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(54) Method and apparatus for controlling a combustion engine

(57) The invention proposes a method and a corresponding apparatus for controlling a combustion engine, more particularly for controlling a throttle position, which relies on a single external sensor (46) and which involves, to make an additional sensor (44) required in a know approach redundant, on a throttle model (50) for estimating a measure pertaining to boost pressure, since the external sensor (44) now redundant was provided as an external boost pressure sensor (44).

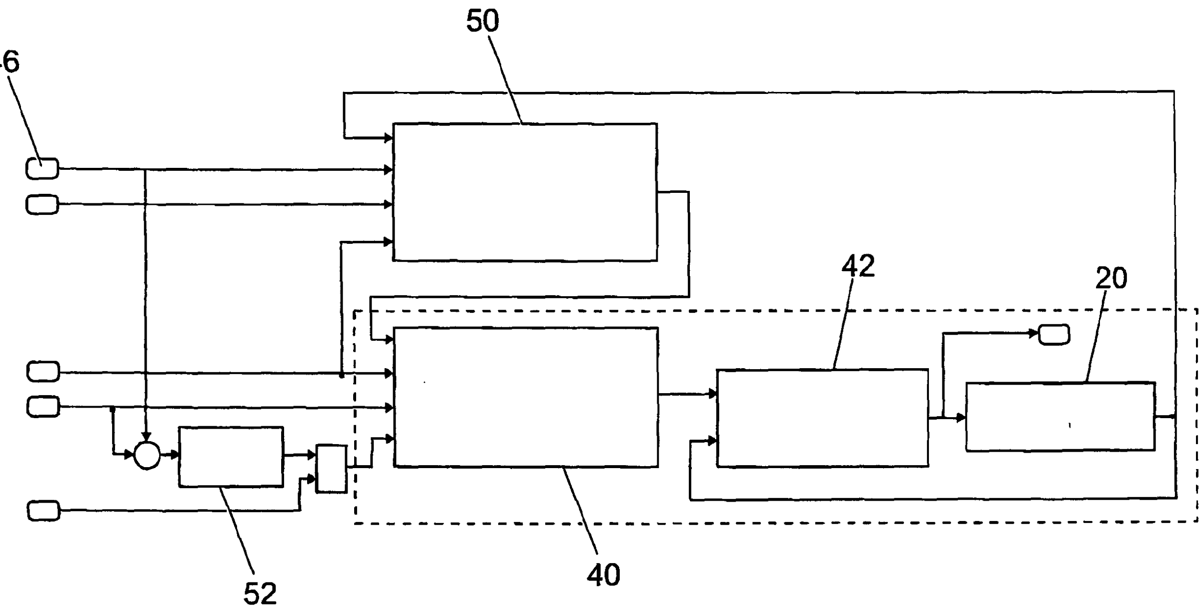

Fig. 3

EP 1 793 106 A1

Description

[0001] The present invention relates to an apparatus for controlling a combustion engine comprising an intake manifold and a throttle disposed before said intake manifold, where an air flow through said intake manifold is subject to a throttle position. More specifically, the invention relates to a method and apparatus for controlling a position, i.e. an opening or closing status, of said throttle. The invention further relates to a method for operating this apparatus.

[0002] An apparatus or a corresponding method known in the art for controlling a throttle position relies on two pressure sensors, a boost press pressure sensor and a manifold pressure sensor. Based on the readings from both these sensors modern turbocharged or supercharged engines are engineered in a way where a desired throttle position required to provide a desired air flow is calculated from a desired pressure ratio, e.g. a ratio between downstream and upstream pressure, more particularly a ratio between manifold air pressure and boost air pressure. Furthermore, throttle flow characteristics are accounted for. An approach to accomplish this, known in the art, is based on a standard orifice equation for compressible fluid flow. The orifice equation is implemented in the control apparatus by means of a throttle model. Furthermore, the known approach relies on a throttle controller, implemented as a standard PID controller, which is provided for ensuring that the throttle position follows the demand. To this end a throttle position feedback is provided.

[0003] This known approach has been found to be not yet fully optimal on account of two pressure sensors being required, which increases the cost of the system. Furthermore, non-model based throttle control has been considered to follow the manifold air pressure demand. However, in the absence of reliable boost pressure information, which is required for accuracy during transient operation, such controls are usually very complex, especially by means of calibration required, software complexity and timing constraints, et cetera.

[0004] An object of the present invention therefore is to provide a remedy for the defects of the prior art. It is furthermore an object of the present invention to overcome problems and drawbacks described above.

[0005] This is achieved by means of an apparatus comprising the features defined in claim 1. To this end an apparatus for controlling a combustion engine comprising an air path and a throttle associated with said air path or disposed in or upstream of an intake manifold comprised in the air path, where an air flow through said air path or intake manifold is subject to a throttle position, wherein the apparatus comprises a first throttle model and a first throttle controller, is characterised by further comprising a second throttle model disposed on an input side of first throttle model and wherein said second throttle model is provided for modelling a measure representative of a boost pressure.

[0006] One advantage of the invention is that by means of the second throttle model, which is provided for modelling a measure representative of a boost pressure, the boost pressure sensor, which was required for prior approaches, is now redundant.

[0007] The dependent claims outline advantageous forms of embodiments of the invention.

[0008] In accord with the present invention the apparatus further comprises a second throttle controller, wherein both the second throttle model and said second throttle controller are disposed on an input side of said first throttle model. This second throttle controller controls the manifold pressure by adapting the second throttle model. Implementing the second throttle controller basically has the same effect as adapting a sonic flow curve of the throttle.

[0009] In further accord with the present invention a real throttle position, which is used as an input for the first throttle controller, is also provided as an input for the second throttle model.

[0010] In still further accord with the present invention a difference between a measure representative of a desired manifold pressure and an output of a manifold pressure sensor, the only external sensor which is required for the approach according to the invention, is fed to the second throttle controller, wherein an output of said second throttle controller and a measure representative of a desired flow through the manifold are combined and wherein said combination is fed as an input to the first throttle model and controller. This embodiment basically pertains to the second throttle controller, its implementation and its connection to external data and the implementation of other function blocks comprised in the apparatus. The benefit of the second throttle controller basically is that, with accounting for a difference between a measure representative of a desired manifold pressure and an output of a manifold pressure sensor, the second throttle controller compensates errors of the apparatus and the function blocks comprised therein. More particularly, the second throttle controller compensates for errors resulting from the second throttle model (boost pressure) and for errors resulting from the first throttle model, since a learn function, which was comprised in the approach known in the art is not applicable when no boost sensor signal is available.

[0011] The invention is also concerned with a computer programme for implementing the new approach according to the invention or a computer programme product with a computer programme for implementing the new approach stored thereon.

[0012] Other features and advantages of the present invention will appear from the following description of a preferred embodiment of the invention, given as a non-limiting example, illustrated in the drawings. All the elements which are not required for the immediate understanding of the invention are omitted. In the drawings, the same elements are provided with the same reference numerals in the various figures, and in which:

Fig. 1 is a schematically simplified block diagram of a combustion engine,

Fig. 2 is a simplified block diagram of an apparatus for controlling a combustion engine known in the art, and

Fig. 3 is a schematically simplified block diagram of an apparatus for controlling a combustion engine according to the invention.

[0013] In the following description, for purposes of explanation and not limitation, specific details are set forth, such as particular embodiments, data flows, signalling implementations, interfaces, techniques, etc. in order to provide a thorough understanding of the present invention. However, it will be apparent to one skilled in the art that the present invention may be practiced in other embodiments that depart from these specific details. For example, while the present invention is sometimes described in the context of turbocharged engines, those skilled in the art will appreciate that the present invention can be implemented for or supercharged engines, as well as other types of combustion engines relying on the same basic principles, using a variety of implementing methods.

[0014] In other instances, detailed descriptions of well-known methods, interfaces, devices, and signalling techniques are omitted so as not to obscure the description of the present invention with unnecessary detail. Moreover, individual function blocks are shown in some of the figures. Those skilled in the art will appreciate that the functions may be implemented using individual hardware circuits, using software functioning in conjunction with a suitably programmed digital microprocessor or general purpose computer, using an application specific integrated circuit (ASIC), and/or using one or more digital signal processors (DSPs).

[0015] Fig. 1 shows a schematically simplified block diagram of a combustion engine 10, considering, as an example, a diesel engine, whereby an engine block 12 is represented by four schematically indicated cylinders 14 and a crank shaft 16. An intake manifold 18, a throttle 20 and an intercooler 22 are, in the direction of the mass flow through the combustion engine 10, located upstream of the engine block 12. A compressor 24 and an air filter 26 are attached thereto and located further upstream of the engine block 12. A fresh air inlet 28 is located at the input of the air filter 26. The aforementioned devices, i.e. the intake manifold 18 and all subsequent devices 20-28 define an air path 18-28, corresponding to which is provided downstream of the engine block 12 and exhaust path comprising at least an exhaust manifold 32 and an exhaust line 34.

[0016] Fig. 2 shows a simplified block diagram of an apparatus for controlling a combustion engine 10 (Fig. 1) known in the art. The known approach relies on a first throttle model 40 and a first throttle controller 42. The apparatus further relies on readings received from two external sensors, namely a boost pressure sensor 44 and a manifold pressure sensor 46. The manifold pressure sensor 46 is, as is known in the art located in our near the intake manifold 18 (Fig. 1). The boost pressure sensor 44 is located between the intercooler 22 and the throttle 20.

[0017] Based on the reading from the boost pressure sensor 44, an input representative of an air temperature, a further input representative of a desired manifold pressure and a still further input representative of a desired flow, the first throttle model 40 generates an output indicative of a desired throttle position. The output of the first throttle model 40 is fed as an input to the first throttle controller 42. A further input to the first throttle controller 42 is a measure indicative of a real throttle position. The real throttle position, derived from the throttle 20 (cf. Fig. 1 also) is fed back from the throttle 20, which is effected by the output of the first throttle controller 42. The approach known in the art further involves means 48 for learning throttle flow characteristics, where the throttle flow learn is based on a reading received from the boost pressure sensor 44 and a reading received from the manifold pressure sensor 46. Further, the throttle flow learn is based on a measure indicative of the air temperature and a measure indicative of a real flow.

[0018] Fig. 3 is a schematically simplified block diagram of an apparatus for controlling a combustion engine according to the invention. As can be seen from Fig. 3 the new approach involves the employment of the first throttle model 40 and the first throttle controller 42 from the approach known in the art (cf. Fig. 2). The new approach further relies on a second throttle model 50 disposed on an input side of the first throttle model 40. The second throttle model 50 is provided for modeling a measure representative of a boost pressure. The output of the second throttle model 50 is fed to the input of the first throttle model 40 where in the known approach (Fig. 2) the reading from the no longer required external boost pressure sensor 44 (Fig. 2) was fed to the first throttle model 40.

[0019] A reading indicative of a real throttle position, which was in the known approach fed back as an input to the first throttle controller 42 is used as an input for the second throttle model 50 also. The second throttle model 50 further relies a reading received from the manifold pressure sensor 46 indicative of a manifold pressure, and data indicative of the real flow and the air temperature as have been employed as inputs in the known approach.

[0020] Furthermore, the new approach relies on a second throttle controller 52 also disposed on an input side of the first throttle model 40. A difference between a measure representative of a desired manifold pressure and the output or reading of the external manifold pressure sensor 46 is fed to the second throttle controller 52, wherein an output of said second throttle controller 52 and a measure representative of the desired flow are combined, e.g. multiplied, and wherein said combination is fed as an input to the first throttle model 40.

[0021] The second throttle model 50 is provided for an estimation of a boost pressure. Said estimation is based on a pressure loss approach. It has been found that a standard orifice flow equation

$$\dot{m} = \frac{A(pos)p_{boost}}{\sqrt{RT_{boost}}}\left(\frac{p_{map}}{p_{boost}}\right)^{\frac{1}{\gamma}}\sqrt{\frac{2\gamma}{\gamma-1}\left[1-\left(\frac{p_{map}}{p_{boost}}\right)^{\frac{\gamma-1}{\gamma}}\right]} \qquad \text{(Equation 1)}$$

cannot be used to model the boost pressure on the basis of the manifold air pressure if the pressure ratio around the throttle 20 (Fig. 1) approaches "1.0", which corresponds to a relatively open throttle 20. This can be seen from Equation 2, derived from Equation 1, where the denominator approaches "0" when the pressure ratio approaches "1.0".

$$p_{boost} = \frac{\dot{m}\sqrt{RT_{boost}}}{A(pos)pr^{\frac{1}{\gamma}}\sqrt{\frac{2\gamma}{\gamma-1}\left[1-pr^{\frac{\gamma-1}{\gamma}}\right]}} \qquad \text{(Equation 2)}$$

[0022] To this end the invention relies on a modified approach to overcome this problem. The standard orifice flow equation (Equation 1) is used to position the throttle 20. However, in order to model the boost sensor (second throttle model 50) a pressure loss method is employed. Equation 3 shows the formula used to estimate the pressure loss over the throttle 20.

$$\Delta p = \frac{8\dot{m}^2(1-(\frac{d}{D})^4)}{\pi^2 d^4 Y^2 \rho C^2} \qquad \text{(Equation 3)}$$

[0023] Thus, the second throttle model 50 is basically an implementation of Equation 3. In Equation 3 Y is a function of both Δp and d/D. Furthermore, C is a discharge co-efficient. Y approaches "1.0" when Δp approaches "0". C never reaches "0". These constraints enable the modeling of the boost pressure sensor on the basis of readings received from the manifold pressure sensor 46 even when the throttle 20 is completely open.

[0024] The second throttle controller 50 is implemented in a preferred embodiment as a (simple) PID controller and is provided for controlling the manifold pressure by adapting the desired flow used in the first throttle model 40 (which is based on the standard orifice flow equation; Equation 1). The second throttle controller 52 aims at compensating for errors of the second throttle model 50 and for errors of the first throttle model 40, since the learn function (48; Fig.2) is not applicable if no boost sensor signal is available.

[0025] Although a preferred embodiment of the invention has been illustrated and described herein, it is recognized that changes and variations may be made without departing from the invention as set forth in the claims. More specifically, while the particular apparatus for controlling a combustion engine and the corresponding method for operating the same as herein shown and described in detail is fully capable of attaining the above-described objects of the invention, it is to be understood that it is the presently preferred embodiment of the invention and thus is representative of the subject matter which is broadly contemplated by the present invention. However, the scope of the present invention fully encompasses other embodiments which may become obvious to those skilled in the art. Accordingly, the scope of the present invention is to be limited by nothing other than the appended claims, in which, for example, reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more". All structural and functional equivalents to the elements of the above-described preferred embodiment that are known, or later come to be known, to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the present claims. Moreover, it is not necessary for a device or method to address each and every problem sought to be solved by the present invention, in order to be regarded as being encompassed by the present claims.

[0026] Summarising the invention described above it can briefly be described as proposing a method and a corresponding apparatus for controlling a combustion engine, more particularly for controlling a throttle position, which relies on a single external sensor 46 and which involves, to make an additional sensor 44 required in a know approach redundant, on a throttle model 50 for estimating a measure pertaining to boost pressure, since the external sensor 44 now redundant was provided as an external boost pressure sensor 44.

Reference Numerals

[0027]

10	combustion engine
12	engine block
14	cylinder
16	crank shaft
18	intake manifold
20	throttle
22	intercooler
24	turbo compressor
26	air filter
28	fresh air inlet
30	--
32	exhaust manifold
34	exhaust line
36	--
38	--
40	first throttle model
42	first throttle controller
44	boost pressure sensor
46	manifold pressure sensor
48	means for learning throttle flow characteristics
50	second throttle model
52	second throttle controller

Claims

1. An Apparatus for controlling a combustion engine comprising an intake manifold and a throttle disposed in said intake manifold, where an air flow through said intake manifold is subject to a throttle position, said apparatus comprising
a first throttle model (40) and
a first throttle controller (42),
characterised in said apparatus further comprising
a second throttle model (50) disposed on an input side of said first throttle model (40) and provided for modelling a measure representative of a manifold pressure.

2. The Apparatus of claim 1, further comprising a second throttle controller (52), wherein both the second throttle model (50) and said second throttle controller (52) are disposed on an input side of said first throttle model (40).

3. The apparatus of claim 1 or 2, wherein a position of a throttle (20) - real throttle position -, which is used as an input for the first throttle controller (42), is also provided as an input for the second throttle model (50).

4. A method for operating the apparatus of claim 1, 2 or 3, wherein a difference between a measure representative of a desired manifold pressure and an output of a manifold pressure sensor (46) is fed to the second throttle controller (52), wherein an output of said second throttle controller (52) and a measure representative of a desired flow are combined and wherein said combination is fed as an input to the first throttle model (40).

5. A method for operating the apparatus of claim 1, 2 or 3, wherein the second throttle model (50) is provided for an estimation of a boost pressure.

6. The method of claim 5, wherein the estimation of the boost pressure is based on a pressure loss-approach.

7. Computer program with a computer readable program code for implementing the method according to any one of claims 4 to 6 when the program code is run on a computer.

8. A Computer program product, such as a storage medium, with a computer readable program code for implementing the method according to any one of claims 4 to 6 when the program code is run on a computer.

Amended claims in accordance with Rule 86(2) EPC.

1. An Apparatus for controlling a combustion engine comprising an intake manifold and a throttle disposed in said intake manifold, where an air flow through said intake manifold is subject to a throttle position, said apparatus comprising

a first throttle model (40) and
a first throttle controller (42), **characterised in** said apparatus further comprising
a second throttle model (50) disposed on an input side of said first throttle model (40) and provided for modelling a measure representative of a throttle pressure.

2. The Apparatus of claim 1, further comprising a second throttle controller (52), wherein both the second throttle model (50) and said second throttle controller (52) are disposed on an input side of said first throttle model (40).

3. The apparatus of claim 1 or 2, wherein a position of a throttle (20) - real throttle position -, which is used as an input for the first throttle controller (42), is also provided as an input for the second throttle model (50).

4. A method for operating the apparatus of claim 2 or 3, wherein a difference between a measure representative of a desired manifold pressure and an output of a manifold pressure sensor (46) is fed to the second throttle controller (52), wherein an output of said second throttle controller (52) and a measure representative of a desired flow are combined and wherein said combination is fed as an input to the first throttle model (40).

5. A method for operating the apparatus of claim 2 or 3, wherein the second throttle model (50) is provided for an estimation of a boost pressure.

6. The method of claim 5, wherein the estimation of the boost pressure is based on a pressure loss-approach.

7. The method of claim 6, wherein the pressure loss-approach involves estimating a pressure loss over the throttle (20).

8. The method of claim 6 or 7, wherein the pressure loss-approach relies on readings received from the manifold pressure sensor (46).

9. Computer program with a computer readable program code for implementing the method according to any one of claims 4 to 8 when the program code is run on a computer.

10. A Computer program product, such as a storage medium, with a computer readable program code for implementing the method according to any one of claims 4 to 8 when the program code is run on a computer.

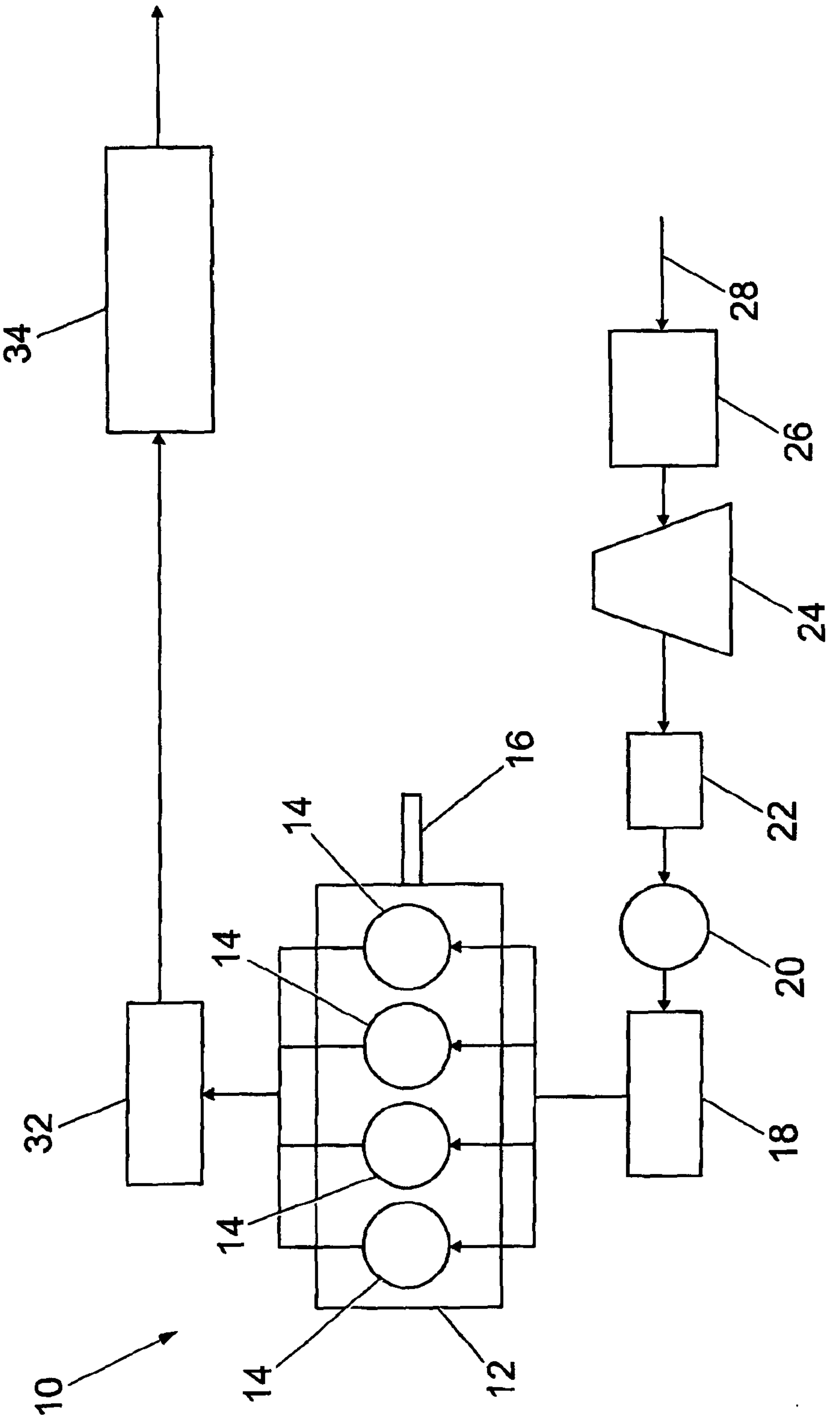

Fig. 1

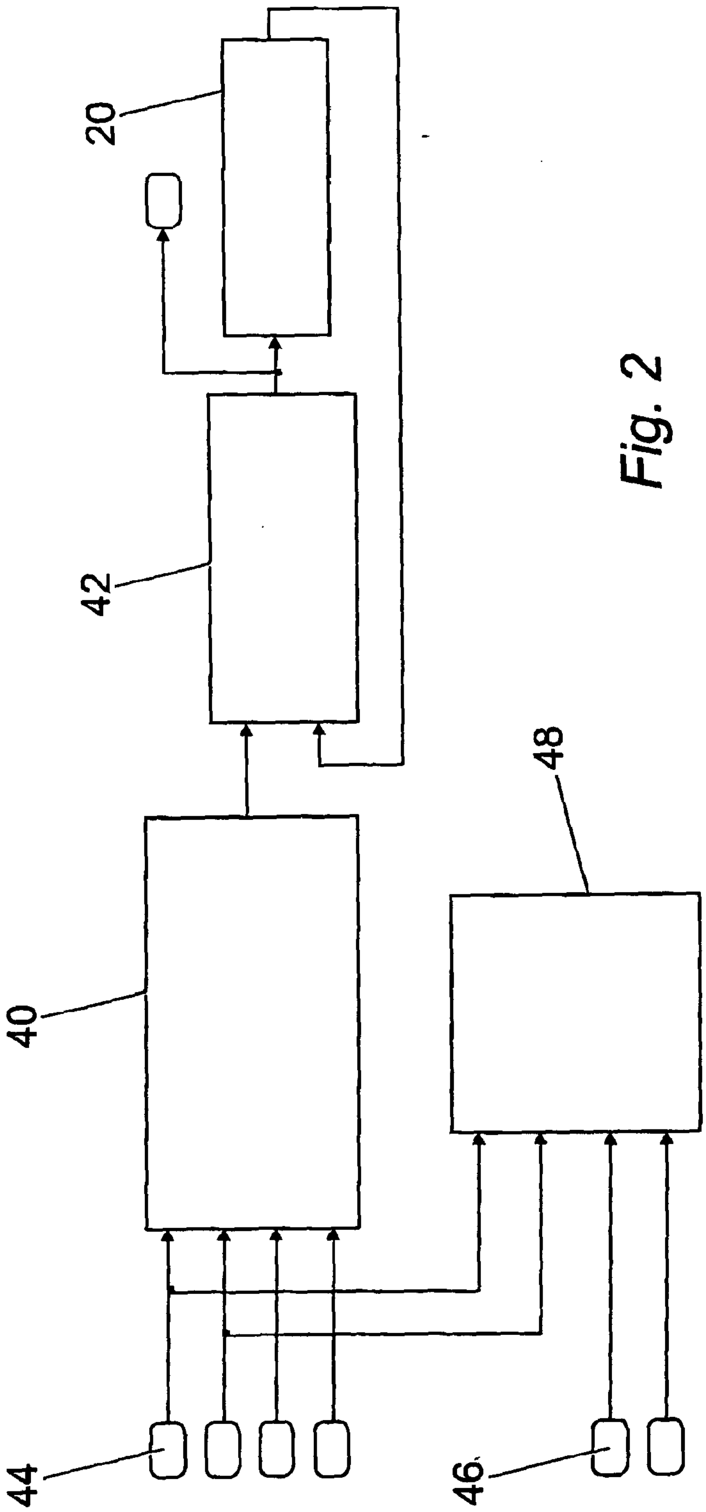

Fig. 2

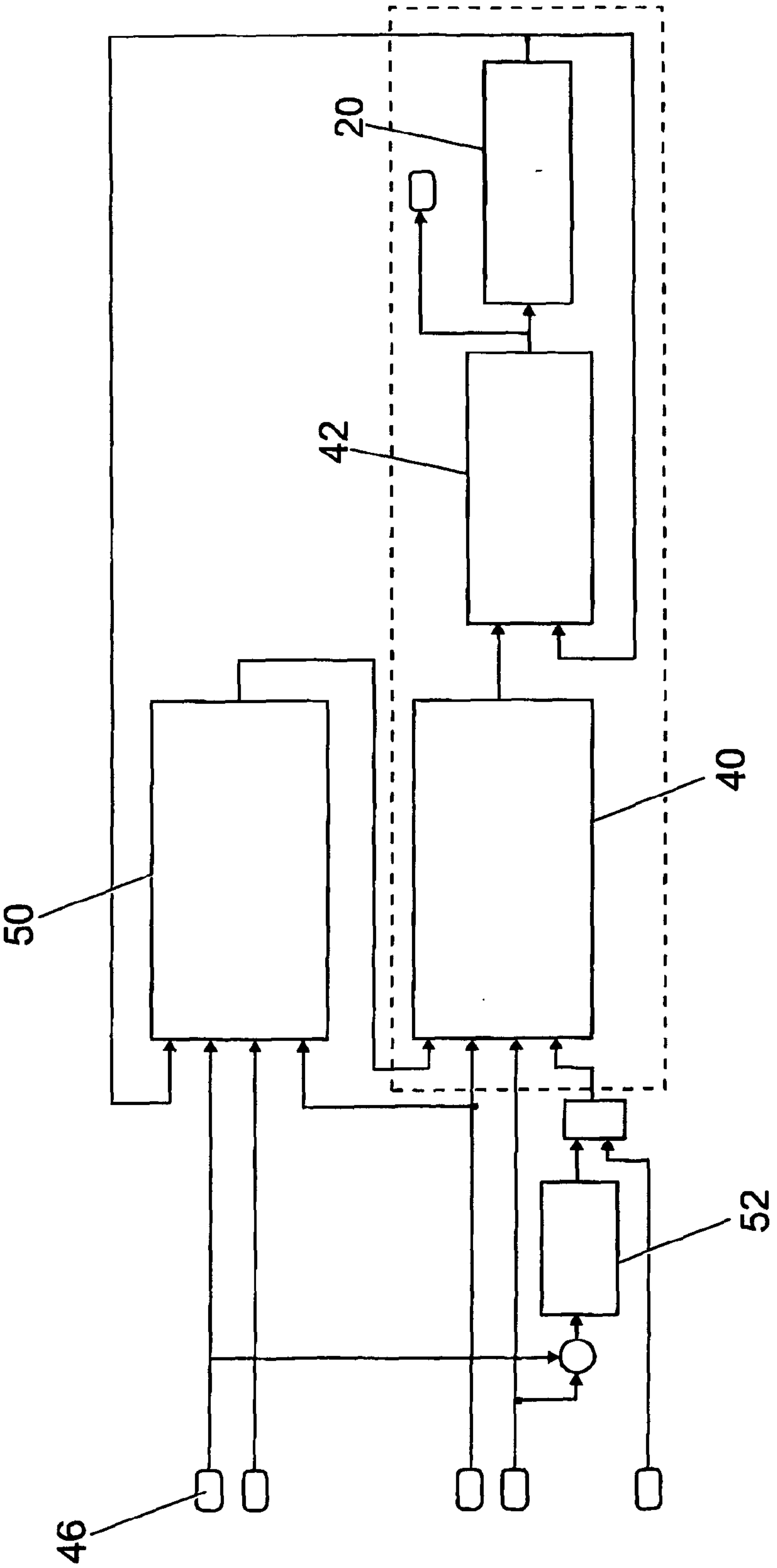

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 05 02 6065

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 1 398 490 A (VOLKSWAGEN AG) 17 March 2004 (2004-03-17) * abstract * * paragraphs [0028], [0042] * * claims * * figures 1,2,7 * -----	1-5,7,8	F02D11/10
X	DE 101 23 034 A1 (ROBERT BOSCH GMBH) 14 November 2002 (2002-11-14) * abstract * * paragraphs [0013], [0015] - [0023] * * claims * * figures * -----	1-5,7,8	
X	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 21, 3 August 2001 (2001-08-03) -& JP 2001 090543 A (UNISIA JECS CORP; NISSAN MOTOR CO LTD), 3 April 2001 (2001-04-03) See computer generated translation, claim1; paragraphs 32-37; figures 3,4 * abstract * -----	1,5,7,8	
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			F02D
A	US 6 895 946 B1 (LIVSHIZ MICHAEL ET AL) 24 May 2005 (2005-05-24) * abstract * * figure 3 * * column 3, line 66 - column 5, line 22 * -----		

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	28 March 2006	Trotereau, D

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 05 02 6065

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28-03-2006

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