United States Patent

[11] 3,624,661

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[54] **ELECTROGRAPHIC PRINTING SYSTEM WITH PLURAL STAGGERED ELECTRODE ROWS**
17 Claims, 12 Drawing Figs.

[52] **U.S. Cl.** .... 346/74 ES, 101/DIG. 13
[51] **Int. Cl.** G03g 15/00
[50] **Field of Search** .... 346/74 ES

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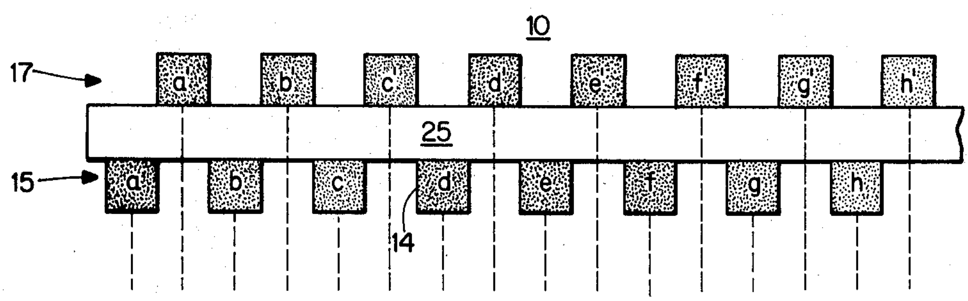
ABSTRACT: In an electrographic printing system, a multiple row electrode structure wherein successive rows are mutually spaced from each other, each row including mutually spaced electrodes, the electrodes of successive rows being positioned in a staggered manner with respect to each other. The system further comprises improved electrode drive circuitry, including a plurality of high-voltage drivers and a selection matrix wherein a plurality of passive elements are coupled to the drivers. A plurality of output lines couple the matrix to the electrodes so as to selectively apply a high voltage to the electrodes in order to produce a latent image on a dielectric medium. Toning means subsequently make the latent image visible.



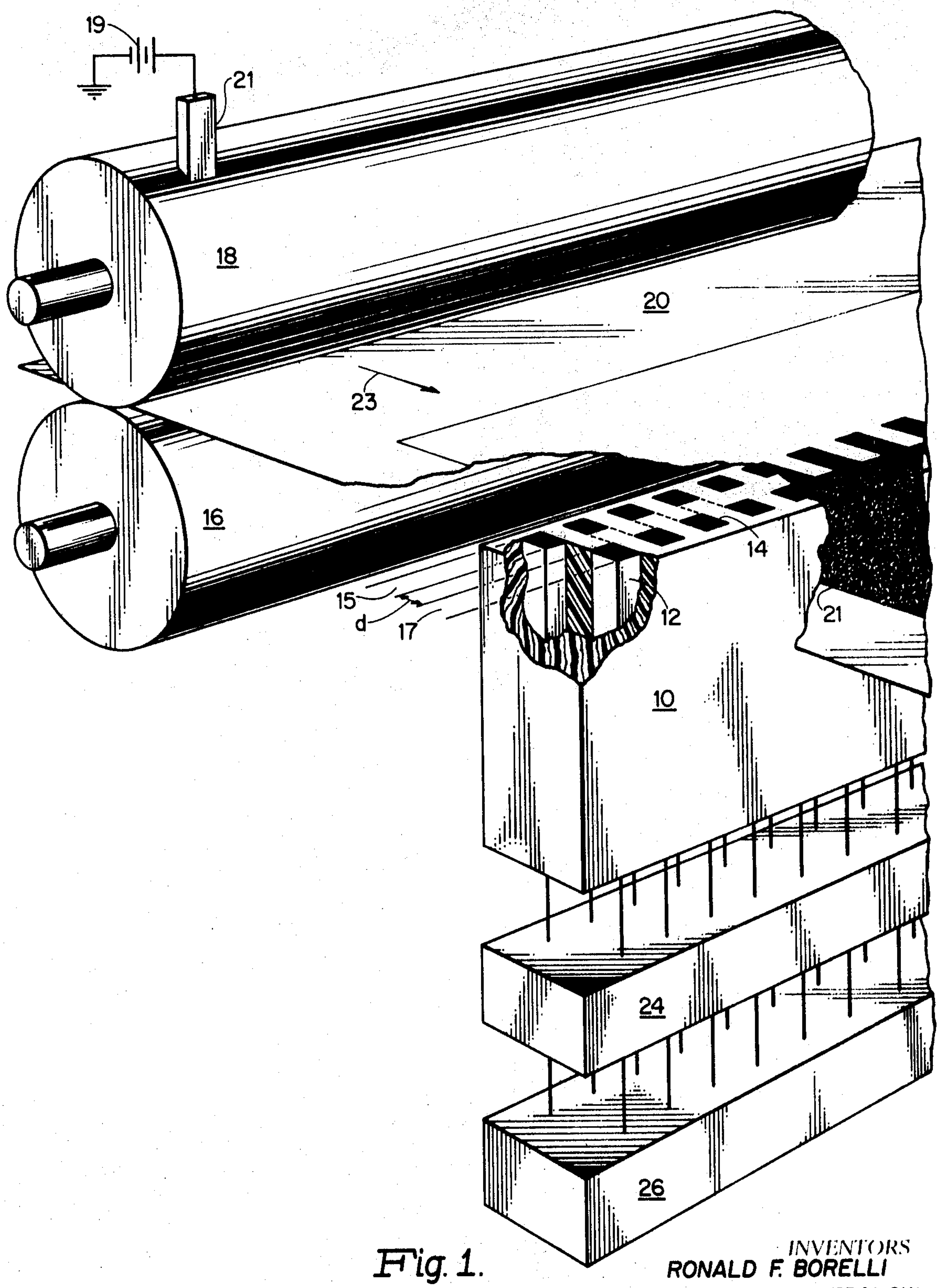


Fig. 1.

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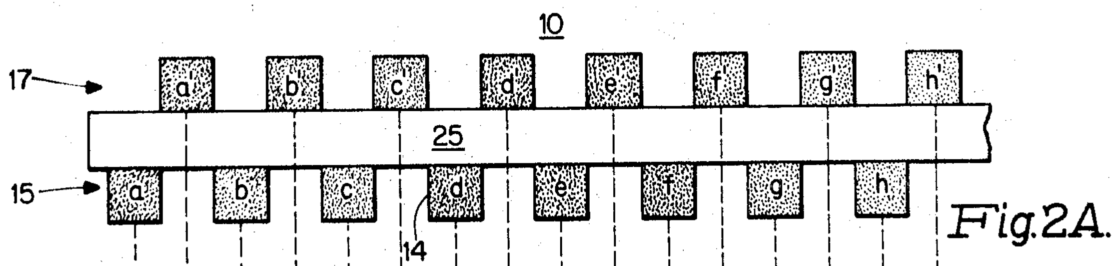

Fig.2A.

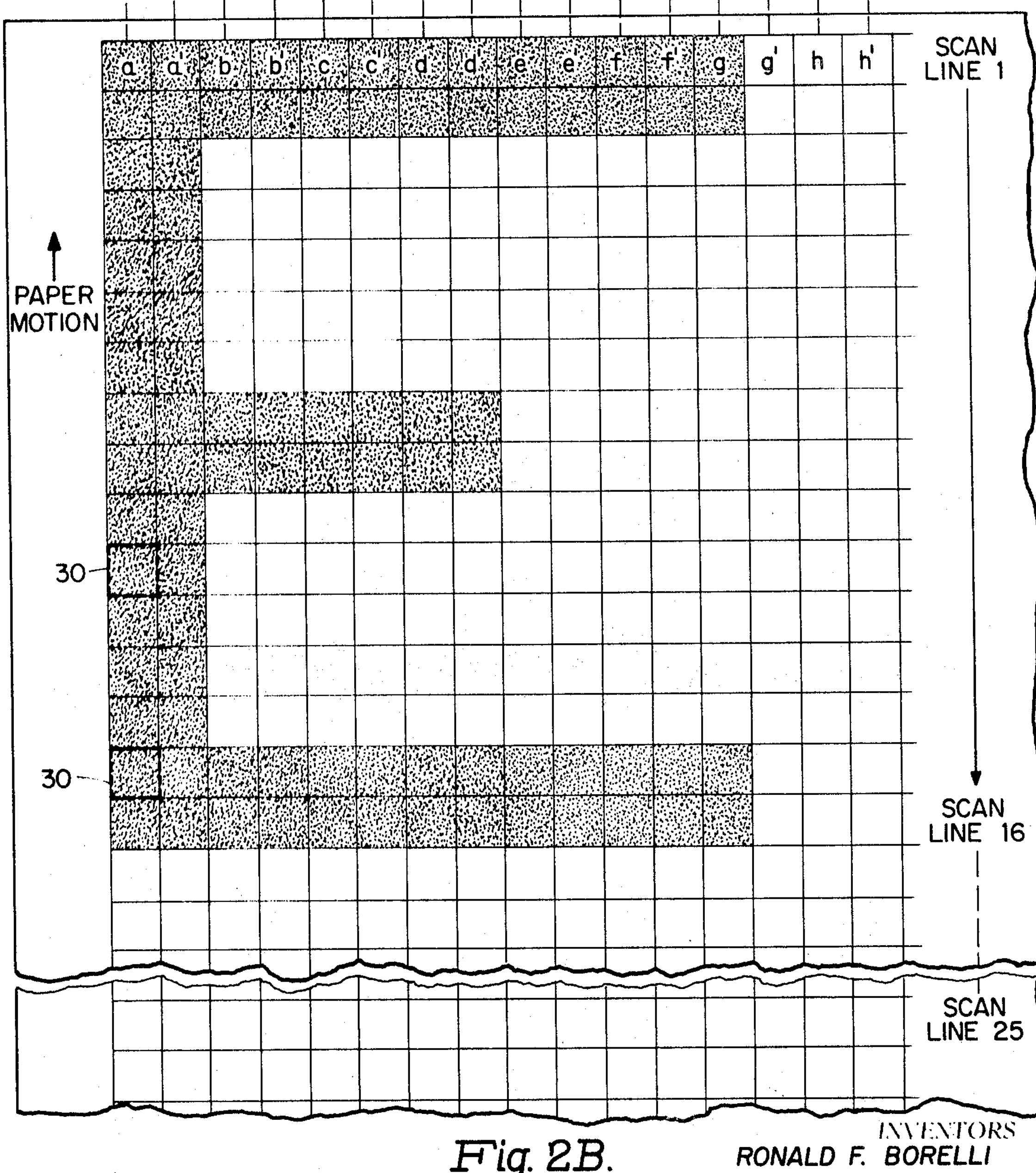

Fig. 2B.

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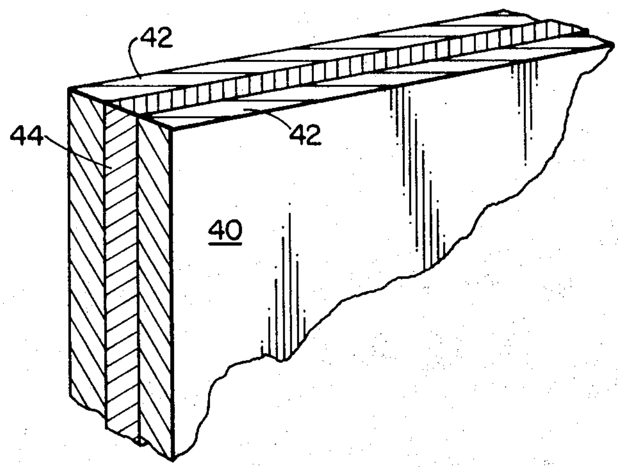

Fig. 3A.

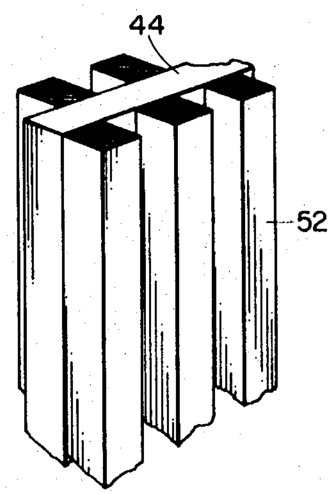

Fig. 3B.

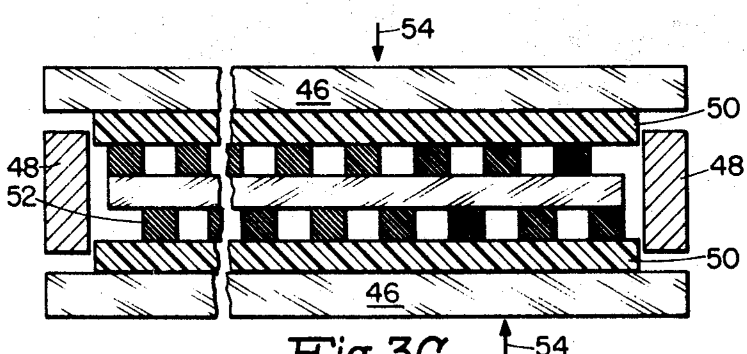

Fig. 3C.

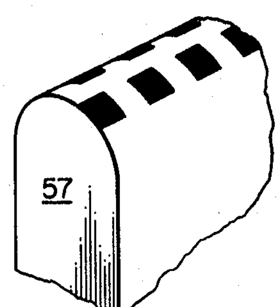

Fig. 3D.

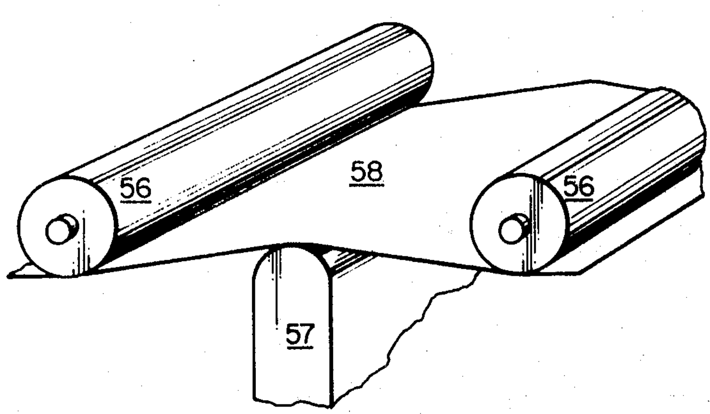

Fig. 3E.

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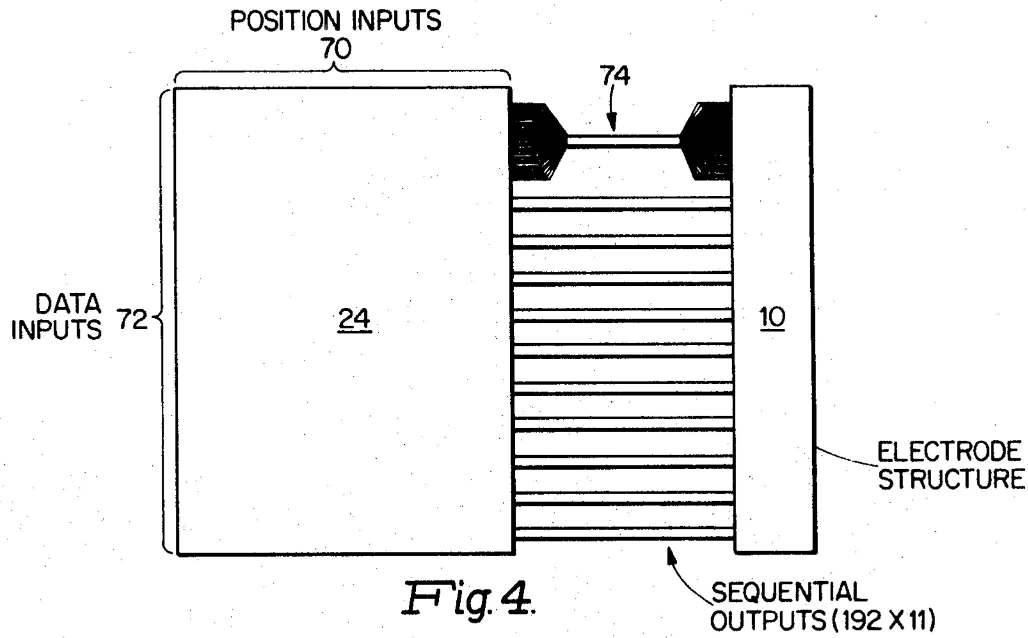

Fig. 4.

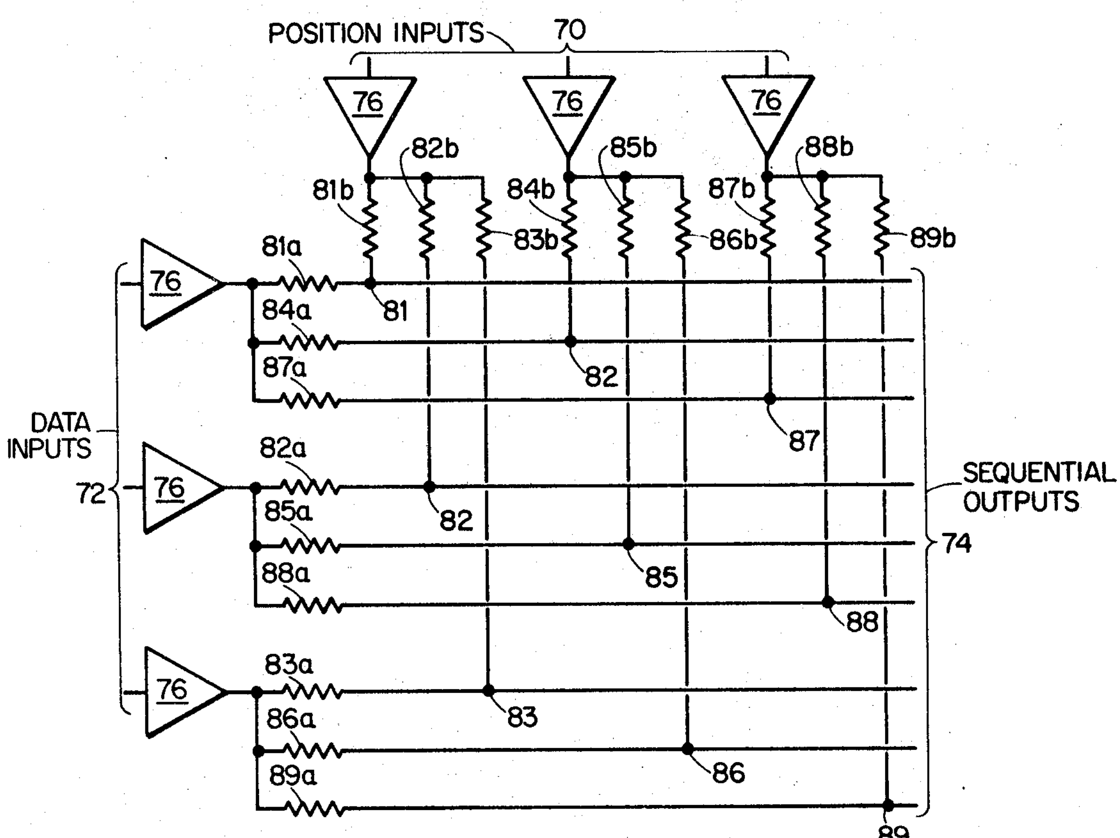

Fig. 5.

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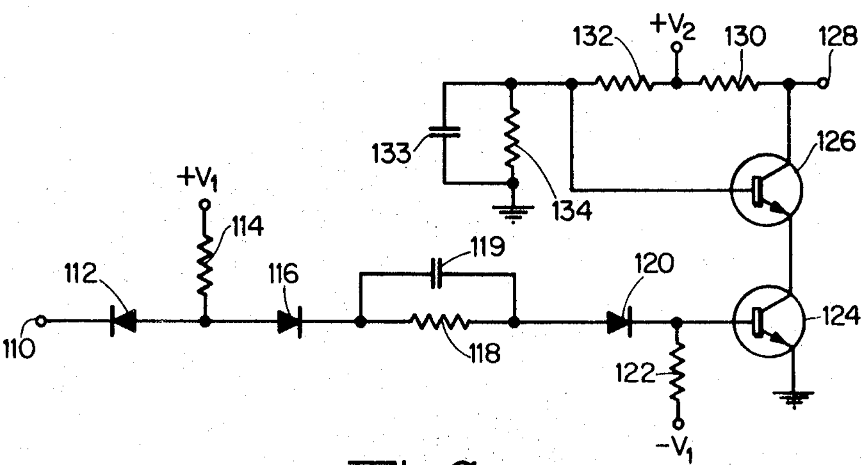

Fig. 6.

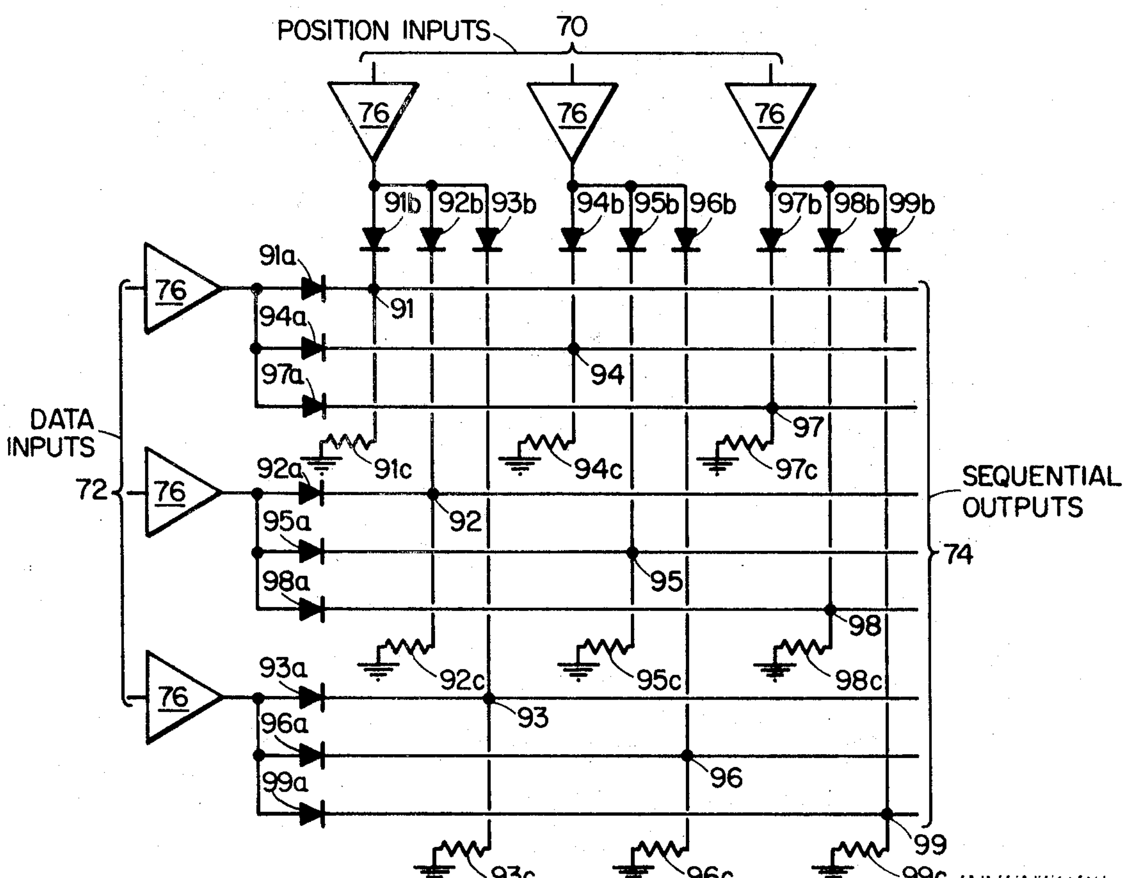

Fig. 7.

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ELECTROGRAPHIC PRINTING SYSTEM WITH PLURAL STAGGERED ELECTRODE ROWS

BACKGROUND AND OBJECTS OF THE INVENTION

The present invention pertains generally to the field of image reproduction and relates more particularly to an electrographic printing system wherein the medium to be recorded on includes a conductive base substrate and a dielectric layer.

There presently exist various specific techniques of image reproduction most of which are concerned with the electrostatic transfer of charges. Generally speaking in electrographic printing systems, including one employing the principles of the present invention, a latent image is formed on a dielectric medium by placing the medium in the field established between two electrodes. These two opposed electrodes which can assume various shapes (round, square, character-shaped, etc.) have a high electrical potential difference applied across them, thereby establishing the necessary field. The latent charged image formed is in the shape of the electrode that faces the dielectric surface of the medium.

Most electrographic printing systems can generally be categorized into two areas with respect to electrode configurations; systems employing character-shaped electrodes and systems employing pin-shaped electrodes. In systems of the former type, for example, a print drum is rotated at high speed and selected electrodes are pulsed when the desired character is facing the dielectric surface, causing the formation of a latent image on the medium at the area where the character electrode was located. Associated with such systems, however, are certain disadvantages. For instance, it has been found necessary to provide a drum consisting of individual, electrically insulated segments and to provide means for commutating to each segment of the rotating character drum. Thus there are mechanical problems associated with the rotating drum. In addition, in order to operate at a reasonable printing speed without causing character smear, the duration of the selection pulse must be short and the paper has to remain stationary during printing. This results in a printing speed limitation with a system of this type.

In printing systems where an array of pin electrodes is employed, various patterns, such as alphanumeric characters, can be reproduced by selecting predetermined electrodes as the recording medium passes these electrodes. Associated with such a system, however, are certain problems that result in a poor quality printout. Two of the more significant problems derive from the poor contrast density and resolution of the finally printed characters. The contrast (shade) density may be defined as the degree of darkness as represented on the gray scale, while resolution may be defined as the capability of forming perfectly shaped characters. Theoretically, 100 percent contrast provides printed characters which are perfectly black. The pin electrodes have to be separated a minimum distance from each other, so that they can be selectively activated. If this is not the case, poor density and poor resolution of the printed character result.

Another problem associated with a pin electrode system derives from the fabrication of the electrode array itself. Usually the electrodes are very small in cross section and are located close together. The structure, therefore is prone to damage and is generally difficult to fabricate.

The cost of presently available electrographic printing systems is relatively high. One of the important factors contributing to the high cost of such systems is the necessity for providing one driver per electrode. In systems requiring relatively high resolution and shade density, the total number of electrodes may be of the order of 200 electrodes per inch. Where a separate high-voltage driver is required for each of these electrodes, the cost of the system becomes inordinately high.

It is an object of the present invention to provide an electrographic printing system which is not subject to the foregoing disadvantages.

It is another object of the present invention to provide an electrographic printing system which provides a printout of improved quality with respect to resolution and shade density.

It is a further object of the present invention to provide an electrographic printing system which is capable of operating at relatively high speeds.

It is still another object of the present invention to provide a novel electrode structure for such a printing system which can be easily and accurately fabricated at relatively low cost.

It is a further object of the present invention to provide an economical electrographic printing system which has improved reliability.

SUMMARY OF THE INVENTION

The foregoing objects are satisfied in the present invention by providing an electrographic printing system of the kind wherein a recording medium has latent images formed thereon by the application of a high potential across the medium and wherein a toner is subsequently applied to the medium to make the latent images visible. The printing system further comprises a multiple row electrode structure, a character generator, and a selection matrix which permits the use of a smaller number of high-speed drivers than the total number of electrodes in the electrode structure.

The printing system which constitutes the subject matter of the present invention permits printing with improved resolution by providing the heretofore unattainable capability of printing between adjacent electrode areas. A staggered electrode structure is employed in the present invention which provides the capability of printing at a far higher shade density (up to 100 percent), than was heretofore possible. Further advantages of the invention derive from its ability to be inexpensively fabricated.

These and other objects of the invention as well as the features and advantages thereof will become apparent from the following detailed specification, when read in connection with the drawings, in which:

FIG. 1 is a perspective drawing (partially in block form) of a portion of a preferred embodiment of the present invention.

FIG. 2A is an end view of the electrode structure shown in FIG. 1.

FIG. 2B discloses a segment of the recording medium showing the latent charge pattern for the letter E.

FIGS. 3A through 3E show the various stages of fabrication of a dual electrode structure.

FIG. 4 is a block diagram of the electrode structure and its associated drive circuitry.

FIG. 5 is a circuit diagram of one embodiment of the electrode drive circuitry.

FIG. 6 is a circuit diagram of the driver shown in FIGS. 5 and 7.

FIG. 7 is a circuit diagram of a second embodiment of the electrode drive circuitry.

ELECTRODE STRUCTURE

FIG. 1 is a perspective view of a portion of a preferred printing system in accordance with the present invention, showing an electrode structure **10** having a section thereof cut away thereby exposing electrodes **12**. For the illustrative embodiment shown, each electrode has a substantially square cross section and terminates in a working surface **14**, which lies within a common surface in close proximity to a recording medium **20**. In one practical embodiment, surface **14** is 0.005 inch square and the electrode rows, as well as adjacent electrodes within a row, are separated by a distance (*d*) of 0.005 inch.

In the preferred embodiment of the invention illustrated, two rows of electrodes **15** and **17** are used. Each working surface **14** (except those at the end of the rows), is aligned with the space between a pair of working surfaces in the adjacent row. The spacing between the two rows of electrodes is a function of paper speed and the time required to print one scan line.

More specifically, a scan line can be represented as an imaginary line on the medium having the width of an electrode, as shown in FIG. 2B. Given an upper limit on the speed with which a row of electrodes can be energized to print a latent image on the scan line above it, the minimum spacing between electrode rows is determined by the paper speed and the completion of printing of a single scan line. Such printing must be completed before that scan line moves above the second row of electrodes.

Rollers **16** and **18** show a means of propelling medium **20** past electrode structure **10**. Various other propelling means can be used all of which fall within the spirit and scope of the present invention. Medium **20** can include a conductive base substrate, such as treated paper having affixed thereto a dielectric layer of a prescribed thickness, usually thinner in dimension than the base material. The dielectric side of medium **20** faces roller **16**, whereas the conductive side faces roller **18**.

As previously mentioned, the generation (printing) of a latent image occurs when a high potential is applied across the recording medium at a predetermined place on the medium. Over this predetermined area (the area above the electrode surface **14**), an electrostatic charge transfer takes place and the dielectric retains this charge pattern for a sufficient period so that a toner can be applied and fused to the medium in areas where the charge is present. This toning steps makes the latent image visible.

With the system shown in FIG. **1**, a source **19** provides the high voltage necessary for printing. This high voltage is coupled to a roller **18** by way of a commutating brush **21**, which is adapted to apply the high voltage to roller **18**, and is then applied to the conductive side of medium **20**. As the medium moves in the direction indicated by arrow **23** at a speed of, for example, 10 inches/second, selected electrodes are pulsed to ground by electrode drive circuitry **24** thereby creating a charge on the dielectric surface of medium **20** in a particular pattern. A character generator **26** is connected to electrode drive circuitry **24** and determines the configuration or printing pattern.

Generator **26** receives suitable electrical waveforms (not shown), e.g. from a computer, representative of pictorial, alphanumeric, or other information to be recorded and converts these waveforms into timed and distributed electrical pulses which are applied to circuitry **24**. Configuration generator **26** may be a typical function generator, such as disclosed in U.S. Pat. No. 3,289,030 to Lewis et al.

By way of illustration, let it be assumed that printing of a latent image is to take place in section **21** of medium **20**. The portion of section **21** that has either passed electrode structure **10**, or is above it, is shown shaded so as to indicate where the latent image has been formed. Actually the dielectric surface of medium **20** retains the charge. For the purposes of illustration, however, the side of medium **20** visible in FIG. **1** is shaded. Directly above electrode structure **10**, the latent image is tooth-shaped, as shown.

At one point in time in the operation of the system, the first electrode row **15** has been energized and the second electrode row **17** has not yet been energized. Had only one electrode row been used for printing, the required minimum spacing between the adjacent electrodes in a row would have yielded a printing density no higher than approximately 60 percent. With the staggered, dual electrode structure shown in FIG. **1**, however, a printing density of up to to 100 percent can be attained. The use of this particular structure also allows for increased resolution, particularly when printing curved alphanumeric characters. This improved resolution is due primarily to the fact that twice as many scans exist in the direction of paper motion as a result of the staggered electrode arrangement, than is the case where a single electrode row is used. As a consequence, better character definition is provided by the present invention.

PRINTING EXAMPLE

As an aid to a better understanding of the printing system of the present invention, reference is directed to FIGS. 2A and 2B. FIG. 2A shows an end view of the staggered dual electrode structure while FIG. 2B shows a segment of medium **20** on which a character has been printed. The segment is shown dissected into imaginary cells (elements) **30** dimensioned identically to the electrode surface **14** (0.005 inch square, for example). The entire character segment consists of a group of cells arranged in a 16×25 matrix. To provide intercharacter spacing, a 13×16 array of cells defines the particular character, an E-shaped character in the example of FIG. 2B.

The electrodes shown in FIG. 2A have been designated *a* through *h* for electrode row **15** and *a'* through *h'* for electrode row **17**. Like designations are shown along scan line **1** of FIG. 2B. Assuming that the electrode structure **10** remains stationary and that the segment of medium **20** shown in FIG. 2B is about to pass over the electrodes in the direction of the arrow showing paper motion, the following occurs. As determined by character generator **26**, for printing the character E, when scan line **1** is positioned above first electrode row **15** electrodes *a* through *g* are excited, but electrode *h* is not. The cells designated *a* through *g* are electrostatically charged, but cell *h* is not. When scan line **2** is above the first electrode row **15**, the same electrodes are excited (*a* through *g*). Simultaneously, scan line **1** is located over an interelectrode surface **25**, which is part of the aforesaid common surface. Electrode row **17** has not yet been excited at this time.

At a later time, when scan line **3** has moved directly above the first electrode row **15**, only electrode *a* is excited. Simultaneously, scan line **1** has moved above the second electrode row **17**. Electrodes *a'* through *f'* are now excited but electrodes *g'* and *h'* are not. This procedure repeats in a manner to permit the printing of latent images in the shaded areas of FIG. 2B. The character generator **26** programs the excitation sequence of each electrode row. Thus, it is possible to print alphanumeric characters, special characters, and virtually any other desired patterns.

Although only a segment of medium **20** is shown in the drawing, in a practical character-printing system 132 characters may be printed in a horizontal direction. With a possible 25 scans being used to complete a character, 132 characters (a character line) may be printed for every 25 scans. The number of electrodes needed to accomplish this is determined as follows. With 132 character positions and 16 cells per character position, there are a total of 2,112 electrodes per scan line (1,056 electrodes per electrode row). If it is desired to print 5,000 lines of characters per minute, with the paper moving at approximately 10 inches/second (maximum character height of one-eighth inch), it takes 12 milliseconds to print a character line (60 sec./min. 5,000 character lines/min.). If 25 scan lines per line of characters are used, a scan line is printed in 0.48 milliseconds (12 milliseconds 25 scan lines).

In order to obtain a print of good quality, a print pulse width of between 40 and 50 microseconds is needed. The pulse width is determined primarily by the RC time constant of the electrographic medium. Using a minimum pulse width of 40 microseconds, one could use 12 (0.48 milliseconds 40 microseconds) print intervals to print a scan line. Using a pulse width of 50 microseconds, only 9.6 print intervals per scan line are required. If one chooses an intermediate value of 11 intervals, one can use 11 intervals each of 12 character positions. The printing pulse for this particular example would be approximately 43.5 microseconds.

Thus, in a practical embodiment of the invention, one scan line may include 132 character positions, and 25 scan lines will complete the printing of the entire line of characters. The 132 character positions are printed in 11 intervals. During each such interval, 12 character positions are printed, i.e. 192 (12×16) cells are printed (corresponding to 192 electrodes). Each print interval thus takes 43.5 microseconds and a total of

12 milliseconds is needed to print an entire character line. With the dual electrode row operation explained with particular reference to FIG. 2B, the 192 electrodes that are excited at one time to print the 12 character positions, physically constitute two rows each having 96 electrodes which are staggered as shown in FIG. 2A.

Electrode Fabrication

The electrode structure of the present invention can be fabricated in various ways. The particular electrode cross section need not be square in shape, but can instead be rectangular, circular or have various other shapes. FIG. 3A shows a portion of a printed circuit board **40** having two conductive copper layers **42** separated by an insulative layer **44** of glass epoxy or like material. These three layers are affixed together by glueing or other suitable means.

One particular way of fabricating the electrode structure is to start with an etched printed circuit board having copper conductors on both sides which, in a preferred embodiment, are 0.005 inch in width and spaced 0.005 inch apart (see FIG. 3B). The techniques used in making this etched board are similar to those used in manufacturing conventional printed circuits. However, due to the small width of the conductors (electrodes) and the small interconductor spacing certain process control is required.

The first step in fabricating the electrode structure is to deposit a photoresist on both sides of the copper-glass epoxy-copper laminate. After suitable cleaning and drying of the board, a negative is aligned with the coated board (one on each side) and it is exposed to ultraviolet light. The board is then developed in a conventional developer. The final step in obtaining the structure of FIG. 3B is a chemical etching step. This is accomplished by immersing the board in a warm 40 percent solution of a mild acid such as ferric chloride. After washing to remove all traces of the acid and drying, the board is ready for the next fabrication step.

Subsequently the gaps between strips **52** must be filled with epoxy. Epoxy sheets **50** are shown abutting against strips **52** in FIG. 3C.

Externally, glass epoxy sheets **46** are placed against sheets **50**. Spacers **48** determine the extent to which sheets **46** can be pressed against sheets **50**. When the assembly is heated and pressure is applied, as shown by arrows **54**, the epoxy sheets **50** melt and fill the cavities between strips **52**. After the structure has cooled, a grinding and polishing operation takes place to obtain the final electrode structure **57** shown in FIG. 3D. An end view of the FIG. 3D structure is shown in FIG. 3E along with rollers **56** and medium **58**.

ELECTRODE DRIVE CIRCUITRY

As previously mentioned, prior art electrographic printing systems use a driver circuit for each electrode that is to be excited. Because of the high voltage levels required for printing (in the vicinity of 750 volts), sharing of the high-voltage driver circuits proved unsuccessful heretofore.

FIG. 4 is a block diagram showing electrode drive circuitry **24** and electrode structure **10**. A preferred implementation of circuitry that can be used as electrode drive circuitry **24** is shown in FIGS. 5, 6 and 7. Electrode drive circuitry **24** has position inputs **70** and data inputs **72**. For the practical embodiment of the invention discussed hereinabove, the position inputs number 11, corresponding to the 11 printing intervals, while the data inputs number 192, corresponding to the 192 electrodes excited to print 12 character positions. (Refer to printing example above). Output lines **74** connect from electrode drive circuitry **24** to electrode structure **10**, 11 such connections being shown. However, in reality each connection includes 192lines capable to excitation of their corresponding segments of electrode structure **10**.

FIG. 5 disclosed one embodiment of a part of electrode drive circuitry **24**, including drivers **76**, data inputs **72**, position inputs **70**, outputs **74** and a resistor matrix. Resistor pairs **81*a***, **81*b*** through **89*a***, **89*b*** connect individually in series with their common joining node being referred to as nodes **81** through **89** respectively. Nodes **81** through **89** then connect externally to output line **74**. The other terminals of resistors **81*a***, **84*a*** and **87*a*** respectively connect in common to a a driver **76**, while the terminal of resistor trios **82*a***, **85*a***, **88*a***; **83*a***, **86*a***, **89*a***; **81*b***, **82*b***, **83*b***; **84*b***, **85*b***, **86*b***; and **87*b***, **88*b***, **89*b*** each connect in common to the other drivers **76** of FIG. 5. In this embodiment, all resistors are of approximately the same value. The drivers that receive the data line inputs **72** are continuously switching with each new data scan line presented. More than one data driver can be and in most cases is, active at one time. The drivers that receive the position inputs **70** on the other hand, are active, one at a time.

The printing scheme of FIG. 1 used with the resistive matrix of FIG. 5 requires that the electrode (roller **18**) on the conductive side of the medium be biased at a high voltage of, for example, 700 volts. The pin electrodes which face the dielectric side of the medium, when switched to ground, provide the necessary high voltage for printing.

In presently available electrographic printing systems, there is insufficient charge established on the dielectric surface of the medium to attract and hold the toner when the applied voltage across the dielectric is of the order of one-half of the usual 700-volt potential. Thus, the 350-volt difference can be considered to be a threshold value below which successful printing will not occur.

This fact is taken advantage of in the present invention, as shown below. The drivers shown in FIGS. 5, 6 and 7 have a binary output of 900 volts for nonselect operation and 0 volts for select operation. The data drivers, therefore, have either 900 or 0 volts at their outputs. Since only one position driver of a total of 11 drivers is on at any one time, this driver will have an output of 0 volts while the remainder are at 900 volts. It will be understood that the position inputs **70** for all the position drivers are sequentially energized by character generator **26**.

Referring to FIG. 5 in particular, assume that the left position driver **76** is selected along with the uppermost data driver **76**. The outputs from these two drivers would therefore be at ground potential and the voltage at node **81** would be essentially ground. In a practical embodiment, the electrode on the other side of the medium is biased to 700 volts. The electrode associated with node **81** then prints. The nodes **85**, **86**, **88** and **89** are then at 900 volts and no printing occurs. (There is actually a reverse 200-volt potential difference across the recording medium.) The remaining nodes, **82**, **83**, **84**, **87** are at one-half of 900 volts or 450 volts. The potential difference across the medium in that case is 250 volts, (i.e. 700 volts, − 450 volts) which is well below the threshold voltage of 350 volts. Node **81** is the only one, therefore, that has the correct potential applied thereto to facilitate printing.

It will be understood that position inputs **70** are sequentially energized for the drivers **76** as a result of the action of character generator **26**. As a result, the action described above will occur in sequence, i.e. the nodes will be selected sequentially in groups of threes, i.e. nodes **81–82–83**; **84–85–86**; and **87–88–89**. Similarly, the outputs **74** will be selected sequentially in accordance with the above sequence and with the selected data input.

FIG. 6 shows a preferred circuit configuration for the driver **76**. The input at terminal **110** is a 0-volt or +15-volt signal. The input signal is normally at ground and goes to the +15-volt level for selection (output **128** goes toward ground for selection). A diode **112** has its cathode connected to an input terminal **110** and its anode connected in common to the anode of a diode **116**. A resistor **114** connects from the anodes of diodes **112** and **116** to a power supply $+V_1$. The parallel combination of resistor **118** and capacitor **119** connect between the cathode of diode **116** and the anode of a diode **120**. The cathode of diode **120** connects to the base of transistor **124** while resistor **122** is coupled from the base of transistor **124** to power supply $-V_1$. Transistors **124** and **126** connect in series with the emitter of transistor 124 grounded, the collector of transistor 124 coupled to the emitter of transistor 126 and the collector of transistor 126 connect via resistor 130 to high-potential supply $+V_2$. Output terminal 128 is connected to the collector of transistor 126. A resistor 132 ties from the base of transistor 126 to a high-potential supply $+V_2$, a resistor 134 connects from the base of transistor 126 to ground and a capacitor 133 connects from the base of transistor 126 to ground.

In operation, when driver 76 is not selected, input terminal 110 is held at ground potential and a forward current of approximately 3.5 ma. flows through diode 112 and resistor 114. Little or no current flows in diodes 116 or 120 and the slight negative bias on the base of transistor 124 determined primarily by resistor 122, maintains transistor 124 turned off. Transistor 126, which is rendered capable of conduction by the positive bias on the base of transistor 126 (resistors 132 and 134 in part provide the positive bias), is maintained in its off condition because there is no path to ground, i.e. transistor 124 is nonconductive.

When driver 76 is to be selected, the voltage applied to input terminal 110 goes to approximately +15 volts. Diode 112 becomes back biased, while diodes 116 and 120 conduct. Current flows from source $+V_1$, through resistor 114, diode 116, resistor-capacitor pair 118, 119, diode 120 and resistor 122 to source $-V_1$. Due to the preselected values of resistors 114, 118 and 122 (the resistance of resistors 122 is greater than the resistance of resistor 114 plus resistor 118), the base voltage of transistor 124 becomes positive, thereby turning transistor 124 on. This action is speeded up by bridging resistor 118 and by capacitor 119.

When the input signal goes positive therefore, capacitor 119 instantaneously shorts resistor 118 and transistor 124 is rapidly saturated. This action causes transistor 126 to conduct due to the positive base voltage established by resistors 132 and 134 and capacitor 133. The voltage output at terminal 128 which was at approximately $+V_2$ (+900 volts, for example) now assumes a value of approximately 0 volts (slightly positive). This voltage is supplied by way of output resistor 130.

In FIG. 7 there is disclosed another embodiment of electrode drive circuitry, corresponding reference numerals having been retained. As shown, drive circuitry 24 includes drivers 76, data inputs 72, position inputs 70, sequential outputs 74 and a diode-resistor matrix. Diode pairs *91a*, *91b* through *99a*, *99b* connect individually in series with their cathodes being connected to nodes 91 through 99, respectively. Nodes 91 through 99 then connect externally to sequential output lines 74 and also, respectively to one side of resistors *91c* through *99c*. The other terminals of resistors *91c* through *99c* connect to ground potential. The anodes of the diodes *91a*, *94a* and *97a* connect in common to a driver 76 while the anodes of diode trios *92a*, *95a*, *98a*; *93a*, *96a*, *99a*; *91b*, *92b*, *93b*; *94b*, *95b*, *96b*; and *97b*, *98b*, *99b* each connect in common to the other drivers 76 of FIG. 7. The drivers that receive the data line inputs 72 are continuously switching with each new data scan line presented. More than one data driver can be, and in most cases is, active at one time. The drivers that receive the position inputs 70 on the other hand, are active one at a time.

Referring to FIG. 7, assume that the left position driver 76 is selected along with the uppermost data driver 76. The outputs from these two drivers (refer to FIG. 6) are therefore at ground potential and the voltage at node 91 is essentially at ground, (diodes *91a* and *91b* are reverse biased). With the electrode on the other side of the medium at 700 volts, the electrode associated with node 91 prints. The nodes 95, 96, 98 and 99 are therefore at 900 volts and no printing occurs. In practice, there is actually a reverse 200-volt potential difference across the medium. The remaining nodes, 92, 93, 94, 97 are at one-half of 900 volts or 450 volts. The potential difference across the medium is that case would 250 volts (700–450 volts) which is well below the threshold voltage of 350 volts. Node 91 is the only one, therefore, that has the correct potential applied thereto to facilitate printing.

The present invention has been described with reference to certain illustrative embodiments. It should be understood, however, that modifications may be made in the apparatus described which lie well within the scope of the present invention. For example, a structure using more than a pair of electrode rows could be used advantageously. If three rows were used, for instance, the individual electrodes in each row could be spaced somewhat further apart. Also, the voltage levels and polarities need not be as set forth in the illustrative example. A potential difference of 700 volts may be needed for printing. However, the roller could be kept at ground and the pin electrodes may be selectively pulsed to the high voltage, either positive or negative. Further, the common surface of the electrode structure can assume various shapes.

From the foregoing it becomes apparent that the apparatus of the present invention provides an improved electrographic printing system. The staggered multiple row electrode structure provides for improved resolution and for the possibility of obtaining 100 percent shade density. This is particularly advantageous when printing alphanumeric characters. The electrode drive circuitry also furnishes additional advantages in that fewer drivers are needed than in presently available systems, with an attendant cost savings. Improved reliability and cost savings is also a feature of the present invention, particularly with reference to the above-illustrated fabrication techniques of the electrode structure.

Having now described the invention, what is claimed as new and novel and for which it is desired to secure Letters Patent is:

1. An electrographic printing system of the kind wherein a recording medium is moved along a path to have latent images formed thereon by the application of a high potential across the medium and wherein a toner is subsequently applied to the medium to make the latent image visible, said electrographic printing system comprising:

a. an electrode structure adjacent said path including

1. a plurality of mutually spaced rows of electrodes, successive electrodes within each row being spaced from each other, the electrodes of successive rows being positioned in a staggered manner with respect to each other,

2. a single steady-state potential means disposed adjacent the opposite side of said path and extending substantially for an entire electrode row width for imparting a continuous potential across the medium over the total medium area covered by said electrode rows, and

b. electrode drive circuitry for selectively energizing each electrode individually including

1. a character generator

2. first and second groups of high-voltage drivers connected to be energized by said character generator,

3. a selection matrix including a first plurality of passive elements coupled to the output of each of said first group of high-voltage drivers, a second plurality of passive elements coupled to the output of each of said second group of high-voltage drivers, each of said elements coupled to one of said first group of drivers being connected to form a common node with a separate element coupled to one of said second group of drivers, an output line connecting each of said nodes to one of said electrodes, each of said output lines being selectively adapted to apply a high voltage to its corresponding electrode in dependence upon the output of said character generator.

2. An electrographic printing system as defined in claim 1 wherein the spacing between successive rows of electrodes is substantially equal to the width of each of said electrodes in a direction transverse to said rows.

3. An electrographic printing system as defined in claim 1 wherein each of said passive elements includes a resistor connected between the output of a high-voltage driver and said common node.

4. An electrographic printing system as defined in claim 1 wherein each of said passive elements includes a diode connected between the output of said high-voltage driver and said common node, said common node being resistively coupled to a reference potential.

5. An electrographic printing system as defined in claim 1 wherein each of said high-voltage drivers has an input terminal and an output terminal and further includes

a. a first transistor having base, emitter and collector electrodes, said emitter being tied to ground and said base being coupled to said input terminal; and

b. a second transistor having base, emitter and collector electrodes, said last-recited emitter being connected to the collector electrode of said first transistor, said last-recited base being coupled to a reference potential, and said last-recited collector being coupled to said output terminal.

6. The printing system of claim 1 wherein said steady-state potential means is a roller employed to feed said medium along the prescribed path.

7. The printing system of claim 1 wherein each of said electrodes terminates in a common surface and said common surface is convex.

8. The printing system of claim 1 wherein said steady-state potential means is biased at a voltage of less magnitude than said high voltage applied to said electrodes when energized and greater than the voltage applied to said electrodes when not energized.

9. An electrographic printing system as defined in claim 1 wherein said electrodes terminate in a common surface, each electrode defining a working surface within said common surface, said working surfaces being aligned with respective spaces between the electrodes of successive rows and being dimensioned to substantially fill said spaces.

10. An electrographic printing system as defined in claim 9 wherein each of said working surfaces has a square shape.

11. In an electrographic printing system of the kind wherein a recording medium is moved along a path to have latent images formed thereon by the application of a high potential across the medium and wherein a toner is subsequently applied to the medium to make the latent image visible, an electrode structure adjacent said path including, a plurality of mutually spaced rows of electrodes, successive electrodes within each row being spaced from each other, the electrodes of successive rows being positioned in a staggered manner with respect to each other, means for selectively energizing individually, and a simple steady-state potential means disposed adjacent the opposite side of said path and extending substantially for an entire electrode row width for imparting a continuous potential across the medium over the width of an electrode row, wherein said single steady-state potential means is effective to provide a continuous potential to the medium for each successive row of said plurality of rows.

12 The apparatus as defined in claim 11, and further including electrode drive circuitry adapted to selectively energize said electrodes by applying a high voltage thereto.

13. The printing system of claim 11 wherein said steady-state potential means is a roller employed to feed said medium along a prescribed path.

14. The apparatus as defined in claim 11 wherein said electrode structure consists of a pair of spaced rows of electrodes, each electrode of a row being aligned with the space defined between the electrodes of the other row and having substantially the same dimension in a direction along said rows.

15. The apparatus of claim 14 wherein each of said electrodes terminates in a square working surface lying within a common surface, the spacing between said rows and between adjacent electrodes within a row being substantially equal to the side of one said square working surfaces.

16. The apparatus of claim 15 wherein said common surface defines a plane.

17. The apparatus of claim 15 wherein said common surface is convex.

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