



Publication number : **0 531 173 A1**

EUROPEAN PATENT APPLICATION

Application number : **92308088.1**

Int. Cl.⁵ : **B41J 2/015**

Date of filing : **07.09.92**

Priority : **05.09.91 JP 226130/91**

Date of publication of application :
10.03.93 Bulletin 93/10

Designated Contracting States :
DE FR GB IT

Applicant : **BROTHER KOGYO KABUSHIKI KAISHA**
15-1, Naeshiro-cho, Mizuho-ku
Nagoya-shi, Aichi-ken (JP)

Inventor : **Zhang, Qiming, c/o Brother Kogyo K.K.**
No. 15-1 Naeshiro-cho, Mizuho-ku
Nagoya-shi, Aichi-ken (JP)
Inventor : **Yoshida, Hitoshi, c/o Brother Kogyo K.K.**
No. 15-1 Naeshiro-cho, Mizuho-ku
Nagoya-shi, Aichi-ken (JP)

Representative : **Senior, Alan Murray et al**
J.A. KEMP & CO., 14 South Square Gray's Inn
London WC1R 5LX (GB)

Method of driving an ink jet printer head and driving circuit.

A method of driving an ink jet printer head is provided in which reverse flow of an ink is prevented so as not to introduce air into an ink chamber (4). Further, production of ink satellites are prevented. A braking voltage is instantaneously applied to a piezoelectric element (3) after a voltage to the piezoelectric element (3) has reached a peak level so that inertia of both the piezoelectric element (3) and the ink contained in the ink chamber (4) is canceled. As a result, the flow of ink in the nozzle (5) and ink ejection from the outlet of the nozzle (5) are abruptly stopped to thus prevent the generation of ink satellite. In order that the deformation of the piezoelectric element (3) may not be quickly restored, the voltage applied to the piezoelectric element (3) is gradually returned to a non-driving voltage level, whereby air is prevented from being introduced into the ink chamber (4).

FIG. 2A

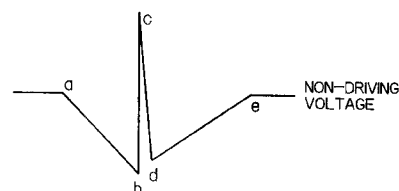
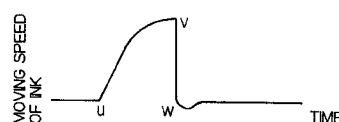


FIG. 2B



The present invention relates to a method of driving the head of an on-demand ink jet printer and to a driving circuit.

A cross-sectional view of an ink jet printer head is shown in FIG. 4. A piezoelectric element 3 is provided at the rear wall of an ink chamber 4 and is inwardly deformable when a voltage is applied thereto, whereby pressure increase is caused in the ink chamber 4. Ink contained in the ink chamber 4 is thus ejected as an ink jet 6 from a nozzle 5.

Heretofore, a voltage applied to the piezoelectric element 3 has such a waveform as shown in FIG. 1A. To actuate the piezoelectric element 3, the voltage applied thereto is increased relatively gradually at a constant rate. After being reached a peak level, the voltage is lowered to a non-driving voltage level relatively quickly to restore the piezoelectric element 3 to the original state and to thus decrease the pressure in the ink chamber 4. With the decreasing pressure in the ink chamber 4, ink ejecting force is no longer applied to the ink but a mass of the ink which has been applied with the force is about to leave from the nozzle 5 due to its inertia and is finally ejected from the nozzle 5 to produce an ink droplet. At the same time, ink is supplemented into the ink chamber 4 from an ink tank (not shown) through an ink supply channel 7.

With the use of the voltage waveform shown in FIG. 1A, the moving speed of the ink staying at the nozzle 5 changes as shown in FIG. 1B. When the voltage applied to the piezoelectric element 3 changes from the peak level to the non-driving level, the moving speed of the ink in the nozzle 5 is not abruptly zeroed due to inertia of the ink within the ink chamber 4 and the ink nozzle 5, as indicated by the inclined down-going line in Fig. 1B. As a result, ink separation is not well achieved at the time of ink ejection, thereby causing to produce a satellite. The satellite refers to a small amount of ink separated from the ejected ink droplet during its flight time.

After an elapse of a brief period of time from the application of a braking force to the ink, ink ejection is stopped and ink is supplemented into the ink chamber 4 through the ink supply channel 7 owing to a suction force caused by the restoration of the piezoelectric element 3. At this time, the suction force is also applied to the ink staying in the nozzle 5 which is balanced with the surface tension of the ink at the outlet of the nozzle 5 and the suction force applied to the ink. If the suction force is greater than the ink surface tension, the ink in the nozzle 5 goes back to the ink chamber 4 and air may eventually be introduced into the ink. If printing is performed with a bubble contained ink, the print quality will be greatly degraded.

According to one aspect of the present invention there is provided a method of driving an ink jet printer head having an ink chamber, a nozzle and a piezoelectric element deformable when a driving voltage is applied thereto to eject a droplet of ink from the nozzle,

the method comprising the steps of:

applying a first voltage to the piezoelectric element to cause ink to be moved in the nozzle in a first direction for ejecting an ink droplet from the nozzle;

applying a second voltage to the piezoelectric element to stop movement of the ink in said first direction; and

applying a third voltage to the piezoelectric element to prevent movement of the ink in a second direction opposite to said first direction.

There is thus provided a method of driving an ink jet printer head wherein a satellite of ink droplet may be prevented from being generated and the reverse flow of the ink from a nozzle to an ink chamber may be prevented.

According to a further aspect of the present invention there is provided a circuit for driving an ink jet printer head by applying a driving voltage to a piezoelectric element associated with the head to eject an ink droplet from a nozzle of the printer head, the circuit comprising means for adding together a plurality of voltage waveforms to produce a driving voltage waveform for substantially stopping movement of ink in the nozzle after ejection of an ink droplet.

In the driving method hereinafter described a first voltage is firstly applied to the piezoelectric element for causing the ink to be moved in the nozzle in a first direction so that the ink droplet is ejected from the nozzle. A second voltage is subsequently applied to the piezoelectric element for causing the first directional movement of the ink to be abruptly stopped. Thereafter, a third voltage is applied to the piezoelectric element so that the ink does not move in a second direction opposite the first direction. The first voltage changes from a non-driving voltage to a peak voltage (level b in Fig. 2A) at a first rate. The non-driving voltage is defined by a voltage with which the piezoelectric element is not deformed. The application of the second voltage to the piezoelectric element momentarily reduces an internal pressure of the ink chamber, and the second voltage is determined so that a total momentum of the ink in both the ink chamber and the nozzle owing to the application of the first voltage is substantially zeroed. The third voltage changes from a near peak level (level d in Fig. 2A) to the non-driving voltage at a second rate smoother than the first rate. The second voltage momentarily applied to the piezoelectric element after the voltage has reached the peak level, whereby inertia of both the piezoelectric element and the ink in the ink chamber is quickly canceled to abruptly stop the flow of ink within the nozzle and the ink ejection at the outlet of the nozzle. By doing so, generation of ink satellites is prevented. Thereafter, the third voltage is applied to the piezoelectric element which changes at a smoother rate than the first voltage so that the deformation of the piezoelectric element is not quickly restored. Further, introduction of air into the ink tank through the nozzle

is prevented by maintaining a balance of the ink surface tension at the outlet of the nozzle and air sucking force caused by the reduced internal pressure of the ink tank.

The particular features and advantages of the invention will become apparent from the following description taken in connection with the accompanying drawings, in which:

FIG. 1A is a graphical representation showing a waveform of a voltage used for driving a conventional ink jet printer head;

FIG. 1B is a graphical representation showing a moving speed of an ink in a nozzle according to a conventional printer;

FIG. 2A is a graphical representation showing a waveform of a voltage used for driving an ink jet printer head according to an embodiment of the invention;

FIG. 2B is a graphical representation showing a moving speed of an ink in a nozzle according to the printer of the present invention;

FIG. 3 is a circuit diagram showing a circuit for generating a driving voltage waveform; and

FIG. 4 is a cross-sectional view showing the head portion of an ink jet printer.

A preferred embodiment of the present invention will now be described with reference to the accompanying drawings. A mechanism for ejecting ink droplets according to the present invention is identical to the conventional mechanism shown in FIG. 4, thus the same figure will be used in the following description.

A driving voltage waveform to be used in this embodiment is shown in FIG. 2A. As shown, in accordance with the present invention, a braking voltage indicated by line b-c is momentarily applied to the piezoelectric element 3 after the voltage has reached a peak level. By the application of the braking voltage, inertia of both the piezoelectric element 3 and the ink contained in the ink chamber 4 is canceled and the flow of ink in the nozzle 5 and the ink ejection at the outlet of the nozzle 5 are abruptly stopped. By doing so, generation of satellites is prevented. Thereafter, the voltage applied to the piezoelectric element 3 is changed to a level $\underline{d}$ which is on the line b-d and is then smoothly changed to the non-driving voltage level as indicated by line d-e, whereby the deformation of the piezoelectric element 3 is not quickly restored. Further, introduction of air into the ink is prevented by maintaining a balance between the ink surface tension at the outlet of the nozzle 5 and a suction force applied to the ink.

In order to abruptly stop the flow of ink within a possible minimum time, it is necessary to zero a total momentum M of the ink in both the ink chamber 4 and the nozzle 5 at the time when the voltage applied to the piezoelectric element 3 is at the level $\underline{b}$. The voltage change from the level $\underline{b}$ to $\underline{c}$ and then from the level $\underline{c}$ to $\underline{d}$ momentarily reduces the internal pressure

of the ink chamber 4. Assuming that an average force for reducing the speed of the ink owing to the momentary reduction of the pressure in the ink chamber 4 is F and that a time from the point $\underline{b}$ to $\underline{c}$ is τ , then F and τ may be determined so that the relation of $F\tau = M$ is met to stop the flow of the ink. It is desirable that τ be selected as small as possible to abruptly stop the flow of ink.

Description will next be made with respect to an ink ejection process when the piezoelectric element 3 is driven with the voltage waveform described above. When the driving voltage changes from level $\underline{a}$ to level $\underline{b}$, the ink speed in the nozzle 5 increases from u to v as shown in FIG. 2B and the ink is finally ejected from the nozzle 5. By the application of the braking voltage as indicated by the line b-c-d in FIG. 2A, the ink ejection speed is abruptly changed from v to w . However, the reverse flow of the ink staying at the nozzle 5 does not occur. Thereafter, by smoothly changing the driving voltage from level $\underline{d}$ to the non-driving voltage level $\underline{e}$, the reverse flow of the ink in the nozzle 5 does not occur due to the ink surface tension in the outlet portion of the nozzle 5.

An addition circuit 12 for generating the driving voltage is shown in FIG. 3. By applying a basic saw-tooth pulse 10 and another saw-tooth pulses of opposite polarity to inputs of the addition circuit 12, the driving voltage waveform as shown in FIG. 2A is output from the circuit 12.

As can be understood from the above description, driving method of the head of the ink jet printer according to this embodiment prevents the generation of satellites as well as introduction of air into the ink caused by the reverse flow of the ink staying at the nozzle 5.

Claims

1. A method of driving an ink jet printer head having an ink chamber (4), a nozzle (5) and a piezoelectric element (3) deformable when a driving voltage is applied thereto to eject a droplet of ink (6) from the nozzle, the method comprising the steps of:

applying a first voltage to the piezoelectric element to cause ink to be moved in the nozzle in a first direction for ejecting an ink droplet from the nozzle;

applying a second voltage to the piezoelectric element to stop movement of the ink in said first direction; and

applying a third voltage to the piezoelectric element to prevent movement of the ink in a second direction opposite to said first direction.

2. A method as claimed in claim 1, wherein the first voltage comprises a change in voltage from a

non-driving voltage to a peak voltage at a first rate of change, said non-driving voltage being a voltage at which the piezoelectric element is not deformed.

5

3. A method as claimed in claim 2, wherein the third voltage comprises a change in voltage from a voltage level near to the level of said peak voltage to said non-driving voltage.

10

4. A method as claimed in claim 3, wherein the rate of voltage change of said third voltage is smaller than the first rate of change.

5. A method as claimed in any of the preceding claims, wherein the application of the second voltage to the piezoelectric element (3) momentarily reduces an internal pressure of the ink chamber (4) to abruptly stop movement of the ink in said first direction.

15

20

6. A method as claimed in any of the preceding claims, wherein the second voltage is selected to counteract the total momentum of the ink in both the ink chamber (4) and the nozzle (5) arising from the application of the first voltage to the piezoelectric element (3).

25

7. A circuit for driving an ink jet printer head by applying a driving voltage to a piezoelectric element (3) associated with the head to eject an ink droplet (6) from a nozzle (5) of the printer head, the circuit comprising means (12) for adding together a plurality of voltage waveforms (10, 11) to produce a driving voltage waveform (13) for substantially stopping movement of ink in the nozzle after ejection of an ink droplet.

30

35

8. A circuit as claimed in claim 7, wherein the adding means (12) are arranged to receive and add together two non-identical saw-tooth pulses (10, 11) of opposite polarity.

40

9. An ink jet printer head including a circuit (12) as claimed in claim 7.

45

10. An ink jet printer including an ink jet printer head as claimed in claim 9.

50

55

FIG. 1A
PRIOR ART

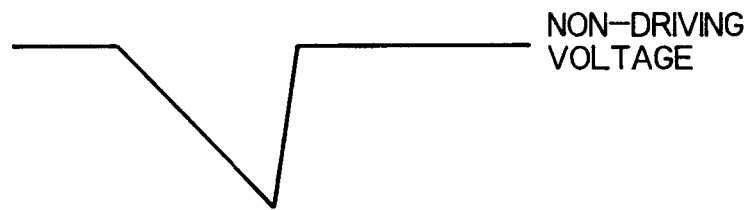


FIG. 1B
PRIOR ART

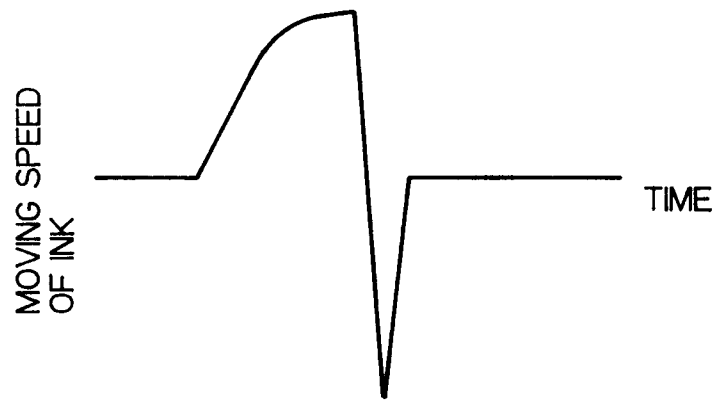


FIG. 2A

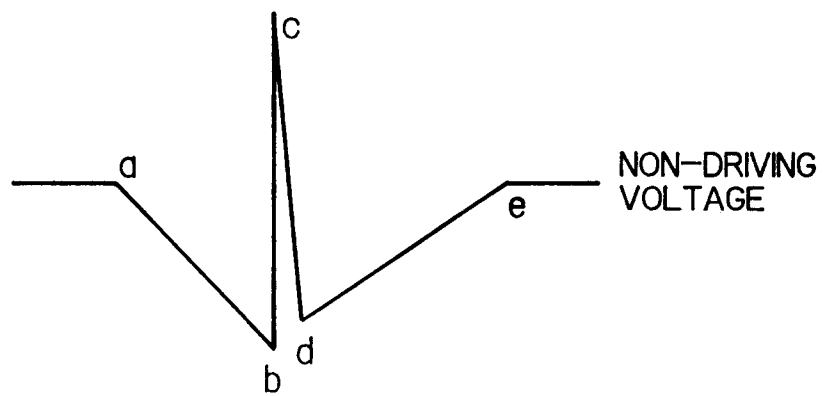


FIG. 2B

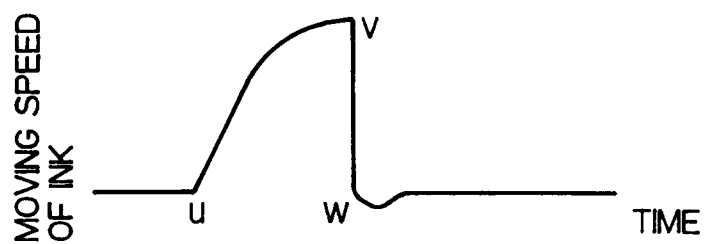


FIG. 3

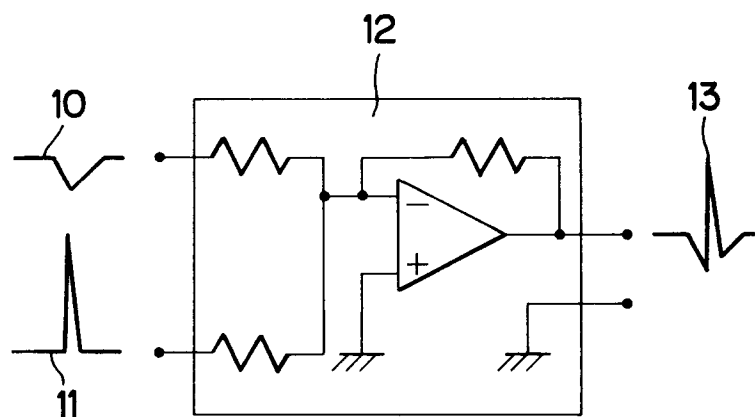
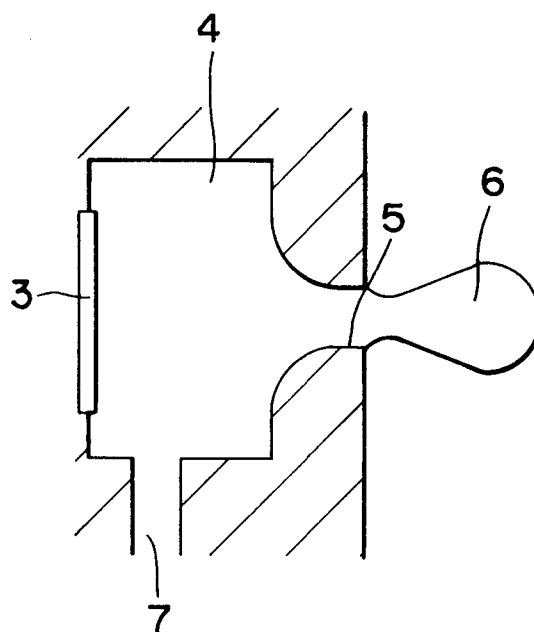


FIG. 4





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 30 8088

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	US-A-4 491 851 (MIZUNO ET AL.) * column 3, line 6 - line 21; figure 5D * ---	1-10	B41J2/015
X	US-A-3 902 083 (ZOLTAN) * column 5, line 3 - line 30; figure 2B * ---	1-7,9-10	
A	PATENT ABSTRACTS OF JAPAN vol. 10, no. 151 (M-483)(2208) 31 May 1986 & JP-A-61 3 753 (RICOH K.K.) 9 January 1986 * abstract *	1-10	
A	PATENT ABSTRACTS OF JAPAN vol. 5, no. 190 (M-100)(862) 4 December 1981 & JP-A-56 113 473 (NIPPON DENKI K.K.) 7 September 1981 * abstract *	1-10	
A	EP-A-0 090 663 (FUJITSU LIMITED) * page 7, line 6 - line 31; figure 15 * -----	1-10	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			B41J
Place of search THE HAGUE		Date of completion of the search 03 DECEMBER 1992	Examiner JOOSTING T.E.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P0401)