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(54) Method for operating an inkjet printhead

(57) A method for operating an inkjet print head is provided, wherein a plurality of nozzles is assigned to a group, wherein the group comprises at least four nozzles. A phase is assigned to each nozzle of the group, wherein the group comprises a first sub-array and a second sub-array. The phases are assigned such that the phase subsequently increases along the first sub-array starting from a minimum phase and decreases along the second sub-array of nozzles starting from a maximum phase. A driving signal is provided to the nozzles according to the assigned phases.

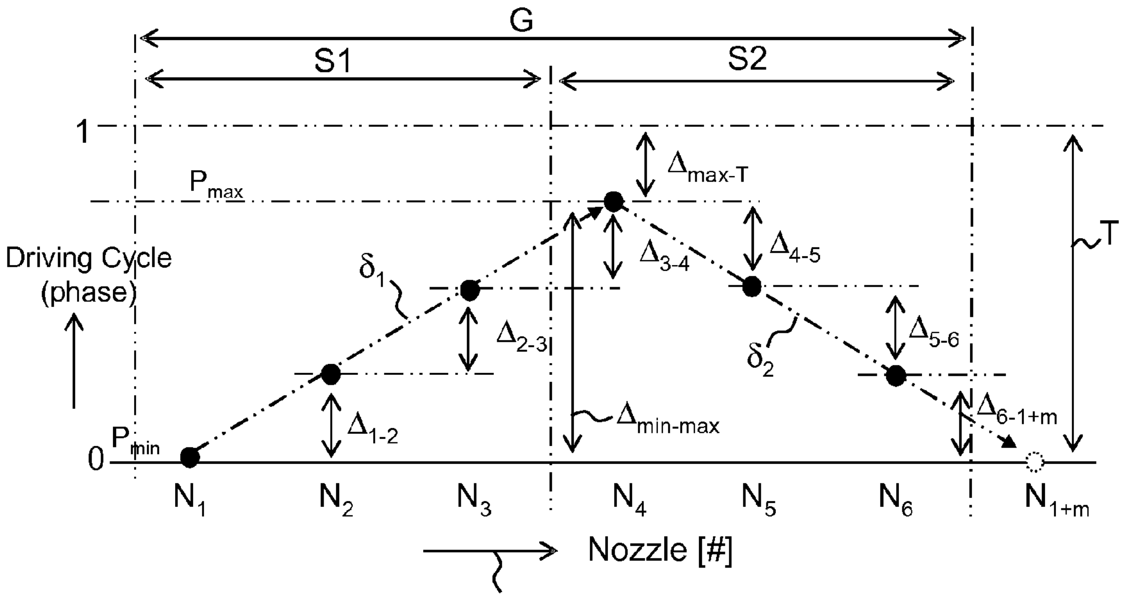

FIG. 4A

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Description

Field of the Invention

[0001] The present invention relates to a method for operating an inkjet print head. The present invention further relates to a control unit for driving at least one print head, the control unit being configured to perform the method for operating the print head according to the method. The present invention further relates to a printing assembly provided with the control unit configured to perform the method for operating at least one print head according to the method. The present invention further relates to a computer readable medium provided with computer executable instructions for having the computer perform the method of the present invention.

Background of the Invention

[0002] From a prior art method for operating an inkjet print head comprising a plurality of nozzles it is known to reduce geometrical cross talk between adjacent pressure chambers by actuating two adjacent pressure chambers shifted in time with respect to each other within a driving period of a frequency of printing.

[0003] In the known method for operating the inkjet print head the plurality of nozzles, which plurality of nozzles is arranged in an array, is assigned to a number of groups, each group comprising a number of sub sequent nozzles along the array. The array of nozzles extends along a line in a first direction.

[0004] The timing of actuation of each nozzle within the driving period of the frequency of printing is referred to as a phase of actuation. The representation of the phases of all nozzles in the first direction of the array of nozzles within the group provides a driving scheme. The nozzles along the array of nozzles within the group have a continuously increasing phase in the first direction as a function of nozzle number. In particular each phase step between two adjacent nozzles is matched with respect to the number of nozzles within the group and with respect to the driving period of the frequency of printing.

[0005] For example in a group having four nozzles consecutively arranged in an array and a drop-on-demand driving period being 18 us, the four nozzles are actuated according to the driving scheme having a consecutive phase of 0 us, 4.5 us, 9 us and 13.5 us along the array of nozzles in the first direction.

[0006] It has been found that a disadvantage of the continuously increasing phase is that a reduction in cross talk is not satisfactory for certain bitmaps, in particular in case pressure chambers are actuated irregularly within a bitmap scheme. Furthermore, when using the known method, the level of geometrical cross talk between adjacent pressure chambers is not accurately predictable at forehand without knowing the contents of the bitmaps.

Summary of the Invention

[0007] It is accordingly an object of the present invention to provide a method for improving the reduction in geometrical cross talk of an inkjet print head for printing bitmaps.

[0008] This object is attained by a method for operating an inkjet print head, the print head comprising a plurality of pressure chambers, each of the plurality of pressure chambers communicating with a nozzle for ejecting ink droplets, the method comprising the steps of:

a) assigning a plurality of nozzles to a group, wherein the group at least comprises a first nozzle, a second nozzle, a third nozzle and a fourth nozzle, all nozzles of the group being arranged consecutively in an array along a first line extending in a first direction,

b) assigning a phase to each nozzle of the group, wherein the group comprises

- a first sub-array of nozzles comprising the first nozzle and the second nozzle being arranged consecutively in the first direction, the first nozzle being assigned a minimum phase, which minimum phase is a lowest phase of all assigned phases within the group; and
- a second sub-array of nozzles comprising the third nozzle and the fourth nozzle being arranged consecutively in the first direction, the third nozzle being assigned a maximum phase, which maximum phase is a highest phase of all assigned phases within the group,

the first sub-array being arranged adjacent to the second sub-array in the first direction,
wherein in the first sub-array the second nozzle and each further nozzle of the first sub-array are assigned a phase in between the minimum phase and the maximum phase such that the phase monotonously increases along the first sub-array in the first direction from the minimum phase towards the maximum phase, wherein in the second sub-array the fourth nozzle and each further nozzle of the second sub-array are assigned a phase in between the maximum phase and the minimum phase such that the phase monotonously decreases along the second sub-array in the first direction from the maximum phase towards the minimum phase; and c) Supplying a driving signal to each nozzle of the group at the assigned phase of said nozzle.

[0009] The inkjet print head comprises a plurality of pressure chambers. The pressure in the pressure chambers may be provided by piezoelectric elements or may be provided by thermal actuation elements or by any other means for providing a pressure in a pressure chamber.

[0010] Each of the pressure chambers communicates with a corresponding nozzle of a plurality of nozzles, i.e. the liquid present in the pressure chamber communicates with the liquid present inside the corresponding nozzle.

The plurality of nozzles may be arranged in one array or may be arranged in a plurality of arrays. The nozzles within an array may be arranged in a linear row of nozzles on a straight line in a first direction. The arrangement of positions of each nozzle within the array may be equidistant between two adjacent nozzles along the first direction of the array or may be arranged in any other way.

[0011] In step a) a plurality of nozzles is assigned to a group, wherein the group at least comprises a first nozzle, a second nozzle, a third nozzle and a fourth nozzle. The group comprises at least four nozzles. The group may comprise a fifth nozzle, a sixth nozzle, etc. All of the nozzles of the group are arranged consecutively in an array along a first line extending in a first direction.

[0012] Step a) may be performed for a plurality of groups, wherein each group may comprise the same number of nozzles. Alternatively step a) may be performed for a plurality of groups, wherein a first group may comprise a number of nozzles different from the number of nozzles of a second group.

[0013] In step b) to each nozzle of the group a phase is assigned. The assigned phase is a timing of actuation of the nozzle within a driving period of the frequency of printing. The assigned phase may be used to drive the group for a plurality of driving cycles.

[0014] The group comprises a first sub-array of nozzles and a second sub-array of nozzles. The first sub-array comprises the first nozzle and the second nozzle. The second nozzle is arranged consecutively adjacent to the first nozzle in the first direction. The first sub-array may comprise a number of nozzles consecutively arranged adjacent to the second nozzle in the first direction.

[0015] The second sub-array comprises the third nozzle and the fourth nozzle. The fourth nozzle is arranged consecutively adjacent to the third nozzle in the first direction. The second sub-array may comprise a number of nozzles consecutively arranged adjacent to the fourth nozzle in the first direction.

[0016] The first sub-array and the second sub-array are arranged consecutively in the first direction. Thus the third nozzle, being the first nozzle in sequence in the first direction along the second sub-array, is arranged subsequently adjacent to the last nozzle of the first sub-array in the first direction.

[0017] The first nozzle is assigned a minimum phase, which minimum phase is a lowest phase of all assigned phases within the group. The first nozzle, which is assigned the minimum phase is a nozzle first in sequence in the first direction along the first sub-array.

[0018] The third nozzle is assigned the maximum phase, which maximum phase is a highest phase of all assigned phases within the group. The third nozzle, which is assigned the maximum phase, is a nozzle first in sequence in the first direction along the second sub-array.

[0019] The second nozzle and each further nozzle of the first sub-array is assigned a phase between the minimum phase and the maximum phase such that the phase monotonously increases along the first sub-array in the first direction from the minimum phase towards the maximum phase.

[0020] Thus along the first sub-array in the first direction the assigned phases of the nozzles monotonously increases. The second nozzle is assigned a phase higher than the minimum phase and lower than the maximum phase. Any further nozzle of the first sub-array in the first direction is assigned a phase higher than the phase of the adjacent nozzle, which is preceding in the first direction, and lower than the maximum phase. The fourth nozzle and each further nozzle of the second sub-array is assigned a phase in between the maximum phase and the minimum phase such that the phase monotonously decreases along the second sub-array in the first direction from the maximum phase towards the minimum phase.

[0021] Thus, along the second sub-array in the first direction, the assigned phases of the nozzles decrease monotonously. The fourth nozzle is assigned a phase lower than the maximum phase and higher than the minimum phase. Any further nozzle of the second sub-array in the first direction is assigned a phase lower than the phase of the adjacent nozzle, which is preceding in the first direction, and higher than the minimum phase.

[0022] The first sub-array is arranged adjacent to the second sub-array along the first direction. The first sub-array may be arranged prior to the second sub-array along the first direction. As a result the phase in the first direction consecutively increases along the first sub-array starting from the minimum phase and decreases along the subsequent second sub-array starting from the maximum phase.

[0023] Alternatively the second sub-array may be arranged prior to the first sub-array along the first direction. As a result the phase in the first direction consecutively decreases along the second sub-array starting from the maximum phase and increases along the subsequent first sub-array starting from the minimum phase.

[0024] The phase assigned to a nozzle within a sub-array is different from each phase assigned to any other nozzle within the same sub-array. The phase assigned to a nozzle of the first sub-array, other than the first nozzle which is assigned the minimum phase, may be the same as a phase assigned to a nozzle of the second sub-array, other than the third nozzle which is assigned the maximum phase. Alternatively each of the nozzles within the group may be assigned a phase different from the phase assigned to all other nozzles within the group.

[0025] In step c) a driving signal is supplied to each nozzle of the group at the assigned phase of said nozzle. The driving signal is supplied in each driving cycle of the frequency of printing according to the bitmap to be printed. The driving signal may actuate a pressure chamber for ejecting one droplet from the corresponding nozzle or may actuate the pressure chamber for ejecting a plurality of droplets.

[0026] In case of printing bitmaps, the method of operating the print head according to the invention provides a more consistent reduction of geometrical cross talk over a variety of bitmaps. When printing a bitmap the level of geometrical cross talk depends on the instantaneous geometrical cross talk at a certain moment in printing and depends also on a short-term history of actuation of a certain nozzle and its adjacent nozzles.

[0027] It has been found that the present method provides a robust geometrical cross talk reduction being less sensitive to a short-term history of actuation. The method according to the present invention is also able to improve inkjet printing of bitmaps for high coverage applications such as photographic applications and display graphics.

[0028] In an embodiment of the method, step a) is performed to compose a plurality of groups which are arranged consecutively along the first line in the first direction and wherein step b) and step c) is performed for each of the plurality of groups. This provides a consistent printing quality over an image by providing a reduction in geometrical cross talk over a plurality of groups within the nozzle array.

[0029] In a further embodiment of the method, wherein in step a) each of the plurality of groups comprises the same number of nozzles. This embodiment supports a simple algorithm for assigning phases to all nozzles of the plurality of groups and supports the printing quality of a variety of printing modes wherein an image is formed by inter mixing a plurality of sub-images. For example a printing mode in which each sub-image is provided by a different group of the nozzle array.

[0030] In a particular embodiment in step b) each of the phases assigned to the nozzles of a first one of the plurality of groups, is the same in value and order as each of the phases assigned to the nozzles of a second one of the plurality of groups. This increases even further the printing quality of a printing mode, wherein an image is formed by inter mixing a plurality of sub-images. For example a printing mode in which a first sub-image is provided by a different group of nozzles than a group of nozzles for providing a second sub-image.

[0031] In another embodiment of the method, in step b) an inter nozzle phase step, which is a difference between the phases assigned to two adjacent nozzles, is substantially constant for each two adjacent nozzles of one of the first sub-array and the second sub-array. This embodiment supports a simple driving method for supplying a driving signal to all nozzles of the sub-array and supports the printing quality of a variety of printing modes.

[0032] In a further embodiment of the method, in step b) an inter sub-array phase step, which is a difference between the phase assigned to a nozzle last in sequence of the first sub-array in the first direction and the phase assigned to the third nozzle, which is a nozzle first in sequence of the second sub-array in the first direction, is the same as each of the inter nozzle phase steps in the first sub-array. As a result the nozzles, starting from the first nozzle and ending with the third nozzle, are assigned a phase which increases constantly along the array in the first direction from the minimum phase to the maximum phase. This embodiment even further improves the printing quality for a variety of printing modes for a variety of bitmaps.

[0033] In a further embodiment of the method, wherein in step b) each of the inter nozzle phase steps in the first sub-array is the same in absolute value as each of the inter nozzle phase steps in the second sub-array. This embodiment supports a simplification of the driving method for supplying a driving signal to all nozzles of the sub-array and supports the printing quality for a variety of printing modes.

[0034] In a particular embodiment of the method, wherein in step b) the phases are assigned such that the maximum phase plus the absolute value of the inter nozzle phase step is substantially equal to the driving period. In this particular embodiment the minimum phase is equal to a zero phase within the driving period (i.e. the start of the driving period). This embodiment enables an efficient use of the driving period for supplying a driving signal to each of the nozzles within the group, thereby enabling a high frequency of printing.

[0035] In a further embodiment of the method, in step b) each of the inter nozzle phase steps in the first sub-array is different in absolute value from each of the inter nozzle phase steps in the second sub-array. Each of the inter nozzle phase steps in the first sub-array may be larger in absolute value than each of the inter nozzle phase steps in the second sub-array. Alternatively each of the inter nozzle phase steps in the first sub-array may be smaller in absolute value than each of the inter nozzle phase steps in the second sub-array.

[0036] In another embodiment of the method, in step b) the phases along the array of nozzles in the first direction are assigned according to samples of a predetermined wave form function. This embodiment supports a simple algorithm for assigning a variety of phases to each nozzle of the group.

[0037] In another embodiment of the method, wherein in step c) a duration of the driving signal, which comprises a driving pulse, is equal to or smaller than each of the phase steps, which is a difference between the phases assigned to two adjacent nozzles, in the group. As a result driving signals of adjacent nozzles do not have an overlap in time. This provides a further reduction in geometrical cross talk.

[0038] In another aspect of the invention a control unit for driving at least one print head is provided, the control unit being configured to perform the method for operating the at least one print head according to the method of the present invention.

[0039] In another aspect of the invention a printing assembly comprising at least one print head is provided with the control unit according to the present invention which is configured to perform the method of to the present invention for operating at least one print head of the printing assembly.

[0040] In another aspect of the invention a computer readable medium is provided with computer executable instructions for having the computer perform the method according to the present invention.

[0041] Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating embodiments of the invention, are given by way of illustration only, since various changes and modifications within the scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042] The present invention will become more fully understood from the detailed description given herein below and the accompanying schematical drawings which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:

Fig. 1A	shows an image forming apparatus, wherein printing is achieved using a wide format inkjet printer.
Fig. 1 B	shows an ink jet printing assembly.
Fig. 1C - 1 E	are views showing nozzles being assigned to a plurality of groups, a driving scheme of a group of nozzles, and a number of driving cycles of two groups of nozzles, respectively, according to the prior art.
Fig. 2A - 2B	shows two examples of nozzles being assigned to a number of groups.
Fig. 3A - 3B	show a driving scheme of a group of nozzles according to a first embodiment of the invention.
Fig. 4A - 4B	are views showing a driving scheme of a group of nozzles and a number of driving cycles of two groups of nozzles, respectively, according to a second embodiment of the invention.
Fig. 5	shows a driving scheme of a group of nozzles according to a third embodiment of the invention.
Fig. 6A	shows a driving scheme of a group of nozzles according to a fourth embodiment of the invention.
Fig. 6B	shows a driving scheme of a group of nozzles according to a fifth and a sixth embodiment of the invention.
Fig. 7A - 7D	are views showing a driving signal for driving a nozzle, nozzles being assigned to three groups of nozzles, a driving scheme for the three groups of nozzles, and the ejected droplets of the three groups of nozzles using the driving scheme, respectively, according to the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0043] The present invention will now be described with reference to the accompanying drawings, wherein the same reference numerals have been used to identify the same or similar elements throughout the several views.

[0044] Fig. 1A shows an image forming apparatus 11, wherein printing is achieved using a wide format inkjet printer. The wide-format image forming apparatus 11 comprises a housing 16, wherein the printing assembly, for example the ink jet printing assembly shown in Fig. 1 B is placed. The image forming apparatus 11 also comprises a storage means for storing image receiving member 18, 19, a delivery station to collect the image receiving member 18, 19 after printing and storage means for marking material 15. In

[0045] Fig. 1A, the delivery station is embodied as a delivery tray 17. Optionally, the delivery station may comprise processing means for processing the image receiving member 18, 19 after printing, e.g. a folder or a puncher. The wide-format image forming apparatus 11 furthermore comprises means for receiving print jobs and optionally means for manipulating print jobs. These means may include a user interface unit 14 and/or a control unit 13, for example a computer.

[0046] Images are printed on a image receiving member, for example paper, supplied by a roll 18, 19. The roll 18 is supported on the roll support R1, while the roll 19 is supported on the roll support R2. Alternatively, cut sheet image receiving members may be used instead of rolls 18, 19 of image receiving member. Printed sheets of the image receiving member, cut off from the roll 18, 19, are deposited in the delivery tray 17.

[0047] Each one of the marking materials for use in the printing assembly are stored in four containers 15 arranged in fluid connection with the respective print heads for supplying marking material to said print heads.

[0048] The local user interface unit 14 is integrated to the print engine and may comprise a display unit and a control panel. Alternatively, the control panel may be integrated in the display unit, for example in the form of a touch-screen control panel. The local user interface unit 14 is connected to a control unit 13 placed inside the printing apparatus 11. The control unit 13, for example a computer, comprises a processor adapted to issue commands to the print engine, for example for controlling the print process. The image forming apparatus 11 may optionally be connected to a network S. The connection to the network S is diagrammatically shown in the form of a cable 12, but nevertheless, the connection could be wireless. The image forming apparatus 11 may receive printing jobs via the network. Further, optionally, the controller of the printer may be provided with a USB port, so printing jobs may be sent to the printer via this USB port.

[0049] Fig. 1 B shows an ink jet printing assembly 3. The ink jet printing assembly 3 comprises supporting means for supporting an image receiving member 2. The supporting means are shown in Fig. 1 B as a platen 1, but alternatively, the supporting means may be a flat surface. The platen 1, as depicted in Fig. 1B, is a rotatable drum, which is rotatable about its axis as indicated by arrow Y. The supporting means may be optionally provided with suction holes for holding the image receiving member in a fixed position with respect to the supporting means. The ink jet printing assembly 3 comprises print heads 4a - 4d, mounted on a scanning print carriage 5. The scanning print carriage 5 is guided by suitable guiding means 6, 7 to move in reciprocation in the main scanning direction X. Each print head 4a - 4d comprises an nozzle plate 9, which nozzle plate 9 is provided with at least one nozzle 8. The print heads 4a - 4d are configured to eject droplets of marking material onto the image receiving member 2. The platen 1, the carriage 5 and the print heads 4a - 4d are controlled by suitable controlling means 10a, 10b and 10c, respectively.

[0050] The image receiving member 2 may be a medium in web or in sheet form and may be composed of e.g. paper, cardboard, label stock, coated paper, plastic or textile. Alternatively, the image receiving member 2 may also be an intermediate member, endless or not. Examples of endless members, which may be moved cyclically, are a belt or a drum. The image receiving member 2 is moved in the sub-scanning direction Y by the platen 1 along four print heads 4a - 4d provided with a fluid marking material.

[0051] A scanning print carriage 5 carries the four print heads 4a - 4d and may be moved in reciprocation in the main scanning direction X parallel to the platen 1, such as to enable scanning of the image receiving member 2 in the main scanning direction X. Only four print heads 4a - 4d are depicted for demonstrating the invention. In practice an arbitrary number of print heads may be employed. In any case, at least one print head 4a - 4d per color of marking material is placed on the scanning print carriage 5. For example, for a black-and-white printer, at least one print head 4a - 4d, usually containing black marking material is present. Alternatively, a black-and-white printer may comprise a white marking material, which is to be applied on a black image-receiving member 2. For a full-color printer, containing multiple colors, at least one print head 4a - 4d for each of the colors, usually black, cyan, magenta and yellow is present. Often, in a full-color printer, black marking material is used more frequently in comparison to differently colored marking material. Therefore, more print heads 4a - 4d containing black marking material may be provided on the scanning print carriage 5 compared to print heads 4a - 4d containing marking material in any of the other colors. Alternatively, the print head 4a - 4d containing black marking material may be larger than any of the print heads 4a - 4d, containing a differently colored marking material.

[0052] The carriage 5 is guided by guiding means 6, 7. These guiding means 6, 7 may be rods as depicted in Fig. 1 B. The rods may be driven by suitable driving means (not shown). Alternatively, the carriage 5 may be guided by other guiding means, such as an arm being able to move the carriage 5. Another alternative is to move the image receiving material 2 in the main scanning direction X.

[0053] Each print head 4a - 4d comprises an nozzle plate 9 having at least one nozzle 8, in fluid communication with a pressure chamber containing fluid marking material provided in the print head 4a - 4d. On the nozzle plate 9, a number of nozzles 8 is arranged in a single linear array parallel to the sub-scanning direction Y. Eight nozzles 8 per print head 4a - 4d are depicted in Fig. 1B, however obviously in a practical embodiment several hundreds of nozzles 8 may be provided per print head 4a - 4d, optionally arranged in multiple arrays. As depicted in Fig. 1B, the respective print heads 4a - 4d are placed parallel to each other such that corresponding nozzles 8 of the respective print heads 4a - 4d are positioned in-line in the main scanning direction X. This means that a line of image dots in the main scanning direction X may be formed by selectively activating up to four nozzles 8, each of them being part of a different print head 4a - 4d. This parallel positioning of the print heads 4a - 4d with corresponding in-line placement of the nozzles 8 is advantageous to increase productivity and/or improve print quality. Alternatively multiple print heads 4a - 4d may be placed on the print carriage adjacent to each other such that the nozzles 8 of the respective print heads 4a - 4d are positioned in a staggered configuration instead of in-line. For instance, this may be done to increase the print resolution or to enlarge the effective print area, which may be addressed in a single scan in the main scanning direction. The image dots are formed by ejecting droplets of marking material from the nozzles 8.

[0054] Upon ejection of the marking material, some marking material may be spilled and stay on the nozzle plate 9 of the print head 4a - 4d. The ink present on the nozzle plate 9 may negatively influence the ejection of droplets and the placement of these droplets on the image receiving member 2. Therefore, it may be advantageous to remove excess of ink from the nozzle plate 9. The excess of ink may be removed for example by wiping with a wiper and/or by application of a suitable anti-wetting property of the surface of the nozzle plate, e.g. provided by a coating.

[0055] Fig. 1C - 1 E are views showing nozzles being assigned to a plurality of groups, a driving scheme of a group of nozzles, and a number of driving cycles of two groups of nozzles, respectively, according to the prior art.

[0056] In Fig. 1C the print head 4a comprises a nozzle plate 9 and an array of sixteen nozzles 8 being consecutively arranged in a first direction indicated by arrow L. Each of the nozzles of the array 8 is assigned to one of the four groups G1, G2, G3 and G4. Each group comprises four nozzles consecutively arranged in the first direction as indicated by arrow L. The first group G1 comprises four nozzles indicated by N_1, N_2, N_3 and N_4. The second group G2 comprises four nozzles indicated by N_{1+m}, N_{2+m}, N_{3+m} and N_{4+m}.

[0057] In Fig. 1 D a driving scheme of the first group G1 is shown. Each nozzle in the group G_1 is assigned a phase, which phase is the timing of actuation within a driving period T of a driving cycle. The driving period T of a driving cycle corresponds to a frequency of printing of the array of nozzles. A first nozzle N_1 is assigned a minimum phase P_{min}, which is a lowest phase within the group G_1. In this embodiment the minimum phase is 0, which corresponds to the start of the driving cycle. Each other nozzle within the group G_1 is assigned another phase such that the phase continuously increases (having a constant slope as indicated by arrow c) along the group G_1 of nozzles in the first direction corresponding to increasing nozzle indices (as indicated by arrow L) towards a maximum phase P_{max}, which is a highest phase within the group G_1. A last nozzle N_4 in sequence of the group G_1 in the first direction is assigned the maximum phase P_{max}. A phase step Δ_{1-2} between two adjacent nozzles N_1, N_2 is the same in value as a phase step Δ_{2-3} between two adjacent nozzles N_2, N_3, and is the same in value as a phase step Δ_{3-4} between two adjacent nozzles N_3, N_4. A phase difference $\Delta_{min-max}$ between the minimum phase P_{min} and the maximum phase P_{max} within the group is equal to the sum of the phase steps Δ_{1-2}, Δ_{2-3}, and Δ_{3-4}. A phase difference Δ_{max-T} between the phase of nozzle N_4 (being the maximum phase P_{max}) and the start of the next driving cycle may be selected the same in value as the constant phase steps (Δ_{1-2}, Δ_{2-3}, Δ_{3-4}) between each two adjacent nozzles within the group G_1.

[0058] Fig. 1 E shows a number of driving cycles of two groups of nozzles according to the prior art driving scheme. The two groups of nozzles G1, G2 have the same driving scheme. As a result the phase continuously increases having a constant slope as is indicated by arrow c in Fig. 1 E along the two of groups of nozzles in the first direction L corresponding to increasing nozzle indices.

[0059] Two subsequent driving cycles are illustrated, each driving cycle having a driving period T according to a frequency of printing. A first driving cycle starts at 0 and ends at 1. A second driving cycle starts at 1 and ends at 2. Any subsequent driving cycle may follow likewise in time. A third group G_3 of nozzles may be arranged adjacent to the second group G_2 along the line extending in the first direction L. Likewise any further groups of nozzles may be arranged in the first direction L of the array of nozzles.

[0060] A disadvantage of the driving scheme is that a reduction in cross talk is not satisfactory for certain bitmaps, in particular in case pressure chambers are actuated irregularly within a bitmap scheme. For example if the nozzle N_4 is not actuated in a driving cycle, the continuous line c is locally interrupted. As a result a cross talk towards an adjacent nozzle (N_{1+m}) in the first direction is considerable different from a cross talk between each other two adjacent nozzles within the group G_1 and within the group G_2.

[0061] Fig. 2A - 2B shows two examples of nozzles being assigned to a number of groups. Fig. 2A shows an example of array of nozzles 8 being assigned to a number of groups A1-A6, each group having the same number of nozzles. In this example each group A1-A6 has eight nozzles being arranged consecutively along a line extending in the first direction of the array of nozzles as indicated by arrow L.

[0062] Fig. 2B shows another example of array of nozzles 8 being assigned to a number of groups, wherein each group A1-A3 has a number of nozzles different from the number of nozzles of each group B1-B3. Each group A1-A3 has eight nozzles, which nozzles are arranged consecutively along the line extending in the first direction L. Each group B1-B3 has four nozzles, which nozzles are arranged consecutively along the line extending in the first direction L. Group A and group B are arranged alternating along the line extending in the first direction L.

[0063] Fig. 3A and Fig. 3B show a driving scheme of a group of nozzles according to a first embodiment of the invention. In Fig. 3A the group of nozzles G has five nozzles N_1, N_2, N_3, N_4 and N_5 being arranged consecutively in an array. The group comprises a first sub-array S1 and a second sub-array S2. The first sub-array S1 has three nozzles (N_1, N_2, N_3,). The second sub-array S2 has two nozzles (N_4, N_5).

[0064] Each nozzle in the group G is assigned a phase, which phase is the timing of actuation within a driving period T of a driving cycle. The driving period T of the driving cycle corresponds to a frequency of printing of the array of nozzles. A nozzle N_{1A} first in sequence of the first sub-array S1 is assigned a minimum phase P_{min}, which is a lowest phase within the group G. In this embodiment the minimum phase P_{min} is 0, which corresponds to the start of each driving cycle. Each other nozzle (N_2, N_3) of the first sub-array S1 is assigned another phase such that the phase monotonously increases along the first sub-array S1 in the first direction L towards a maximum phase P_{max}, which is a highest phase within the group G. The assigned phase of each other nozzle (N_2, N_3) of the first sub-array S1 is selected between the maximum phase P_{max} and the minimum phase P_{min}. Thus the phase of nozzle N_2 is selected higher than the phase of nozzle N_1 and is selected lower than the maximum phase P_{max}. The phase of nozzle N_3 is selected higher than the phase of nozzle N_2 and is selected lower than the maximum phase P_{max}. As an example a possible selection of phases for nozzles N_2 and N_3 within these restrictions is indicatively depicted in Fig. 3A.

[0065] Optionally an inter nozzle phase step, which is a difference between the phases assigned to two adjacent nozzles in a sub-array, is selected to be substantially constant for each two adjacent nozzles in the first sub-array S1, such that the phase continuously increases along the first sub-array S1 (having a constant slope as schematically indicated by arrow C_1) in the first direction L from the minimum phase P_{min} towards the maximum phase P_{max}.

[0066] Nozzle N_4, which is first in sequence of the second sub-array S2, is assigned the maximum phase P_{max}. The maximum phase P_{max} is selected such that a phase difference $\Delta_{min-max}$ between the maximum phase P_{max} and the minimum phase P_{min} is smaller than the driving period T. Furthermore an inter sub-array phase step, which is a difference between the phase assigned to a nozzle (N_3) last in sequence of the first sub-array and the phase assigned nozzle (N_4) first in sequence of the second sub-array in the first direction, may in an embodiment be selected to be the same as each inter nozzle phase step in the first sub-array S1.

[0067] The other nozzle N_5 of the second sub-array S2 is assigned another phase such that the phase monotonously decreases along the second sub-array S2 in the first direction L towards the minimum phase. Thus the assigned phase of nozzle N_5 is selected in between the maximum phase P_{max} and the minimum phase P_{min}. As an example a possible selection of phase for nozzle N_5 within these restrictions is indicatively depicted in Fig. 3A.

[0068] In Fig. 3A further a phase of a nozzle N_{1+m} is shown, which is adjacent to nozzle N_5 in the first direction L. Nozzle N_{1+m} may be assigned the same phase P_{min} as the minimum phase of the group G. As a result an inter group phase step, which is a difference between the assigned phase of nozzle (N_5) last in sequence of the group G and the assigned phase of adjacent nozzle N_{1+m}, is the same in direction (i.e. decreasing phase step in the direction L) as each inter nozzle phase step in the second sub-array S2. Optionally the inter nozzle phase step between each two adjacent nozzles in the second sub-array S2 is selected to be constant and is the same in value as the inter group phase step (between nozzle N_5 and nozzle N_{1+m}), such that the phase continuously decreases along the first sub-array S2 (having a constant slope as schematically indicated by arrow C_2) in the first direction L from the maximum phase P_{max} towards the minimum phase P_{min}.

[0069] In fig. 3B the first-sub-array S1 and the second sub-array S2 are shown in a different order in the first direction of the array of nozzles as indicated by arrow L. The second sub-array S2 has two nozzles (N_1, N_2). The first sub-array S1 has three nozzles (N_3, N_4, N_5). Fig. 3A and 3B are both illustrations of the first embodiment of the present invention.

[0070] Both the first sub-array S1 and the second sub-array S2 may in embodiments comprise a different number of nozzles.

[0071] Fig. 4A - 4B are views showing a driving scheme of a group of nozzles and a number of driving cycles of two groups of nozzles, respectively, according to a second embodiment of the invention. In Fig. 4A the group G has six nozzles (N_1, N_2, N_3, N_4, N_5, N_6) being arranged consecutively in an array. The group comprises the two sub-arrays S1 and S2. The first sub-array S1 has three nozzles (N_1, N_2, N_3). The second sub-array S2 has three nozzles (N_4, N_5, N_6).

[0072] Each nozzle in the group G is assigned a phase, which phase is the timing of actuation within a driving period T of a driving cycle. The driving period T of a drive cycle corresponds to a frequency of printing of the array of nozzles.

[0073] The nozzle N_1, which isfirst in sequence of the first sub-array S1, is assigned a minimum phase P_{min}, which is a lowest phase within the group G. In this embodiment the minimum phase P_{min} is 0, which corresponds to the start of a driving cycle. A nozzle N_4, which isfirst in sequence of the second sub-array S2, is assigned a maximum phase P_{max}, which is a highest phase within the group G.

[0074] Each other nozzle (N_2, N_3) of the first sub-array S1 is assigned a phase such that the phase continuously increases along the first sub-array S1 (indicated by arrow δ_1) in the first direction L from the minimum phase P_{min} towards the maximum phase P_{max}.

[0075] An inter nozzle phase step Δ_{1-2} between nozzle N_1 and nozzle N_2 is the same in value as an inter nozzle phase step Δ_{2-3} between nozzle N_2 and nozzle N_3 and the same in value as an inter sub-array phase step Δ_{3-4} between a nozzle N_3 last in sequence of the first sub-array S1 and a nozzle N_4 first in sequence of the second sub-array S1 (i.e. $\Delta_{1-2} = \Delta_{2-3} = \Delta_{3-4}$).

[0076] A phase difference $\Delta_{min-max}$ between the minimum phase P_{min} and the maximum phase P_{max} is equal to the sum of Δ_{1-2}, Δ_{2-3}, and Δ_{3-4}. The phase difference $\Delta_{min-max}$ between the maximum phase P_{max} and the minimum phase P_{min} is selected smaller than the driving period T.

[0077] Each other nozzle N_5, N_6 of the second sub-array S2 is assigned a phase such that the phase continuously decreases along the second sub-array S2 (indicated by arrow δ_2) in the first direction L from the maximum phase P_{max} towards the minimum phase. Thus each of the assigned phases of nozzles N_5, N_6 is between the maximum phase P_{max} and the minimum phase P_{min}. In particular an inter nozzle phase step Δ_{4-5} between nozzle N_4 and nozzle N_5 is the same in value as an inter nozzle phase step Δ_{5-6} between nozzle N_5 and nozzle N_6 and the same in value as an inter group phase step Δ_{6-1+m} between nozzle N_6 and nozzle N_{1+m}, being assigned the minimum phase P_{min} (i.e. $\Delta_{4-5} = \Delta_{5-6} = \Delta_{6-1+m}$).

[0078] Furthermore each of the inter nozzle phase steps in the first sub-array S1 is the same in absolute value as each of the inter nozzle phase steps in the second sub-array S2 (i.e. arrow δ_1 has the same absolute value in slope as arrow δ_2).

[0079] A phase difference Δ_{max-T} between the maximum phase P_{max} of nozzle N_4 and the end of the driving period T is selected to be the same in absolute value as the each of the inter nozzle phase steps in the group (Δ_{1-2}, Δ_{2-3} and Δ_{4-5}, Δ_{5-6}).

[0080] Fig. 4B shows a number of driving cycles of two groups of nozzles according to the second embodiment. The first group G_1 is arranged adjacent to the second group G_2 along the line extending in the first direction L.

[0081] The phase of the nozzles alternatingly rises and falls within each group along the first and second group of nozzles in the first direction L as indicated by arrow δ^. Each of the phase steps (inter nozzle phase steps, inter sub-array phase steps and inter group phase step) between two adjacent nozzles is the same in absolute value along the first group G_1 and the second group G_2.

[0082] Two subsequent driving cycles are illustrated, each driving cycle having a driving period T according to a frequency of printing. The first driving cycle starts at 0 and ends at 1. The second driving cycle starts at 1 and ends at 2. Any subsequent driving cycle may follow likewise in time. A third group of nozzles may be arranged adjacent to the second group G2 along the line extending in the first direction L. Likewise more groups of nozzles may be arranged along the line extending in the first direction L.

[0083] Fig. 5 shows a driving scheme of a group of nozzles according to a third embodiment of the invention. The group of nozzles G has five nozzles (N_1-N_5) being arranged consecutively in an array. The group comprises a first sub-array S1 having three nozzles (N_1-N_3) and a second sub-array S2 having two nozzles (N_4-N_5).

[0084] A nozzle N_1 which is first in sequence of the first sub-array S1, is assigned a minimum phase P_{min}, which is a lowest phase within the group G. In this embodiment the minimum phase P_{min} is 0, which corresponds to the start of each driving cycle. A nozzle N_4, which isfirst in sequence of the second sub-array S2, is assigned a maximum phase P_{max}, which is a highest phase within the group G.

[0085] Each other nozzle (N_2, N_3) of the first sub-array S1 is assigned a phase such that the phase continuously increases along the first sub-array S1 (indicated by arrow δ_1) in the first direction L from the minimum phase P_{min} towards the maximum phase P_{max}. Thus an inter nozzle phase step Δ_{1-2}, Δ_{2-3} between each two adjacent nozzles in the first sub-array S1 is constant in value including an inter sub-array phase step Δ_{3-4} between nozzle N_3 and nozzle N_4 (i.e. $\Delta_{1-2} = \Delta_{2-3} = \Delta_{3-4}$). Alternatively the inter sub-array phase step Δ_{3-4} may be selected different in value from each of the inter nozzle phase steps in the first sub-array S1 (i.e. $\Delta_{1-2} = \Delta_{2-3} \neq \Delta_{3-4}$).

[0086] Each other nozzle (N_5) of the second sub-array S2 is assigned a phase such that the phase continuously decreases along the second sub-array S2 (indicated by arrow δ_2) in the first direction L from the maximum phase P_{max} towards the minimum phase P_{min}. In particular an inter nozzle phase step Δ_{4-5} between two adjacent nozzles N_4, N_5 in the second sub-array S2 is the same in value as an inter group phase step Δ_{5-1+m} between nozzle N_5 and a nozzle N_{1+m}, which is assigned the minimum phase P_{min}(i.e. $\Delta_{4-5} = \Delta_{5-i+m}$). Alternatively the inter group phase step Δ_{5-min} may be selected different in value from the inter nozzle phase step Δ_{4-5} in the second sub-array S2 (i.e. $\Delta_{4-5} \neq \Delta_{5-1+m}$).

[0087] In this embodiment each of the inter nozzle phase steps between two adjacent nozzles in the first sub-array S1 is different in absolute value from each of the inter nozzle phase steps between two adjacent nozzles in the second sub-array S2 (i.e. arrow δ_1 has a different absolute value in slope than arrow δ_2).

[0088] A phase difference Δ_{max-T} between the maximum phase P_{max} of nozzle N_4 and the end of the driving period T is selected to be the same in value as each of the inter nozzle phase steps Δ_{1-2}, Δ_{2-3} in the first sub-array S1. Alternatively Δ_{max-T} may be selected to be the same in value as the inter nozzle phase step (Δ_{4-5}) in the second sub-array S2. Or the phase difference Δ_{max-T} may be selected in any other way.

[0089] Fig. 6A shows a driving scheme of a group of nozzles according to a fifth embodiment of the invention. The group of nozzles G has six nozzles (N_1-N_6) being arranged consecutively in an array. The group comprises a first sub-array S1 having three nozzles N_1-N_3 and a second sub-array S2 having three nozzles N_4-N_6. Each nozzle in the group G is assigned a phase.

[0090] A nozzle first in sequence of the first sub-array S1 having index N_1 is assigned a minimum phase P_{min}, which is a lowest phase within the group G. In this embodiment the minimum phase P_{min} is 0, which corresponds to the start of each driving cycle. Each other nozzle (N_2,N_3) of the first sub-array S1 is assigned a phase such that the phase monotonously increases along the first sub-array S1 in the first direction L towards a maximum phase P_{max}, which is a highest phase within the group G.

[0091] A nozzle N_4, which is first in sequence of the second sub-array S2, is assigned a maximum phase P_{max}. A phase difference Δ_{max-T} between the maximum phase P_{max} of nozzle N_4 and the end of the driving period T is at least larger than 0. Each other nozzles (N_5, N_6) of the second sub-array S2 is assigned a phase such that the phase monotonously decreases along the second sub-array S2 in the first direction L towards the minimum phase. A nozzle N_{1+m} is assigned the same phase P_{min} as the minimum phase of the group G. In this embodiment the inter nozzle phase step Δ_{1-2} is substantially equal to the inter group phase step Δ_{6-1+m}, the inter nozzle phase step Δ_{2-3} is substantially equal to the inter nozzle phase step Δ_{4-5} and the inter sub-array phase step Δ_{3-4} is substantially equal to inter nozzle phase step Δ_{4-5}. Furthermore the inter nozzle phase steps Δ_{2-3} and Δ_{5-6} are different in value (e.g. larger) than the inter nozzle phase steps Δ_{1-2} and Δ_{4-5}. As a result the assigned phases are arranged symmetrical between the minimum phase P_{min} and the maximum phase P_{max}.

[0092] Fig. 6B shows a driving scheme of a group of nozzles according to a sixth and a seventh embodiment of the invention. The group of nozzles G has six nozzles (N_1-N_6) being arranged consecutively in an array. The group comprises a first sub-array S1 having three nozzles N_1-N_3 and a second sub-array S2 having three nozzles N_4-N_6. Each nozzle in the group G is assigned a phase.

[0093] A nozzle N_1, first in sequence of the first sub-array S1, is assigned a minimum phase P_{min}, which is a lowest phase within the group G. In this embodiment the minimum phase P_{min} is 0, which corresponds to the start of a driving cycle. Each other nozzle (N_2, N_3) of the first sub-array S1 is assigned a phase such that the phase monotonously increases along the first sub-array S1 in the first direction L towards a maximum phase P_{max}, which is a highest phase within the group G.

[0094] A nozzle N4, first in sequence of the second sub-array S2, is assigned the maximum phase P_{max}. Each other nozzles (N_5, N_6) of the second sub-array S2 is assigned a phase such that the phase monotonously decreases along the second sub-array S2 in the first direction L towards the minimum phase.

[0095] In Fig. 6B further a nozzle N_{1+m} is shown, which is assigned the same phase P_{min} as the minimum phase of the group G. The phases of the nozzles of the group G according to the sixth embodiment are assigned according to a predetermined waveform function w_1 along the array of nozzles within the group. When following the predetermined waveform function indicated by line w_1, the phases of nozzles N_2 - N_6 may be assigned according to the intersecting points $X_{2'}$ - $X_{6'}$ of the waveform function w_1 with the respective nozzle positions along the array of nozzles.

[0096] Similarly when following a second predetermined waveform function indicated by line w_2, the phases of nozzles N_2 - N_6 according to a seventh embodiment may be assigned according to the intersecting points $X_{2''}$ - $X_{6''}$ of the waveform function w_2 with the respective nozzle positions along the array of nozzles.

[0097] Fig. 7A- Fig. 7D are views showing a driving signal for driving a nozzle, nozzles being assigned to three groups of nozzles, a driving scheme for the three groups of nozzles, and the ejected droplets of the three groups of nozzles using the driving scheme, respectively, according to the present invention.

[0098] In Fig. 7A the driving signal 30 comprises two driving pulses (32, 34). The first driving pulse 32 has a duration d_1 between time 0 and T_1. The second driving pulse 34 has a duration d_2 between time T_2 and T_3. The signal amplitude of both driving pulses (32,34) is Vs. In between the two driving pulses (32, 34) is an interval time having a duration d_i between T_1 and T_2. The driving signal 30 has a duration S between time 0 and T3. The amplitude V_s and the duration (d_1,d_2) of both driving pulses (32,34) and the interval time d_i may be adjusted according to the desired droplet characteristics of the ejected droplet (such as droplet speed, droplet size, droplet shape and / or number of droplets). Optionally a third driving pulse (36) may be added to the driving signal (30). Furthermore, if needed, a quenching pulse may be added to the driving signal 30 (not shown).

[0099] In Fig. 7B each of the nozzles of the array 8 has been assigned to one of the three groups G1, G2 and G3, wherein each group has eight nozzles being arranged consecutive in a row in the direction as indicated by arrow L. Each group comprises two sub-arrays S1 and S2. The first sub-array S1 has four nozzles N_1-N_4. The second sub-array S2 has three nozzles N_5-N_8. Each nozzle in the groups G1, G2 and G3 is assigned a phase according to the present invention.

[0100] In Fig. 7C two driving cycles are schematically shown for the three groups of nozzles. Each driving cycle comprises five driving blocks B1 - B5. Within a group, each nozzle is assigned to one of the five driving blocks B1 - B5. Nozzles being assigned to the same block are driven at once.

[0101] Within each group the nozzle first in sequence of the first sub-array S1 having nozzle index N_1 is assigned a minimum phase P_{min} and is assigned to a block B1. Within each group the nozzle first in sequence of the second sub-array S2 having nozzle index N_5 is assigned a maximum phase P_{max} and is assigned to a block B5. The phases of nozzles N_2 and N_8 within each group are the same and these nozzles (N_2, N_8) are assigned to a block B2. The phases of nozzles N_3 and N_7 are the same and these nozzles (N_3, N_7) are assigned to a block B3. The phases of nozzles N_4 and N_6 are the same and these nozzles (N_4, N_6) are assigned to a block B4.

[0102] Each of the blocks B1 - B5 has a duration in time which is preferably at least equal or larger than the duration S of the respective driving signals (30) and the blocks B1 - B5 do not mutually have an overlap in time As a result two adjacent nozzles are not actuated at the same time. This further enhances a reduction in geometrical cross talk. In Fig. 7D ejected droplets 40 of two driving cycles are schematically shown for the three groups of nozzles using the driving scheme of Fig. 7C. It is shown that droplets of group B1 are ejected prior to the droplets of group B2, which are ejected prior to the droplets of group B3, etc.

[0103] Detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually any appropriately detailed structure. In particular, features presented and described in separate dependent claims may be applied in combination and any advantageous combination of such claims are herewith disclosed.

[0104] Further, the terms and phrases used herein are not intended to be limiting; but rather, to provide an understandable description of the invention. The terms "a" or "an", as used herein, are defined as one or more than one. The term plurality, as used herein, is defined as two or more than two. The term another, as used herein, is defined as at least a second or more. The terms including and/or having, as used herein, are defined as comprising (i.e., open language). The term coupled, as used herein, is defined as connected, although not necessarily directly.

[0105] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

Claims

1. A method for operating an inkjet print head, the print head comprising a plurality of pressure chambers, each of the plurality of pressure chambers communicating with a nozzle for ejecting ink droplets, the method comprising the steps of:

   a) assigning a plurality of nozzles to a group, wherein the group at least comprises a first nozzle, a second nozzle, a third nozzle and a fourth nozzle, all nozzles of the group being arranged consecutively in an array along a first line extending in a first direction;
   b) assigning a phase to each nozzle of the group, wherein the group comprises:

      - a first sub-array of nozzles comprising the first nozzle and the second nozzle being arranged consecutively in the first direction, the first nozzle being assigned a minimum phase, which minimum phase is a lowest phase of all assigned phases within the group; and
      - a second sub-array of nozzles comprising the third nozzle and the fourth nozzle being arranged consecutively in the first direction, the third nozzle being assigned a maximum phase, which maximum phase is a highest phase of all assigned phases within the group,
      the first sub-array being arranged adjacent to the second sub-array in the first direction, wherein in the first sub-array the second nozzle and each further nozzle of the first sub-array are assigned a phase in between the minimum phase and the maximum phase such that the phase monotonously increases along the first sub-array in the first direction from the minimum phase towards the maximum phase,
      wherein in the second sub-array the fourth nozzle and each further nozzle of the second sub-array are assigned a phase in between the maximum phase and the minimum phase such that the phase monotonously decreases along the second sub-array in the first direction from the maximum phase towards the minimum phase; and

   c) supplying a driving signal to each nozzle of the group at the assigned phase of said nozzle.

2. The method according to claim 1, wherein step a) is performed to compose a plurality of groups which are arranged consecutively along the first line in the first direction and wherein step b) and step c) are performed for each of the plurality of groups.

3. The method according claim 2, wherein in step a) each of the plurality of groups comprises the same number of nozzles.

4. The method according to claim 3, wherein in step b) each of the phases assigned to the nozzles of a first one of the plurality of groups, is the same in value and order as each of the phases assigned to the nozzles of a second one of the plurality of groups.

5. The method according to claim 1, wherein in step b) an inter nozzle phase step, which is a difference between the phases assigned to two adjacent nozzles, is substantially constant for each two adjacent nozzles of one of the first sub-array and the second sub-array.

6. The method according to claim 5, wherein in step b) an inter sub-array phase step, which is a difference between the phase assigned to a nozzle last in sequence of the first sub-array in the first direction and the phase assigned to the third nozzle, which is a nozzle first in sequence of the second sub-array in the first direction, is the same as each of the inter nozzle phase steps in the first sub-array.

7. The method according to claim 5, wherein in step b) each of the inter nozzle phase steps in the first sub-array is the same in absolute value as each of the inter nozzle phase steps in the second sub-array.

8. The method according to claim 7, wherein in step b) the phases are assigned such that the maximum phase plus the absolute value of the inter nozzle phase step is substantially equal to the driving period.

9. The method according to claim 5, wherein in step b) each of the inter nozzle phase steps in the first sub-array is different in absolute value from each of the inter nozzle phase steps in the second sub-array.

10. The method according to claim 1, wherein in step b) the phases along the array of nozzles in the first direction are assigned according to samples of a predetermined wave form function.

11. The method according to claim 1, wherein in step c) a duration of the driving signal, which comprises a

driving pulse, is equal to or smaller than each of the phase steps, which is a difference between the phases assigned to two adjacent nozzles, in the group.

12. A control unit for driving at least one print head, the control unit being configured to perform the method for operating the at least one print head according to the method of anyone of claims 1 - 11.

13. A printing assembly comprising at least one print head provided with the control unit according to claim 12 configured to perform the method for operating the at least one print head.

14. A computer readable medium provided with computer executable instructions for having the computer perform the method according to anyone of claims 1 - 11.

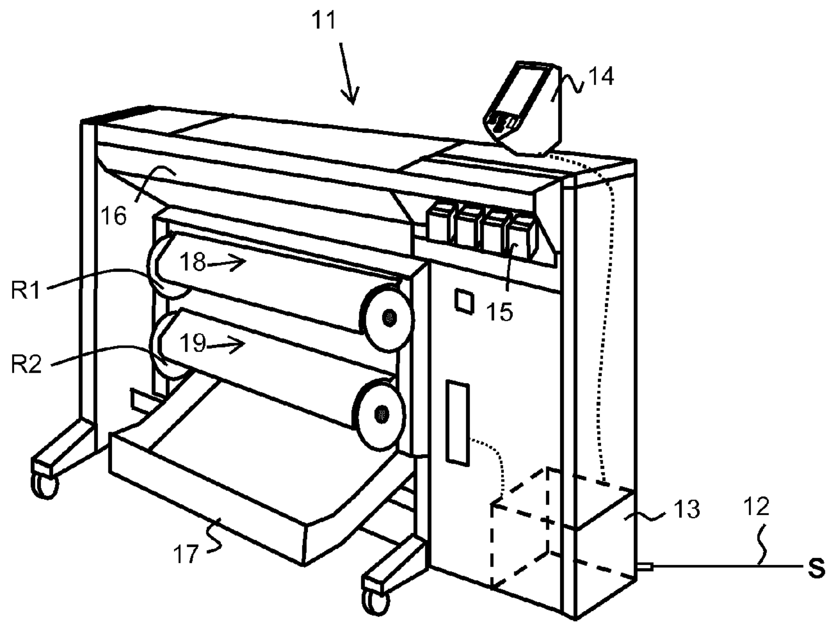
11
14
16
18
R1
19
R2
15
13
12
S
17

FIG. 1A

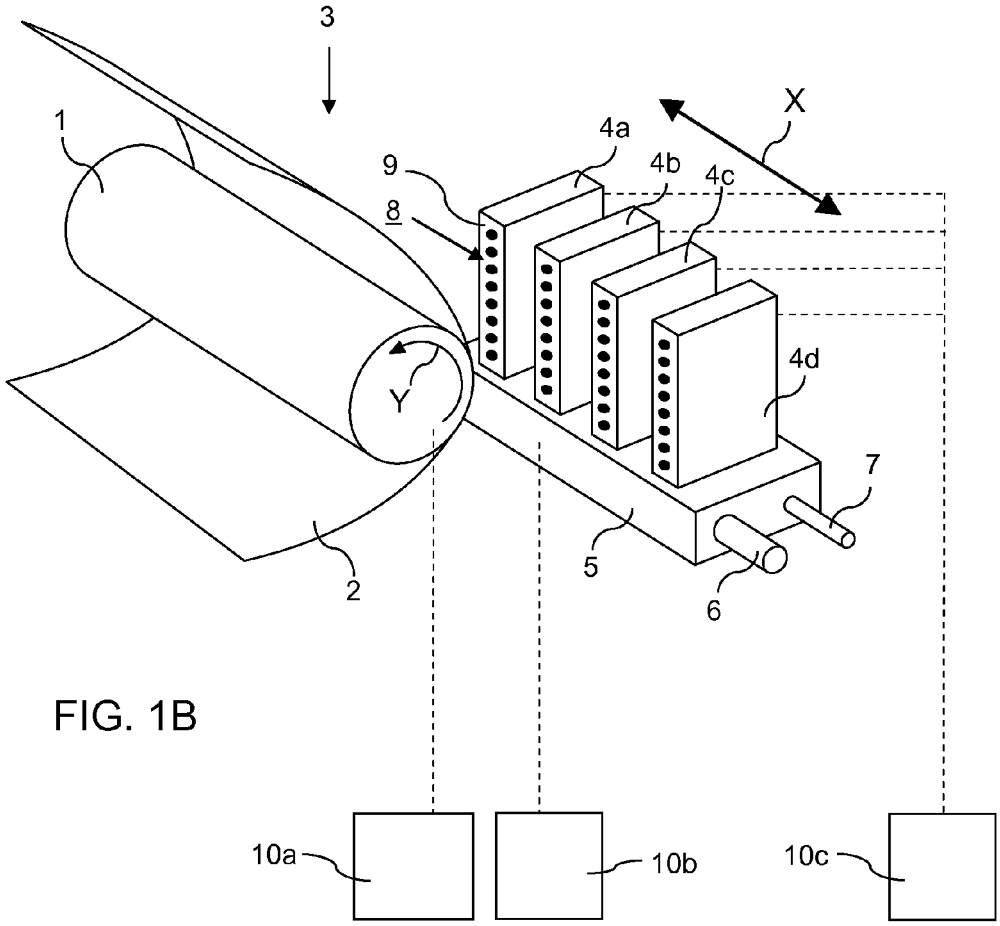
3
1
X
4a
9
4b
4c
8
4d
Y
7
5
2
6
10a
10b
10c

FIG. 1B

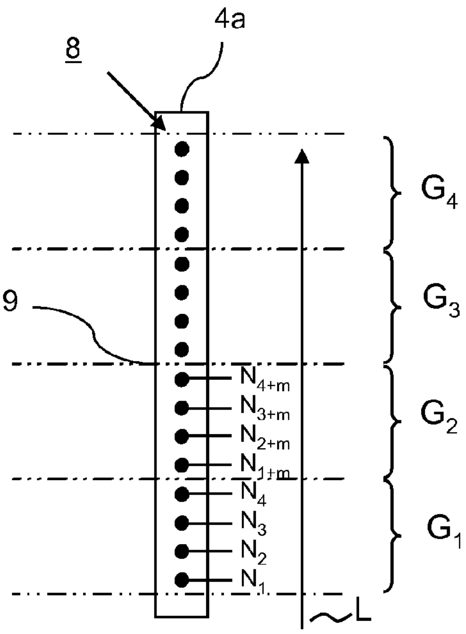
8
4a
9
G4
G3
G2
G1
N4+m
N3+m
N2+m
N1+m
N4
N3
N2
N1
L

FIG. 1C

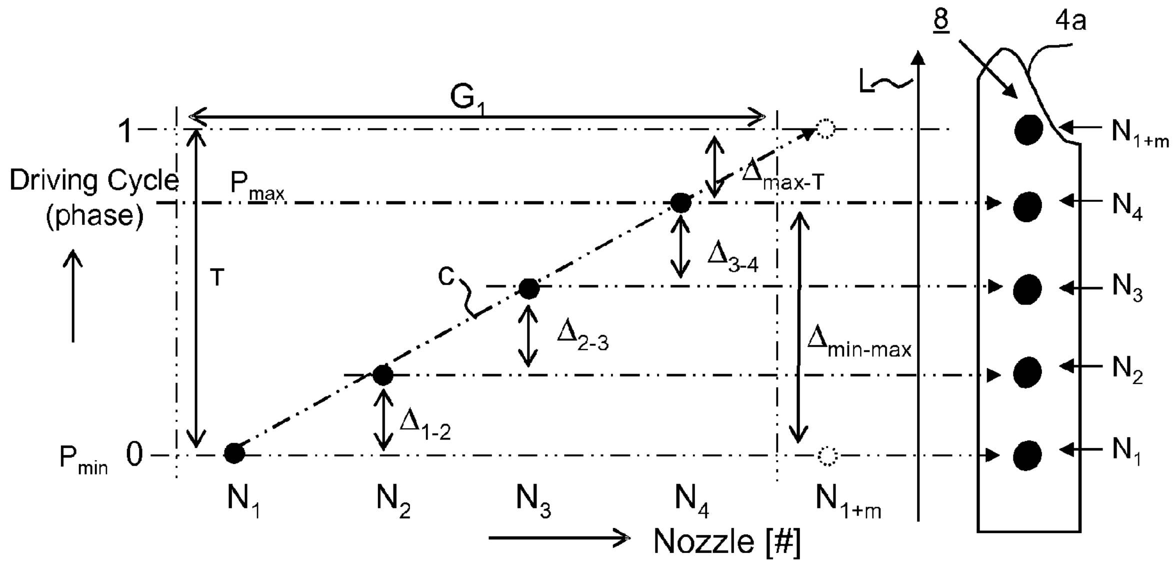
8
4a
L
G1
1
0
Driving Cycle (phase)
Pmax
Pmin
T
C
Δmax-T
Δ3-4
Δ2-3
Δ1-2
Δmin-max
N1
N2
N3
N4
N1+m
Nozzle [#]

FIG. 1D

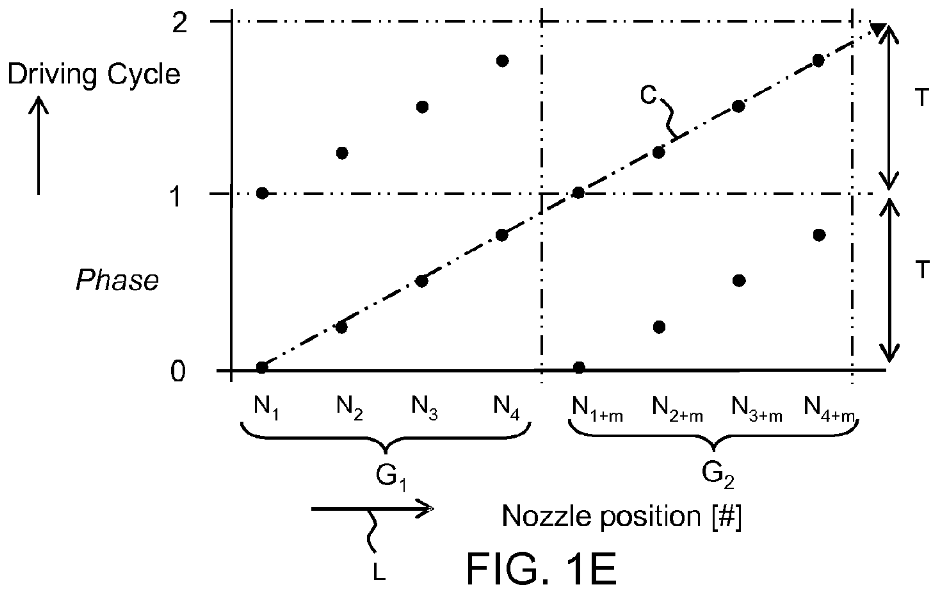

FIG. 1E

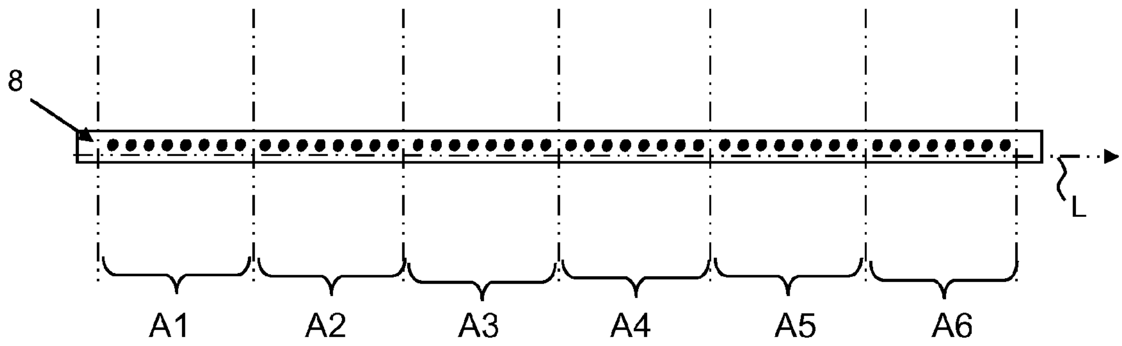

FIG. 2A

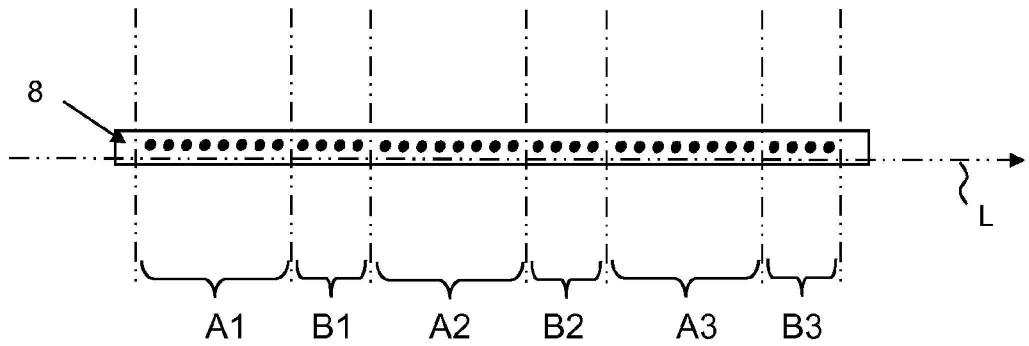

FIG. 2B

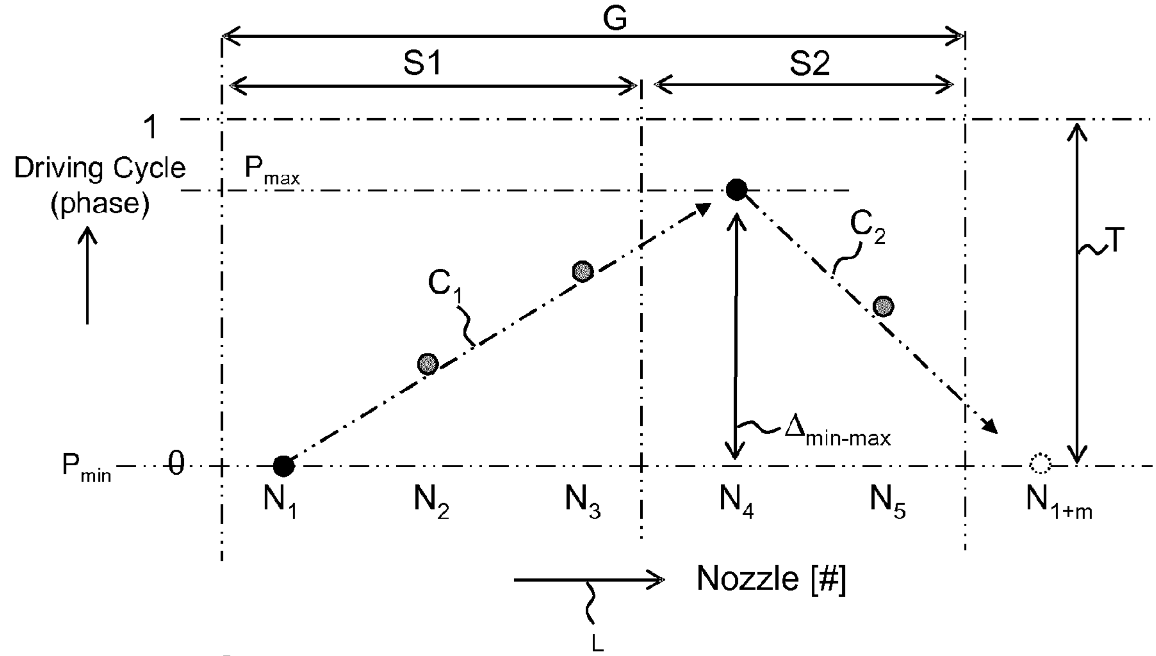
G
S1
S2
1
Driving Cycle (phase)
Pmax
C1
C2
T
Δmin-max
Pmin
0
N1
N2
N3
N4
N5
N1+m
Nozzle [#]
L

FIG. 3A

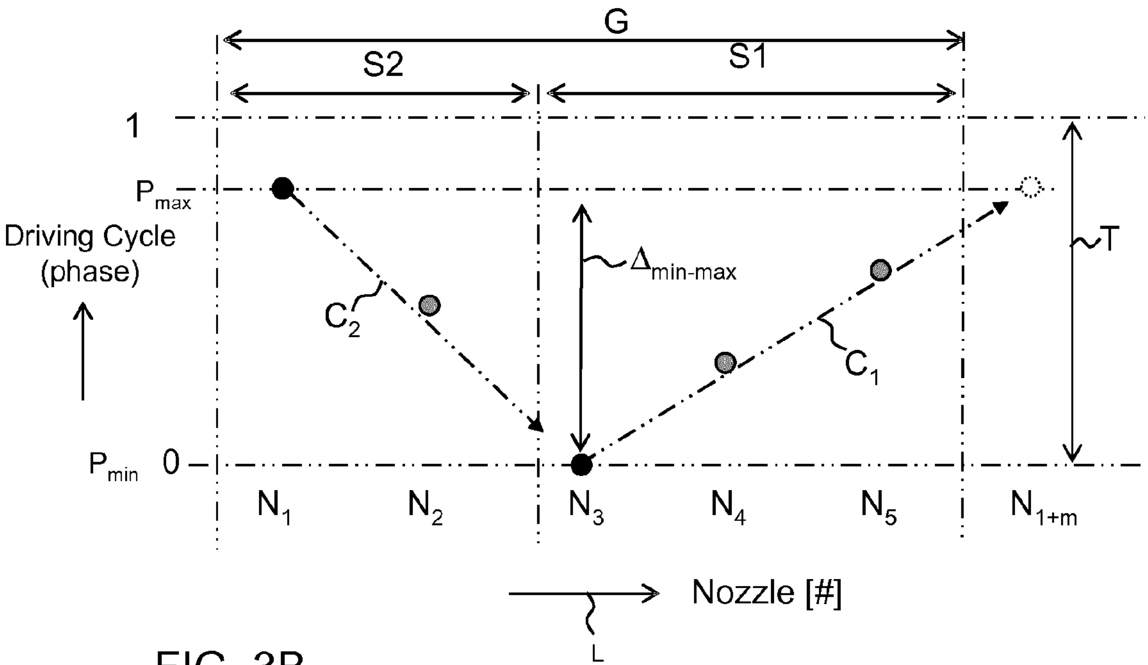
G
S2
S1
1
Pmax
Driving Cycle (phase)
Δmin-max
C2
C1
T
Pmin
0
N1
N2
N3
N4
N5
N1+m
Nozzle [#]
L

FIG. 3B

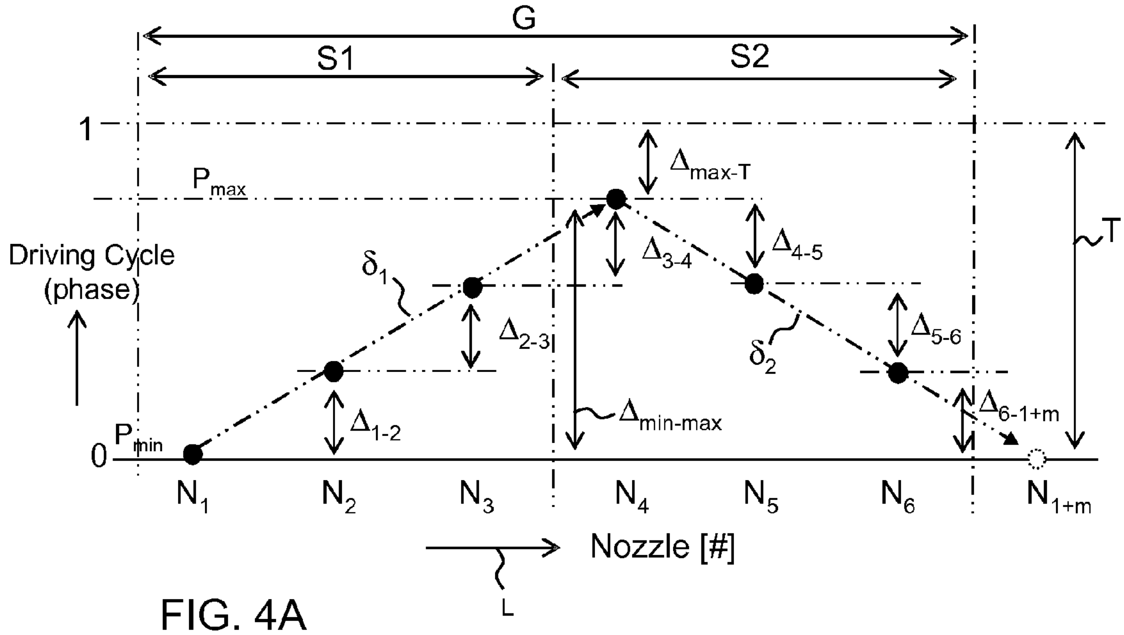
G
S1
S2
1
0
P_max
P_min
Driving Cycle (phase)
δ1
δ2
Δmax-T
Δ3-4
Δ4-5
Δ2-3
Δ5-6
Δ1-2
Δmin-max
Δ6-1+m
T
N1
N2
N3
N4
N5
N6
N1+m
Nozzle [#]
L

FIG. 4A

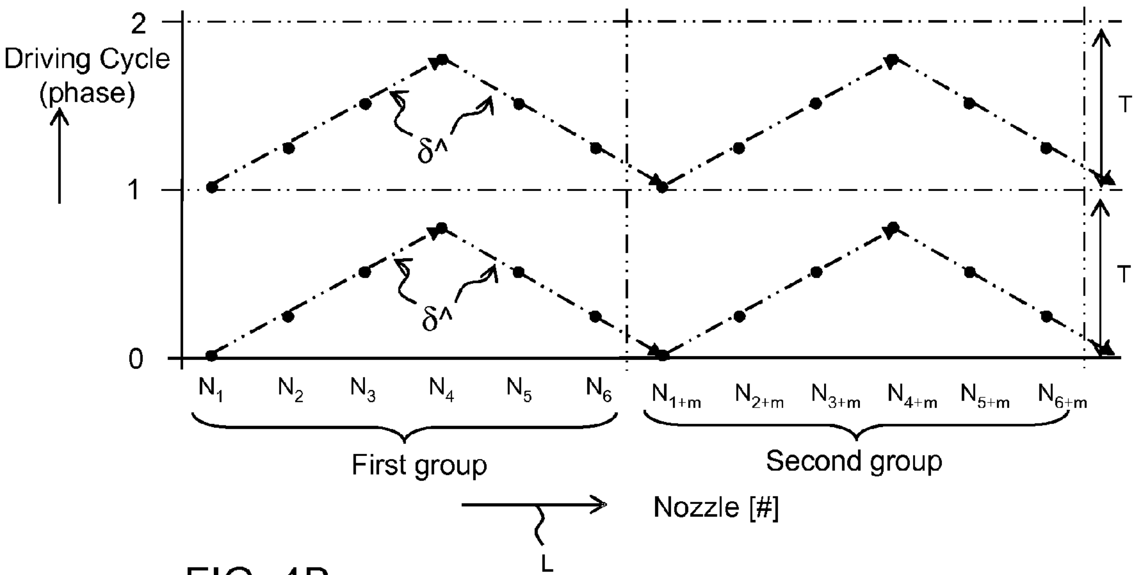
2
1
0
Driving Cycle (phase)
δ^
δ^
T
T
N1
N2
N3
N4
N5
N6
N1+m
N2+m
N3+m
N4+m
N5+m
N6+m
First group
Second group
Nozzle [#]
L

FIG. 4B

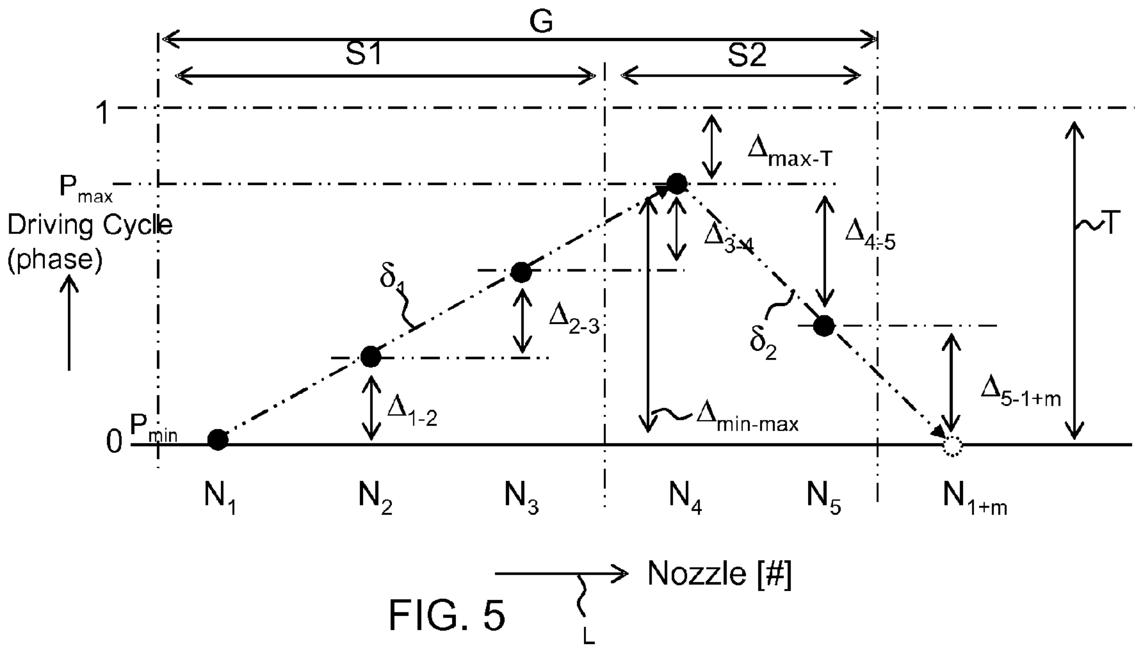
G
S1
S2
1
P_{max}
Driving Cycle
(phase)
0
P_{min}
Δ_{max-T}
Δ_{3-4}
Δ_{4-5}
T
δ_1
Δ_{2-3}
δ_2
Δ_{5-1+m}
Δ_{1-2}
$\Delta_{min-max}$
N_1
N_2
N_3
N_4
N_5
N_{1+m}
Nozzle [#]
L

FIG. 5

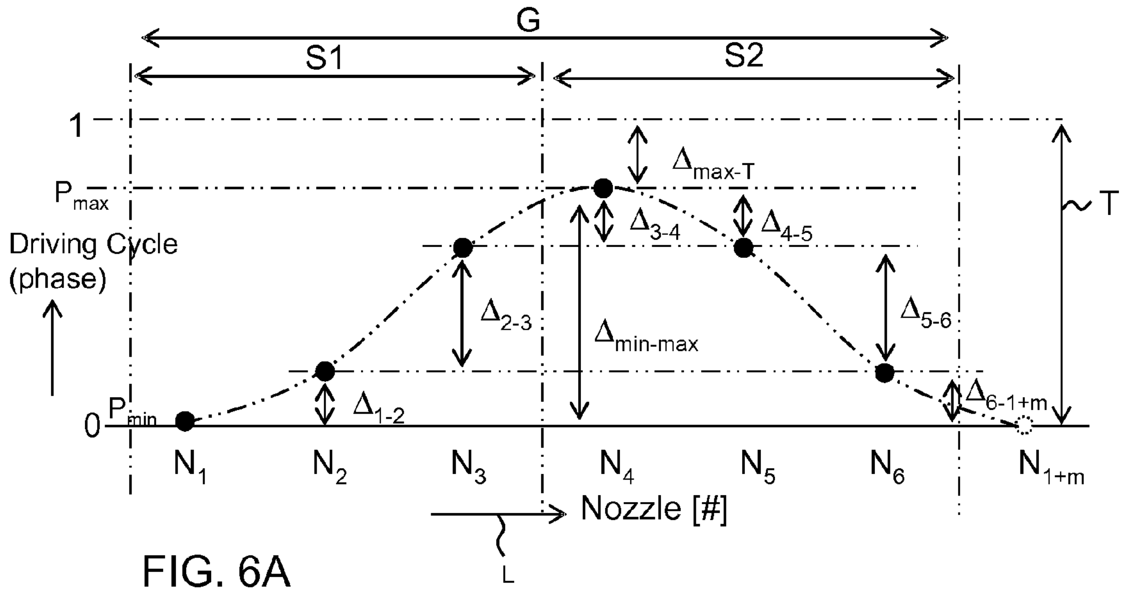
G
S1
S2
1
P_{max}
Driving Cycle (phase)
0
P_{min}
Δ_{max-T}
Δ_{3-4}
Δ_{4-5}
Δ_{2-3}
$\Delta_{min-max}$
Δ_{5-6}
Δ_{1-2}
Δ_{6-1+m}
T
N_1
N_2
N_3
N_4
N_5
N_6
N_{1+m}
Nozzle [#]
L

FIG. 6A

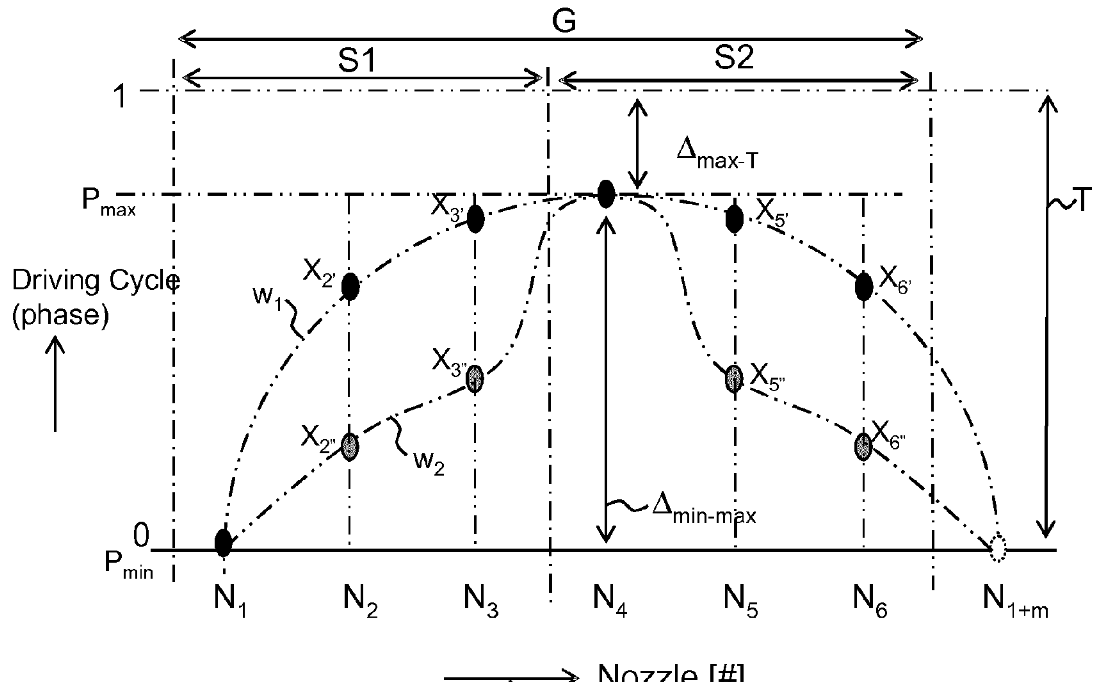
G
S1
S2
1
P_{max}
Δ_{max-T}
T
Driving Cycle (phase)
$X_{2'}$
$X_{3'}$
$X_{5'}$
$X_{6'}$
w_1
$X_{3''}$
$X_{5''}$
$X_{2''}$
$X_{6''}$
w_2
$\Delta_{min-max}$
0
P_{min}
N_1
N_2
N_3
N_4
N_5
N_6
N_{1+m}
Nozzle [#]
L

FIG. 6B

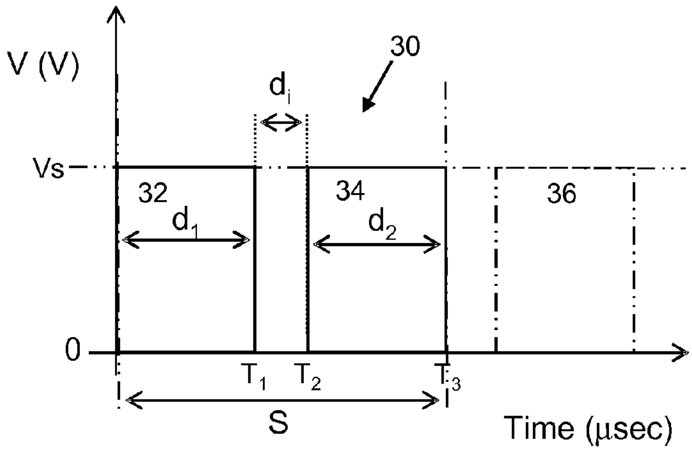

FIG. 7A

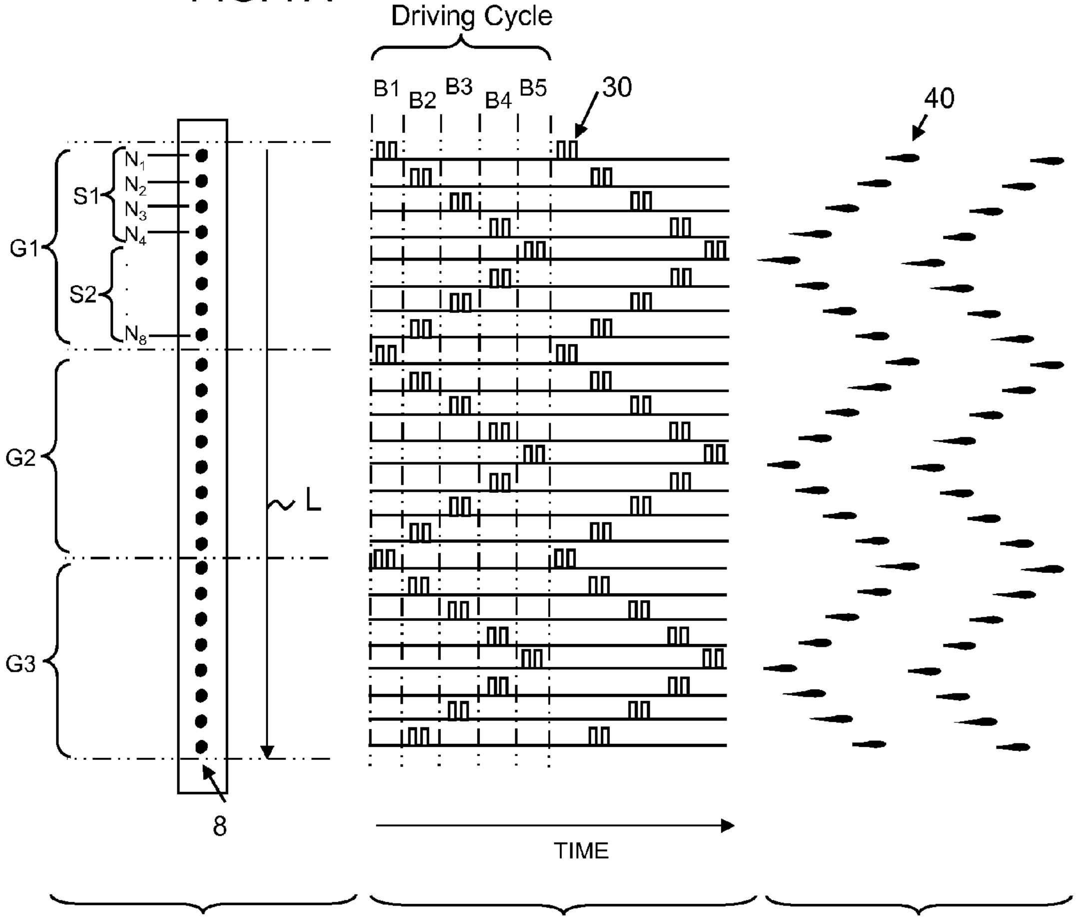

FIG. 7B FIG. 7C FIG. 7D

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EUROPEAN SEARCH REPORT

Application Number
EP 12 16 7476

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 0 461 940 A2 (CANON KK [JP]) 18 December 1991 (1991-12-18) * figures 17a,17b * -----	1-7, 11-14	INV. B41J2/045
X	EP 0 710 560 A2 (CANON KK [JP]) 8 May 1996 (1996-05-08) * figures 7c,7d * -----	1-5,7, 10-14	
X	JP 7 276640 A (CANON KK) 24 October 1995 (1995-10-24) * figures * -----	1-7,9, 11-14	
A	US 6 439 687 B1 (INOUE TAKASHI [JP]) 27 August 2002 (2002-08-27) * figures 6b,6c * -----	1,12-14	

TECHNICAL FIELDS SEARCHED (IPC)

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	12 September 2012	Bardet, Maude

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12-09-2012

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0461940 A2	18-12-1991	AT 174267 T	15-12-1998
		AT 195904 T	15-09-2000
		DE 69130591 D1	21-01-1999
		DE 69130591 T2	12-05-1999
		DE 69132396 D1	05-10-2000
		DE 69132396 T2	01-02-2001
		EP 0461940 A2	18-12-1991
		EP 0770485 A2	02-05-1997
		ES 2124221 T3	01-02-1999
		ES 2149541 T3	01-11-2000
		US 6244693 B1	12-06-2001
		US 6341849 B1	29-01-2002
		US 6439692 B1	27-08-2002
EP 0710560 A2	08-05-1996	AT 221826 T	15-08-2002
		AU 706934 B2	01-07-1999
		AU 3664795 A	16-05-1996
		CN 1129173 A	21-08-1996
		DE 69527690 D1	12-09-2002
		DE 69527690 T2	03-04-2003
		EP 0710560 A2	08-05-1996
		US 6062666 A	16-05-2000
JP 7276640 A	24-10-1995	NONE	
US 6439687 B1	27-08-2002	NONE	

EPO FORM P0459

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