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(54) **Apparatus and method for controlling a charging voltage in ink jet printers**

(57) The present invention provides for adjustment of the charging voltage to a discrete section of the array, increasing the operating range of the printhead. The array of charging electrodes (22) are broken into segments with relative voltage adjustment to each segment. The voltage to the charge plate electrodes is then switchably controlled by discrete high voltage driver chips (56) to enable drop selection for printing. The integrated circuit within each chip converts serial input data at low voltages to parallel outputs at high voltage. The supplied high voltage to each of these chips is varied to compensate for impact variations on the catcher face caused by non-uniform parts. The compensation levels required for a set of aligned parts are stored within the printhead memory. The printhead will then function with the correct compensation levels on any system in which it is installed.

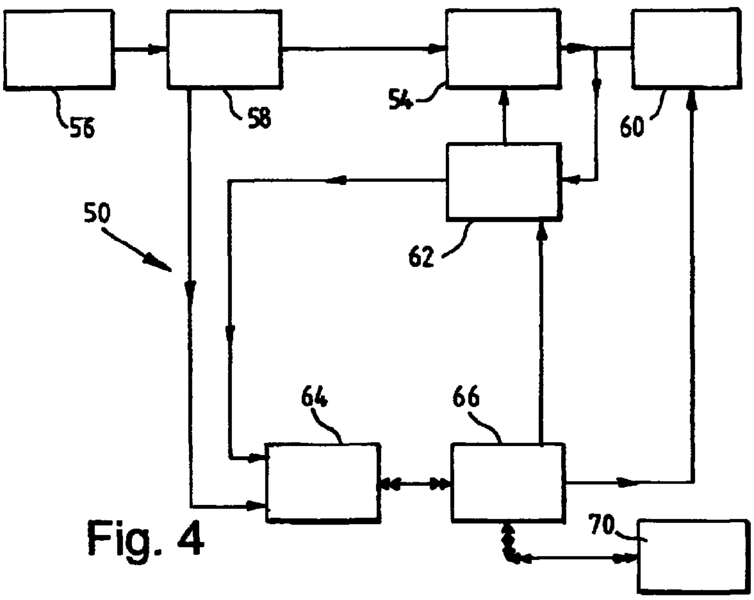

Fig. 4

Printed by Xerox (UK) Business Services
2.16.7 (HRS)/3.6

Description

Technical Field

[0001] The present invention relates to the field of continuous ink jet printing and, more particularly, to a method for improving charge voltage print windows for ink jet printers which utilize arrays of charging electrodes and orifice arrays.

Background Art

[0002] Ink jet drops are controlled via high voltage electrodes built into a planar array. The planar array is aligned to an array of orifices and the drops are deflected onto a catcher surface which is parallel to the charging array. The catch drops flow down the catcher surface and are returned to a fluid tank to be recycled. Print drops are selected by switching the voltage off, on specific electrodes. The print drops must clear the fluid film generated by previous catch drops, while the characteristics of the fluid film changes depending on the selected drop patterns used to generate the images.

[0003] A series of print patterns are used to determine a charge voltage, or print, window, which is the range of voltages which can be applied to the charging electrodes and still provide perfect print. It is desired to maximize the print window to allow operation of the printer in a variety of operating conditions including, for example, ambient temperature, print speed, and related print features.

[0004] The precise location of the drop generation point in an electric field requires parts that are flat and parallel, (catchers, charge plates, and orifice arrays) at tolerances utilizing state of the art manufacturing techniques. The voltage required for charging and deflecting the catch drops is applied to all electrodes. The fluid impact on the catcher face is uniform when the ideal flat and parallel parts are assembled. Variations in part tolerances result in a range of impact heights on the catcher face, and this non-uniformity reduces the print window. If the range is excessive, there is no voltage that can be applied to provide acceptable operation. Higher density and longer arrays make it more difficult to fabricate the components to the desired tolerances.

[0005] It is seen, therefore, that an alternative method to increase the print window is needed.

Summary of the Invention

[0006] This need is met by the segmented charging technique of the present invention.

[0007] In accordance with one aspect of the present invention, means are provided to adjust the charging voltage to a discrete section of the array, increasing the operating range of the printhead. The array of charging electrodes are broken into segments with means to provide relative voltage adjustment to each segment. The voltage to the charge plate electrodes is then switchably controlled by discrete high voltage driver chips to enable drop selection for printing. The integrated circuit within each chip converts serial input data at low voltages (5V typical) to parallel outputs at high voltage (~170 Vdc). The supplied high voltage to each of these chips is varied to compensate for impact variations on the catcher face caused by non-uniform parts. The compensation levels required for a set of aligned parts are stored within the printhead memory. The printhead will then function with the correct compensation levels on any system in which it is installed.

[0008] Other objects and advantages of the invention will be apparent from the following description, the accompanying drawing and the appended claims.

Brief Description of the Drawing

[0009]

Fig. 1 is a side view of an aligned printhead indicating the major components required for a continuous flow ink jet printer;

Fig. 2 is a front view of the printhead of Fig. 1;

Fig. 3 is a front view of a printhead, similar to Fig. 2, but with the drop deflection modified by changing the voltage on segments of the charging electrodes;

Fig. 4 is a block diagram of a preferred embodiment of the present invention using a main supply and individual segment regulators; and

Fig. 5 illustrates one embodiment of an individual segment controller, in accordance with the present invention.

Detailed Description of the Preferred Embodiments

[0010] Present ink jet devices typically use a single voltage level applied to all electrodes to provide the drop charge required for deflecting the catch drops. When a single voltage is applied and the parts are uniform, the fluid impact on the catcher face is uniform. However, the variation in part tolerances causes the impact on the catcher face to vary, and this variation or non-uniformity reduces the print window. In accordance with the present invention, a method is provided to compensate for this variation in part tolerances, by providing different voltages to different regions of the electrode array. The average impact will be more uniform and the size of the print window will increase.

[0011] Referring to Fig. 1, there is illustrated a side view of an aligned printhead 14 showing the major components required for a continuous flow ink jet printer. A drop generator 10 is aligned to a charge plate assembly 20 to cause drops 12 to form within the electric fields generated by high voltage electrodes 22. The charged drops are then attracted to a nearby catcher surface 30. The drops which strike the catcher form a fluid layer 32 which flows down catcher face 28 into the catcher opening.

[0012] As the fluid flows down the catcher face 28, the fluid slows down and the fluid layer 32 gets thicker. If the fluid layer gets too thick, the fluid layer can interfere with the non-deflected print drops. This can cause areas of missing print. On the other hand, too thin of a fluid layer can allow some catch drops to print, producing a dark defect. As the fluid layer thickness depends on the height at which the drops strike the catcher, there is a range of impact heights on the catcher that produces defect-free print.

[0013] The impact height of the drops on the catcher depends on the amount of charging and deflection produced by the charge plate. The charging and deflection depend on the charging voltage and on the spacing between the charge plate and the jets. The impact height further depends on the recess distance of the catcher behind the charge plate. Deviations in jet directionality, charge plate flatness, catcher flatness or the parallelism of the components all result in variations in impact height.

[0014] Fig. 2 illustrates a front view of the printhead 14. Ink is seen to flow down the catcher face below the impact line 35 of drops on the catcher. As discussed, the impact line 35 varies up and down the catcher face. Fig. 2 also shows the boundaries for the acceptable drop impacts, defined by pick out of the print drops in areas with the impact line high up in the catcher face such as at 34 and printing of catch drops where the impact line is low on the catcher face such as at 36.

[0015] To ensure maximum reliability, it is desirable to minimize the variation in impact heights within the acceptable range of impacts. This makes the printer less sensitive to variations in pressure, ink properties or other environmental variables.

[0016] In accordance with the present invention, it is possible to minimize the impact variation by using different charge voltage levels for different sections of the ink jet array. Fig. 3 shows the same impact on the catcher face from Fig. 2, but the drop deflection has been modified by changing the voltage on the charging electrodes. The voltage in segment D has been raised relative to segments C and E to minimize the depth of the low impacting center section of the array. Similarly segments B and F have also been raised relative to segments C and E. The impact line 35 shows discrete jumps or breakpoints at the voltage steps. With the total impact variation reduced, the print latitude improves accordingly.

[0017] The number and width of each fixed voltage segment may vary as desired. While the best print window would be achieved by adjusting the charging voltage electrode by electrode, one electrode segments, such an implementation would add considerable cost to the electronics. A more cost effective option, which still provides most of the virtue provided by the single electrode segmenting option, is to chose a segment size which corresponds to the number of electrodes controlled by a charge voltage driver IC. In one such implementation of the invention, the segment size is 64 jets or charge leads, since the charge voltage switching electronics, Supertex HV34, which produces the necessary print voltage pulses, are designed to control 64 charging electrodes. In a still more cost effective embodiment the typical impact profile was considered, so that the segment width, corresponding to the number of charge driver IC's per segment, is varied across the array. In areas that tend to have flat impact profiles, the segment width was wider, the segment includes a larger number of charge driver IC's. In areas where the impact height tends to change more rapidly, the segment width is narrower, the number of charge driver IC's is less. For this particular embodiment, forty two charge driver IC's are separated non-uniformly into 18 segments.

[0018] The high voltage supplied to each segment, or can be provided by either individual high voltage supplies or by a main supply with individual segment regulators. When using the individual segment regulators, voltage may be added to or subtracted from the main supply voltage. In the particular embodiment described here the individual segment regulators subtract voltage from the main supply voltage. To prevent damage to the charge driver IC's from excessive reverse current, it is important to block reverse current from one high voltage segment to the next. This can be accomplished using any suitable means such as, for example, by using a diode in the high voltage supply line to each charge driver IC.

[0019] Fig. 4 shows a block diagram 50 of a preferred embodiment of the present invention for supplying high voltage to each segment. The embodiment illustrated in Fig. 4 uses a main supply 56 and individual segment regulators 54. High voltage is supplied to the individual segment regulators 54 by the main high voltage supply 56. Current sensing electronics at block 58 measure the current drawn by the individual segments. This allows shorts to be detected. Furthermore the shorts can be located to the individual charging segment. The segment regulators 54 then supply the voltage to the charge drivers, as indicated by block 60.

[0020] Continuing with Fig. 4 and referring also to Fig. 5, there is illustrated in Fig. 5 one embodiment of an individual segment regulator. This segment regulator 54 adjusts the voltage across capacitor 82. The voltage across the capacitor has a polarity such that it will oppose or subtract from the voltage from the high voltage supply, 56. The resulting voltage, supplied high voltage from source 56 minus the voltage drop across capacitor 56 is applied to the charge driver IC 60 through the reverse blocking diode 96. By subtracting voltage from the main supply level, this design ensures all segments drop to zero volts when the main supply voltage is dropped to zero volts. This is an important consideration during charge plate short recovery.

[0021] During operation, the load current drawn by the HV34 charge driver IC's 60 cause the voltage across capacitor 82 to increase, decreasing the voltage across capacitor 84. To reduce the voltage increase across capacitor 82, the switch 72 is turned on. This discharges capacitor 82 through resistor 80, which controls the discharge time constant. The on time of switch 72 is adjusted by the analog control circuit 62 to maintain the voltage across capacitor 82 at the desired level.

[0022] The voltage across capacitor 82 is sensed by means of the difference amplifier 90 and two resistive voltage dividers. One voltage divider consisting of resistors 86 and 88 supplies the difference amplifier with a voltage proportional to the output voltage from the regulator, while the other resistive voltage divider consisting of resistors 92 and 94 supplies the other input of the difference amplifier with a voltage proportional to the input voltage to the regulator. The resulting voltage from the difference amplifier, which is proportional to the voltage across the capacitor 82, is supplied to the analog control section 62. In this way the output voltage from each segment regulator can be controlled by its analog control circuit. The set point for each segment is dictated by a common digital control circuit 66.

[0023] It is desirable to store the segment and main supply voltage information needed by the digital control circuit 66 in a nonvolatile memory 70 that is part of the printhead. In this way, the printhead appropriate set point information for each segment, established during manufacture of the printhead to provide the widest printhead latitude, can be supplied to the digital control circuit.

[0024] In operation, the digital control electronics 66 reads the configuration data stored in the printhead and sets the segment voltage appropriately. Should changes in ink properties require a change in the charge voltage, the baseline high voltage value would be changed. This maintains the relative voltages between segments.

[0025] For diagnostic purposes, the segment voltage levels and current levels are monitored by the analog measure circuit 64, which passes the data on to the digital control circuit 66. In this way, the digital control can perform diagnostics tests related to the printhead and the segment charging electronics.

[0026] The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that modifications and variations can be effected within the spirit and scope of the invention.

Claims

1. A method for improving charge voltage print windows for ink jet printers comprising the steps of:

   utilizing arrays of charging electrodes;
   breaking the array of charging electrodes into segments;
   providing relative voltage adjustment to each segment, whereby the charging electrodes charge the ink drops.

2. A method as claimed in claim 1 wherein each segment has a charge voltage window for proper charging of the drops and the relative voltage adjustment is used to supply each segment with a charging voltage near a center of its charge voltage window.

3. A method as claimed in claim 1 further comprising the step of storing relative voltage adjustment levels in the printhead.

4. A method as claimed in claim 1 further comprising the step of detecting charge plate shorts in each segment.

5. A method as claimed in claim 1 further comprising the step of carrying out diagnostic tests related to the printhead and segment charging electronics.

6. A method as claimed in claim 1 further comprising the step of adjusting baseline voltage while maintaining desired relative voltage adjustment between segments.

7. A system for improving charge voltage print windows for ink jet printers comprising:

   arrays of charging electrodes;
   means for breaking the array of charging electrodes into segments;
   relative voltage adjustment provided to each segment, whereby the charging electrodes charge the ink drops.

8. A system as claimed in claim 7 wherein the relative voltage adjustment further comprises individual segment regulators.

9. A system as claimed in claim 7 further comprising means to detect charge plate shorts in each segment.

10. A system as claimed in claim 7 further comprising means to adjust baseline voltage while maintaining desired relative voltage adjustment between segments.

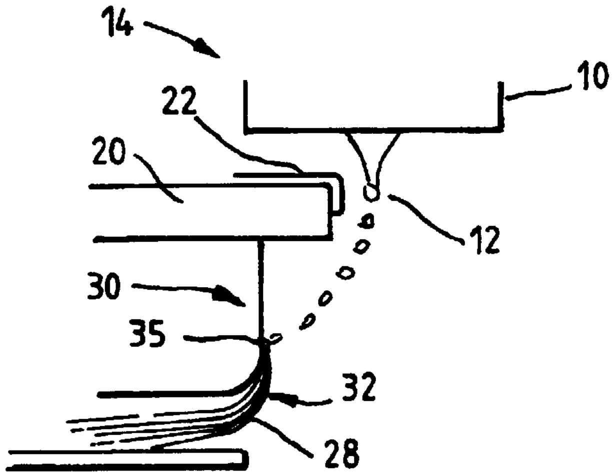

Fig. 1

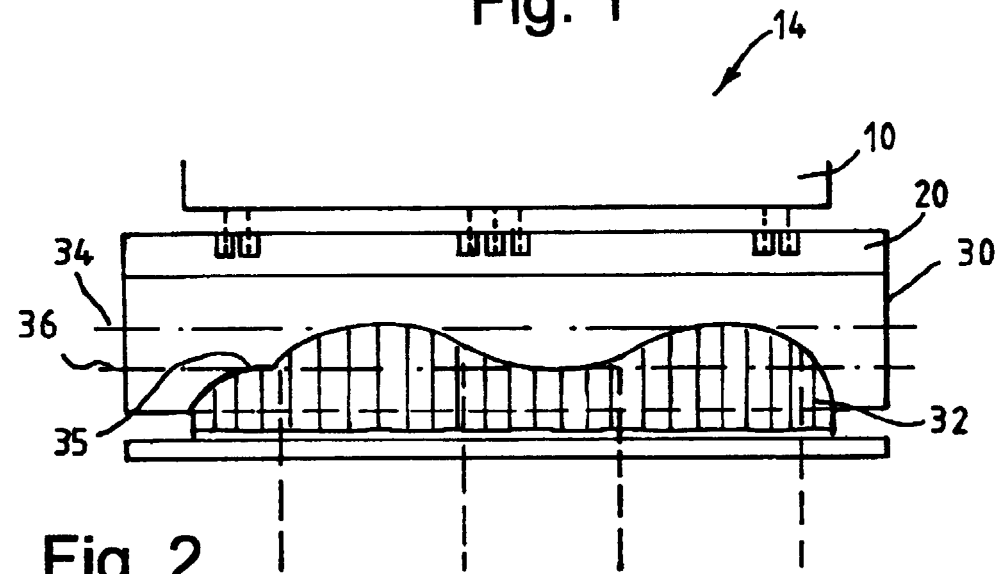

Fig. 2

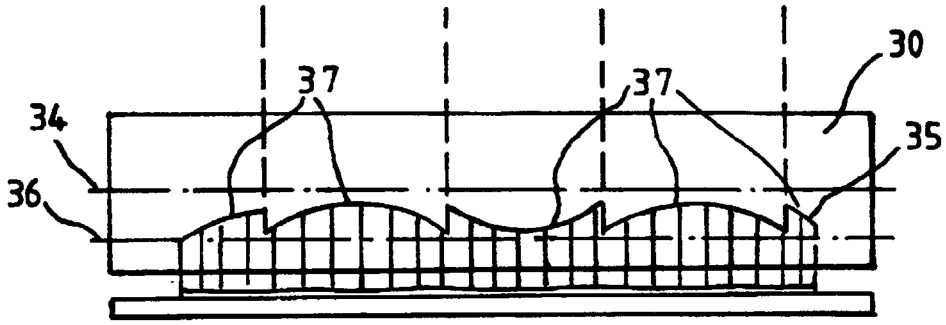

Fig. 3

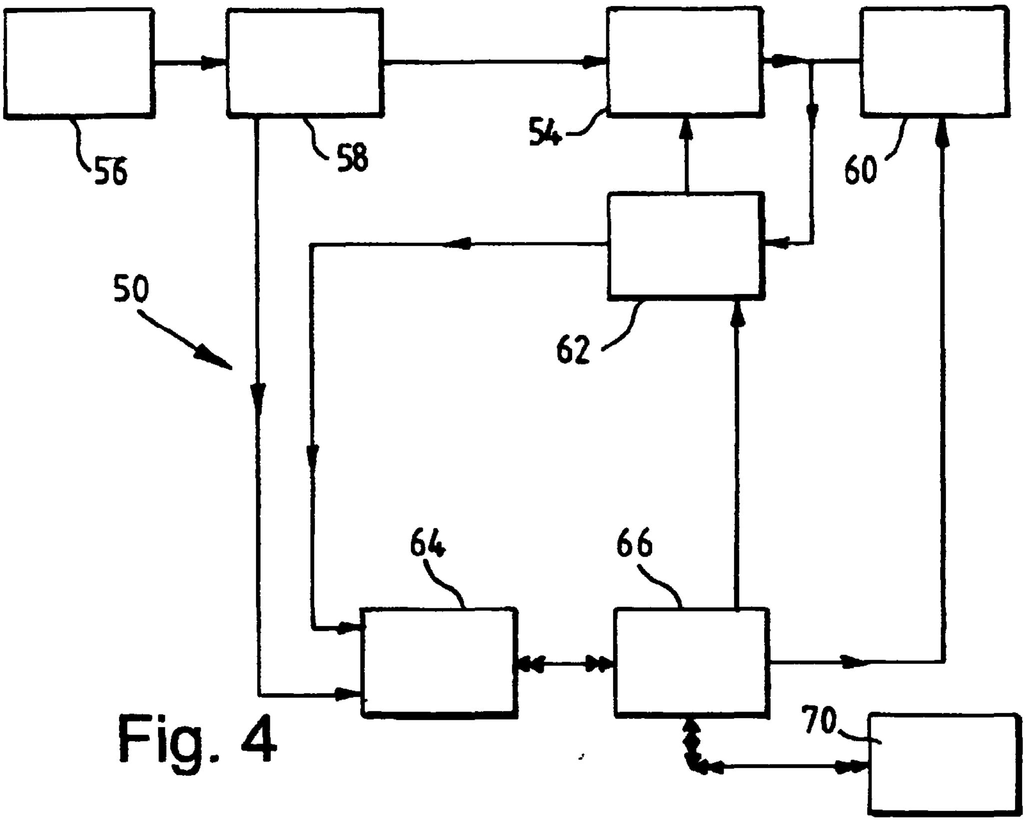

Fig. 4

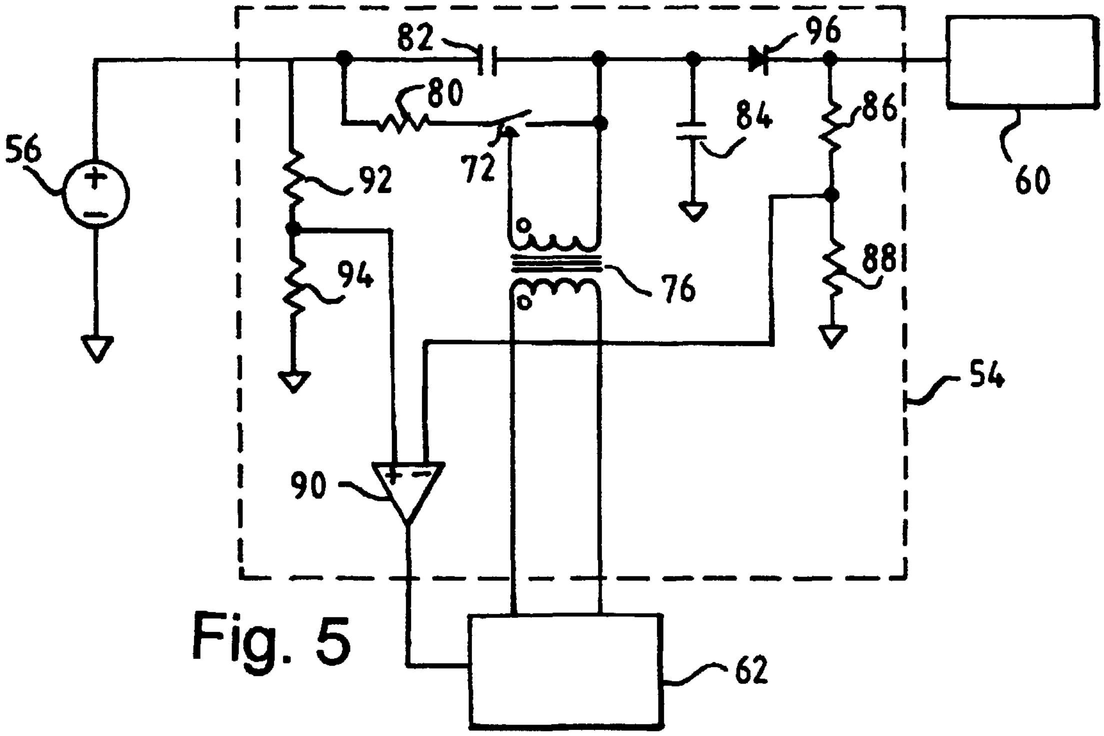

Fig. 5