A stepping motor control system for controlling the bi-directional movement of a plurality of styli across a recording medium. The control system includes a feedback path for energizing selected styli at predetermined intervals whereby substantially distortion free characters are printed on the recording medium. The styli, in a preferred embodiment, are etched on a strip of insulating material and driven by the stepping motor within a slotted support member.

9 Claims, 5 Drawing Figures
FIG. 1

STEPPING MOTOR CONTROL CIRCUIT

SHAFT ENCODER

CHARACTER GENERATOR

FIG. 2
BACKGROUND OF THE INVENTION

The quality of recording at a low noise level characteristic of non-impact printers has contributed to make electrographic printing, or recording, attractive in various commercial applications. As is well known, electrography, as it relates to the present invention, may be defined as the deposition of electrostatic charge on an insulating recording medium in a charge pattern corresponding to the information to be recorded. The charge pattern is developed to provide a visible representation of the recorded information.

The conventional technique of matrix printing has particular usefulness in electrographic recording. In this technique, a linear array of a styli are driven across the recording medium at a constant speed and, as various signal voltages are applied to the styli, alphanumeric charge patterns are recorded as portions of a two-dimensional matrix. For example, if a five by seven character matrix is utilized, by selectively pulsing the styli corresponding to the desired character, a latent electrostatic image corresponding to the selected character will be formed within the confines of the five by seven matrix. Development of the latent electrostatic charge converts the otherwise latent pattern into a visible recording. This may be done by applying to the latent charge pattern electroscopic marking particles, commonly referred to as toner, and charged to a polarity opposite to that of the latent charge pattern. Cascade or brush development, among others, may be used for applying the toner. Fusing the toner to the recording medium, which renders the visible recording permanent on the recording medium, may be accomplished with heat, flash fusing, organic solvents, pressure, etc.

Prior art printers of a matrix type generally use varied mechanical techniques for driving the styli across the recording medium to print a line at a time. In particular, the prior art matrix printers generally included clutches, gear trains, solenoids and various other mechanical elements to drive the styli. The speed and accuracy of the printers are limited by the mechanical elements utilized. Further, the number of mechanical elements in the prior art drive systems lead to high wear of the elements. Therefore, the prior art electrographic drive systems have been generally unattractive due to the cost, limited speeds, high wear rates, and the unreliability of a drive system utilizing a large number of mechanical and electromechanical components.

SUMMARY OF THE PRESENT INVENTION

The present invention relates generally to an electrographic recording technique wherein a plurality of styli are driven across, and in contact with, a recording medium by a stepping motor, the stepping motor being driven and controlled by a novel control system in accordance with the principles of this invention. In particular, a plurality of electrical conductors or styli, corresponding to the number of rows of the character matrix, are connected to a carrier member. The carrier member is inserted into a carrier guide which includes a slotted portion to allow a driving member access to the carrier member. The driving member, comprising an engagement means mounted onto the shaft of the stepping motor, is placed adjacent the carrier guide whereby the engagement means engages the carrier member. When the stepping motor is energized, the carrier member is incremented from an initial position within the carrier guide in a manner to traverse the recording medium so that the styli may be controlled to print a complete line of characters. After a line is printed, the stepping motor is driven in the reverse direction to return the styli to the initial position. The stepping motor may be driven continuously or in a composite, or low speed mode, or a print, or high speed mode, dependent upon the input to the printer.

It is an object of the present invention to provide a novel stylus drive control system for use in an electrographic printer.

It is a further object of the present invention to provide a novel stylus drive control system for controlling an electrographic stylus, the stylus being driven by a stepping motor. In the preferred mode of operation, the stylus comprises a plurality of conductors forming on a stylus carrier member, the stylus carrier being driven between first and second positions within a carrier guide by the stepping motor.

It is a further object of the present invention to provide a novel stylus drive system which utilizes a stepping motor and a novel stepping motor control circuit which provides a reliable, economical and accurate method of driving an electrographic stylus across a recording medium.

It is a further object of the present invention to provide a novel stylus carrier which has a low mass, can be driven at high rates of speed, is economical, has a high index of durability and a low wear rate.

DESCRIPTION OF THE DRAWING

For a better understanding of the invention as well as other objects and further features thereof, reference is made to the following description which is to be read in conjunction with the accompanying drawing wherein:

FIG. 1 is a perspective view of an electrographic recording apparatus utilizing the novel stylus drive system of the present invention;

FIG. 2 is a plan view of the stylus carrier of the present invention;

FIG. 3 illustrates in block diagram form the novel circuitry for controlling the apparatus of FIG. 1 in accordance with the teachings of the present invention;

FIG. 4 is a schematic diagram of the stepping motor control logic; and

FIG. 5 is a schematic diagram of the stepping motor drive circuit.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, an insulating recording medium 2, such as plastic coated paper, is shown supported in a recording zone generally by a backing electrode 4 which holds the recording medium 2 against pressure contact by a plurality of styli 6. This plurality of styli may be formed in a linear array and may include a series of parallel conductive electrodes suitably electrically isolated from one another as shown in FIG. 2. The array is etched on an insulating medium, or carrier member 8, such as Mylar, through which electrical recording signals are supplied individually to selected styli corresponding to the character to
be recorded. The styli are connected to a source of recording signals, such as a character generator.

The technique for producing alphanumeric characters by selectively pulsing corresponding styli within a matrix of styli is well known. In the preferred embodiment, character generator 1 causes motion to be imparted to the stylus carrier member 8 by stepping motor 10, the shaft 12 of which is coupled to an engaging member 14. A shaft encoder 16 is also mounted on shaft 12. Stepping motor control circuit 18 is coupled to stepping motor 10 and responds to signals from character generator 1 to control the incrementing of motor 10. Any motor which is capable of high speed incrementing may be used as stepping motor 10, such as Model Ts25, manufactured by the Superior Electric Company, Bristol, Conn.

Engaging member 14 is mounted adjacent to slot portion 20 of stylus carrier guide 22. Stylus carrier guide 22 is illustratively U-shaped and includes a channel-shaped opening 24. The stylus carrier member, generally indicated by reference numeral 30, is flexibly mounted and includes a plurality of styli, or conductors, 6 corresponding to the number of rows in the character matrix, as shown in FIG. 2. Carrier member 30 is inserted within the slotted carrier guide 22. Also included on stylus carrier member 30 are a plurality of perforations 34. Stylus carrier member 30 illustratively comprises a belt made of a double layer of Mylar and has a plurality of stainless steel conductors etched thereon. At the right-hand end of member 30 is connector 36 for connecting stylis 6 to character generator 1. As flexible carrier member 30 is driven from left to right, guide rollers 41 cause the portion of member 30 which is between the right end of guide 22 and connector 36 to form a loop. This allows for a saving in space over apparatus using a stiff carrier member. Furthermore, the use of a flexible carrier member in the manner illustrated avoids the use of a continuous belt with its attendant disadvantage of requiring a commutator which is subject to toner contamination.

In operation, stylus carrier member 30 is driven from left to right across the recording medium 2 during the application of suitable recording signals to the styli. During the movement of the stylus array a predetermined amount, referred to as a character space, a character is recorded on the electrographic recording medium 2 in the form of a latent electrostatic charge pattern. Recording medium 2 may be stationary in the recording zone during the left to right transversal of the stylus array during which an entire line of characters may be recorded. At the right-hand terminal point of the stylus movement, the direction of stepping motor 10 is reversed via stepping motor control circuit 18. The electrostatic charge patterns recorded by the transversal of the stylus are rendered visible by depositing electrophotographic marking particles, or toner, on these patterns. After development, the toner may be fixed to the recording medium in any of several conventional manners. For example, recording medium support and guide member 39 may have a platen fuser employing a resistance heating coil over which the medium is moved, thus rendering the developed images permanent.

In the embodiment illustrated, engaging means 14 is selected to be a sprocket wheel. The dimensions of carrier member 30 are selected so that, when inserted in carrier guide 22, the perforations 34 thereon are accessible via slot 20 to the teeth on the sprocket wheel. When the stepping motor 10 is energized for forward incrementing, the sprocket wheel rotates in the direction of the arrow and drives stylus carrier member 30 from left to right. When stepping motor 10 is energized for reverse incrementing, sprocket wheel 14 rotates in the opposite direction, thereby driving carrier member 30 from right to left.

Various features of the drive mechanisms shown in FIG. 1, such as a stylus retract mechanism have not been illustrated for the purpose of conciseness and since such features are well known in the prior art.

Referring now to FIG. 3, there is shown a block diagram of the novel stepping motor control system of the present invention. Input data, such as data encoded into ASCII code, comprising a parallel seven bit pattern corresponding to a character to be printed, is applied to character buffer register 100. The output of character buffer register 100 is gated to character generator 102 in time sequence with the strobe, or clock, signal generated by circuitry not shown and applied to strobe control gate 104. The output of character generator 100 is also coupled to function decoder 106 which decodes a suitable character or a control word to and generates a pulse to enable the stepping motor. Character generator 102 converts the input code from register 100 into signals suitable to form a representation of the character in a five by seven matrix format. The output of character generator 102 is connected to the input of stylus drivers 108 which operate to amplify and shape the output of character generator 102. The output of the stylus drivers 108 are applied to selected conductors of stylus 6 to print a character corresponding to the data applied to character buffer register 100. The output of function decoder 106 is connected to control gate 112 which determines in which direction the stepping motor is to be advanced. The output of strobe control gate 104 is connected to function decoder 106 and step generator 114. Character bit shift register 116 has its output connected to character generator 102 and to the input of step generator 114. The outputs of control gate 112 and step generator 114 are connected to the input of stepping motor control logic circuit 118 which operates to control stepping motor drive circuit 119. Drive circuit 119 in turn controls stepping motor 10. The output shaft of stepping motor 10 is coupled to stylus 6 to drive the stylus across the recording medium, as shown in FIG. 1, and to shaft encoder 16. Shaft encoder 16 operates to break each step of stepping motor 10 into seven equal elements, corresponding to five columns of data and two columns of inter-character space, so as to provide a substantially distortion free printed character. The output of shaft encoder 16 is connected to the input of feedback control gate 124 which operates to synchronize character bit shift register 116 and step generator 114. The step pulse output of step generator 114 is also connected to one input of column counter and decoder 126, the output thereof being connected to control gate 112. Initialization logic circuit 128 is connected to step generator 114 and column counter 126 and operates to initialize the system when it is turned on by resetting the column counter to zero and returning stylus 6 to a location corresponding to zero.

In operation, ASCII input data is applied to character buffer register 100 in parallel, the output thereof being clocked into character generator 102 and function de-
coder 106 by strobe control 104. Function decoder 106 steps motor 10 when a suitable character, or a space for example, is decoded and the signal applied to control gate 112 determines whether the stepping motor is to advance or return towards the initial point. If the motor is to advance, a signal is applied to lead 200; if the motor is to return, a signal is applied to lead 210. Step generator 114 applies a stepping pulse to stepping motor control logic circuit 118, enabling the shaft of stepping motor 10 to rotate an amount dependent upon the stepping angle of the motor (for example, 5° of rotation per step pulse). Stylus 6 moves a distance equivalent to one step and shaft encoder 16 generates seven pulses per step. The output pulses produced by shaft encoder 16, which are generated in both the high and low speed modes of operation, are fed to character bit shift register 116 via the feedback control gate 124. Character bit shift register 116 transmits to character generator 102 the second through sixth of the seven pulses generated by shaft encoder 16 for each step of motor 10. These pulses strobe out each character from character generator 102 in time sequence with the shaft encoder output and enables the five by seven data matrix to be printed by stylus 6 accurately in correspondence with the movement of the stylus across the recording medium. The first bit in character bit shift register 116 on line 125, serves to step stepping motor 10. Column counter and decoder 126, reset by initialization logic 128 at appropriate times, counts the number of stepping pulses produced by step generator 114. When the number of pulses counted is equivalent to movement of the stylus from the initial position to the right-hand margin, a signal is applied to control gate 112 which in turn generates a signal on lead 210 causing generator 114 to reserve the direction of stepping motor 10.

Referring now to FIG. 4, the schematic logic diagram of stepping motor control logic circuit 118 shown in FIG. 3 is illustrated. The output signal from turn around control logic 112, corresponding to driving stylus carrier member 30 in a forward direction, appears on lead 200 and is applied to one input of NAND gates 202, 204, 206 and 208. The output appearing on lead 210 also generated by control logic 112, is the inverse of the signal on lead 200 and is applied to one input of NAND gates 212, 214, 216 and 218. The Q output of flip-flop 220 is connected to the other input of NAND gates 202 and 212 while the Q output thereof is connected to the other input of NAND gates 204 and 214. The Q output of flip-flop 222 is applied to the other input of NAND gates 206 and 216 while the Q output thereof is connected to the other inputs of NAND gates 208 and 218. The output of NAND gate 216 is coupled to the K input of flip-flop 220 via inverter 224 while the output of NAND gate 204 is connected to the J input of flip-flop 222 via inverter 226. The output of NAND gates 202 and 214 are connected together and coupled to the K input of flip-flop 222 via inverter 228. The output of NAND gates 206 and 218 are connected together and coupled to the J input of flip-flop 220 via inverter 230. The CLK input of flip-flops 220 and 222 are coupled to step pulse output 120 of step generator 114 via inverting amplifier 232.

In operation, a positive signal level appears on lead 200, corresponding to a forward step operation to be initiated. The characteristics of the TS 25-1008 stepping motor requires a predetermined time sequence of pulses to be supplied to the stepping motor coils to get the forward stepping operation. Assuming that the Q outputs of flip-flops 220 and 222 are initially zero, the following sequence at the Q outputs will provide forward stepping: For flip-flop 220; 1, 1, 0, 0; for flip-flop 222; 0, 1, 1, 0. The JK flip-flops 220 and 222 each have two conditioning inputs and a clock input.

The operation and construction of JK flip-flops is well known in the art. If both conditioning inputs are disabled at clocktime, the flip-flop will remain in its present state. If the J input is enabled and the K input is disabled, the flip-flop will be set at clocktime. If the K input is enabled and the J input disabled, the flip-flop will be reset at clocktime. If both J and K inputs are enabled, the flip-flop will change states when a clock pulse occurs.

Gates 208, 206, 204 and 207 control the forward stepping inputs to flip-flops 220 and 222. Gates 218, 216, 214 and 212 control the reverse stepping inputs.

The outputs of the gates are wire "ored" as shown and inverters 226, 224, 228 and 230 correct the sense of the inputs to flip-flops 220 and 222. If in the initial state both flip-flops are reset and forward line 200 is enabled, the following count will occur:

<table>
<thead>
<tr>
<th>step pulse</th>
<th>Init</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF 220</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FF 222</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

enabling forward stepping operation. If forward line 200 is disabled and reverse line 210 is enabled, the following count will occur:

<table>
<thead>
<tr>
<th>step pulse</th>
<th>Init</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF 220</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FF 222</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

enabling reverse stepping operation.

In summary, the logic circuitry shown in FIG. 4 provides a technique for providing a sequence of pulses to the stepping motor coils which determines whether the stepping motor is to be incremented in the forward or reverse direction.

Referring now to FIG. 5, there is shown a schematic diagram of stepping motor drive circuit 119 connected to stepping motor 10. Output leads 300, 302, 304 and 306 (FIG. 4) are coupled as shown to the respective gate inputs shown in FIG. 5. Input lead 300 is connected to the input of inverter 308 and one input of NAND gate 310. Input lead 302 is connected to the input of inverter 312 and to one input of NAND gate 314, input 304 is connected to inverter 316 and to one input of NAND gate 322. The outputs of the gates set forth hereinabove are connected to inverting amplifiers 324, 326 . . . 338, respectively. The outputs of the inverting amplifiers are connected to resistors 340, 342 . . . 354, respectively, sequential pairs of resistors (340 and 342, 344 and 346, etc.) being connected to a common point and thence to the associated stepping motor coils a, b, c and d. The other input of the NAND gates of FIG. 5 is called the "PRINT" line input. As set forth previously, the system described in the present invention is adapted for use in a dual mode printer system which comprises a print (or high speed) mode and a compose (or low speed) mode. It should be noted at this point that the invention may be also utilized in a system wherein the stepping motor is driven continuously. When the printer is conditioned
to be in the compose mode of operation, a logic 0 is
generated on the PRINT line (by means not shown).
The logic 0 causes a logic 1 to be present at the NAND
gate outputs. However, the inverting amplifiers cou-
pled thereto invert the logic 1 into a logic 0. The cur-
cent generated in resistors 342, 346, 350 and 354 is of
such direction as to cause the total current at the com-
mon point (and entering the stepping motor coils) to be
less than if the output of the aforementioned inverting
amplifier was a logic 1. This logic 1 is generated when
the system is in the print mode of operation, the logic
1 on the print line appearing at the output of its asso-
ciated inverting amplifier as a logic 0. For example, as-
aume the system is in the compose mode and the cy-
cling sequence is at the point wherein a stepping pulse
sequence has appeared on lead 302. The output of in-
verter 328 will be a logic 1, causing current to flow into
resistor 344. Since the print line is a logic 0, the output
of inverter 330 will be at logic 0, reducing the current
to the common point of resistors 344 and 346 and
therefore reducing the current to coil b. If the system
is in the print mode at the time the pulse sequence is
on lead 302, a logic 1 will appear at the output of in-
verter 330, causing current to flow through resistor
346. The total current through resistors 344 and 346 is
summed at the common point thereof and flows into
coil b. It can therefore be seen, assuming that the resis-
tors are of equal value, that the current to the stepping
motor coils in the compose mode is one-half the cur-
tent to the coils in the print mode.

Since the amount of torque and speed of the stepping
motor is dependent upon the current through its coils,
it can be observed that the circuitry shown in FIG. 5
provides a simple and reliable control for the stepping
motor whereby it may be utilized efficiently in both
high speed and low speed modes of operation. Further-
more, additional amplifiers and resistors may be added
so that a plurality of stepping speeds may be attained.
In addition, further control logic may be added so that
asynchronous operation at varying speeds is achieved.

While the invention has been described with refer-
ence to its preferred embodiment, it will be understood
by those skilled in the art that various changes may be
made and equivalents substituted for elements thereof
without departing from the true spirit and scope of the
invention. In addition, many modifications may be
made to adapt a particular situation or material to the
 teachings of the invention without departing from its
essential teachings.

What is claimed is:
1. Apparatus for recording latent electrostatic images
in the form of alphanumeric characters in spaces on an
insulating medium comprising
a carrier member having a stylus formed thereon,
said stylus comprising a plurality of electrical con-
ductors,
a guide member having a slot along a portion of its
surface for receiving said carrier member and hold-
ing said stylus in spatial relation to said recording
medium, said carrier member having freedom of
linear movement within said slot,
a bi-directional stepping motor coupled to said car-
rier member for moving said carrier member within
said slot,
means responsive to input signals representing said
alphanumeric characters for energizing said step-
ping motor to move said carrier member between
a first and a second position in discrete predeter-
mined steps, and
character generating means responsive to said input
signals for applying electrical signals to said electro-

cial conductors to record said latent electrostatic
images on said recording medium.

2. The apparatus as defined in claim 1 wherein said
discrete step of said stepping motor causes said carrier
member to move across said recording medium a single
one of said spaces, said apparatus further including en-
coder means coupled to said stepping motor for provid-
ing signals which represent divisions of the discrete
step, said character generating means being responsive
to said encoder means signals for recording characters
within said spaces.

3. The apparatus as defined in claim 1 wherein said
carrier member comprises a flexible strip of material
having a connector at one end thereof for connection
to said character generating means, said apparatus fur-
ther including loop forming means for directing said
carrier member to form a loop as said carrier member
exits from said guide member.

4. Printing apparatus comprising
an insulated recording medium,
a carrier member,
a stylus comprising a columnar array of electrical
conductors mounted on said carrier member,
guide means for retaining said carrier member and
holding said stylus at a fixed distance from said rec-
ording medium, said guide means including means
for allowing said stylus to move in a linear fashion
between a first position and a second position,
a bi-directional stepping motor coupled to said car-
rier member for moving said carrier member in
said guide means,
control means responsive to a signal representing an
alphanumeric character for controlling said step-
ping motor to move said stylus on said carrier
member a predetermined distance from said first
position toward said second position, and

means responsive to said alphanumeric character sig-

al for applying electrical pulses to the conductors
of said stylus so as to form an electrostatic image of
said alphanumeric character on said recording
medium in the space defined by said predeter-
mined distance.

5. The apparatus of claim 4 wherein said control
means comprises means responsive to said stylus reach-
ing said second position for activating said stepping
motor to return said stylus to said first position.

6. The apparatus of claim 5 wherein said carrier
member comprises a flexible strip of material, said ap-
paratus further including loop forming means for di-
recting said carrier member to form a loop as said car-
rier member exits from said guide means when said sty-
lus is moved from said first position toward said second
position.

7. The apparatus of claim 5 wherein said control
means comprises
first means controllable for generating either a first
or a second set of signals,
second means controllable for generating either said
first or said second set of signals,
means for applying the signals generated by said first
means and said second means to said stepping mo-
tor, and
direction control means for controlling said first means to generate said first set of signals and said second means to generate said second set of signals whereby said stepping motor is driven in a first direction and for controlling said first means to generate said second set of signals and said second means to generate said first set of signals whereby said stepping motor is driven in a second direction.

8. The system of claim 7 wherein said applying means includes speed control means for varying the magnitude of the signals applied to said stepping motor whereby the speed of said stepping motor may be controlled.

9. The system of claim 8 wherein said speed control means includes a plurality of amplifiers and means for activating selected ones of said amplifiers to provide incremental motor speed variations.

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