

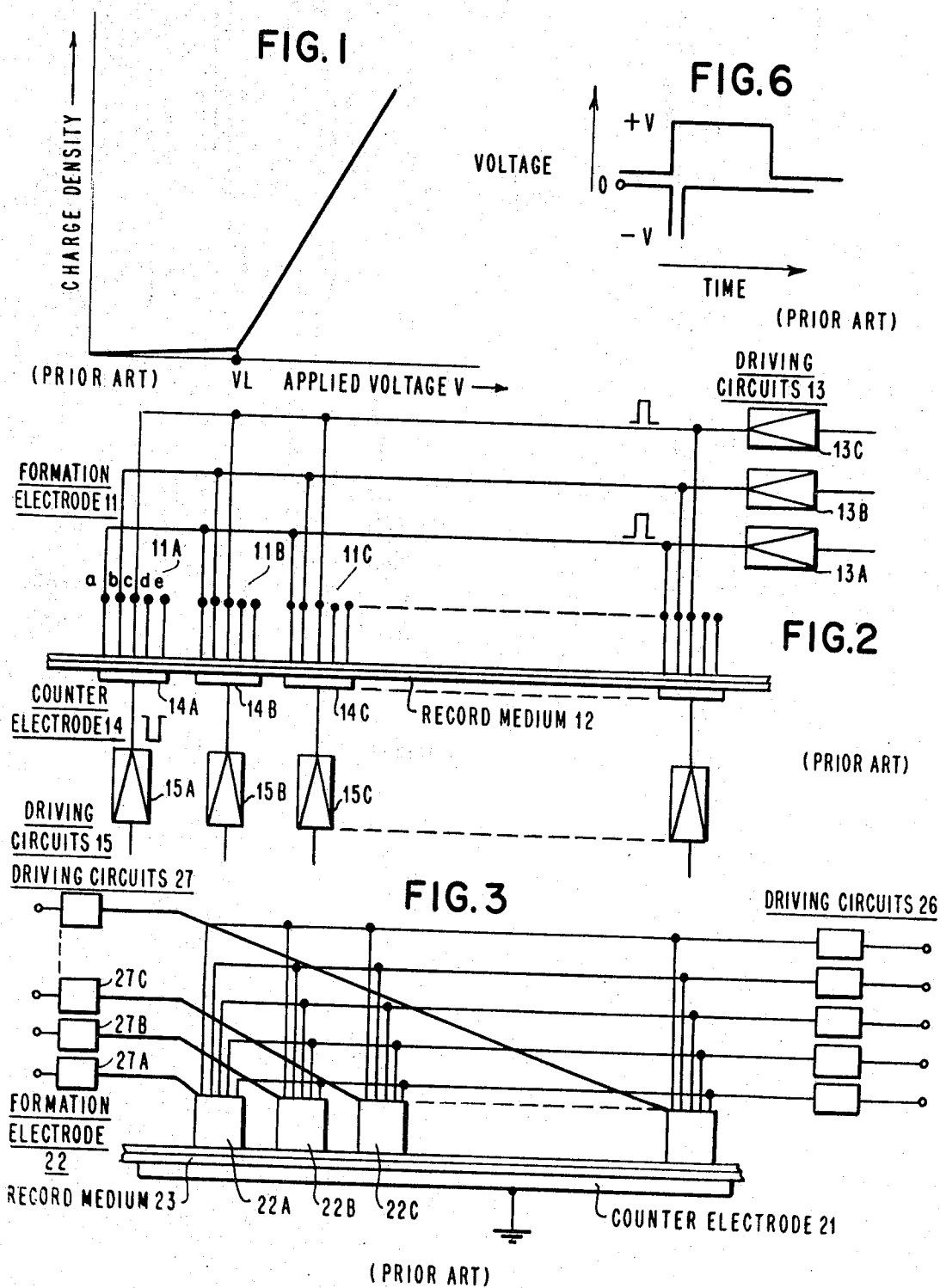
Feb. 16, 1971

KENMI TSUKATANI ET AL
ELECTROSTATIC PRINTING APPARATUS

3,564,556

Filed Feb. 20, 1969

3 Sheets-Sheet 1



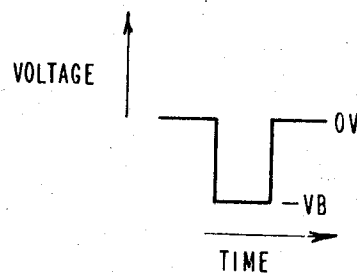
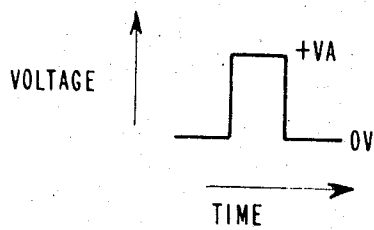
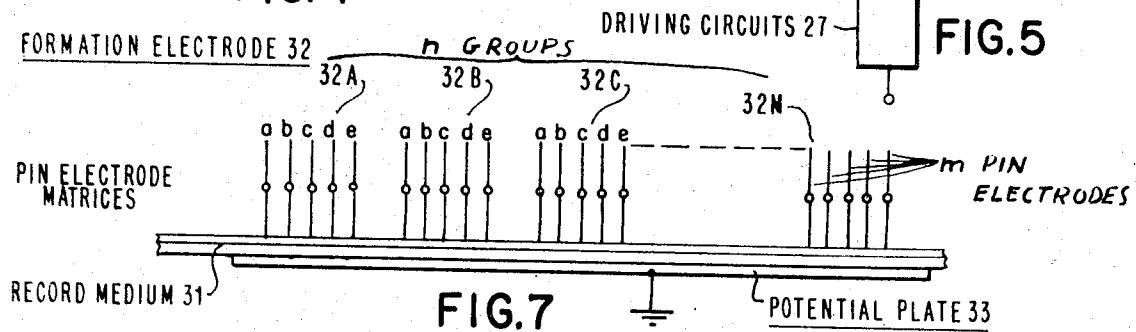
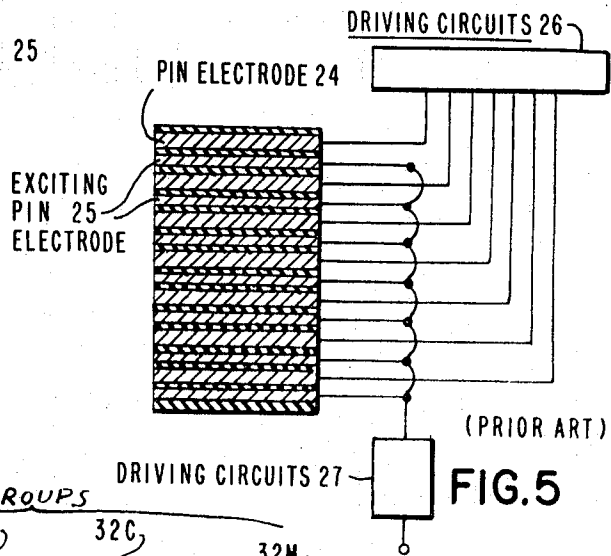
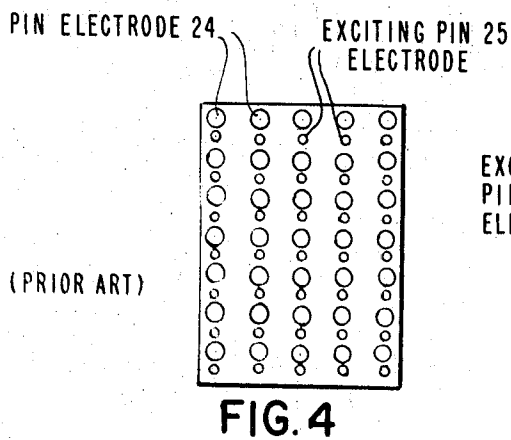
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PIN DRIVING CIRCUITS 34

COLUMN DRIVING CIRCUITS 35

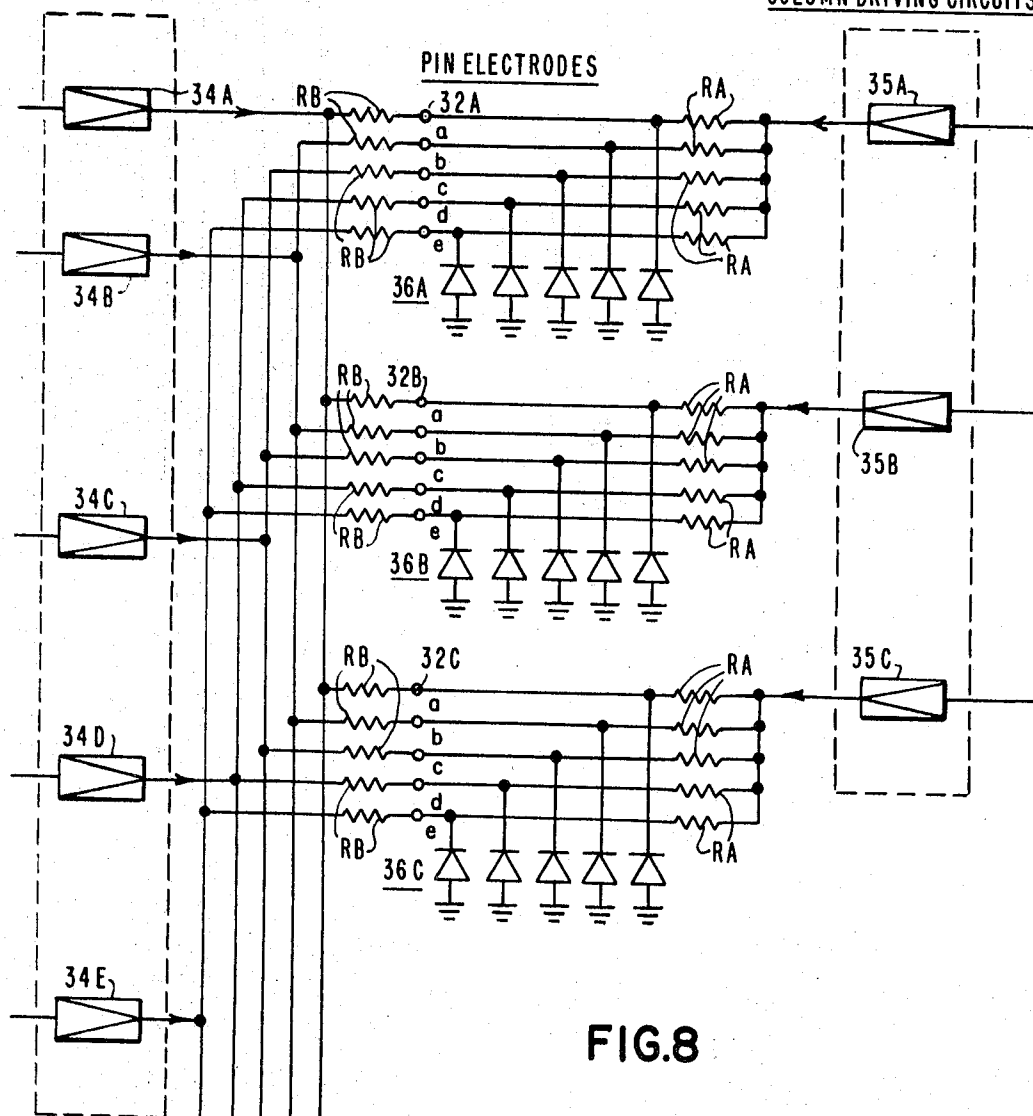


FIG.8

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ELECTROSTATIC PRINTING APPARATUS

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Int. Cl. G01d 15/06; H04I 15/34

U.S. Cl. 346—74

7 Claims

ABSTRACT OF THE DISCLOSURE

Each of n groups of pin electrodes comprises m pin electrodes for printing n columns in a line, each column including m pin electrodes. m pin driving circuits are connected to and drive the pin electrodes and n column driving circuits are connected to and drive the pin electrodes with a signal of opposite polarity. Each of a plurality of clamping circuits clamps a corresponding one of the pin electrodes to a potential between it and a potential plate lower than a no-printing threshold level. The pin electrodes are selectively driven by signals supplied by only one of the pin driving and column driving circuits to print an electrostatic image on a record medium interposed between the pin electrodes and the potential plate. The signals have a polarity which is not clamped by the clamping circuits.

DESCRIPTION OF THE INVENTION

The present invention relates to electrostatic printing apparatus.

The apparatus of the present invention prints or produces an electrostatic latent image on a record medium interposed between a plurality of pin electrodes and a potential plate. An electrostatic latent image may be produced on a record medium in an electrostatic printing process when the record medium comprises a thin layer of highly insulating material and is positioned between spaced electrodes. When a voltage is applied between the electrodes, an electrostatic charge image is produced on the record medium.

The principal object of the present invention is to provide a new and improved electrostatic printing circuit.

An object of the present invention is to provide an electrostatic printing circuit having a simple structure.

An object of the present invention is to provide an electrostatic printing circuit with a smaller number of components than known circuits of similar type.

An object of the present invention is to provide electrostatic printing apparatus which functions with effectiveness, efficiency and reliability.

In accordance with the present invention, electrostatic printing apparatus comprises n groups of pin electrodes. Each group of pin electrodes comprises m pin electrodes for printing n columns in a line. Each of the columns includes m pin electrodes. Each of m and n is a whole number. A potential plate is spaced from and in operative proximity with the pin electrodes. A record medium is interposed between the pin electrodes and the potential plate. The pin electrodes print an electrostatic image on the record medium. The pin electrodes and the potential plate have a threshold voltage level beneath which there can be no printing by the pin electrodes on the record medium. m pin driving circuits are connected to the pin electrodes, each simultaneously driving a corresponding one of the pin electrodes of each of the groups of pin electrodes. n column driving circuits are connected to the pin electrodes, each supplying a signal of a polarity opposite that of the pin driving circuits to the pin electrodes

of a corresponding one of the columns. Each of a plurality of clamping circuits is connected to a corresponding one of the pin electrodes for clamping the pin electrodes so that the potential difference between the pin electrodes and the potential plate becomes lower than the threshold level. The pin electrodes are selectively driven by signals supplied from only one of the pin driving circuits and the column driving circuits to print an electrostatic image on the record medium. The signals have a polarity which is not clamped by the clamping circuits.

Each of the pin electrodes driven by the pin driving circuits corresponds to the others in its column. Each of the pin driving circuits is connected to each of the corresponding pin electrodes via a resistor. Each of the column driving circuits is connected to each of the corresponding pin electrodes via a resistor. Each of the clamping circuits comprises a diode.

In order that the present invention may be readily carried into effect, it will now be described with reference to the accompanying drawings, wherein:

FIG. 1 is a graphical presentation of the applied voltage versus the charge density of an electrostatic charge image produced by known electrostatic printing apparatus;

FIG. 2 is a schematic diagram of an embodiment of known electrostatic printing apparatus;

FIG. 3 is a schematic diagram of another embodiment of known electrostatic printing apparatus;

FIG. 4 is a diagram of a pin electrode matrix;

FIG. 5 is a schematic diagram, partly in section, of known electrostatic printing apparatus utilizing the pin electrode matrix of FIG. 4;

FIG. 6 is a graphical presentation of the voltage applied to the pin electrodes of the matrix of FIGS. 4 and 5;

FIG. 7 is a schematic diagram of an embodiment of the electrostatic printing apparatus of the present invention;

FIG. 8 is a schematic diagram of the embodiment of the electrostatic printing apparatus of the present invention schematically shown in FIG. 7;

FIG. 9 is a graphical presentation of the voltage for forming the printed pattern in the embodiment of FIGS. 7 and 8; and

FIG. 10 is a graphical presentation of the voltage for positioning the column in the embodiment of FIGS. 7 and 8.

In the figures, the same components are identified by the same reference numerals.

In FIG. 1, the abscissa represents the applied voltage V and the ordinate represents the charge density of an embodiment of known electrostatic printing apparatus. The applied voltage is applied to a record medium and the charge density is that of the electrostatic image produced on said record medium. As illustrated in FIG. 1, the charge density increases proportionately with the applied voltage when said applied voltage is greater than a critical or threshold point or level V_L .

There can be no production of an electrostatic charge image when the applied voltage V is lower than the critical voltage V_L . Generally, in the production or printing of an electrostatic image, corona discharge is of considerable influence in the initial stages of the production of the image. For this reason, it is known that the image production voltage is decreased if the image is produced in an atmosphere which readily permits the production of corona. The voltage required to produce corona is greater than that required to maintain a corona discharge, so that, utilizing this principle, an image producing system may apply a high voltage only at the time of production of corona.

If the corona principle is utilized, the production of an electrostatic charge image comprises positioning a record medium such as, for example, a sheet of paper

coated with a thin layer of film or highly insulating material, between a pair of spaced electrodes. One of the electrodes is a formation or pattern-forming electrode such as, for example, a character or pattern electrode or a pin electrode matrix. The formation electrode determines the pattern or configuration of the electrostatic image by signals. The other of the pair of electrodes is a counter electrode and applies voltages of the reverse polarity between said pair of electrodes, distributed in a manner whereby the resultant sum of said voltages may exceed the critical or threshold voltage level VL and produce the electrostatic image.

FIG. 2 shows an embodiment of known electrostatic printing apparatus in the embodiment of FIG. 2, a formation electrode 11 is positioned in operative proximity with a record medium 12 and comprises a plurality of groups or columns of pin electrode matrices 11a, 11b, 11c Each pin electrode matrix comprises a plurality of pin electrodes a, b, c, d and e. The pin electrodes of each group of pin electrodes a, b, c, d and e are electrically connected in common to corresponding driving circuits 13A, 13B and 13C, and so on, of a plurality of driving circuits 13.

The driving circuit 13A is thus connected to and drives the first pin electrode a of each of the pin electrode matrices 11A, 11B, and so on, of the formation electrode 11. The driving circuit 13B is electrically connected to and drives the second pin electrode b of each pin electrode matrix 11A, 11B, 11C, and so on, of the formation electrode 11. The driving circuit 13C is electrically connected to and drives the third pin electrode of each of the pin electrode matrices 11A, 11B, and so on, of the formation electrode 11. Additional driving circuits, not shown in FIG. 2, are connected to and control the remaining pin electrodes in the aforescribed manner.

A counter electrode 14 is spaced from the formation electrode 11 and the record medium 12 is interposed between said counter electrode and said formation electrode. The counter electrode comprises a plurality of counter electrodes 14A, 14B, 14C, ... Each counter electrode 14A, 14B, 14C, and so on, is positioned in operative proximity with a corresponding one of the pin electrode matrices 11A, 11B, 11C, and so on The counter electrodes 14A, and so on, are driven by a plurality of driving circuits 15. The driving circuits 15 comprise a plurality of driving circuits 15A, 15B, 15C The driving circuit 15A is electrically connected to and drives the counter electrode 14A, and so on.

To produce an electrostatic charge image, the driving circuits 13 apply to the formation electrode 11 a voltage corresponding to the pattern to be produced. Simultaneously, the driving circuits 15 apply a voltage of the reverse or opposite polarity to the counter electrode 14. The pin electrodes of the formation electrode 11 have voltage applied to them selectively in accordance with the pattern to be produced and the counter electrodes of the counter electrode 14 have the opposite voltage applied to them in accordance with the required column position. This process is successively repeated, column by column, until the production or printing of one line is completed. Since this embodiment designates the position of the column in which the pattern or character is printed by controlling the counter electrode, it is generally referred to as the back face control system. The advantages of the back face control system are that the electrodes may be readily and facily provided and only a few electrode driving circuits are required.

Another embodiment of known electrostatic printing apparatus, as shown in FIG. 3, produces or prints an electrostatic image by utilizing the principle that the initial voltage for producing a corona discharge is greater than that required to maintain such discharge. In the embodiment of FIG. 3, a single counter electrode 21 is provided in spaced relation with a formation electrode 22. A record medium 23 is interposed between the formation electrode

22 and the counter electrode 21. The formation electrode 22 comprises a plurality of groups 22A, 22B, 22C . . . of pin electrode matrices.

Each of the groups 22A, 22B, 22C, and so on, of pin electrode matrices comprises a plurality of pin electrodes 24 and a plurality of exciting pin electrodes 25, as shown in FIGS. 4 and 5. The pin electrodes 24, in the embodiment of FIGS. 4 and 5, are arranged in alternate rows or columns and the exciting pin electrodes 25 are also arranged in alternate rows or columns interposed between adjacent rows or columns of pin electrodes. Thus, the rows or columns of pin electrodes 24 and exciting pin electrodes 25 alternate.

A plurality of driving circuits 26 are electrically connected to and drive the pin electrode matrices 22A, 22B, 22C, and so on, in the manner of the embodiment of FIG. 2. FIG. 5 illustrates a circuit for driving a single pin electrode matrix. A plurality of driving circuits 27, comprising driving circuits 27A, 27B, 27C . . . , are connected to and drive the exciting pin electrodes of the pin electrode matrices 22A, and so on, of the formation electrode 22. Thus, the driving circuit 27A is connected to and drives the exciting pin electrodes 25 of the pin electrode matrix 22A, the driving circuit 27B is connected to and drives the exciting pin electrodes 25 of the pin electrode matrix 22B, and so on. The counter electrode 21 is connected to ground.

If a positive voltage +V is applied to the pin electrodes 24 of the pin electrode matrices 22A, and so on, in accordance with the pattern to be produced on the record medium 23 by electrostatic charge image, and a voltage of opposite polarity -V is simultaneously applied to the exciting pin electrodes 25 of said pin electrode matrices in the appropriate areas corresponding to the position of the column, a voltage sufficiently high to initiate a corona discharge is applied to said pin electrode matrices. Consequently, the production of a corona discharge is expedited and the corona discharge is thereafter maintained by the voltage applied to the pin electrodes 24, so that the electrostatic image is produced.

In the embodiment of FIGS. 3, 4 and 5, there is no need for a plurality of counter electrodes in position for each of a plurality of columns. It is only necessary to provide the single counter electrode 21 in position for all the columns. The electrostatic image is produced by grounding or by applying a constant bias voltage to the counter electrode 21.

The known electrostatic printing apparatus disclosed in FIGS. 3, 4 and 5, is referred to as a front face control system since the pattern or configuration of the electrostatic image is determined on the formation electrode side of the record medium 23. In this apparatus, however, the pin electrode matrices are complicated and have complex structures. Furthermore, the control of the excitation voltage applied to the exciting pin electrodes 25 and the period of application of such voltage must be undertaken under considerably rigid conditions.

In accordance with the present invention, electrostatic printing apparatus is provided which produces an electrostatic charge image. The apparatus is of single pin electrode matrix front face control type and is different from the apparatus of know types hereinbefore described. In the apparatus of the present invention, the formation electrode is of simple structure. There is no necessity for designating the position of the column for printing via the counter electrode. The electrostatic printing apparatus of the present invention is shown in, and described with reference to, FIGS. 7, 8, 9 and 10.

In FIG. 7, a record medium 31 is interposed between a formation electrode 32 and a potential plate 33. The record medium 31 comprises a film of highly insulating material or a sheet of paper coated with a film or a thin layer of highly insulating material.

The formation electrode 32 comprises a plurality of n pin electrode matrices 32A, 32B, 32C . . . 32N. Each

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of the pin electrode matrices or groups of pin electrodes comprises m pin electrodes a, b, c, d, e for printing n columns in a line. Each of the columns includes m pin electrodes. Each of m and n is a whole number. The potential plate 33 is spaced from and in operative proximity with the pin electrodes of the pin electrode matrices 32A to 32N. The potential plate 33 provides a potential difference between the pin electrodes of the pin electrode matrices of the formation electrode 32 and said potential plate and is itself provided with a constant voltage. Thus, for example, the potential plate 33 is connected to ground.

In FIG. 8, which is a circuit diagram of the electrostatic printing apparatus of the present invention, illustrating the first three pin electrode matrices 32A, 32B and 32C, and the corresponding components, the pin electrodes are connected to and driven in common by m pin driving circuits 34 connected to said pin electrodes. The pin driving circuits 34 comprise a pin driving circuit 34A, a pin driving circuit 34B, a pin driving circuit 34C, a pin driving circuit 34D and a pin driving circuit 34E. Each of the pin driving circuits 34A to 34E is connected to and simultaneously drives a corresponding one of the pin electrodes of each of the groups of matrices 32A to 32C of pin electrodes. Thus, the pin driving circuit 34A is connected to and drives the pin electrode a of each of the pin electrode matrices 32A, 32B and 32C, the pin driving circuit 34B is connected to and drives the pin electrode b of each of said matrices, and so on. Each of the pin driving circuits 34A to 34E is connected to each of the pin electrodes via a resistor RB.

The pin electrodes are also connected to and driven by n column driving circuits 35. The column driving circuits 35 comprise a column driving circuit 35A, a column driving circuit 35B and a column driving circuit 35C. Each of the column driving circuits 35A to 35C is connected to and simultaneously drives each of the pin electrodes of a corresponding one of the pin electrode matrices 32A to 32C. Thus, the column driving circuit 35A is connected to and drives the pin electrodes a, b, c, d and e of the pin electrode matrix 32A, and so on. Each of the column driving circuits 35A to 35C is connected to each of the pin electrodes of the corresponding pin electrode matrix via a resistor RA.

Each of the column driving circuits 35A to 35C supplies a signal of a polarity opposite that of the pin driving circuits 34A to 34E to the pin electrodes of a corresponding one of the columns. Each of a plurality of clamping circuits is connected to a corresponding one of the pin electrodes and functions to ground the corresponding pin electrode thereby clamping said pin electrode so that the potential difference between said pin electrode and the potential plate 33 becomes lower than the threshold level beneath which there is no production of an electrostatic image. Each clamping circuit comprises a diode connected in reverse direction between a corresponding one of the pin electrodes and a point at ground potential.

A clamping diode of a group of clamping diodes 36A is thus connected between the pin electrode a of the pin electrode matrix 32A and ground, a clamping diode of said group is connected between the pin electrode b of said matrix and ground, a clamping diode of said group is connected between the pin electrode c of said matrix and ground, and so on. In the same manner, each clamping diode of a group of clamping diodes 36B is connected between a corresponding one of the pin electrodes of the pin electrode matrix 32B and ground. The clamping diodes of the third group of clamping diodes 36C are connected to the pin electrodes of the pin electrode matrix 32C in the same manner.

The voltage $+VA$ applied by the pin driving circuits 34 is illustrated in FIG. 9, wherein the abscissa represents time and the ordinate represents the voltage V . The voltage $-VB$ applied by the column driving circuits 35 is

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illustrated in FIG. 10, wherein the abscissa indicates time and the ordinate indicates the voltage V .

In FIG. 8, an image may be electrostatically produced by only the pin electrode a of the pin electrode matrix 32B, if only the pin driving circuit 34A drives said pin electrode and each of the column driving circuits 35, with the exception of the column driving circuit 35B, drives the pin electrodes. Under these conditions, the potential of the pin electrode a of the pin electrode matrix 32B is

$$\frac{VA}{RA+RB}(RA)$$

wherein RA is the resistance value of the resistors RA, RB is the resistance value of the resistors RB and VA is the voltage applied by the pin driving circuits 34. The voltage VA, applied by the pin driving circuits 34, must be determined so that it is higher than the critical or threshold voltage magnitude or level VL of the record medium 31.

With regard to the pin electrodes which do not produce an electrostatic image, under the foregoing circumstances, the pin electrodes b to e of each of the pin electrode matrices 32A to 32C are not driven by the signal from the pin driving circuit 34B, whereas said pin electrodes are driven by the signal from the column driving circuits 35A and 35C. The potentials of the pin electrodes b to e are thus

$$\frac{-VB}{RA+RB}(RA)$$

wherein $-VB$ is the voltage applied by the column driving circuits 35. The potentials of the pin electrodes a to e are thus negative, but in actuality are clamped at about zero volts by the clamping diodes 36A, and so on. The potentials of the pin electrodes b to e are lower than the critical or threshold voltage level VL of the record medium, so that there is no production of an electrostatic image by said pin electrodes of the pin electrode matrices 32A and 32C.

If the pin electrodes a of the pin electrode groups or matrices 32A and 32C are driven by signals from the pin driving circuits 34A and signals from the column driving circuits 35A and 35C, the potentials applied to said pin electrodes are

$$VA - \frac{VA+VB}{RA+RB}(RA)$$

If the voltages VA and VB are so determined that the voltage level may decrease below the critical or threshold voltage level VL of the medium record, there is no production of an electrostatic image. Furthermore, with regard to the pin electrodes b to e of the group or matrix of pin electrodes 32B, neither the pin driving circuits nor the column driving circuits provide a driving voltage, so that the potentials of said pin electrodes are zero volts.

If RA equals RB equals 10,000 ohms, VA equals $-VB$ equals 1,000 volts, and VL equals 300 volts, the voltage of a pin electrode a of the pin electrode matrix or group 32B, which provides an electrostatic image in the embodiment of FIG. 8, may be expressed as

$$\begin{aligned} & \frac{VA}{RA+RB}(RB) \\ &= \frac{1,000 V}{10,000 \text{ ohms} + 10,000 \text{ ohms}}(10,000 \text{ ohms}) \\ &= \frac{1,000 V}{20,000 \text{ ohms}}(10,000 \text{ ohms}) \\ &= \frac{1,000 V}{2} = 500 V \end{aligned}$$

Since 500 volts is greater in magnitude than the critical or threshold voltage level VL, which is 300 volts, an electrostatic image is produced.

The voltages of the pin electrodes *b* to *e* of the pin electrode matrices or groups 32A and 32C, which do not produce an electrostatic image, are

$$\begin{aligned} & \frac{-VB}{RA+RB}(RA) \\ &= \frac{-1,000 V}{10,000 \text{ ohms} + 10,000 \text{ ohms}} (10,000 \text{ ohms}) \\ &= \frac{-1,000 V}{20,000 \text{ ohms}} \\ &= \frac{-1,000 V}{2} = -500 V \end{aligned}$$

The pin electrodes *b* to *e* are clamped at approximately zero volts by the clamping diodes 36A and 36C. Since the potential of the pin electrodes *b* to *e* is thus less than the critical or threshold voltage level VL of 300 volts, there is no production of an electrostatic image. The voltages of the pin electrodes *a* of the pin electrode matrices or groups 32A and 32C, which do not produce an electrostatic image, are

$$\begin{aligned} VA - \frac{VA+VB}{RA+RB}(RA) &= 1,000 V \\ &= \frac{1,000 V + 1,000 V}{10,000 \text{ ohms} + 10,000 \text{ ohms}} (10,000 \text{ ohms}) \\ &= 1,000 V - \frac{2,000 V}{20,000 \text{ ohms}} (10,000 \text{ ohms}) \\ &= 1,000 V - \frac{2,000 V}{2} = 1,000 V - 1,000 V = 0 \text{ volts} \end{aligned}$$

Since this voltage is lower than in magnitude than the threshold level VL of 300 volts, there is no production of an electrostatic image.

If only the pin electrode *a* of the pin electrode matrix or group 34B of FIG. 8 produces an electrostatic image, the aforescribed result is obtained. An electrostatic image of excellent quality is produced by preventing the pin driving circuit 34A from providing a driving signal and permitting each of the pin driving circuits 34B to 34E to provide a driving signal, and permitting only the column driving circuit 34B to provide a driving signal and preventing the column driving circuits 35A and 35C from providing a driving signal. Under these circumstances, it is necessary to connect the clamping diodes in the direction opposite that shown in FIG. 8 and to produce a negative electrostatic charge image on the record medium, or reverse the polarities of the voltages VA and VB, shown in FIGS. 9 and 10, applied by the pin driving circuits 34 and the column driving circuits 35, respectively.

The electrostatic printing apparatus of the present invention may be constructed with facility and rapidity, since each pin electrode comprises a single pin. In accordance with the present invention, the number of driving circuits may be decreased, since the driving circuits utilized to produce the electrostatic pattern or character are constituted by the number of groups of pin electrodes required for the production of the pattern of one column and by the number of groups of pin electrodes corresponding to the number of columns for driving the pin electrodes of the columns in common. Furthermore, in accordance with the present invention, there is no need in the electrostatic printing apparatus for a plurality of counter electrodes. This permits the pin electrodes to be positioned in a line and thus enables the production of continuous patterns and graphs with efficiency and effectiveness, regardless of the positions of the columns.

While the invention has been described by means of specific examples and in specific embodiments, we do not wish to be limited thereto, for obvious modifications will occur to those skilled in the art without departing from the spirit and scope of the invention.

We claim:

1. Electrostatic printing apparatus, comprising
 - n* groups of pin electrodes, each group of pin electrodes comprising *m* pin electrodes for printing *n* columns in a line, each of said columns including *m* pin electrodes, wherein each of *m* and *n* is a whole number;
 - a potential plate spaced from and in operative proximity with said pin electrodes;
 - a record medium interposed between said pin electrodes and said potential plate, said pin electrodes printing an electrostatic image on said record medium, said pin electrodes and said potential plate having a threshold voltage level beneath which there can be no printing by said pin electrodes on said record medium;
 - m* pin driving circuits connected to said pin electrodes, each simultaneously driving a corresponding one of the pin electrodes of each of said groups of pin electrodes;
 - n* column driving circuits connected to said pin electrodes, each supplying a signal of a polarity opposite that of said pin driving circuits to the pin electrodes of a corresponding one of said columns;
 - a plurality of clamping circuits each connected to a corresponding one of said pin electrodes for clamping said pin electrodes so that the potential difference between said pin electrodes and said potential plate becomes lower than said threshold level, whereby said pin electrodes are selectively driven by signals supported from only one of said pin driving circuits and said column driving circuits to print an electrostatic image on said record medium, said signals having a polarity which is not clamped by said clamping circuits.
2. Electrostatic printing apparatus as claimed in claim 1, wherein each of the pin electrodes driven by said pin driving circuits corresponds to the others in its position in its column.
3. Electrostatic printing apparatus as claimed in claim 1, wherein each of said pin driving circuits is connected to each of the corresponding pin electrodes via a resistor.
4. Electrostatic printing apparatus as claimed in claim 1, wherein each of said column driving circuits is connected to each of the corresponding pin electrodes via a resistor.
5. Electrostatic printing apparatus as claimed in claim 1, wherein each of said clamping circuits comprises a diode.
6. Electrostatic printing apparatus as claimed in claim 1, wherein each of said pin driving circuits is connected to each of the corresponding pin electrodes via a resistor and each of said column driving circuits is connected to each of the corresponding pin electrodes via a resistor.
7. Electrostatic printing apparatus as claimed in claim 1, wherein each of the pin electrodes driven by said pin driving circuits corresponds to the others in its position in its column; each of said pin driving circuits is connected to each of the corresponding pin electrodes via a resistor, each of said column driving circuits is connected to each of the corresponding pin electrodes via a resistor, and each of said clamping circuits comprises a diode.

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U.S. Cl. X.R.