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(54) Ink-jet print head.

(57) The invention relates to an ink-jet print head which functions according to the drop-on-demand principle. Said print head operates without the ink being subjected to heat and is suited for high resolution. Proceeding from an ink-jet print head having a plurality of ink channels which are separated from each other by walls (8) forming integral units of an insulating housing (11), it is proposed that the surfaces of the separating walls (8), limiting the channels, be provided with conductive coatings (28). In order that a drop be ejected, the coatings (28) associated with the ink channel (16) concerned are pulsewise provided with charges of opposite polarities. Due to the electrostatic attraction forces of the coatings (28), the separating walls (8) limiting the ink channel (16) concerned move toward each other at least partially and cause excess pressure to be produced in the ink channel (16), which leads to the ejection of an ink drop. During printing breaks, readiness for use can be determined by measuring the capacity of the coatings (28) associated with an ink channel (16).

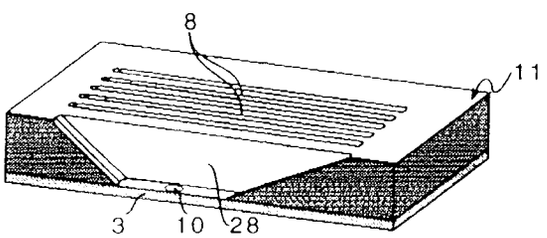


FIG 3

EP 0 611 654 A2

The invention relates to an ink-jet print head having at least one row of adjacent ink channels each of which includes means which can be electrically activated separately and serve for ejecting ink drops from outlets opening associated with each of said channels in accordance with printing data.

From DE 30 12 698, ink-jet print heads are known which function according to the bubble-jet principle. i.e. the electrically activatable element for ejecting ink drops is a heating element which is energized pulsewise. The ink in the ink channel is heated locally so that an ink vapour bubble develops which collapses as soon as the power supply is cut. This bubble causes a pressure wave in the ink channel, which allows an ink jet of a restricted mass to be ejected from the outlet opening onto the surface of a close record carrier.

Although the bubble-jet technology has proved to be useful in practice, the chemistry of the ink causes a number of problems. On the one hand, the ink used must necessarily consist of a mixture of substances with evaporating capacities in order that the vapour bubble be produced on which the bubble-jet principle is based, and on the other hand the ink has to meet permanently all the requirements regarding color saturation, long-term stability, fastness properties, drying behaviour and resistance against wiping despite the fact that the ink is heated.

Usually, such ink material mainly consists of water which lends the ink properties which interfere with the requirements for resistance against wiping and fastness.

In order to be able to also use inks of different compositions such as water-free inks, it is known for the walls confining each channel to be moved mechanically thus causing a pressure wave which leads to the ejection of an ink drop. EP 0 278 590 relates to an electrically pulsed drop depositing device whose channel partition walls are tongue-shaped piezo elements fixed to one side of said walls. When two piezo elements which limit an ink channel are electrically activated, their free ends shift towards each other in a transverse direction and thus produce in the ink channel concerned the pressure wave required.

However, the microstructural working of piezo chrystals by using known operating methods is very costly and cannot be realized in ink-jet print heads of high resolution.

Moreover, WO 91/17891 discloses an ink-jet print head of the bubble-jet type which consists of one integral piece made of a silicon block by anisotropic etching. In addition to the aforementioned disadvantages of bubble-jet technology, ink-jet print heads of this type need a lot of energy, produce a progressively growing amount of cross-stalk as their resolution increases, and a high mechanical and thermal load on the actuating elements. Besides, it is very complicated and unreliable to determine the readiness for use if sensors are used which are heating elements.

It is therefore the object of the invention to create an inkjet print head where the ink is not thermally influenced in order that ink drops be ejected, which is suitable for high resolution, can be produced by known means in a simple and inexpensive way, uses little energy and where each actuating element also functions as a sensor for determining the readiness for use.

This problem is solved by an ink-jet print head whose separating walls are designed as resilient carriers of the electrodes of a capacitor, said electrodes being applied in the form of an electrically conductive insulated coating.

The material which is electrically insulating towards the outside is either an insulator, a semiconductor with surface passivation or a conductor provided with an insulating layer.

The conductive coatings which are arranged in a channel are insulated from each other electrically and connected to output terminals of a pulse supplying device and to input terminals of a device for determining the readiness for use.

In a further embodiment of the invention, the coatings of a wall separating the channels are each short-circuited.

When the coatings associated with an ink channel are provided with different charges, an electrostatic field develops which exerts tensile forces on the walls confining the ink channel and separating the individual channels so that said walls at least partially move towards each other. This movement causes excess pressure to be produced in the ink channel concerned, said pressure being relieved as soon as a predetermined amount of ink has been ejected.

When the coatings associated with an ink channel receive identical charges, an electrostatic field develops which exerts tensile forces on the walls confining and separating the ink channels so that said walls at least partially move away from each other. This movement causes a vacuum to be produced in the ink channel concerned, said vacuum leading to the ink channel concerned to be refilled promptly.

The amplitude of the operating voltage required for drop ejection decreases with the square of the distance between the walls separating the channels. This ink-jet print head is thus particularly suitable for very high resolutions, especially resolutions exceeding 300 dpi.

During printing intervals which can also be the time between two directly successive print dots, the conductive coatings are used to control the

readiness for use of the ink channel concerned. For this purpose, the coatings on the walls which confine an ink channel and separate the individual channels serve as capacitor plates with a dielectric medium between them. When ready for operation, this dielectric medium is ink, and in the case of disturbances it is air.

The surface and the distance between associated capacitor plates are known in the case of a given ink-jet print head and so are the dielectricity constants of air and of the ink used. Readiness for use is determined by measuring the capacity of the capacitor thus formed.

The invention will be explained in the following with reference to embodiments and the drawings in which

- Fig. 1 is a schematic diagram of an ink jet print head particularly suited for use with the invention,
- Fig. 2 is a perspective view of a chip with a cover plate,
- Fig. 3 is a perspective view of the chip,
- Fig. 4 are partially sectional views of the chip,
- Fig. 5 is a perspective view of a chip with outlet openings arranged in a row,
- Fig. 6 a perspective view of a chip with outlet openings alternately offset, and
- Fig. 7 is a schematic view of the forces acting on the walls separating the channels.

Fig. 1 is a perspective view of an ink-jet print head. Said head essentially consists of only two parts to be combined, namely of a chip 11 which includes the actuating elements, the electric lead wires and the contact points 9 for the electric connection as well as the outlet openings 10, and of an ink supply container 12 to which the chip is attached and joined. The actuating elements not illustrated in this schematic diagram, namely the electric lead wires, the contact points 9 and the outlet openings 10 can be manufactured in a number of planar processing steps to form a single chip 11 preferably consisting of silicon.

The ink supply container 12 into which a medium such as a sponge 13 soaked with ink is inserted has a rectangular configuration. On the upper side of the ink supply container 12 facing the chip 11, outlet openings with filters 14 are provided in the form of two supply channels 15. Said supply channels 15 extend parallel with each other in the longitudinal direction of the ink supply container 12 such that when a chip 11 has been mounted, they are in flow connection with the outlet openings 10 via ink channels 16. The chip 11 is mounted on the ink supply container 12 in a simple manner by using mounting clamps 17 which are arranged on the longitudinal sides of the ink supply container 12 and serve as a mechanical connection and, via contact points 9, as an electrical contact.

In order to increase its efficiency, the ink-jet print head 24 is provided with a cover plate 2 arranged between the 11 and the ink supply container 12.

Fig. 2 is a perspective view of such a cover plate 1 prior to its mounting on chip 11. Cover plate 1 has elongate openings 2 which extend parallel with each other and which cover the marginal areas of the ink channels 16 in chip 11.

In the direction of ink ejection, the ink channels 16 are sealed by a membrane 3 which comprises the outlet opening 10.

Cover plate 1 consists e.g. of glass, silicon or ceramics and is anodically bonded to chip 11. However, cover plate 1 could also be made of a platic sheet adapted to be laminated onto the plate or to be self-adhesive. The latter embodiment which does not require any other technical means ensures in particular that the joint between chip 11 and the ink supply container 12 is leakproof.

To more clearly explain the invention, Fig. 3 is a perspective separate view of the chip 11 of the ink-jet print head 24. The ink channels 16 are separated from each other by walls 8 which are provided on both sides with a conductive coating 28, preferably a metal layer which is applied together with the leads to the contact points 9.

Fig. 4 shows sectional views along lines I-I and II-II of Fig. 1.

Fig. 4a is a sectional view of chip 11 along line I-I of Fig. 1 and shows in particular the geometric design of an ink channel 16 with parallel walls which terminate in inclined zones 30.

As can be inferred from Fig. 3, a thin layer seals the nozzle of the ink channel 16. This layer is designed as a membrane 3 which is provided with outlet openings 10.

According to Fig. 2, chip 11 comprises a cover plate 1 on its side facing the ink supply container 12. Said cover plate 1 has openings 2 which are arranged at the points where the ink channels 16 and the supply channels 15 overlap. The cross-sectional surface of the openings 2 may be as big as the section resulting from the overlapping of the ink channel 16 and the supply channel 15 concerned.

Fig. 4b shows a sectional view of an ink-jet print head along line II-II of Fig. 1. The walls 8 which separate the channels and are coated on both sides with a conductive coating 28 are arranged between the individual trapezoidal ink channels 16. Membrane 3 includes outlet openings 10 which are each associated with one of the ink channels 16. In the direction of the ink supply container 12 not illustrated, the ink channels 16 are limited by a cover plate 1.

Fig. 5 shows a chip 11 in which ink channels 16 are configured which are covered by a membrane 3. In said membrane 3, the outlet openings 10 are arranged such that every ink channel 16 is associated with an outlet opening 10. In the simplest case illustrated in Fig. 5 all outlet openings 10 are arranged in a row which extends transversely to the longitudinal extension of the ink channels 16. The outlet openings 10 are preferably aligned in the middle of the ink channel 16 concerned.

When the ink-jet print head 24 and a record carrier move continuously relative to each other, the print dots recorded through directly adjacent ink channels 16 are offset because only every other ink channel 16 can be activated at a time. Due to this offsetting, the distance between adjacent print dots on the record carrier increases in an advantageous manner. This distance is required for recordings on overhead transparencies and corresponds to the draft mode .

In a further modification of the invention, the outlet openings 10 are alternately arranged in two parallel rows. This embodiment is illustrated in Fig. 6 which corresponds to Fig. 5 except for the arrangement of the outlet openings 10. The two rows of outlet openings 10 are preferably aligned symmetrically with the center line of the ink channels 16.

Directly adjacent ink channels 16 are activated one after the other. When the ink-jet print head 24 and a record carrier move continuously relative to each other, the outlet openings 10 which are positioned at the front in the direction of relative movement of the ink-jet print head 24, carry out the recording operation, and after a time interval which corresponds to the quotient of the distance between the parallel rows of outlet openings 10 and the speed at which the ink-jet print head 24 moves relative to the record carrier, those ink channels 16 are activated whose outlet openings 10 are arranged at the rear in the direction of movement. Thus, print dots can be placed on points of intersection of an orthogonal grid at a high recording speed.

The ink-jet print head according to the invention can be operated with a bi-polar control voltage. In the simplest case, a positive voltage (+) to ground (0) is provided. Fig. 7 shows a section of an ink-jet print head whose ink channels 16 are each associated with two control terminals. In the case of the ink channels with the reference numerals 16/1, 16/3 and 16/5, the two coatings carry positive charges. The coatings of ink channels 16/2, 16/4, 16/6, 16/7 and 16/9 are discharged. The coatings of the ink channel 16/8 have different potentials. Due to the activation chosen, a full direct vacuum is produced in ink channels 16/1, 16/3 and 16/5 and a full indirect excess pressure in ink channels 16/2 and 16/4 which leads to ink drops being ejected. In the ink channel 16/8, a full direct excess pressure is produced which leads to ink drops being ejected, and in ink channels 16/5, 16/7 and 16/9 half an indirect vacuum is produced.

Direct vacuum or excess pressure means that the pressure ratio is based on the difference in the potential of the coating associated with the ink channel concerned. An indirect excess pressure or vacuum in an ink channel is caused by differences in the potential of coatings of adjacent ink channels. Half an excess pressure does not lead to drop ejection.

During breaks in the printing operation, the capacity of the individual ink channels can be measured and it can thus be detected whether or not ink is still present in the ink channel concerned, i.e. whether or not the ink channel is ready for operation or whether or not air has intruded the ink channel because of obstructions, lack of ink or other disturbances.

In the case of an ink-jet print head which is adapted to produce a resolution of 600 dpi, the distance between the coatings of each channel amounts to about 15 μm. For producing a pressure of about 1 bar, a pulse voltage of about 250 V is required between the coatings of an ink channel. With the surface of the coating being about 0.6 x 10^{-6} m^2, the two coatings of a channel filled with ink have a capacity of about 30 pF and require an energy supply of about 0.9 μJ for ejecting an ink drop. A comparable bubble-jet print head requires at least 30 μJ per drop ejection.

The ink channels are formed, for example, in a known manner in that the plane 110 is anisotropically etched in silicon. Subsequently, the surface of the walls separating the individual channels is oxydized or nitrified. The coatings are produced by evaporization and galvanization. Finally, an insulating protective layer such as silicon oxyde or silicon nitrite is applied to the coatings.

Claims

1. Ink-jet print head consisting of an electrically insulating housing (11) with a plurality of ink channels (16) arranged parallel with each other,

- each channel being associated with an outlet opening (10),
- being separated from adjacent channels by separating walls (8),
- being in flow connection with an ink supply container (12), and
- comprising electrically actuable means for drop ejection,

the separating walls (8) and the housing (11) being formed as an integral unit,

characterized in that the separating walls (8) are designed as resilient carriers of the electrodes of a capacitor, said electrodes being applied in an insulating manner in the form of an electrically conductive coating (28).

2. Ink-jet print head according to claim 1, characterized in that the electrically insulating housing (11) consists of a material which is either an insulator, a surface-passivated semiconductor or a conductor provided with an insulating layer.

3. Ink-jet print head according to claims 1 and 2, characterized in that the coatings (28) associated with an ink channel (16) are insulated from each other and connected to output terminals of a pulse supplying device and to input terminals of a device for determining the readiness for use.

4. Ink-jet print head according to claim 1 or 3, characterized in that the coatings (28) of each separating wall (8) are short-circuited.

5. Ink-jet print head according to one of claims 1 to 4, characterized in that the outlet openings (10) are arranged in one row and normal and centrally to the longitudinal extension of the ink channels (16).

6. Ink-jet print head according to one of claims 1 to 4, characterized in that the outlet openings (10) are alternately arranged in two parallel rows which are symmetrical to the normal of the longitudinal extension of the ink channels (16).

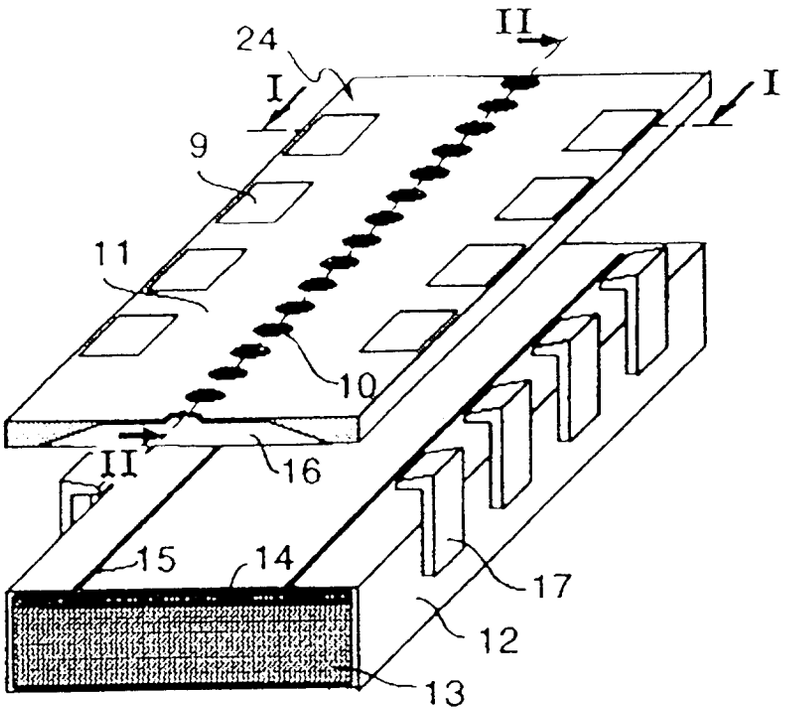


FIG 1

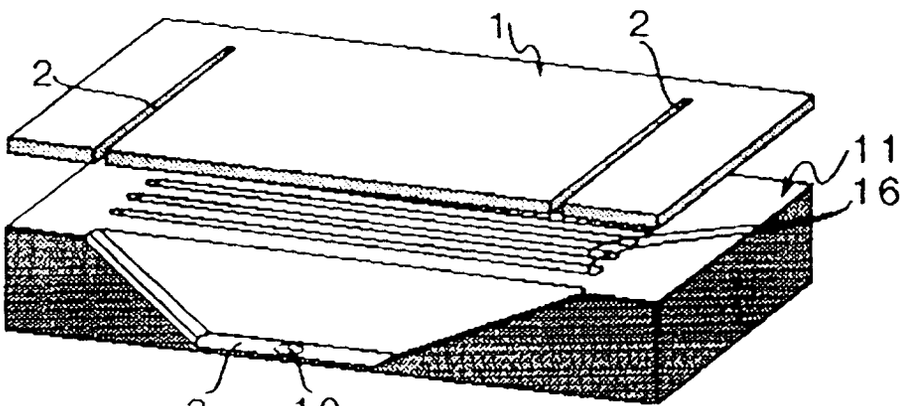


FIG 2

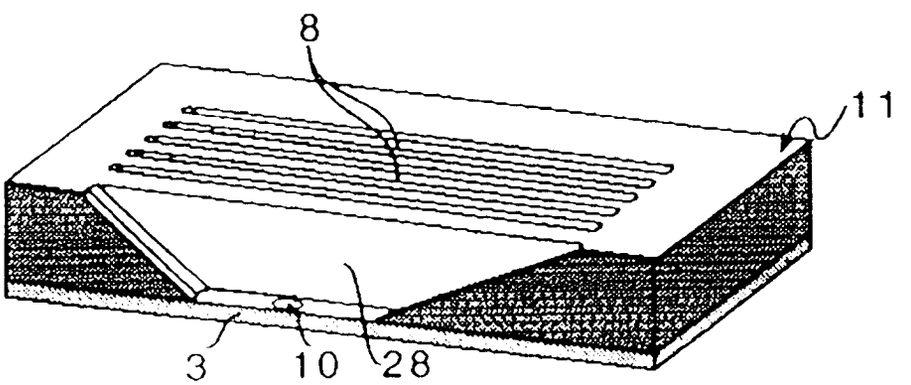


FIG 3

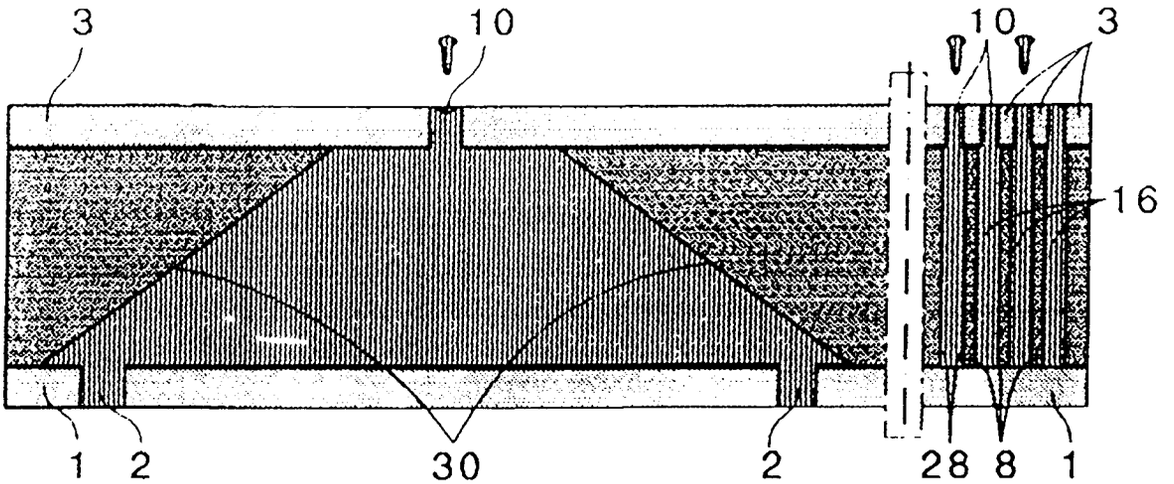


FIG 4

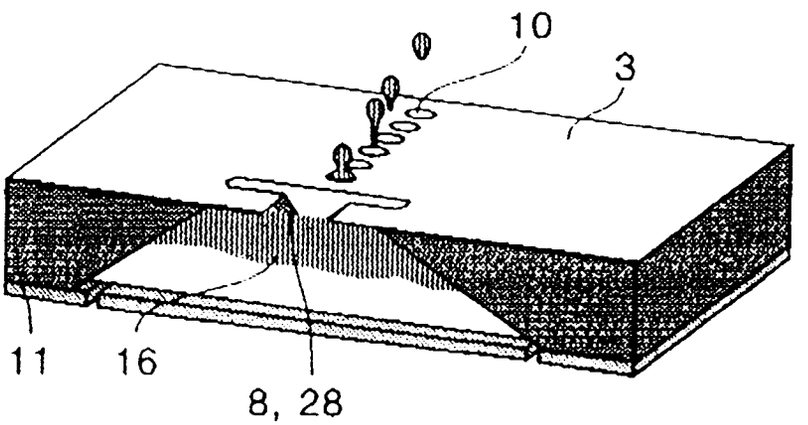


FIG 5

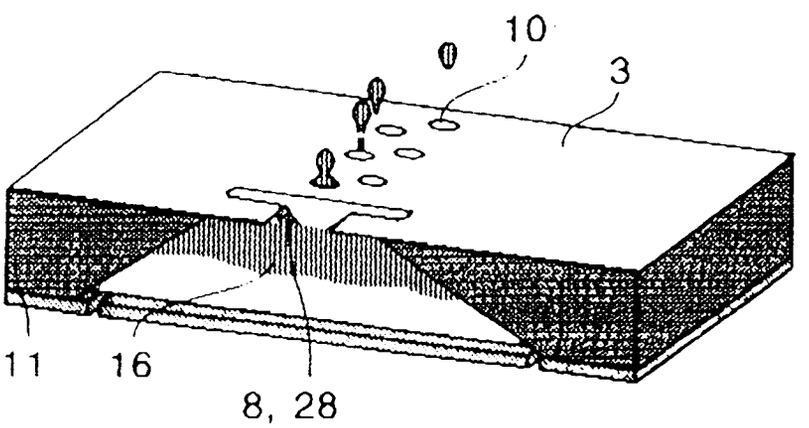


FIG 6

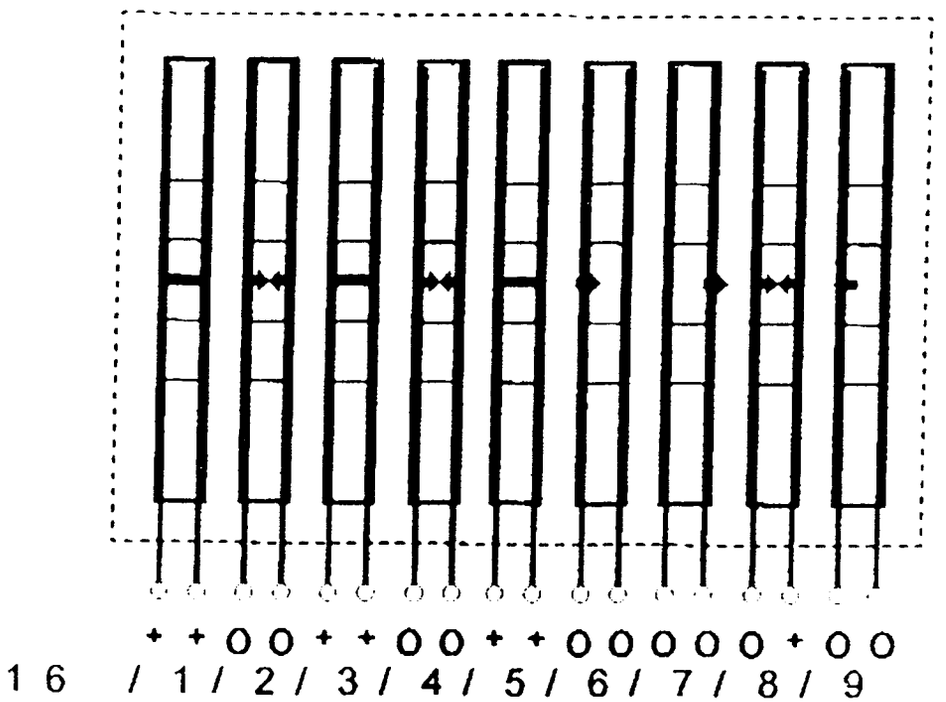


FIG 7