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(54) SYSTEM AND METHOD FOR INKJET SYSTEM

(57) The present invention describes a printing system comprising an inkjet printhead (1), a nozzle (11) activated by one or several piezo actuators, and a sensing unit (20), comprising a sensing line (210, 200'), a signal generator (22), a compensation network (24, 24') arranged so that an ideal virtual nozzle can be simulated and a mean to compare the currents passing through the printing line and the sensing line. The invention also concerns a sensing method based on the system and a printer comprising such a system.

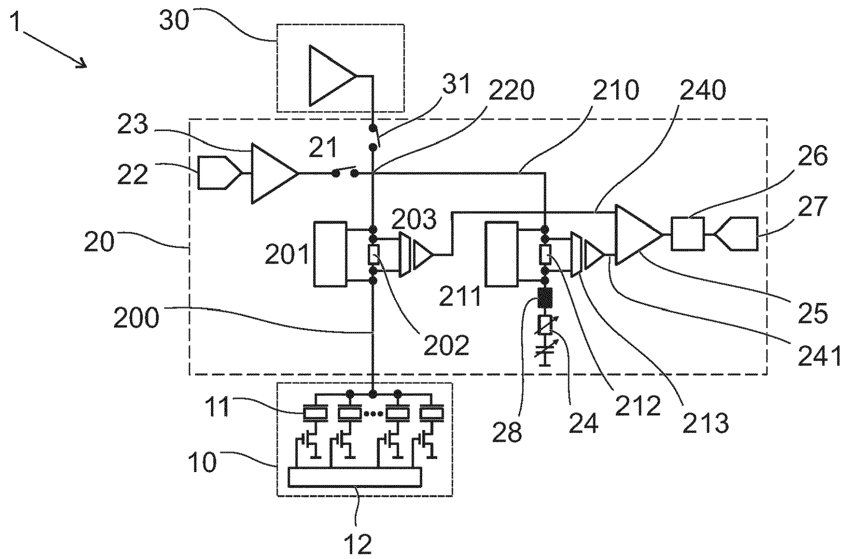

Fig. 1

Processed by Luminess, 75001 PARIS (FR)

Description

Technical domain

[0001] The present invention concerns an inkjet printhead of a printer, in particular a piezoelectric printhead, as well as the corresponding circuitry. The printhead is adapted to establish a fast status or diagnostic of the nozzles, based on the sensed deformation of the piezo elements. The invention also covers a printer and/or a system equipped with such a printhead. The present invention further concerns a method of determining the status of the nozzles of an inkjet printhead, based on the sensed deformation of the corresponding piezo elements. The present invention further concerns a method of compensating potential defects of an inkjet printhead, in particular during printing operations, so as to maintain a good quality of impression.

Related art

[0002] In the field of inkjet printers, significant development has been made to improve the reliability and the durability of the printhead.

[0003] The document US10500846B1 discloses a system of several piezo-actuators adapted to detect some impedance variations between distinct banks. The document US4498088 describes an inkjet printhead adapted to detect air bubbles. A defect can be detected through resonance frequencies such as described in EP2765003, EP 2328756, EP3419829, US 2006038858 or US 2016016400.

[0004] Despite the efforts, there is still room for improvement of inkjet printheads, in particular to increase the variety of sensed defects, to improve the sensing to inks having unknown properties, to provide more accurate corrective actions, to automatically implement some adjustments and/or any other improvements which become self-evident in the following details.

Short disclosure of the invention

[0005] An aim of the present invention is the provision of a system and a method that overcomes the shortcomings and limitations of the state of the art. It is in particular an aim of the present invention to provide a system for inkjet system adapted to sense the nozzles during a printing operation so that no time is wasted to determine the status of the nozzle beside regular printing jobs. For industrial applications, maintenance operations can have a significant cost due to the non functioning time of the printhead. In particular, it is a further aim of the present invention to keep the possibility of scanning the nozzle status between prints, when the printer is at idle.

[0006] Another aim is to provide a system for inkjet printhead which is adapted to accurately discriminate several types of defects of the nozzles. It is in particular necessary to improve the sensing quality and the diversity of defects.

[0007] Another aim of the present invention is to provide a system for inkjet printhead allowing to automatically initiate curative or preventive operations, or compensation programs, so as to maintain a good quality of impression despite some nozzle defects. It is more particularly an aim to provide a system more reliable than the current ones, wherein defects are precisely detected and automatically compensated, limited, or avoided so that manual maintenance is limited.

[0008] It is another aim to provide a system, or modular elements adapted to be implemented onto existing printers, so as to upgrade them to an improved level of performance, reliability and durability.

[0009] Another aim of the invention is to provide an inkjet printer adapted to address all or part of the above-mentioned problems. It is in particular an aim to provide an inkjet printer adapted for industrial applications.

[0010] Another aim is to provide a method to detect, discriminate and characterized nozzle defects of an inkjet printhead in an accurate and automatic way. The method is furthermore aimed at being applicable during printing operations and in automatic way.

[0011] Another way is to provide a method of accurately sensing a variety of nozzle defects of an inkjet printer and automatically provide adaptative responses of the printer so as to anticipate, cure or compensate such nozzle defects.

[0012] According to the invention, these aims are attained by the object of the attached independent claims, and better defined through the dependent claims. In particular, the system according to the present description comprises one or several sensing units each provided with a signal generator and a compensation network adapted to simulate an ideal virtual nozzle. Each sensing unit is also provided with a mean to compare the current of such an ideal virtual nozzle with the one of a real nozzle and a mean to compute the signal differences so that a nozzle defect can be detected and characterized. The system according to the present invention further comprises means to detect phase differences, magnitude and/or capacitance so as to improve the sensing accuracy. In particular, the system allows not only to detect nozzle defects but also surrounding parameters having an impact on the impression, such as the ink characteristics, the aging, the temperature etc...

[0013] The present method allows to sense some or all the nozzles of a printhead during a printing operation. In particular, the sensing step can occur immediately after a drop of ink is ejected. Furthermore, non ejecting sensing can still be performed, for an improved flexibility, wherein the operator does not have to worry about unwanted drops.

[0014] With respect to what is known in the art, the invention provides the advantage of a more accurate and more complete sensing of an inkjet printhead. It further provides the advantage of limiting or avoiding manual control and maintenance operations.

Short description of the drawings

[0015] Exemplar embodiments of the invention are disclosed in the description and illustrated by the following drawings :

Figure 1 : Schematic representation of a system according to an embodiment of the present description,

Figure 2 : Details of a sensing unit according to an embodiment of the present description.

Figure 3: Schematic representation of a system according to an embodiment of the present description.

Figure 4: Schematic representation of a system according to an embodiment of the present description.

Figure 5: Schematic representation of a system according to an embodiment of the present description.

Figure 6: Example of an arrangement of the sensing unit according to an embodiment of the present description.

Figure 7: Example of an arrangement of the sensing unit according to an embodiment of the present description.

Figure 8: Schematic representation of a system according to an embodiment of the present description.

Figure 9 : Schematic representation of a system according to an embodiment of the present description.

Figures 10, 10a, 10b, 10c, 10d: schematic representation of the different unit of the system according to different embodiments of the present description.

Figure 11a: Schematic representation of an arrangement according to the present description during an activation step.

Figure 11b: Schematic representation of an arrangement according to the present description during a sensing step.

Figure 12a: Schematic representation of the driving and sensed signal for a non-printing activation step according to the present description.

Figure 12b: Schematic representation of the driving and sensed signal for a printing activation step according to the present description.

Examples of embodiments of the present invention

[0016] With reference to figure 1, the system according to the present description comprises a printhead 1, at least one nozzle bank 10 comprising several nozzles 11 and a nozzle command unit 12 adapted to pilot the nozzles according to a determined printing operation. The system also comprises at least one nozzle sensing unit 20 adapted to detect potential defects of a nozzle or a nozzle bank. The system further comprises at least one printing power amplifier 30, which activates the nozzles or some of the nozzles to provide a suitable inkjet, and a printing amplifier switch 31 so as to be connected to a nozzle or a nozzle bank.

[0017] A nozzle bank here denotes a group or an array of several nozzles. A system according to the present description can comprise 1 or 2 banks of nozzles or a higher even number of banks such as 4, 8, 16 banks. Independently of the number of banks, each nozzle can be activated by means of one or several piezoelectric actuators, better described below. For the purpose of the present description, a pair of nozzles or a pair of nozzle banks defines a pair of nozzles or nozzle banks which are both connected to a given sensing circuit.

[0018] Unless specified differently, a nozzle is here understood as comprising or being combined to the necessary piezo actuator or piezo actuators, adapted to eject the ink through the nozzle.

[0019] The nozzle sensing unit **20** is here described in line with figure 2. It comprises a signal generator **22** adapted to generate a sensing excitation signal to one or several nozzles. The signal generator **22** can be coupled to a sensing amplifier **23.** The sensing amplifier **23** is designed to have low power and low noise. The ensemble defined by the signal generator **22** and the sensing amplifier **23** can be disconnected or connected to a sensing line **210** by means of sensing amplifier switch **21.** The signal generator **22** is particularly adapted for a non-printing activation or for calibration of the corresponding nozzle or nozzle bank.

[0020] The sensing line **210** can be connected to the printing line **200** at the connection point **220.**

[0021] The sensing unit **20** further comprises a mean to compare the two currents passing through the printing line **200** and through the sensing line **210.** Such a mean can be a difference amplifier **25,** connected to the printing line **200** through a first connection line **240** and to the sensing line **210** through a second connection line **241.** In such a way, the mean to compare the two currents can detect and measure difference between the two currents passing through the printing line and through the sensing line. Alternatively, the mean to compare the two currents passing through the printing line **200** and through the sensing line **210** can be a high input common mode difference amplifier. It is understood that any suitable device adapted to compare two currents, detect a difference between two currents and/or measure such a difference can be used.

[0022] The sensing unit **20** comprises or is combined with an analogue to digital conversion device **27..**

[0023] The mean to compare the two currents passing through the printing line **200** and through the sensing line **210,** in particular the difference amplifier **25** or the alternative high input common mode difference amplifier, can be combined to a filtering unit **26,** adapted to filter the measured currents of the printing line **200** and the sensing line **210,** and/or to condition or transform the signal in a way to be properly analysed.

[0024] The printing line **200** comprises a first bypass **201** adapted to bypass the mean to compare the two currents passing through the printing line **200** and through the sensing line **210.** The first bypass **201** is typically activated when the corresponding printing power amplifier **30** is activated so as to operate the printing. The printing line **200** further comprises a first shunt **202** adapted to connect the printing line **200** and the first connection line **240.** The first shunt **202** allows the mean to compare the two currents passing through the printing line **200** and through the sensing line **210** to measure the current passing through the printing line **200.** Typically, the first shunt **202** is activated soon after the corresponding printing power amplifier **30** is deactivated, so as to detect the residual current. A sensing step can occur as soon as few microseconds after the drop ejection. To this end, the switches, in particular the sensing amplifier switch 21 and the printing power amplifier switch **31** have leakage and parasitic capacitance as low as possible.

[0025] The sensing line **210** comprises a second bypass **211** and a second shunt **212** at the connection point between the sensing line **210** and the second connection line **241.**

[0026] The sensing line **210** comprises a sensing compensation network Such a sensing compensation network can take the form of an impedance matching circuit **24.** It can comprise for example a variable capacitor **24a** and a resistor **24b.** It allows to mimic the current signal of a virtual nozzle having an ideal response during and/or after an activation of the corresponding nozzle **11** or nozzle bank **10.** The sensing compensation network can allow to mimic a virtual ideal nozzle during the activation of the corresponding printing power amplifier **30.** It is however necessary that the sensing compensation network mimics an ideal virtual nozzle during the sensing period, through the activation of the corresponding signal generator **22** and sensing amplifier **23.** Thus, the sensing compensation network can be active permanently during a printing operation, or at least activated for the sensing step. This is particularly convenient in case of a sensing step following a printing activation step, wherein an ink drop is ejected by the corresponding nozzle **11** or nozzle bank **10.**

[0027] For a better performance, the sensing compensation network can comprise or being combined with an inductive element **28.** Such an inductive element **28** is adapted to simulate the lead inductance of the cable connections which are used to connect the sensing unit **20** to the other parts of the printhead.

[0028] Coming back to figure 1, the sensing unit **20** can further comprise isolated shunt amplifiers allowing a better performance of the sensing. A first isolated shunt amplifier **203** can be combined to the first shunt **202,** on the printing line **200.** A second shunt amplifier **213** can be combined to the second shunt **212** on the sensing line **210.** The difference amplifier **25** thus receives the currents from the first shunt amplifier **203** and the second shunt amplifier **213** so that a more accurate measure can be performed.

[0029] Figures 2 represents a simplified version of figure 1, comprising only one nozzle bank.

[0030] Figure 3 illustrates an embodiment wherein the present printhead comprises 2 nozzles banks **10, 10'** and 2 printing power amplifiers **30, 30'.** The same reference numbers correspond to the same features already described. Under such a configuration, the sensing line corresponds to a second printing line **200'** connected to a non active nozzle bank **10'** at the time when the sensed nozzle bank **10** is activated. In particular, the corresponding printing power amplifiers **30'** remains inactive, so that no ink is ejected. As previously described, the sensing unit **20** comprises a signal generator **22** and a sensing amplifier **23,** which are connected to the printing line **200** by means of a sensing amplifier switch **21** and a connection point **220.** A second printing power amplifier **30'** is connected to a second printing line **200',** by means of a second printing power amplifier switch **31'.** The second printing line **200'** is linked to a second nozzle bank **10',** independent from the first nozzle bank **30,** and comprising several second nozzles **11'** and a second nozzle command unit **12'.** The ensemble of signal generator **22** and sensing amplifier **23** is also connected to the second printing line **200'** by means of a second sensing amplifier switch **21'.** According to such a configuration, the ensemble of signal generator **22** and sensing amplifier **23** can independently activate the first or the second printing lines, which thus plays the role of a sensing line. When the first nozzle bank **10** is activated, the second nozzle bank **10'** remains inactivated so that it can be used to simulate a virtual ideal nozzle. The second printing line **200'** comprises a second first bypass **201'** and a second first shunt **203'.** The mean to compare the two currents passing through the first printing line **200** and through the second printing line **200',** in particular the difference amplifier **25** or the alternative high input common mode difference amplifier, can thus detect and characterize the signal difference at the sensing step, just after the ejection of an ink drop by the first nozzle bank **10.** The reverse configuration is also possible, saying that when the second printing line **200'** is activated to initiate ejection of an ink drop by the second nozzle bank **10',** the first printing line **200** is used as a sensing line.

[0031] Figure 4 represents a similar arrangement wherein the shunts are combined with shunt amplifiers **203, 203'.** In particular the first shunt **202** is combined with a first shunt amplifier **203.** The second first shunt **202'** is combined with the second first shunt amplifier **203'.**

[0032] For better performances, one or several printing lines can be provided with compensation networks **24, 24',** each comprising a variable capacitor and a resistor. In this case, there is no need for an inductive element **28** since the printing lines are actually connected to nozzle banks through a connection cable. The compensation networks **24, 24'** have the same role and effect as above-described.

[0033] For all the above-described arrangements, the mean to compare the two currents passing through the printing line **200** and through the sensing line, is preferably a difference amplifier **25** when the shunt amplifiers **203, 203', 213** are present. Alternatively, it corresponds to a high input common mode difference amplifier when the circuit does not comprise the shunt amplifiers **203, 203', 213** above described.

[0034] Figure 5 illustrates a configuration wherein the printhead comprises an even number of nozzle banks, such as 4, 8, 16 nozzle banks. In this particular case, the feature of the sensing unit **20** above described for two nozzle banks are duplicated. All the variations above-mentioned for the sensing unit are of course applicable. It is for example possible to include compensation networks or not. It is further possible to include shunt amplifiers or not.

[0035] The system according to the present description can comprise a mean to determine the phase and/or the magnitude of the pressure waves during the sensing step. Figure 8 shows an example of such an arrangement. The sensing unit **20** comprises a phase comparator **260,** a logarithmic amplifier **270** or a combination of both. The phase comparator **260** is combined to an analogue to digital conversion unit (ADC) for phase response **261.** The logarithmic amplifier **270** is combined to an analogue to digital conversion unit (ADC) for magnitude response **271.** According to a possible arrangement, the phase comparator **260** is connected to the assembly of a signal generator **22** and a sensing amplifier **23** through a first phase line **263** and just after the means for comparing the two currents passing through the printing line **200** and through the sensing line, by means of a second phase line **264.** The phase difference between the original signal delivered by the signal generator **22** and the sensed signal can thus be determined. The logarithmic amplifier **270** can be connected through the second phase line **264** to the same point as the phase comparator **260,** that is to say after the means for comparing the two currents passing through the printing line **200** and through the sensing line. One or both of the phase difference and the amplitude of the signal can be detected during the sensing step, providing a more accurate analysis. This circuits can especially be used by exciting the piezo with a standing wave, such as a sinusoidal or other repetitive excitation, during a non-printing sensing step, wherein no ink drop is ejected. In this specific case, excitation and sensing can be done simultaneously. Although the phase and the magnitude detection system is here described in combination with a specific sensing unit **20,** all the above-mentioned variations can be considered. For example, compensation networks, and or shunt amplifiers, can be present or absent.

[0036] Alternatively or in addition, the system according to the present description can comprise a capacitance measurement system **CC,** such as shown in figure 9. A capacitance measurement system **CC** can be connected to the first printing line **200** to a second printing line **200'** or a sensing line **210** through a first capacitance switch **C1,** connecting the capacitance system **CC** to the first printing line **200,** and a second capacitance switch **C2,** connecting the capacitance system **CC** to the second printing line **200'.** The capacitor measurement system **CC** can comprise any suitable element. It can for example be based on constant current charging, on charge transfer or on an oscillator circuit. Although the capacitor measurement system is here described in combination with a specific sensing unit **20,** all the above-mentioned variations can be considered. For example, compensation networks and/or shunt amplifiers can be present or absent. It is also applicable to the configuration based on one printing line and a sensing line **210.**

[0037] In the above-described embodiments, illustrated by figures 1, 2, 3, 4, 5, 8 and 9, a sensing unit **20** is provided for several nozzles. In particular, a sensing unit **20** is provided for at least one nozzle bank **10, 10'.** In this configuration, only one nozzle of a given nozzle bank is activated so that the sensing activity can be performed.

[0038] According to another embodiment, each nozzle, or some of the nozzles, can be individually sensed, meaning that each nozzle, or some of them are connected with a sensing unit **20** as above described. Figures 6 and 7 illustrate some examples of such a configuration.

[0039] In figure 6, The system comprises a printing power amplifier **30** adapted to activate several nozzles **11a, 11b,**

11c...11n. The nozzles are individually commanded by means of a suitable nozzle command unit **12.** Each one of the nozzles is connected to a dedicated sensing unit **20a, 20b, 20c...20n.** The sensing units can be integrated with the corresponding nozzle, inside the printhead. Alternatively, the sensing units **20a, 20b, 20c...20n** can be arranged remote the corresponding nozzles. According to an embodiment, each sensing unit comprises a printing line and a dedicated sensing line, as described above in combination with figures 1 or 2. With such a configuration, all the nozzles can be tested simultaneously. Alternatively, a sensing unit can be connected to 2 nozzles, with 2 distinct printing lines, one of which can be used as a sensing line, as above-described in combination with figures 3 and 4. In this specific case, half of the nozzles can be simultaneously tested. In figure 6, the sensing units **20a, 20b, 20c...20n** are arranged between the printing power amplifier **30** and the corresponding nozzles **11a, 11b, 11c...11n.** Suitable switches such as the printing amplifier switch **30, 30'** above described can be provided. Each one of the sensing units **20a, 20b, 20c...20n** comprises an assembly of a signal generator **22,** a sensing amplifier **23** and a sensing amplifier switch **21,** such as those described above.

[0040] Figure 7 illustrates a configuration wherein the sensing units **20a, 20b, 20c...20n** are arranged downstream the corresponding nozzles **11a, 11b, 11c...11n.** Any other suitable arrangement can be considered.

[0041] Independently of the arrangements above described, a given nozzle can be activated by one piezo actuator or by several piezo actuators. For example, each nozzle, or some of them, can be activated by 2, 3, 5, 7 or more piezo actuators. An accurate sensing system is thus necessary, such as the sensing system here described. According to a configuration, each piezo actuator, or a part of the several piezo actuator dedicated to a given nozzle, can be connected to a dedicated sensing unit. A given nozzle is driven by the corresponding printing power amplifier.

[0042] Figures 10, 10a, 10b, 10c, 10d show examples of different arrangements of the sensing unit withing the global system comprising the printhead **1.** In particular, the sensing system according to the present description comprises the sensing unit **20** above-described. It is connected to a command unit **U1** of the printhead. Such a command unit **U1** comprises at least the electronic means adapted to pilot the nozzles during a printing operation or a maintenance operation. Printhead connection cables **PH** allow to connect the different units of the system. A signal processing unit **U2** is provided downstream the sensing unit **20** so as to analyse the sensed signal transmitted by the sensing unit **20.** The signal processing unit **U2** comprises all the necessary computational means, adapted to detect and identify a printing default at a given nozzle or nozzle bank. A default can also be characterized so as to identify the type of default. It can be for example a bubble air, a problem of viscosity, a complete or partial obstruction of a nozzle, an inkjet deviation or any other parameter. A given type of defect can be identified based on predetermined signal responses in the signal processing unit **U2.** The computation of the sensed data in the signal processing unit **U2** allows to obtain a response signal **RS.** The response signal **RS** can be limited to the detection of a default or a failure at a given nozzle and an alert, so that a user can take suitable actions to remedy to the default. Alternatively, the response signal **RS** can comprise predetermined instructions corresponding to the identified defects so that the actions of the user actually corresponds to the type of defect. Alternatively or in addition, the response signal **RS** can comprise a command loop adapted to automatically compensate the defect. In case a certain type of defect is identified on a given nozzle or nozzle bank, the command unit **U1** can receive adequate instructions based on the response signal **RS** so as to automatically compensate the defect. This does not exclude that an alert signal is also sent to a user.

[0043] Figure 10a illustrate a standard configuration without any sensing unit as described here. Figure 10b corresponds to a configuration wherein the sensing unit **20** represents an independent module arranged between the printhead, which comprises the nozzles, and the command unit of the printhead. This configuration allows the retrofit of existing systems so that they can be upgraded with a sensing unit as described here. External printhead connection cable **PH** can be used to associate the sensing unit to the other modules of the systems, in particular to the printhead **1** and its command unit **U1.**

[0044] Figure 10c represents an arrangement wherein the sensing unit **20** is integrated into the command unit **U1** of the printhead **1.** A more compact arrangement is here possible. It also allows to combine or merge some functions with some of the command functions, for example by using common features already present in the command unit **U1.** For example the signal processing unit **U2** can share some functions with the command unit **U1.** A printhead connection cable **PH** can be used to connect the printhead **1** to the assembly of sensing unit **20** and command unit **U1.**

[0045] Figure 10d represents an arrangement wherein the sensing unit **20,** as well as the corresponding signal processing unit **U2** is integrated in the printhead **1,** meaning that it remains close to the nozzles. A printhead connection cable **PH** can be used to connect the command unit U1 to the assembly of the sensing unit **20** and the printhead **1.**

[0046] All the above-described circuits are adapted for providing an activation of one or more nozzles or nozzle banks and their sensing. The activation and the sensing are successive. This is in particular the case when the activation corresponds to an ink drop ejection, meaning that the corresponding printing power amplifier **30** is activated. In this specific case, the sensing of the corresponding nozzle or nozzle bank occurs just after the activation step, as better described below. The present description also covers a method for sensing at least one nozzle or at least one nozzle bank of an inkjet printhead 1 described here. The method is based on the comparison of a signal provided by a piezo actuator of a nozzle and an ideal virtual signal provided by a signal generator **22** as above described. The signal comparison is done through a mean to compare the two currents passing through a printing line **200** and through a corresponding sensing line, being either a dedicated sensing line **210** or another printing line **200',** which is inactivated and used for a virtual ideal signal. Depending on the configuration, the mean to compare the two currents can be a difference amplifier **25** or a high input common mode difference amplifier or any other suitable circuit.

[0047] The method comprises an activation step **51.** The activation step of at least one nozzle or one nozzle bank includes the excitation of the corresponding piezo actuator by mean of a suitable electrical signal. The activation step **S1** corresponds to a printing step wherein at least one ink drop is ejected from the corresponding nozzle or nozzle bank.. Figure 11a represents the circuit configuration under such an activation step. One printing power amplifier **30** is activated and connected to the corresponding printing line **200.** This means that the corresponding printing power amplifier switch **31** is closed so that a drop of ink is ejected from a nozzle **11** according to a predetermined program, which can correspond to a printing program or only to a sensing program wherein some drop of ink are ejected. Preferably, only one printing power amplifier **30** of a pair of printing power amplifier **30, 30'** is activated so that only one nozzle bank **10** of a pair of nozzle banks **10, 10'** is activated during the activation step. This is applicable to arrangements wherein a second printing line is used as a sensing line, as described above. Preferably, only one nozzle **11** of the corresponding nozzle bank **10** is activated where applicable. Alternatively, only one nozzle of a pair of nozzles is activated where applicable. The activation step **S1** applies in the same way in case of a single printing power amplifier **30** as described for example in figures 1 and 2 above, wherein the sensing line is a dedicated line. During the activation step **S1,** the signal generator 22 is disconnected from all the lines including the printing lines and the sensing lines. In other words, all the corresponding sensing amplifier switches **21, 21'** are open. Also, if applicable, the compensation networks **24, 24',** when present, are not active. Also, the sensing circuit is bypassed, through the suitable first **201, 201'** and second **211, 211'** bypass. A pair of nozzles or a pair of nozzle banks define a pair of nozzles or nozzles banks which are both connected to a given sensing circuit.

[0048] The method comprises a sensing step **S2.** The sensing step **S2** occurs just after an activation step S1 above described. The sensing step **S2** allows to sense the piezo actuator, or some or all of the piezo actuators, of the nozzle which has been activated. In particular, the sensing step allows to sense the acoustic response of the piezo actuator or piezo actuators after activation of the corresponding nozzle. It allows to sense the response of the corresponding piezo actuator or piezo actuators so as to determine the status of the corresponding nozzle. Figure 11b illustrates the circuit configuration under the conditions of the sensing step **S2** after an activation step The printing power amplifier **30** is deactivated, for example by opening the corresponding printing power amplifier switch **31, 31'.** The signal generator **22** is connected to all the lines, including the printing line **200** which as been used during the activation step **S1** and the other printing line **200'** or the sensing line **210.** This means that all the corresponding sensing amplifier switches **21, 21'** are closed. The nozzle or the nozzle bank, where applicable, which has not been activated during the activation step **S1,** are compensated by means of the corresponding compensation network **24, 24'.** In particular, variable capacitor and resistor comprised in the compensation network are tuned in a way to simulate the characteristics of the nozzle, or nozzle bank, which as been used during the activation step **S1.** With an ideal compensation, the current difference between the nozzle or nozzle bank which has been activated during the activation step **S1** and the non active nozzle or nozzle bank only corresponds to the response of the corresponding piezo actuator or piezo actuators. The current difference is determined by a mean to compare the two currents passing through the printing line **200** and through the sensing line, whether it is a difference amplifier **25** or a high input common mode difference amplifier or an equivalent circuit. The pressure waveform, resulting from the activation can thus be reconstructed, wherein the measure current is proportional to the derivation in respect of time of the pressure exerted onto the piezo. The sensing step **S2** applies similarly in case only one printing line **200** and a dedicated sensing line **210** is provided. During the sensing step **S2,** the suitable first **202, 202'** and second **212** shunt are activated so that the current can be measured by the mean to compare the two currents passing through the printing line **200** and through the sensing line.

[0049] The sensing step **S2,** although it occurs short after a printing activation step **S1** for a given nozzle, can be activated during a printing program, wherein several nozzles are successively activated and deactivated. There is thus no need to stop the printing program so as to apply a specific maintenance program. The switches of the system, in particular the sensing amplifier switches **21, 21'** and the printing power amplifier switches **30, 30',** are designed so as to have a very low leakage and parasitic capacitance so as to not disturb the system. The shunt and shunt amplifiers **203, 303', 213** are advantageous elements allowing a very accurate current measurement.

[0050] Figure 12b represents the sensing signal after an activation step **S1.** The piezo drive signal **PS** is represented by the first diagram. It comprises an inactivation period **T1** wherein the measured piezo remains at idle. The following driving period **T2** corresponds to the activation of a piezo actuator, which is optimized to properly eject a drop of ink. Just after the activation of the piezo starts the observation period **T3,** wherein the activated piezo is no longer driven by the corresponding printing power amplifier **30, 30'** while still being excited by effects resulting from the drop ejection. The sensed signal **SS** is measured during the observation period **T3.**

[0051] The signal sensed during the observation period **T3** is stored in a memory for further signal processing, for example through a signal processing unit **U2,** as above described, so that a response signal **RS** is generated.

[0052] The present method further comprises a computing step **S3** of computing the sensed parameters so as to provide a response signal **RS.**

[0053] Depending an on signal provided by the signal generator **22** and the sensed signal, it is possible to discriminate the sensed defects. For examples defects such as angle jetting, non-jetting, wetting, air bubbles can be identified.

[0054] The sensing step **S2** can further comprise a step of determining one or both of the phase and the magnitude of the pressure waves resulting from the activation step **S1.** The phase can be determined by means of a phase comparator **260** and the corresponding arrangement above-described. The amplitude can be defined by means of logarithmic amplifier **270** and the corresponding arrangement above-described.

[0055] The sensing step **S2** can alternatively or in addition comprise a capacitance measurement. Such a capacitance measurement can be performed by means of the capacitance measurement system **CC** and the corresponding arrangement above-described. According to embodiment, the **CC** system does the activation of the nozzle itself. This means that the sensing amplifier switches **21, 21',** and the printing amplifier switches **31** and **31'** are open and the capacitance switches **C1** and **C2** closed.

[0056] The present method further comprises a calibration step **S0** adapted to determine the electrical characteristics of the virtual ideal nozzle. The calibrating step **S0** comprises an excitation of the nozzle through the corresponding signal generator **22** and a concomitant sensing of the response of the piezo-actuator or piezo actuators. The currents passing through the printing line **200** and the sensing line are compared. The characteristics of the compensation network **24, 24'** are tuned so as to mimic the real nozzle.- The calibration step **S0** can be performed according to different activation profiles depending on the parameters to be sensed. For example, the characteristics of a nozzle can be determined by exciting the corresponding nozzle according to a predetermined voltage and/or frequency so as to obtain a reference waveform of the measure response. The corresponding sensing can then involve a damped oscillator function fitting with the activation parameters in real time. Other methods such as Fourrier transformation, wavelet transformation can be considered. In case of standing wave sinusoidal excitation a frequency sweep with phase and magnitude mapping can be considered. For example, the nozzle can be excited with a sinusoidal sweep from 60KHz to 600KHz so that the magnitude and phase response can be mapped and resonance and/or antiresonance frequencies are determined. Alternatively, a transient mode is used wherein a pulse waveform having defined low and high level, pulse width and slew rate is applied to one nozzle pf the printhead, which is preferably empty, but which can also be filed with some ink. After charging an new ink and/or when the temperature varies, the sensing system can be tuned. To this end, the set resistance can be tuned to zero, the sweep capacitive can be tuned, the capacitor value and/or the resistor value can be selected so that the sensed signal is the lowest, the sweep resistive can be tuned. Once the sensing system is tuned, the active nozzle or nozzle bank of a given pair of nozzle or nozzle bank as the same impedance that the corresponding non active nozzle or nozzle bank.

[0057] The calibration step **S0** is performed in absence of any printing operation. In particular, the printing power amplifier 30, 30' are inactive.

[0058] The response of a given nozzle under standard conditions can then be determined. The standard conditions can vary with the type of ink, the temperature and/or any other parameters. The characteristics of a nozzle can thus be determined even with an ink having unknown characteristics, and in particular rheological characteristics. This allows to adapt the calculation step to do correct sensing.

[0059] According to an embodiment, the rheological properties of an ink can be determined. For example, a nozzle can be excited with a sinusoidal signal over a large frequency range while preventing any drop ejection. The nozzle excitation step can corresponds to the calibration activation step **S0a** above-described. The acoustic frequency and the phase response can be mapped during concomitant sensing step, such as the calibration sensing step **S0b**. The rheological properties of the ink can be deduced from the magnitude and phase of the responding signal. In this case, the necessary phase comparator, logarithmic amplifier and the corresponding arrangements are necessary.

[0060] Figure 12a represents an example of sensed signals measured during a calibration step **S0**. The piezo drive signal **PS** is represented by the first diagram. It comprises an inactivation period **T1** wherein the measured piezo remains at idle. It comprises a driving period **T2** wherein the measure piezo is activated by means of the corresponding signal generator **23. .** The driving period **T2** can correspond to a calibration activation step **S0a.**. The driving period **T2** is followed by an observation period **T3** wherein the considered piezo actuator is still under excitation. It can be considered as a calibration sensing step **S0b,** concomitant to the excitation of the nozzle. The sensed signal **SS** corresponds to the response over time of the excited piezo. The observation period **T3** allows to properly determine the electrical characteristics of an ideal virtual piezo and to tune the compensation network accordingly. It is followed by a relaxation period **T4.** Another period after the relaxation period **T4** can be determined as a monitoring period **T5.** A second calibrating sensing step **S0c** can be performed after the relaxation period **T4,** during a monitoring time **T5,** so as to monitor the piezo.

[0061] According to an embodiment, the meniscus pressure can be sensed. The resonance frequency of all the nozzles of the printhead can be determined and averaged. It is possible to determine the mean resonance frequencies for different known meniscus pressures so as to built a calibration table. Based on such a calibration, an unknown pressure condition can be quantified and characterized. This measurement can be improved by the rheological measurement and the capacitance measurement to compensate for ink changes (temperature, viscosity...).

[0062] According to an embodiment, the flow rate can be determined. To this end, a piezo actuator can be heated by electrical excitation. The cooling effect of the flow rate can be sensed for each nozzle so as to determine the corresponding flow rate. The temperature can be determined based on the piezo capacitance and the leakage current sensed by the system. Such a piezo capacitance and leakage current can be determined by mean of the capacitance measurement system and the corresponding arrangement above described. The flow rate distribution over the different nozzles can thus be determined.

[0063] According to an embodiment, the aging of the system is determined. A capacitance variation can be attributed to a certain aging of the system. When testing all the nozzles as above described, and determine their capacitance, the corresponding aging can be deduced. A mean capacitance can also be determined. Alternatively, the capacitance can be used to identify some electronic failures.

[0064] It results that parameters such as nozzle status, ink rheology characteristics, flow mapping, capacitance mapping can be sensed according to the present method. They can be individually analysed or combined so as to identify more specific parameters. The sensed parameters can be combined to other parameters originating from different sources, being integrated to the printer or remote. According to an embodiment, the data above-mentioned can be stored in a memory and computed with an artificial intelligence program.

[0065] Different actions can be initiated based on the above data. For example, one or several maintenance operations can be initiated as reactive and/or as preventive measure, use redundant nozzle to compensate failure of a given nozzle, adjust the printing parameters of nozzles adjacent a non-functional nozzle such as over-printing, replacing a non functioning nozzle by combination of alternative colours, adapting the ejection waveform, activate a nozzle with a tickling pulse for recovery or repair, correct ink system parameters such as pressure, flow rate, temperature reverse flow, alert an operator, etc..

[0066] The present method comprises an automatic adjusting step **S4** based on the response signal **RS** resulting from the sensed signal. Additional data can be combined to the sensed signal, where appropriate, so that the response signal is more accurate. For example, data originating from external devices such as ambient temperature, hygrometry, or know physical parameters of the used ink can be considered and computed by the signal computing unit **U2** or another dedicated unit.

[0067] The aim of such an automatic adjusting step **S4** is to modulate the driving signal of a given nozzle in response to the sensed signal and potential additional data, so as to avoid or limit the manual intervention of an operator.

[0068] Based on the sensed data, when a defect is identified, some or several actions are automatically initiated during the automatic adjusting step **S4.** These actions comprises automatically use redundant nozzle to compensate failure of a given nozzle, automatically adjust the printing parameters of nozzles adjacent a non-functional nozzle such as over-printing, automatically replacing a non functioning nozzle by combination of alternative colours, automatically adapting the ejection waveform, automatically activate a nozzle with a tickling pulse for recovery or repair, automatically correct ink system parameters such as pressure, flow rate, temperature or reverse flow. Other actions can be performed depending on the needs.

[0069] Furthermore, based on the sensed data, the characteristics of the ideal virtual nozzle can be automatically adjusted. In particular, the compensation network can be automatically tuned so as to mimic an ideal virtual nozzle.

reference symbols in the figures

[0070]

1	Printhead
10, 10’	Nozzle bank
11, 11’, 11a, 11b, 11c, 11n	Nozzle
12, 12’	Nozzle command unit
20, 20a, 20b, 20c, 20n	Sensing unit
21, 21’	Sensing amplifier switch
22	Signal generator
23	Sensing amplifier
24, 24’	Compensation network
24a	Variable capacitor
24b	Resistor
25	Difference amplifier
26	Filtering unit
27	AD converting device
28	Inductive element

200	Printing line
201, 201'	First bypass
202, 202'	First shunt
203	First shunt amplifier
210, 210'	Sensing line
211	Second bypass
212	Second shunt
220	Connection point
240	First connection line
241	Second connection line
260	Phase comparator
261	ADC for phase response
263	First phase line
270	Logarithmic amplifier
271	ADC for magnitude response
30, 30'	Printing power amplifier
31, 31'	Printing power amplifier switch
C1, C2	Capacitance switch
CC	Capacitor measurement system
U1	Command unit of printhead
U2	Signal processing unit
RS	Response signal
S1	Activation step
S2	Sensing step
S3	Computing step
S4	Adjusting step
S0	Calibration step
S0a	Calibration activation step
S0b	Calibration sensing step
S0c	Second calibration sensing step
T1	inactivation period
T2	Driving period
T3	Observation period
T4	Relaxation period
T5	Monitoring period
PS	Piezo drive signal
SS	Sensed signal

Claims

1. A printing system comprising an inkjet printhead (1), at least one nozzle (11) activated by one or several piezo actuators, connected to a printing power amplifier (30) through a first printing line (200) and printing power amplifier switch (31) and at least one sensing unit (20), **characterized in that** the at least one sensing unit (20) comprises :

   - a sensing line (210, 200'),
   - a signal generator (22) connected to the sensing line and to the printing line (200) through a sensing amplifier switch (21, 21'),
   - a first bypass (201, 201') and a first shunt (202, 202') arranged on the printing line (200),
   - a second bypass (211) and a second shunt (212) arranged on the sensing line,
   - a compensation network (24, 24'),
   - a mean to compare the two currents passing through the printing line and through the sensing line,

   so that an ideal virtual nozzle can be simulated and that the current passing through the first printing line and the sensing line can be compared.

2. A system according to claim 1, further comprising a phase comparator (260) connected to the signal generator (22) through a first phase line (263) and after said mean to compare the two currents passing through the first printing

line and through the sensing line, by means of a second phase line (264), so that the phase difference between the original signal delivered by the signal generator (22) and the sensed signal can be determined.

3. A system according to one of claims 1 and 2, further comprising a logarithmic amplifier (270) adapted to determine a magnitude response of the sensed signal.

4. A system according to one of claims 1 to 3, further comprising a capacitance measurement system (CC), which is connected to the first printing line (200) through a first capacitance switch (C1) and to the sensing line through a second capacitance switch (C2).

5. A system according to one of claims 1 to 4, wherein said sensing line denotes a second printing line (200') connected to a second nozzle (11') through a second printing power amplifier switch (31').

6. A system according to one of claims 1 to 5, wherein said compensation network (24, 24') comprises a variable capacitor (24a) and a resistor (24b).

7. A system according to claim 6, wherein said compensation network further comprises an inductive element (28).

8. A system according to one of claims 1 to 7, wherein said mean to compare the two currents passing through the printing line and through the sensing line denotes a difference amplifier (25) or a high input common mode difference amplifier.

9. A system according to one of claims 1 to 8, wherein said first shunt (202, 202') is combined to a first shunt amplifier (203) and the second shunt is combined to a second shunt amplifier (213, 203').

10. A system according to one of claims 1 to 9, wherein each one of said nozzles is connected to a dedicated sensing unit (20).

11. A system according to one of claims 1 to 9, wherein said at least one nozzle (11) is part of a nozzle bank (10) comprising several nozzles which are piloted by means of a nozzle command unit (12) so that one nozzle of the nozzle bank can be activated at once.

12. A method for sensing at least one nozzle of an inkjet printhead (1) activated by one or several piezo actuators, comprising :

- an activation step (S1) wherein said at least one nozzle is activated by means of a printing power amplifier (30) through a first printing line (200) and printing power amplifier switch (31), and
- a sensing step (S2) immediately following the activation step (S1) wherein said at least one nozzle is no longer activated while still excited by the response of the activation step (S1),

characterized in that the sensing step (S1) includes providing an ideal virtual nozzle signal through a sensing line (210, 200') and comparing the sensed signal of the nozzle activated during the activation step (S1) to said ideal virtual nozzle signal.

13. A method according to claim 12, further comprising a calibration step (S0) comprising a concomitant excitation of the nozzle and sensing of its response.

14. A method of claim 13, wherein the calibration step (S0) is adjusted based on the data sensed during the sensing step (S2),

15. A method according to one of claims 12 and 14, further comprising a computing step (S3) of computing the sensed signal of the sensing step (S2) in a signal processing unit (U2) so as to generate a response signal (RS) adapted to the detected failure.

16. A method according to one of claims 12 and 15, further comprising an automatic adjusting step (S4) wherein, if a failure has been detected for the sensed nozzle, an automatic remedy is initiated to compensate said failure.

17. A printer comprising the system according to claims 1 to 11.

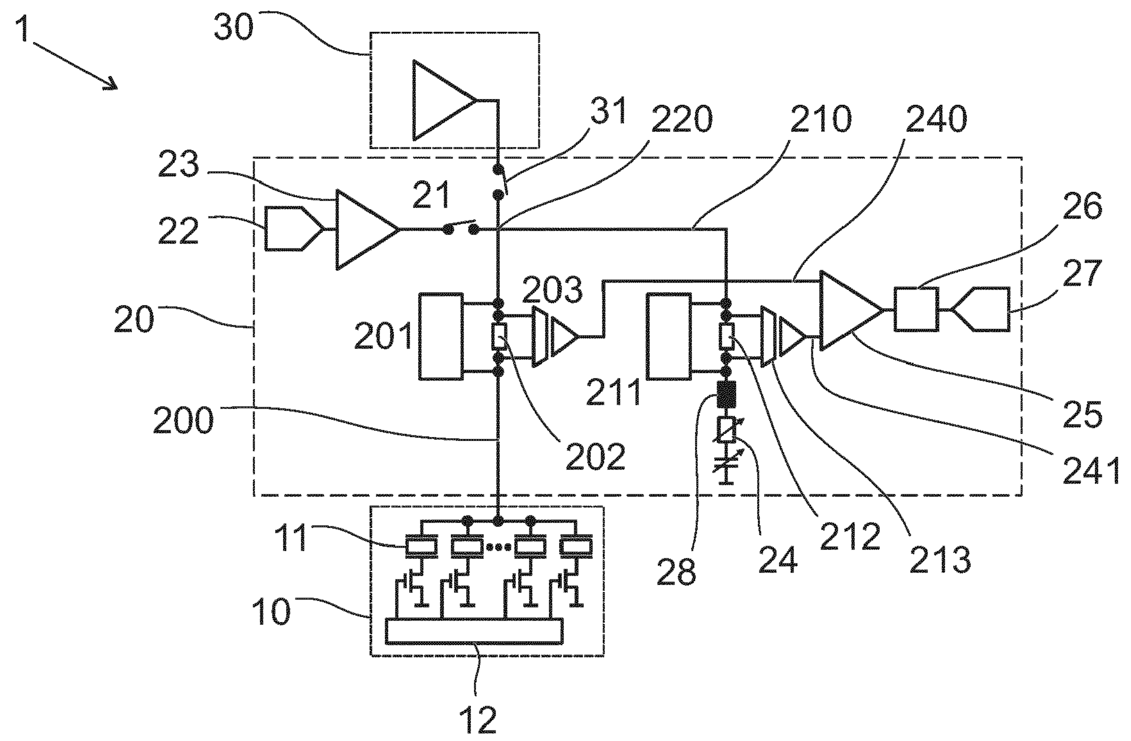
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Fig. 1

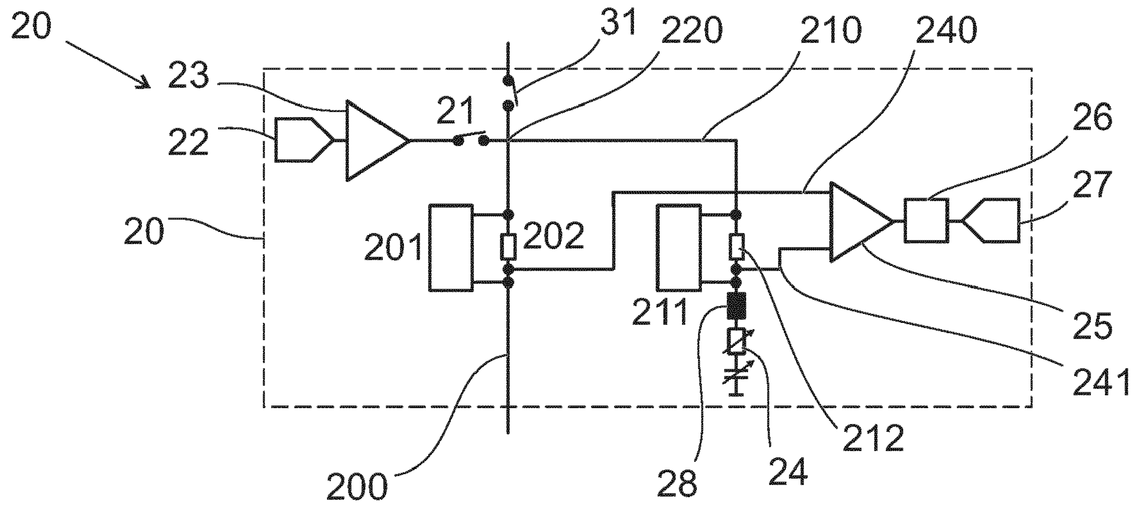
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Fig. 2

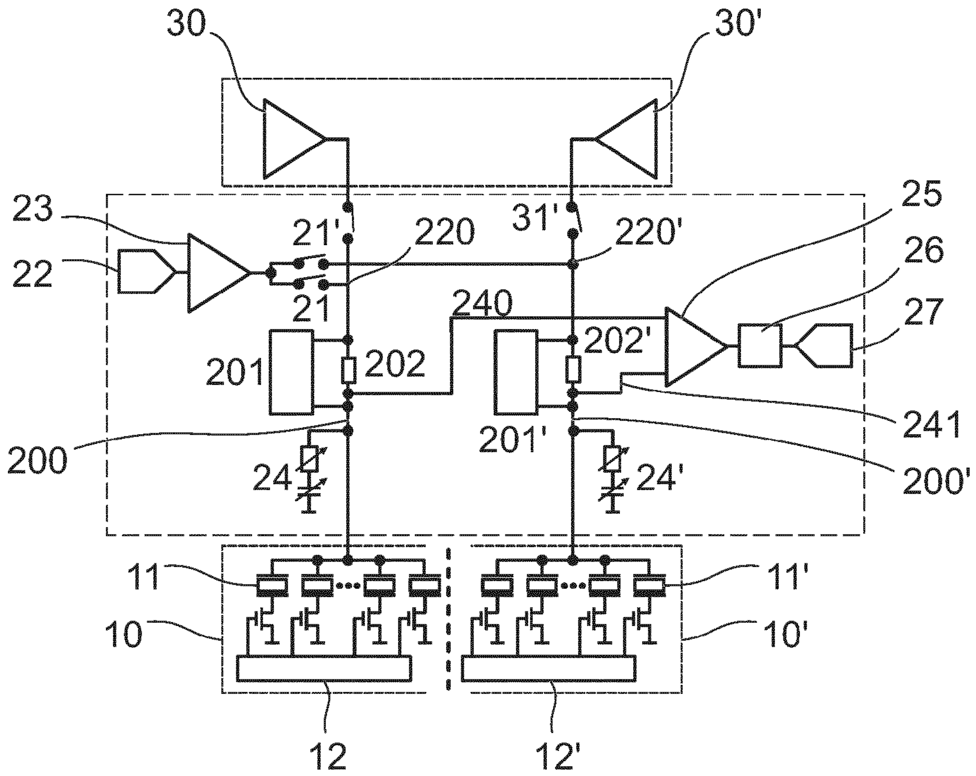
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Fig. 3

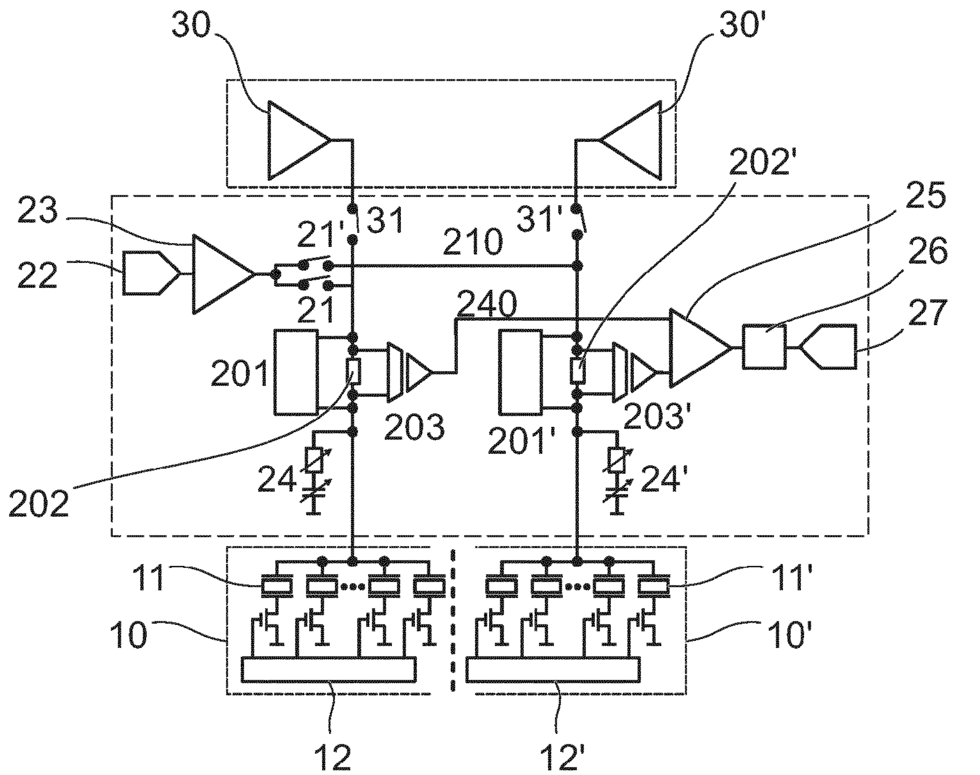
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Fig. 4

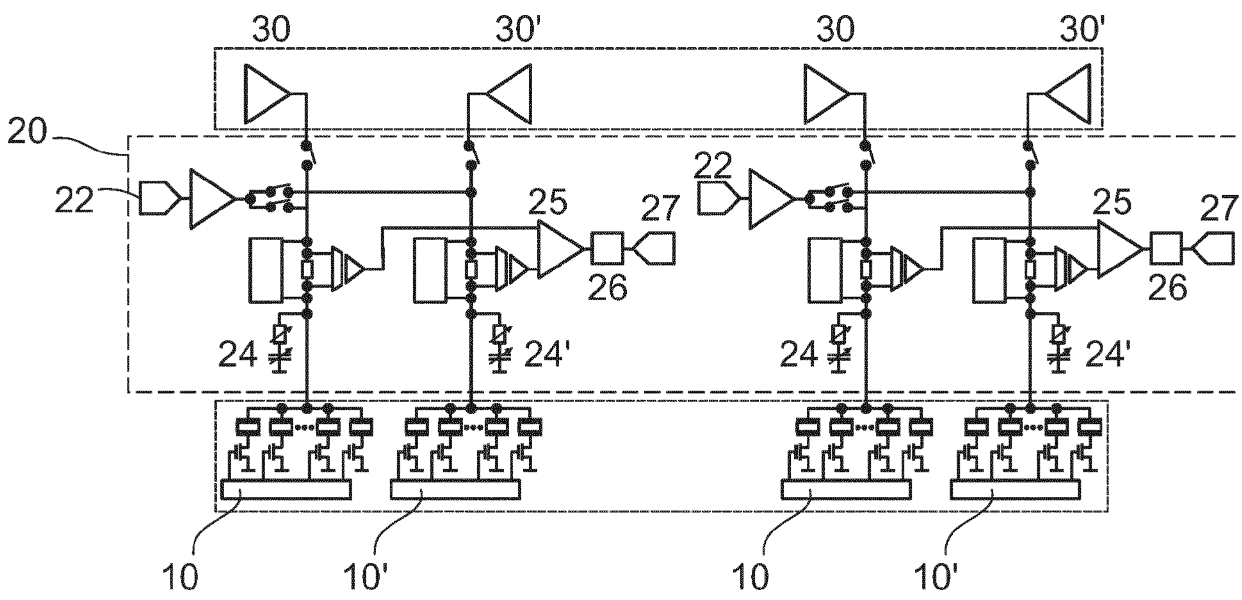
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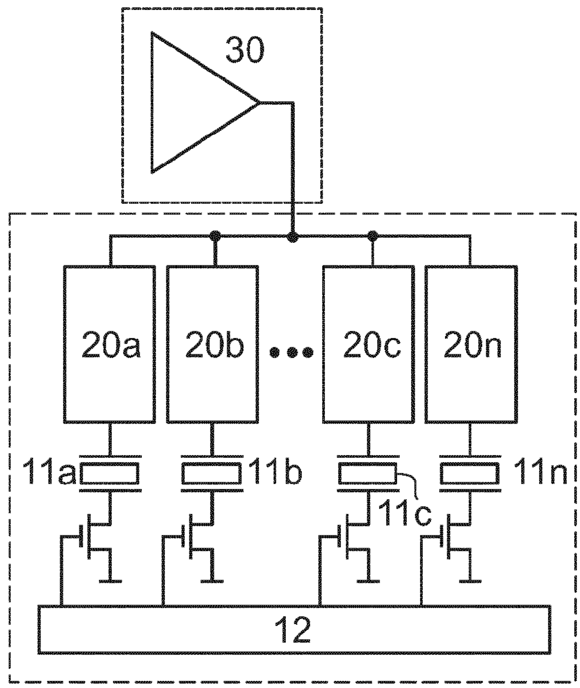
Fig. 5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20c
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11b
11c
11n
12

Fig. 6

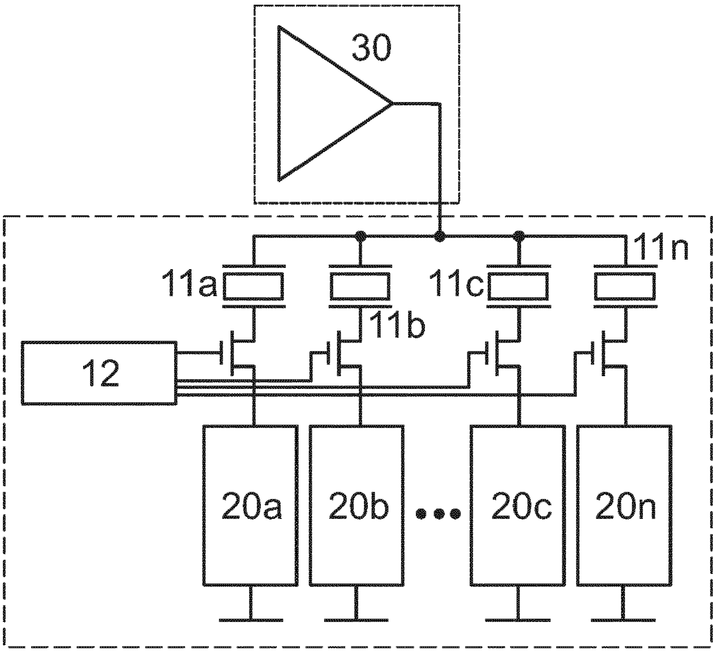
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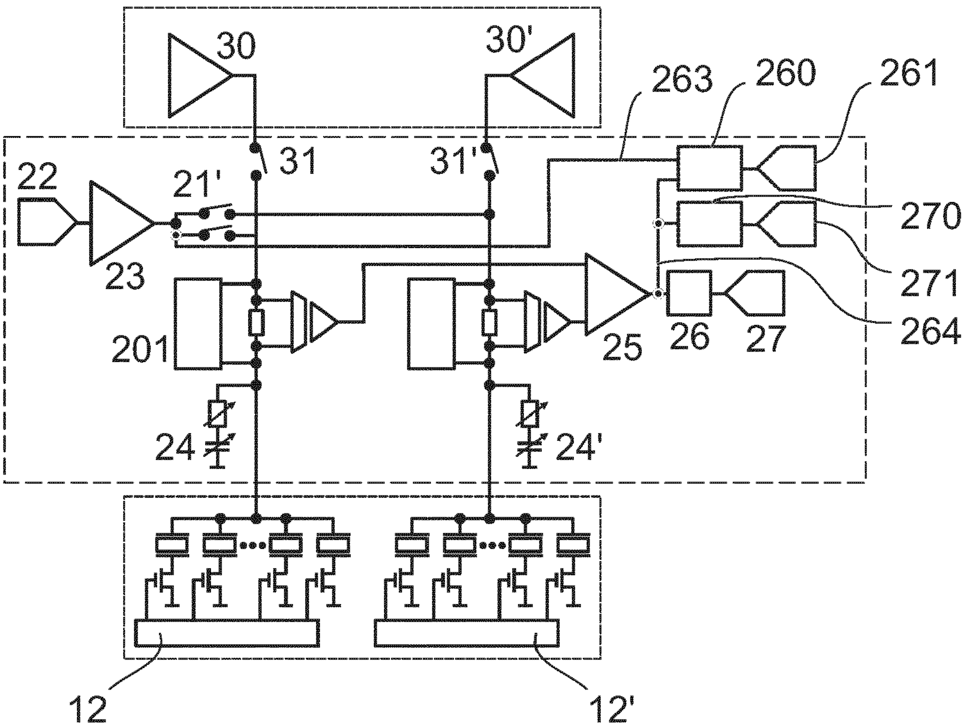
Fig. 7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12
12'

Fig. 8

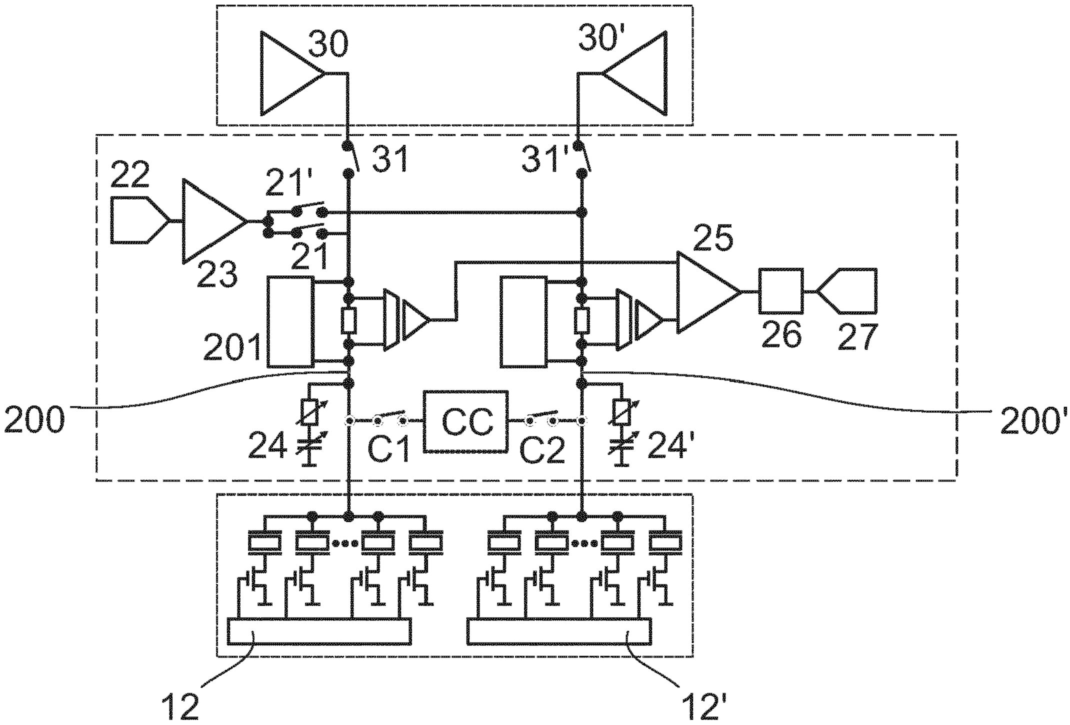


Fig. 9

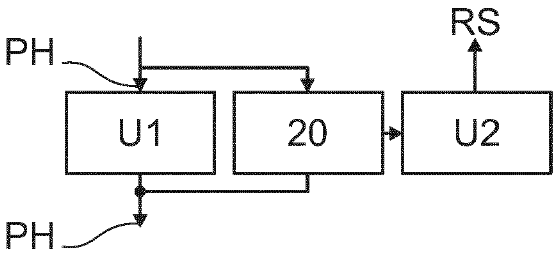


Fig. 10

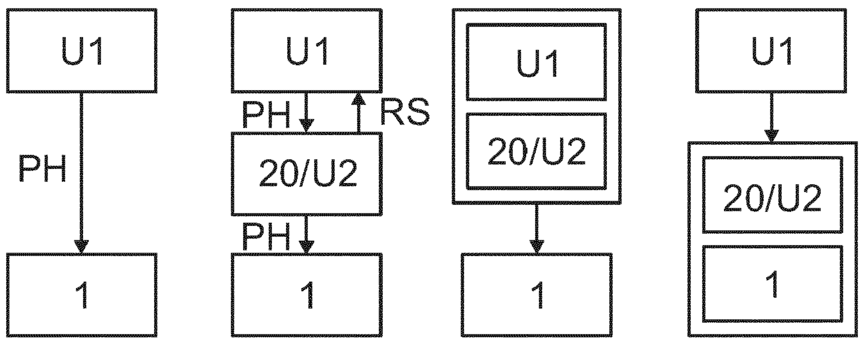


Fig. 10a Fig. 10b Fig. 10c Fig. 10d

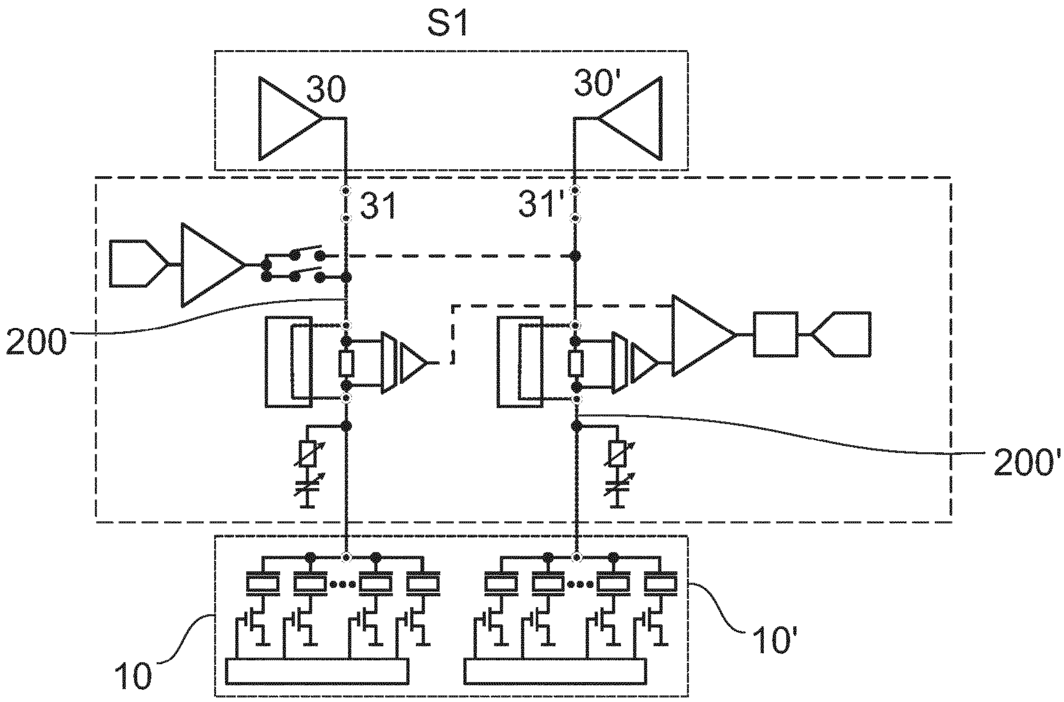


Fig. 11a

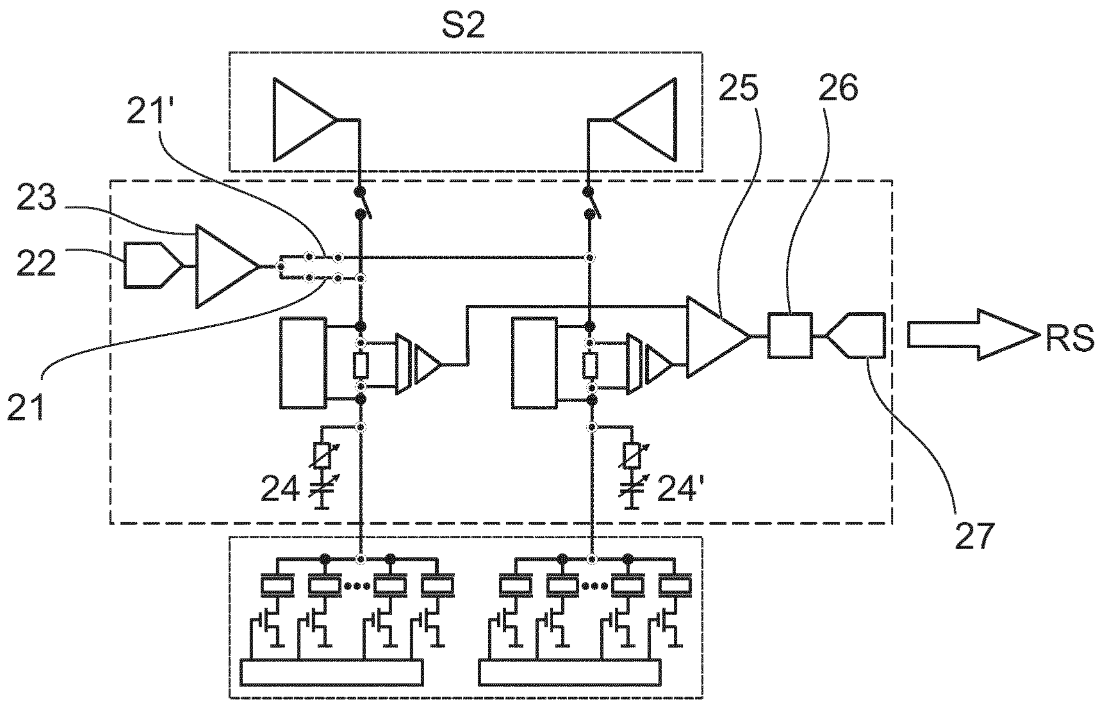
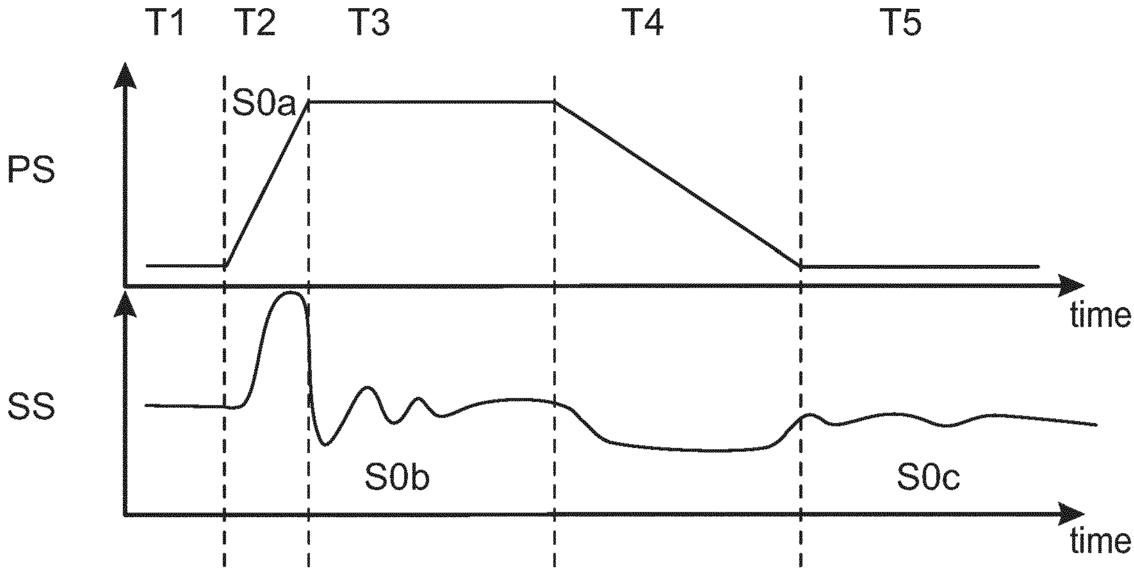


Fig. 11b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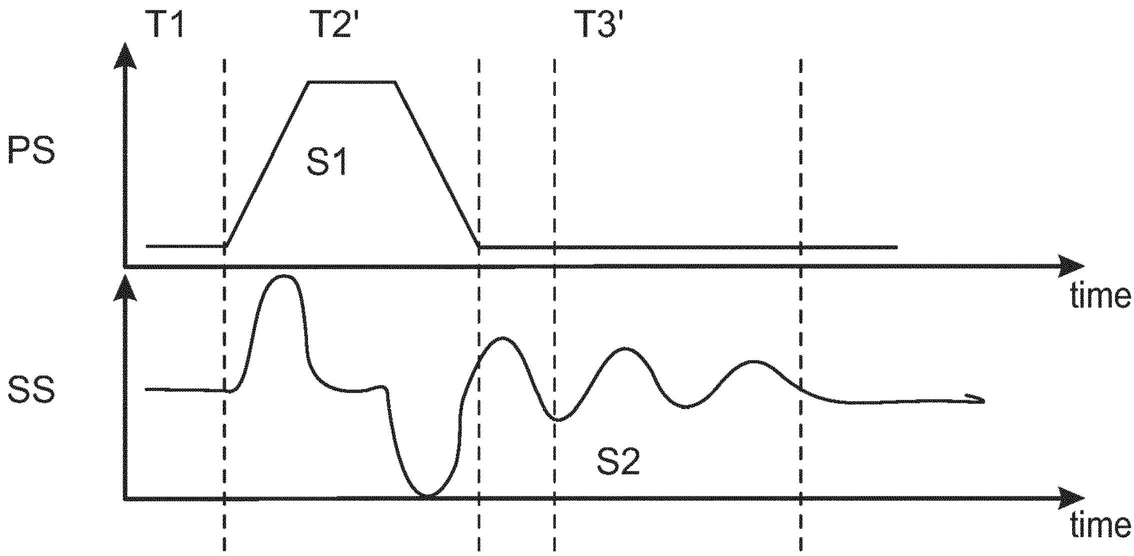
T3
T4
T5
S0a
PS
time
SS
S0b
S0c
time

12a


T1
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T3'
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time
SS
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time

12b

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EUROPEAN SEARCH REPORT

Application Number
EP 23 15 6473

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A,D	EP 2 765 003 A1 (PALO ALTO RESEARCH CENTER INCORPORATED [US]; XEROX CORP [US]) 13 August 2014 (2014-08-13) * paragraphs [0002], [0010] - [0014]; claims 1-15; figures 1A, 1B, 2 * -----	1-17	INV. B41J2/045 ADD. B41J2/14

TECHNICAL FIELDS SEARCHED (IPC)

B41J
G01N

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	26 June 2023	Bacon, Alan

CATEGORY OF CITED DOCUMENTS

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EP 23 15 6473

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26-06-2023

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