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(54) **Title**: EXHAUST POST-TREATMENT SYSTEM FOR A COMBUSTION ENGINE

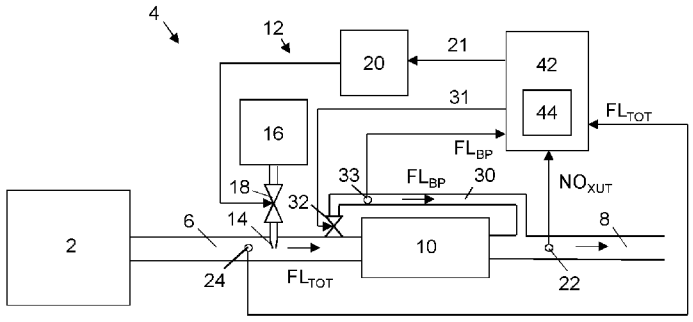


FIG. 1

(57) **Abstract**: Exhaust post-treatment system (4) for a combustion engine (2), comprising a selective catalytic reduction catalyst (SCR catalyst) (10); an NO_x sensor (22) adapted to determining the content of nitrogen oxides (NO_x) in exhaust gases which flow out from said SCR catalyst (10) and to delivering a measurement signal (NO_{XUT}) based on the NO_χ content; an injection device (12) adapted to adding a reducing agent to the exhaust gases which flow into the SCR catalyst (10); a processing means (42) comprising a memory (44) and adapted to receiving the measurement signal from the NO_Xsensor (22) and to generating a control signal (21) for the injection device (12), and a mass flowmeter (24) adapted to measuring the mass flow (FL_{TOT}) of the exhaust gases upstream of the SCR catalyst and to delivering a mass flow signal (FL_{TOT}) based on mass flow measured. The exhaust post-treatment system (4) comprises a bypass line (30) adapted to leading exhaust gases for a predetermined period of time from a location upstream of the SCR catalyst (10), past the SCR catalyst (10), to rejoin at a location upstream of said NO_x sensor (22) the exhaust gases which pass through the SCR catalyst (10), such that the processing means (42) is adapted to storing NO_x values ($NO_{\chi 1}$) measured by the NOx sensor (22) when the bypass line (30) is connected, with NO_χ values ($NO_{\chi 2}$) which are measured when the bypass line is not connected but are measured close in time to its connection, and that the processing means (42) is adapted to calculating a virtual value (NOx-us) for the NO_χ content of the exhaust gases upstream of the SCR catalyst on the basis of NO_{x1}, $NO_{\chi 2}$, the mass flow FL_{TOT} and a flow FL_{BP} through the bypass line when connected.

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Exhaust post-treatment system for a combustion engine

Field of the invention

The present invention relates to a system according to the preamble of the independent claim.

Background to the invention

A combustion engine burns a mixture of air and fuel in order to generate a driving torque. The combustion process generates exhaust gases which are released from the engine to the atmosphere. The exhaust gases comprise nitrogen oxides (NO_X), carbon dioxide (CO_2), carbon monoxide (CO) and particles. NO_X is a composite term for exhaust gases which consist primarily of nitrogen oxide (NO) and nitrogen dioxide (NO_2). An exhaust post-treatment system treats exhaust discharges in order to decrease them before they are released to the atmosphere. In an example of an exhaust post-treatment system, a dosing system injects a reducing agent into the exhaust gases upstream of a selective catalytic reduction catalyst (SCR catalyst). The mixture of exhaust gases and reducing agent reacts in the SCR catalyst and thereby reduces the amounts of NO_X discharged to the atmosphere.

An example of a reducing agent is liquid urea, commercially available in the form of AdBlue®. This liquid is a non-toxic urea solution in water which is used to chemically reduce discharges of nitrogen oxides, particularly for diesel-powered heavy vehicles.

The reducing agent reacts with NO_X in the SCR catalyst to effect the NO_X reduction. More specifically, the reducing agent is broken down and forms ammonia (NH_3) which then reacts with NO_X to form water and nitrogen gas (N_2).

To achieve the NO_X reduction described, NH_3 has to be stored in the SCR catalyst. For the SCR catalyst to work effectively, this storage has to be at an appropriate level. In more detail, the NO_X reduction, the conversion effectiveness, depends on the storage level. Maintaining high conversion effectiveness in different operating states depends on

maintaining the store of NH_3. The NH_3 level does however have to be decreased progressively as the temperature of the SCR catalyst rises, to avoid NH_3 discharges (i.e. surplus NH_3 being released from the SCR catalyst) which might decrease the conversion effectiveness of the catalyst.

In brief, to meet stricter environmental requirements, vehicle manufacturers are increasingly using SCR catalyst systems to remove nitrogen oxides (NO_X) from diesel exhaust gases. This is done by injecting ammonia solution into a SCR catalyst to help to convert NO_X particles to nitrogen gas and water. The exhaust cleaning strategy needs to cater for sufficient NO_X to be converted while at the same time trying not to inject too much ammonia, for both environmental and operational economy reasons.

American patent application US-2008/0250778 and Swedish patent SE-530435 describe known devices within the technical field.

US-2008/0250778 refers to a method for regulating the amount of NH_3 stored in a catalyst for an exhaust post-treatment system, which involves determining the amount of NH_3 entering the catalyst on the basis of a dosing frequency for a dosing agent which is injected into the exhaust flow upstream of the catalyst, and determining the amount of NH_3 leaving the catalyst. The cumulative weight of NH_3 in the catalyst is calculated on the basis of the respective amounts entering and leaving the catalyst, and the dosing frequency is then calculated on the basis of the cumulative weight.

SE-530435 refers to a method for supervising the function of an exhaust post-treatment system for a motor vehicle. This known system does a frequency analysis of a parameter related to exhaust gases flowing out from, for example, a catalyst. Information about the system's function is obtainable on the basis of the result of the frequency analysis.

Minimising discharges of NO_X thus requires careful regulation of the dosing of the reducing agent, e.g. urea, to the catalyst. The aim is to achieve optimum stored amounts of ammonia at different temperatures. However, the amount stored cannot be measured

directly, which combines with the catalyst functioning very differently at different temperatures to make regulation very difficult.

It is a legal requirement that discharges of nitrogen oxides (NO_X) must be measured by a sensor situated after the SCR catalyst. The driver can thus be made aware that the vehicle is discharging impermissible amounts of nitrogen oxides, e.g. possibly through having been provided with urea at too low a concentration.

The sensors used for measuring the nitrogen oxides content of exhaust gases are often very expensive components. NO_X sensors are often made of ceramic metal oxides, usually yttrium-stabilised zirconium (YSZ). YSZ is pressed to form a solid ceramic which conducts oxygen ions at high temperatures, from about 400°C. To obtain a measurement signal, a pair of noble metal electrodes are placed on the surface, making it possible for the variations in voltage or current of an electrical signal to be measured as a function of the NO_X concentration.

High requirements have to be met for the sensor to achieve the sensitivity and robustness required in exhaust flow measurement. The cost of NO_X sensors is therefore relatively high.

It is also very difficult to use the downstream NO_X sensor to also control the SCR system on a feedback basis, partly because the dynamics of the SCR catalyst vary greatly at different temperatures and it is not possible to observe the state of the SCR catalyst. To achieve optimum regulation, a further NO_X sensor, with attendant extra cost, is therefore often provided upstream of the SCR catalyst to control the amount of reducing agent added.

JP-3124907 describes an exhaust post-treatment system which has a bypass duct with an oxygen sensor and uses the output signal from this sensor as a basis for an indication about the SCR catalyst's function.

The object of the present invention is to propose a system for determining and calibrating a virtual NO_X sensor upstream of the SCR catalyst without having to have an actual NO_X sensor situated there.

Summary of the invention

The above object is achieved with the invention defined by the independent claim.

Preferred embodiments are defined by the dependent claims.

According to the invention the problem is solved by so configuring the SCR catalyst that a small flow of exhaust gases, i.e. a small proportion of the total exhaust flow, is for a short period of time allowed to follow an alternative path bypassing the SCR catalyst. The bypass line is configured to impose a brief time delay upon the flow passing through it so that the measured value downstream of the SCR catalyst will correspond as well as possible to a virtual NO_X value calculated upstream of the SCR catalyst. A further requirement is that the flow in the bypass line be substantially smaller than the flow through the SCR catalyst in order to avoid too much addition of emissions.

The contribution of the smaller flow to the NO_X content measured by the NO_X sensor downstream of the SCR catalyst is detectable in that the NO_X content increases during the time when the bypass line is connected, and the measured NO_X contents will then be a function of NO_X contents upstream.

The present invention is based on periodically allowing an amount of exhaust gases to pass through the bypass line so that it is possible to calibrate a modelled virtual value for the NO_X content upstream of the SCR catalyst on the basis of measured NO_X content downstream of the SCR catalyst. This needs to be done often enough to enable calibration to allow for disturbances which for example occur when a different fuel is used or the air humidity changes.

The present invention results in robust regulation of the addition of reducing agent and eliminates the need for an NO_X sensor upstream of the SCR catalyst, resulting in a simplified and therefore less expensive configuration.

The invention thus uses the variation in NO_X content measured downstream of the SCR catalyst as a result of a partial flow being led past the SCR catalyst. The present invention thus achieves periodic calibration of the virtual NO_X sensor situated upstream of the SCR catalyst.

Brief description of drawings

Figure 1 is a schematic block diagram illustrating the present invention.

Figure 2 presents graphs illustrating the present invention.

Detailed description of preferred embodiments of the invention

The invention is described in detail below with reference to the attached drawings.

Figure 1 depicts schematically a combustion engine 2 with an associated exhaust post-treatment system 4. The exhaust gases leaving the engine 2 are led through an exhaust line 6 and are discharged to the surroundings via an exhaust outlet 8. A selective catalytic reduction catalyst (SCR catalyst) 10 is provided in the exhaust line 6 and the exhaust gases from the engine 2 pass through the catalyst 10 before they are released to the surroundings via the exhaust outlet 8. The engine is preferably situated in a motor vehicle but it is of course possible, within the scope of the present invention, to apply the invention to a combustion engine used, for example, in industry or on other means of transport.

Reducing agent, e.g. urea, is injected into the exhaust gases in the exhaust line upstream of the SCR catalyst 10 by means of an injection device 12 which comprises one or more injection means 14 situated in the exhaust line 6 in the form of injection nozzles or the like, and a storage container 16 connected thereto for reducing agent. The injection device comprises also a control means 20 connected to the regulating means 18. The regulating means 18 is controlled by the control means 20, which determines how much reducing agent is to be injected into the exhaust gases on the basis of the prevailing operating conditions of the engine 2 and the catalyst 10 and in response to a control signal 21 from a processing means 42.

The reducing agent may be urea ($CO(NH_2)_2$), ammonia (NH_3) or hydrocarbon (fuel).

The exhaust post-treatment system often comprises also a diesel oxidation catalyst (DOC) (not depicted in the diagram) which is situated upstream of the catalyst 10 and in which reactions which lower the emission levels of the exhaust gases take place. A diesel particle filter (DPF) (not depicted in the diagram) may also be provided upstream or downstream of the SCR catalyst to further lower the emission levels.

An NO_X sensor 22 provided in the exhaust line 6 downstream of the catalyst 10 is adapted to generating a measurement signal (NO_{XUT}) which represents the NO_X content of the exhaust gases flowing out from the catalyst, i.e. their NO_X content at the outlet of the catalyst. The measurement signal may be a continuous signal representing the continuous changes in the parameter measured, i.e. resulting in a continuous flow of measured values for the magnitude of the parameter, but is usually registered as a discrete time signal in the form of a series of consecutive discrete measured values for the magnitude of the parameter.

The processing means 42 comprises a memory 44 and is adapted to receiving the measurement signal NO_{XUT} from the sensor 22 and to generating the control signal 21 for the injection device 12. A mass flowmeter 24 is also provided to measure the mass flow (FL_{TOT}) of the exhaust gases upstream of the SCR catalyst 10 and to deliver a mass flow signal (FL_{TOT}) which is based on mass flow measured and is conveyed to the processing means 42.

The exhaust post-treatment system 4 comprises according to the invention a bypass line 30 adapted to leading exhaust gases for a predetermined period of time from a location upstream of the SCR catalyst 10, past the SCR catalyst 10, to rejoin at a location upstream of said NO_X sensor 22 the exhaust gases which pass through the SCR catalyst 10. The processing means 42 is then adapted to storing NO_X values (NO_{X1}) measured by the NO_X sensor 22 when the bypass line 30 is connected, with NO_X values (NO_{X2}) which are measured when the bypass line is not connected but are measured close in time to the connection. Close in time to when the connection is effected means that the values are respectively measured in magnitude a number of seconds at most before and after the connection.

The processing means 42 is adapted to calculating a virtual value ($NO_{X\text{-}US}$) for the NO_X content of the exhaust gases upstream of the SCR catalyst on the basis of NO_{X1}, NO_{X2}, the mass flow FL_{TOT} and a flow FL_{BP} through the bypass line when connected.

According to an embodiment, the system 4 has a valve device 32 situated in the bypass line 30, and the supervision device 40 is adapted to delivering a connection signal 31 to control the connection of the bypass line 30 by opening and closing the valve device 32. The diagram shows the valve device situated at the orifice of the bypass line but it may be situated anywhere in the bypass line.
The valve device may for example take the form of a simple damper capable of assuming two states, viz. a closed state whereby no flow is allowed to pass and an open state whereby a flow FL_{BP} is allowed to pass through the line. The period of time when the bypass line is connected is preferably longer than one second but preferably shorter than 30 seconds and still more preferably shorter than 10 seconds. It needs to be long enough to result in a stable measurement signal but not so long as to result in too much increase in discharges.

According to a further embodiment, the system comprises a second flowmeter 33 adapted to measuring said bypass flow FL_{BP}.

An alternative to a second flowmeter is to calculate instead the bypass flow FL_{BP} on the basis of FL_{TOT} and the dimensions of the bypass line. This calculation is for example performed by the processing means 42.

The control signal 21 used for controlling the injection device 12 is determined and generated by the processing means 42, partly on the basis of $NO_{X\text{-}US}$.

According to an embodiment, the bypass line 30 is connected periodically at specific intervals of between 0.5 and 3 hours.

To achieve stable values it is important that the flow FL_{TOT} be relatively constant when the bypass line 30 is connected, e.g. it needs to be substantially constant for at least a predetermined time which may be of the order of 10-15 seconds.

The calculation of $NO_{X\text{-}US}$ is preferably only performed when the values of NO_{X2} are relatively constant at the time of connection of the bypass line. This means that the calculation of $NO_{X\text{-}US}$ is only performed when the value of NO_{X2} measured just before the time of connection is substantially equal to its value measured when the bypass line is again not connected after having been connected.

During the period of time when the bypass line is connected and a flow passes through it, the NO_X sensor downstream will therefore measure an NO_X content which is the aggregate of the NO_X content of the bypass flow, i.e. the same NO_X content as before the SCR catalyst, and of the NO_X content which passes through the SCR catalyst, which will have been lowered by the reduction.

The processing means is adapted to calculating a virtual value for the NO_X content of the exhaust gases upstream of the SCR catalyst on the basis of measured values from the sensor and mass flow values taken during said period of time when the bypass line is connected.

This calculated value is used to calibrate the virtual NO_X sensor which delivers a value representing the value upstream of the SCR catalyst.

More specifically, the calculation of the virtual value for the NO_X content upstream of the SCR catalyst is performed as follows:

Assuming for example that the flow through the bypass line F_{BP} is 10% of the total flow F_{TOT}, the NO_X content measured downstream of the SCR catalyst during the connection will be $NO_{X1} = 0.9\times NO_{X2} + 0.1\times NO_{X\text{-}US}$ making it possible for the virtual calculated NO_X content upstream of the SCR catalyst to be expressed as

$NO_{X\text{-}US} = (NO_{X1} - 0.9\times NO_{X2})/0.1 = 10\times NO_{X1} - 9\times NO_{X2}$

If instead and more realistically the flow through the bypass line is 1% of the total flow, the expression for the NO_X content upstream of the SCR catalyst will be

$NO_{X\text{-}US} = (NO_{X1} - 0.99 \times NO_{X2})/0.01 = 100 \times NO_{X1} - 99 \times NO_{X2}$

The calculation of $NO_{X\text{-}US}$ is performed at regular intervals with preferably as much time as possible between consecutive calibrations, to reduce discharges of exhaust gases which do not pass through the SCR catalyst, but calibration needs to be done often enough for the calculations to be as reliable as possible. As mentioned above, the calibration is for example done when a different fuel is used or if the air humidity or other circumstances change. According to an embodiment, the bypass line is connected periodically with a specific interval between connections which may range from a number of seconds upwards.

The time for which the bypass line is connected, i.e. the length of the measuring period, comprises according to an embodiment a predetermined number of reducing agent dosing periods, e.g. 5-15, corresponding to 5-15 seconds if the dosing period is 1 second long. However, connection need not be synchronised with reducing agent injection times.

The control signal for the injection device does of course also comprise control instructions related to its normal function, i.e. when the bypass line is not connected.

The reducing agent is added by the injection device 12 by injection at a dosing frequency F, with a dosing period time L (L=1/F) defined as the time between the beginning of two consecutive injections, which injection takes place for a settable dosing time t of said dosing period time such that $0<t<L$. The amount of reducing agent injected into the exhaust gases may thus be varied by varying the dosing frequency and/or dosing time for its injection.

It is also possible to vary the amount of reducing agent added by altering the dosing pressure, i.e. the pressure imparted to the agent during injection. This may of course be done in combination with variation of the dosing frequency and/or the dosing time.

The proportion of untreated exhaust gases reaching the NO_X sensor 22 when the bypass is connected will vary with the mass flow. A larger flow will result in a reduced proportion through the smaller connection, i.e. the bypass line, since the backpressure increases more in the smaller passage at higher flows. According to an embodiment, if there is no flowmeter in the bypass line 30, values for FL_{BP} are for example taken from a table which is preferably stored in the memory 44, in which pertinent values for FL_{TOT} and the exhaust mass flow FL_{BP} are stored.

Figure 2 presents graphs showing not only measured NO_X content after the SCR catalyst (top graph) with the contents for measured values NO_{X1} and NO_{X2}, but also the dosing of reducing agent (middle graph) and the control signal to the valve device for connecting the bypass line, with "O" meaning valve device open and "C" valve device closed (bottom graph).

As mentioned above, the reducing agent is added by the injection device 12 by injection at a dosing frequency F, with a dosing period time L (L=1/F) defined as the time between the beginning of two consecutive injections, which injection takes place for a settable dosing time t of said dosing period time such that $0<t<L$. The amount of reducing agent injected into the exhaust gases may thus be varied by varying the dosing frequency and/or dosing time for its injection. In the example in Figure 2, the bypass line is connected during three injection periods numbered 1, 2 and 3.

In the graphs the connection of the bypass line is synchronised with injection of reducing agent, but the invention may also be applied without such synchronisation.

Measuring the amplitudes of the NO_X content during, before and after the connection period and taking into account the flow measured thus makes it possible to determine for the NO_X content upstream of the SCR catalyst a calculated value which may inter alia be used to control the injection device.

During the period of time when the bypass is connected, a flow will pass through it with no change in NO_X content, a fact which is used to calculate a virtual value for the NO_X content of the exhaust gases upstream of the SCR catalyst ($NO_{X\text{-}US}$) on the basis of

measured values from the NO_X sensor 22, mass flow values taken over the period of time when the bypass line 30 is connected, and values taken close in time to the connection of the bypass line.

The present invention is not restricted to the preferred embodiments described above. Sundry alternatives, modifications and equivalents may be used. The above embodiments are therefore not to be regarded at limiting the invention's protective scope which is defined by the attached claims.

Claims

1. An exhaust post-treatment system (4) for a combustion engine (2), comprising

an SCR catalyst (10) (selective catalytic reduction catalyst);

an NO_X sensor (22) adapted to determining the content of nitrogen oxides (NO_X) in exhaust gases which flow out from said SCR catalyst (10) and to delivering a measurement signal (NO_{XUT}) based on the NO_X content;

an injection device (12) adapted to adding a reducing agent to the exhaust gases which flow into the SCR catalyst (10);

a processing means (42) comprising a memory (44) and adapted to receiving the measurement signal from the NO_X sensor (22) and to generating a control signal (21) for the injection device (12), and

a mass flowmeter (24) adapted to measuring the mass flow (FL_{TOT}) of the exhaust gases upstream of the SCR catalyst and to delivering a mass flow signal (FL_{TOT}) based on mass flow measured,

characterised in that the exhaust post-treatment system (4) comprises a bypass line (30) adapted to leading part of the total amount of exhaust gases for a predetermined period of time from a location upstream of the SCR catalyst (10), past the SCR catalyst (10), to rejoin at a location upstream of said NO_X sensor (22) the exhaust gases which pass through the SCR catalyst (10), such that the processing means (42) is adapted to storing NO_X values (NO_{X1}) measured by the NO_X sensor (22) when the bypass line (30) is connected, with NO_X values (NO_{X2}) which are measured when the bypass line is not connected but are measured close in time to its connection, the processing means (42) being adapted to calculating a virtual value ($NO_{X\text{-}US}$) for the NO_X content of the exhaust gases upstream of the SCR catalyst on the basis of NO_{X1}, NO_{X2}, the mass flow FL_{TOT} and a flow FL_{BP} through the bypass line when connected.

2. An exhaust post-treatment system according to claim 1, such that the system comprises a valve device (32) situated in the bypass line (30) and that the processing means (42) is adapted to delivering a connection signal (31) to control the connection of the bypass line (30) by opening and closing the valve device (32).

3. An exhaust post-treatment system according to claim 1 or 2, in which said period of time when the bypass is connected is shorter than 30 seconds.

4. An exhaust post-treatment system according to any one of claims 1-3, in which said period of time is shorter than 10 seconds.

5. An exhaust post-treatment system according to any one of claims 1-4, comprising a second flowmeter (33) adapted to measuring said flow through the bypass FL_{BP}.

6. An exhaust post-treatment system according to any one of claims 1-4, in which said flow through the bypass FL_{BP} is calculated on the basis of FL_{TOT} and the dimensions of the bypass line.

7. An exhaust post-treatment system according to any one of the foregoing claims, in which said processing means (42) is adapted to generating said control signal on the basis of $NO_{X\text{-}US}$.

8. An exhaust post-treatment system according to any one of claims 1-7, in which the bypass line (30) is connected when FL_{TOT} has been constant for at least a predetermined time.

9. An exhaust post-treatment system according to any one of claims 1-8, in which the calculation of $NO_{X\text{-}US}$ is only performed when the values of NO_{X2} are substantially equal before and after the bypass line connection in time.

1/1

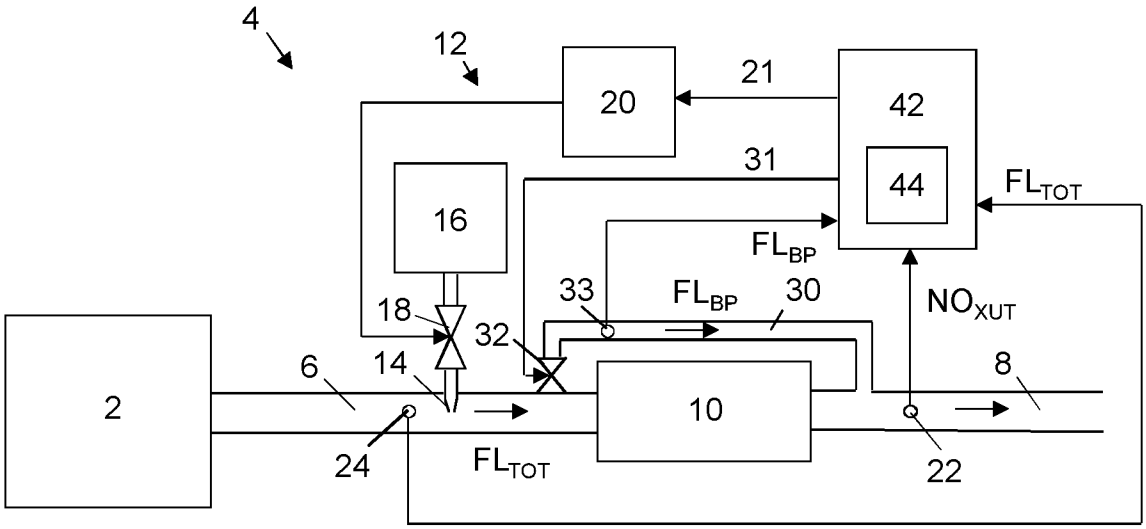

4
12
20
21
42
31
44
16
FL_{TOT}
FL_{BP}
33
FL_{BP}
30
NO_{XUT}
18
32
6
14
8
2
10
24
FL_{TOT}
22

FIG. 1

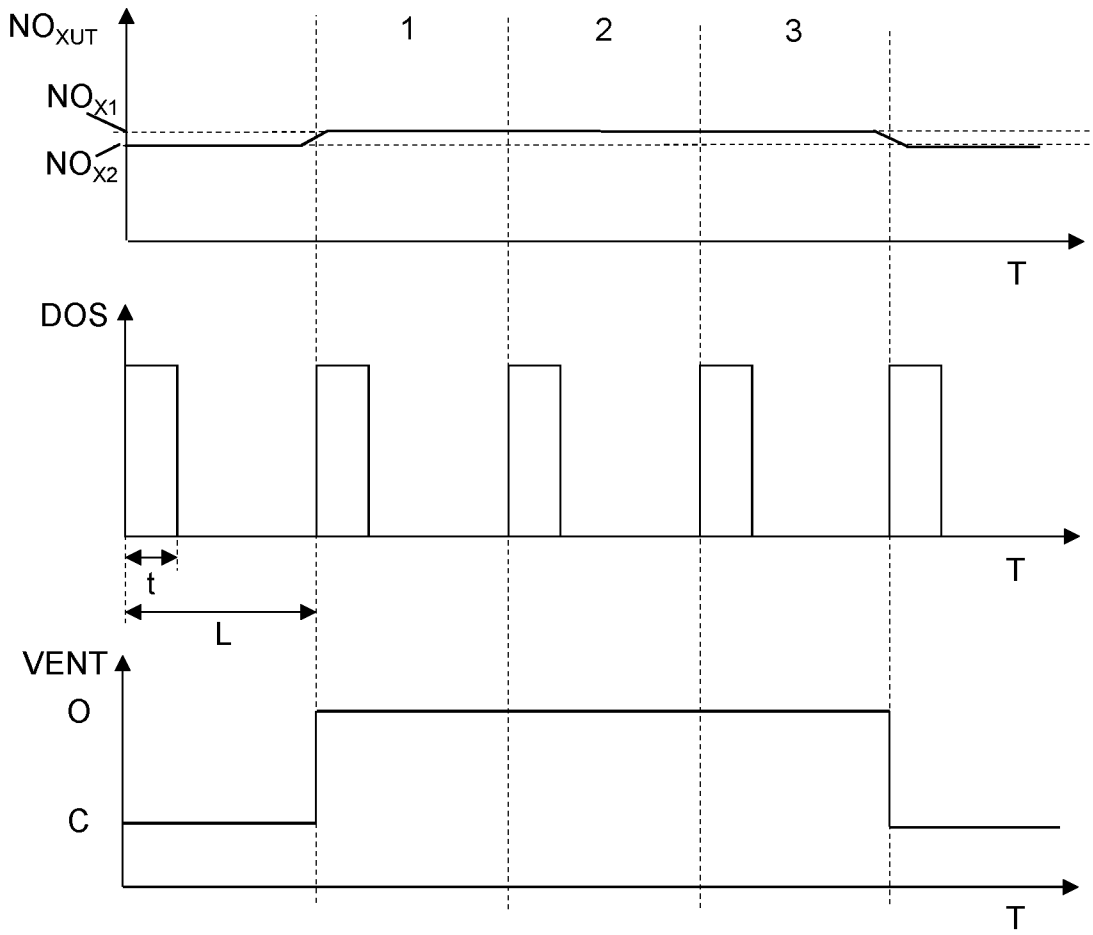

NO_{XUT}
1
2
3
NO_{X1}
NO_{X2}
T
DOS
T
t
L
VENT
O
C
T

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2012/050056

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: F01N

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, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 20080250778 A1 (SOLBRIG CHARLES E), 16 October 2008 (2008-10-16); abstract; figures 1-3 --	1-9
A	WO 2010109946 A1 (BOSCH CORP ET AL), 30 September 2010 (2010-09-30); abstract --	1-9
A	JP 2003120399 A (TOYOTA MOTOR CORP), 23 April 2003 (2003-04-23); (abstract) Retrieved from: PAJ database --	1-9
A	US 20080127633 A1 (KESSE MARY LOUISE ET AL), 5 June 2008 (2008-06-05); abstract; figure 4 --	1-9

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

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30-04-2012	08-05-2012

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INTERNATIONAL SEARCH REPORT

International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 3124907 A (MITSUBISHI MOTORS CORP), 28 May 1991 (1991-05-28); (abstract) Retrieved from: PAJ database -- --------	1-9

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Continuation of: second sheet

International Patent Classification (IPC)

F01N 9/00 (2006.01)
F01N 3/20 (2006.01)
F01N 11/00 (2006.01)

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