(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 241 030 A2**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **87105268.4**

(22) Date of filing: **09.04.87**

(51) Int. Cl.[4]: **F02D 41/34**, F02D 41/14, F02D 41/24

(30) Priority: **09.04.86 JP 81647/86**

(43) Date of publication of application: **14.10.87 Bulletin 87/42**

(84) Designated Contracting States: **CH DE FR GB IT LI NL SE**

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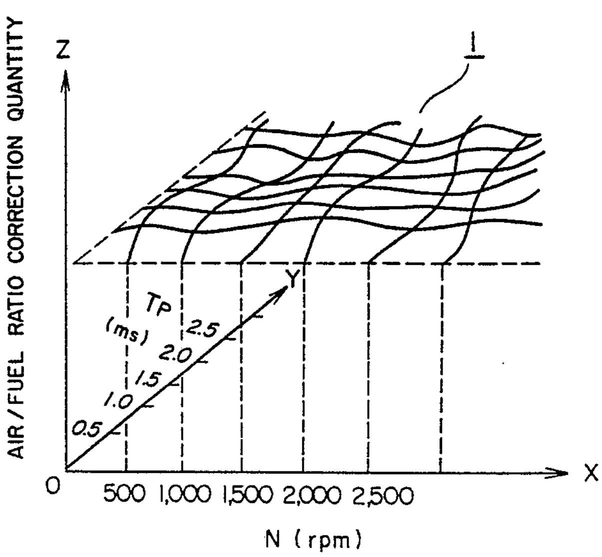
(54) Fuel control method and apparatus therefor.

(57) Disclosed is a fuel-injection system controlling method and an apparatus therefor, in which a running status of an engine (5) is successively detected so as to determine a fuel-injection time on the basis of a fuel-injection pulse width and a quantity of pulse width correction in accordance with the detected engine running status. In the method and apparatus, there is provided a map (I) having a plurality of areas corresponding to various running statuses of the engine (5), each of said areas having a quantity of pulse width correction written therein, so that when the engine running status has varied from a certain one area to another one of the map, the boundary of the certain one area is expanded by a predetermined quantity, and if a current engine running status exists in the area encircled by the expanded boundary the pulse width correction quantity is not changed but if the current engine running status exists in a different area outside the area encircled by the expanded boundary the final fuel-injection pulse width is determined on the basis of the pulse width correction quantity written in the different area.

FIG. 1



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FUEL CONTROL METHOD AND APPARATUS THEREFOR

BACKGROUND OF THE INVENTION

The present invention relates to a method and an apparatus for controlling fuel in an engine, and particularly relates to a method and an apparatus suitable for basic air-fuel ratio learning control to control the optimum mixture ratio in response to an O_2 sensor signal.

Here, description will be made as to the air-fuel ratio learning control. In a fuel control apparatus using an O_2 sensor, the air-fuel ratio of an air-fuel mixture sucked into an engine is controlled by feedback of the output of the O_2 sensor so as to be a theoretical air-fuel ratio with which three way catalyst can act most effectively. In this case, the object to be controlled is the injection-valve opening time, that is the basic fuel-injection pulse width T_p. The basic fuel-injection pulse width T_p corresponds to a load of the engine and is determined on the basis of a suction flow rate and an engine speed. The basic fuel-injection pulse width is multiplied by a feedback factor derived from the output of the O_2 sensor to thereby obtain a final fuel-injection pulse width which is the theoretical air-fuel ratio. The range of change of this feedback factor may vary owing to the time aging of the O_2 sensor. If the feedback changes in a range largely shifted from the initial range of change, the width of change of the feedback factor becomes so large that control becomes impossible to follow the change of engine status. Accordingly, it becomes necessary to properly correct the quantity of change of the feedback factor due to the time aging so as to make the range of change of the feedback factor minimum. Since the quantity of correction varies depending on the time aging cf the O_2 sensor, the time aging of an airflow meter, and variations in manufacture of those O_2 sensor and airflow meter, the output of the O_2 sensor is always monitored to correct the quantity of correction. The feedback factor is multiplied by the quantity of correction and the resultant product is further multiplied by the basic fuel-injection pulse width to thereby determine the final fuel-injection pulse width. This is the brief of the air-fuel ratio learning control.

In the air-fuel ratio learning control, each of two parameters, the engine speed N and the basic fuel-injection pulse width T_p, is sectioned into a plurality of, for example, eight, regions. A map of the quantity of correction is provided, the map being divided into $8 \times 8 = 64$ areas arranged into a matrix with an N-axis representing the ranges of the parameter engine speed and a T_p-axis representing the ranges of the parameter basic fuel-injection pulse width. The map is stored in a storage such as a random access memory (RAM). The width of each region of the respective parameter (definition of a lower and an upper limit) may be suitably established. Addresses are assigned to the respective areas of the map and the quantity of correction is written in the respective area address. The quantity of correction in the respective area address is renewed at fixed intervals of time by the above-mentioned air-fuel ratio learning control. By way of example, assume that setting is made so that a certain region of the engine speed N-axis has a range of from 800 rpm to I,200 rpm, and a certain region of the basic fuel-injection pulse width T_p has a range of from 2.0 msec to 3.0 msec, then one address and one quantity of correction are assigned to one map area encircled by the engine speed region of 800-I,200 rpm and the fuel-injection pulse width region of 2.0-3.0 msec, the lower limit portion of 800 rpm and 2.0 msec being inclusive in the one address area while the upper limit portion of I,200 rpm and 3.0 msec being exclusive in the address area but inclusive in an adjacent one address area.

In the air-fuel ratio learning control, the renewal of the quantity of correction is performed when not only all the five conditions as shown below are satisfied but the engine running status (the region of each of the engine speed N-axis and the basic fuel-injection pulse width T_p-axis) is changing within one area during a period in which the output of the O_2 sensor has changed a plurality of times. The conditions of the air-fuel ratio learning control are as follows:

(I) When the cooling water temperature has reached a predetermined value;

(2) The air-fuel ratio feedback control by means of O_2 sensor is being effected;

(3) The air-fuel ratio feedback control is not being in the clamped state;

(4) The one cycle of the air-fuel ratio feedback control operation is within a range of certain set values of the lower and upper limits; and

(5) The width between the minimum and maximum of the output signal of the O_2 sensor is not smaller than a predetermined value.

An air-fuel ratio control method with learning control is, for example, disclosed in the Japanese Patent Application JP-A-60-III034 filed by the same applicant as of the present application on November 2I, I983.

To execute the air-fuel ratio learning control, there are two systems. In one of the systems, as the engine running status changes and shifts from one area to the next one, the quantity of correction in the next area is immediately read so as to renew the final fuel-injection pulse width. In the other system, on the contrary, the renewal is effected after the shifting from one area to the next one has been confirmed two or three times. In the former system, there is a defect that when the running status changes in the vicinity of an boundary of the areas, the controlled value, that is the fuel-injection pulse width changes up and down in a short time to cause chattering. In the latter system, on the other hand, there is a tendency that in spite of continuous changes of the engine speed the control cannot sufficiently follow the change to cause a delay in control so that the engine running property deteriorates.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a fuel control method and an apparatus therefor in which no chattering as well as no control delay is caused in the engine even if the engine running status fluctuates in the vicinity of an boundary of the areas of the map.

To achieve the above object, according to the fuel control method and apparatus, when the running status changes to shift from one area of the other in the map, the boundary of the shifted area is enlarged by a predetermined value. When the area is again shifted to another area, if the current running status (another area) exists in the previous area encircled by the new boundary the quantity of correction is not altered, while if the current running status exists in another different area outside the area defined by the new boundary the final fuel-injection pulse width is determined by the quantity of correction indicated by the different area.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become apparent upon a reading of the following detailed description and drawings, in which:

Fig. I is a schematic diagram of an air-fuel ratio correction quantity map;

Fig. 2 is a diagram showing an embodiment of the air-fuel ratio correction quantity map, the engine speed table and the basic fuel-injection pulse width table;

Fig. 3 is a block diagram of an engine provided with an air-fuel ratio feedback control system by means of an O_2 sensor;

Fig. 4 is a diagram for explaining the method of determining the air-fuel ratio correction quantity according to the present invention; and

Fig. 5 is a flowchart showing a procedure of determination of the air-fuel ratio correction quantity according to an embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. I shows a schematic diagram of an air-fuel ratio correction quantity map I. In the map I, the X-axis, the Y-axis and the Z-axis represent the engine speed, the basic fuel-injection pulse width and the air-fuel ratio correction quantity The air-fuel ratio correction quantity is calculated by the above-mentioned air-fuel ratio learning control corresponding to the running status of the engine and is written into the map.

Fig. 2 shows the map I of Fig. I when viewed in the direction of the Z-axis, together with an engine speed table 2 and a basic fuel-injection pulse width table 3 respectively for defining boundaries of the areas in the map I. Although each of the tables 2 and 3 defines four boundaries and the map I is divided into twenty five areas for the sake of convenience, the present invention is not limited to those numerical values but the number of the boundaries and areas may take any values desiredly. It is a matter of course that the larger the number of division of the map areas is selected, the more precisely the air-fuel ratio control can be effected. N_1, N_2, N_3 and N_4 in the engine speed table 2 represent the boundary values of the engine speed N (rpm) of the respective areas in the map I, and T_{p1}, T_{p2}, T_{p3} and T_{p4} in the basic fuel-injection pulse width table 3 represent the boundary values of the basic fuel-injection pulse width T_p (msec) of the respective areas in the map I. Area addresses (0,I), (I,0), (2,0) .... are assigned to the respective areas of the map I. A quantity of correction of the air-fuel ratio is written in each area address.

Fig. 3 shows an outline of an engine 5 provided with an air-fuel ratio feedback control apparatus employing an O_2 sensor. A control unit 4 includes: a memory for storing the map I, the engine speed table 2, and the basic fuel-injection pulse width table 3, and other data; a CPU for controlling the operation of the air-fuel ratio feedback control; and a memory for storing programs for the control. The flow rate of air passed through an air cleaner 6 is measured by an airflow meter 7. The engine speed is detected by an engine speed pickup 8. The data about the current air flow rate and the current engine speed are applied to the control unit 4 which determines the respective regions of the engine speed table 2 and the basic fuel-injection pulse width 3 relevant to the applied data. The reference numerals 9 and I0 designate a throttle valve and a valve for controlling the quantity of suction air. These members 9 and I0 are not directly relevant to the present invention and therefore no explanation about them is made here. The reference numeral II designates an igniter for generating a high voltage ignition pulse in response to an ignition timing signal from the control unit 4. The reference numeral I2 designates a distributor for distributing the ignition pulse to ignition plugs of respective cylinders. The reference numeral I3 designates a fuel injector responsive to a fuel-injection pulse width signal from the control unit 4 to open its valve to jet fuel into an inlet port I4 for a time corresponding to the pulse width. An O_2 sensor I6 is disposed in an exhaust gas flowing in an exhaust manifold I5 so as to detect the air-fuel ratio of a suction air-fuel mixture, and a detection signal of the O_2 sensor I6 is applied to the control unit 4.

As shown in Fig. 4, even if the running status of the engine changes from a point A which is located in a region encircled by solid lines to another point B which is not located in the region encircled by the solid lines but located in a region encircled by dotted lines, the area address (a,b) is not changed and therefore the air-fuel ratio correction quantity is not altered. On the contrary, when the engine running status shifts from the point A to a point C which is located outside the region encircled by the dotted lines, the area address is changed and the air-fuel ratio correction quantity in the new area address is read out. ΔN and ΔT_p represent the respective quantities of expansion of the boundary setting values of the region of the engine speed table and the basic fuel-injection pulse width table. The second tables 2′ and 3′ for setting the boundaries of the expanded region are stored in another memory different from the memory where the first tables 2 and 3 are stored.

Fig. 5 shows a flowchart for executing the air-fuel ratio correction quantity control according to the present invention. In a step I00, the first engine speed table 2 and the first basic fuel-injection pulse width table 3 are referred to on the basis of the current engine speed N and the current basic fuel-injection pulse width T_p to thereby obtain the current area address in the map I. In a step I0I, the preceding area address stored in the RAM corresponding to the preceding engine running status is read out. In a step I02, the current area address and the preceding area address are compared with each other. If the current and preceding area addresses are not coincident with each other, the operation is shifted to a step I03. In the step I03, the preceding area address in the RAM is changed to a new area address. In a step I04, each of the respective boundaries of the lower and upper limits of the first basic fuel-injection pulse width table 3 is expended by ΔT_p and each of thè respective boundaries of the lower and upper limits of the first engine speed table 2 is expanded by ΔN, and the expanded values are written into the second basic fuel-injection pulse width table 3′ and the second engine speed table 2′ respectively. In a step I05, the second tables 2′ and 3′ are referred to on the basis of the current engine speed N and the current basic fuel-injection pulse width T_p to thereby obtain the area address in the map I. In a step I06, the air-fuel ratio correction quantity stored in the thus obtained area address is read out. If the current and preceding area addresses are coincident with each other in the step I02, the operation is shifted to the step I06 by by-passing the steps I02 through I05. After the step I06, a final fuel-injection pulse width is calculated on the basis of the read-out air-fuel ratio correction quantity so that the control is made to open the value of the fuel injector for the time of the thus obtained final fuel-injection pulse width.

Claims

I. A fuel-injection system control apparatus in which a running status of an engine is successively detected so as to determine a fuel-injection time on the basis of a fuel-injection pulse width and a quantity of pulse width correction in accordance with the detected engine running ststus, said apparatus comprising:

a first table (2,3) having a plurality of regions corresponding to various values of a parameter representing a running status of said engine into;

a correction quantity map (I) having a plurality of areas respectively corresponding to said regions of said first table;

judgement means (4) for determining an area address of said correction quantity map corresponding to a current engine running status on the basis of said first table to thereby judge whether the area address corresponding to the current engine running status is coincident with an area address corresponding to a preceding engine running status or not;

operation means (4) for expanding a range of each of said plurality of regions of said first table by a predetermined quantity when said judgement means proves that the area address corresponding to the current engine running status is not coincident with the area address corresponding to the preceding engine running status;

a second table (2',3') having a plurality of regions expanded by said operation means; and

correction quantity read-out means (4) for reading out a correction quantity indicated by an area address of said correction quantity map determined by said first table when said judgement means proves that the area address corresponding to the current engine running status is coincident with the area address corresponding to the preceding engine running status and for reading out a correction quantity indicated by an area address of said correction quantity map determined by said second table when said judgement means proves that the area address corresponding to the current engine running status is not coincident with the area address corresponding to the preceding engine running status.

2. A fuel-injection system control apparatus according to Claim l, wherein said parameter includes a basic fuel-injection pulse width (T_p) and an engine speed (N) each corresponding to a load of said engine.

3. A fuel-injection system control apparatus in which a running status of an engine is successively detected so as to determine a fuel-injection time on the basis of a fuel-injection pulse width and a quantity of pulse width correction in accordance with the detected engine running status, in which the fuel-injection time is subject to feedback control by means of an O_2 sensor disposed in an exhaust gas so as to make an air-fuel ratio in said engine be a theoretical mixture ratio, and in which the quantity of pulse width correction is successively renewed so as to make a quantity of the feedback control minimum, said apparatus comprising:

a first basic fuel-injection pulse width table (3) having a plurality of regions corresponding to various values of a basic fuel-injection pulse width (T_p);

a first engine speed table (2) having a plurality of regions corresponding to various values of an engine speed (N);

a correction quantity map (l) having a plurality of areas respectively corresponding to said respective regions of said first and second tables, each of said areas indicating a quantity of correction for said basic fuel-injection pulse width;

judgement means (4) for determining an area of said correction quantity map corresponding to a current engine running status on the basis of said first basic fuel-injection pulse width table and said first engine speed table to thereby judge whether the area address corresponding to the current engine running status is coincident with an area address corresponding to a preceding engine running status or not;

operation means (4) for expanding a range of each of said plurality of regions of each of said first basic fuel-injection pulse width table and said first engine speed table by a predetermined quantity when said judgement means proves that the area address corresponding to the current engine running status is not coincident with the area address corresponding to the preceding engine running status;

a second basic fuel-injection pulse width table (3') having a plurality of regions expanded by said said operation means;

a second engine speed table (2') having a plurality of regions expanded by said operation means;

correction quantity read-out means (4) for reading out a correction quantity indicated by an area address of said correction quantity map determined by said first basic fuel-injection pulse width table and said first engine speed table when said judgement means proves that the area address corresponding to the current engine running status is coincident with the area address corresponding to the preceding engine running status and for reading out a correction quantity indicated by an area address of said correction quantity map determined by said second basic fuel-injection pulse width table and said second engine speed table when said judgement means proves that the area address corresponding to the current engine running status is not coincident with the area address corresponding to the preceding engine running status.

4. A method of controlling a fuel-injection system in which a running status of an engine is successively detected so as to determine a fuel-injection time on the basis of a fuel-injection pulse width and a pulse width correction quantity in accordance with the detected engine running status, said system provided with a first table (2,3) having a plurality of regions corresponding to various values of the running status of said engine and a correction quantity map (l) having a plurality of areas corresponding to said regions of said first table, each area indicating a pulse width correction quantity, said method comprising the steps of:

reading out a region of said first table corresponding to a current engine running status;

reading out an area address of said map corresponding to the read-out region of said first table;

judging whether the read-out area address of said map is coincident with an area address corresponding to a preceding engine running status or not;

reading out the pulse width correction quantity in the read-out area address of said map when said judgement proves agreement, while performing the following steps when said judgement proves disagreement;

rewriting the area address corresponding to the preceding engine running status into the area address corresponding to the area address corresponding to the current engine running status;

expanding each of said regions of said first table by a predetermined quantity;

writing the expanded regions into a second table;

reading out an expanded region of said second table corresponding to the current engine running status;

reading out an area address of said map corresponding to the read-out region of said second table from said read-out region of said second table; and

reading out a pulse width correction quantity in the read-out area address from said map.

5. A method of controlling a fuel-injection system according to Claim 4, wherein each of said first and second tables includes a basic fuel-injection pulse width table (3,3') having a plurality of regions corresponding to various values of a basic fuel-injection pulse width (T_p), and an engine speed table (2,2') having a plurality of regions corresponding to various values of an engine speed (N), so that when respective region of said basic fuel-injection pulse width table and said engine speed table are indicated, an area address of said correction quantity map corresponding to the indicated regions is determined, and wherein in each of said table region reading-out steps the respective regions of said basic fuel-injection pulse width table and said engine speed table are read out, and in said table region expanding step each of the regions of each of said basic fuel-injection pulse width table and said engine speed table is expanded by a predetermined quantity.

6. A method of controlling a fuel-injection system according to Claim 5, wherein in said table region expanding step, the respective region is expanded by a predetermined quantity at each of lower and upper limits thereof.

FIG. 1

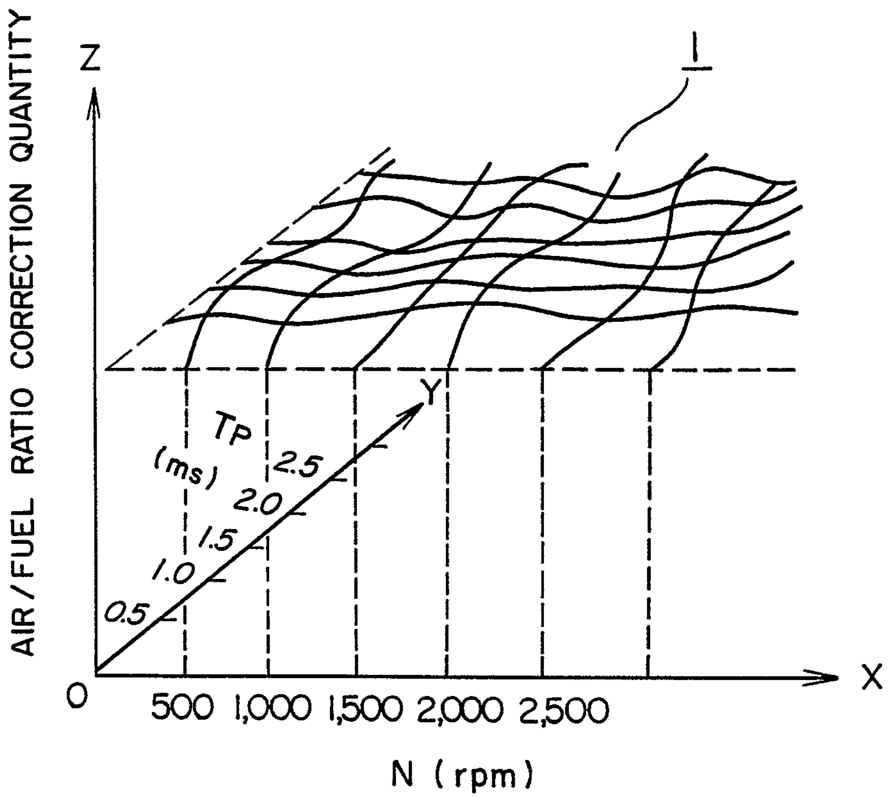

AIR / FUEL RATIO CORRECTION QUANTITY
Z
1
Y
TP
(ms)
2.5
2.0
1.5
1.0
0.5
0
X
500
1,000
1,500
2,000
2,500
N (rpm)

FIG. 2

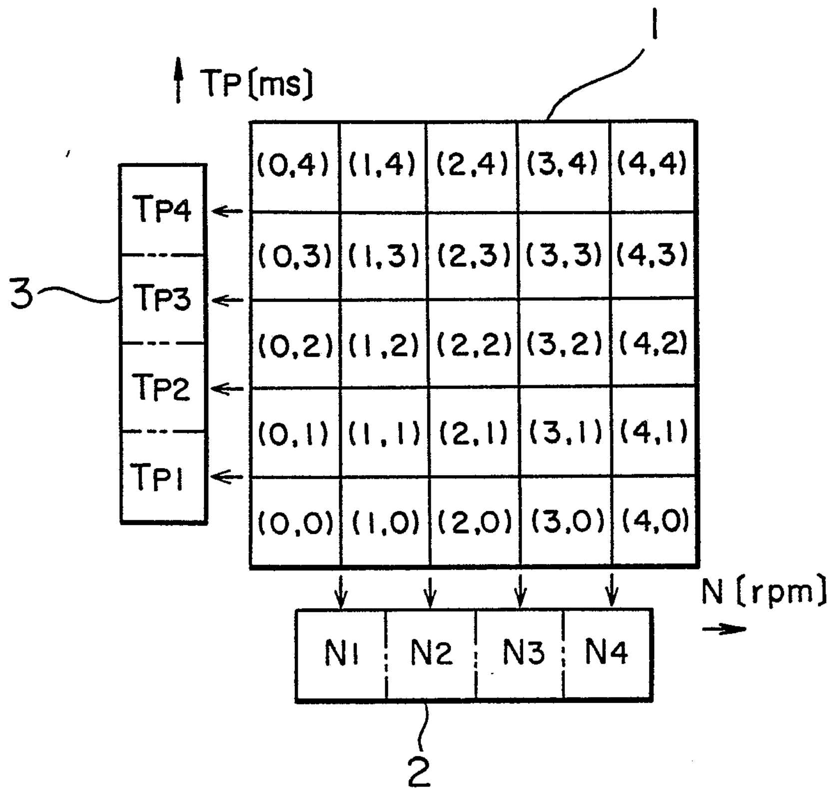

1
TP [ms]
3
TP4
TP3
TP2
TP1
(0,4) (1,4) (2,4) (3,4) (4,4)
(0,3) (1,3) (2,3) (3,3) (4,3)
(0,2) (1,2) (2,2) (3,2) (4,2)
(0,1) (1,1) (2,1) (3,1) (4,1)
(0,0) (1,0) (2,0) (3,0) (4,0)
N [rpm]
N1
N2
N3
N4
2

FIG. 3

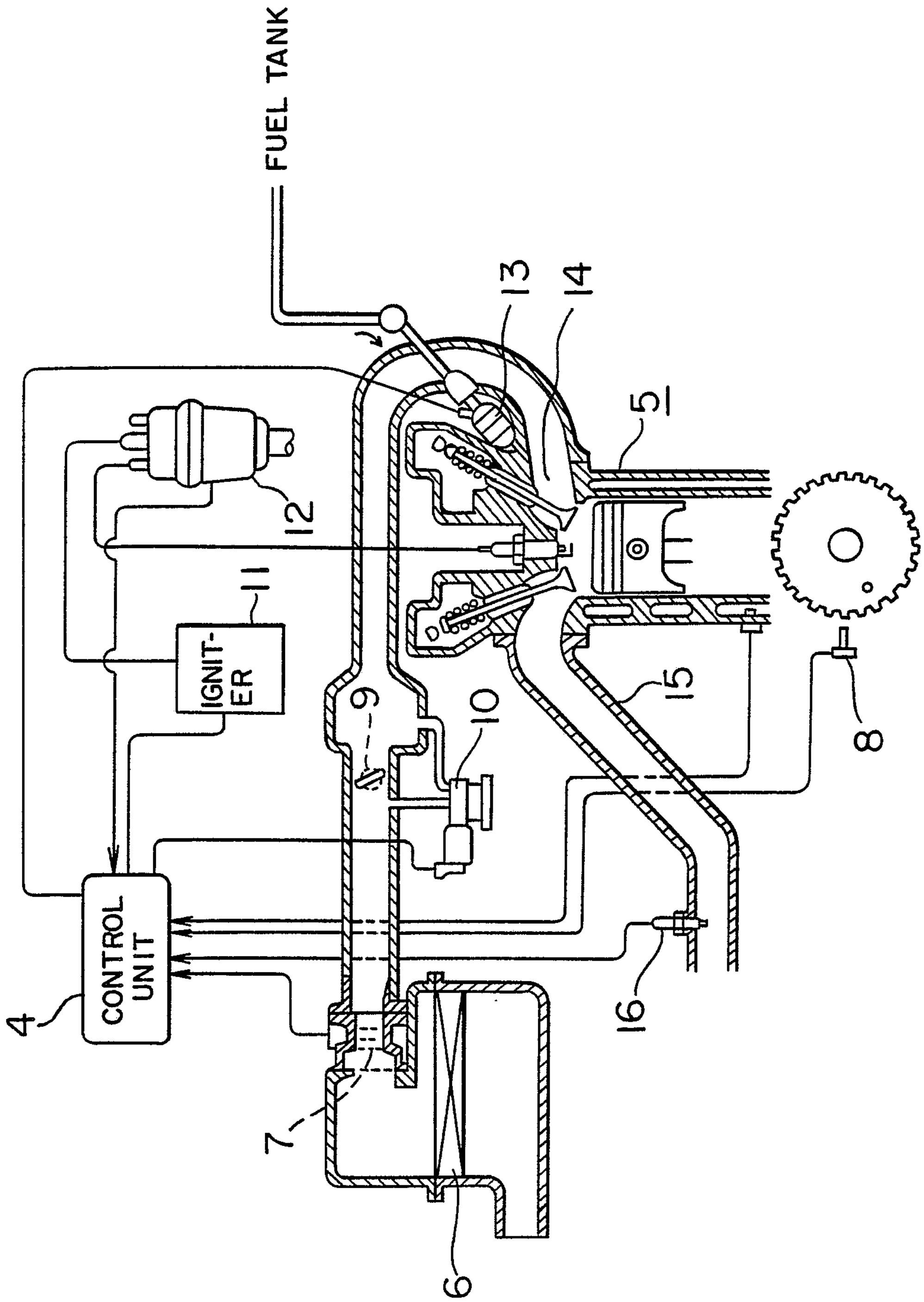
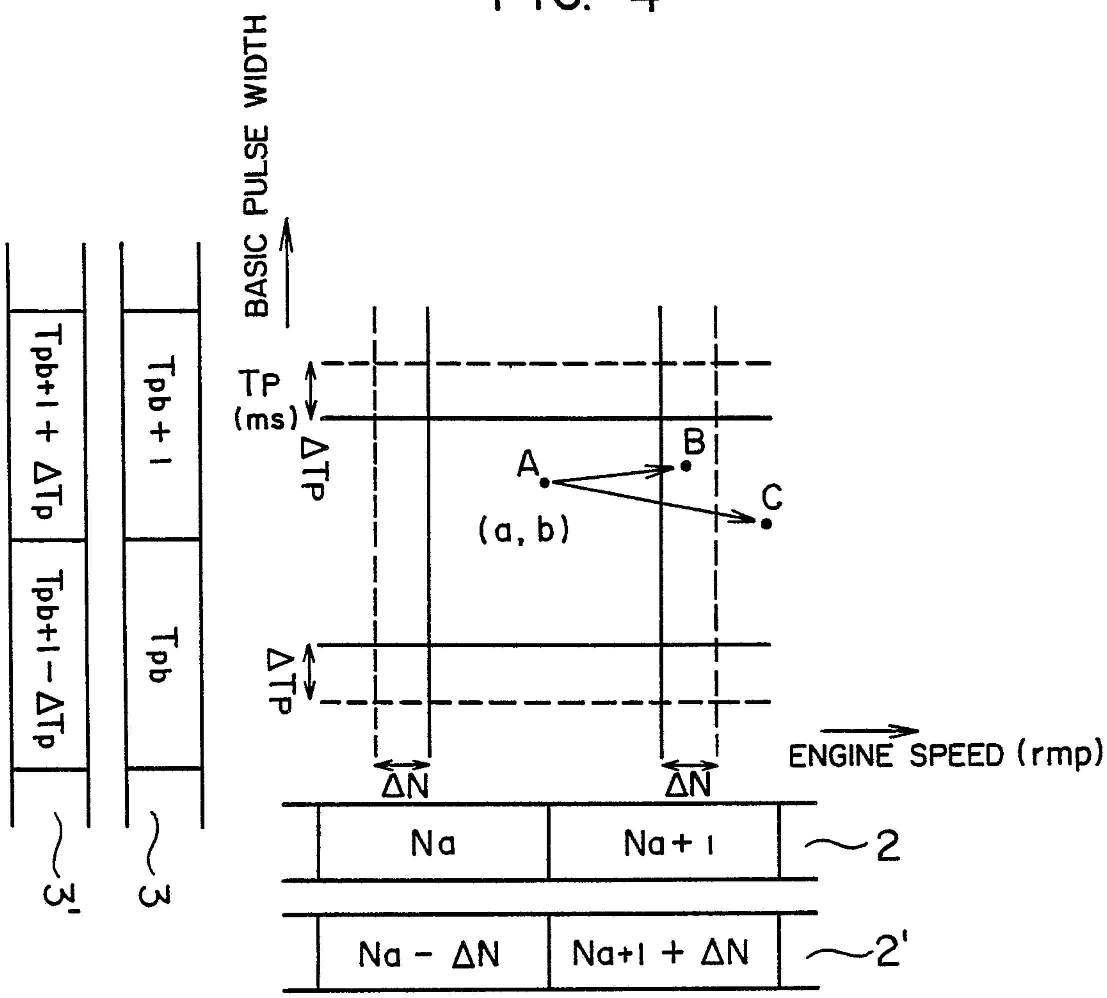
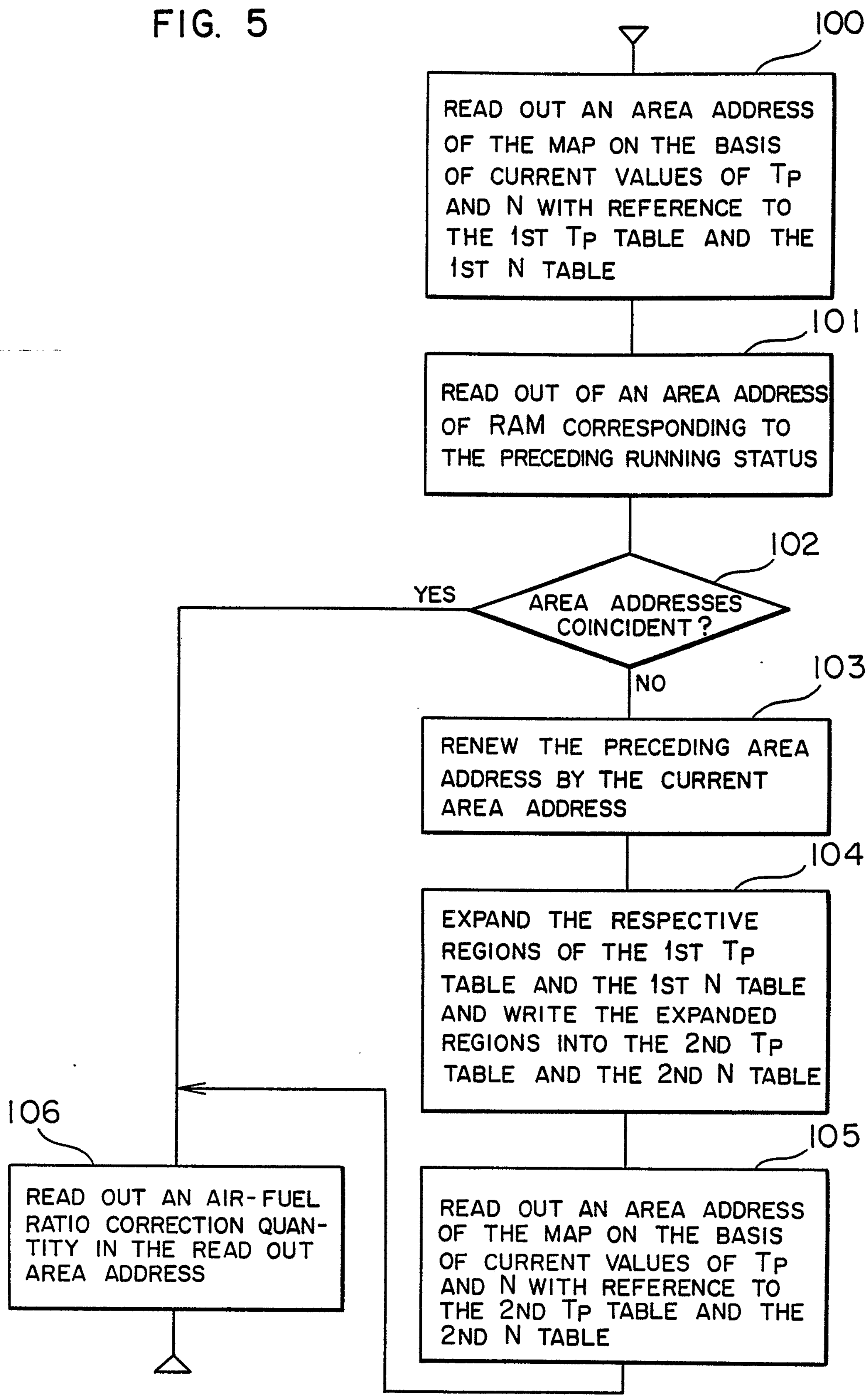


FIG. 4



BASIC PULSE WIDTH
TP
(ms)
ΔTP
ΔTP
A
(a, b)
B
C
ΔN
ΔN
ENGINE SPEED (rmp)
Na
Na+1
2
Na - ΔN
Na+1 + ΔN
2'
Tpb+1 + ΔTp
Tpb+1 - ΔTp
3'
Tpb + 1
Tpb
3

FIG. 5


100
READ OUT AN AREA ADDRESS OF THE MAP ON THE BASIS OF CURRENT VALUES OF Tp AND N WITH REFERENCE TO THE 1ST Tp TABLE AND THE 1ST N TABLE
101
READ OUT OF AN AREA ADDRESS OF RAM CORRESPONDING TO THE PRECEDING RUNNING STATUS
102
AREA ADDRESSES COINCIDENT?
YES
NO
103
RENEW THE PRECEDING AREA ADDRESS BY THE CURRENT AREA ADDRESS
104
EXPAND THE RESPECTIVE REGIONS OF THE 1ST Tp TABLE AND THE 1ST N TABLE AND WRITE THE EXPANDED REGIONS INTO THE 2ND Tp TABLE AND THE 2ND N TABLE
105
READ OUT AN AREA ADDRESS OF THE MAP ON THE BASIS OF CURRENT VALUES OF Tp AND N WITH REFERENCE TO THE 2ND Tp TABLE AND THE 2ND N TABLE
106
READ OUT AN AIR-FUEL RATIO CORRECTION QUANTITY IN THE READ OUT AREA ADDRESS