Jan. 10, 1967 A. M. LEWIS ETAL 3,298,030

ELECTRICALLY OPERATED CHARACTER PRINTER

Filed July 12, 1965 3 Sheets-Sheet 1

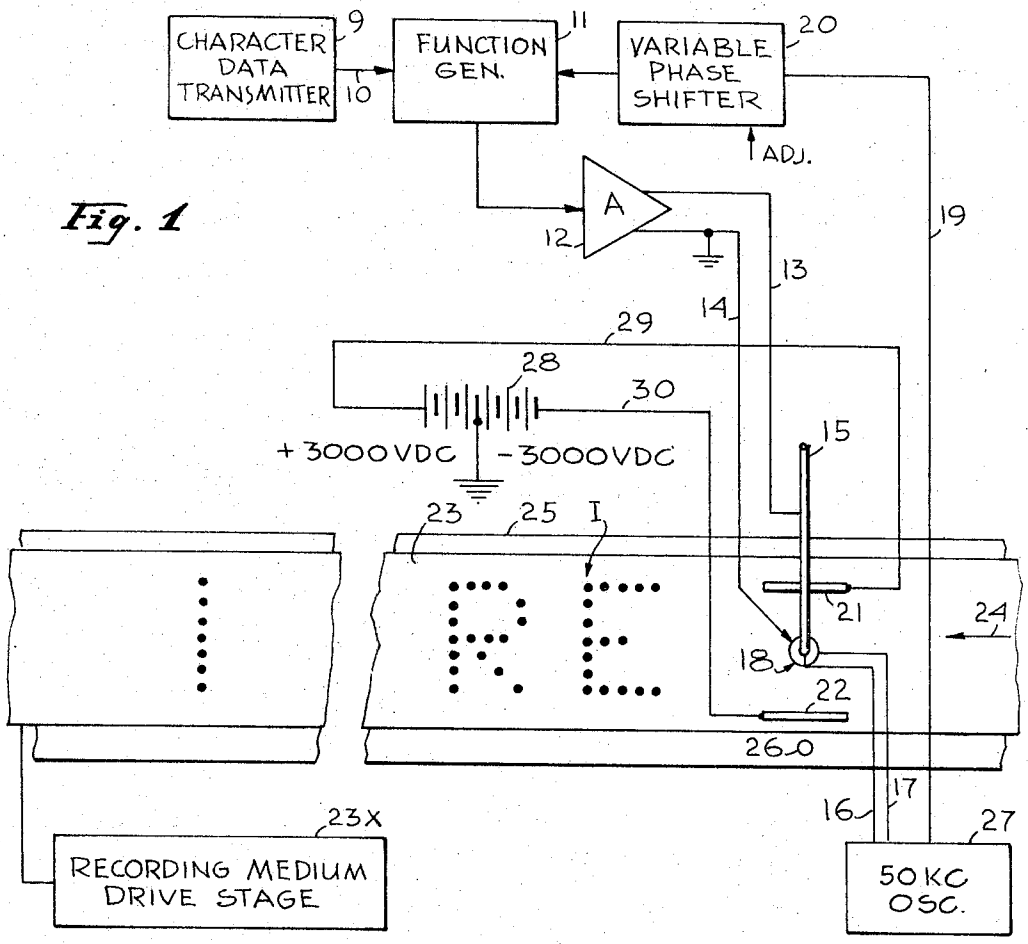

Fig. 1

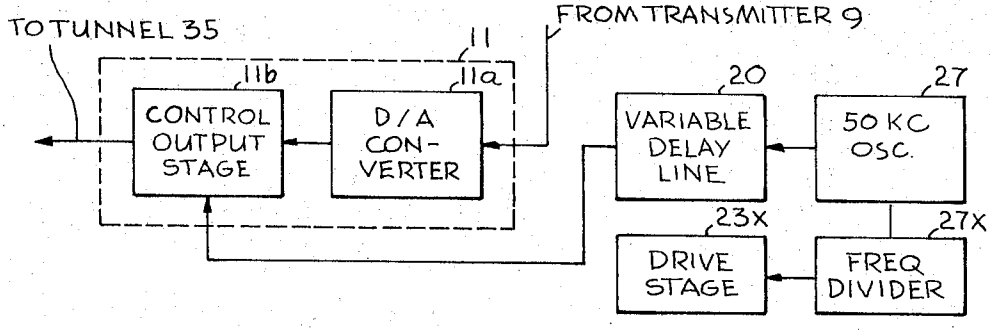

Fig. 2 (a)

INVENTORS
ARTHUR M. LEWIS
ARLING DIX BROWN, JR.
BY
ATTORNEY

Jan. 10, 1967 A. M. LEWIS ETAL 3,298,030

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Filed July 12, 1965 3 Sheets-Sheet 2

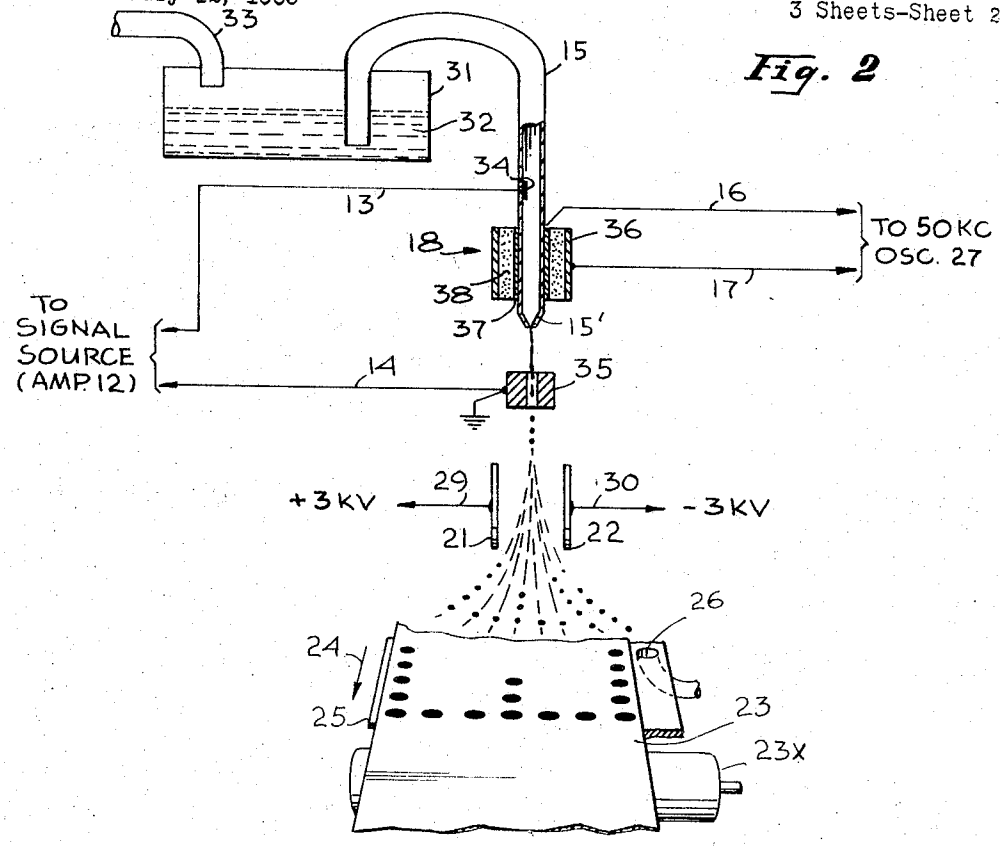

Fig. 2

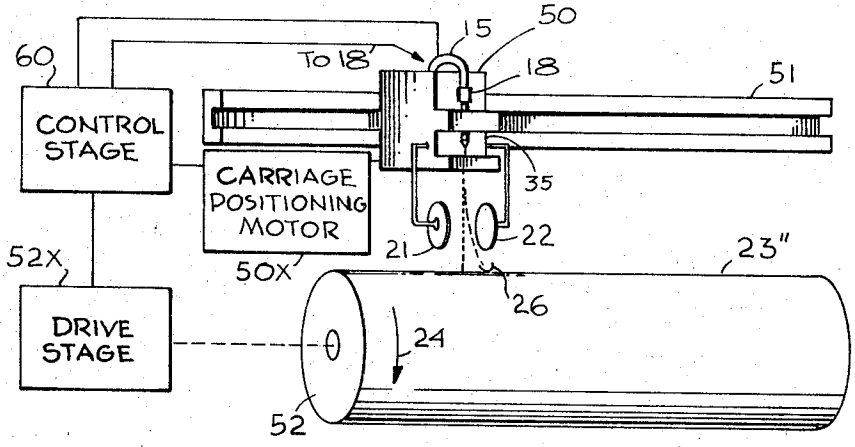

Fig. 5

INVENTORS
ARTHUR M. LEWIS
ARLING DIX BROWN, JR.
BY James A. Smith
ATTORNEY

Jan. 10, 1967 A. M. LEWIS ETAL 3,298,030

ELECTRICALLY OPERATED CHARACTER PRINTER

Filed July 12, 1965 3 Sheets-Sheet 3

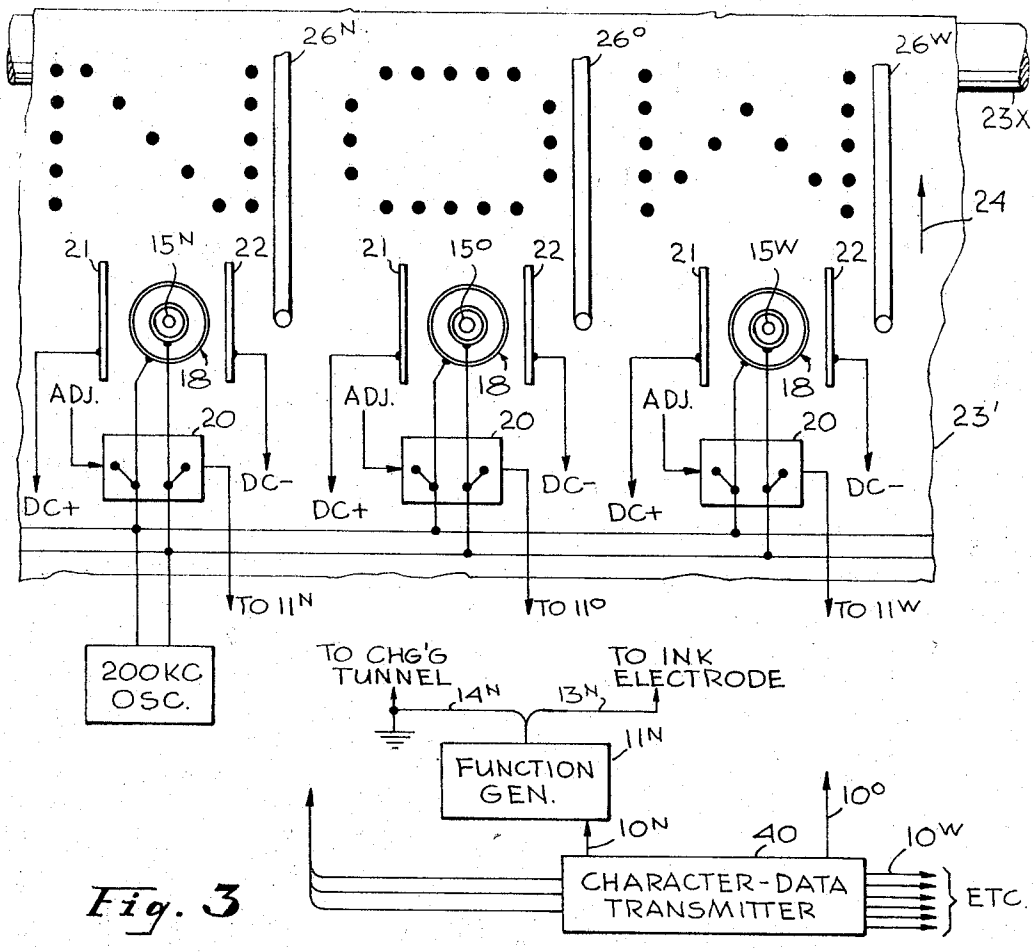

Fig. 3

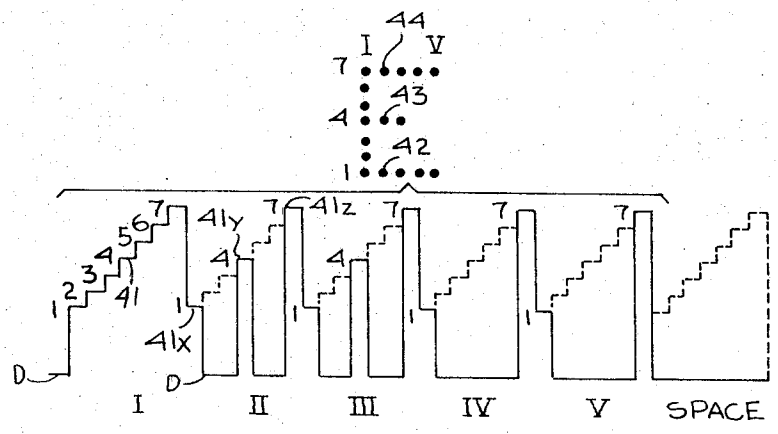

Fig. 4

INVENTORS
ARTHUR M. LEWIS
ARLING DIX BROWN, JR.
BY James A. Scott
ATTORNEY

United States Patent Office

3,298,030

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3,298,030
ELECTRICALLY OPERATED CHARACTER PRINTER

Arthur M. Lewis, Shaker Heights, and Arling Dix Brown, Jr., Cleveland Heights, Ohio, assignors to Clevite Corporation, a corporation of Ohio

Filed July 12, 1965, Ser. No. 471,259
18 Claims. (Cl. 346—75)

This application is a continuation-in-part of application Serial No. 425,164, filed January 13, 1965, and now abandoned which is in turn a continuation-in-part of application Serial No. 399,291, filed on September 25, 1964, and now abandoned. The invention relates to improved apparatus for electric signal responsive printing of predetermined characters, for example, substantially duplicating an alphanumeric or pictorial record, upon a recording or receiving medium. More particularly, the invention relates to apparatus for print-out of characters, or to set type or resist (e.g. photo-resist or chemical-resist) areas upon a recording or receiving medium through electrostatic charge control of appropriately spaced discrete drops of a marking fluid which might be ordinary ink.

In the prior art, for example in U.S. Patent 2,512,743 issued June 27, 1950, to Hansell, it has been known to set up a fluid pressure in a liquid thus to cause non-uniform droplets to issue from a nozzle and impinge upon a receiving surface. Such systems while having adequate accuracy for hand painting (air brush work) have the disadvantage that because the non-uniformity of the drops as formed makes them not well adapted for automatic, electrically controlled, print-out of legible characters. Thus, such a system not only introduces inaccuracies but also its speed of operation is uneconomic for many applications.

In "Electronic Design" magazine for October 11, 1963, an article entitled "Fast Oscillograph Squirts Ink" suggests a nozzle vibrated at 120 kc. and a D.C. transverse field acting upon droplets which, in effect, are individually charged and, according to the article, uniform in size and spacing, and capable of recording a sample of an electrical (e.g. sine wave) analogous signal input. Here again there exist limitations of accuracy, and of speed or frequency of response; also, mechanical equipment is employed with unsuitable space and maintenance requirements as well as with limited applicability to alphanumeric or facsimile readout.

It is an object of the present invention to provide simple means for overcoming the above-mentioned difficulties.

Another object is to provide, in a drop writing apparatus of a type adapted, for example, to squirt ink upon paper while breaking the ink into discrete and uniform drops, improved means for insuring uniformity of drop size and spacing and means which permits a tolerance as regards the relation between drop charge and drop time of arrival as hereinafter more fully explained.

A further object of the invention is the provision of novel means for controlling the uniformity of a plurality of ink drops and the charging of each drop in accordance with input signals.

Other objects and advantages will become apparent and the invention may be better understood from consideration of the following description taken in connection with the accompanying drawings in which:

FIGURE 1 is a schematic and partial diagram of apparatus according to one aspect of the invention;

FIGURE 2 is a part sectional view showing a portion of the apparatus of FIGURE 1. In FIGURE 2, a nozzle portion 15' is shown enlarged in relation to other parts, for the purpose of clarity.

FIGURE 2(*a*) is a simplified block diagram of the embodiment shown in FIGURES 1 and 2;

FIGURE 3 shows a modification of the embodiment of the invention;

FIGURE 4 is a diagram showing electrical signal "steps" useful for forming a single letter according to one way of accomplishing the so-called "matrix" embodiment of FIGURES 1, 2, and 3; and

FIGURE 5 shows a modified form of apparatus for illustrating application of many of the present invention principles to a fascimile system.

Referring first to FIGURE 1, there is shown a character data transmitter **9**, which supplies character data to a function generator **11** through a signal line **10**. The data received by the generator **11** is generally in the form of groups of signals or pulses, each group corresponding to a particular character to be recorded. The signals of each group are converted by the function generator into related output signals, each of which is supplied to an amplifier **12**. The output of the amplifier is connected through output lines **13**, **14** to the ink within and issuing from a conduit **15** in order to charge drops of the ink in a manner hereafter more fully explained in connection with FIGURE 2.

As shown in FIGURE 1, a high frequency source **27**, such as a 50 kc. oscillator, energizes a transducer **18** through connections **16** and **17**, and the output of the oscillator **27** is connected by a line **19** to a variable phase shifter **20** which controls the time relationship between the signals from the function generator **11** which control the drop charging, and the signals applied to the transducer **18**.

A pair of electrically charged deflection plates **21**, **22**, respectively, establish a field which serves to differentially deflect ink drops, which are differentially charged, while they are in transit toward a recording medium. As illustrated in FIGURES 1 and 2, the recording medium is assumed to be a paper tape **23** moved, as in the direction indicated by arrow **24**, along a supporting base **25**. The motion is provided by a recording medium drive stage **23***x*, which moves the tape at a rate which is related to the rate at which ink drops are deposited on the tape, so that the proper characters are recorded thereon. Base **25** is provided with an ink dump or "catcher" funnel or pipe end **26** for the purpose of receiving ink which is "dumped," rather than allowed to come to rest upon the recording medium, as also explained hereafter.

A grounded center tapped source of relatively high voltage D.C., for simplicity shown as a 6000 volt battery **28** in FIGURE 1, is used to oppositely charge the deflecting plates **21**, **22** through connections **29**, **30**.

In other drawing figures, like structures bear the same reference numerals as are used in FIGURE 1. In FIGURE 2, there is additionally shown a marking liquid reservoir **31** containing an electrically conductive marking liquid such as ordinary ink **32**. The ink in the reservoir is pressurized as by introducing compressed air through a conduit **33**.

If the ink supply conduit and reservoir are of electrically insulating material, such as glass, then an inner electrode **34** is provided within the conduit (or alternatively within the reservoir). Optionally, if either conduit **15** or the reservoir **31** itself is conductive, then a signal line may be connected to the conduit or container itself. The other signal line **14** is connected to a charging tunnel **35**.

The function of the charging tunnel **35** is to respond to each signal from the function generator **11** (FIGURE 1) and induce a charge in each of the ink drops formed thereat. The charge induced in each drop is proportional to the input signal which is applied to the tunnel as the drop passes therethrough. Thus, each ink drop that leaves the charging tunnel carries with it a charge which is proportional to the input signal at the instant the drop was formed and passed through the tunnel. Since the

signals applied to the tunnel are related to the signals from the transmitter, the charge of each drop is similarly related thereto. Since the drops are of uniform size, the resulting charge-to-mass ratio is proportional to the input signals. As these charged drops pass between the electrodes **21** and **22**, they are subjected to an electrostatic transverse field which modifies the path of each drop proportionally to its charge. Thus, the position of the mark made by each ink drop on the recording medium is related to the particular input signal supplied to the tunnel **35** as the particular drop passes therethrough. By controlling the charges applied to a plurality of ink drops (as a function of a set of input signals from the transmitter), a particular character, such as the "E" shown in FIGURE 2, may be recorded.

In accordance with a preferred embodiment of the invention, and as will now be described in connection with FIGURE 2, conduit **15** terminates in a nozzle portion **15'** with which there is associated the coaxial transducer **18**, being preferably an electrically energizable piezoelectric device which surrounds the ink. We prefer that the piezoelectric device be a tube of a polarized ceramic **38** having suitable electrodes **36, 37**. The ceramic may be a polarized barium titanate as disclosed and claimed in U.S. Patent 2,486,560 issued on an application of Gray, or the ceramic material may be a polarized lead zirconate lead titanate, which is also known. Both are commercially available as piezoelectric devices having a cylindrical form and provided with an outer cylindrical electrode **36**, and a concentric inner cylindrical electrode **37** with ceramic **38** extending between the electrodes. Electrical oscillations applied (as shown through connections **16, 17**) to the inner and outer electrodes across the ceramic layer **38**, produce radial mechanical vibrations thereof. These vibrations are transmitted to the conduit **15** which is coaxially aligned with, and mechanically coupled to, the transducer **18** near the nozzle **15'**. The nozzle **15'**, due to the variable pressures applied at **33**, will cause the ink flowing therethrough to break up into droplets. The coaxial transducer which produces the mechanical vibrations cooperates with the conduit **15** and nozzle **15'** to assure that the ink drops are of uniform size and uniformly spaced. The drop formation frequency may be controlled to be the same as the frequency of the electrical oscillations of the piezoelectric transducer **18**.

Good results have been obtained using piezo ceramic and nozzle dimensions as follows:

	Inches
Effective ceramic and electrode length	.250
Ceramic (38) O.D.	.125
Ceramic (38) I.D.	.085
Glass nozzle (15') O.D.	.070
Nozzle I.D. before taper	.013
Nozzle exit orifice dia.	.001

Glass as a material for the nozzle is not essential, but glass can be conveniently formed (drawn down or melted down) to form the nozzle orifice. Since the oscillations move the glass so slightly, the glass does not shatter in this application. The use of glass provides a convenient way of isolating drop charge signal circuitry from oscillatory circuitry, although other circuit isolating means (e.g., a transformer coupling in one circuit) could be used instead if it is desired to pass ink directly through the inner electrode of the piezo device to achieve the closest possible mechanical coupling between the piezo device and the ink.

From the foregoing description, it should be appreciated that in order to satisfactorily record each character on the recording medium **23** (FIGURE 2), such as the character "E," it is necessary to synchronize the oscillator **27** and the function generator **11** so that each drop is of uniform size with precise spacing between drops and that each drop is charged at the proper time while passing through tunnel **35** (FIGURE 2). Also, it is necessary to synchronize the motion of the tape **23** with the operations of oscillator **27** and generator **11** in order to insure that successively charged drops are deposited unto the tape **23** at the proper locations as the tape is being moved by the driver stage **23***x* (FIGURE 1).

The synchronization of the operations of oscillator **27** and function generator **11** is accomplished by the adjustable variable phase shifter **20**, shown in FIGURE 1 connected between the oscillator **27** and the generator **11**. The particular circuitry incorporated in the phase shifter **20** depends on the mode of operation of the generator **11** in producing the required signals to be supplied to the charging tunnel **35**. In one embodiment of the invention as block diagrammed in FIGURE 2(*a*), to which reference is made herein, the variable phase shifter **20** is assumed to comprise a variable delay line disposed between the oscillator **27** and generator **11**. The generator **11** is assumed to comprise a digital-to-analog converter **11***a* which receives groups of digital signals from transmitter **9** and converts them to related analog signals, supplied to a control output stage **11***b*. The latter stage is also provided with the output of the variable delay line from phase shifter **20** which delays the signal from oscillator **27**. By adjusting the delay introduced by line **20** in the signal of oscillator **27**, the output of the generator **11** is controlled so that the signals from the oscillator **27** to piezo device **18** (FIGURE 2) and the signals from the generator **11** (through amplifier **12**) to the charging tunnel **35** are in proper time relationship to properly charge each ink drop passing through the tunnel **35**.

The phase shifter **20** may also include a differentiating circuit (not shown) which can be used to convert the delayed signal from oscillator **27** into a delayed series of pulses which can in turn be used to control the output of the generator **11**. Also, the synchronization of the signals supplied to the piezo device **18** (from oscillator **27**) and to the charging tunnel **35** (from generator **11**) can be accomplished by connecting the variable delay line of phase shifter **20** between the oscillator **27** and the piezo device **18**. By varying the delay of the signal from oscillator **27** supplied to the device **18**, an optimum delay can be selected to insure proper charging of each of the ink drops passing through the tunnel **35**. As another alternative, proper signal synchronization may be accomplished by mechanically adjusting the position of the nozzle **15'** with respect to tunnel **35**, to achieve proper drop charging.

The novel system of the present invention diagrammed in FIGURES 1 and 2 may be more fully explained in conjunction with FIGURE 4 which represents one example of the output of function generator **11**. The output comprises a plural step wave form shape **41** produced in response to a set of signals from character data transmitter **9**. Referring back to FIGURE 1, assume that the transmitter **9** is to provide the system with signals so that the ultimate print-out will constitute he words "I READ YOU." Therefore, for an individual character, such as the "E," the transmitter **9** provides the generator **11** (through line **10**) a set of digital pulses characteristic of an "E." The technique of providing sets of digital pulses which are characteristic of predetermined characters is well known to those familiar with the art, and therefore need not be described in detail. For example, such techniques are employed in presently known character generators or in computer readout stages where characters recorded on tape or magnetic core memory as pulse signals are read out by the computer readout stage and are then printed by a typewriter or high speed drum printer. A set of digital pulses representative of the letter "E" requires the pulses be provided for charging and thus positioning each drop which makes up the letter "E."

Digital signals, characteristic of the "E," are supplied to the function generator **11** which converts them into related analog signals such as voltage signals of varying

amplitudes, as diagrammed by the plural step waveform shape **41** (FIGURE 4). The voltage level or amplitude of the output of generator **11** rises in a series of abrupt levels **1** through **7** in response to the digital signals, thereby to produce on the recording medium, a full set of ink drops in a more or less vertical column I. The column is indicated by the solid line waveform **41** at I in FIGURE 4, and by the full column I of ink drops in FIGURE 1. It shoud be appreciated by those familiar with the art that the waveform at I in FIGURE 4 is a staircase type waveform which is produceable by presently known techniques and circuits. For example, such a waveform is often available as an analog output of digital counters which respond to digital pulses or signals. As an illustration, see Patent No. 2,958,828.

As shown in FIGURE 2(*a*), in one embodiment, the function generator **11** incorporates a D/A converter **11***a*. The converter may comprise a multibit unit similar to a multibit register used in digital computers, with each unit connected to the transmitter **9**. At each instant a group of signals may be simultaneously supplied to the converter which produces an analog output related thereto. Thus, by varying the signals supplied to the converter **11***a*, the analog output thereof is controlled.

It should be appreciated that for each of the drops produced in the tunnel **35** (FIGURE 2) the function generator **11** produces a related output voltage so that the drop is either deflected to the catcher **26** (FIGURE 2) or is deflected unto the recording medium to form a part of a desired character. To form column I, the transmitter supplies a group of signals for each successive drop so that the seven drops are deposited as a straight column on medium **23**. Then for the next column II of the character matrix, the transmitter provides a group of signals which produce an output voltage represented by a solid line **41***x* at level **1** so that a drop **42** (see FIGURE 4) is deposited on the recording medium. During the formation of the succeeding two drops, the signals from the transmitter cause the function generator to produce an output voltage represented by "D" in FIGURE 4. The magnitude of the voltage is sufficient to deflect the two drops to the catcher **26** so that they do not form a part of the character "E."

A subsequent output voltage **41***y* deflects the next drop **43** to the fourth row of the character. Then, the voltage is again controlled to deflect the next two drops to the catcher **26** with a voltage **41***z* being subsequently provided to deflect a subsequent drop **44** to form a part of the "E" at the 7th row of the column II. In such a manner, the apparatus records each character by controlling the voltage produced by the function generator **11** as each drop is created in the tunnel **35**, so that only drops which are to form a part of the character are properly deflected unto the tape, with all the rest of the drops being deflected to the catcher **26**.

The particular circuitry incorporated in function generator **11** is dependent on the type of signals corresponding to different characters, which are supplied by the transmitter **9** to the generator **11**. Therefore, it should be appreciated that the foregoing description of the generator which is assumed to convert digital signals to related analog signals, is exemplary of the teachings of the invention. Other arrangements, such as switching circuits, may be employed to convert each set of signals from the transmitter into related signals which are then used to energize tunnel **35** to deflect groups of drops so that particular characters are recorded on medium **23**.

Alternatively, it is possible to construct and use a function generator so that selected drops of the series of drops produced while printing a particular character are directed to various levels of the character according to a sequence other than the stair-step scanning sequence illustrated in FIGURE 4. Such an alternative arrangement might be used so as to waste fewer ink drops in the dump.

From the foregoing, it is thus seen that the signals from the transmitter **9** corresponding to an "E" are converted by function generator **11** into a related set of analog signals which are used to deflect a plurality of ink drops so that an "E" is recorded on the medium **23** (see FIGURE 2). It should be appreciated that as the ink drops are deposited on the recording medium **23**, the medium is moved by the drive stage **23***x*. Thus it is necessary to synchronize the motion of the medium **23** with the rate of deposition of the drops so that as each column is recorded (such as column I by depositing seven drops), the medium **23** is moved by a distance sufficient to deposit another group of drops to form an adjacent column, such as column II, comprising of three drops.

The synchronization may be accomplished by connecting the output of oscillator **27** (see FIGURE 2(*a*)) to the drive stage **23***x* so that the frequency of the oscillator which controls the rate at which ink drops are produced is also used to control the motion of the recording medium **23**. The frequency of the oscillator **27** supplied to the drive stage **23***x* may be divided by a frequency divider **27***x* disposed therebetween in order to insure that the frequency of the signal supplied to stage **23***x* properly controls the motion of the recording medium **23** with respect to the rate at which ink drops are produced.

In FIGURE 3, like parts are like numbered as before but, in order to achieve a much greater speed of print-out, and also to take full advantage of the very small size of nozzle and uniform drop control arrangements according to the present invention, there are shown plural combinations of nozzle means **15'**, piezo devices **18**, deflecting plates **21**, **22**, all substantially alike. Many of the connections are, as shown, electrically in parallel for the various nozzles assemblies, but individual diverting catchers and individual drop charging means (including connections to ink electrode **34** and charging tunnel **35** which are not shown in FIGURE 3) are provided separately for each nozzle assembly, and the recording medium instead of being a relatively narrow tape (as in FIGURES 1 and 2) is a wide sheet of paper of which only a portion is shown at **23'** in FIGURE 3.

The embodiments of the invention diagrammed in FIGURE 3 includes a character data transmitter **40** consisting of a plurality of stages each one of which performs in a manner similar to that described in conjunction with transmitter **9** (see FIGURE 1). The transmitter **40** may furnish simultaneously signals to a plurality of function generators, each one of which is operated to produce signals corresponding to another character to be recorded. Thus for example, the characters of the word "NOW" can be simultaneously recorded by using a signal line 10^N to feed one function generator 11^N and in turn, ink electrode and charging tunnel through connections 13^N, 14^N, respectively, while other signal lines 10^O, 10^W, etc., simultaneously feed other function generators (not shown in FIGURE 3) and other charging tunnels and other ink electrodes. It will be observed, too, that whereas in FIGURES 1–2 a single dump catcher **26** was located beside and somewhat below the level of the paper strip **23**, in FIGURE 3 plural dump troughs 26^N, etc., are located above the paper **23'**. In each case, the catchers form intercepting means displaced from the recording medium and for intercepting drops and preventing them from reaching the recording medium.

Many of the principles of the present invention disclosure, which includes the subcombination of an electrically energizable piezoelectric device coaxially surrounding the ink associated with the nozzle, may be used without utilizing the matrix concept. The various elements used to form the plurality of ink drops and for charging each drop (i.e. elements **15**, **18** and **35**) may be mounted on a carriage **50** shown in FIGURE 5 to which reference is made herein. The carriage which also supports the deflecting plates **21** and **22** and an intercepting trough **26** is supported on a guideway **51** which is mounted adjacent a revolving cylinder or drum **52**. The drum

supports a recording medium 23'', mounted thereon. A drive stage 52*x* used to control the rotation of the drum 52 in the direction of arrow 24 is coupled to a control stage 60 to which the various drop forming and charging elements (15, 18, 35) and the deflecting plates 21 and 22 are also connected. In addition, a carriage positioning motor 50*x*, used to control the position of the carriage along the guideway 51, is also connected to the control stage 60.

The function of stage 60 is to control the rotational motion of the drum 52, the linear motion of carriage 50 and the supply of the signals from the function generator 11 and oscillator 27 so that each character is properly recorded unto the recording medium 23''. The arrangement shown in FIGURE 5 which hereafter will be referred to as a "facsimile system" may be operated so that each line of recorded characters is either circumferentially oriented with respect to drum 52, or is axially oriented with respect thereto.

In operation (see FIGURE 2), the ink under pressure (e.g. at 25 p.s.i.) issuing from the small diameter (e.g. 001'') nozzle orifice is first a continuous stream but soon separates into drops while the constant frequency oscillations control the uniformity of the size and of the spacing of the drops. Appropriate pressure and nozzle diameters can be used so that the drop frequency can be controlled even at frequencies as low as 5 kc. and at frequencies at least as high as 200 kc. The relationship of stream velocity, nozzle diameter and natural break-up frequency is already known from the published literature of the past eighty-six years. The break-up can be controlled over a frequency range greater than an octave about such natural frequency. In operation, good results have been obtained with an ink drop velocity in the range of 100 to 1000 inches per second using nozzle exit diameters from .001'' to .002''. Meanwhile, a transport means (shown for example in FIGURE 5) drives a recording medium such as paper "across" the ink drop whereby ink drops may "normally" impinge on different portions "along" said recording medium (for FIGURE 1 that would be rightwardly along the paper tape 25 as it moves to the left) with speed of transport correlated to speed of drop formation to achieve proper width of letters while avoiding piling up excess ink at any one spot.

An intercepting (or trough or catcher) means is displaced from the "normal" ink drop path and displaced from the recording medium, and an electrostatic charging and deflecting means deflect drops from an otherwise "normal" or general path (for either the matrix or the facsimile embodiment) so that drops can be controlled alternatively to be intercepted as in the catcher or to impinge predeterminedly "across" the recording medium; that would be horizontally as viewed in FIGURES 2 and 3, and vertically in FIGURE 1 (though the printed characters may appear otherwise because of movement during the "sweep"). In operation, good results have been obtained with characters .08'' high having a nominal width of .03'' (between character centers) at a print-out speed of 1200 characters per second.

Of course, with a plurality of *n* nozzle assemblies, as in FIGURE 3, the print-out can be almost *n* times as fast as the arrangement just described, a decided advantage when there is to be an abundance of text printed in the shortest possible time.

Besides speed, an advantage of the arrangements described is that the drops are precisely under control, and, for the function generator and matrix embodiments particularly, any signal complexity other than at the receiving end of a transmission line is obviated, and (with a staircase generator or many other possible function generator arrangements) even in the receiving end apparatus there is a tolerance, and time of arrival of a drop in the deflecting plate region that can vary a few microseconds one way or the other and the charge on the drop will still be correct because of the length of each plateau or step of the stepped ramp voltage, the electrostatic deflection thus being better able to achieve control of which one of, say, eight levels (seven matrix levels plus a dump level) a particular drop is to be placed at while the paper motion spreads the drops along the transverse dimension of the letter. Further, two drops need never be intended for the same place on the paper; hence (since the parts are preferably arranged so that the ink stream maintains its continuity until well within the tunnel and then almost within the influence of the deflecting plates) distortion due to repulsion of like charged drops following a like path is substantially obviated.

Controlling the drop charge required only a modest potential (up to 100 volts peak) between the charging tunnel and ink stream electrode. The subsequent deflection is accomplished with only a D.C. high potential (1 to 10 kv.) on the deflection plates.

With an embodiment using the cylindrical mode coaxial piezo device only a very, very small amount of constant frequency power is required for assuring optimum drop spacing. There is a further advantage in that the cylindrical device permits a substantial reduction in size (over ink drop apparatus heretofore known), thus making possible an arrangement like FIGURE 3 (side by side jet assemblies) and optimizing an arrangement like FIGURE 5 (moving jet assembly). Additionally, the small mass cylindrical transducer permits making a nozzle assembly which is simple and which can operate at a wider range of frequencies than uniform ink drop formation apparatus heretofore, thus permitting higher speed print-out, or lower speed operation (e.g. lower signal frequency than heretofore) should that be desired, in order to adapt to some printing requirement with reliability.

While we have illustrated and described particular embodiments, various modifications may obviously be made. Thus, for example, apparatus according to aspects of the invention might be used as a "toner" with various lengths of "signal off" (dump) or "signal on" (print level) signals. Another modification could combine features of FIGURES 1–4 with those of FIGURE 5 and provide a facsimile system incorporating a sweep or scan to analogous places on (as well as to the dump off of) the recording medium according to an input (as from a function generator) thus to achieve greater speed or print-out than would be the case for the on-off system of FIGURE 5 where it is assumed that the only purpose of the lateral scan is to turn the ink "on" or "off" so far as reaching the recording paper 23'' is concerned. In any event, the true spirit and scope of the invention is intended to be defined only by the appended claims taken with all reasonable equivalents.

As used herein, and in the claims hereafter, we intend the words "marking fluid," "marking liquid" and "ink" to cover any organic or inorganic material which is in liquid form and is capable of taking a charge. Thus, the words are intended to cover inks, paints, alcohol (usable to put an invisible record on a paper sooner or later heat or chemical sensitized), an acid (or other) etch material, mercury or other metal in the liquid phase, plastic rendered semiconductive (as by addition of carbon particles) and liquified with a fast drying solvent to provide photo or chemical-resist area for later printing, or any coating composition originally in the form of a liquid and which dries or otherwise sets up to provide a visible or invisible record, mask, type face, or circuit. When we use the words "recording medium" we do not intend to be limited to the paper of the specific examples, for obviously the medium might be a plastic, or glass, cloth, metal or other material. When we use the words "characters" or "print-out" in the title, in the specification, and in the claims, we do not mean to be limited to letters and numerals, since the print-out might be of non-alphanumeric design, in the form of pictures, printed circuitry (e.g. formed by superposed layers of "drops") or image reversed (or not reversed) intaglio, offset or raised type, or resist areas, for further processing.

In addition, the word character or characters is meant

to include other non-alphanumeric designs such as waveforms and various geometric configurations. From the foregoing description, it is seen that the system operates in a go-no go mode in that each drop is either deposited on the recording medium or deflected to the catcher. Thus, each drop is individually controlled independently of any other drop. Also, by controlling the motion of the recording medium with respect to the rate at which the drops are formed as well as controlling the deflecting voltages applied to each drop, a particular design is created. The arrangement of FIGURE 5 is especially adapted to produce non-alphanumeric designs since in addition to the controllable variable herebefore described, the carriage **50** is movable on guideway **51** with respect to the recording medium **23''** on drum **52**, thereby providing additional means for controlling the deposition of each of the drops on the recording medium.

What is claimed is:

1. Apparatus for printing predetermined characters on a recording medium as a function of input signals characteristic of each of said characters, said apparatus comprising: a marking liquid reservoir; a nozzle means communicating with said reservoir for forming discrete and uniform marking liquid drops directed in a path generally towards said recording medium; transport means for driving said recording medium across said path whereby drops may normally impinge on different portions along said recording medium; intercepting means displaced from said path and displaced from said recording medium and for intercepting drops and preventing them from reaching said recording medium; electrostatic charge and deflecting means for deflecting drops from said path to be intercepted by said intercepting means or to impinge on said recording medium at predetermined points across said recording medium; and signal generating means responsive to said input signals characteristic of each of said characters for controlling said electrostatic charge and deflecting means to displace predetermined ones of said drops to reach discrete places across said medium and to displace predetermined others of said drops to reach said intercepting means, to print each of said predetermined characters on said recording medium.

2. Apparatus responsive to input signals characteristic of predetermined characters for printing said predetermined characters on a recording medium, said apparatus comprising: an ink reservoir; a nozzle communicating with said reservoir to provide ink in the nozzle; an electrically energizable piezoelectric device mechanically coupled to said nozzle; electrical means for producing mechanical vibration in said piezoelectric device and the nozzle coupled thereto to induce the ultimate formation of ink drops which are discrete and uniform; a recording medium which traverses the path generally taken by said ink drops; intercepting means displaced from said recording medium and for preventing predetermined ones of said drops from reaching said recording medium; electrostatic charge means for charging said ink drops, as a function of the input signals characteristic of said characters; and deflecting means for deflecting said drops from said path, as a function of the charges thereof to provide a print-out of each of said predetermined characters on the recording medium.

3. Apparatus for printing a visible record on a recording medium, said apparatus comprising: an ink reservoir; means for forming discrete and uniform ink drops at a constant rate, said last mentioned means including a nozzle communicating with said reservoir and directing drops in a path generally toward said recording medium; means for driving said recording medium transversely with respect to said path so that said drops may impinge on said recording medium; means for deflecting said ink drops across said recording medium at a rate related in a predetermined manner to the rate of formation of said ink drops so that said deflection and the motion of said driving means may form a matrix capable of having a predetermined number of said ink drops in rows and in columns; and means for deflecting selected ones of said drops beyond said matrix to form a printed character by the drops remaining on said matrix.

4. Apparatus for printing visible characters on a recording medium as a function of received input signals, said apparatus comprising:

(a) a reservoir containing a marking fluid,

(b) a nozzle means coupled to said reservoir for forming from the marking fluid contained thereat discrete, substantially uniform sized, fluid drops at a substantially constant frequency,

(c) a recording medium arranged generally in the path of said fluid drops as formed by said nozzle means,

(d) means for selectively deflecting predetermined ones of said fluid drops across a portion of said recording medium according to discrete levels corresponding to a predetermined number of columnar positions on said recording medium,

(e) means for driving said recording medium in a direction substantially transverse to the line of columnar positions to which fluid is directed by the selective action of said deflecting means, said driving means having a speed which is correlated with the speed of the deflecting means, so that said deflection and the motion of the recording medium as driven by said driving means combine to form plural matrices each capable of receiving a predetermined number of fluid drops arranged in cross rows as well as in columns for each matrix, the means for deflecting predetermined ones of the fluid drops having associated therewith a separate means for diverting others of the drops to points off the recording medium whereby to form printed characters consisting of drops remaining on said matrices on the recording medium.

5. Apparatus as in claim **4** further characterized by the (b) nozzle means comprising a piezoelectric device and means for energizing said device to control the mechanical forces on said fluid in a predetermined time oriented sequence for controlling the uniformity of said drops and the spacings therebetween, the (d) deflecting means including a pair of electrically oppositely energized deflecting plates arranged one on either side of a portion of the paths of drops from nozzle toward recording medium, said deflecting means further comprising electrodes and connections thereto for electrostatically charging the drops of marking fluid according to said received input signals to control the action of the deflecting plates on the differentially charged drops.

6. Apparatus in claim **5** further characterized by the (b) nozzle means comprising a conduit, said piezoelectric device being in the form of a polarized ceramic tube having a conductive material electrode at its internal diameter and a conductive material electrode at its outside diameter, said ceramic tube being mechanically coupled at the internal diameter thereof to said conduit to be coaxially aligned with the direction of flow of the marking fluid, and

(g) electrical oscillator means for oppositely energizing the electrodes of said piezoelectric device at a frequency related to the rate of electrostatically charging said drops in accordance with said received input signals.

7. Apparatus as in claim **4** further characterized by the (c) recording medium being in the form of a relatively wide, relatively long, single sheet, a plurality of combinations arranged, transversely of the direction of motion of said sheet, each cobination having (b) nozzle means, having (d) deflecting means, and having (f) diverting means, and means for providing each of said combinations with received input signals characteristic of another character to be recorded to simultaneously print a plurality of sequentially readable characters on said single sheet.

8. In a drop apparatus of the type having a nozzle fed with a marking liquid under pressure and having associated with said nozzle and the liquid therewithin means to control the uniform formation of drops which are discrete, of uniform mass and uniformly separated from one another, the improvement comprising: a transducer comprising a cylindrical tube of ceramic material with piezoelectric properties, a first electrode coupled to said ceramic material at its inside diameter and a second electrode coupled at its outside diameter and means for mechanically coupling said transducer to said nozzle with said tube of ceramic material surrounding at least a portion of the liquid associated with the nozzle, to control the uniform formation of said drops.

9. Apparatus for recording a character on a recording medium as a function of a set of input signals characteristic of said character comprising: a source of marking liquid; drop forming means in communication with said source of marking liquid for forming a plurality of uniform marking liquid drops at a predetermined rate; a recording medium disposed with respect to said drop forming means, said recording medium having a surface sensitive to liquid drops deposited thereon; drive means for controlling the motion of said recording means at a rate related to said predetermined rate at which said liquid drops are formed; means for controlling the deposition of said marking liquid drops on the sensitive surface of said recording medium to record said character thereon, said means including electrostatic charge means responsive to said input signals for depositing liquid drops on said sensitive surface to record said character thereon, and for deflecting the rest of the liquid drops of said plurality of drops from said sensitive surface; and intercepting means disposed adjacent said recording medium for receiving the liquid drops deflected by said electrostatic charge means from said sensitive surface.

10. An apparatus for recording a character on a recording medium as a function of a set of input signals related to said character comprising: a source of marking liquid; a recording medium having a surface which is sensitive to said liquid for producing a record as a function of the deposition of said liquid on said surface; drop forming means in communication with said source, and displaced from said recording medium for forming a sequence of uniform liquid drops at a predetermined rate, each drop being of substantially equal size and weight and uniformly spaced from one another; means for directing said drops in a selected path toward said surface of said recording medium; and deflection means for controlling the deposition of said drops on said surface to record said character thereon, said deflection means including means responsive to said set of input signals for deflecting some of said drops in said sequence unto said surface to produce said character and for deflecting other drops in said sequence away from said surface.

11. An apparatus as recited in claim 10 further including drive means for controllably moving said recording medium at a rate related to said predetermined rate at which said drops are formed to control the recording of said character on said surface.

12. An apparatus as recited in claim 11 wherein said drop forming means include a conduit having one end in communication with said source for containing liquid therein; nozzle means coupled at the other end of said conduit for controlling the flow of liquid therefrom; transducer means having piezoelectric characteristics mechanically coupled to said conduit about the outer surface thereof adjacent said nozzle means for applying mechanical vibratory forces to said conduit; and means for energizing said transducer means to provide said sequence of uniform liquid drops by controlling the mechnical vibratory forces applied to said conduit.

13. An apparatus as recited in claim 12 wherein means for energizing include a source of oscillatory signals of a frequency related to said predetermined rate at which said drops are formed.

14. An apparatus as recited in claim 10 wherein said deflection means disposed between said drop forming means and said recording medium include a pair of deflecting plates for providing an electric field therebetween, said field being in a direction substantially perpendicular to said selected path; and electrostatic charging means responsive to said set of input signals for variably deflecting some of said drops unto said surface by variably charging said drops in accordance with said set of input signals.

15. An apparatus as recited in claim 14 wherein said electrostatic charging means includes function generating means responsive to said set of input signals for converting them to related voltage signals; a charging tunnel disposed between said means for directing said drops and said pair of deflecting plates for charging drops therein, said tunnel having an aperture sufficient to enable said drops directed in said selected path to pass therethrough; and means for supplying said related voltage signals to said charging tunnel.

16. In an apparatus responsive to a set of input signals characteristic of a character for recording said character on a recording medium by controlling the deposition of a plurality of liquid drops on a sensitive surface of said recording medium, said apparatus including a source of liquid, a conduit having a nozzle at one end which is directed toward said sensitive surface and which is large enough to pass therethrough liquid from said source, the improvement comprising: a piezoelectric transducer mechanically coupled to said conduit near the nozzle end thereof; and means for energizing said transducer to control the flow of liquid through said nozzle and the formation of a sequence of liquid drops each drop being of substantially equal mass and size and the spacings between drops in said sequence being substantially equal.

17. In an apparatus as recited in claim 16 wherein said means for energizing include a source of oscillatory signals of a predetermined frequency for energizing said piezoelectric transducer with said signals to mechanically vibrate the nozzle end of said conduit to form said sequence of liquid drops at a rate substantially equal to said predetermined frequency.

18. In an apparatus as recited in claim 17 wherein said piezoelectric transducer comprises a tube-like piezoelectric material, a first electrode coupled thereto at the inside diameter of said tube-like material, and a second electrode coupled to the outside diameter, means for coupling said source of oscillatory signals to said first and second electrodes, said transducer being axially mechanically coupled to said conduit at the inside diameter thereof, whereby said tube-like piezoelectric material surrounds a portion of said conduit.

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RICHARD B. WILKINSON, *Primary Examiner.*