

[54] **TRAVELING WAVE ACTUATED  
SEGMENTED CHARGING ELECTRODE  
FOR AN INK JET PRINTER**

[75] Inventor: **John B. Gunn**, Mount Kisco, N.Y.

[73] Assignee: **International Business Machines  
Corporation**, Armonk, N.Y.

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[52] U.S. Cl. .... **346/1, 317/3, 346/75**

[51] Int. Cl. .... **G01d 15/18**

[58] Field of Search .... **346/75, 1; 317/3**

[56] **References Cited**

**UNITED STATES PATENTS**

3,596,275 7/1971 Sweet..... 346/1

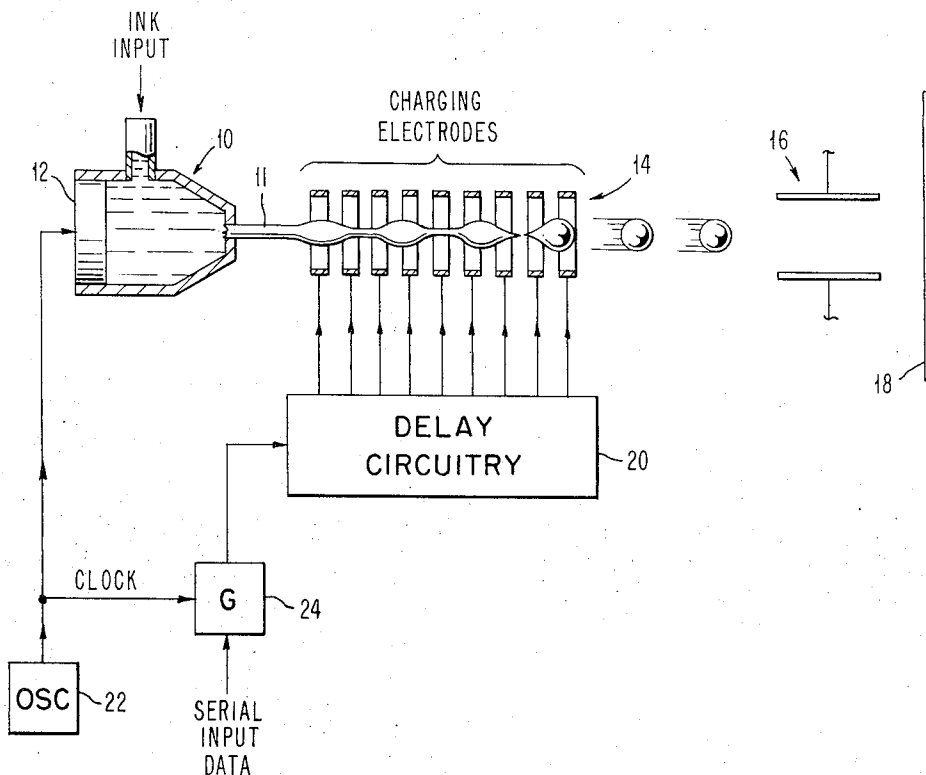
*Primary Examiner*—Joseph W. Hartary  
*Attorney*—Roy R. Schlemmer, Jr. et al.

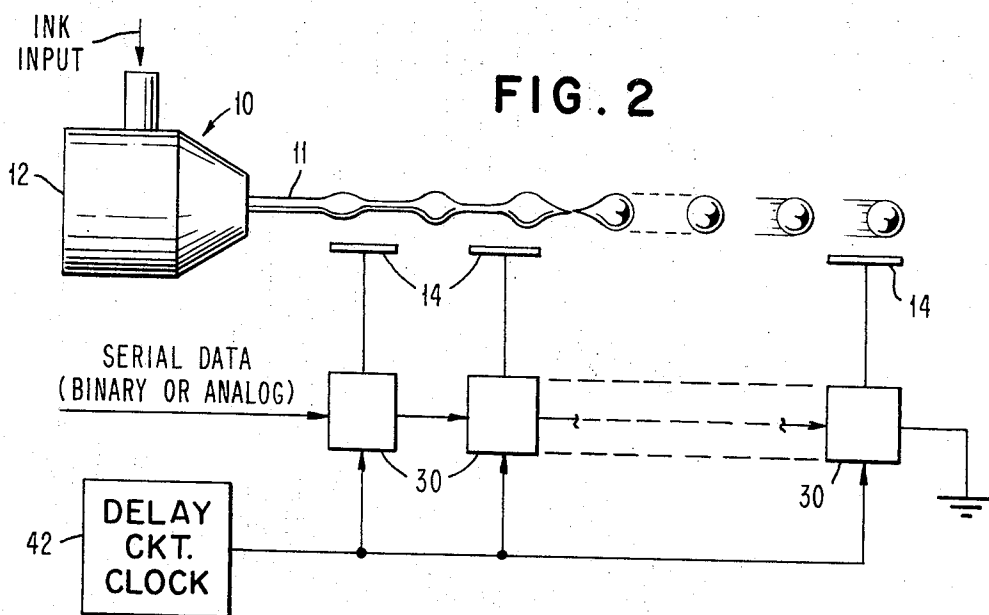
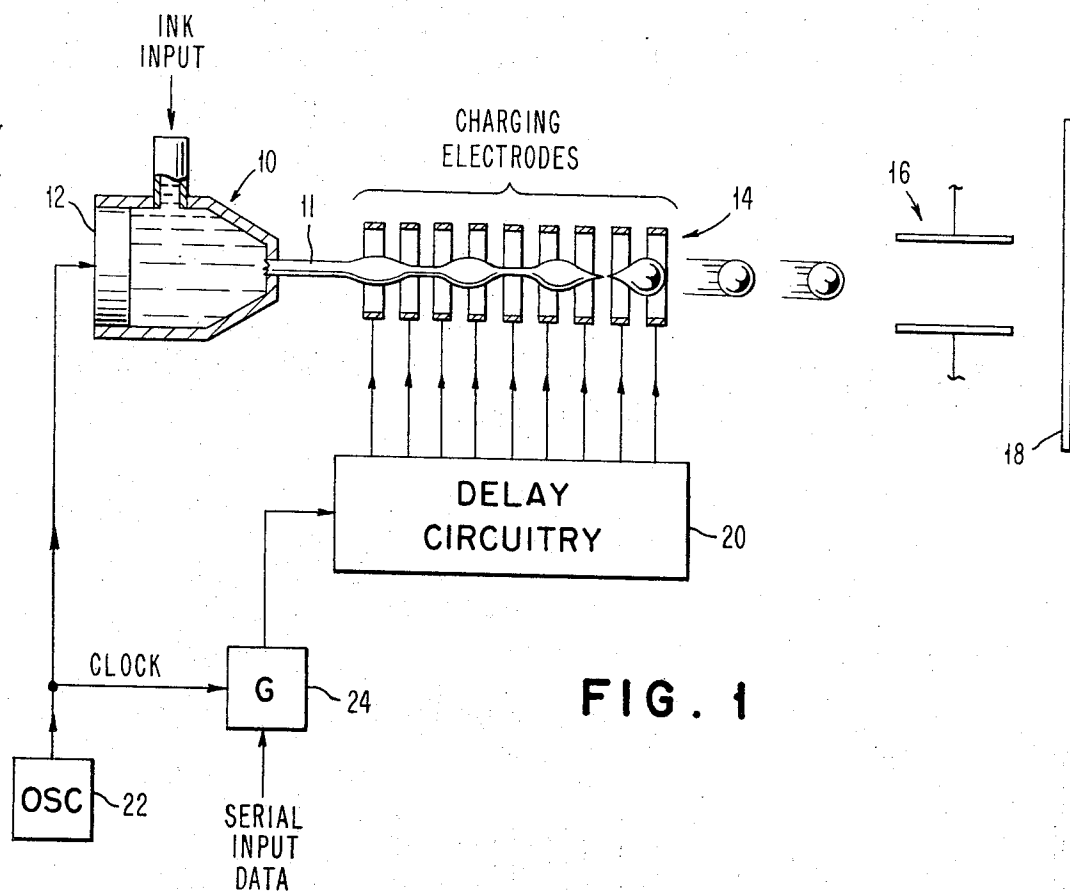
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**ABSTRACT**

The present invention comprises a segmented charging electrode for use in an ink jet printing system wherein the segments are connected to the taps of a delay line or circuit of similar function which in effect produces a traveling wave along the charging electrode. The rate of propagation of the delay line is such that it substantially equals the velocity of the ink jet stream. Use of the disclosed circuitry obviates the synchronization circuitry usually necessary to maintain the proper phase relationship between the droplet forming transducer and the ink droplet charging pulse applied to the charging electrode.

**11 Claims, 8 Drawing Figures**





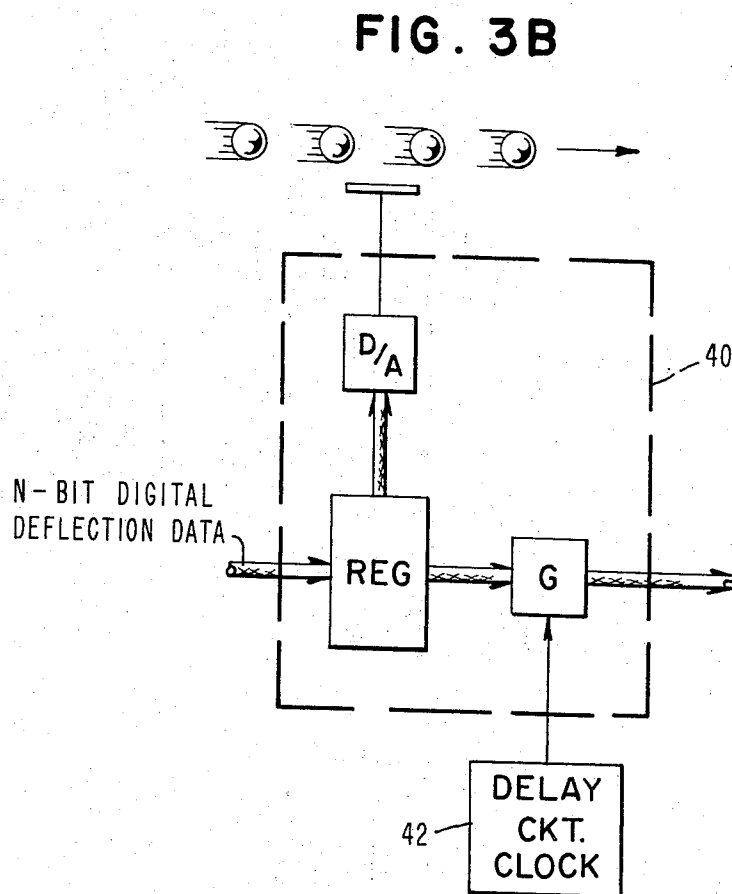
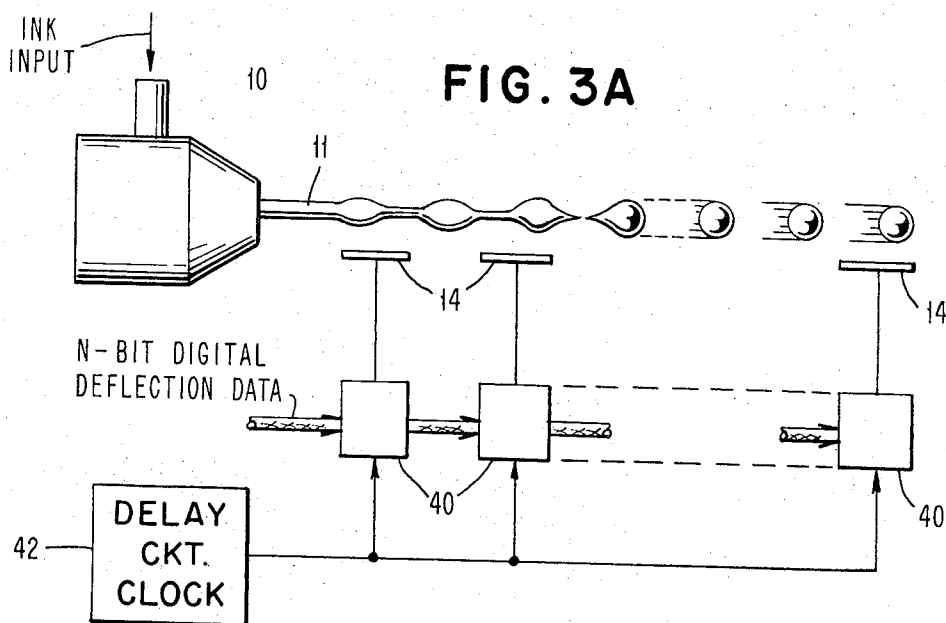


FIG. 4A

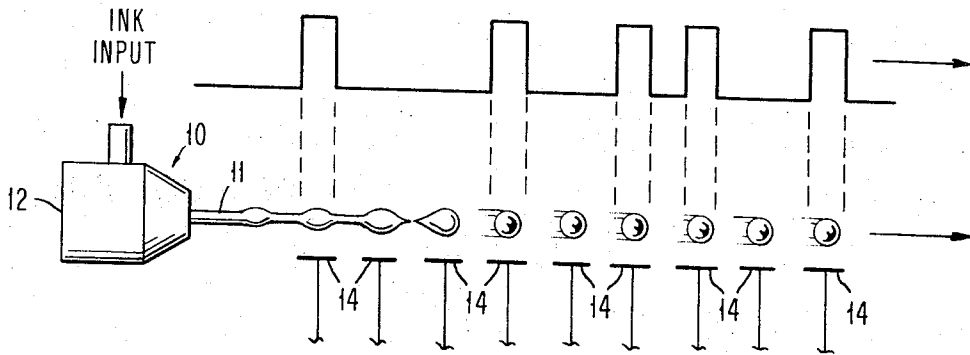


FIG. 4B

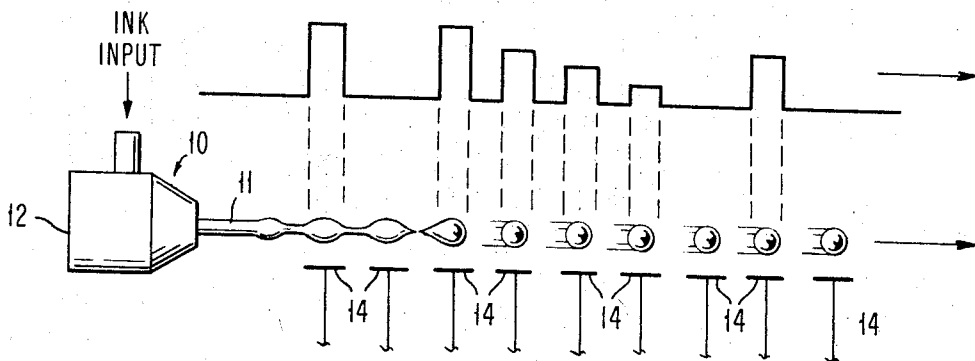


FIG. 5A

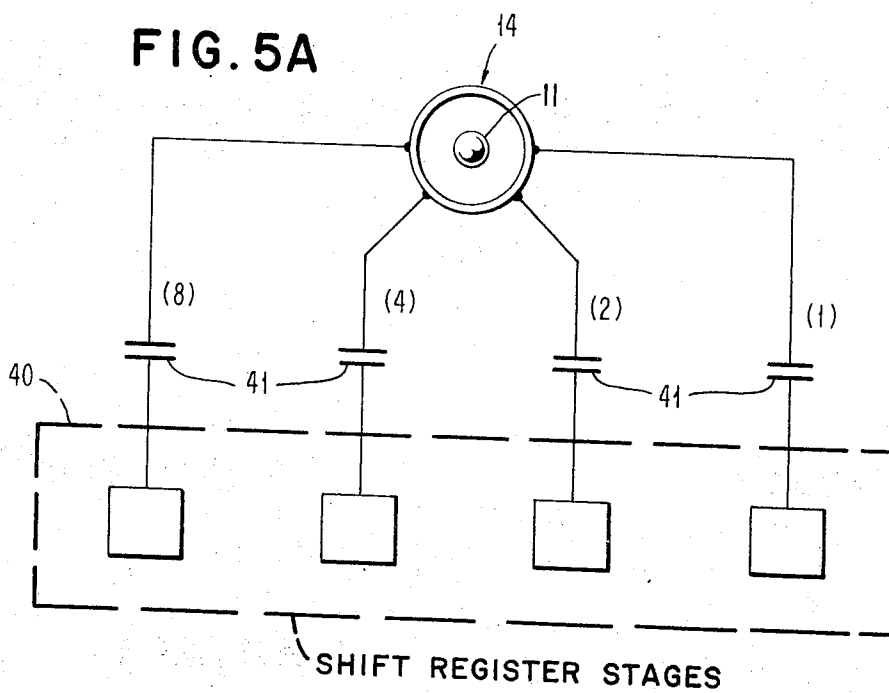
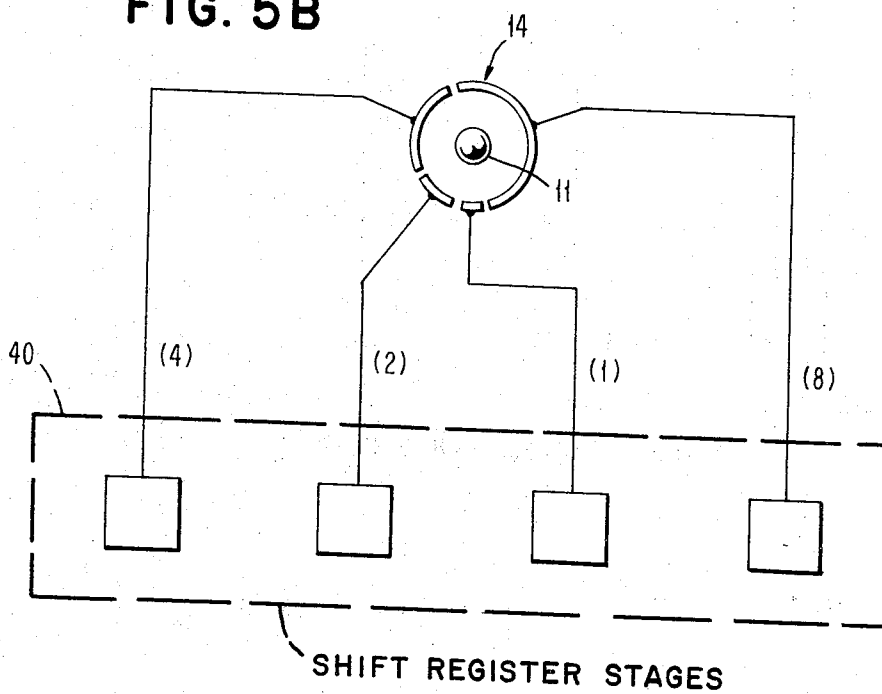


FIG. 5B



# TRAVELING WAVE ACTUATED SEGMENTED CHARGING ELECTRODE FOR AN INK JET PRINTER

## BACKGROUND OF THE INVENTION

The need for improved high speed printers has increased drastically in recent years. A particular application for such printers is for producing computer printout records wherein the actual printing devices utilized to produce human readable records has long been a major bottleneck in the overall computer system. In such computer systems, data which is produced by the system must often be held in temporary storage such as magnetic tapes, discs, drums, etc., for many hours before the particular printing devices attached to the system can produce the required readable outputs. Most currently available printers in this general area today are of the impact type where a printing element must actually be moved forcibly against a record member to produce a visible letter or symbol.

In recent years ink jet printing has been developed wherein ink is applied under pressure to a suitable nozzle. The ink is caused to break up into individual droplets which must be controllably directed onto the recording medium. The droplet formation may be controlled by a number of different methods available in the art including physical vibration of the nozzle, pressure perturbations introduced into the ink supply feed to the nozzle, etc. The result of applying such external perturbations to the ink jet apparatus is to cause the jet stream emerging from the nozzle to break up into uniform droplets at a predetermined frequency and at a somewhat variable distance from the tip of the nozzle. It is necessary in such conventional systems, however, that the precise time of droplet formation and the application of video charging signals to the ink droplet stream be synchronized. The rate of drop formation in such systems is determined by the signal applied to the physical perturbation means, e.g., vibrating the nozzle. A means for applying an electrostatic charge to each droplet produced by the nozzle is provided in such systems adjacent to the location where the ink stream begins to form such droplets. Conventionally, this means is a hollow tube or electrode surrounding the emerging stream and connected to a suitable charging circuit. Video signals are applied between the nozzle and the charging electrode in response to which a drop will assume a charge determined by the amplitude of the particular signal on the charging electrode at the time that the drop breaks away from the jet stream.

The drop thereafter passes through a fixed electric field and the amount of deflection is determined by the amplitude of the charge on the drop at the time it passes through said deflecting field. A suitable recording surface is positioned downstream from the deflecting means with the result that the droplet strikes such recording surface and forms a small spot. As will be appreciated, the position of the drop on the writing surface is determined by the deflection the drop experiences which in turn is determined by the charge on the droplet. Thus, by suitably varying the charge, the location at which the droplet strikes the recording surface may be controlled with the result that by applying suitable video signals to such a system, a visible human readable printed record may be formed upon the recording surface. U.S. Pat. No. 3,596,275 of Richard G.

Sweet entitled "Fluid Droplet Recorder" broadly discloses such a recording or printing system.

As will be further appreciated with such a system, the time that the drop separates from the fluid stream emerging from the nozzle is quite critical since the charge carried by the droplet is produced by electrostatic induction. The field established by the charging signal is maintained while the drop separates. The drop will carry a charge determined by this signal and proportional to the magnitude thereof. However, if at the time of separation the charging signal on a conventional single element charging electrode such as shown in U.S. Pat. No. 3,596,275 of Sweet is in the process of either rising or falling or is not present at all at the time of drop separation, the exact charge on the drop will be some time function of the maximum signal rather than being proportional thereto in accordance with some predetermined and fixed relationship. In order to place exact predetermined charges on individual droplets in accordance with successive video signals, it has been considered necessary to know exactly the time of droplet separation in relationship to the timing of the video signal. Stated differently, the droplet separation time and the application of the video signal must be very precisely synchronized. Failure to properly synchronize droplet formation and the video signal results in very imprecise control of the printing process with attendant severe degradation of the uniformity, clarity, and generally the quality of the final printer result.

U. S. Pat. No. 3,465,351 of Keur et al. entitled "Ink Drop Writing Apparatus" discloses a system for broadly detecting whether or not the drop producing transducer and the charging signals are in synchronization and for introducing a corrective signal to the system.

U. S. Pat. No. 3,596,276 of K. T. Lovelady entitled "Ink Jet Printer with Droplet Phase Control Means" discloses another system for detecting synchronization and establishing a phase change to maintain said synchronization. The former patent utilizes a very coarse control over the transducer vibrating means and the latter Lovelady patent discloses a considerably more complex analog control system for controlling the phase of the charging signal generating means.

Both of the above patents utilize a single charging electrode having a finite length; i.e., surrounds the stream from the point of earliest probable droplet break off to a point downstream beyond maximum probable break off distance. This length itself makes timing very critical lest a given signal affect the wrong drop. With such systems, synchronization must be precise to obtain good print quality. With such systems sensing means must be provided to detect whether or not synchronization is being maintained and some sort of feedback control provided to insure the proper phase relationship between drop forming and charging.

There is accordingly a need in this art for a drop forming and charging system wherein the synchronization criticality between such drop forming and charging is all but eliminated with attendant improvement in print quality and elimination of the synchronization circuitry.

## SUMMARY AND OBJECTS OF THE INVENTION

It has been found that the problem of synchronizing droplet break-off time with the applied charging signal can be greatly reduced by in effect utilizing a traveling

wave as a charging signal along the length of the ink jet stream emanating from the nozzle. By selecting the speed of the traveling wave to coincide with the velocity of the stream, the criticality of the exact point of droplet break-off is eliminated since the traveling wave charging pulse will by definition be in the vicinity of a given volume of ink at the time it forms a droplet. The signal applied to the charging means and thus to the droplet stream may either be binary in nature, i.e., having one of two predetermined fixed potentials or be analog in nature, i.e., having a varying amplitude between some minimum and maximum by suitably choosing the circuitry for producing said traveling wave.

It is accordingly a primary object of the present invention to provide a method and apparatus for producing a traveling wave charging signal for charging individual ink droplets in an ink jet recording system which substantially reduces synchronization problems.

It is another object of the invention to provide such a system wherein the traveling wave essentially follows the given volume of ink which it is assigned to charge, both prior to and after droplet break-off.

It is a still further object of the invention to provide such a charging system having a unique charging electrode structure.

It is a still further object of the invention to provide such a charging system utilizing a tapped delay circuit to produce the traveling wave effect.

These and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view of an ink jet printing system illustrating the present droplet charging means.

FIG. 2 is a logical schematic of a tapped delay line utilizing active or switched components for use with a binary serial bit stream.

FIG. 3A illustrates another embodiment of the invention utilizing an active delay circuit wherein the deflection data is in digital format specifying an analog deflection.

FIG. 3B is a detailed functional schematic diagram illustrating one of the stages of the delay circuit of FIG. 3A.

FIG. 4A is a diagrammatic illustration showing a cross-section of an ink jet stream both prior to and subsequent to break-off at a given instant in time and showing the relative location of the traveling wave charging pulses and the individual ink droplets for a binary system.

FIG. 4B is similar to FIG. 4A with the exception that the particular traveling wave, in this case, illustrates analog deflection data being fed to the charging electrodes.

FIG. 5A is a cross-sectional view of a segment of the charging electrode showing circuitry connected thereto for obtaining direct digital-to-analog conversion.

FIG. 5B is a view similar to FIG. 5A illustrating an alternative physical structure for obtaining digital-to-analog conversion.

#### DESCRIPTION OF THE DISCLOSED EMBODIMENTS

The objects of the present invention are achieved by establishing a jet of ink which breaks up into droplets,

under the combined influence of surface tension and an applied oscillatory disturbance. Individually controlled charges are induced on the separate drops by subjecting the ink stream to a variable electrostatic field at the point where it breaks up into drops. This electrostatic field is established as a moving pattern, corresponding to the charges on several successive drops, said pattern varying over an extended region of time and space so as to represent, over said region, a substantially constant shape moving with a velocity substantially equal to that of the ink jet. Said region begins at a point upstream of the earliest probable drop break-off point, and extends downstream to a point beyond the latest probable break-off point. Said pattern may conveniently be established, for example, by means of a multi-element charging electrode in conjunction with delay circuitry. Said multi-element charging electrode is connected to sequential taps of a tapped delay circuit having a charging pulse input at one end thereof, said delay circuitry forming a traveling wave of electric field along the path of said ink droplet stream which moves at substantially the same velocity as said stream.

Said delay circuitry may comprise a conventional passive lumped parameter delay line comprising essentially inductors, capacitors and a terminating resistor together with appropriate tap points or alternatively may be an active delay line. The active delay line may be a simple shift register, each stage having a connection or tap point which is connected to a corresponding segment of the multi-element charging electrode wherein the pulse stored in a given stage of the shift register appears on its associated electrode segment. Depending upon the type of shift register stage used, it will be apparent that the storage signal may be binary or analog.

In another embodiment, the shift register stages may be capable of storing a plurality of binary digits such, for example, as a binary coded number wherein, for example, charging signals varying in discrete steps from zero to a maximum value may be specified. The output of each such stage of the shift register would then be connected through a digital-to-analog converter and thence to the associated charging electrode as will be apparent to those skilled in the art. Alternatively, digital-to-analog conversion may take place at the individual charging electrode, each such electrode being split into parts, each of said parts inducing a charge on the ink stream in proportion to the weight of the digit it represents.

The preceding general description of the underlying concept of utilizing a traveling wave charging pulse with such an ink jet system sets forth the general functional relationship of the various apparatus components necessary to perform the present droplet charging method. Before proceeding with a specific description of the various embodiments of the invention set forth in FIGS. 1-4, the following general description of the underlying concepts will render the operation and principles of the present invention more readily understandable.

To briefly restate the underlying problems involved in ink jet printing practices utilizing electrostatic deflection, in the synchronized jet method of ink jet printing, the ink jet is caused to break up into droplets, each carrying an electrostatic charge which causes the droplet to be deflected a prescribed amount on passing subsequently through a fixed transverse electrostatic field.

The deflection is controlled by varying the charge carried on the droplet, which is determined by the surface charge density on the jet at the instant when the droplet breaks away. This surface charge is controlled in the prior art by the potential of a single charging electrode, which produces an electrostatic field, and hence an induced charge, at the jet surface. Problems arise because variations in the control voltage must take place between the breaking away of successive droplets, and the timing of the latter is uncertain. The result is difficulty in controlling droplet charge. However, the number of droplets formed per unit time, and their times of arrival at a given position, are quite predictable if the stream is excited mechanically.

The surface of a jet of liquid leaving an orifice is inherently unstable and the jet ultimately breaks up into droplets. The process can be described by a surface wave which grows exponentially in amplitude along the jet until the peaks become comparable with the jet dimensions. Then the narrow sections between peaks decrease to zero thickness, and the jet breaks up, each peak becoming a droplet. This is illustrated in the figures. The time (after leaving the orifice) at which the droplet breaks away is essentially the time it takes for the wave to grow exponentially to a certain fixed amplitude, and hence is rather uncertain. Even for a smooth orifice and steady liquid flow, the wave will grow from random noise, and the uncertainty is worst in this case. It is common to excite the wave intentionally, e.g., by modulating the flow of liquid at a frequency near that of the naturally occurring (i.e., fastest growing) wave. This has two direct effects: it fixes the frequency of droplet production and the size of droplets, and it fixes the phase at which droplets pass a given point. It does not fix the phase of the breakaway process. It does, however, exert indirectly a steadying effect on the latter, because the wave has to grow less to reach the critical amplitude, and hence the time required is shorter and less uncertain. Even so, the variations in timing remain unacceptable.

It has been discovered that this difficulty can be overcome by abandoning the concept of applying a single controlling field to the jet as a whole, which has to be changed between the breaking away of one droplet and the next. The present invention provides a pattern of electric field and of resultant induced charge, moving along the jet stream synchronously with the growing wave. Then each wave peak carries an unvarying charge during the whole time it is inside the field pattern, and the exact time at which it breaks away into a droplet becomes unimportant. All that is required is that the break-away should occur inside the region where the moving field pattern exists. Of course, the relative phase of the moving charge distribution and the growing wave must be maintained, but the latter can be controlled by exciting the wave directly.

The required moving field distribution can be obtained by sequentially applying a desired charging potential to a series of electrodes, as shown in FIG. 1, for example. It is possible to generate the phase delay between electrodes by using a passive L-C delay line, however, the delay required is long by electrical standards. A better way of obtaining the requisite delay is to use an active delay line as mentioned previously. Since in certain printing systems analog charging signals are required, a "bucket brigade" type of circuit may be used. Other methods of obtaining analog con-

trol such as the aforementioned digital shift register coupled to D/A converters may be used in addition to a number of physical D/A conversion schemes such as illustrated in FIGS. 5A and 5B.

An additional advantage of the present invention is that the charge for each droplet does not have to flow through the narrow neck of liquid existing just before break-away, but has time to build up while the neck is still large. This reduces interaction problems with low-conductivity inks.

Having thus set forth and described the general features and advantages of the present invention there will now follow a description of the operation of the specific embodiments disclosed.

Referring first to FIG. 1 an overall diagram of an ink jet recording system in simplified form is shown. It will be noted that even in this form the operation of the present invention is clearly apparent insofar as the necessary hardware is concerned. Referring now to the figure, an ink nozzle is shown at 10 connected to an appropriate ink input.

The actual ink jet 11 emanates from the nozzle 10 and the effect of the droplet formation is shown in this figure as well as the others wherein the gradual necking down due to surface tension and other effects takes place until the droplet actually breaks off.

A transducer 12 is utilized, as described previously, to introduce physical perturbations into the ink jet to stabilize the drop rate. A multi-segment charging electrode 14 is shown downstream from the nozzle and, as illustrated, surrounds the jet emanating from the nozzle both upstream and downstream of the break-off point. As was clearly described previously, it is this exact break-off point that is somewhat uncertain and fluctuates in such systems although the ink velocity and droplet rate remain substantially uniform. Downstream from the charging station 14 is the deflection station 16 which, as will be appreciated, is conventionally connected to a fixed high voltage source whereby the ink droplets are appropriately deflected before striking the recording medium 18.

Returning now to the charging circuitry, it will be noted that the individual segments making up the charging electrode are connected to the outputs of a delay circuit 20. It will, of course be obvious that the first (smallest delay) output of the delay circuit is connected to the first segment of the charging electrode structure, etc., so that as a pulse travels along the delay circuit a corresponding charge signal travels along the series of individual charging electrode segments. As stated previously, the speed of propagation of the signal through the delay circuitry is substantially the same as the velocity of the individual ink droplets forming the jet stream.

The oscillator 22 performs the initial function of supplying the pulses to the transducer 12 which determines the precise droplet rate in the system and also provides a synchronizing signal to gate a new serial input data pulses through gate circuit 24 in synchronization with the droplet formation rate.

The source of "serial input data" would come from an appropriate character generating means such as shown, for example, in U.S. Pat. No. 3,298,030 of Lewis et al. entitled "Electrically Operated Character Printer." As is well known with such systems, character printing may be done with a matrix of nozzles wherein various nozzles are simply fed binary information so



that a dot either will or will not be printed. For example, if a line is to be printed, all of the nozzles in a line might be energized, etc. Alternatively, with single jet printing system, analog deflection of the jet is necessary to produce the requisite sweep of the jet in one of the printing directions, it being understood that the movement of the record receiving member would produce the other direction of movement of the jet stream with respect to the recording surface.

Referring now to FIG. 2, there are shown in details of a simple shift register type of active delay circuit wherein each stage is connected to the next adjacent stage and also has an output tap whereby the signal content of the individual stage may be selectively placed on the connected segment of the charging electrodes 14. Although in this embodiment a serial binary data stream is possibly preferred as being fed into the shift register, it should be understood that it would be possible to utilize an analog shift register, such as a bucket-brigade circuit, wherein the serial signals propagated would be analog in nature. Since the analog deflection data will usually be generated first in digital form, the embodiment disclosed in FIGS. 3A and 3B is believed to be a more convenient version.

FIG. 3A is very similar to FIG. 2 in appearance, the exception being that the data fed into the various stages 40 of the shift register in this case, comprises a plurality of  $n$  bits, i.e., a byte of four bits to represent the numbers, for example, 0-15. This would allow 16 separate analog deflections of the jet stream under control of said binary coded input data. As with FIGS. 1 and 2, the outputs of the individual shift register stages 40 are shown connected to respective elements of the segments of the charging electrode 14.

The details of each of the blocks 40 of FIG. 3A are shown by way of example in FIG. 3B wherein each of the blocks 40 comprises a register for storing all  $n$  bits of the input code, a digital-to-analog converter for changing the digital information into the appropriate analog signal and finally the gate means under control of the delay circuit clock 42 which gates the contents of the register to the next subsequent register stage. In this way it will be noted that the  $n$  bit digital deflection data is entered at one end of the delay circuit and is propagated therethrough under control of the delay circuit clock. The frequency of this clock must obviously be chosen so that the propagation of the wave through the delay circuit exactly matches that of the velocity of the ink jet stream. It should be understood that the frequency of this clock is not necessarily the same as the frequency of the oscillator 22 as shown in FIG. 1 which establishes the actual droplet rate which in turn is controlled by the various physical characteristics of the particular ink being used, nozzle pressures, diameters, etc. Conversely, the frequency of the delay circuit clock is determined solely by the spacing of the various segments of the charging electrode and the velocity of the ink jet. The requisite frequency may readily be determined by dividing this velocity by the spacing of said individual electrode segments.

It should be clearly understood that the relative size, drop spacings, electrode segment spacings, etc. are merely shown for illustrative purposes. It is further noted that the droplet rate or spacing is not critical, as long as the drop formation rate is known, so that the appropriate input data are gated into the system as required and also the the velocity of the droplet stream

is known so that the proper stepping frequency may be applied in the case of the active delay line embodiments utilizing shift registers. The spacing of the electrodes from each other and from the ink jet is not critical either, as long as their spacings permit the electric field at the jet to be controlled over distances of the order of the drop spacing. Preferably, both sets of distances should be comparable with or less than the inter-droplet spacing. If they are not, it is possible to compensate for the interaction between electrodes by suitably distorting the data propagated in the delay circuit.

FIGS. 4A and 4B are for the purpose of illustrating binary and analog charging signals on the multi-segment charging electrode 14. For purposes of ease of illustration, a droplet has been shown adjacent each of the electrodes and an appropriate charging signal on the electrode which is to be placed on the specific droplet adjacent thereto. FIG. 4B differs from FIG. 4A only in that an analog charging signal is illustrated. It will be noted from the figures that the actual droplet break-off occurs between the second and third electrode segments. Hence, for this particular illustrated condition only these three electrodes would have any significant effect on the ultimate charge carried by the individual droplets of the stream. However, as explained previously, this break-off point could theoretically move from the illustrated point down to a point very near the right-most or last electrode segment. Regardless of this fact, a desired droplet or wave peak will be followed by the requisite charging signal throughout its traverse of the overall charging electrode structure 14. Thus, the illustrated construction is essentially independent of break-off point so long as it occurs within the overall structure. It has been found that this break-off point can vary considerably while the velocity of the droplet stream does not have any significant amount of variation. For this reason the speed of propagation of the tapped delay circuitry once established is subject to the need for very little additional adjustment. However, this adjustment if needed, can be satisfactorily performed by hand wherein with a given test charge the frequency of the delay circuit oscillator is adjusted to provide deflection which is independent, over a limited range, of the excitation of transducer 12. As will be well understood this will occur only when the charging pulse is traveling at the same velocity as the individual wave peak at the time of break-off or droplet formation.

Two straightforward physical digital-to-analog conversion schemes are shown in FIGS. 5A and 5B. In FIG. 5A a single charging electrode segment 14 is shown as well as four digit positions of the shift register 40 (as shown in FIG. 3B). In this embodiment it is assumed that the magnitude of the output signal from each bit position is identical and each of the capacitors 41 is digitally weighted in capacitance, i.e., 1, 2, 4 and 8, whereby a cumulative analog signal comprising the instantaneous contents of the attached shift register 40 will appear on the electrode segment 14.

In the embodiment of FIG. 5B precisely the same effect is obtained by splitting each segment 14 of the multi-element charging electrode up into radial segments having a size and thus charging effect on the ink stream 11 proportional to the particular bit storage location of the shift register stage 40. Fringing effects and the like must be taken into effect in selecting the size of the

weighted radial segments, however, these may be readily determined by routine experimentation.

The circuitry disclosed is believed to be completely within the knowledge of those skilled in the electronic arts.

"Bucket brigade" circuits of the variety used to temporarily store TV video signals may be used in the analog version of FIG. 2.

For the passive delay line circuitry as shown in FIG. 1, a simple L-C lumped delay line may be used.

For the simple binary shift register embodiment illustrated in FIG. 2, any tube or solid state circuit having shift register charges would be acceptable wherein the output from each shift register stage could be applied directly to the associated charging electrode segment or could be passed through a suitable amplifier.

For the embodiment of FIG. 3B, any conventional  $n$  bit binary shift register such as  $n$  parallel shift registers described as suitable for the embodiment of FIG. 2 could be utilized together with any well known type of electronic digital-to-analog converter. The embodiments of FIGS. 5A and 5B obviously need no further D/A conversion.

There has thus been shown and described a novel method of, and apparatus for placing desired charges on the individual ink droplets of an electrostatic deflection type of ink jet recording system wherein the method essentially obviates the normal synchronization problems between droplet forming means and the droplet charging means. The physical construction is quite simple and straightforward and although in the active versions considerable circuitry is required initially, it is believed to be essentially trouble free and would require very little maintenance.

The only criticality of dimension of the structure shown is that the individual segments of the charging electrode 14 which must be placed sufficiently close to the ink droplet stream so that the electric field appearing thereon couples with the stream rather than with adjacent electrode segments. However, this is believed to be obvious, and precise dimensions are not given since they would vary considerably with size of the droplets in a given embodiment, the nature of the dielectric materials and also the magnitude of the charging voltages applied.

While the invention has been disclosed and described with reference to the specifically disclosed embodiments, other minor modifications and changes could readily be made with those skilled in the art without departing from the spirit and scope of the present invention.

What is claimed is:

1. A method for charging individual ink droplets produced in an ink jet recording system including the steps of forming a high speed ink stream from a suitable nozzle, adjusting the ink volume and velocity so that a desired droplet break-off point is obtained, forming a traveling wave charging pulse along said stream in charging relationship therewith beginning at a point upstream from said break-off point and ending at a point downstream from said break-off point, selecting the speed of said traveling wave to be substantially identical to the velocity of individual droplets making up said stream and synchronizing the traveling wave to coincide with the volume peaks of the stream prior to break-off and the droplets subsequent to break-off.

2. A method as set forth in claim 1 wherein the steps of forming said traveling wave comprises supplying an appropriate signal to a commutating delay circuit means and applying the output of said commutating circuit means to a spaced series of charging electrodes located adjacent to the ink jet stream in an electrostatic charging relationship therewith.

3. In an ink jet recording system including an ink supply, a nozzle, means for projecting a high pressure ink stream from said nozzle at a predetermined velocity which breaks up into droplets downstream therefrom at a fixed predetermined rate, means for applying an electrical charge to individual droplets as they break off from said stream, means for deflecting said droplets and a recording medium on which said droplets impinge to produce a visible record, the improvement in said charge application means which comprises:

a multi-segment charging electrode, said segments being spaced along the axis of said stream beginning at a point prior to earliest expected droplet break-off and extending to a point beyond latest expected droplet break-off;

a tapped delay circuit having a signal input end; one of said charging segments connected to each tap; means for introducing charging pulses into one end of said delay circuit whereby a traveling wave charging signal appears on the segments of said charging electrode;

said delay circuit having an inter-tap delay equal to the transit time of a droplet making up said stream to move from one segment to the next segment whereby a traveling charging wave is produced on said charging electrode traveling at substantially the same velocity as the ink stream.

4. An ink jet recording system as set forth in claim 3 wherein said tapped delay circuit comprises a passive lumped parameter delay line having a signal input means at one end and a signal terminating means at the other, said tap points being equally spaced in time wherein the tap closest to the signal input end is connected to the charging electrode segment closest to said nozzle and wherein adjacent tap points are connected to subsequent charging electrode signals downstream from said first segment.

5. An improved ink jet recording system as set forth in claim 3 wherein said delay circuitry comprises an active multi-stage shift register having as many stages as there are segments of said charging electrode, each stage having an output line connected to one of said charging electrode segments,

clock means for advancing an input signal applied to the input of said delay circuitry between said stages, the frequency of said clock being chosen to advance an input signal applied at one end of said delay circuit through said delay circuit at the same velocity as an ink droplet in said stream passing through said charging electrode structure.

6. An improved ink jet recording system as set forth in claim 5 wherein each stage of said shift register comprises a single binary storage element which may store a binary 1 or a 0 and including means for serially applying binary input data to said delay circuitry in binary form.

7. An improved ink jet recording system as set forth in claim 5 wherein each stage of said shift register comprises a bucket-brigade analog storage element for storing an analog signal and means for supplying a serial

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string of analog pulses to the input of said delay circuit.

8. An improved ink jet recording system as set forth in claim 5 wherein each stage of said shift register comprises plural bit storage means for storing a digitally encoded bit group, representing an analog deflection signal to be applied to said charging electrode structure, digital-to-analog converter means for converting said digital bit group to an analog charging signal on said elements of the charging electrode, means for supplying a series of digitally encoded analog values to the input of said shift register representing analog signals to be applied to sequential ink droplets in said system.

9. An ink jet recording system as set forth in claim 8 wherein said digital-to-analog converter means comprises an electronic circuit directly connected to the output of each multi-bit shift register stage and which decodes the digital information into an analog charging signal.

10. An ink jet recording system as set forth in claim 8 wherein said digital-to-analog converter means com-

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prises a capacitor connected between each bit storage element of the shift register stage and the associated charging electrode segment the size of each capacitor being such that it passes a signal representative of the digital weighting of the digit stored by its associated shift register element and wherein any binary 1 or 0 in any shift register element is represented by a signal of a predetermined magnitude.

11. An ink jet recording system as set forth in claim 8 wherein said digital-to-analog converter means comprises said each segment of said charging electrode being divided into arcuate sections having different capacitance with respect to the ink stream and being of different size, each section connected to each bit storage element of said shift register the size of each section being such that if a uniform signal is placed on each section the charging effect will be proportional to the digital weighting of the digit element of the shift register stage to which it is connected.

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