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(54) Inkjet printer having spaced nozzle firing sequence

Tintenstrahldrucker mit Ausstoßsequenz aus weitgestellten Düsen

Imprimante à jet d'encre comprenant une séquence de démarrage de gicleur

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to the field of inkjet printers. In particular, the invention relates to inkjet printers that have printheads with a number of separate printhead integrated circuits (IC's) defining the nozzles that eject the ink or other printing fluid.

CROSS REFERENCES TO RELATED APPLICATIONS

[0002] Various methods, systems and apparatus relating to the present invention are disclosed in the following US Patents/ Patent Applications filed by the applicant or assignee of the present invention:

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[0003] An application has been listed by its docket number. This will be replaced when application number is known.

BACKGROUND OF THE INVENTION

[0004] Inkjet printers eject drops of ink through an array of nozzles to effect printing on a media substrate. The nozzles are typically formed on a silicon wafer substrate using semiconductor fabrication techniques. Each nozzle is a MEMS (micro electro-mechanical systems) device driven by associated drive circuitry formed on the same silicon wafer substrate. The MEMS nozzle devices and associated drive circuitry formed on a single nozzle is commonly referred to as a printhead integrated circuit (IC).

[0005] Traditional inkjet printers use scanning inkjet printheads. These have a single printhead IC that traverses back and forth across the width of a page as the printer indexes the page along. The Applicant has developed a range ofpagewidth printheads. These printheads use a series of printhead IC's mounted end to end to provide an array of nozzles that extends the entire width of the page. Instead of scanning back and forth, the printhead remains stationary in the printer as the page is fed past This allows much higher print speeds but is more complicated in terms of controlling the operation of a much larger array of nozzles.

[0006] Fabrication of the MEMS nozzle structures on wafer substrates will invariably result in some detective nozzles. These 'dead nozzles' can be located using a wafer probe immediately after fabrication. Knowing the location of the dead nozzles, the print engine controller (PEC) can be programmed with a dead nozzle map. This is used to compensate for the dead nozzles with techniques such as nozzle redundancy (the printhead IC is has more nozzles than necessary and uses the 'spare' nozzles to print the dots normally assign to the dead nozzles).

[0007] Unfortunately, nozzles also fail during the operational life of the printhead. It is not possible to locate these nozzles using a wafer probe once they have been mounted to the printhead assembly and installed in the printer. Over time, the number of dead nozzles increases and as the PEC is not aware of them, there is no attempt to compensate for them. This eventually causes visible artifacts that are detrimental to the print quality.

[0008] US 2006/092222 relates to a printhead module including at least one row that comprises a plurality of sets of n adjacent nozzles, each of the nozzles being configured to expel ink in response to a fire signal, such that, for each set of nozzles, a fire signal is provided in accordance with the sequence: [nozzle position 1, nozzle position n, nozzle position 2, nozzle position (n-1), ... , nozzle position x], wherein nozzle position x is at or adjacent the centre of the set of nozzle.

SUMMARY OF THE INVENTION

[0009] The present invention provides an inkjet printer comprising:

an array of nozzles arranged into rows, each row consisting of a plurality of nozzle groups, the nozzles in each group being interspersed with nozzles from the other groups; and,

associated drive circuitry for actuating the nozzles in the row in accordance with a firing sequence, the firing sequence enabling the nozzles in each group to eject printing fluid simultaneously, and enabling each of the groups to eject printing fluid in succession; wherein,

the nozzles in each group are spaced from each other by at least a predetermined minimum number of nozzles and, each of the nozzles in a group is spaced from the nozzles in the subsequently enabled group by at least the predetermined minimum number of nozzles.

[0010] The invention sets the nozzle firing sequence in each row such that the nozzles fire in staggered groups, the nozzles within each group can be selected so that they are not too close to a simultaneously fired nozzle, or a nozzle that is fired immediately afterwards. Staging the nozzle firings avoids the high current required for firing the whole row simultaneously. Maintaining a minimum spacing between simultaneously fired nozzles and the nozzles fired immediately after them avoids the detrimental effects of fluidic cross talk and aerodynamic interference.

[0011] It should be noted that the print data is unlikely to require every nozzle in a row to fire in the same firing sequence. However, the invention enables every nozzle to fire at a certain time within the firing sequence, regardless of whether it does fire a drop. Therefore, the spacing between simultaneously firing nozzles, or sequentially firing nozzles, will often be more than the predetermined minimum spacing, but this is not detrimental to the print quality. The invention is concerned with ensuring the spacing between two potentially interfering drops is never less than the predetermined minimum.

[0012] The row is divided into spans having only one nozzle from every group so that the number of spans across the row equals the number of groups of nozzles. The predetermined minimum number of nozzles between sequentially enabled nozzles is a uniform shift along each span in a uniform direction, the shift being a number of nozzles that is an integer greater than one and not a factor of the number of nozzles in the span, such that, the successively enabled nozzles in each span progress toward one end of the span until there are insufficient nozzles left at the end to fill the shift, in which case, the shift is completed with nozzles at the opposite end of the span so that all the nozzles in the span are enabled once during the firing sequence.

[0013] In a particularly preferred form, the shift is the number of nozzles that is the nearest integer to the square root of the span, that is not a factor (i.e. the span can not be divisible by the shift without a remainder). The Applicant has found that this provides a maximum spacing in time and space for ejected drops.

[0014] Optionally, the row is divided into spans having only one nozzle from every group so that the number of spans across the row equals the number of groups of nozzles.

[0015] Optionally, the predetermined minimum number of nozzles between sequentially enabled nozzles is a uniform shift along each span in a uniform direction, the shift being a number of nozzles that is an integer greater than one and not a factor of the number of nozzles in the span, such that, the successively enabled nozzles in each span progress toward one end of the span until there are insufficient nozzles left at the end to fill the shift, in which case, the shift is completed with nozzles at the opposite end of the span so that all the nozzles in the span are enabled once during the firing sequence.

[0016] Optionally, the shift is the number of nozzles that is the nearest integer to the square root of the span, that is not a factor.

[0017] In a another aspect the present invention provides an inkjet printer further comprising a plurality of temperature sensors positioned along the array of nozzles such that the drive circuitry adjusts the drive pulses in response to the temperature sensor outputs.

[0018] Optionally, each of the plurality of temperature sensors is activated sequentially for a period of time during the print job.

[0019] Optionally, the plurality of temperatures sensors are divided into two or more groups, each group being activated for a sensing period in accordance with a predetermined repeating sequence for the duration of a print job.

[0020] Optionally, each of the plurality of temperature sensors, is configured to sense the temperature a corresponding region of the array such that the drive pulse for the nozzles in one region can differs from the drive pulse for the nozzles in another region.

[0021] Optionally, every second temperature sensor in the plurality of temperature sensors is de-activated such that the drive circuitry adjusts the drive pulse profile for the region corresponding to each activated temperature sensor and applies the same adjustment to the adjacent region where the temperature sensor is de-activated.

[0022] Optionally, the drive circuitry is programmed with a series of temperature thresholds defining a set of temperature zones, each of the zones having a different pulse profile for the drive pulses sent to the nozzles in the region currently operating in that temperature zone.

[0023] Optionally, the pulse profile for each temperature zone differs in its duration.

[0024] Optionally, the drive circuitry sets the pulse duration to zero if the temperature sensor indicates that region is operating at a temperature above the highest of the temperature thresholds.

[0025] Optionally, the drive circuitry sets the duration of the pulse profile to a sub ejection value for any of the nozzles in the row that are not to eject a drop during that firing sequence.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Specific embodiments of the invention will now be described by way of example only witch reference to the accompanying drawings, in which:

Figure 1 is a schematic representation of the linking printhead IC construction;

Figure 2 is a schematic representation of the unit cell;

Figure 3 shows the configuration of the nozzle array on a printhead IC;

Figure 4 is a schematic representation of the column and row positioning of the nozzles in the array;

Figure 5A is a schematic representation of the non-distorted array of nozzles;

Figure 5B is a schematic representation of the distortion of the array for continuity with adjacent printhead IC's;

Figure 5C is an enlarged view of the sloped section of the array with the ink supply channels overlaid;

Figure 6A shows the prior art configuration of a linking printhead IC with drop triangle;

Figure 6B shows the ink supply channels corresponding to the nozzle array shown in Figure 6A;

Figure 7 is a schematic representation of the printhead connection to SoPEC;

Figure 8 is a schematic representation of the printhead connection to MoPEC;

Figure 9 show self clocking data signals for a '1' bit and a '0' bit;

Figure 10 shows a sketch of the eight TCPG regions across an Udon IC;

Figure 11 is a sketch of the two nozzle tows firing in sequences defined by different span and shifts;

Figure 12 is a schematic representation of the firing sequence of a nozzle row segment with a span of five and a shift of three;

Figure 13A the current drawn over one row time for each TCPG region and the total row during a uniformly initiated region firing sequence;

Figure 13B is the current drawn over one row time for each TCPG region and the total row during a delayed region firing sequence;

Figure 14 is the dot data loading and row firing sequence for a ten row Udon IC;

Figure 15 shows the drop triangle and sloping segment ofa nozzle row together with the relevant printing delay for the dot data at the 'dropped' nozzles;

Figure 16 shows de-clog pulse train;

Figure 17A is the circuitry for the Open Actuator Test in a unit cell with p-type drive FET; and,

Figure 17B is the circuitry for the Open Actuator Test in a unit cell with n-type drive FET.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0027] The Applicant has developed a range of printhead devices that use a series of printhead integrated circuits (ICs) that link together to form a pagewidth printhead. In this way, the printheads IC's can be assembled into printheads used in applications ranging from wide format printing to cameras and cellphones with inbuilt printers. One of the more recent printhead IC's developed by the Applicant is referred to internally as wide range of printing applications. The Applicant refers to these printhead IC's as 'Udon' and the various aspects of the invention will be described with particular reference to these printhead IC's. However, it will be appreciated that this is purely for the purposes of illustration and in no way limiting to the scope and application of the invention.

Overview

[0028] The Udon printhead IC is designed to work with other Udon ICs to make a linking printhead. The Applicant has developed a range of linking printheads in which a series of the printhead IC's are mounted end-to-end on a support member to form a pagewidth printhead. The support member mounts the printhead IC's in the printer and also distributes ink to the individual IC's. An examples of this type of printhead is described in USSN 11/293,820, the disclosure of which is incorporated herein by cross reference.

[0029] It will be appreciated that any reference to the term 'ink' is to be interpreted as any printing fluid unless it is clear from the context that it is only a colorant for imaging print media. The printhead IC's can equally eject invisible inks, adhesives, medicaments or other functionalized fluids.

[0030] Figure 1 shows a sketch of a pagewidth printhead 10 with the series ofUdon printheads ICs 12 mounted to a support member 14, The angled sides 16 allow the nozzles from one of the IC's 12 overlap with those of an adjacent IC in the paper feed direction 18. Overlapping the nozzles in each IC 12 provides continuous printing across the junction between two IC's. This avoids any 'banding' in the resulting print. Linking individual printhead IC's in this manner allows printheads of any desired length to be made by simply using different numbers of IC's.

[0031] The printhead IC's 12 are integrated CMOS and MEMS 'chips'. Figure 3 shows the configuration of MEMS nozzles 20 on the ink ejection side of the printhead IC 12. The nozzles 20 are arranged into rows 26 and columns 24 to form a parallelogram array 22 with 'kinked' or inclined portion 28. The columns 24 are not aligned with the paper feed direction 18 because the sides of the array 22 are angled approximately 45° for the purposes of linking with adjacent IC's. The columns 24 follow this incline. The rows 26 are perpendicular to the paper feed direction except for a sloped section 28 inclined towards a 'drop triangle' 30 which has the nozzles 20 that overlap the adjacent pnnthead IC. This is discussed in more detail below.

[0032] Figure 2 shows the elements of a single MEMS nozzle device 20 or 'unit cell'. The construction of the unit cell 20 is discussed in detail in USSN 11/246,687, the contents of which is incorporated herein by cross reference. Briefly, Figure 2 shows the unit cell as if the nozzle plate (the outer surface of the printhead) were transparent to expose the interior features. The nozzle 32 is the ejection aperture through which the ink is ejected. The heater 34 is positioned in the nozzle chamber 36 to generate a vapour bubble that ejects a drop of ink through the nozzle 32. The U-shaped sidewall 38 defines the edges of the chamber 36. Ink enters the chamber 36 through the inlet 42 which has two rows of column features 44 that baffle pressure pulses in the ink to stop cross talk between unit cells. The CMOS layer defines the drive circuitry and has a drive FET 40 for the heater 34 and logic 46 for pulse timing and profiling. This is discussed in more detail below.

[0033] Ink is supplied to the unit cells 20 from channels in the opposite side of the wafer substrate of the printhead IC. These are described below with reference to Figure 5C. The channels in the 'back side' of the printhead IC 12 are in fluid communication with the unit cells 20 on the front side via deep etched conduits (not shown) through the CMOS layer.

[0034] Separate linking printhead ICs 12 are bonded to the support member 14 so that there are no printed artifacts across the join between neighbouring printhead IC's. Each IC 12 contains ten rows 26 of nozzles 32. As shown in Figure 4, there are two adjacent rows 26 for each color to allow up to five separate types of ink. Each pair of rows 26 shares a common ink supply channel in the back side of the wafer substrate.

[0035] There are 640 nozzles per row and 2 x 640 =1280 nozzles per color channel, which equates to 5 x 1280 = 6400 nozzles per IC 12. An A4/Letter width printhead requires a series of eleven printhead IC's (see for example Figure 1), making the total nozzle count for the assembled printhead 11 x 6400 = 70 400 nozzles.

Color and Nozzle Arrangement

[0036] At 1600 dpi, the distance between printed dots needs to be 15,875 □m: This is referred to as the dot pitch (*DP*). The unit cell 20 has a rectangular footprint that is 2*DP* wide by 5*DP* long. To achieve 1600 dpi per color, the rows 26 are offset from eachother relative to the feed direction 18 of the paper 48 as best shown in Figure 4. Figure 5A shows the parallelogram that the nozzle forms by offsetting each subsequent row 26 by *5 DP.*

Linking Nozzle Arrangement

[0037] The parallelogram 50 does not allow the array 22 to link with those of adjacent printhead IC's. To maintain a constant dot pitch between the edge nozzles of one printhead IC and the opposing edge nozzles of the adjacent IC, the parallelogram 50 needs to be slightly distorted. Figure 5B shows the distortion used by the Udon design. A portion 30 of the array 22 is displaced or 'dropped' relative to the rest of the array with respect to the paper feed direction 18. For convenience, the Applicant refers to this portion as the drop triangle 30. The unit cells 20 on the outer edge of the drop triangle 30 are directly adjacent the unit cells 20 at the edge of the adjacent printhead IC 11 in terms of their dot pitch. In this way, the separate nozzle arrays link together as if they were a single continuous array.

[0038] The 'drop' of the drop triangle 30 is 10 *DP.* Dots printed by the nozzles in the triangle 30 are delayed by ten 'line times' (the line time is the time taken to print one line from the printhead IC, that is fire all ten rows in accordance with the print data at that point in the print job) to match the triangle offset. There is a transition zone 28 between the drop triangle 30 and the rest of the array 22. In this zone the rows 26 'droop' towards the drop triangle 30. Nine pairs of unit cells 20 sequentially drop by one line time (1 *DP*, 1 row time) at a time to gradually bridge the gap between dropped and normal nozzles.

[0039] The droop zone is purely for linking and not necessary from a printing point of view. As shown in Figure 6A, the rows 26 could simply terminate 10 DP above the corresponding row in the drop triangle 30. However, this creates a sharp corner in the ink supply channels 50 in the back of the IC 12 (see Figure 6B). The sharp change of direction in the ink flow is problematic because outgassing bubbles can become lodged and difficult to remove from stagnation areas 54 at the corners 52. Figure 5C shows the configuration of the ink supply channels 50 in the back of an Udon printhead IC 12. It can be seen that the droop zone 28 keeps the ink supply channels 50 less angled and therefore free of flow stagnation areas.

Compatibility with Different Print Engine Controllers

[0040] The Udon printhead IC, can operate in different modes depending on the print engine controller (PEC) from which it is receiving its print data. Specifically, Udon runs in two distinct modes—SoPEC mode and MoPEC mode. SoPEC is the PEC that the Applicant uses in its SOHO (small office, home office) printers, and MoPEC is the PEC used in its mobile telecommunications (e.g. cell phone or PDA) printers. Udon does not use any type of adaptor or intermediate interface to connect to differing PEC's. Instead, Udon determines the correct operating mode (SoPEC or MoPEC) when it powers up. In each mode, the contacts on each of the printhead IC's assume different functions.

SoPEC Mode Connection

[0041] Figure 7 is a schematic representation of the connection of the Udon IC's 12 to a SoPEC 56. Each of the printhead IC's 12 has a clock input 60, a data input 58, a reset pin 62 and a data out pin 64. The clock and data inputs are each 2 LVDS (low voltage differential signalling) receivers with no termination. The reset pin 62 is a 3.3V Schmitt trigger that puts all control registers into a known state and disables printing. Nozzle firing is disabled combinatorially and three consecutive clocked samples are required to reset the registers. The data output pin 64 is a general purpose output but is usually used to read register values back from the printhead IC 12 to the SoPEC 56. The interface between SoPEC 56 and the printhead 10 has six connections.

MoPEC Mode Convection

[0042] Figure 8 shows the connection between a MoPEC 66 and the printhead IC's 12 of a printhead 10 installed in a mobile device. Some of the same connection pins are used when the IC operates in the MoPEC mode. However, as the MoPEC printheads 10 will be physically smaller (only three chips wide for printing onto business card sized media) and more frequently replaced by the user, it is necessary to simplify the interface between the MoPEC and the printhead as much as possible. This reduces the scope for incorrect installation and enhances the intuitive usability of the mobile device.

[0043] The address carry in (ACI) 70 is the positive pin of the LVDS pair of clock input 60 in the SoPEC mode. The first printhead IC 12 in the series has the ACI 70 set to ground 68 for addressing purposes described further below. The negative pin 60 is grounded to hold it to '0' voltage. The data out pin 64 connects directly to the ACI 70 of the adjacent printhead IC 12. All the IC's 12 are daisy-chained together in this manner with the last printhead IC 12 in the series having the data out 64 connected back to the MoPEC 66.

[0044] In MoPEC mode, the reset pin 62 remains unconnected and the negative pin 72 of the data LVDS pair is grounded. The data and clock are inputted through a single connectionusing the self-clocking data signal discussed below. The daisy-chained connection of the IC's 12 and the self clocking data input 58 reduce the number of connections between MoPEC and the printhead to just two. This simplifiers the printhead cartridge replacement process for the user and reduces the chance of incorrect installation.

Combined Clock and Data

[0045] The combined clock and data 58 is a pulse width modulated signal as shown in Figure 9. The signal 74 shows one clock period and a '0' bit and the signal 76 shows one clock period and a '1' bit. "The Udon IC's 12 (when in MoPEC mode) takes its clock from every rising edge 78 as the signal switches from low to high (0 to 1). Accordingly, the signal has a rising edge 78 at every period. A '0' bit drops the signal back to '0' at 1/3 of the clock period. A '1' bit drops the signal to ’0’ at 2/3 of the clock period. The IC looks to the state of the signal at the mid point 80 of the period to read the ’0’ or the ’1’ bit

External Printhead IC Addressing

[0046] Each of the printhead IC’s 12 are given a write address when connected to the MoPEC 66. To do this using a two wire connection between the PEC and the printhead requires an iterative process of broadcast addressing to each device individually. Udon achieves this by daisy-chaining the data output or one IC to the address carry in of the next IC. The default or reset value at the data output 64 is high or ’1’. Therefore every printhead IC 12 has a ’1’ address except the first printhead IC 12 which has its address pulled to ’0’ by its connection to ground 68. To give the IC’s 12 unique write addresses, the MoPEC 66 sends a broadcast command to all devices with a ’0’ address. In response to the broadcast command, the only IC with a ’0’ address, re-writes its write address to a unique address specified by MoPEC and sets its data out 64 to ’0’. That in turn pulls the ACI 70 of the second IC 12 in the series to ’0’ so that when MoPEC again sends a broadcast command to write address ’0’ so that the second IC, and only the second IC, rewrites its address to a new and unique address, as well as setting its data output to ’0’,

[0047] The process repeats until all the printheads IC’s 12 have mutually unique write addresses and the last IC sends a ’0’ back to MoPEC 66. Using this system for addressing the IC’s at start up, the interface need only have a connection for a combined data and clock ’multi-dropped’ (connected in parallel) to all devices and a data out from the IC’s back to MoPEC. As discussed above, a simplified electrical interface between the PEC and printhead cartridge enhances the ease and convenience of cartridge replacement.

Power On Reset

[0048] Udon printhead IC’s 12 have a power on reset (FOR) circuit. The ability to self initialize to a known state allows the printhead IC to operate in the MoPEC mode with only two contacts at the PEC/printhead 10 interface.

[0049] The POR circuit is implemented as a bidirectional reset pin 62 (see Figure 7). The POR circuit always drives out the reset pin 62, and the IC listens to the reset pin input side. This allows SoPEC 56 to overdrive reset when required.

PEC Interface Type Detection

[0050] On power up, the Udon printhead IC 12 switches from mode to mode and suppresses fire commands until it determines the type of PEC to which it is connected. Once it selects the correct operating mode for the PEC, it will not try to align with another PEC type again until a software reset or power down/power up cycle.

[0051] An Udon printhead IC 12 can be in three interface modes:

- SoPEC mode, where both clock and data 58 are LVDS (low voltage differential signalling) contacts pairs (see Figures 7 and 8);
- MoPEC single-ended mode, where clock and data are combined 58 and single ended (see Figure 8) because the data is pulse width modulated along the clock signal; and,
- MoPEC LVDS mode, where the clock 60 is single ended and data 58 is LVDS (this mode can be used if there are EMI issues).

[0052] Udon spends sufficient time in each state to align, then moves on in order if alignment is not achieved.

Multi-Stage Print Data Loading

[0053] In previous printhead IC designs, each unit cell had a shift register for the print data. Print data for the entire nozzle array was loaded and then, after the fire command from the PEC, the nozzles are fired in a predetermined sequence for that line of print. The shift register occupies valuable space in the unit cell which could be better used for a bigger, more powerful drive FET. A more powerful drive FET can provide the actuator (thermal or thermal bend actuator) with a drive pulse of sufficient energy (about 200 nJ) in a shorter time.

[0054] A bigger more powerful FET has many benefits, particularly for thermally actuated printheads. Less power is converted to wasteful heat in the FET itself, and more power is delivered to the heater. Increasing the power delivered to the heater causes the heater surface to reach the ink nucleation temperature more quickly, allowing a shorter drive pulse. The reduced drive pulse allows less time for heat diffusion from the heater into regions surrounding the heater, so the total energy required to reach the nucleation temperature is reduced. A shorter drive pulse duration also provides more scope to sequence to the nozzle firings within a single row time (the time to fire a row of nozzles).

[0055] Moving the print data shift registers out of the unit cells makes room for bigger drive FETs. However, it substantially increases the wafer area needed for the IC. The nozzle array would need an adjacent shift register array. The connections between each register and its corresponding nozzle would be relatively long contributing to greater resistive losses. This is also detrimental to efficiency.

[0056] As an effective compromise, the Udon printhead IC stages the loading and firing of the print data from the nozzle array. Print data for a first portion of the nozzle array is loaded to registers outside the array of nozzles. The PEC sends a fire command after the registers are loaded. The registers send the data to the corresponding nozzles within the first portion where they fire in accordance to the fire sequence (discussed below). While the nozzles in the first portion fire, the registers are loaded with the print data for the next portion of the array. This system removes the register from the unit cell to make way for a larger, more powerful drive FET. However, as there are only enough registers for the nozzles in a portion of the array, the resistive losses in the connection between register and nozzle is not excessive.

[0057] The drive logic on the IC 12 sends the print data to the array row by row. The nozzle array has rows of 640 nozzles in 10 rows. Adjacent to the array, 640 registers store the data for one row. The data is sent to the registers from the PEC in a predetermined row fring sequence. Previously, when the data for the entire array was loaded at once, the PEC could simply send the data for each row sequentially - row 0 to row 9. However, with each row fired as soon as its data is loaded, the PEC needs to align with Udon's row firing sequence.

[0058] Udon's normal operating steps are described as follows:

1. Program registers to control the firing sequence and parameters.
2. Load data into the registers for a single row of the printhead.
3. Send a fire command, which latches the loaded data in the corresponding nozzles, and begins a fire sequence.
4. Load data for the next row while the fire sequence is in progress.
5. Repeat for all rows in the line.
6. Repeat for all lines on the page.

Temperature Controlled Profile Generator (TCPG) regions

[0059] Ink viscosity is dependent on the ink temperature. Changes in the viscosity can alter the drop ejection characteristics of a nozzle. Along the length of a pagewidth printhead, the temperature may vary significantly, These variations in temperature and therefore drop ejection characteristics leave artefacts in the print. To compensate for temperature variations, each Udon printhead IC has a series of temperature sensors which output to the on-chip drive logic. This allows the drive pulse to be conditioned in accordance with the current ink temperature at that point along the printhead and thereby eliminate large differences in drop ejection characteristics.

[0060] Referring to Figure 10, each Udon IC 12 has eight temperature sensors 74 positioned along the array 22. Each sensor 74 senses the temperature in the adjacent region of nozzles, referred to as Temperature Controlled Profile Generator regions, or TCPG regions 76. A TCPG region 76 is a 'vertical' band down the IC 12 that shares temperature and firing data (see the row firing sequences described later). Pulse width is set for each color on the basis of region, and temperature within that region.

Periodic Sensor Activation

[0061] The sensors 74 allow temperature detection between 0° C and 70° C with a typical accuracy after calibration of 2° C. Individual temperature sensors may be switched off and a region may use the temperature sensor 74 of an adjoining region 78. This will save power with minimal effect on the correct conditioning of the drive pulse as the sensors will sense heat generated in regions outside their own because of conduction. If the steady state operating temperatures shown little or no variation along the IC, then it may be appropriate to turn off all the sensors except one, or indeed turn off all the sensors and not use any temperature compensation. Reducing the number of sensors operating at once not only reduces power consumption, but reduces the noise in other circuits in the IC.

Temperature Categories

[0062] Each TCPG region 76 has separate registers for each of the five inks. The temperature of the ink is is categorised into four temperature ranges defined by three predetermined temperature thresholds. These thresholds are provided by the PEC. The profile generator within the Udon logic adjust the profile of the drive pulse to suit the current temperature category.

Sub-Ejection Pulses

[0063] Heat dissipates into the ink as the heater temperature rises to the bubble nucleation temperature. Because of this, the temperature of the ink in a nozzle will depend on how frequently it is being fired at that stage of the print job. A pagewidth printhead has a large array of nozzles and at any given time during the print job, a portion of the nozzles will not be ejecting ink. Heat dissipates into regions of the chip surrounding nozzles that are firing, increasing the temperature of those regions relative to that of non-firing regions. As a result, the ink in non-ejecting nozzles will be cooler than that in nozzles firing a series of drops.

[0064] The Udon IC 12 can send non-firing nozzles 'sub-ejection' pulses during periods of inactivity to keep the ink temperature the same as that of the nozzles that are being fired frequently. A sub-ejection pulse is not enough to eject a drop of ink, but heat dissipates into ink. The amount of heat is approximately the same as the heat that conducts into the ink prior to bubble nucleation in the firing nozzles. As a result, the temperature in all the nozzles is kept relatively uniform. This helps to keep viscosity and drop ejection characteristics constant The sub-ejection pulse reduces its energy by shortening its duration.

Drive Pulse Profiling

[0065] Actively changing the profile of the drive pulse offers many benefits including:

- optimum firing pulse for varying inks and temperatures
- warming a region before it fires
- shutting down or just slowing down an IC that gets too hot (Udon provides the information, PEC controls speed)
- adjusting for voltage drop caused by distance (extra resistance) from the power source
- reducing the energy input to the chip, as warm ink requires less energy to eject than cold ink

[0066] The pulse profile can vary according to temperature and ink type. The firing pulses generated by the TCPG regions are stored in large registers that contain values for each of five inks in each of four temperature ranges, plus universal ink and region values, and threshold values. These values must be supplied to the Udon and may be stored in and/or delivered by the QA chip on the ink cartridge (see RRCOO 1US incorporated herein by reference), the PEC, or elsewhere.

Controlling the Pulse Width

[0067] It is convenient to adjust the firing pulses by varying the pulse duration instead of voltage or current. The voltage is externally applied. Varying the current would involve resistive losses. In contrast, the pulse timing is completely programmable.

[0068] Ideal ink ejection firing pulses for Udon are typically between 0.4 □s and 1.4 □s. Sub-ejection firing pulses are usually less than 0.3 □s. More generally, the firing pulse is a function of several factors:

- MEMs characteristics
- Ink characteristics
- Temperature
- FET type

[0069] The magnitude of the optimum firing pulse may vary depending on color and temperature. Udon stores the ejection pulse time for each color, in all temperature zones, in all regions.

Row Firing Sequence

[0070] If all nozzles in a row were fired simultaneously, the sudden increase in the current drawn would be too high for the printhead IC and supporting circuitry. To avoid this, the nozzles, or groups of nozzles, can be fired in staggered intervals. However, firing adjacent nozzles simultaneously, or even consecutively, can lead to drop misdirection. Firstly the droplet stalks (the thin column of ink connecting an ejected ink drop to the ink in the nozzle immediately prior to droplet separation) can cause micro flooding on the surface of the nozzle plate. The micro floods can partially occlude an adjacent nozzle and draw an ejected drop away from its intended trajectory. Secondly, the aerodynamic turbulence created by one ejected drop can influence the trajectory of a drop ejected simultaneously (or immediately after) from a neighboring nozzle. The second fired drop can be drawn into the slipstream of the first and thereby misdirected. Thirdly the fluidic cross talk between neighboring nozzles can cause drop misdirection.

[0071] Udon addresses this by dispersing the group of nozzles that fire simultaneously, and then fires nozzles from every subsequent dispersed group such that sequentially fired nozzles are spaced from each other. The nozzle firing sequence continues in this manner until all the nozzles (that are loaded with print data) in the row have fired.

[0072] To do this, each row of nozzles is divided into a number of adjacent spans and one nozzle from each span fires simultaneously. The subsequently firing nozzle from each span is spaced from the previously firing nozzle by a shift value. The shift value can not be a factor of the span number (that is, the shift and the span should be mutually prime) so nozzles at the boundary between neighbouring spans do not fired simultaneously, or consecutively.

Span

[0073] The span is the number of consecutive nozzles in the row from which only one nozzle will fire at a time. Figure 11 shows a partial row of nozzles being fired with a span of three, and the same row segment with a span of five. For the purposes of illustration, the shift value is one. However, as discussed above, this is not an appropriate shift value in practice as the adjacent nozzles will fire consecutively. The turbulent wake from the drop fired from the first nozzle can interfere with the drop fired from the adjacent model immediately afterwards. It can also be a problem for the ink supply flow to the adjacent nozzles.

[0074] For a span of three, there are three firings before the entire row is fired.

- First firing: every third nozzle in a row fires.
- Second firing: the nozzle to one side of the first nozzle fires.
- Third firing: the nozzle two across from the first nozzle fires all nozzles on this row have now fired.
- The nozzles in row N + 2 now begin their fire cycle using the same span pattern.
- One third of a row's nozzles fire at any one time.

[0075] For a span of five, there are five firings before the entire row is fired and one fifth of the row's nozzles fire at any one time.

[0076] At the extremes (for Udon printhead IC's):

- span = 1 fires all nozzles in a row simultaneously, draws too much current and will damage the IC;
- span = 640 fires one nozzle at a time, but may take too long to complete in the time allotted to a single row.

[0077] In any case, span only controls the maximum number of nozzles that are able to fire at any one time. Each individual nozzle still needs a 1 in its shift register to actually fire. In the examples below, we assume that the IC is printing a solid color line, so every nozzle of the color will fire. In reality, this is rarely the case.

Shift

[0078] The examples shown in Figure 11 have a shift value of one. That is, one nozzle fires, then the next nozzle left fires, then the next, etc. As discussed above, this is impractical. Figure 12 shows a segment of the nozzle row with a span of 5 with a span shift of 3.

- First firing: column 1 fires.
- Second firing: the firing nozzle is 3 nozzles across at column 4.
- Third firing: the count has wrapped around and is back at nozzle 2.
- Fourth firing: nozzle 5 fires.
- Fifth firing: nozzle 3 fires-all 5 nozzles in the span have now fired.

[0079] To fire every nozzle in the row exactly once, the shift can not be a factor of the span, i.e. the span can not be divided by the shift (without remainder). To maximize droplet separation in time and space and still fire every nozzle exactly once per row, the closest mutual prime to the square root of the span should be chosen for span shift. For example, for a span of 27, a span shift of 5 would be appropriate.

Firing Delay

[0080] Firing all the nozzles in a row simultaneously, will draw a large amount of current that remains (approximately) constant for the duration of the row time. This still requires the power supply to step from zero current to a maximum current in a very short time. This creates a high rate of change of current drawn until the maximum value is reached. Unfortunately, a rapid increase in the current creates inductance which increases the circuit impendance. With high impendance, the drive voltage 'sags' until the inductance returns to normal, i.e. the current stops increasing. In printhead IC's, it is necessary to keep the actuator supply voltage within a narrow range to maintain consistent ink drop size and directionality.

[0081] As the firing pulses in each region can be varied by the TCPG, it can be used to delay the start of firing in each region across the printhead. This reduces the rate of change in current during firing. Figures 13A and 13B show the relationship between region firing delay and current drain. Figure 13A shows the two extremes of power usage when printing a solid line of a color (this is the worst case for power supply because 80 dots will fire across the region).

[0082] Figure 13A shows no firing delay between regions. Each region has 4 spans of 20 nozzles each. Each of the regions fire for the entire row time (row time is the time available for a complete row of nozzles to fire). Therefore, at any time during the row time, four nozzles from all of the eight regions are firing (drawing current). Hence the profile of the supply current is a long flat step function 78 and identical for each region. The profile for the entire row is the accumulated step function 80 of the individual profiles 78. Theoretically the leading edge 90 of step function 80 is vertical but in fact it is very steep until it reaches the maximum current level 82. The high rate of change in the current can cause the undesirable voltage sags.

[0083] Figure 13B shows the current supply profiles when the regions are fired in stages. To stagger the firing of each region, the time in which the nozzles in each span can fire must be reduced. In the example shown in Figure 13B, each span has half the row time in which to fire its nozzles. To compress the time needed for each span to fire, the number of nozzles in the span can be reduced. For example, the span in Figure 13B is 10, so 8 nozzles (10 x 8 = 80 nozzles/ region) from each span will fire simultaneously. The cumulative current drawn for eight nozzles is greater than that for the four nozzles firing per span shown in Figure 13A. So the current drawn for each region in Figure 13B is twice that of the regions in Figure 13A, but the current is drawn for half the time. Region 1 is supply with current 84 at the beginning of the row time. The current supply 94 to region 2 starts after a set delay period and region 3 is similarly delayed relative to region 2, and so on until region 8 starts its firing sequence. The delays for each region need to be timed so that region 8 starts firing at or before half the row time has elapsed.

[0084] The cumulative current supply profile 86 shows the series of 8 rapid steps in the current supply as it reaches its maximum value 88. The maximum current 88 is greater than the maximum current 82 in the non-delayed region firing, but the rate of increase in the supply current 92 is less. This induces less impedance in the circuit so that the voltage sag is lower. In each case, the total energy used is the same for a given row time but the distribution of energy consumption is adjusted.

Formal Firing Order

[0085] As discussed above, print data is sent to the printhead IC's 12 one row at a time followed by a fire command. Previously, each individual unit cell in the nozzle array had a shift register to store the print data (a '1' or '0') for each nozzle, for each line time (the line time is the time taken for the printhead to print one line of print). The print data for the entire array would be loaded into the shift registers before a fire command initiated the firing sequence. By loading and firing the print data for each line in stages, a smaller number of shift registers can be positioned adjacent the array instead of within each unit cell. Removing the shift registers from the unit cell 20 allows the drive FET 40 (see Figure 2) to be larger. This improves the printhead efficiency for the reasons set out below.

[0086] Thermal printhead IC's are more efficient if the vapor bubble generated by heater element is nucleated quickly. Less heat dissipates into the ink prior to bubble nucleation. Faster nucleation of the bubble reduces the time that heat can diffuse into wafer regions surrounding the heater. To get the bubble to nucleate more quickly, the electrical pulse needs to have a shorter duration while still providing the same energy to the heater (about 200 nJ). This requires the drive FET for each nozzle to increase the power of the drive pulse. However, increasing the power of the drive FET increases its size. This enlarges the wafer area occupied by the nozzle and its associated circuitry and therefore reduces the nozzle density of the printhead. Reducing the nozzle density is detrimental to print quality and compact printhead design. By removing the shift register from the unit cell, the drive FET can be more powerful without compromising nozzle density.

[0087] The Udon design writes data to the nozzle array one row at a time. However, a printhead IC that loaded and fired several rows at a time would also be achieving the similar benefits. However, it should be noted that the electrical connection between the shift register and the corresponding nozzle should be kept relatively short so as not to cause high resistive losses.

[0088] Loading and firing the print data one row at a time requires the PEC to send the data in the row order that it is printed. Previously the data for the entire nozzle array was loaded before firing so the PEC was indifferent to the row firing order chosen by the printhead IC. With Udon, the PEC will need to transmit row data in a predetermined order.

[0089] Printhead nozzles are normally fired according to the span/shift fire sequence and the delayed region start discussed above. The supply channels 50 in the back of the printhead IC 12 (see Figure 5C) supply ink to two adjacent rows of nozzle on the front of the IC, that is rows 0 and 1 eject the same color, rows 2 and 3 eject another color, and so on. The Udon printhead IC has ten row of nozzles, these can be designated colors CMYK,IR (infra-red ink for encoding the media with data invisible to the eye) or CMYKK. To avoid ink supply flow problems, every second row is fired in two passes, that is row 0, row 2, row 4, row 6, row 8, then row 1, row 3, row 5, and so on until all ten row are fired.

[0090] Row firings should be timed such that each row takes just under 10% of the total line time to fire. A fire command simply fires the data that is currently loaded. When operating in SoPEC mode, Udon printhead IC receives a 'data next' command that loads the next row of data in the predetermined order. In MoPEC mode, each row of data must be specifically addressed to its row.

[0091] Taking paper movement into account, a row time of just less than 0.1 line time, together with the 10.1DP (dot pitch) vertical color pitch appears on paper as a 10DP line separation. Odd and even same-color rows of nozzles, spaced 3.5DP apart vertically and fired 0.5 line time apart results as dots on paper 5DP apart vertically.

Fire Cycle

[0092] Figure 14 shows the data flows and fire command sequences for a line of data. When a fire command is received in the data stream, the data in the row of shift registers transfers to a dot-latch in each of the unit cells, and a fire cycle is started to eject ink from every nozzle that has a 1 in its dot-latch. Meanwhile the data for the next row in the firing order is loaded.

Drop Triangle and Droop Section Firing Delay

[0093] Drop compensation is the compensation applied by Udon drive logic 46 (see Figure 2) to the sloping region 28 and drop triangle 30 of nozzles at the left of the nozzle array22 on each IC 12 (see Figure 5C). As shown in Figure 15, the print data to the nozzles that are displaced from the rest of the array 22 needs to be delayed by a certain number of line times. Figure 15 shows the nozzles in one row 26 of the IC 12. The nozzles in the drop triangle 30 are all displaced 10 dot pitches from the non-displaced nozzles in the row. The nozzles in the droop section 28 that connects the drop triangle 30 and the non-displaced nozzles have a displacement that indexes by one dot pitch every two nozzles. In the sloping droop region 28 the drive logic indexes the delay in firing the dot data correspondingly.

Nozzle Blockage Clearing

[0094] During periods of inactivity, or even between pages, and especially at higher ambient temperatures, nozzles may become blocked with more viscous or dried ink. Water can evaporate from the ink in the nozzles thereby increasing the viscosity of the ink to the point where the bubble is unable to eject the drop. The nozzle becomes clogged and inoperable.

[0095] Many printers have a printhead maintenance regime that can recover clogged nozzles and clean the exterior face of the printhead. These create a vacuum to suck the ink through the nozzle so that the less viscous ink refills the nozzle. A relatively large volume of ink is wasted by this process requiring the cartridges to be replaced more frequently.

[0096] Udon printhead IC's have a maintenance mode that can operate before or during a print job. During maintenance mode the drive logic generates a de-clog pulse for the actuators in each nozzle unless the dead nozzle map (described below) indicates that the actuator has failed. To operate during a print job, the nozzles should fire the de-clog pulse into the gap between pages without interruption to the paper.

[0097] The de-clog pulse is longer than the normal drive pulses. The bubble formed from a longer duration pulse is larger and imparts a greater impulse to the ink than a firing impulse. This gives the pulse the additional force that may be needed to eject high viscosity ink.

[0098] As a preliminary measure, the de-clog pulse can be preceded by a series of sub-ejection pulses to warm the ink and lower viscosity. Figure 16 shows a typical de-clog pulse train with a series of short (relative to a firing pulse) sub-ejection pulses 94 followed by a single de-clog pulse 96. The individual sub-ejection pulses 94 have insufficient energy to nucleate a bubble and therefore eject ink. However, a rapid series of them raises the ink temperature to assist the subsequent de-clog pulse 96.

Open Actuator Testing

[0099] The Udon printhead IC 12 supports an open actuator test. The open actuator test (OAT) is used to discover whether any actuators in the nozzles array have burnt out and fractured (usually referred to as becoming 'open' or 'open circuit').

[0100] Fabrication of the MEMS nozzle structures on wafer substrates will invariably result in some defective nozzles. These 'dead nozzles' can be located using a wafer probe immediately after fabrication. Knowing the location of the dead nozzles, the print engine controller (PEC) can be programmed with a dead nozzle map. This is used to compensate for the dead nozzles with techniques such as nozzle redundancy (the printhead IC is has more nozzles than necessary and uses the 'spare' nozzles to print the dots normally assigned to the dead nozzles).

[0101] Unfortunately, nozzles also fail during the operational-life of the printhead. It is not possible to locate these nozzles using a wafer probe once they have been mounted to the printhead assembly and installed in the printer. Over time, the number of dead nozzles increases and as the PEC is not aware of them, there is no attempt to compensate for them. This eventually causes visible artifacts that are detrimental to the print quality.

[0102] In thermal inkjet printheads and thermal bend inkjet printheads, the vast majority of failures are the result of the resistive heater burning out or going open circuit. Nozzles may fail to eject ink because of clogging but this is not a 'dead nozzle,' and may be recovered through the printer maintenance regime. By determining which nozzles are dead with an on-chip test, the print engine controller can periodically update its dead nozzle map. With an accurate dead nozzles map, the PEC can use compensation techniques (e.g. nozzle redundancy) to extend the operational life of the printhead.

[0103] The Udon IC open actuator test compares the resistance of the actuator to a predetermined threshold. A high (or infinite) resistance indicates that the actuator has failed and this information is fed back to the PEC to update its dead nozzle compensation tables. It is important to note that the OAT can discover open circuit nozzles, but not clogged nozzles.

[0104] Thermal actuators and thermal bend actuator both use heater elements and the OAT can be equally applied to either. Likewise, the drive FET can be N-type or P-type. Figure 17A and 17B show the circuits for the OAT as applied to a single unit cell with a single heater element driven by a p-FET and an n-FET respectively.

[0105] In Figure 17A, the drive p-FET 40 is enabled during printing whenever the 'row enable' (RE) 98 and 'column enable' (CE) 100 are both asserted (receive '1's at their contacts). Enabling the drive FET 40 opens the heater element 34 to Vpos 104 to activate the unit cell. When the row enable 98 or the column enable 100 are not asserted, the bleed n-FET is enabled. The bleed n-FET 112 ensures that the voltage at the sense node 120 is pulled low when the unit cell is not activated to eliminate any electrolysis path.

[0106] When the OAT 106 is asserted, the AND gate 108 pulls the gate of the drive p-FET 40 high to disable it. Asserting the OAT 106 also pulls the gate of the sense n-FET 114 high to connect the sense output 116 to the sense node 120. With the bleed n-FET 112 disabled the voltage at the sense node 120 will still be pulled low through the heater element 34 to ground 68. Accordingly, the sense output 116 is low to indicate that the actuator is still operational. However, if the heater element 34 is open (failed), the voltage at the sense node 120 remains high and this pulls the sense output 116 high to indicate a dead nozzle. This is fed back to the PEC which updates the dead nozzle map and initiates measures to compensate (if possible).

[0107] The unit cell circuitry shown in Figure 17B uses a drive n-FET 40. In this embodiment, asserting the row enable 98 and the column enable 100 pulls the gate of the drive n-FET 40 high to enable it and allow Vpos 104 to drain to ground through the heater 34. Again the bleed p-FET 118 is disabled whenever the row enable 98 and column enable 100 are asserted.

[0108] To initiate an actuator test, the OAT 106 is asserted, together with the row enable 98 and column enable 100. This disables the drive n-FET 40 by pulling the gate low using NAND logic 110. It also opens the sense n-FET 114 to connect the sense output 116 to the sense node 120. With the heater 34 insulated from ground 68 when the drive FET 40 is disabled, the sense node 120 is pulled high and a high sense output 116 indicates a working actuator. If the heater 34 is broken, the sense node 120 is left at low voltage following the last time the drive FET 40 was enabled. Accordingly when the OAT is enabled, the sense output 116 is low and the PEC records the dead nozzle to the dead nozzle map.

[0109] It will be appreciated that the open actuator test should be performed shortly after the printhead IC has been printing. After a period of inactivity, the bleed p-FET 118 or n-FET 112 drops the sense node to low voltage. The gap in printing between pages is a convenient opportunity to perform an open actuator test.

[0110] The present invention has been described herein by way of example only. Skilled workers in this field will readily recognise many variations and modification.

[0111] The present teaching may also extend to the features of one or more of the following numbered clauses:

1. A printhead IC comprising: an array of nozzles; an ejection actuator corresponding to each of the nozzles respectively, the ejection actuator having a resistive heater that is activated when the actuator ejects ink through the corresponding nozzle; drive circuitry for receiving print data and activating the actuators with drive signals in accordance with the print data; and, open actuator test circuitry for selectively disabling the actuators when they receive a drive signal while comparing the resistance of the resistive heater to a predetermined threshold to assess whether the actuator is defective.

2. A printhead IC according to clause 1 wherein during use feedback from the open actuator test circuitry is used to adjust the print data subsequently received by the drive circuitry.

3. A printhead IC according to clause 1 wherein the open actuator test circuitry generates defective nozzle feedback

during print jobs.

4. A printhead IC according to clause 1 wherein the open actuator test circuitry generates defective nozzle feedback within a predetermined time period after printhead operation.

5. A printhead IC according to clause 1 wherein the open actuator test circuitry generates defective nozzle feedback between each page of a print job.

6. A printhead IC according to clause 1 wherein the drive circuitry has a drive FET controlling current to the resistive heater and logic for enabling the drive FET when a drive signal is received and disabling the drive FET when a drive signal and a open actuator test signal are received.

7. A printhead IC according to clause 1 wherein the drive circuitry has a bleed FET that slowly drains any voltage drop across the resistive heater to zero when the drive circuitry is not receiving a drive signal or an open actuator test signal.

8. A printhead IC according to clause 1 wherein the drive circuitry has a sense node between the drain of the drive FET and the resistive heater, and the open actuator test circuitry has a sense FET that is enabled when open actuator test signal is received such that the voltage at the drain of the sense FET is used to indicate whether the heater element is defective.

9. A printhead IC according to clause 8 wherein the drive FET is a p-type FET.

10. A printhead IC according to clause 1 wherein the drive circuitry receives the print data for the array in a plurality of sequential portions with a fire command at the end of each portion.

11. A printhead IC according to clause 1 further comprising a plurality of temperature sensors for sensing the temperature of the printhead IC within each of the regions respectively.

12. A printhead IC according to clause 1 wherein the drive circuitry adjusts the drive pulses sent to the nozzles in accordance with the temperature of the printing fluid within the nozzles.

13. A printhead IC according to clause 11 wherein the drive circuitry blocks the dive pulses sent to at least some of the nozzles in the array when one or more of the temperature sensors indicate the temperature exceeds a predetermined maximum.

14. A printhead IC according to clause 1 wherein the drive pulses consist of ejection pulses with sufficient energy to eject printing fluid from the nozzles designated to fire at that time, and sub-ejection pulses with insufficient energy to eject printing fluid from the nozzles not designated to fire at that time.

15. A printhead IC according to clause 1 wherein during use the drive circuitry adjusts the drive pulse profile in response to the temperature sensor output.

16. A printhead IC according to clause 1 wherein during use, the temperature sensor can be de-activated after a period of use.

17. A printhead IC according to clause 1 wherein the drive circuitry delays sending the drive pulses to one of the groups relative to at least one of the other groups.

18. A printhead IC according to clause 1 wherein each row of nozzles is divided into a plurality of groups, each having at least one nozzle the drive circuitry delays sending the drive pulses to one of the groups relative to at least one of the other groups.

19. A printhead IC according to clause 17 wherein during use the drive circuitry actuates the nozzles in the row in accordance with a firing sequence, the firing sequence enabling the nozzles in each group to eject printing fluid simultaneously, and enabling each of the groups to eject printing fluid in succession such that, the nozzles in each group are spaced from each other by at least a predetermined minimum number of nozzles and, each of the nozzles in a group is spaced from the nozzles in the subsequently enabled group by at least the predetermined minimum

number of nozzles.

20. A printhead IC according to clause 1 wherein the drive circuitry is configured to operate in two modes, a printing mode in which the drive pulses it generates are printing pulses, and a maintenance mode in which the drive pulses are de-clog pulses, such that, the de-clog pulse has a longer duration than the printing pulse.

Claims

1. An inkjet printer comprising:

an array (22) of nozzles (32) arranged into rows (26), each row (26) consisting of a plurality of nozzle groups, the nozzles (32) in each group being interspersed with nozzles (32) from the other groups; and,
associated drive circuitry (42, 46) for actuating the nozzles (32) in the row (26) in accordance with a firing sequence, the firing sequence enabling the nozzles in each group to eject printing fluid simultaneously, and enabling each of the groups to eject printing fluid in succession;
wherein:

each row is divided into spans, each span having only one nozzle from every group so that the number of spans across the row (26) equals the number of groups of nozzles;
the nozzles (32) in each group are spaced from each other by at least a predetermined minimum number of nozzles (32); and
each of the nozzles in a group is spaced from the nozzles (32) in the subsequently enabled group by at least the predetermined minimum number of nozzles (32)

characterized in that:
the predetermined minimum number of nozzles (32) between sequentially enabled nozzles is a uniform shift along each span in a uniform direction, the shift being a number of nozzles that is an integer greater than one and not a factor of the number of nozzles (32) in the span.

2. The inkjet printer of claim 1, wherein the successively enabled nozzles (32) in each span progress from a first end towards a second end of the span until there are insufficient nozzles (32) left at the second end to fill the shift, in which case, the shift is completed by enabling a non-enabled at the first end of the span until all the nozzles (32) in the span are enabled once during the firing sequence.

3. The inkjet printer of claim 1, wherein the shift is the number of nozzles (32) that is the nearest integer to the square root of the span, and that is not a factor of the span.

4. The inkjet printer of any one of the preceding claims, further comprising a plurality of temperature sensors (74) positioned along the array (22) of nozzles (32) such that the drive circuitry (42, 46) adjusts the drive pulses in response to the temperature sensor (74) outputs.

5. The inkjet printer of claim 4, wherein each of the plurality of temperature sensors (74) is activated sequentially for a period of time during the print job.

6. The inkjet printer of claim 4 or claim 5, wherein the plurality of temperatures sensors (74) are divided into two or more groups, each group being activated for a sensing period in accordance with a predetermined repeating sequence for the duration of a print job.

7. The inkjet printer of claim 6, wherein each of the plurality of temperature sensors (74) is configured to sense the temperature of a corresponding region of the array (22) such that the drive pulse for the nozzles (32) in one region can differ from the drive pulse for the nozzles (32) in another region.

8. The inkjet printer of claim 4, wherein every second temperature sensor in the plurality of temperature sensors (74) is de-activated such that the drive circuitry (42, 46) adjusts the drive pulse profile for the region corresponding to each activated temperature sensor (74) and applies the same adjustment to the adjacent region where the temperature sensor (74) is de-activated.

9. The inkjet printer of claim 4, wherein the drive circuitry (42, 46) is programmed with a series of temperature thresholds defining a set of temperature zones, each of the zones having a different pulse profile for the drive pulses sent to the nozzles (32) in the region currently operating in that temperature zone.

10. The inkjet printer of claim 9, wherein the pulse profile for each temperature zone differs in its duration.

11. The inkjet printer of claim 10, wherein the drive circuitry (42, 46) sets the pulse duration to zero if the temperature sensor (74) indicates that region is operating at a temperature above the highest of the temperature thresholds.

12. The inkjet printer of 11, wherein the drive circuitry (42, 46) sets the duration of the pulse profile to a sub ejection value for any of the nozzles (32) in the row (26) that are not to eject a drop during that firing sequence.

13. The inkjet printer of any one of the preceding claims, wherein the drive circuitry (42, 46) is configured to operate in two modes: a printing mode in which the drive pulses generated are printing pulses, and a maintenance mode in which the drive pulses generated are de-clog pulses, such that, the de-clog pulse has a longer duration than the printing pulse.

Patentansprüche

1. Tintenstrahldrucker, der umfasst:

eine Anordnung (22) von Düsen (32), die in Reihen (26) angeordnet sind, wobei jede Reihe (26) aus einer Mehrzahl von Düsengruppen besteht, wobei zwischen den Düsen (32) in jeder Gruppe Düsen (32) aus den anderen Gruppen zwischengestreut sind; und
eine zugeordnete Treiberschaltung (42, 46) zum Betätigen der Düsen (32) in der Reihe (26) gemäß einer Abfeuerungssequenz, wobei die Abfeuerungssequenz ermöglicht, dass die Düsen in jeder Gruppe gleichzeitig Druckfluid ausstoßen und dass jede der Gruppen Druckfluid nacheinander ausstößt;
wobei:

jede Reihe in Spannen aufgeteilt ist, wobei jede Spanne nur eine Düse aus jeder Gruppe aufweist, so dass die Anzahl von Spannen über die Reihe (26) der Anzahl von Düsengruppen gleicht;
die Düsen (32) in jeder Gruppe um zumindest eine vorab definierte Mindestanzahl von Düsen (32) voneinander beabstandet sind; und
jede der Düsen in einer Gruppe um zumindest die vorab definierte Mindestanzahl von den Düsen (32) von den Düsen (32) in der darauf folgend aktivierten Gruppe beabstandet ist, **dadurch gekennzeichnet, dass**:

die vorab definierte Mindestanzahl von Düsen (32) zwischen sequentiell aktivierten Düsen eine einheitliche Verschiebung entlang jeder Spanne in einer einheitlichen Richtung ist, wobei die Verschiebung eine Anzahl von Düsen ist, die eine ganze Zahl größer als 1 und kein Faktor der Anzahl von Düsen (32) in der Spanne ist.

2. Tintenstrahldrucker nach Anspruch 1, wobei die sukzessiv aktivierten Düsen (32) in jeder Spanne von einem ersten Ende hin zu einem zweiten Ende der Spanne fortschreiten, bis am zweiten Ende nicht mehr ausreichend Düsen (32) vorhanden sind, um die Verschiebung zu füllen, wobei die Verschiebung in diesem Fall vervollständigt wird, indem eine nicht-aktivierte Düse am ersten Ende der Spanne einmal während der Abfeuerungssequenz aktiviert wird, bis alle Düsen (32) in der Spanne aktiviert sind.

3. Tintenstrahldrucker nach Anspruch 1, wobei die Verschiebung die Anzahl von Düsen (32) ist, die die nächste ganze Zahl zur Quadratwurzel der Spanne ist und die kein Faktor der Spanne ist.

4. Tintenstrahldrucker nach einem der vorstehenden Ansprüche, die ferner eine Mehrzahl von Temperatursensoren (74) umfasst, die entlang der Anordnung (22) von Düsen (32) positioniert sind, so dass die Treiberschaltung (42, 46) die Treiberimpulse in Reaktion auf die Ausgaben der Temperatursensoren (74) einstellt.

5. Tintenstrahldrucker nach Anspruch 4, wobei jeder der Mehrzahl von Temperatursensoren (74) für einen Zeitraum während des Druckauftrags sequentiell aktiviert wird.

6. Tintenstrahldrucker nach Anspruch 4 oder 5, wobei die Mehrzahl von Temperatursensoren (74) in zwei oder mehr

Gruppen unterteilt ist, wobei jede Gruppe für einen Erfassungszeitraum gemäß einer vorab definierten Wiederholungssequenz für die Dauer eines Druckauftrags aktiviert wird.

7. Tintenstrahldrucker nach Anspruch 6, wobei jeder der Mehrzahl von Temperatursensoren (74) so konfiguriert ist, dass er die Temperatur eines entsprechendes Bereichs der Anordnung (22) erfasst, so dass sich der Treiberimpuls für die Düsen (32) in einem Bereich vom Treiberimpuls für die Düsen (32) in einem weiteren Bereich unterscheiden kann.

8. Tintenstrahldrucker nach Anspruch 4, wobei jeder zweite Temperatursensor in der Mehrzahl von Temperatursensoren (74) deaktiviert ist, so dass die Treiberschaltung (42, 46) das Treiberimpulsprofil für den Bereich einstellt, der jedem aktivierten Temperatursensor (74) entspricht, und die gleiche Einstellung auf den benachbarten Bereich anwendet, in dem der Temperatursensor (74) deaktiviert ist.

9. Tintenstrahldrucker nach Anspruch 4, wobei die Treiberschaltung (42, 46) mit einer Reihe von Temperaturgrenzwerten programmiert ist, die einen Satz von Temperaturzonen definieren, wobei jede der Zonen ein unterschiedliches Impulsprofil für die an die Düsen (32) gesendeten Treiberimpulse in dem Bereich aufweist, der derzeit in dieser Temperaturzone arbeitet.

10. Tintenstrahldrucker nach Anspruch 9, wobei sich das Impulsprofil für jede Temperaturzone in seiner Dauer unterscheidet.

11. Tintenstrahldrucker nach Anspruch 10, wobei die Treiberschaltung (42, 46) die Impulsdauer auf 0 setzt, wenn der Temperatursensor (74) anzeigt, dass der Bereich in einer Temperatur über dem höchsten der Temperaturgrenzwerte arbeitet.

12. Tintenstrahldrucker nach Anspruch 11, wobei die Treiberschaltung (42, 46) die Dauer des Impulsprofils auf einen Subausstoßwert für beliebige der Düsen (32) in der Reihe (26) festlegt, die während dieser Abfeuerungssequenz keinen Tropfen ausstoßen sollen.

13. Tintenstrahldrucker nach einem der vorstehenden Ansprüche, wobei die Treiberschaltung (42, 46) so konfiguriert ist, dass sie in zwei Modi arbeitet: einem Druckmodus, in dem die erzeugten Treiberimpulse Druckimpulse sind, und einem Wartungsmodus, in dem die erzeugten Treiberimpulse Verstopfungsbeseitigungsimpulse sind, so dass der Verstopfungsbeseitigungsimpuls eine längere Dauer als der Druckimpuls hat.

Revendications

1. Imprimante à jet d'encre comprenant :

un réseau (22) de buses (32) agencées en rangées (26), chaque rangée (26) consistant en une pluralité de groupes de buses, les buses (32) dans chaque groupe étant entrecoupées de buses (32) d'autres groupes ; et,
des circuits de commande associés (42, 46) pour actionner les buses (32) dans la rangée (26) selon une séquence de déclenchement, la séquence de déclenchement activant les buses dans chaque groupe pour éjecter simultanément du fluide d'impression, et activant chacun des groupes pour éjecter successivement du fluide d'impression ;
dans laquelle :

chaque rangée est divisée en plages, chaque plage ayant seulement une buse de chaque groupe de telle sorte que le nombre de plages sur toute la rangée (26) est égal au nombre de groupes de buses ;
les buses (32) dans chaque groupe sont espacées les unes des autres par au moins un nombre minimal prédéterminé de buses (32) ; et
chacune des buses dans un groupe est espacée des buses (32) dans le groupe activé ensuite par au moins

le nombre minimal prédéterminé de buses (32) **caractérisée par le fait que** :

le nombre minimal prédéterminé de buses (32) entre des buses activées de façon séquentielle est un décalage uniforme le long de chaque plage dans une direction uniforme, le décalage étant un nombre de buses qui est un entier supérieur à un et qui n'est pas un facteur du nombre de buses (32) dans la plage.

2. Imprimante à jet d'encre selon la revendication 1, dans laquelle les buses activées successivement (32) dans chaque plage avancent à partir d'une première extrémité vers une seconde extrémité de la plage jusqu'à ce qu'il n'y ait pas suffisamment de buses (32) à la seconde extrémité pour remplir le décalage, auquel cas le décalage est terminé par activation d'une buse non activée à la première extrémité de la plage jusqu'à ce que toutes les buses (32) dans la plage soient activées une fois pendant la séquence de déclenchement.

3. Imprimante à jet d'encre selon la revendication 1, dans laquelle le décalage est le nombre de buses (32) qui est l'entier le plus proche de la racine carrée de la plage et qui n'est pas un facteur de la plage.

4. Imprimante à jet d'encre selon l'une quelconque des revendications précédentes, comprenant en outre une pluralité de capteurs de température (74) positionnés le long du réseau (22) de buses (32) de telle sorte que les circuits de commande (42, 46) ajustent les impulsions de commande en réponse aux sorties des capteurs de température (74).

5. Imprimante à jet d'encre selon la revendication 4, dans laquelle chacun de la pluralité de capteurs de température (74) est activé de façon séquentielle pendant une période de temps lors du travail d'impression.

6. Imprimante à jet d'encre selon l'une des revendications 4 ou 5, dans laquelle la pluralité de capteurs de température (74) est divisée en deux ou plusieurs groupes, chaque groupe étant activé pendant une période de détection selon une séquence de répétition prédéterminée pendant la durée d'un travail d'impression.

7. Imprimante à jet d'encre selon la revendication 6, dans laquelle chacun de la pluralité de capteurs de température (74) est configuré pour détecter la température d'une région correspondante du réseau (22) de telle sorte que l'impulsion de commande pour les buses (32) dans une région peut différer de l'impulsion de commande pour les buses (32) dans une autre région.

8. Imprimante à jet d'encre selon la revendication 4, dans laquelle un capteur de température sur deux dans la pluralité de capteurs de température (74) est désactivé de telle sorte que les circuits de commande (42, 46) ajustent le profil d'impulsion de commande pour la région correspondant à chaque capteur de température activé (74) et applique le même ajustement à la région adjacente dans laquelle le capteur de température (74) est désactivé.

9. Imprimante à jet d'encre selon la revendication 4, dans laquelle les circuits de commande (42, 46) sont programmés avec une série de seuils de température définissant un ensemble de zones de température, chacune des zones ayant un profil d'impulsion différent pour les impulsions de commande envoyées aux buses (32) dans la région fonctionnant actuellement dans cette zone de température.

10. Imprimante à jet d'encre selon la revendication 9, dans laquelle le profil d'impulsion pour chaque zone de température diffère en durée.

11. Imprimante à jet d'encre selon la revendication 10, dans laquelle les circuits de commande (42, 46) règlent la durée d'impulsion à zéro si le capteur de température (74) indique que la région fonctionne à une température au-dessus du seuil le plus haut parmi les seuils de température.

12. Imprimante à jet d'encre selon la revendication 11, dans laquelle les circuits de commande (42, 46) règlent la durée du profil d'impulsion à une valeur de sous-éjection pour l'une quelconque des buses (32) dans la rangée (26) qui ne doivent pas éjecter une goutte pendant cette séquence de déclenchement.

13. Imprimante à jet d'encre selon l'une quelconque des revendications précédentes, dans laquelle les circuits de commande (42, 46) sont configurés pour fonctionner dans deux modes : un mode d'impression dans lequel les impulsions de commande générées sont des impulsions d'impression, et un mode d'entretien dans lequel les impulsions de commande générées sont des impulsions de désobstruction, de telle sorte que l'impulsion de désobstruction a une plus longue durée que l'impulsion d'impression.

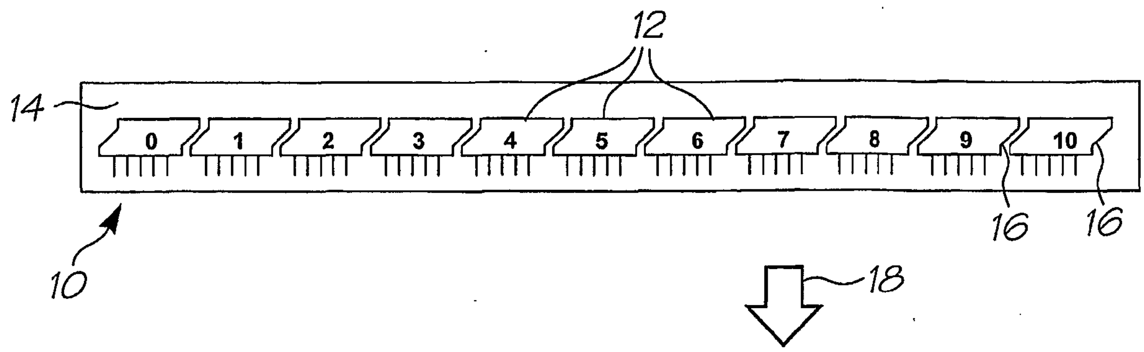
12
14
0
1
2
3
4
5
6
7
8
9
10
16
16
10
18

FIG. 1

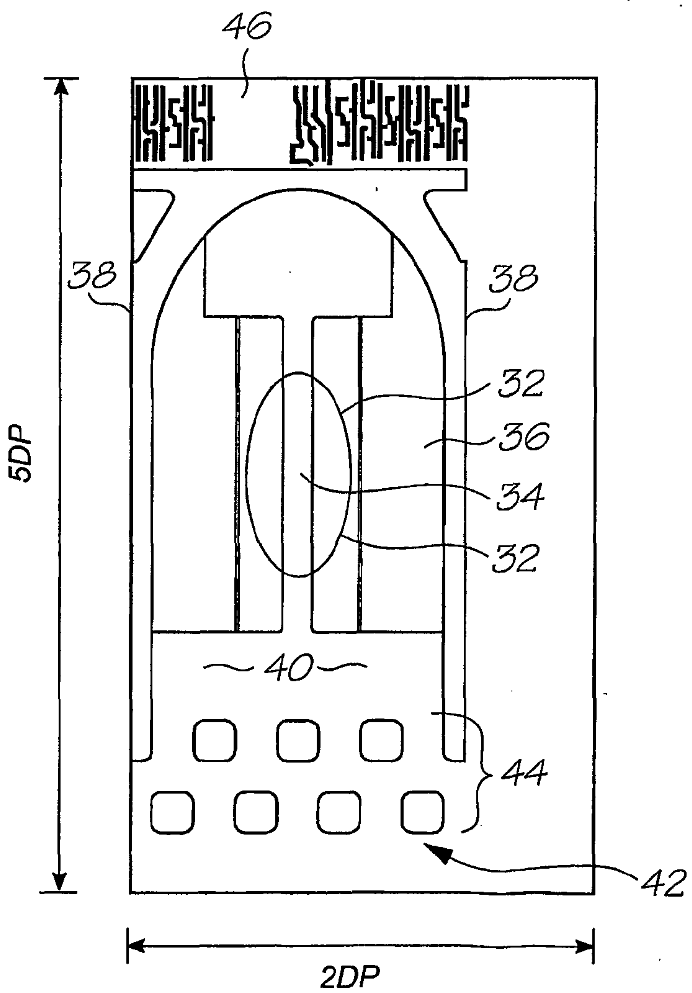
46
38
38
32
36
34
32
5DP
40
44
42
2DP

FIG. 2

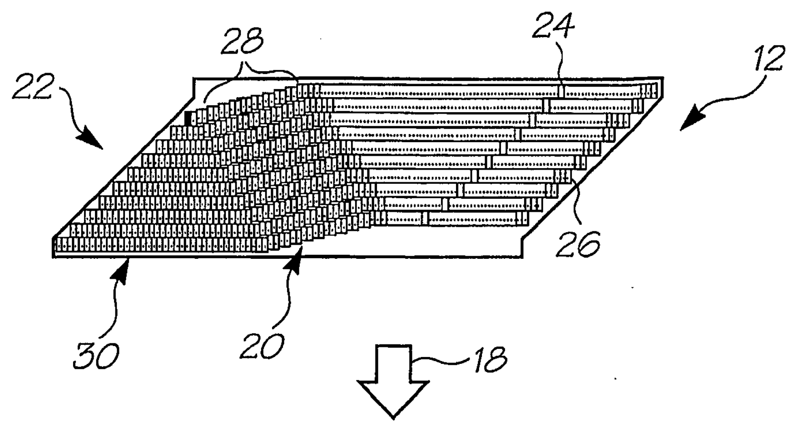
28
24
12
22
26
30
20
18

FIG. 3

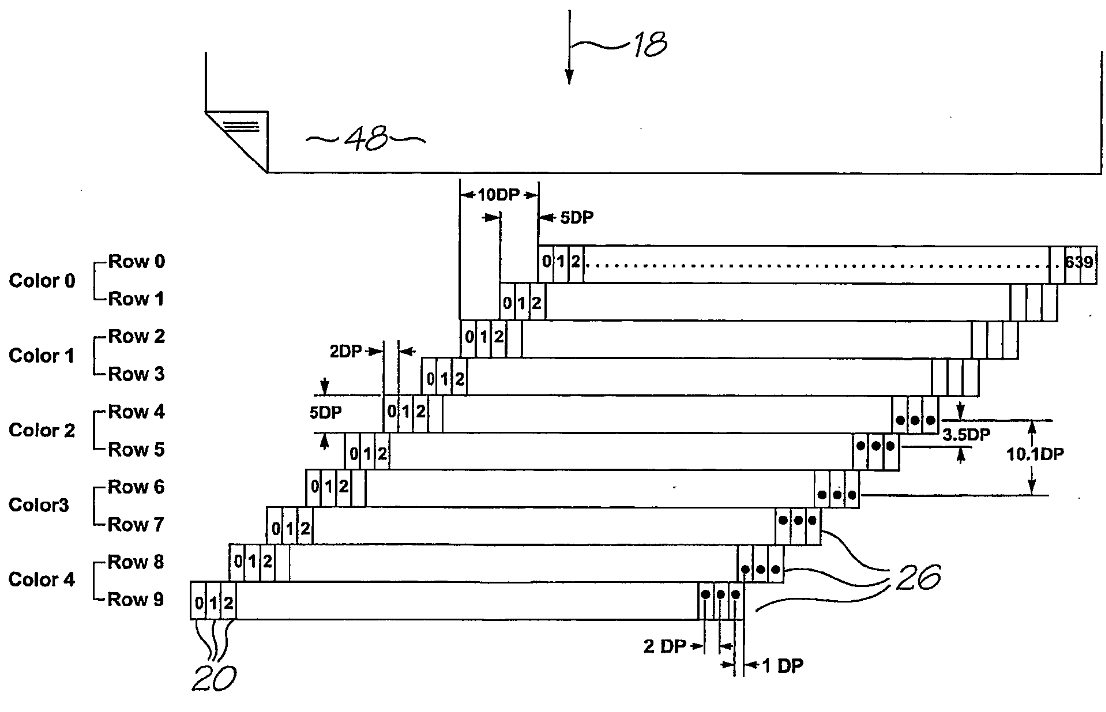
18
48
10DP
5DP
Color 0
Row 0
Row 1
Color 1
Row 2
Row 3
Color 2
Row 4
Row 5
Color3
Row 6
Row 7
Color 4
Row 8
Row 9
2DP
5DP
0 1 2
639
3.5DP
10.1DP
26
2 DP
1 DP
20

FIG. 4

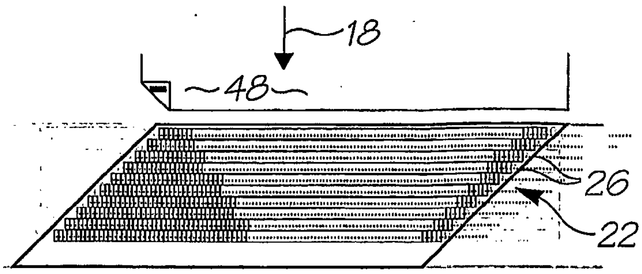

FIG. 5A

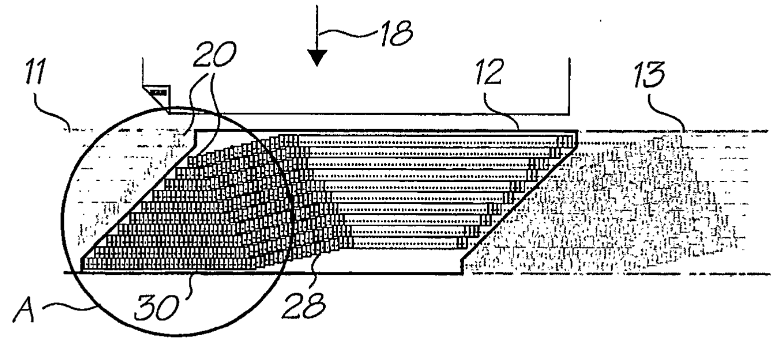

FIG. 5B

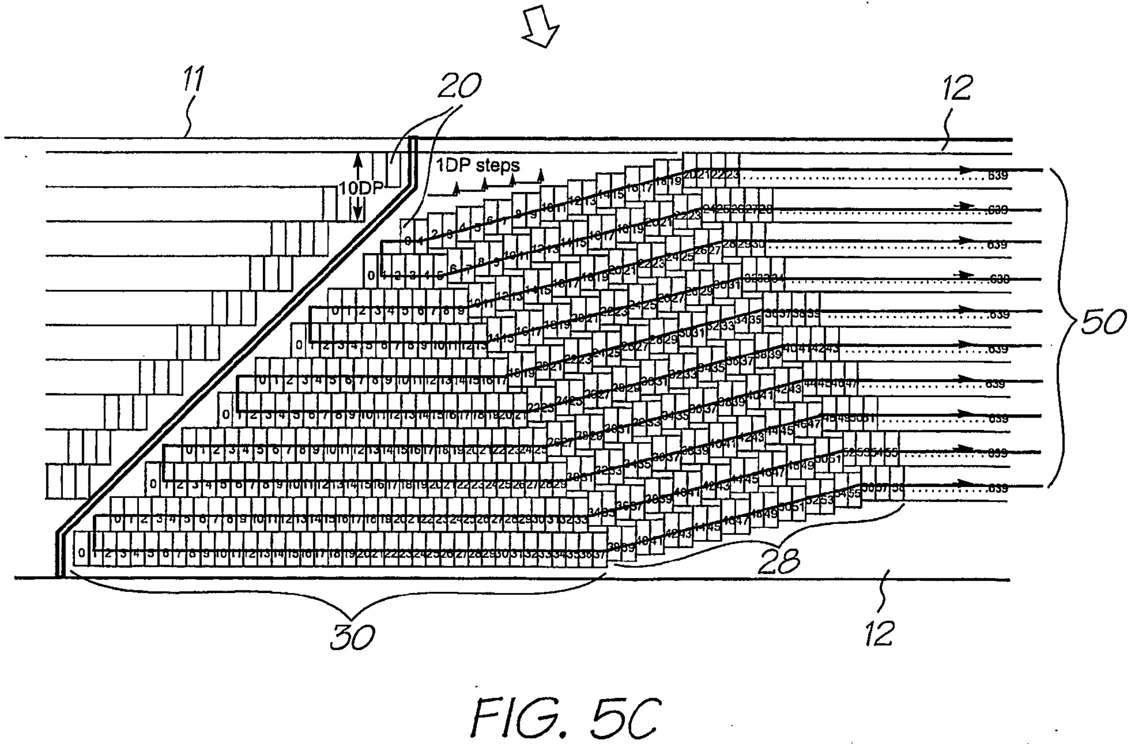

FIG. 5C

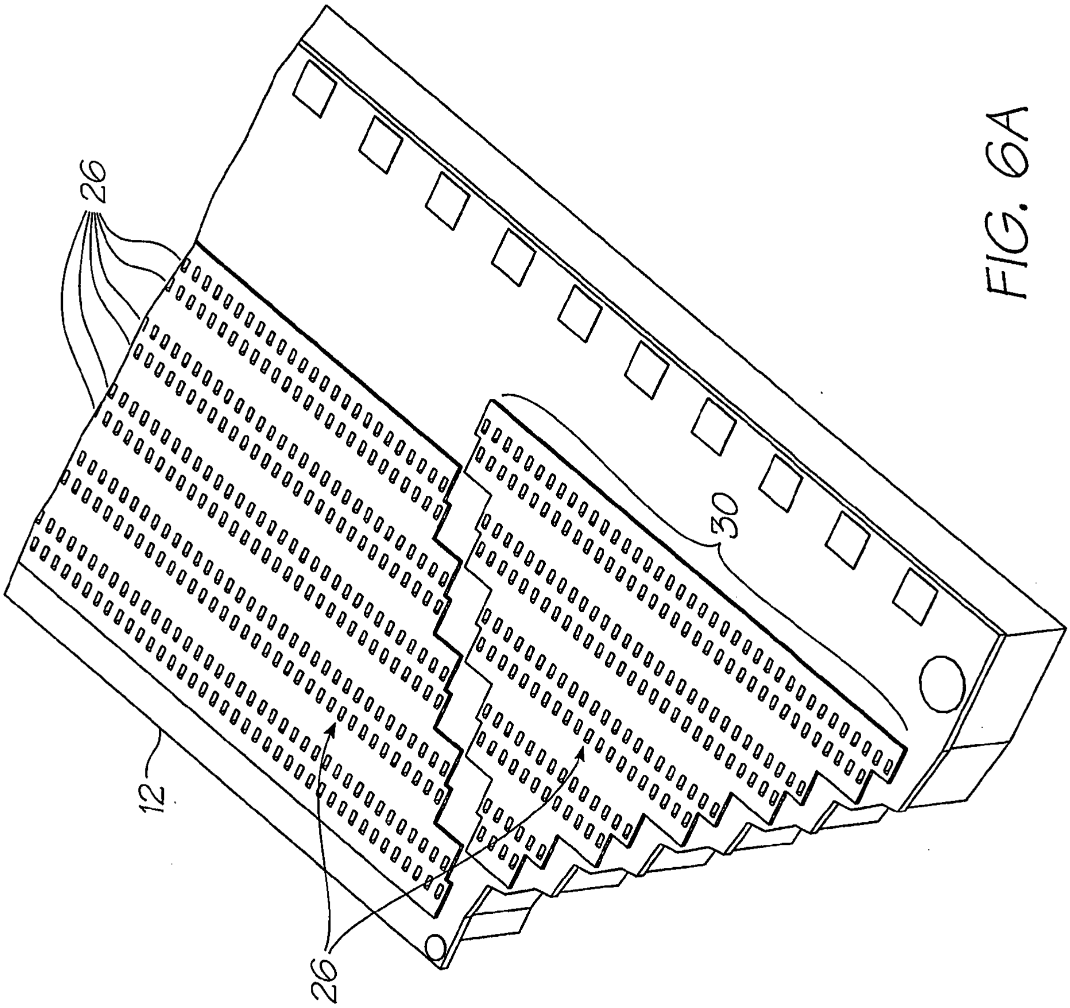

FIG. 6A

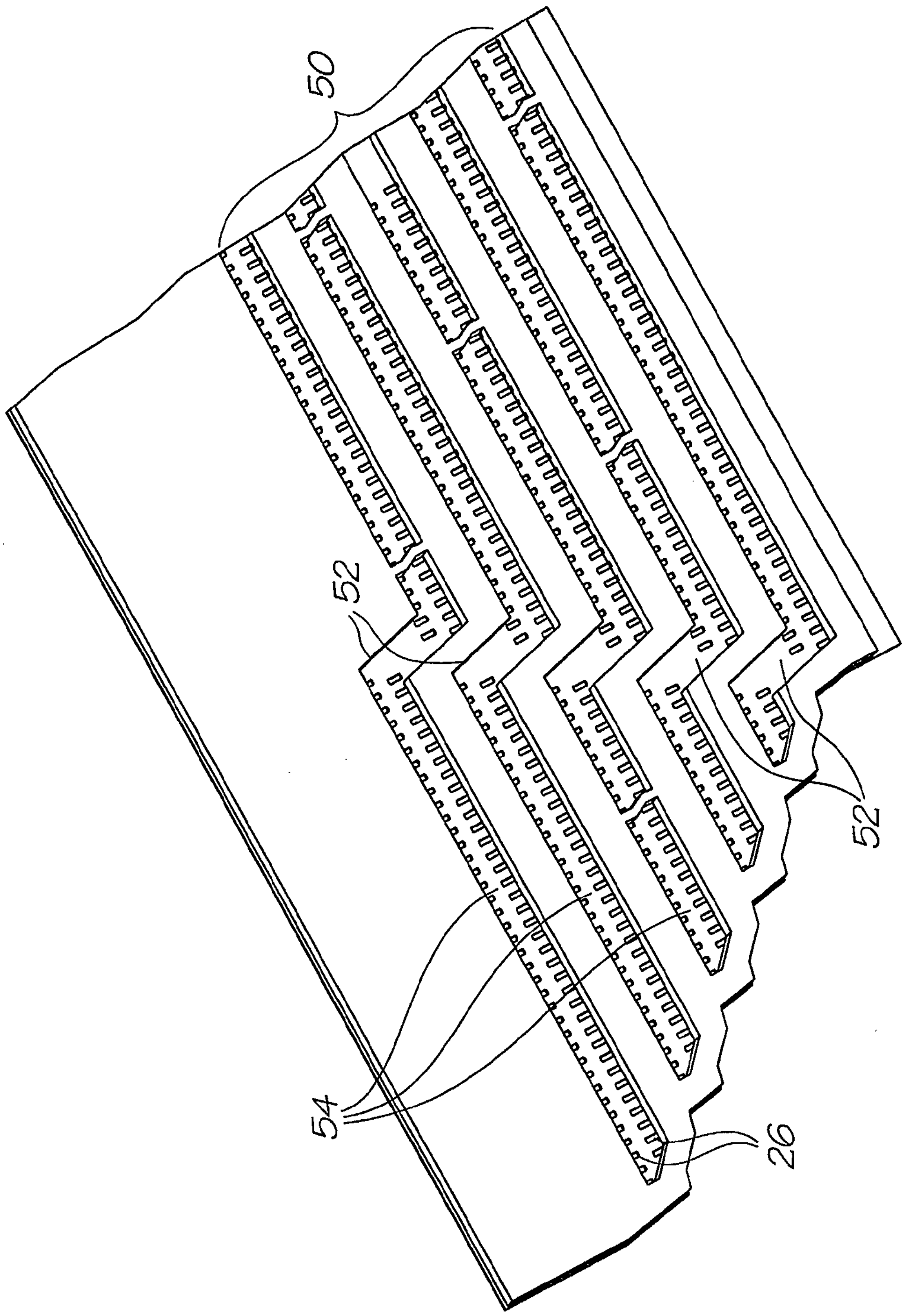

FIG. 6B (Prior Art)

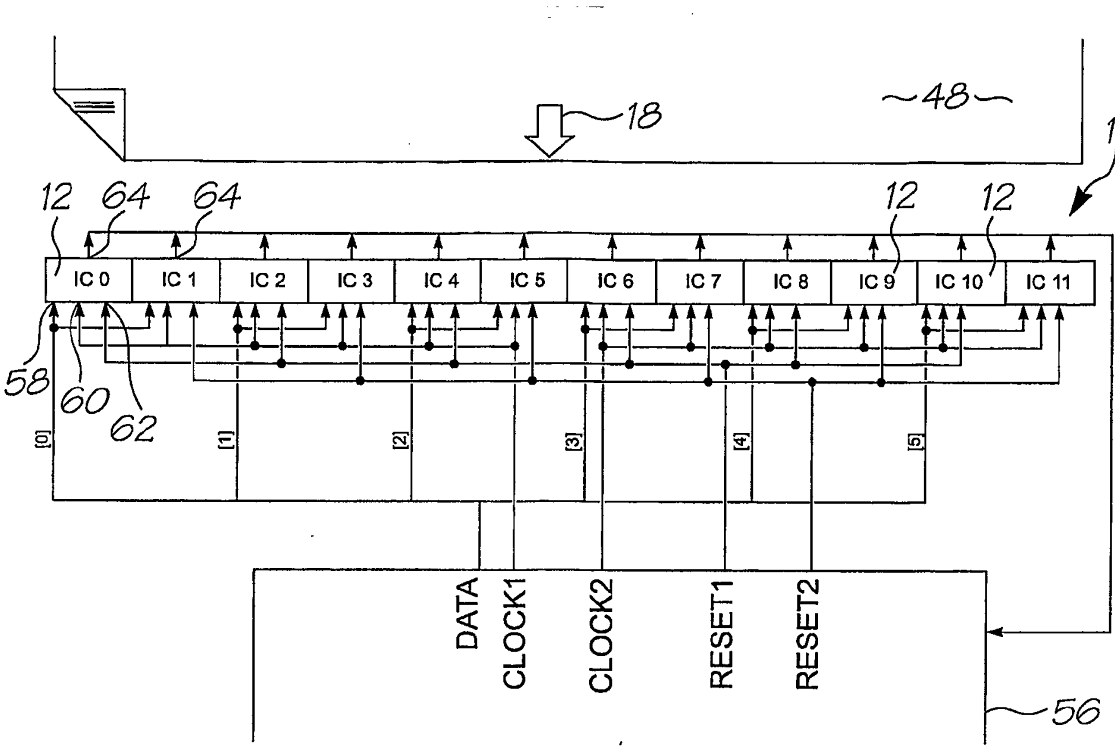
18
48
10
12
64
64
12
12
IC 0
IC 1
IC 2
IC 3
IC 4
IC 5
IC 6
IC 7
IC 8
IC 9
IC 10
IC 11
58
60
62
[0]
[1]
[2]
[3]
[4]
[5]
DATA
CLOCK1
CLOCK2
RESET1
RESET2
56

FIG. 7

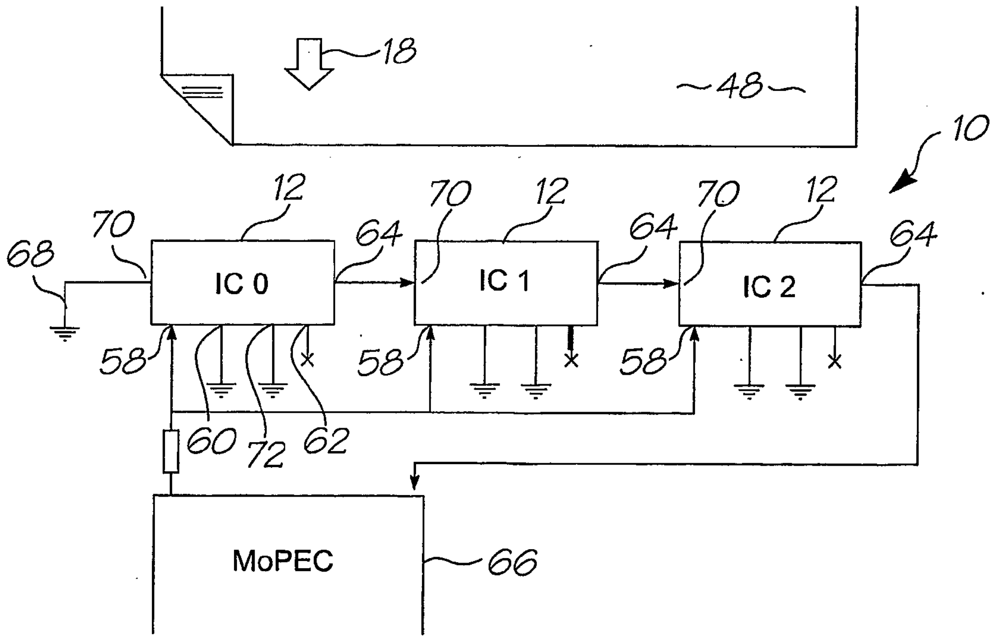
18
48
10
12
70
12
70
12
68
70
64
64
64
IC 0
IC 1
IC 2
58
58
58
60
72
62
MoPEC
66

FIG. 8

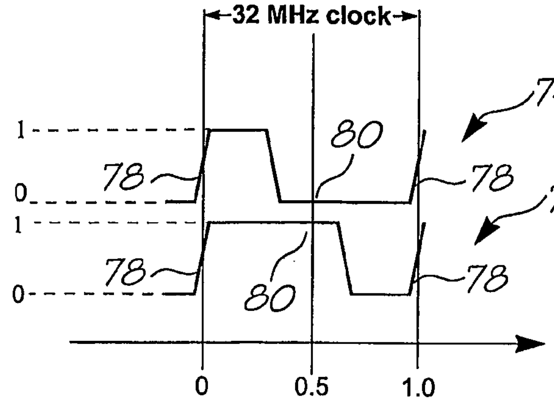
32 MHz clock
74
76
78
80
1
0
1
0
0
0.5
1.0

FIG. 9

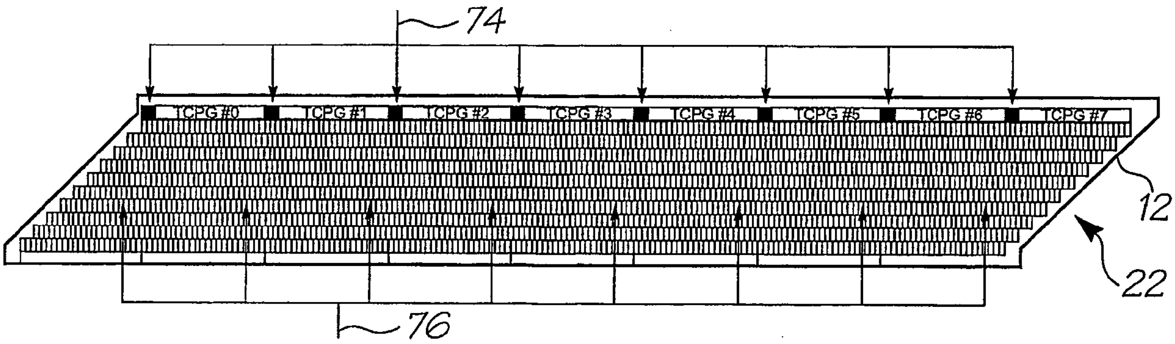
74
TCPG #0
TCPG #1
TCPG #2
TCPG #3
TCPG #4
TCPG #5
TCPG #6
TCPG #7
12
22
76

FIG. 10

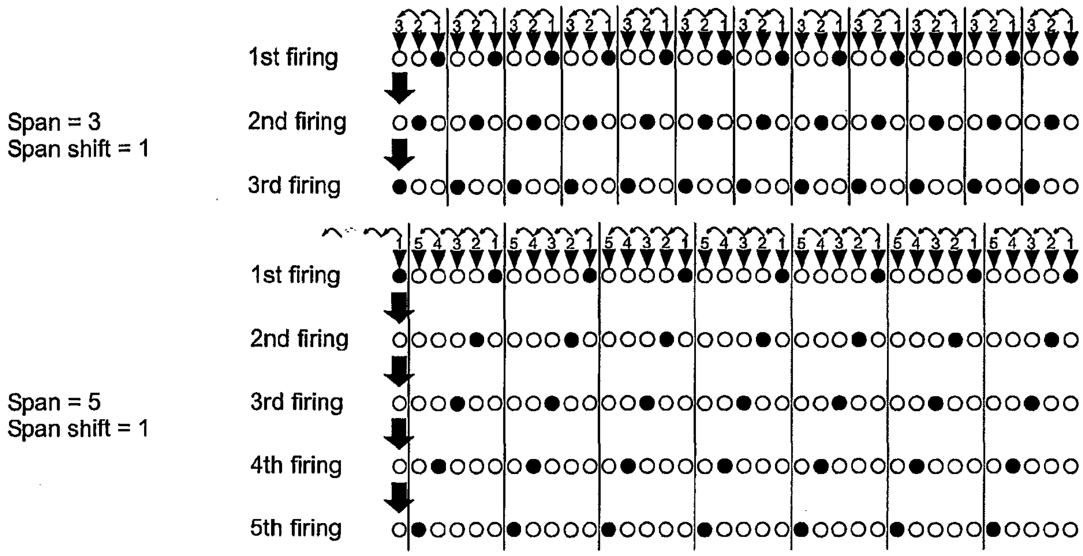
Span = 3
Span shift = 1
1st firing
2nd firing
3rd firing
Span = 5
Span shift = 1
1st firing
2nd firing
3rd firing
4th firing
5th firing

FIG. 11

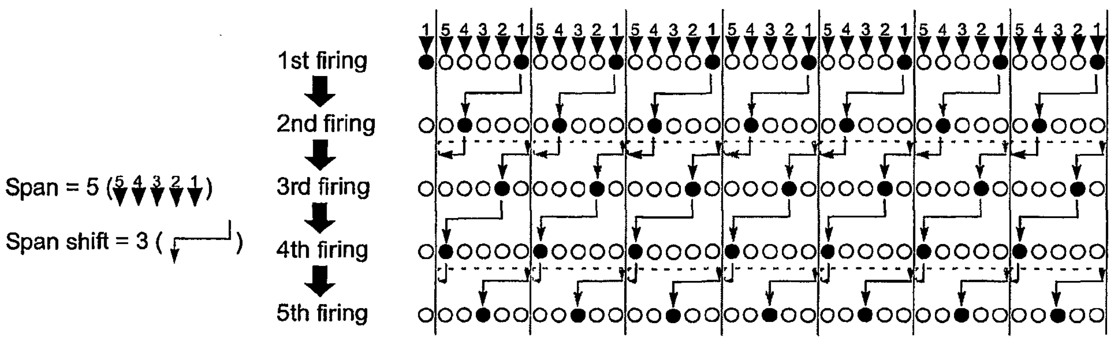
Span = 5
Span shift = 3
1st firing
2nd firing
3rd firing
4th firing
5th firing

FIG. 12

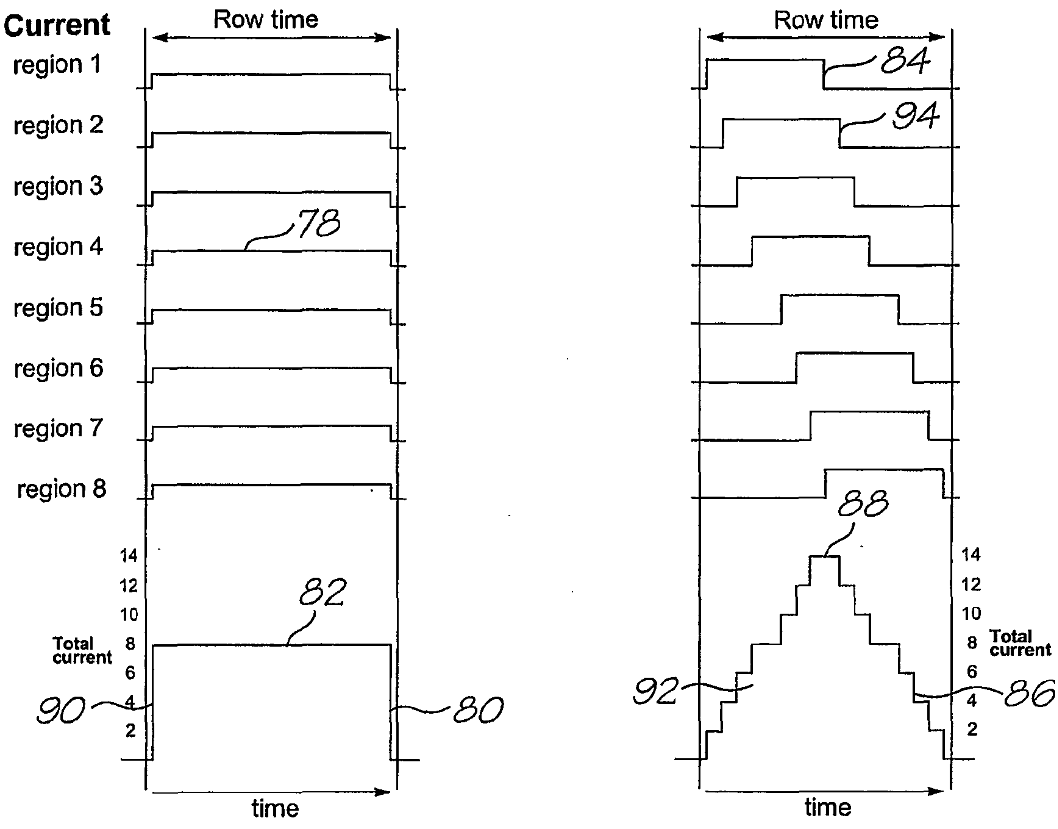

FIG. 13A FIG.13B

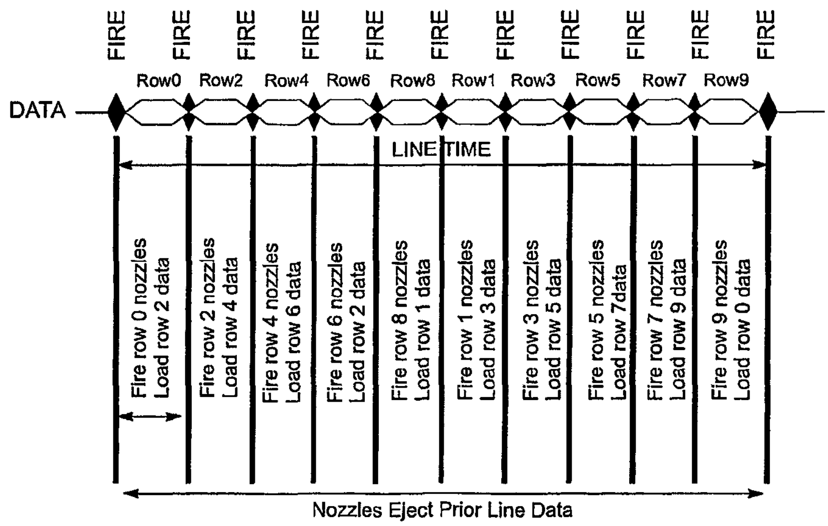

FIG. 14

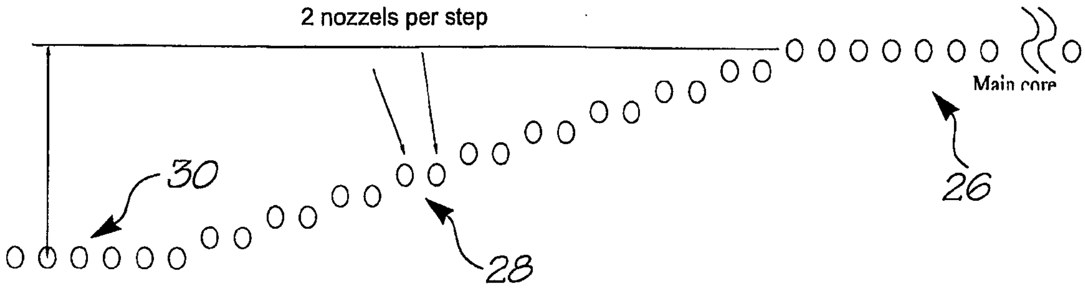
2 nozzels per step
Main core
30
28
26

FIG. 15

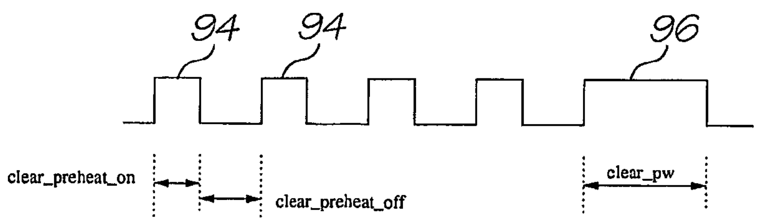
94
94
96
clear_preheat_on
clear_preheat_off
clear_pw

FIG. 16

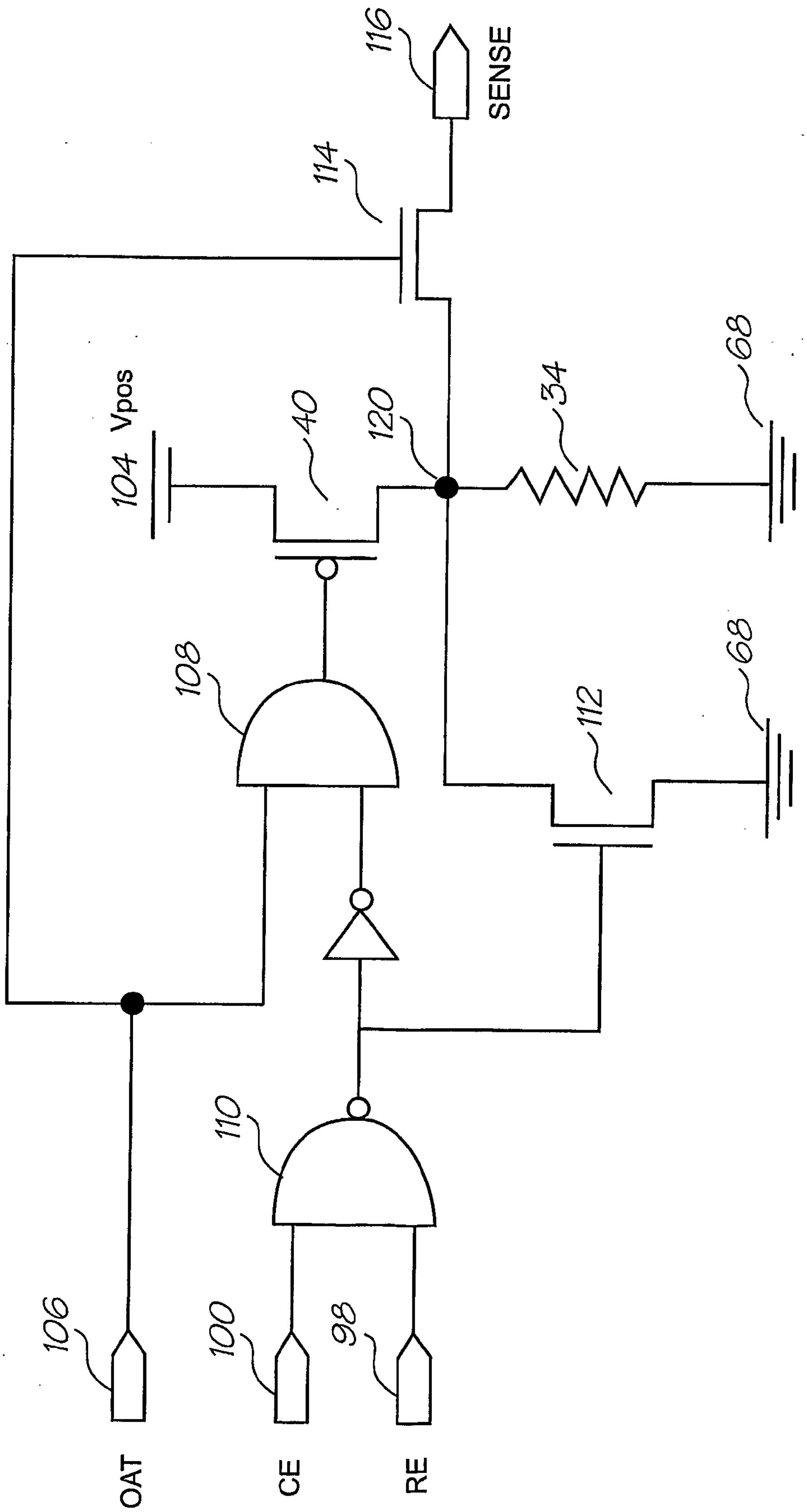
116
SENSE
114
104
Vpos
40
120
34
68
108
68
112
110
106
100
98
OAT
CE
RE

FIG. 17A

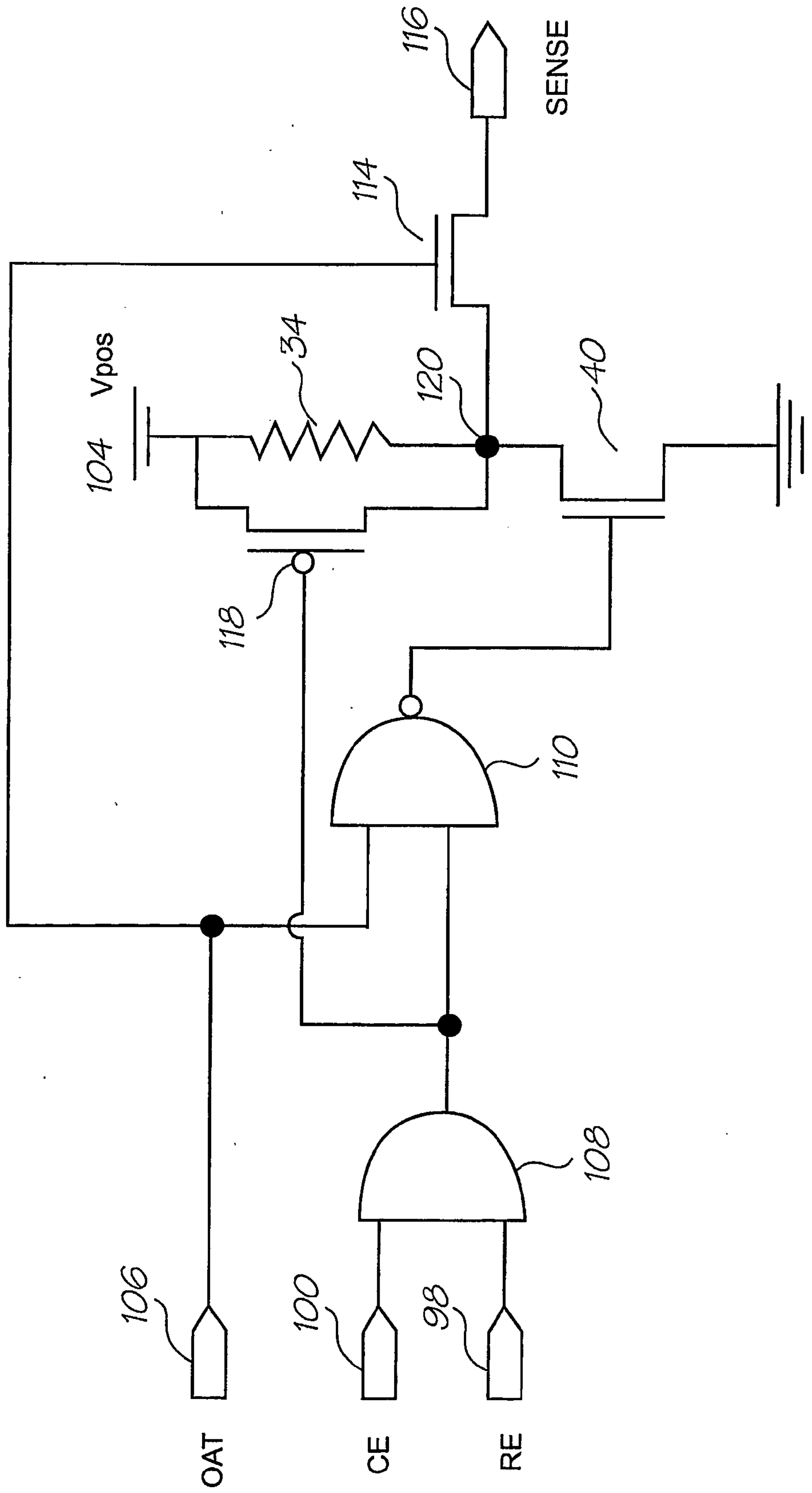

FIG. 17B

REFERENCES CITED IN THE DESCRIPTION

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