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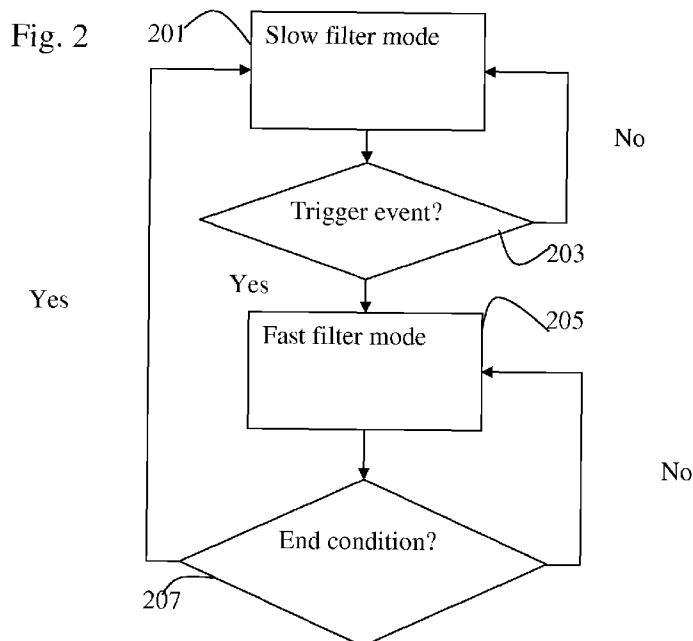
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(54) Title: A METHOD OF CONTROLLING A COMBUSTION ENGINE



(57) Abstract: In a control system used for controlling the engine speed / torque of a combustion engine of a motor vehicle, the system is set to operate in different modes at different modes of operation of the engine. In particular, the control system is adapted to apply filter parameters providing a fast filter for filtering the signal(s) representing charging pressure and exhaust gas pressure of a combustion engine when there is a need for a very accurate torque control / engine speed control. Hereby a faster and more accurate control of the engine speed / torque is obtained which, for example, is beneficial when shifting gear.

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## A METHOD OF CONTROLLING A COMBUSTION ENGINE

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## TECHNICAL FIELD

The present invention relates to a method and a system for controlling a combustion engine. In particular the present invention relates to a method and a system for controlling the speed  
10 / torque of a combustion engine.

## BACKGROUND

When controlling the engine speed of a motor vehicle such as a truck or bus or any other type of motor vehicle, it is important that the electronic control unit ECU of the control  
15 system controlling the engine of the motor vehicle is supplied with correct information about different control parameters affecting the engine speed in order to issue correct control signals for the engine to operate in accordance with the intentions of the driver of the vehicle.

20 Equally important is that the ECU is programmed with a control model that provides an accurate model of the parameters not directly measured by sensors onboard the vehicle. The result of an incorrect model for modeling such parameters can result in undesired behavior and a performance below what would otherwise be possible to achieve. In particular the crankshaft torque will deviate from the set value of the control method used.

25

One parameter that is commonly used in engine speed control is the amount of fuel required to compensate for losses related to an existing exhaust gas pressure and an existing charge gas pressure, i.e. the pumping work for overcoming the pressure difference between the existing charge gas pressure and the existing exhaust gas pressure. Hence, if there is a  
30 higher exhaust gas pressure than inlet/charger gas pressure fuel is required to generate the “pumping” work for overcoming the pressure difference. For example in a diesel engine provided with a turbocharger, the exhaust gas pressure will under typical operational conditions be higher than the charge gas pressure, but can also during some conditions be

lower. For an engine with Exhaust Gas Recirculation (EGR) it is common to operate the engine in a state where the exhaust gas pressure is higher than the charge gas pressure to enable exhaust gas recirculation. To estimate the losses related to pumping work, differences between inlet gas pressure and exhaust gas pressure are continuously sampled. If  
5 the difference is incorrectly modeled, the crankshaft torque will differ from what is intended.

In existing control methods for controlling engine speed and crankshaft torque, there is a problem of correctly modeling the work required for compensating for losses related to the  
10 difference between the current exhaust gas pressure and the existing charge gas pressure, in particular when there is a rapid change in the difference between inlet/charger gas pressure and exhaust gas pressure.

Hence there is a need for a control system that can provide optimal control signals both  
15 during ordinary operation of the engine and during times when there is a rapid change in inlet/charger gas pressure and/or exhaust gas pressure.

## SUMMARY

It is an object of the present invention to provide a method and a system that is capable of  
20 providing improved control for a combustion engine of a motor vehicle.

It is another object of the present invention to provide a method and a system that is capable of providing a more accurate engine speed /torque control during phases of rapid changes in inlet/charger gas pressure and/or exhaust gas pressure or other parameters affecting engine  
25 speed/torque control such as rapid changes in engine speed.

These objects and others are obtained by the method, apparatus and computer program product as set out in the appended claims. Thus, by realizing that there exist different control needs at different modes of operation of a combustion engine, the control system can  
30 be adapted to operate in different modes at different modes of operation of the engine. In particular, the control system is adapted to apply filter parameters providing a fast filter for filtering the signal(s) representing charging pressure and/or exhaust gas pressure of a

combustion engine when there is a need for a very accurate torque control / engine speed control. Such need is for example present when shifting gear or when slow driving and during start/stop, while having clutch slip and other conditions when the drive line is not fully engaged. When creep driving/crawling under such conditions there is a risk of stalling the engine due to an erroneously calculated torque generated by the engine, which of course is an undesired event. At times when there is no particular need for a very accurate engine speed control or torque control, other control parameters are more important and the filter is advantageously given parameters proving a longer response time.

In accordance with one embodiment an internal combustion engine powering a motor vehicle control of the engine is performed using sensor input signals from at least an exhaust gas pressure sensor and / or an inlet gas pressure sensor filtered through a filter having a first response time. The control system is adapted to detect an event triggering a second control mode. In the second control mode, the sensor signal from the exhaust gas pressure sensor and/ or the inlet gas pressure sensor is filtered through a filter having second response time where the second response time is shorter than the first response time. Hereby the engine speed/ torque can be controlled with higher precision when such control is advantageous.

In accordance with one embodiment, when the engine has a turbo charger, the charger gas pressure sensor signal is also filtered using a faster filter while in the second mode, whereby a more precise engine speed/ torque is obtained. Other signals such as an engine speed sensor signal can also be filtered using a faster filter while in the second mode in order to improve engine speed / torque control.

Using the method and system in accordance with the invention will provide faster and more accurate control of the engine speed / torque.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described in more detail by way of non-limiting examples and with reference to the accompanying drawings, in which:

- Fig. 1 is a general view of an engine including a turbo charger.
- Fig. 2 is a flowchart illustrating steps performed when controlling engine speed / torque of a motor vehicle.

## 5 DETAILED DESCRIPTION

In Fig.1 selected parts of an engine 100 of a motor vehicle 10 is schematically depicted. The engine depicted in Fig. 1 can for example be designed to be part of a truck or any other heavy vehicle such as a bus or the like. The exemplary engine 100 in Fig. 1 is a diesel engine provided with a turbocharger and having five cylinders 105. The turbo charger can  
10 be of any type for example a turbo charger having a Variable Turbine Geometry (VTG) also termed Variable Geometry Turbocharger (VTG). The turbo charger comprises a compressor 102 driven by a turbine 103. Furthermore, a pressure sensors 115 is located downstream the compressor 102, and another pressure sensor 116 is located upstream the turbine 103.

15 The engine is controlled by an electronic control unit (ECU) 106 and possibly also other control units generally denoted 107. Both the ECU 106 and other control units 107 are connected to the engine to control the engine. In addition sensors provided in association with the engine provide sensor signals to the control units 106 and 107. Using the sensor input signals obtained by different sensors located on the vehicle, the control units 106 and  
20 107 exercise control of the engine using some programmed computer instructions or similar means. Typically, the programmed computer instructions are provided in the form of computer software in the form of a computer program product 110 stored on a readable digital storage medium 108, such as memory card, a Read Only Memory (ROM) a Random Access Memory (RAM), an EPROM, an EEPROM or a flash memory. The other control  
25 units 107 can include other control unit receiving pressure sensor input signals either directly or via digital communication such as via a serial bus. A common way of communication sensor signal values and other information between different control units in a heavy motor vehicle is via a Controller Area Network bus (CAN-bus). In the example described herein the control units 106 and 107 are interconnected via a CAN-bus 109, but  
30 may alternatively be connected via e.g. FlexRay and TTCAN.

In operation the engine will experience many different modes of operation. For example, the pressure drop over the engine, i.e. the pressure difference between the air intake of the engine downstream the compressor 102 and the exhaust gas pressure upstream the turbine 103, will vary vastly depending on the mode of operation. If there is a higher pressure upstream the turbine than downstream the compressor the engine will have to perform some work, pumping work, to generate a gas mass flow through the engine. When controlling the engine speed / torque, the work required to generate the gas mass flow need to be taken into account to feed a correct amount of fuel to the cylinders 105 of the engine. In some scenarios, there will be rapid changes in either pressure downstream the compressor 102 and /or upstream the turbine 103 resulting in a transient change in the work required to generate the gas mass flow.

If the filter used to filter the signals from sensors for pressure downstream the compressor 102 and upstream the turbine 103 have a relatively long response time, there will be a delay in the control of the fuel provided to the cylinders. The result is that for a period of time after such a transient event, the work required to generate the gas mass flow will be incorrectly modeled and as a consequence the amount of fuel provided to the cylinders will be incorrect. The ultimate result is that the engine speed / torque will deviate from the value set by the control system for a period of time after such a transient event.

During most operation such a deviation of the engine speed / torque is acceptable because the benefits of having a relatively slow filter by far outweigh the negative impact. For example using a slow filter will generate a signal having a low noise level when compensation for pumping work losses, which in turn will result in a more stable running of the engine. Another advantage can be if the filtered exhaust gas pressure signal is used as input signal for controlling other parameters. In such a scenario it may be advantageous to use a signal having a low noise level.

However, in some scenarios it is important to provide an accurate control of the engine speed / torque. When such a scenario is detected by a detection mechanism in the control unit 106 and/or 107, the control system switches mode. In the new mode, the control system applies a faster filter to the sensor signals received from the pressure sensor 115 located

downstream the compressor 102 and the pressure sensor 116 located upstream the turbine 103 than the filter used in conventional operation of the control system. By switching between two different filtering modes in response to detection of an event indicating that a fast filter may be beneficial, the control system can better adjust to the current mode of operation of the motor vehicle that the engine propels. Different events that may trigger a mode where a fast filter is employed can for example be when conditions are such that there is or will be a transient in the pressure sensor signals and the engine is operated in a state where an accurate torque generated by the engine is required.

10 Because the gear box control unit knows when a gear shift is to take place it can be programmed to issue a flag FLAG = True to the engine control unit when a gear shift is in progress. When the engine control unit receives the flag FLAG = True from the gear box control unit, the engine control unit operates in a mode where a fast filter is applied.

15 Other sensor signals that can be used to trigger the mode with fast filter filtering of the pressure signal are signals indicative of clutch position and/or the accelerator pedal position. When no signal is triggering the fast filter filtering mode of the pressure sensor signal, the fast filter mode is un-triggered.

20 In Fig. 2, a flowchart illustrating some procedural steps performed when controlling the engine of a motor vehicle in accordance with one embodiment of the present invention is shown. Thus, first in a first step 201, the control unit operates in a first conventional mode where the sensor signals from the pressure sensor located downstream the compressor 102 and from the pressure sensor 115 located upstream the turbine 103 in the exhaust gas system are filtered using a filter having a relatively long response time. Next, in a second step 203 the control unit checks if an event has occurred that triggers a second control mode. The events that will trigger the second control mode can for example include but are not limited to the events listed above or can also be a subset thereof.

30 If in step 203, a trigger event is detected, the procedure depicted in Fig. 2 proceeds to a third step 205, else the procedure returns to step 201. In step 205 the control unit applies a second mode of operation where the sensor signals from the pressure sensor located downstream

the compressor 102 and from the pressure sensor located upstream the turbine 103 are filtered using a fast filter having a relatively short response time. In particular the filter used in the second mode of operation is faster than the filter used in the first conventional mode of operation and hence has a shorter response time than the filter used in the first mode.

5

In the second mode also other signals may be filtered using a faster filter if that is determined to be beneficial. An example of such another signal that may be adapted to change filter when changing filtering mode is the engine speed signal, other signals may also be set to change filter to a faster filter.

10

The filter used can be any suitable filter for example a Butterworth low pass filter. An example of a filter, in this case a second order Butterworth low pass filter can be as follows

$$H(z) = \frac{b_1 + b_2 z^{-1} + b_3 z^{-2}}{1 + a_2 z^{-1} + a_3 z^{-2}}$$

15  $z$  is the  $z$ -transform

In the ECU the values of the filter parameters  $b_1$ ,  $b_2$ ,  $b_3$ ,  $a_2$ , and  $a_3$  are changed in order to achieve different bandwidths.

20 For example, using a 100Hz sample frequency and a low bandwidth (2Hz)

$$B1 = 0.0036$$

$$B2 = 0.0072$$

$$B3 = 0.0036$$

$$A2 = -1.8227$$

25  $A3 = 0.8372$ 

For example, using a 100Hz sample frequency and a higher bandwidth (20Hz)

$$B1 = 0.2066$$

$$B2 = 0.4131$$

30  $B3 = 0.2066$ 

$$A2 = -0.3695$$

$$A3 = 0.1958$$

Thereupon, the procedure checks if an end condition has occurred in a fourth step 207. The end condition may for example be the resetting of a flag initially triggering the second fast filter mode or any other suitable end condition. If an end condition is determined to have occurred in step 207 the control unit switches back to the first mode of operation using a filter having a relatively long response time and the procedure returns to step 201. If, on the

35

other hand, no end condition is determined to be fulfilled, the control unit remains in the second mode and the procedure returns to step 205.

5 Using the method and system in accordance with the invention will provide faster and more accurate control of the engine speed / torque. This is particularly useful to prevent incorrect engine speed control /torque control. For example during gear shift it is important to quickly generate a correct target engine speed in order to enable a quick and smooth gear shift.

## CLAIMS

1. A method of controlling of an internal combustion engine (100) powering a motor vehicle (10), where control of the engine is performed using sensor signals from at least one exhaust gas pressure sensor (116) and / or an inlet gas pressure (115) sensor filtered through a filter having a first response time, **characterized by** the steps of:
- detecting (203) an event triggering a second control mode,
  - entering (205) the second control mode, where the sensor signal from the exhaust gas pressure sensor and or the inlet gas pressure sensor is filtered through a filter having second response time where the second response time is shorter than the first response time.
2. The method according to claim 1, when the engine has a turbo charger, **characterized by** the step of: filtering a charger gas pressure sensor signal using a faster filter while in the second mode.
3. The method according to claim 1 or 2, **characterized by** the step of: filtering an engine speed sensor signal using a faster filter while in the second mode.
4. The method according to any of claims 1 – 3, **characterized by** the step of: detecting an event triggering a second control mode by identifying a condition that there is or will be a transient in the pressure sensor signal as one input parameter.
5. The method according to any of claims 1 – 4, **characterized by** the step of: detecting an event triggering a second control mode by receiving a signal indicative of a gear shift.
6. The method according to any of claims 1 – 5, **characterized by** the step of: detecting an event triggering a second control mode by identifying a predetermined clutch position and /or accelerator pedal position as input parameter(s).
7. A system for controlling of an internal combustion engine (100) powering a motor vehicle (10), the control system adapted to control the engine using sensor signals from at least an exhaust gas pressure sensor (116) and/or an inlet gas pressure sensor (115) filtered through a filter having a first response time, **characterized by**:

- means (106) for detecting an event triggering a second control mode, and
- means (106) for entering the second control mode, where the sensor signal from the exhaust gas pressure sensor and or inlet gas pressure sensor is filtered through a filter having second response time where the second response time is shorter than the first response time.

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8. The system according to claim 7, when the engine is provided with a turbo charger, **characterized by** means for filtering a charger gas pressure sensor signal using a faster filter while in the second mode.

10 9. The system according to claim 7 or 8, **characterized by** means for filtering an engine speed sensor signal using a faster filter while in the second mode.

10. The system according to any of claims 7 – 9, **characterized by** means for identifying a condition that there is or will be a transient in the pressure sensor signal as one input  
15 parameter connected to the means for triggering the second control mode..

11. The system according to any of claims 7 – 10, **characterized by** means for by receiving a signal indicative of a gear shift and adapted to trigger the second control mode in response to receiving a signal indicative of a gear shift.

20

12. The system according to any of claims 7 – 11, **characterized by** means for detecting an event triggering a second control mode by identifying a predetermined clutch position and /or accelerator pedal position as input parameter(s).

25 13. A computer program product (110) for controlling an internal combustion engine (100) powering a motor vehicle (10), where control of the engine is performed using sensor signals from at least an exhaust gas pressure sensor (116) and/or an inlet gas pressure sensor (115) filtered through a filter having a first response time, **characterized in** that the computer program product comprises program segments that when executed on a computer  
30 for controlling the internal combustion engine causes the computer to perform the steps of:  
- detecting an event triggering a second control mode, and

- entering the second control mode, where the sensor signal from the exhaust gas pressure sensor and or inlet gas pressure sensor is filtered through a filter having second response time where the second response time is shorter than the first response time.

5 14. The computer program product according to claim 13, when the computer program product is adapted to control an engine having a turbo charger, **characterized by:** program segments for filtering a charger gas pressure sensor signal using a faster filter while in the second mode.

10 15. The computer program product according to claim 13 or 14, **characterized by** program segments for filtering an engine speed sensor signal using a faster filter while in the second mode.

15 16. The computer program product according to any of claims 13 – 15, **characterized by** program segments for detecting an event triggering a second control mode by identifying a condition that there is or will be a transient in the pressure sensor signal as one input parameter.

20 17. The computer program product according to any of claims 13 – 16, **characterized by** program segments for detecting an event triggering a second control mode by receiving a signal indicative of a gear shift.

25 18. The computer program product according to any of claims 13 – 17, **characterized by** program segments for detecting an event triggering a second control mode by identifying a predetermined clutch position and /or accelerator pedal position as input parameter(s).

19. A digital storage medium (108) having the computer program product according to any of claims 13 - 18 stored thereon.

1/2

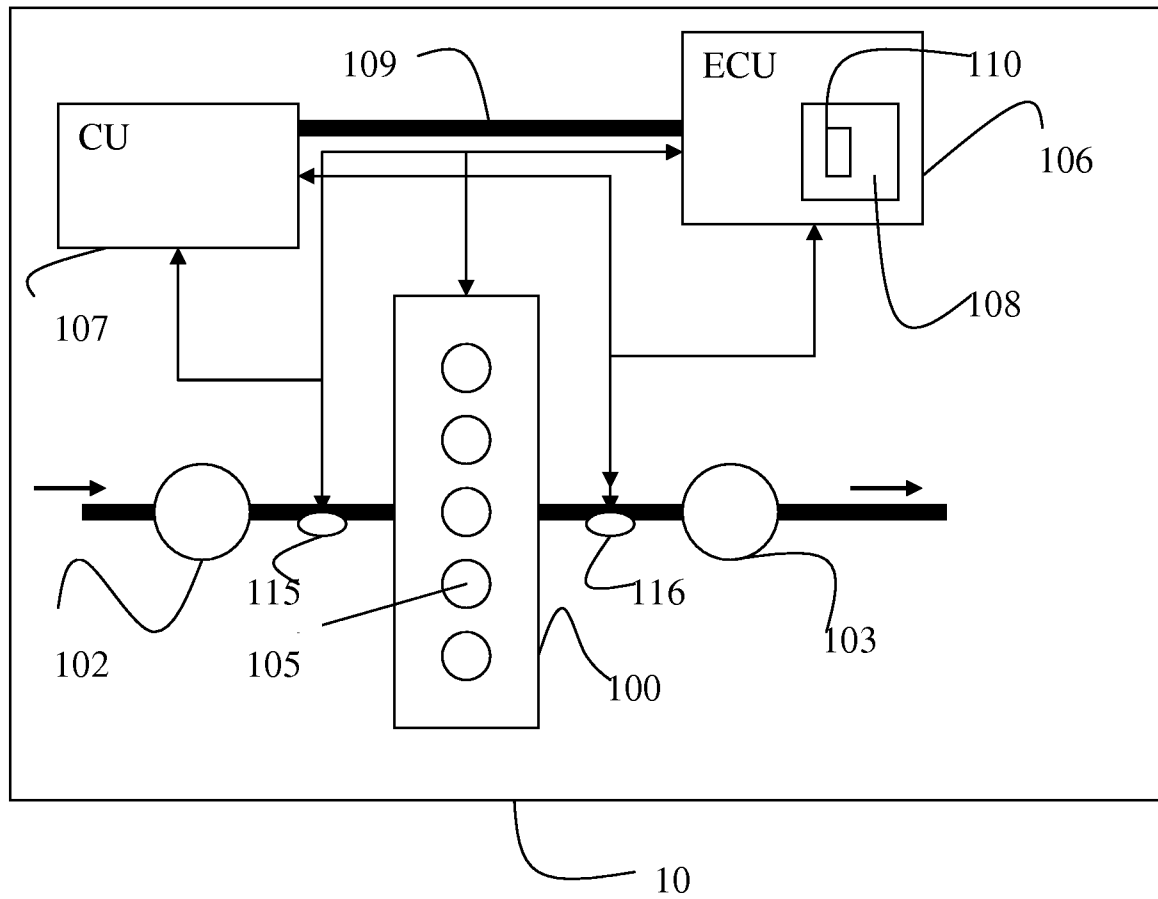


Fig. 1

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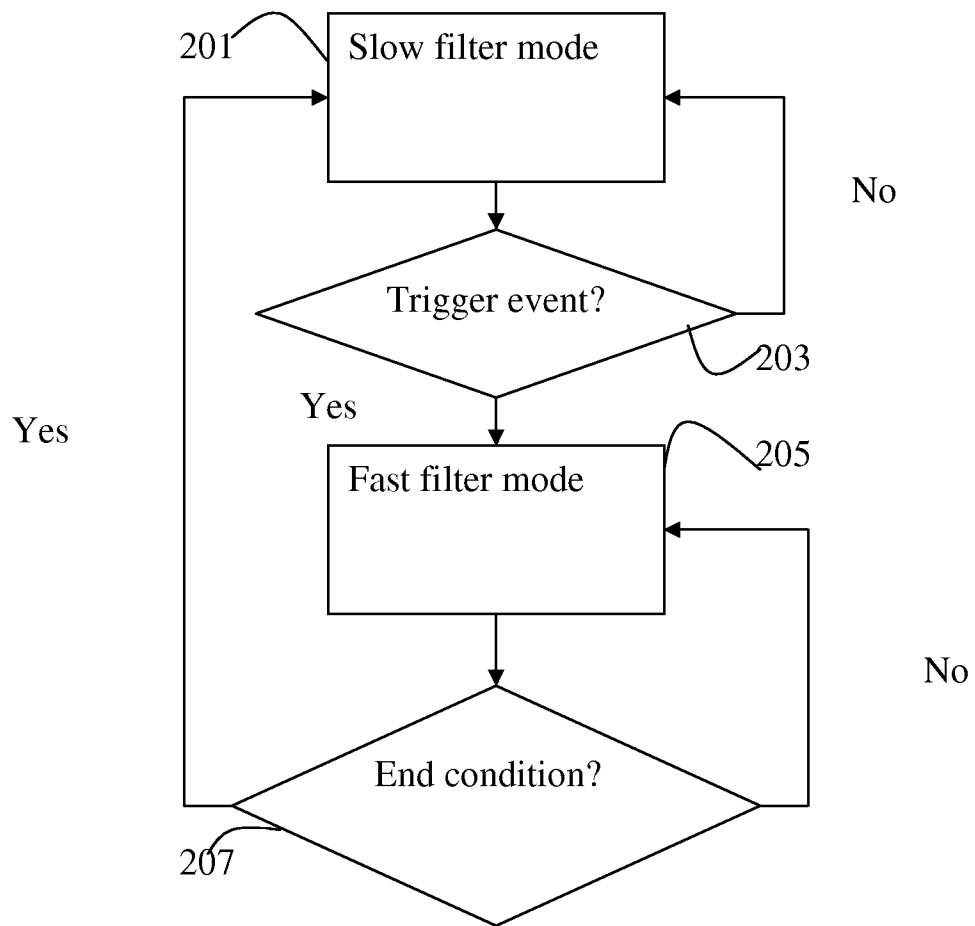


Fig. 2

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE2008/050522

## A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: F02D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

|                                                                                                                                                                         |                                                                                                                                                                                                                                                  |
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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE2008/050522

| C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                                                                       |                       |
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*F02D 41/04* (2006.01)

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Cited literature, if any, will be enclosed in paper form.

## INTERNATIONAL SEARCH REPORT

Information on patent family members

28/06/2008

International application No.

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