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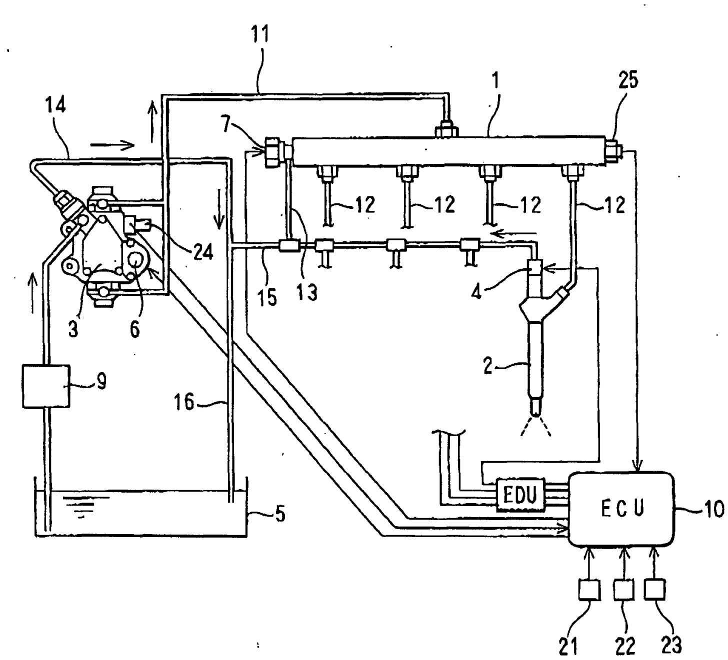
(54) **Fuel injection system for internal combustion engine**

(57) An electronic control unit (ECU) (10) of a fuel injection system for an internal combustion engine performs feedback control of a fuel discharging quantity in both of normal control and learning control based on a pressure deviation between a target fuel pressure and an actual fuel pressure. In the learning control, the ECU (10) calculates a difference between first demand driving current and second demand driving current as a current learning value for learning and correcting target driving current. The ECU (10) renews and stores the current learning value in a memory. The first demand driving current is converted from the fuel discharging quantity as a target discharging quantity calculated through the above feedback control based on a reference property. The second demand driving current is converted from a known idling fuel discharging quantity.

FIG. 1

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## Description

**[0001]** The present invention relates to a fuel injection system for an internal combustion engine having a suction control type fuel supply pump for pressurizing fuel, which is drawn into a pressurizing chamber through a suction control valve, to a high pressure and for pressure-feeding the fuel into a common rail. Specifically, the present invention relates to a fuel injection system for an internal combustion engine for feedback-controlling a discharging quantity of fuel discharged from a fuel supply pump so that a fuel pressure in a common rail substantially coincides with a target fuel pressure.

**[0002]** Conventionally, there is a pressure accumulation type fuel injection system, which accumulates high-pressure fuel in a common rail and supplies the fuel into a combustion chamber of each cylinder of an internal combustion engine through injection. The injection is performed at predetermined timing from an electromagnetic fuel injection valve (an injector) connected to a downstream end of a fuel pipe branching from the common rail. The common rail is required to continuously accumulate the fuel pressure corresponding to a fuel injection pressure. Therefore, a suction control type fuel supply pump pressure-feeds the high-pressure fuel into the common rail through a fuel pipe and is feedback-controlled so that the fuel pressure in the common rail substantially coincides with the target fuel pressure.

**[0003]** The above control is disclosed in Japanese Patent Application Unexamined Publication No. 2001-82230 (pp. 1-18 and Figs. 1 to 20), for instance. In the control, a command injection quantity Q is calculated in accordance with an operating condition or an operating state of the internal combustion engine. Then, a target fuel pressure PFIN is calculated in accordance with engine rotation speed NE and the command injection quantity Q. Then, driving current applied to a suction control valve included in the fuel supply pump is feedback-controlled in accordance with a pressure deviation $\Delta P$ between an actual fuel pressure NPC in the common rail, which is sensed by a fuel pressure sensor disposed in the common rail, and the target fuel pressure PFIN.

**[0004]** Next, a method for calculating the target driving current, which is applied to the suction control valve in normal control, through publicly known proportional, integral and differential control (PID control) will be explained based on control logic shown in Fig. 7. Such a method is disclosed in Japanese Patent Application Unexamined Publication No. 2000-282929 (pp. 1-12 and Figs. 1 to 15), for instance. In this method, a feedback pressure PFB is calculated through the publicly known PID control from the pressure deviation $\Delta P$ between the actual fuel pressure NPC and the target fuel pressure PFIN based on a following formula (1). In the formula (1), GP represents a proportional gain, GI is an integral gain and GD is a differential gain.

$$PFB = GP \times \Delta P + GI \times \int \Delta P + GD \times d(\Delta P)/dt, \quad (1)$$

**[0005]** Then, a feedback fuel discharging quantity QFB is calculated by multiplying the feedback pressure PFB by a value obtained by dividing a modulus $K\alpha$ of volume elasticity by a common rail inner volume V. Then, a fuel discharging quantity QPMP is calculated by adding a fuel injection quantity QINJ in a predetermined crank angle period, a fuel leak quantity QLEAK in the predetermined crank angle period, and the feedback fuel discharging quantity QFB together. Then, the fuel discharging quantity QPMP is converted into a command fuel drawing quantity by using a two-dimensional map, whose parameters are the fuel discharging quantity QPMP and the fuel pressure. Then, the command fuel drawing quantity is converted into driving current I by using another two-dimensional map, whose parameters are the drawing quantity and the engine rotation speed NE.

**[0006]** Then, target driving current IPMP is calculated by adding a previous current learning value ISTUDY, which is stored in a memory and the like through previous learning control, to the driving current I. A lifting degree or an opening area of the suction control valve is adjusted by applying the target driving current IPMP to the suction control valve included in the fuel supply pump so that an optimum discharging quantity of the fuel is discharged from the fuel supply pump into the common rail.

**[0007]** As shown in Fig. 6, there is a large individual difference per every fuel supply pump in a property of the fuel discharging quantity QREAL with respect to the driving current I applied to an electromagnetic coil of the suction control valve, or a property between the driving current I and the discharging quantity QREAL. Moreover, the property of the discharging quantity QREAL during an idling operation deviates from a reference property of a master fuel supply pump, which has a median property among the products, in a direction of the axis of the driving current I as shown by a solid line "b" in Fig. 6. In Fig. 6, a broken line "a" represents the reference property of the discharging quantity QREAL of the master fuel supply pump, which has the median property among the products, with respect to the driving current I. A solid line "b" represents the estimated property of the discharging quantity QREAL of the fuel supply pump. with respect to the driving current I during the idling operation. The quantity QIDLE represents the discharging quantity provided during the idling operation. Therefore, a learning value ISTUDY should preferably be stored in the form of the driving current. Accordingly, conventionally, the feedback control during the learning control is performed based on the driving current, though the feedback control during the normal control is performed based on the fuel discharging quantity.

**[0008]** Next, a method for calculating the target driving current IPMP applied to the suction control valve during the learning control through publicly known proportional and integral control (PI control) will be explained based on control logic shown in Fig. 8. This calculating method is executed when a learning condition such as a steady idling state is established. In this calculating method, a demand fuel pressure calculated from the pressure deviation $\Delta P$ between the actual fuel pressure NPC and the target fuel pressure PFIN is converted into a demand fuel discharging quantity QDEMAND. Then, the demand fuel discharging quantity QDEMAND is further converted into demand driving current IDEMAND. Then, feedback current PFI is calculated from the demand driving current IDEMAND through the publicly known PI control.

**[0009]** Then, a present current learning value ISTUDY is calculated by adding a previous current learning value ISTUDY, which is stored in the memory and the like in the previous learning control, to the feedback current PFI. Then, the present current learning value ISTUDY is stored in the memory and the like as the previous current learning value ISTUDY. Then, target driving current IPMP is calculated by adding the fuel injection quantity QINJ in a predetermined crank angle period, the fuel leak quantity QLEAK in the predetermined crank angle period, and the present current learning value ISTUDY together.

**[0010]** The conventional fuel injection system uses two kinds of feedback correction values of the feedback fuel discharging quantity QFB and the feedback current PFI. The feedback fuel discharging quantity QFB is calculated through the feedback control based on the fuel discharging quantity during the normal control as shown by an area QFB-F/B in Fig. 7. The feedback current PFI is calculated through the feedback control based on the driving current during the learning control as shown by an area PFI-F/B in Fig. 8. Therefore, the conventional fuel injection system has the problem that a fitting load is increased because of the complexity of the control. The fitting load is a load of a fitting operation between the feedback control based on the fuel discharging quantity and the feedback control based on the driving current. Moreover, when the control is switched from the learning control to the normal control, the feedback control is changed from the feedback control based on the driving current to the feedback control based on the fuel discharging quantity. Since the control must be changed smoothly, the control is complicated and the number of steps of the fitting operation is increased, and the management of the fitting operation becomes more troublesome.

**[0011]** It is therefore an object of the present invention to provide a fuel injection system for an internal combustion engine capable of inhibiting an increase in a fitting load caused by complexity of control. It is another object of the present invention to provide a fuel injection system for an internal combustion engine capable of inhibiting complexity of control, an increase in the number of steps of a fitting operation and an increase in trouble in management.

**[0012]** According to an aspect of the present invention, control (feedback control based on a fuel discharging quantity) for calculating a feedback fuel discharging quantity, which is required for achieving a demand discharging quantity, from a pressure deviation between a target fuel pressure and an actual fuel pressure is performed during both of normal control and learning control. The demand discharging quantity corresponds to at least one of a fuel injection quantity, a fuel leak quantity and a target fuel pressure. In the normal control, feedback control for regulating an opening area or a lifting degree of a discharging quantity control valve is performed by applying target driving current to the discharging quantity control valve so that the actual fuel pressure substantially coincides with the target fuel pressure. The target driving current corresponds to the sum of first demand driving current and a current learning value. The first demand driving current is converted from the fuel discharging quantity as a target discharging quantity with a predetermined conversion coefficient.

**[0013]** In the learning control, the current learning value is calculated from a deviation between the first demand driving current and second demand driving current, which is converted from a predetermined known fuel discharging quantity with a predetermined conversion coefficient. In the learning control, the feedback control for regulating the opening area or the lifting degree of the discharging quantity control valve is performed by applying target driving current to the discharging quantity control valve so that the actual fuel pressure substantially coincides with the target fuel pressure. The target driving current corresponds to the sum of the first demand driving current and the current learning value.

**[0014]** Thus, the feedback control of the fuel discharging quantity is performed in both of the normal control and the learning control based on the pressure deviation between the target fuel pressure and the actual fuel pressure. Therefore, an increase in a fitting load caused by the complexity of control can be inhibited. Moreover, when the control is switched from the learning control to the normal control, it is not required to change the control from the feedback control based on the driving current to the feedback control based on the fuel discharging quantity. Accordingly, complexity of the control, an increase in the number of steps of a fitting operation, an increase in trouble in management and the like can be inhibited.

**[0015]** Features and advantages of an embodiment will be appreciated, as well as methods of operation and the function of the related parts, from a study of the following detailed description, the appended claims, and the drawings, all of which form a part of this application. In the drawings:

Fig. 1 is a schematic diagram showing a common rail type fuel injection system according to an embodiment of the present invention;

Fig. 2 is a time chart showing transition of an NE pulse signal and positions of plungers of a fuel supply pump of the fuel injection system according to the present embodiment;

Fig. 3 is a diagram showing control logic executed by an electronic control unit of the fuel injection system according to the present embodiment;

Fig. 4(a) is a diagram showing control logic executed by the electronic control unit of the fuel injection system according to the present embodiment;

Fig. 4(b) is a diagram showing a waveform of suction control valve driving current according to the present embodiment;

Fig. 5 is a flowchart showing calculation processing of a current learning value for learning and correcting target driving current according to the present embodiment;

Fig. 6 is a graph showing a property of a relationship between driving current and fuel discharging quantity according to the present embodiment;

Fig. 7 is a diagram showing control logic executed by an electronic control unit of a related art; and

Fig. 8 is a diagram showing another control logic executed by the electronic control unit of the related art.

**[0016]** Referring to Fig. 1, a common rail type fuel injection system according to the embodiment of the present invention is illustrated.

**[0017]** The common rail type fuel injection system according to the present embodiment has a common rail 1, a plurality of (four, in the present embodiment) electromagnetic fuel injection valves (injectors) 2, a fuel supply pump 3 and an electronic control unit (ECU) 10. The common rail 1 accumulates the fuel at a high pressure corresponding to an injection pressure of fuel injected into each cylinder of a four-cylinder type internal combustion engine such as a diesel engine, which is mounted to a vehicle such as an automobile. Each injector 2 is connected to the common rail 1 and injects the fuel into each cylinder of the engine. The engine drives the supply pump 3 to rotate. The ECU 10 electronically controls the operation of the injectors 2 and the supply pump 3. In Fig. 1, only the injector 2 corresponding to one cylinder of the four-cylinder engine is shown, and the injectors corresponding to the other cylinders are not shown.

**[0018]** The common rail 1 is required to continuously accumulate the high pressure corresponding to the fuel injection pressure. Therefore, the high-pressure fuel is supplied from the supply pump 3 to the common rail 1 through a high-pressure pipe 11 and is accumulated in the common rail 1. A normally-close type pressure reduction valve 7 is disposed in the common rail 1. The pressure reduction valve 7 can adjust an opening degree of a fuel discharging passage (a fuel returning passage) 13 connected with fuel discharging passages (fuel returning passages) 15, 16. The fuel discharging passages 15, 16 are connected with a fuel tank 5. Instead of the pressure reduction valve 7, a pressure limiter for releasing the fuel pressure in the common rail 1 may be disposed between the common rail 1 and the fuel returning passage 13 so that the fuel pressure in the common rail 1 does not exceed limit set pressure.

**[0019]** The pressure reduction valve 7 is electronically controlled by pressure reduction valve driving current applied from the ECU 10 through a pressure reduction valve driving circuit. The pressure reduction valve 7 is an electromagnetic valve having excellent performance of rapidly reducing the fuel pressure in the common rail 1 (the common rail pressure) from a high pressure to a low pressure when a vehicle is decelerated or the engine is stopped, for instance.

**[0020]** The pressure reduction valve 7 has a valve body for adjusting the opening degree of the fuel returning passage 13 for returning the fuel from the common rail 1 to the fuel tank 5, a solenoid coil (an electromagnetic coil) for driving the valve body in a value-opening direction, and valve biasing means such as a spring for biasing the valve body in a valve-closing direction. The pressure reduction valve 7 adjusts a returning quantity (a pressure reduction valve flow rate) of the fuel returned from the common rail 1 to the fuel tank 5 through the fuel returning passages 13, 15, 16 in proportion to the intensity of the pressure reduction valve driving current, which is applied to the solenoid coil through the pressure reduction valve driving circuit. Thus, the pressure reduction valve 7 changes the common rail pressure in the common rail 1.

**[0021]** The injector 2 mounted to every cylinder of the engine is an electromagnetic fuel injection valve having a fuel injection nozzle, an electromagnetic actuator, needle biasing means such as a spring, and the like. The fuel injection nozzle is connected to the downstream end of one of high-pressure pipes 12 branching from the common rail 1, and injects the fuel into each cylinder of the engine. The electromagnetic actuator drives a nozzle needle stored in the fuel injection nozzle in a valve-opening direction. The needle biasing means biases the nozzle needle in a valve-closing direction.

**[0022]** The fuel injection from the injector 2 to each cylinder of the engine is electronically controlled by turning on and off the energization to an electromagnetic valve 4 of the injector 2. The electromagnetic valve 4 functions as an electromagnetic actuator for controlling an increase and a decrease of a pressure in a back pressure control chamber of a command piston, which is connected to the nozzle needle. More specifically, while the electromagnetic valve 4 of the injector 2 of each cylinder is open, the high-pressure fuel supplied from the common rail 1 into the back pressure control chamber is overflowed to a low-pressure side, or the fuel tank 5, of a fuel system. Accordingly, the nozzle needle and the command piston are lifted against the biasing force of the needle biasing means so that an injection hole is opened. Thus, the high-pressure fuel accumulated in the common rail 1 is injected and supplied into the combustion chamber of each cylinder of the engine.

**[0023]** The supply pump 3 is a suction control type high-pressure supply pump. The supply pump 3 pressurizes the low-pressure fuel drawn from the fuel tank 5 through a filter 9 to a high pressure and pressure-feeds the high-pressure fuel to the common rail 1. The supply pump 3 has excellent pressure-raising performance of rapidly raising the common rail pressure in the common rail 1 from a low pressure to a high pressure when the vehicle is accelerated or when the engine is started.

**[0024]** The supply pump 3 has a known feed pump (a low-pressure supply pump), a cam, two plungers #1, #2, two pressurizing chambers (plunger chambers), and two discharging valves. A pump drive shaft rotates in accordance with the rotation of a crankshaft of the engine. Thus, the feed pump draws the low-pressure fuel from the fuel tank 5. The pump drive shaft drives the cam to rotate. The plungers #1, #2 are driven by the cam and are reciprocated between top dead center positions and bottom dead center positions respectively. The pressurizing chambers pressurize the drawn fuel through the reciprocating and sliding motion of the plungers #1, #2 in cylinders. The discharging valve opens when the fuel pressure in the pressurizing chamber exceeds a predetermined value.

**[0025]** As shown in Fig. 2, the supply pump 3 draws the low-pressure fuel into the pressurizing chamber during a drawing period "D" since the plunger #1 or the plunger #2 moves from the top dead center (TDC) position until the plunger #1 or the plunger #2 passes the bottom dead center position. The supply pump 3 pressure-feeds the high-pressure fuel during a pressure-feeding period "P" in which the discharging valve is open, or a period until the plunger #1 or the plunger #2 returns to the top dead center (TDC) position after the plunger #1 or the plunger #2 passes the bottom dead center position. In Fig. 2, SP#1 represents the position of the plunger #1 of the supply pump 3 and SP#2 represents the position of the plunger #2 of the supply pump 3. In Fig. 2. TDCP#1 represents the top dead center position of the plunger #1, TDCP#2 is the top dead center position of the plunger #2, TDCC#1 is the top dead center position of the cylinder #1, TDCC#2 is the top dead center position of the cylinder #2, TDCC#3 is the top dead center position of the cylinder #3, and TDCC#4 is the top dead center position of the cylinder #4. The fuel drawing is started at time point ts in Fig. 2.

**[0026]** A leak port is formed in the supply pump 3 so that the fuel inside the supply pump 3 is not heated to high temperature. Leak fuel from the supply pump 3 is returned from the leak port to the fuel tank 5 through a fuel returning passage 14 and the fuel returning passage 16.

**[0027]** A suction control valve (an SCV, hereafter) 6 is attached to a fuel supply passage, which is formed in the supply pump 3 and leads from the feed pump to the pressurizing chambers. The suction control valve 6 changes the discharging quantity (pump discharging quantity, pump pressure-feeding quantity) of the fuel discharged from the supply pump 3 to the common rail 1 by adjusting an opening degree (a lifting degree of a valve body, an opening area of a valve hole) of the fuel supply passage. Thus, the suction control valve 6 controls the common rail pressure.

**[0028]** The SCV 6 is electronically controlled by SCV driving current applied from the ECU 10 through a pump driving circuit. Thus, the SCV 6 regulates the drawing quantity of the fuel drawn into the pressurizing chambers of the supply pump 3. The SCV 6 has a valve body for adjusting the opening degree of the fuel supply passage for sending the fuel from the feed pump into the pressurizing chambers, a solenoid coil (an electromagnetic coil) for driving the valve body in a valve-closing direction, and valve biasing means such as a spring for biasing the valve body in a valve-opening direction. The SCV 6 regulates the pressures-feeding quantity (the pump discharging quantity) of the high-pressure fuel discharged from the pressurizing chambers of the supply pump 3 to the common rail 1 in proportion to the intensity of the SCV driving current applied to the solenoid coil through the pump driving circuit. Thus, the SCV 6 changes the common rail pressure in the common rail 1, or the injection pressure of the fuel injected from each injector 2 into each cylinder of the engine.

**[0029]** The ECU 10 has a microcomputer of a publicly-known structure including functions of a CPU for performing control processing and calculation processing, a memory device (a memory such as EEPROM, RAM, and the like) for storing various kinds of programs and data, an input circuit, an output circuit, a power source circuit, an injector driving circuit (EDU), the pump driving circuit, the pressure reduction valve driving circuit and the like. A previous current learning value for performing control logic shown in Fig. 5 is renewed and stored in the memory device. An initial value of the previous current learning value is the driving current corresponding to an idling fuel discharging quantity (a discharging quantity in the idling operation) as a reference property of a master supply pump having a median property. The known idling fuel discharging quantity is stored in the memory in advance. The sensor signals from various kinds of sensors are inputted to the microcomputer after the sensor signals are converted from analog signals into digital signals by an A/D converter.

**[0030]** As shown in Fig. 1, a voltage signal from a fuel pressure sensor (fuel pressure sensing means) 25 and the sensor signals from the other various kinds of sensors are inputted to the microcomputer in the ECU 10 after the signals are converted from analog signals into digital signals by the A/D converter. The ECU 10 electronically controls the actuators of respective control parts of the injector 2, the supply pump 3 and the like based on control programs stored in the memory if an ignition switch is turned on by returning an engine key to an IG position after the engine is cranked.

**[0031]** A crank angle sensor 21, an accelerator position sensor (engine load detecting means) 22, a cooling water temperature sensor 23, a fuel temperature sensor 24 and the like are connected to the microcomputer of the ECU 10. The crank angle sensor 21 senses a rotational angle of the crankshaft of the engine as operating condition detecting means for detecting the operating state or the operating condition of the engine. The accelerator position sensor 22 senses an accelerator position ACCP. The cooling water temperature sensor 23 senses the temperature THW of engine cooling water. The fuel temperature sensor 24 senses the temperature THF of the fuel drawn into the supply pump 3.

**[0032]** The crank angle sensor 21 is disposed so that the crank angle sensor 21 faces an outer periphery of an NE timing rotor attached to the crankshaft of the engine or the pump drive shaft of the supply pump 3. A plurality of convex teeth is disposed on the outer peripheral surface of the NE timing rotor at a predetermined interval of the rotational angle. In the present embodiment, as shown in Fig. 2, four convex teeth are disposed at every predetermined angle (180° CA) in order to distinguish reference positions of the respective cylinders, or the TDC position of the cylinder #1 (TDCC#1), the TDC position of the cylinder #3 (TDCC#3), the TDC position of the cylinder #4 (TDCC#4) and the TDC position of the cylinder #2 (TDCC#2). Thus, the convex teeth are disposed in accordance with the respective cylinders of the engine. Moreover, two convex teeth for distinguishing timing ts at which the supply pump 3 starts to draw the fuel, or the TDC position of the plunger #1 (TDCP#1) and the TDC position of the plunger #2 (TDCP#2), are disposed at every predetermined angle (360° CA).

**[0033]** The crank angle sensor 21 is formed of an electromagnetic pickup. The crank angle sensor 21 outputs pulse-shaped rotational position signals (NE pulse signals) through electromagnetic induction in accordance with approach and separation between each convex tooth of the NE timing rotor and the crank angle sensor 21. More specifically, the crank angle sensor 21 outputs the NE pulse signals synchronized with the rotation speed (the pump rotation speed) of the supply pump 3. The ECU 10 serves as rotation speed sensing means for sensing the engine rotation speed NE by measuring interval periods among the NE pulse signals outputted from the crank angle sensor 21.

**[0034]** The ECU 10 includes injection quantity determining means, injection timing determining means, injection period determining means and injector driving means. The injection quantity determining means calculates a command injection quantity QFIN in accordance with the engine rotation speed NE sensed by the rotation speed sensing means such as the crank angle sensor 21 and the accelerator position ACCP sensed by the accelerator position sensor 22. The injection timing determining means calculates command injection timing TFIN from the engine rotation speed NE and the command injection quantity QFIN. The injection period determining means calculates a command injection pulse period TQ from the command injection quantity QFIN and the common rail pressure NPC sensed by the fuel pressure sensor 25. The injector driving means applies pulse-shaped injector driving current to the electromagnetic valve 4 of the injector 2 of each cylinder through the injector driving circuit EDU.

**[0035]** The ECU 10 has a fuel pressure controller (a pump controller, an SCV controller, a pressure reduction valve controller) for calculating an optimum fuel injection pressure in accordance with the operating condition or the operating state of the engine and for operating the solenoid coil of the SCV 6 through the pump driving circuit. The fuel pressure controller calculates a target fuel pressure PFIN from the command injection quantity QFIN and the engine rotation speed NE. The fuel pressure controller regulates the SCV driving current applied to the solenoid coil of the SCV 6 in order to control the discharging quantity (the pump discharging quantity) of the fuel discharged from the supply pump 3 into the common rail 1, or regulates the pressure reduction valve flow rate (the fuel returning quantity) of the fuel returned from the common rail 1 to the fuel tank 5. Thus, the fuel pressure controller achieves the target fuel pressure PFIN.

**[0036]** More preferably, the SCV driving current applied to the solenoid coil of the SCV 6 should be feedback-controlled through PID control so that the common rail pressure NPC in the common rail 1 sensed by the fuel pressure sensor 25 substantially coincides with the target fuel pressure PFIN. Thus, control accuracy of the fuel injection quantity can be improved. The SCV driving current should preferably be controlled in duty cycle control. Highly-accurate digital control can be performed by employing the duty cycle control, in which an on/off ratio (an energization period ratio, a duty ratio) of a control pulse signal (a pulse-shaped pump driving signal) per unit time is adjusted to change the lifting degree and the opening area of the SCV 6 in accordance with the pressure deviation $\Delta P$ between the common rail pressure NPC and the target fuel pressure PFIN. Thus, control response ability and following ability of the actual fuel pressure NPC with respect to the target fuel pressure PFIN can be improved.

**[0037]** Next, a control method of the SCV driving current applied to the solenoid coil of the SCV 6 of the present embodiment will be explained based on Figs. 1 to 6. A method for calculating the SCV driving current by using the publicly known PID control is shown in the control logic of Figs. 3 and 4(a).

**[0038]** The ECU 10 includes injection quantity determining means for calculating the command injection quantity QFIN by adding an injection quantity correction value to a basic injecting quantity Q. The basic injection quantity Q is calculated in accordance with the engine rotation speed NE sensed by the rotation speed sensing means such as the crank angle sensor 21 and the accelerator position ACCP sensed by the accelerator position sensor 22. The injection quantity correction value is calculated in accordance with the engine cooling water temperature THW sensed by the cooling water temperature sensor 23, the fuel temperature THF sensed by the fuel temperature sensor 24 and the like. The ECU 10 also includes injection timing determining means for calculating the command injection timing (injection start timing) TFIN in accordance with the command injection quantity QFIN and the engine rotation speed NE. Moreover, the ECU 10 includes fuel pressure determining means for calculating the target fuel pressure PFIN in accordance with the command injection quantity QFIN and the engine rotation speed NE.

**[0039]** The ECU 10 includes fuel leak quantity calculating means for calculating a reference value of the fuel leak quantity based on a characteristic map or a formula. The characteristic map or the formula is made in advance by calculating relationships among the engine rotation speed NE, the actual common rail pressure NPC sensed by the fuel pressure sensor 25, and the reference value of the fuel leak quantity through experimentation and the like. Then, the fuel leak quantity calculating means calculates the fuel leak quantity QLEAK by multiplying the reference value of the fuel leak quantity by a fuel temperature correction coefficient considering the fuel temperature THF sensed by the fuel temperature sensor 24.

**[0040]** The ECU 10 calculates feedback gains (a proportional gain GP, an integral gain GI and a differential gain GD) based on a feedback gain map. The feedback gain map is made in advance by measuring the relationships among the pressure deviation $\Delta P$ of the actual fuel pressure NPC from the target fuel pressure PFIN and the feedback gains (the proportional gain GP, the integral gain GI and the differential gain GD) through experimentation and the like. Then, the ECU 10 calculates a feedback pressure PFB based on a following formula (2).

$$PFB = GP \times \Delta P + GI \times \int \Delta P + GD \times d(\Delta P)/dt, \qquad (2)$$

**[0041]** Then, correction value determining means included in the ECU 10 converts the feedback pressure PFB into a feedback fuel discharging quantity QFB required for achieving a demand discharging quantity QDEMAND by using a predetermined conversion coefficient K1. The demand discharging quantity QDEMAND corresponds to the fuel injection quantity QINJ, the fuel leak quantity QLEAK and the target fuel pressure PFIN. For instance, the correction value determining means calculates the feedback fuel discharging quantity QFB by multiplying the feedback pressure PFB by a value obtained by dividing a modulus $K\alpha$ of volume elasticity by an inner volume V of the common rail 1. The calculation process of the feedback pressure PFB and the conversion process of the feedback pressure PFB into the feedback fuel discharging quantity QFB correspond to the feedback control based on the fuel discharging quantity, which is shown by an area QFB-F/B in Fig. 3.

**[0042]** Then, demand discharging quantity determining means included in the ECU 10 calculates the demand discharging quantity QDEMAND in accordance with the fuel injection quantity QINJ in a predetermined crank angle (for instance, 360° CA), the fuel leak quantity QLEAK in the predetermined crank angle (for instance, 360° CA) and the target fuel pressure PFIN. The actual injection quantity may be used as the fuel injection quantity QINJ in the predetermined crank angle (for instance, 360° CA). In the present embodiment, a doubled value of the command injection quantity QFIN is used as the fuel injection quantity QINJ in the predetermined crank angle for the sake of convenience. Fuel discharging quantity determining means included in the ECU 10 calculates the fuel discharging quantity QPMP as a target discharging quantity by adding the above feedback fuel discharging quantity QFB to the demand discharging quantity QDEMAND.

**[0043]** Then, first discharging quantity and current converting means included in the ECU 10 converts the fuel discharging quantity QPMP into first demand driving current 11 with a predetermined conversion coefficient. For instance, the fuel discharging quantity QPMP is converted into a command drawing quantity based on a two-dimensional map, in which the fuel discharging quantity QPMP and the fuel pressure are employed as parameters. Further, the first discharging quantity and current converting means converts the command drawing quantity into the first demand driving current 11 based on a two-dimensional map, in which the drawing quantity of the fuel and the engine rotation speed NE are employed as parameters.

**[0044]** Then, learning value reflecting means included in the ECU 10 calculates target driving current IPMP by adding the first demand driving current I1 and the previous current learning value ISTUDY based on a following formula (3).

$$IPMP = I1 + ISTUDY, \qquad (3)$$

**[0045]** Then, drawing interval calculating means included in the ECU 10 calculates pump rotation speed NP by reading the NE pulse signals, which are outputted from the crank angle sensor 21 and are synchronized with the pump rotation speed as shown in Fig. 2. The drawing interval calculating means of the ECU 10 receives TDC position determination signals of the plungers #1, #2. Then, as shown in Fig. 4(a), the drawing interval calculating means calculates a pump drawing interval (an interval for drawing the fuel) INTDRAW of the supply pump 3 from the pump rotation speed

NP and the two TDC position determination signals. A cam profile or a cam phase of the supply pump 3 provide waveforms similar to the waveforms of the transition of the position SP#1 of the plunger #1 and the position SP#2 of the plunger #2 of the supply pump 3 shown in Fig. 2.

**[0046]** Then, driving current interval determining means included in the ECU 10 calculates a driving current interval INTISCV of the SCV 6 (an interval of the driving current ISCV applied to the SCV 6) in accordance with the pump drawing interval INTDRAW of the supply pump 3. Then, duty ratio determining means included in the ECU 10 calculates a duty ratio of the SCV driving current ISCV from the driving current interval INTISCV and the target driving current IPMP required for achieving the target fuel pressure PFIN. The duty ratio determining means calculates a duty value (DUTY) with respect to the SCV driving current interval INTISCV as shown in Fig. 4(b) based on a map or a formula for converting the driving current into the duty value, which is made in advance by measuring the relationship between the target driving current IPMP and the duty value DUTY through experimentation and the like.

**[0047]** Then, the ECU 10 converts the duty value DUTY with respect to the driving current interval INTISCV of the SCV 6 into a control pulse signal (a pulse-shaped pump driving signal) by using a predetermined conversion coefficient. Then, the ECU 10 applies the pulse-shaped pump driving signal (the SCV driving current ISCV) to the solenoid coil of the SCV 6 through an SCV driving circuit. Thus, the valve lifting degree and the opening area of the SCV 6 are regulated in accordance with the SCV driving current ISCV, and the discharging quantity of the 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. Thus, the actual fuel pressure NPC in the common rail 1 is feedback-controlled so that the actual fuel pressure NPC substantially coincides with the target fuel pressure PFIN.

**[0048]** Next, a method for calculating the current learning value for learning and correcting the target driving current IPMP by using the publicly known PID. control will be explained based on Figs. 3 to 5. Fig. 5 is a flowchart showing calculation processing (learning control) of the current learning value ISTUDY for learning and correcting the target driving current IPMP. A control routine shown in Fig. 5 is repeated at every predetermined timing after the ignition switch is turned on.

**[0049]** When the processing proceeds to the control routine shown in Fig. 5, the pressure deviation $\Delta P$ of the actual fuel pressure NPC from the target fuel pressure PFIN is calculated and the feedback pressure PFB is calculated from the pressure deviation $\Delta P$ based on the formula (2) in Step S1. Then, the feedback pressure PFB is converted into the feedback fuel discharging quantity QFB by using the predetermined conversion coefficient K1 in Step S2.

**[0050]** Then, the fuel discharging quantity QPMP as the target discharging quantity is calculated by adding the feedback fuel discharging quantity QFB and the demand discharging quantity QDEMAND corresponding to the fuel injecting quantity QINJ in the predetermined crank angle (for instance, 360° CA), the fuel leak quantity QLEAK in the predetermined crank angle (for instance, 360° CA) and the target fuel pressure PFIN in Step S3. Then, the first discharging quantity and current converting means converts the fuel discharging quantity QPMP into the first demand driving current I1 by using the above conversion processing method in Step S4.

**[0051]** Then, it is determined whether a learning condition is established or not in Step S5. If the result of the determination in Step S5 is "NO", the processing proceeds to Step S8 and normal control is performed. The learning condition is established (YES) when it is determined that the operating state of the engine is in a steady idling state. The learning condition is not established (NO) when it is determined that the operating condition of the engine is not in the steady idling operating state.

**[0052]** It is determined whether the operating state of the engine is in the steady idling state based on the signals from the various kinds of sensors and switches attached to the engine or the vehicle. For instance, the operating state of the engine is determined to be in the steady idling state when a state, in which the engine rotation speed NE is equal to or less than a predetermined value (1000 rpm) or is within a predetermined range (800 to 1000 rpm), the accelerator position ACCP is equal to or less than a predetermined value (5%), the target fuel pressure PFIN is within a predetermined range (30 to 40 MPa), the pressure deviation AP between the actual fuel pressure NPC and the target fuel pressure PFIN is equal to or less than a predetermined value (30 MPa), the command injecting quantity QFIN is equal to or less than a predetermined value (1 $mm^3$/st), 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 a gear position of a transmission is located in an N (neutral) position or a shift position of a select lever is located in an N (neutral) range, is detected.

**[0053]** In the present embodiment, a timer starts counting when the steady idling state is achieved. When the count CN of the timer reaches a predetermined value, or when a certain period passes after the steady idling state is achieved, the calculation processing (the learning control) of the current learning value ISTUDY for learning and correcting the target driving current IPMP is performed. When the steady idling state is eliminated before the count CN of the timer reaches the predetermined value, the count CN of the timer is reset. The timer restarts the counting from the beginning when the steady idling state is achieved again.

**[0054]** If the result of the determination in Step S5 is "YES", or if the learning condition is established, the calculation processing (the learning control) of the current learning value ISTUDY is performed by learning control performing means included in the ECU 10.

**[0055]** First, as shown in Fig. 3, the known idling fuel discharging quantity QIDLE, or the discharging quantity of the master supply pump, during the idling operation is read out of the memory device. The known idling fuel discharging quantity QIDLE during the idling operation is a fuel discharging quantity measured in advance through experimentation and the like. The known idling discharging quantity QIDLE is a discharging quantity, which should originally be provided when a certain period passes after the steady idling state is achieved, or when the learning control is performed.

**[0056]** Then, second discharging quantity and current converting means included in the ECU 10 converts the known idling fuel discharging quantity QIDLE into second demand driving current I2 with a predetermined conversion coefficient in step S6. For instance, the known idling fuel discharging quantity QIDLE during the idling operation is converted into a command drawing quantity by using a two-dimensional map, in which the known idling fuel discharging quantity QIDLE during the idling operation and the fuel pressure are employed as parameters. Subsequently, the second discharging quantity and current converting means converts the command drawing quantity into the second demand driving current I2 by using a two-dimensional map, in which the drawing quantity of the fuel and the engine rotation speed NE are employed as parameters.

**[0057]** Then, learning value storing means included in the ECU 10 calculates the present current learning value ISTUDY by subtracting the second demand driving current 12 from the first demand driving current 11 in Step S7. The learning value storing means stores the present current learning value ISTUDY in the memory device as a renewed previous current learning value ISTUDY in Step S7. Then, the learning value reflecting means calculates the target driving current IPMP required for achieving the target fuel pressure PFIN by adding the first demand driving current I1 and the previous current learning value ISTUDY based on the formula (3) in Step 58. Then, the calculation processing (the learning control) of the current learning value ISTUDY for learning and correcting the target driving current IPMP is ended.

**[0058]** As explained above, in the common rail type fuel injection system according to the present embodiment, the feedback control based on the fuel discharging quantity is performed in both of the normal control and the learning control. In the feedback control based on the fuel discharging quantity, the feedback pressure PFB is calculated from the pressure deviation ΔP between the target fuel pressure PFIN and the actual fuel pressure NPC. Then, the feedback pressure PFB is converted into the feedback fuel discharging quantity QFB by using the predetermined conversion coefficient K1. The feedback fuel discharging quantity QFB is the quantity required for achieving the demand discharging quantity QDEMAND corresponding to the fuel injecting quantity QINJ, the fuel leak quantity QLEAK and the target fuel pressure PFIN. More specifically, the feedback control of the fuel discharging quantity is performed based on the pressure deviation ΔP between the target fuel pressure PFIN and the actual fuel pressure NPC in both of the normal control and the learning control.

**[0059]** In the normal control, like the conventional control, the fuel discharging quantity QPMP as the target discharging quantity is calculated by adding the feedback fuel discharging quantity QFB and the demand discharging quantity QDEMAND. Then, the fuel discharging quantity QPMP is converted into the first demand driving current 11 by using a predetermined conversion coefficient. Then, the target driving current IPMP corresponding to the sum of the previous current learning value ISTUDY and the first demand driving current I1 is calculated. In the calculation processing (the learning control) of the current learning value ISTUDY, the difference between the first demand driving current I1 and the second demand driving current 12 is calculated as the current learning value ISTUDY for learning and correcting the target driving current IPMP, and is stored in the memory device as the renewed current learning value ISTUDY. The first demand driving current I1 is converted from the fuel discharging quantity QPMP, which is provided based on the reference property, by using the predetermined conversion coefficient. The second demand driving current I2 is converted from the known idling fuel discharging quantity QIDLE. The known idling fuel discharging quantity QIDLE is the quantity that should originally be obtained when a certain period passes after the steady idling condition is achieved, or when the learning control is performed.

**[0060]** The above calculating method of the current learning value ISTUDY is much simpler than the calculation processing of the current learning value ISTUDY using the feedback control based on the driving current as in the related art. Moreover, the calculation processing of the current learning value ISTUDY according to the present embodiment has accuracy equal to or higher than the accuracy of the related art. Therefore, the control of the fuel discharging quantity discharged from the supply pump 3 and the control logic of the common rail pressure control can be simplified. Thus, control response ability and following ability of the actual fuel pressure NPC with respect to the target fuel pressure PFIN can be improved. Moreover, the feedback control of the fuel discharging quantity based on the pressure deviation ΔP between the target fuel pressure PFIN and the actual fuel pressure NPC is performed in both of the normal control and the learning control. Therefore, an increase in the fitting load caused by complexity of the control can be inhibited.

**[0061]** In addition, when the control is switched from the learning control to the normal control, it is not required to change the control from the feedback control based on the driving current to the feedback control based on the fuel discharging quantity. Therefore, the complexity of the control, an increase in the number of steps of the fitting operation, an increase in trouble in management and the like can be inhibited. As shown in Fig. 6, there is a large individual difference per every supply pump 3 in the property of the relationship between the driving current I and the fuel discharging quantity QREAL. As shown in Fig. 6, the property deviates along the axis of the driving current I. Therefore, the current learning value ISTUDY can be reflected in the entire operating area of the engine in addition to the idling operation area.

(Modifications)

**[0062]** In the above embodiment, the present invention is applied to the common rail type fuel injection system as an example of the fuel injection system for the internal combustion engine. Alternatively, the present invention may be applied to a fuel injection system for the internal combustion engine, which does not have a pressure accumulating vessel such as the common rail and directly supplies the high-pressure fuel from the fuel supply pump to the injector through a high-pressure pipe. In the present embodiment, the present invention is applied to the method for feedback-controlling the discharging quantity of the fuel discharged from the supply pump 3 through the PID control. Alternatively, the present invention may be applied to a method for feedback-controlling the discharging quantity of the fuel discharged from the supply pump 3 through the PI control.

**[0063]** In the present embodiment, the fuel pressure sensor 25 is directly attached to the common rail 1 for sensing the actual fuel pressure (the common rail pressure) NPC accumulated in the common rail 1. Alternatively, the fuel pressure sensing means may be attached to the fuel pipe and the like leading from the plunger chambers (the pressurizing chambers) of the supply pump 3 to the fuel passages within the injectors 2. Thus, the discharging pressure (the actual fuel pressure) of the fuel discharged from the pressurizing chambers of the supply pump 3 or the injection pressure (the actual fuel pressure) of the fuel supplied into the injector 2 and injected into each cylinder of the engine can be sensed.

**[0064]** In the present embodiment, the suction control valve (SCV) 6 is disposed for controlling the discharging quantity of the fuel discharged from the supply pump 3 by changing the quantity of the fuel drawn from the feed pump into the pressurizing chambers in accordance with the driving current. The SCV 6 changes the quantity of the fuel drawn into the pressurizing chambers by regulating the opening degree (the valve lifting degree or the opening area of the valve hole) of the fuel supply passage leading from the feed pump to the pressurizing chambers. The SCV 6 may be formed of a normally-open type electromagnetic valve whose valve body is completely opened, or the opening area of the valve hole and the valve lifting degree are maximized, when the energization to its electromagnetic coil (the solenoid coil) is stopped. Alternatively, the SCV 6 may be formed of a normally-close type electromagnetic valve whose valve body is completely closed, or the opening area of the valve hole and the lifting degree are minimized, when the energization to the solenoid coil is stopped. An electric motor driving type suction control valve may be also used as the suction control valve.

**[0065]** In the present embodiment, the memory such as the EEPROM is used as the learning value storing means for storing the difference between the first demand driving current I1 and the second demand driving current I2 as the renewed previous current learning value ISTUDY in the learning control. Alternatively, the previous current learning value ISTUDY may be stored into another memory medium such as standby RAM, EPROM, a nonvolatile memory such as a flash memory, a DVD-ROM, a CD-ROM, or a flexible disc. Also in this case, the stored contents are preserved even after the ignition switch is turned off (IG OFF), or even after the engine key is pulled out of a key cylinder.

**[0066]** In the case where the difference between the previous current learning value stored in the memory in the previous learning control and the present current learning value calculated in the present learning control is equal to or greater than a predetermined value, there is a possibility of an abnormality in the supply pump 3 itself, a control abnormality of the ECU 10 or the like. Therefore, in this case, an abnormality warning lamp (an indicator lamp) may be turned on to urge a driver to change the supply pump 3, the ECU 10 or the like. The calculation processing (the learning control) of the current learning value for learning and correcting the above target driving current IPMP may be performed at a constant learning correction frequency or a variable learning correction frequency based on the traveling distance of a vehicle, a period of use of the supply pump 3 and the like. Alternatively, the learning control may be performed when the engine is started.

**[0067]** The current learning value calculated in the present learning control may be calculated as the present current learning value (or a present temporary current learning value), and the present current learning value may be stored in the memory such device as the renewed previous current learning value. Alternatively, the current learning value calculated in the present learning control may be calculated as the present current learning value, and the sum of the present current learning value and the previous current learning value stored in the memory in the previous learning control may be stored in the memory device as the renewed previous current learning value.

**[0068]** Alternatively, the present current learning value calculated in the present learning control, or the sum (a present final learning value) of the present temporary current learning value and the previous current learning value may be stored and held in the memory device as the previous current learning value when the engine is stopped or during the control for stopping the engine. The stored and held previous current learning value may be reflected in the calculation of the target driving current in the normal control after the restart of the engine after the engine is once stopped. Thus, destabilization of drivability, which is caused when the control data such as the current learning value are renewed during the operation of the engine and the actual fuel discharging quantity discharged from the supply pump 3 is suddenly changed, can be avoided.

**[0069]** In the present embodiment, the target driving current IPMP is learned and corrected in the learning control. The target driving current IPMP with respect to the fuel discharging quantity QPMP as the target discharging quantity, which is affected by a product difference (an individual difference of the SCV 6) such as variation in the shape of an opening of the SCV 6 caused in a manufacturing process, the variation in biasing force of a spring member for biasing the valve body of the SCV 6, or functional deterioration (performance reduction or change in property) of the SCV 6 with time, may be learned and corrected. Alternatively, the driving current applied to the solenoid coil of the SCV 6 may be learned and corrected in the learning control with respect to the actual fuel discharging quantity discharged from the supply pump 3, which is affected by the product difference (the individual difference of the SCV 6) such as the variation in the shape of the opening of the SCV 6 caused in the manufacturing process, the variation in the biasing force of the spring member for biasing the valve body of the SCV 6, or the functional deterioration (the performance reduction or the change in the property) of the SCV 6 with time.

**[0070]** The present invention should not be limited to the disclosed embodiment, but may be implemented in many other ways without departing from the spirit of the invention.

**[0071]** An electronic control unit (ECU) (10) of a fuel injection system for an internal combustion engine performs feedback control of a fuel discharging quantity in both of normal control and learning control based on a pressure deviation between a target fuel pressure and an actual fuel pressure. In the learning control, the ECU (10) calculates a difference between first demand driving current and second demand driving current as a current learning value for learning and correcting target driving current. The ECU (10) renews and stores the current learning value in a memory. The first demand driving current is converted from the fuel discharging quantity as a target discharging quantity calculated through the above feedback control based on a reference property. The second demand driving current is converted from a known idling fuel discharging quantity.

## Claims

1. A fuel injection system for an internal combustion engine, **characterized by**:

   a fuel supply pump (3), which is driven by the internal combustion engine for pressurizing and pressure-feeding drawn fuel;
   a discharging quantity control valve (6) for changing a discharging quantity of the fuel discharged from the fuel supply pump (3) in accordance with driving current;
   fuel pressure sensing means (25) for sensing actual fuel pressure of the fuel discharged from the fuel supply pump (3) or the actual fuel pressure of the fuel supplied into a cylinder of the internal combustion engine through injection;
   fuel pressure determining means for calculating a target fuel pressure in accordance with an operating state or an operating condition of the internal combustion engine;
   correction value determining means (S2) for calculating a feedback fuel discharging quantity required to achieve a demand discharging quantity corresponding to at least one of a fuel injection quantity, a fuel leak quantity or the target fuel pressure from a pressure deviation between the actual fuel pressure and the target fuel pressure;
   fuel discharging quantity determining means (S3) for calculating the fuel discharging quantity as a target discharging quantity by adding at least the demand discharging quantity and the feedback fuel discharging quantity;
   learning control performing means (S4, S5, S6, S7, S8) including learning value calculating means (S7) for calculating a current learning value in learning control from a deviation between first demand driving current, which is converted from the fuel discharging quantity as the target discharging quantity by using a predetermined conversion coefficient, and second demand driving current, which is converted from a predetermined known fuel discharging quantity by using a predetermined conversion coefficient, the learning control performing means (S4, S5, 56, S7, S8) performing feedback control for approximately conforming the actual fuel pressure to the target fuel pressure by applying target driving current corresponding to the sum of the first demand driving current and the current learning value to the discharging quantity control valve (6); and
   normal control performing means (S4, S8) for performing feedback control for approximately conforming the actual fuel pressure to the target fuel pressure in normal. control by applying the target driving current corre-

sponding to the sum of the current learning value and the first demand driving current converted from the fuel discharging quantity as the target discharging quantity by using the predetermined conversion coefficient to the discharging quantity control valve (6).

**2.** The fuel injection system for the internal combustion engine as in claim 1, further **characterized in that**
the learning control performing means (S4, S5, S6, S7, S8) includes first discharging quantity and current converting means (S4) for converting the fuel discharging quantity as the target discharging quantity into the first demand driving current by using the predetermined conversion coefficient, and second discharging quantity and current converting means (S6) for converting the predetermined known fuel discharging quantity into the second demand driving current by using the predetermined conversion coefficient.

**3.** The fuel injection system for the internal combustion engine as in claim 1, further **characterized in that**
the learning control performing means (S4, S5, S6, S7, S8) includes learning value storing means (S7) for calculating the current learning value as the present current learning value and for storing the present current learning value as the renewed previous current learning value.

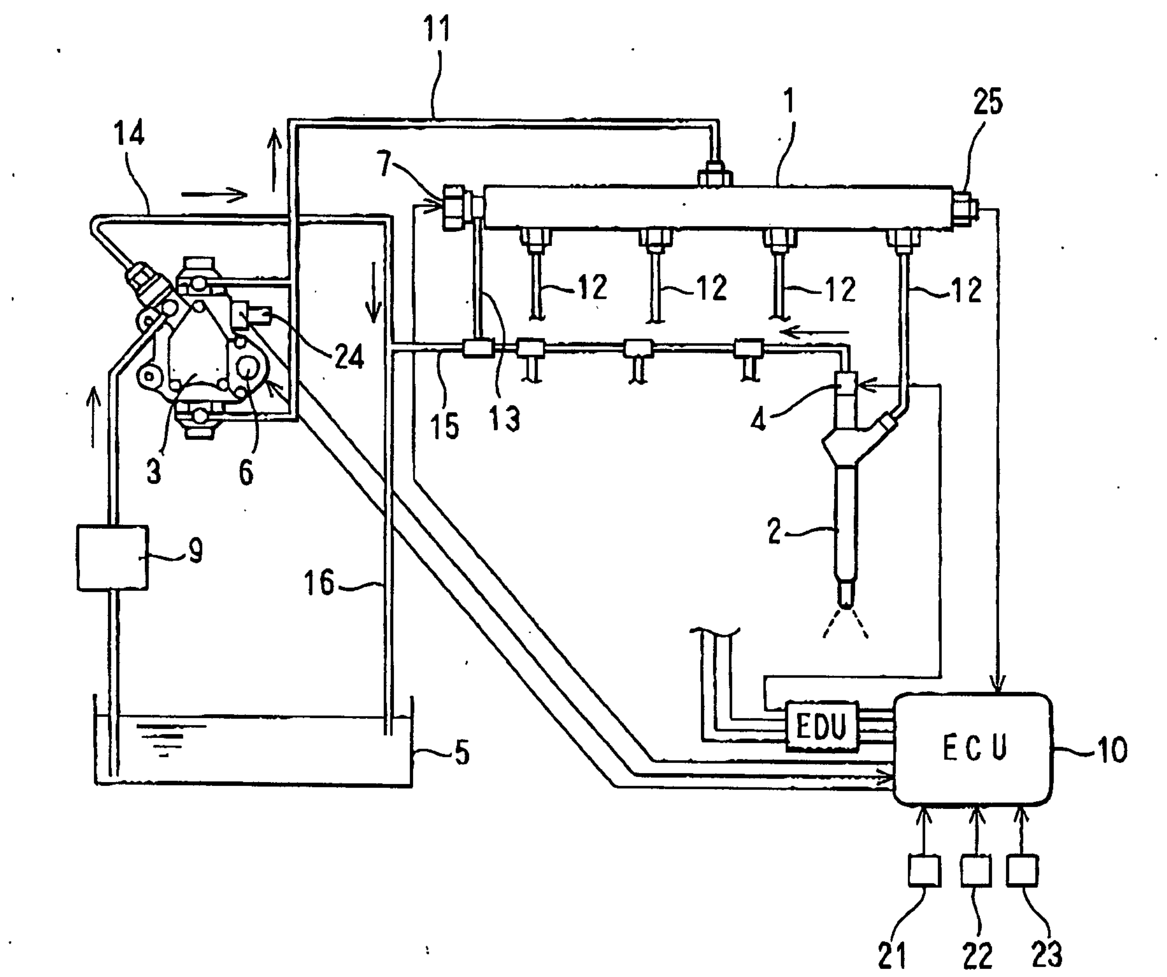
**4.** The fuel injection system for the internal combustion engine as in claim 1, further **characterized in that**
the learning control performing means (S4, S5, S6, S7, S8) includes learning value storing means (S7) for calculating the current learning value as the present current learning value and for storing the sum of the present current learning value and the previous current learning value as the renewed previous current learning value.

**5.** The fuel injection system for the internal combustion engine as in claim 1, further **characterized in that**
the learning control is performed when a learning condition is established, the learning condition being established when the internal combustion engine is in a steady idling state or a starting state or when a traveling distance of a vehicle reaches a predetermined distance.

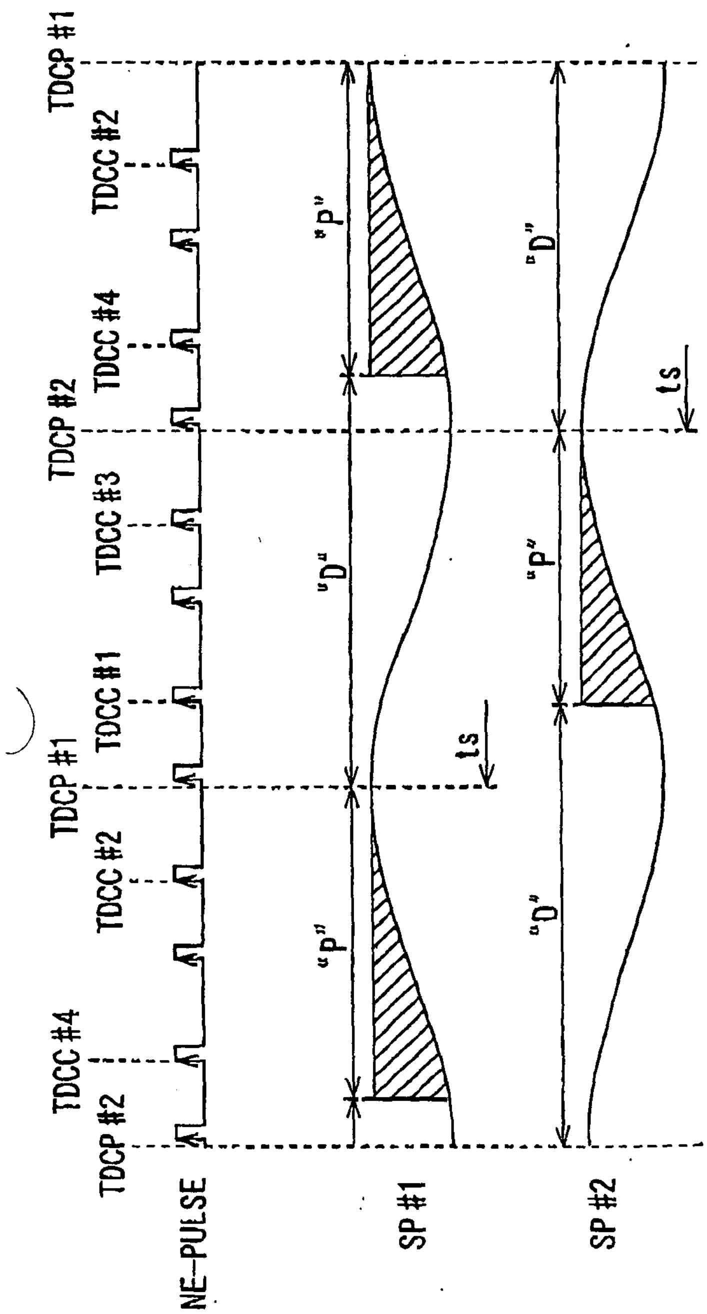
**6.** The fuel injection system for the internal combustion engine as in claim 1, further **characterized in that**
the normal control performing means (S4, S8) includes discharging quantity and current converting means (S4) for converting the fuel discharging quantity as the target discharging quantity into the first demand driving current by using the predetermined conversion coefficient.

**7.** The fuel injection system for the internal combustion engine as in claim 1, further **characterized in that**
the fuel injection system has a common rail (1) for accumulating the fuel at a high pressure corresponding to the fuel injecting pressure, and for distributing and supplying the accumulated high-pressure fuel to a plurality of fuel injection valves (2) mounted on respective cylinders of the internal combustion engine;
the discharging quantity control valve (6) is a suction control valve for changing the quantity of the fuel drawn into a pressuring chamber of the fuel supply pump (3) in accordance with the driving current; and
the fuel supply pump (3) is a suction control type fuel supply pump for pressurizing the fuel drawn into the pressurizing chamber through the suction control valve and for pressure-feeding the pressurized fuel into the common rail (1).

FIG. 1



# FIG. 2


NE-PULSE
SP #1
SP #2
TDCP
TDCP #2
TDCC #4
TDCC #2
TDCP #1
TDCC #1
TDCC #3
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TDCC #4
TDCC #2
TDCP #1
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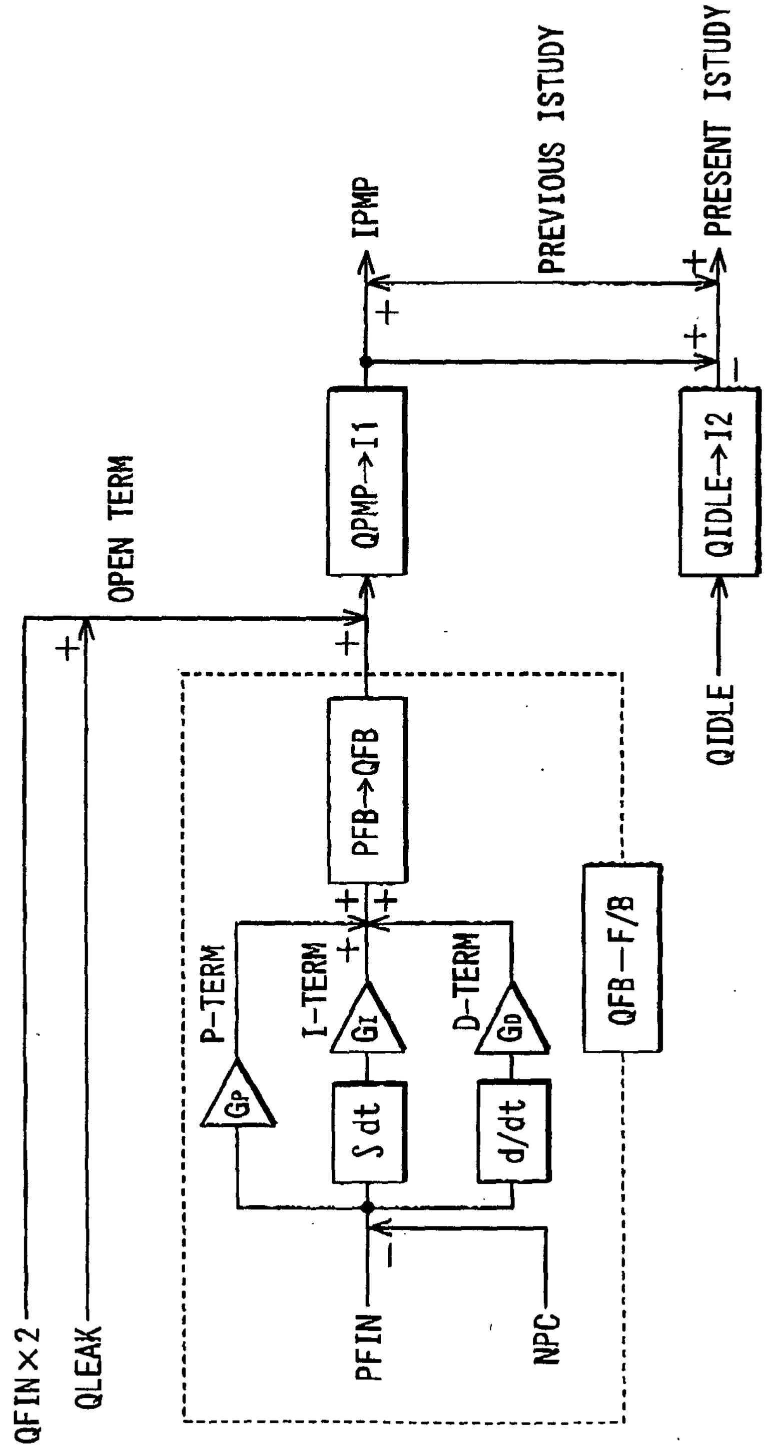
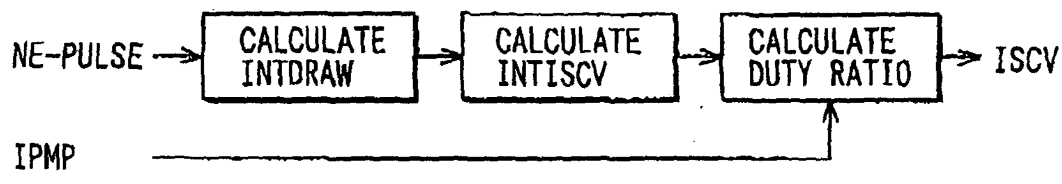
"D"
ts

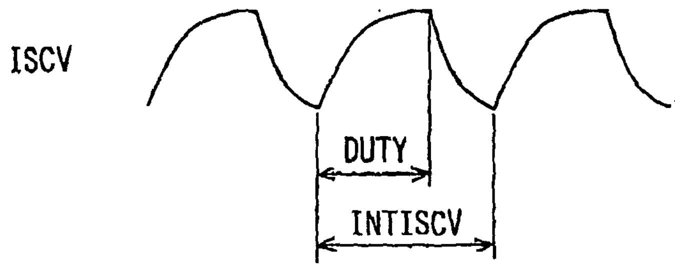
FIG. 3


QFIN×2
QLEAK
OPEN TERM
PFIN
NPC
P-TERM
I-TERM
D-TERM
∫dt
d/dt
PFB→QFB
QFB—F/B
QPMP→I1
QIDLE→I2
QIDLE
IPMP
PREVIOUS ISTUDY
PRESENT ISTUDY

# FIG. 4(a)




# FIG. 4(b)




# FIG. 6

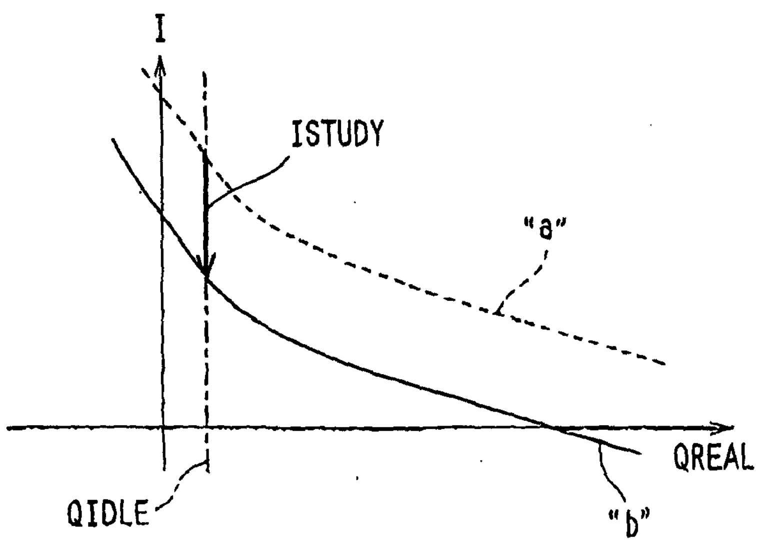


FIG. 5

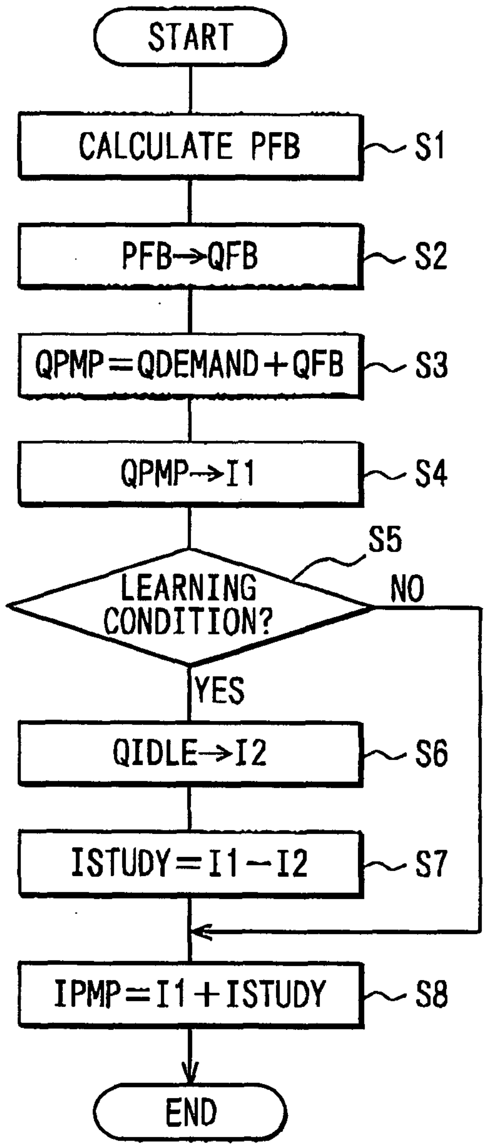

START
CALCULATE PFB
S1
PFB→QFB
S2
QPMP=QDEMAND+QFB
S3
QPMP→I1
S4
S5
LEARNING CONDITION?
NO
YES
QIDLE→I2
S6
ISTUDY=I1−I2
S7
IPMP=I1+ISTUDY
S8
END

FIG. 7

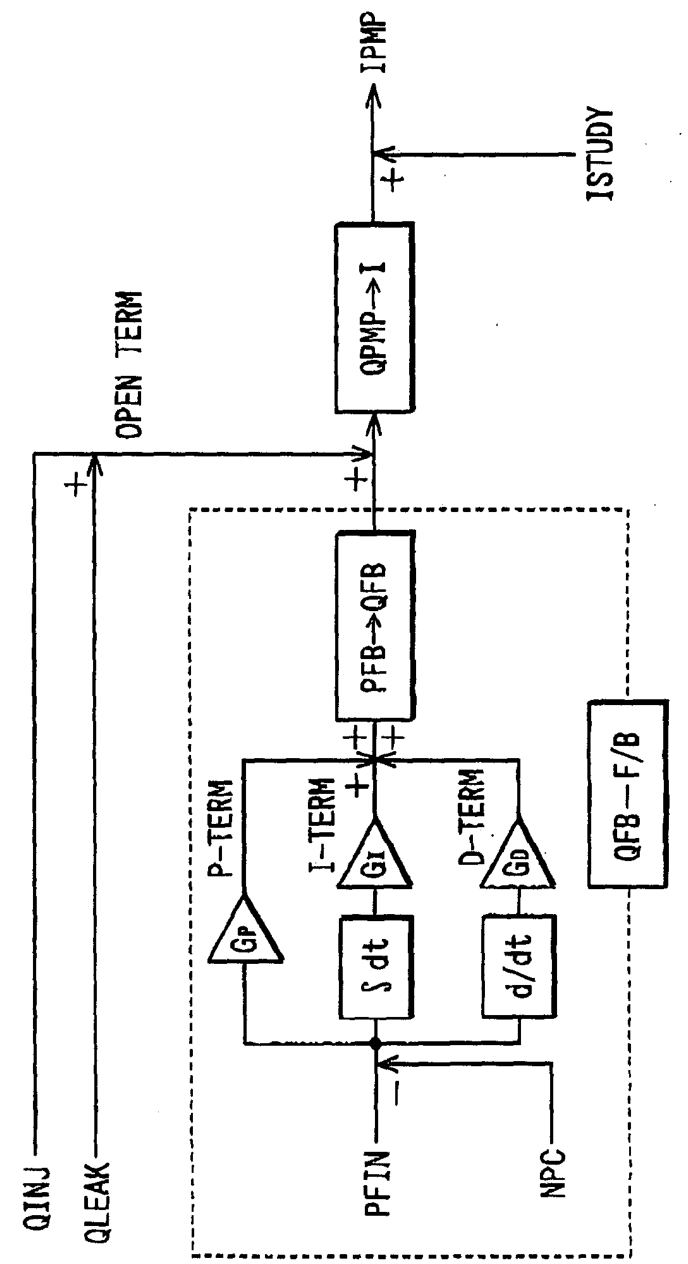
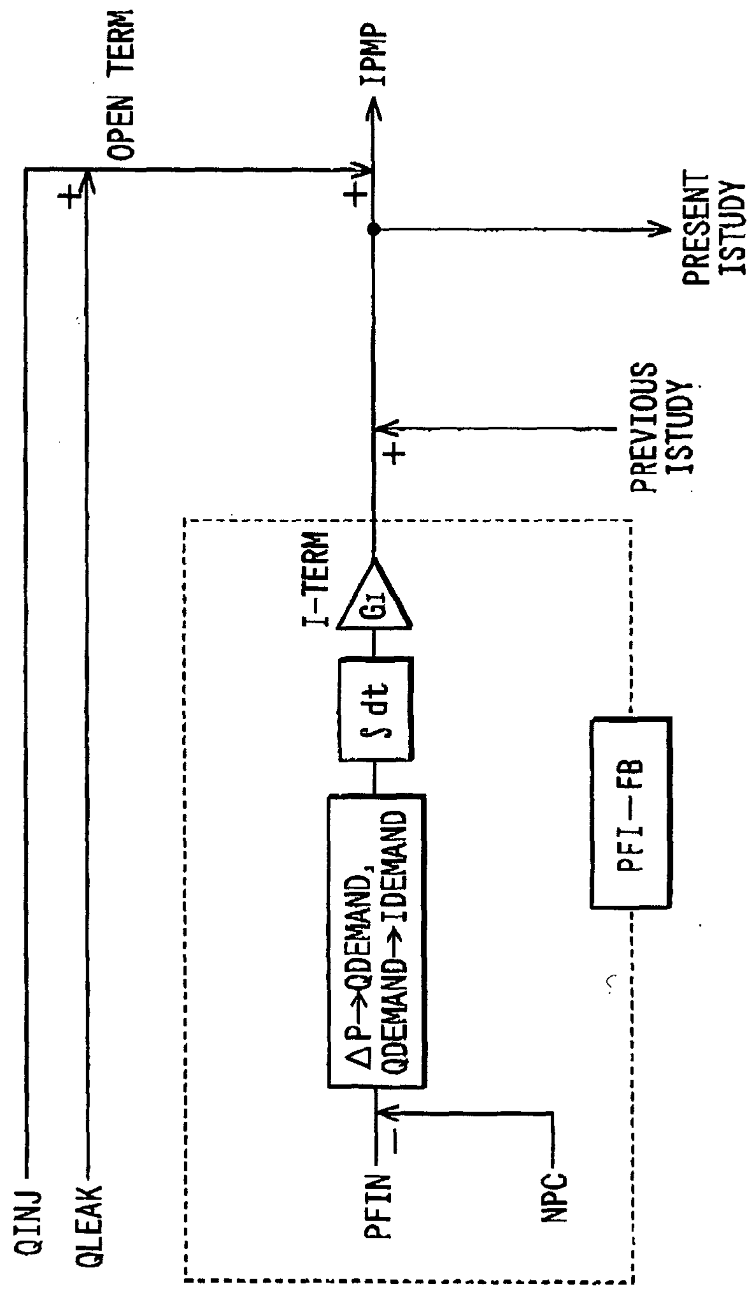

QINJ
QLEAK
OPEN TERM
PFIN
NPC
P-TERM
I-TERM
D-TERM
Gp
GI
GD
∫dt
d/dt
PFB→QFB
QPMP→I
IPMP
ISTUDY
QFB—F/B

FIG. 8


QINJ
QLEAK
PFIN
NPC
ΔP→QDEMAND,
QDEMAND→IDEMAND
∫ dt
GI
I-TERM
PFI—FB
PREVIOUS
ISTUDY
PRESENT
ISTUDY
OPEN TERM
IPMP