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54 **Process and device for regulating the richness of an air/fuel mixture feeding an internal-combustion engine.**

57 The device according to the invention comprises an oxygen sensor placed in the stream of the exhaust gases of the engine 2 for supplying a bistable signal s_λ representing the richness of the air/fuel mixture in the engine. In the direct branch of the loop are a sampler 4 and a corrector 5 supplying a signal Δtid for correcting an estimated injection time ($\tilde{t}_{is}$), the sum (t_i) of these signals being sampled at 7 before the opening time of a fuel injector forming part of the engine 2 is controlled. According to the invention, at the moment of sampling the corrector 5 supplies an additive correction Δtid_n which obeys a recurrent law taking the form of a linear combination of at least one of the values Δtid_{n-k} of the corrections made at the immediately preceding moments of sampling and of the sampled values of the signal s_λ at at least one of these immediately preceding moments of sampling and at the current moment.

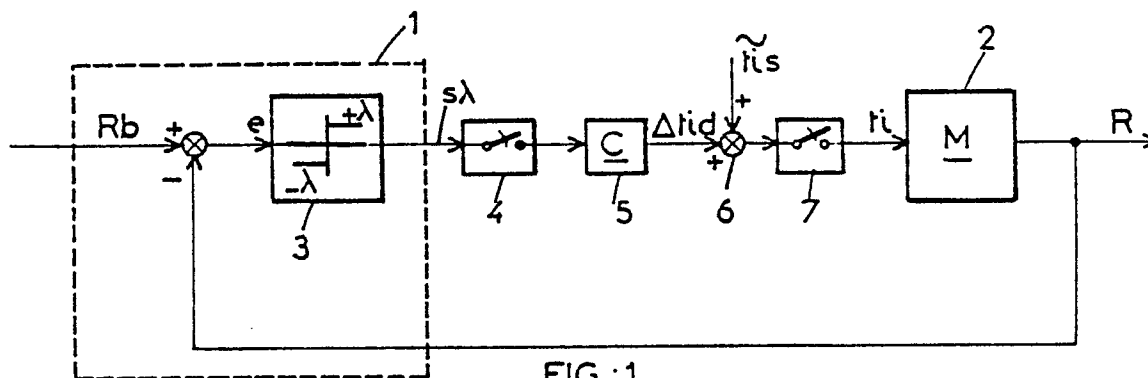


FIG.: 1

Process and device for regulating the richness of an air/fuel mixture feeding an internal-combustion engine.

The present invention relates to a process and a device for regulating the fuel richness (= fuel to air ratio) of an air/fuel mixture used for feeding an internal-combustion engine and, more particularly, to such a process and such a device operating by closed loop from a signal supplied by an oxygen sensor placed in the exhaust gases of the engine.

5 Such processes and such devices ensuring regulation by modulating an opening time (or duration) of a fuel injector by means of a multiplicative term, this regulation being adjusted to provide a uniform and continuous oscillation of the air/fuel ratio about a nominal value, are known. Whether the exhaust gases of the engine pass or do not pass through a catalytic converter limiting pollution of the environment by these exhaust gases, the modulation of the air/fuel ratio is optimized, if appropriate in relation to the characteristics of this converter, by means of two types of correction, proportional and integral, introduced into the
10 calculation of the opening time of the injectors equipping the engine to be regulated.

These corrections are usually calculated at the top dead centre of the engine cylinder in question. The result of this is that the frequency of the oscillations of the air/fuel ratio are not controlled correctly because this depends on the speed of the engine. Likewise, the amplitude of these oscillations cannot be controlled
15 correctly since it depends on the amplitude of the corrections calculated and used, and because the corrections are calculated systematically at the top dead centre it is not possible to take into account the dynamics of the system, thus giving rise to a loss in the information to be processed and therefore less accuracy in the calculations used for controlling the amplitude of the oscillations of the richness of the mixture.

20 The object of the present invention is to provide a process and produce a device for regulating the richness of an air/fuel mixture feeding an internal-combustion engine, operating by closed loop from a signal supplied by an oxygen sensor placed in the exhaust gases of the engine, which make it possible to control completely the frequency and amplitude of the oscillations of the richness by making these independent of the speed of the engine.

25 Another object of the present invention is to provide such a process and such a device which implement a law of richness regulation having a recurrent nature, that is to say dependent on the prior states of the richness measurements and the values of the preceding corrections of the opening time of the injectors, so as to provide a truly closed-loop regulation, in contrast to the artificial construction of the signal representing the opening time of the injectors, with proportional correction and integral correction, used in
30 the above-mentioned richness-regulating processes and devices of the prior art.

Another object of the present invention is to provide such a process and such a device possessing means making it possible to control a possible drift of the switching threshold of the oxygen sensor used.

Yet another object of the present invention is to provide such a process and such a device which employ the calculation of a "basic" injector opening time which is a linear function of the intake pressure of
35 the engine, and which are equipped with means for correcting this calculation on the basis of the average value of the corrections made by closed loop by means of the signal supplied by the oxygen sensor, as a function of the confidence given to the measurements used.

A self-adaptivity characteristic can thus be introduced into the process according to the invention, as can a diagnostic aid capacity.

40 These objects of the invention and others which will emerge later are achieved, in a process with a closed-loop regulation of the fuel richness of an air/fuel mixture for feeding an internal-combustion engine, by controlling a fuel-injection time (t_i) from a signal (s_λ) supplied by a bistable oxygen sensor placed in the stream of the exhaust gases of the engine, this signal representing the sign of the difference between the richness R of the mixture and a nominal value R_c , the process being characterized in that:

45 a) a signal $\hat{t}_{is}$ corresponding to an estimated static injection time is obtained from measurements of parameters representing the instantaneous operating point of the engine,

b) the signal s_λ supplied by the sensor is sampled, and the sampled signal is processed in a corrector which generates a sampled signal Δt_{id_n} representing a dynamic correction to be applied to the estimated injection time $\hat{t}_{is}$ at the moment of sampling n ,

50 c) the signal Δt_{id_n} and the signal $\hat{t}_{is}$ are added to form a signal representing the injection time t_i , and this signal is sampled in synchronism with the sampling of the signal s_λ , the sampled correction signal Δt_{id_n} taking the form of a linear combination of at least one of the values $\Delta t_{id_{n-k}}$ of the corrections made at the immediately preceding moments of sampling and of the sampled values $s_{\lambda_{n-k}}$ of the signal supplied by the sensor at at least one of the immediately preceding moments of sampling and at the

current moment.

The farthest moment of sampling (n-k) taken into account in this linear combination defines the order of the control thus obtained.

According to a first embodiment of the invention, said to be of the first order, the sampled correction Δtid_n is of the form:

$$\Delta tid_n = \Delta tid_{n-1} + k(s\lambda_n - \eta s\lambda_{n-1})$$

where k and η are constants adjusted to ensure the stability of the amplitude and frequency of the oscillations of the richness of the mixture in a given operating range of the engine.

According to a second embodiment of the invention, said to be of the second order, the sampled correction Δtid_n is of the form:

$$\Delta tid_n = \alpha \Delta tid_{n-1} + \beta \Delta tid_{n-2} + g_0 s\lambda_n + g_1 s\lambda_{n-1} + g_2 s\lambda_{n-2}$$

where α , β , g_0 , g_1 , g_2 are constants adjusted according to the same criteria as for the first embodiment.

For carrying out this process, the invention provides a device for the closed-loop regulation of an internal-combustion engine by means of a signal supplied by a bistable oxygen sensor sensitive to the oxygen richness of the exhaust gases of the engine, characterized in that it comprises:

- a) a sampler fed with a signal (s λ) supplied by the sensor,
- b) a corrector fed with the sampled signal (s λ) and supplying a sampled correction signal (Δtid_n) taking the form of a linear combination of at least one of the values Δtid_{n-k} of the corrections made at the immediately preceding moments of sampling and of the sampled values $s\lambda_{n-k}$ of the signal supplied by the sensor at at least one of the immediately preceding moments of sampling and at the current moment,
- c) means for calculating an estimated static injection time, supplying a signal ($\widetilde{tis}$) representing this, and an adder for combining the signals (Δtid_n) and ($\widetilde{tis}$) so as to form a signal representing an effective injection time (ti),
- e) a second sampler for sampling the signal representing the effective injection time (ti) in synchronism with the sampling of the signal (s λ) and for supplying the sampled signal to a member for controlling the opening time of a fuel injector forming part of the engine.

According to a first embodiment of the invention, the transfer function of the corrector used is a first order one.

According to a second embodiment of the invention, the transfer function of the corrector used is a second order one.

Other embodiments using correctors, the transfer function of which is of an order higher than 2, can be considered.

The device according to the invention can also possess a means for correcting a drift of the switching threshold of the oxygen sensor or for adjusting the value of the switching threshold of a signal obtained from the signal supplied by the sensor, so as to vary the value of the threshold actually taken into account by the device.

In the accompanying drawing given purely by way of example:

- Figure 1 is a functional diagram of the regulating device according to the invention, and
- Figure 2 is a functional diagram of an alternative version of the device according to Figure 1, possessing means for correcting a possible drift of the switching threshold of an oxygen sensor forming part of the device.

Reference is made to Figure 1 of the drawing, where it is clear that the device according to the invention for regulating the richness of the air/fuel mixture feeding an internal-combustion engine is of the type comprising an oxygen sensor 1, currently called a "lamBda sensor". This sensor is sensitive to the oxygen concentration of the exhaust gases of an engine 2 and supplies a bistable signal s λ representing the sign of the difference between the richness R of the mixture, as estimated from the oxygen concentration of the exhaust gases, and the sensor-switching richness Rb. Thus, the signal s λ has two states + λ and - λ respectively representing a richness R below or above the switching richness Rb desired to ensure a controlled combustion of the mixture, for example designed to ensure that the composition of the exhaust gases conforms to the standards relating to emissions of hydrocarbons and carbon monoxide, with or without the assistance of catalysers, as is well known in the art.

The bistable behaviour of the signal s λ is indicated diagrammatically in Figure 1 by a non-linear relay 3 fed with a signal (e) representing the richness difference (Rb-R).

The device of Figure 1 also possesses a sampler 4 for receiving at its input the signal s λ supplied by the sensor 1 and supplying a sampled signal to a corrector 5, the function of which will be explained later. An adder 6 receives:

- on the one hand, a signal, representing an estimated static injection time ($\widetilde{tis}$), for example calculated from a mapping in a pressure/speed system (air pressure at the engine intake, engine speed)

and possible corrections taking into account the temperature of the air, that of the coolant of the engine, etc.,

- on the other hand, a signal representing a dynamic injection correction (Δtid) prepared by the corrector from the sampled signal $s\lambda$.

5 The sum of these two quantities is processed in a second sampler 7, and the resulting sampled signal representing the effective injector-opening time t_i , or injection time, controls the opening duration of a fuel injector forming part of the engine 2.

According to the present invention, the two samplers 4 and 7 operate synchronously with the same sampling period T_e independent of the rotational speed of the engine, or engine speed, thus allowing
10 oscillations of the regulating device according to the invention to be made independent of this speed. This ensures a complete control of these oscillations.

A modelling of the regulating device of Figure 1 makes it possible to calculate the parameters of the system from the choice of value e_o of the amplitude and f_o of the frequency of the oscillation of the richness difference $e = R_b - R$. For this purpose, a dynamic frequential model is used for reproducing the bistable
15 behaviour of the oxygen sensor, and the characteristic closed-loop equation of the model at the desired dynamics is identified, this being a function of the amplitude and frequency required for the richness oscillation. As seen above, by means of the sampling used, the regulation defined in this way is independent of the engine speed.

Thus, using the first harmonic method, if

20 $S(e) = 4\lambda/\pi \cdot e$

defines the "equivalent gain" of the non-linear relay modelling the oxygen sensor 1, the characteristic closed-loop equation D_{BF} of a model of the regulating device of Figure 1 is written:

$$D_{BF} = 1 + S(e) \cdot C(p) \cdot M(p)$$

with

25 p = Laplace operator, sometimes referred to as s in English speaking countries,

$C(p)$ = Laplace model of corrector 5,

$M(p)$ = Laplace model of engine 2.

This will write $M(Z) = \mathcal{Z}[B_o \cdot M(p)]$, the Z-transform of $B_o \cdot M$, where

$B_o(p) = (1 - e^{-T_e \cdot p})/p$ = the zero-order hold modelling the samplers 4 and 7, and:

30 $Z^{-1} = e^{-T_e \cdot p}$ being the discrete delay, the equation in Z of D_{BF} is then written:

$$D_{BF} = 1 + S(e) \cdot C(Z) \cdot M(Z)$$

The stable oscillations will be obtained for the solutions e_o and Z_o of the equation $D_{BF} = 0$.

With a constant period sampling T_e carried out by the samplers 4 and 7, the model $M(Z)$ being assumed to be known, from the choice of e_o and f_o :

35 $Z_o = e^{j \cdot T_e \cdot 2 \pi \cdot f_o}$,

a root of the characteristic polynomial:

$$1 + S(e_o) \cdot C(Z) \cdot M(Z) = 0$$

is obtained.

From the value Z_o found, the coefficients of the expression in Z, $C(Z)$ of the Laplace model $C(p)$ chosen
40 for the corrector 5 will be set.

Thus, according to a first embodiment of the invention employing models of the first order, the transfer function chosen for modelling the engine 2 is:

$$M(p) = G/(1 + \tau p)$$

where G and τ are constants.

45 The expression in Z of this model is

$$M(Z) = G(1-a)/(Z-a), \text{ where } a = e^{-T_e/\tau}.$$

A model of the first order is then chosen for the corrector $C(Z)$, this being of the form:

$$C(Z) = k(Z - \eta)/(Z - 1),$$

where k and η are constants, the integral $1/(Z-1)$ being introduced into this expression in order to integrate
50 the disturbances and ensure a zero average error in a steady state.

With these models $M(Z)$ and $C(Z)$, writing that for values e_o and Z_o :

$$D_{BF}(e_o, f_o) = 0,$$

there is: $e_o + 4\lambda/\pi \cdot G(1-a) k (Z_o - \eta)/(Z_o - a) (Z_o - 1) = 0$. This expression linking the parameters k and η makes it possible, from the choice of one of these, to calculate the other and therefore adjust the coefficients of the

55 model $C(Z)$ chosen for the corrector 5.

It is thus demonstrated that the sampled injection correction Δtid_n added to the estimated injection time $\widetilde{t}_{is}$ to define the injector opening time $t_i = \widetilde{t}_{is} + \Delta tid$ is expressed by the relation:

$$\Delta tid_n = \Delta tid_{n-1} + k(s\lambda_n - \eta s\lambda_{n-1}) \quad (1)$$

Thus, with a modelling of the first order of the engine 2 and the corrector 5, it emerges that the regulating process according to the invention makes an additive correction of the injection time t_i by means of a recurrent value $\Delta t_{id,n}$ which is deduced from the value $\Delta t_{id,n-1}$ of this correction at the immediately preceding moment of sampling by the addition of a linear function of the difference in the values of the signal $s\lambda$ supplied by the sensor at the moments of sampling n and $n-1$.

According to a second embodiment of the invention employing models of the second order, with:

$$M(Z) = G(\alpha'Z + \beta')/(Z^2 - \gamma'Z + \delta')$$

$$\text{and } C(Z) = (g_0Z^2 + g_1Z + g_2)/(Z^2 - \alpha Z - \beta)$$

where $\alpha, \beta, \gamma, \delta$ and $g_0, g_1, g_2, \alpha, \beta$ are constants, it is demonstrated that the sampled injection correction $\Delta t_{id,n}$ assumes the form:

$$\Delta t_{id,n} = \alpha \Delta t_{id,n-1} + \beta \Delta t_{id,n-2} + g_0 s\lambda_n + g_1 s\lambda_{n-1} + g_2 s\lambda_{n-2} \quad (2)$$

The correction thus takes the form of a linear combination of the values of the correction Δt_{id} and of the signal $s\lambda$ at the two immediately preceding moments of sampling and of the value of the signal $s\lambda$ at the current moment of sampling. Such a correction thus follows more closely the variations of the signals taken into account and therefore ensures a quicker correction of the disturbances than that obtained with modelling of the first order.

It will be seen, in this respect, that the sum $\alpha + \beta$ of the coefficients of the terms $\Delta t_{id,n-1}$ and $\Delta t_{id,n-2}$ satisfies the relation $\alpha + \beta = 1$. This reflects the presence in the model $C(Z)$ of the integral $1/(Z-1)$ which is precisely what ensures the integration of the disturbances.

Putting the invention into practice involves providing means for calculating the term $\widetilde{t_{is}}$ and a recurrent law, as designated by (1) or (2) above.

Although it is possible for these means to work in the analog mode, it is preferable to use digital calculators for this purpose, calculators of this type being in common use today in electronic devices for controlling the fuel injection in an internal-combustion engine. A suitable programming of the digital calculation means incorporated in such a device then makes it possible to calculate the term $\widetilde{t_{is}}$ from a pressure/speed mapping and from the determination of other parameters, such as the temperature of the air or of the engine coolant, as seen above. The recurrent law making it possible to obtain Δt_{id} is itself programmed, a programme of this type being known as a digital corrector.

Thus, according to the set objects, the present invention makes it possible to provide a process and produce a device for regulating the richness of an air/fuel mixture for feeding an internal-combustion engine by additive correction, having improved characteristics in terms of the dynamics and stability of the regulation by taking into account several successive states of the system and not its state at a particular moment only.

The constant sampling used in the present invention also makes it possible to ensure a better control of the oscillations, allowing their amplitude and their frequency to be set independently of the engine speed.

Figure 2 shows an alternative version of the regulating device of Figure 1, which makes it possible to correct a drift of the signal $s\lambda$ supplied by the sensor, this signal being essential for the proper functioning of the device according to the invention. In Figure 2, members identical or similar to members of the device of Figure 1 are designated by the same numeral.

It will be seen, in fact, that, in time, the value of the richness of the mixture causing the switching of the signal $s\lambda$ can vary, thereby affecting the adjustment of the injection time which controls the functioning of the fuel injectors of the engine.

Referring to Figure 2, it emerges that if:

R_b is the sensor-switching richness and

R_c is the desired nominal richness,

it will be seen that continually, with time, R_b falls below the value R_c , thus giving a drift e^* in the richness difference:

$$e^* = -R_b + R_c,$$

which affects the signal $s\lambda$.

Another object of the present invention is, therefore, to provide means for correcting this possible drift e^* between the actual switching value and the reference or nominal value R_c .

Yet another object of the present invention is, by the use of the same means, to allow an adjustment of the nominal value R_c to a value different from 1 (value corresponding to the stoichiometric value), in order, for example, to obtain an enrichment of the mixture during regulation at the time of an engine acceleration command. R_c will then be set at a value higher than 1.

Conversely, setting R_c at a value below 1 makes it possible to adapt the regulating device to the adjustment of a "lean" mixture in order, for example, to conform to anti-pollution standards.

For this purpose, according to the invention, there is added in the direct loop, between the output of the

sensor 1 and the sample 4, a means 8 which delays an edge of the signal $s\lambda$, so as to form a signal $s\lambda^*$ equivalent to that which a non-linear relay 3 having hysteresis would generate.

A delay δ is thus applied to the rising or falling edge of the square-wave signal $s\lambda$ in order to obtain a shift of the threshold in the direction of an increase or a decrease of the switching threshold respectively.

5 The introduction of this delay asymmetrises the signal $s\lambda$ towards information of a lower or higher average richness, and the closed loop of the regulating device ensures a stabilization of the richness towards a higher or lower reference value respectively.

The delay δ is tuned by comparison of the actual richness R with the desired nominal richness. The threshold of the corrected signal $s\lambda^*$ is thus shifted either to correct a drift of the sensor or to change this threshold deliberately for the reasons mentioned above.

10 The closed-loop regulating device can be rendered inoperative in some situations, for example a period of preheating or when a temporary or permanent failure of the oxygen sensor has been detected.

In all other cases, the device is operative in various modes, such as:

- a regulating mode at $R_c = 1$ in a stabilized state or in a pollution control zone,
- 15 - a follow-up mode with $R_c \neq 1$ outside pollution control zones and in transient states (accelerations, decelerations, etc.)

In this case, the nominal value R_c to be used can be set by means of a mapping, for example in a reference system of the intake-pressure/engine-speed type, this mapping being contained in a suitable memory of any known type.

20 Thus, by means of the invention, the switching threshold of the sensor can be controlled continuously and by closed loop and a regulation about this threshold can be provided, both in a stabilized state and in a transient state (functioning of the engine to conform to anti-pollution standards or under full load, for example during acceleration).

It was seen above that the effective injection time corresponding to the opening time of an injector is of the form:

$$t_i = \widetilde{t_{is}} + \Delta t_{id}$$

where $\widetilde{t_{is}}$ represents a base value or estimated static injection time, the estimation being carried out, for example, from mapped values, to which, if appropriate, various corrections of temperature, altitude, etc... have been applied.

30 The present invention proposes to improve the evaluation of the basic estimated injection time $\widetilde{t_{is}}$ from the calculation of an average of the previous corrections Δt_{id} introduced by the use of a closed loop incorporating an oxygen sensor, by bringing to bear a "confidence" function assigned to the measurements made and correction validation zones. Such a procedure makes it possible to give the regulating device according to the invention a self-adaptive nature.

35 According to the invention, the calculation of the estimated injection time $\widetilde{t_{is}}$ is based on the expression:

$$\widetilde{t_{is}} = R \cdot \alpha_o \cdot (P_r + p_o) = R \cdot g_o, \text{ with}$$

R the richness of the mixture

P_r the intake pressure at the engine manifold

40 α_o, p_o constants

$$g_o = \alpha_o (P_r + p_o)$$

The oxygen sensor makes it possible to introduce a periodic correction Δt_{id} which is such that

$$t_i = \widetilde{t_{is}} + \Delta t_{id}$$

45 Over a sufficiently long time interval, in a stabilized state characterized by small gradients of the speed N of the engine and of the intake pressure P_r , with a functioning without a failure of the sensor and normal operating conditions, the average pressure P_r and the associated average correction $\overline{\Delta t_{id}}$ are measured. These measurements make it possible to integrate the continuous part $\overline{\Delta t_{id}}$ into the basic calculation of the function:

$$g_o = \alpha_o (P_r + p_o)$$

50 by reupdating the coefficients α_o and p_o . From g_o , $\widetilde{t_{is}}$ is obtained.

According to the invention, the method of recursive least squares, weighted by a confidence function, is used, this calculation method aiming to minimize a criterion C which is such that:

$$55 \quad C = \sum_n \mu_n^2 (\overline{t_{i_n}} - \widetilde{t_{is_n}})^2 = \sum_n \mu_n^2 \cdot (\overline{\Delta t_{id_n}})^2$$

The parameters μ_n represents the confidence given to the measurement $\overline{\Delta t_{id_n}}$. This value is low or high, depending on whether the measurement is to be taken into account to a lesser or greater extent. The

weighting thus obtained can be linked to the various operating zones of the engine, so as to have a directly workable physical significance. For example, a greater confidence will be given to the measurements Δtid_n made at intake pressures of mean values, in order to eliminate or at least reduce the influence of the measurements made when the engine is operating under extreme conditions, at high or low speed, which are attributable to exceptional circumstances.

The current measurements can also be preferred over the previous measurements, in order to obtain a stricter and simplified self-adaptive correction of the injection time by means of the procedure described above. The latter makes it possible to reveal possible drifts in the functioning of the regulating system which signify an operating fault. Thus, the detection of several drifts in the zones of measurements of low confidence can be used as an aid in diagnosing operating faults.

Of course, mapped corrections can be used in systems other than the intake-pressure/engine-speed system described above, for example in the intake-mass airflow/engine-speed system, or in another system employing any other combination of physical measurements accessible on the engine, without departing from the scope of the present invention.

Claims

1. Process for the closed-loop regulation of the fuel richness of an air/fuel mixture for feeding an internal-combustion engine by controlling a fuel injection time (t_i) from a signal $s\lambda$ supplied by a bistable oxygen sensor placed in the stream of the exhaust gases of the engine, this signal representing the sign of the difference between the richness R of the mixture and a nominal value R_c , the process being characterized in that:

a) a signal $\widetilde{t_i s}$ corresponding to an estimated static injection time is obtained from measurements of parameters representing the instantaneous operating point of the engine,

b) the signal $s\lambda$ supplied by the sensor is sampled, and the sampled signal is processed in a corrector which generates a sampled signal (Δtid_n) representing a correction to be applied to the estimated injection time $\widetilde{t_i s}$ at the moment of sampling n ,

c) the signal Δtid_n and the signal $\widetilde{t_i s}$ are added to form a signal representing the injection time (t_i), and this signal is sampled in synchronism with the sampling of the signal $s\lambda$, the sampled correction signal Δtid_n taking the form of a linear combination of at least one of the values Δtid_{n-k} of the corrections made at the immediately preceding moments of sampling and of the sampled values of the signal supplied by the sensor at at least one of the immediately preceding moments of sampling and at the current moment.

2. Process according to Claim 1, characterized in that the sampled correction Δtid_n of the opening time takes the form:

$$\Delta \text{tid}_n = \Delta \text{tid}_{n-1} + k(s\lambda_n - \eta s\lambda_{n-1})$$

where k and η are constants adjusted to ensure the stability of the amplitude and frequency of the oscillations of the richness of the mixture in a given operating range of the engine, $s\lambda_n$ and $s\lambda_{n-1}$ are two values of the signal $s\lambda$ at the sampling moments n and $n-1$.

3. Process according to Claim 1, characterized in that the sampled correction Δtid_n of the opening time takes the form:

$$\Delta \text{tid}_n = \alpha \Delta \text{tid}_{n-1} + \beta \Delta \text{tid}_{n-2} + g_0 s\lambda_n + g_1 s\lambda_{n-1} + g_2 s\lambda_{n-2}$$

where α , β , g_0 , g_1 and g_2 are constants adjusted to ensure the stability of the amplitude and frequency of the oscillations of the richness of the mixture in a given operating range of the engine, and $s\lambda_n$, $s\lambda_{n-1}$, $s\lambda_{n-2}$ are values of the signal $s\lambda$ at the sampling moments n , $n-1$ and $n-2$.

4. Process according to Claim 3, characterized in that the coefficients α and β satisfy the relation $\alpha + \beta = 1$.

5. Process according to any one of the preceding claims, characterized in that a possible drift of the switching threshold of the bistable oxygen sensor is corrected.

6. Process according to any one of the preceding claims, characterized in that the switching threshold of a corrected signal $s\lambda^*$ obtained from the signal $s\lambda$ supplied by the bistable oxygen sensor is adjusted in order to provide a continuous closed-loop regulation of the engine either in a stabilized state or in a transient phase.

7. Process according to Claim 6, characterized in that the switching threshold of the corrected signal $s\lambda^*$ is adjusted by means of a value of the corresponding richness of the mixture obtained from a mapping defining the value of this richness as a function of the various operating zones of the engine.

8. Process according to any one of the preceding claims, characterized in that the calculation of the

estimated injection time $\widetilde{t_{is}}$ is corrected from the mean of the successive corrections Δtid_n .

9. Process according to Claim 8, characterized in that the method of recursive least squares is used for correcting the estimated injection time $\widetilde{t_{is}}$.

10. Process according to either one of Claims 8 and 9, characterized in that the measurements of the mean corrections $\overline{\Delta tid}_n$ taken into account in the calculation of the means are weighted with a confidence function linked to the various operating zones of the engine.

11. Device for carrying out the process according to Claim 1, for the closed-loop regulation of an internal-combustion engine by means of a signal supplied by a bistable oxygen sensor sensitive to the oxygen richness of the exhaust gases of the engine, characterized in that it comprises:

- a) a sampler (4) fed with a signal $s\lambda$ supplied by the sensor,
- b) a corrector (5) fed with the sampled signal $s\lambda$ and supplying a sampled correction signal (Δtid) taking the form of a linear combination of at least one of the values (Δtid_{n-k}) of the corrections made at the immediately preceding moments of sampling and of the sampled values $s\lambda_{n-k}$ of the signal supplied by the sensor at at least one of the immediately preceding moments of sampling and at the current moment,
- c) means for calculating an estimated static injection time, supplying a signal ($\widetilde{t_{is}}$) representing this,
- d) an adder (6) for combining the signals (Δtid) and ($\widetilde{t_{is}}$) so as to form a signal representing an effective injection time (t_i),
- e) a second sampler (7) for sampling the signal representing the effective injection time (t_i) in synchronism with the sampling of the signal ($s\lambda$) and for supplying the sampled signal to a member for controlling the opening time of a fuel injector forming part of the engine.

12. Device according to Claim 1, characterized in that the corrector is a first order one and supplies the sampled correction signal Δtid_n of the form:

$$\Delta tid_n = \Delta tid_{n-1} + k(s\lambda_n - \eta s\lambda_{n-1})$$

where k and η are constants adjusted to ensure the stability of the amplitude and frequency of the oscillations of the richness of the mixture in a given operating range of the engine, and $s\lambda_n$ and $s\lambda_{n-1}$ are two values of the signal $s\lambda$ at the moments of sampling n and $n-1$.

13. Device according to Claim 11, characterized in that the corrector is a second order one and supplies a sampled correction signal Δtid_n of the form:

$$\Delta tid_n = \alpha \Delta tid_{n-1} + \beta \Delta tid_{n-2} + g_0 s\lambda_n + g_1 s\lambda_{n-1} + g_2 s\lambda_{n-2}$$

where α , β , g_0 , g_1 , g_2 are constants adjusted to ensure the stability of the amplitude and frequency of the oscillations of the richness of the mixture in a given operating range of the engine, and $s\lambda_n$, $s\lambda_{n-1}$, and $s\lambda_{n-2}$ are values of the signal $s\lambda$ at the moments of sampling n , $n-1$ and $n-2$.

14. Device according to Claim 13, characterized in that the coefficients α and β are linked by the relation:

$$\alpha + \beta = 1.$$

15. Device according to any one of Claims 11 to 14, characterized in that the corrector is a digital corrector.

16. Device according to any one of Claims 11 to 15, characterized in that it possesses a means (8) for correcting a drift of the switching threshold of the oxygen sensor (1).

17. Device according to any one of Claims 11 to 15, characterized in that it possesses a means (8) for adjusting the switching threshold of an adjusted signal $s\lambda^*$ obtained from the signal $s\lambda$ supplied by the sensor, so as to provide a continuous closed-loop regulation of the engine either in a stabilized state or in a transient phase.

18. Device according to Claim 17, characterized in that it possesses a memory containing a mapping of the richnesses corresponding to the various switching thresholds set by the means (8).

19. Device according to any one of Claims 11 to 18, characterized in that it possesses means for correcting the estimated injection time $\widetilde{t_{is}}$ from the average value of the successive corrections Δtid_n .

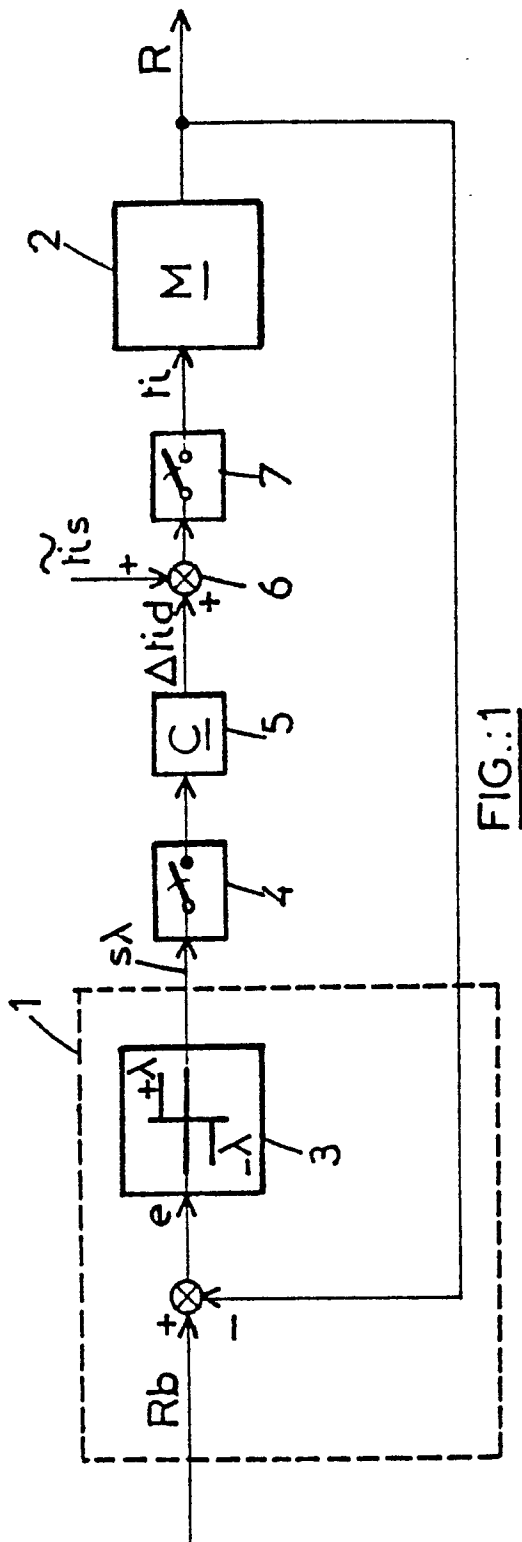


FIG.:1

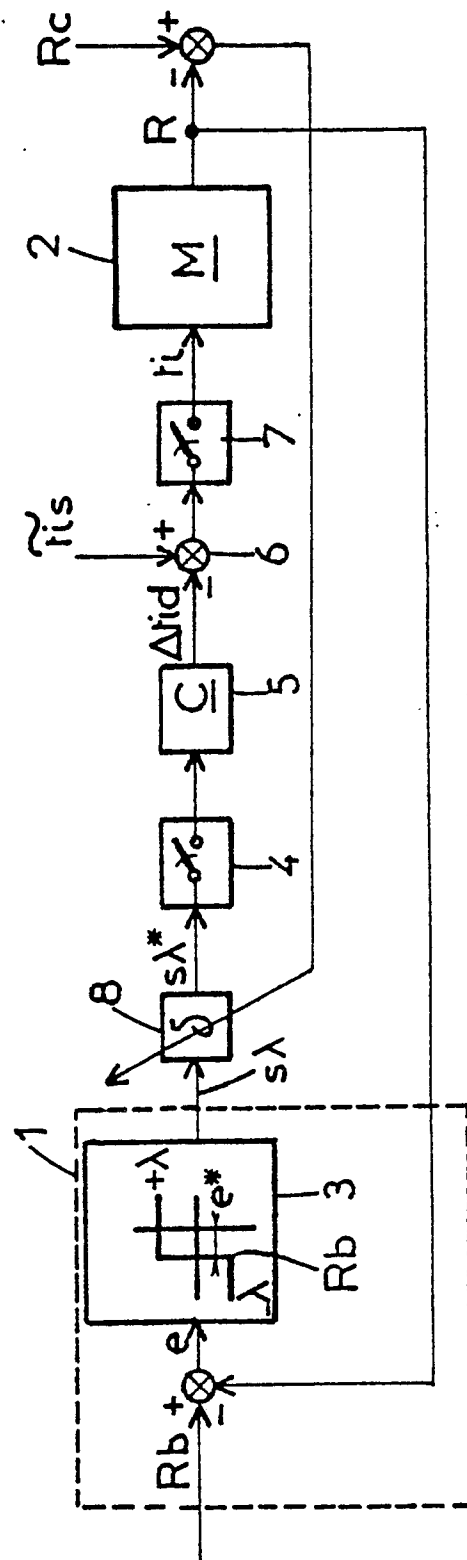


FIG.:2



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	PATENT ABSTRACTS OF JAPAN, vol. 8, no. 40 (M-278)[1477], 21st February 1984, page 9 M 278; & JP-A-58 195 044 (MITSUBISHI DENKI K.K.) 14-11-1983 ---	1-3,8-13,19	F 02 D 41/14
A	G. MARRO: "Fondamenti di teoria dei sistemi", edition 3, 1979, pages 91-92,286-289, Patron, Bologna, IT * Page 91, paragraph 2.9; figure 9.1; page 286, paragraph 5.13 * ---	1-4,11-14	
A	PATENT ABSTRACTS OF JAPAN, vol. 8, no. 35 (M-276)[1472], 15th February 1984, page 8 M 276; & JP-A-58 190 532 (NISSAN JIDOSHA K.K.) 07-11-1983 ---	1,5-7,11,15-17	
A	US-A-4 528 962 (BOSCH) * Whole document * ---		
A	US-A-4 122 811 (BOWLER) * Abstract * -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			F 02 D
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 09-10-1989	Examiner GAGLIARDI P.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			