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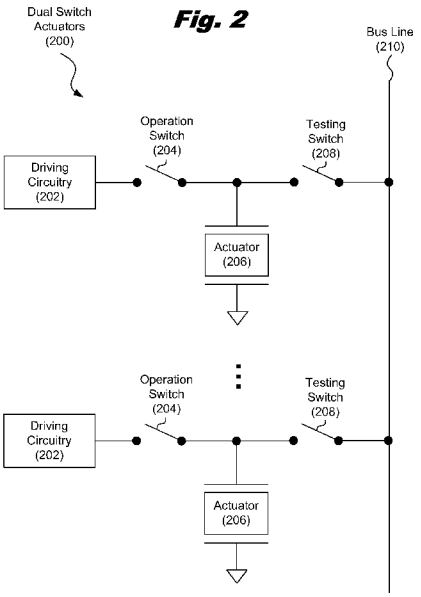
(54) Title: PRINTHEAD WITH DUAL SWITCHED PIEZOELECTRIC ACTUATORS



(57) Abstract: A printhead with dual switched piezoelectric actuators (206) includes an operation switch (204) connected between a piezoelectric actuator (206) for a printhead nozzle (100) and driving circuitry (202) to drive the piezoelectric actuator (206), and a testing switch (208) connected between the piezoelectric actuator (206) and a bus line (210), the bus line (210) connected to multiple piezoelectric actuators (206) through testing switches (208).

PRINTHEAD WITH DUAL SWITCHED PIEZOELECTRIC ACTUATORS

BACKGROUND

[0001] Printing systems utilize a variety of technologies to eject ink onto a print medium. One type of technology used in printing systems is piezoelectric technology. A piezoelectric material is one that expands and contracts under applied electrical conditions such as a voltage. Such material can be used as an actuator for inkjet nozzles within a printhead. Specifically, application of a voltage to a specific nozzle's piezoelectric actuator is done to eject ink from that nozzle as the printhead holding that nozzle moves in relation to the print medium.

[0002] Throughout the manufacturing process and life of a printhead that utilizes piezoelectric actuators, it is often desirable to perform tests on the piezoelectric actuators or the circuitry that drives those actuators. While many electronic products can be tested through use of a probe card connected to the semiconductor wafer on which the circuitry is formed, use of a probe card can be difficult in the case of printheads. Moreover, a probe card cannot be used to perform diagnostics once the printhead is finalized within a printing system product.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The accompanying drawings illustrate various examples of the principles described herein and are a part of the specification. The drawings are merely examples and do not limit the scope of the claims.

[0004] Fig. 1 is a diagram showing a piezoelectric printhead nozzle, according to one example of principles described herein.

[0005] Fig. 2 is a diagram showing illustrative dual switch actuators, according to one example of principles described herein.

[0006] Fig. 3A is a diagram showing an illustrative standard operation of the dual switch actuator, according to one example of principles described herein.

[0007] Fig. 3B is a diagram showing an illustrative testing operation of the dual switch actuator, according to one example of principles described herein.

[0008] Fig. 4 is a diagram showing an illustrative multiplexing of bus lines for the dual switch actuators within a printhead, according to one example of principles described herein.

[0009] Fig. 5 is a flowchart showing an illustrative method for operating a dual switch piezoelectric nozzle actuator, according to one example of principles described herein.

[0010] Throughout the drawings, identical reference numbers designate similar, but not necessarily identical, elements.

DETAILED DESCRIPTION

[0011] As mentioned above, it is beneficial to perform various diagnostic tests on piezoelectric actuators and the circuitry that drives those actuators. Such tests may be, for example, to test the capacitance voltage curve of the piezoelectric actuator or the resonant frequency of the piezoelectric actuator. However, such testing can be complicated and expensive.

[0012] In light of this and other issues, the present specification discloses methods and system for a dual switched piezoelectric actuator that allows for efficient testing and diagnostics. According to certain illustrative examples, a first switch, which will be referred to as the operation switch, is used to connect the piezoelectric actuator to the driving circuitry that provides a voltage pulse to the actuator. A second switch, which will be referred to as the testing switch, is used to connect the actuator to a testing bus line. The testing bus line is connected to multiple piezoelectric actuators through similar testing switches associated with each of those piezoelectric actuators. During normal operation, the testing switch remains open while the operation switch remains closed, allowing voltage pulses to drive the actuator at the appropriate times.

[0013] During testing operation, the second switch is closed to allow connection of the piezoelectric actuator to testing circuitry on the other end of the bus line. The operation switch may be open or closed depending on the type of testing. If the operation switch is closed, the testing circuitry can test the driving circuitry. Alternatively, if the operation switch is open, then the testing circuitry can run tests on the piezoelectric actuator itself.

[0014] Through use of methods and systems embodying principles described herein, efficient diagnostic of piezoelectric actuators and the circuitry that drives them can be performed at relatively low cost. Moreover, the circuitry and nozzle actuators for each of the many nozzles within a printhead can be testing for specific nozzle actuators. This allows for monitoring the reliability of the nozzle actuators and driving circuitry over the life of the printhead.

[0015] In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present systems and methods. It will be apparent, however, to one skilled in the art that the present apparatus, systems and methods may be practiced without these specific details. Reference in the specification to “an example” or similar language means that a particular feature, structure, or characteristic described in connection with that example is included as described, but may not be included in other examples.

[0016] Referring now to the figures, Fig. 1 is a diagram showing a piezoelectric printhead nozzle. According to certain illustrative examples, a nozzle includes a small chamber (108) which is filled with ink. A piezoelectric actuator (104) is placed within the small chamber (108). When a voltage is applied to the actuator (104), the actuator (104) expands. This expansion creates a pressure wave within the chamber (108) which forces the ink out of the nozzle opening (110). The ejected ink droplet (106) is then propelled onto a print medium. When the voltage is no longer applied to the actuator (104), the actuator (104) contracts. This contraction creates a void in the chamber. This void will draw in more ink through a feed line (102).

[0017] Fig. 2 is a diagram showing illustrative dual switch actuators (200). According to certain illustrative examples, a number of nozzle actuators (206) share a single bus line (210) for testing purposes. As mentioned above, each nozzle actuator (206) is connected to driving circuitry (202) through an operation switch (204). Additionally, each actuator (206) is connected to the bus line (210) through a testing switch (208). Based on the configuration of the switches (204, 206) the actuators may operate as normal or have diagnostic tests performed thereon.

[0018] The driving circuitry (202) is used to cause the actuator (208) to expand at the appropriate time, expelling an ink droplet from the associated ink nozzle. The driving circuitry typically includes a Digital-to-Analog Converter (DAC) that receives a digital input signal. The DAC then outputs an analog voltage pulse. This analog voltage pulse is then amplified by an amplifier circuit. The amplifier circuit ensures that the voltage pulse is of a large enough value so as to expand the actuator (206) appropriately.

[0019] Both the operation switch (204) and the testing switch (208) may be made out of made of standard electronic switching devices. For example, the switches (204, 206) may be standard Field Effect Transistor (FET) devices or Bipolar Junction Transistor (BJT) devices. The switches (204, 206) may be connected to controlling circuitry to cause them to open and close at the appropriate times, either for standard operations or testing operations.

[0020] Fig. 3A is a diagram showing an illustrative standard operation (300) of the dual switched actuator. As mentioned above, during standard operation, the operation switch (302) is closed and the testing switch (304) is open. In this state, the driving circuitry provides voltage pulses which passes through the closed operation switch (302) and to the nozzle actuator (206). To print the appropriate image, the driving circuitry (202) sends the pulse at a particular time for each nozzle to eject ink onto a specific spot on the print medium as it passes in relation to that nozzle.

[0021] Fig. 3B is a diagram showing an illustrative testing operation (310) of the dual switch actuator. As mentioned above, to perform various tests, the testing switch (314) is closed. The operation switch (312) may be opened or closed depending on the type of testing being done. While several actuators (206) are connected to the same bus line (210), each through a testing switch (314), only the actuator (206) or accompanying driving circuitry (202) being tested will have its testing switch (314) closed. This allows for testing of specific nozzle actuators (206) or driving circuitry (202).

[0022] To testing the driving circuitry (202), the operation switch (312) is closed. Thus, the voltage pulse sent to the actuator can also be measured by testing circuitry (316) on the other side of the bus line (210). This sensing circuitry can make sure that an appropriate voltage level is being supplied to the piezoelectric actuator (206).

[0023] To test the piezoelectric actuator itself, the operation switch (312) is opened. The testing circuitry (316) can then apply various signals along the bus line (210) to the actuator (206) with its associated testing switch (314) closed. Based on the nature of these signals and how they are affected by the actuator (206), the testing circuitry can take various measurements of that actuator. For example, the testing circuitry can determine a capacitance/voltage curve for the actuator. The testing circuitry (316) may also measure the resonant frequency of the piezoelectric actuator (206).

[0024] These examples of tests which may be performed are not an exhaustive list of possible tests which may be performed on the actuator (206) or associated driving circuitry (202). Various other tests that are helpful in

measuring the reliability and robustness of the actuators and driving circuitry may be performed through use of the dual switched actuator described herein.

[0025] Fig. 4 is a diagram showing an illustrative multiplexing (400) of bus lines for the dual switch actuators within a printhead. A printhead may include hundreds or thousands of nozzles. If each of those nozzles were connected to testing circuitry (408) though a single bus line, then the capacitive loading on that testing circuitry (408) may interfere with the testing operations.

[0026] In light of this issue, a multiplexing scheme may be used to connect each nozzle to the testing circuitry. According to certain illustrative examples, multiple bus lines may be multiplexed using at least one multiplexer. In some cases, the multiplexing scheme may be hierarchical. This reduces the number of nozzle actuators connected to a single bus line and thus the capacitive loading on the testing circuitry (408).

[0027] Fig. 4 illustrates a two layer multiplexing scheme. A first multiplexing layer includes a first multiplexer (404) and a second multiplexer (406). Both the first multiplexer (404) and the second multiplexer (406) switch four different bus lines (402) to a single output. The outputs of the first multiplexer (404) and the second multiplexer (406) are input into a third multiplexer (410). The third multiplexer switches between the two different multiplexer inputs to the testing circuitry (408). In this example, there are eight total bus lines (402). If, for example, each bus line connects to 50 different nozzle actuators, then the multiplexing scheme can select any of the 400 nozzles within the printhead while being limited to having 50 nozzles connected to a single bus line (403)

[0028] Fig. 5 is a flowchart showing an illustrative method for operating a dual switch piezoelectric nozzle actuator. According to certain illustrative examples, the method includes closing (block 502) an operation switch connected between a piezoelectric actuator for a printhead nozzle and driving circuitry used to drive the actuator. The method further includes opening (block 504) a testing switch connected between the piezoelectric actuator and a bus line for normal operation of the printhead nozzle.

[0029] In conclusion, through use of methods and systems embodying principles described herein, efficient diagnostic of piezoelectric actuators and the circuitry that drives them can be performed at relatively low cost. Moreover, the circuitry and nozzle actuators for each of the many nozzles within a printhead can be testing for specific nozzle actuators. This allows for monitoring the reliability of the nozzle actuators and driving circuitry over the life of the printhead.

[0030] The preceding description has been presented only to illustrate and describe examples of the principles described. This description is not intended to be exhaustive or to limit these principles to any precise form disclosed. Many modifications and variations are possible in light of the above teaching.

CLAIMS

WHAT IS CLAIMED IS:

1. A printhead with dual switched piezoelectric actuators (206) comprising:

an operation switch (204) connected between a piezoelectric actuator (206) for a printhead nozzle (100) and driving circuitry (202) to drive said piezoelectric actuator (206);

a testing switch (208) connected between said piezoelectric actuator (206) and a bus line (210), said bus line (210) connected to multiple piezoelectric actuators (206) through testing switches (208).

2. The printhead of claim 1, wherein said bus line (210) is multiplexed between a number of actuators (210) for nozzles of said printhead.

3. The printhead of claim 2, wherein said multiplexing (400) is hierarchical.

4. The printhead of claim 1, further comprising, testing circuitry (316) to test a voltage signal from said driving circuitry (202) while both said operation switch (204) and said testing switch (208) are closed.

5. The printhead of claim 1, further comprising, testing circuitry (316) to test said piezoelectric actuator (206) with said operation switch (204) open and said testing switch (208) closed.

6. The printhead of claim 5, wherein said testing circuitry (316) is to apply a signal to said bus line (210), said signal being used to test characteristics of said piezoelectric actuator (206).

7. The printhead of claim 6, wherein said characteristics comprise at least one of: a capacitance/voltage curve and a resonant frequency.

8. A method for operating a dual switched piezoelectric actuator (206), the method comprising:

closing an operation switch (204) connected between a piezoelectric actuator (206) for a printhead nozzle (100) and driving circuitry (202) used to drive said actuator (206); and

opening a testing switch (208) connected between said piezoelectric actuator (206) and a bus line (210) for normal operation of said printhead nozzle (100).

9. The method of claim 8, further comprising, closing said testing switch (208) to test a voltage signal from said voltage pulse signal input.

10. The method of claim 8, further comprising:

closing said testing switch (208);

opening said operation switch (204); and

applying testing signals to said bus line (210) to test said actuator (206).

11. The method of claim 10, wherein said signals are to test at least one of: a capacitance voltage curve of said actuator (206) and a resonant frequency of said actuator (206).

12. The method of claim 8, wherein said bus line (210) is one of several bus lines connected to multiple dual switched actuators (210), each of said bus lines being multiplexed to said testing signals.

13. The method of claim 12, wherein said multiplexing (400) is hierarchical.

14. A printhead comprising:

a number of piezoelectric nozzles (100), wherein a piezoelectric actuator (206) for each of said nozzles comprises:

an operation switch (204) connecting said actuator to a voltage pulse signal input; and

a testing switch (208) connecting said actuator (206) to a bus line (210), said bus line (210) common to each of said nozzles (100);

wherein said testing switch (208) is open during normal operation of said printhead and closed during testing operation of said printhead.

15. The printhead of claim 14, further comprising a number of multiplexers (404, 406, 410) to connect multiple bus lines (210) to testing circuitry (310), each of said bus lines (210) connected to multiple piezoelectric actuators (206) through testing switches (208).

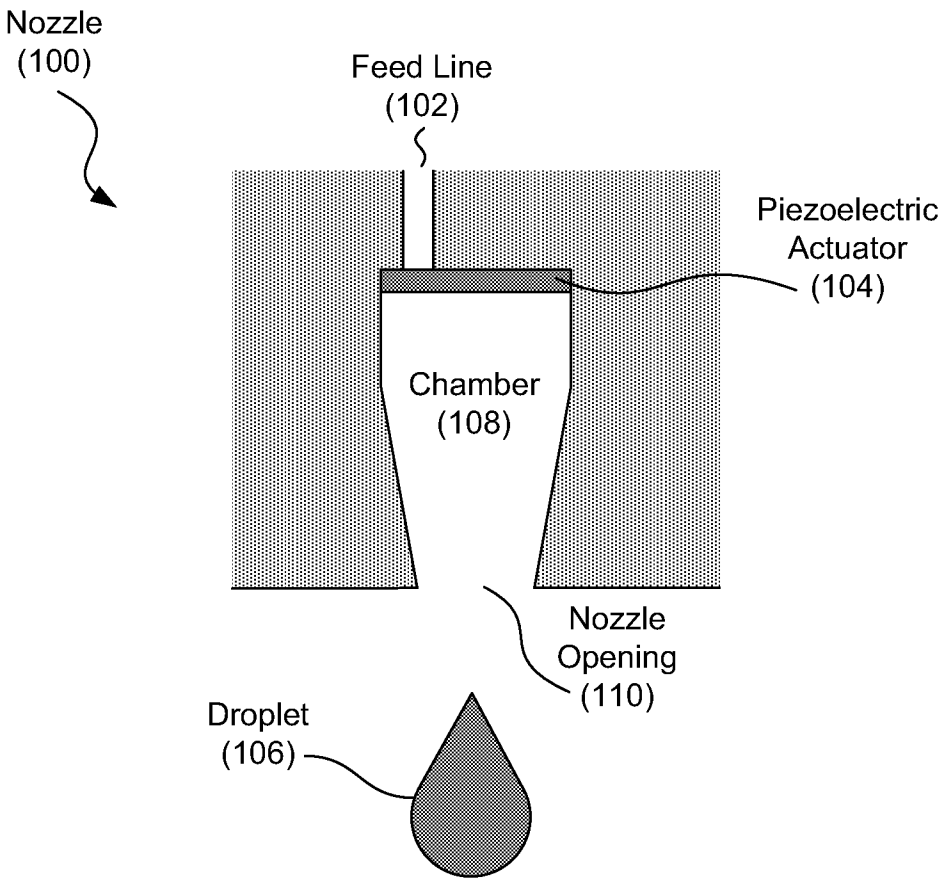

Nozzle
(100)
Feed Line
(102)
Piezoelectric
Actuator
(104)
Chamber
(108)
Nozzle
Opening
(110)
Droplet
(106)

Fig. 1

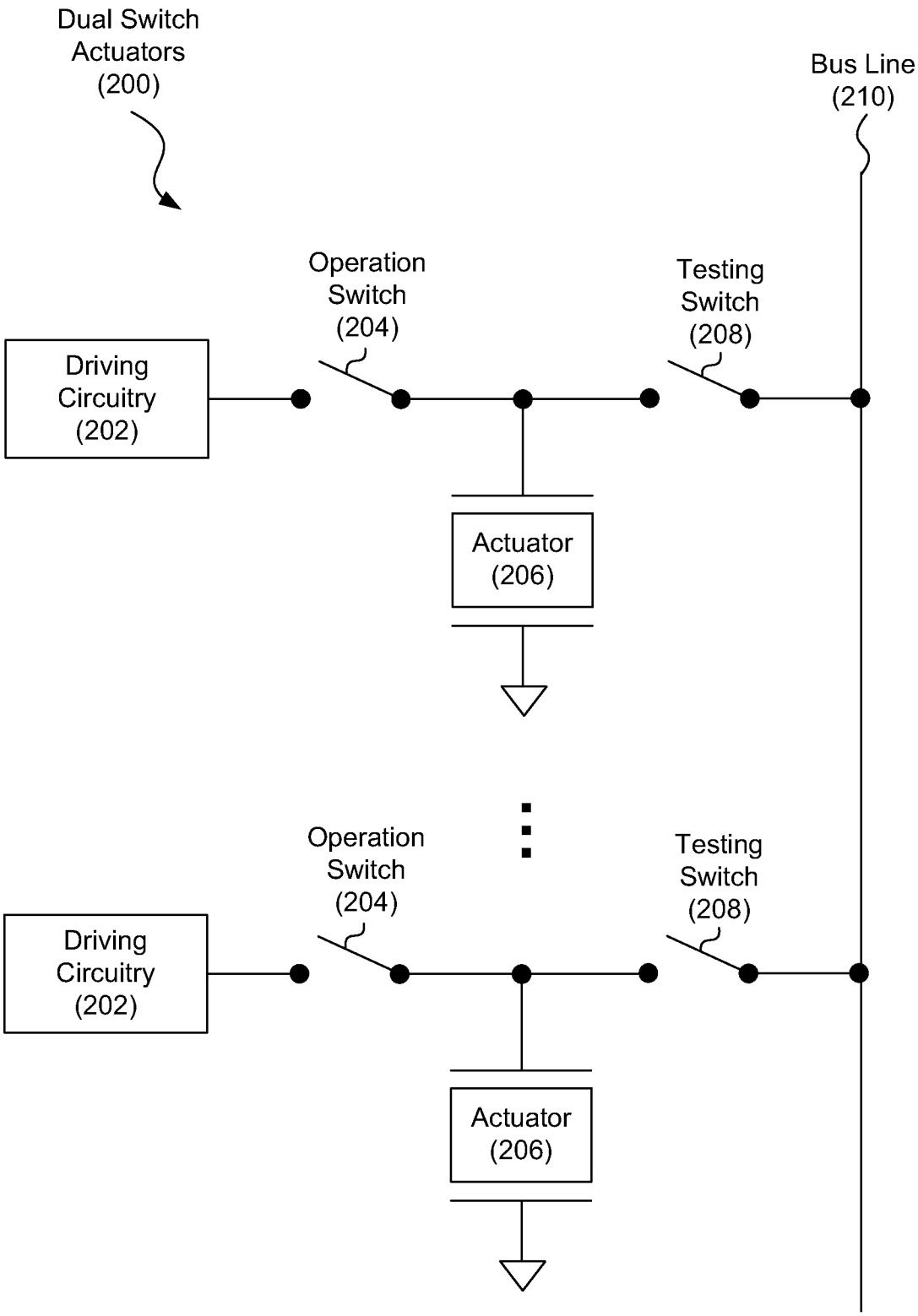

Dual Switch Actuators (200)
Bus Line (210)
Operation Switch (204)
Testing Switch (208)
Driving Circuitry (202)
Actuator (206)
Operation Switch (204)
Testing Switch (208)
Driving Circuitry (202)
Actuator (206)

Fig. 2

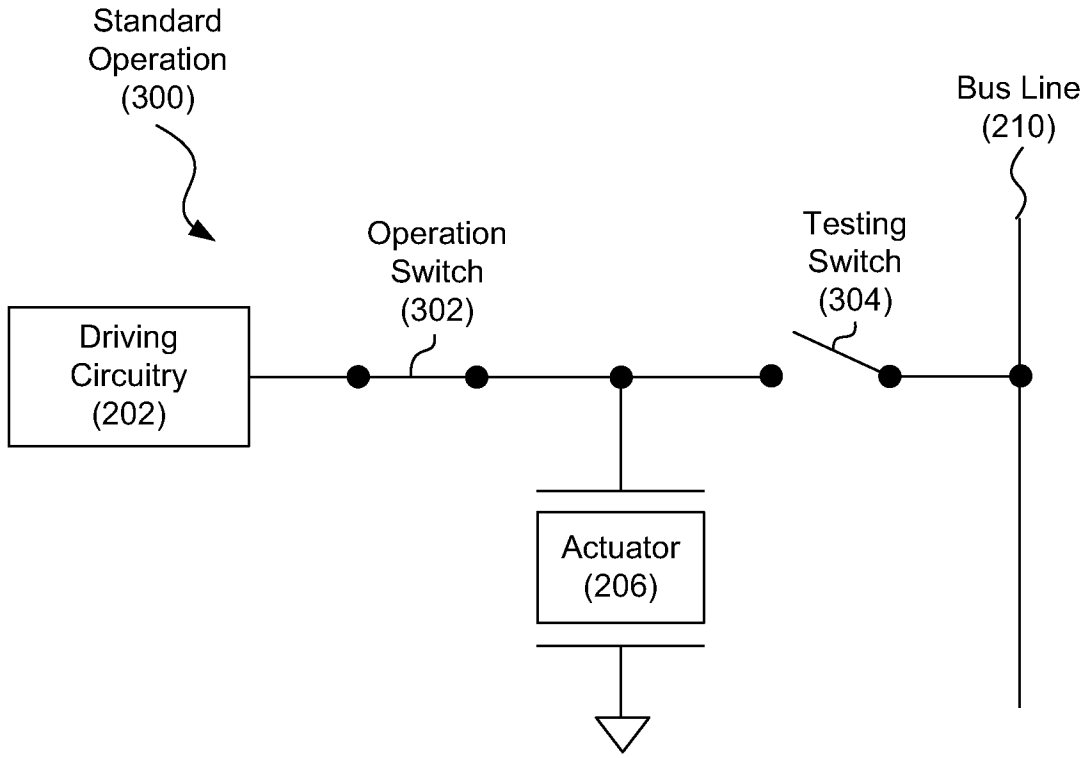

Standard
Operation
(300)
Bus Line
(210)
Operation
Switch
(302)
Testing
Switch
(304)
Driving
Circuitry
(202)
Actuator
(206)

Fig. 3A

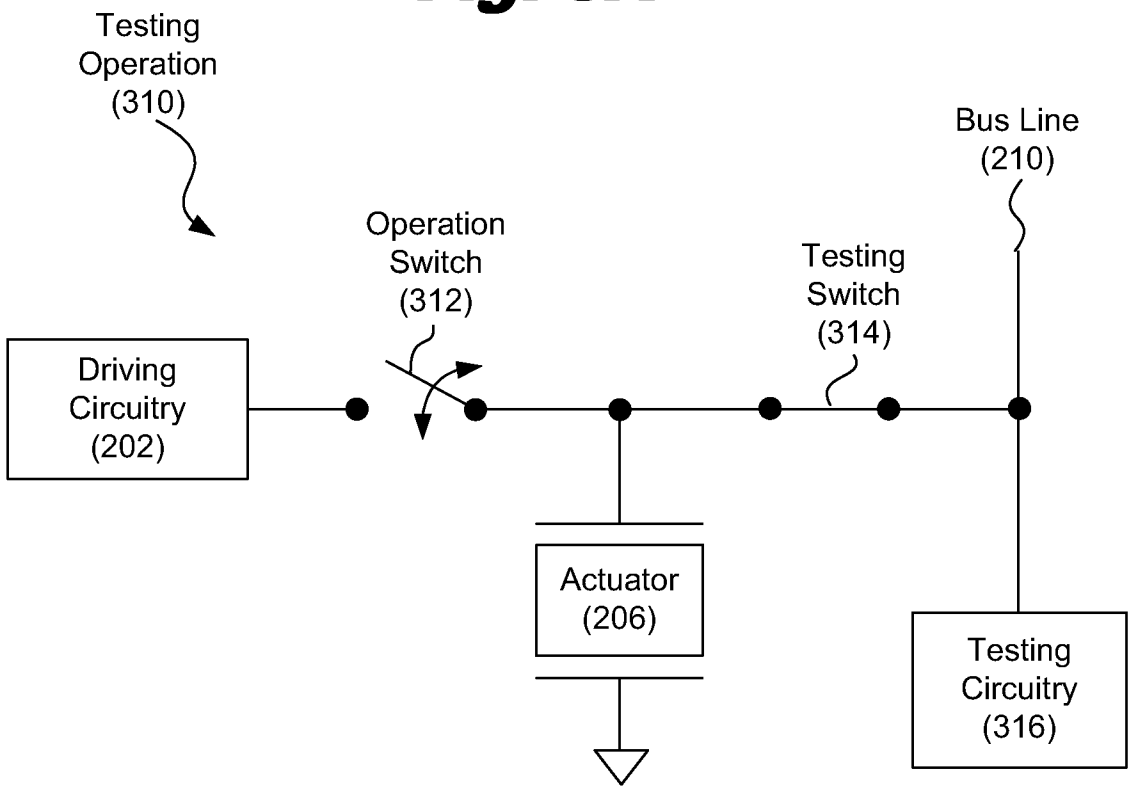

Testing
Operation
(310)
Bus Line
(210)
Operation
Switch
(312)
Testing
Switch
(314)
Driving
Circuitry
(202)
Actuator
(206)
Testing
Circuitry
(316)

Fig. 3B

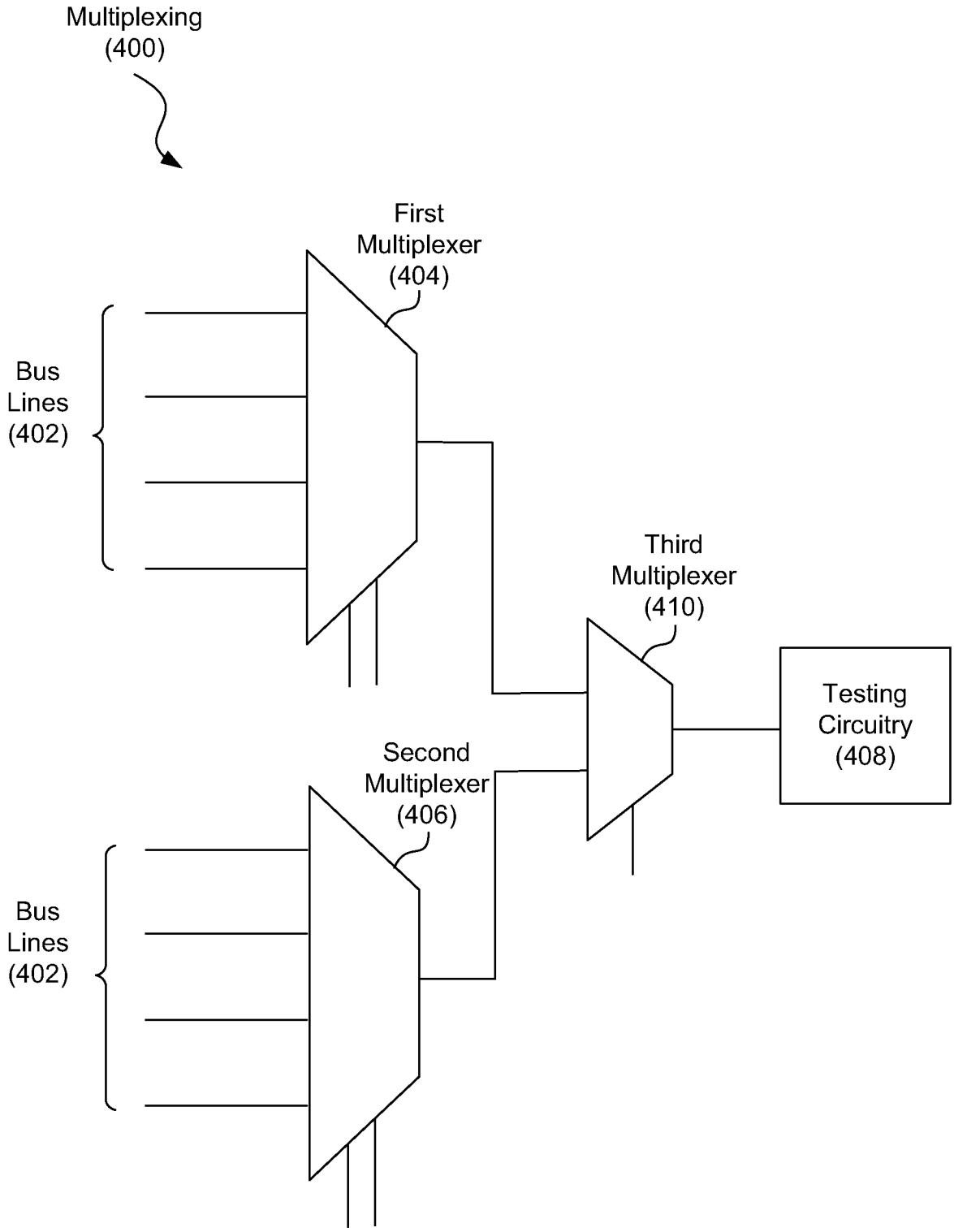

Multiplexing
(400)
First
Multiplexer
(404)
Bus
Lines
(402)
Third
Multiplexer
(410)
Testing
Circuitry
(408)
Second
Multiplexer
(406)
Bus
Lines
(402)

Fig. 4

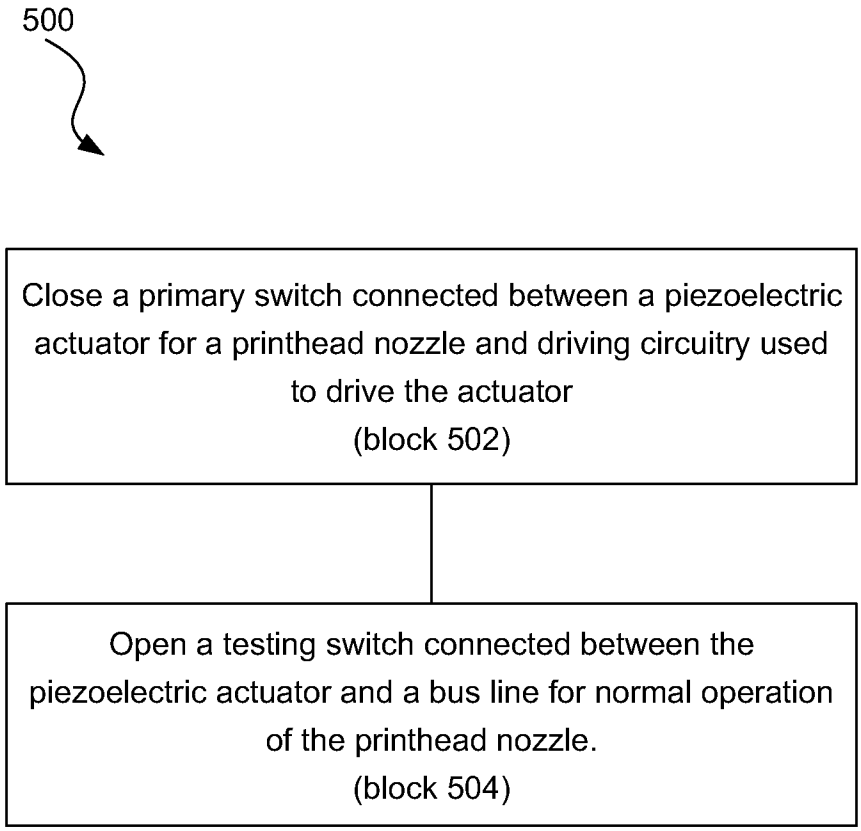

500
Close a primary switch connected between a piezoelectric actuator for a printhead nozzle and driving circuitry used to drive the actuator
(block 502)
Open a testing switch connected between the piezoelectric actuator and a bus line for normal operation of the printhead nozzle.
(block 504)

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/033638

A. CLASSIFICATION OF SUBJECT MATTER

B41J 2/175(2006.01)i, B41J 2/045(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B41J 2/175; H01L 41/09; B06B 1/06; B41J 29/38; B41J 2/045; B41J 2/01

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: printhead, piezoelectric, actuator, switch, test, diagnostic, bus line, circuitry.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2007-0236521 A1 (YOSHINAO KONDOH) 11 October 2007 See paragraphs [0022], [0026], [0027] and figure 1	1-15
A	US 05502468 A (KNIERIM; DAVID L.) 26 March 1996 See column 3 lines 35-46 and figure 4	1-15
A	WO 94-26524 A1 (COMPAQ COMPUTER CORPORATION) 24 November 1994 See abstract, page 9 lines 19-33 and figure 3A	1-15
A	JP 11-197602 A (NEC CORP) 27 July 1999 See paragraphs [0009]-[0012] and figure 1	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 NOVEMBER 2012 (29.11.2012)	**06 DECEMBER 2012 (06.12.2012)**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea	KIM, Sang Bae
Facsimile No. 82-42-472-7140	Telephone No. 82-42-481-5454

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2012/033638

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007-0236521 A1	11.10.2007	JP 04-894333 B2	06.01.2012
		JP 2007-276240 A	25.10.2007
US 05502468 A	26.03.1996	EP 0605216 A2	06.07.1994
		EP 0605216 B1	31.03.1999
		JP 03-211918 B2	19.07.2001
		JP 07-032651 A	03.02.1995
		JP 3211918 B2	25.09.2001
WO 94-26524 A1	24.11.1994	AU 6786294 A	12.12.1994
		US 05521618 A	28.05.1996
		WO 94-26524 A1	24.11.1994
JP 11-197602 A	27.07.1999	CN 1235409 A0	17.11.1999
		JP 03-116886 B2	06.10.2000
		JP 3116886 B2	11.12.2000
		TW 399345 A	21.07.2000
		TW 399345 B	21.07.2000
		US 6204591 B1	20.03.2001