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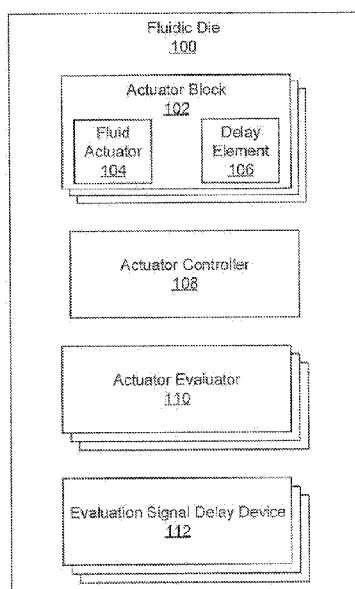
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(54) Title: FLUID ACTUATOR EVALUATION BASED ON A DELAYED FIRE SIGNAL

Fig. 1

(57) Abstract: In one example, a fluidic die is described. The fluidic die includes an array of actuator blocks grouped into primitives. An actuator block includes a firing delay element to generate a delayed fire signal and a fluid actuator to be activated via the delayed fire signal. The fluidic die also includes an actuator controller to group actuator blocks into primitives and to activate fluid actuators. Each actuator evaluator of an array is grouped with a subset of actuator blocks and is to evaluate an actuator characteristic of a corresponding fluid actuator based on 1) an output of an actuator sensor paired with the fluid actuator and 2) a delayed evaluation signal which is based on the delayed fire signal. An evaluation signal delay device is paired with the actuator evaluator and generates a delayed evaluation signal based on an initial evaluation signal and the delayed fire signal.

FLUID ACTUATOR EVALUATION BASED ON A DELAYED FIRE SIGNAL

BACKGROUND

[0001] A fluidic die is a component of a fluid ejection system that includes a number of fluid ejecting nozzles. The fluidic die can also include other non-ejecting actuators such as micro-recirculation pumps. Through these nozzles and pumps, fluid, such as ink and fusing agent among others, is ejected or moved. Over time, these nozzles and pumps can become clogged or otherwise inoperable. As a specific example, ink in a printing device can, over time, harden and crust. This can block the nozzle and interrupt the operation of subsequent ejection events. Other examples of issues affecting these actuators include fluid fusing on an ejecting element, particle contamination, surface puddling, and surface damage to die structures. These and other scenarios may adversely affect operations of the device in which the fluidic die is installed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] The accompanying drawings illustrate various examples of the principles described herein and are part of the specification. The illustrated examples are given merely for illustration, and do not limit the scope of the claims.

[0003] Fig. 1 is a block diagram of a fluidic die for fluid actuator evaluation based on a delayed fire signal, according to an example of the principles described herein.

[0004] Fig. 2 is a diagram of a fluid actuator controller for fluid actuator evaluation based on a delayed fire signal, according to an example of the principles described herein.

[0005] Fig. 3 is a diagram of a fluidic die for fluid actuator evaluation based on a delayed fire signal, according to an example of the principles described herein.

[0006] Fig. 4 is a flow chart of a method for fluid actuator evaluation based on a delayed fire signal, according to an example of the principles described herein.

[0007] Throughout the drawings, identical reference numbers designate similar, but not necessarily identical, elements. The figures are not necessarily to scale, and the size of some parts may be exaggerated to more clearly illustrate the example shown. Moreover, the drawings provide examples and/or implementations consistent with the description; however, the description is not limited to the examples and/or implementations provided in the drawings.

DETAILED DESCRIPTION

[0008] Fluidic dies, as used herein, may describe a variety of types of integrated devices with which small volumes of fluid may be pumped, mixed, analyzed, ejected, etc. Such fluidic dies may include ejection dies, such as printheads, additive manufacturing distributor components, digital titration components, and/or other such devices with which volumes of fluid may be selectively and controllably ejected. Other examples of fluidic dies include fluid sensor devices, lab-on-a-chip devices, and/or other such devices in which fluids may be analyzed and/or processed.

[0009] In a specific example, these fluidic systems are found in any number of printing devices such as inkjet printers, multi-function printers (MFPs), and additive manufacturing apparatuses. The fluidic systems in these devices are used for precisely, and rapidly, dispensing small quantities of fluid. For example, in an additive manufacturing apparatus, the fluid ejection system dispenses fusing agent. The fusing agent is deposited on a build material,

which fusing agent facilitates the hardening of build material to form a three-dimensional product.

[0010] Other fluid ejection systems dispense ink on a two-dimensional print medium such as paper. For example, during inkjet printing, fluid is directed to a fluid ejection die. Depending on the content to be printed, the device in which the fluid ejection system is disposed determines the time and position at which the ink drops are to be released/ejected onto the print medium. In this way, the fluid ejection die releases multiple ink drops over a predefined area to produce a representation of the image content to be printed. Besides paper, other forms of print media may also be used.

[0011] Accordingly, as has been described, the systems and methods described herein may be implemented in a two-dimensional printing, i.e., depositing fluid on a substrate, and in three-dimensional printing, i.e., depositing a fusing agent or other functional agent on a material base to form a three-dimensional printed product.

[0012] Returning to the fluid actuators, a fluid actuator may be disposed in a nozzle, where the nozzle includes a fluid chamber and a nozzle orifice in addition to the fluid actuator. The fluid actuator in this case may be referred to as an ejector that, upon actuation, causes ejection of a fluid drop via the nozzle orifice.

[0013] Fluid actuators may also be pumps. For example, some fluidic dies include microfluidic channels. A microfluidic channel is a channel of sufficiently small size (e.g., of nanometer sized scale, micrometer sized scale, millimeter sized scale, etc.) to facilitate conveyance of small volumes of fluid (e.g., picoliter scale, nanoliter scale, microliter scale, milliliter scale, etc.). Fluidic actuators may be disposed within these channels which, upon activation, may generate fluid displacement in the microfluidic channel.

[0014] Examples of fluid actuators include a piezoelectric membrane based actuator, a thermal resistor based actuator, an electrostatic membrane actuator, a mechanical/impact driven membrane actuator, a magneto-strictive drive actuator, or other such elements that may cause displacement of fluid

responsive to electrical actuation. A fluidic die may include a plurality of fluid actuators, which may be referred to as an array of fluid actuators.

[0015] In some examples, a fluid actuator forms part of an actuator block along with a delay element for that fluid actuator. The array of fluid actuators, and actuator blocks, may be formed into groups referred to as "primitives." A primitive generally includes a group of fluid actuators that each have a unique actuation address. In some examples, electrical and fluidic constraints of a fluidic die may limit which fluid actuators of each primitive may be actuated concurrently for a given actuation event. Therefore, primitives facilitate addressing and subsequent actuation of fluid ejector subsets that may be concurrently actuated for a given actuation event.

[0016] The number of fluid actuators corresponding to a respective primitive may be referred to as a size of the primitive. To illustrate by way of example, if a fluidic die has four primitives and each respective primitive has eight respective fluid actuators (the different fluid actuators having an address 0 to 7), the primitive size is eight. In this example, each fluid actuator within a primitive has a unique in-primitive address. In some examples, electrical and fluidic constraints limit actuation to one fluid actuator per primitive. Accordingly, a total of four fluid actuators (one from each primitive) may be concurrently actuated for a given actuation event. For example, for a first actuation event, the respective fluid actuator of each primitive having an address of 0 may be actuated. For a second actuation event, the respective fluid actuator of each primitive having an address of 1 may be actuated. In some examples, the primitive size may be fixed and in other examples the primitive size may vary, for example after the completion of a set of actuation events.

[0017] A fluid actuator controller facilitates the actuation of the actuators. For example, a fluid actuator controller may include an actuation data register and a mask register. The actuation data register stores actuation data that indicates fluid actuators to actuate for a **set** of actuation events. The mask register stores mask data that indicates a subset of fluid actuators of the array of fluid actuators enabled for actuation for a **particular** actuation event of the set of actuation events. Accordingly, the fluid actuator controller facilitates

concurrent actuation of different arrangements of fluid actuators based on the mask data of the mask register. In some examples, the mask data groups fluid actuators, and thereby defines the primitive size.

[0018] At different points in time, the mask data may change, such that the fluid actuator controller facilitates variable primitive sizes. For example, for a first set of actuation events, fluid actuators may be arranged in primitives of a first primitive size, as defined by first mask data stored in the mask register, and for a second set of actuation events, second mask data may be loaded into the mask register such that fluid actuators may be arranged in primitives of a second primitive size.

[0019] While such fluid ejection systems and dies undoubtedly have advanced the field of precise fluid delivery, some conditions impact their effectiveness. For example, the actuators on a die are subject to many cycles of heating, drive bubble formation, drive bubble collapse, and fluid replenishment from a fluid reservoir. Over time, and depending on other operating conditions, the actuators may become blocked or otherwise defective. As the process of depositing fluid on a surface is a precise operation, these blockages can have a deleterious effect on print quality. If one of these fluid actuators fail, and is continually operating following failure, then it may cause neighboring actuators to fail.

[0020] Accordingly, the present specification is directed to a fluidic die that includes actuator evaluators to determine a characteristic of a particular fluid actuator. For example, the actuator evaluators can determine whether a drive bubble has properly formed in a fluid actuator, which proper formation of a drive bubble can be used to determine whether an associated fluid actuator is operating as expected. In these examples, the evaluation of a fluid actuator is tied to an actuation of the particular fluid actuator.

[0021] In some examples, to maintain peak currents on the fluidic die to a reduced level, the fire signals that activate a particular fluid actuator are delayed. Accordingly, coupled to each fluid actuator is a delay element, which propagates, and increases the delay along a column of fluid actuators. A series of these delay elements ensures that the number of simultaneously actuated

fluid actuators does not exceed a predetermined level. For example, the delay elements may ensure that no two fluid actuators are actuated at the same time. In this example, to ensure proper pairing of actuation events and evaluation events, the evaluation system includes a delay structure that is similar to the delay structure found in the actuation system.

[0022] While delaying the actuation and evaluation can improve the reliability and efficiency of the fluidic die, there are some complications when implemented in a system where the number of fluid actuators per primitive changes. For example, in a fixed primitive scenario, one delay element is instantiated per primitive. As the primitive size is fixed, and one fluid actuator per primitive is activated, a clone delay structure can be used in the evaluation system of a fixed-primitive fluidic die. However, when the size of primitive changes, one delay element per primitive is not possible. That is, an evaluation signal should travel along the array of fluid actuators with the same delay structure, but offset in time, as the fire signals, in order to make sure that the evaluation signal arrives at an actuator evaluator with the same amount of delay as the activation signal was received at the fluid actuator.

[0023] In the case of primitives that change size over time, the evaluation delay structure cannot simply be a mirror of the activation delay structure. This is, in variable primitive structures, at most one actuator per virtual primitive is fired at a time. Delay elements are instantiated per actuator, but just those actuators that are actuated for a given actuation event are active. Accordingly, for every actuation event, a different number/subset of delay elements may be active. Accordingly, the delay chain state, i.e., which fluid activators have been delayed, will change between the time of activation and evaluation, thus causing the delay between the activation events and evaluation events to vary by unacceptable amounts.

[0024] Accordingly, the present specification describes a system wherein the delay state of fire signals for each fluid actuator are cloned, and used by an actuator evaluator to pair a particular delayed actuation event with an evaluation event.

[0025] Specifically, the present application describes a fluidic die. The fluidic die includes an array of actuator blocks grouped into primitives. Each actuator block includes a firing delay element to generate a delayed fire signal and a fluid actuator to be activated by the delayed fire signal. The fluidic die also includes an actuator controller to group actuator blocks into primitives and to activate fluid actuators. The fluidic die also includes an array of actuator evaluators. Each actuator evaluator is grouped with a subset of actuator blocks and evaluates an actuator characteristic of the fluid actuator based on 1) an output of an actuator sensor paired with the fluid actuator and 2) a delayed evaluation signal which is delayed based on the delayed fire signal. The fluidic die also includes an evaluation signal delay device paired with each actuator evaluator to generate a delayed evaluation signal based on an initial evaluation signal and a state of any firing delay element in the subset.

[0026] In another example, the fluidic die includes the array of actuator blocks grouped into primitives, the array of actuator evaluators, the fluid actuator controller, and an evaluation signal delay device paired with the actuator evaluator. The fluidic die of this example also includes an array of actuator sensors to generate a signal indicative of a characteristic of a fluid actuator. Each actuator sensor is coupled to a respective fluid actuator. In this example, the fluid actuator controller includes 1) an actuation data register to store actuation data that indicates fluid actuators to actuate for a set of actuation events and 2) a mask register that includes a respective bit for each respective fluid actuator to store mask data that indicates a set of fluid actuators of the array enabled for actuation for a particular actuation event of the set of actuation events.

[0027] The present specification also describes a method for fluid actuator evaluation. According to the method, a fluid actuator is activated based on a delayed fire signal to generate a sense voltage measured at a corresponding actuator sensor. An actuator evaluator grouped with the fluid actuator is selected and a delayed evaluation signal is generated based on the delayed fire signal and an initial evaluation signal. Upon receipt of the

delayed evaluation signal, a characteristic of the fluid actuator is determined, based on the sense voltage.

[0028] In one example, using such a fluidic die 1) allows for actuator evaluation circuitry to be included on a die as opposed to sending sensed signals to actuator evaluation circuitry off die; 2) increases the efficiency of bandwidth usage between the device and die; 3) reduces computational overhead for the device in which the fluid ejection die is disposed; 4) provides improved resolution times for malfunctioning actuators; 5) allows for actuator evaluation in one primitive while allowing continued operation of actuators in another primitive; and 6) places management of nozzles on the fluid ejection die as opposed to on the printer in which the fluid ejection die is installed, 7) accommodates for variation in primitive size, and 8) ensures an evaluation delay per fluidic die matches an actuation delay for the fluidic die. However, it is contemplated that the devices disclosed herein may address other matters and deficiencies in a number of technical areas.

[0029] As used in the present specification and in the appended claims, the term "fluid actuator" refers to a nozzle or another non-ejecting fluid actuator. For example, a nozzle, which is a fluid actuator, operates to eject fluid from the fluid ejection die. A recirculation pump, which is an example of a non-ejecting fluid actuator, moves fluid through the fluid slots, channels, and pathways within the fluidic die.

[0030] Accordingly, as used in the present specification and in the appended claims, the term "nozzle" refers to an individual component of a fluidic die that dispenses fluid onto a surface. The nozzle includes at least an ejection chamber, an ejector, and a nozzle orifice.

[0031] Further, as used in the present specification and in the appended claims, the term "fluidic die" refers to a component of a fluid ejection system that includes a number of fluid actuators. Groups of actuator blocks which include fluid actuators are categorized as "primitives" of the fluidic die, the primitive having a size referring to the number of fluid actuators grouped together. In one example, a primitive size may be between 8 and 16. The fluid ejection die may be organized first into two columns with 30-150 primitives per column.

[0032] Still further, as used in the present specification and in the appended claims, the term "actuation event" refers to a substantially concurrent actuation, accounting for the delay of fire signals reaching each fluid actuator that are to fire for an actuation event, of fluid actuators of the fluidic die to thereby cause fluid displacement.

[0033] Yet further, as used in the present specification and in the appended claims, the term "activation data" refers to data that targets a particular fluid actuator or set of fluid actuators for actuation. For example, when primitive size varies, activation data may include per-actuator actuation data and mask data.

[0034] Yet further, as used in the present specification and in the appended claims, the number of elements in a "subset" and "array" may be 1 or any integer value greater than 1.

[0035] Even further, as used in the present specification and in the appended claims, the term "a number of" or similar language is meant to be understood broadly as any positive number including 1 to infinity.

[0036] Turning now to the figures, Fig. 1 is a block diagram of a fluidic die (100) for fluid actuator evaluation based on a delayed fire signal, according to an example of the principles described herein. As described above, the fluidic die (100) is part of a fluid ejection system that houses components for ejecting fluid and/or transporting fluid along various pathways. The fluid that is ejected and moved throughout the fluidic die (100) can be of various types including ink, biochemical agents, and/or fusing agents. The fluid is moved and/or ejected via fluid actuators (104). Each fluid actuator (104) is paired with a delay element (106) and together form an actuator block (102). Each fluidic die (100) includes an array of actuator blocks (102). Any number of actuator blocks (102) may be formed on the fluidic die (100).

[0037] The fluid actuators (104) may be of varying types. For example, the fluidic die (100) may include an array of nozzles, wherein each nozzle includes a fluid actuator (104) that is an ejector. In this example, a fluid ejector, when activated, ejects a drop of fluid through a nozzle orifice of the nozzle.

[0038] Another type of fluid actuator (104) is a recirculation pump that moves fluid between a nozzle channel and a fluid slot that feeds the nozzle channel.

In this example, the fluidic die (100) includes an array of microfluidic channels. Each microfluidic channel includes a fluid actuator (104) that is a fluid pump. In this example, the fluid pump, when activated, displaces fluid within the microfluidic channel. While the present specification may make reference to particular types of fluid actuators (104), the fluidic die (100) may include any number and type of fluid actuators (104).

[0039] Actuation of the fluid actuators (104) is carried out by the fluid actuator controller (108). In this example, the fluid actuator controller (108) includes components to manage the actuation of the various fluid actuators (104). That is, the fluid actuator controller (108) passes data to activate a firing delay element (106) associated with each fluid actuator (104). A firing delay element (106) that has received this actuation data as well as a fire signal, which is passed from one fluid actuator (104) to the next, is said to be "active" meaning that it is actively delaying the received fire signal. A firing delay element (106) that is not active, still allows the fire signal to pass, but does not delay it. Accordingly, this actuation data, in addition to activating a particular fluid actuator (104), is indicative of an "active" delay element (106). As described above, the evaluation signal delay device (112) includes a delay element that may be similar to the firing delay element (106) of an actuator block (102) such that the firing delay element (106) delays the fire signal by a predetermined amount and the delay element of the evaluation system, delays the evaluation signal by the same amount.

[0040] As described above, the fluid actuators (104), in their respective actuator blocks (102), are grouped into primitives. A primitive refers to a grouping of fluid actuators (104) where each fluid actuator (104) within the primitive has a unique address. For example, within a first primitive, a first fluid actuator (104) has an address of 0, a second fluid actuator (104) has an address of 1, a third fluid actuator (104) has an address of 2, and a fourth fluid actuator (104) of the primitive has an address of 3. The fluid actuators (104) that are grouped into subsequent primitives respectively have similar addressing. A fluidic die (100) may include any number of primitives having any number of fluid actuators (104) disposed therein. In some cases, a quantity of

fluid actuators (104) within the primitive that can be concurrently fired may be designated. For example, it may be designated that in a given primitive, one fluid actuator (104) is enabled at a time.

[0041] The fluid actuators (104) within the array may be activated based on a delayed fire signal. That is, a fire signal may be passed among various fluid actuators (104). Specifically, a global fire signal is passed to a first actuator block (102), which passes the global fire signal to a second actuator block (102). In this fashion, the fire signal is passed from actuator block to actuator block.

[0042] To reduce maximum current peaks across the fluidic die (100), this fire signal is delayed as it is passed to different fluid actuators (104), such that fluid actuators (104) that are selected to be activated for a particular actuation event are not actuated at the same time. To carry out this delay, a firing delay element (106) may be coupled to each fluid actuator (104), which firing delay element (106) generates the delayed fire signal. That is, the firing delay element (106), receives as input, a fire signal. Actuation data, such as bits from an actuation data register and a mask register enable, or activate, the firing delay element (106) such that the firing delay element (106) delays the fire signal.

[0043] The fluidic die (100) also includes a fluid actuator controller (108) to group multiple actuator blocks (102) into primitives. Note that the primitive grouping may not align with the group of actuator blocks (102) that are coupled to an actuator evaluator (110). The fluid actuator controller (108) selectively activates fluid actuators (104) via activation data. For example, if the number of fluid actuators (104) within a primitive is not fixed, i.e., it varies, then the activation data may include 1) actuation data that indicates a set of fluid actuators (104) to activate for a set of actuation events and 2) mask data that indicates fluid actuators (104) to activate for a particular activation event. This activation data gates the fire signal at the firing delay element (106).

[0044] The fluidic die (100) also includes an array of actuator evaluators (110). Each actuator evaluator (110) is grouped with a subset of actuator blocks (102) of the array. The actuator evaluators (110) evaluate a

characteristic of any fluid actuator (104) within the subset that pertains to that actuator evaluator (110) and generates an output indicative of the fluid actuator (104) characteristic. Note that the primitive grouping does not necessarily align with the group of fluid actuators (104) that are coupled to an actuator evaluator (110).

[0045] The evaluation by an actuator evaluator (110) is based on various components. For example, the actuator evaluator (110) is activated via an evaluation signal. That is, when it is desired that an actuator analysis be performed on a particular fluid actuator (104) or set of fluid actuators (104), an evaluation signal is passed to an actuator evaluator (110), which indicates that an evaluation of a particular fluid actuator (104) is desired. Specifically, the evaluation signal may be a delayed evaluation signal which is delayed to a same degree, and based on, the delayed fire signal. Specifically, the state of any firing delay element (106) coupled to the actuator evaluator (110) is based on actuation data and mask data, i.e., activation data. This state is latched, and used to enable the initial evaluation signal to pass as a delayed evaluation signal.

[0046] For example, if the state of a first firing delay element (106) associated with a first fluid actuator (104) is active, meaning a delayed fire signal has been passed to the first fluid actuator (104), this state of the first firing delay element (106) is latched, i.e., stored. At a subsequent point in time, this "state" data is used to delay the evaluation signal by the same amount that the fire signal was delayed. That is, the firing delay element (106) is similar to the delay element of the evaluation system, such that when the delay element of the evaluation system is active, it delays in the same amount as the firing delay element (106).

[0047] The evaluation of a characteristic of a fluid actuator is also based on an output of an actuator sensor that is paired with a fluid actuator (104). That is, the actuator evaluators (110) are coupled to actuator sensors, which sensors output a value indicative of a condition of the fluid actuator. This output value can be compared to a threshold value, or considered over time, to determine a status of the associated fluid actuator (104).

[0048] The actuator evaluator (110) may include various components to determine a characteristic of the fluid actuator (104). For example, the actuator evaluator (110) may include a compare device to compare an output of an actuator sensor coupled to a respective fluid actuator (104) against a threshold value to determine when the respective fluid actuator (104) is malfunctioning. That is, the compare device determines whether the output of the actuator sensor, V_o , is greater than or less than the threshold voltage, V_{th} . The compare device then outputs a signal indicative of which is greater.

[0049] The output of the compare device may then be passed to a storage device of the actuator evaluator (110). In one example, the storage device may be a latch device that stores the output of the compare device and selectively passes the output on. While specific reference is made to evaluation by comparison, other types of evaluation may occur, such as comparison of sense voltages from a sensor over time.

[0050] The fluidic die (100) also includes multiple evaluation signal delay devices (112), each paired with an actuator evaluator (110) to generate the delayed evaluation signal. The delayed evaluation signal is based on an initial evaluation signal and a state of any firing delay element (106) of the subset that is grouped with the actuator evaluator (110). That is, the evaluation signal delay device (112) receives as input an evaluation signal, which indicates that the actuator evaluator (110) is to carry out actuator evaluation. The evaluation signal delay device (112) also receives as input, a state of the firing delay element (106) for any actuator block (102) within the subset that has been activated. That is, if a particular fluid actuator (104) has been activated via a delayed fire signal, i.e., the firing delay element (106) associated with the particular fluid actuator (104) is active, the state of this firing delay element (106) is passed to the evaluation signal delay device (112).

[0051] The evaluation signal delay device (112) receives the state, and uses it to delay the evaluation signal to generate the delayed evaluation signal, which delayed evaluation signal activates the corresponding actuator evaluator (110). By using the active state of the firing delay element (106) to enable the delay element of the evaluation system, it can be ensured that a timing difference

between firing and evaluation can be maintained. That is, an initial firing signal is offset from the initial evaluation signal by a predetermined amount of time. To ensure the integrity of actuator evaluation, it is desirable that this offset be maintained. Due to the varying nature of primitive size of the present specification, using a state of the firing delay element (106) to trigger a delay element of the evaluation system ensures that this timing is preserved.

[0052] Fig. 2 is a diagram of a fluid actuator controller (108) for fluid actuator evaluation based on a delayed fire signal, according to an example of the principles described herein. In this example, the fluid actuator controller (108) includes components to manage the actuation of the various fluid actuators (Fig. 1, 104). For example, the fluid actuator controller (108) includes an actuation data register (214) and a mask register (218).

[0053] The actuation data register (214) stores actuation data that indicates each fluid actuator (104) to actuate for a set of actuation events. For example, the actuation data register (214) may include a set of bits (216-1 through 216-12) to store actuation data, where each respective bit (216-1 through 216-12) of the actuation data register (214) corresponds to a respective fluid actuator (Fig. 1, 104). The actuation data register (214) indicates each fluid actuator (104) to actuate for a *set* of actuation events. For example, for those fluid actuators (104) that are to be actuated for a set of actuation events, the corresponding respective bit (216-1 through 216-12) can be set to "1." For those fluid actuators (104) that are not to be actuated for the set of actuation events, the corresponding respective bit (216-1 through 216-12) can be set to "0." In the example depicted in Fig. 2, all of the fluid actuators (104) have been activated for a set of actuation events as indicated by each having the respective bit (216-1 through 216-12) value set to "1."

[0054] The mask register (218) stores mask data that indicates fluid actuators (104) of the array enabled for actuation for a particular actuation event of the set of actuation events. That is, the mask register (218) indicates a set of fluid actuators (104) of the array that are actively enabled for actuation for a respective actuation event of the set of actuation events. For example, for those fluid actuators (104) that are to be actuated for a particular actuation

event, the corresponding respective bit (220-1 through 220-12) can be set to "1." For those fluid actuators (104) that are not to be actuated for the particular actuation events, the corresponding respective bit (220-1 through 220-12) can be set to "0." In so doing, the mask register (218) configures the size of the primitives. That is, the mask register (218) identifies a first fluid actuator, a fifth fluid actuator, and a ninth fluid actuator to be activated for a particular actuation event. Accordingly, the primitive size is established by the mask register (218) to be four fluid actuators. Note that over time, the primitive size may change based on the information presented in the mask register (218). That is, the primitive size is not fixed.

[0055] The fluid actuator controller (108) also includes actuation logic (222). The actuation logic (222) is coupled to the actuation data register (214) and the mask register (218) to determine which fluid actuators (Fig. 1, 104) to actuate for a particular actuation event. The actuation logic (222) is also coupled to the fluid actuators (104) to electrically actuate those fluid actuators (104) selected for actuation based on the actuation data register (214) and the mask register (218).

[0056] The fluid actuator controller (108) also includes shift logic (224) to shift mask data stored in the mask register (218) responsive to the performance of a particular actuation event of a set of actuation events. By shifting the mask data, different fluid actuators (104) are indicated for actuation of a subsequent actuation event of the set of actuation events. To effectuate such shifting, the shift logic (224) may include a shift count register to store a shift pattern that indicates a number of shifts that are input into the mask register and a shift state machine which inputs a shift clock to cause the shifting indicated in the shift count register.

[0057] Fig. 3 is a diagram of a fluidic die (100) for fluid actuator evaluation based on a delayed fire signal, according to an example of the principles described herein. Fig. 3 depicts the fluid actuator controller (108) that groups actuator blocks (Fig. 1, 102) and their corresponding fluid actuators (104) and firing delay elements (106) into primitives and also that passes activation data

that enables a fire signal to activate a particular fluid actuator (104). Fig. 3 also depicts the grouping of particular fluid actuators to different actuator evaluators.

[0058] In this example, a fire signal (314) is received at a first firing delay element (106-1) and is propagated down a chain of delay elements (106-2, 106-3, 106-4, 106-5, 106-6, 106-7, 106-8), each delay element corresponding to a fluid actuator (104-2, 104-3, 104-4, 104-5, 104-6, 104-7, 104-8). In this example, the delayed fire signal (314) has a delay amount that changes as the number of activated fluid actuators (104) changes. For example, the initial fire signal (314) is delayed first by the first firing delay element (106-1), assuming the first firing delay element (106-1) is enabled via the activation data from the fluid actuator controller (108). In this example, it may be the case that remaining fluid actuators coupled to the first actuator evaluator (110-1) are not activated, but fluid actuators coupled to the second actuator evaluator (110-2) may be activated. Accordingly, a fifth firing delay element (106-5) coupled to a different actuator evaluator (110-2), may further delay this delayed fire signal via activation data provided by the fluid actuator controller (108).

[0059] The fire signal (314) is allowed to pass to a particular fluid actuator (104) when activation data (315) is passed to the corresponding firing delay element (106). In other words, the firing delay element (106) receives a fire signal (314), that is delayed, by the activation data (315) that is passed from the fluid actuator controller (108). In this fashion, just those fluid actuators (104) that are activated have their firing delay elements (106) in an active state. Activation data (315) activating a particular fluid actuator (104) is also passed to the corresponding fluid actuator (104). This activation data (315) thereby not only instructs a delay element (106) to delay the fire signal (314), but also instructs the corresponding fluid actuator (104) to actuate. In other words, a fluid actuator (104) is actuated when it receives the activation data (315) and the delayed fire signal (314) output from the corresponding delay element (106). As will be described below, this activation data (315) is also passed to the latch (316) for storage.

[0060] The state of a particular firing delay element (106) is then passed to the evaluation signal delay device (Fig. 1, 112). In some examples, the

evaluation signal delay device (Fig. 1, 112) includes a latch (316) that stores information to indicate if any one of the firing delay elements (106) associated with that actuator evaluator (110) are in an active state. That is, if any one of the fluid actuators (104) is activated via the delayed fire signal, the latch (316) stores this information. The latch (316) is controlled by a latch control signal (318) which instructs the latch (316) to store data at a particular point in time. The latch (316) aids in maintaining the predetermined time difference between the firing and evaluation of a particular fluid actuator (104). For example, assume four fluid actuators (104) fire for a first actuation event and that the last of those fluid actuators (104) at some time later point in time, for example four actuation events in the future. At that future time, it is desirable to delay the evaluation signals in the same way that the fire signals were delayed for the first actuation event. Accordingly, the state of the fire delay elements (106) is saved off in the latch (316) and applied to the evaluation delay elements (320).

[0061] The evaluation signal delay device (Fig. 1, 112) also includes a delay element (320) to generate the delayed evaluation signal based on the output of a latch (316) and an initial evaluation signal. That is, the initial evaluation signal (322) may indicate when a particular actuator evaluator (110) is to carry out an evaluation on a fluid actuator (104) that was selected by the activation data (315). That is, the initial evaluation signal (322) passes down the evaluation delay chain, touching all primitives, but just those with information stored in a latch (316) will trigger an evaluation. This initial evaluation signal (322) may be offset in time from the initial fire signal (314). However, as the initial fire signal (314) has been delayed, it is beneficial for the initial evaluation signal (322) to similarly be delayed to maintain a predetermined spacing between firing and evaluation of a particular fluid actuator (104).

[0062] Accordingly, the evaluation signal delay device (Fig. 1, 112) includes an evaluation delay element (320) to generate the delayed evaluation signal based on an output of the latch (316) and the initial evaluation signal (322). That is the initial evaluation signal (322) is delayed by the output of the latch (316). As the latch (316) indicates when any of the associated firing delay elements

(106) are active, the output of the latch (316) would enable the evaluation delay element (320) to delay the initial evaluation signal (322) to pass when any of the firing delay elements (106) were active. If none of the associated firing delay elements (106) are active, the output of the latch (316) still passes, just not delayed. In this fashion, the delay chain of the firing system is replicated at the evaluation side to ensure that whatever delay profile is formed during actuation, is replicated along the evaluation chain. Note that as depicted in Fig. 3, the actuator evaluators (110) and evaluation signal delay devices (Fig. 1, 112) are coupled with just those actuator blocks (Fig. 1, 102) of the subset.

[0063] With an actuator evaluator (110) activated via the delayed evaluation signal, the actuator evaluator (110) is prepared to determine a characteristic of a corresponding fluid actuator (104). Accordingly, the actuator evaluator (110) receives information from actuator sensors (326) that are coupled to each fluid actuator (104). That is, the selection of which sensor (326) to couple to the actuator evaluator (110) is controlled by a field-effect transistor (317) having a source connected to a corresponding sensor (326) and a drain connected to the actuator evaluator (110). The gates of the field-effect transistors (317) are connected to the activation data (315). In this way, the activation data (315) connects the sensor (326) plate of the fluid actuator (104) to be actuated to the actuator evaluator (110) via the corresponding field-effect transistor (317).

[0064] The actuator sensors (326) may be drive bubble detectors that detect the presence of a drive bubble within a chamber in which the fluid actuator (104) is disposed. That is, a drive bubble is generated by a fluid actuator (104) to move fluid.

[0065] As a specific example, in thermal inkjet printing, a thermal ejector heats up to vaporize a portion of fluid in an ejection chamber. As the bubble expands, it forces fluid out of a nozzle orifice or through a microfluidic channel. As the bubble collapses, a negative pressure within the ejection chamber draws fluid from the fluid feed slot of the fluidic die (100). Sensing the proper formation and collapse of such a drive bubble can be used to evaluate whether a particular fluid actuator (104) is operating as expected. That is, a blockage will affect the formation of the drive bubble. If a drive bubble has not formed as

expected, it can be determined that the chamber is blocked and/or not working in the intended manner.

[0066] The presence of a drive bubble can be detected by measuring impedance values within the chamber at different points in time. That is, as the vapor that makes up the drive bubble has a different conductivity than the fluid that otherwise is disposed within the chamber, when a drive bubble exists in the chamber, a different impedance value will be measured. Accordingly, a drive bubble detection device measures this impedance and outputs a corresponding voltage. As will be described below, this output can be used to determine whether a drive bubble is properly forming and therefore determining whether the corresponding nozzle or pump is in a functioning or malfunctioning state. This output can be used to trigger subsequent fluid actuator (104) management operations. While description has been provided of an impedance measurement, other characteristics may be measured to determine the characteristic of the corresponding fluid actuator (104).

[0067] The drive bubble detection devices may include a single electrically conductive plate, such as a tantalum plate, which can detect impedance of whatever medium is within the chamber. Specifically, each drive bubble detection device measures an impedance of the medium within the ejection chamber, which impedance measure can indicate whether a drive bubble is present in the chamber. The drive bubble detection device then outputs a first voltage value indicative of a characteristic, i.e., drive bubble formed or not, of the corresponding fluid actuator (104). This output can be compared against a threshold voltage to determine whether the fluid actuator (104) is malfunctioning or otherwise inoperable. Note, that as depicted in Fig. 3, in some examples, the actuator sensors (326) are uniquely paired with a corresponding fluid actuator (104), i.e., fluid pump and/or fluid ejector and that a single actuator evaluator (110) is shared among all the fluid actuators (104) within the subset. In this example, the subset of actuator sensors (326) that correspond to the subset of fluid actuators (104), the actuator evaluator (110) associated with the subset of fluid actuators (104), and an evaluation signal delay device (Fig. 1, 112) coupled

with the actuator evaluator (110) associated with the subset from an actuator evaluation module (328).

[0068] Fig. 4 is a flow chart of a method (400) for fluid actuator evaluation based on a delayed fire signal, according to an example of the principles described herein. According to the method, a fluid actuator (Fig. 1, 104) is activated (block 401) based on a delayed fire signal. Specifically, the fluid actuator controller (Fig. 1, 108) passes activation data, which is based on data in an actuation data register and a mask register. This activation data targets a particular fluid actuator (Fig. 1, 104) during a particular actuation event. This activation data also delays an initial fire signal to the fluid actuator (Fig. 1, 104). That is, the activation data is received at a firing delay element (Fig. 1, 106) which uses the activation data to delay an initial firing signal. This delayed fire signal activates (block 401) the fluid actuator (Fig. 1, 104). For example, in thermal inkjet printing, the heating element in a thermal ejector is heated so as to generate a drive bubble that forces fluid out the nozzle orifice. Doing so generates a sense voltage output by the corresponding actuator sensor (Fig. 3, 326), which output is indicative of an impedance measure at a particular point in time within the chamber.

[0069] A particular actuator evaluator (Fig. 1, 110) is then selected (block 402) for activation. The actuator evaluator (Fig. 1, 110) that is activated corresponds to a particular fluid actuator (Fig. 1, 104) to be evaluated. The selection (block 402) for activation of the actuator evaluator (Fig. 1, 110) is via the initial evaluation signal. A delayed evaluation signal is generated (block 403), which delay is commensurate with, and based on, the delay imposed on a fluid actuator (Fig. 1, 104) during activation. That is, the state of a firing delay element (Fig. 1, 106) is stored in a latch (Fig. 3, 310) and used to gate the initial evaluation signal to generate the delayed evaluation signal. That is the delayed evaluation signal is based on the delayed fire signal, which is indicative of a state of the firing delay element (Fig. 1, 106), and the initial evaluation signal.

[0070] With this signal received, an actuator characteristic (block 404) is evaluated. In this example, the sense voltage is used to determine the characteristic of the fluid actuator (Fig. 1, 104). In some examples, evaluating

(block 404) a characteristic of the fluid actuator (Fig. 1, 104) includes comparing the sense voltage, i.e., the output of the sensor (Fig. 3, 326) against a threshold voltage. In this example, the threshold voltage may be selected to clearly indicate a blocked, or otherwise malfunctioning, fluid actuator (Fig. 1, 104). That is, the threshold voltage may correspond to an impedance measurement expected when a drive bubble is present in the chamber, i.e., the medium in the chamber at that particular time is fluid vapor. Accordingly, if the medium in the chamber were fluid vapor, then the received sense voltage would be comparable to the threshold voltage. By comparison, if the medium in the chamber is print fluid such as ink, which may be more conductive than fluid vapor, the impedance would be lower, thus a lower voltage would be present. Accordingly, the threshold voltage is configured such that a voltage lower than the threshold indicates the presence of fluid, and a voltage higher than the threshold indicates the presence of fluid vapor. If the sense voltage is thereby greater than the threshold voltage, it may be determined that a drive bubble is present and if the sense voltage is lower than the threshold voltage, it may be determined that a drive bubble is not present when it should be, and a determination made that the fluid actuator (Fig. 1, 104) is not performing as expected. While specific reference is made to output a low voltage to indicate low impedance, in another example, a high voltage may be output to indicate low impedance.

[0071] In another example, evaluating (block 404) a characteristic of the fluid actuator (Fig. 1, 104) includes passing multiple instances of the output to a controller for analysis. In this example, the multiple instances, received over time, may be analyzed to determine if the resulting sense profile indicates a healthy functioning fluid actuator (Fig. 1, 104) or a particular actuator malfunction.

[0072] In one example, using such a fluidic die 1) allows for actuator evaluation circuitry to be included on a die as opposed to sending sensed signals to actuator evaluation circuitry off die; 2) increases the efficiency of bandwidth usage between the device and die; 3) reduces computational overhead for the device in which the fluid ejection die is disposed; 4) provides

improved resolution times for malfunctioning actuators; 5) allows for actuator evaluation in one primitive while allowing continued operation of actuators in another primitive; and 6) places management of nozzles on the fluid ejection die as opposed to on the printer in which the fluid ejection die is installed, 7) accommodates for variation in primitive size, and 8) ensures an evaluation delay per fluidic die matches an actuation delay for the fluidic die. However, it is contemplated that the devices disclosed herein may address other matters and deficiencies in a number of technical areas.

[0073] The preceding description has been presented 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

1. A fluidic die comprising:
 - an array of actuator blocks grouped into primitives, an actuator block comprising:
 - a firing delay element to generate a delayed fire signal; and
 - a fluid actuator to be activated via the delayed fire signal;
 - an actuator controller to group actuator blocks into primitives and to activate fluid actuators;
 - an array of actuator evaluators, wherein each actuator evaluator:
 - is grouped with a subset of actuator blocks; and
 - is to evaluate an actuator characteristic of a corresponding fluid actuator based on:
 - an output of an actuator sensor paired with the fluid actuator; and
 - a delayed evaluation signal which is delayed based on the delayed fire signal; and
 - an evaluation signal delay device paired with each actuator evaluator to generate a delayed evaluation signal based on an initial evaluation signal and a state of any firing delay element in the subset.
2. The fluidic die of claim 1, wherein a number of fluid actuators in the primitive is not fixed.
3. The fluidic die of claim 2, wherein the delayed fire signal:
 - is propagated through a number of primitives; and
 - has a delay amount that changes as the number of activated fluid actuators change.
4. The fluidic die of claim 1, wherein the evaluation signal delay device includes:

a latch to store the state of a firing delay element for any fluid actuator of the subset to be evaluated; and

an evaluation delay element to generate the delayed evaluation signal based on an output of the latch and the initial evaluation signal.

5. The fluidic die of claim 1, further comprising an array of actuator sensors, wherein each actuator sensor is paired with a fluid actuator, an actuator sensor to generate a signal indicative of a characteristic of a fluid actuator.

6. A fluidic die comprising:

an array of actuator blocks grouped into primitives, an actuator block comprising:

a firing delay element to generate a delayed fire signal; and

a fluid actuator to be activated via the delayed fire signal;

an array of actuator sensors to generate a signal indicative of a characteristic of a fluid actuator, wherein each actuator sensor is coupled to a respective fluid actuator;

a fluid actuator controller to group actuator blocks into primitive and to activate fluid actuators, wherein the fluid actuator controller comprises:

an actuation data register to store actuation data that indicates fluid actuators to actuate for a set of actuation events; and

a mask register comprising a respective bit for each respective fluid actuator to store mask data that indicates a set of fluid actuators of the array enabled for actuation for a particular actuation event of the set of actuation events;

an array of actuator evaluators, wherein each actuator evaluator:

is grouped with a subset of actuator blocks; and

is to evaluate an actuator characteristic of a corresponding fluid actuator based on:

an output of an actuator sensor paired with the fluid actuator; and

a delayed evaluation signal which is delayed based on the delayed fire signal; and

an evaluation signal delay device paired with each actuator evaluator to generate a delayed evaluation signal based on an initial evaluation signal and a state of any firing delay element in the subset.

7. The fluidic die of claim 6, further comprising an array of nozzles, wherein:

each nozzle comprises a fluid actuator of the array of fluid actuators;

each fluid actuator is a fluid ejector which, when activated, ejects a drop of fluid through a nozzle orifice of the nozzle.

8. The fluidic die of claim 6, further comprising an array of microfluidic channels, wherein:

each microfluidic channel comprises a fluid actuator of the array of fluid actuators; and

each fluid actuator is a fluid pump which, when activated, displaces fluid within the microfluidic channel.

9. The fluidic die of claim 6, further comprising shift logic to shift the mask register upon completion of the particular actuation event to indicate another subset of fluid actuators enabled for actuation for another actuation event of the set of actuation events.

10. The fluidic die of claim 6, wherein the evaluation signal delay is bypassable.

11. The fluidic die of claim 6, wherein the evaluation signal delay device generates a delayed evaluation signal such that a difference between the delayed evaluation signal and the delayed fire signal is the same as a difference between the initial evaluation signal and an initial fire signal.

12. The fluidic die of claim 6, wherein the actuator evaluator and the evaluation signal delay device are coupled with just those fluid actuators of the subset.
13. The fluidic die of claim 6, wherein a subset of the actuator sensors that correspond to the subset of fluid actuators, the actuator evaluator associated with the subset of fluid actuators, and an evaluation signal delay device coupled with the actuator evaluator associated with the subset form an actuator evaluation module.
14. A method comprising:
activating a fluid actuator based on a delayed fire signal to generate a sense voltage measured at a corresponding actuator sensor;
selecting an actuator evaluator grouped with the fluid actuator;
generating a delayed evaluation signal based on the delayed fire signal and an initial evaluation signal; and
determine, upon receipt of the delayed evaluation signal, a characteristic of the fluid actuator based on the sense voltage.
15. The method of claim 14, wherein the initial evaluation signal is offset from an initial fire signal by a predetermined amount.

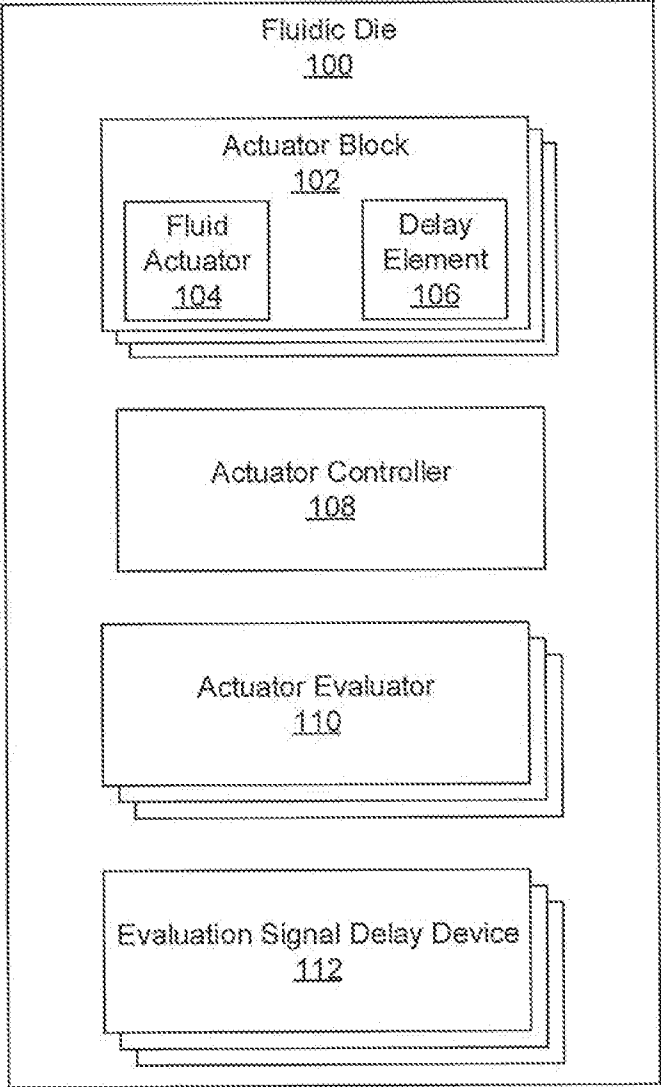
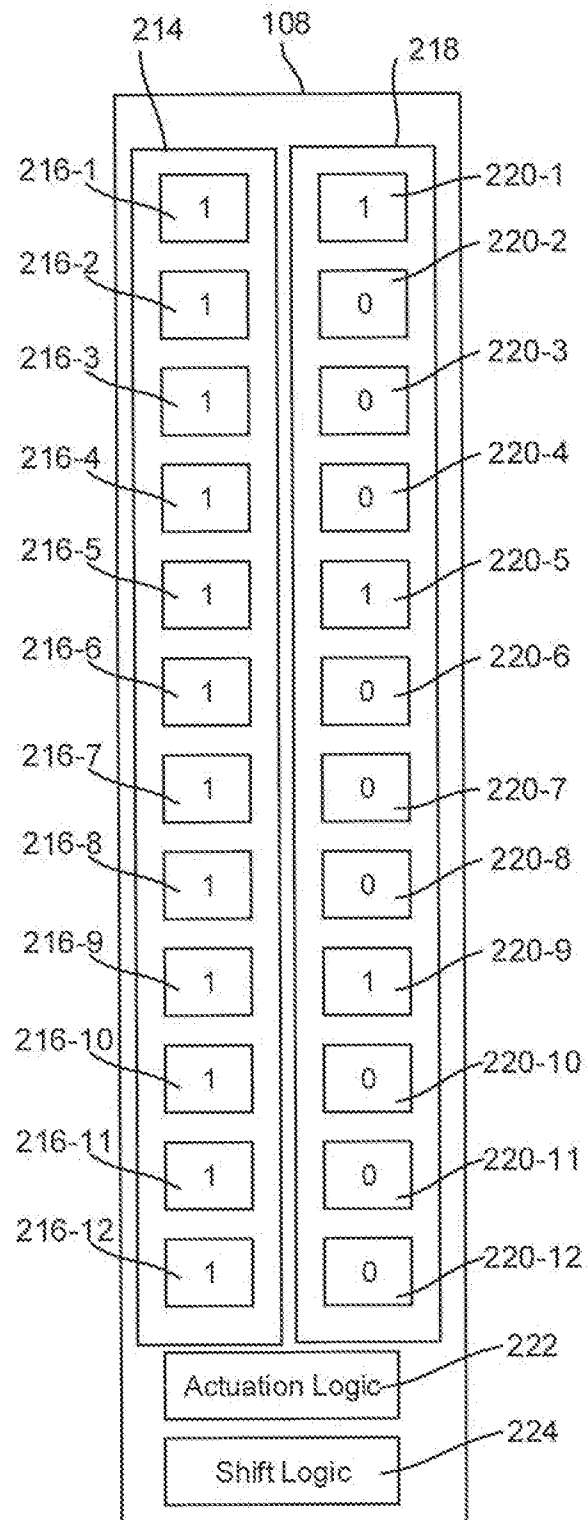
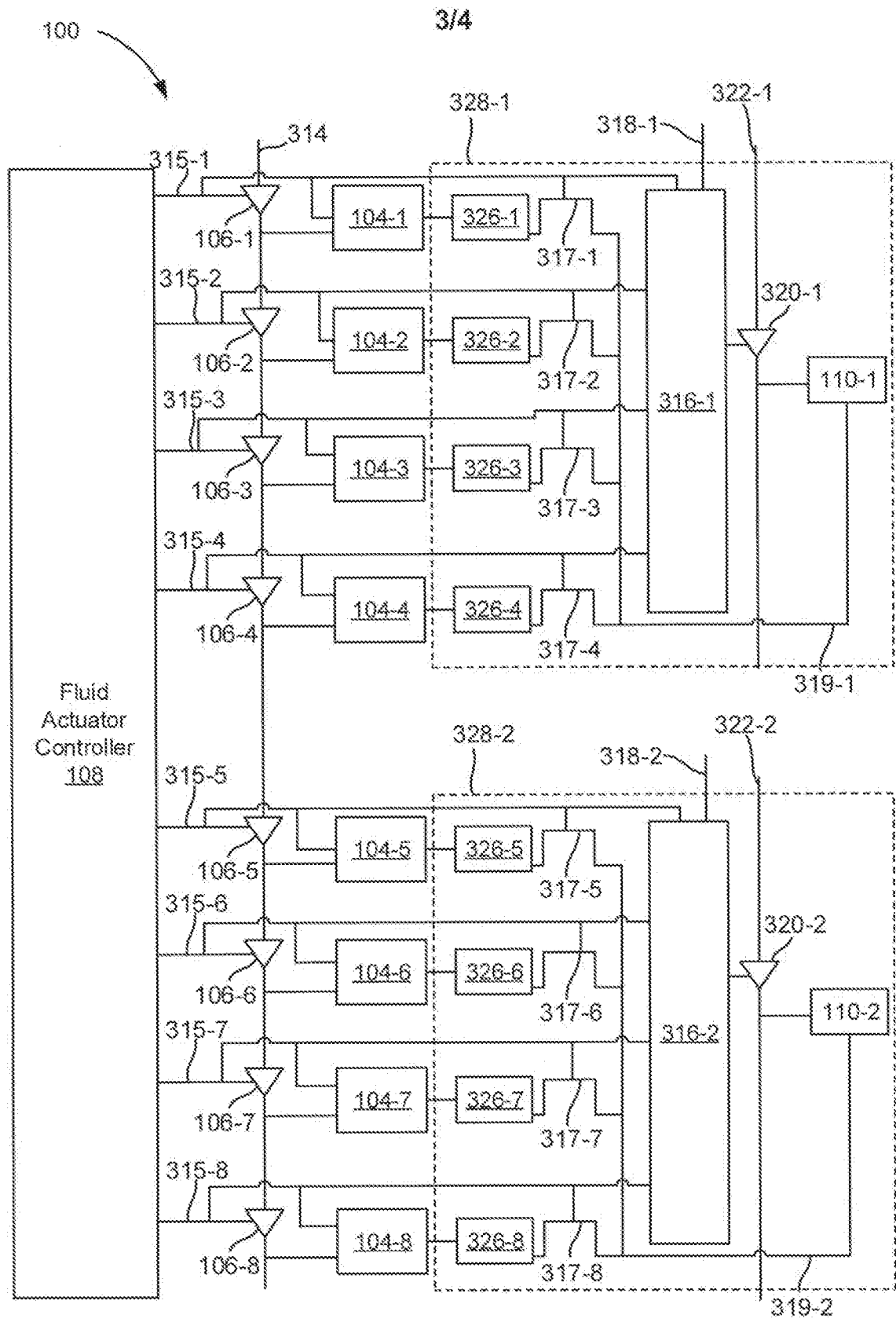


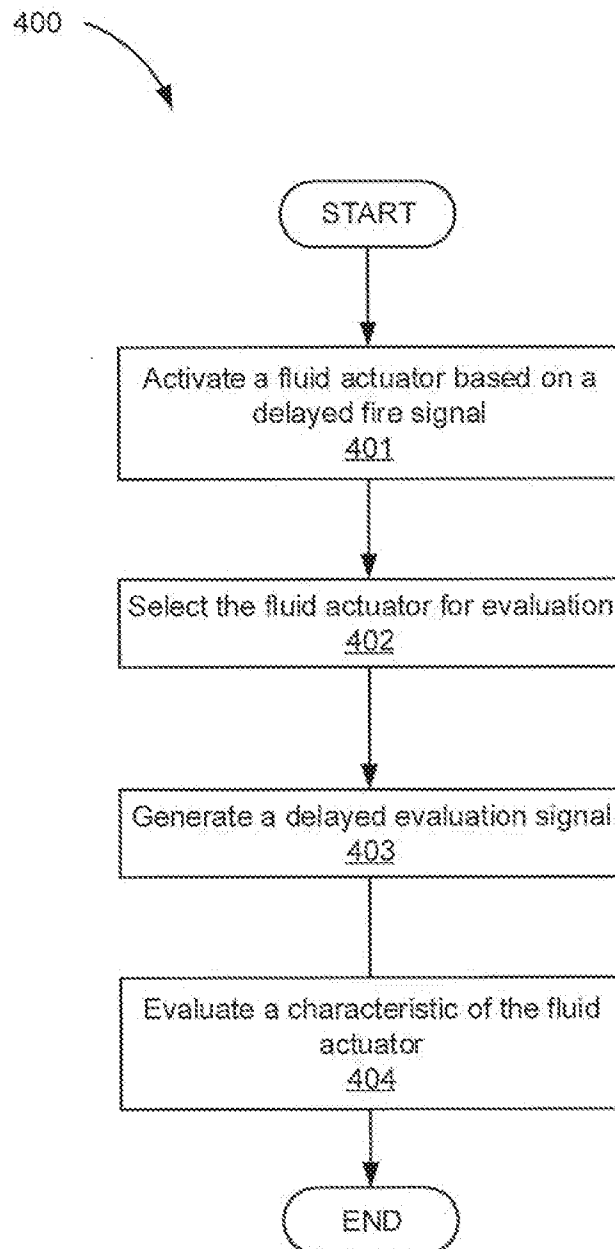
Fig. 1

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**Fig. 2**

**Fig. 3**

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**Fig. 4**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2017/041543

A. CLASSIFICATION OF SUBJECT MATTER		
B41J2/175 (2006.01) B41J2/135 (2006.01) 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 2/00-2/525		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
Espacenet, PatSearch, USPTO, WIPO, Google		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2015/167561 A1 (HEWLETT-PACKARD DEVELOPMENT COMPANY, L.P.) 05.11.2015, paragraphs [0021]-[0029], [0033]-[0039]	1-5, 14
Y		6-13, 15
Y	WO 2015/022018 A1 (HEWLETT-PACKARD DEVELOPMENT COMPANY, L.P.) 19.02.2015, paragraphs [0034]-[0042]	6-7, 11-13
Y	US 7735945 B1 (JOHN W. SLIWA, JR. et al.) 15.06.2010, col.3 lines 3-44	8
Y	WO 96/32267 A1 (EASTMAN KODAK COMPANY) 17.10.1996, p.27 line 6 – p.28 line 20	9, 15
Y	US 4818127 A1 (MANNESMANN AG) 04.04.1989, claim 1	10
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents:	“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
“A” document defining the general state of the art which is not considered to be of particular relevance	“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
“E” earlier document but published on or after the international filing date	“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
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“P” document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search	Date of mailing of the international search report	
11 May 2018 (11.05.2018)	17 May 2018 (17.05.2018)	
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37	Authorized officer P.Bystrov Telephone No. (8-495) 531-65-15	