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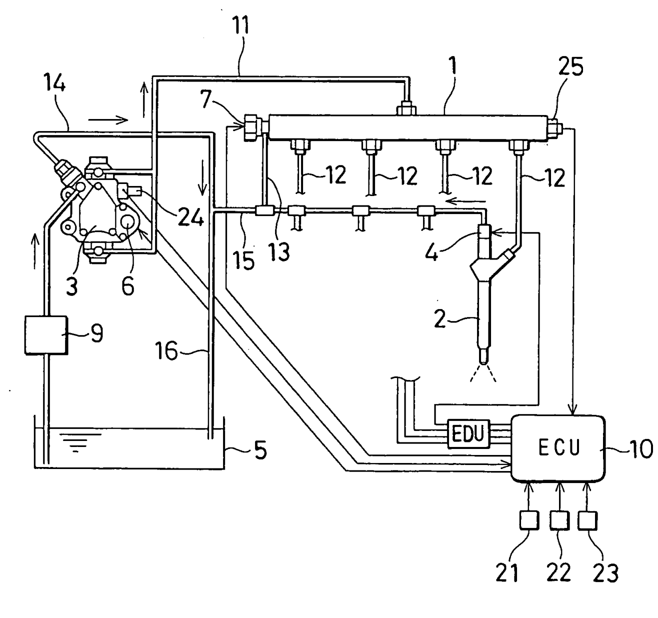
(54) **Operating condition learning control device for internal combustion engine**

(57) Learning control is carried out to learn and correct degradation in the functionality of a fuel supply pump (3) having a solenoid coil (6) for an engine. During the learning control, a temporary present learned value (ITL) to be utilized in the calculation of a target value of driving current applied to the solenoid coil is calculated. Thereafter, a final present learned value (IFL) is calculated by adding up a previous learned value (IPL) and the temporary present learned value (ITL). The final present learned value (IFL) is not immediately utilized in the calculation of the target value of driving current. Instead, the final present learned value is just stored in a memory in place of the previous learned value when the engine is stopped.

FIG. 1



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Description

[0001] The present invention relates to an operating condition learning control device for an internal combustion engine capable of carrying out learning control wherein degradation in the performance or variation in the characteristics of a fuel supply pump or fuel injection valves due to the individual specificity or aging change of the fuel supply pump or fuel injection valves.

[0002] Conventionally, fuel injection learning control devices for an internal combustion engine have been proposed (for instance, Patent Document 1: Japanese Patent laid-open publication No. 2001-82230, pages 1 to 18, FIGS. 1 to 20). A fuel injection learning control device for an internal combustion engine comprises, for example, a common rail which accumulates high-pressure fuel whose pressure is equivalent to the injection pressure of the fuel; fuel injection valves which inject the high-pressure fuel in the common rail into the cylinders of an internal combustion engine; a suction control-type fuel supply pump which pressurizes fuel, taken into a pressurizing chamber through a suction control valve, and feeds the fuel into the common rail under pressure; and a fuel pressure sensor which detects the pressure of the high-pressure fuel in the common rail.

[0003] The fuel injection learning control device controls the fuel pressure in the common rail as follows: a target discharge amount is calculated based on the pressure difference between a common rail pressure (actual fuel pressure) detected by the fuel pressure sensor and a target fuel pressure established according to the operating condition of the internal combustion engine. The target discharge amount is converted into a target driving current value using a predetermined coefficient of conversion. Then, the driving current of the target value is applied to the suction control valve. Thereby, the fuel pressure in the common rail is controlled.

[0004] In this case, there is a possibility that the actual fuel discharge amount greatly deviates from the target discharge amount for various reasons. Such reasons include degradation in the performance or variation in the characteristics of the fuel supply pump due to: variation in the opening shape of the suction control valve which may occur during manufacturing; differences from device to device (the individual specificity of the fuel supply pump or suction control valve), including variation in spring force from a spring member which biases the valve body of the suction control valve; or aging change. To cope with this, variation from device to device in the suction control characteristics (discharge amount characteristics) of suction control valves is learned and corrected to enhance the controllability with respect to the fuel pressure in the common rail.

[0005] However, the conventional control involves a problem. A learned value (learning control amount) is calculated during learning control. If this value is utilized in the calculation of a target driving current value immediately after learning and correction are carried out when the operating condition of the internal combustion engine is idle stable state (at the completion of the learning control) , as illustrated in FIG 7 (a), the stable state comes undone. As a result, a step is produced in control of the fuel pressure in the common rail, and the driver can feel something is wrong.

[0006] In the conventional control, this is coped with as follows: a learned value is calculated during learning control and then the status of control is changed from learning control state to normal control state. At this time, to reflect the learned value (learning control amount) calculated during the learning control into the calculation of a target driving current value, gradual change control, integral term clearing, or the like is adopted. Thereby, the driver is prevented from feeling something is wrong when a learned value is utilized.

[0007] However, this poses a problem. When the status of control is changed from learning control state to normal control state, superfluous and complicated control, such as gradual change control or integral term clearing, is carried out. This leads to increase in the number of relevant man-hours.

[0008] The object of the present invention is to provide an operating condition learning control device for an internal combustion engine wherein when the status of control is changed from learning control state to normal control state, a learned value can be utilized in the calculation of a basic control amount to be given to an operating condition changing means without carrying out superfluous or complicated control.

[0009] According to the present invention, during learning control wherein degradation in the performance or variation in the characteristics of the operating condition changing means due to the individual specificity or aging change of the operating condition changing means is learned and corrected, a learning control amount to be utilized in a basic control amount is calculated. In the present operation, however, the previous learned value stored in the learned value storing means is utilized in the calculation of a basic control amount. When or after the present operation of the internal combustion engine is stopped or when or before the next operation of the internal combustion engine is started, a value obtained by adding up a learning control amount and the previous learned value is stored into the learned value storing means, instead of the previous learned value.

[0010] Thus, a learning control amount is prevented from being utilized in operating condition changing control for changing the operating condition of an internal combustion engine immediately after the learning control amount is calculated during learning control. More specifically, the learning control amount is prevented from being utilized in the calculation of a basic control amount by the operating condition changing means. Thus, transient fluctuation is prevented from occurring when learning and correction are added to operating condition changing control wherein the operating condition of the internal combustion engine is changed. Specifically, the operating condition changing means is controlled based on the previous learned value. Thereby, it is made unnecessary to carry out superfluous and complicated control, such as gradual change control or integral term clearing, when the status of control is changed from learning control state to normal control state. As a result, drivability is enhanced.

[0011] The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

FIG. 1 is a schematic diagram illustrating the overall construction of a common rail-type fuel injection system provided with a fuel injection learning control device for an internal combustion engine;
FIG. 2 is a timing chart illustrating transition of a NE signal pulse, position of a plunger #1 of a supply pump, and position of a plunger #2 of the supply pump;
FIG. 3 is a flowchart illustrating the process of learned value calculation and learned value utilization;
FIG. 4 is a diagram illustrating the control logic of an ECU;
FIG. 5 (a) is a diagram illustrating the control logic of the ECU;
FIG. 5(b) is a diagram illustrating the waveform of SCV driving current;
FIG. 6 is a diagram illustrating the control logic of the ECU;
FIG. 7 (a) is a diagram illustrating conventional control wherein a learned value is utilized in the present operation; and
FIG. 7(b) is a diagram illustrating learning control wherein a learned value is utilized in the next operation.

[0012] FIG. 1 to FIG. 3 illustrate an embodiment of the present invention. FIG. 1 is a diagram illustrating the overall construction of a common rail-type fuel injection system provided with a fuel injection learning control device for an internal combustion engine.

[0013] The common rail-type fuel injection system in this embodiment comprises a common rail 1 which accumulates high-pressure fuel whose pressure is equivalent to the injection pressure of the fuel injected and supplied into each cylinder of an internal combustion engine, such as a four-cylinder diesel engine, mounted on, for example, a vehicle such as an automobile; a plurality (four units in this example) of electromagnetic fuel injection valves (injectors) 2 which are respectively connected with the common rail 1 and inject fuel into the respective cylinders of the engine; a fuel supply pump (supply pump) 3 which is rotationally driven by the engine; and an engine control device (engine control unit: hereafter, abbreviated as "ECU") 10 which electronically controls a plurality of the injectors 2 and the supply pump 3. FIG. 1 shows only one injector 2 corresponding to one cylinder of the four-cylinder engine, and the other cylinders are omitted from the figure.

[0014] The common rail 1 is required to continuously accumulate high-pressure fuel equivalent to the injection pressure of fuel. For this purpose, high-pressure fuel accumulated in the common rail 1 is supplied from the supply pump 3 through a high-pressure pipe 11. On the common rail 1, a normally closed pressure reducing valve 7 is installed which allows adjustment of the degree of opening of a fuel discharge path (fuel return path) 13 to fuel discharge paths (fuel return paths) 15 and 16 connecting to a fuel tank 5. In place of the pressure reducing valve 7, a pressure limiter may be installed between the common rail 1 and the fuel return path 13. The pressure limiter is for relieving the fuel pressure in the common rail 1 so as to prevent the fuel pressure from exceeding a preset pressure limit.

[0015] The pressure reducing valve 7 is an electromagnetic valve excellent in pressure reducing capability. The valve 7 is electronically controlled by a pressure reducing valve driving current applied from the ECU 10 through a pressure reducing valve drive circuit. Thereby, the valve 7 rapidly reduces the fuel pressure (common rail pressure) in the common rail 1 from high to low, for example, in deceleration or when the engine is stopped.

[0016] The pressure reducing valve 7 has a valve (valve body: not shown) which adjusts the opening of the fuel return path 13 for returning fuel from the common rail 1 to the fuel tank 5; a solenoid coil (electromagnetic coil: not shown) which drives the valve in the valve opening direction; and a valve biasing means (not shown), such as a spring, for biasing the valve in the valve closing direction. The pressure reducing valve 7 adjusts the return flow rate (pressure reducing valve flow rate) of fuel returned from the common rail 1 to the fuel tank 5 through the fuel return paths 13, 15, and 16. Thereby, the valve 7 varies the fuel pressure (common rail pressure) in the common rail 1. The above adjustment is made in proportion to the magnitude of a pressure reducing valve driving current applied to the solenoid coil through the pressure reducing valve drive circuit.

[0017] The injectors 2 installed in the individual cylinders of the engine are connected to the downstream ends of a plurality of high-pressure pipes 12 branched from the common rail 1. Each of the injections 2 is an electromagnetic fuel injection valve comprising a fuel injection nozzle for injecting fuel into each cylinder of the engine; an electromagnetic actuator which drives a nozzle needle, housed in the fuel injection nozzle, in the valve opening direction; a needle biasing means, such as a spring, for biasing the nozzle needle in the valve closing direction; and the like.

[0018] Fuel injection from the injectors 2 into the respective cylinders of the engine is electronically controlled by supplying a current through an electromagnetic valve 4 or interrupting the supply of the current. The electromagnetic valve 4 functions as an electromagnetic actuator which controls increase/decrease in the pressure in the back pressure control chamber of a command piston coupled with the nozzle needle.

[0019] When the electromagnetic valve 4 of the injector 2 of each cylinder is open, high-pressure fuel supplied from the common rail 1 into the back pressure control chamber is caused to overflow to the low pressure side (fuel tank 5) of the fuel system. Thereby, the nozzle needle and the command piston are lifted against biasing force from the needle biasing means to open an injection hole. As a result, high-pressure fuel accumulated in the common rail 1 is injected and supplied into the combustion chamber in each cylinder of the engine.

[0020] The supply pump 3 is a suction control-type high-pressure supply pump excellent in pressure increasing capability. The pump 3 pressurizes low-pressure fuel taken in from the fuel tank 5 through a filter 9, and feeds the fuel into the common rail 1 under pressure. Thereby, the pump 3 rapidly increases the fuel pressure (common rail pressure) in the common rail 1 from low to high, for example, in acceleration or when the engine is started.

[0021] The supply pump 3 comprises a known feed pump (low-pressure supply pump: not shown) which pumps low-pressure fuel out of the fuel tank 5 when the pump drive shaft thereof is rotated with the rotation of the crankshaft of the engine; a cam (not shown) which is rotationally driven by the pump drive shaft; two plungers #1 and #2 which are driven by the cam and reciprocate between top dead center and bottom dead center; two pressurizing chambers (plunger chambers: not shown) for pressuring fuel which is taken in when the plungers #1 and #2 reciprocate in cylinders; two delivery valves (not shown) which are opened when the fuel pressure in these pressurizing chambers exceeds a predetermined value.

[0022] As illustrated in FIG. 2, the supply pump 3 is constructed as follows: the period from when the plungers (PL) #1 and #2 are respectively positioned at the top dead center (TDC) to when they respectively move past the bottom dead center is taken as suction period. In this period, low-pressure fuel is taken into the pressurizing chambers. The subsequent period for which the delivery valves are open, that is, the period until the plungers #1 and #2 respectively return to the top dead center (TDC) is taken as pressure feed period. In this period, high-pressure fuel pressurized in the pressurizing chambers is fed under pressure. Further, the supply pump 3 is provided with a leak port for preventing the temperature of fuel therein from excessively rising. Fuel leaking from the supply pump 3 is returned to the fuel tank 5 through the fuel return path 14 and then the fuel return path 16.

[0023] In the fuel flow path formed in the supply pump 3, that is, the fuel supply path (not shown) running from the feed pump to the pressurizing chambers, a suction control valve (SCV) 6 is installed. The valve 6 is for controlling the fuel pressure (common rail pressure) in the common rail 1. This control is carried out as follows: the degree of opening of the fuel supply path (the lift amount of the valve body or the area of opening of a valve port) is adjusted. Thereby, the discharge amount of fuel from the supply pump 3 to the common rail 1 (pump discharge amount, pump pressure feed amount) is varied. Thus, the fuel pressure in the common rail 1 is controlled.

[0024] The SCV 6 is electronically controlled by a SCV driving current applied by the ECU 10 through the pump drive circuit. Thereby, the SCV 6 adjusts the suction amount of fuel taken into the pressurizing chambers of the supply pump 3. The SCV 6 comprises a valve (valve body: not shown) which adjusts the opening of the fuel supply path for feeding fuel from the feed pump into the pressurizing chambers; a solenoid coil (electromagnetic coil: not shown) which drives the valve in the valve closing direction; and a valve biasing means (not shown), such as a spring, which biases the valve in the valve opening direction.

[0025] The SCV 6 adjusts the pressure feed amount (pump discharge amount) of high-pressure fuel discharged from the pressurizing chambers of the supply pump 3 to the common rail 1. Thereby, the SCV 6 varies the fuel pressure (common rail pressure) in the common rail 1, that is, the injection pressure of fuel injected and supplied from the individual injectors 2 into the respective cylinders (CYL) of the engine. This adjustment is made in proportion to the magnitude of SCV driving current applied to the solenoid coil through the pump drive circuit.

[0026] The ECU 10 is provided with a microcomputer of known structure. The microcomputer comprises CPU which performs control processing and arithmetic operations; and a storage device (memory such as EEPROM and RAM) which stores various programs and data. The microcomputer is provided with functions for an input circuit; an output circuit; a power circuit; an injector drive circuit (EDU); the pump drive circuit; a pressure reducing valve drive circuit; and the like.

[0027] The ECU 10 in this embodiment constitutes the operating condition learning control device for an internal combustion engine (fuel injection learning control device for an internal combustion engine). The memory such as EEPROM holds the previously learned current value as is updated for executing the control logics illustrated in FIG. 4 and FIG. 6. (The initial value of previously learned current value is a driving current value to the fuel discharge amount in idle running with standard characteristics (item of median of differences from device to device)). Further, a known fuel discharge amount in idle running which should optimize the operation is also stored beforehand. Sensor signals from various sensors are converted from analog to digital through an A-D converter, and then inputted into the microcomputer.

[0028] The ECU 10 in this embodiment is provided with various functions. Such functions include IG-ON signal detecting function and main relay driving function. The IG-ON signal detecting function is a function of detecting on (IG=ON) signals or off (IG=OFF) signals of an ignition switch (not shown). The main relay driving function is a function of closing (turning on) a main relay (not shown) when the IG-ON signal is detected by the IG-ON signal detecting function. The main relay is for connecting and disconnecting an ECU power line for supplying ECU power from a battery (not shown) to the ECU 10. The IG-ON signal detecting and main relay driving functions can be enabled even if ECU power is not supplied to the microcomputer.

[0029] Further, the main relay driving function is capable of delaying opening (turn-off) of the main relay until a predetermined condition is met, even if the ignition switch is abruptly turned off (IG=OFF) by a person (driver) driving the vehicle concerned. "Until a predetermined condition is met" means "until the engine 1 is stopped after the ignition switch is turned off," or "until a predetermined time passes after the ignition switch is turned off."

[0030] The ECU 10 is constructed as follows: when an engine key is inserted into the key cylinder in the interior of the vehicle and turned from the OFF position to the ST position and a starter switch (not shown) is turned on (ST=ON), the ECU 10 energizes a starter. Further, when after the engine 1 is cranked, the engine key is returned to the IG position and the ignition switch is turned on (IG=ON), the ECU 10 starts ECU power supply, and electronically controls the actuators for various control components, such as the injectors 3 and the supply pump 3, according to control programs stored in memory.

[0031] As illustrated in FIG. 1, the ECU 10 is constructed as follows: voltage signals from the fuel pressure sensor (fuel pressure detecting means) 25 or sensor signals from other various sensors are converted from analog to digital through the A-D converter and thereafter inputted into the microcomputer built in the ECU 10.

[0032] The microcomputer is connected with a crank angle sensor 21 for detecting the rotation angle of the crankshaft of the engine which sensor 21 functions as an operating condition detecting means for detecting the operating condition or operating conditions of the engine; an accelerator position sensor (engine load detecting means) 22 for detecting accelerator position (ACCP); a cooling water temperature sensor 23 for detecting engine cooling water temperature (THW); a fuel temperature sensor 24 for detecting the pump-suction side fuel temperature (THF) of fuel taken into the supply pump 3; and the like.

[0033] Of these sensors, the crank angle sensor 21 is installed opposite the periphery of a NE timing rotor (not shown) installed on the crankshaft of the engine or the pump drive shaft of the supply pump 3. On the periphery of the NE timing rotor, a plurality of projected teeth are formed at predetermined angular intervals. In this embodiment, four projected teeth are provided at predetermined angular intervals (180° CA) in correspondence with the individual cylinders of the engine. The projected teeth are for identifying the reference position of each piston in a cylinder as datums, as illustrated in FIG. 2. The reference positions (top dead center positions) include the TDC position of cylinder #1, the TDC position of cylinder #3, the TDC position of cylinder #4, and the TDC position of cylinder #2.

[0034] Further, two projected teeth are also formed at a predetermined angular interval (360° CA) for identifying the suction start timing of the supply pump 3 (top dead center positions: the TDC position of plunger #1 and the TDC position of plunger #2).

[0035] The crank angle sensor 21 comprises an electromagnetic pickup. Each of the projected teeth on the NE timing rotor gets close to or away from the crank angle sensor 21. As a result, a pulsed rotational position signal (NE signal pulse), especially, a NE signal pulse in synchronization with the revolution (pump revolution speed) of the supply pump 3 is outputted by electromagnetic induction. The ECU 10 functions as a revolution speed detecting means which measures the time intervals of NE signal pulses outputted from the crank angle sensor 21 and thereby detects engine revolution speed (NE).

[0036] The ECU 10 comprises an injection volume determining means which calculates a command injection volume (QFIN) which is set according to an engine revolution speed (NE) detected by the revolution speed detecting means, such as the crank angle sensor 21, and the accelerator position (ACCP) detected by the accelerator position sensor 22; an injection timing determining means which calculates a command injection timing (TFIN) from the engine revolution speed (NE) and the command injection volume (QFIN); an injection period determining means which calculates a command injection pulse time (TQ) from the command injection volume (QFIN) and a common rail pressure (NPC) detected by the fuel pressure sensor 25; and an injector driving means which applies a pulsed injector driving current to the electromagnetic valve 4 of the injector 2 of each cylinder through the injector drive circuit (EDU).

[0037] The ECU 10 also has fuel pressure control devices (pump control device, SCV control device, pressure reducing valve control device). The control devices compute the injection pressure of fuel suitable for the operating conditions or operating condition of the engine, and drive the solenoid coil of the SCV 6 through the pump drive circuit. The fuel pressure control devices are constructed as follows: a target fuel pressure (PFIN) is calculated from a command injection volume (QFIN) and an engine revolution speed (NE). To attain the target fuel pressure (PFIN), a SCV driving current applied to the solenoid coil of the SCV 6 is adjusted. Thereby, the discharge amount (pump discharge amount) of fuel discharged from the supply pump 3 into the common rail 1 or the pressure reducing valve flow rate (fuel return flow rate) at which fuel is returned from the common rail 1 to the fuel tank 5 is controlled.

[0038] To enhance the accuracy of fuel injection volume control, it is more desirable that the SCV driving current applied to the solenoid coil of the SCV 6 is subjected to feedback control. This feedback control is carried out by PID control so that the fuel pressure (NPC) in the common rail 1 detected by the fuel pressure sensor 25 will be substantially matched with the target fuel pressure (PFIN). The control of SCV driving current is preferably carried out by duty (DUTY) control. More specifically, the on-to-off ratio (energization time ratio, duty ratio) of a control pulse signal (pulsed pump driving signal) per unit time is adjusted according to the pressure difference (ΔP) between common rail pressure (NPC) and target fuel pressure (PFIN). Then, duty control is carried out to vary the lift amount of the SCV 6 or the area of opening of the SCV 6. Thus, accurate digital control is implemented. As a result, the response of actual fuel pressure (NPC) control and compliance with a target fuel pressure (PFIN) can be improved.

[Control Method in Embodiment]

[0039] Next, referring to FIG. 1 to FIG. 6, the control processing for common rail pressure in this embodiment will be described. FIG. 3 is a flowchart illustrating the processes of learned value calculation and learned value utilization. The flowchart in FIG. 3 corresponds to a control program stored in memory. The program is started when the setting of the ignition switch is changed from OFF to ON and thereby the main relay is turned on to start ECU power supply from the battery to the ECU 10, and is executed at predetermined time intervals.

[0040] When the control program (main routine) in FIG. 3 is started, it is checked whether that is the start of the engine in the present operation (Step 1). If the result of the check is NO, that is, now is not the start of the engine in the present operation, the control processing proceeds to Step 3.

[0041] If the result of the check at Step 1 is YES, that is, now is the start of the engine in the present operation, the previous learned value (e.g., previously learned current value) is read from memory, such as EEPROM (Step 2). Next, using the previous learned value stored beforehand in memory, such as EEPROM, control (common rail pressure control, injection volume control, injection timing control) is carried out in the present operation (Step 3).

[0042] The control logics illustrated in FIG. 4 and FIG. 5(a) show a method for calculating a target driving current value and a SCV driving current applied to the solenoid coil of the SCV 6, for use in common rail pressure control (discharge amount control), using known proportional-integral-derivative (PID) control.

[0043] The ECU 10 adds injection volume correction amounts to a basic injection volume (Q) to compute a command injection volume (QFIN) (injection volume determining means). The basic injection volume (Q) is set based on an engine revolution speed (NE) detected by the revolution speed detecting means, such as the crank angle sensor 21, and an accelerator position (ACCP) detected by the accelerator position sensor 22. The injection volume correction amounts are determined based on an engine cooling water temperature (THW) detected by the cooling water temperature sensor 23, a fuel temperature (THF) detected by the fuel temperature sensor 24, and the like.

[0044] Further, the ECU 10 calculates a command injection timing (injection start timing: TFIN) from the command injection volume (QFIN) and the engine revolution speed (NE) (injection timing determining means). Furthermore, the ECU 10 calculates a target fuel pressure (PFIN) from the command injection volume (QFIN) and the engine revolution speed (NE) (fuel pressure determining means).

[0045] The ECU 10 calculates a reference value for fuel leak amount using a characteristic map or a calculating equation. The characteristic map is prepared beforehand by determining the relation between engine revolution speeds (NE) detected by the revolution speed detecting means, such as the crank angle sensor 21, actual fuel pressures (common rail pressures: NPC) detected by the fuel pressure sensor 25, and reference values for fuel leak amount by experiments or the like. Then, the ECU 10 multiplies the reference value for fuel leak amount by a correction coefficient for fuel temperature with a fuel temperature (THF), detected by the fuel temperature sensor 24, taken into account and thereby calculates a fuel leak amount (QLEAK) (fuel leak amount calculating means).

[0046] Further, the ECU 10 calculates feedback gains (proportional gain GP, integral gain GI, derivative gain GD) based on a feedback gain map. The feedback gain map is prepared beforehand by measuring the relation between the pressure differences (=ΔP) between actual fuel pressure (NPC) and target fuel pressures (PFIN) and feedback gains (proportional gain GP, integral gain GI, derivative gain GD) by experiments or the like. Then, the ECU 10 calculates a feedback pressure amount (PFB) based on the following calculating equation (Eq. 1):

[Eq. 1] $$PFB = GP \times \Delta P + GI \times 1/S\ \Delta P + GD \times du/dt \Delta P$$

where ΔP is the pressure difference between a target fuel pressure (PFIN) and an actual fuel pressure (NPC).

[0047] Next, the ECU 10 converts the feedback pressure amount (PFB) into a feedback fuel discharge amount (QFB) using a predetermined coefficient of conversion. The feedback fuel discharge amount (QFB) is that required for a required discharge amount corresponding to the fuel injection volume (QINJ), fuel leak amount (QLEAK), and target fuel pressure (PFIN). For example, the ECU 10 multiplies the feedback pressure amount (PFB) by a value obtained by dividing a modulus of volume elasticity (Kα) by the volume in common rail (V) to compute a feedback fuel discharge amount (QFB) (correction amount determining means). The above processes of calculating the feedback pressure amount (PFB) and converting the feedback pressure amount (PFB) into the feedback fuel discharge amount (QFB) are equivalent to feedback control by fuel discharge amount (fuel discharge amount F/B. Refer to FIG. 4).

[0048] Next, the ECU 10 calculates a required discharge amount corresponding to a fuel injection volume (QINJ) for the period of a predetermined crank angle (e. g. 360° CA), a fuel leak amount (QLEAK) for the period of a predetermined crank angle (e.g. 360° CA), and the target fuel pressure (PFIN) (required discharge amount determining means). At this time, an actual injection volume may be used for the fuel injection volume (QINJ) for the period of the predetermined crank angle (e.g. 360° CA). Here, however, the command injection volume (QFIN)$\times$2 is used for the sake of convenience. The ECU 10 adds up the required discharge amount and the above feedback fuel discharge amount (QFB) to compute a fuel discharge amount as a target (target discharge amount: QPMP) (fuel discharge amount determining means).

[0049] Next, the ECU 10 converts the fuel discharge amount (QPMP) as a target into a basic driving current value (IB) using a predetermined coefficient of conversion. For example, the ECU 10 converts the fuel discharge amount (QPMP) as a target into a suction command amount using a two-dimensional map (not shown) with fuel discharge amount (QPMP) and fuel pressure taken as parameters. Further, the ECU 10 converts the suction command amount into a basic driving current value (basic control amount) using a two-dimensional map (not shown) with suction amount and engine revolution speed (NE) taken as parameters (basic control amount determining means, discharge amount-to-current converting means). Then, the ECU 10 adds up the basic driving current value IB and the previously learned current value IPL to compute a target driving current value (IPMP) (learned value utilizing means).

[0050] Thereafter, the ECU 10 reads NE signal pulses in synchronization with the pump revolution outputted from the crank angle sensor 21, and calculates a pump revolution speed (NP), as illustrated in FIG. 2 and FIG. 5(a). Further, the ECU 10 is fed with a TDC position check signal for the plunger #1 of the supply pump 3 and a TDC position check signal for the plunger #2 of the same. Then, the ECU 10 calculates a pump suction period of the supply pump 3 from the pump revolution speed (NP) and the two TDC position check signals (suction period calculating means). FIG. 2 illustrates the transition of the positions of the plunger #1 and the plunger #2 of the supply pump 3. However, similar waveform will be depicted even in case of the cam profile or cam phase of the supply pump 3.

[0051] The ECU 10 calculates a driving current period of the SCV 6 according to the pump suction period of the supply pump 3 (driving current period determining means). Then, the ECU 10 calculates a DUTY ratio of SCV driving current from the driving current period and the target driving current value (IPMP) required for the target fuel pressure (PFIN) (DUTY ratio determining means). The DUTY ratio is calculated in the ECU 10 for SCV driving current period, as illustrated in FIG. 5(b). This calculation is carried out based on a driving current value-to-DUTY value conversion map, prepared beforehand by measuring the relation between target driving current value (IPMP) and DUTY value by experiments or the like, or a calculating equation.

[0052] Then, the ECU 10 converts the DUTY value for the driving current period of the SCV 6 into a control pulse signal (pulsed pump driving signal) using a predetermined coefficient of conversion. Then, the ECU 10 applies the pulsed pump driving signal (SCV driving current) to the solenoid coil of the SCV 6 through the SCV drive circuit. Thus, the valve lift amount and the area of opening of the SCV 6 are adjusted in correspondence with the SCV driving current. Thereby, the fuel discharge amount of fuel pressure fed from the pressurizing chambers of the supply pump 3 to the common rail 1 through the high-pressure pipe 11 is controlled. Therefore, feedback control is carried out so that the actual fuel pressure (NPC) in the common rail 1 will be substantially matched with the target fuel pressure (PFIN).

[0053] Next, it is checked whether the control processing has been brought under learning conditions. That is, it is checked whether learning executing conditions are met (Step 4). If the result of the check is NO, the control processing proceeds to Step 7, which is the same as Step 3, to carry out normal control. At this time, if all the following conditions are met, the learning executing conditions are considered to be met (YES). If any one of the following conditions is not met, the learning executing conditions are considered not to be met (NO).

[0054] First, it is checked from signals from various sensors and switches installed on the engine or vehicle whether the operating condition of the engine is idle stable state. That the operating condition of the engine is idle stable state can be detected, for example, when the engine revolution speed (NE) is a predetermined value (1000 rpm) or below or within a predetermined range (800 to 1000 rpm); the accelerator position (ACCP) is a predetermined value (5%) or below; the target fuel pressure (PFIN) is within a predetermined range (30 to 40MPa); the pressure difference (ΔP) between actual fuel pressure (NPC) and target fuel pressure (PFIN) is a predetermined value (30MPa) or below; the command injection volume (QFIN) is a predetermined value ($1 mm^3/st$) or below; the fuel temperature (THF) is within a predetermined range (20 to 60°C); the engine cooling water temperature (THW) is within a predetermined range (60 to 100°C); and the gear position of the transmission is N (Neutral) or the shift position of the select lever is in the N (Neutral) range.

[0055] This embodiment is so constructed that: when idle stable state is established, timer count (CN) is started. When the count (CN) reaches a predetermined value, that is, when a certain time has passed after idle stable state is established, the processing (learning control) for calculating a learned current value for learning and correcting a target driving current value (IPMP) is carried out. If idle stable state ceases before the timer count (CN) reaches the predetermined value, the timer count (CN) is reset. When idle stable state is established again, timer count (CN) is started from the beginning.

[0056] The control logic illustrated in FIG. 6 shows a method for calculating a final present learned value (e.g. final present learned current value) for use in common rail pressure control (discharge amount control). This method uses known proportional-integral-derivative (PID) control.

[0057] As in normal control, the ECU 10 calculates a feedback pressure amount (PFB) based on the pressure difference (=ΔP) between actual fuel pressure (NPC) and target fuel pressure (PFIN). Then, the ECU 10 converts the feedback pressure amount (PFB) into a feedback fuel discharge amount (QFB) using a predetermined coefficient of conversion. Next, as described above, the ECU 10 calculates a fuel discharge amount as a target (target discharge amount: QPMP). This calculation is carried out by adding up a required discharge amount corresponding to a fuel injection volume (QINJ) for the period of a predetermined crank angle (e.g. 360° CA), a fuel leak amount (QLEAK) for the period of a predetermined crank angle (e.g. 360° CA), and the target fuel pressure (PFIN) and the feedback fuel discharge amount (QFB). Then, the ECU 10 converts the fuel discharge amount as a target (QPMP) into a first basic driving current value (I1: basic control amount) using the above converting method (basic control amount determining means, first discharge amount-to-current converting means).

[0058] Then, the ECU 10 takes a known fuel discharge amount (KQFB) in idle running (discharge amount of master item) out of memory, such as EEPROM. The known fuel discharge amount in idle running is a fuel discharge amount measured beforehand by experiments or the like. It is a discharge amount in idle running which should be taken when a certain time has passed after idle stable state is established, that is, when learning control is carried out.

[0059] Then, the ECU 10 converts the known fuel discharge amount in idle running into a second basic driving current value (I2) using a predetermined coefficient of conversion. For example, the ECU 10 converts the known fuel discharge amount in idle running into a suction command amount using a two-dimensional map (not shown) with known fuel discharge amount in idle running and fuel pressure taken as parameters. Further, the ECU 10 converts the suction command amount into a target driving current value (I2) using a two-dimensional map (not shown) with suction amount and engine revolution speed (NE) taken as parameters (second discharge amount-to-current converting means).

[0060] Then, the ECU 10 calculates a temporary present learned value (temporary present learned current value ITL) by subtracting the second basic driving current value from the first basic driving current value (Step 5). Then, the ECU 10 calculates a final present learned value (final present learned current value) IFL by adding up the temporary present learned current value ITL and the previous learned value IPL (Step 6). Thereafter, the ECU 10 completes the processing (learning control) of calculating a learned value (e.g. learned current value) for learning and correcting degradation in the performance or variation in the characteristics of the supply pump 3 or SCV 6 due to the individual specificity or aging change of the supply pump 3 or SCV 6.

[0061] Then, the ECU 10 carries out control (common rail pressure control, injection volume control, injection timing control) in the present operation (Step 7). This control (common rail pressure control, injection volume control, injection timing control) does not use the above final present learned value (final present learned current value) but uses the previous learned value stored beforehand in memory, such as EEPROM. Then, it is checked in the present operation whether the ignition switch has been turned off (IG=OFF) (Step 8). If the result of the check is NO, the control processing proceeds to Step 3.

[0062] If the result of the check at Step 8 is YES, the ECU 10 stores the above final present learned value (final present learned current value) into memory, such as EEPROM, instead of the previous learned value (e.g. previously learned current value) (learned value storing means: Step 9). When the setting of the ignition switch is thereafter changed from ON to OFF and a predetermined time passes, the main relay is turned off to interrupt ECU power supply to the ECU 10. Thus, the above control program is forcedly terminated.

[0063] As described above, the common rail-type fuel injection system in this embodiment operates as follows: when idle stable state is detected and learning executing conditions are met, learning control is carried out. The learning control is for learning and correcting degradation in the functionality (degradation in the performance) of the supply pump 3 or SCV 6 due to the individual specificity or aging change of the supply pump 3 or SCV 6. The individual specificity is variation from device to device, including variation in the opening shape of the SCV 6 which may occur during manufacturing and variation in spring force from a spring which biases the valve of the SCV 6.

[0064] During the learning control, a temporary present learned value (e.g., temporary present learned current value) to be utilized in the calculation of a target value of driving current (IPMP) applied to the solenoid coil of the SCV 6 is calculated. Thereafter, a final present learned value (learning control amount: e.g., final present learned current value) is calculated by adding up the previous learned value (e.g., previously learned current value) calculated and stored in memory, such as EEPROM, during the previous operation and the temporary present learned value.

[0065] However, in the present operation whose status is changed from learning control state to normal control state, the above final present learned value calculated during learning control is not immediately utilized in the calculation of a target value of driving current (IPMP) applied to the solenoid coil of the SCV 6. Instead, when the ignition switch is turned off (IG=OFF) to stop the engine, as illustrated in FIG. 7(b), the above final present learned value is just stored in memory, such as EEPROM, in place of the previous learned value. Thereafter, the engine is stopped. From immediately after the start of the engine in the next operation, the previous learned value updated and stored in memory, such as EEPROM, when the previous operation is terminated is utilized in the calculation of a target value of driving current (IPMP) applied to the solenoid coil of the SCV 6.

[0066] Therefore, a problem which would occur if immediately after calculated, a final present learned value is utilized in common rail pressure control (e.g., feedback control by fuel discharge amount: fuel discharge amount F/B) is prevented. , transient fluctuation which would occur if the final present learned value just calculated is utilized in the calculation of a target driving current value (IPMP) and learning and correction are added to common rail pressure control is prevented from occurring. As a result, drivability is enhanced.

[0067] In addition, when after a final present learned value is calculated during the present operation, the status of control is changed from learning control state to normal control state to use the learned value, superfluous and complicated control, such as gradual change control and integral term clearing, is unnecessary. Therefore, complication of control or increase in the number of relevant man-hours does not result.

[0068] As described above, the control logic illustrated in FIG. 6 is adopted for learning control. The learning control is for learning and correcting variation in driving current-discharge amount characteristics. Specifically, the characteristics of the fuel discharge amount discharged from the supply pump 3 into the common rail 1 to the value of driving current applied to the solenoid coil of the suction control valve (SCV) 6 can deviate from standard characteristics so that the fuel discharge amount characteristics are offset in the direction of current. The learning control is used to learn and correct this deviation.

[0069] Further, the learning control is for learning and correcting degradation in the performance or variation in the characteristics of the supply pump 3 or SCV 6 due to the individual specificity (variation from device to device) or aging change of the supply pump 3 or SCV 6. If the control logic in FIG. 6 is used in this learning control, control is not changed from current feedback control to fuel discharge amount feedback control when the status thereof is changed from learning control state to normal control state. Therefore, it is unnecessary to carry out gradual change control or the like. Thus, complication of control or increase in a number of relevant man-hours does not result.

[0070] The above embodiment is an example of the application of the operating condition learning control device for an internal combustion engine of the present invention. It is a common rail-type fuel injection system provided with the fuel injection learning control device for an internal combustion engine. The present invention may be applied to a fuel injection system for an internal combustion engine wherein such an accumulator as a common rail is not provided and high-pressure fuel is directly supplied from a fuel supply pump to injectors through a high-pressure pipe. In the above embodiment, the present invention is applied to a method for feedback-controlling a fuel discharge amount discharged from the supply pump 3 by P-I-D control. The present invention may be applied to a method for feedback-controlling a discharge amount of fuel discharged from a supply pump 3 by PI control.

[0071] In the above embodiment, the present invention is applied to the calculation (learning control) of a learned value for learning and correcting degradation in the performance or variation in the characteristics of the supply pump 3 or SCV 6 due to the individual specificity or aging change of the supply pump 3 or SCV 6. An example of the learned value is a learned current value to be added to a target driving current value. The present invention may be applied to the calculation (learning control) of a learned value for learning and correcting degradation in the performance or variation in the characteristics of a supply pump 3 or SCV 6 due to the individual specificity or aging change of the supply pump 3 or SCV 6. An example of the learned value is a discharge amount learned value to be added to a fuel discharge amount as a target (target discharge amount. Further, fuel discharge amount feedback control (fuel discharge amount F/B) may be carried out in normal control and current feedback control (current F/B) may be carried out in learning control.

[0072] Further, the present invention may be applied to an operating condition learning control device for an internal combustion engine (injection volume learning control device for an internal combustion engine) constructed as follows: the individual specificity of injectors and the deviation of an actual injection volume from an injection volume command value using revolution speed fluctuation and cylinder-to-cylinder injection volume correction (FCCB correction). In this case, the revolution speed fluctuation of each cylinder of an internal combustion engine is detected, and is compared with the average value of the revolution speed fluctuations of all the cylinders. According to the result of the comparison, the correction amount of injection volume or the correction amount of injection period for each cylinder of the internal combustion engine is updated so that revolution speed fluctuations from cylinder to cylinder will be smoothed.

[0073] Further, the present invention may be applied to an operating condition learning control device for an internal combustion engine (injection volume learning control device for an internal combustion engine) constructed as follows: degradation in the functionality (degradation in the performance) of injectors due to aging change or the like is learned and corrected using average revolution speed correction (ISC correction). In this case, the average revolution speed of the internal combustion engine is compared with a target revolution speed. According to the result of the comparison, the correction amount of injection volume or the correction amount of injection period for each cylinder of the internal combustion engine is uniformly updated for all the cylinders so that the target revolution speed will be obtained.

[0074] In the above embodiment, the fuel pressure sensor 25 is installed directly on the common rail 1 so as to detect the actual fuel pressure (common rail pressure: NPC) accumulated in the common rail 1. Alternatively, a fuel pressure detecting means may be installed in a fuel pipe or the like between the plunger chambers (pressurizing chambers) of the supply pump 3 and the fuel paths in the injectors 2. Thus, the discharge pressure (actual fuel pressure) of fuel discharged from the pressurizing chambers of the supply pump 3, or the injection pressure (actual fuel pressure) of fuel supplied into the injectors 2 and injected into the cylinders of the engine is detected.

[0075] The above embodiment is provided with a suction control valve (SCV) 6. The valve 6 is so constructed as to adjust the degree of opening (the lift amount of a valve or the area of opening of a valve port) of the fuel supply path running from the feed pump to the pressurizing chambers. Thus, the value 6 varies the suction amount of fuel taken from the feed pump into the pressurizing chambers according to a driving current value, and thereby controls the discharge amount of fuel discharged from the supply pump 3.

[0076] The SCV 6 may be a normally open electromagnetic valve wherein the valve is fully opened when power supply to the electromagnetic coil (solenoid coil) thereof is interrupted. That is, when the power supply is interrupted, the area of opening of the valve port is maximized and the lift amount is minimized. The SCV 6 may be a normally closed electromagnetic valve wherein the valve is fully closed when power supply to the solenoid coil is interrupted. That is, when the power supply is interrupted, the area of opening of the valve port is minimized and the lift amount is minimized. An electric motor-driven suction control valve may be used for the suction control valve.

[0077] In the above embodiment, memory, such as EEPROM, is used as a learned value storing means for storing final present learned values in place of previous learned values. Alternatively, a nonvolatile memory, such as standby RAM, EPROM, and flash memory, or any other storage medium, such as DVD-ROM, CD-ROM, and a flexible disk, may be used to store final present learned values in place of previous learned values. In these cases as well, the memory contents are maintained even after a predetermine time passes after the ignition switch is turned off (IG=OFF) or after the engine key is removed from the key cylinder. In the above embodiment, final present learned values are stored in EEPROM or the like, in place of previous learned values when the engine is stopped or when control shifts to engine stop control. Alternatively, final present learned values may be stored in memory, such as EEPROM, in place of previous learned values before or when the engine is started.

[0078] If there is a difference greater than a predetermined value between the previously learned current value stored in memory during the previous learning control and the present learned current value calculated during the present learning control, such an anomaly as trouble in the supply pump 3 itself and control failure of the ECU 10 is suspected. To cope with this, a malfunctional warning lamp (indicator lamp) may be turned on to prompt the driver to replace the supply pump 3, ECU 10, or the like. Further, the above calculation (learning control) of a learned current value for learning and correcting a target driving current value (IPMP) may be carried out at a learning correction frequency, fixed or variable. (For example, the learning control may be carried out on the basis of mileage or the duration of service of the supply pump 3.)

[0079] Learning control is carried out to learn and correct degradation in the functionality of a fuel supply pump (3) having a solenoid coil (6) for an engine. During the learning control, a temporary present learned value (ITL) to be utilized in the calculation of a target value of driving current applied to the solenoid coil is calculated. Thereafter, a final present learned value (IFL) is calculated by adding up a previous learned value (IPL) and the temporary present learned value (ITL). The final present learned value (IFL) is not immediately utilized in the calculation of the target value of driving current. Instead, the final present learned value is just stored in a memory in place of the previous learned value when the engine is stopped.

Claims

1. An operating condition learning control device for an internal combustion engine comprising:

    an operating condition changing means (2, 3) which changes the operating condition of an in-

ternal combustion engine;
an operating condition detecting means (21-24) which detects the operating condition of the internal combustion engine;
a basic control amount determining means (10) which calculates a basic control amount given to the operating condition changing means so that the operating condition of the internal combustion engine will be matched with a target operating condition;
a learned value utilizing means (10) which utilizes a previous learned value in the calculation of the basic control amount in the present operation; and
a learning control amount calculating means (10) which calculates a learning control amount to be utilized in the basic control amount during learning control, wherein degradation in the performance or variation in the characteristics of the operating condition changing means due to individual specificity or aging change of the operating condition changing means is learned and corrected, **characterized by**
a learned value storing means (10) which stores a value obtained by adding up the learning control amount and the previous learned value in place of the previous learned value when or after the present operation of the internal combustion engine is stopped or when or before the next operation of the internal combustion engine is started.

2. The operating condition learning control device according to Claim 1, **characterized in that**:

the learning control amount calculating means (10) comprises a temporary learned value calculating means (S5) which calculates a temporary present learned value to be utilized in the basic control amount during learning control wherein degradation in the performance or variation in the characteristics of the operating condition changing means due to the individual specificity or aging change of the operating condition changing means is learned and corrected, and a final learned value calculating means (S6) which calculates a present learned value by adding up the temporary present learned value and the previous learned value; and
the learned value storing means (10) stores the present learned value in place of the previous learned value.

3. The operating condition learning control device according to Claim 1, **characterized in that**:

the operating condition changing means (2, 3) is a fuel supply pump which pressurizes fuel taken in and discharges the obtained high-pressure fuel into a common rail (1); and
the basic control amount determining means (10) comprises a fuel pressure detecting means (25) which detects the fuel pressure in the common rail and a fuel pressure determining means which calculates a target fuel pressure according to the operating condition of the internal combustion engine,

wherein the target discharge amount of fuel discharged from the fuel supply pump is calculated based on the pressure difference between the fuel pressure in the common rail and the target fuel pressure.

4. The operating condition learning control device according to Claim 3, **characterized in that**:

the basic control amount is the target discharge amount; and
the learning control amount is a temporary present learned value to be utilized in the target discharge amount during learning control wherein degradation in the performance or variation in the characteristics of the fuel supply pump due to the individual specificity or aging change of the fuel supply pump is learned and corrected.

5. The operating condition learning control device according to Claim 1, **characterized in that**:

the operating condition changing means (2, 3) is a fuel supply pump which pressurizes fuel taken into pressurizing chambers and discharges the obtained high-pressure fuel into a common rail (1);
the fuel supply pump (2, 3) comprises a suction control valve (6) which adjusts the suction amount of fuel taken into the pressurizing chambers according to a driving current value and thereby varies the discharge amount of fuel discharged from the fuel supply pump; and
the basic control amount determining means (10) comprises a fuel pressure detecting means (25) which detects the fuel pressure in the common rail and a fuel pressure determining means which calculates a target fuel pressure according to the operating condition of the internal combustion engine,

wherein a target value of driving current applied to the suction control valve is calculated based on the pressure difference between the fuel pressure in the common rail and the target fuel pressure.

6. The operating condition learning control device according to Claim 5, **characterized in that**:

the basic control amount is the target driving current value; and
the learning control amount is a temporary present learned value to be utilized in the target driving current value during learning control wherein degradation in the performance or variation in the characteristics of the fuel supply pump due to the individual specificity or aging change of the fuel supply pump is learned and corrected.

7. The operating condition learning control device according to Claim 1, **characterized in that**:

the operating condition changing means (2, 3) is a plurality of fuel injection valves (2) which are installed on the respective cylinders of the internal combustion engine and inject high-pressure fuel accumulated in a common rail (1) into the respective cylinders of the internal combustion engine;
the plurality of the fuel injection valves (2) comprise actuators which vary the injection volume, injection period, or injection timing of fuel injected into the respective cylinders of the internal combustion engine; and
the basic control amount determining means (10) comprises a fuel pressure detecting means which detects the fuel pressure in the common rail and an injection volume determining means which calculates a command injection volume according to the operating condition of the internal combustion engine,

wherein a command injection timing is calculated according to the operating condition of the internal combustion engine and the command injection volume and further a command injection period is calculated according to the fuel pressure in the common rail and the command injection volume.

8. The operating condition learning control device according to Claim 7, **characterized in that**:

the basic control amount is the command injection timing, the command injection volume, or the command injection period; and
the learning control amount is a temporary present learned value to be utilized in the command injection timing, the command injection volume, or the command injection period during learning control wherein degradation in the performance or variation in the characteristics of the fuel injection valves due to the individual specificity or aging change of the fuel injection valves is learned and corrected.

9. The operating condition learning control device according to Claim 1, **characterized in that**:

the operating condition changing means (2, 3) is a plurality of fuel injection valves (2) which are installed on the respective cylinders of the internal combustion engine and inject high-pressure fuel accumulated in a common rail (1) into the respective cylinders of the internal combustion engine;
the plurality of the fuel injection valves (2) comprise actuators which vary the injection volume or injection period of fuel injected into the respective cylinders of the internal combustion engine;
the learning control amount calculating means (10) comprises a fuel pressure detecting means which detects the fuel pressure in the common rail, an injection volume determining means which calculates a command injection volume according to the operating condition of the internal combustion engine, and an injection period determining means which calculates a command injection period according to the fuel pressure in the common rail and the command injection volume,

wherein the revolution speed fluctuation of each cylinder of the internal combustion engine is detected and compared with the average value of revolution speed fluctuations of all the cylinders, and according to the result of the comparison, the correction amount of injection volume or the correction amount of injection period for each cylinder of the internal combustion engine is calculated so that cylinder-to-cylinder revolution speed fluctuations will be smoothed, and

the learned value storing means stores a value obtained by adding up the correction amount of injection volume or the correction amount of injection period for each cylinder of the internal combustion engine and the previous learned value in place of the previous learned value.

10. The operating condition learning control device according to Claim 1, **characterized in that**:

the operating condition changing means (2, 3) is a plurality of fuel injection valves (2) which are installed on the respective cylinders of the internal combustion engine and inject high-pressure fuel accumulated in a common rail (1) into the respective cylinders of the internal combustion engine;
the plurality of the fuel injection valves (2) comprise actuators which vary the injection volume

or injection period of fuel injected into the respective cylinders of the internal combustion engine;
the learning control amount calculating means (10) comprises a fuel pressure detecting means (25) which detects the fuel pressure in the common rail, an injection volume determining means which calculates a command injection volume according to the operating condition of the internal combustion engine, and an injection period determining means which calculates a command injection period according to the fuel pressure in the common rail and the command injection volume,

wherein

the average revolution speed of the internal combustion engine is detected and compared with a target revolution speed, and according to the result of the comparison, the correction amount of injection volume or the correction amount of injection period for each cylinder of the internal combustion engine is calculated so that the target revolution speed will be obtained; and

the learned value storing means (10) stores a value obtained by adding up the correction amount of injection volume or the correction amount of injection period for each cylinder of the internal combustion engine and the previous learned value in place of the previous learned value.

FIG. 1

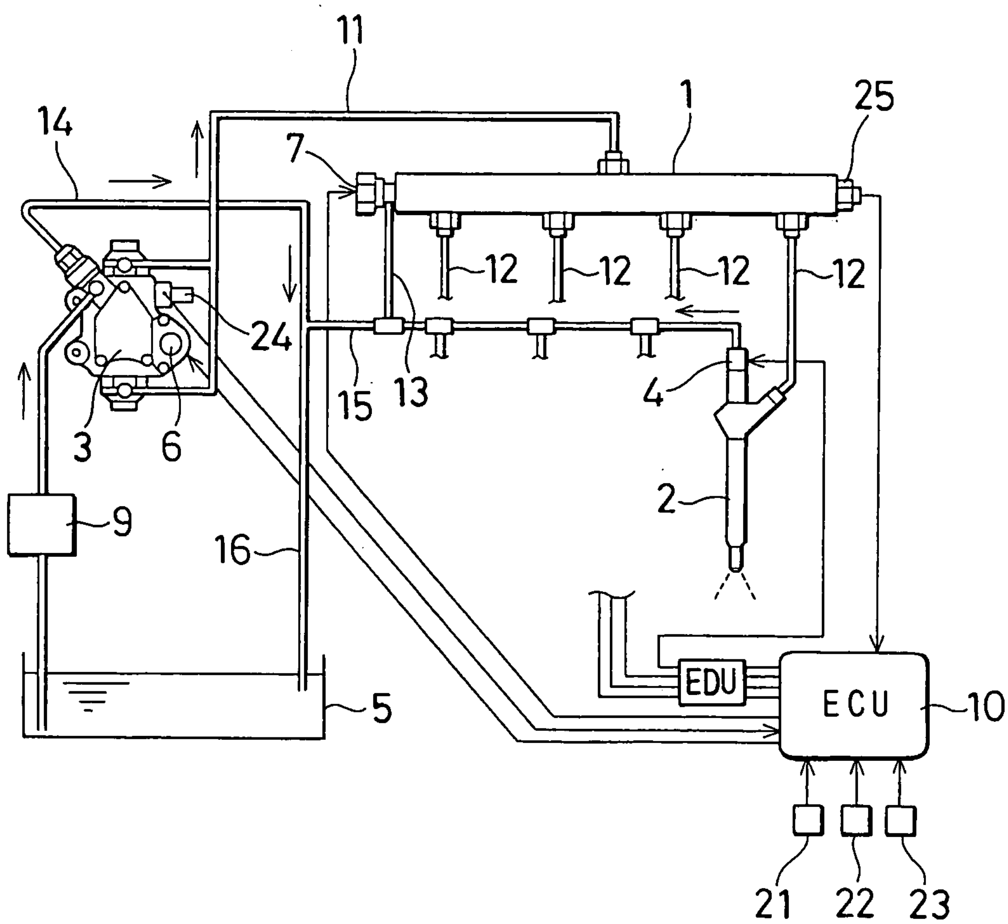
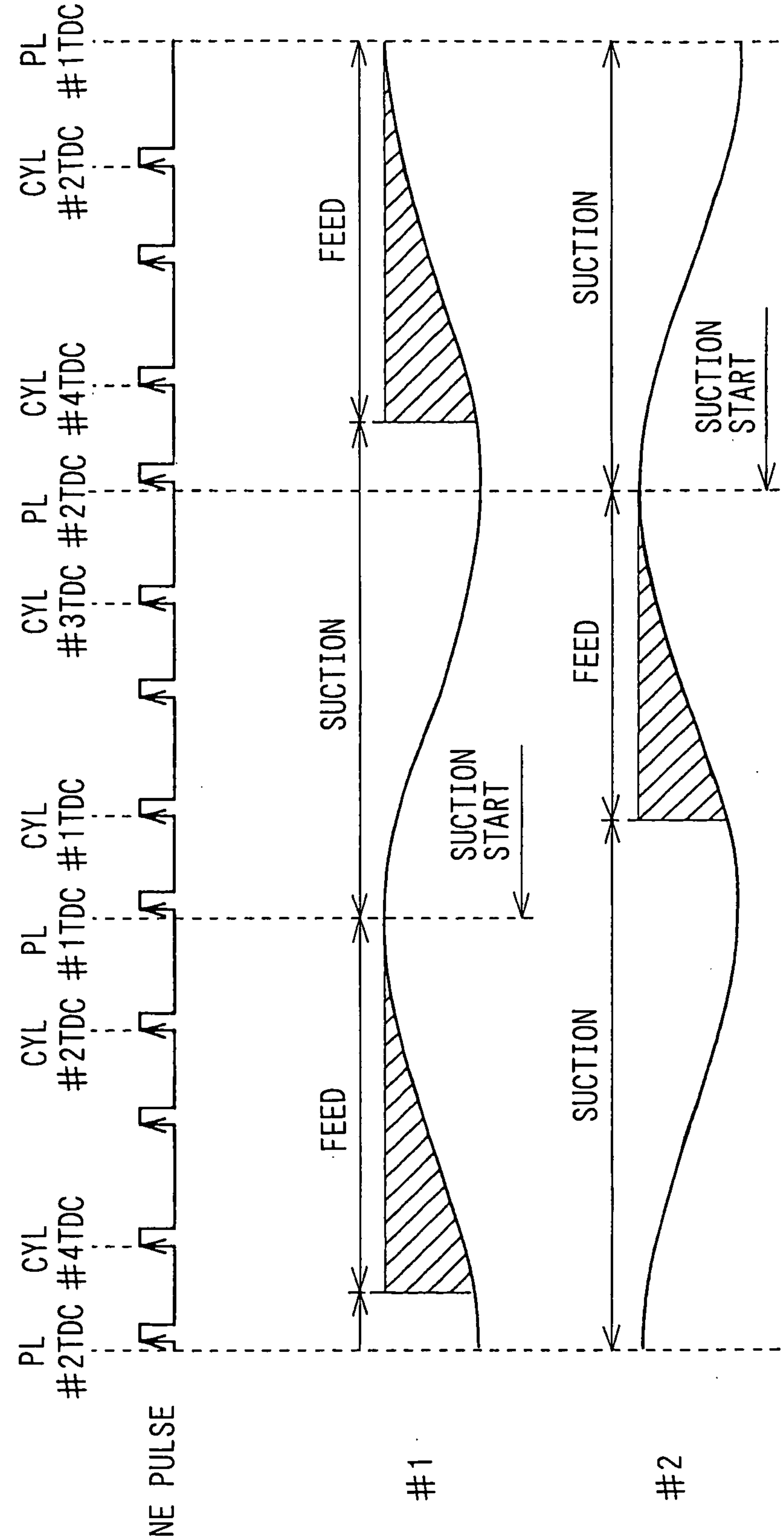


FIG. 2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#2
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CYL #4TDC
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CYL #3TDC
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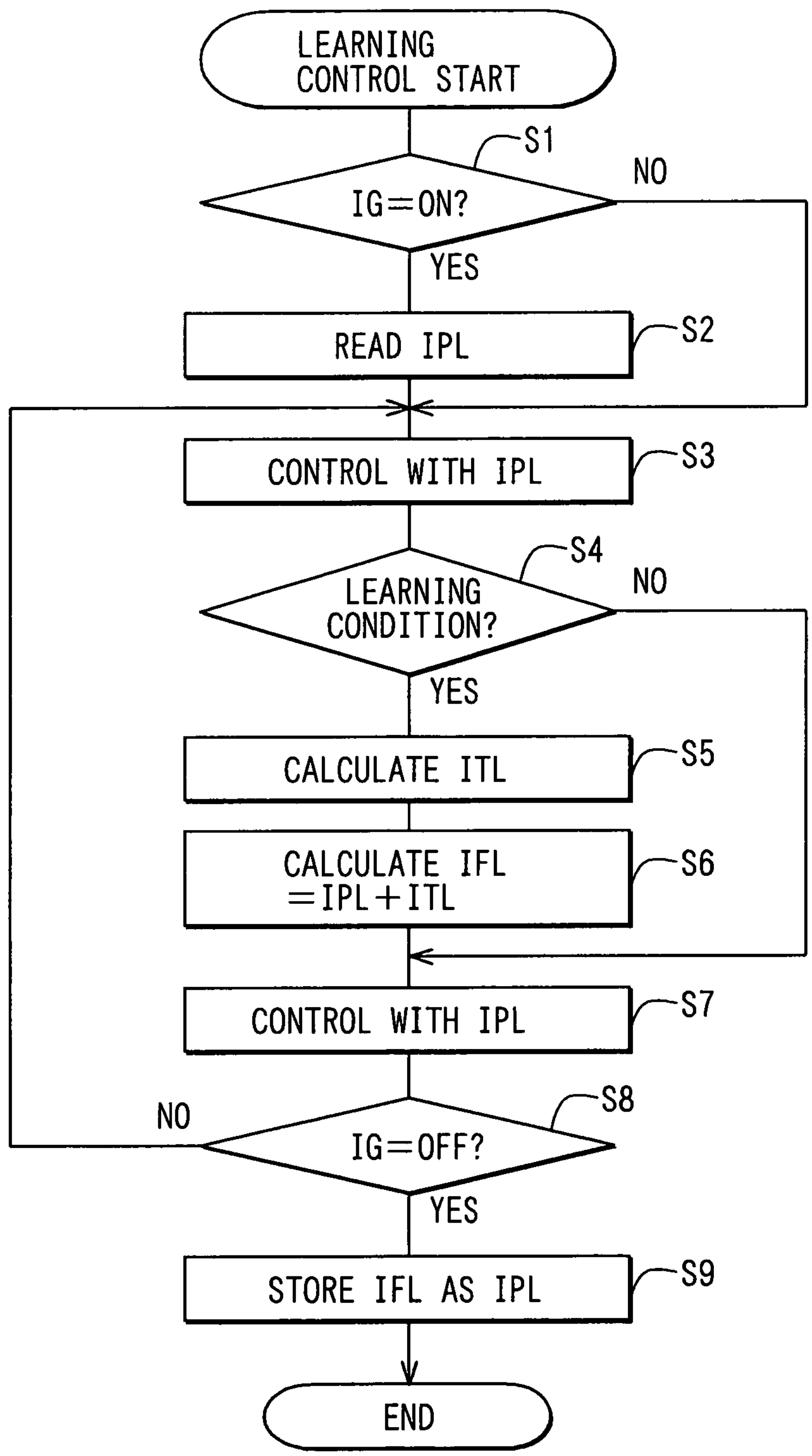
PL #1TDC
FEED
SUCTION
SUCTION START
SUCTION
FEED
SUCTION START

FIG. 3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YES
READ IPL
S2
CONTROL WITH IPL
S3
S4
LEARNING
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YES
CALCULATE ITL
S5
CALCULATE IFL
=IPL+ITL
S6
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S7
NO
IG=OFF?
S8
YES
STORE IFL AS IPL
S9
END

FIG. 4

NORMAL CONTROL

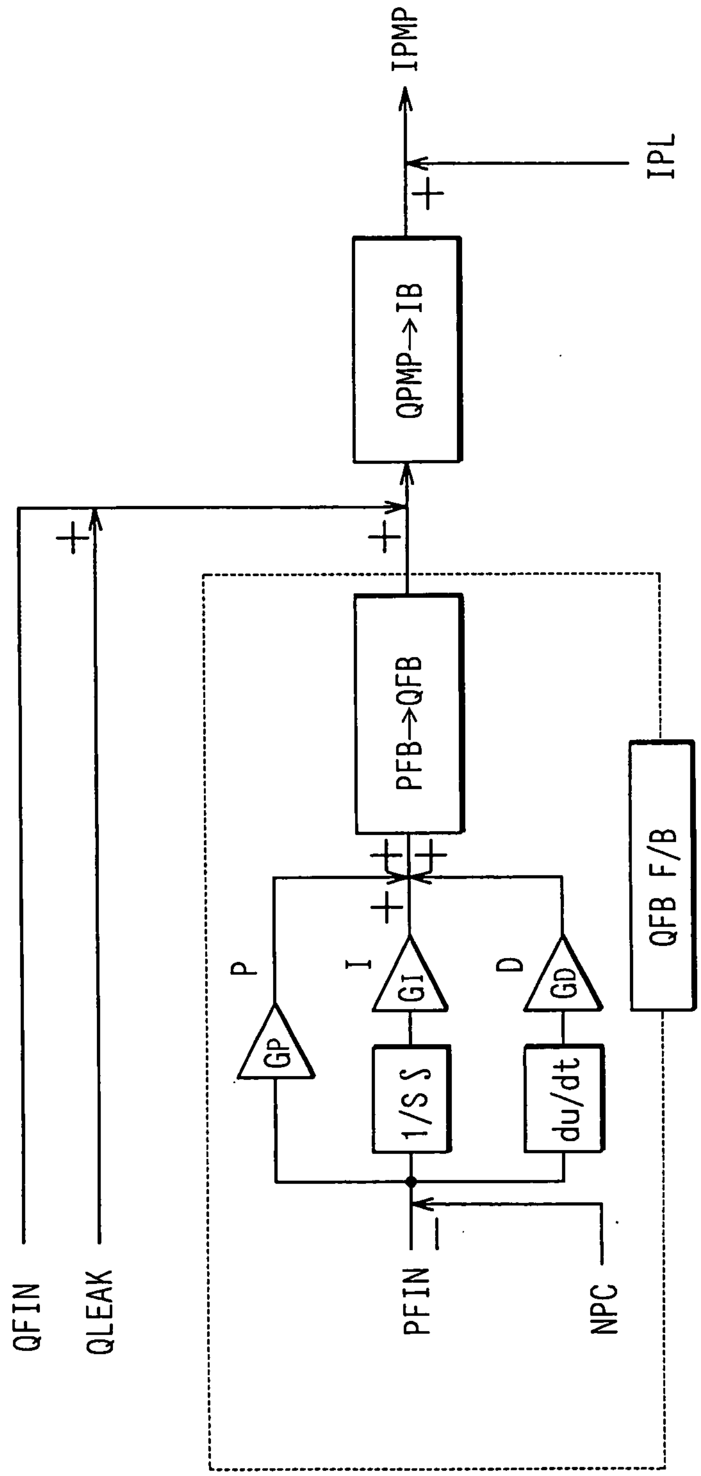


FIG. 5

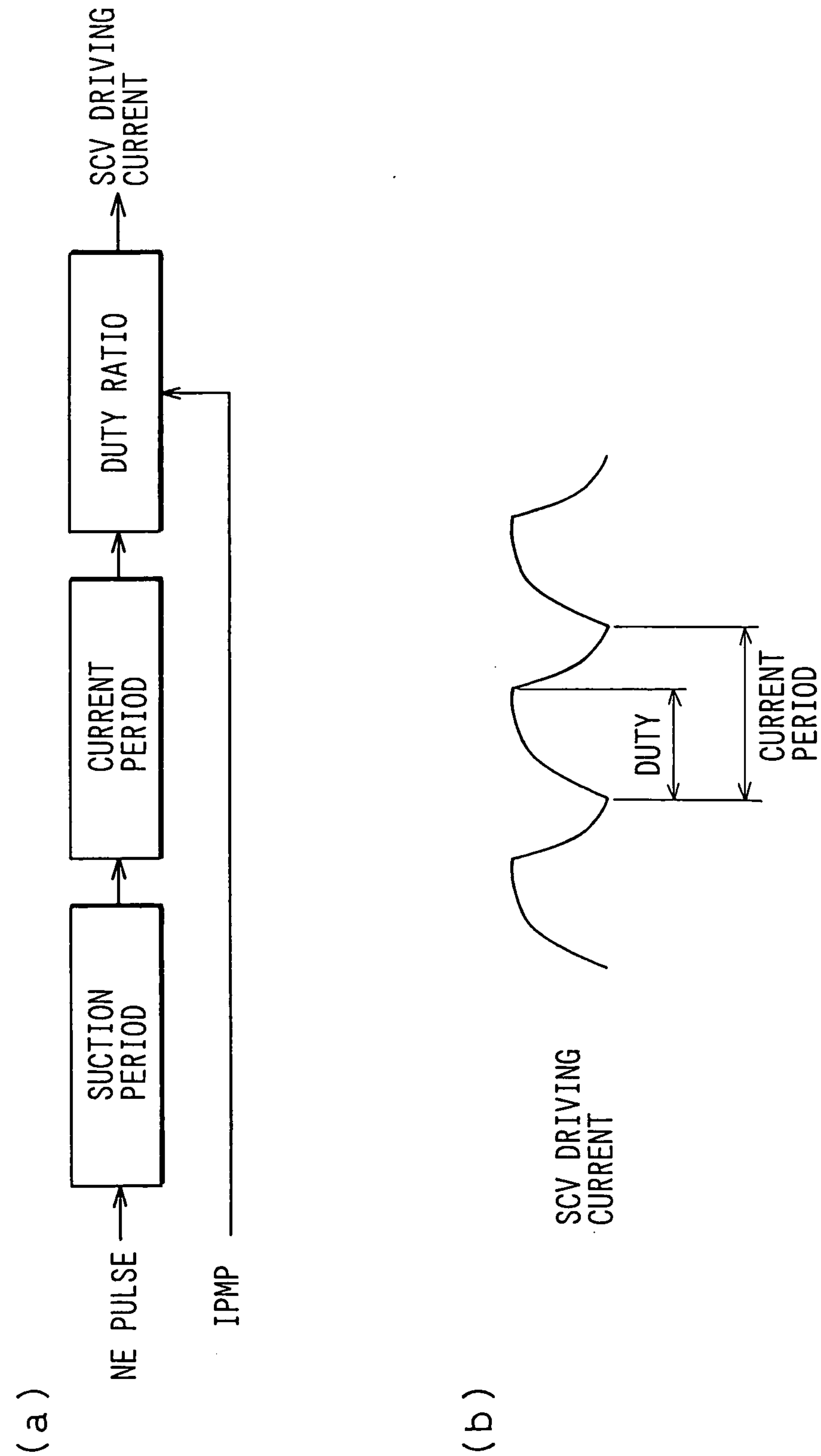

(a)
NE PULSE
IPMP
SUCTION PERIOD
CURRENT PERIOD
DUTY RATIO
SCV DRIVING CURRENT
(b)
SCV DRIVING CURRENT
DUTY
CURRENT PERIOD

FIG. 6

LEARNING CONTROL

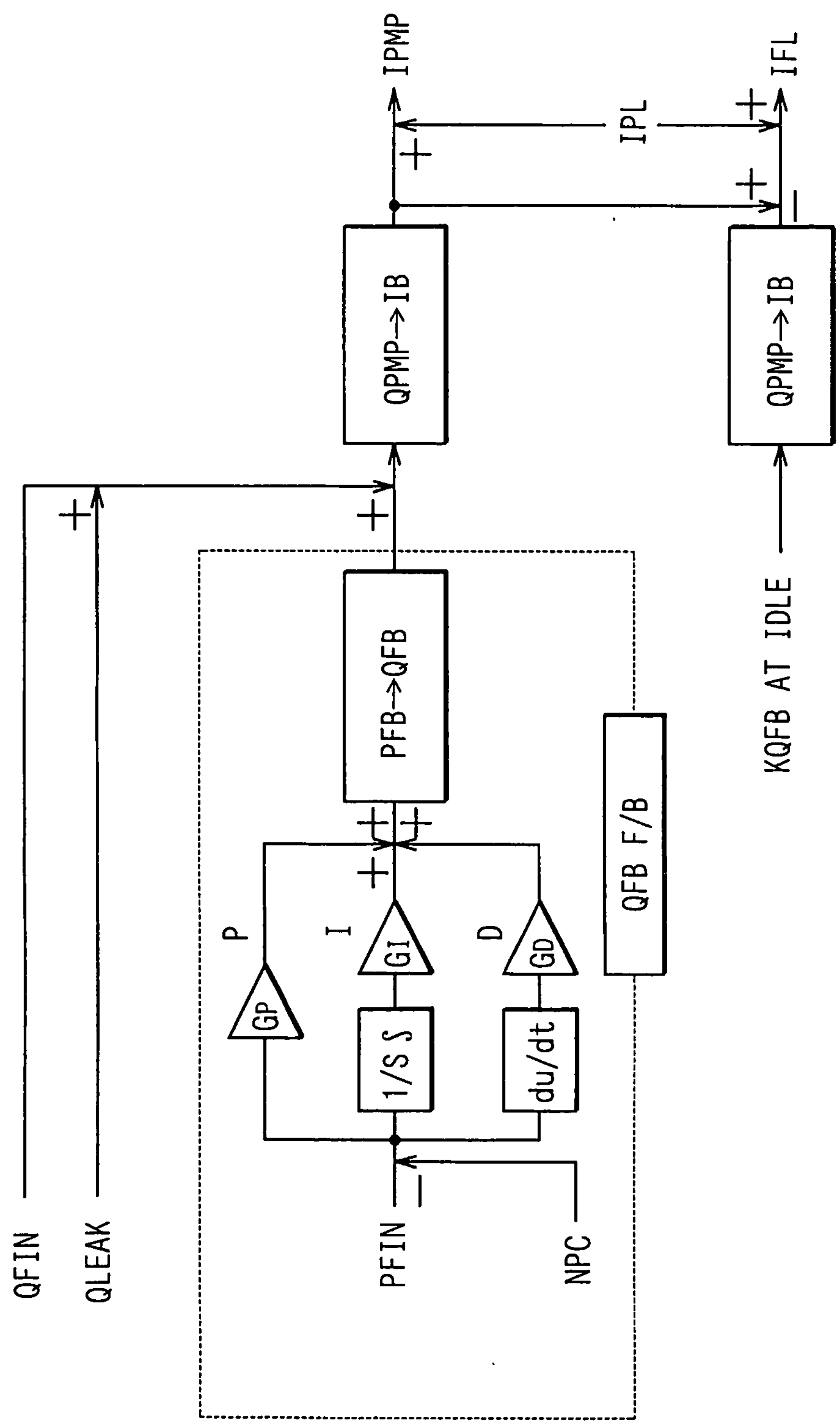
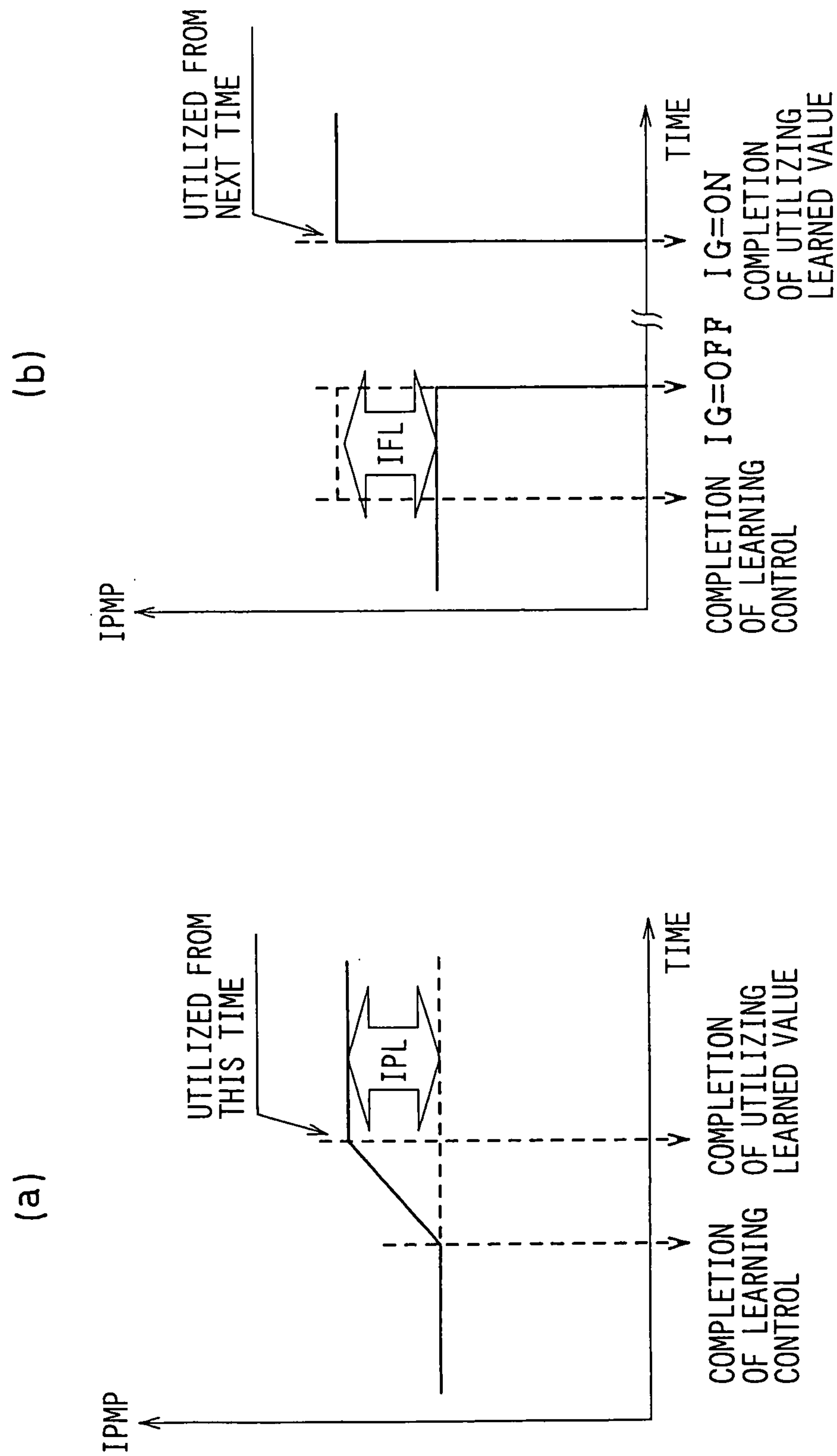


FIG. 7


(a)
IPMP
UTILIZED FROM THIS TIME
IPL
TIME
COMPLETION OF LEARNING CONTROL
COMPLETION OF UTILIZING LEARNED VALUE
(b)
IPMP
IFL
UTILIZED FROM NEXT TIME
TIME
COMPLETION OF LEARNING CONTROL
IG=OFF
IG=ON
COMPLETION OF UTILIZING LEARNED VALUE