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(54) ## DROPLET DISCHARGE HEAD, DRIVE CIRCUIT THEREOF, AND PRINTER

(57) According to one embodiment, a drive circuit includes a generation unit, a selection unit, and a control unit. The generation unit generates a plurality of the drive signals in parallel for deforming the actuators by a plurality of patterns, in which a part of the plurality of patterns is a plurality of different patterns for achieving respective discharge amounts of the plurality of stages, and the other part of the plurality of patterns is a plurality of different patterns for achieving discharge amounts of a part of the plurality of stages. The selection unit selects and supplies one of the drive signals generated by the generation unit to each of the actuators. The control unit controls the selection unit so as to supply the drive signal correlated with the received data to the plurality of actuators, based on a lookup table showing which of the plurality of drive signals is to be supplied to each of the plurality of actuators in correlation with each data.

FIG. 16

GRADATION VALUE	FIRST DROP		SECOND DROP		THIRD DROP		FOURTH DROP	
	FIRST	SECOND	FIRST	SECOND	FIRST	SECOND	FIRST	SECOND
0	SA	SA	SA	SA	SA	SA	SA	SA
1	SB	SA	SA	SA	SA	SA	SA	SA
2	SB	SB	SA	SA	SA	SA	SA	SA
3	SF	SE	SA	SA	SA	SA	SA	SA
4	SF	SF	SA	SA	SA	SA	SA	SA
5	SF	SF	SB	SA	SA	SA	SA	SA
6	SF	SF	SB	SB	SA	SA	SA	SA
7	SF	SF	SF	SE	SA	SA	SA	SA
8	SF	SF	SF	SF	SA	SA	SA	SA
9	SF	SF	SF	SF	SB	SA	SA	SA
10	SF	SF	SF	SF	SB	SB	SA	SA
11	SF	SF	SF	SF	SF	SE	SA	SA
12	SF	SF	SF	SF	SF	SF	SA	SA
13	SF	SF	SF	SF	SF	SF	SB	SA
14	SF	SF	SF	SF	SF	SF	SB	SB
15	SF	SF	SF	SF	SF	SF	SF	SE

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Description

FIELD

[0001] Embodiments described herein relate generally to a droplet discharge head, a drive circuit thereof, and a printer.

BACKGROUND

[0002] The droplet discharge head is known as, for example, an inkjet head. In a droplet discharge head that discharges droplets by changing the volume of one pressure chamber due to deformation of each of the plurality of actuators, the same discharge amount may be implemented by a plurality of drive patterns.

[0003] In the case of such a droplet discharge head, which drive pattern to be applied for the discharge of a discharge amount that can be implemented by a plurality of drive patterns is selected at the design stage of the drive circuit or the droplet discharge head.

[0004] Therefore, it is not easy to change the drive pattern to be used for discharging a certain discharge amount.

[0005] Under such circumstances, it is desired to easily change the drive pattern to be applied for the discharge of the discharge amount that can be implemented by the plurality of drive patterns.

DESCRIPTION OF THE DRAWINGS

[0006]

FIG. 1 is a block diagram illustrating a main circuit configuration of a printer according to an embodiment;
FIG. 2 is a diagram illustrating a main configuration of an inkjet head illustrated in FIG. 1;
FIG. 3 is a perspective view illustrating a part of the inkjet head illustrated in FIG. 1 in an exploded manner;
FIG. 4 is a diagram illustrating the operation of an actuator formed by a protrusion and an electrode of a piezoelectric member illustrated in FIG. 2;
FIG. 5 is a diagram illustrating a first drive pattern;
FIG. 6 is a diagram illustrating a second drive pattern;
FIG. 7 is a diagram illustrating a third drive pattern;
FIG. 8 is a diagram illustrating a fourth drive pattern;
FIG. 9 is a diagram illustrating a fifth drive pattern;
FIG. 10 is a diagram illustrating a sixth drive pattern;
FIG. 11 is a diagram illustrating a seventh drive pattern;
FIG. 12 is a diagram illustrating an eighth drive pattern;
FIG. 13 is a diagram illustrating a ninth drive pattern;
FIG. 14 is a diagram illustrating a tenth drive pattern;
FIG. 15 is a diagram illustrating six types of waveforms of a first drive signal and a second drive signal; and
FIG. 16 is a diagram schematically illustrating the contents of a look-up table.

DETAILED DESCRIPTION

[0007] An object to be solved by exemplary embodiments is to provide a droplet discharge head, a drive circuit thereof, and a printer capable of easily changing a drive pattern to be applied for discharge of a discharge amount that can be implemented by a plurality of drive patterns.

[0008] In general, according to one embodiment, a drive circuit includes a generation unit, a selection unit, and a control unit. The drive circuit is configured to drive a droplet discharge head including a plurality of actuators which deform according to a supplied drive signal to change a volume of a pressure chamber, and discharging liquid from the pressure chamber by changing the volume of the pressure chamber, in which a discharge amount at one time is adapted to be changed to a plurality of stages by combining respective deformation patterns of the plurality of actuators, and at least a part of the plurality of stages is achieved by any of the plurality of combinations of the deformation patterns. The generation unit is configured to generate a plurality of the drive signals in parallel for deforming the actuators by a plurality of patterns, in which a part of the plurality of patterns is a plurality of different patterns for achieving respective discharge amounts of the plurality of stages, and the other part of the plurality of patterns is a plurality of different patterns for achieving discharge amounts of a part of the plurality of stages. The selection unit is configured to select and supply one of the plurality of drive signals generated by the generation unit to each of the plurality of actuators. The control unit is configured to, if any of a plurality of pieces of data representing different discharge amounts is received, control the selection unit so as to supply the drive signal correlated with the received data to each of the plurality of actuators, based on a lookup table showing which of the plurality of drive signals is to be supplied to each of the plurality of actuators in correlation with each of the plurality of pieces of data.

[0009] Preferably, if the plurality of drive signals are represented in the look-up table for one actuator, in correlation with the received data, the control unit may control the selection unit so as to sequentially supply the plurality of drive signals to the corresponding one actuator.

[0010] Preferably, the drive circuit may further comprise a storage unit configured to store the lookup table in an updatable manner.

[0011] There is also provided a droplet discharge head comprising a head body and the above described drive circuit.

[0012] There is also provided a printer comprising the above described droplet discharge head, and a moving unit configured to move at least one of the head body and paper facing the head body so as to change a relative positional relationship between the head body and the paper.

[0013] Hereinafter, a droplet discharge device as an example of the embodiment will be described with reference to the drawings. In the following, an example of achieving a droplet discharge device as a printer suitable for printing an image by spraying ink droplets on paper (recording medium) will be described.

[0014] FIG. 1 is a block diagram illustrating a main circuit configuration of the printer 100 according to the present embodiment.

[0015] As illustrated in FIG. 1, the printer 100 includes a processor 101, a main memory 102, an auxiliary storage unit 103, an operation panel 104, a communication interface 105, a conveyance unit 106, a conveyance control unit 107, a supply unit 108, a supply control unit 109, an inkjet head 110, and a transmission line 111.

[0016] The processor 101, the main memory 102, and the auxiliary storage unit 103 are connected via the transmission line 111 to configure a computer that performs information processing for controlling the printer 100.

[0017] The processor 101 corresponds to the central portion of the computer. The processor 101 executes the above information processing according to an information processing program such as an operating system, middleware, and an application program.

[0018] The main memory 102 corresponds to the main memory portion of the computer. The main memory 102 includes a non-volatile memory area and a volatile memory area. The main memory 102 stores an information processing program in the non-volatile memory area. In addition, the main memory 102 stores data necessary for the processor 101 to execute processing for controlling each unit in a non-volatile or volatile memory area. The main memory 102 uses the volatile memory area as a work area into which data is appropriately rewritten by the processor 101.

[0019] The auxiliary storage unit 103 corresponds to an auxiliary storage portion of the computer. As the auxiliary storage unit 103, for example, well-known storage devices such as an electric erasable programmable read-only memory (EEPROM), a hard disk drive (HDD), and a solid state drive (SSD) can be used by themselves or in combination of two or more. The auxiliary storage unit 103 stores data used by the processor 101 to perform various processes and data generated by the processes of the processor 101. The auxiliary storage unit 103 stores the information processing program.

[0020] The operation panel 104 includes an input device and a display device. The operation panel 104 inputs an operator's instruction by using the input device. The operation panel 104 displays various types of information to be notified to the operator, by the display device. As the operation panel 104, for example, a touch panel can be used. However, as the above input device and display device, various other devices can be appropriately used.

[0021] The communication interface 105 transmits and receives data to and from an external device via a communication network such as a local area network (LAN). The external device is, for example, an information processing device that requests the printer 100 to perform printing. As the communication interface 105, a well-known device such as a communication device for LAN can be used.

[0022] The conveyance unit 106 includes a motor, gears, rollers, and the like, and conveys the paper in a state of crossing the flight path of the ink droplets discharged from the inkjet head 110. The conveyance unit 106 may move the inkjet head 110 along the surface of the fixed paper. Further, the conveyance unit 106 may move both the inkjet head 110 and the paper such that the inkjet head 110 moves along the surface of the paper. That is, the conveyance unit 106 may move the inkjet head 110 and the paper so as to change the relative positional relationship between the inkjet head 110 and the paper, and is an example of the moving unit. The conveyance control unit 107 controls the conveyance unit 106 such that the paper is conveyed at a predetermined timing synchronized with the discharge operation of ink droplet by the inkjet head 110, under the control of the processor 101.

[0023] The supply unit 108 includes, for example, an ink tank, a pump, a pipe, a valve, and the like, and supplies ink to the inkjet head 110. If the inkjet head 110 is the circulation type, the supply unit 108 can also collect ink from the inkjet head 110 that does not discharge ink. The supply control unit 109 controls the supply unit 108 under the control of the processor 101.

[0024] The inkjet head 110 discharges the ink supplied by the supply unit 108 as ink droplets, based on the line data. The ink droplet is an example of a droplet, and the inkjet head 110 is an example of a droplet discharge head. The transmission line 111 includes an address bus, a data bus, a control signal line, and the like, and transmits data and control signals exchanged between the connected units.

[0025] FIG. 2 is a diagram illustrating a main configuration of the inkjet head 110. FIG. 3 is a perspective view illustrating a part of the inkjet head 110 in an exploded manner. In the following description with respect to FIGS. 2 and 3, the vertical direction and the horizontal direction in FIG. 2 are the vertical direction and the width direction of the inkjet head 110. The front side in FIG. 2 and the upper left side in FIG. 3 are referred to as a rear end side. The back side in FIG. 2 and the lower right side in FIG. 3 are referred to as a front end side.

[0026] The inkjet head 110 includes a substrate 1, a piezoelectric unit 2, electrodes 3, 4, and 5, a top plate 6, a nozzle plate 7, and a drive IC 8. The substrate 1 is an elongated plate-shaped member having a width direction as a longitudinal direction. It is desirable that the substrate 1 has a small dielectric constant. It is desirable that the substrate 1 has a small difference in thermal expansion coefficient from that of the piezoelectric unit 2. Materials suitable for the substrate 1 are, for example, alumina (Al_2O_3), silicon nitride (Si_3N_4), silicon carbide (SiC), aluminum nitride (AlN), lead zirconate titanate (PZT), and the like.

[0027] The piezoelectric unit 2 is joined to the upper surface of the substrate 1. The piezoelectric unit 2 includes a first piezoelectric member 21 and a second piezoelectric member 22. The materials of the first piezoelectric member 21 and the second piezoelectric member 22 are, for example, lead zirconate titanate (PZT), lithium niobate ($LiNbO_3$), lithium tantalate ($LiTaO_3$), and the like. The first piezoelectric member 21 is joined to the upper surface of the substrate 1. The second piezoelectric member 22 is joined onto the first piezoelectric member 21. The first piezoelectric member 21 and the second piezoelectric member 22 are polarized, with the joint surface therebetween as boundaries, in opposite directions with each other.

[0028] The piezoelectric unit 2 extends in the vertical direction, and forms a plurality of plate-shaped protrusions PRA and PRB formed in a state of being arranged in parallel with each other along the width direction. The joint surface between the first piezoelectric member 21 and the second piezoelectric member 22 is located near the center of each of the plurality of protrusions PRA and PRB in the vertical direction. The protrusions PRA and PRB have similar shapes and are arranged alternately. The distance between the right side surface of the protrusion PRA in FIG. 2 and the left side surface of the protrusion PRB in FIG. 2 is narrower than the distance between the left side surface of the protrusion PRA in FIG. 2 and the right side surface of the protrusion PRB in FIG. 2. That is, the distance between the protrusion PRA and the protrusion PRB is alternately different. However, the distance between the protrusion PRA and the protrusion PRB is not limited to this relationship. With respect to the space between the right side surface of the protrusion PRA in FIG. 2 and the left side surface of the protrusion PRB in FIG. 2, the upper part is covered by the top plate 6 and the front end side is covered by the nozzle plate 7, which forms a pressure chamber CHA. With respect to the space between the left side surface of the protrusion PRA in FIG. 2 and the right side surface of the protrusion PRB in FIG. 2, the upper part is covered by the top plate 6 and the discharge side is covered by the nozzle plate 7, which forms an air chamber CHB. The rear end side of the pressure chamber CHA and the air chamber CHB is closed by the piezoelectric unit 2.

[0029] The electrode 3 is a conductive film in a state of covering the side surface of the protrusion PRA facing the air chamber CHB. The electrode 4 is a conductive film in a state of covering the side surface of the protrusion PRB facing the air chamber CHB. The electrode 5 is a conductive film in a state of covering the side surface of the protrusion PRA facing the pressure chamber CHA and the side surface of the protrusion PRB facing the pressure chamber CHA and being connected by the bottom surface of the pressure chamber CHA. The electrodes 3, 4, and 5 have, for example, a two-layer structure of nickel (Ni) and gold (Au). The electrodes 3, 4, and 5 are uniformly formed by, for example, a plating method. The method for forming the electrodes 3, 4, and 5 is not limited to the plating method, and a sputtering method, a vapor deposition method, or the like may be used. In FIG. 1, the thicknesses of the electrodes 3, 4 and 5 are exaggerated. The electrode 4 is grounded via a conductive path formed by a conductive pattern, a wire, or the like.

[0030] The top plate 6 is an elongated plate-shaped member having a width direction as a longitudinal direction. The top plate 6 is joined to the upper surface of the piezoelectric unit 2 and closes the upper parts of the pressure chamber CHA and the air chamber CHB.

[0031] The nozzle plate 7 is joined to the end surface on the front end side of the piezoelectric unit 2, and closes the front end side of each of the pressure chamber CHA and the air chamber CHB. A plurality of nozzles 71 are formed on the nozzle plate 7 in association with the plurality of pressure chambers CHA, respectively. The nozzle 71 connects one corresponding pressure chamber CHA among the plurality of pressure chambers CHA, to the outside of the inkjet head 110. The nozzle 71 has a constricted portion at a position slightly on the front end side from the center, and gradually expands from the constricted portion toward both the front end side and the rear end side. The nozzle 71 is not limited to this shape. For example, the shape may be a tapered cone shape in which the nozzle diameter on the discharge surface side becomes smaller. The plurality of nozzles 71 are arranged in a row along the width direction.

[0032] The structure including the substrate 1, the piezoelectric unit 2, the electrodes 3, 4, and 5, the top plate 6, and the nozzle plate 7 as described above is hereinafter referred to as a head body.

[0033] The drive IC 8 drives the head body so as to cause ink discharge from the nozzle 71.

[0034] As illustrated in FIG. 2, the drive IC 8 includes a pixel separator 81, a waveform generator 82, and a plurality of drive units 83.

[0035] Line data is input to the pixel separator 81. The line data is a set of pixel data representing the gradation value of each of a plurality of pixels included in one line. The pixel separator 81 outputs the pixel data included in the line data to each of the plurality of drive units 83 in parallel. The waveform generator 82 simultaneously generates a plurality of drive signals having different waveforms, and outputs the plurality of drive signals in parallel.

[0036] The number of drive units 83 is the same as the number of pressure chambers CHA provided in the head body. The plurality of drive units 83 and the plurality of pressure chambers CHA form pairs, respectively. The drive unit 83 supplies drive signals to the electrodes 3 and 4 provided on the protrusions PRA and PRB that sandwich the paired pressure chamber CHA.

[0037] As illustrated in FIG. 2, the drive unit 83 includes selectors 831 and 832, amplifiers 833 and 834, and a LUT converter 835. Although FIG. 2 illustrates only the configuration of one drive unit 83, the other drive units 83 have the same configuration.

[0038] A plurality of drive signals output from the waveform generator 82 are input to the selectors 831, and 832 in parallel. The selector 831 selects and outputs one drive signal to be supplied to the electrode 3, among the plurality of drive signals, under the control of the LUT converter 835. The selector 832 selects and outputs one drive signal to be supplied to the electrode 4, among the plurality of drive signals. The amplifier 833 amplifies the drive signal output from the selector 831 to a signal level for causing the required deformation in the protrusion PRA to which the electrode 3 of the supply destination is attached.

[0039] The amplifier 834 amplifies the drive signal output from the selector 832 to a signal level for causing the required deformation in the protrusion PRB to which the electrode 4 of the supply destination is attached. The drive signals output from the amplifiers 833 and 834 are supplied to the electrodes 3 and 4 via individual conductive paths formed by a conductive pattern, wires, and the like.

[0040] The LUT converter 835 controls the selectors 831 and 832 so as to cause ink discharge according to the gradation value represented by the pixel data given from the pixel separator 81. The LUT converter 835 has a built-in memory 8351 that stores the look-up table in an updatable manner. The memory 8351 is an example of a storage unit.

[0041] Next, the operation of the printer 100 configured as described above will be described. Since the characteristic operation of the printer 100 is the operation of the inkjet head 110, the following description will be focused on the operation of the inkjet head.

[0042] FIG. 4 is a diagram illustrating the operation of the actuator formed by the protrusion PRA of the piezoelectric unit 2 and the electrodes 3 and 5.

[0043] As described above, as illustrated in FIG. 4, the inkjet head 110 includes a structure in which electrodes 3 and 5 are provided on both side surfaces of the protrusion PRA

[0044] Since the electrode 5 is grounded, if the potential of the electrode 3 is 0 V, no electric field acts on the protrusion PRA, and the protrusion PRA maintains a flat plate shape as illustrated in the center of FIG. 4.

[0045] If the level of the drive signal supplied to the electrode 3 is +Va, the electric field generated according to the potential difference between the electrode 3 and the electrode 5 acts on the protrusion PRA, and as illustrated on the left side in FIG. 4, the protrusion PRA is deformed so as to bend to the left side in FIG. 4 at the joint surface between the first piezoelectric member 21 and the second piezoelectric member 22.

[0046] If the level of the drive signal supplied to the electrode 3 is -Va, the electric field generated according to the potential difference between the electrode 3 and the electrode 5 acts on the protrusion PRA, and as illustrated on the right side in FIG. 4, the protrusion PRA is deformed so as to bend to the right side in FIG. 4 at the joint surface between the first piezoelectric member 21 and the second piezoelectric member 22.

[0047] However, FIG. 4 schematically illustrates how the protrusion PRA is deformed, and does not strictly represent the state after deformation and the amount of deformation.

[0048] As compared with the case where the protrusion PRA is in the state illustrated in the center in FIG. 4, if the protrusion PRA is in the state on the left side in FIG. 4, the volume of the pressure chamber CHA adjacent to the protrusion PRA is increased. Further, as compared with the case where the protrusion PRA is in the state illustrated in the center in FIG. 4, if the protrusion PRA is in the state on the right side in FIG. 4, the volume of the pressure chamber CHA adjacent to the protrusion PRA is reduced. Thus, the protrusion PRA and the electrodes 3 and 5 configure an actuator for changing the volume of the pressure chamber CHA.

[0049] Although not illustrated, the protrusion PRB and the electrodes 4 and 5 also configure an actuator for increasing the volume of the adjacent pressure chamber CHA if the level of the drive signal supplied to the electrode 4 is +Va and decreasing the volume of the adjacent pressure chamber CHA if the level of the drive signal supplied to the electrode 4 is -Va.

[0050] The inkjet head 110 changes the amount of ink droplets to be discharged at one time, by changing the volume of each of the plurality of pressure chambers CHA. The change in the volume of the pressure chamber CHA is a cycle of returning from the neutral state, which will be described later, to the neutral state after a draw period and a push period. The draw period is a period for adjusting the amount of ink contained in the pressure chamber CHA. The push period is a period during which the ink contained in the pressure chamber CHA is discharged from the nozzle 71.

[0051] In the neutral state and the draw period, if the ink is sucked into the pressure chamber CHA, the supply control unit 109 controls the supply unit 108 so as to supply ink. Further, in the neutral state and the draw period, if the ink is extruded from the pressure chamber CHA, the supply control unit 109 controls the supply unit 108 so as to collect ink. In the push period, the supply control unit 109 controls the supply unit 108 so as not to supply or collect ink.

[0052] Hereinafter, some drive patterns for causing ink discharge in the inkjet head 110 will be described with reference to FIGS. 5 to 14. Here, attention is paid to discharge of ink from one pressure chamber CHA.

[0053] In FIGS. 5 to 14, on the upper side, the deformation of the protrusions PRA and PRB is illustrated by omitting the illustrations of the electrodes 3, 4 and 5. The upper signal waveform illustrated in FIG. 5 shows the waveform of the drive signal supplied to the electrode 3 (hereinafter referred to as a first drive signal), and the lower signal waveform shows the waveform of the drive signal supplied to the electrode 4 (hereinafter referred to as a second drive signal).

[0054] FIG. 5 is a diagram illustrating a first drive pattern.

[0055] The neutral state is a state in which neither the protrusions PRA nor PRB adjacent to the pressure chamber CHA is deformed. In the neutral state, the signal level of both the first drive signal and the second drive signal is set to 0.

[0056] In the first drive pattern, in the draw period PA, the signal level of both the first drive signal and the second drive signal is set to +Va. Thus, the volume of the pressure chamber CHA is expanded to the maximum. Assuming that the amount of ink contained in the pressure chamber CHA in this state is 100%, the amount of ink contained in the pressure chamber CHA in the neutral state is 50%. In the first drive pattern, in the push period PB, the signal level of the first drive signal is set to 0, and the signal level of the second drive signal is set to +Va. Thus, the volume of the pressure chamber CHA is reduced. In this state, the amount of ink contained in the pressure chamber CHA is 75%. Thus, in the first drive pattern, an amount equivalent to 25% of ink is discharged from the nozzle 71.

[0057] FIG. 6 is a diagram illustrating a second drive pattern.

[0058] In the second drive pattern, in the draw period PA, the signal level of the first drive signal is set to +Va, and the signal level of the second drive signal is set to 0. Thus, the volume of the pressure chamber CHA is expanded until the amount of ink reaches 75%. In the second drive pattern, in the push period PB, the signal level of both the first drive signal and the second drive signal is set to 0. Thus, the neutral state is set, and the volume of the pressure chamber CHA is reduced until the amount of ink reaches 50%. Thus, in the second drive pattern, an amount equivalent to 25% of ink is discharged from the nozzle 71.

[0059] FIG. 7 is a diagram illustrating a third drive pattern.

[0060] In the third drive pattern, in the draw period PA, the signal level of both the first drive signal and the second drive signal is set to 0. Thus, the volume of the pressure chamber CHA does not change, and the amount of ink is 50%. In the third drive pattern, in the push period PB, the signal level of the first drive signal is set to -Va, and the signal level of the second drive signal is set to 0. Thus, the volume of the pressure chamber CHA is reduced until the amount of ink reaches 25%. Thus, in the third drive pattern, an amount equivalent to 25% of ink is discharged from the nozzle 71.

[0061] FIG. 8 is a diagram illustrating a fourth drive pattern.

[0062] In the fourth drive pattern, in the draw period PA, the signal level of the first drive signal is set to -Va, and the signal level of the second drive signal is set to 0. Thus, the volume of the pressure chamber CHA is reduced until the amount of ink reaches 25%. However, the ink extruded from the pressure chamber CHA at this time is collected by the supply unit 108 and is not discharged from the nozzle 71. In the fourth drive pattern, in the push period PB, the signal level of both the first drive signal and the second drive signal is set to -Va. Thus, the volume of the pressure chamber CHA is reduced to the minimum. Even in this state, ink may be contained in the pressure chamber CHA, but here, the amount of ink in this state is set to 0%. Thus, in the fourth drive pattern, an amount equivalent to 25% of ink is discharged from the nozzle 71.

[0063] FIG. 9 is a diagram illustrating a fifth drive pattern.

[0064] In the fifth drive pattern, in the draw period PA, the signal level of both the first drive signal and the second drive signal is set to +Va. Thus, the volume of the pressure chamber CHA is expanded until the amount of ink reaches 100%. In the fifth drive pattern, in the push period PB, the signal level of both the first drive signal and the second drive signal is set to 0. Thus, the volume of the pressure chamber CHA is reduced until the amount of ink reaches 50%. Thus, in the fifth drive pattern, an amount equivalent to 50% of ink is discharged from the nozzle 71.

[0065] FIG. 10 is a diagram illustrating a sixth drive pattern.

[0066] In the sixth drive pattern, in the draw period PA, the signal level of the first drive signal is set to +Va, and the signal level of the second drive signal is set to 0. Thus, the volume of the pressure chamber CHA is expanded until the amount of ink reaches 75%. In the sixth drive pattern, in the push period PB, the signal level of the first drive signal is set to -Va, and the signal level of the second drive signal is set to 0. Thus, the volume of the pressure chamber CHA is reduced until the amount of ink reaches 25%. Thus, in the sixth drive pattern, an amount equivalent to 50% of ink is discharged from the nozzle 71.

[0067] FIG. 11 is a diagram illustrating a seventh drive pattern.

[0068] In the seventh drive pattern, in the draw period PA, the signal level of both the first drive signal and the second drive signal is set to 0. Thus, the neutral state is maintained, and the volume of the pressure chamber CHA is maintained at 50% of the ink amount. In the seventh drive pattern, in the push period PB, the signal level of both the first drive signal and the second drive signal is set to -Va. Thus, the volume of the pressure chamber CHA is reduced until the amount of ink reaches 0%. Thus, in the seventh drive pattern, an amount equivalent to 50% of ink is discharged from the nozzle 71.

[0069] FIG. 12 is a diagram illustrating an eighth drive pattern.

[0070] In the eighth drive pattern, in the draw period PA, the signal level of both the first drive signal and the second drive signal is set to +Va. Thus, the volume of the pressure chamber CHA is expanded until the amount of ink reaches 100%. In the eighth drive pattern, in the push period PB, the signal level of the first drive signal is set to -Va, and the signal level of the second drive signal is set to 0. Thus, the volume of the pressure chamber CHA is reduced until the amount of ink reaches 25%. Thus, in the eighth drive pattern, an amount equivalent to 75% of ink is discharged from the nozzle 71.

[0071] FIG. 13 is a diagram illustrating a ninth drive pattern.

[0072] In the ninth drive pattern, in the draw period PA, the signal level of the first drive signal is set to +Va, and the signal level of the second drive signal is set to 0. Thus, the volume of the pressure chamber CHA is expanded until the amount of ink reaches 75%. In the ninth drive pattern, in the push period PB, the signal level of both the first drive signal and the second drive signal is set to -Va. Thus, the volume of the pressure chamber CHA is reduced until the amount of ink reaches 0%. Thus, in the ninth drive pattern, an amount equivalent to 75% of ink is discharged from the nozzle 71.

[0073] FIG. 14 is a diagram illustrating a tenth drive pattern.

[0074] In the tenth drive pattern, in the draw period PA, the signal level of both the first drive signal and the second drive signal is set to +Va. Thus, the volume of the pressure chamber CHA is expanded until the amount of ink reaches 100%. In the tenth drive pattern, in the push period PB, the signal level of both the first drive signal and the second drive signal is set to -Va. Thus, the volume of the pressure chamber CHA is reduced until the amount of ink reaches 0%. Thus, in the tenth drive pattern, an amount equivalent to 100% of ink is discharged from the nozzle 71.

[0075] As described above, in the first to fourth drive patterns illustrated in FIGS. 5 to 8, the amount of ink droplets discharged is the same. In the fifth to seventh drive patterns illustrated in FIGS. 9 to 11, the amount of ink droplets discharged is the same, and the amount is twice the amount in the first to fourth drive patterns. In the eighth and ninth drive patterns illustrated in FIGS. 12 and 13, the amount of ink droplets discharged is the same, and the amount is three times the amount in the first to fourth drive patterns. In the tenth drive pattern illustrated in FIG. 14, the amount of ink droplets discharged is four times the amount in the first to fourth drive patterns.

[0076] On the other hand, the first drive signal and the second drive signal include drive signals having the same waveform such as the first drive signal of the first drive pattern and the second drive signal of the second drive pattern. When summarized, there are six types of waveforms for the first drive signal and the second drive signal.

[0077] FIG. 15 is a diagram illustrating six types of waveforms of the first drive signal and the second drive signal.

[0078] It should be noted that FIG. 15 also illustrates the signal level for returning to the neutral state after the push period PB.

[0079] The drive signal SA corresponds to the second drive signal of the second drive pattern, the second drive signal of the third drive pattern, and the second drive signal of the sixth drive pattern. The drive signal SB corresponds to the first drive signal of the first drive pattern, the first drive signal of the second drive pattern, the first drive signal of the fifth drive pattern, the second drive signal of the fifth drive pattern, and the second drive signal of the eighth drive pattern. The drive signal SC corresponds to the second drive signal of the first drive pattern. The drive signal SD corresponds to the first drive signal of the fourth drive pattern. The drive signal SE corresponds to the first drive signal of the third drive pattern, the second drive signal of the fourth drive pattern, the first drive signal of the seventh drive pattern, the second drive signal of the seventh drive pattern, and the second drive signal of the ninth drive pattern. The drive signal SF corresponds to the first drive signal of the sixth drive pattern, the first drive signal of the eighth drive pattern, the first drive signal of the ninth drive pattern, the first drive signal of the tenth drive pattern, and the second drive signal of the tenth drive pattern.

[0080] The plurality of drive signals generated by the waveform generator 82 are the above-described six types of drive signals SA to SF. Thus, the waveform generator 82 is an example of the generation unit.

[0081] As described above, in the inkjet head 110, gradation reproduction with four gradations is possible by multi-drop. In the printer 100 of the present embodiment, 16-step gradation recording is possible by forming one pixel by discharging ink droplets four times. Then, pixel data included in the line data represents gradation values of "0" to "15", respectively.

[0082] FIG. 16 is a diagram schematically illustrating the contents of the look-up table built in the LUT converter 835.

[0083] The lookup table illustrated in FIG. 16 indicates which of the drive signals SA to SF is to be supplied as the first drive signal and the second drive signal, in order to achieve the gradation value, for each of the first to fourth drops, in correlation with the gradation value.

[0084] If pixel data is given from the pixel separator 81, the LUT converter 835 controls the selectors 831 and 832 such that each drive signal correlated with the gradation value represented by the pixel data is sequentially selected.

[0085] For example, if the gradation value represented by the given pixel data is "1", the LUT converter 835 controls the selectors 831 and 832 such that the drive signal SB and the drive signal SA are output as the first drive signal and the second drive signal, for the first drop. Further, the LUT converter 835 controls the selectors 831 and 832 such that the drive signal SA is output as the first drive signal and the second drive signal, for the second drop to the fourth drop. That is, the LUT converter 835 controls the selectors 831 and 832 to cause ink discharge according to the second drive pattern, as the first drop, and not to cause ink discharge as the second to fourth drops. Thus, one pixel is formed by the above-described amount of ink corresponding to 25%. The amount of ink discharged at this time is referred to as a unit amount.

[0086] For example, if the gradation value represented by the given pixel data is "2", the LUT converter 835 controls the selectors 831 and 832 such that the drive signal SB is output as the first drive signal and the second drive signal, for the first drop. That is, the LUT converter 835 causes ink discharge according to the fifth drive pattern, as the first drop. The LUT converter 835 controls the selectors 831 and 832 so as not to cause ink discharge as described above, as the second to fourth drops. Thus, one pixel is formed by the above-described amount equivalent to 50%, that is, an amount twice the unit amount of ink.

[0087] For example, if the gradation value represented by the given pixel data is "3", the LUT converter 835 controls the selectors 831 and 832 such that the drive signal SF and the drive signal SE are output as the first drive signal and the second drive signal, for the first drop. That is, the LUT converter 835 causes ink discharge according to the ninth drive pattern, as the first drop. The LUT converter 835 controls the selectors 831 and 832 so as not to cause ink discharge as described above, as the second to fourth drops. Thus, one pixel is formed by the above-described amount equivalent to 75%, that is, an amount three times the unit amount of ink.

[0088] For example, if the gradation value represented by the given pixel data is "4", the LUT converter 835 controls the selectors 831 and 832 such that the drive signal SF is output as the first drive signal and the second drive signal, for the first drop. That is, the LUT converter 835 causes ink discharge according to the tenth drive pattern, as the first drop. The LUT converter 835 controls the selectors 831 and 832 so as not to cause ink discharge as described above, as the second to fourth drops. Thus, one pixel is formed by the above-described amount equivalent to 100%, that is, an amount four times the unit amount of ink.

[0089] For example, if the gradation value represented by the given pixel data is "5", the LUT converter 835 controls the selectors 831 and 832 such that the drive signal SF is output as the first drive signal and the second drive signal, for the first drop. The LUT converter 835 controls the selectors 831 and 832 such that the drive signal SB and the drive signal SA are output as the first drive signal and the second drive signal, for the second drop. That is, the LUT converter 835 causes ink discharge according to the tenth drive pattern as the first drop, and causes ink discharge according to the second drive pattern as the second drop. The LUT converter 835 controls the selectors 831 and 832 so as not to cause ink discharge as described above, as the third and fourth drops. Thus, one pixel is formed by a total of five times the unit amount of ink, by discharging four times the unit amount of ink and discharging the unit amount of ink as described above.

[0090] For example, if the gradation value represented by the given pixel data is "10", the LUT converter 835 controls the selectors 831 and 832 such that the drive signal SF is output as the first drive signal and the second drive signal, for the first and second drops. The LUT converter 835 controls the selectors 831 and 832 such that the drive signal SB is output as the first drive signal and the second drive signal, for the third drop. That is, the LUT converter 835 causes ink discharge according to the tenth drive pattern as the first and second drops, and causes ink discharge according to the fifth drive pattern as the third drop. The LUT converter 835 controls the selectors 831 and 832 so as not to cause ink discharge as described above, as the fourth drop. Thus, one pixel is formed by a total of 10 times the unit amount of ink, by discharging four times the unit amount ink twice and discharging twice the unit amount of ink as described above.

[0091] For example, if the gradation value represented by the given pixel data is "15", the LUT converter 835 controls the selectors 831 and 832 such that the drive signal SF is output as the first drive signal and the second drive signal, for the first to third drops. The LUT converter 835 controls the selectors 831 and 832 such that the drive signal SF and the drive signal SE are output as the first drive signal and the second drive signal, for the fourth drop. That is, the LUT converter 835 causes ink discharge according to the tenth drive pattern as the first to third drops, and causes ink discharge according to the ninth drive pattern as the fourth drop. Thus, one pixel is formed by a total of 15 times the unit amount of ink, by discharging four times the unit amount ink three times and discharging three times the unit amount of ink as described above.

[0092] Thus, the function as a selection unit is implemented by the selectors 831 and 832. The LUT converter 835 is an example of a control unit.

[0093] As described above, the printer 100 implements 16-step gradation recording from 0 to 15 times the unit amount, by combining discharge of a unit amount of ink according to the second drive pattern, discharge of twice the unit amount of ink according to the fifth drive pattern, discharge of three times the unit amount of ink according to the ninth drive pattern, discharge of four times the unit amount of ink according to the tenth drive pattern, and the states in which ink is not discharged.

[0094] Incidentally, in the above specific example, the second drive pattern is used for discharging a unit amount of ink. However, the first, third or fourth drive pattern can also be used by rewriting the look-up table built in the LUT converter 835. For example, by rewriting the look-up table such that the drive signal SC is set as the second drive signal in which the drive signal SB and the drive signal SA are set as the first drive signal and the second drive signal, respectively, the first drive pattern can be used for discharging a unit amount of ink.

[0095] The first to fourth drive patterns are described above as discharging the same amount of ink, but in reality, due to variations in the characteristics of the piezoelectric unit 2, an error may occur in the discharge amount according to each drive pattern for individual inkjet head 110. In this case, it is possible to select and use a drive pattern by which the most preferable discharge amount is achieved, for individual inkjet head 110.

[0096] The same applies to ink discharge of twice or three times the unit amount.

[0097] It is also possible to change the ratio of ink discharge in a plurality of drops by rewriting the lookup table. In this case, if the ink discharge of any one of the unit amount, twice the unit amount, or three times the unit amount is performed by a plurality of different drops, it is possible to apply different drive patterns, respectively. For example, for the gradation value "2", the first drive signal and the second drive signal of the first drop are set as the drive signal SB and the drive signal SA, and the first drive signal and the second drive signal of the second drop are set as the drive signal SD and the drive signal SE, so that pixel formation can be performed by ink of twice the unit amount, by ink discharge of a unit amount according to the third drive pattern and ink discharge of a unit amount according to the fourth drive pattern.

[0098] That is, it is possible to finely adjust the amount of ink used for forming one pixel, by combining different drive patterns.

[0099] Further, for example, if the second drive pattern is always used for discharging a unit amount of ink as described above, the protrusion PRA is deformed more than the protrusion PRB, and the deterioration of the protrusion PRA is significant, which causes a risk that the life of the inkjet head 110 will be shortened. In such a case, if the drive pattern is selected such that the frequency of deformation between the protrusion PRA and the protrusion PRB can be leveled, or if the drive pattern used periodically is changed, a load is distributed to the protrusion PRA and the protrusion PRB to extend the life of the inkjet head 110.

[0100] This embodiment can be modified in various ways as follows.

[0101] For each drive pattern other than the fifth drive pattern, the seventh drive pattern, and the tenth drive pattern, ink can be discharged by any discharge even if the first drive signal and the second drive signal are reversed. Therefore, each of these drive patterns may be replaced with such a reverse drive pattern, or such a reverse drive pattern may be additionally used. It should be noted that such a reverse drive pattern can be easily achieved by rewriting the lookup table.

[0102] The number of drops in multi-drop can be changed freely. This case can also be achieved by changing the look-up table. Further, one pixel may be formed by only one discharge.

[0103] The look-up table may not be included in the drive unit 83. One look-up table may be shared by a plurality of drive units 83. Further, the look-up table may be stored in a storage device provided outside the inkjet head 110, for example, the auxiliary storage unit 103.

[0104] The specific structure of the inkjet head is not limited as long as the inkjet head can discharge ink with the same discharge amount in any of a plurality of drive patterns.

[0105] Some or all of the components of the drive IC 8 may be provided as a drive circuit for the head body in the printer 100 outside the inkjet head 110.

[0106] The droplet discharge device can also be achieved as a printer for other purposes such as for document printing, barcode printing, and printing of certificates such as receipts. Alternatively, the droplet discharge device can also be achieved as a printer for purposes other than image printing, such as for forming a three-dimensional object. Therefore, the liquid to be discharged is not limited to ink, but may be a material for forming an object or the like.

[0107] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the scope of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope of the inventions.

Claims

1. A drive circuit configured to drive a droplet discharge head including a plurality of actuators which deform according to a supplied drive signal to change a volume of a pressure chamber, and discharging liquid from the pressure chamber by changing the volume of the pressure chamber, in which a discharge amount at one time is adapted to be changed to a plurality of stages by combining respective deformation patterns of the plurality of actuators, and at least a part of the plurality of stages is achieved by any of the plurality of combinations of the deformation patterns,

the drive circuit comprising:

a generation unit configured to generate a plurality of the drive signals in parallel for deforming the actuators by a plurality of patterns, in which a part of the plurality of patterns is a plurality of different patterns for achieving respective discharge amounts of the plurality of stages, and the other part of the plurality of patterns is a plurality of different patterns for achieving discharge amounts of a part of the plurality of stages;

a selection unit configured to select and supply one of the plurality of drive signals generated by the generation unit to each of the plurality of actuators; and

a control unit configured to, if any of a plurality of pieces of data representing different discharge amounts is received, control the selection unit so as to supply the drive signal correlated with the received data to each of the plurality of actuators, based on a lookup table showing which of the plurality of drive signals is to be supplied to each of the plurality of actuators in correlation with each of the plurality of pieces of data.

2. The drive circuit according to claim 1, wherein if the plurality of drive signals are represented in the look-up table for one actuator, in correlation with the received data, the control unit controls the selection unit so as to sequentially supply the plurality of drive signals to the corresponding one actuator.

3. The drive circuit according to claim 1 or 2, further comprising:
a storage unit configured to store the lookup table in an updatable manner.

4. A droplet discharge head comprising:

a head body configured to include a plurality of actuators which deform according to a supplied drive signal to change a volume of a pressure chamber, and discharge liquid from the pressure chamber by changing the volume of the pressure chamber, in which a discharge amount at one time is adapted to be changed to a plurality of stages by combining respective deformation patterns of the plurality of actuators, and at least a part of the plurality of stages is achieved by any of the plurality of combinations of the deformation patterns; and
the drive circuit according to any one of claims 1 to 3.

5. A printer comprising:

the droplet discharge head according to claim 4; and
a moving unit configured to move at least one of the head body and paper facing the head body so as to change a relative positional relationship between the head body and the paper.

FIG. 1

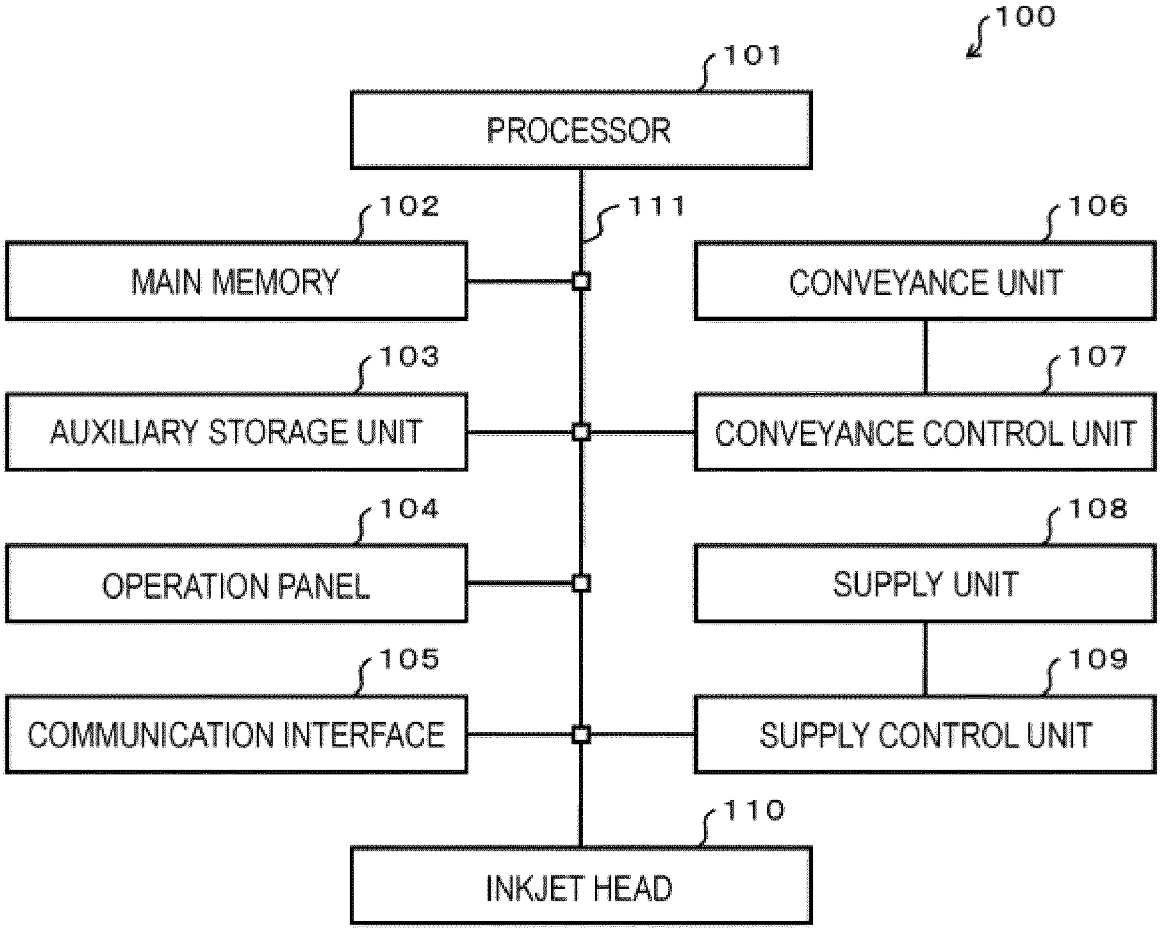
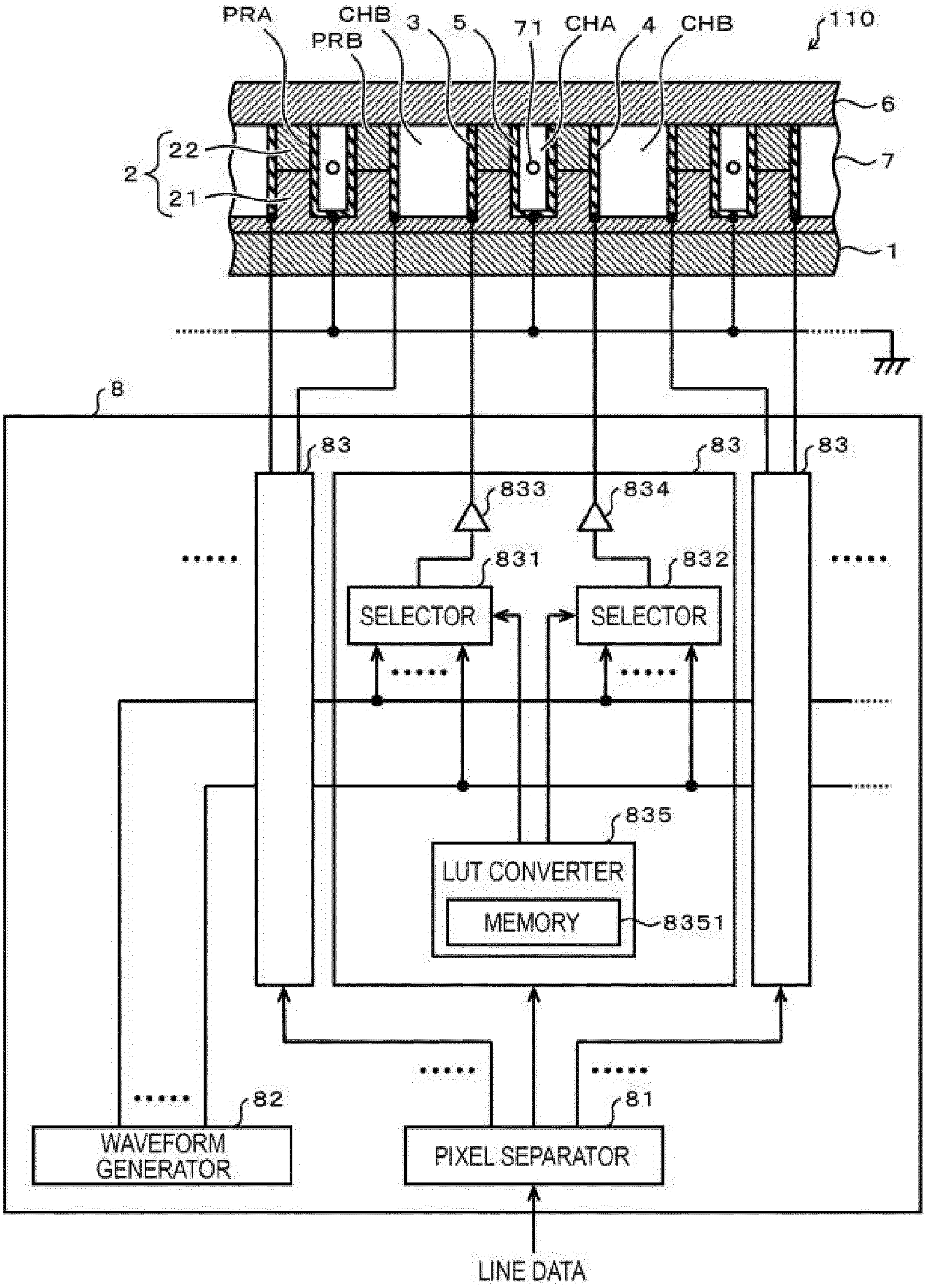

100
101
PROCESSOR
111
102
MAIN MEMORY
106
CONVEYANCE UNIT
103
AUXILIARY STORAGE UNIT
107
CONVEYANCE CONTROL UNIT
104
OPERATION PANEL
108
SUPPLY UNIT
105
COMMUNICATION INTERFACE
109
SUPPLY CONTROL UNIT
110
INKJET HEAD

FIG. 2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CHB
PRB
3
5
71
CHA
4
CHB
110
6
7
1
2
22
21
8
83
83
83
833
834
831
832
SELECTOR
SELECTOR
835
LUT CONVERTER
MEMORY
8351
82
81
WAVEFORM GENERATOR
PIXEL SEPARATOR
LINE DATA

FIG. 3

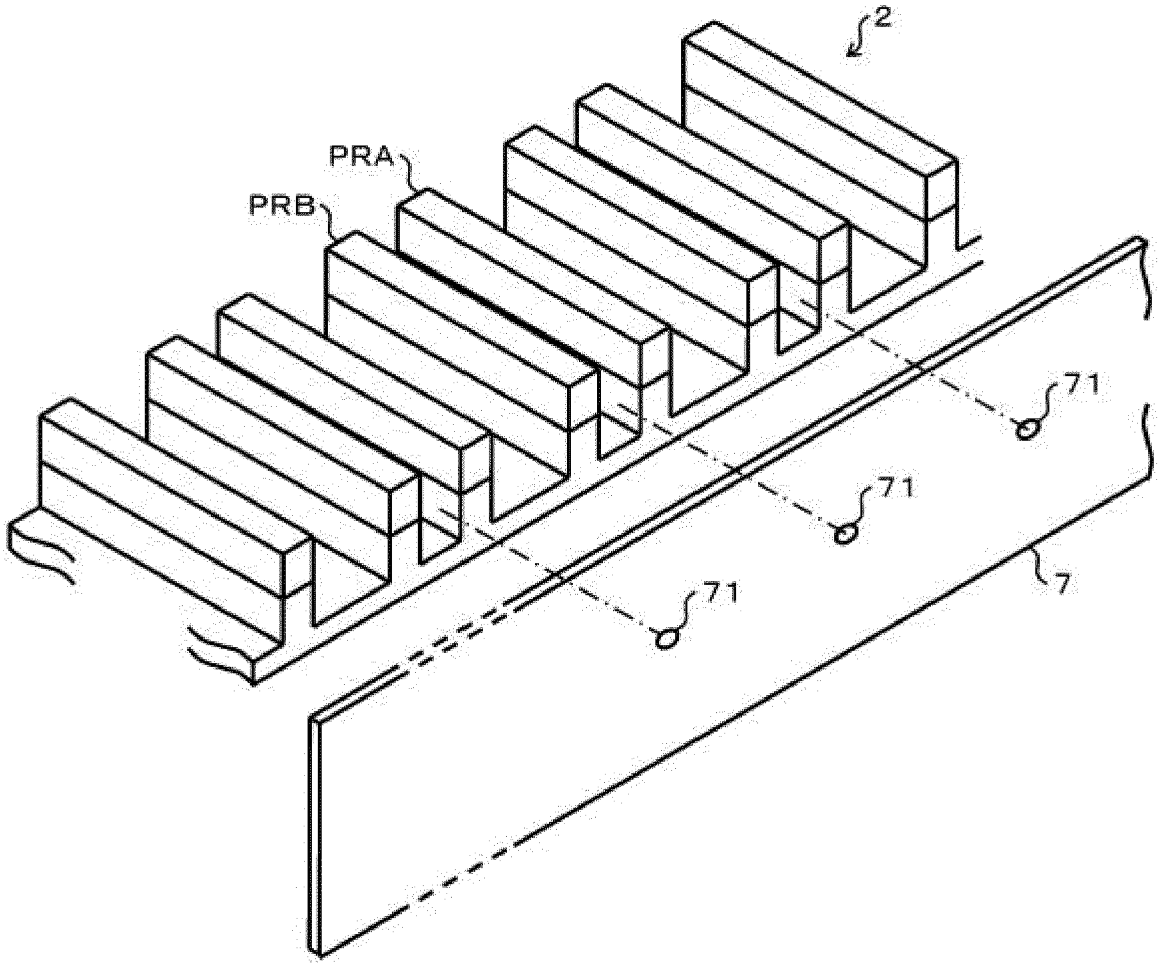

FIG. 4

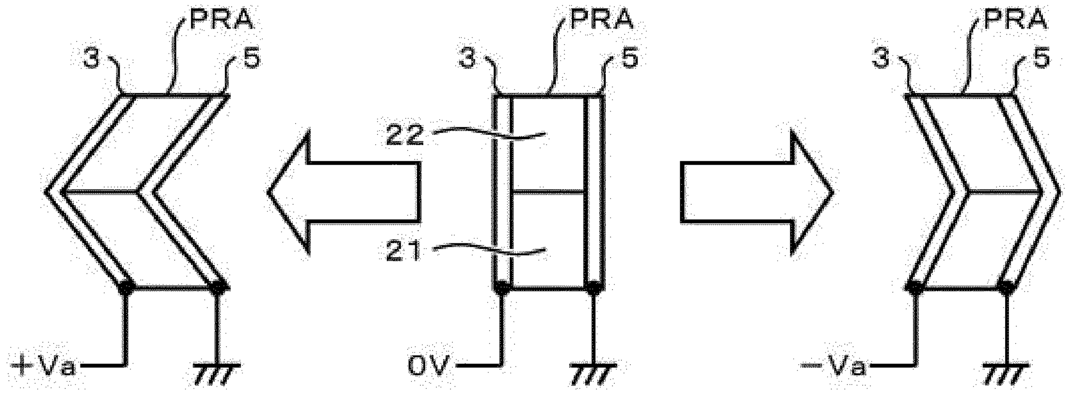

FIG. 5

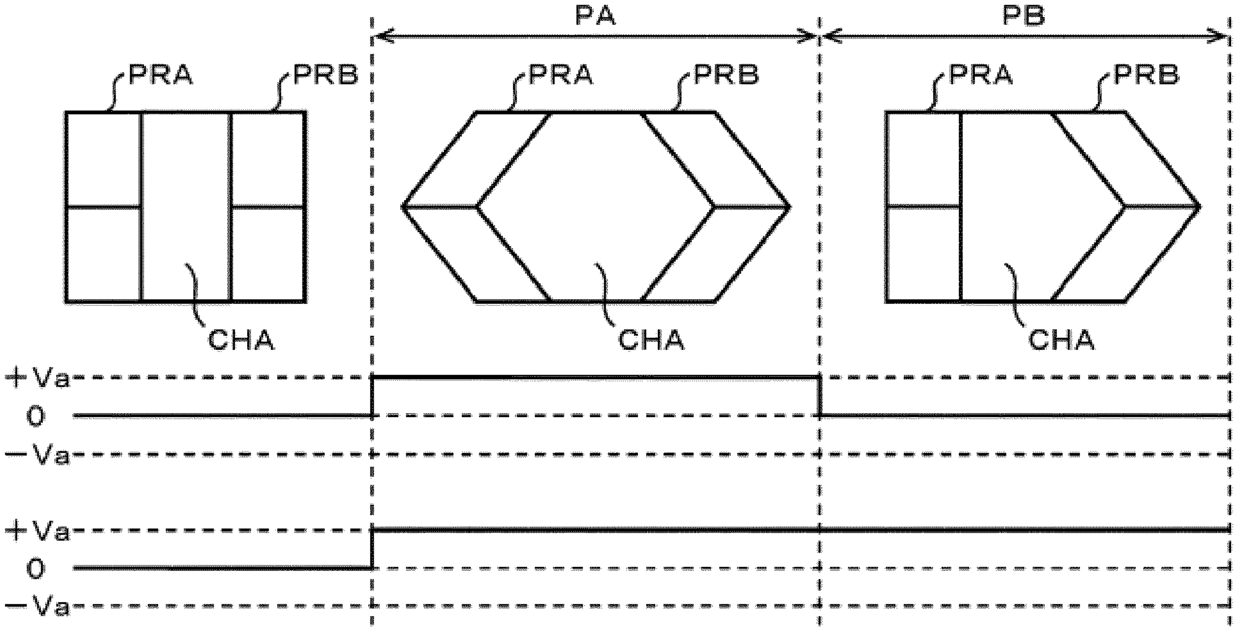
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FIG. 6

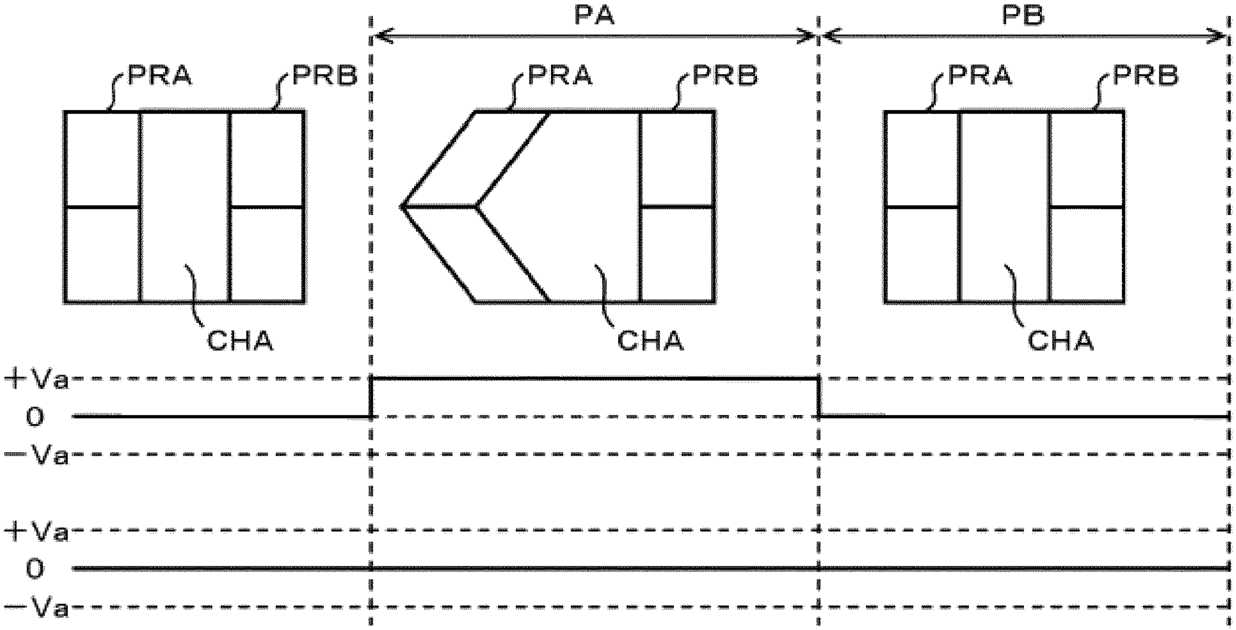
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FIG. 7

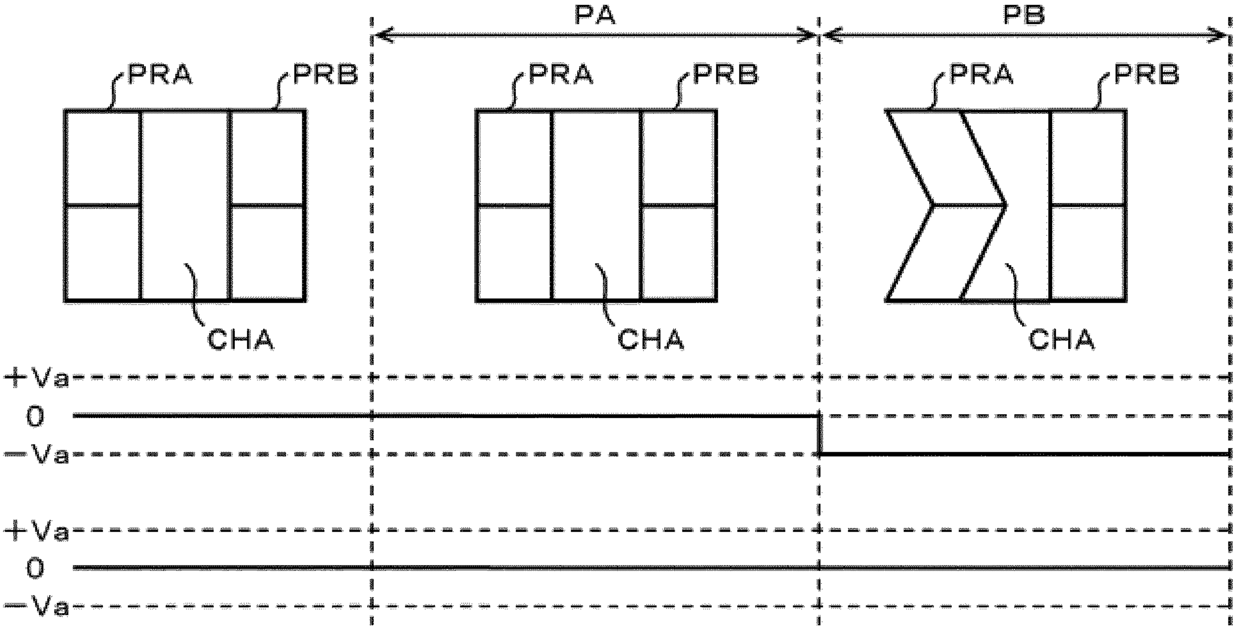
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FIG. 8

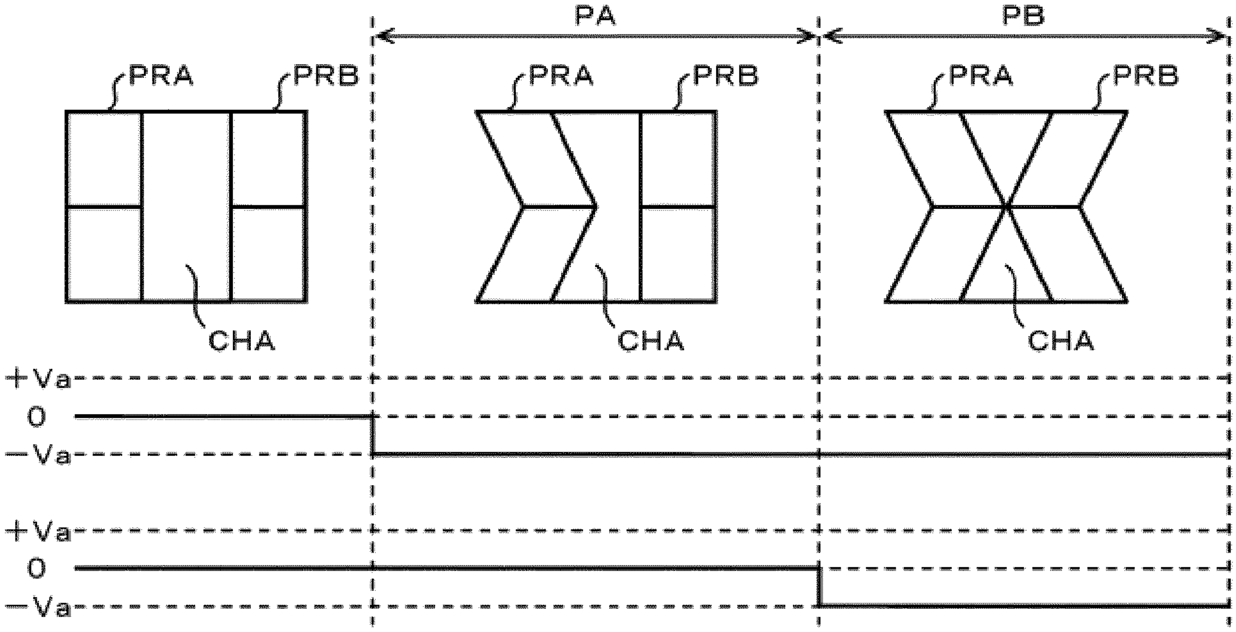
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FIG. 9

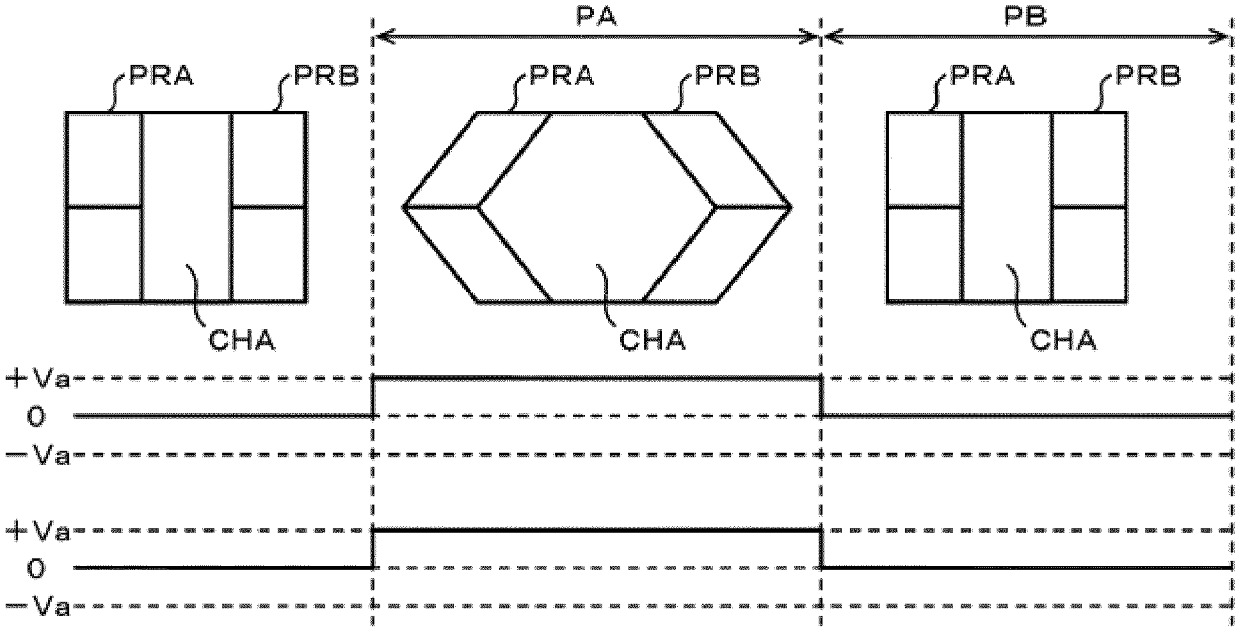
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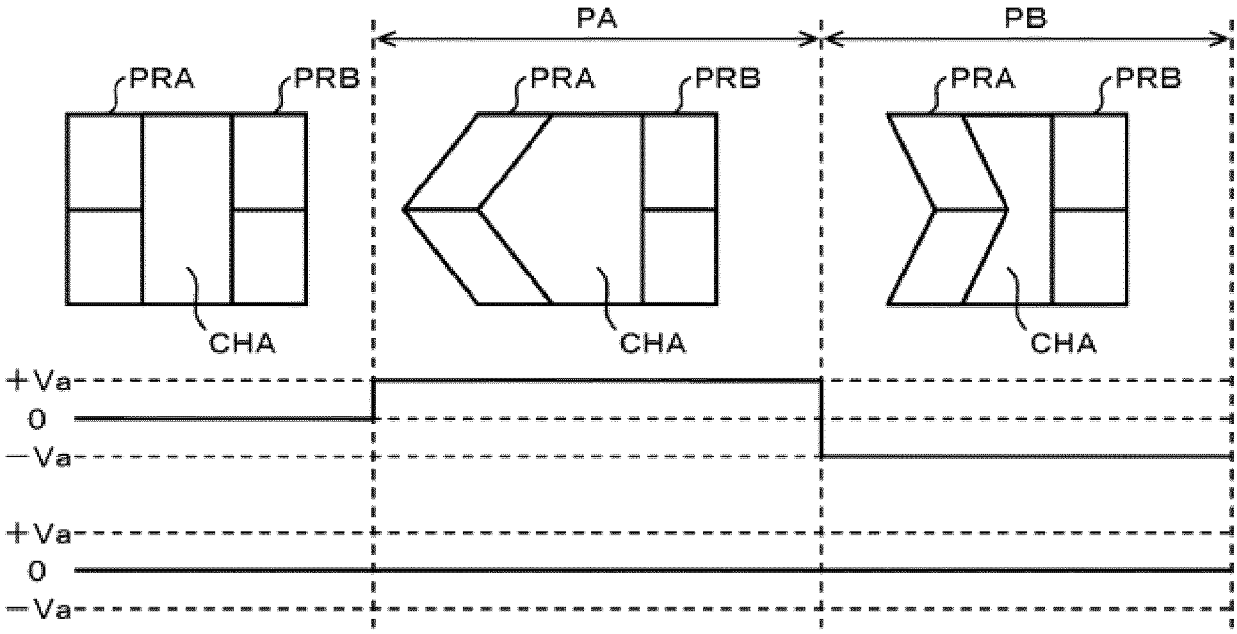
FIG. 10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−Va

FIG. 11

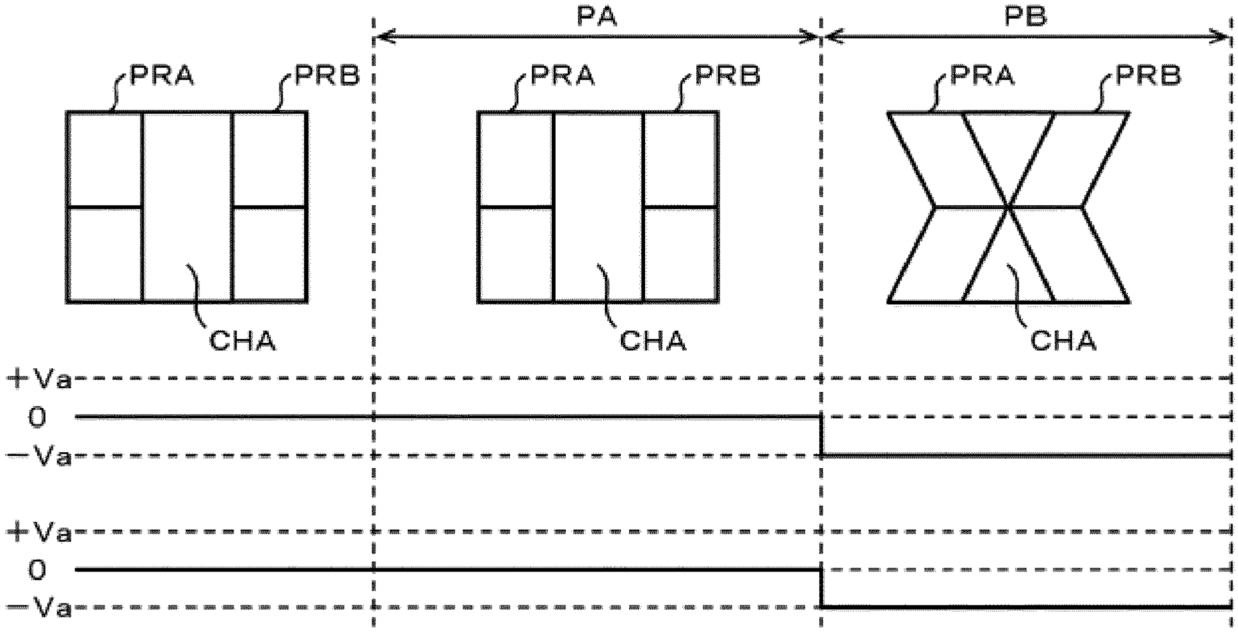
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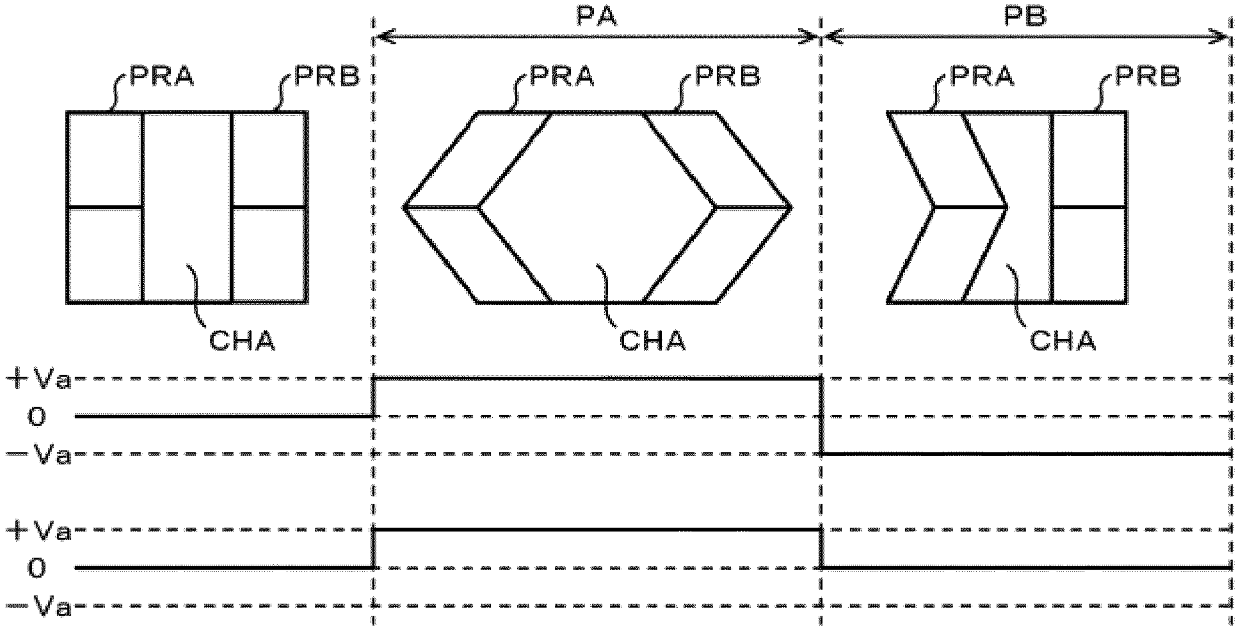
FIG. 12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−Va
+Va
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−Va

FIG. 13

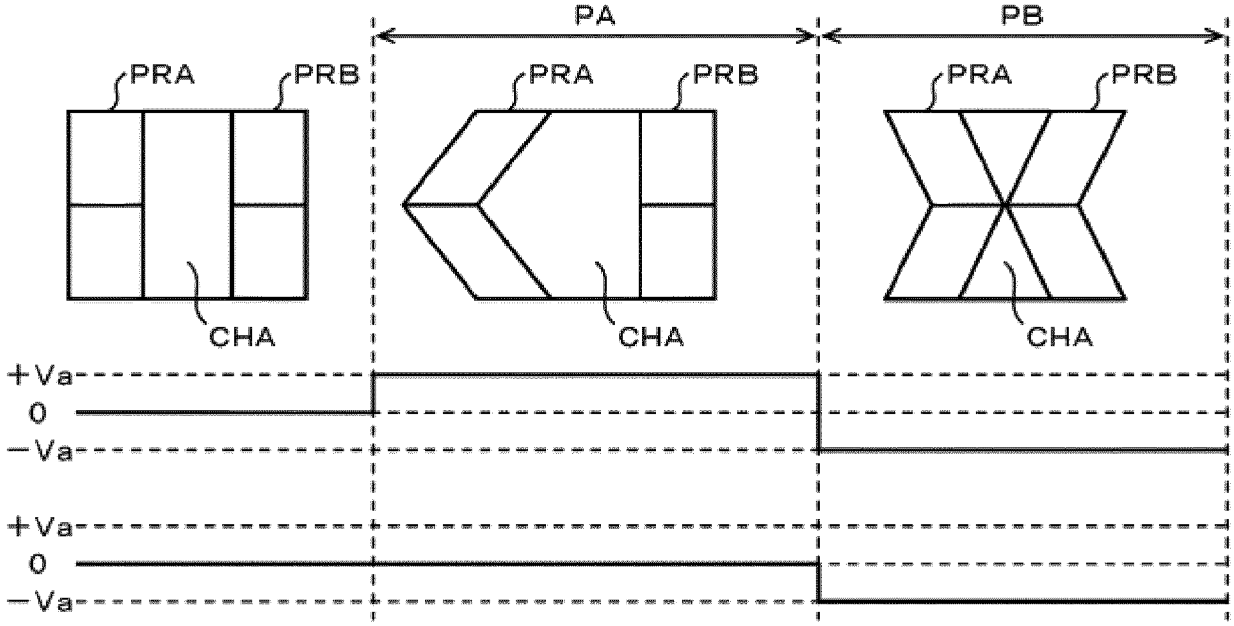

FIG. 14

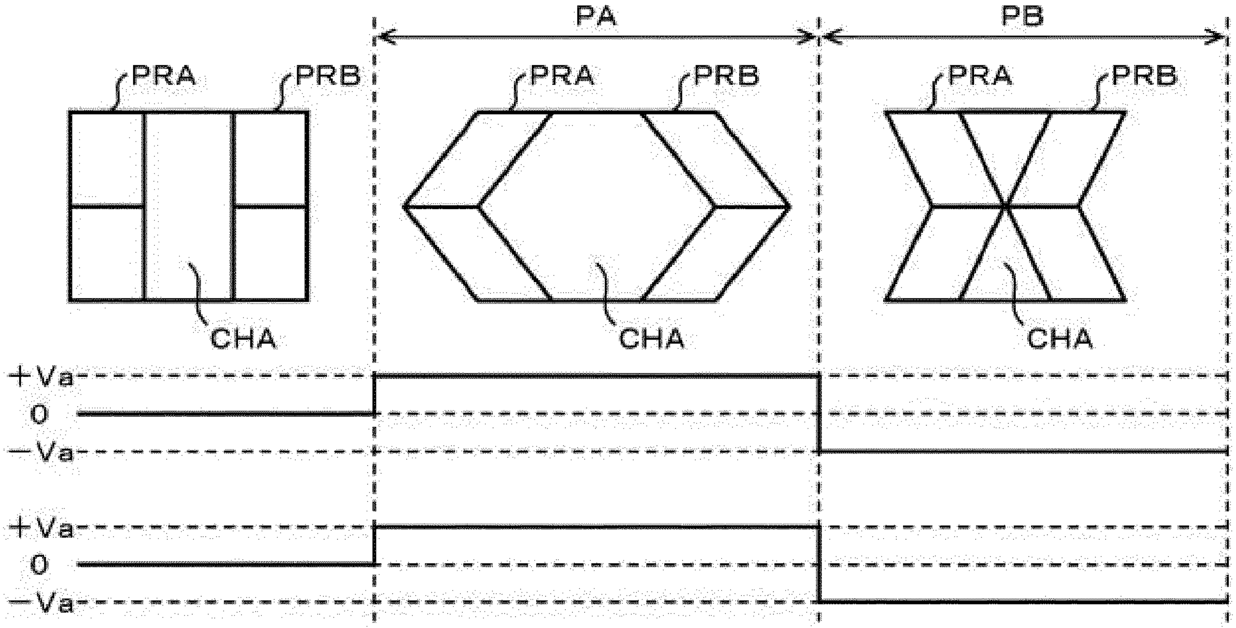

FIG. 15

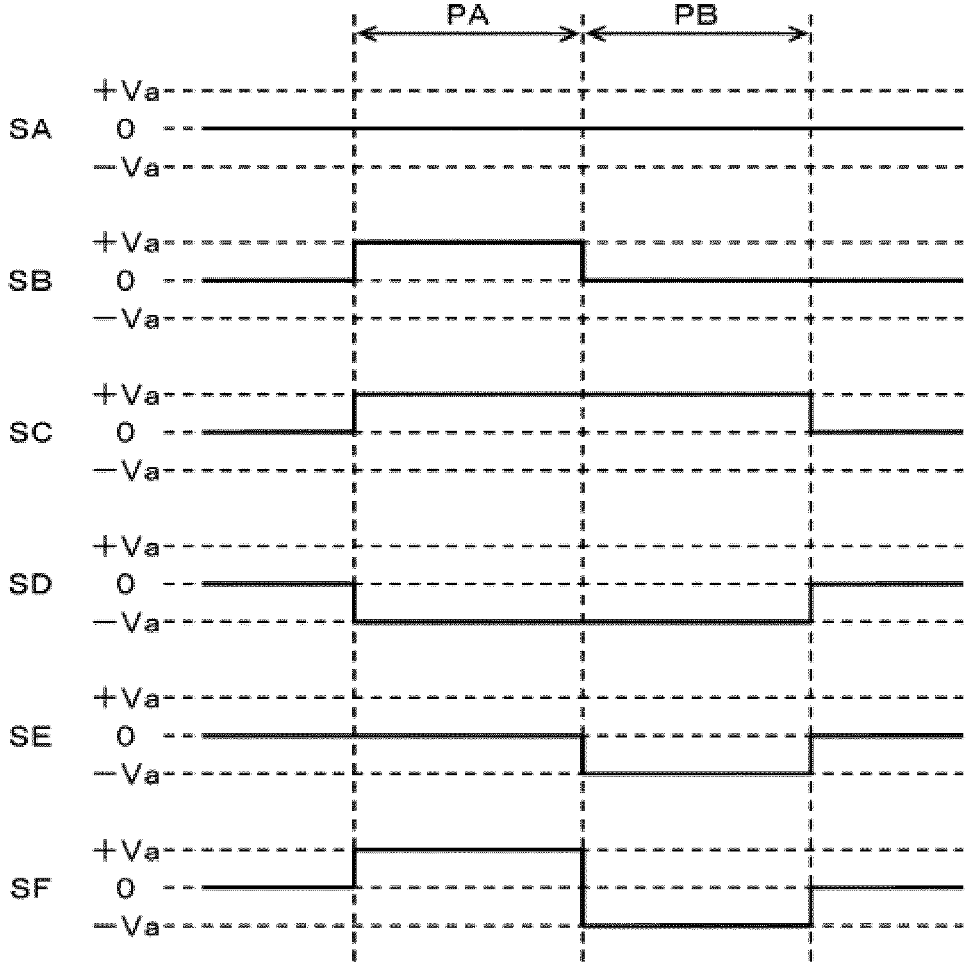

FIG. 16

GRADATION VALUE	FIRST DROP		SECOND DROP		THIRD DROP		FOURTH DROP	
	FIRST	SECOND	FIRST	SECOND	FIRST	SECOND	FIRST	SECOND
0	SA	SA	SA	SA	SA	SA	SA	SA
1	SB	SA	SA	SA	SA	SA	SA	SA
2	SB	SB	SA	SA	SA	SA	SA	SA
3	SF	SE	SA	SA	SA	SA	SA	SA
4	SF	SF	SA	SA	SA	SA	SA	SA
5	SF	SF	SB	SA	SA	SA	SA	SA
6	SF	SF	SB	SB	SA	SA	SA	SA
7	SF	SF	SF	SE	SA	SA	SA	SA
8	SF	SF	SF	SF	SA	SA	SA	SA
9	SF	SF	SF	SF	SB	SA	SA	SA
10	SF	SF	SF	SF	SB	SB	SA	SA
11	SF	SF	SF	SF	SF	SE	SA	SA
12	SF	SF	SF	SF	SF	SF	SA	SA
13	SF	SF	SF	SF	SF	SF	SB	SA
14	SF	SF	SF	SF	SF	SF	SB	SB
15	SF	SF	SF	SF	SF	SF	SF	SE

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EUROPEAN SEARCH REPORT

Application Number
EP 21 20 6529

DOCUMENTS CONSIDERED TO BE RELEVANT

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X A	EP 3 127 705 A1 (KONICA MINOLTA INC [JP]) 8 February 2017 (2017-02-08) * paragraph [0039]; figures 5,11 *	1,3-5 2	INV. B41J2/045
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A	EP 3 228 457 A1 (TOSHIBA TEC KK [JP]) 11 October 2017 (2017-10-11) * figure 5 *	1-5	

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B41J

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	14 April 2022	Bardet, Maude

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EP 21 20 6529

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14-04-2022

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