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(57) An electric circuit for monitoring a condition of an ink ejection unit in an array of ink ejection units (111, 112, 113, 114) is described. Each ejection unit comprises an ink channel connected to a piezo-electric element. The monitoring is done by a measurement of a residual pressure wave in the ink channel. The circuit comprises a controllable switch (4) for making contact with the piezo-electric element, a comparator (8) for comparing an

electric signal from the piezo-electric element with a reference signal, a digital memory (6) for saving a digital reference signal and a digital-analog converter. In this circuit each piezo-electric element or group of elements is associated with a specific part of the digital memory, comprising a corresponding reference signal. This enables a parallel monitoring of several ejection units during printing.

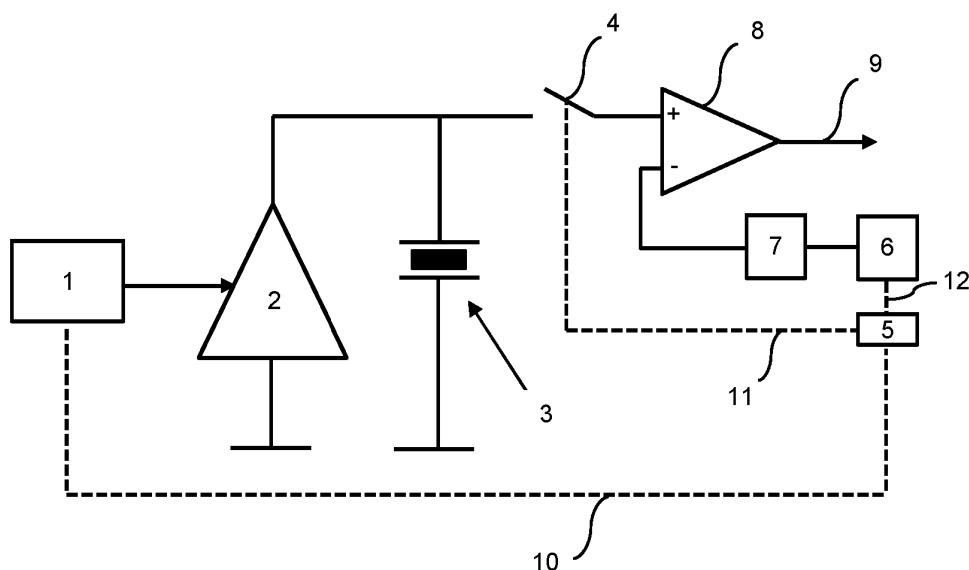


Fig. 1

Description

FIELD OF THE INVENTION

[0001] The present invention generally pertains to an electric circuit that is used in determining an operating state of a piezo-actuated ejection element of an inkjet print head.

BACKGROUND ART

[0002] A known inkjet print head comprises an array of ejection elements, wherein each ejection element comprises a liquid chamber for holding an amount of liquid. Commonly, the liquid is an ink, such as a solvent-based or water-based ink, a hot-melt ink at an elevated temperature or a UV-curable ink. However, the liquid may be any other kind of liquid, such as a liquid that needs to be dosed accurately. In the following the word "ink" is used for any liquid that may be ejected from a print head, either or not at elevated temperatures, in the form of small droplets. The term "print head", "print" and derivatives thereof are to be understood to include any device or technique that deposits or creates material on a surface in a controlled manner.

[0003] Each ejection unit of the known inkjet print head further comprises an electromechanical transducer, usually a piezo-electric actuator, operatively coupled to the liquid chamber, for generating a pressure wave in the liquid held in the liquid chamber. This actuator comprises two electrodes and a layer of piezo-electric material arranged therebetween. When an electric field is applied by application of a voltage over the electrodes, the piezo-material mechanically deforms and the deformation of the piezo-actuator generates the pressure wave in the liquid. Other kinds of electromechanical transducers are also known for use in an inkjet print head, such as an electrostatic actuator. Hereinafter, the electromechanical transducer may also be referred to as the actuator or piezo-electric element.

[0004] The liquid chamber terminates at one end in a nozzle. If a suitable pressure wave is generated in the liquid in the liquid chamber, a droplet of the liquid is expelled through the nozzle. In this way an ink droplet may be ejected towards a recording medium to form an image dot on the recording medium. A pattern of such image dots thus forms a printed image on the recording medium as is well-known in the art.

[0005] A known disadvantage of the above-described inkjet print head is the susceptibility to malfunctioning of the ejection units. In particular, it is known that an air bubble may be entrained in the nozzle or in the liquid chamber. Such an air bubble changes the acoustics of the ejection unit and as a consequence a droplet may not be formed when the pressure wave is generated. Another known cause for malfunctioning is the occurrence of dirt or dust particles (partly) blocking the nozzle. The presence of dirt does not only block the liquid flow,

but also changes the acoustics of the liquid chamber.

[0006] It is well-known in the art to sense a residual pressure wave in the liquid. After the generation of a pressure wave, the acoustics of the ejection unit result in a residual pressure wave that damps over time. The residual pressure wave may either exist as a result from a generated wave for expelling a droplet or as a result from an excitation with the sole purpose of obtaining a residual pressure wave, without expelling a droplet. Sensing and analyzing this residual pressure wave provides detailed information on the acoustics of the ejection unit. A comparison between the acoustics derived from the residual pressure wave and the acoustics of an ejection unit in an operative state enables a determination of the operating state of the ejection unit. Moreover, it is known to determine a cause for a malfunctioning state from the residual pressure wave, if a malfunction state is established.

[0007] A disadvantage of the known measurement circuits that are used to detect an operating state is the time needed for sensing the residual pressure wave and the time needed for analysis of the residual pressure wave. Due to this relatively long period needed for sensing and analyzing, it is not possible to perform the analysis for each ejection unit after each droplet ejection. Moreover, even if there would be sufficient time between consecutive droplet ejections, the computational power needed to analyze each ejection unit after each droplet ejection would be so high, that this would not be commercially feasible. In particular, a parallel operation for all ejection units is desired.

SUMMARY OF THE INVENTION

[0008] In an aspect of the present invention, a circuit according to claim 1 is provided. In this circuit a reference signal is provided that is specific for the ejection unit that is monitored or for a group of ejection units that show similar behavior and/or acoustics. Because there are differences between the efficiency of the various piezo-electric elements, the electric signals that result from the residual pressure waves in the various ink channels vary in strength. Thus, for a correct assessment of the functioning of an ejection unit, the reference signal needs to be as close as possible to the signal that is associated with a correctly working element. This is achieved by associating each ejection unit with a specific part of a digital memory for saving the digital reference signals. If ejection elements show sufficiently similar behavior, they may of course share the same memory and use the same reference signals.

[0009] In another aspect of the present invention, a circuit is exclusively connectable to a single ejection unit. This means that there are as many monitoring circuits as there are ejection units, which can be monitored all at the same time. This satisfies the desire to enable a parallel operation for all ejection units.

[0010] Further details of the invention are indicated in the dependent claims.

[0011] The invention also pertains to an inkjet printer that comprises a circuit for monitoring a condition of the inkjet elements that are used in printing an image. This monitoring may even be scheduled during the print process, wherein an appropriate timing may be selected. In extension, this monitoring may be scheduled after each droplet ejection to make sure a droplet is excreted from the inkjet element. The condition of an inkjet element is determined based on an output of the comparator using both the electric signal from the residual pressure wave and the analog version of the reference signal as input signals. After determining a deviating ejection element, also known as a failing nozzle, it may be decided not to use this element for generating an ink drop, but to amend the print data in such a way that the original image is printed without the use of this element. Another way of coping with this situation is to have another ejection element fulfil the task the deviating element is not capable to do.

[0012] Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The present invention will become more fully understood from the detailed description given herebelow and the accompanying schematical drawings which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:

- Figure 1 is a circuit according to the present invention;
- Figure 2 shows an inkjet printer wherein the circuit is useful; and
- Figure 3 shows an example of a reference signal, a response signal from a well operating inkjet element, and a response signal of a failing element.

DETAILED DESCRIPTION OF THE DRAWINGS

[0014] The present invention will now be described with reference to the accompanying drawings, wherein the same reference numerals have been used to identify the same or similar elements throughout the several views.

[0015] Figure 1 shows a circuit that can be easily implemented in an integrated circuit. It comprises a print data module 1 that generates waveforms in accordance with the print data of an image. The waveforms are amplified by the driver 2 for driving the ink ejection element 3, wherein the electric voltage across a piezo-electric element or, equivalently, the current in the element gener-

ates an acoustic wave in the ink in the ink chamber, resulting in the ejection of an ink droplet. The switch 4 is open during the application of the waveforms and is closed after a waveform is finished to monitor the voltage across the ejection element 3 as a result of a residual acoustic wave in the ink chamber. Switch 4 is controlled by trigger element 5. Each ejection element is associated with a memory 6 that comprises a digital reference signal. This signal has been saved in a procedure wherein the functioning of an ejection element is associated with a determination of a residual acoustic wave signal. Trigger element 5 indicates the timing of sending this digital signal to the digital-analog converter (DAC) 7. The comparator 8 subtracts the reference signal from the residual acoustic wave signal, thus obtaining an output signal 9 that indicates whether these signals cancel or not. If they cancel, the ejection element 3 functions as required. If they do not, the ejection element may need maintenance or some other action is necessary. The output signal 9 may be analyzed to suggest the various actions. Trigger element 5 is connected to the print data module 1, the switch 4 and the digital memory 6 by the various control lines 10, 11, and 12 in order to obtain a proper timing of the signals.

[0016] Figure 2 shows the outline of an inkjet printer wherein the circuit of Figure 1 is applied. Herein a substrate 50 is conveyed in direction 51 by a belt that moves over rollers 21 and 22. Several processes are performed on the substrate, which may be a sheet of paper or other material. All processes are performed over the full width 52 of the substrate.

[0017] A first process 13 involves a pretreatment, such as a preheater, for example a heater by infrared radiation, or a corona or plasma treatment. This is not necessary for all kind of substrates, but its presence makes the printer more versatile. Then the substrate passes a roller coating 14, comprising an auxiliary roll 16 and a main roll 17 for coating the substrate with a pre-treatment liquid, such as a primer material. This is used to affect the way the ink spreads on some substrate materials. Each surface of the double rolls may be covered with a porous resin material such as sponge. After providing the aqueous pre-treatment liquid to auxiliary roll 16 first, the aqueous pre-treatment liquid is transferred to main roll 17, and a predetermined quantity of the liquid is applied on the surface of the receiving medium. Subsequently, the coated substrate, on which the aqueous pretreatment liquid was supplied may optionally be heated and dried by drying member 18. This element is composed of a drying heater installed at the downstream position of the aqueous pre-treatment liquid applying member 14 in order to decrease the quantity of the water content in the aqueous pretreatment liquid to a predetermined range.

[0018] In Figure 2, 110 represents an inkjet marking module comprising four inkjet marking devices, indicated with 111, 112, 113 and 114, each arranged to eject an ink of a different color, usually cyan, magenta, yellow and black, or CMYK. Each inkjet marking device is as wide

as the substrate that passes underneath. The number of ejection units is so high that only one pass is needed to completely print an image on the substrate. If one of the ejection units fails to eject ink drops or ejects droplets in a skew direction, a streaklike defect may occur in the print. This may be remedied by enhancing the ink density in neighboring ejection units. Hence, it is extremely useful to know if an ejection unit operates as required. Each of the ejection units in the inkjet printer in Figure 2 is actuated by a circuit as indicated in Figure 1. This has the advantage that during printing the condition of the ejection unit is monitored and immediate intervention is possible. Thereby the amount of streaklike defects in the print is reduced considerably. Underneath the belt at the position of the inkjet marking devices a temperature control device 19 is arranged to control the temperature of the substrate during the ink application, for example in the range of 30°C to 60°C. It may comprise heaters, such as radiation heaters, and a cooling means, for example a cold blast, in order to control the surface temperature of the receiving medium within a predetermined range.

[0019] The final process is a drying process. In Figure 2 a drying and fixing unit 20 is schematically shown. This unit may comprise a heater, for example a radiation heater. After an image has been formed, the print is conveyed to and passed through the drying and fixing unit 20. The print is heated such that solvents present in the printed image, which is to a large extent water, evaporate. The speed of evaporation and hence drying may be enhanced by increasing the air refresh rate in the drying and fixing unit 20. Simultaneously, film formation of the ink occurs, because the prints are heated to a temperature above the minimum film formation temperature. The residence time of the print in the drying and fixing unit 20 and the temperature at which the unit operates are optimized, such that when the print leaves the unit a dry and robust print has been obtained.

[0020] Figure 3 shows three signals as obtained from a residual pressure wave in the ejection element 3 in Figure 1. The signals are given as a voltage 60 as a function of time 61. Signal 62 is obtained during a start-up procedure wherein the functioning of ejection elements is determined. This signal is digitized and stored in the digital memory 6 as a reference signal. Signal 63 is obtained during the printing process and is sent to comparator 8 after closing switch 4. Since the reference signal, coming from the memory 6 is also led to the comparator, the output signal 9 will be substantially zero. However, if the ejection element 3 is not functioning properly, a signal like signal 64 will be obtained and after comparing this to signal 62, the output signal 9 will not be zero and immediate action may be taken. Thus the amount of streaklike defects in the print will be greatly reduced.

[0021] The invention being thus described, it will be understood that the same may be varied in many ways. Modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

Claims

1. An electric circuit for monitoring a condition of an ink ejection unit in an array of ink ejection units, each unit comprising an ink channel connected to a piezo-electric element, by a measurement of a residual pressure wave in the ink channel, the circuit comprising a controllable switch for making contact with the piezo-electric element, a comparator for comparing an electric signal from the piezo-electric element with a reference signal, a digital memory for saving a digital reference signal and a digital-analog converter, **characterized in that** for each piezo-electric element an association is present with a specific part of the digital memory, comprising an applicable reference signal.
2. The electric circuit according to claim 1, wherein the circuit is exclusively connectable to a single ejection unit.
3. The electric circuit according to claim 1, wherein the circuit is at least partly included in an Application Specific Integrated Circuit (ASIC).
4. The electric circuit according to claim 3, wherein the ASIC further comprises an electric circuit to drive the ink ejection unit such that an ink droplet is ejected.
5. An inkjet printer for positionally selective application of ink according to image data, the printer comprising a print head with at least one array of ink ejection units and an electric circuit according to claim 1.
6. A method for monitoring a condition of an ink ejection unit in an array of ink ejection units, each unit comprising an ink channel connected a piezo-electric element, by a measurement of a residual pressure wave in the ink channel, the method comprising the steps of: saving a reference signal in a digital memory associated with one of the ejection units, determining an electric signal from the piezo-electric element of said ejection unit, leading the reference signal to a digital-analog convertor to obtain a base signal, simultaneously leading the electric signal from the piezo-electric element and the base signal to a comparator and determining the condition of said ejection unit from the output of the comparator.

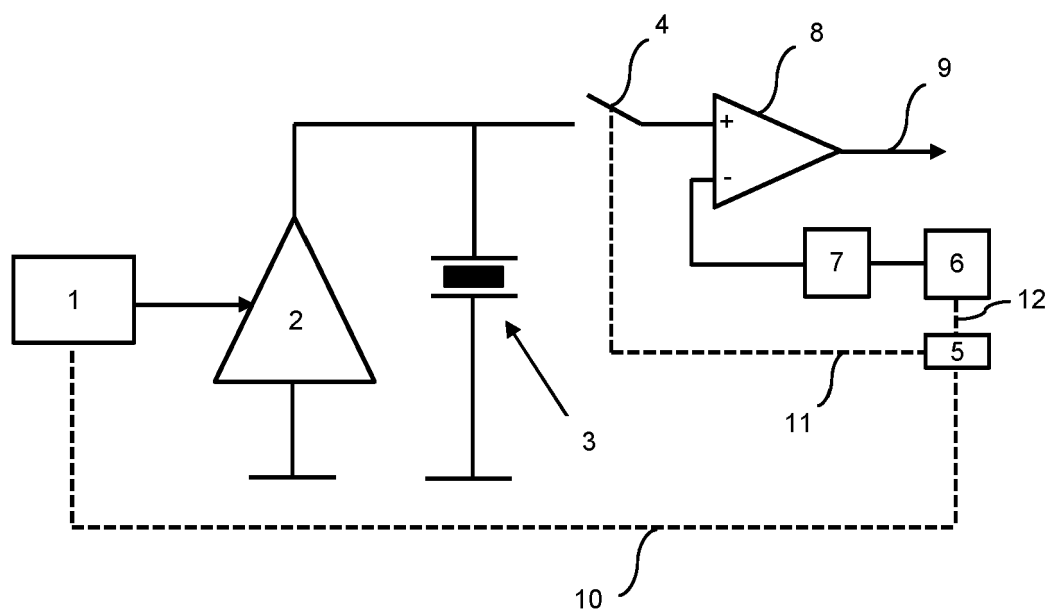


Fig. 1

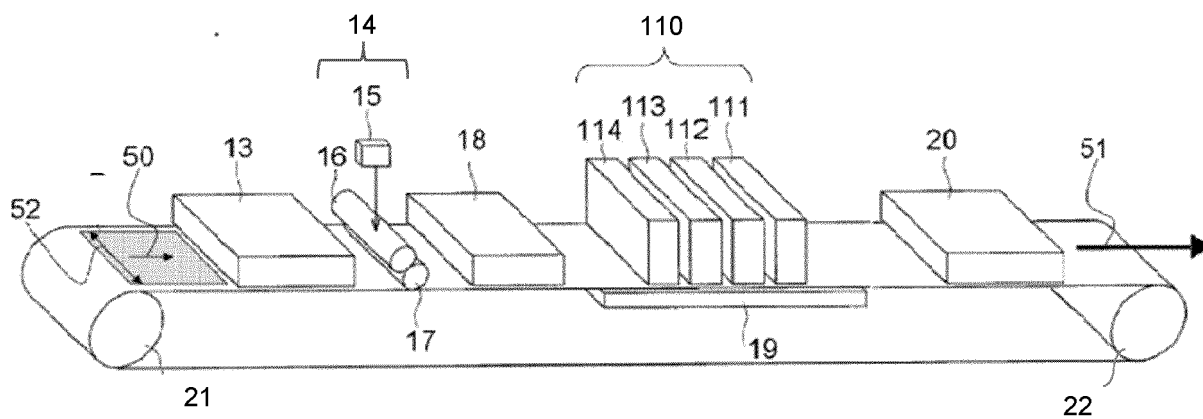


Fig. 2

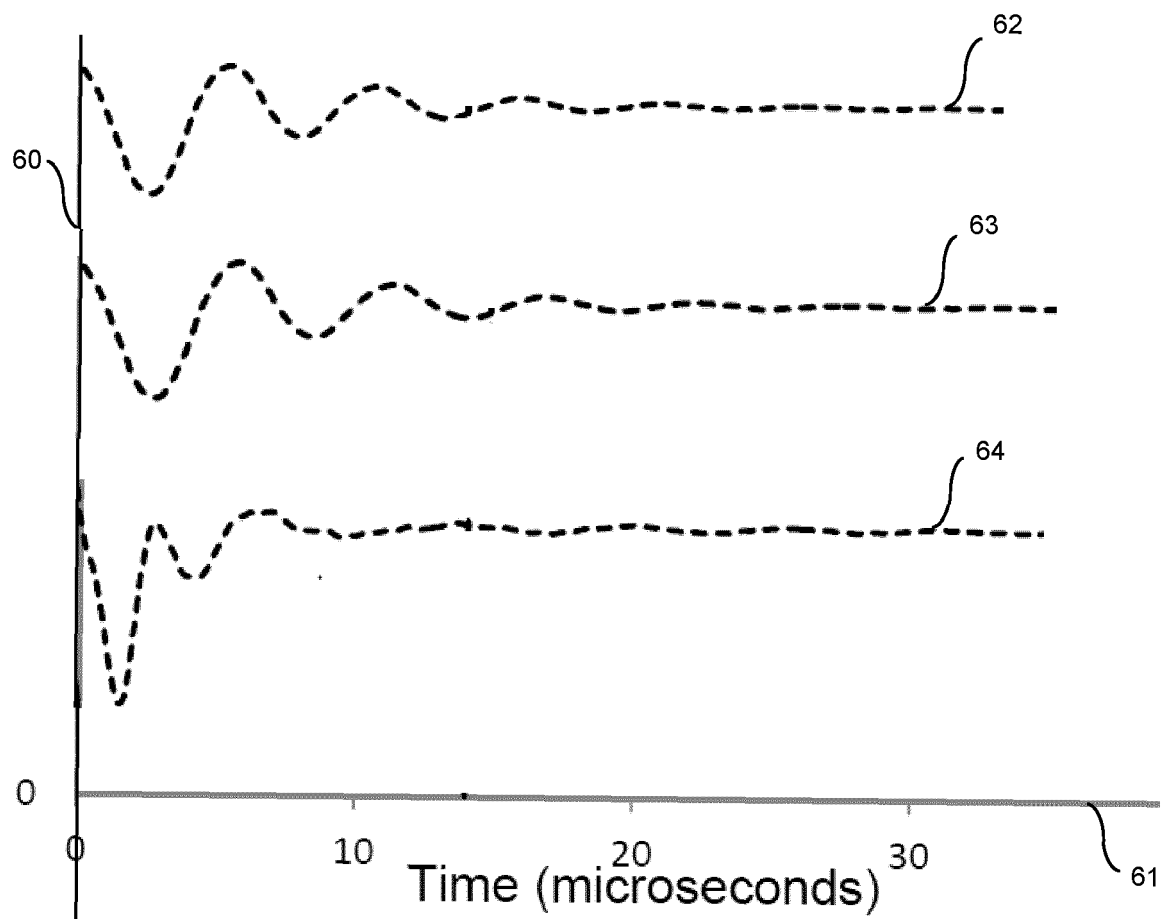


Fig. 3



EUROPEAN SEARCH REPORT

Application Number

EP 22 18 3845

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2011/285773 A1 (SHINKAWA OSAMU [JP]) 24 November 2011 (2011-11-24) * the whole document *	1-6	INV. B41J2/045
A	US 2015/367633 A1 (MURATE HIROHITO [JP]) 24 December 2015 (2015-12-24) * the whole document *	1-6	
A	US 2012/293577 A1 (KYOSO TADASHI [JP] ET AL) 22 November 2012 (2012-11-22) * the whole document *	1-6	
			TECHNICAL FIELDS SEARCHED (IPC)
			B41J
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 23 November 2022	Examiner Dewaele, Karl
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	

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EP 22 18 3845

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011285773 A1	24-11-2011	CN 102248789 A	23-11-2011
		JP 5533238 B2	25-06-2014
		JP 2011240563 A	01-12-2011
		US 2011285773 A1	24-11-2011
US 2015367633 A1	24-12-2015	JP 2016020088 A	04-02-2016
		US 2015367633 A1	24-12-2015
US 2012293577 A1	22-11-2012	CN 102785477 A	21-11-2012
		JP 5285742 B2	11-09-2013
		JP 2012240305 A	10-12-2012
		US 2012293577 A1	22-11-2012