United States Patent [19]

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[54] **METHOD AND APPARATUS FOR ELECTROSTATICALLY RECORDING WITH A CLOSED LOOP WEB DRIVE**

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[52] **U.S. Cl.** .... **346/74 ES**

[51] **Int. Cl.** **G01d 15/02,** G01d 9/26

[58] **Field of Search** .... 346/74 ES, 74 M; 340/174.1 A

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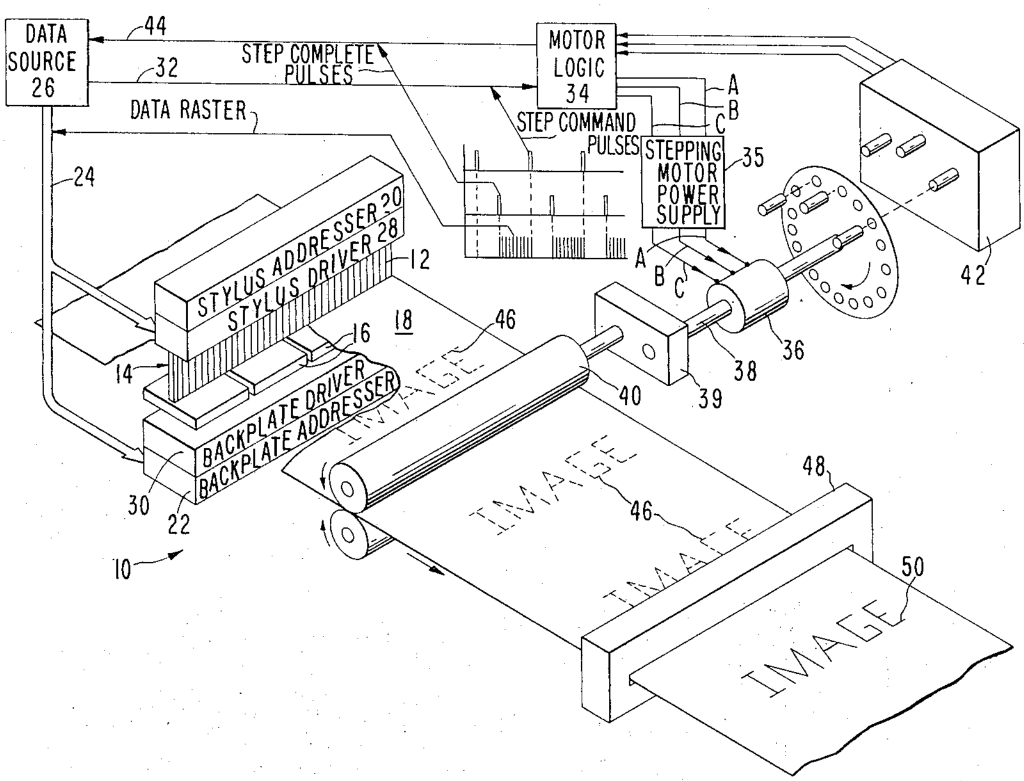
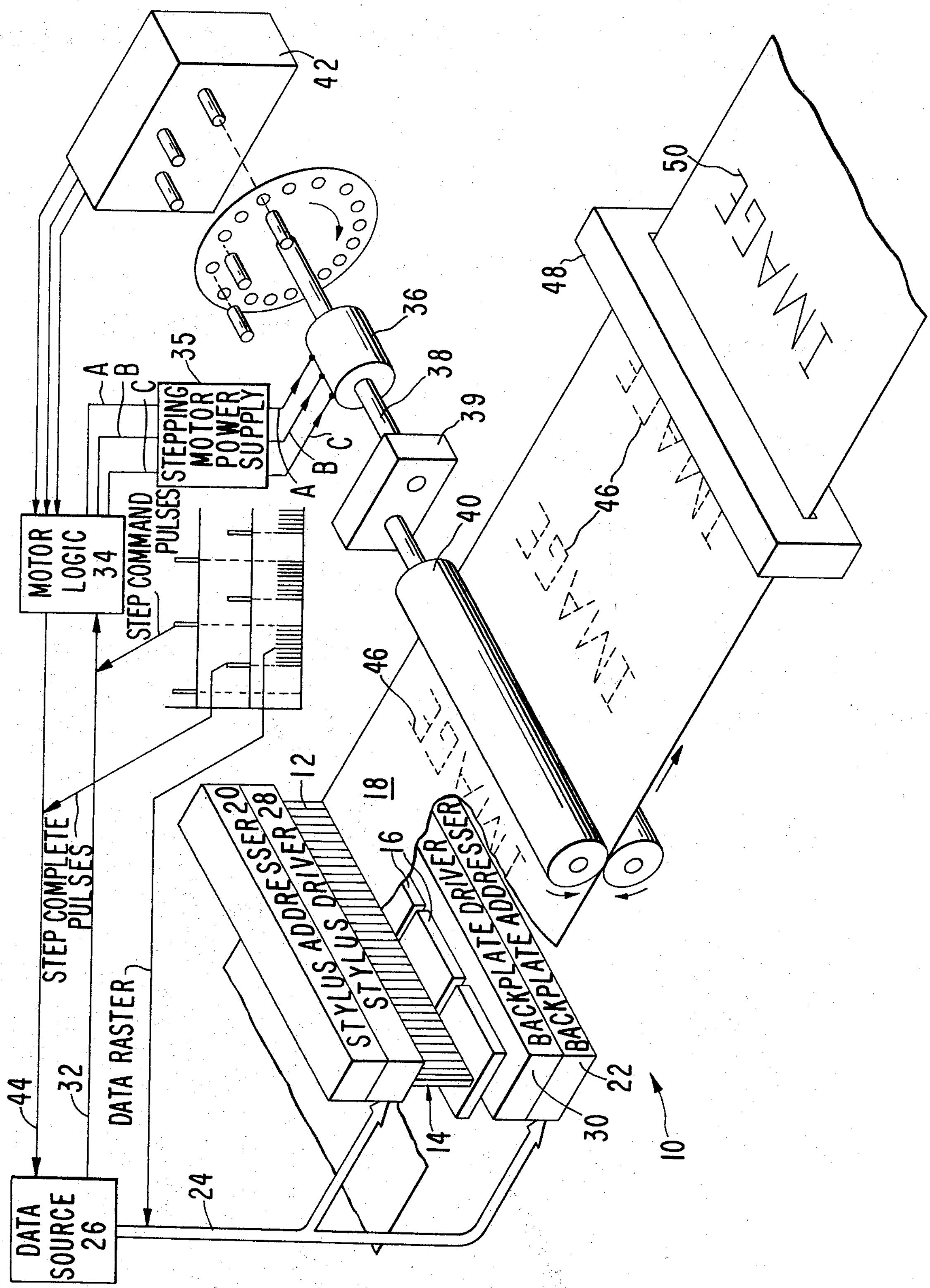
Attorney—Stanley Z. Cole et al.

[57] **ABSTRACT**

A charge image is electrostatically recorded on a web through an array of writing electrodes. A stepping motor moves the web in response to a digital data source which also selects and activates the writing electrodes. The motor stepping and web motion is synchronized with the digital data input to the writing electrodes. The stepping motor is provided with a shaft encoder for detecting each step as it is completed and for feeding back this web change-in-position information to the digital data source. Upon receiving the step completion pulse, the digital data source releases the next raster of digital bits to the writing electrode array. Feedback between the shaft encoder and the digital data source preserves writing integrity on the web during start-up acceleration and subsequent deceleration of the web.

6 Claims, 1 Drawing Figure




MOTOR LOGIC 34
STEPPING MOTOR POWER SUPPLY
STEP COMMAND PULSES
STEP COMPLETE PULSES
DATA RASTER
DATA SOURCE 26
STYLUS ADDRESSER
STYLUS DRIVER
BACKPLATE DRIVER
BACKPLATE ADDRESSER
IMAGE

METHOD AND APPARATUS FOR ELECTROSTATICALLY RECORDING WITH A CLOSED LOOP WEB DRIVE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to electrostatic recording and more particularly to web position feedback to the data source.

2. Description of the Prior Art

Heretofore, stepping motors in electrostatic recorders have been operated at a constant speed without position feedback to the data source. The rasters of digital bits were uniformly spaced with sufficient time therebetween to permit the stepping motor to complete the stepping action. An additional safety factor time was included to accommodate possible variances in motor response time due to varying line voltage, motor wear, differing motor characteristics, etc. It was assumed that each step was completed within the time allowed and the raster information proceeded on time regardless of the web position. A less than optimum time efficiency and other difficulties accompanied this open loop mode of prior art operation. First, raster information was not processed until the stepping motor reached full speed of about 500 steps per second which requires about ½ second. One-half second of motor acceleration up to full speed operation is about 125 steps, or 12 lines of print. If raster information was processed during start-up, the writing on the web would be unevenly spaced — crowded at the slower initial speeds and approaching normal spacing as the stepping motor approached full speed. Second, subsequent accelerations and decelerations of the stepping motor produced undesirable discontinuities of the recording. Momentary increases in friction in the motor or in the web, or momentary fluctuations or loss of power which exceeded the margin permitted by the safety factor produced line crowding in the recording. Third, stepping motors, unlike synchronous motors, stall after a critical slippage is reached. The stepping motor has to be started all over again with a series of progressively decreasing spaced step commands. At increased stepping rates loss of synchronism may be introduced by a single stray noise pulse pickup by the stepping motor control circuit. These extraneous pulses advance the energization of the stepping motor winding inducing slipping. As the speed is increased, the sensitivity to extraneous pulse increases. At high speeds the stepping motor may be completely stalled by a flourescent lamp or nearby induction apparatus.

SUMMARY OF THE INVENTION

It is therefore an object of this invention to provide an electrostatic recording system in which web position feedback is established between the stepping motor and the data source; provide an electrostatic recording system in which the effects of stepping motor accelerations and decelerations is eliminated; provide an electrostatic recording system in which the raster input rate is dependent upon the web position; and to provide an electrostatic recording system in which stepping motor stalling is avoided.

BRIEF DESCRIPTION OF THE DRAWING

Further objects and advantages of the electrostatic recorder and the operation of the closed loop web position control will become apparent from the following detailed description taken in conjunction with the drawing which is a schematic view of the electrostatic recording system operating in the closed loop web position showing the wave forms present at various points within the system.

Referring to the drawing, an electrostatic recorder **10** is shown. A stylus array **12** consisting of 640 writing electrodes **14** is positioned proximate a segmented backplate **16** with a dielectric coated paper or recording medium **18** passing therebetween. The styli and backplate segments are selected for writing by a stylus addresser **20** and a backplate addresser **22** in response to an output **24** of a digital data source **26.** The writing electrodes are activated in groups of eight, about 60 microseconds per group, by stylus driver **28** over a raster period of from about 1200 to about 300 microseconds by a digital raster from output **24.** The segments of backplate **16** are activated in synchronism with styli **14** by packplate driver **30.** The resulting current flowing between the selected and activated writing electrode and backplate segment pair transfers charge to the charge retentive surface of web **18.** After each digital raster, data source **26** provides a step command at output **32** to a motor logic circuit **34** having three outputs, A, B and C which are amplified by power supply **35.** A stepping motor **36** is provided having three sets of windings, A, B and C, which are alternately activated by the three outputs of logic circuit **34.** Stepping motor **36** turns one angular step in response to the step command initiated in output **32.** Stepping motor **36** turns a shaft **38** which rotates a drive roller **40** to move web **18** one linear step, about 1/80th of an inch, placing fresh paper underneath stylus array **12.** A shaft encoder **42** is provided on the other end of shaft **38** to detect the completion of each angular step of stepping motor **36.** Shaft encoder **42** generates a separate step completion pulse for each of the three windings of motor **36.** These pulses are returned to motor logic circuit **34** where they are combined or logically OR'ed to form a single pulse train which is communicated to data source **26** through feedback loop **44.** Upon receipt of the step completed pulse, data source **26** releases the next digital raster to addressers **20** and **22.** Synchronism between web motion and raster input is thus established and maintained. Any variation in the speed of stepping motor **36** causes a corresponding variation in the raster feed rate in output **24** from data source **26.** The structure and operation of shaft encoder **42** is described in more detail in IEEE Transactions On Automatic Control, Vol. AC-13, No. 5, October 1968, entitled "Applications Of The Closed-Loop Stepping Motor" by T. Roland Fredriksen. The charge transfered from writing electrodes **14** onto moving web **18** forms a charge image **46** on web **18.** The web passed through a toning station **48** developing the charge images **46** into visible images **50.**

The time sequence of the operation of electrostatic recording system **10** is illustrated in the integrated waveform chart shown in the FIGURE. First, data source **26** provides a step command pulse in output **32** to motor logic circuit **34.** In response to the step command pulse, motor logic circuit **34** provides an energizing pulse to winding A of stepping motor **36** causing the motor to step 10°. Shaft encoder **42** determines when the step is completed and provides a step completed pulse in one of its three outputs. The three outputs of shaft encoder **42** correspond to the three windings of motor 36. A step completion by each winding causes a pulse to appear in the shaft encoder output corresponding thereto. The three outputs are combined in motor logic 34 and a single train of step completed pulses appears in feedback loop 44 to data source 26. Data source 26 then releases raster pulses in output 24 to addressers 20 and 22. After completion of the digital raster, data source 26 provides step command B in output 32 which ultimately energizes winding B in stepping motor 36 causing the stepping motor to rotate another 10°. At step B completion shaft encoder 42 supplies the step completion pulse to data source 26 which releases the next raster of digital information. Each raster of digital information is released after the step completion pulse arrives at data source 26. This ensures that web 18 is properly advanced to maintain writing integrity notwithstanding accelerations and decelerations of stepping motor 36.

The closed loop web position feedback permits writing during startup of stepping motor 36 because the raster digital information feed rate cannot be faster than the stepping rate of the motor. Both the feed rate and the stepping rate increase together until full stepping rate is reached. The ½ second of wasted startup time of the prior art is eliminated. If there is a slowdown in stepping speed due to a temporary increase in turning friction or a temporary drag on web 18, or operater interference, the raster feed rate is slowed down a corresponding amount and remains synchronized with the web drive speed. Recorder 10 operating with web position feedback is so insensitive to irregularities in web drive speed that the web may be manually pulled out of the recorder past stylus array 12 with all of the imprecision that one might expect without disturbing the writing integrity. The raster rate accommodates the non-uniform tugs and pulls of the operator because the raster pulses are released by the step completed pulse which is necessarily in synchronism with the web movement. This manual feature is convenient in the event of stepping motor power supply failure.

The feedback control is effective in the opposite direction as well. Uneven raster feed rates produce a complimentary change in the web drive. The stepping command pulses appearing at the end of each raster become spaced thus adjusting the stepping rate and synchronization is maintained.

Further, synchronization between the raster feed rate and the stepping speed prevents a type of motor stalling which appears in stepping motors. Stepping motors proceed from one stable position of minimum reluctance to the adjacent position of minimum reluctance in response to an energizing pulse on the adjacent windings. Slippage caused by a stepping command rate faster than the angular stepping rate of the motor does not generate corresponding increase in torque which increases the speed of the motor and re-establish synchronization as is the case with conventional synchronous motors. Instead, the turning torque decreases after a critical slippage is reached and the motor stalls completely. Stray rf noise and arcing cause motor logic 34 to advance the winding energization of motor 36 causing loss of synchronization. Stepping motors are increasingly sensitive to this type stalling at higher speeds. Without web position feedback stepping motor speeds are limited to about 800 steps per second. The feedback of the present invention permits a stepping rate of at least 2400 steps per second. In the present invention stalling caused by loss of synchronization is eliminated because motor logic circuit 34 receives feedback as to which winding has just been energized to cause the last step completion. With this information, logic circuit 34 can always provide the proper subsequent winding energization. Stray pulses cannot effect this controlled loop to destroy synchronization.

Clearly, various changes may be made in the structure and embodiments shown herein without departing from the concept of the present invention. For example the web position may be determined in other ways besides the shaft encoder. The web position may be determined directly from the web motion.

What is claimed is:

1. An electrostatic recording apparatus for forming a charge image on the charge retentive surface of a recording medium in response to input signals, and for maintaining the proper spacing of the charge image regardless of variations in the speed of the recording medium or variations in the pulse rate of the input signals, the combination comprising:

a stylus array formed by a plurality of writing electrodes mounted proximate the charge retentive surface of the recording medium;

backplate means mounted proximate the other side of the recording medium and spaced from the stylus array to permit passage of the recording medium therebetween;

data processing means responsive to the input signals for providing rasters of pulses for addressing and activating the stylus array and the backplate means to cause charge to transfer from selected styli to the charge retentive surface, and also for providing a step command pulse for advancing the recording medium;

a motor logic circuit having a plurality of outputs and responsive to the step command pulses for providing winding step command pulses alternatively in the plurality of outputs;

a variable speed stepping motor having a plurality of windings corresponding to the plurality of logic circuit outputs, each winding responsive to the winding step command pulses in the corresponding logic circuit output to rotate the stepping motor a defined angular step increment;

drive means responsive to the angular steps of the stepping motor to drive the recording medium a corresponding linear step increment to move the recording medium past the stylus array; and

detection means responsive to the step increment for generating a step completion pulse which is communicated to the data processing means to effect synchronization between the raster rate and the stepping rate for preserving the proper spacing of the charge image on the recording medium.

2. The apparatus of claim 1, wherein the detection means is a shaft encoder responsive to the angular step increments of the stepping motor, the shaft encoder having a plurality of outputs corresponding to the plurality of windings of the stepping motor, and wherein the shaft encoder provides step completion pulses for each winding which are communicated to the motor logic circuit permitting the motor logic circuit to energize the windings sequentially and maintain stepping synchronism unaffected by externally generated noise pulses.

3. The apparatus of claim **2**, wherein the stepping motor has three windings and the motor logic circuit and the shaft encoder have three outputs corresponding thereto.

4. The apparatus of claim **1**, wherein the data processing means consists of a data source, and addressing means for the stylus array and the backplate, and driving means for the styli and backplate.

5. The apparatus of claim **1**, wherein the step command pulse is provided by the data processing means immediately after each raster of pulses is provided to the stylus array and the backplate means by the data processing means, and the step completion pulse is communicated to the data processing means permitting the data processing means to release the next raster of pulses.

6. A method of electrostatically recording a properly

positioned charge image on a recording medium in response to input data, regardless of the speed of the recording medium or the rate of input data, the method comprising:

providing a raster of pulses to a stylus array and a backplate for selectively transferring charge to the recording medium positioned therebetween;

providing a step command pulse for activating a stepping motor in increments which advances the recording medium in increments past the stylus array;

detecting the completion of each increment; and

providing a step completion pulse which maintains synchronism between the input rate and the stepping motor stepping rate.

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