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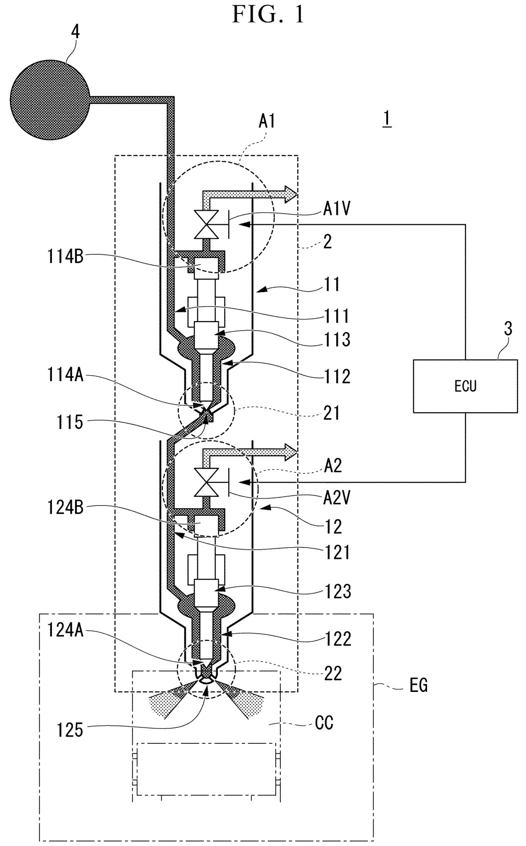
(54) **FUEL INJECTION DEVICE**

(57) Provided is a fuel injection system (1) that injects fuel into a combustion chamber (CC) of an internal combustion engine (EG). The fuel injection system (1) includes a pressure accumulating unit (122) to which fuel is supplied from a high-pressure source (4) that supplies the fuel at a prescribed pressure, a first valve (21) that supplies the fuel supplied from the high-pressure source (4) into the pressure accumulating unit (122), and a second valve (22) that injects the fuel supplied to the pressure accumulating unit (122) into the combustion chamber (CC) from the pressure accumulating unit (122).

FIG. 1



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Description

[Technical Field]

[0001] The present invention relates to a fuel injection system.

[0002] Priority is claimed on Japanese Patent Application No. 2016-235334, filed December 2, 2016, the content of which is incorporated herein by reference.

[Background Art]

[0003] Research and development of technology for fuel combustion in combustion chambers of internal combustion engines have been performed.

[0004] In this connection, a device for injecting fuel into a combustion chamber of an internal combustion engine is known (see Patent Document 1), in which a high-pressure source, a pressure booster, and a metering valve are provided. The pressure booster has a working chamber and a control chamber, both of which are separated by a movable piston. A change in pressure inside the control chamber of the pressure booster is made to cause a change in pressure inside a compression chamber of the pressure booster. The pressure booster is of a type that is made to impinge a nozzle chamber surrounding an injection valve member via a fuel inlet. A pressure relief valve having a valve body is disposed in a control line between the control chamber of the pressure booster and the metering valve. The valve body is made to impinge at least one hydraulic chamber of the pressure relief valve, and the hydraulic chamber can be linked with a pressure prevailing in a high-pressure accumulator chamber.

[Citation List]

[Patent Document]

[Patent Document 1]

[0005] Published Japanese Translation No. 2005-531712 of the PCT International Publication

[Summary of Invention]

[Technical Problem]

[0006] According to Patent Document 1, the device for injecting fuel into a combustion chamber of an internal combustion engine is provided with a common rail acting as the high-pressure source that supplies the fuel at a reference pressure. The device for injecting fuel boosts a pressure of the fuel injected into the combustion chamber of the internal combustion engine using a pressure boosting mechanism to a pressure that is higher than the reference pressure of the high-pressure source. In this case, the device for injecting fuel needs to discharge part of the high-pressure fuel to the outside differently from the combustion chamber in order to operate the pressure boosting mechanism. In this case, an amount of the fuel discharged to the outside by operating the pressure boosting mechanism using fuel is more than that of the fuel injected into the combustion chamber. For this reason, the device for injecting fuel dissipates part of the energy of the high-pressure fuel as thermal energy. That is, the device for injecting fuel increases a fuel consumption rate in proportion to the energy dissipated as thermal energy.

[0007] Therefore, the present invention was made in view of the problems in the related art, and provides a fuel injection system capable of changing a pressure of fuel injected into a combustion chamber to a pressure desired by a user while suppressing an increase in fuel consumption rate.

[Solution to Problem]

[0008] To solve the above problems, a fuel injection system according to an aspect of the present invention is a fuel injection system that injects fuel into a combustion chamber of an internal combustion engine, and includes: a pressure accumulating unit to which the fuel is supplied from a high-pressure source that supplies the fuel at a prescribed pressure; a first valve configured to supply the fuel, which is supplied from the high-pressure source, into the pressure accumulating unit; and a second valve configured to inject the fuel, which is supplied to the pressure accumulating unit, into the combustion chamber from the pressure accumulating unit.

[0009] Further, to solve the above problems, a fuel injection system according to an aspect of the present invention is a fuel injection system that injects fuel into a combustion chamber of an internal combustion engine, and includes: an injection part configured to inject the fuel into the combustion chamber; a high-pressure source configured to supply the fuel to the injection part at a prescribed pressure; and a pressure reducing unit configured to reduce a pressure of the fuel provided between the injection part and the high-pressure source.

[0010] Further, to solve the above problems, a fuel injection system according to an aspect of the present invention is a fuel injection system that injects fuel into a combustion chamber of an internal combustion engine, and enables a pressure at which the fuel supplied from a high-pressure source at a prescribed pressure is injected into a combustion chamber to be changed to a pressure that is lower than or equal to a prescribed pressure corresponding to each of at least three or more stages.

[Advantageous Effects of Invention]

[0011] According to the present invention, a fuel injection system capable of changing a pressure of fuel injected into a combustion chamber to a pressure desired by a user while suppressing an increase in fuel consumption rate can be provided.

[Brief Description of Drawings]

[0012]

FIG. 1 is a diagram illustrating an example of a constitution of a fuel injection system (1).
FIG. 2 is a diagram illustrating an example of a logical structure of the fuel injection system (1).
FIG. 3 is a diagram illustrating an example of a hardware configuration of an ECU (3).
FIG. 4 is a diagram illustrating an example of a functional configuration of the ECU (3).
FIG. 5 is a timing diagram for illustrating Embodiment 1 of a control method of the fuel injection system (1).
FIG. 6 is a timing diagram for illustrating Embodiment 2 of the control method of the fuel injection system (1).
FIG. 7 is a timing diagram for illustrating Embodiment 3 of the control method of the fuel injection system (1).
FIG. 8 is a timing diagram for illustrating Embodiment 4 of the control method of the fuel injection system (1).
FIG. 9 is a timing diagram for illustrating Embodiment 5 of the control method of the fuel injection system (1).
FIG. 10 is a timing diagram for illustrating Embodiment 6 of the control method of the fuel injection system (1).
FIG. 11 is a timing diagram for illustrating Embodiment 7 of the control method of the fuel injection system (1).
FIG. 12 is a timing diagram for illustrating Embodiment 8 of the control method of the fuel injection system (1).
FIG. 13 is a timing diagram for illustrating Embodiment 9 of the control method of the fuel injection system (1).
FIG. 14 is a timing diagram for illustrating Embodiment 10 of the control method of the fuel injection system (1).
FIG. 15 is a timing diagram for illustrating Embodiment 11 of the control method of the fuel injection system (1).
FIG. 16 is a timing diagram for illustrating Embodiment 12 of the control method of the fuel injection system (1).
FIG. 17 is a timing diagram for illustrating Embodiment 13 of the control method of the fuel injection system (1).
FIG. 18 is a timing diagram for illustrating Embodiment 14 of the control method of the fuel injection system (1).
FIG. 19 is a flow chart illustrating a procedure of selecting an injection pattern of the embodiment.

[Description of Embodiments]

<Embodiments>

[0013] Hereinafter, embodiments of the present invention will be described with reference to the drawings.

<Outline of fuel injection system>

[0014] First, an outline of a fuel injection system 1 according to an embodiment will be described.

[0015] The fuel injection system 1 is a system that is provided on a self-ignition type internal combustion engine EG and injects (supplies) fuel to a combustion chamber CC of the internal combustion engine EG. The internal combustion engine EG is an internal combustion engine having a pressure accumulating injection system (a common rail injection system). The internal combustion engine EG is a diesel engine that is provided in, for example, a motor vehicle, a ship, a railroad vehicle, a heavy machine, or the like. For this reason, an example of the fuel is light oil. In place of the diesel engine, the internal combustion engine EG may be another self-ignition type internal combustion engine such as a self-ignition type gasoline engine.

[0016] For example, when a pressure of fuel injected into a combustion chamber of an internal combustion engine having a fuel injection system is increased to a higher pressure than a reference pressure using a pressure boosting mechanism, a fuel injection system (e.g., a conventional fuel injection system) different from the fuel injection system 1 needs to discharge part of the high-pressure fuel to the outside in order to operate the pressure boosting mechanism. For this reason, the fuel injection system dissipates part of energy of the high-pressure fuel as thermal energy. That is, the fuel injection system increases a fuel consumption rate by the energy dissipated as the heat energy.

[0017] Therefore, the fuel injection system 1 includes a pressure accumulating unit to which fuel is supplied from a high-pressure source (a common rail) that supplies the fuel under a prescribed pressure, a first valve that supplies the fuel supplied from the high-pressure source to the inside of the pressure accumulating unit, and a second valve that injects the fuel supplied to the pressure accumulating unit from the pressure accumulating unit into a combustion chamber. The prescribed pressure is a reference pressure in the fuel injection system 1. That is, the fuel injection system (e.g., the conventional fuel injection system) different from the fuel injection system 1 can set a pressure of fuel injected by the fuel injection system to a higher pressure than the reference pressure in the fuel injection system, whereas the fuel injection system 1 can set a pressure of fuel injected by the fuel injection system 1 to a pressure that is lower than or equal to the prescribed pressure that is the reference pressure in the fuel injection system 1. Further, the fuel injection system 1 does not include a pressure boosting mechanism provided in the fuel injection system (e.g., the conventional fuel injection system) different from the fuel injection system 1, and thus has a lower fuel consumption rate than the fuel injection system. That is, in the fuel injection system 1, a user can change a pressure of fuel injected into a combustion chamber CC to a desired pressure while not dissipating part of energy of high-pressure fuel as thermal energy, namely while suppressing an increase in fuel consumption rate of the internal combustion engine EG. As a result, the fuel injection system 1 enables a pattern of temporal change in the pressure of fuel injected into a combustion chamber CC of the internal combustion engine EG to match with a pattern desired by a user. The matching between these patterns may include an error. Here, in the internal combustion engine EG, depending on the pattern of temporal change, some or all of a fuel consumption rate per unit time according to a combustion state in the combustion chamber CC, an amount of noise from the internal combustion engine EG in a driven state, a magnitude of vibration of the internal combustion engine EG in a driven state, and an amount of generation of emissions (e.g., NOx, HC, CO, other particulate matter, etc.) from the internal combustion engine EG vary. For this reason, in a case where a user who uses the internal combustion engine EG having the fuel injection system 1 feels uncomfortable about an increase in the fuel consumption rate, an increase in the amount of noise, an increase in the magnitude of vibration, a reduction in the amount of power generation, and so on, the fuel injection system 1 can cause a reduction in the fuel consumption rate, a reduction in the amount of noise, a reduction in the magnitude of vibration, an increase in the amount of generation, and so on, and improve comfort of the user. Hereinafter, a constitution of the fuel injection system 1 and a control method for the fuel injection system 1 will be described in detail.

<Constitution of fuel injection system>

[0018] Hereinafter, a constitution of the fuel injection system 1 according to the embodiment will be described.

[0019] FIG. 1 is a view illustrating an example of a constitution of the fuel injection system 1. The fuel injection system 1 includes a fuel injector 2, and an electronic control unit (ECU) 3 that controls the fuel injector 2. The fuel injection system 1 may not include the ECU 3.

[0020] The fuel injector 2 is located on a downstream side from the high-pressure source 4 in a fuel supply path (not shown) starting from a fuel tank (not shown), and is supplied with fuel from the high-pressure source 4. The fuel injector 2 injects the fuel supplied from the high-pressure source 4 into the combustion chamber CC of the internal combustion engine EG in response to control of the ECU 3 at a pressure corresponding to the control. In FIG. 1, to emphasize portions filled with the fuel, hatching of sectional portions of the fuel injector 2 and the internal combustion engine EG is omitted. One fuel injector 2 illustrated in FIG. 1, but there is no limitation to providing a plurality of fuel injectors 2 on the downstream side from the single high-pressure source 4. For example, the plurality of fuel injectors 2 may have the same specification. In this case, the fuel injectors 2 may be connected to the high-pressure source 4 independently of each other, and be partly used in common with the high-pressure source 4.

[0021] The high-pressure source 4 is a common rail provided in the internal combustion engine EG. For example, the fuel supplied from the fuel tank is pressurized by a pressurizing pump (not shown), and is supplied to the high-pressure source 4. The high-pressure source 4 supplies the fuel to the fuel injector 2 at a prescribed pressure.

[0022] The fuel injector 2 includes, for example, an electric injector 11 and an electric injector 12 that are two electric injectors.

[0023] The electric injector 11 includes a fuel supply pipeline 111, a first pressure accumulating unit 112, a nozzle needle 113, a first opening 115 formed in the first pressure accumulating unit 112, and a drive unit A1.

[0024] The fuel supply pipeline 111 is a pipe that is formed inside a housing of the electric injector 11. The fuel supply pipeline 111 is a pipe along which the fuel supplied from the high-pressure source 4 at a prescribed pressure flows. Further, the fuel supply pipeline 111 is a pipe that connects the high-pressure source 4 and the first pressure accumulating unit 112. That is, the first pressure accumulating unit 112 of the electric injector 11 is connected to the high-pressure source 4 by the fuel supply pipeline 111. The fuel supplied from the high-pressure source 4 at a prescribed pressure is supplied to the first pressure accumulating unit 112 through the fuel supply pipeline 111.

[0025] The first pressure accumulating unit 112 includes a pressure accumulator that is formed inside the housing of the electric injector 11. Fuel is supplied to the pressure accumulator of the first pressure accumulating unit 112 from the high-pressure source 4, and the first pressure accumulating unit 112 is formed to be able to hold a pressure of the fuel. The first pressure accumulating unit 112 includes a first valve 21. The first valve 21 is provided, for example, on a discharge port for the fuel of the first pressure accumulating unit 112. The electric injector 12 is provided on the downstream side of the electric injector 11 on the fuel supply path. That is, the first valve 21 cuts off supply of the fuel to the electric injector 12, and supplies the fuel supplied from the high-pressure source 4 to the electric injector 12. To be more specific, in a case where the first valve 21 is opened, the fuel accumulated in the first pressure accumulating unit 112 is supplied to the electric injector 12 at a prescribed pressure. Meanwhile, in a case where the first valve 21 is closed, the fuel supplied from the high-pressure source 4 at a prescribed pressure is accumulated in the first pressure accumulating unit 112. For example, if the fuel is always supplied from the high-pressure source 4 to the first pressure accumulating unit 112 at a prescribed pressure, a pressure inside the first pressure accumulating unit 112 always becomes a prescribed pressure at a prescribed pressure except for an error. In a case where a dynamic effect accompanied by movement of the fuel (to be described below) occurs, the pressure inside the first pressure accumulating unit 112 is sometime higher than the prescribed pressure in the high-pressure source 4. To simplify the description, a case where a dynamic effect does not occur will be described in advance.

[0026] The first valve 21 is made up of a tip portion 114A of the nozzle needle 113 and a first opening 115 formed in the first pressure accumulating unit 112. The nozzle needle 113 includes, for example, a shaft portion that is formed in at least an axial part thereof. The tip portion 114A and a tip portion 114B are provided in regions of ends of the nozzle needle 113 in an extending direction (a longitudinal direction). The nozzle needle 113 is disposed toward the tip portion 114A in a direction in which fuel flows, and is movably supported in the extending direction thereof. For example, the tip portion 114A is formed in a tapered shape in symmetry with respect to an axis of the shaft portion. The first opening 115 is provided in an outlet portion to which fuel is discharged from the first pressure accumulating unit 112. The first opening 115 is blocked or opened by the tip portion 114A due to movement of the nozzle needle 113 in the extending direction. That is, the tip portion 114A of the nozzle needle 113 blocks the first opening 115 in a state where the first valve 21 is closed. In a case where the ECU 3 drives the drive unit A1, the nozzle needle 113 moves in a direction that is directed from the tip portion 114A to a tip, which is close to the tip portion 114B in the extending direction thereof, namely which is opposite to the tip portion 114A, of the tips of the nozzle needle 113 and that is one of directions parallel to the longitudinal direction, and opens the first opening 115. That is, in this case, the first valve 21 is opened. In a case where the drive unit A1 is not driven by the ECU 3, the tip portion 114A of the nozzle needle 113 is pushed to the first opening 115 by a pressure (e.g., a prescribed pressure) of the fuel supplied through the fuel supply pipeline 111, and blocks the first opening 115. Thus, the drive unit A1 closes the first valve 21. On the other hand, in a case where the drive unit A1 is driven by the ECU 3, a pressure (e.g., a prescribed pressure) of the fuel supplied to the first pressure accumulating unit 112 through the fuel supply pipeline 111 is reduced by opening a valve A1V provided on the drive unit A1 to discharge part of the fuel adjacent to the tip portion 114B from the valve A1V. In association with this pressure reduction, an actuator (a command piston) provided in the drive unit A1 moves the nozzle needle 113 in a direction of the tip portion 114B, and opens the first opening 115. Thus, the drive unit A1 opens the first valve 21. A flow rate area of the first valve 21 in the open state is set to be equal to or wider than that of the fuel supply pipeline 111, and thus the electric injector 11 can reduce a loss of energy stored in the fuel raised to the prescribed pressure. The fuel discharged from the valve A1V flows back to the fuel tank (not shown) or the like. Further, since a structure and motion for setting a state of the first valve 21 to any of an open state and a closed state may be a well-known structure and motion or a structure and motion developed therefrom, more detailed description will be omitted. The valve A1V that is an electromagnetic valve is shown for the drive unit A1 as an example, but it may include a piezo element (a laminated piezoelectric element) instead of the valve A1V. In this case, description of supplying a drive current to the valve A1V may be replaced with description of applying a drive voltage to the piezo element.

[0027] The electric injector 12 includes a fuel supply pipeline 121, a second pressure accumulating unit 122, a nozzle needle 123, a second opening 125 formed in the second pressure accumulating unit 122, and a drive unit A2.

[0028] The fuel supply pipeline 121 is a pipe that is formed inside a housing of the electric injector 12. The fuel supply pipeline 121 is a pipe along which the fuel supplied from the first pressure accumulating unit 112 of the electric injector 11 at a prescribed pressure flows. Further, the fuel supply pipeline 121 is a pipe that connects the first opening 115 of the electric injector 12 and the second pressure accumulating unit 122. That is, the second pressure accumulating unit 122 of the electric injector 12 is connected to the first pressure accumulating unit 112 of the electric injector 11 by the fuel supply pipeline 121. The fuel supplied from the first pressure accumulating unit 112 at a prescribed pressure is supplied to the second pressure accumulating unit 122 through the fuel supply pipeline 121 in a case where the first valve 21 is opened.

[0029] The second pressure accumulating unit 122 includes a pressure accumulator that is formed inside the housing of the electric injector 12. Fuel is supplied to the pressure accumulator of the second pressure accumulating unit 122 from the first pressure accumulating unit 112 of the electric injector 11, and the second pressure accumulating unit 122 is formed to be able to hold a pressure of the fuel. A combination of the fuel supply pipeline 121 and the second pressure accumulating unit 122 (or the second pressure accumulating unit 122) is an example of the pressure accumulating unit in Claims. Hereinafter, for convenience of description, a pressure inside each of the fuel supply pipeline 121 and the second pressure accumulating unit 122 will be described as a pressure inside the second pressure accumulating unit 122. The fuel injection system 1 may not include the fuel supply pipeline 121. In this case, in the fuel injection system 1, for example, the first pressure accumulating unit 112 and the second pressure accumulating unit 122 are adjacent to each other with the first valve 21 interposed therebetween, and are partitioned by the first valve 21. The second pressure accumulating unit 122 includes a second valve 22. The second valve 22 is provided, for example, on a discharge port for the fuel in the second pressure accumulating unit 122. The combustion chamber CC of the internal combustion engine EG is provided on a downstream side of the electric injector 12 on the fuel supply path. That is, the second valve 22 cuts off supply of the fuel to the combustion chamber CC, and injects the fuel supplied to the second pressure accumulating unit 122 into the combustion chamber CC from the second pressure accumulating unit 122. To be more specific, in a case where the second valve 22 is opened, the fuel accumulated in the second pressure accumulating unit 122 is injected into the combustion chamber CC in response to the pressure inside the second pressure accumulating unit 122. A state where the first valve 21 is open and the second valve 22 is closed is referred to as a first state. In a case of the first state, the pressure is raised, for example, up to a prescribed pressure that is a pressure of the high-pressure source 4 at a maximum. A state where the first valve 21 is closed and the second valve 22 is open is referred to as a second state. In a case of the second state, the pressure is reduced according to an elapsed time after the second valve 22 is opened. In this case, an amount of change of the pressure per unit time is expressed by Formula (1) below.

$$\Delta P = -K(q/V) \cdots\cdots\cdots\cdots\cdots (1)$$

[0030] ΔP indicates an amount of change of the pressure inside the second pressure accumulating unit 122 per unit time in the second state. Further, K indicates a bulk modulus of elasticity of fuel accumulated in the second pressure accumulating unit 122. Further, q indicates a fuel injection amount that is an amount of fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 per unit time in the second state. Further, V indicates a volume of the sum of a volume of the fuel supply pipeline 121 and a volume of the second pressure accumulating unit 122. That is, the amount of change of the pressure per unit time inside the second pressure accumulating unit 122 is inversely proportional to the volume V of the second pressure accumulating unit 122, and is proportional to the fuel injection amount q injected per unit time from the second pressure accumulating unit 122.

[0031] Here, in a case where an amount by which the pressure of the second pressure accumulating unit 122 in the second state is reduced per unit time is greater than an amount by which the pressure of the second pressure accumulating unit 122 in the first state is raised per unit time, the pressure of the second pressure accumulating unit 122 in a third state is reduced. The third state is a state where the first valve 21 is open and the second valve 22 is opened. To be more specific, in a case where the amount of change ΔP of the pressure inside the second pressure accumulating unit 122 in the second state is greater than the amount of change of the pressure inside the second pressure accumulating unit 122 in the first state, the amount of change of the pressure inside the second pressure accumulating unit 122 in the third state is smaller than a difference in amount of change ΔP between the amount of change ΔP of the pressure inside the second pressure accumulating unit 122 in the second state and the amount of change of the pressure inside the second pressure accumulating unit 122 in the first state.

[0032] Further, in a case where an amount by which the pressure of the second pressure accumulating unit 122 in the second state is reduced per unit time is smaller than an amount by which the pressure of the second pressure accumulating unit 122 in the first state is raised per unit time, the pressure of the second pressure accumulating unit 122 in the third state is raised. To be more specific, in a case where the amount of change ΔP of the pressure inside the second pressure accumulating unit 122 in the second state is smaller than the amount of change of the pressure inside the second pressure accumulating unit 122 in the first state, the amount of change of the pressure inside the second pressure accumulating unit 122 in the third state is increased whenever a difference unit time between the amount of change ΔP of the pressure inside the second pressure accumulating unit 122 in the second state and the amount of change of the pressure inside the second pressure accumulating unit 122 in the first state has elapsed.

[0033] Hereinafter, the case where the amount of change ΔP of the pressure inside the second pressure accumulating unit 122 in the second state is smaller than the amount of change of the pressure inside the second pressure accumulating unit 122 in the first state will be described as an example. That is, in this example, an amount by which the pressure of the second pressure accumulating unit 122 in the second state is reduced per unit time is smaller than an amount by which the pressure of the second pressure accumulating unit 122 in the first state is raised per unit time. For this reason, the fuel injection system 1 can change the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 into an arbitrary pressure within a range lower than or equal to a prescribed pressure depending on the open and closed states of the first valve 21 and the second valve 22.

[0034] The second valve 22 is made up of a tip portion 124A of the nozzle needle 123 and a second opening 125 formed in the second pressure accumulating unit 122. The nozzle needle 123 includes, for example, a shaft portion that is formed in at least an axial part thereof. The tip portion 124A and a tip portion 124B are provided in regions of ends of the nozzle needle 123 in an extending direction (a longitudinal direction). The nozzle needle 123 is disposed toward the tip portion 124A in a direction in which fuel flows, and is movably supported in the extending direction thereof. For example, the tip portion 124A is formed in a tapered shape in symmetry with respect to an axis of the shaft portion. The second opening 125 is provided in an outlet portion to which fuel is discharged from the second pressure accumulating unit 122. The second opening 125 is blocked or opened by the tip portion 124A due to movement of the nozzle needle 123 in the extending direction. That is, the tip portion 124A of the nozzle needle 123 blocks the second opening 125 in a state where the second valve 22 is closed. In a case where the ECU 3 drives the drive unit A2, the nozzle needle 123 moves in a direction that is directed from the tip portion 124A to a tip, which is close to the tip portion 124B in the extending direction thereof, namely which is opposite to the tip portion 124A, of the tips of the nozzle needle 123 and that is one of directions parallel to the longitudinal direction, and opens the second opening 125. That is, in this case, the second valve 22 is opened. In a case where the drive unit A2 is not driven by the ECU 3, the tip portion 124A of the nozzle needle 123 is pushed to the second opening 125 by a pressure (e.g., a prescribed pressure) of the fuel supplied through the fuel supply pipeline 121, and blocks the second opening 125. Thus, the drive unit A2 closes the second valve 22. On the other hand, in a case where the drive unit A2 is driven by the ECU 3, part of the fuel that is supplied to the second pressure accumulating unit 122 through the fuel supply pipeline 121 and is adjacent to the tip portion 124B is discharged from the valve A2V by opening a valve A2V provided on the drive unit A2, and a pressure of the fuel adjacent to the tip portion 124B is reduced. In association with this pressure reduction, an actuator (a command piston) provided in the drive unit A2 moves the nozzle needle 123 in a direction of the tip portion 124B, and opens the second opening 125. Thus, the drive unit A2 opens the second valve 22. The fuel discharged from the valve A2V flows back to the fuel tank (not shown) or the like. Further, since a structure and motion for setting a state of the second valve 22 to any of an open state and a closed state may be a well-known structure and motion or a structure and motion developed therefrom, more detailed description will be omitted. The valve A2V that is an electromagnetic valve is shown for the drive unit A2 as an example, but it may include a piezo element instead of the valve A2V. In this case, description of supplying a drive current to the valve A2V may be replaced with description of applying a drive voltage to the piezo element.

<Logical structure of fuel injection system>

[0035] Hereinafter, a logical structure of the fuel injection system 1 will be described with reference to FIG. 2. The constitution of the fuel injection system 1 is not limited to that described in FIG. 1. Therefore, a logical structure in which essential components which the fuel injection system 1 should have to realize the first to third states are combined will be described here. FIG. 2 is a view illustrating an example of the logical structure of the fuel injection system 1.

[0036] A high-pressure source PR1, a first valve VI, a pressure accumulating unit PR2, a second valve V2, and an injection part CR are illustrated in FIG. 2. The high-pressure source PR1, the first valve VI, the pressure accumulating unit PR2, the second valve V2, and the injection part CR are logically connected in the order of the high-pressure source PR1, the first valve VI, the pressure accumulating unit PR2, the second valve V2, and the injection part CR. That is, the logical structure of the fuel injection system 1 is shown as a structure in which the high-pressure source PR1, the first valve VI, the pressure accumulating unit PR2, the second valve V2, and the injection part CR are logically connected in the order of the high-pressure source PR1, the first valve VI, the pressure accumulating unit PR2, the second valve V2, and the injection part CR.

[0037] The high-pressure source PR1 is a common rail that supplies fuel to the pressure accumulating unit PR2 at a prescribed pressure. In a case where the first valve V1 is open in a state where the second valve V2 is closed, the fuel supplied from the high-pressure source PR1 at a prescribed pressure is accumulated in the pressure accumulating unit PR2 through the first valve V1. In this case, a pressure inside the pressure accumulating unit PR2 is raised depending on a time for which the first valve V1 is opened, and becomes, for example, a prescribed pressure at the maximum. Further, in a case where the second valve V2 is open in a state where the first valve V1 is closed, the fuel accumulated in the pressure accumulating unit PR2 is injected into a combustion chamber CC from the injection part CR by the pressure inside the pressure accumulating unit PR2 which is a pressure corresponding to a time that has elapsed after the second valve V2 is opened. That is, in a case where the fuel injection system 1 is formed by a combination of members corresponding to the high-pressure source PR1, the first valve VI, the pressure accumulating unit PR2, the second valve V2, and the injection part CR and where the logical structure of the fuel injection system 1 is coincident with the logical structure illustrated in FIG. 2, conditions relating to open or closed states of the first valve V1 and the second valve V2 are combined with the logical structure, and the aforementioned first to third states can be realized.

[0038] Here, in the example illustrated in FIG. 1, the member corresponding to the high-pressure source PR1 is the high-pressure source 4. In this example, the member corresponding to the first valve V1 is the first valve 21. Further, in this example, the member corresponding to the pressure accumulating unit PR2 is a combination of the fuel supply pipeline 121 and the second pressure accumulating unit 122. Further, in this example, the member corresponding to the second valve V2 is the second valve 22. Further, in this example, the member corresponding to the injection part CR is the second opening 125. As described above, the members are made to correspond to the corresponding components, and thus treatment required for analysis of pressure variation of each component can be simplified.

<Constitution of ECU>

[0039] Hereinafter, a constitution of the ECU 3 will be described with reference to FIG. 3. FIG. 3 is a diagram illustrating an example of a hardware configuration of the ECU 3. The ECU 3 includes, for example, a central processing unit (CPU) 31, a storage unit 32, a first valve drive circuit 33, and a second valve drive circuit 34. These components are connected to be able to communicate with each other via a bus Bus. Further, the ECU 3 may be configured to include a communication unit for mutually communicating with another ECU.

[0040] The CPU 31 includes a processor that executes software programs (hereinafter referred to as programs), and reads out and executes various programs stored in the storage unit 32 or the like.

[0041] The storage unit 32 includes, for example, an electrically erasable programmable read-only memory (EEPROM), a read-only memory (ROM), a random access memory (RAM), and so on. The storage unit 32 stores various pieces of information processed by the ECU 3.

[0042] The first valve drive circuit 33 supplies the drive unit A1 with a drive current that drives the drive unit A1 for opening/closing the first valve 21.

[0043] The second valve drive circuit 34 supplies the drive unit A2 with a drive current that drives the drive unit A2 for opening/closing the second valve 22.

<Functional configuration of ECU>

[0044] Hereinafter, a functional configuration of the ECU 3 will be described with reference to FIG. 4. FIG. 4 is a diagram illustrating an example of a functional configuration of the ECU 3. The ECU 3 includes the storage unit 32, the first valve drive circuit 33, the second valve drive circuit 34, and a controller 36.

[0045] The controller 36 controls the first valve drive circuit 33 such that the drive unit A1 is driven, and sets a state of the first valve 21 to an open state or a closed state depending on a timing prestored in the storage unit 32. Further, the controller 36 controls the second valve drive circuit 34 such that the drive unit A1 is driven, and sets a state of the second valve 22 to an open state or a closed state depending on a timing prestored in the storage unit 32. For example, the CPU 31 executes the various programs stored in the storage unit 32, and thus the controller 36 is realized. Further, the controller 36 may be a hardware functional unit such as a large scale integration (LSI) or an application specific integrated circuit (ASIC).

<Control method of fuel injection system>

[0046] Hereinafter, specific examples of a control method of the fuel injection system 1 will be described with reference to FIGS. 5 to 18. Hereinafter, for convenience of description, control under which the controller 36 controls the first valve drive circuit 33 in the state where the second valve 22 is opened, and drives the drive unit A1 to open the first valve 21 will be described as pressure boost control, and control under which the controller 36 controls the second valve drive circuit 34 with the first valve 21 closed, and drives the drive unit A2 to open the second valve 22 will be described as pressure reduction control. Hereinafter, a case where the first valve drive circuit 33 supplies a drive current A0 to the drive unit A1 and opens the first valve 21 and where the second valve drive circuit 34 supplies a drive current A0 to the drive unit A2 and opens the second valve 22 will be described as an example. That is, the drive unit A1 closes the first valve 21 when the supply of the drive current A0 from the first valve drive circuit 33 is stopped, and the drive unit A2 closes the second valve 22 when the supply of the drive current A0 is stopped.

[0047] FIG. 5 is a timing diagram for illustrating Embodiment 1 of the control method of the fuel injection system 1. The timing diagram illustrated in FIG. 5 includes four graphs from a graph CH11 to a graph CH14. The horizontal axis of each of the graphs CH11 to CH14 indicates time. Further, the vertical axis of the graph CH11 indicates a drive current supplied from the first valve drive circuit 33 to the drive unit A1. Further, the vertical axis of the graph CH12 indicates a pressure inside the second pressure accumulating unit 122. Further, the vertical axis of the graph CH13 indicates a drive current supplied from the second valve drive circuit 34 to the drive unit A2. Further, the vertical axis of the graph CH14 indicates a pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122. Further, a time t11 on the graphs CH11 to CH14 indicates a time when the drive current is supplied from the first valve drive circuit 33 to the drive unit A1 and the first valve 21 is opened. A time t12 on the graphs CH11 to CH14 indicates a time when the drive current is supplied from the second valve drive circuit 34 to the drive unit A2 and the second valve 22 is opened. A time t13 on the graphs CH11 to CH14 indicates a time when the supply of the drive current from the second valve drive circuit 34 to the drive unit A2 is stopped and the second valve 22 is closed. Here, the time t11 is a time before the time t12, and the time t12 is a time before the time t13.

[0048] In the example illustrated in FIG. 5, in an 11th time slot that is a time slot from the time t11 to the time t12, the fuel injection system 1 realizes the aforementioned first state. Here, a case where, in this example, a pressure inside the second pressure accumulating unit 122 is zero (0) in a time slot before the time t11 will be described. In the 11th time slot, the pressure inside the second pressure accumulating unit 122 is raised depending on an elapsed time that is a time elapsed from the time t11. Further, since a pressure of fuel supplied to the second pressure accumulating unit 122 is a prescribed pressure P0, the pressure inside the second pressure accumulating unit 122 can be raised to the prescribed pressure P0 at the maximum. In this example, the pressure in the 11th time slot is raised from zero (0) to the prescribed pressure P0. A time required to raise the pressure inside the second pressure accumulating unit 122 in the first state from zero (0) to the prescribed pressure P0 can be investigated by an experiment or the like, and can be estimated by calculation based on hydrodynamics or the like. A user can determine a length of the 11th time slot to be a time longer than or equal to the time on the basis of a result of an experiment or a calculation.

[0049] Next, in a 12th time slot that is a time slot from the time t12 to the time t13, the fuel injection system 1 realizes the aforementioned third state by performing pressure boost control. Since the pressure inside the second pressure accumulating unit 122 in the 11th time slot is raised to the prescribed pressure P0, and the first valve 21 remains open also in the 12th time slot, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 while continuously keeping the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 intact at the prescribed pressure P0 in the 12th time slot. Since the fuel injection system 1 closes the second valve 22 at the time t13, the injection of the fuel into the combustion chamber CC from the second pressure accumulating unit 122 is stopped, and the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 becomes zero (0) in a time slot after the time t13. Meanwhile, since the fuel injection system 1 keeps the first valve 21 open in this time slot, the pressure inside the second pressure accumulating unit 122 is continuously still kept at the prescribed pressure P0.

[0050] According to the control method represented by the timing diagram illustrated in FIG. 5, the fuel injection system 1 easily enables a pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC to coincide with a pattern of temporal change in the pressure of fuel which a fuel injection system (e.g., a conventional fuel injection system) different from the fuel injection system 1 injects into a combustion chamber of an internal combustion engine equipped with the different fuel injection system while suppressing an increase in fuel consumption rate. Hereinafter, for convenience of description, the pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC, which is the pattern illustrated in FIG. 5, will be described as a rectangular pattern.

[0051] FIG. 6 is a timing diagram for illustrating Embodiment 2 of the control method of the fuel injection system 1. The timing diagram illustrated in FIG. 6 includes four graphs from a graph CH21 to a graph CH24. The horizontal axis of each of the graphs CH21 to CH24 indicates time. Further, the vertical axis of the graph CH21 indicates a drive current supplied from the first valve drive circuit 33 to the drive unit A1. Further, the vertical axis of the graph CH22 indicates a pressure inside the second pressure accumulating unit 122. Further, the vertical axis of the graph CH23 indicates a drive current supplied from the second valve drive circuit 34 to the drive unit A2. Further, the vertical axis of the graph CH24 indicates a pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122. Further, a time t21 on the graphs CH21 to CH24 indicates a time when the drive current is supplied from the first valve drive circuit 33 to the drive unit A1 and the first valve 21 is opened. Further, a time t22 on the graphs CH21 to CH24 indicates a time when the supply of the drive current from the first valve drive circuit 33 to the drive unit A1 is stopped and the first valve 21 is closed. Further, a time t23 on the graphs CH21 to CH24 indicates a time when the drive current is supplied from the second valve drive circuit 34 to the drive unit A2 and the second valve 22 is opened. Further, a time t24 on the graphs CH21 to CH24 indicates a time when the supply of the drive current from the second valve drive circuit 34 to the drive unit A2 is stopped and the second valve 22 is closed. Here, the time t21 is a time before the time t22, the time t22 is a time before the time t23, and the time t23 is a time before the time t24.

[0052] In the example illustrated in FIG. 6, in a 21st time slot that is a time slot from the time t21 to the time t22, the fuel injection system 1 realizes the aforementioned first state. Here, a case where, in this example, a pressure inside the second pressure accumulating unit 122 is a pressure P11 in a time slot before the time t21 will be described. The pressure P11 is lower than a prescribed pressure P0. In the 21st time slot, the pressure inside the second pressure accumulating unit 122 is raised depending on an elapsed time that is a time elapsed from the time t21. Further, since a pressure of fuel supplied to the second pressure accumulating unit 122 is the prescribed pressure P0, the pressure inside the second pressure accumulating unit 122 can be raised to the prescribed pressure P0 at the maximum. In this example, the pressure in the 21st time slot is raised from the pressure P11 to the prescribed pressure P0. Like the length of the 11th time slot, a length of the 21st time slot is determined by a user.

[0053] Next, in a 22nd time slot that is a time slot from the time t22 to the time t23, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 in the 21st time slot is raised from the pressure P11 to the prescribed pressure P0. For these reasons, the pressure inside the second pressure accumulating unit 122 in the 22nd time slot is still kept at the prescribed pressure P0.

[0054] Next, in a 23rd time slot that is a time slot from the time t23 to the time t24, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 in the 22nd time slot is still kept at the prescribed pressure P0, the fuel injection system 1 injects the fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 23rd time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P11 corresponding to a length of the 23rd time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P11, namely the length of the 23rd time slot, can be calculated on the basis of the prescribed pressure P0, the pressure P11, and Formula (1) described above. Since the fuel injection system 1 closes the second valve 22 at the time t24, the injection of the fuel into the combustion chamber CC from the second pressure accumulating unit 122 is stopped, and the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 becomes zero (0) in a time slot after the time t24. Meanwhile, since the fuel injection system 1 keeps the first valve 21 closed in this time slot, the pressure inside the second pressure accumulating unit 122 is kept at the pressure P11.

[0055] According to the control method represented by the timing diagram illustrated in FIG. 6, the fuel injection system 1 enables a pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC to coincide with an inverted deltaic pattern among patterns desired by a user while suppressing an increase in fuel consumption rate. The inverted deltaic pattern is the pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC, which is the pattern illustrated in FIG. 6. That is, the inverted deltaic pattern is a pattern in which the pressure of the fuel injected into the combustion chamber CC by the fuel injection system 1 is monotonously reduced from the prescribed pressure P0 to the pressure P11 over time in a period (e.g., the 23rd time slot illustrated in FIG. 6) in which the fuel injection system 1 injects the fuel. In the inverted deltaic pattern, the fuel injected into the combustion chamber CC from the fuel injection system 1 is nearly homogeneously injected into the combustion chamber CC in the 23rd time slot. This is because a speed of the fuel injected into the combustion chamber CC from the fuel injection system 1 becomes slow with the elapse of time (i.e., along with a reduction in the pressure inside the second pressure accumulating unit 122) in the 23rd time slot. As a result, the fuel injection system 1 can suppress a cooling loss caused when fuel flames are cooled at an inner wall of the combustion chamber CC by either collision of fuel with the inner wall of the combustion chamber due to excessive fuel spraying or collision of fuel with the inner wall of the combustion chamber CC due to flames after ignition. Here, the fuel flames are flames generated by combustion of the fuel.

[0056] FIG. 7 is a timing diagram for illustrating Embodiment 3 of the control method of the fuel injection system 1. The timing diagram illustrated in FIG. 7 includes four graphs from a graph CH31 to a graph CH34. The horizontal axis of each of the graphs CH31 to CH34 indicates time. Further, the vertical axis of the graph CH31 indicates a drive current supplied from the first valve drive circuit 33 to the drive unit A1. Further, the vertical axis of the graph CH32 indicates a pressure inside the second pressure accumulating unit 122. Further, the vertical axis of the graph CH33 indicates a drive current supplied from the second valve drive circuit 34 to the drive unit A2. Further, the vertical axis of the graph CH34 indicates a pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122. Further, a time t31 on the graphs CH31 to CH34 indicates a time when the drive current is supplied from the first valve drive circuit 33 to the drive unit A1, the drive current is supplied from the second valve drive circuit 34 to the drive unit A2, and both the first valve 21 and the second valve 22 are open. Further, each of a time t33, a time t35, and a time t37 on the graphs CH31 to CH34 indicates a time when the drive current is supplied from the first valve drive circuit 33 to the drive unit A1 and the first valve 21 is opened. Further, each of a time t32, a time t34, a time t36, and a time t38 on the graphs CH31 to CH34 indicates a time when the supply of the drive current from the first valve drive circuit 33 to the drive unit A1 is stopped and the first valve 21 is closed. Further, a time t39 on the graphs CH31 to CH34 indicates a time when the supply of the drive current from the second valve drive circuit 34 to the drive unit A2 is stopped and the second valve 22 is closed. Here, the time t31 is a time before the time t32, the time t32 is a time before the time t33, the time t33 is a time before the time t34, the time t35 is a time before the time t36, the time t36 is a time before the time t37, the time t37 is a time before the time t38, and the time t38 is a time before the time t39. Further, each of a pressure P21, a pressure P22, a pressure P23, a pressure P24, and a pressure P25 on the graphs CH32 and CH34 is lower than a prescribed pressure P0. Further, the pressure P21 is lower than the pressure P22, the pressure P22 is lower than the pressure P23, the pressure P23 is lower than the pressure P24, the pressure P24 is lower than the pressure P25, and the pressure P25 is lower than the pressure P26.

[0057] In the example illustrated in FIG. 7, in a 31st time slot that is a time slot from the time t31 to the time t32, the fuel injection system 1 realizes a third state by performing pressure boost control. Here, a case where, in this example, the pressure inside the second pressure accumulating unit 122 is the pressure P21 in a time slot before the time t31 will be described. In the 31st time slot, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 while raising the pressure inside the second pressure accumulating unit 122 from the pressure P21 to the pressure P23 corresponding to a length of the 31st time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P21 at the time t31, and is raised from the pressure P21 to the pressure P23 in the 31st time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P21 to the pressure P23, namely the length of the 31st time slot, can be calculated on the basis of the pressure P21, the pressure P23, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0058] Next, in a 32nd time slot that is a time slot from the time t32 to the time t33, the fuel injection system 1 performs pressure reduction control, and thus realizes a second state. For this reason, in the 32nd time slot, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 while reducing the pressure inside the second pressure accumulating unit 122 from the pressure P23 to the pressure P22 corresponding to a length of the 32nd time slot. As a result, in the 32nd time slot, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P23 at the time t32, and is reduced from the pressure P23 to the pressure 22 in the 32nd time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P23 to the pressure P22, namely the length of the 32nd time slot, can be calculated on the basis of the pressure P23, the pressure P22, and Formula (1) described above.

[0059] Next, in a 33rd time slot that is a time slot from the time t33 to the time t34, the fuel injection system 1 realizes a third state by performing pressure boost control. In the 33rd time slot, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 while raising the pressure inside the second pressure accumulating unit 122 from the pressure P22 to the pressure P25 corresponding to a length of the 33rd time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P22 at the time t33, and is raised from the pressure P22 to the pressure P25 in the 33rd time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P22 to the pressure P25, namely the length of the 33rd time slot, can be calculated on the basis of the pressure P22, the pressure P25, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0060] Next, in a 34th time slot that is a time slot from the time t34 to the time t35, the fuel injection system 1 realizes a second state by performing pressure reduction control. For this reason, in the 34th time slot, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 while reducing the pressure inside the second pressure accumulating unit 122 from the pressure P25 to the pressure P24 corresponding to a length of the 34th time slot. As a result, in the 34th time slot, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P25 at the time t34, and is reduced from the pressure P25 to the pressure P24 in the 34th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P25 to the pressure P24, namely the length of the 34th time slot, can be calculated on the basis of the pressure P25, the pressure P24, and Formula (1) described above.

[0061] Next, in a 35th time slot that is a time slot from the time t35 to the time t36, the fuel injection system 1 realizes a third state by performing pressure boost control. In the 35th time slot, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 while raising the pressure inside the second pressure accumulating unit 122 from the pressure P24 to the prescribed pressure P0. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P24 at the time t35, and is raised from the pressure P24 to the prescribed pressure P0 in the 35th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P24 to the prescribed pressure P0, namely a length of the 35th time slot, can be calculated on the basis of the pressure P24, the prescribed pressure P0, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0062] Next, in a 36th time slot that is a time slot from the time t36 to the time t37, the fuel injection system 1 realizes a second state by performing pressure reduction control. For this reason, in the 36th time slot, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 while reducing the pressure inside the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P26 corresponding to a length of the 36th time slot. As a result, in the 36th time slot, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the prescribed pressure P0 at the time t36, and is reduced from the prescribed pressure P0 to the pressure P26 in the 36th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P26, namely the length of the 36th time slot, can be calculated on the basis of the prescribed pressure P0, the pressure P26, and Formula (1) described above.

[0063] Next, in a 37th time slot that is a time slot from the time t37 to the time t38, the fuel injection system 1 realizes a third state by performing pressure boost control. In the 37th time slot, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 while increasing the pressure inside the second pressure accumulating unit 122 from the pressure P26 to the prescribed pressure P0. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P26 at the time t37, and is raised from the pressure P26 to the prescribed pressure P0 in the 37th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P26 to the prescribed pressure P0, namely the length of the 37th time slot, can be calculated on the basis of the pressure P26, the prescribed pressure P0, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0064] Next, in a 38th time slot that is a time slot from the time t38 to the time t39, the fuel injection system 1 realizes a second state by performing pressure reduction control. For this reason, in the 38th time slot, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 while reducing the pressure inside the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P21 corresponding to a length of the 38th time slot. As a result, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the prescribed pressure P0 at the time t38 in the 38th time slot, and is reduced from the prescribed pressure P0 to the pressure P21 in the 38th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P21, namely the length of the 38th time slot, can be calculated on the basis of the prescribed pressure P0, the pressure P21, and Formula (1) described above.

[0065] Since the fuel injection system 1 closes the second valve 22 at the time t39, the injection of the fuel into the combustion chamber CC from the second pressure accumulating unit 122 is stopped, and the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 becomes zero (0) in a time slot after the time t39. On the other hand, since the fuel injection system 1 still closes the first valve 21 in this time slot, the pressure inside the second pressure accumulating unit 122 is kept at the pressure P21. The pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 does not include a pressure caused by a compression process of the combustion chamber CC. In a case where the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is zero (0), this is equivalent to, for example, a case where the fuel is injected in an open state.

[0066] According to the control method represented by the timing diagram illustrated in FIG. 7, the fuel injection system 1 enables a pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC to coincide with a deltaic pattern among patterns desired by a user while suppressing an increase in fuel consumption rate. The deltaic pattern is a pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC, which is the pattern illustrated in FIG. 7. That is, the deltaic pattern is a pattern in which the pressure of the fuel injected into the combustion chamber CC by the fuel injection system 1 is nearly monotonously raised from the pressure P21 to the prescribed pressure P0 over time in a period (a time slot from the time t31 to the time t39 in the example illustrated in FIG. 7) in which the fuel injection system 1 injects the fuel. In the deltaic pattern, the fuel injected into the combustion chamber CC from the fuel injection system 1 is injected at a high pressure in a latter period subsequent to a former period in the period in which the fuel injection system 1 injects the fuel into the combustion chamber CC. For this reason, the fuel injection system 1 can atomize the fuel injected into the combustion chamber CC, and can perform agitation and combustion of the fuel in the combustion chamber CC. As a result, the fuel injection system 1 can reduce an amount of noise of the internal combustion engine EG in a driving state, and can further reduce an amount of emissions generated from the internal combustion engine EG.

[0067] FIG. 8 is a timing diagram for illustrating Embodiment 4 of the control method of the fuel injection system 1. The timing diagram illustrated in FIG. 8 includes four graphs from a graph CH41 to a graph CH44. The horizontal axis of each of the graphs CH41 to CH44 indicates time. Further, the vertical axis of the graph CH41 indicates a drive current supplied from the first valve drive circuit 33 to the drive unit A1. Further, the vertical axis of the graph CH42 indicates a pressure inside the second pressure accumulating unit 122. Further, the vertical axis of the graph CH43 indicates a drive current supplied from the second valve drive circuit 34 to the drive unit A2. Further, the vertical axis of the graph CH44 indicates a pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122. Further, each of a time t41 and a time t44 on the graphs CH41 to CH44 indicates a time when the drive current is supplied from the first valve drive circuit 33 to the drive unit A1 and the first valve 21 is opened. Further, each of a time t42 and a time t45 on the graphs CH41 to CH44 indicates a time when the supply of the drive current from the first valve drive circuit 33 to the drive unit A1 is stopped and the first valve 21 is closed. Further, a time t43 on the graphs CH41 to CH44 indicates a time when the drive current is supplied from the second valve drive circuit 34 to the drive unit A2 and the second valve 22 is opened. Further, a time t46 on the graphs CH41 to CH44 indicates a time when the supply of the drive current from the second valve drive circuit 34 to the drive unit A2 is stopped and the second valve 22 is closed. Here, the time t41 is a time before the time t42, the time t42 is a time before the time t43, the time t43 is a time before the time t44, and the time t45 is a time before the time t46. Further, a pressure P31 on the graphs CH42 and CH44 is lower than a prescribed pressure P0.

[0068] In the example illustrated in FIG. 8, in a 41st time slot that is a time slot from the time t41 to the time t42, the fuel injection system 1 realizes a first state. Here, a case where, in this example, the pressure inside the second pressure accumulating unit 122 is the pressure

P31 in a time slot before the time t41 will be described. In the 41st time slot, the pressure inside the second pressure accumulating unit 122 is raised depending on an elapsed time that is a time elapsed from the time t41. Further, since a pressure of fuel supplied to the second pressure accumulating unit 122 is the prescribed pressure P0, the pressure inside the second pressure accumulating unit 122 can be raised to the prescribed pressure P0 at the maximum. In this example, the pressure in the 41st time slot is raised from the pressure P31 to the prescribed pressure P0. Like the length of the 11th time slot, a length of the 41st time slot is determined by a user.

[0069] Next, in a 42nd time slot that is a time slot from the time t42 to the time t43, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 in the 41st time slot is raised from the pressure P31 to the prescribed pressure P0. For these reasons, the pressure inside the second pressure accumulating unit 122 in the 42nd time slot is still kept at the prescribed pressure P0.

[0070] Next, in a 43rd time slot that is a time slot from the time t43 to the time t44, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 in the 42nd time slot is still kept at the prescribed pressure P0, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 43rd time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P31 corresponding to a length of the 43rd time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P31, namely the length of the 43rd time slot, can be calculated on the basis of the prescribed pressure P0, the pressure P31, and Formula (1) described above.

[0071] Next, in a 44th time slot that is a time slot from the time t44 to the time t45, the fuel injection system 1 realizes a third state by performing pressure boost control. The fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 44th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P31 to the prescribed pressure P0. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P31 at the time t44, and is raised from the pressure P31 to the prescribed pressure P0 in the 44th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P31 to the prescribed pressure P0, namely a length of the 44th time slot, can be calculated on the basis of the pressure P31, the prescribed pressure P0, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0072] Next, in a 45th time slot that is a time slot from the time t45 to the time t46, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the prescribed pressure P0 at the time t45, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 45th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P31 corresponding to a length of the 45th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P31, namely the length of the 45th time slot, can be calculated on the basis of the prescribed pressure P0, the pressure P31, and Formula (1) described above.

[0073] Since the fuel injection system 1 closes the second valve 22 at the time t46, the injection of the fuel into the combustion chamber CC from the second pressure accumulating unit 122 is stopped, and the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 becomes zero (0) in a time slot after the time t46. On the other hand, since the fuel injection system 1 still closes the first valve 21 in this time slot, the pressure inside the second pressure accumulating unit 122 is kept at the pressure P31.

[0074] According to the control method represented by the timing diagram illustrated in FIG. 8, the fuel injection system 1 enables a pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC to coincide with a concave pattern among patterns desired by a user while suppressing an increase in fuel consumption rate. The concave pattern is a pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC, which is the pattern illustrated in FIG. 8. That is, the concave pattern is a pattern in which the pressure of the fuel injected into the combustion chamber CC by the fuel injection system 1 is monotonously reduced from the prescribed pressure P0 to the pressure P31 over time in a period (a time slot from the time t43 to the time t46 in the example illustrated in FIG. 8) in which the fuel injection system 1 injects the fuel, and then is monotonously raised from the pressure P31 to the prescribed pressure P0. In the concave pattern, the fuel injected into the combustion chamber CC from the fuel injection system 1 is nearly homogeneously injected into the combustion chamber CC in the 43rd time slot, and is again injected at the prescribed pressure P0 that is higher than the pressure P31 after the 44th time slot. Thus, the fuel injection system 1 can perform agitation and combustion of the fuel in the combustion chamber CC in a latter period subsequent to a former period in the period in which the fuel injection system 1 injects the fuel into the combustion chamber CC. As a result, the fuel injection system 1 can reduce an amount of emissions generated from the internal combustion engine EG. That is, the control method represented by the timing diagram illustrated in FIG. 8 becomes a control method that combines the control method represented by the timing diagram illustrated in FIG. 6 and the control method represented by the timing diagram illustrated in FIG. 7. For this reason, the fuel injection system 1 can obtain both the effects described in FIG. 6 and the effects described in FIG. 7.

[0075] FIG. 9 is a timing diagram for illustrating Embodiment 5 of the control method of the fuel injection system 1. The timing diagram illustrated in FIG. 9 includes four graphs from a graph CH51 to a graph CH54. The horizontal axis of each of the graphs CH51 to CH54 indicates time. Further, the vertical axis of the graph CH51 indicates a drive current supplied from the first valve drive circuit 33 to the drive unit A1. Further, the vertical axis of the graph CH52 indicates a pressure inside the second pressure accumulating unit 122. Further, the vertical axis of the graph CH53 indicates a drive current supplied from the second valve drive circuit 34 to the drive unit A2. Further, the vertical axis of the graph CH54 indicates a pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122. Further, a time t51 on the graphs CH51 to CH54 indicates a time when the drive current is supplied from the second valve drive circuit 34 to the drive unit A2 and the second valve 22 is opened. Further, each of a time t52, a time t54, and a time t56 on the graphs CH51 to CH54 indicates a time when the drive current is supplied from the first valve drive circuit 33 to the drive unit A1 and the first valve 21 is opened. Further, each of a time t53, a time t55, and a time t57 on the graphs CH51 to CH54 indicates a time when the supply of the drive current from the first valve drive circuit 33 to the drive unit A1 is stopped and the first valve 21 is closed. Further, a time t58 on the graphs CH51 to CH54 indicates a time when the supply of the drive current from the second valve drive circuit 34 to the drive unit A2 is stopped and the second valve 22 is closed. Here, the time t51 is a time before the time t52, the time t52 is a time before the time t53, the time t53 is a time before the time t54, the time t54 is a time before the time t55, the time t55 is a time before the time t56, the time t56 is a time before the time t57, and the time t57 is a time before the time t58. Further, each of a pressure P41, a pressure P42, a pressure P43, a pressure P44, a pressure P45, and a pressure P46 on the graphs CH52 and CH54 is lower than a prescribed pressure P0. Further, the pressure P41 is lower than the pressure P42, the pressure P42 is lower than the pressure P43, the pressure P43 is lower than the pressure P44, the pressure P44 is lower than the pressure P45, and the pressure P45 is lower than the pressure P46.

[0076] In the example illustrated in FIG. 9, in a 51st time slot that is a time slot from the time t51 to the time t52, the fuel injection system 1 realizes a second state by performing pressure reduction control. Here, a case where, in this example, the pressure inside the second pressure accumulating unit 122 is the pressure P42 in a time slot before the time t51 will be described. In the 51st time slot, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 while reducing the pressure inside the second pressure accumulating unit 122 from the pressure P42 to the pressure P41 corresponding to a length of the 51st time slot. As a result, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 in the 51st time slot is the pressure P42 at the time t51, and is reduced from the pressure P42 to the pressure P41 in the 51st time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P42 to the pressure P41, namely the length of the 51st time slot, can be calculated on the basis of the pressure P42, the pressure P41, and Formula (1) described above.

[0077] Next, in a 52nd time slot that is a time slot from the time t52 to the time t53, the fuel injection system 1 performs pressure boost control, and thus realizes a third state. In the 52nd time slot, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 while raising the pressure inside the second pressure accumulating unit 122 from the pressure P41 to the pressure P44 corresponding to a length of the 52nd time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P41 at the time t52, and is raised from the pressure P41 to the pressure 44 in the 52nd time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P41 to the pressure P44, namely the length of the 52nd time slot, can be calculated on the basis of the pressure P41, the pressure P44, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0078] Next, in a 53rd time slot that is a time slot from the time t53 to the time t54, the fuel injection system 1 realizes a second state by performing pressure reduction control. For this reason, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 53rd time slot while reducing the pressure inside the second pressure accumulating unit 122 from the pressure P44 to the pressure P43 corresponding to a length of the 53rd time slot. As a result, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 in the 53rd time slot is the pressure P44 at the time t53, and is reduced from the pressure P44 to the pressure P43 in the 53rd time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P44 to the pressure P43, namely the length of the 53rd time slot, can be calculated on the basis of the pressure P44, the pressure P43, and Formula (1) described above.

[0079] Next, in a 54th time slot that is a time slot from the time t54 to the time t55, the fuel injection system 1 realizes a third state by performing pressure boost control. For this reason, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 54th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P43 to the pressure P46 corresponding to a length of the 54th time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P43 at the time t54, and is raised from the pressure P43 to the pressure P46 in the 54th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P43 to the pressure P46, namely the length of the 54th time slot, can be calculated on the basis of the pressure P43, the pressure P46, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0080] Next, in a 55th time slot that is a time slot from the time t55 to the time t56, the fuel injection system 1 realizes a second state by performing pressure reduction control. For this reason, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 55th time slot while reducing the pressure inside the second pressure accumulating unit 122 from the pressure P46 to the pressure P45 corresponding to a length of the 55th time slot. As a result, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 in the 55th time slot is the pressure P46 at the time t55, and is reduced from the pressure P46 to the pressure P45 in the 55th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P46 to the pressure P45, namely the length of the 55th time slot, can be calculated on the basis of the pressure P46, the pressure P45, and Formula (1) described above.

[0081] Next, in a 56th time slot that is a time slot from the time t56 to the time t57, the fuel injection system 1 realizes a third state by performing pressure boost control. In the 56th time slot, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 while raising the pressure inside the second pressure accumulating unit 122 from the pressure P45 to a prescribed pressure P0. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P45 at the time t56, and is raised from the pressure P45 to the prescribed pressure P0 in the 56th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P45 to the prescribed pressure P0, namely a length of the 56th time slot, can be calculated on the basis of the pressure P45, the prescribed pressure P0, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0082] Next, in a 57th time slot that is a time slot from the time t57 to the time t58, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the prescribed pressure P0 at the time t57, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 57th time slot while reducing pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P42 corresponding to a length of the 57th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P42, namely the length of the 57th time slot, can be calculated on the basis of the prescribed pressure P0, the pressure P42, and Formula (1) described above.

[0083] Since the fuel injection system 1 closes the second valve 22 at the time t58, the injection of the fuel into the combustion chamber CC from the second pressure accumulating unit 122 is stopped, and the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 becomes zero (0) in a time slot after the time t58. On the other hand, since the fuel injection system 1 still closes the first valve 21 in this time slot, the pressure inside the second pressure accumulating unit 122 is kept at the pressure P42.

[0084] According to the control method represented by the timing diagram illustrated in FIG. 9, the fuel injection system 1 enables a pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC to coincide with a convex pattern among patterns desired by a user while suppressing an increase in fuel consumption rate. The convex pattern is a pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC, which is the pattern illustrated in FIG. 9. That is, the convex pattern is a pattern in which the pressure of the fuel injected into the combustion chamber CC by the fuel injection system 1 is nearly monotonously raised from the pressure P42 to the prescribed pressure P0 over time in a period (a time slot from the time t51 to the time t58 in the example illustrated in FIG. 9) in which the fuel injection system 1 injects the fuel, and then is monotonously reduced from the prescribed pressure P0 to the pressure P42. In the convex pattern, the fuel injected into the combustion chamber CC from the fuel injection system 1 is injected at a pressure that is higher than that in former and latter periods on the basis of the middle period in the period in which the fuel injection system 1 injects the fuel into the combustion chamber CC. Thus, the fuel injection system 1 can atomize the fuel injected into the combustion chamber CC. As a result, the fuel injection system 1 can reduce an amount of noise of the internal combustion engine EG in a driving state, and can further reduce an amount of emissions generated from the internal combustion engine EG.

[0085] FIG. 10 is a timing diagram for illustrating Embodiment 6 of the control method of the fuel injection system 1. The control method represented by the timing diagram illustrated in FIG. 10 is a control method that increases an injection amount of fuel in the inverted deltaic pattern described in FIG. 6. The timing diagram illustrated in FIG. 10 includes four graphs from a graph CH61 to a graph CH64. The horizontal axis of each of the graphs CH61 to CH64 indicates time. Further, the vertical axis of the graph CH61 indicates a drive current supplied from the first valve drive circuit 33 to the drive unit A1. Further, the vertical axis of the graph CH62 indicates a pressure inside the second pressure accumulating unit 122. Further, the vertical axis of the graph CH63 indicates a drive current supplied from the second valve drive circuit 34 to the drive unit A2. Further, the vertical axis of the graph CH64 indicates a pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122. Further, each of a time t61, a time t64, a time t66, a time t68, and a time t70 on the graphs CH61 to CH64 indicates a time when the drive current is supplied from the first valve drive circuit 33 to the drive unit A1 and the first valve 21 is opened. Further, each of a time t62, a time t65, a time t67, a time t69, and a time t71 on the graphs CH61 to CH64 indicates a time when the supply of the drive current from the first valve drive circuit 33 to the drive unit A1 is stopped and the first valve 21 is closed. Further, a time t63 on the graphs CH61 to CH64 indicates a time when the drive current is supplied from the second valve drive circuit 34 to the drive unit A2 and the second valve 22 is opened. Further, a time t72 on the graphs CH61 to CH64 indicates a time when the supply of the drive current from the second valve drive circuit 34 to the drive unit A2 is stopped and the second valve 22 is closed. Here, the time t61 is a time before the time t62, the time t62 is a time before the time t63, the time t63 is a time before the time t64, the time t64 is a time before the time t65, the time t65 is a time before the time t66, the time t66 is a time before the time t67, the time t67 is a time before the time t68, the time t68 is a time before the time t69, and the time t69 is a time before the time t70. Further, each of a pressure P51, a pressure P52, a pressure P53, a pressure P54, a pressure P55, a pressure P56, a pressure P57, a pressure P58, and a pressure P59 on the graphs CH62 and CH64 is lower than a prescribed pressure P0. Further, the pressure P51 is lower than the pressure P52, the pressure P52 is lower than the pressure P53, the pressure P53 is lower than the pressure P54, the pressure P54 is lower than the pressure P55, the pressure P55 is lower than the pressure P56, the pressure P56 is lower than the pressure P57, the pressure P57 is lower than the pressure P58, and the pressure P58 is lower than the pressure P59.

[0086] In the example illustrated in FIG. 10, in a 61st time slot that is a time slot from the time t61 to the time t62, the fuel injection system 1 realizes a first state. Here, a case where, in this example, the pressure inside the second pressure accumulating unit 122 is the pressure P51 in a time slot before the time t61 will be described. In the 61st time slot, the pressure inside the second pressure accumulating unit 122 is raised depending on an elapsed time that is a time elapsed from the time t61. Further, since a pressure of fuel supplied to the second pressure accumulating unit 122 is the prescribed pressure P0, the pressure inside the second pressure accumulating unit 122 can be raised to the prescribed pressure P0 at the maximum. In this example, the pressure in the 61st time slot is raised from the pressure P51 to the prescribed pressure P0. Like the length of the 11th time slot, a length of the 61st time slot is determined by a user.

[0087] Next, in a 62nd time slot that is a time slot from the time t62 to the time t63, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 in the 61st time slot is raised from the pressure P51 to the prescribed pressure P0. For these reasons, the pressure inside the second pressure accumulating unit 122 in the 62nd time slot is still kept at the prescribed pressure P0.

[0088] Next, in a 63rd time slot that is a time slot from the time t63 to the time t64, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 in the 62nd time slot is still kept at the prescribed pressure P0, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 63rd time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P58 corresponding to a length of the 63rd time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P58, namely the length of the 63rd time slot, can be calculated on the basis of the prescribed pressure P0, the pressure P59, and Formula (1) described above.

[0089] Next, in a 64th time slot that is a time slot from the time t64 to the time t65, the fuel injection system 1 realizes a third state by performing pressure boost control. The fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 64th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P58 to the pressure P59 corresponding to a length of the 64th time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P58 at the time t64, and is raised from the pressure P58 to the pressure P59 in the 64th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P58 to the pressure P59, namely the length of the 64th time slot, can be calculated on the basis of the pressure P58, the pressure

P59, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0090] Next, in a 65th time slot that is a time slot from the time t65 to the time t66, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the pressure P59 at the time t65, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 65th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P59 to the pressure P56 corresponding to a length of the 65th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P59 to the pressure P56, namely the length of the 65th time slot, can be calculated on the basis of the pressure P59, the pressure P56, and Formula (1) described above.

[0091] Next, in a 66th time slot that is a time slot from the time t66 to the time t67, the fuel injection system 1 realizes a third state by performing pressure boost control. The fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 66th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P56 to the pressure P57 corresponding to a length of the 66th time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P56 at the time t66, and is raised from the pressure P56 to the pressure P57 in the 66th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P56 to the pressure P57, namely the length of the 66th time slot, can be calculated on the basis of the pressure P56, the pressure P57, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0092] Next, in a 67th time slot that is a time slot from the time t67 to the time t68, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the pressure P57 at the time t67, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 67th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P57 to the pressure P54 corresponding to a length of the 67th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P57 to the pressure P54, namely the length of the 67th time slot, can be calculated on the basis of the pressure P57, the pressure P54, and Formula (1) described above.

[0093] Next, in a 68th time slot that is a time slot from the time t68 to the time t69, the fuel injection system 1 realizes a third state by performing pressure boost control. The fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 68th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P54 to the pressure P55 corresponding to a length of the 68th time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P54 at the time t68, and is raised from the pressure P54 to the pressure P55 in the 68th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P54 to the pressure P55, namely the length of the 68th time slot, can be calculated on the basis of the pressure P54, the pressure P55, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0094] Next, in a 69th time slot that is a time slot from the time t69 to the time t70, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the pressure P55 at the time t69, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 69th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P55 to the pressure P52 corresponding to a length of the 69th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P55 to the pressure P52, namely the length of the 69th time slot, can be calculated on the basis of the pressure P55, the pressure P52, and Formula (1) described above.

[0095] Next, in a 70th time slot that is a time slot from the time t70 to the time t71, the fuel injection system 1 realizes a third state by performing pressure boost control. The fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 70th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P52 to the pressure P53 corresponding to a length of the 70th time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P52 at the time t70, and is raised from the pressure P52 to the pressure P53 in the 70th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P52 to the pressure P53, namely the length of the 70th time slot, can be calculated on the basis of the pressure P52, the pressure P53, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0096] Next, in a 71st time slot that is a time slot from the time t71 to the time t72, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the pressure P53 at the time t71, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 71st time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P53 to the pressure P51 corresponding to a length of the 71st time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P53 to the pressure P51, namely the length of the 71st time slot, can be calculated on the basis of the pressure P53, the pressure P51, and Formula (1) described above.

[0097] Since the fuel injection system 1 closes the second valve 22 at the time t72, the injection of the fuel into the combustion chamber CC from the second pressure accumulating unit 122 is stopped, and the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 becomes zero (0) in a time slot after the time t72. On the other hand, since the fuel injection system 1 still closes the first valve 21 in this time slot, the pressure inside the second pressure accumulating unit 122 is kept at the pressure P51.

[0098] According to the control method represented by the timing diagram illustrated in FIG. 10, like the control method represented by the timing diagram illustrated in FIG. 6, the fuel injection system 1 enables a pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC to coincide with an inverted deltaic pattern among patterns desired by a user while suppressing an increase in fuel consumption rate. Further, according to the control method represented by the timing diagram illustrated in FIG. 10, the fuel injection system 1 can inject fuel more than the fuel, which is injected into the combustion chamber CC by the control method represented by the timing diagram illustrated in FIG. 6, into the combustion chamber CC. As a result, the fuel injection system 1 can suppressing a cooling loss caused because fuel flames are cooled at an inner wall of the combustion chamber CC by either collision of fuel with the inner wall of the combustion chamber CC due to excessive fuel spray or collision of fuel with the inner wall of the combustion chamber CC due to flames after ignition.

[0099] FIG. 11 is a timing diagram for illustrating Embodiment 7 of the control method of the fuel injection system 1. The timing diagram illustrated in FIG. 11 includes four graphs from a graph CH71 to a graph CH74. The horizontal axis of each of the graphs CH71 to CH74 indicates time. Further, the vertical axis of the graph CH71 indicates a drive current supplied from the first valve drive circuit 33 to the drive unit A1. Further, the vertical axis of the graph CH72 indicates a pressure inside the second pressure accumulating unit 122. Further, the vertical axis of the graph CH73 indicates a drive current supplied from the second valve drive circuit 34 to the drive unit A2. Further, the vertical axis of the graph CH74 indicates a pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122. Further, each of a time t81, a time t84, a time t86, and a time t88 on the graphs CH71 to CH74 indicates a time when the drive current is supplied from the first valve drive circuit 33 to the drive unit A1 and the first valve 21 is opened. Further, each of a time t82, a time t85, a time t87, and a time t89 on the graphs CH71 to CH74 indicates a time when the supply of the drive current from the first valve drive circuit 33 to the drive unit A1 is stopped and the first valve 21 is closed. Further, a time t83 on the graphs CH71 to CH74 indicates a time when the drive current is supplied from the second valve drive circuit 34 to the drive unit A2 and the second valve 22 is opened. Further, a time t90 on the graphs CH71 to CH74 indicates a time when the supply of the drive current from the second valve drive circuit 34 to the drive unit A2 is stopped and the second valve 22 is closed. Here, the time t81 is a time before the time t82, the time t82 is a time before the time t83, the time t83 is a time before the time t84, the time t84 is a time before the time t85, the time t85 is a time before the time t86, the time t86 is a time before the time t87, the time t87 is a time before the time t88, the time t88 is a time before the time t89, and the time t89 is a time before the time t90. Further, each of a pressure P61 and a pressure P62 on the graphs CH72 and CH74 is lower than a prescribed pressure P0. Further, the pressure P61 is lower than the pressure P62.

[0100] In the example illustrated in FIG. 11, in an 81st time slot that is a time slot from the time t81 to the time t82, the fuel injection system 1 realizes a first state. Here, a case where, in this example, the pressure inside the second pressure accumulating unit 122 is the pressure P61 in a time slot before the time t81 will be described. In the 81st time slot, the pressure inside the second pressure accumulating unit 122 is raised depending on an elapsed time that is a time elapsed from the time t81. Further, since a pressure of fuel supplied to the second pressure accumulating unit 122 is the prescribed pressure P0, the pressure inside the second pressure accumulating unit 122 can be raised to the prescribed pressure P0 at the maximum. In this example, the pressure in the 81st time slot is raised from the pressure P61 to the prescribed pressure P0. Like the length of the 11th time slot, a length of the 81st time slot is determined by a user.

[0101] Next, in an 82nd time slot that is a time slot from the time t82 to the time t83, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 in the 81st time slot is raised from the pressure P61 to the prescribed pressure P0. For these reasons, the pressure inside the second pressure accumulating unit 122 in the 82nd time slot is still kept at the prescribed pressure P0.

[0102] Next, in an 83rd time slot that is a time slot from the time t83 to the time t84, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 in the 82nd time slot is still kept at the prescribed pressure P0, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 83rd time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P61 corresponding to a length of the 83rd time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P61, namely the length of the 83rd time slot, can be calculated on the basis of the prescribed pressure P0, the pressure P61, and Formula (1) described above.

[0103] Next, in an 84th time slot that is a time slot from the time t84 to the time t85, the fuel injection system 1 realizes a third state by performing pressure boost control. The fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 84th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P61 to the pressure P62 corresponding to a length of the 84th time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P61 at the time t84, and is raised from the pressure P61 to the pressure P62 in the 84th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P61 to the pressure P62, namely the length of the 84th time slot, can be calculated on the basis of the pressure P61, the pressure P62, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0104] Next, in an 85th time slot that is a time slot from the time t85 to the time t86, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the pressure P62 at the time t85, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 85th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P62 to the pressure P61 corresponding to a length of the 85th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P62 to the pressure P61, namely the length of the 85th time slot, can be calculated on the basis of the pressure P62, the pressure P61, and Formula (1) described above.

[0105] Next, in an 86th time slot that is a time slot from the time t86 to the time t87, the fuel injection system 1 realizes a third state by performing pressure boost control. The fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 86th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P61 to the pressure P62 corresponding to a length of the 86th time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P61 at the time t86, and is raised from the pressure P61 to the pressure P62 in the 86th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P61 to the pressure P62, namely the length of the 86th time slot, can be calculated on the basis of the pressure P61, the pressure P62, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0106] Next, in an 87th time slot that is a time slot from the time t87 to the time t88, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the pressure P62 at the time t87, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 87th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P62 to the pressure P61 corresponding to a length of the 87th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P62 to the pressure P61, namely the length of the 87th time slot, can be calculated on the basis of the pressure P62, the pressure P61, and Formula (1) described above.

[0107] Next, in an 88th time slot that is a time slot from the time t88 to the time t89, the fuel injection system 1 realizes a third state by performing pressure boost control. The fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 88th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P61 to the pressure P62 corresponding to a length of the 88th time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P61 at the time t88, and is raised from the pressure P61 to the pressure P62 in the 88th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P61 to the pressure P62, namely the length of the 88th time slot, can be calculated on the basis of the pressure P61, the pressure P62, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0108] Next, in an 89th time slot that is a time slot from the time t89 to the time t90, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the pressure P62 at the time t89, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 89th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P62 to the pressure P61 corresponding to a length of the 89th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P62 to the pressure P61, namely the length of the 89th time slot, can be calculated on the basis of the pressure P62, the pressure P61, and Formula (1) described above.

[0109] Since the fuel injection system 1 closes the second valve 22 at the time t90, the injection of the fuel into the combustion chamber CC from the second pressure accumulating unit 122 is stopped, and the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 becomes zero (0) in a time slot after the time t90. On the other hand, since the fuel injection system 1 still closes the first valve 21 in this time slot, the pressure inside the second pressure accumulating unit 122 is kept at the pressure P61.

[0110] According to the control method represented by the timing diagram illustrated in FIG. 11, the fuel injection system 1 enables a pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC to coincide with an L-shaped pattern among patterns desired by a user while suppressing an increase in fuel consumption rate. The L-shaped pattern is a pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC, which is the pattern illustrated in FIG. 11. That is, the L-shaped pattern is a pattern in which the pressure of the fuel injected into the combustion chamber CC by the fuel injection system 1 is monotonously reduced from the prescribed pressure P0 to the pressure P61 over time in a period (a time slot from the time t83 to the time t90 in the example illustrated in FIG. 11) in which the fuel injection system 1 injects the fuel, and then is still kept at nearly the pressure P61. In the L-shaped pattern, the fuel injected into the combustion chamber CC from the fuel injection system 1 is further homogeneously injected into the combustion chamber CC in this period, compared to an inverted deltaic pattern. As a result, the fuel injection system 1 can further suppress a cooling loss caused because fuel flames are cooled at an inner wall of the combustion chamber CC by either collision of fuel with the inner wall of the combustion chamber CC due to excessive fuel spray or collision of fuel with the inner wall of the combustion chamber CC due to flames after ignition.

[0111] FIG. 12 is a timing diagram for illustrating Embodiment 8 of the control method of the fuel injection system 1. The timing diagram illustrated in FIG. 12 includes four graphs from a graph CH81 to a graph CH84. The horizontal axis of each of the graphs CH81 to CH84 indicates time. Further, the vertical axis of the graph CH81 indicates a drive current supplied from the first valve drive circuit 33 to the drive unit A1. Further, the vertical axis of the graph CH82 indicates a pressure inside the second pressure accumulating unit 122. Further, the vertical axis of the graph CH83 indicates a drive current supplied from the second valve drive circuit 34 to the drive unit A2. Further, the vertical axis of the graph CH84 indicates a pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122. Further, each of a time t91, a time t94, a time t96, and a time t98 on the graphs CH81 to CH84 indicates a time when the drive current is supplied from the first valve drive circuit 33 to the drive unit A1 and the first valve 21 is opened. Further, each of a time t92, a time t95, a time t97, and a time t99 on the graphs CH81 to CH84 indicates a time when the supply of the drive current from the first valve drive circuit 33 to the drive unit A1 is stopped and the first valve 21 is closed. Further, a time t93 on the graphs CH81 to CH84 indicates a time when the drive current is supplied from the second valve drive circuit 34 to the drive unit A2 and the second valve 22 is opened. Further, a time t100 on the graphs CH81 to CH84 indicates a time when the supply of the drive current from the second valve drive circuit 34 to the drive unit A2 is stopped and the second valve 22 is closed. Here, the time t91 is a time before the time t92, the time t92 is a time before the time t93, the time t93 is a time before the time t94, the time t94 is a time before the time t95, the time t95 is a time before the time t96, the time t96 is a time before the time t97, the time t97 is a time before the time t98, the time t98 is a time before the time t99, and the time t99 is a time before the time t100. Further, each of a pressure P71, a pressure P72, and a pressure P73 on the graphs CH82 and CH84 is lower than a prescribed pressure P0. Further, the pressure P71 is lower than the pressure P72, and the pressure P72 is lower than the pressure P73.

[0112] In the example illustrated in FIG. 12, in a 91st time slot that is a time slot from the time t91 to the time t92, the fuel injection system 1 realizes a first state. Here, a case where, in this example, the pressure inside the second pressure accumulating unit 122 is the pressure P71 in a time slot before the time t91 will be described. In the 91st time slot, the pressure inside the second pressure accumulating unit 122 is raised depending on an elapsed time that is a time elapsed from the time t91. Further, since a pressure of fuel supplied to the second pressure accumulating unit 122 is the prescribed pressure P0, the pressure inside the second pressure accumulating unit 122 can be raised to the prescribed pressure P0 at the maximum. In this example, the pressure in the 91st time slot is raised from the pressure P71 to the pressure P73 corresponding to a length of the 91st time slot. Like the length of the 11th time slot, the length of the 91st time slot is determined by a user.

[0113] Next, in a 92nd time slot that is a time slot from the time t92 to the time t93, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 in the 91st time slot is raised from the pressure P71 to the pressure P73. For these reasons, the pressure inside the second pressure accumulating unit 122 in the 92nd time slot is still kept at the pressure P73.

[0114] Next, in a 93rd time slot that is a time slot from the time t93 to the time t94, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 in the 92nd time slot is still kept at the pressure P73, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 93rd time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P73 to the pressure P71 corresponding to a length of the 93rd time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P73 to the pressure P71, namely the length of the 93rd time slot, can be calculated on the basis of the pressure P73, the pressure P71, and Formula (1) described above.

[0115] Next, in a 94th time slot that is a time slot from the time t94 to the time t95, the fuel injection system 1 realizes a third state by performing pressure boost control. The fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 94th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P71 to the pressure P72 corresponding to a length of the 94th time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P71 at the time t94, and is raised from the pressure P71 to the pressure P72 in the 94th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P71 to the pressure P72, namely the length of the 94th time slot, can be calculated on the basis of the pressure P71, the pressure P72, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0116] Next, in a 95th time slot that is a time slot from the time t95 to the time t96, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the pressure P72 at the time t95, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 95th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P72 to the pressure P71 corresponding to a length of the 95th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P72 to the pressure P71, namely the length of the 95th time slot, can be calculated on the basis of the pressure P72, the pressure P71, and Formula (1) described above.

[0117] Next, in a 96th time slot that is a time slot from the time t96 to the time t97, the fuel injection system 1 realizes a third state by performing pressure boost control. The fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 96th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P71 to the pressure P72 corresponding to a length of the 96th time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P71 at the time t96, and is raised from the pressure P71 to the pressure P72 in the 96th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P71 to the pressure P72, namely the length of the 96th time slot, can be calculated on the basis of the pressure P71, the pressure P72, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0118] Next, in a 97th time slot that is a time slot from the time t97 to the time t98, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the pressure P72 at the time t97, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 97th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P72 to the pressure P71 corresponding to a length of the 97th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P72 to the pressure P71, namely the length of the 97th time slot, can be calculated on the basis of the pressure P72, the pressure P71, and Formula (1) described above.

[0119] Next, in a 98th time slot that is a time slot from the time t98 to the time t99, the fuel injection system 1 realizes a third state by performing pressure boost control. The fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 98th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P71 to the prescribed pressure P0. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P71 at the time t98, and is raised from the pressure P71 to the prescribed pressure P0 in the 98th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P71 to the prescribed pressure P0, namely a length of the 98th time slot can be calculated on the basis of the pressure P71, the prescribed pressure P0, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0120] Next, in a 99th time slot that is a time slot from the time t99 to the time t100, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the prescribed pressure P0 at the time t99, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 99th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P71 corresponding to a length of the 99th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P71, namely the length of the 99th time slot, can be calculated on the basis of the prescribed pressure P0, the pressure P71, and Formula (1) described above.

[0121] Since the fuel injection system 1 closes the second valve 22 at the time t100, the injection of the fuel into the combustion chamber CC from the second pressure accumulating unit 122 is stopped, and the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 becomes zero (0) in a time slot after the time t100. On the other hand, since the fuel injection system 1 still closes the first valve 21 in this time slot, the pressure inside the second pressure accumulating unit 122 is kept at the pressure P71.

[0122] According to the control method represented by the timing diagram illustrated in FIG. 12, the fuel injection system 1 enables a pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC to coincide with an inverted L-shaped pattern among patterns desired by a user while suppressing an increase in fuel consumption rate. The inverted L-shaped pattern is a pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC, which is the pattern illustrated in FIG. 12. That is, the inverted L-shaped pattern is a pattern in which the pressure of the fuel injected into the combustion chamber CC by the fuel injection system 1 is still kept at nearly the pressure P72 over time in a period (a time slot from the time t93 to the time t100 in the example illustrated in FIG. 12) in which the fuel injection system 1 injects the fuel, and then is again monotonously reduced to the pressure P71 after being monotonously raised to the prescribed pressure. In the inverted L-shaped pattern, like the deltaic pattern, the fuel injected into the combustion chamber CC from the fuel injection system 1 is injected at a high pressure in a latter period subsequent to a former period in this period. However, in the inverted L-shaped pattern, in comparison with the deltaic pattern, the fuel injection system 1 can atomize the fuel injected into the combustion chamber CC, and can further perform agitation and combustion of the fuel in the combustion chamber CC. As a result, in comparison with the deltaic pattern, the fuel injection system 1 can further reduce an amount of noise of the internal combustion engine EG in a driving state, and can further reduce an amount of emissions generated from the internal combustion engine EG.

[0123] FIG. 13 is a timing diagram for illustrating Embodiment 9 of the control method of the fuel injection system 1. The timing diagram illustrated in FIG. 13 includes four graphs from a graph CH91 to a graph CH94. The horizontal axis of each of the graphs CH91 to CH94 indicates time. Further, the vertical axis of the graph CH91 indicates a drive current supplied from the first valve drive circuit 33 to the drive unit A1. Further, the vertical axis of the graph CH92 indicates a pressure inside the second pressure accumulating unit 122. Further, the vertical axis of the graph CH93 indicates a drive current supplied from the second valve drive circuit 34 to the drive unit A2. Further, the vertical axis of the graph CH94 indicates a pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122. Further, each of a time t101, a time t104, a time t106, a time t108, and a time t110 on the graphs CH91 to CH94 indicates a time when the drive current is supplied from the first valve drive circuit 33 to the drive unit A1 and the first valve 21 is opened. Further, each of a time t102, a time t105, a time t107, a time t109, and a time t111 on the graphs CH91 to CH94 indicates a time when the supply of the drive current from the first valve drive circuit 33 to the drive unit A1 is stopped and the first valve 21 is closed. Further, a time t103 on the graphs CH91 to CH94 indicates a time when the drive current is supplied from the second valve drive circuit 34 to the drive unit A2 and the second valve 22 is opened. Further, a time t112 on the graphs CH91 to CH94 indicates a time when the supply of the drive current from the second valve drive circuit 34 to the drive unit A2 is stopped and the second valve 22 is closed. Here, the time t101 is a time before the time t102, the time t102 is a time before the time t103, the time t103 is a time before the time t104, the time t104 is a time before the time t105, the time t105 is a time before the time t106, the time t106 is a time before the time t107, the time t107 is a time before the time t108, the time t108 is a time before the time t109, the time t109 is a time before the time t110, the time t110 is a time before the time t111, and the time t111 is a time before the time t112. Further, each of a pressure P81, a pressure P82, and a pressure P83 on the graphs CH92 and CH94 is lower than a prescribed pressure P0. Further, the pressure P81 is lower than the pressure P82, and the pressure P82 is lower than the pressure P83.

[0124] In the example illustrated in FIG. 13, in a 101st time slot that is a time slot from the time t101 to the time t102, the fuel injection system 1 realizes a first state. Here, a case where, in this example, the pressure inside the second pressure accumulating unit 122 is the pressure P81 in a time slot before the time t101 will be described. In the 101st time slot, the pressure inside the second pressure accumulating unit 122 is raised depending on an elapsed time that is a time elapsed from the time t101. Further, since a pressure of fuel supplied to the second pressure accumulating unit 122 is the prescribed pressure P0, the pressure inside the second pressure accumulating unit 122 can be raised to the prescribed pressure P0 at the maximum. In this example, the pressure in the 101st time slot is raised from the pressure P81 to the pressure P83 corresponding to a length of the 101st time slot. Like the length of the 11th time slot, the length of the 101st time slot is determined by a user.

[0125] Next, in a 102nd time slot that is a time slot from the time t102 to the time t103, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 in the 101st time slot is raised from the pressure P81 to the pressure P83. For these reasons, the pressure inside the second pressure accumulating unit 122 in the 102nd time slot is still kept at the pressure P83.

[0126] Next, in a 103rd time slot that is a time slot from the time t103 to the time t104, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 in the 102nd time slot is still kept at the pressure P83, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 103rd time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P83 to the pressure P82 corresponding to a length of the 103rd time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P83 to the pressure P82, namely the length of the 103rd time slot, can be calculated on the basis of the pressure P83, the pressure P82, and Formula (1) described above.

[0127] Next, in a 104th time slot that is a time slot from the time t104 to the time t105, the fuel injection system 1 realizes a third state by performing pressure boost control. The fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 104th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P82 to the pressure P83 corresponding to a length of the 104th time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P82 at the time t104, and is raised from the pressure P82 to the pressure P83 in the 104th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P82 to the pressure P83, namely the length of the 104th time slot, can be calculated on the basis of the pressure P82, the pressure P83, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0128] Next, in a 105th time slot that is a time slot from the time t105 to the time t106, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the pressure P83 at the time t105, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 105th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P83 to the pressure P82 corresponding to a length of the 105th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P83 to the pressure P82, namely the length of the 105th time slot, can be calculated on the basis of the pressure P83, the pressure P82, and Formula (1) described above.

[0129] Next, in a 106th time slot that is a time slot from the time t106 to the time t107, the fuel injection system 1 realizes a third state by performing pressure boost control. The fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 106th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P82 to the pressure P83 corresponding to a length of the 106th time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P82 at the time t106, and is raised from the pressure P82 to the pressure P83 in the 106th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P82 to the pressure P83, namely the length of the 106th time slot, can be calculated on the basis of the pressure P82, the pressure P83, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0130] Next, in a 107th time slot that is a time slot from the time t107 to the time t108, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the pressure P83 at the time t107, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 107th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P83 to the pressure P82 corresponding to a length of the 107th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P83 to the pressure P82, namely the length of the 107th time slot, can be calculated on the basis of the pressure P83, the pressure P82, and Formula (1) described above.

[0131] Next, in a 108th time slot that is a time slot from the time t108 to the time t109, the fuel injection system 1 realizes a third state by performing pressure boost control. The fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 108th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P82 to the pressure P83 corresponding to a length of the 108th time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P82 at the time t108, and is raised from the pressure P82 to the pressure P83 in the 108th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P82 to the pressure P83, namely a length of the 108th time slot, can be calculated on the basis of the pressure P82, the pressure P83, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0132] Next, in a 109th time slot that is a time slot from the time t109 to the time t110, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the pressure P83 at the time t109, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 109th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P83 to the pressure P82 corresponding to a length of the 109th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P83 to the pressure P82, namely the length of the 109th time slot, can be calculated on the basis of the pressure P83, the pressure P82, and Formula (1) described above.

[0133] Next, in a 110th time slot that is a time slot from the time t110 to the time t111, the fuel injection system 1 realizes a third state by performing pressure boost control. The fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 110th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P82 to the pressure P83 corresponding to a length of the 110th time slot. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P82 at the time t110, and is raised from the pressure P82 to the pressure P83 in the 110th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P82 to the pressure P83, namely a length of the 110th time slot, can be calculated on the basis of the pressure P82, the pressure P83, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0134] Next, in a 111th time slot that is a time slot from the time t111 to the time t112, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the pressure P83 at the time t111, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 111th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P83 to the pressure P81 corresponding to a length of the 111th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P83 to the pressure P81, namely the length of the 111th time slot, can be calculated on the basis of the pressure P83, the pressure P81, and Formula (1) described above.

[0135] Since the fuel injection system 1 closes the second valve 22 at the time t112, the injection of the fuel into the combustion chamber CC from the second pressure accumulating unit 122 is stopped, and the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 becomes zero (0) in a time slot after the time t112. On the other hand, since the fuel injection system 1 still closes the first valve 21 in this time slot, the pressure inside the second pressure accumulating unit 122 is kept at the pressure P81.

[0136] According to the control method represented by the timing diagram illustrated in FIG. 13, the fuel injection system 1 can inject the fuel into the combustion chamber CC while the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC is kept at nearly the pressure P83 that is a pressure lower than the prescribed pressure P0 while suppressing an increase in fuel consumption rate. That is, the fuel injection system 1 can inject the fuel into the combustion chamber CC at a pressure that is a pressure lower than or equal to a pressure supplied from the high-pressure source 4 and is desired by a user.

[0137] FIG. 14 is a timing diagram for illustrating Embodiment 10 of the control method of the fuel injection system 1. Embodiment 10 of the control method is a control method in which multi-stage injections, for example, pilot injection, pre-injection, main injection, and after-injection are performed on the fuel injection system 1 in turn by combining some or all of the control methods described above. The timing diagram illustrated in FIG. 14 includes four graphs from a graph CH101 to a graph CH104. The horizontal axis of each of the graphs CH101 to CH104 indicates time. Further, the vertical axis of the graph CH101 indicates a drive current supplied from the first valve drive circuit 33 to the drive unit A1. Further, the vertical axis of the graph CH102 indicates a pressure inside the second pressure accumulating unit 122. Further, the vertical axis of the graph CH103 indicates a drive current supplied from the second valve drive circuit 34 to the drive unit A2. Further, the vertical axis of the graph CH104 indicates a pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122. Further, each of a time t125 and a time t129 on the graphs CH101 to CH104 indicates a time when the drive current is supplied from the first valve drive circuit 33 to the drive unit A1 and the first valve 21 is opened. Further, each of a time t127 and a time t130 on the graphs CH101 to CH104 indicates a time when the supply of the drive current from the first valve drive circuit 33 to the drive unit A1 is stopped and the first valve 21 is closed. Further, each of a time t121, a time t123, a time t126, and a time t130 on the graphs CH101 to CH104 indicates a time when the drive current is supplied from the second valve drive circuit 34 to the drive unit A2 and the second valve 22 is opened. Further, each of a time t122, a time t124, a time t128, and a time t131 on the graphs CH101 to CH104 indicates a time when the supply of the drive current from the second valve drive circuit 34 to the drive unit A2 is stopped and the second valve 22 is closed. Here, the time t121 is a time before the time t122, the time t122 is a time before the time t123, the time t123 is a time before the time t124, the time t124 is a time before the time t125, the time t125 is a time before the time t126, the time t126 is a time before the time t127, the time t127 is a time before the time t128, the time t128 is a time before the time t129, the time t129 is a time before the time t130, and the time t130 is a time before the time t131. Further, each of a pressure P91, a pressure P92, a pressure P93, a pressure P94, a pressure P95, and a pressure P96 on the graphs CH102 and CH104 is lower than a prescribed pressure P0. Further, the pressure P91 is lower than the pressure P92, the pressure P92 is lower than the pressure P93, the pressure P93 is lower than the pressure P94, the pressure P94 is lower than the pressure P95, and the pressure P95 is lower than the pressure P96.

[0138] In the example illustrated in FIG. 14, in a 121st time slot that is a time slot from the time t121 to the time t122, the fuel injection system 1 realizes a second state by performing pressure reduction control, and performs pilot injection. Here, a case where, in this example, the pressure inside the second pressure accumulating unit 122 is the pressure P94 in a time slot before the time t121 will be described. Since the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P94 in the 121st time slot, fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 121st time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P94 to the pressure P93 corresponding to a length of the 121st time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P94 to the pressure P93, namely the length of the 121st time slot, can be calculated on the basis of the pressure P94, the pressure P93, and Formula (1) described above.

[0139] Next, in a 122nd time slot that is a time slot from the time t122 to the time t123, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 in the 121st time slot is reduced from the pressure P94 to the pressure P93. For these reasons, the pressure inside the second pressure accumulating unit 122 in the 122nd time slot is still kept at the pressure P93.

[0140] Next, in a 123rd time slot that is a time slot from the time t123 to the time t124, the fuel injection system 1 realizes a second state by performing pressure reduction control, and performs pre-injection. Since the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P93 in the 122nd time slot, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 123rd time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P93 to the pressure P92 corresponding to a length of the 123rd time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P93 to the pressure P92, namely the length of the 123rd time slot, can be calculated on the basis of the pressure P93, the pressure P92, and Formula (1) described above.

[0141] Next, in a 124th time slot that is a time slot from the time t124 to the time t125, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 is reduced from the pressure P93 to the pressure P92 in the 123rd time slot. For these reasons, the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P92 in the 124th time slot.

[0142] Next, in a 125th time slot that is a time slot from the time t125 to the time t126, the fuel injection system 1 realizes a first state. In the 125th time slot, the pressure inside the second pressure accumulating unit 122 is raised depending on an elapsed time that is a time elapsed from the time t125. Further, since a pressure of fuel supplied to the second pressure accumulating unit 122 is the prescribed pressure P0, the pressure inside the second pressure accumulating unit 122 can be raised to the prescribed pressure P0 at the maximum. In this example, the pressure in the 125th time slot is raised from the pressure P92 to the pressure P96. Like the length of the 11th time slot, a length of the 125th time slot is determined by a user.

[0143] Next, in a 126th time slot that is a time slot from the time t126 to the time t127, the fuel injection system 1 realizes a third state by performing pressure boost control. The fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 126th time slot while raising the pressure inside the second pressure accumulating unit 122 from the pressure P96 to the prescribed pressure P0. Thus, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P96 at the time t126, and is raised from the pressure P96 to the prescribed pressure P0 in the 126th time slot. A time required to raise the pressure inside the second pressure accumulating unit 122 from the pressure P96 to the prescribed pressure P0, namely a length of the 126th time slot, can be calculated on the basis of the pressure P96, the prescribed pressure P0, Formula (1) described above, and the method of determining the length of the 11th time slot.

[0144] Next, in a 127th time slot that is a time slot from the time t127 to the time t128, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the prescribed pressure P0 at the time t127, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 127th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P91 corresponding to a length of the 127th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P91, namely the length of the 127th time slot, can be calculated on the basis of the prescribed pressure P0, the pressure P91, and Formula (1) described above.

[0145] Next, in a 128th time slot that is a time slot from the time t128 to the time t129, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 is reduced from the prescribed pressure P0 to the pressure P91 in the 128th time slot. For these reasons, the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P91 in the 128th time slot.

[0146] The fuel injection system 1 performs main injection in a period from the time t125 to the time t129.

[0147] Next, in a 129th time slot that is a time slot from the time t129 to the time t130, the fuel injection system 1 realizes a first state. In the 129th time slot, the pressure inside the second pressure accumulating unit 122 is raised depending on an elapsed time that is a time elapsed from the time t129. Further, since a pressure of fuel supplied to the second pressure accumulating unit 122 is the prescribed pressure P0, the pressure inside the second pressure accumulating unit 122 can be raised to the prescribed pressure P0 at the maximum. In this example, the pressure in the 129th time slot is raised from the pressure P91 to the pressure P95. Like the length of the 11th time slot, a length of the 129th time slot is determined by a user.

[0148] Next, in a 130th time slot that is a time slot from the time t130 to the time t131, the fuel injection system 1 realizes a second state by performing pressure reduction control, and performs after-injection. Since the pressure inside the second pressure accumulating unit 122 is the pressure P95 at the time t130, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 130th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P95 to the pressure P94 corresponding to a length of the 130th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P95 to the pressure P94, namely the length of the 130th time slot, can be calculated on the basis of the pressure P95, the pressure P94, and Formula (1) described above.

[0149] Since the fuel injection system 1 closes the second valve 22 at the time t131, the injection of the fuel into the combustion chamber CC from the second pressure accumulating unit 122 is stopped, and the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 becomes zero (0) in a time slot after the time t131. On the other hand, since the fuel injection system 1 still closes the first valve 21 in this time slot, the pressure inside the second pressure accumulating unit 122 is kept at the pressure P94.

[0150] According to the control method represented by the timing diagram illustrated in FIG. 14, the fuel injection system 1 can perform the pilot injection, the pre-injection, the main injection, and the after-injection described above while suppressing an increase in fuel consumption rate. In the example illustrated in FIG. 14, the fuel injection system 1 injects fuel into the combustion chamber CC in the pilot injection and the pre-injection at a pressure that is lower than the pressure of the fuel injected into the combustion chamber CC in the main injection. Thus, the fuel injection system 1 can further reduce an amount of noise of the internal combustion engine EG, and can further reduce an amount of emissions generated from the internal combustion engine EG. Further, in this example, the fuel injection system 1 injects fuel into the combustion chamber CC by the inverted deltaic pattern described above. Further, the fuel injection system 1 injects fuel into the combustion chamber CC in the after-injection at a pressure that is lower than the pressure of the fuel injected into the combustion chamber CC in the main injection and is higher than the pressure of the fuel injected into the combustion chamber CC in the pilot injection. Thus, the fuel injection system 1 can perform agitation and combustion of the fuel in the combustion chamber CC in the 130th time slot, and reduce an amount of emissions generated from the internal combustion engine EG.

[0151] Next, a case where dynamic effects associated with movement of fuel in the fuel injection system 1 is exerted will be described with reference to FIGS. 15 to 18.

[0152] FIG. 15 is a timing diagram for illustrating Embodiment 11 of the control method of the fuel injection system 1. Embodiment 11 of the control method is a control method in which multi-stage injections, for example, pilot injection, pre-injection, and main injection are performed on the fuel injection system 1 by combining some or all of the control methods described above. The control method may be carried out by appropriately adding after-injection without limiting performing of the after-injection. The timing diagram illustrated in FIG. 15 includes four graphs from a graph CH111 to a graph CH114. The horizontal axis of each of the graphs CH111 to CH114 indicates time. Further, the vertical axis of the graph CH111 indicates the state of the valve A1V as two values of an open state and a closed state (hereinafter referred to simply as "indicates the state of the valve A1V"). A timing at which the state of the valve A1V varies is later than a timing at which a drive current supplied from the first valve drive circuit 33 to the drive unit A1 is changed by a minute time. Further, the vertical axis of the graph CH112 indicates a pressure inside the second pressure accumulating unit 122. Further, the vertical axis of the graph CH113 indicates the state of the valve A2V as two values of an open state and a closed state (hereinafter referred to simply as "indicates the state of the valve A2V"). A timing at which the state of the valve A2V varies is later than a timing at which a drive current supplied from the second valve drive circuit 34 to the drive unit A2 is changed by a minute time. Further, the vertical axis of the graph CH114 indicates a pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122. Further, each of a time t141, a time t150, a time t154, and a time t158 on the graphs CH111 to CH114 indicates a time when the drive current is supplied from the first valve drive circuit 33 to the drive unit A1 and the first valve 21 is opened. Further, each of a time t142, a time t152, a time t156, and a time t160 on the graphs CH111 to CH114 indicates a time when the supply of the drive current from the first valve drive circuit 33 to the drive unit A1 is stopped and the first valve 21 is closed. Further, each of a time t151, a time t155, and a time t159 on the graphs CH111 to CH114 indicates a time when the drive current is supplied from the second valve drive circuit 34 to the drive unit A2 and the second valve 22 is opened. Further, each of a time t153, a time t157, and a time t161 on the graphs CH111 to CH114 indicates a time when the supply of the drive current from the second valve drive circuit 34 to the drive unit A2 is stopped and the second valve 22 is closed. Each of a time t143, a time t145, and a time t147 on the graphs CH111 to CH114 indicates a time when the drive current is supplied from the second valve drive circuit 34 to the drive unit A2 and the valve A2V starts to discharge fuel from the second pressure accumulating unit 122. Further, each of a time t144, a time t146, and a time t148 on the graphs CH111 to CH114 indicates a time when the supply of the drive current from the second valve drive circuit 34 to the drive unit A2 is stopped and the valve A2V stops discharging fuel from the second pressure accumulating unit 122. Here, the time t141 is a time before the time t142, the time t142 is a time before the time t143, the time t143 is a time before the time t144, the time t144 is a time before the time t145, the time t145 is a time before the time t146, the time t146 is a time before the time t147, the time t147 is a time before the time t148, the time t148 is a time before the time t150, the time t150 is a time before the time t152, the time t152 is a time before the time t151, the time t151 is a time before the time t153, the time t153 is a time before the time t154, the time t154 is a time before the time t156, the time t156 is a time before the time t155, the time t155 is a time before the time t157, the time t157 is a time before the time t158, the time t158 is a time before the time t159, the time t159 is a time before the time t160, and the time t160 is a time before the time t161. Further, each of a pressure P101, a pressure P103, a pressure P104, and a pressure P105 on the graphs CH112 and CH114 is higher than zero (0), and is lower than a prescribed pressure P0, and a pressure P107 is higher than the prescribed pressure P0. Further, the pressure P101 is lower than the pressure P103, the pressure P103 is lower than the pressure P104, and the pressure P104 is lower than the pressure P105.

[0153] In the example illustrated in FIG. 15, in a 141st time slot that is a time slot from the time t141 to the time t142, the fuel injection system 1 realizes a first state. Here, a case where, in this example, the pressure inside the second pressure accumulating unit 122 is the pressure P101 in a time slot before the time t141 will be described. In the 141st time slot, the pressure inside the second pressure accumulating unit 122 is raised depending on an elapsed time that is a time elapsed from the time t141. For example, the pressure inside the second pressure accumulating unit 122 is raised from the pressure P103 to the pressure P107 due to a pressure boosting effect associated with movement of fuel. The pressure boosting effect associated with movement of fuel means that a pressure higher than the prescribed pressure P0 occurs at a pressure of the high-pressure source 4, for example, due to an inertial force of fuel caused by movement of fuel that is present, for example, in the fuel supply pipeline 121 between the high-pressure source 4 and the second pressure accumulating unit 122. With use of a dynamic effect caused by the inertial force of fuel, the pressure inside the second pressure accumulating unit 122 can be increased to a pressure that exceeds the prescribed pressure P0 without using an active pressure boosting mechanism (a pressurizer). Like the length of the 11th time slot, a length of the 141st time slot is determined by a user.

[0154] Next, in a 142nd time slot that is a time slot from the time t142 to the time t143, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 is raised from the pressure P101 to the pressure P107 in the 141st time slot. For these reasons, the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P107 in the 142nd time slot.

[0155] Next, in a 143rd time slot that is a time slot from the time t143 to the time t144, the fuel injection system 1 realizes a fourth state by performing non-injection pressure reduction control. The fourth state is a state where the first valve 21 is closed state and the valve A2V is subjected to the non-injection pressure reduction control while the second valve 22 maintains a closed state. Further, the non-injection pressure reduction control is an example of a technique for reducing the pressure inside the second pressure accumulating unit 122 without injecting fuel into the combustion chamber CC from the second pressure accumulating unit 122, and is realized, for example, by supplying a drive current for a short time such that the valve A2V put in a closed state is open for such a minute time that an actuator makes no response. Since the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P107 in the previous 142nd time slot, the fuel injection system 1 in the 143rd time slot reduces the pressure of the fuel in the second pressure accumulating unit 122 from the pressure P107 to the pressure P105 corresponding to a length of the 143rd time slot. The pressure P105 depends on the length of the 143rd time slot. The length of the 143rd time slot is previously determined to be a time that is longer than a time until the drive current starts to be supplied to the valve A2V and then the valve A2V makes a response to start to discharge fuel, and that is shorter than a time until the second valve 22 makes a response to start to inject fuel. That is, the second valve drive circuit 34 supplies a prescribed drive current to the valve A2V in a period of the 143rd time slot, and thus the pressure inside the second pressure accumulating unit 122 is reduced from the pressure P107 to the pressure P105.

[0156] Next, in a 144th time slot that is a time slot from the time t144 to the time t145, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 is reduced to the pressure P105 in the 143rd time slot. For these reasons, the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P105 in the 144th time slot.

[0157] Next, in a 145th time slot that is a time slot from the time t145 to the time t146, the fuel injection system 1 realizes a fourth state by performing non-injection pressure reduction control.

[0158] Since the pressure inside the second pressure accumulating unit 122 is kept at the pressure P105 in the 144th time slot, the fuel injection system 1 reduces the pressure of the fuel in the second pressure accumulating unit 122 from the pressure P105 to the pressure P104 in the 145th time slot.

[0159] Next, in a 146th time slot that is a time slot from the time t146 to the time t147, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 is reduced to the pressure P104 in the 145th time slot. For these reasons, the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P104 in the 146th time slot.

[0160] Next, in a 147th time slot that is a time slot from the time t147 to the time t148, the fuel injection system 1 realizes a fourth state by performing non-injection pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is kept at the pressure P104 in the previous 146th time slot, the fuel injection system 1 reduces the pressure of the fuel in the second pressure accumulating unit 122 from the pressure P104 to the pressure P103 in the 145th time slot. The pressure P103 is a target pressure to be reduced. Here, due to this non-injection pressure reduction control, the pressure of the fuel in the second pressure accumulating unit 122 is assumed to reach the pressure P103 that is the target pressure to be reduced. The number of times which the fourth state is repeated is not limited to the above, and may be appropriately determined on the basis of a magnitude of pressure that can be reduced by single non-injection pressure reduction control, the pressure P107, and the pressure P103 that is the target pressure to be reduced. Alternatively, a pressure inside the second pressure accumulating unit 122 which is reached by performing the non-injection pressure reduction control the prescribed number of times may be regarded as the target pressure to be reduced (the pressure P103).

[0161] Next, in a 148th time slot that is a time slot from the time t148 to the time t150, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 is reduced to the pressure P103 in the 147th time slot. For these reasons, the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P103 in the 148th time slot.

[0162] Next, in a time slot from the time t150 to the time t153, the fuel injection system 1 performs so-called pilot injection. For example, in a 150th time slot that is a time slot from the time t150 to the time t152, the fuel injection system 1 realizes the aforementioned first state. In the 150th time slot, the pressure inside the second pressure accumulating unit 122 is raised depending on an elapsed time that is a time elapsed from the time t150, and becomes the pressure P104. A period of the 150th time slot is so minute as to make up for a reduction in the pressure inside the second pressure accumulating unit 122 by controlling the valve A2V, and an increment of the pressure P103 becomes small. The period of the 150th time slot is minute, but the first state is provided, and thus pressure reduction can be offset by controlling the valve A2V. Like the length of the 11th time slot, a length of the 150th time slot is determined by a user.

[0163] Next, in a 152nd time slot that is a time slot from the time t152 to the time t151, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 is raised to the pressure P104 in the 150th time slot. For these reasons, the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P104 in the 152nd time slot.

[0164] Next, in a 151st time slot that is a time slot from the time t151 to the time t153, the fuel injection system 1 realizes a second state by performing pressure reduction control. Here, a case where, in this example, the pressure inside the second pressure accumulating unit 122 is the pressure P104 at the time t151 will be described. Since the pressure inside the second pressure accumulating unit 122 is the pressure P104 at the time t151 in the previous 152nd time slot, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 151st time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P104 to the pressure P103 depending on a length of the 151st time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P104 to the pressure P103, namely the length of the 151st time slot, can be calculated on the basis of the pressure P104, the pressure P103, and Formula (1) described above.

[0165] The time t152 may be disposed in the 151st time slot.

[0166] Next, in a 153rd time slot that is a time slot from the time t153 to the time t154, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 is reduced from the pressure P104 to the pressure P103 in the 151st time slot. For these reasons, the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P103 in the 153rd time slot.

[0167] Next, in a time slot from the time t154 to the time t157, the fuel injection system 1 performs so-called pre-injection. For example, in a 154th time slot that is a time slot from the time t154 to the time t156, the fuel injection system 1 realizes the aforementioned first state. In the 154th time slot, the pressure inside the second pressure accumulating unit 122 is raised depending on an elapsed time that is a time elapsed from the time t154, and becomes the pressure P104. A period of the 154th time slot is so minute as to make up for a reduction in the pressure inside the second pressure accumulating unit 122 by controlling the valve A2V, and an increment of the pressure P103 becomes small. The period of the 154th time slot is minute, but the first state is provided, and thus pressure reduction can be offset by controlling the valve A2V. Like the length of the 11th time slot, a length of the 154th time slot is determined by a user.

[0168] Next, in a 155th time slot that is a time slot from the time t155 to the time t157, the fuel injection system 1 realizes a second state by performing pressure reduction control. Here, a case where, in this example, the pressure inside the second pressure accumulating unit 122 is the pressure P104 at a point in time of the time t155 will be described. Since the pressure inside the second pressure accumulating unit 122 is the pressure P104 at the time t155 in the previous 154th time slot, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 155th time slot while reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P104 to the pressure P103 depending on a length of the 155th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P104 to the pressure P103, namely the length of the 155th time slot, can be calculated on the basis of the pressure P104, the pressure P103, and Formula (1) described above.

[0169] The time t156 may be disposed in the 155th time slot.

[0170] Next, in a 157th time slot that is a time slot from the time t157 to the time t158, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 is reduced from the pressure P104 to the pressure P103 in the 155th time slot. For these reasons, the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P103 in the 157th time slot.

[0171] Next, in a 158th time slot that is a time slot from the time t158 to the time t159, the fuel injection system 1 realizes a first state. In the 158th time slot, the pressure inside the second pressure accumulating unit 122 is raised depending on an elapsed time that is a time elapsed from the time t158. For example, the pressure inside the second pressure accumulating unit 122 is raised from the pressure P103 to the pressure P107 due to a pressure boosting effect associated with movement of fuel. Like the length of the 11th time slot, a length of the 158th time slot is determined by a user.

[0172] Next, in a 159th time slot that is a time slot from the time t159 to the time t160, the fuel injection system 1 opens both the first valve 21 and the second valve 22. The pressure inside the second pressure accumulating unit 122 is previously raised to the pressure P107 in the previous 158th time slot. For these reasons, the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P107 in the 159th time slot without being raised. The 159th time slot may be omitted.

[0173] Next, in a 160th time slot that is a time slot from the time t160 to the time t161, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the pressure P107 at the time t160, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 160th time slot while at least reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P107 to the pressure P101 corresponding to a length of the 160th time slot. A time required to at least reduce the pressure inside the second pressure accumulating unit 122 from the pressure P107 to the pressure P101, namely the length of the 160th time slot, can be calculated on the basis of the pressure P107, the pressure P101, and Formula (1) described above.

[0174] Since the fuel injection system 1 closes the second valve 22 at the time t161, the injection of the fuel into the combustion chamber CC from the second pressure accumulating unit 122 is stopped, and the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 becomes zero (0) in a time slot after the time t161. On the other hand, since the fuel injection system 1 still closes the first valve 21 in this time slot, the pressure inside the second pressure accumulating unit 122 is kept at the pressure P101.

[0175] According to the control method represented by the timing diagram illustrated in FIG. 15, the fuel injection system 1 can perform the pilot injection, the pre-injection, the main injection, and the after-injection described above while suppressing an increase in fuel consumption rate. In the example illustrated in FIG. 15, the fuel injection system 1 adjusts a pressure inside the second pressure accumulating unit 122 when performing the pilot injection and the pre-injection to a desired pressure that is higher than zero (0) and is lower than the prescribed pressure P0. That is, the desired pressure is a pressure that is lower than a pressure of fuel injected into the combustion chamber CC during the main injection. The fuel injection system 1 injects fuel into the combustion chamber CC at the desired pressure in each of the pilot injection, the pre-injection, and the main injection. Thus, the fuel injection system 1 can reduce an amount of noise of the internal combustion engine EG, and can further reduce an amount of emissions generated from the internal combustion engine EG. In this example, the fuel injection system 1 can adjust the pressure inside the second pressure accumulating unit 122 during the pilot injection and the pre-injection, and realize control of making good use of a unique characteristic of an inverted deltaic pattern in the main injection.

[0176] The horizontal axis of each graph illustrated in FIG. 15 has been described as indicating the time, but the time may be replaced with an angle of a crank (not shown) (a crank angle) of the internal combustion engine EG. In this case, FIG. 15 shows one period of a combustion cycle. In this case, the ECU 3 may acquire information about a crank angle using a known method. This is also the same in the following figures.

[0177] FIG. 16 is a timing diagram for illustrating Embodiment 12 of the control method of the fuel injection system 1. Embodiment 12 of the control method is a control method in which multi-stage injections, for example, pilot injection, pre-injection, and main injection are performed on the fuel injection system 1 by combining some or all of the control methods described above. The control method may be carried out by appropriately adding after-injection without limiting performing of the after-injection. The timing diagram illustrated in FIG. 16 includes four graphs from a graph CH121 to a graph CH124. The horizontal axis of each of the graphs CH121 to CH124 indicates time. Further, the vertical axis of the graph CH121 indicates the state of the valve A1V. Further, the vertical axis of the graph CH122 indicates a pressure inside the second pressure accumulating unit 122. Further, the vertical axis of the graph CH123 indicates the state of the valve A2V. Further, the vertical axis of the graph CH124 indicates a pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122. Further, each of a time t150, a time t154, a time t158, and a time t162 on the graphs CH121 to CH124 indicates a time when the drive current is supplied from the first valve drive circuit 33 to the drive unit A1 and the first valve 21 is opened. Further, each of a time t152, a time t156, a time t160, and a time t163 on the graphs CH121 to CH124 indicates a time when the supply of the drive current from the first valve drive circuit 33 to the drive unit A1 is stopped and the first valve 21 is closed. Further, each of a time t151, a time t155, and a time t159 on the graphs CH121 to CH124 indicates a time when the drive current is supplied from the second valve drive circuit 34 to the drive unit A2 and the second valve 22 is opened. Further, each of a time t153, a time t157, and a time t161 on the graphs CH121 to CH124 indicates a time when the supply of the drive current from the second valve drive circuit 34 to the drive unit A2 is stopped and the second valve 22 is closed. Here, the time t161 is a time before the time t162, and the time t162 is a time before the time t163. Description of the time t150 to the time t161 on the graphs CH121 to CH124 refers to the description of Embodiment 11 illustrated in FIG. 15. A difference from Embodiment 11 illustrated in FIG. 15 is a method of adjusting a pressure of the second pressure accumulating unit 122 for the pilot injection and the pre-injection. In Embodiment 11 illustrated in FIG. 15, once the pressure of the second pressure accumulating unit 122 is applied to a pressure P107 after the main injection before the pilot injection and the pre-injection, the pressure of the second pressure accumulating unit 122 is adjusted to a desired pressure. In the present embodiment, this is omitted, and the pressure of the second pressure accumulating unit 122 is adjusted without being applied to the pressure P107 once after the time t161. Hereinafter, the pressure adjustment performed after the time t161 will be described.

[0178] The fuel injection system 1 performs the pilot injection, the pre-injection, and the main injection in turn from the time t150 to the time t161.

[0179] Next, in a 161st time slot that is a time slot from the time t161 to the time t162, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 is reduced from the pressure P107 to a pressure P101 in the 161st time slot. For these reasons, the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P101 in the 161st time slot. Since the fuel injection system 1 closes the second valve 22 at the time t161, the injection of the fuel into the combustion chamber CC from the second pressure accumulating unit 122 is stopped, and the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 becomes zero (0) in a time slot after the time t161.

[0180] Next, in a 162nd time slot that is a time slot from the time t162 to the time t163, the fuel injection system 1 realizes a first state. In the 162nd time slot, the pressure inside the second pressure accumulating unit 122 is raised depending on an elapsed time that is a time elapsed from the time t162. Further, a pressure of fuel supplied to the second pressure accumulating unit 122 is a prescribed pressure P0. According to a dynamic effect caused by movement of fuel, the pressure inside the second pressure accumulating unit 122 can be raised, for example, to the pressure P107 at the maximum. However, in this example, a length of the 162nd time slot is determined to be a relatively short time, and the pressure inside the second pressure accumulating unit 122 is at least kept at a pressure raised to the pressure P103 lower than the prescribed pressure P0. Like the length of the 11th time slot, the length of the 162nd time slot is determined by a user.

[0181] Next, the fuel injection system 1 closes both the first valve 21 and the second valve 22 up to a timing of the pilot injection of the next combustion cycle in a period after the time t163. Thus, the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P103.

[0182] According to the control method represented by the timing diagram illustrated in FIG. 16, the fuel injection system 1 can perform the pilot injection, the pre-injection, and the main injection described above while suppressing an increase in fuel consumption rate. In the example illustrated in FIG. 16, the fuel injection system 1 at least adjusts a pressure inside the second pressure accumulating unit 122 when performing the pilot injection and the pre-injection to a desired pressure that is higher than zero (0) and is lower than the prescribed pressure P0. That is, the desired pressure is a pressure that is lower than the pressure P107 of the fuel injected into the combustion chamber CC during the main injection. The fuel injection system 1 injects fuel into the combustion chamber CC at the desired pressure in each of the pilot injection, the pre-injection, and the main injection. Furthermore, the fuel injection system 1 can at least adjust the pressure inside the second pressure accumulating unit 122 during the pilot injection and the pre-injection without rising to the prescribed pressure P0. Thus, the fuel injection system 1 can reduce an amount of noise of the internal combustion engine EG, and can further reduce an amount of emissions generated from the internal combustion engine EG. In this example, the fuel injection system 1 can adjust the pressure inside the second pressure accumulating unit 122 during the pilot injection and the pre-injection, and realize control of making good use of a unique characteristic of an inverted deltaic pattern in the main injection.

[0183] FIG. 17 is a timing diagram for illustrating Embodiment 13 of the control method of the fuel injection system 1. Embodiment 13 of the control method is a control method in which multi-stage injections, for example, pilot injection, pre-injection, and main injection are performed on the fuel injection system 1 by combining some or all of the control methods described above. The control method may be carried out by appropriately adding after-injection without limiting performing of the after-injection. The timing diagram illustrated in FIG. 17 includes four graphs from a graph CH131 to a graph CH134. The horizontal axis of each of the graphs CH131 to CH134 indicates time. Further, the vertical axis of the graph CH131 indicates the state of the valve A1V. Further, the vertical axis of the graph CH132 indicates a pressure inside the second pressure accumulating unit 122. Further, the vertical axis of the graph CH133 indicates the state of the valve A2V. Further, the vertical axis of the graph CH134 indicates a pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122. Further, each of a time t171, a time t173, a time t175, and a time t177 on the graphs CH131 to CH134 indicates a time when the drive current is supplied from the first valve drive circuit 33 to the drive unit A1 and the first valve 21 is opened. Further, each of a time t172, a time t174, a time t176, and a time t178 on the graphs CH131 to CH134 indicates a time when the supply of the drive current from the first valve drive circuit 33 to the drive unit A1 is stopped and the first valve 21 is closed. Further, a time t170 on the graphs CH131 to CH134 indicates a time when the drive current is supplied from the second valve drive circuit 34 to the drive unit A2 and the second valve 22 is opened. Further, a time t179 on the graphs CH131 to CH134 indicates a time when the supply of the drive current from the second valve drive circuit 34 to the drive unit A2 is stopped and the second valve 22 is closed. Here, the time t157 is a time before the time t170, the time t170 is a time before the time t171, the time t171 is a time before the time t172, the time t172 is a time before the time t173, the time t173 is a time before the time t174, the time t174 is a time before the time t175, the time t175 is a time before the time t176, the time t176 is a time before the time t177, the time t177 is a time before the time t178, and the time t178 is a time before the time t179. Further, each of a pressure P21, a pressure P101, a pressure P103, a pressure P104, and a pressure P105 on the graphs CH132 to CH134 is a pressure that is higher than zero (0) and is lower than a prescribed pressure P0, and a pressure P107 is higher than the prescribed pressure P0. Further, the pressure P101 is lower than the pressure P103, the pressure P103 is lower than the pressure P104, the pressure P104 is lower than the pressure P105. At least the pressure P21 is lower than the pressure P103.

[0184] Description from the time t141 to the time t157 on the graphs CH131 to CH134 refers to the description of Embodiment 11 illustrated in FIG. 15. A case where the pressure inside the second pressure accumulating unit 122 is the pressure P103 at the time t141 is given as an example. The pressure inside the second pressure accumulating unit 122 at the time t141 varies sometimes depending on the state of the previous fuel injection cycle. A main difference from Embodiment 11 illustrated in FIG. 15 is a method of adjusting a pressure of the second pressure accumulating unit 122 during the main injection. Embodiment 11 illustrated in FIG. 15 is a case of inverted deltaic main injection, but the present embodiment is a case of deltaic main injection. Hereinafter, the pressure adjustment performed after the time t170 will be described.

[0185] The fuel injection system 1 performs pressure adjustment for the pilot injection and the pre-injection from the time t141 to the time t148 prior to the main injection. Afterward, the pilot injection and the pre-injection are performed in turn from the time t150 to the time t157.

[0186] Further, in a 157th time slot that is a time slot from the time t157 to the time t170, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 is reduced from the pressure P104 to the pressure P103 in the aforementioned 156th time slot. For these reasons, the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P103 in the 157th time slot.

[0187] In the example illustrated in FIG. 17, the fuel injection system 1 realizes main injection in a time slot from the time t170 to the time t179. For example, in a 170th time slot that is a time slot from the time t170 to the time t171, the fuel injection system 1 realizes a second state by performing pressure reduction control. For this reason, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 170th time slot while reducing the pressure inside the second pressure accumulating unit 122 from the pressure P103 to the pressure P21 corresponding to a length of the 170th time slot. As a result, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the pressure P103 at the time t170 in the 170th time slot, and is reduced from the pressure P103 to the pressure P21 in the 170th time slot. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the pressure P103 to the pressure P21, namely the length of the 170th time slot, can be calculated on the basis of the pressure P103, the pressure P21, and Formula (1) described above.

[0188] Next, the fuel injection system 1 performs the aforementioned deltaic main injection illustrated in FIG. 7 in a time slot from the time t171 to the time t179. Detailed description thereof refers to FIG. 7, and the times t31 to t39 of FIG. 7 are replaced with the times t171 to t179.

[0189] A broken line denoted by a range from the time t170 to the time t179 on the graph CH134 models a pressure based on a deltaic pattern. In actual control, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is reduced in a time slot from the time t178 to the time t179 like a solid line. For example, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the time slot from the time t178 to the time t179 while reducing the pressure inside the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P103 corresponding to a length of the time slot from the time t178 to the time t179. As a result, the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 is the prescribed pressure P0 at the time t178 in the time slot from the time t178 to the time t179, and is reduced from the prescribed pressure P0 to the pressure P103 in the time slot from the time t178 to the time t179. A time required to reduce the pressure inside the second pressure accumulating unit 122 from the prescribed pressure P0 to the pressure P103, namely the length of the time slot from the time t178 to the time t179, can be calculated on the basis of the prescribed pressure P0, the pressure P103, and Formula (1) described above.

[0190] According to the control method represented by the timing diagram illustrated in FIG. 17, the fuel injection system 1 can adjust the pressure inside the second pressure accumulating unit 122 during the pilot injection and the pre-injection, and realize control of making good use of a unique characteristic of a deltaic pattern in the main injection.

[0191] FIG. 18 is a timing diagram for illustrating Embodiment 14 of the control method of the fuel injection system 1. Embodiment 14 of the control method is a control method in which multi-stage injections, for example, pilot injection, pre-injection, and main injection are performed on the fuel injection system 1 by combining some or all of the control methods described above. The control method may be carried out by appropriately adding after-injection without limiting performing of the after-injection. The timing diagram illustrated in FIG. 18 includes four graphs from a graph CH141 to a graph CH144. The horizontal axis of each of the graphs CH141 to CH144 indicates time. Further, the vertical axis of the graph CH141 indicates the state of the valve A1V. Further, the vertical axis of the graph CH142 indicates a pressure inside the second pressure accumulating unit 122. Further, the vertical axis of the graph CH143 indicates the state of the valve A2V. Further, the vertical axis of the graph CH144 indicates a pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122. Further, times t188 to t193 on the graphs CH141 to CH144 are as follows. Each of the time t188 and the time t191 on the graphs CH141 to CH144 indicates a time when the drive current is supplied from the first valve drive circuit 33 to the drive unit A1 and the first valve 21 is opened. Further, each of the time t190 and the time t193 on the graphs CH141 to CH144 indicates a time when the supply of the drive current from the first valve drive circuit 33 to the drive unit A1 is stopped and the first valve 21 is closed. Further, the time t189 on the graphs CH141 to CH144 indicates a time when the drive current is supplied from the second valve drive circuit 34 to the drive unit A2 and the second valve 22 is opened. Further, the time t192 on the graphs CH141 to CH144 indicates a time when the supply of the drive current from the second valve drive circuit 34 to the drive unit A2 is stopped and the second valve 22 is closed. Here, the time t188 is a time before the time t189, the time t189 is a time before the time t190, the time t190 is a time before the time t191, the time t191 is a time before the time t192, and the time t192 is a time before the time t193. Further, each of a pressure P101, a pressure P103, a pressure P104, a pressure P105, and a pressure P108 on the graphs CH142 to CH144 is a pressure that is higher than zero (0) and is lower than a prescribed pressure P0, and a pressure P107 is higher than the prescribed pressure P0. Further, the pressure P101 is lower than the pressure P108, the pressure P108 is lower than the pressure P103, the pressure P103 is lower than the pressure P104, and the pressure P104 is lower than the pressure P105.

[0192] Description from the time t141 to the time t157 on the graphs CH141 to CH144 refers to the description of Embodiment 11 illustrated in FIG. 15. A case where the pressure inside the second pressure accumulating unit 122 is the pressure P103 at the time t141 is given as an example. The pressure inside the second pressure accumulating unit 122 at the time t141 varies sometimes depending on the state of the previous fuel injection cycle. A main difference from Embodiment 11 illustrated in FIG. 15 is a method of adjusting a pressure of the second pressure accumulating unit 122 during the main injection. Embodiment 11 illustrated in FIG. 15 is a case of inverted deltaic main injection, but the present embodiment is a case of V-shaped main injection. Hereinafter, the pressure adjustment performed after the time t188 will be described.

[0193] The fuel injection system 1 performs pressure adjustment for the pilot injection and the pre-injection from the time t141 to the time t148 prior to the main injection. Afterward, the pilot injection and the pre-injection are performed in turn from the time t150 to the time t157.

[0194] Next, in a 157th time slot that is a time slot from the time t157 to the time t188, the fuel injection system 1 closes both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 is reduced from the pressure P104 to the pressure P103 in the aforementioned 155th time slot. For these reasons, the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P103 in the 157th time slot.

[0195] In the example illustrated in FIG. 18, in a time slot that is a time slot from the time t188 to the time t193, the fuel injection system 1 realizes main injection. For example in the 188th time slot from the time t188 to the time t189, the fuel injection system 1 realizes a first state. In the 188th time slot, the pressure inside the second pressure accumulating unit 122 is raised depending on an elapsed time that is a time elapsed from the time t188. For example, the pressure inside the second pressure accumulating unit 122 is raised from the pressure P103 to the pressure P107 due to a pressure boosting effect associated with movement of fuel. Like the length of the 11th time slot, a length of the 188th time slot is determined by a user.

[0196] Next, in a 189th time slot that is a time slot from the time t189 to the time t190, the fuel injection system 1 opens both the first valve 21 and the second valve 22. Further, the pressure inside the second pressure accumulating unit 122 is reduced to the pressure P107 in the previous 188th time slot. For these reasons, the pressure inside the second pressure accumulating unit 122 is still kept at the pressure P107 in the 189th time slot without being raised. The 189th time slot may be omitted.

[0197] Next, in a 190th time slot that is a time slot from the time t190 to the time t191, the fuel injection system 1 realizes a second state by performing pressure reduction control. Since the pressure inside the second pressure accumulating unit 122 is the pressure P107 at the time t190, the fuel injection system 1 injects fuel into the combustion chamber CC from the second pressure accumulating unit 122 in the 190th time slot while at least reducing the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC from the second pressure accumulating unit 122 from the pressure P107 to the pressure P108 corresponding to a length of the 190th time slot. A time required to at least reduce the pressure inside the second pressure accumulating unit 122 from the pressure P107 to the pressure P108, namely the length of the 190th time slot, can be calculated on the basis of the pressure P107, the pressure P108, and Formula (1) described above.

[0198] Next, in a 191st time slot that is a time slot from the time t191 to the time t192, the fuel injection system 1 realizes the aforementioned third state by performing pressure boost control. In the 191st time slot, the pressure inside the second pressure accumulating unit 122 is raised to the prescribed pressure P0. Since the first valve 21 is still open even in the 191st time slot, the fuel injection system 1 gradually raises the pressure of the fuel injected into the combustion chamber CC from the second pressure accumulating unit 122 to become the pressure inside the second pressure accumulating unit 122, and injects fuel into the combustion chamber CC from the second pressure accumulating unit 122. The case illustrated in FIG. 18 is an example in which the pressure inside the second pressure accumulating unit 122 reaches the prescribed pressure P0 prior to reaching the time t192. Since the fuel injection system 1 closes the second valve 22 at the time t192, the injection of the fuel into the combustion chamber CC from the second pressure accumulating unit 122 is stopped, and the pressure of the fuel into the combustion chamber CC from the second pressure accumulating unit 122 becomes zero (0) in a time slot after the time t192. On the other hand, since the fuel injection system 1 still opens the first valve 21 in this time slot, the pressure inside the second pressure accumulating unit 122 is still kept at the prescribed pressure P0. The pressure inside the second pressure accumulating unit 122 is adjusted to a suitable pressure until the pilot injection is initiated in the next combustion cycle.

[0199] According to the control method represented by the timing diagram illustrated in FIG. 18, the fuel injection system 1 can adjust the pressure inside the second pressure accumulating unit 122 during the pilot injection and the pre-injection, and realize control of making good use of a unique characteristic of a V-shaped pattern in the main injection. In the case of the V-shaped pattern, like the aforementioned concave pattern, the fuel injection system 1 can perform agitation and combustion of the fuel in the combustion chamber CC in a latter period subsequent to a former period in the period in which the fuel injection system 1 injects the fuel into the combustion chamber CC. As a result, the fuel injection system 1 can reduce an amount of emissions generated from the internal combustion engine EG.

[0200] Here, according to the various control methods described above, the fuel injection system 1 injects fuel into the combustion chamber CC of the internal combustion engine EG. This fuel injection system 1 can change a pressure at which fuel supplied from the high-pressure source 4 at the prescribed pressure P0 is injected into the combustion chamber CC to a pressure that is lower than or equal to the prescribed pressure corresponding to each of at least three or more stages. For example, the controller 36 of the fuel injection system 1 divides the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC into a plurality of stages such that they are different from one another, and injects fuel from the fuel injector 2 under pressures corresponding to the stages. The controller 36 sets the plurality of stages to, for example, three or more, so that it can form an injection pattern in which an injection amount or the like varies depending on the elapse of time from a starting point of time of single main injection, for example, like an initial stage of injection, a middle stage within an injection period, a last stage of the injection period, and so on. Thus, the fuel injection system 1 can change the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber into a pressure desired by a user while suppressing an increase in fuel consumption rate.

[0201] The fuel injection system 1 enables a pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC to coincide with a pattern that is another arbitrary pattern and is desired by a user.

[0202] For example, the fuel injection system 1 may select a desired injection pattern as illustrated in FIG. 19, and control the fuel injector 2. FIG. 19 is a flow chart illustrating a procedure of selecting injection patterns of the embodiments.

[0203] Prior to the following processes, basic data for generating various injection patterns that can be applied to the fuel injection system 1 is stored in the storage unit 32. The controller 36 reads the basic data corresponding to the injection pattern out of the storage unit 32, and controls the fuel injector 2 according to the basic data. For example, selection of the injection pattern is based on the following procedure.

[0204] First, the controller 36 acquires identification information of an injection pattern to be selected (step S11). For example, the controller 36 may settle identification information of an injection pattern to be selected according to a prescribed rule on the basis of data relating to an operation of an accelerator (not shown) by a user or a rotational speed of the internal combustion engine EG, and acquire the identification information.

[0205] Next, the controller 36 determines the acquired identification information (step S12). According to a result of the determination of step S12, the controller 36 performs processes corresponding to the following cases.

[0206] For example, in a case where the identification information corresponds to a deltaic pattern, the controller 36 reads basic data corresponding to the deltaic pattern out of the storage unit 32 (step S13). Further, in a case where the identification information corresponds to an inverted deltaic pattern, the controller 36 reads basic data corresponding to the inverted deltaic pattern out of the storage unit 32 (step S14). Further, in a case where the identification information corresponds to an L-shaped pattern, the controller 36 reads basic data corresponding to the L-shaped pattern out of the storage unit 32 (step S15). Further, in a case where the identification information corresponds to an inverted L-shaped pattern, the controller 36 reads basic data corresponding to the inverted L-shaped pattern out of the storage unit 32 (step S16). Further, in a case where the identification information corresponds to a concave pattern, the controller 36 reads basic data corresponding to the concave pattern out of the storage unit 32 (step S17). Further, in a case where the identification information corresponds to a convex pattern, the controller 36 reads basic data corresponding to the convex pattern out of the storage unit 32 (step S18). Further, in a case where the identification information corresponds to a rectangular pattern, the controller 36 reads basic data corresponding to the rectangular pattern out of the storage unit 32 (step S19). Further, in a case where the identification information corresponds to a V-shaped pattern, the controller 36 reads basic data corresponding to the V-shaped pattern out of the storage unit 32 (step S20).

[0207] Next, the controller 36 controls a pressure of the first pressure accumulating unit 112 in the fuel injector 2 on the basis of the basic data read out of the storage unit 32 in any of steps S13 to S20 (step S21), and completes a series of processes illustrated in the figure. In a case where desired basic data is previously read out of the storage unit 32, using this is not limited.

[0208] According to this process, it is possible to select a desired injection pattern from candidates to be selected and to switch an injection pattern performed statically or dynamically. Instead of this, the fuel injection system 1 can also set the pattern of temporal change in the pressure of the fuel injected from the second pressure accumulating unit 122 to a pattern including at least one of the deltaic pattern, the inverted deltaic pattern, the L-shaped pattern, the inverted L-shaped pattern, the concave pattern, the convex pattern, the rectangular pattern, and the V-shaped pattern.

[0209] Each of the various patterns described in FIGS. 5 to 18 is merely an example of the pattern with which the fuel injection system 1 enables the pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC to coincide. Depending on the type of the pattern applied to the fuel injection system 1, selection conditions in FIG. 19 may be changed.

[0210] Further, the fuel injection system 1 changes a pressure of injected fuel by combining an open/closed state of the first valve 21 and an open/closed state of the second valve 22. On the other hand, a fuel injection system having the aforementioned pressure boosting mechanism (a fuel injection system that is different from the fuel injection system 1) changes a pressure of injected fuel by operating the pressure boosting mechanism. A response time until a pressure of the fuel injected from the fuel injection system 1 is changed after the fuel injection system 1 changes a drive current supplied to each of the first valve 21 and the second valve 22 is shorter than that until a pressure of the fuel injected from the different fuel injection system is changed after the different fuel injection system operates the pressure boosting mechanism. Due to this difference in the response time, the different fuel injection system may be difficult to cause the pattern of temporal change in the pressure of the fuel which the different fuel injection system injects into the combustion chamber CC to coincide with a pattern that is another arbitrary pattern and is desired by a user. For example, the different fuel injection system does not enable the pattern of temporal change in the pressure of the fuel which the different fuel injection system injects to coincide with a pattern, such as a concave pattern, a convex pattern, a V-shaped pattern, or the like, that causes a repetitive change in pressure for a short time within a period of single main injection. In contrast, as described above, the fuel injection system 1 enables the pattern of temporal change in the pressure of the fuel which the fuel injection system 1 injects into the combustion chamber CC to coincide with a pattern that is another arbitrary pattern and is desired by a user. This is important in connection with improving a degree of freedom of design of the internal combustion engine EG.

[0211] Further, each of the times described in FIGS. 5 to 18 indicates a timing at which the fuel injection system 1 switches each of the first valve 21 and the second valve 22 to any of the open state and the closed state. The ECU 3 puts each of the first valve 21 and the second valve 22 in any of the open state and the closed state depending on a timing prestored in the storage unit 32. Since a user prestores a timing desired by the user in the storage unit 32, the user performs switching (opening/closing) of the state of each of the first valve 21 and the second valve 22 on the fuel injection system 1 at a timing desired by the user. Data relating to the timing is included in the basic data of the various injection patterns. Here, in each of FIGS. 5 to 18, for convenience of description, the timing at which the fuel injection system 1 opens/closes each of the first valve 21 and the second valve 22 has been described to be represented by the time. However, the timing prestored in the storage unit 32 may be represented by an elapsed time from a reference time instead of the time, by another known method, or by a method developed from this known method.

[0212] As described above, the fuel injection system 1 according to the embodiment is a fuel injection system that injects fuel into a combustion chamber (an example of which is a combustion chamber CC) of an internal combustion engine (an example of which is an internal combustion engine EG), and includes: a pressure accumulating unit (an example of which is a second pressure accumulating unit 122) to which the fuel is supplied from a high-pressure source (an example of which is a high-pressure source 4) that supplies the fuel at a prescribed pressure (an example of which is a prescribed pressure P0); a first valve (an example of which is a first valve 21) that supplies the fuel, which is supplied from the high-pressure source, into the pressure accumulating unit; and a second valve (an example of which is a second valve 22) that injects the fuel, which is supplied to the pressure accumulating unit, into the combustion chamber from the pressure accumulating unit. Thus, the fuel injection system 1 can change a pressure of the fuel injected into the combustion chamber into a pressure desired by a user while suppressing an increase in fuel consumption rate.

[0213] Further, the fuel injection system 1 further includes: a first drive unit (an example of which is a drive unit A1) that at least puts a state of the first valve in any of an open state and a closed state; a second drive unit (an example of which is a drive unit A2) that at least puts a state of the second valve in any of an open state and a closed state; and a controller (an example of which is a controller 36) that controls the first drive unit and the second drive unit. Thus, the fuel injection system 1 can change a pressure of the fuel injected into the combustion chamber into a pressure desired by a user under control by the controller while suppressing an increase in fuel consumption rate.

[0214] Further, the fuel injection system 1 opens the second valve in a state where the first valve is closed, and performs control including pressure reduction control of a pressure of the pressure accumulating unit. Thus, the fuel injection system 1 can reduce a pressure of the fuel injected into the combustion chamber to a pressure desired by a user.

[0215] Further, in the fuel injection system 1, an amount of change of the pressure per unit time inside the pressure accumulating unit under the pressure reduction control is inversely proportional to a volume of the pressure accumulating unit, and is proportional to an amount of the fuel injected from the pressure accumulating unit. Thus, the fuel injection system 1 can reduce a pressure of the fuel injected into the combustion chamber to a pressure desired by a user at a speed corresponding to the volume of the pressure accumulating unit and the amount of the fuel injected from the pressure accumulating unit.

[0216] Further, the fuel injection system 1 performs control including pressure boost control that opens the first valve in a state where the second valve is open. Thus, the fuel injection system 1 can raise a pressure of the fuel injected into the combustion chamber to a pressure which a user desires up to a prescribed pressure at the maximum and which is a pressure reduced by the injection of the fuel into the combustion chamber.

[0217] Further, the fuel injection system 1 can set a pattern of temporal change in pressure of the fuel injected from the pressure accumulating unit to at least one of a deltaic pattern, an inverted deltaic pattern, an L-shaped pattern, an inverted L-shaped pattern, a concave pattern, a convex pattern, a rectangular pattern, and a V-shaped pattern. Thus, the fuel injection system 1 can set the pattern of temporal change in the pressure of the fuel injected from the pressure accumulating unit to a pattern desired by a user.

[0218] Further, the fuel injection system 1 is a fuel injection system that injects fuel into a combustion chamber of an internal combustion engine, and includes: an injection part (an example of which is a second opening 125) that injects the fuel into the combustion chamber; a high-pressure source that supplies the fuel to the injection part at a prescribed pressure; and a pressure reducing unit (an example of which is a second pressure accumulating unit 122) that reduces a pressure of the fuel provided between the injection part and the high-pressure source. Thus, the fuel injection system 1 can change a pressure of the fuel injected into the combustion chamber into a pressure desired by a user under control by the controller while suppressing an increase in fuel consumption rate. As described above, the second pressure accumulating unit 122 is an example of the pressure reducing unit. When movement of the fuel between the second pressure accumulating unit 122 and the high-pressure source 4 is at least selectively interrupted, the second pressure accumulating unit 122 reduces a pressure of the fuel during fuel injection. The fuel injection system 1 may select a state where the movement of the fuel is less than or equal to a prescribed amount and limits a flow rate of the fuel instead of the interruption. The second pressure accumulating unit 122 may form the pressure reducing unit by a combination with a controller 36.

[0219] Further, the fuel injection system 1 is a fuel injection system that injects fuel into a combustion chamber of an internal combustion engine, and can change a pressure at which the fuel supplied from a high-pressure source at a prescribed pressure is injected into a combustion chamber to a pressure that is lower than or equal to a prescribed pressure corresponding to each of at least three or more stages. Thus, the fuel injection system 1 can set a pattern of temporal change in the pressure of the fuel injected from the pressure accumulating unit to a pattern desired by a user.

[0220] While the embodiments of this invention have been described in detail with reference to the drawings, the specific constitution is not limited to the embodiments, and also includes modifications, substitutions, eliminations, etc. thereof without departing from the gist of the present invention.

[0221] Further, a program for realizing a function of an arbitrary component in the device (e.g., the ECU 3) described above may be recorded on a computer readable recording medium, and be read and executed in a computer system. The "computer system" used therein includes an operating system (OS) and hardware such as peripheral devices. Further, the "computer readable recording medium" refers to a portable medium suc has a flexible disk, a magneto-optical disk, a ROM, or a compact disk (CD)-ROM, or a storage device such as a hard disk installed in the computer system. Furthermore, the "computer readable recording medium" also includes a medium that holds a program for a fixed time like a volatile memory (RAM) in the computer system serving as a server or a client when a program is sent via a network such as Internet and a communication link such as a telephone line.

[0222] Further, the program may be transmitted from a computer system in which this program is stored in a storage device or the like to another computer system via a transmission medium or by transmission waves in the transmission medium. Here, the "transmission medium" for transmitting the program refers to a medium that has a function of transmitting information like a network (a communication network) such as Internet or a communication link (a communication line) such as a telephone line.

[0223] Further, the program may be a program for realizing a part of the aforementioned function. Furthermore, the program may be a so-called differential file (a differential program) that can be realized by combining the aforementioned function with a program that previously recorded in a computer system.

[Reference Signs List]

[0224]

1	Fuel injection system
2	Fuel injector
11	Electric injector
12	Electric injector
21	First valve
22	Second valve
31	CPU
32	Storage unit
33	First valve drive circuit
34	Second valve drive circuit
36	Controller
111	Fuel supply pipeline
112	First pressure accumulating unit
113	Nozzle needle
114A, 114B	Tip portion
115	First opening
121	Fuel supply pipeline

122	Second pressure accumulating unit
123	Nozzle needle
124A, 124B	Tip portion
125	Second opening
A1	Drive unit
A2	Drive unit
Bus	Bus
CC	Combustion chamber
CR	Injection part
EG	Internal combustion engine
PR1	High-pressure source
PR2	Pressure accumulating unit
V1	First valve
V2	Second valve
A1V, A2V	Valve

Claims

1. A fuel injection system that injects fuel into a combustion chamber of an internal combustion engine, the fuel injection system comprising:

a pressure accumulating unit to which the fuel is supplied from a high-pressure source that supplies the fuel at a prescribed pressure;
a first valve configured to supply the fuel, which has been supplied from the high-pressure source, into the pressure accumulating unit; and
a second valve configured to inject the fuel, which has been supplied to the pressure accumulating unit, into the combustion chamber from the pressure accumulating unit.

2. The fuel injection system according to claim 1, further comprising:

a first drive unit configured to at least put a state of the first valve into any of an open state and a closed state;
a second drive unit configured to at least put a state of the second valve into any of an open state and a closed state; and
a controller configured to control the first drive unit and the second drive unit.

3. The fuel injection system according to claim 2, wherein the controller opens the second valve in a state where the first valve is closed, and performs control including pressure reduction control of a pressure of the pressure accumulating unit.

4. The fuel injection system according to claim 3, wherein an amount of change in pressure per unit time inside the pressure accumulating unit under the pressure reduction control is inversely proportional to a volume of the pressure accumulating unit, and is proportional to an amount of the fuel injected from the pressure accumulating unit.

5. The fuel injection system according to any one of claims 2 to 4, wherein the controller performs control including pressure boosting control that opens the first valve in a state where the second valve is open.

6. The fuel injection system according to any one of claims 2 to 5, wherein the controller enables a pattern of temporal change in pressure of the fuel injected from the pressure accumulating unit to be set to at least one of a deltaic pattern, an inverted deltaic pattern, an L-shaped pattern, an inverted L-shaped pattern, a concave pattern, a convex pattern, a rectangular pattern, and a V-shaped pattern.

7. The fuel injection system according to claim 1, wherein, due to a dynamic effect in the pressure of the fuel generated when, by moving the fuel pressurized at the prescribed pressure from the high-pressure source to the pressure accumulating unit via a pipeline by controlling a state of the first valve, the fuel moves in a pipeline, a pressure of the fuel in the pressure accumulating unit is made higher than the prescribed pressure, and the second valve injects the fuel having a higher pressure than the prescribed pressure into the combustion chamber.

8. The fuel injection system according to claim 1, wherein the first valve, the pressure accumulating unit, and the second valve are consecutively provided between the high-pressure source and an injection part that injects the fuel into the combustion chamber in the order of the first valve, the pressure accumulating unit, and the second valve from the high-pressure source, and at least the first valve selectively limits movement of the fuel from the high-pressure source toward the pressure accumulating unit, and reduces a pressure of the fuel injected into the combustion chamber.

9. The fuel injection system according to claim 8, wherein:

each of the first valve and the second valve switches a state thereof to any of an open state and a closed state under control of a controller, and reduces a pressure of the fuel accumulated on the pressure accumulating unit to a pressure determined by the prescribed pressure and the method of switching the state thereof; and
the second valve injects the fuel into the combustion chamber at the determined pressure in a state where the second valve is open.

10. A fuel injection system that injects fuel into a combustion chamber of an internal combustion engine, the fuel injection system comprising:

an injection part configured to inject the fuel into the combustion chamber;
a high-pressure source configured to supply the fuel to the injection part at a prescribed pressure; and
a pressure reducing unit configured to reduce a pressure of the fuel provided between the injection part and the high-pressure source.

11. The fuel injection system according to claim 10, wherein the pressure reducing unit is provided between the injection part and the high-pressure source, and reduces a pressure of the fuel when movement of the fuel between the pressure reducing unit and the high-pressure source is at least selectively interrupted.

12. The fuel injection system according to claim 10, wherein:

the pressure reducing unit includes at least a pressure accumulating unit; and
each of a first valve, which is at least provided on an upstream side with respect to the pressure accumulating unit, and a second valve, which is provided on a downstream side with respect to the pressure accumulating unit, switches a state thereof to an open state and a closed state under control of a controller, and reduces a pressure of the fuel in the pressure accumulating unit to a pressure determined by the prescribed pressure and the method of switching the state thereof.

13. A fuel injection system that injects fuel into a combustion chamber of an internal combustion engine, the fuel injection system configured to allow a pressure, at which the fuel supplied from a high-pressure source at a prescribed pressure is injected into a combustion chamber, to be changed to a pressure that is equal to or lower than a prescribed pressure corresponding to each of at least three or more stages.

FIG. 1

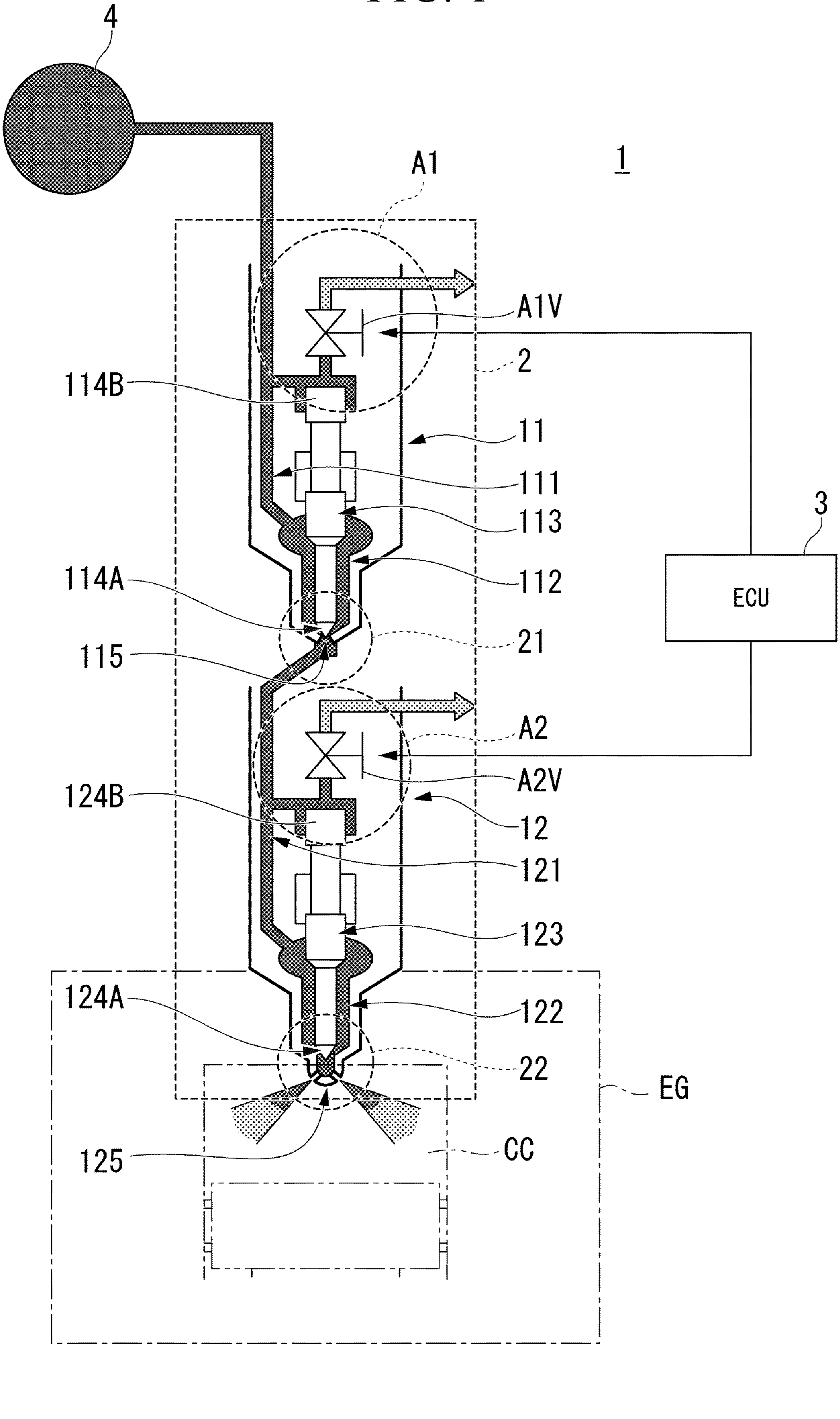

4
A1
1
A1V
2
114B
11
111
113
3
112
ECU
114A
21
115
A2
A2V
124B
12
121
123
124A
122
22
EG
125
CC

FIG. 2

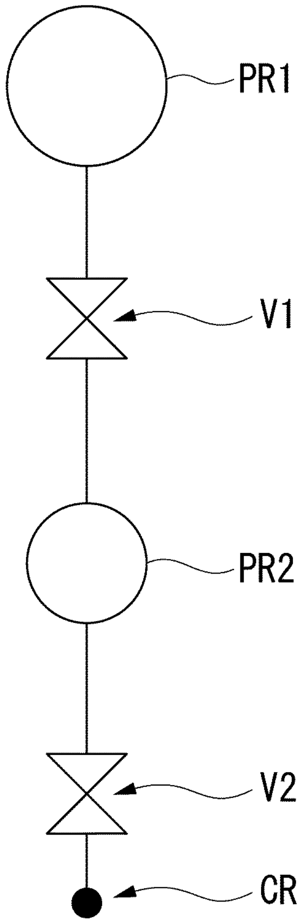

PR1
V1
PR2
V2
CR

FIG. 3

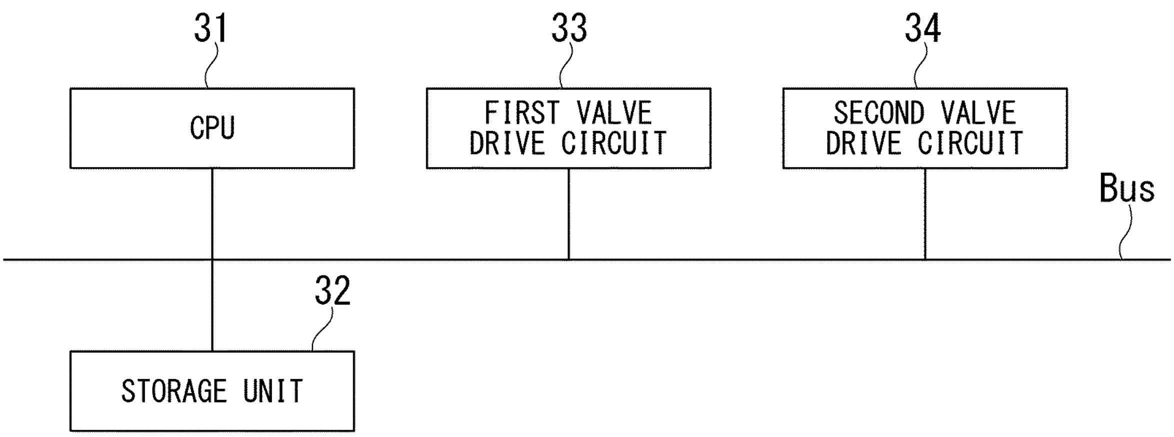
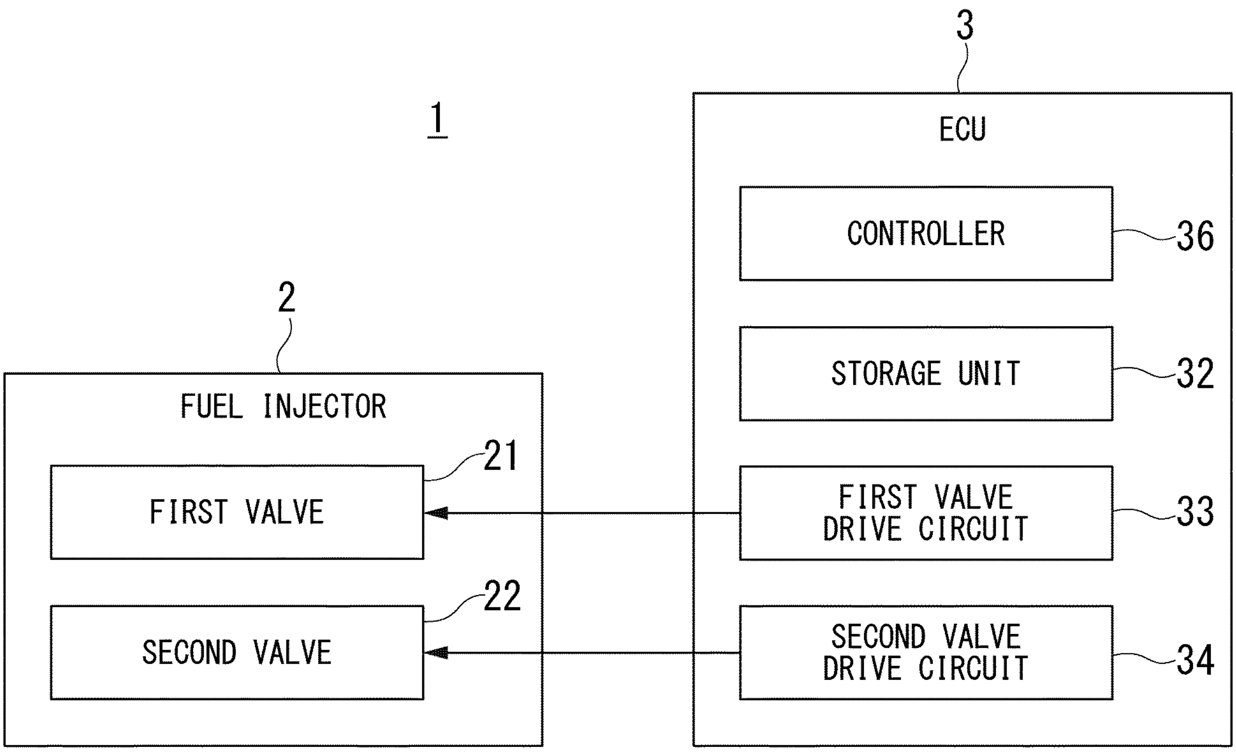
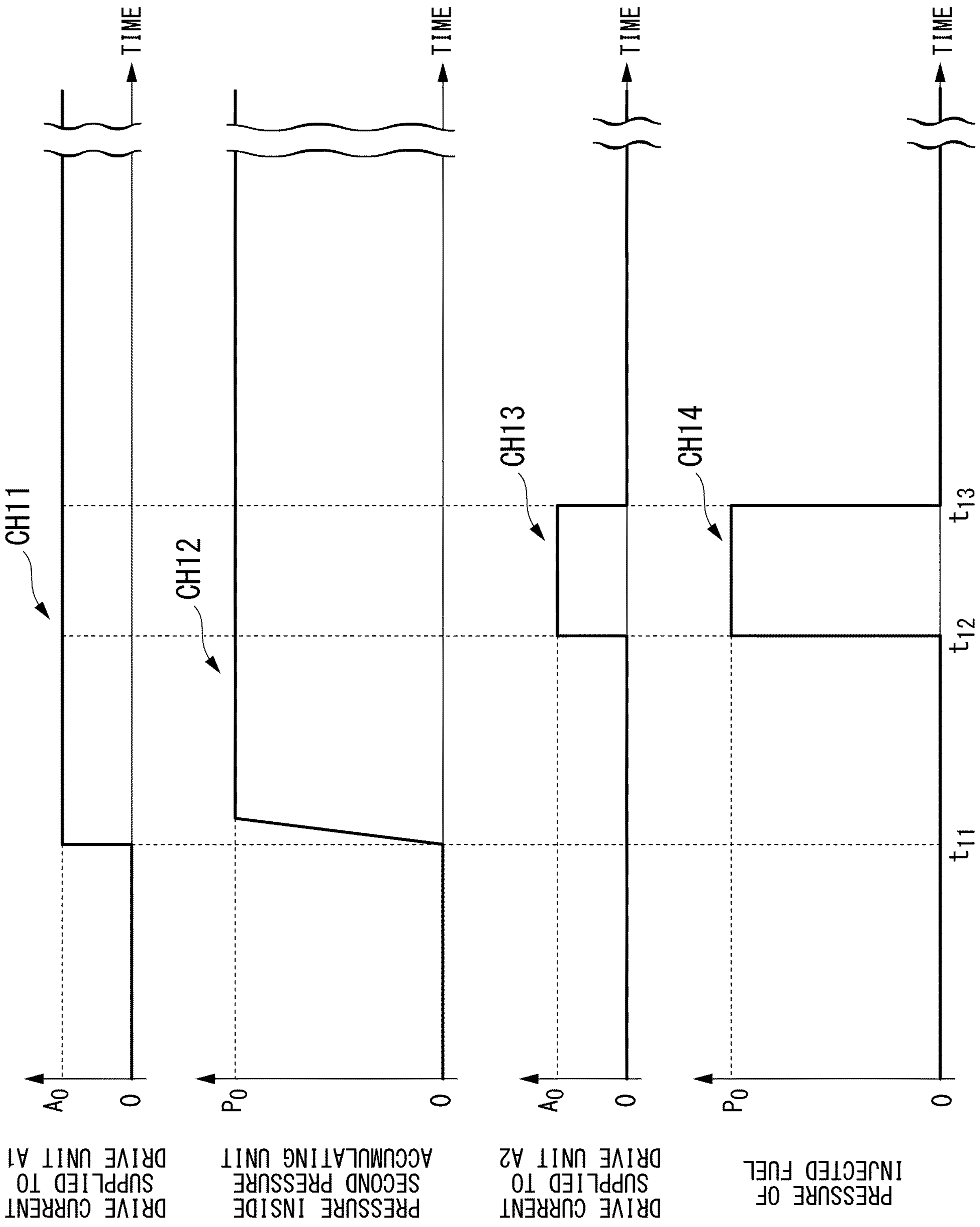

31
CPU
33
FIRST VALVE DRIVE CIRCUIT
34
SECOND VALVE DRIVE CIRCUIT
Bus
32
STORAGE UNIT

FIG. 4


3
1
ECU
CONTROLLER
36
2
STORAGE UNIT
32
FUEL INJECTOR
21
FIRST VALVE
FIRST VALVE
DRIVE CIRCUIT
33
22
SECOND VALVE
SECOND VALVE
DRIVE CIRCUIT
34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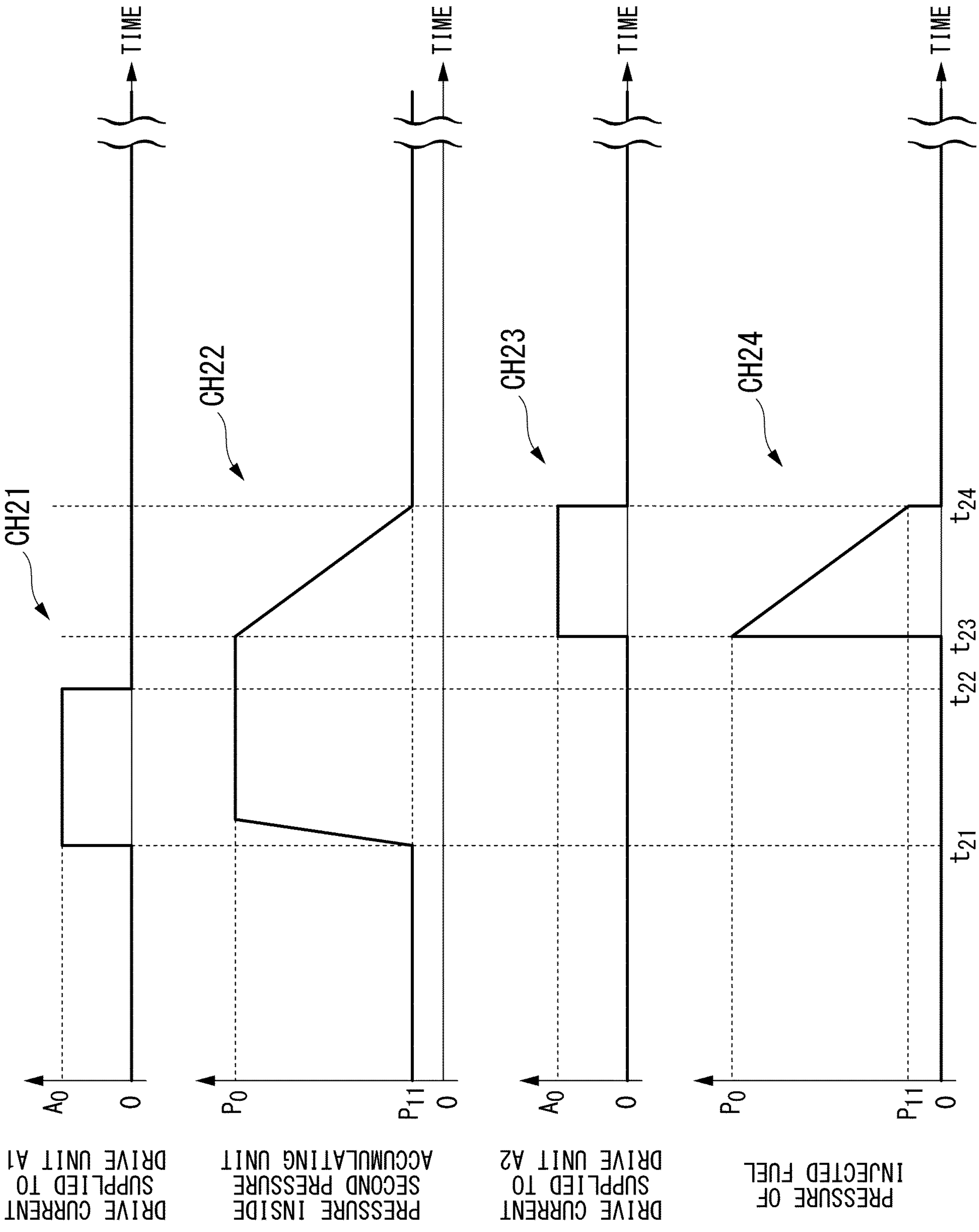
PRESSURE INSIDE SECOND PRESSURE ACCUMULATING UNIT
DRIVE CURRENT SUPPLIED TO DRIVE UNIT A2
PRESSURE OF INJECTED FUEL
A0
P0
0
CH11
CH12
CH13
CH14
t11
t12
t13
TIME

FIG. 5

FIG. 6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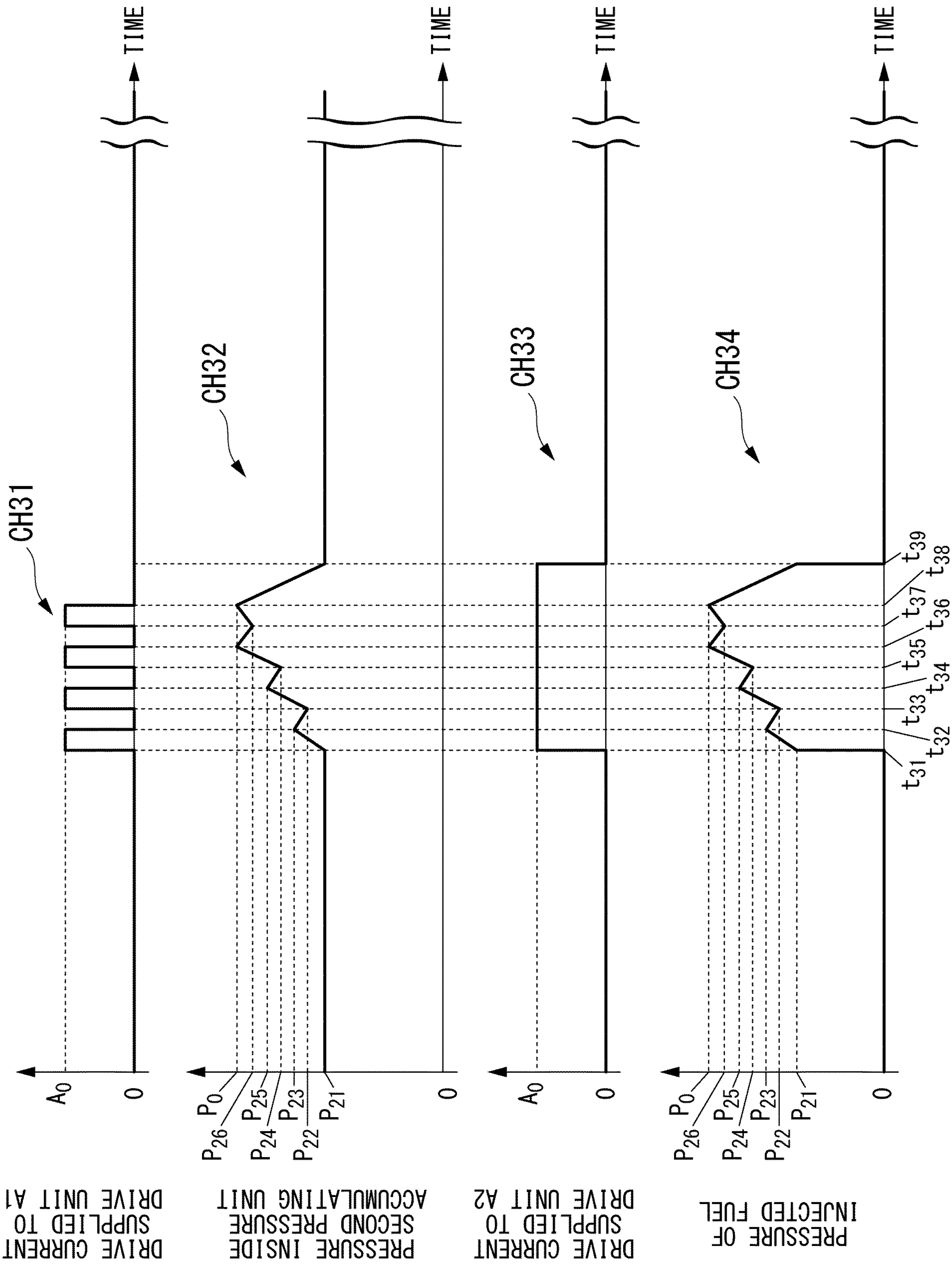
PRESSURE INSIDE SECOND PRESSURE ACCUMULATING UNIT
DRIVE CURRENT SUPPLIED TO DRIVE UNIT A2
PRESSURE OF INJECTED FUEL
A0
0
P0
P11
CH21
CH22
CH23
CH24
TIME
t21
t22
t23
t24

FIG. 7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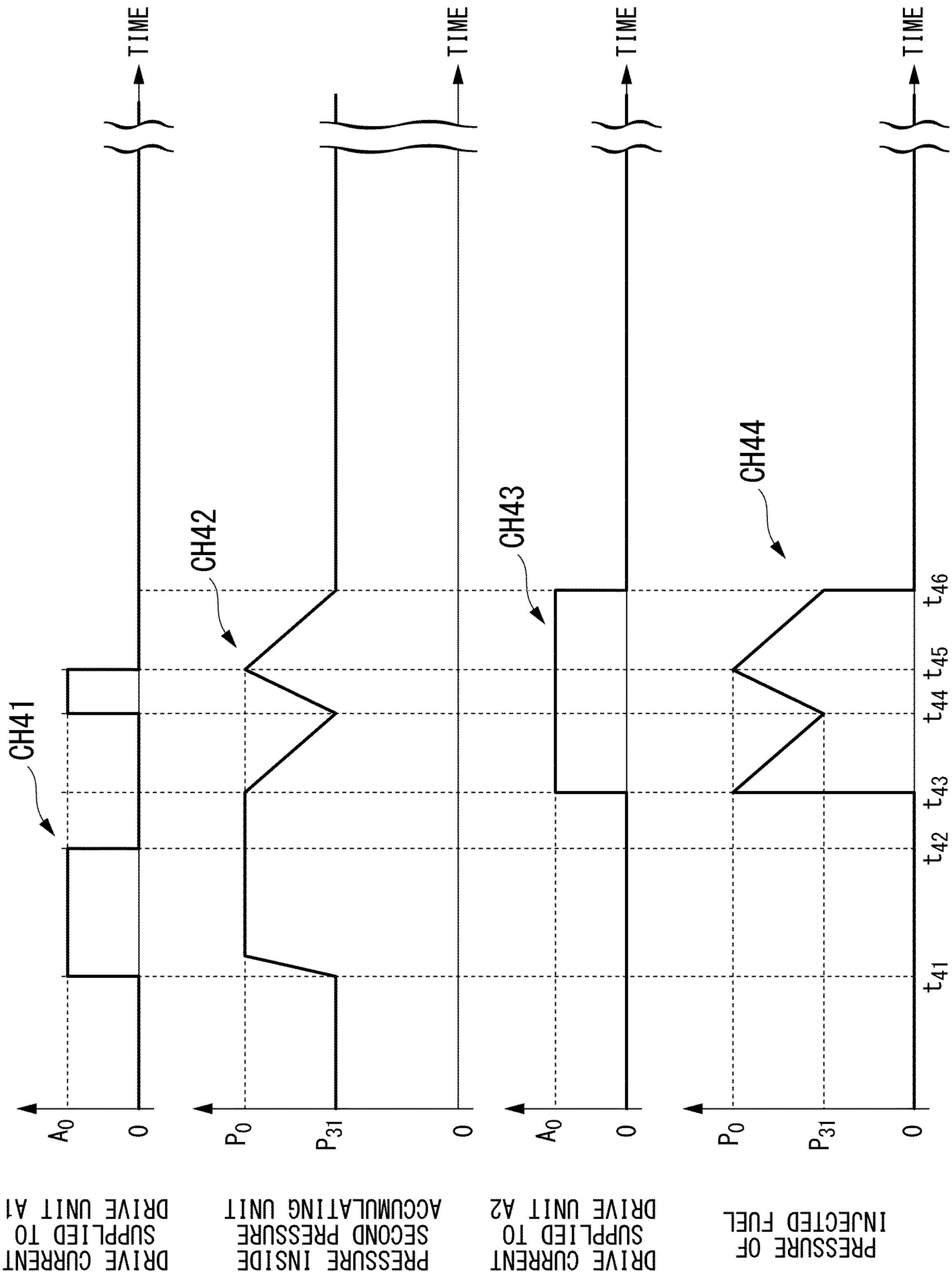
PRESSURE INSIDE SECOND PRESSURE ACCUMULATING UNIT
DRIVE CURRENT SUPPLIED TO DRIVE UNIT A2
PRESSURE OF INJECTED FUEL
CH31
CH32
CH33
CH34
TIME
A0
0
P0
P21
P22
P23
P24
P25
P26
t31
t32
t33
t34
t35
t36
t37
t38
t39

FIG. 8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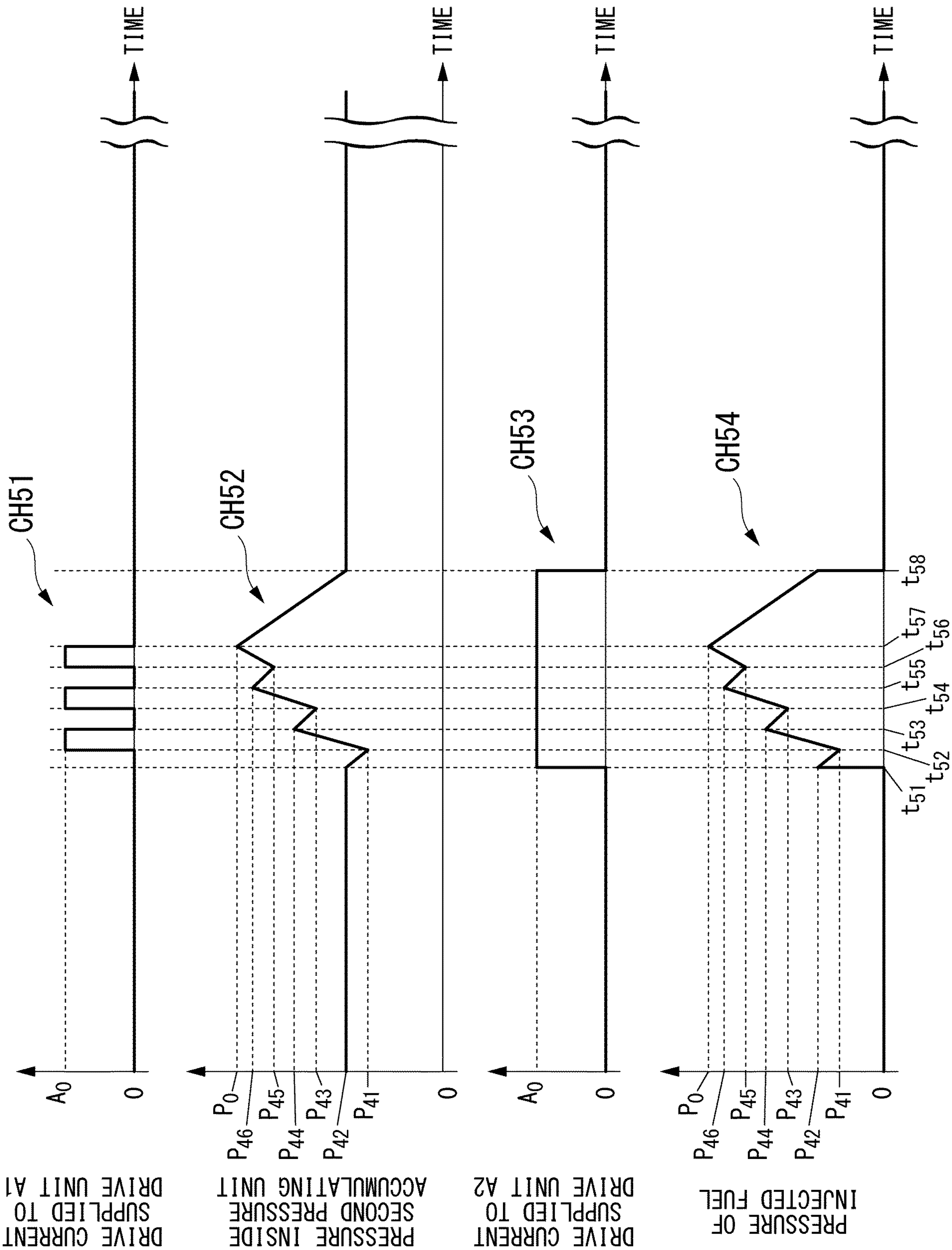
PRESSURE INSIDE SECOND PRESSURE ACCUMULATING UNIT
DRIVE CURRENT SUPPLIED TO DRIVE UNIT A2
PRESSURE OF INJECTED FUEL
A0
0
P0
P31
CH41
CH42
CH43
CH44
t41
t42
t43
t44
t45
t46
TIME

FIG. 9


DRIVE CURRENT SUPPLIED TO DRIVE UNIT A1
PRESSURE INSIDE SECOND PRESSURE ACCUMULATING UNIT
DRIVE CURRENT SUPPLIED TO DRIVE UNIT A2
PRESSURE OF INJECTED FUEL
CH51
CH52
CH53
CH54
TIME
A0
0
P0
P46
P45
P44
P43
P42
P41
t51
t52
t53
t54
t55
t56
t57
t58

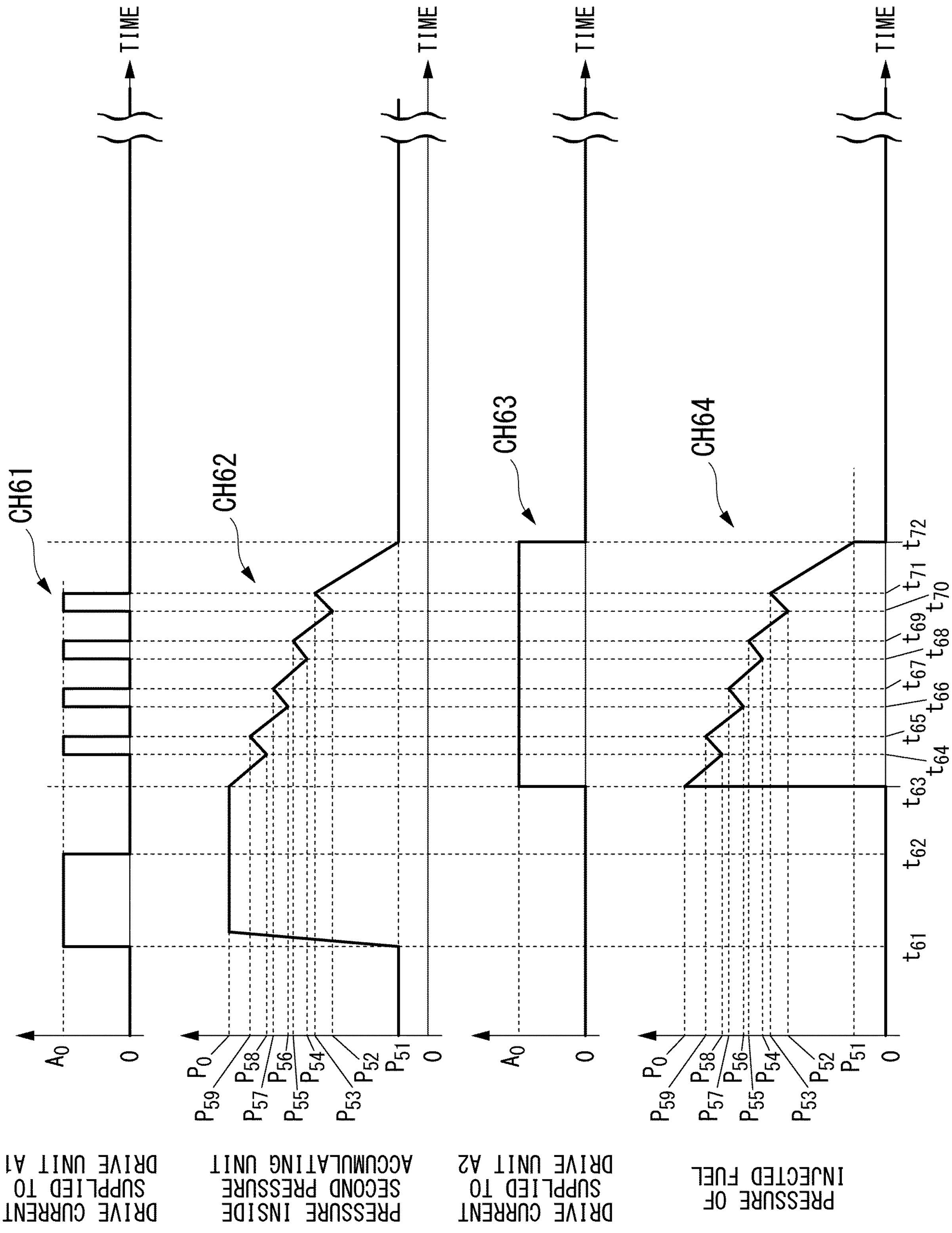
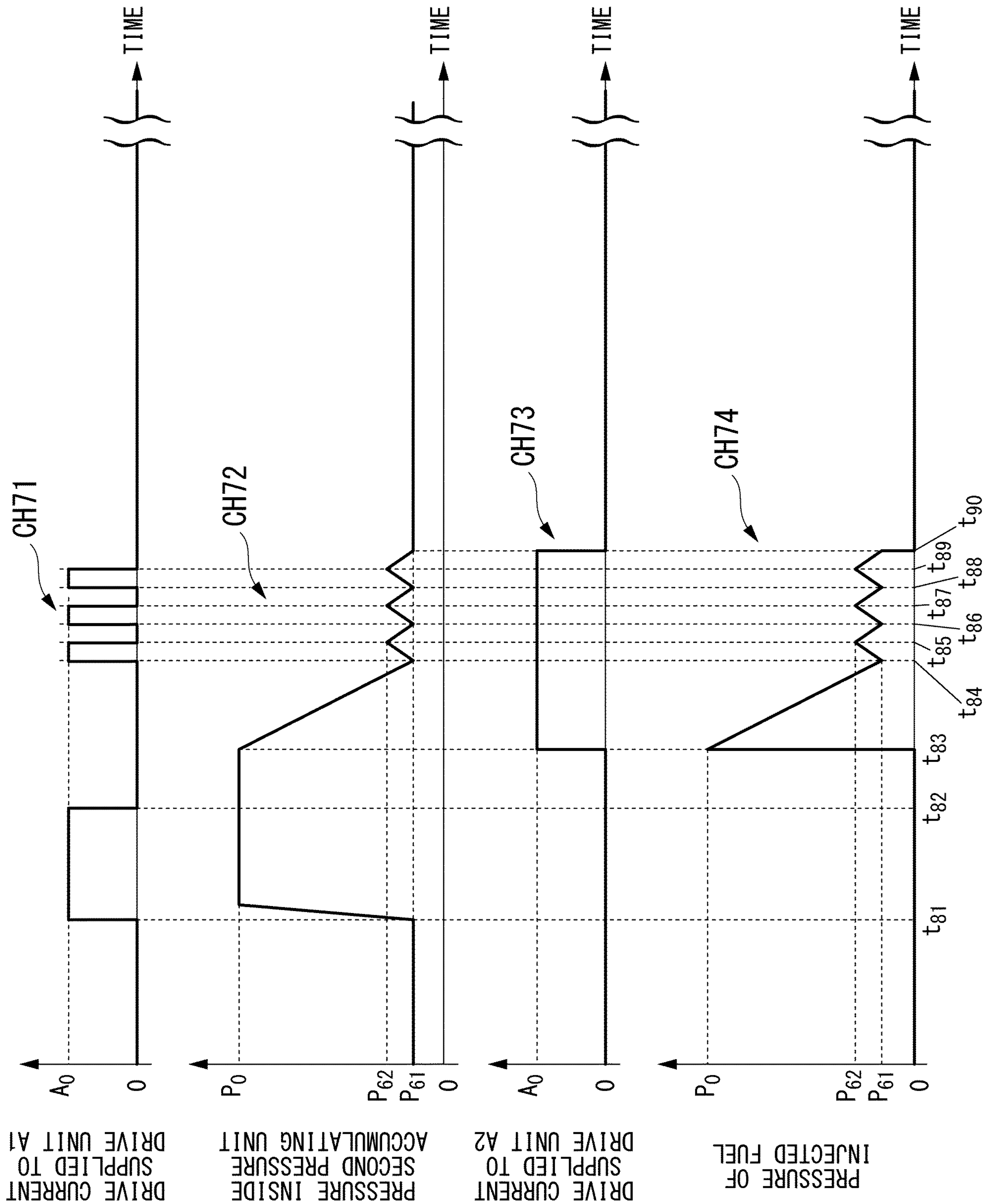

DRIVE CURRENT SUPPLIED TO DRIVE UNIT A1
PRESSURE INSIDE SECOND PRESSURE ACCUMULATING UNIT
DRIVE CURRENT SUPPLIED TO DRIVE UNIT A2
PRESSURE OF INJECTED FUEL
CH61
CH62
CH63
CH64
A0
0
P0
P59
P58
P57
P56
P55
P54
P53
P52
P51
TIME
t61
t62
t63
t64
t65
t66
t67
t68
t69
t70
t71
t72

FIG. 10

FIG. 11


DRIVE CURRENT SUPPLIED TO DRIVE UNIT A1
PRESSURE INSIDE SECOND PRESSURE ACCUMULATING UNIT
DRIVE CURRENT SUPPLIED TO DRIVE UNIT A2
PRESSURE OF INJECTED FUEL
A_0
0
P_0
P_{62}
P_{61}
TIME
CH71
CH72
CH73
CH74
t_{81}
t_{82}
t_{83}
t_{84}
t_{85}
t_{86}
t_{87}
t_{88}
t_{89}
t_{90}

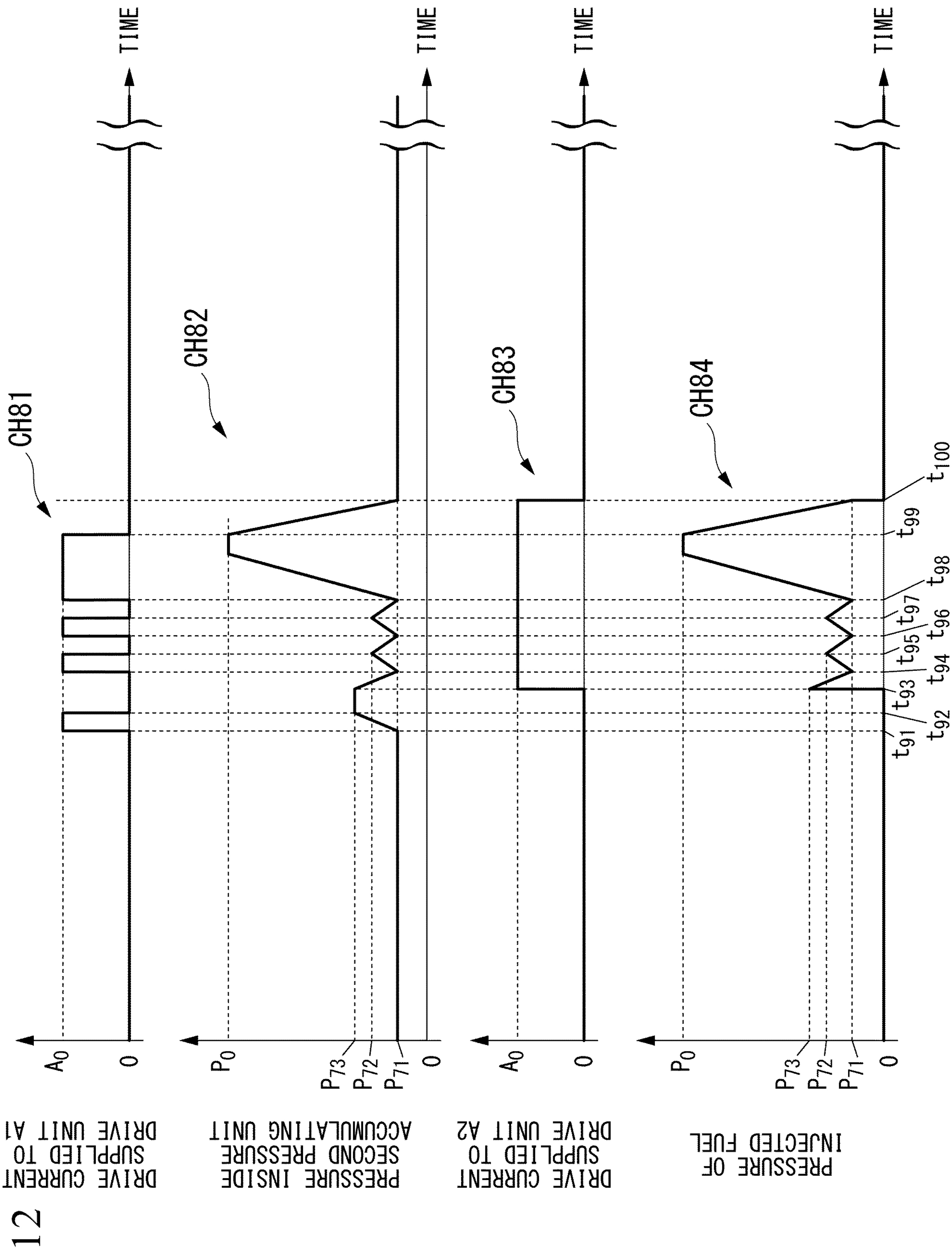

DRIVE CURRENT SUPPLIED TO DRIVE UNIT A1
PRESSURE INSIDE SECOND PRESSURE ACCUMULATING UNIT
DRIVE CURRENT SUPPLIED TO DRIVE UNIT A2
PRESSURE OF INJECTED FUEL
CH81
CH82
CH83
CH84
A_0
0
P_0
P_{73}
P_{72}
P_{71}
TIME
t_{91}
t_{92}
t_{93}
t_{94}
t_{95}
t_{96}
t_{97}
t_{98}
t_{99}
t_{100}

FIG. 12

FIG. 13

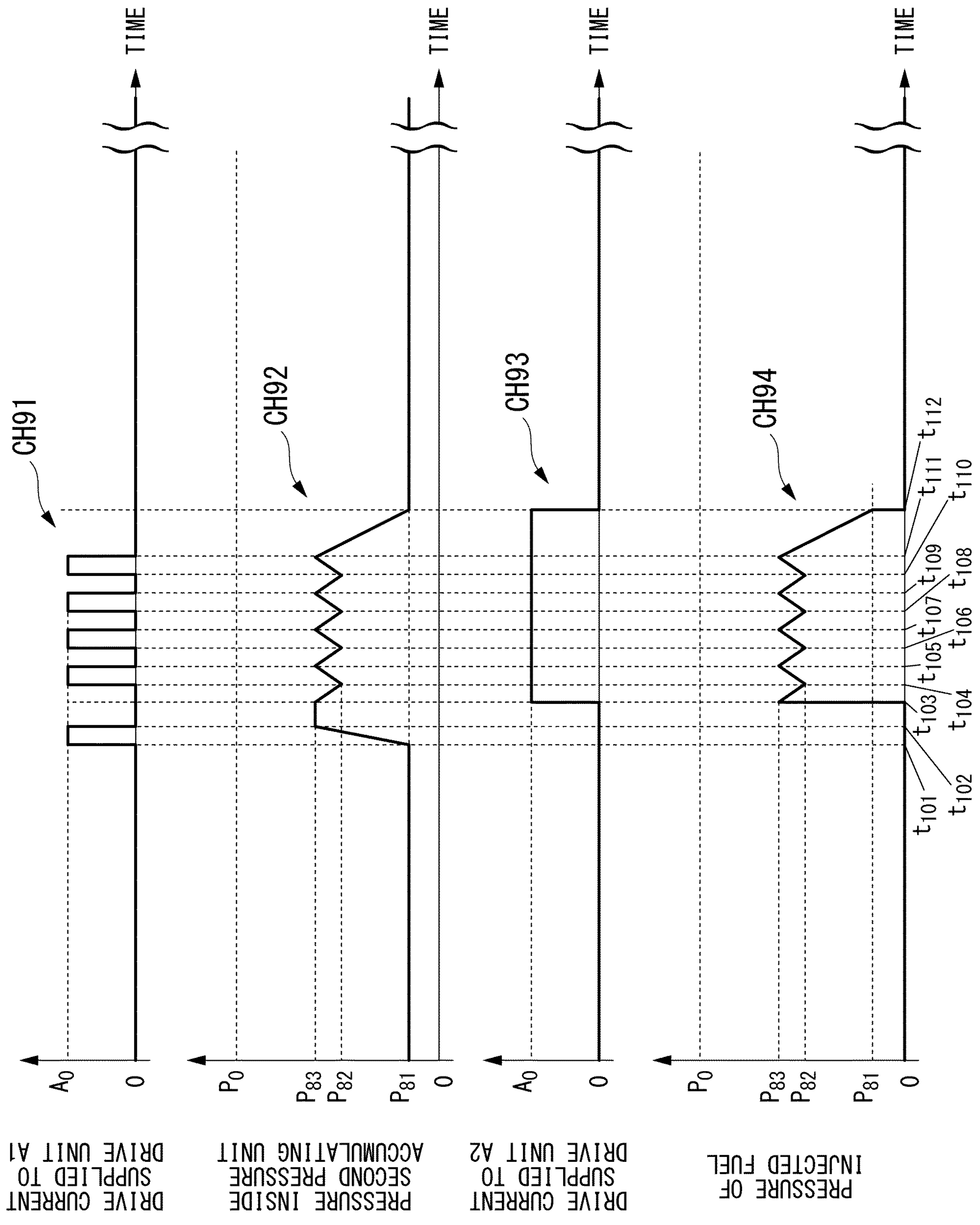
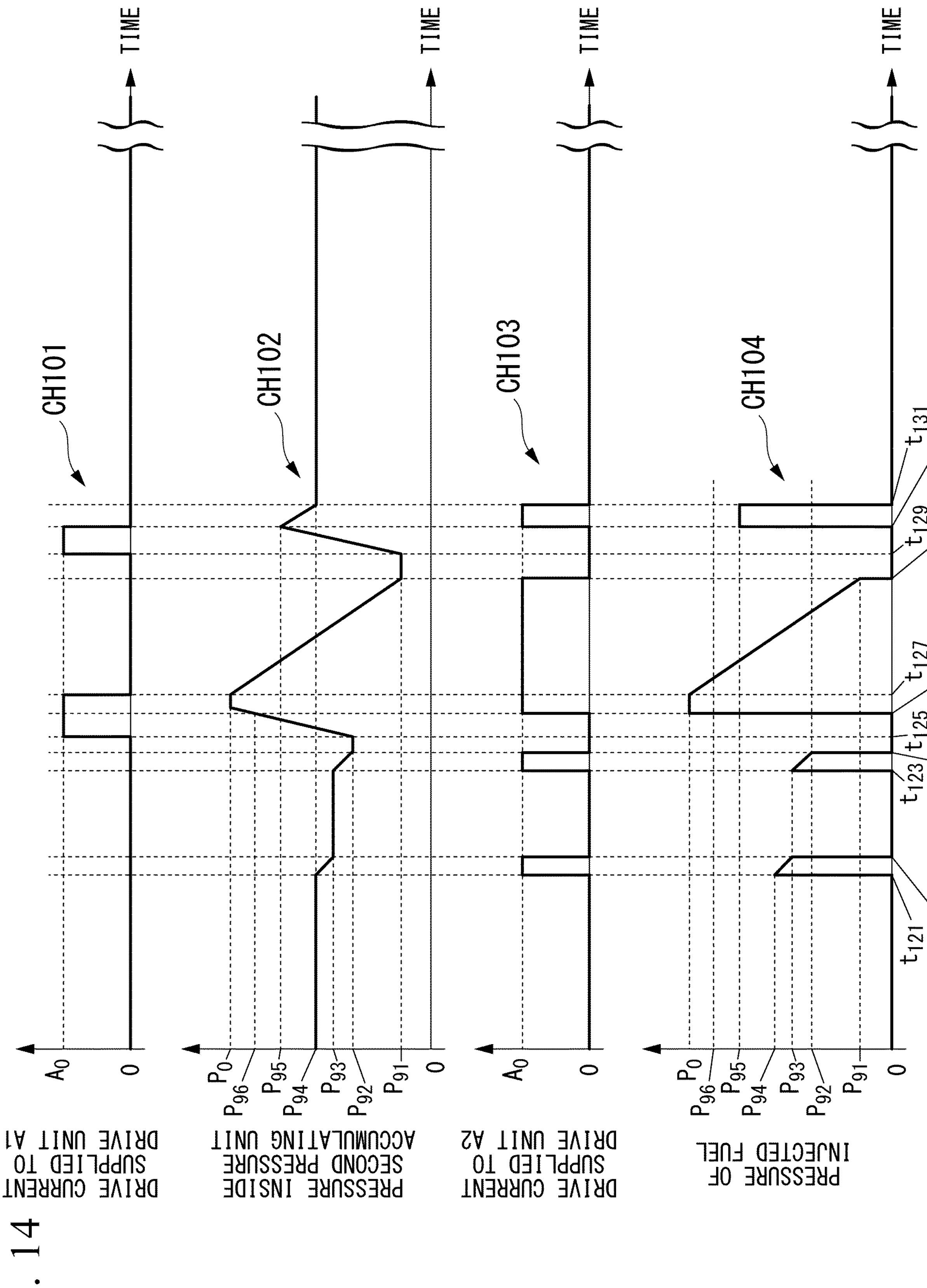

DRIVE CURRENT SUPPLIED TO DRIVE UNIT A1
A0
0
TIME
CH91
PRESSURE INSIDE SECOND PRESSURE ACCUMULATING UNIT
P0
P83
P82
P81
0
TIME
CH92
DRIVE CURRENT SUPPLIED TO DRIVE UNIT A2
A0
0
TIME
CH93
PRESSURE OF INJECTED FUEL
P0
P83
P82
P81
0
TIME
CH94
t101
t102
t103
t104
t105
t106
t107
t108
t109
t110
t111
t112

FIG. 14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PRESSURE INSIDE SECOND PRESSURE ACCUMULATING UNIT
DRIVE CURRENT SUPPLIED TO DRIVE UNIT A2
PRESSURE OF INJECTED FUEL
CH101
CH102
CH103
CH104
TIME
A0
0
P0
P96
P95
P94
P93
P92
P91
t121
t122
t123
t124
t125
t126
t127
t128
t129
t130
t131

FIG. 15

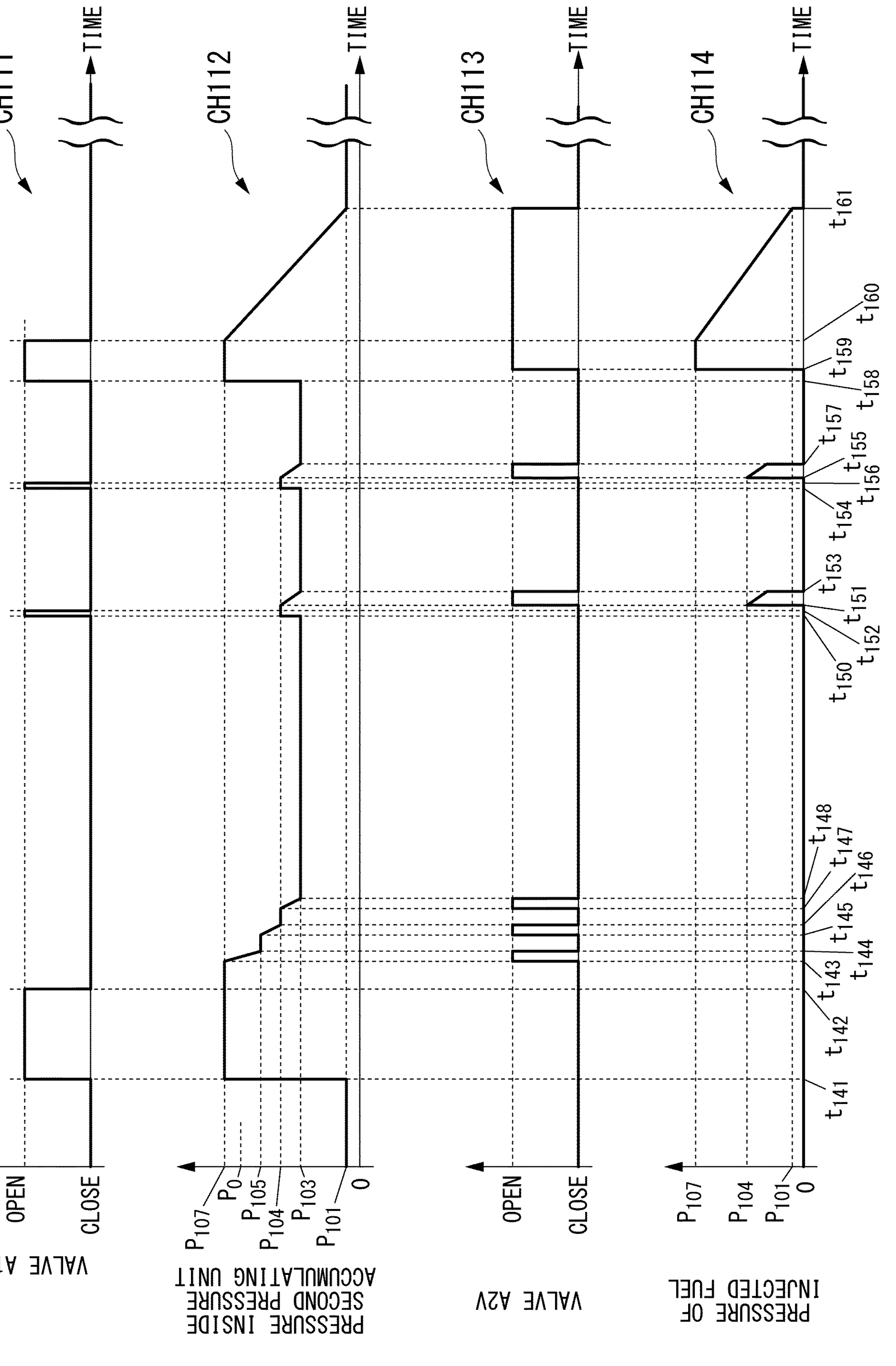
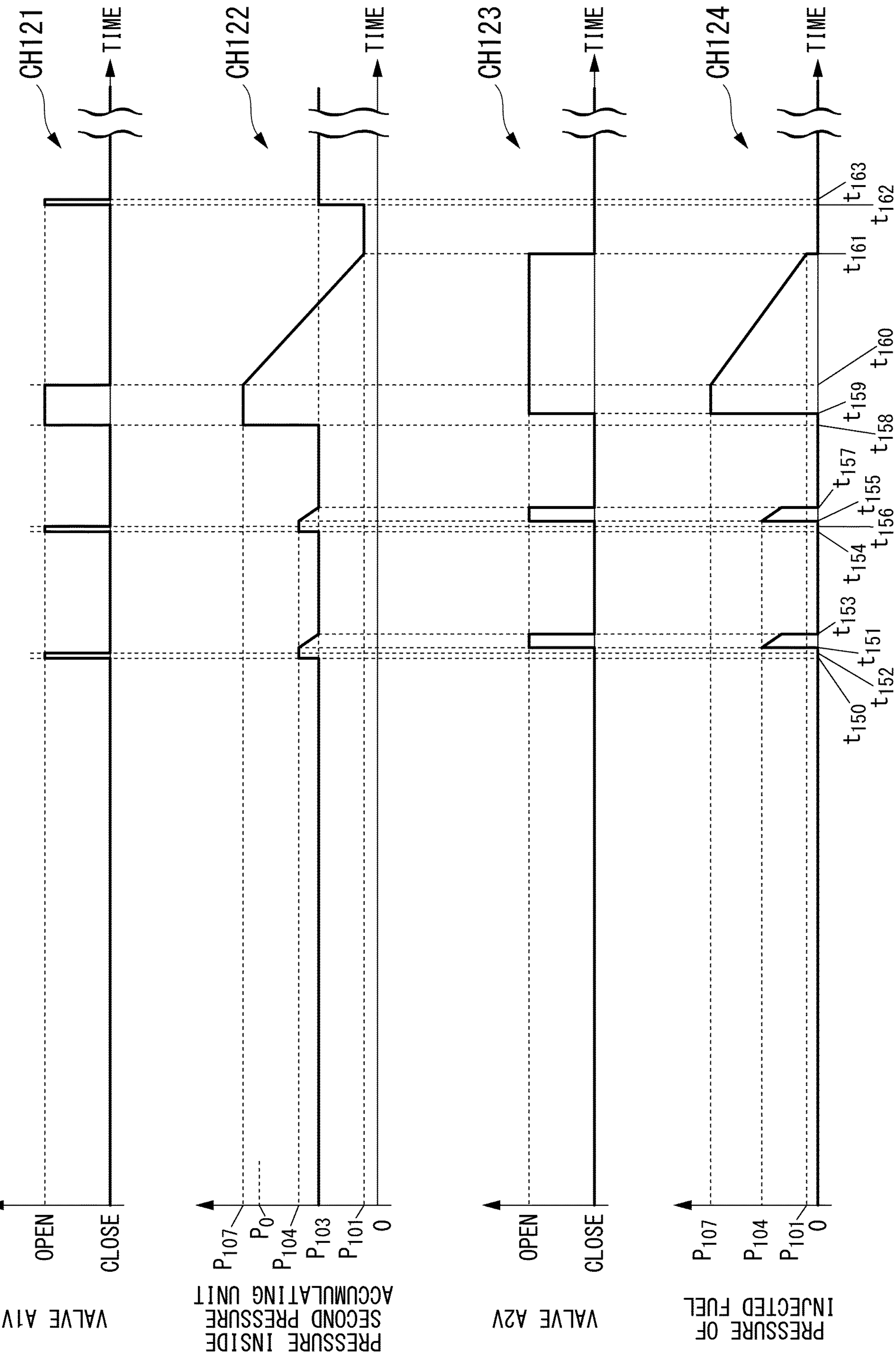

CH111
CH112
CH113
CH114
TIME
VALVE A1V
OPEN
CLOSE
PRESSURE INSIDE SECOND PRESSURE ACCUMULATING UNIT
P107
P0
P105
P104
P103
P101
0
VALVE A2V
PRESSURE OF INJECTED FUEL
t141
t142
t143
t144
t145
t146
t147
t148
t150
t151
t152
t153
t154
t155
t156
t157
t158
t159
t160
t161

FIG. 16


CH121
TIME
VALVE A1V
OPEN
CLOSE
CH122
TIME
PRESSURE INSIDE SECOND PRESSURE ACCUMULATING UNIT
P_{107}
P_0
P_{104}
P_{103}
P_{101}
0
CH123
TIME
VALVE A2V
OPEN
CLOSE
CH124
TIME
PRESSURE OF INJECTED FUEL
P_{107}
P_{104}
P_{101}
0
t_{150}
t_{151}
t_{152}
t_{153}
t_{154}
t_{155}
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t_{157}
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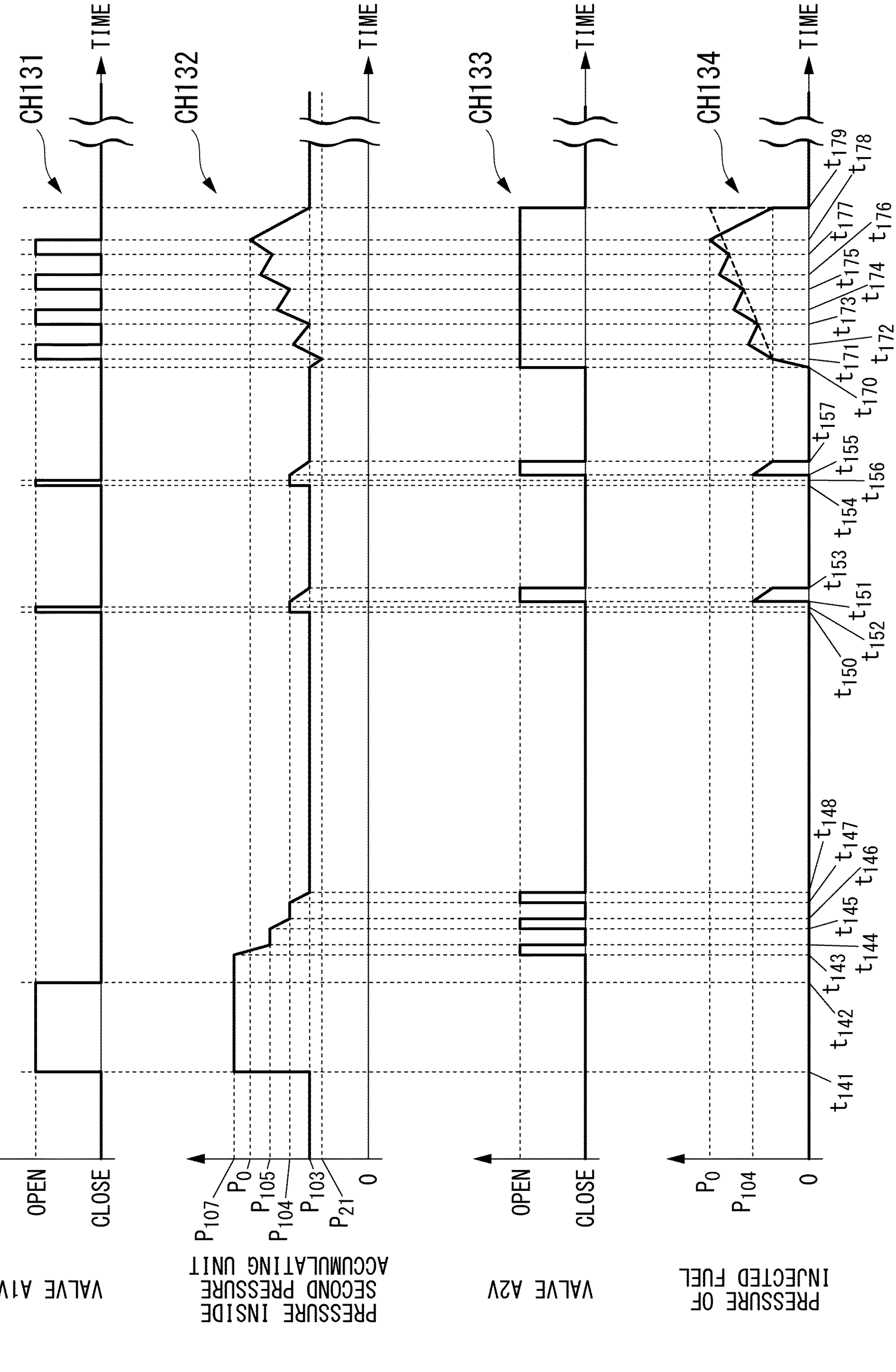
t_{159}
t_{160}
t_{161}
t_{162}
t_{163}

FIG. 17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CH132
CH133
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P105
P104
P103
P21
0
VALVE A2V
PRESSURE OF INJECTED FUEL
t141
t142
t143
t144
t145
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t147
t148
t150
t151
t152
t153
t154
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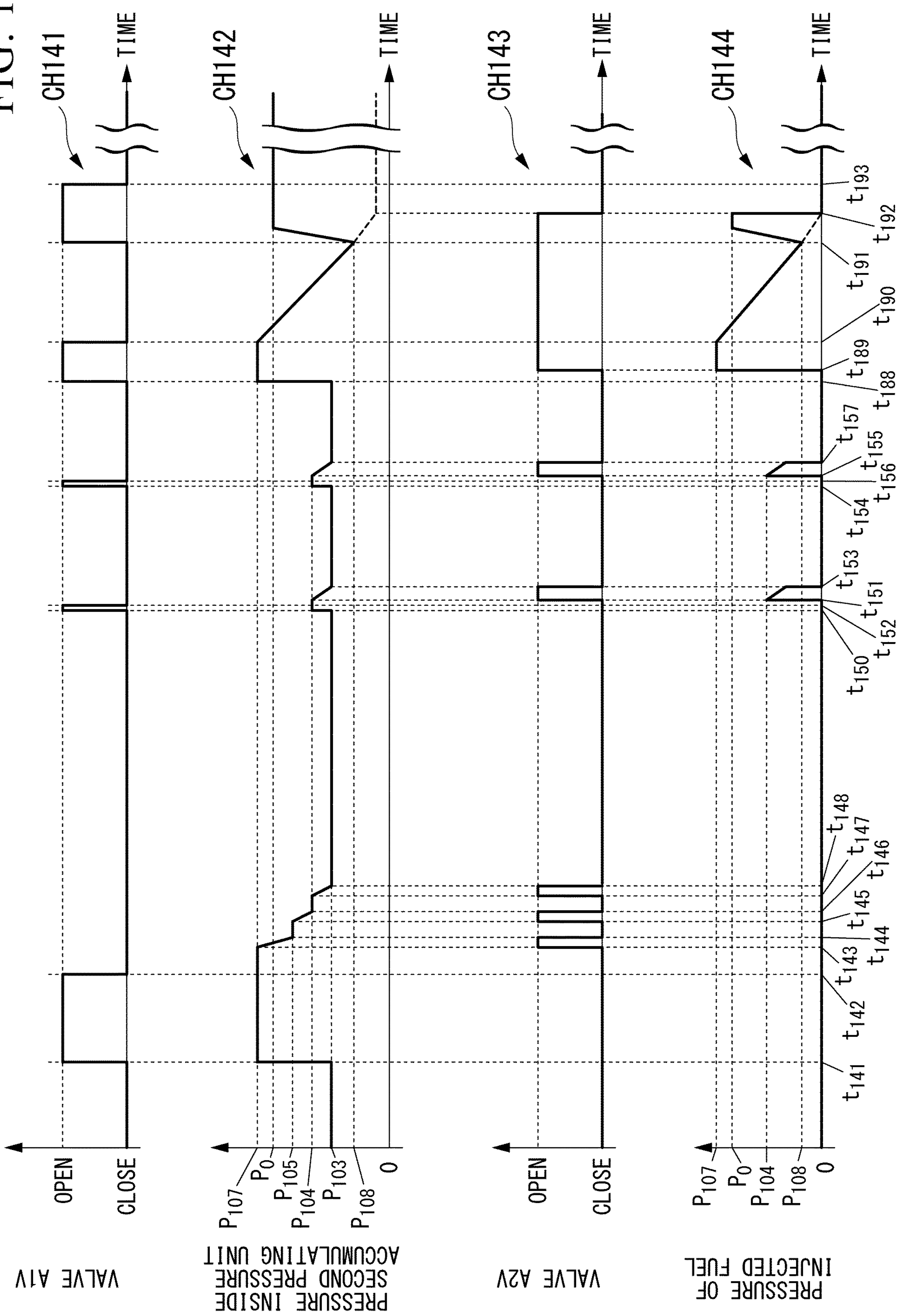
t171
t172
t173
t174
t175
t176
t177
t178
t179

FIG. 18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CH142
CH143
CH144
TIME
VALVE A1V
OPEN
CLOSE
PRESSURE INSIDE SECOND PRESSURE ACCUMULATING UNIT
P107
P0
P105
P104
P103
P108
0
VALVE A2V
PRESSURE OF INJECTED FUEL
t141
t142
t143
t144
t145
t146
t147
t148
t150
t151
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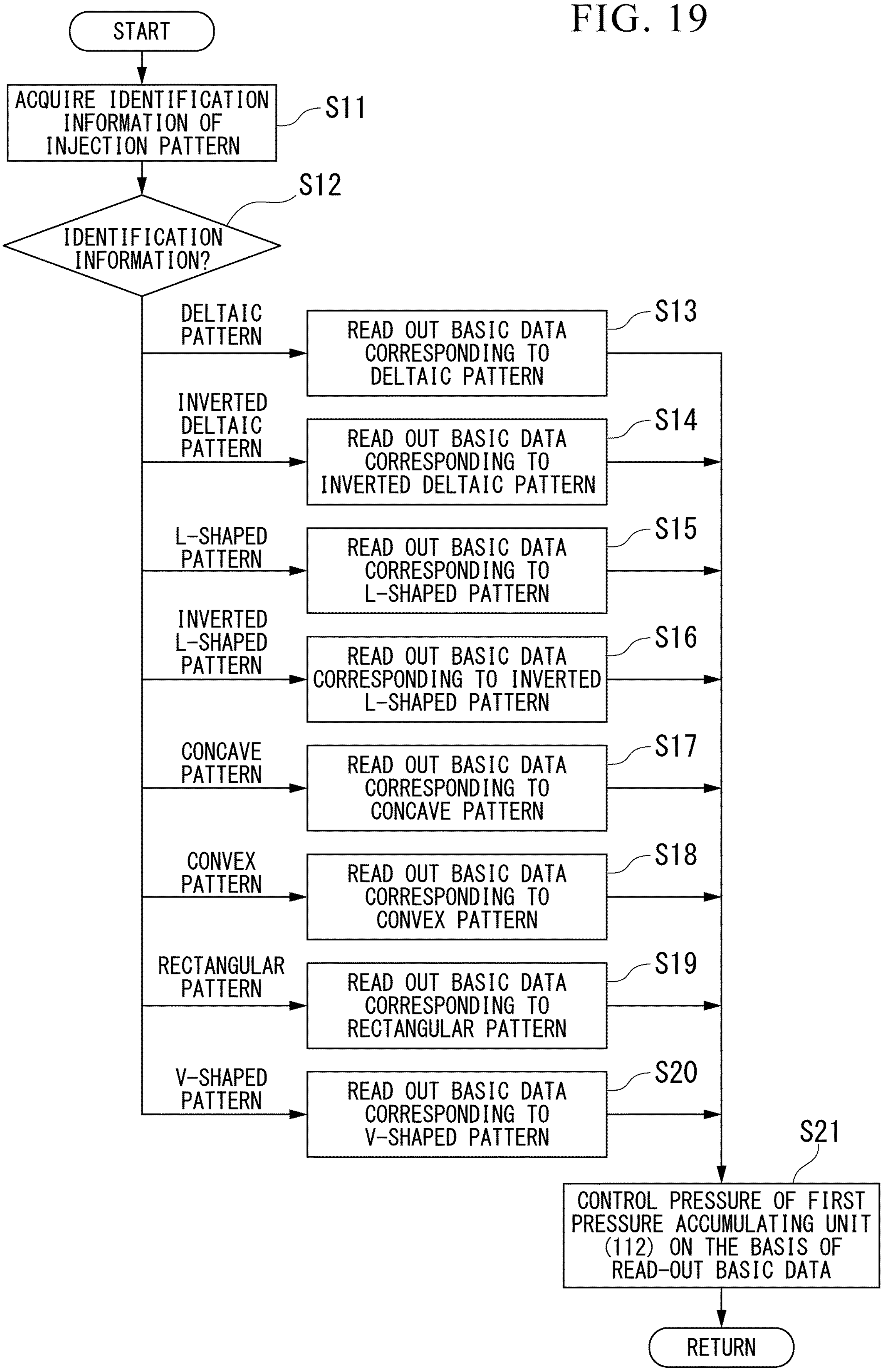
t153
t154
t155
t156
t157
t188
t189
t190
t191
t192
t193

FIG. 19


START
ACQUIRE IDENTIFICATION INFORMATION OF INJECTION PATTERN
S11
S12
IDENTIFICATION INFORMATION?
DELTAIC PATTERN
READ OUT BASIC DATA CORRESPONDING TO DELTAIC PATTERN
S13
INVERTED DELTAIC PATTERN
READ OUT BASIC DATA CORRESPONDING TO INVERTED DELTAIC PATTERN
S14
L-SHAPED PATTERN
READ OUT BASIC DATA CORRESPONDING TO L-SHAPED PATTERN
S15
INVERTED L-SHAPED PATTERN
READ OUT BASIC DATA CORRESPONDING TO INVERTED L-SHAPED PATTERN
S16
CONCAVE PATTERN
READ OUT BASIC DATA CORRESPONDING TO CONCAVE PATTERN
S17
CONVEX PATTERN
READ OUT BASIC DATA CORRESPONDING TO CONVEX PATTERN
S18
RECTANGULAR PATTERN
READ OUT BASIC DATA CORRESPONDING TO RECTANGULAR PATTERN
S19
V-SHAPED PATTERN
READ OUT BASIC DATA CORRESPONDING TO V-SHAPED PATTERN
S20
S21
CONTROL PRESSURE OF FIRST PRESSURE ACCUMULATING UNIT (112) ON THE BASIS OF READ-OUT BASIC DATA
RETURN

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2017/043077

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. F02M51/06(2006.01)i, F02M47/00(2006.01)i, F02M51/00(2006.01)i, F02M61/10(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int. Cl. F02M51/06, F02M47/00, F02M51/00, F02M61/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2018
Registered utility model specifications of Japan 1996-2018
Published registered utility model applications of Japan 1994-2018

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2001-159379 A (MITSUBISHI MOTORS CORP.) 12 June 2001, paragraphs [0011]-[0039], fig. 1-6 & US 6363914 B1, columns 4-8, fig. 1-3 & EP 1087130 A2	1-2, 7,13 3-6, 8-12
X Y	JP 2004-44493 A (TOYOTA CENTRAL RESEARCH AND DEVELOPMENT LABORATORIES, INC.) 12 February 2004, paragraphs [0054]-[0104], fig. 1-9 & US 2004/0237930 A1, paragraphs [0108]-[0138], fig. 1-9 & WO 2004/007947 A1 & EP 1522718 A1 & EP 1790847 A2 & EP 1790848 A2	13 3-6, 8-12

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

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Patent documents cited in the description

- JP 2016235334 A **[0002]**
- JP 2005531712 W **[0005]**