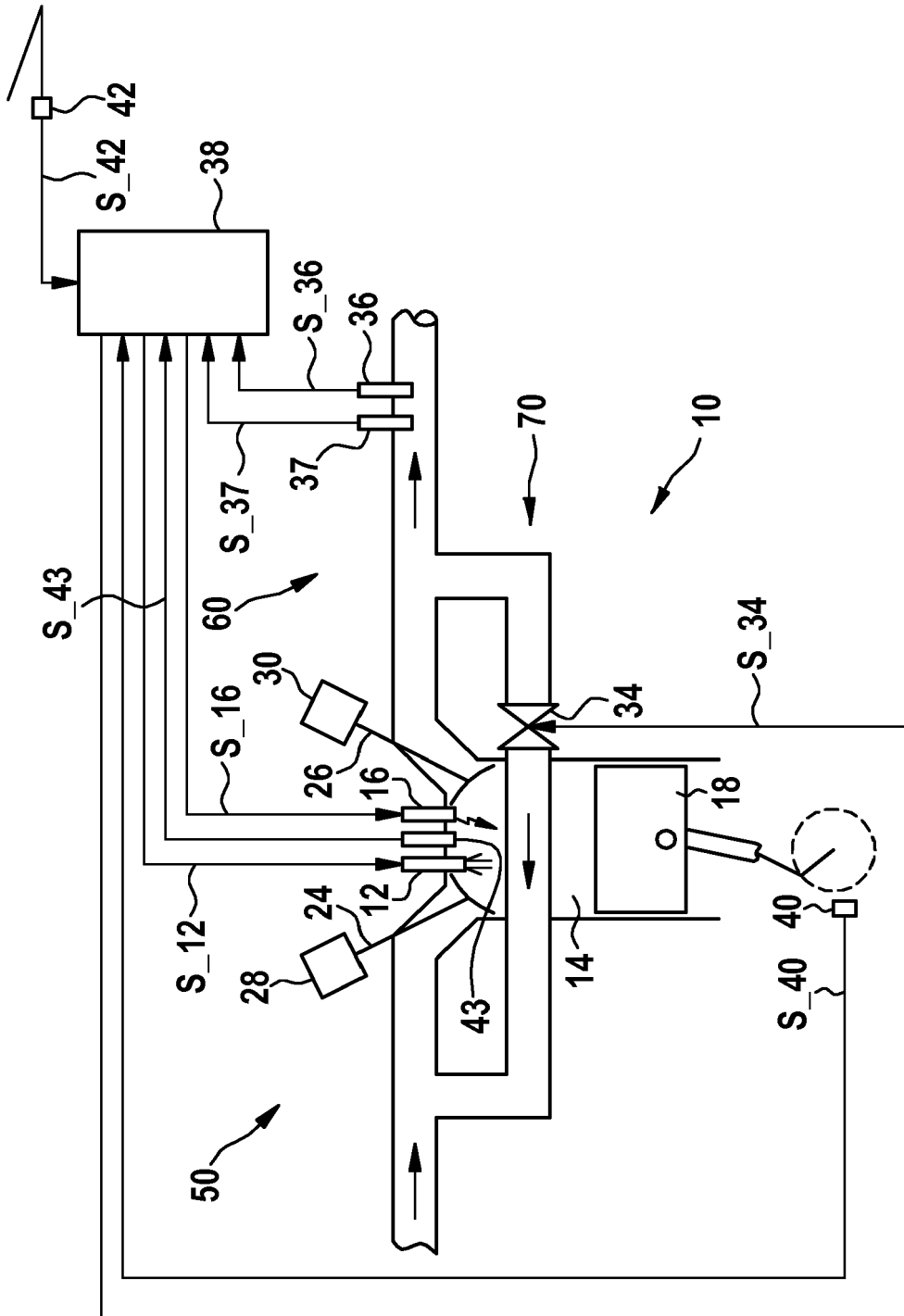


Fig. 1

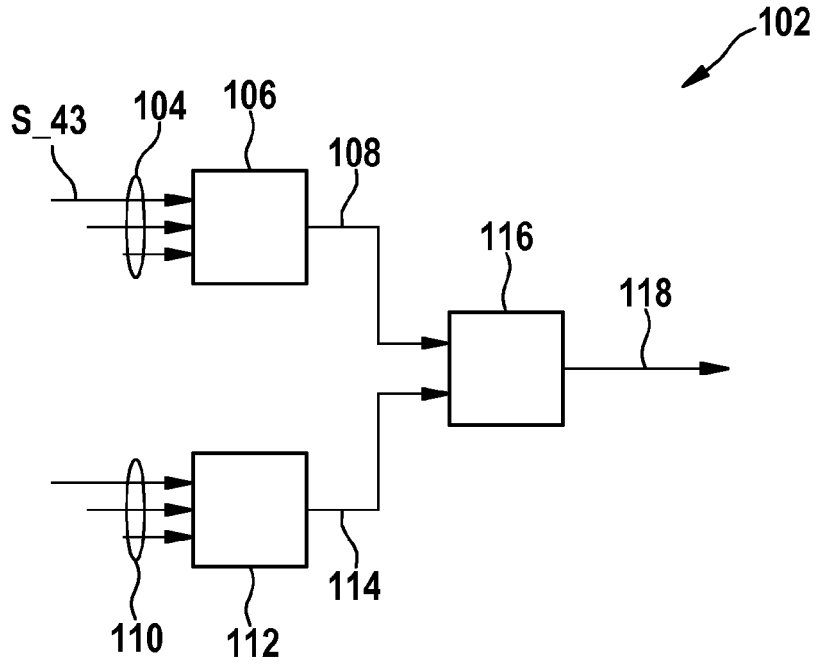


Fig. 2

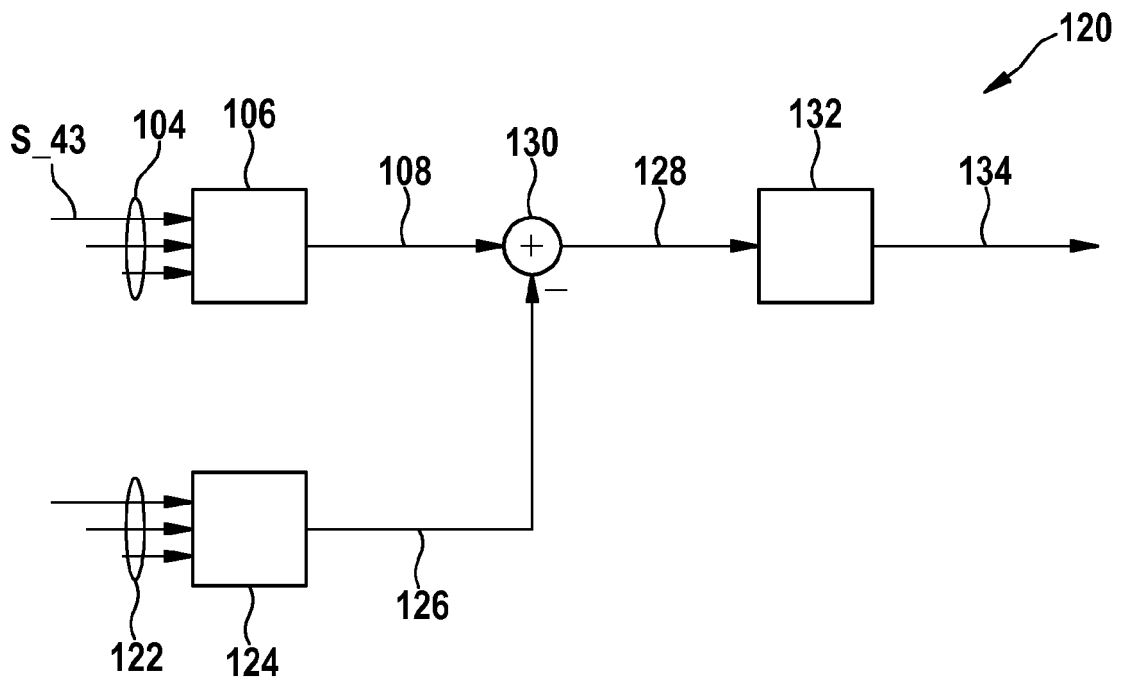


Fig. 3



EUROPEAN SEARCH REPORT

Application Number  
EP 15 19 7693

5

10

15

20

25

30

35

40

45

50

55

| 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  | JP S58 13137 A (MORITA YOSHIYUKI)<br>25 January 1983 (1983-01-25)<br>* abstract *  | 1-3,5-10  | INV.<br>F02D41/14<br>F02D35/02              |
| X  | US 6 425 372 B1 (HILTNER JOEL D [US])<br>30 July 2002 (2002-07-30)<br>* column 4, line 42 - column 5, line 27;<br>figure 68 *  | 1-4,6-10  | ADD.<br>F02D41/40<br>F02D41/00<br>F02D37/02 |
| X  | DE 10 2008 057494 A1 (DAIMLER AG [DE])<br>2 July 2009 (2009-07-02)<br>* claims 1-3 *<br>* paragraph [0031] *   | 1-10  |   |
| X  | US 2010/126481 A1 (WILLI MARTIN L [US] ET AL)<br>27 May 2010 (2010-05-27)<br>* paragraphs [0022], [0031] *<br>* abstract *   | 1-3,5-10  |   |
| X  | FR 2 945 320 A1 (RENAULT SAS [FR])<br>12 November 2010 (2010-11-12)<br>* page 7, line 32 - page 12, line 20 *  | 1-3,5-10  | TECHNICAL FIELDS SEARCHED (IPC)             |
| X  | EP 1 416 143 A1 (ST MICROELECTRONICS SRL [IT])<br>6 May 2004 (2004-05-06)<br>* paragraphs [0059] - [0079] *  | 1-3,5-10  | F02D  |
| X  | CHRISTOPHE BARRO ET AL: "Entwicklung eines virtuellen Russensors für Dieselmotoren",<br>MTZ MOTORTECHNISCHE ZEITSCHRIFT, VIEWEG VERLAG, WIESBADEN, DE,<br>vol. 75, no. 6, 1 June 2014 (2014-06-01),<br>pages 60-67, XP001590997,<br>ISSN: 0024-8525, DOI:<br>10.1007/S35146-014-0368-7<br>* paragraph [0005] * | 1-3,5-10  |   |
| -----<br>-/--  |  |   |   |
| The present search report has been drawn up for all claims   |  |   |   |
| Place of search<br><b>The Hague</b>  |  | Date of completion of the search<br><b>25 May 2016</b>  | Examiner<br><b>Röttger, Klaus</b>           |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document |  | T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>.....<br>& : member of the same patent family, corresponding document |   |

EPO FORM 1503 03.02 (P04C01)



EUROPEAN SEARCH REPORT

Application Number  
EP 15 19 7693

5

10

15

20

25

30

35

40

45

50

55

| 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  | EP 1 712 763 A1 (DAIMLER CHRYSLER AG [DE])<br>18 October 2006 (2006-10-18)<br>* claims 7-9, 13, 17 *<br>----- | 1-3,5-10  |   |
|  |   |   | TECHNICAL FIELDS SEARCHED (IPC)         |
|  |   |   |   |
| The present search report has been drawn up for all claims   |   |   |   |
| Place of search<br>The Hague   |   | Date of completion of the search<br>25 May 2016   | Examiner<br>Röttger, Klaus              |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document |   | T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>.....<br>& : member of the same patent family, corresponding document |   |

1  
EPO FORM 1503 03.02 (P04C01)

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

EP 15 19 7693

5 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.

25-05-2016

| Patent document cited in search report | Publication date | Patent family member(s)                                    | Publication date                       |
|--|------------------|--|--|
| JP S5813137 A                          | 25-01-1983       | NONE   |  |
| US 6425372 B1                          | 30-07-2002       | DE 10228299 A1<br>JP 2003097247 A<br>US 6425372 B1         | 20-03-2003<br>03-04-2003<br>30-07-2002 |
| DE 102008057494 A1                     | 02-07-2009       | NONE   |  |
| US 2010126481 A1                       | 27-05-2010       | DE 112009003516 T5<br>US 2010126481 A1<br>WO 2010062460 A1 | 31-05-2012<br>27-05-2010<br>03-06-2010 |
| FR 2945320 A1                          | 12-11-2010       | EP 2430298 A1<br>FR 2945320 A1<br>WO 2010130937 A1         | 21-03-2012<br>12-11-2010<br>18-11-2010 |
| EP 1416143 A1                          | 06-05-2004       | EP 1416143 A1<br>US 2004112125 A1                          | 06-05-2004<br>17-06-2004               |
| EP 1712763 A1                          | 18-10-2006       | DE 102005017348 A1<br>EP 1712763 A1                        | 19-10-2006<br>18-10-2006               |

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

**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**

- EP 1398483 A2 [0003]