EUROPEAN PATENT APPLICATION

This application was filed on 09 - 07 - 1991 as a divisional application to the application mentioned under INID code 60.

(71) Applicant: **JAPAN ELECTRONIC CONTROL SYSTEMS CO., LTD.**
1671-1, Kasukawa-cho
Isesaki-shi Gunma-ken, 372(JP)

(72) Inventor: **Tomisawa, Naoki, c/o Japan Electronic**
Control Systems Co., Ltd., 1671-1,
Kasukawa-cho
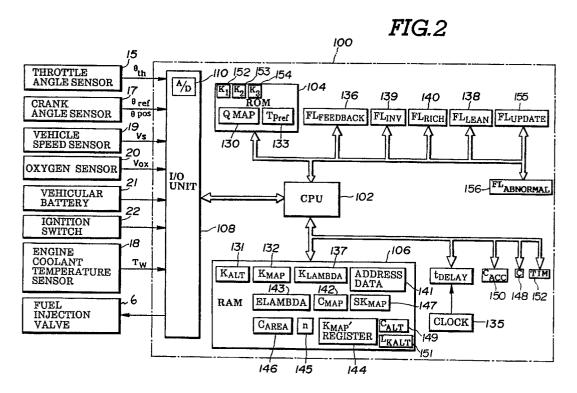**Isesaki-shi, Gunma-ken, 372(JP)**

(74) Representative: **Schoppe, Fritz, Dipl.-Ing. et al**
Seitnerstrasse 42
W-8023 Pullach bei München(DE)

(54) Air/fuel mixture ratio control system for internal combustion engine with feature of learning correction coefficient including altitude dependent factor.

(57) A method for controlling a mixture ratio of an air/fuel mixture for an engine, comprises the steps of: monitoring (1002) preselected basic first engine operation parameter to produce a first sensor signal indicative thereof; monitoring (1204) an air/fuel mixture ratio indicative parameter (V_{ox}) for producing a second sensor signal indicative of a deviation of the air/fuel mixture from a stoichiometric value; deriving (1002, 1006) a basic fuel metering amount (Tp) on the basis of said first sensor signal value; deriving (1008) an air/fuel ratio dependent correction factor (COEF) from said second sensor signal value; deriving (1610) a first correction coefficient (K_{ALT}) on the basis of said air/fuel ratio dependent correction factor (COEF), which first correction coefficient is commonly applicable for correcting said basic fuel metering amount (Tp) in all engine driving ranges, said step (1610) comprising the updating of the first correction coefficient (K_{ALT}) when a feedback condition is satisfied; deriving (1012) a second correction coefficient (K_{MAP}) which is variable depending upon the engine driving range on the basis of said air/fuel ratio dependent correction factor (COEF) and setting a plurality of second correction coefficients (K_{MAP})

for respective engine driving ranges and updating each of said second correction coefficients with an instantaneous value derived based on said air/fuel ratio dependent correction factor in the corresponding engine driving range; detecting (1002-1014) an engine driving condition on the basis of said first sensor values and governing said steps (1610, 1012) of deriving said first and second correction coefficients (K_{ALT}, K_{MAP}) depending upon the detected engine driving condition; and correcting (1018, 1020) said basic fuel metering amount (Tp) with said first and second correction coefficients (K_{ALT}, K_{MAP}).

For achieving an enhanced accuracy in determining the fuel metering amount the step of deriving the first correction coefficient (K_{ALT}) further comprises the steps of determining (1724) a first component ratio indicative value (k1) based on at least one of an engine load indicative signal (α, Q), a basic fuel injection amount (Tp) and the engine speed (N); determining a predetermined number of engine driving ranges for which the second correction coefficient (K_{MAP}) was recently updated; detecting (1726) for each range the difference between a present second correction coefficient (K_{MAP}) and a previous

EP 0 452 996 A2

one for distinguishing between positive difference regions, where the difference between the present and the previous second correction coefficient (K_{MAP}) for this region is positive, and negative difference regions; determining (1726-1732) a second component ratio indicative value (k2) based on the number of positive and/or negative difference regions; and modifying (1732-1736) the first correction coefficient (K_{ALT}) based on said first and second component ratio indicative values (k1, k2).

FIG.2

100

- THROTTLE ANGLE SENSOR — 15 — θ_{th}
- CRANK ANGLE SENSOR — 17 — θ_{ref} / θ_{pos}
- VEHICLE SPEED SENSOR — 19 — Vs
- OXYGEN SENSOR — 20 — Vox
- VEHICULAR BATTERY — 21
- IGNITION SWITCH — 22
- ENGINE COOLANT TEMPERATURE SENSOR — 18 — Tw
- FUEL INJECTION VALVE — 6

A/D

I/O UNIT — 108

ROM — 104
110 152 153 154
K_1 K_2 K_3
Q MAP — 130
T_{pref} — 133

$FL_{FEEDBACK}$ — 136
FL_{INV} — 139
FL_{RICH} — 140
FL_{LEAN} — 138
FL_{UPDATE} — 155
$FL_{ABNORMAL}$ — 156

CPU — 102

RAM — 106
K_{ALT} — 131
K_{MAP} — 132
K_{LAMBDA} — 137
ADDRESS DATA
ELAMBDA — 143
C_{MAP} — 142
SK_{MAP} — 147
C_{AREA} — 146
n — 145
K_{MAP}' REGISTER — 144
C_{ALT} — 149
L'_{KALT} — 151
141

t_{DELAY} — 141
CLOCK — 135
C_{ACC}
C — 150 148 152
TIM

The present invention relates to a method for controlling a mixture ratio of an air/fuel mixture for an engine in accordance with the prior art portion of claim 1 and to a air/fuel ratio control system in accordance with the prior art portion of claim 5.

A method for controlling the mixture ratio of an air/fuel mixture for an engine of the above-mentioned type and a system for controlling the air/fuel ratio of the above-mentioned type are known from EP-A-191923 and from the prior, non-prepublished EP-A-0265078.

In a control method of the above-mentioned type, a lambda-sensor generates a signal indicative of the deviation of the actual air/fuel mixture from a stoichiometric value. A correction factor is derived from this sensor signal. Thereinafter, the first correction coefficient which can be regarded as an altitude dependent correction coefficient which is commonly applicable for correcting the basic fuel metering amount in all engine driving ranges is derived from the correction coefficient when a feedback condition is fulfilled. Furthermore, a number of second correction coefficients which can be regarded as areal learning correction coefficients are determined for each engine driving range on the basis of the actual value of the air/fuel ratio dependent correction factor. The actual fuel metering amount is derived from the basic fuel metering amount on the basis of said first and second correction coefficients. The accuracy in determining the actual fuel metering amount is negatively affected by numerous factors such as errors in the measurement of the throttle angle position and tolerances of various components of the overall system.

Starting from the above prior art, the present invention is based on the object of providing a method for controlling a mixture ratio of an air/fuel mixture for an engine of the above-mentioned type and an air/fuel ratio control system of the above-mentioned type having a higher degree of accuracy in determining the fuel metering amount.

This object is achieved by a method in accordance with claim 1 and by a system in accordance with claim 5.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood more fully from the detailed description given herebelow and from the accompanying drawings of the preferred embodiment of the invention, which, however, should not be taken to limit the invention to the specific embodiment but are for explanation and understanding only.

In the drawings:
Fig. 1 is a diagram of the preferred embodiment of a learning air/fuel ratio control system according to the invention;
Fig. 2 is a block diagram of a control unit employed in the preferred embodiment of the air/fuel ratio control system of the invention;
Fig. 3 is a flowchart of a routine for deriving and setting a fuel injection pulse width representative of a fuel injection amount;
Fig. 4 is a block diagram of an input/output unit in the control unit to be employed in the preferred embodiment of the air/fuel ratio control system of Fig. 2;
Fig. 5 is a flowchart of a routine for discriminating engine operating condition for governing control operation mode between FEEDBACK control mode and OPEN LOOP control mode;
Fig. 6 is a flowchart of a routine for deriving feedback correction coefficient composed of a proportional component and an integral component;
Fig. 7 is a flowchart of a learning governing routine for governing learning of K_{ALT} and K_{MAP};
Fig. 8 is a flowchart of a K_{ALT} learning routine for updating a map storing an air density dependent uniform correction coefficients;
Figs. 9 is a flowchart showing a K_{MAP} learning routine for updating an engine driving range based correction coefficients;
Fig. 10 is a timing chart showing operation of the preferred embodiment of the air/fuel ratio control system of the invention;
Fig. 11 is a flowchart of an automatically modifying routine for K_{ALT} for modifying the K_{ALT} automatically;
Fig. 12 is a chart showing FEEDBACK control range which is defined in terms of engine speed N and engine load Tp;
Fig. 13 is a chart showing range to perform learning of K_{ALT} which is defined by throttle angular position θ_{th}, intake air flow rate Q and engine speed N;
Figs. 14 and 15 are flowcharts showing a sequence of K_{MAP} learning routine as modification of the routine of Fig. 8.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, particularly to Figs. 1 and 2, the preferred embodiment of an air/fuel ratio control system, according to the invention, is applied to a fuel injection internal combustion engine which is generally represented by the reference numeral "1". The engine 1 has an air induction system including an air cleaner 2, a throttle body 3 and an intake manifold 4. A throttle valve 5 is disposed within the throttle body 3 for adjusting induction rate of an air/fuel mixture.

In the shown embodiment, a fuel injection valve

6 is disposed within the throttle body **3** and up-stream of the throttle valve **5**. Therefore, the air/fuel mixture is formed at the position in the induction system upstream of the throttle valve. The air/fuel mixture flows through the throttle body **3** and intro-duced into an engine combustion chamber via the intake manifold **4** and an intake port which is open and closed by means of an intake valve.

The air/fuel mixture introduced into the engine combustion chamber is combustioned by spark ignition taken place by means of an ignition plug **7** which receives an ignition power from an ignition coil unit **8** via a distributor **9**.

The engine **1** also has an exhaust system including an exhaust manifold **10**, an exhaust duct **11**, a catalytic converter unit **12** and a muffler **13**.

In order to monitor the angular position of the throttle valve **5**, a throttle angle sensor **15** is asso-ciated with the throttle valve **5** to produce a throttle angle indicative signal θ_{th} having a value indicative of the monitored throttle angle. In practice, the throttle angle sensor **15** comprises a potentiometer producing analog form throttle angle indicative sig-nal having a voltage variable depending upon the throttle valve angular position. Also, an an engine idling condition detector switch **16** is associated with the throttle valve **5** for detecting fully closed or approximately fully closed position of the throttle valve. The engine idling condition detector switch **16** outputs an engine idling condition indicative signal IDL which is held LOW level while the throt-tle valve **5** is not in fully closed or approximately fully closed position and is held HIGH level while the throttle valve is maintained at fully closed or approximately fully closed position.

A crank angle sensor **17** is coupled with the distributor **9** for monitoring a crank shaft angular position. For this, the crank angle sensor **17** has a rotary disc which is so designed as to rotate syn-chroneously with rotation of a rotor of the distribu-tor. The crank angle sensor **17** produces a crank reference signal θ_{ref} at each of predetermined an-gular position and a crank position signal θ_{pos} at every time of predetermined angle of angular dis-placement of the crank shaft. In practice, the crank reference signal is generated every time the crank shaft is rotated at an angular position correspond-ing on 70° or 66° before top-dead-center (BTDC) in compression stroke of one of engine cylinder. Therefore, in case of the 6-cylinder engine, the crank reference signal θ_{ref} is produced at every 120° of the crank shaft angular displacement. On other hand, the crank position θ_{pos} is generated every given angular displacement, i.e. 1° or 2°, of the crank shaft.

An engine coolant temperature sensor **18** is disposed within an engine cooling chamber to monitor a temperature of an engine coolant filled in

the cooling chamber. The engine coolant tempera-ture sensor **18** is designed for monitoring the tem-perature of the engine coolant to produce an en-gine coolant temperature indicative signal Tw. In practice, the engine coolant temperature sensor **18** produces an analog form signal having a voltage variable depending upon the engine coolant tem-perature condition. A vehicle speed sensor **19** monitors a vehicle speed for producing a vehicle speed indicative signal Vs. Furthermore, the shown embodiment of the air/fuel ratio control system includes an oxygen sensor **20** disposed in the exhaust manifold **10**. The oxygen sensor **20** moni-tors oxygen concentration contained in the exhaust gas to produce an oxygen concentration indicative signal V_{ox} indicative of the monitored oxygen con-centration. The oxygen concentration indicative sig-nal V_{ox} is a voltage signal variable of the voltage depending upon the oxygen concentration. In prac-tice, the voltage of the oxygen concentration indi-cative signal varies across a zero voltage depend-ing on rich and lean of the air/fuel ratio relative to a stoichiometric value.

In addition, the preferred embodiment of the air/fuel ratio control system, according to the inven-tion, has a control unit **100** which comprises a microprocessor. The control unit **100** is connected to a vehicular battery **21** to receive power supply therefrom. An ignition switch **22** is interposed be-tween the control unit **100** and the vehicular battery **21** to establish and block power supply.

As shown in **Fig. 2**, the control unit **100** com-prises CPU **102**, RAM **104**, ROM **106** and an input/output unit **108**. The input/output unit **108** has an analog-to-digital converter **110** for converting analog inputs, such as the throttle angle indicative signal θ_{th}, the engine coolant temperature indica-tive signal Tw and so forth, into digital signals.

The control unit **100** receives the throttle angle indicative signal θ_{th}, the engine idling position indi-cative signal IDL, the crank reference signal θ_{ref},the crank position signal θ_{pos}, the engine coolant tem-perature indicative signal Tw, the vehicle speed indicative signal Vs and oxygen concentration indi-cative signal V_{ox}. The control unit **100** derives an engine revolution speed data N on the basis of a period of the crank reference signal θ_{pos}. Namely, the period of the crank reference signal θ_{ref} is inversely proportional to the engine speed, the engine speed data N can be derived from recipro-cal of the period of the crank reference signal θ_{re}. Also, the control unit **100** projects an intake air flow amount indicative data Q on the basis of the throt-tle angle position indicative signal value θ_{th}.

Although the shown embodiment projects the intake air flow rate indicative data Q based on the throttle angle position indicative signal, it is, of course, possible to obtain the air flow rate indica-

tive data Q directly by a known air flow meter. In the alternative, the intake air flow rate indicative data may also be obtained from intake vaccum pressure which may be monitored by a vaccum sensor to be disposed within the induction system.

Generally, the control unit **100** derives a basic fuel injection amount or a basic fuel injection pulse width Tp on the basis of the engine speed data N and the intake air flow rate indicative data Q which serves to represents an engine load. The basic fuel injection amount Tp is corrected by a correction factors derived on the basis of the engine coolant temperature Tw, the rich/lean mixture ratio indicative oxygen concentration indicative signal V_{ox} of the oxygen sensor **20**, a battery voltage and so forth, and an enrichment factor, such as engine start up enrichment factor, acceleration enrichment factor. The fuel injection amount modified with the correction factors and enrichment factors set forth above, is further corrected by a air/fuel ratio dependent correction coefficient derived on the basis of the oxygen concentration indicative signal V_{ox} for adjusting the air/fuel ratio toward the stoichiometric value.

The practical operation to be performed in the control unit **100** of the preferred embodiment of the air/fuel ratio control system according to the invention, will be discussed herebelow with reference to **Figs. 3** to **9**. In the following discussion, components of the control unit **100** which are not discussed in the preceding disclosure will be discussed with the functions thereof.

Fig. 3 shows a flowchart of a fuel injection pulse setting routine for setting a fuel injection pulse width Ti in the input/output unit **108** of the control unit **100**. The fuel injection pulse width Ti setting routine may be triggered at every given timing for updating fuel injection pulse width data Ti in the input/output unit **108**.

At a step **1002**, the throttle angle indicative signal value θ_{th} and the engine speed data N are read out. With the throttle angle indicative signal value θ_{th} and the engine speed data N as read at the step **1002**, search is performed against an intake air flow rate map stored in a memory block **130** of ROM **104** to project an intake air flow rate indicative data Q, which map will be hereafter referred to as "Q map", at a step **1004**.

In practice, the Q map contains various intake flow rate indicative data Q, each of which data is accessible in terms of the throttle angle indicative signal value θ_{th} and the engine speed data N. Each of the intake air flow rate indicative data Q is determined through experimentation. Relationship between the throttle angle indicative data θ_{th}, the engine speed data N and the intake air flow rate Q is as shown in the block representing the step **1004**.

Based on the engine speed data N as read at the step **1002** and the intake air flow rate indicative data Q as projected at the step **1004**, the basic fuel injection amount Tp is derived at a step **1006**. Practically, the basic fuel injection amount Tp can be calculated by the following equation:

$$Tp = K \times Q/N$$

where K is constant

At a step **1008**, correction coefficients COEF is set. In practice, the correction coefficient COEF to be set here is constituted by an engine coolant temperature dependent component which will be hereafter referred to as "Tw correction coefficient", an engine start-up acceleration enrichment component which will be hereafter referred to as "start-up enrichment correction coefficient", an acceleration enrichment component which will be hereafter referred to as "acceleration enrichment correction coefficient" and so forth. The Tw correction coefficient may be derived on the basis of the engine coolant temperature indicative signal Tw. The start-up enrichment correction coefficient may be derived in response to the ignition switch operated to a cranking position. In addition, the acceleration enrichment correction coefficient can be derived in response to an acceleration demand which may be detected from variation of the throttle angle indicative signal values. Manner of derivation of these correction coefficients are per se well known and unnecessary to be discussed in detail. For example, manner of derivation of the acceleration enrichment coefficient has been disclosed in the co-pending United States Patent Application Serial No. **115,371**, filed on November 2, 1987, assigned to the common assignee to the present invention, for example. The disclosure of the above-identified co-pending U. S. Patent Application is herein incorporated by reference for the sake of disclosure.

At a step **1010**, a correction coefficient K_{ALT} is read out. The correction coefficient K_{ALT} is stored in a given address of memory block **131** in RAM **106** and continuously updated through learning process. This correction coefficient will be applicable for air/fuel ratio control for maintaining the air/fuel ratio of the air/fuel mixture at a stoichiometric value at any engine driving range. Therefore, the correction coefficient K_{ALT} will be hereafter referred to as "air density dependent uniform correction coefficient". Furthermore, address of the memory block **131** storing the air density dependent uniform correction coefficient K_{ALT} will be hereafter referred to as "K_{ALT} address". At the initial stage before learning, the air density dependent uniform correction coefficient K_{ALT} is set at a value "0". After the process at the step **1010**, a correction coefficient K_{MAP} is determined by map

search in terms of the engine speed indicative data N and the basic fuel injection amount Tp, at a step **1012**. In the process of map search, the engine speed indicative data N and the basic fuel injection amount Tp are used as parameters identifying the engine driving range.

A map containing a plurality of mutually distinct correction coefficients K_{MAP} is stored in a memory block **132** RAM **106**. This map will be hereafter referred to as "K_{MAP} map". The K_{MAP} map storing memory block **132** is constituted by a plurality of memory addresses each storing individual correction coefficient K_{MAP}. Each memory block storing individual correction coefficient K_{MAP} is identified by known address which will be hereafter referred to as "K_{MAP} address". The K_{MAP} address to be accessed is identified in terms of the engine speed indicative data N and the basic fuel injection amount Tp. The correction coefficient K_{MAP} stored in each K_{MAP} address is determined in relation to the engine driving range defined by the engine speed data N and the fuel injection amount Tp and continuously updated through learning process. Therefore, this correction coefficient K_{MAP} will be hereafter referred to as "driving range based learnt correction coefficient". Imaginally, the K_{MAP} map is formed by setting the engine speed data N in x-axis and the basic fuel injection amount Tp in y-axis. The x-axis component is divided into a given number n_N of engine speed ranges. Similarly, the y-axis component is divided into a given number n_{Tp} of basic fuel injection ranges. Therefore, the K_{MAP} map is provided ($n_N \times n_{Tp}$) addresses. Practically, the x-axis component and y-axis component are divided into 8 ranges respectively. Therefore, 64 (8 x 8) addresses are formed to store the driving range based learnt correction coefficient respectively.

It should be noted that each K_{MAP} address in the K_{MAP} initially stores a value "0" before learning process is initiated.

At a step **1014**, a feedback correction coefficient K_{LAMBDA} is read out. Process of derivation of the feedback correction coefficient K_{LAMBDA} will be discussed later with reference to **Fig. 6**. At a step **1016**, a battery voltage dependent correction value Ts is set in relation to a voltage of the vehicular battery **21**.

Based on the basic fuel injection amount Tp derived at the step **1006**, the correction coefficient coefficient COEF derived at the step **1008**, the air density dependent uniform correction coefficient K_{ALT} read at the step **1010**, the driving range based learnt correction coefficient K_{MAP} derived at the step **1012**, the feedback correction coefficient K_{LAMBDA} read at the step **1014** and the battery voltage dependent correction value Ts set at the step **1016**, a fuel injection amount Ti is calculated

at a step **1018** according to the following equation:

$$Ti = Tp \times COEF \times (K_{LAMBDA} + K_{ALT} + K_{MAP}) + Ts$$

A fuel injection pulse width data corresponding to the fuel injection amount Ti derived at the step **1018**, which will be hereafter referred to as "Ti data", is set in the input/out unit **108**.

Fig. 4 shows one example of construction of part of the input/output unit **108** which is used for controlling fuel injection timing and fuel injection amount according to the set Ti data.

Fig. 4 shows detailed construction of the relevant section of the input/output unit **108**. The input/output unit **108** has a fuel injection start timing control section **124**. The fuel injection start timing control section **124** has an angle (ANG) register **121**, to which a fuel injection start timing derived by CPU during process of fuel injection control data, e.g. the air flow rate, throttle angle position, the engine speed and so forth. The fuel injection start timing control section **124** also has a crank position signal counter **122**. The crank position signal counter **122** is designed to count up the crank position signals θ_{pos} and to be reset in response to the crank reference signal θ_{ref}. A comparator **123** is also provided in the fuel injection start timing control section **124**. The comparator **123** compares the fuel injection start timing indicative value set in the ANG register **121** and the crank position signal counter value in the counter **122**. The comparator **123** outputs HIGH level comparator signal when the crank position signal counter value becomes the same as that of the fuel injection start timing indicative value. The HIGH level comparator signal of the comparator **123** is fed to a fuel injection pulse output section **127**.

The fuel injection pulse output section **130** has a fuel injection pulse generator **127a**. The fuel injection pulse generator **127a** comprises a fuel injection (EGI) register **125**, a clock counter **126**, a comparator **128** and a power transistor **129**. A fuel injection pulse width data which is determined through data processing during execution of fuel injection control program to be discussed later, is set in the EGI register **125**.

The output of the comparator **123** is connected to the clock counter **126**. The clock counter **126** is responsive to the leading edge of HIGH level output of the comparator to be reset. On the other hand, the clock counter **126** is connected to a clock generator **112** in the control unit **100** to receive therefrom a clock pulse. The clock counter **126** counts up the clock pulse as triggered by the HIGH level gate signal. At the same time, the comparator **128** is triggered in response to resetting of the clock counter **126** to output HIGH level comparator signal to the base electrode of the power transistor

129. The power transistor **129** is thus turned ON to open the fuel injection valve **6** to perform furl injection.

When the counter value of the clock counter **126** reaches the fuel injection pulse width value set in the EGI register **125**, the comparator signal of the comparator **128** turns into LOW level to turn OFF the power transistor **129**. By turning OFF of the power transistor **129**, the fuel injection valve **4** closes to terminate fuel injection.

The ANG register **121** in the fuel injection start timing control section **124** updates the set fuel injection start timing data at every occurrence of the crank reference signal θ_{ref}.

With this arrangement, fuel injection starts at the timing set in the ANG register **121** and is maintained for a period as set in the EGI register **125**. By this, the fuel injection amount can be controlled by adjusting the fuel injection pulse width.

Fig. 5 shows a routine governing control mode to switch the mode between FEEDBACK control mode and OPEN LOOP control mode based on the engine driving condition. Basically, FEEDBACK control of air/fuel ratio is taken place while the engine is driven under load load and at low speed and OPEN LOOP control is performed otherwise. In order to selectively perform FEEDBACK control and OPEN LOOP control, the basic fuel injection amount Tp is taken as a parameter for detecting the engine driving condition. For distinguishing the engine driving condition, a map containing FEED-BACK condition indicative criteria Tp_{ref} is set in a memory block **133** of ROM **104**. The map is designed to be searched in terms of the engine speed N, at a step **1102**. The FEEDBACK condition indicative criteria set in the map are experimentarily obtained and define the engine driving range to perform FEEDBACK control, which engine driving range is explanatorily shown by the hatched area of the map illustrated within the process block **1102** of **Fig. 5**.

At a step **1104**, the basic fuel injection amount Tp derived in the process of the step **1006** is then compared with the FEEDBACK condition indicative criterion Tp_{ref}, at a step **1104**. When the basic fuel injection amount Tp is smaller than or equal to the FEEDBACK condition indicative criterion Tp_{ref} as checked at the step **1104**, a delay timer **134** in the control unit **100** and connected to a clock generator **135**, is reset to clear a delay timer value t_{DELAY}, at a step **1106**. On the other hand, when the basic fuel injection amount Tp is greater than the FEEDBACK condition indicative criterion Tp_{ref} as checked at the step **1104**, the delay timer value t_{DELAY} is read and compared with a timer reference value t_{ref}, at a step **1108**. If the delay timer value t_{DELAY} is smaller than or equal to the timer reference value t_{ref}, the engine speed data N is read and compared with an engine speed reference N_{ref}, at a step **1110**. The engine speed reference N_{ref} represents the engine speed criterion between high engine speed range and low engine speed range. Practically, the engine speed reference N_{ref} is set at a value corresponding to a high/low engine speed criteria, e.g. 3800 r.p.m. When the engine speed indicative data N is smaller than the engine speed reference N_{ref}, or after the step **1106**, a FEEDBACK condition indicative flag $FL_{FEEDBACK}$ which is to be set in a flag register **136** in the control unit **100**, is set at a step **1112**. When the delay timer value t_{DELAY} is greater than The timer reference value t_{ref}, a FEED-BACK condition indicative flag $FL_{FEEDBACK}$ is reset, at a step **1114**. After one of the step **1112** and **1114**, process goes END and is returned to a background job which governs execution of various routines.

By providing the delay timer to switch mode of control between FEEDBACK control and OPEN LOOP control, hunting in selection of the control mode can be successfully prevented. Furthermore, by providing the delay timer for delaying switching timing of control mode from FEEDBACK control to OPEN LOOP mode, FEEDBACK control can be maintained for the period of time corresponding to the period defined by the timer reference value. This expands period to perform FEEDBACK control and to perform learning.

For example, during hill or mountain climbing, FEEDBACK control can be maintained for the given period corresponding to the set delay time to learning of correction coefficient for adapting the air/fuel ratio to the air density even though the engine driving condition is in transition state.

Fig. 6 shows a routine for deriving the feedback correction coefficient K_{LAMBDA}. The feedback correction coefficient K_{LAMBDA} is composed of a proportional (P) component and an integral (I) component. The shown routine is triggered every given timing, i. e. every 10 ms., in order to regularly update the feedback control coefficient K_{LAMBDA}. The feedback control coefficient K_{LAMBDA} is stored in a memory block **137** and cyclically updated during a period in which FEEDBACK control is performed.

At a step **1202**, the FEEDBACK condition indicative flag $FL_{FEEDBACK}$ is checked. When the FEED-BACK condition indicative flag $FL_{FEEDBACK}$ is not set as checked at the step **1202**, which indicates that the on-going control mode is OPEN LOOP. Therefore, process directly goes END. At this occasion, since the feedback correction coefficient K_{LAMBDA} is not updated, the content in the memory block **137** storing the feedback correction coefficient is held in unchanged.

When the FEEDBACK condition indicative flag

FL$_{FEEDBACK}$ is set as checked at a step **1202**, the oxygen concentration indicative signal V$_{ox}$ from the oxygen sensor **20** is read out at a step **1204**. The oxygen concentration indicative signal value V$_{ox}$ is then compared with a predetermined rich/lean criterion V$_{ref}$ which corresponding to the air/fuel ratio of stoichiometric value, at a step **1206**. In practice, in the process, judgment is made that the air/fuel mixture is lean when the oxygen concentration indicative signal value V$_{ox}$ is smaller than the rich/lean criterion V$_{ref}$, a lean mixture indicative flag FL$_{LEAN}$ which is set in a lean mixture indicative flag register **138** in the control unit **100**, is checked at a step **1208**.

On the other hand, when the lean mixture indicative flag FL$_{LEAN}$ is set as checked at the step **1208**, a counter value C of a faulty sensor detecting timer **148** in the control unit **100** is incremented by one (1), at a step **1210**. The counter value C will be hereafter referred to as "faulty timer value". The, the faulty timer value C is compared with a preset faulty timer criterion C$_0$ which represents acceptable maximum period of time to maintain lean mixture indicative O$_2$ sensor signal while the oxygen sensor **20** operates in normal state, at a step **1212**. When the faulty timer value C is smaller than the faulty timer criterion C$_0$, the rich/lean inversion indicative flag FL$_{INV}$ is reset at a step **1214**. Thereafter, the feedback correction coefficient K$_{LAMBDA}$ is updated by adding a given integral constant (I constant), at a step **1216**. On the other hand, when the faulty timer value C as checked at the step **1212** is greater than or equal to the faulty timer criterion C$_0$, a faulty sensor indicative flag FL$_{ABNORMAL}$ is set in a flag register **156** at a step **1218**. After setting the faulty sensor indicative flag FL$_{ABNORMAL}$ process goes END.

On the other hand, when the lean mixture indicative flag FL$_{LEAN}$ is not set as checked at the step **1208**, fact of which represents that the air/fuel mixture ratio is adjusted changed from rich to lean, an rich/lean inversion indicative flag FL$_{INV}$ which is set in a flag register **139** in the control unit **100**, is set at a step **1220**. Thereafter, a rich mixture indicative flag FL$_{RICH}$ which is set in a flag register **139**, is reset and the lean mixture indicative flag FL$_{LEAN}$ is set, at a step **1222**. Thereafter, the faulty timer value C in the faulty sensor detecting timer **148** is reset and the faulty sensor indicative flag FL$_{ABNORMAL}$ is reset, at a step **1224**. Then, the feedback correction coefficient K$_{LAMBDA}$ is modified by adding a proportional constant (P constant), at a step **1226**.

On the other hand, when the oxygen concentration indicative signal value V$_{ox}$ is greater than the rich/lean criterion V$_{ref}$ as checked at the step **1206**, a rich mixture indicative flag FL$_{RICH}$ which is set in a rich mixture indicative flag register **141** in

the control unit **100**, is checked at a step **1228**.

When the rich mixture indicative flag FL$_{RICH}$ is set as checked at the step **1228**, the counter value C of the faulty sensor detecting timer **148** in the control unit **100** is incremented by one (1), at a step **1230**. The, the faulty timer value C is compared with the preset faulty timer criterion C$_0$, at a step **1232**. When the faulty timer value C is smaller than the faulty timer criterion C$_0$, the rich/lean inversion indicative flag FL$_{INV}$ is reset at a step **1234**. Thereafter, the feedback correction coefficient K$_{LAMBDA}$ is updated by subtracting the I constant, at a step **1236**.

On the other hand, when the faulty timer value C as checked at the step **1232** is greater than or equal to the faulty timer criterion C$_0$, a faulty sensor indicative flag FL$_{ABNORMAL}$ is set at a step **1238**. After setting the faulty sensor indicative flag FL$_{ABNORMAL}$ process goes END.

When the rich mixture indicative flag FL$_{RICH}$ is not set as checked at the step **1228**, fact of which represents that the air/fuel mixture ratio is just changed from lean to rich, an rich/lean inversion indicative flag FL$_{INV}$ which is set in a flag register **139** in the control unit **100**, is set at a step **1240**. Thereafter, a rich mixture indicative flag FL$_{LEAN}$ is reset and the rich mixture indicative flag FL$_{RICH}$ is set, at a step **1242**. Thereafter, the faulty timer value C in the faulty sensor detecting timer **148** is reset and the faulty sensor indicative flag FL$_{ABNORMAL}$ is reset, at a step **1244** Then, the feedback correction coefficient K$_{LAMBDA}$ is modified by subtracting the P constant, at a step **1246**.

After one of the process of the steps **1216**, **1218, 1226, 1236, 1238** and **1246**, process goes to the END.

It should be noted that, in the shown embodiment, the P component is set at a value far greater than that of I component.

Fig. 7 shows a learning governing routine for selectively updating air density dependent uniform correction coefficient K$_{ALT}$ and the driving range based learnt correction coefficient K$_{MAP}$. Since learning of the correction coefficients K$_{ALT}$ and K$_{MAP}$ can be performed only when the FEEDBACK control is performed. The FEEDBACK condition indicative flag FL$_{FEEDBACK}$ is checked at a step **1302**. When the FEEDBACK condition indicative flag FL$_{FEEDBACK}$ is not set as checked at the step **1302**, a K$_{ALT}$ learning cycle counter value C$_{ALT}$ in a K$_{ALT}$ counter **149** in RAM **106** and a K$_{MAP}$ learning cycle counter value C$_{MAP}$ in a K$_{MAP}$ counter **142** are cleared at a step **1304** and thereafter process goes END.

On the other hand, when the FEEDBACK condition indicative flag FL$_{FEEDBACK}$ as checked at the step **1302** is set, a throttle angle reference value θth$_{ref}$ is derived on the basis of the engine speed

data N, at a step **1306**. The throttle angle reference value θth_{ref} is set in a form of a table data to be read in terms of the engine speed N. Each value of the throttle angle reference value θth_{ref} is representative of high engine load condition criteria at respective engine speed range, above which the intake air flow rate Q is held unchanged. Namely, when the throttle angle position θ_{th} is greater than or equal to the throttle angle reference value θth_{ref}, the air flow rate is held substantially unchanged. In such engine driving condition, air density dependent uniform correction coefficient K_{ALT} isto be updated. The throttle angle reference value θth_{ref} will be hereafter referred to as "Q flat range threshold".

At a step **1308**, the throttle angle indicative signal value θ_{th} is compared with the Q flat range threshold θth_{ref} derived at the step **1306**. If the throttle angle indicative signal value θ_{th} is greater than or equal to the Q flat range threshold θth_{ref},another throttle angle reference value $\theta th_{inhibit}$ is derived in terms of the engine speed data N at a step **1310**. In the practice, the throttle angle reference value $\theta th_{inhibit}$ represents substantially high engine load range where flow velocity of the intake is lowered to make distribution of the air/fuel mixture worse. This may cause substantial fluctuation of the air/fuel ratio to cause significant variation of the oxygen concentration indicative signal value V_{ox}. Therefore, when the throttle angle indicative signal value θ_{th} is greater than or equal to this throttle angle reference value $\theta th_{inhibit}$, updating of the air density dependent uniform correction coefficient K_{ALT} is better not to be performed. This throttle angle reference value $\theta th_{inhibit}$ as derived at the step **1310**, will be hereafter referred to as "learning inhibiting threshold".

At a step **1312**, the throttle angle indicative signal value θ_{th} is compared with the learning inhibiting threshold $\theta th_{inhibit}$. When the the throttle angle indicative signal value θ_{th} is smaller than or equal to the learning inhibiting threshold $\theta th_{inhibit}$,check is performed whether a timer value t_{ACC} of a timer **150** in the control unit **100** is greater than or equal to a timer reference value t_{enable}, at a step **1314**. The timer reference value t_{enable} represents possible maximum period required after recovery of stability after rapid acceleration. Namely, during rapid acceleration, part of the fuel injection through the fuel injection valve **6** flows on the inner periphery of the induction passage to influence of stability of the air/fuel ratio. This peripheral flow of the fuel may be maintained even after termination of the engine acceleration. Therefore, in order to avoid influence of unstability of the air/fuel radio during the engine acceleration period and subsequent period required for stabilization, it is better not to perform learning of the air density dependent uni-

form correction coefficient K_{ALT}.

When the timer value t_{ACC} is greater than or equal to the timer reference value t_{enable} as compared at, the K_{MAP} learning cycle counter value C_{MAP} is cleared at the step **1316**. Then, at a step **1318**, K_{ALT} learning sub-routine of **Fig. 8** is triggered.

On the other hand, when the throttle angle indicative signal value θ_{th} is smaller than the Q flat range threshold θth_{ref} as checked at the step **1308**, when the throttle angle indicative signal value θ_{th} is greater than the learning inhibiting threshold $\theta th_{inhibit}$ or when the timer value t_{ACC} is smaller than the timer reference value t_{enable}, the K_{ALT} learning cycle counter value C_{ALT} is cleared at a step **1320** and then a K_{MAP} learning sub-routine of **Fig. 9** id triggered at a step **1322**.

Fig. 8 shows the K_{ALT} learning sub-routine to be triggered at the step **1318** of the learning governing routine of **Fig. 7**. Here, as will be seen from **Fig. 13**, K_{ALT} learning is performed in the hatched area which is defined by the throttle angular position θ_{th}' the intake air flow rate Q and the engine speed. In the shown embodiment, the air density dependent uniform correction coefficient K_{ALT} is updated every occurrence of inversion of polarity of the oxygen concentration indicative signal V_{ox}. Therefore, immediately after execution of the sub-routine of **Fig. 8**, the rich/lean inversion indicative flag FL_{INV} which is set and reset through the steps **1214**, **1220**, **1234** and **1244** of the routine of **Fig. 6**, is checked, at a step **1402**, so as to detect whether inversion of the rich/lean of the air/fuel mixture occurs or not. When the rich/lean inversion indicative flag FL_{INV} is not set as checked at the step **1402**, an updating indicative flag FL_{UPDATE} to be set in a flag register **155** of the control unit **100**, is reset, at a step **1404**. Thereafter, the process directly goes END and returns to the background job. On the other hand, when the rich/lean inversion indicative flag FL_{INV} is set as checked at the step **1402**, the K_{ALT} learning cycle counter value C_{ALT} is incremented by one (1) at a step **1406**. Then, the K_{ALT} learning cycle counter value C_{ALT} is checked at a step **1408**. When the K_{ALT} learning cycle counter value C_{ALT} is 1 or 2 as checked at the step **1408**, process goes to the step **1404** to reset the updating indicative flag FL_{UPDATE}.Thereafter, process goes END. This is required for obtaining reliable air density dependent uniform correction coefficient K_{ALT} by deriving the coefficient based on a greater number of the feedback correction coefficient K_{LAMBDA}.

When the K_{ALT} learning cycle counter value C_{ALT} is 3, a first correction coefficient error value $ELAMBDA_1$ is derived at a step **1410**. The first correction coefficient error value $ELAMBDA_1$ represents a difference between the feedback correction

coefficient K_{LAMBDA} and a coefficient reference value $LAMBDA_{ref}$, e.g. 1, and is temporarily stored in a memory block **143** of RAM **106**. After this the updating flag FL_{UPDATE} is reset at a step **1412**. Thereafter, process goes END.

It should be appreciated that, as shown in **Fig. 10**, first and second correction coefficient error value $ELAMBDA_1$ and $ELAMBDA_2$ represents upper and lower peaks of difference of the feedback correction coefficient K_{LAMBDA} and the reference value, which peak values appear at zero-crossing of the the oxygen concentration indicative signal value V_{ox}.

On the other hand, when the K_{ALT} learning cycle counter value C_{ALT} is greater than or equal to 4, the second correction coefficient error value $ELAMBDA_2$ is derived on the basis of the instantaneous feedback correction coefficient K_{LAMBDA} and the coefficient reference value $LAMBDA_{ref}$, at a step **1412**. An average value $LAMBDA_{ave}$ of the first and second correction coefficient error values $ELAMBDA_1$ and $ELAMBDA_2$ is then calculated at a step **1416**.

At a step **1418**, the relevant air density dependent uniform correction coefficient K_{ALT} is read in terms of the engine speed data N and the basic fuel injection value Tp. Based on the average value $LAMBDA_{ave}$ derived at the step **1416**, read relevant air density dependent uniform correction coefficient K_{ALT} asread at the step **1418**, is modified, at a step **1420**. Modification of the engine driving range based correction coefficient K_{ALT} is performed by:

$$K_{ALT}' = K_{ALT} + M_{ALT} \times LAMBDA_{ave}$$

where K_{ALT}' is a modified correction coefficient; and

M_{ALT} is a constant determining the correction coefficient K_{ALT} modification rate, which is set in a value range of $0 < M_{ALT} < 1$.

The modified correction coefficient K_{ALT}' is temporarily stored in a temporary register **144**. After the step **1420**, the updating indicative flag FL_{UPDATE} is set at a step **1422** and the second correction coefficient error value $ELAMBDA_2$ is set in the memory block **143** as the first correction coefficient error value $ELAMBDA_1$ for next cycle of execution, at a step **1424**. Then, K_{ALT} learning counter value L_{KALT} in a K_{ALT} learning counter **151** in RAM **106** is incremented by 1, at a step **1426**. After the step **1426**, process goes END.

By providing the updating counter C_{ALT}, updating of the correction coefficient K_{ALT} in the K_{ALT} map is performed only when the learning routine is repeated four cycles or more under substantially the same engine driving condition in the same engine driving range.

Fig. 9 shows a process for learning the engine driving range based learnt correction coefficient

K_{MAP}. As set forth above, learning of the correction coefficient is performed only when the control mode is FEEDBACK mode. Therefore, at a step **1502**, check is performed whether the FEEDBACK condition indicative flag $FL_{FEEDBACK}$ is set or not. If the FEEDBACK condition indicative flag $FL_{FEEDBACK}$ is set as checked at the step **1502**, check is performed whether the engine speed data N and the basic fuel injection amount Tp identifies the same engine driving range as that identified in the former execution cycle, at a step **1504**. In practice, check in the step **1504** is performed by comparing the address data identifying corresponding memory block in the K_{MAP} map. The address data identified by the engine speed data N and the basic fuel injection amount Tp is temporarily stored in a memory block **141** of RAM **106**. When FEEDBACK condition indicative flag $FL_{FEEDBACK}$ is not set as checked at the step **1502** or when the address data as compared at the step **1504** do no match with the address data stored in the memory block **141** which means that the engine speed data N and the basic fuel injection amount Tp identifies different engine driving range than that identified in the former execution cycle, an updating counter **142** in the control unit **100** is reset to clear the K_{MAP} learning cycle counter value C_{MAP}, at a step **1506**. At a step **1508**, the updating indicative flag FL_{UPDATE} is reset.

On the other hand, when the address data compared the address data stored in the memory block **142** matches with the latter, the inversion indicative flag FL_{INV} is checked at a step **1510**. When the inversion indicative flag FL_{INV} is not set as checked at the step **1510**, process goes to the step **1508** to reset the updating indicative flag FL_{UPDATE}.

When the inversion indicative flag FL_{INV} is set as checked at the step **1510**, the K_{MAP} learning cycle counter C_{MAP} is incremented by 1, at a step **1512**. After this, the K_{MAP} learning cycle counter value C_{MAP} is checked at a step **1514**. This K_{MAP} learning cycle counter C_{MAP} serves to count up occurrence of updating of updating of the feedback correction coefficient K_{LAMBDA} while the engine driving range is held in the one range.

When the K_{MAP} learning cycle counter value C_{MAP} is 1 or 2, process goes to the step **1508**. On the other hand, when the K_{MAP} learning cycle counter value C_{MAP} is 3, a first correction coefficient error value $ELAMBDA_1$ is derived at a step **1516**. The first correction coefficient error value ELAMBDA represents a difference between the feedback correction coefficient K_{LAMBDA} and a coefficient reference value $LAMBDA_{ref}$, e.g. 1, and is temporarily stored in a memory block **143** of RAM **106**. After this the updating flag FL_{UPDATE} is reset at a step **1518**.

After the process at the step **1508** or **1518**, process goes END.

On the other hand, when the K_{MAP} learning cycle counter value C_{MAP} is greater than or equal to 4, a second correction coefficient error value $ELAMBDA_2$ is derived on the basis of the instantaneous feedback correction coefficient K_{LAMBDA} and the coefficient reference value $LAMBDA_{ref}$, at a step **1520**. An average value $LAMBDA_{ave}$ of the first and second correction coefficient error values $ELAMBDA_1$ and $ELAMBDA_2$ is then calculated at a step **1522**.

At a step **1524**, the engine driving range based learnt correction coefficient K_{MAP} is read in terms of the engine speed data N and the basic fuel injection value Tp. At a step **1526**, the K_{ALT} learning counter value L_{KALT} is read out from the K_{ALT} learning counter **151** and compared with a K_{ALT} learning threshold value $LKALT_{ref}$. When the K_{ALT} learning counter value L_{KALT} is greater than or equal to the K_{ALT} learning threshold $LKALT_{ref}$, a K_{MAP} modification rate indicative constant M_{MAP} is set at a given first value, at a step **1528**. On the other hand, when the K_{ALT} learning counter value L_{KALT} is smaller than the K_{ALT} learning threshold $LKALT_{ref}$, a K_{MAP} modification rate indicative constant M_{MAP} is set at a given second value which is smaller than the first value at a step **1530**.

Based on the average value $LAMBDA_{ave}$ derived at the step **1522** and the K_{MAP} modification rate indicative constant M_{MAP} as derived at the step **1528** or **1530**, data of the engine driving range based learnt correction coefficient K_{MAP} as read at the step **1524**, is modified, at a step **1532**. Modification of the engine driving range based correction coefficient K_{MAP} is performed by:

$$K_{MAP}' = K_{MAP} + M_{MAP} \times LAMBDA_{ave}$$

where K_{MAP}' is a modified correction coefficient.

The modified correction coefficient K_{MAP}' is temporarily stored in a temporary register **144**. After the step **1532**, the updating indicative flag FL_{UPDATE} is set at a step **1534** and the second correction coefficient error value $ELAMBDA_2$ is set in the memory block **143** as the first correction coefficient error value $ELAMBDA_1$ for next cycle of execution, at a step **1536**.

By providing the K_{MAP} learning cycle counter C_{MAP}, updating of the correction coefficient K_{MAP} in the K_{MAP} map is performed only when the learning routine is repeated four cycles or more under substantially the same engine driving condition in the same engine driving range.

Fig. 11 shows a routine for automatically modifying the learnt uniform correction coefficient K_{ALT} during engine driving at substantially high engine speed and high engine load condition. Such auto-

matic modification of the air density dependent uniform correction coefficient K_{ALT} becomes necessary when the engine is held at high speed and high load condition where FEEDBACK control is held inactive for a long period of time. Such engine driving condition tends to appear during hill or mountain climbing, for example.

Immediately after starting execution, the faulty sensor indicative flag $FL_{ABNORMAL}$ is checked at a step **1602**. When the faulty sensor indicative flag $FL_{ABNORMAL}$ is set as checked at the step **1602**, a FEEDBACK OFF timer value TIM of a FEEDBACK OFF timer **152** is cleared at a step **1604**. Thereafter, process goes END.

On the other hand, when the faulty sensor indicative flag $FL_{ABNORMAL}$ is not set as checked at the step **1602**, the engine speed data N and the engine load data Tp are checked so as to check whether the engine is driven in high speed and high load condition, at a step **1606**. In the practice, distinction of the engine driving condition is performed with respect to the air/fuel ratio FEEDBACK control criteria set with respect to the engine speed N and the engine load indicative basic fuel injection amount value Tp, as shown in **Fig. 12**. As will be seen from **Fig. 12**, when the engine driving condition as defined by the engine speed data N and the engine load Tp is out of the hatched region where air/fuel ratio FEEDBACK control is to be performed, judgement is to be made that the engine is in high speed and high load range. In the chart of **Fig. 12**, the high speed and high load range is set to include part of the engine medium speed and medium load range which is possible to perform air/fuel ratio FEEDBACK control and thus is possible to perform K_{ALT} learning during driving in high altitude area.

When the engine driving condition as checked at the step **1606** is not the high speed and high load range, process goes to the step **1604** and subsequently goes END. On the other hand, when the engine driving condition is within high speed and high load range, the FEEDBACK OFF timer value TIM is incremented by one (1), at a step **1608**. Then, the FEEDBACK OFF timer value TIM is compared with a predetermined FEEDBACK OFF timer threshold TIM_{ref} at a step **1610**. If the FEEDBACK OFF timer value TIM is smaller than the FEEDBACK OFF timer threshold TIM_{ref} as checked at the step **1610**, process goes END. On the other hand, when the FEEDBACK OFF timer value TIM is greater than or equal to the FEEDBACK OFF timer threshold TIM_{ref}, a given value $KALT_{modi}$ is subtracted from the air density dependent uniform cirrection coefficient K_{ALT}, at a step **1612** for modification. After modifying the air density dependent uniform correction coefficient at the step **1612**, the FEEDBACK OFF timer value TIM is

cleared at a step **1614**. Then, process goes END.

As will be appreciated herefrom, according to the shown process to be performed by the preferred embodiment of the air/fuel ratio control system, according to the invention, air density dependent uniform correction coefficient can be learnt even at high speed and high load engine driving condition so as to follow the air/fuel mixture ratio control to the air density at any environmental condition.

Figs. 14 and **15** shows a modification of the K_{MAP} learning routine, which modification is intended to divide correction coefficient error value ELAMBDA to be used in derivation of the engine driving range based learnt correction coefficient K_{MAP} into first altitude dependent component and second component depending on other factors in order to introduce fuzzy inference factor in air/fuel ratio control.

In **Figs. 14** and **15**, there is shown a sequence of routine for learning the engine driving range based learnt correction coefficient K_{MAP}. As set forth above, learning of the correction coefficient is performed only when the control mode is FEEDBACK mode. Therefore, at a step **1702**, check is performed whether the FEEDBACK condition indicative flag $FL_{FEEDBACK}$ is set or not. If the FEEDBACK condition indicative flag $FL_{FEEDBACK}$ is set as checked at the step **1702**, check is performed whether the engine speed data N and the basic fuel injection amount Tp identifies the same engine driving range as that identified in the former execution cycle, at a step **1704**. In practice, check in the step **1704** is performed by comparing the address data identifying corresponding memory block in the K_{MAP} map. The address data identified by the engine speed data N and the basic fuel injection amount Tp is temporarily stored in a memory block **141** of RAM **106**. When FEEDBACK condition indicative flag $FL_{FEEDBACK}$ is not set as checked at the step **1702** or when the address data as compared at the step **1704** do no match with the address data stored in the memory block **141** which means that the engine speed data N and the basic fuel injection amount Tp identifies different engine driving range than that identified in the former execution cycle, an updating counter **142** in the control unit **100** is reset to clear the K_{MAP} learning cycle counter value C_{MAP}, at a step **1706**. At a step **1708**, the updating indicative flag FL_{UPDATE} is reset.

On the other hand, when the address data compared the address data stored in the memory block **142** matches with the latter, the inversion indicative flag FL_{INV} is checked at a step **1710**. When the inversion indicative flag FL_{INV} is not set as checked at the step **1710**, process goes to the step **1708** to reset the updating indicative flag FL_{UPDATE}.

When the inversion indicative flag FL_{INV} is set as checked at the step **1710**, the K_{MAP} learning cycle counter C_{MAP} is incremented by 1, at a step **1712**. After this, the K_{MAP} learning cycle counter value C_{MAP} is checked at a step **1714**. This K_{MAP} learning cycle counter C_{MAP} serves to count up occurrence of updating of updating of the feedback correction coefficient K_{LAMBDA} while the engine driving range is held in the one range.

When the K_{MAP} learning cycle counter value C_{MAP} is 1 or 2, process goes to the step **1708**. On the other hand, when the K_{MAP} learning cycle counter value C_{MAP} is 3, a first correction coefficient error value $ELAMBDA_1$ is derived at a step **1716**. The first correction coefficient error value ELAMBDA represents a difference between the feedback correction coefficient K_{LAMBDA} and a coefficient reference value $LAMBDA_{ref}$, e.g. 1, and is temporarily stored in a memory block **143** of RAM **106**. After this the updating flag FL_{UPDATE} is reset at a step **1718**.

After the process at the step **1708** or **1718**, process goes END.

On the other hand, when the K_{MAP} learning cycle counter value C_{MAP} is greater than or equal to 4, a second correction coefficient error value $ELAMBDA_2$ is derived on the basis of the instantaneous feedback correction coefficient K_{LAMBDA} and the coefficient reference value $LAMBDA_{ref}$, at a step **1720**. An average value $LAMBDA_{ave}$ of the first and second correction coefficient error values $ELAMBDA_1$ and $ELAMBDA_2$ is then calculated at a step **1722**.

The average value $LAMBDA_{ave}$ may includes the first altitude dependent component and the second component depending upon other factors. Therefore, in the shown process, a ratio k of the first component versus the second component is derived through steps **1724** through **1734** which will be discussed later.

At the step **1724**, a throttle angle dependent first component ratio indicative value k_1 is derived in terms of the throttle angle indicative signal value θ_{th} utilizing a k_1 map **153** set in ROM **104**. This k_1 table **153** contains experimentarily obtained values, which becomes greater at greater throttle open angle range, as shown in the block of the step **1724** in **Fig. 15**. This k_1 value corresponds to membership coefficient in <u>fuzzy</u> inference. Since the influence to the air/fuel <u>ratio</u> fluctuation of error in fuel injection amount, error in measurement of the throttle angle position, tolerance of various components and so forth is relatively great in engine low load condition, the k_1 ratio representing ratio of the first altitude dependent component versus the second component depending on the other factor is held small. Since the influence of the second component to the air/fuel ratio fluctuation

becomes smaller in the engine high load range, the influence of the altitude become greater as shown.

Though the shown embodiment employs the throttle angle position as a factor representing the engine load condition, it may possible to take other equivalent factor, such as basic fuel injection amount Tp, the intake air flow rate Q. Furthermore, the k_1 value may also be derived in terms of a combination of the engine speed and the engine load.

At a step **1726**, number of K_{MAP} table areas which is recently updated is checked for a given number of most recently updated areas. In the process of the step **1726**, polarities of differences between previously set values and the updated values in respective of the K_{MAP} table areas to be checked, are detected. Namely, when the engine driving range based learnt correction coefficient K_{MAP} is increased in updating, the polarity of the difference becomes positive, and, on the other hand, when the the engine driving range based learnt correction coefficient K_{MAP} is decreased in updating, the polarity of the difference becomes negative. The area in which the positive difference is detected will be hereafter referred to as "positive difference area" and the area in which the negative difference is detected will be hereafter referred to as "negative difference area". In operation of the step **1726**, numbers of the positive difference areas and the negative difference areas are counted. One of the greater number of the positive difference area number and the negative difference area number is taken as a same difference polarity area number A_1. Based on the same difference polarity area number A_1 as derived at the step **1726**, a second component ratio indicative value k_2 is derived by utilizing a k_2 map **154** in ROM **104**, at a step **1728**. As will be seen in the block **1728** of **Fig. 15**, the second component ratio indicative value k_2 increases according to increasing of the same difference polarity area number A_1. Namely, during up-hill driving or down-hill driving, updating area tends to incline to one of the the positive difference areas and the negative difference area. For instance, during up-hill driving where altitude is gradually increased and air density is gradually decreased, number of the negative difference areas becomes substantially greater than that of the positive difference areas. On the other hand, during downhill driving, the number of positive difference areas is increased to be substantially greater than the negative difference area.

At a step **1730**, number of K_{MAP} areas having the same polarity with respect to a reference value (0). Namely, number of the positive polarity areas and number of the negative polarity areas are compared. Greater number of one of the positive polarity areas and the negative polarity areas will

be taken as same polarity area number A_2. Based on this same polarity area number A_2, a third component ratio indicative value k_3 is determined at a step **1732**, by utilizing k_3 map **154** set in ROM **104**. At the high altitude region, the air/fuel ratio tends to be richer due to lower air density to cause increasing of lean-side correction coefficient. Therefore, in such high altitude region, negative polarity area tends to be increased. In the alternative, at low altitude region, the air/fuel ratio tends to become leaner due to higher air density to require richer-side air/fuel ratio control. Therefore, in this region, positive polarity area is increased. In this view, the k_3 map is designed to increase the value according to increasing of the same polarity area number A_2.

After the step **1732**, an average component ratio value which serves as a fuzzy control coefficient k, is derived by obtaining average value of the first, second and third component ratio indicative values k_1, k_2 and k_3, at a step **1734**.

At a step **1736**, the air density dependent uniform correction coefficient K_{ALT} is read. Based on the average value $LAMBDA_{ave}$ derived at the step **1722** and the fuzzy control coefficient k as derived at the step **1734**, data of the air density dependent uniform correction coefficient K_{ALT} as read at the step **1736**, is modified, at a step **1738**. Modification of the air density dependent uniform correction coefficient K_{ALT} isperformed by:

$$K_{ALT}' = K_{ALT} + M_{ALT} \times LAMBDA_{ave} \times k$$

where K_{ALT}' is a modified correction coefficient.

The modified correction coefficient K_{ALT}' is temporarily stored in a temporary register **144**.

At a step **1740**, the engine driving range based learnt correction coefficient K_{MAP} is read in terms of the engine speed data N and the basic fuel injection value Tp. Based on the average value $LAMBDA_{ave}$ derived at the step **1722** and the fuzzy control coefficient k as derived at the step **1734**, data of the engine driving range based learnt correction coefficient K_{MAP} as read at the step **1740**, is modified, at a step **1742**. Modification of the engine driving range based correction coefficient K_{MAP} is performed by:

$$K_{MAP}' = K_{MAP} + M_{MAP} \times LAMBDA_{ave} \times (1 - k)$$

where K_{MAP}' is a modified correction coefficient.

The modified correction coefficient K_{MAP}' is temporarily stored in a temporary register **144**. After the step **1742**, the updating indicative flag FL_{UPDATE} is set at a step **1744** and the second correction coefficient error value $ELAMBDA_2$ is set in the memory block **143** as the first correction coefficient error value $ELAMBDA_1$ for next cycle of

execution, at a step **1746**.

By the modifies process shown in **Figs. 14** and **15**, fuzzy control feature can be introduced in learning of the air density dependent uniform correction coefficient K_{ALT}.

It should be appreciated that, though the shown embodiment takes three component ratio indicative values k_1, k_2 and k_3, fuzzy control feature may be introduced in derivation of the air density dependent uniform correction coefficient K_{ALT} by utilizing two of three values.

Claims

1. Method for controlling a mixture ratio of an air/fuel mixture for an engine, comprising the steps of:

   monitoring (1002) preselected basic first engine operation parameter to produce a first sensor signal indicative thereof;

   monitoring (1204) an air/fuel mixture ratio indicative parameter (V_{ox}) for producing a second sensor signal indicative of a deviation of the air/fuel mixture from a stoichiometric value;

   deriving (1002, 1006) a basic fuel metering amount (Tp) on the basis of said first sensor signal value;

   deriving (1008) an air/fuel ratio dependent correction factor (COEF) from said second sensor signal value;

   deriving (1610) a first correction coefficient (K_{ALT}) on the basis of said air/fuel ratio dependent correction factor (COEF), which first correction coefficient is commonly applicable for correcting said basic fuel metering amount (Tp) in all engine driving ranges, said step (1610) comprising the updating of the first correction coefficient (K_{ALT}) when a feedback condition is satisfied;

   deriving (1012) a second correction coefficient (K_{MAP}) which is variable depending upon the engine driving range on the basis of said air/fuel ratio dependent correction factor (COEF) and setting a plurality of second correction coefficients (K_{MAP}) for respective engine driving ranges and updating each of said second correction coefficients with an instantaneous value derived based on said air/fuel ratio dependent correction factor in the corresponding engine driving range;

   detecting (1002-1014) an engine driving condition on the basis of said first sensor values and governing said steps (1610, 1012) of deriving said first and second correction coefficients (K_{ALT}, K_{MAP}) depending upon the detected engine driving condition; and

   correcting (1018, 1020) said basic fuel metering amount (Tp) with said first and second correction coefficients (K_{ALT}, K_{MAP})

   characterized in

   that the step of deriving the first correction coefficient (K_{ALT}) further comprises the steps of:
   - determining (1724) a first component ratio indicative value (k1) based on at least one of an engine load indicative signal (α, Q), a basic fuel injection amount (Tp) and the engine speed (N);
   - determining a predetermined number of engine driving ranges for which the second correction coefficient (K_{MAP}) was recently updated;
   - detecting (1726) for each range the difference between a present second correction coefficient (K_{MAP}) and a previous one for distinguishing between positive difference regions, where the difference between the present and the previous second correction coefficient (K_{MAP}) for this region is positive, and negative difference regions;
   - determining (1726-1732) a second component ratio indicative value (k2) based on the number of positive and/or negative difference regions; and
   - modifying (1732-1736) the first correction coefficient (K_{ALT}) based on said first and second component ratio indicative values (k1, k2).

2. Method as claimed in claim 1, characterized in

   that the step of detecting second component ratio indicative value comprises the steps of:
   - counting (1726) the numbers of positive difference regions and negative difference regions, and
   - deriving (1728) the second component ratio indicative value (k2) based on the greater number (A1) among these numbers.

3. Method as claimed in claim 2, characterized by

the step of deriving a third component ratio indicative value (k3) based on the number (A2) of positive or negative difference regions having the same polarity as a reference value;

wherein the step of modifying the first correction coefficient (K_{ALT}) is also based on the third component ratio indicative value (K3).

4. Method as claimed in claim 3, characterized in

that the step of modifying the first correction coefficient (K_{ALT}) comprises:
- determining a fuzzy correction coefficient (K) based on said first, second and third component ratio indicative values (k1, k2, k3).

5. An air/fuel ratio control system comprising:

an air/fuel mixture induction system (6, 14) for introducing an intake air and a controlled amount (Ti) of fuel to an engine;

a first sensor means (15, 17) for monitoring a preselected basic first engine operation parameter to produce a first sensor signal indicative thereof;

a second sensor means (20) for monitoring a air/fuel mixture ratio indicative parameter for producing a second sensor signal indicative of deviation of the air/fuel mixture from a stoichiometric value;

third means (1002-1006) for deriving a basic fuel metering amount on the basis of said first sensor signal value;

fourth means (1008) for deriving an air/fuel ratio dependent correction factor (COEF) from said second sensor signal value;

fifth means (1610) for deriving a first correction coefficient (K_{ALT}) on the basis of said air/fuel ratio dependent correction factor (COEF), which first correction coefficient is commonly applicable for correction of said basic fuel metering amount in all engine driving ranges, said fifth means (1610) updating said first correction coefficient when a feedback condition is satisfied;

a sixth means (1012) for deriving a second correction coefficient (K_{MAP}) which is variable depending upon the engine driving range on the basis of said air/fuel ratio dependent correction factor (COEF), said sixth means setting

a plurality of said second correction coefficients (K_{MAP}) for respective engine driving ranges and updating each of said second correction coefficients with an instantaneous value derived based on said air/fuel ratio dependent correction factor in the corresponding engine driving range;

a seventh means (1002-1004) for detecting an engine driving condition on the basis of said first sensor signal values and governing said fifth and sixth means (1610, 1012) depending upon the detected engine driving condition; and

an eighth means (1018, 1020) for correcting said basic fuel metering amount with said first and second correction coefficients (K_{ALT}, K_{MAP});

characterized in

that said fifth means (1610) for deriving the first correction coefficient (K_{ALT}) further comprises:
- means (1724) for determining a first component ratio indicative value (k1) based on at least one of an engine load indicative signal (α, Q), a basic fuel injection amount (Tp) and the engine speed (N);
- means for determining a predetermined number of engine driving ranges for which the second correction coefficient (K_{MAP}) was recently updated;
- means (1726) for determining for each range the difference between a present second correction coefficient (K_{MAP}) and a previous one for distinguishing between positive difference regions, where the difference between the present and the previous second correction coefficient (K_{MAP}) for this region is positive, and negative difference regions;
- means (1726-1732) for determining the second component ratio indicative value (k2) based on the number of positive and/or negative difference regions; and
- means (1732-1736) for modifying the first correction coefficient (K_{ALT}) based on said first and second component ratio indicative values (k1, k2).

FIG.1

FIG.2

FIG.3

START

READ θ_{th} AND N — 1002

SEARCH MAP
DERIVE Q — 1004

DERIVE Tp — 1006

SET COEF — 1008

READ K_{ALT} — 1010

SEARCH MAP
DERIVE K_{MAP} — 1012

READ K_{LAMBDA} — 1014

SET K_{Ts} — 1016

CALCULATE Ti — 1018

SET Ti — 1020

END

FIG.4

FIG.5

START

SEARCH MAP
DERIVE Tp_{ref} — 1102

$Tp \leq Tp_{ref}$? — 1104   NO

YES

CLEAR t_{DELAY} — 1106

$t_{DELAY} > t_{ref}$? — 1108 $\leq$

$N \leq N_{ref}$? — 1110   >

>

$\leq$

SET $FL_{FEEDBACK}$ — 1112

RESET $FL_{FEEDBACK}$ — 1114

END

FIG.6

START

1202 — FL.$_{FEEDBACK}$ = 1 ?

1204 — READ V$_{ox}$

1206 — V$_{ox}$ < V$_{ref}$?

< >

FL$_{LEAN}$ = 1 ? — 1208

NO

YES

INCREMENT C BY 1 — 1210

C ≥ C$_0$? — 1212

YES

NO

1218 — SET FL$_{ABNORMAL}$

1220 — SET FL$_{INV}$

CLEAR FL$_{RICH}$ SET FL$_{LEAN}$ — 1222

CLEAR C RESET FL$_{ABNORMAL}$

1244

UPDATE K$_{LAMBDA}$ BY LAMBDA + P — 1226

1214 — RESET FL$_{INV}$

1216 — UPDATE K$_{LAMBDA}$ BY LAMBDA + I

FL$_{RICH}$ = 1 ?

1228

NO

YES

INCREMENT C BY 1 — 1230

1232 — C ≥ C$_0$? — YES

NO — 1238 — SET FL$_{ABNORMAL}$

1240 — SET FL$_{INV}$

CLEAR FL$_{LEAN}$ SET FL$_{RICH}$ — 1242

1234 — RESET FL$_{INV}$

1236 — UPDATE K$_{LAMBDA}$ BY LAMBDA − I

CLEAR C RESET FL$_{ABNORMAL}$

1244

UPDATE K$_{LAMBDA}$ BY LAMBDA − P — 1246

END

FIG.7

FIG.8

```
                    ┌──────────┐
                    │  START   │
                    └────┬─────┘
                         │
                         ▼                    1402
              ╱──────────────────╲
     NO      ╱                    ╲
   ◄─────────   FL_INV  = 1  ?    
             ╲                    ╱
              ╲──────────────────╱
                         │ YES
                         ▼
                ┌──────────────────┐    1404
                │ INCREMENT C_ALT  │
                │      BY 1        │
                └────────┬─────────┘
                         │            1314
                         ▼
    1.2     ╱──────────────────╲        4
  ◄─────────        C_ALT   ?    ─────────────┐
             ╲──────────────────╱             │
                    │ 3                        ▼                1414
  1406          1410│                   ┌──────────────┐
                    ▼                   │   DERIVE     │
 ┌──────────────┐ ┌──────────────┐      │  ELAMBDA_2   │
 │ RESET FL     │ │   DERIVE     │      └──────┬───────┘
 │   UPDATE     │ │  ELAMBDA_1   │   1416       ▼
 └──────┬───────┘ └──────┬───────┘     ┌──────────────┐
        │                │             │  CALCULATE   │
        │          1412  ▼             │  ELAMBDA_ave │
        │         ┌──────────────┐     └──────┬───────┘
        │         │ RESET FL     │  1418        ▼
        │         │   UPDATE     │     ┌──────────────┐
        │         └──────┬───────┘     │  READ K_ALT  │
        │                │             └──────┬───────┘
        │                │      1420           ▼
        │                │         ┌────────────────────┐
        │                │         │ UPDATE K_ALT  DATA │
        │                │         └──────────┬─────────┘
        │                │      1422           ▼
        │                │         ┌────────────────────┐
        │                │         │   SET FL_UPDATE    │
        │                │         └──────────┬─────────┘
        │                │      1424           ▼
        │                │         ┌────────────────────┐
        │                │         │  SET ELAMBDA_2     │
        │                │         │  AS ELAMBDA_1      │
        │                │    1426  └──────────┬─────────┘
        │                ▼                      ▼
        │          ┌──────────┐      ┌────────────────────┐
        └─────────►│   END    │      │ INCREMENT L_KALT   │
                   └──────────┘      │      BY 1           │
                                     └────────────────────┘
```

23

FIG.9

START

$FL_{FEEDBACK} = 1 ?$ — 1502

0 →

1 ↓

ARE N AND Tp SAME RANGE ? — 1504

NO → 1506

CLEAR C_{MAP}

YES ↓

$FL_{INV} = 1 ?$ — 1510

NO →

YES ↓

INCREMENT C_{MAP} BY 1 — 1512

C_{MAP} ? — 1514

1.2 →

3 ↓

4 →

1508 — RESET FL_{UPDATE}

1516 — DERIVE $ELAMBDA_1$

1518 — RESET FL_{UPDATE}

1520 — DERIVE $ELAMBDA_2$

1522 — CALCULATE $ELAMBDA_{ave}$

1524 — READ K_{MAP}

1526 — $L_{KALT} \leqq LKALT_{ref}$

1528 — SET M_{MAP} (first value)

1530 — SET M_{MAP} (second value)

1532 — UPDATE K_{MAP} DATA

1534 — SET FL_{UPDATE}

1536 — SET $ELAMBDA_2$ AS $ELAMBDA_1^2$

END

FIG.10

FIG.11

```
                    ┌─────────┐
                    │  START  │
                    └────┬────┘
                         │
                         ▼
            0      ╱◇◇◇◇◇◇◇◇◇◇◇◇◇╲      1602
       ◄──────────◇ FL          ◇
                   ◇   ABNORMAL =1 ? ◇
                    ╲◇◇◇◇◇◇◇◇◇◇◇◇◇╱
                         │ 1
                         ▼
           NO      ╱◇◇◇◇◇◇◇◇◇◇◇◇◇╲      1606
       ◄──────────◇  HIGH SPEED  ◇
                   ◇     AND      ◇
                   ◇  HIGH LOAD   ◇
                    ╲◇◇◇◇◇ ? ◇◇◇◇╱
                         │ YES
   1604                  ▼
  ┌──────────────┐   ┌──────────────────┐ 1608
  │   TIM ← 0    │   │  TIM ← TIM + 1   │
  └──────┬───────┘   └────────┬─────────┘
         │                    │
         │                    ▼
         │          ╱◇◇◇◇◇◇◇◇◇◇◇◇╲     1610
         │     ◄────◇ TIM : TIM   ◇
         │      <    ◇        ref ◇
         │           ╲◇◇◇◇◇◇◇◇◇◇◇╱
         │                │ ≥
         │                ▼
         │        ┌──────────────────┐ 1612
         │        │  UPDATE K        │
         │        │           ALT    │
         │        └────────┬─────────┘
         │                 │
         │                 ▼
         │        ┌──────────────────┐ 1614
         │        │    TIM ← 0       │
         │        └────────┬─────────┘
         │                 │
         └─────────────────┤
                           ▼
                      ┌─────────┐
                      │   END   │
                      └─────────┘
```

FIG.12

FIG.13

FIG. 14

```
                    START

                        │
                        ▼
                                      1702
         0    ╱────────────────────╲
    ◄─────────  FL        = 1 ?
              ╲   FEEDBACK          ╱
               ╲──────────────────╱
                        │ 1
                        ▼
                                        1704
         NO     ╱──────────────────────╲
  1706 ◄────────      ARE
                    N AND Tp SAME
                ╲    RANGE ?         ╱
                 ╲──────────────────╱
    ┌──────────┐          │ YES
    │ CLEAR C  │          ▼
    └──────────┘                    1710
         │       NO   ╱──────────────╲
         │   ◄────────   FL    = 1 ?
         │            ╲    INV        ╱
         │             ╲─────────────╱
         │                    │ YES
         │                    ▼
         │            ┌──────────────┐   1712
         │            │ INCREMENT C  │
         │            │    MAP  BY 1 │
         │            └──────────────┘
         │                    │
         │                    ▼
         │                          1714
         │  1.2   ╱──────────────────╲   4
         │ ◄──────    C      ?        ────────►
         │        ╲    MAP            ╱         1720
         │         ╲─────────────────╱    ┌──────────────┐
         │   1708       │ 3               │   DERIVE     │
         │          1716│                 │  ELAMBDA     │
         ▼              ▼                 │         2    │
 ┌──────────────┐ ┌──────────────┐        └──────────────┘
 │ RESET FL     │ │   DERIVE     │   1722         │
 │       UPDATE │ │  ELAMBDA     │          ┌──────────────┐
 └──────────────┘ │         1    │          │  CALCULATE   │
         │        └──────────────┘          │  ELAMBDA     │
         │            1718│                 │         ave  │
         │                ▼                 └──────────────┘
         │        ┌──────────────┐                 │
         │        │ RESET FL     │                 ▼
         │        │       UPDATE │               ( 1 )
         │        └──────────────┘
         │                │
         └────────────────┤
                          ▼
                        END
```

FIG.15

①

DERIVE K_1 — 1724

DERIVE A_1 — 1726

DERIVE K_2 — 1728

DERIVE A_2 — 1730

DERIVE K_3 — 1732

DERIVE K — 1734

READ K_{ALT} — 1736

UPDATE K_{ALT} DATA — 1738

READ K_{MAP} — 1740

UPDATE K_{MAP} DATA — 1742

SET FL_{UPDATE} — 1744

SET $ELAMBDA_2$ AS $ELAMBDA_1$ — 1746

END