

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

EP 0 648 606 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
01.07.1998 Bulletin 1998/27

(51) Int. Cl.⁶: **B41J 2/045**

(21) Application number: **94307663.8**

(22) Date of filing: **19.10.1994**

(54) Drop-on demand ink-jet head apparatus and method

Auf Abruf arbeitender Tintenstrahlkopf und Verfahren

Tête à jet d'encre à la demande et méthode

(84) Designated Contracting States:
DE FR GB IT

(30) Priority: **19.10.1993 US 139349**

(43) Date of publication of application:
19.04.1995 Bulletin 1995/16

(73) Proprietor: **TEKTRONIX, INC.**
Wilsonville, Oregon 97070-1000 (US)

(72) Inventors:
• **Regimbal, Laurent A.**
Boise, Idaho 83704 (US)

• **Burr, Ronald F.**
Wilsonville, Oregon 97070 (US)

(74) Representative:
Lawrence, Malcolm Graham et al
Hepworth, Lawrence, Bryer & Bizley
Merlin House
Falconry Court
Baker's Lane
Epping Essex CM16 5DQ (GB)

(56) References cited:
EP-A- 0 084 458 **EP-A- 0 437 062**
EP-A- 0 467 656 **US-A- 4 730 197**
US-A- 5 170 117

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

EP 0 648 606 B1

Description

This invention relates to ink-jet printing and more particularly to a method and an apparatus for ejecting ink drops from an ink-jet head at substantially constant ejection velocities over a wide range of ejection repetition rates.

There are previously known apparatus and methods for ejecting ink drops from an ink-jet print head at a high repetition rate. The physical laws governing ink-jet drop formation and ejection are complexly interactive. Therefore, U.S. Pat. No. 4,730,197, issued March 8, 1988 for an IMPULSE INK JET SYSTEM describes and characterizes numerous interactions among ink-jet geometric features, transducer drive waveforms, ink meniscus and pressure chamber resonance, and ink drop ejection characteristics. A multiple-orifice print head is thereafter described in which "dummy channels" and compliant chamber walls are provided to minimize drop nonuniformity caused by jet-to-jet cross-talk. Increased drop ejection rates are achieved with piezoelectric transducer ("PZT") drive waveform compensation techniques that account for print head resonances, fluidic resonances, and past droplet timing compensation. The adaptive PZT drive waveform circuitry and complex ink-jet head structures achieve drop ejection rates "up to and including seven KHz."

U.S. Pat. No. 5,170,177, issued December 8, 1992, for a METHOD OF OPERATING AN INK JET TO ACHIEVE HIGH PRINT QUALITY AND HIGH PRINT RATE, assigned to the assignee of the present application, describes PZT drive waveforms having a spectral energy distribution that is minimized at the "dominant acoustic resonant frequency". The dominant frequency is described as including any of the meniscus resonance frequency, Helmholtz resonance frequency, PZT drive resonance frequency, and various acoustic resonance frequencies of the different channels and passageways forming the ink-jet print head. Suppressing PZT energy at the ink-jet outlet channel resonant frequency is said to produce a constant ink drop volume and ejection velocity at drop ejection rates up to 10 KHz.

Subjecting ink drops to an electric field is known to increase ink drop ejection repetition rate as described in copending European Patent EP-A-437062 (corresponding to U.S. Pat. Application No. 07/892494 of Roy et al., filed June 3, 1992, for METHOD AND APPARATUS FOR PRINTING WITH A DROP-ON-DEMAND INK-JET PRINT HEAD USING AN ELECTRIC FIELD). A time invariant electric field provides time-to-paper compensation for ink drops of different volumes, provides a wider range of drop volume ejection, and provides ink drop injection with decreased PZT drive energy, thereby allowing an increased maximum drop ejection rate of "up to eight KHz or greater". Unfortunately, the electric field apparatus adds complexity, cost, and shock hazard. Reliability and print quality are possible problems because the electric field attracts dust.

What is needed, therefore, is a simple, ink-jet print head system that provides substantially constant ink drop ejection velocity, without using an electric field, for ink drops ejected at rates ranging from zero to beyond 13,000 drops per second.

An object of this invention is, therefore, to provide an ink-jet apparatus and printing method for ejecting ink drops from an ink-jet head at substantially constant ejection velocities over a wide range of ejection repetition rates.

Another object of this invention is to provide an improved method of driving a conventional ink-jet head to enhance its jetting performance without requiring an electric field.

According to a first aspect of the invention there is provided an apparatus for ejecting a fluid from an orifice, the apparatus comprising a pressure chamber fluidically coupled to a fluid manifold by an inlet channel and to the orifice by an outlet channel, a transducer driver generating an energy input; a transducer coupled to the pressure chamber to excite in the orifice a modal meniscus shape in response to the energy input, the energy input having a spectral energy distribution which is concentrated around a dominant resonant frequency of the affected fluid mass in the apparatus, excluding the fluid in the fluid manifold, and which is substantially reduced around resonant frequencies of the inlet channel and the outlet channel; whereby a drop of the fluid is ejected at an ejection velocity from the orifice in response to the energy input.

According to a second aspect of the present invention there is provided a method of ejecting an ink drop from an orifice of an individual ink-jet apparatus having a pressure chamber that is fluidically coupled to an ink manifold by an inlet channel and to an orifice by an outlet channel, the method comprising providing a source of energy input; adjusting the source of energy to concentrate a spectral energy contents of the energy input around a dominant resonant frequency of an affected fluid mass in the ink-jet apparatus, excluding the ink in the ink-jet manifold; adjusting the source of energy to suppress the spectral energy content of the energy input near resonant frequencies of the inlet channel and the outlet channel; and connecting the energy input to a transducer coupled to the pressure chamber to eject from the orifice an ink drop having an ejection velocity.

It is an advantage that the invention provides for ejection of ink drops that have substantially the same ejection velocity over a wide range of ejection repetition rates, thereby providing high-resolution, high-speed printing.

It is another advantage that the invention provides drive waveform shaping principles usable to enhance the jetting performance of conventional ink-jet heads.

Additional objects and advantages of this invention will be apparent from the following detailed description of a preferred embodiment thereof that proceeds with reference to the accompanying drawings.

Fig. 1 is a diagrammatical cross-sectional view of a PZT-driven ink-jet representative of one found in a typical ink-jet array print head of a type used with this invention.

Figs. 2A, 2B, and 2C are enlarged pictorial cross-sectional views of an orifice portion of the print head of Fig. 1 showing illustrative orifice fluid flow operational modes zero, one, and two to which this invention could be applied.

Fig. 3 is a schematic block diagram showing the electrical interconnections of a prior art apparatus used to generate a PZT drive waveform according to this invention.

Fig. 4 is a waveform diagram showing a preferred electrical voltage versus timing relationship of a PZT drive waveform used to produce ink drops at a high repetition rate in a manner according to this invention.

Fig. 5 graphically shows spectral energy as a function of frequency for the PZT drive waveform shown in Fig. 4.

Fig. 6 graphically compares ink drop time-to-paper as a function of drop ejection rate for ink drops ejected with a prior art PZT drive waveform that does not suppress energy at the frequency of an inlet channel and with the preferred drive waveform (160) shown in Fig. 4.

Fig. 1 shows a cross-sectional view of an ink-jet 10 that is part of a multiple-orifice ink-jet print head suitable for use with the invention. Ink-jet 10 has a body that defines an ink manifold 12 through which ink is delivered to the ink-jet print head. The body also defines an ink drop forming orifice 14 together with an ink flow path from ink manifold 12 to orifice 14. In general, the ink-jet print head preferably includes an array of orifices 14 that are closely spaced from one another for use in printing drops of ink onto a print medium (not shown).

A typical color ink-jet print head has at least four manifolds for receiving black, cyan, magenta, and yellow ink for use in black and color printing. However, the number of such manifolds may be varied depending upon whether a printer is designed to print solely in black ink or with less than a full range of color. Ink flows from manifold 12, through an inlet port 16, an inlet channel 18, a pressure chamber port 20, and into an ink pressure chamber 22. Ink leaves pressure chamber 22 by way of an offset channel port 24, flows through an optional offset channel 26 and an outlet channel 28 to nozzle 14, from which ink drops are ejected.

Ink pressure chamber 22 is bounded on one side by a flexible diaphragm 34. An electromechanical transducer 32, such as a PZT, is secured to diaphragm 30 by an appropriate adhesive and overlays ink pressure chamber 22. In a conventional manner, transducer 32 has metal film layers 34 to which an electronic transducer driver is electrically connected. Although other forms of transducers may be used, transducer 32 is operated in its bending mode such that when a voltage is applied across metal film layers 34, transducer 32 attempts to change its dimensions. However, because it is securely and rigidly attached to the diaphragm, transducer 32 bends, deforming diaphragm 30, thereby displacing ink in ink pressure chamber 22, causing the outward flow of ink through passage 26 to nozzle 14. Refill of ink pressure chamber 22 following the ejection of an ink drop is augmented by reverse bending of transducer 34 and the concomitant movement of diaphragm 30.

To facilitate manufacture of the ink-jet print head usable with the present invention, ink-jet 10 is preferably formed of multiple laminated plates or sheets, such as of stainless steel. These sheets are stacked in a superimposed relationship. In the illustrated Fig. 1 embodiment of the present invention, these sheets or plates include a diaphragm plate 40 that forms diaphragm 30; an ink pressure chamber plate 42 that defines ink pressure chamber 22; a separator plate 44 that defines pressure chamber port 20, bounds one side of ink pressure chamber 22, and defines a portion of outlet channel port 24; an inlet channel plate 46 that defines inlet channel 18 and a portion of outlet channel port 24; another separator plate 48 that defines inlet port 16 and portions of outlet channel port 24 and manifold 12; an offset channel plate 50 that defines offset channel 26 and a portion of manifold 12; a separator plate 52 that defines portions of outlet channel 28 and manifold 12; an outlet plate 54 that defines a portion of outlet channel 28; and an orifice plate 56 that defines orifice 14 of the ink-jet.

More or fewer plates than those illustrated may be used to define the various ink flow passageways, manifolds, and pressure chambers of the ink-jet print head. For example, multiple plates may be used to define an ink pressure chamber instead of the single plate illustrated in Fig. 1. Also, not all of the various features need be in separate sheets or layers of metal. For example, patterns in the photoresist that are used as templates for chemically etching the metal (if chemical etching is used in manufacturing) could be different on each side of a metal sheet. Thus, as a more specific example, the pattern for the ink inlet passage could be placed on one side of the metal sheet while the pattern for the pressure chamber could be placed on the other side and in registration front to back. Thus, with carefully controlled etching, separate ink inlet passage and pressure chamber containing layers could be combined into one common layer.

To minimize fabrication costs, all of the metal layers of the ink-jet print head, except orifice plate 56, are designed so that they may be fabricated using relatively inexpensive conventional photo-patterning and etching processes in metal sheet stock. Machining or other metal working processes are not required. Orifice plate 56 has been made successfully using any number of processes, including electroforming with a sulfamate nickel bath, micro-electric discharge machining in 300 series stainless steel, and punching 300 series stainless steel, the last two approaches being used in concert with photo-patterning and etching all of the features of orifice plate 56 except the orifices themselves. Another suitable approach is to punch the orifices and use a standard blanking process to form any remaining features in the plate.

Table 1 shows acceptable dimensions for the ink-jet of Fig. 1. The actual dimensions employed are a function of the ink-jet array and its packaging for a specific application. For example, the orifice diameter of the orifices 14 in orifice plate 56 may vary from about 25 microns to about 150 microns.

Table 1

All dimensions in millimeters				
Feature	Length	Width	Height	Cross Section
Inlet port	0.2	.41	.41	Circular
Inlet channel	6.4	.30	0.2	Rectangular
Pressure chamber port	.2	.41	.41	Circular
Pressure chamber	.2	2.20	2.20	Circular
Offset channel port	0.8	.41	.41	Circular
Offset channel	2.1	.41	.81	Rectangular
Outlet separator	.2	.36	.36	Circular
Outlet channel	.2	.25	.25	Circular
Orifice	.08	.08	.08	Circular

The electromechanical transducer mechanism selected for the ink-jet print heads of the present invention can comprise hexagonally kerfed ceramic transducers bonded with epoxy to the diaphragm plate 40, with each of the transducers being centered over a respective ink pressure chamber 22. For this type of transducer mechanism, the hexagonal shape is substantially circular, a shape which has the highest electromechanical efficiency with regard to volume displacement for a given area of the piezoceramic element.

Ejecting ink drops having controllable volumes from an ink-jet head such as that of Fig. 1 entails providing from transducer driver 36, multiple selectable drive waveforms to transducer 32. Transducer 32 responds to the selected waveform by inducing pressure waves in the ink that cause ink fluid flow in orifice 14.

Referring to Figs. 2A, 2B, and 2C, an ink column 60 having a meniscus 62 is shown positioned in orifice 14. Meniscus 62 is shown excited in three operational modes, referred to respectively as modes zero, one, and two in Figs. 2A, 2B, and 2C. Fig. 2C shows a center excursion C_e of the meniscus surface of a high order oscillation mode.

In Fig. 2A, operational mode zero corresponds to a bulk forward displacement of ink column 60 within a wall 64 of orifice 14. Prior workers have based ink-jet and drive waveform design on mode zero operation but have failed to fully exploit its possibilities. Ink surface tension and viscous boundary layer effects associated with wall 64 cause meniscus 62 to have a characteristic rounded shape indicating the lack of higher order modes. The natural resonant frequency of mode zero is primarily determined by the bulk motion of the ink mass interacting with the compression of the ink inside the ink-jet (i.e., like a Helmholtz oscillator in which a "capacitive" pressure chamber 22 forms a parallel resonant circuit with "inductive" inlet channel 18 and combined outlet channel structures 24, 26, 28, and orifice 14. The geometric dimensions of the various fluidically coupled ink-jet components, such as the channels 18, 26, and 28; the manifold 12; the part 16, 20, and 22; and the pressure chamber 22, all of Fig. 1, are sized to avoid extraneous or parasitic resonant frequencies that would interact with the orifice resonance modes.

Designing drive waveforms suitable for constant drop ejection velocity over a wide range of ejection rates requires knowledge of the natural frequencies of the system elements so that a waveform can be designed that concentrates energy at frequencies near the natural frequency of the desired mode and suppresses energy at the natural frequencies of other mode(s) and extraneous or parasitic resonant frequencies that compete with the desired mode for energy. These extraneous or parasitic resonant frequencies adversely affect the ejection of ink droplets from the ink-jet orifice in several ways, including, but not limited to, ink drop size and the drop speed or the time it takes the drop to reach the print media once ejected from the orifice, thereby also affecting the drop placement accuracy on the media.

To design the waveform used to operate ink-jet 10 of Fig. 1, we must know the fundamental resonant frequencies of inlet channel 18 and the combined outlet channel structures that include offset channel port 24, offset channel 26, outlet channel 28, and orifice 14.

Using basic organ-pipe frequency calculations, and assuming that manifold 12 and ink pressure chamber 22 act as constant pressure boundaries, the approximate resonant frequency of inlet channel can be calculated using the equation $f=a/2L$, where "a" is the velocity of sound in a fluid and "L" is the inlet channel length. In like manner for the combined outlet channel structures, assuming that orifice 14 behaves as a closed (zero velocity) boundary, the approximate

resonant frequency of the combined outlet channel structures can be calculated using the equation $f=a/4L$.

Referring to Table 1, ink-jet 10 has an inlet channel length of about 6.35 millimeters and an a combined outlet channel length of about 3.50 millimeters. The speed of sound in a fluid is about 1,000 meters per second. Therefore, the inlet resonant frequency is approximately 79 KHz and the outlet resonant frequency is approximately 73 KHz.

The foregoing theory has been applied in practice together with the fluid flow theory to design PZT drive waveforms for ink-jet 10. The electrical waveforms generated by transducer driver 36 concentrate energy in the frequency range of the desired mode while suppressing energy in other competing modes and at the resonant frequencies of the inlet and outlet channel structures of ink jet 10.

Fig. 3 diagrammatically shows a conventional apparatus representative of transducer driver 36 that is suitable for generating PZT drive waveforms according to this invention. Of course, other waveform generators may be employed.

A processor 100 provides a trigger pulse to negative pulse timer 102 that drives a field-effect transistor 104 such that a resistor network 106 is electrically connected to a negative voltage source $-V_o$ for a time period determined by processor 100.

When negative pulse timer 102 times out, a wait period timer 108 is triggered for a wait time period determined by processor 100. When wait period timer 108 times out, a positive pulse timer 110 drives a field-effect transistor 112 such that resistor network 106 is electrically connected to a positive voltage source $+V_o$ for a time period determined by processor 100.

Resistor network 106 is electrically disconnected from voltage sources $+V_o$ and $-V_o$ during periods when timers 102 and 110 are inactive or when timer 108 is active. A bipolar electrical drive is thereby produced that is electrically connected through resistor network 106 to metal one of film layers 34 of transducer 32.

Resistor network 106 includes a series resistor 114 having a value ranging between 5,000 and 6,000 ohms and a shunt resistor 116 having a value of about 5,560 ohms. Series resistor 114 is trimmed to a value that establishes a predetermined drop ejection velocity from ink jet 10 as described in U.S. Pat. No. 5,212,497, issued May 18, 1993 for ARRAY JET VELOCITY NORMALIZATION, which is assigned to the assignee of this application. This application is not directly concerned with establishing the predetermined ejection velocity, but rather describes how to maintain a substantially constant ejection velocity over a wide range of drop ejection rates.

Fig. 4 shows a preferred PZT drive waveform 160 that provides a substantially constant mode zero drop ejection velocity at drop ejection rates approaching 14 KHz. Drive waveform 160 is shaped to concentrate energy around the dominant (Helmholtz) resonant frequency and to suppress energy near the resonant frequencies of input channel 18 and the combined outlet channel structures. Many drive waveform shapes can achieve the same result, but drive waveform 160 achieves the desired result by having transducer driver 36 (Fig. 3) generate a bipolar drive waveform 162 that includes a 12.5-microsecond duration negative 50-volt pulse 164 separated by a 12.5-microsecond wait period 166 from a 12.5-microsecond duration positive 50-volt pulse 168. Suitable drive waveforms may be generated in which each of the above-described pulse durations and wait periods may be in a range from about 4-microseconds to about 30-microseconds.

Pressure transducer 32 has a characteristic capacitance of about 500 picofarads which together with resistor network 106 forms a simple resistance-capacitance ("RC") filter that causes the characteristic rolled-off shape of drive waveform 160. Skilled workers will recognize that other RC value combinations are possible and that bipolar waveform 162 may be suitably adjusted to compensate.

Fig. 5 shows a Fourier series approximation of an energy distribution 170 versus frequency resulting from driving pressure transducer 32 with drive waveform 160. Energy distribution 170 is concentrated at a peak 172 surrounding the 19 KHz dominant resonant frequency of ink-jet 10 and is suppressed at a null 174 near the respective inlet and outlet channel resonant frequencies of 79 KHz and 73 KHz.

Fig. 6 graphically compares the jetting performance that results from driving ink-jet 10 with a prior art waveform and with preferred drive waveform 160 of Fig. 4. The prior art drive waveform was shaped as described in U.S. Pat. No. 5,170,177 to concentrate energy around a 19 KHz dominant frequency but to minimize energy only at the 73 KHz resonant frequency of the outlet channel. The prior art waveform results when transducer driver 36 (Fig. 3) generates a bipolar drive waveform having a 12.0-microsecond duration negative 50-volt pulse separated by a 3.0-microsecond wait period from an 11.0-microsecond duration positive 50-volt pulse.

Ink-jet 10 was driven with the prior art waveform and the time required for ejected ink drops to travel from orifice 14 to a print medium spaced 0.81 millimeter away was recorded versus the drop ejection rate. A curve 180 shows that 100-microsecond time-to-media variations result when ink-jet 10 is driven by the prior art waveform over a range of ejection rates from one to 10 KHz. The 50 percent time-to-media variation can cause drop placement errors that limit printing speed in high-resolution printing applications.

Ink-jet 10 was then driven with preferred drive waveform 160, and the time required for ejected ink drops to travel from orifice 14 to a print medium spaced 0.81 millimeter away was again recorded versus the drop ejection rate. A curve 182 shows that 65-microsecond time-to-media variations result when ink-jet 10 is driven by preferred drive waveform 160 over a range of ejection rates from one to 13 KHz. Time-to-media variations of 40 microseconds result if ink-jet 10

is limited to an ejection rate of 12.5 KHz. The resulting 20 to 30 percent time-to-media variations represent a 50 percent variation improvement combined with a 25 percent to 30 percent drop ejection rate improvement.

High-speed, high-resolution printing applications may likewise be improved by using transducer drive waveforms designed and shaped according to the principles described in this application.

Alternative embodiments of portions of this invention include, for example, its applicability to jetting various fluid types including, but not limited to, aqueous and phase-change inks of various colors.

Skilled workers will realize that waveforms other than waveform 160 can achieve the desired results and that a spectrum analyzer or fast-Fourier-transform displaying oscilloscope may be used to view a resulting energy spectrum while shaping a waveform to achieve a predetermined energy distribution. Moreover, filtering other than RC filtering, or no filtering at all may be employed to achieve the desired drive waveform energy distribution.

It should be noted that this invention is useful in combination with various prior art techniques including dithering and electric field drop acceleration to provide further enhanced image quality and drop placement accuracy.

In summary, the invention is amenable to any fluid jetting drive mechanism and architecture capable of providing the required drive waveform energy distribution to a suitable orifice.

It will be obvious to skilled workers that many changes may be made to the details of the above-described embodiments of this invention without departing from the underlying principles thereof. For example, electromechanical transducers other than the PZT bending-mode type described may be used. Shear-mode, annular constrictive, electrostrictive, electromagnetic, and magnetostrictive transducers are suitable alternatives. Similarly, although described in terms of electrical energy waveforms to drive the transducers, any other suitable energy form could be used to actuate the transducer, such as, but not limited to, acoustical or microwave energy. Where electrical waveforms are employed, the desired energy distribution can be equally well established by unipolar or bipolar pairs or groups of pulses. Accordingly, it will be appreciated that this invention is, therefore, applicable to fluid ejection applications other than those found in ink-jet printers.

Claims

1. An apparatus for ejecting a fluid from an orifice (14), the apparatus comprising a pressure chamber (22) fluidically coupled to a fluid manifold (12) by an inlet channel (18) and to the orifice (14) by an outlet channel (24, 26, 28), a transducer driver generating an energy input; a transducer (32) coupled to the pressure chamber (22) to excite in the orifice (14) a modal meniscus shape in response to the energy input, the energy input having a spectral energy distribution which is concentrated around a dominant resonant frequency of the affected fluid mass in the apparatus, excluding the fluid in the fluid manifold (12), and which is substantially reduced around resonant frequencies of the inlet channel (18) and the outlet channel (24, 26, 28); whereby a drop of the fluid is ejected at an ejection velocity from the orifice (14) in response to the energy input.
2. An apparatus as claimed in Claim 1 in which the modal meniscus shape is a mode zero type, a mode one type and a mode two type.
3. An apparatus as claimed in Claim 1 or Claim 2 in which the dominant resonant frequency is a Helmholtz resonance resulting from co-action among the pressure chamber (22), the inlet channel (18), the outlet channel (24, 26, 28) and the orifice (14).
4. An apparatus as claimed in Claim 3 in which the outlet path from the pressure chamber (22) to the orifice (14) is formed from outlet channel (24) and outlet channel (28) and optionally offset channel (26), said channels being formed by separator plate (48), outlet plate (54) and optionally offset channel plate (50) when offset channel (26) is included.
5. An apparatus as claimed in any preceding claim in which the energy input is repetitively applied to actuate the transducer (32) in a repetition rate range of from 1 KHz to at least about 15 KHz and in which the drop ejection velocity remains substantially constant over the range.
6. An apparatus as claimed in any preceding claim in which the energy input is an electrical waveform.
7. An apparatus as claimed in Claim 6 in which the character of the electrical waveform is established by a bipolar pair of pulses separated by a wait period.
8. An apparatus as claimed in Claim 6 or Claim 7 in which the transducer driver (36) includes a processor that causes repetitive generation of the electrical waveform such that the drops of fluid are ejected at a drop ejection rate rang-

ing from 1,000 to at least about 15,000 drops per second.

9. An apparatus as claimed in any preceding claim in which the transducer (32) is of a piezoelectric type.

10. An apparatus as claimed in any preceding claim in which the orifice (14) is an ink-jet orifice and the fluid is ink.

11. A method for ejecting an ink drop from an orifice of an individual ink-jet apparatus having a pressure chamber (22) that is fluidically coupled to an ink manifold (12) by an inlet channel (18) and to an orifice (14) by an outlet channel (24, 26, 28), the method comprising providing a source of energy input; adjusting the source of energy to concentrate a spectral energy content of the energy input around a dominant resonant frequency of an affected fluid mass in the ink-jet apparatus, excluding the ink in the ink-jet manifold (12); adjusting the source of energy to suppress the spectral energy content of the energy input near resonant frequencies of the inlet channel (18) and the outlet channel (24, 26, 28); and connecting the energy input to a transducer (32) coupled to the pressure chamber (22) to eject from the orifice (14) an ink drop having an ejection velocity.

12. A method as claimed in Claim 11 in which the dominant resonant frequency is a Helmholtz resonance resulting from co-action among the pressure chamber (22), the inlet channel (18), the outlet channel (24, 26, 28), and the orifice (14).

13. A method as claimed in Claim 12 and including the step of forming the outlet path from the pressure chamber (22) to the orifice (14) formed from outlet channel (24) and outlet channel (28) and optionally offset channel (26), said channels being formed by separator plate (48), outlet plate (54) and optionally offset channel plate (50) when offset channel (26) is included.

14. A method as claimed in any one of Claims 11 to 13 and including the step of applying the energy input repetitively to the transducer (32) at a repetition rate within a range of from 1 KHz to at least about 15 KHz, wherein the drop ejection velocity remains substantially constant over the repetition rate range.

15. A method as claimed in any one of Claims 11 to 14 in which the generating step comprises generating an electrical waveform.

16. A method as claimed in Claim 15 and including the step of shaping the electrical waveform with an RC network.

17. A method as claimed in Claim 15 or Claim 16 in which the generating step comprises forming an electrical pulse having a first relative voltage polarity and a first duration; waiting a predetermined time period; and forming an electrical pulse having a second relative voltage polarity and a second duration.

18. A method as claimed in Claim 17, in which the first and second time durations and the predetermined time period are all substantially equal.

19. A method as claimed in Claim 17 or Claim 18 in which the first and second time durations and the predetermined time period each range from about 4 microseconds to about 30 microseconds.

Patentansprüche

1. Vorrichtung zum Auswerfen eines Fluids aus einer Öffnung (14), wobei die Vorrichtung eine Druckkammer (22), die strömungstechnisch mit einem Fluidverteiler (12) über einen Einlaßkanal (18) und mit der Öffnung (14) über einen Auslaßkanal (24, 26, 28) gekoppelt ist, einen Transducer-Treiber (32), der mit der Druckkammer (22) gekoppelt ist, um in der Öffnung (14) eine modale Meniskusform in Antwort auf den Energieeingang zu erregen, umfaßt, wobei der Energieeingang eine spektrale Energieverteilung aufweist, die um eine dominante Resonanzfrequenz der beteiligten Fluidmasse in der Vorrichtung herum konzentriert ist, welche das Fluid in dem Fluidverteiler (12) ausschließt, und die im wesentlichen um Resonanzfrequenzen des Einlaßkanals (18) und des Auslaßkanals (24, 26, 28) reduziert ist, wobei ein Tropfen des Fluids mit einer Auswurfgeschwindigkeit aus der Öffnung (14) in Antwort auf den Energieeingang ausgeworfen wird.

2. Vorrichtung nach Anspruch 1, bei welcher die modale Meniskusform ein Null-Typ-Modus, ein Ein-Typ-Modus und ein Zwei-Typ-Modus ist.

3. Vorrichtung nach Anspruch 1 oder 2, bei welcher die dominante Resonanzfrequenz eine Helmholtz-Frequenz ist, die aus einem Zusammenwirken zwischen der Druckkammer (22), dem Einlaßkanal (18), dem Auslaßkanal (24, 26, 28) und der Öffnung (14) resultiert.
- 5 4. Vorrichtung nach Anspruch 3, bei welcher der Auslaßweg aus der Druckkammer (22) hin zu der Öffnung (14) aus einem Auslaßkanal (24) und einem Auslaßkanal (28) und optional einem Offset-Kanal (26) gebildet ist, wobei die Kanäle durch eine Trennplatte (48), einer Auslaßplatte (54) und optional eine Offset-Kanalplatte (50), wenn ein Offset-Kanal (26) umfaßt, gebildet sind.
- 10 5. Vorrichtung nach einem der vorhergehenden Ansprüche, bei welcher der Energieeingang wiederholt angelegt wird, um den Transducer (32) in einem Wiederholungsgeschwindigkeitsbereich von 1 KHz bis wenigstens etwa 15 KHz zu betätigen, und bei welcher die Tropfenauswurfgeschwindigkeit im wesentlichen über den Bereich konstant bleibt.
- 15 6. Vorrichtung nach einem der vorhergehenden Ansprüche, bei welcher der Energieeingang eine elektrische Schwingungsform ist.
7. Vorrichtung nach Anspruch 6, bei welcher die Art der elektrischen Schwingungsform durch ein bipolares Paar von Impulsen, die durch eine Wartezeit getrennt sind, aufgebaut ist.
- 20 8. Vorrichtung nach Anspruch 6 oder 7, bei welcher der Transducer-Treiber (36) einen Prozessor umfaßt, der eine wiederholte Erzeugung der elektrischen Schwingungsform hervorruft, derart, daß die Fluidtropfen mit einer Tropfenauswurfrate in einem Bereich von 1.000 bis wenigstens etwa 15.000 Tropfen pro Sekunde ausgeworfen werden.
- 25 9. Vorrichtung nach einem der vorhergehenden Ansprüche, bei welchem der Transducer (32) von piezoelektrischem Typ ist.
10. Vorrichtung nach einem der vorhergehenden Ansprüche, bei welcher die Öffnung (14) eine Tintenstrahldüse ist und das Fluid Tinte ist.
- 30 11. Verfahren zum Auswerfen eines Tintentropfens aus einer Öffnung einer individuellen Tintenstrahlvorrichtung, die eine Druckkammer (22) aufweist, welche strömungstechnisch mit einem Tintenverteiler (12) über einen Einlaßkanal (18) und mit einer Öffnung (14) über einen Auslaßkanal (24, 26, 28) gekoppelt ist, wobei das Verfahren ein Bereitstellen einer Energieeingangsquelle, ein Einstellen der Energiequelle, um einen spektralen Energiegehalt des Energieeingangs um eine dominante Resonanzfrequenz einer betätigten Fluidmasse in der Tintenstrahlvorrichtung herum zu konzentrieren, welche die Tinte in dem Tintenstrahlverteiler (14) ausschließt, ein Einstellen der Energiequelle, um den spektralen Energiegehalt des Energieeingangs nahe von Resonanzfrequenzen des Einlaßkanals (18) und des Auslaßkanals (24, 26, 28) zu unterdrücken, und eine Verbinden des Energieeingangs mit einem Transducer (32), der mit der Druckkammer (22) gekoppelt ist, um einen Tintentropfen mit einer Auswurfgeschwindigkeit aus der Öffnung (14) auszuwerfen, umfaßt.
- 35 12. Verfahren nach Anspruch 11, bei welchem die dominante Resonanzfrequenz eine Helmholtz-Frequenz ist, die aus einem Zusammenwirken zwischen der Druckkammer (22), des Einlaßkanals (18), des Auslaßkanals (24, 26, 28) und der Öffnung (14) resultiert.
- 40 13. Verfahren nach Anspruch 12, und umfassend den Schritt eines Bildens des Auslaßweges aus der Druckkammer (22) hin zu der Öffnung (14), der aus einem Auslaßkanal (24) und einem Auslaßkanal (28) sowie optional einem Offset-Kanal (26) gebildet ist, wobei die Kanäle durch eine Trennplatte (48), eine Auslaßplatte (54) und optional eine Offset-Kanalplatte (50), wenn ein Offset-Kanal (26) umfaßt ist, gebildet sind.
- 45 14. Verfahren nach einem der Ansprüche 11 bis 13, und umfassend den Schritt eines wiederholten Anlegens des Energieeingangs an den Transducer (32) mit einer Wiederholungsgeschwindigkeit innerhalb eines Bereiches von 1 KHz bis wenigstens etwa 15 KHz, wobei die Tropfenauswurfgeschwindigkeit im wesentlichen über den Wiederholungsgeschwindigkeitsbereich konstant bleibt.
- 50 15. Verfahren nach einem der Ansprüche 11 bis 14, bei welchem der Erzeugungsschritt ein Erzeugen einer elektrischen Schwingungsform umfaßt.
- 55

16. Verfahren nach Anspruch 15, und umfassend den Schritt einer Formgebung der elektrischen Schwingungsform mit einem RC-Zweipol.

17. Verfahren nach Anspruch 15 oder 16, bei welchem der Erzeugungsschritt ein Bilden eines elektrischen Impulses mit einer ersten relativen Spannungspolarität und einer ersten Dauer, einem Zuwarten einer vorbestimmten Zeitdauer, und einem Bilden eines elektrischen Impulses mit einer zweiten relativen Spannungspolarität und einer zweiten Dauer umfaßt.

18. Verfahren nach Anspruch 17, bei welchem die erste und zweite Zeitdauer und die vorbestimmte Zeitdauer sämtlich im wesentlichen gleich sind.

19. Verfahren nach Anspruch 17 oder 18, bei welchem die erste und zweite Zeitdauer und die vorbestimmte Zeitdauer jeweils von etwa 4 Mikrosekunden bis etwa 30 Mikrosekunden betragen.

Revendications

1. Appareil pour éjecter un fluide depuis un orifice (14), l'appareil comprenant une chambre de pression (22) couplée de manière fluïdique à un collecteur de fluide (12) par un canal d'entrée (18) et à l'orifice (14) par un canal de sortie (24, 26, 28), un dispositif de commande à transducteur produisant une entrée d'énergie, un transducteur (32) coupé à la chambre de pression (22) pour exciter dans l'orifice (14) une forme en ménisque modal en réponse à l'entrée d'énergie, l'entrée d'énergie ayant une distribution d'énergie spectrale qui est concentrée autour d'une fréquence de résonance dominante de la masse de fluide affectée dans l'appareil, en excluant le fluide dans le collecteur de fluide (12), et qui est sensiblement réduite autour de fréquences de résonances du canal d'entrée (18) et du canal de sortie (24, 26, 28), de sorte qu'une goutte de fluide est éjectée à une vitesse d'éjection depuis l'orifice (14) en réponse à l'entrée d'énergie.

2. Appareil selon la revendication 1, dans lequel la forme en ménisque modal est d'un type de mode 0, d'un type de mode 1 et d'un type de mode 2.

3. Appareil selon la revendication 1 ou 2, dans lequel la fréquence de résonance dominante est une résonance de Helmholtz résultant de la coaction entre la chambre de pression (22), le canal d'entrée (18), le canal de sortie (24, 26, 28) et l'orifice (14).

4. Appareil selon la revendication 3, dans lequel le trajet de sortie depuis la chambre de pression (22) vers l'orifice (14) est formé à partir d'un canal de sortie (24) et d'un canal de sortie (28) et optionnellement d'un canal de décalage (26), lesdits canaux étant formés par une plaque de séparateur (48), une plaque de sortie (54) et optionnellement par une plaque de canal de décalage (50) lorsqu'un canal de décalage (26) est inclus.

5. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'entrée d'énergie est appliquée de manière répétitive pour actionner le transducteur (32) dans une plage de taux de répétition s'étendant de 1kHz jusqu'à au moins environ 15 kHz et dans lequel la vitesse d'éjection de gouttes reste sensiblement constante sur la plage.

6. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'entrée d'énergie est une forme d'onde électrique.

7. Appareil selon la revendication 6, dans lequel le caractère de la forme d'onde électrique est établi par une paire bipolaire d'impulsions séparées par une période d'attente.

8. Appareil selon la revendication 6 ou 7, dans lequel le dispositif de commande à transducteur (36) inclut un processeur qui provoque la production répétitive de la forme d'onde électrique de sorte que les gouttes de fluide sont éjectées à un taux d'éjection de gouttes variant depuis 1.000 jusqu'à environ 15.000 gouttes par seconde.

9. Appareil selon l'une quelconque des revendications précédentes, dans lequel le transducteur (22) est du type piézoélectrique.

10. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'orifice (14) est un orifice à jet d'encre et le fluide est de l'encre.

- 5 11. Procédé pour éjecter une goutte d'encre depuis un orifice d'un appareil à jet d'encre individuel ayant une chambre de pression (22) qui est couplée de manière fluide à un collecteur d'encre (12) par un canal d'entrée (18) et à un orifice (14) par un canal de sortie (24, 26, 28), le procédé comprenant la fourniture d'une source d'entrée d'énergie, le réglage de la source d'énergie pour concentrer un contenu d'énergie spectral de l'entrée d'énergie autour d'une fréquence de résonance dominante d'une masse de fluide affectée dans l'appareil à jet d'encre, en excluant l'encre dans le collecteur à jet d'encre (12), le réglage de la source d'énergie pour supprimer le contenu d'énergie spectral de l'entrée d'énergie à proximité de fréquences de résonance du canal d'entrée (18) et du canal de sortie (24, 26, 28) et la connexion de l'entrée d'énergie à un transducteur (32) couplé à la chambre de pression (22) pour éjecter depuis l'orifice (14) une goutte d'encre ayant une vitesse d'éjection.
10
12. Procédé selon la revendication 11, dans lequel la fréquence de résonance dominante est une résonance de Helmholtz résultant de la coaction entre la chambre de pression (22), le canal d'entrée (18), le canal de sortie (24, 26, 28) et l'orifice (14).
- 15 13. Procédé selon la revendication 12 et incluant l'étape de formation du trajet de sortie depuis la chambre de pression (22) jusqu'à l'orifice (14) formé à partir d'un canal de sortie (24) et d'un canal de sortie (28) et optionnellement d'un canal de décalage (26), lesdits canaux étant formés par une plaque de séparateur (48), une plaque de sortie (54) et optionnellement une plaque de canal de décalage (50) lorsqu'un canal de décalage (26) est inclus.
- 20 14. Procédé selon l'une quelconque des revendications 11 à 13 et incluant l'étape d'application de l'énergie d'entrée de manière répétitive au transducteur (32) à un taux de répétition compris dans une plage s'étendant de 1kHz jusqu'à environ au moins 15 kHz, dans lequel la vitesse d'éjection des gouttes reste sensiblement constante sur la plage de taux de répétition.
- 25 15. Procédé selon l'une quelconque des revendications 11 à 14 dans lequel l'étape de production comprend la production d'une forme d'onde électrique.
16. Procédé selon la revendication 15 et incluant l'étape de mise en forme de la forme d'onde électrique avec un réseau RC.
- 30 17. Procédé selon la revendication 15 ou 16, dans lequel l'étape de production comprend la formation d'une impulsion électrique ayant une première polarité de tension relative et une première durée, l'attente pendant une période de temps prédéterminée, et la formation d'une impulsion électrique ayant une seconde polarité de tension relative et une seconde durée.
- 35 18. Procédé selon la revendication 17, dans lequel les première et deuxième durées de temps et la période de temps prédéterminée sont toutes sensiblement égales.
- 40 19. Procédé selon la revendication 17 ou 18, dans lequel les première et seconde durées de temps et la période de temps prédéterminée s'étendent chacune entre environ 4 μ s jusqu'à environ 30 μ s.

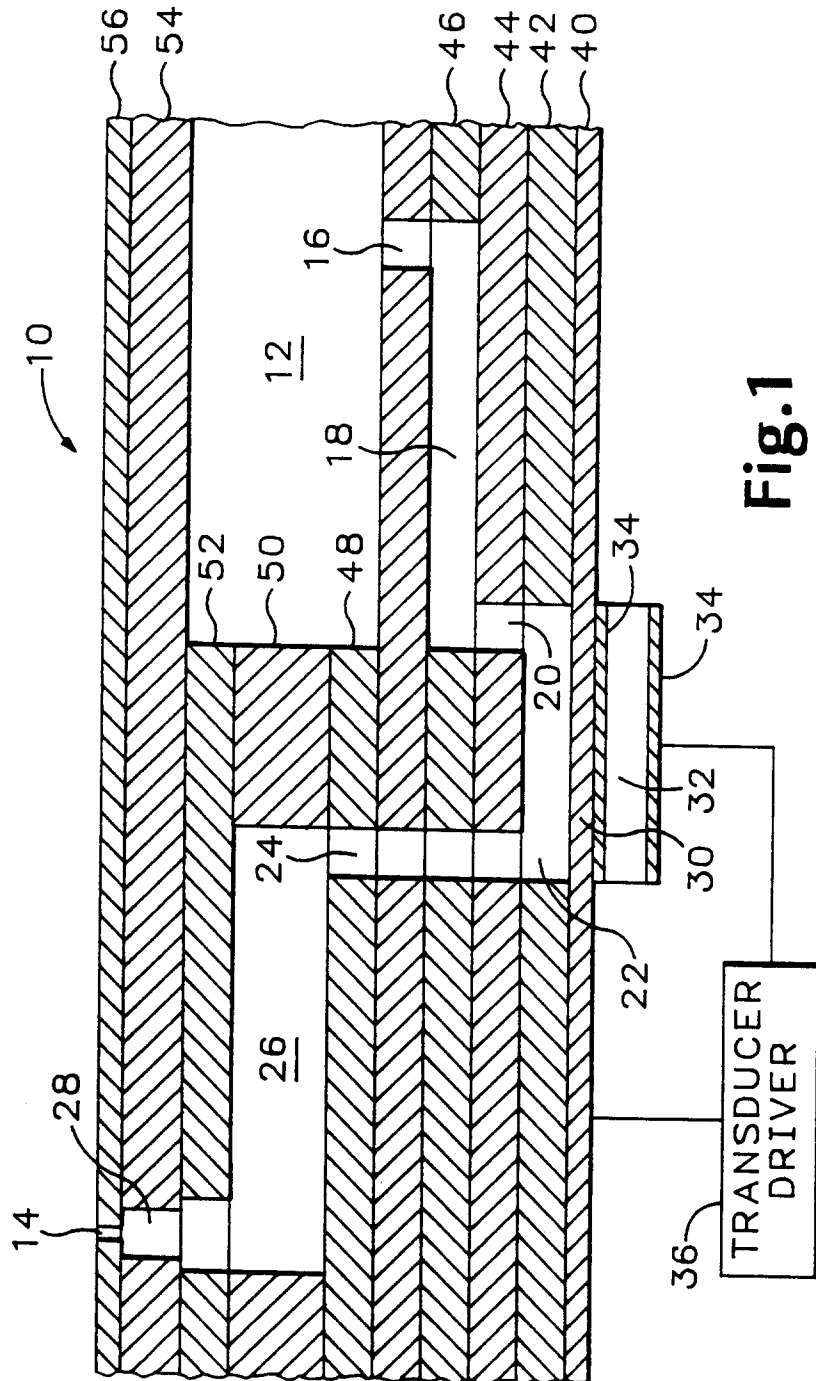


Fig.1

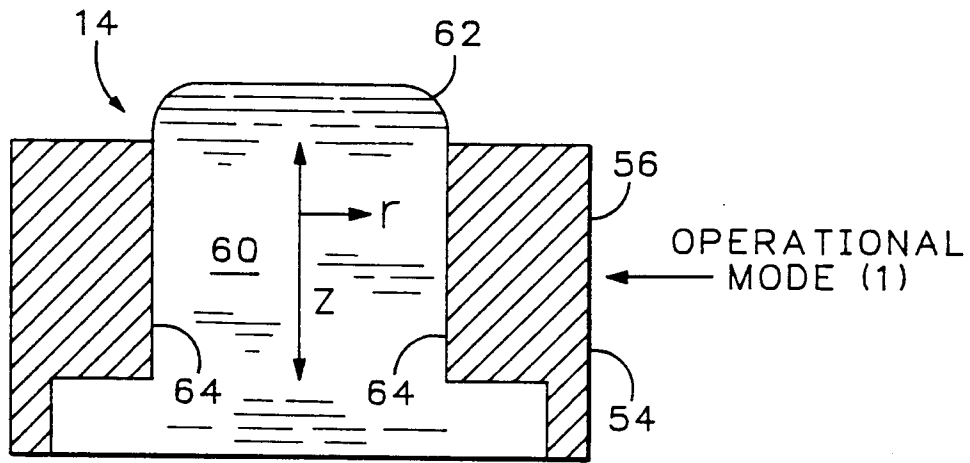


Fig. 2A

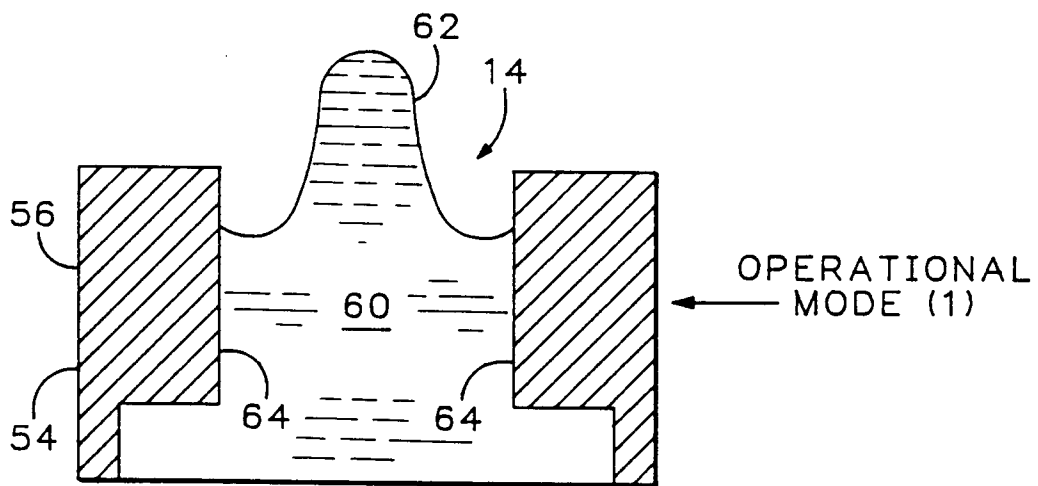


Fig. 2B

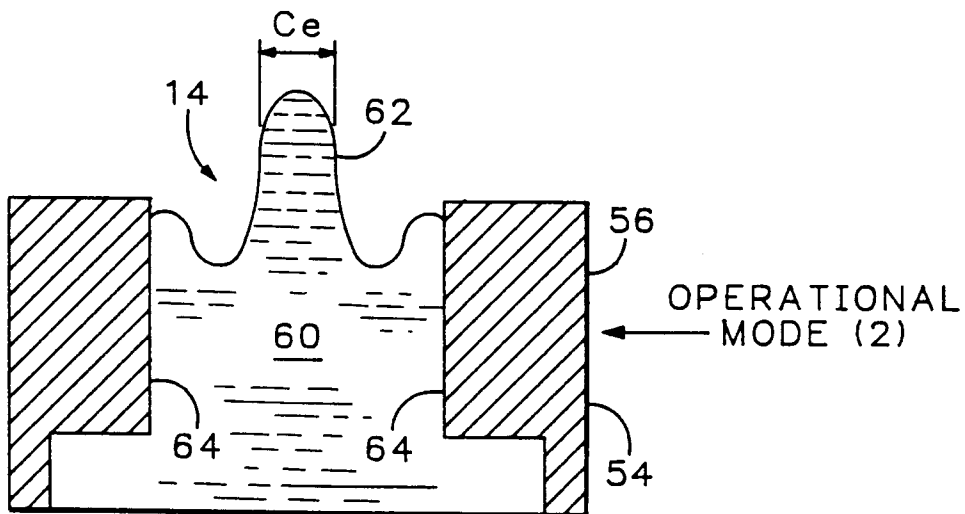


Fig. 2C

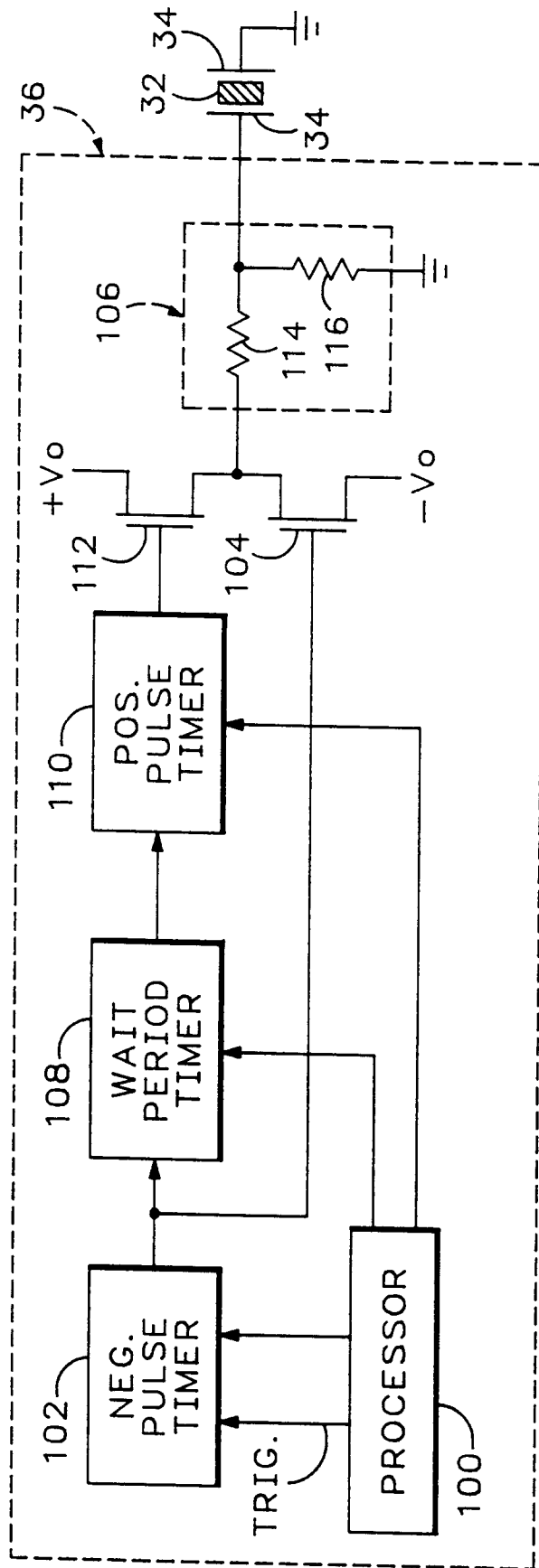


Fig.3
(PRIOR ART)

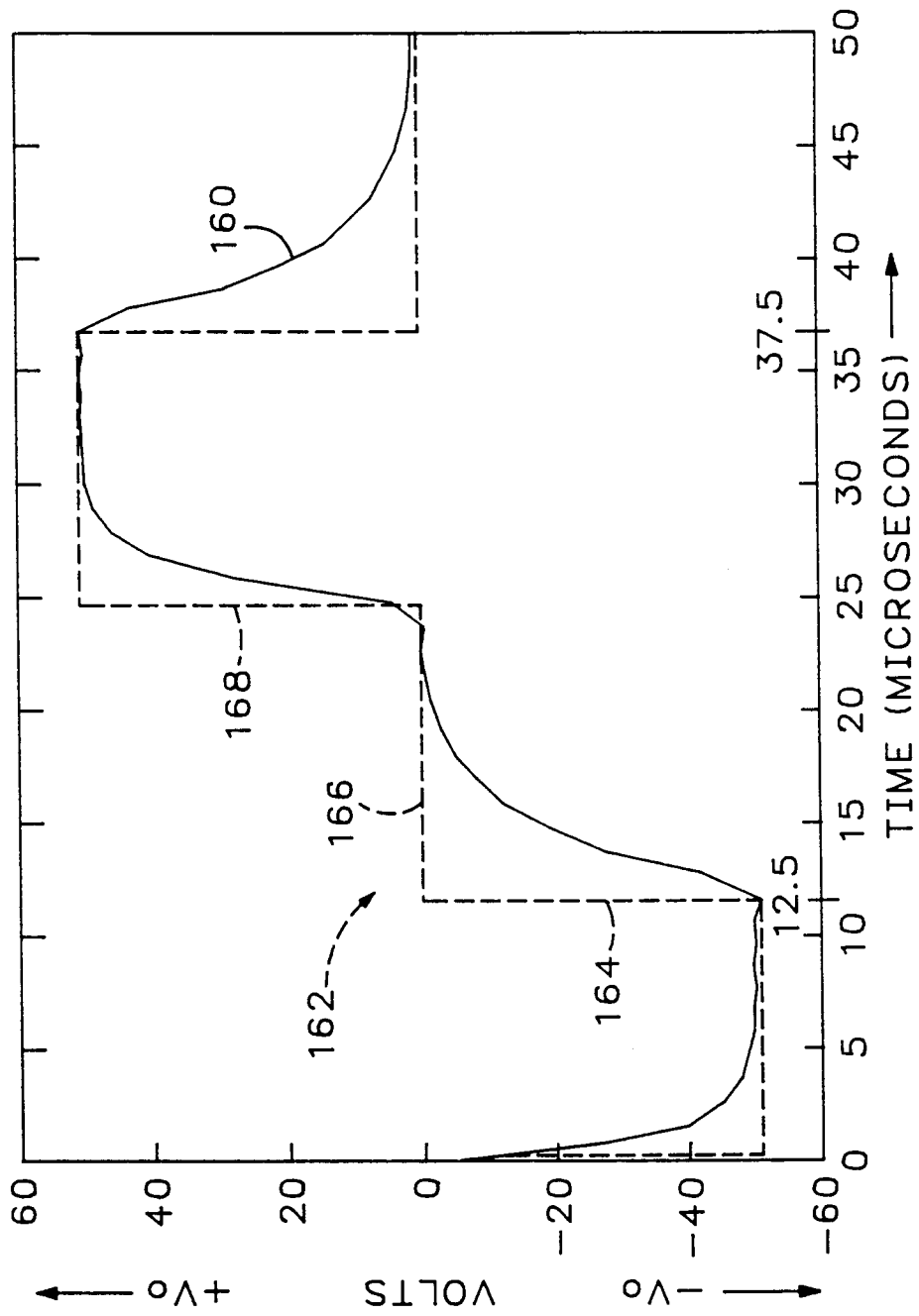


Fig. 4

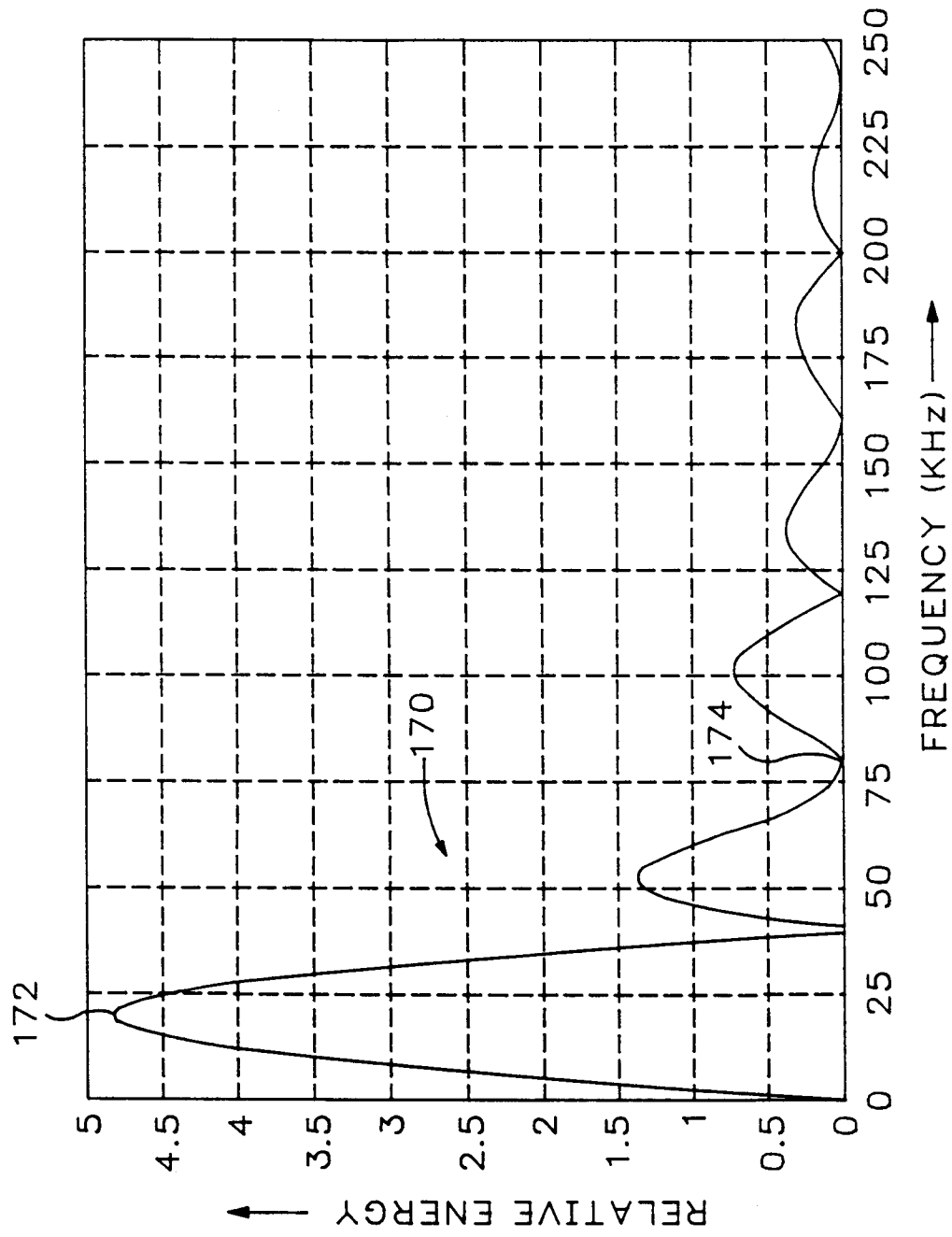


Fig.5

