[54] INK JET SYSTEM OF CHARGE AMPLITUDE CONTROLLING TYPE

Inventors: Takeshi Kasubuchi; Yuji Sumitomo; Masahiko Aiba, all of Nara, Japan

Assignee: Sharp Kabushiki Kaisha, Osaka, Japan

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References Cited

UNITED STATES PATENTS
3,298,030 1/1967 Lewis et al. ..................... 346/75
3,562,757 2/1971 Bischoff .......................... 346/75 X
3,596,275 7/1971 Sweet .............................. 346/75 X
3,888,034 8/1972 Kashio ......................... 346/75 X

Primary Examiner—Joseph W. Hartary
Attorney, Agent, or Firm—Stewart and Kolasch, Ltd.

ABSTRACT

Control of the printing velocity is of importance for application of ink jet systems of the charge amplitude controlling type to intermittently operating recorders or asynchronous recorders. In order to alternate the printing velocity, the velocity of travel of a head carrying a nozzle and the charging signals to the total number of ink drops in the stream of ink drops emitted from the nozzle also is changed. In this charging signals to a total of ink drop in the wake also is changed. In such way there is provided ink jet systems of the charge amplitude controlling type suitable for intermittent or asynchronous printing wherein the printing velocity can be varied without alternating the frequency of formation of the ink drops.

1 Claim, 2 Drawing Figures
INK JET SYSTEM OF CHARGE AMPLITUDE CONTROLLING TYPE

BACKGROUND OF THE INVENTION

This invention relates to an inkjet system printer wherein ink drops issuing at a constant rate from a nozzle are charged in accordance with charging signals and, then deflected in accordance with the charges carried by the drops as they pass through a fixed electric field, thereby to form images representative of input signals, and more particularly to a method for controlling the printing velocity in the inkjet system printer of the charge amplitude controlling type whereby the head carrying the nozzle and the charging electrode is intermittently moved in response to intermittent inputs from keypads or the like to enable intermittent or asynchronous printing. In a U.S. Pat. No. 3,596,275 granted to Richard G. Sweet there is disclosed the inkjet system printer of the charge amplitude controlling type wherein ultrasonic vibration is applied to ink fluid issuing under pressure from an nozzle to form ink drops at a predetermined rate and the ink drops are charged in accordance with the signals and then the ink drops are electrostatically deflected into predetermined trajectories in accordance with the amplitude of the charges on the drops so that symbols corresponding to the charging signals are recorded on a record receiving member such as a paper on which the charged drops impinge. In this form vertical deflection of the recording symbols is under the control of the charging signals while its horizontal deflection is substituted by constant velocity movement of the record receiving member or constant velocity horizontal movement of the head carrying the nozzle and the charging electrode. It is, therefore, important that the record receiving member or the head is advanced at a constant velocity in operation. Although the frequency of ink drop formation from the nozzle is correctly identical with the exciting frequency of the ultrasonic transducer vibrating the nozzle, the timing of separation of the drops from the stream of the ink supply will vary with various factors, for example, temperature variations and viscosity of the ink liquid, especially during a short period of time after the application of the exciting signals. For this reason it is desirable that the ink drops issuing from the nozzle always are formed at a constant rate to ensure steady printing.

According to the prior art inkjet printers of the charge amplitude controlling type, the head continues travelling at a constant velocity to carry out continuous or synchronous printing operation for one line printing period. Hence, the printers of these types are necessarily expensive, and many of them fail to achieve suitable speed and performance. An object of this invention is the provision of an inkjet printer capable of serving the functions of both successive and intermittent printing operations.

Another object of this invention is the provision of an inkjet printer capable of facilitating intermittent drive scheme for the head or the record receiving member without alternation of the drop formation frequency.

In accordance with this invention, when the recorder is in intermittent printing mode, the velocity of movements of the head is altered to a small rate so that the printing velocity is decreased by lowering a ratio of the ink drops charged with the charging signals to the total number of ink drops in the jet or stream of ink drops. An ink charging technique disclosed in a U.S. Pat. No. 3,562,757 teaches the provision of guard drops between the charged drops. It should be noted that they act as a shield to minimize the adverse effects of drop charge repulsion but do not serve to control the printing velocity.

These and other objects of this invention are achieved, in a preferred embodiment, by an arrangement wherein the exciting signals for the ultrasonic transducer secured to the nozzle are entered into a charging signal generator via a variable frequency divider and the ratio of the ink drops each having a charge to the number of ink drops in the jet stream is modified and the moving velocity of the head is varied proportionally with the modification of the ratio of the charged to uncharged drops, permitting the printing velocity to fall during the intermittent printing mode.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block schematic diagram showing a circuit arrangement of an embodiment of this invention.

FIG. 2 is a block schematic diagram showing a circuit arrangement of another embodiment of this invention with a simplified frequency divider.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is illustrated an inkjet system printer of a type controlling the amplitude of charge wherein, by exciting an ultrasonic transducer (not shown) tightly secured to a nozzle 2, ink liquid issuing under pressure from the nozzle 2 breaks up into drops 4 at a predetermined rate. The ink drop 4 is controlled in amplitude of charges thereon upon application of charging signals to a charging electrode and then deflected electrostatically in accordance with the amplitude of charges carried by the drops by means of a pair of deflection plates 8 to make records on a record receiving paper wound on a drum 10.

The ultrasonic transducer is excited at all times in operation of the recorder and the ink drops 4 are successively emitted from the nozzle 2. The ink drops 4 serving no function of printing are collected and returned to the nozzle 2 after they impinge upon a screen 12 as is well known in the art.

The vertical deflection of the ink drops 4 is practiced by the electrostatic deflection previously described, whereas the displacements thereof in the horizontal direction are effected by horizontal movements of the printing head 1 carrying the nozzle 2 and the charging electrode 6.
where \( f \) is the exciting frequency of the ultrasonic transducer, \( m \) is the number of dots in the lateral direction of a character pattern, \( n \) is the number of dots in the longitudinal direction of the character pattern, \( 2r \) is the number of dots indicative of a spacing between the two characters, and \( K \) is a thinning coefficient indicative of a ratio of the ink drops 4 received by the charging signals to the ink drops 4 projected from the nozzle 2.

In accordance with innovative concept of this invention both the thinning coefficient set forth in the equation (11) and the velocity of horizontal advancement of the head 1 are modified for control purposes of the printing velocity \( V \).

In the illustrated embodiment output signals from a high velocity input device 14 such as tape recorders, etc. which operates at a high rate, namely, the same rate as that of the printing head 1 in a continuous printing mode (255 characters per second in this example), are connected with a terminal 15 of a transmission/reception selection switch 18 and high velocity control signals \( X \) in input information are connected with a control circuit 30 to be later explained. An intermittent or low velocity input device 16 such as keyboards or typewriters includes character (and numeral) key switches and encoders. The outputs from the intermittent input device 16 are asynchronous and provided at a low velocity (normally, less are 10 characters per second) and then connected with the other terminal 17 of the switch 18. Low velocity control signals \( Y \) containing the input information from the intermittent input device 16 are similarly introduced to the control circuit 30. As shown in FIG. 1, the high velocity input device 14 provides the high velocity control signals \( X \) when in its operative condition while the low velocity input device 16 provides the low velocity control signals \( Y \) when in its operative condition. Provision of these signals \( X \) and \( Y \) may be accomplished through the use of various types of circuits well known to one skilled in the art, such as flip-flops.

A common terminal 19 of the switch 18 is connected with an input terminal of a buffer memory 22 included in a charging signal generator 21. In accordance with conventional ink drop printing techniques the charging signals to be supplied to the charging electrode 6 should be of the graded waveform type (see for example, U.S. Pat. No. 3,298,030 to Lewis et al. Jan. 10, 1967 with particular reference to FIG. 4).

Circuit arrangements suited for this purpose have been shown or disclosed in prior art systems are within the purview of one of ordinary skill in the art and the construction and operation of the charging signal generator circuit arrangement are not critical to the primary object of the present invention, namely, the system for modifying the printing velocity in compliance with the velocity of inputs to be printed. In the illustrated embodiment, the generator 21 for generating charging signals to the charging electrode 6, namely comprises the buffer memory 22, a read only memory 24 and a video generator 26. The charging signals must be synchronized with the dot formation timing and with the position of the ink drops in the dot matrix to form various printed characters. In this regard, the video counter 28 counts the number of ink drops to be charged with the charging signals and determines the position of the ink drops in the dot matrix by counting the pulses applied thereto from the adjustable frequency divider 48. In this embodiment the video counter 28 is implemented to count the number representing the product \( mn \), where \( m \) is the number of dots in the lateral direction of the dot (character) matrix and \( n \) is the number of dots in the longitudinal direction of that matrix as previously defined herein. This count may be accomplished by any suitable counter of a type well known in the art or combinations of such counters which is also a well known expedient. The generator 21 comprises the above buffer memory 22 temporarily storing the input information and synchronizing the same with operation of the printer, a read only memory 24 providing a train of ink drop control pulse signals each corresponding to individual dots of the character pattern, to be printed a video generator 26 providing both deflecting signals, and charging signals, the deflecting signals, being sampled by the ink drop control pulse signals to provide the charging signals, a video counter 28 counting the number of the ink drops to be charged with the charging signals out of the ink drops projected from the nozzle 2 and the control circuit 30 timing the various circuit arrangements.

The control circuit 30 is adapted so that the circuit produces

1. continuous operation control signal \( Z \) when it receives the high velocity control signals \( X \) from the high velocity input device 14,
2. intermittent operation control signals \( W \) when it receives the low velocity control signals \( Y \) from the low velocity input device 16,
3. frequency division rate control signals \( CON \) in response to the high velocity control signals \( X \) and the low velocity control signals \( Y \). The circuit 30 may be constituted by known logic circuits, since the correlation between the inputs and outputs thereof may be simply expressed under logical formulas within the purview of those of ordinary skill in the art.

Continuous operation control signals \( Z \) included in outputs from the control circuit 30 are applied to a continuous drive circuit 32 for the printing head 1 and intermittent operation control signals \( W \) therein are applied to an intermittent drive circuit 34 for the same.

Outputs from a printing head position detector 36 also control both the continuous and intermittent drive circuits 32, 34, of which outputs are entered into a servomotor 40 via an OR circuit 38. The servomotor 40 is mechanically coupled with the printing head 1 to control the horizontal movements thereof. The velocity of movements of the printing head 1 is determined by the continuous and intermittent drive control signals \( Z \) and \( W \) together with frequency division rate control signals \( CON \) and thus is controlled in accordance with the ratio of the ink drops charged with the charging signals to the number of drops \( 4 \) in the stream of ink drops. Suitable print head positioning arrangements are well known in the prior art, such as that shown in FIG. 5 of U.S. Pat. No. 3,298,030 to Lewis et al. issued Jan. 1967.

The exciting signals which activate the ultrasonic transducer 2A secured to the nozzle 2 are derived from
an ultrasonic amplifier 44 amplifying outputs from an oscillator 42. Typically, the oscillation frequency of the oscillator 42 is 25kHz which is provided from two-stage flipflops added to a 100kHz crystal oscillator. The outputs from the oscillator 42 also are introduced to an adjustable frequency divider 48 to convert to low frequency signals and thereafter are entered to the video counter 28 in the charging signal generator 21. The frequency division rate of the frequency divider 48 is variable in accordance with the frequency division control signals CON which in the control circuit 30 are produced based upon the connection relations with the high velocity input device 14 or the intermittent and low velocity input device 16. In this way a rate of the frequency division is dependent upon the rate of the input information.

When the high velocity input device 14 is coupled with the system, the ink jet printer will operate as follows:

From the high velocity input device 14 such as tape recorders the high velocity control signals X are applied to the control circuit 30 and the adjustable frequency divider 48 is set at a desired rate of frequency division corresponding to the input rate of the high velocity input device 14 by means of the frequency division rate control signals CON. In the other hand the continuous drive control signals Z corresponding to the frequency division control signals are inputted from the control circuit 30 to the continuous drive circuit 32 for the printing head 1 so that continuous drive signals for the head are applied to the servomotor 40 through the OR circuit 38 to effect continuous advancement of the printing head 1.

At this time the input information from the high velocity input device 14 is applied via the switch 18 to the buffer memory 22 in the charging signal generator 21. Various control signals for printing operation are simultaneously applied to individual circuit arrangements. The outputs from the oscillator 42 are impressed on the nozzle 2 through the ultrasonic amplifier 44 and thus the ink drops 4 are continuously projected from the nozzle 2. A portion of the outputs from the oscillator 42 activates the video counter 28 via the adjustable frequency divider 48. The video counter 28 starts counting to the control circuit 30 and, transmits the input information stored in the buffer memory 22 to the read only memory 24 and the video generator 26 to produce the charging signals.

The printing head 1 is continuously advanced for one horizontal line of printing upon the appearance of the continuous drive control signals Z to effect the continuous printing operation at the high velocity. When the termination of one line of printing is reached, the signals of the position detector 36 causes head return signals from the continuous drive circuit 32 to be applied to the servomotor 40. It follows that the printing head 1 is returned to the original position and the drum 10 is rotated by one step equivalent to one line of the printing.

The operation of the intermittent mode of the present invention utilizing the manually operated intermittent input device 16 will now be described.

Upon depression of keys, etc., the low velocity control signals Y are introduced to the control circuit 30 and the adjustable frequency divider 48 is set at the rate of frequency division which corresponds to the printing velocity of the intermittent mode. At the same time the intermittent drive control signals W corresponding to the frequency division rate control signals CON are introduced to the intermittent drive circuit 34 so that intermittent drive signals for the head 1 are applied to the servomotor 40 via the OR circuit 38. The result of application of the outputs from the intermittent drive circuit 34 to the servomotor 40 is that the printing head 1 is advanced and then stopped at the place just before the first character printing position.

The data information from the intermittent input device 16 is introduced to and stored in the buffer memory 22 and the video counter 28 starts counting upon the appearance of the control signals on line 28A from the control circuit 30 to initiate the printing operation.

At this time, since signals applied to the video counter 28 are identical with the signals which are provided by considerable frequency division in the adjustable frequency divider 48 of the 25kHz ultrasonic transducer exciting signals, the number of the ink drops 4 directly associated with printing (charged ink drops) substantially decreases in relation to the total number of drops emitted from the nozzle 2 over a given interval and accordingly the velocity of travel of the printing head 1 becomes lower. Accordingly time required to acceleration the printing head 1 is shortened and control of intermittent drive of the printing head 1 is readily accomplished.

Upon completion of one character printing the printing head 1 is stopped in response to the intermittent drive control signals W. In such way the printing head 1 is intermittently advanced at every key depression of the input device 16 and, after reaching the end position of a printing character line, is returned to the original position or the start position of the next character line upon appearance of the signals from the position detector 36. Paper feeding is, thereafter, allowed and the system is ready to commence the next line of printing.

FIG. 2 is a circuit diagram of another embodiment of this invention for the purpose of simplifying implementation of the variable frequency divider 48 shown in FIG. 1, wherein corresponding parts are given reference numerals which correspond to those of FIG. 1.

Outputs of an oscillator 42 are applied to and divided into an ultrasonic amplifier 44 and an adjustable frequency divider 48 and an adjustable frequency divider 52 by which provision is to minimize the adverse effects of electric charge repulsion between adjacent ink drops 4 by alternate application of the charging signals to the ink drops. This first frequency divider 50 is made of a single flip-flop of which the output terminal is connected with the input terminal of the second frequency divider 52 for the purpose of a considerable reduction in the printing velocity and the output is also connected with a terminal 51 of a switch 54. The provision of the second frequency divider 52 is to reduce the number of the ink drops having the charges on them, namely, ink drops directly associated with the printing thereby to decrease the printing velocity. This differs from the first frequency divider 50 in that the frequency division rate of the former 52 is larger, for example, 1/10 - 1/20, than that of the latter 50. The frequency division rate of the second divider 52 is further variable in accordance with the types of input devices.

The output terminal of the second frequency divider 52 is connected with the other terminal 53 of the switch 54 of which the common terminal 55 is, in turn, con-
The switch 54 moves in unison with the switch 18. In the case where the printer serves as a high velocity terminating receiver the movable terminals of the switches 18, 54 are turned to the terminals 15, 51.

The operation of the printer is as follows: The high velocity control signals X from the high velocity input devices 14 such as tape recorders are entered into the control circuit 30 and at this time the continuous drive control signals Z are entered into the continuous drive circuit 32 for the printing head 1. Thus the printing head 1 starts travelling upon supply of the continuous drive signals to the servomotor 40 via the OR circuit 38. Simultaneously, the input information signals from the high velocity input device 14 are fed to the buffer memory 22 within the charging signal generator 31 through the switch 18. The control circuit 30 provides the printing control signals to various circuits. In the meanwhile, the nozzle 2 receives the outputs from the oscillator 42 through the ultrasonic amplifier 44 and issues a continuous stream of the ink drops 4. A portion of the outputs from the oscillator 42 is frequency-halved by the first frequency divider 50 and supplied to the video counter 28 through the switch 54.

Other modes of the operation are substantially the same as that shown in FIG. 1 and will not be described.

In the case where the movable terminals of the switches 18, 54 are turned to the terminals 15, 51, respectively the printer serves as a high velocity terminating receiver in which ink drops 4 projected from the nozzle 2 are subjected to alternate application of the charging signals thereto and then the printing head 1 is continuously advanced for a single row of the printing characters.

On the other hand, in the case where the ink jet printer is used as a manually operated low velocity terminating transmitter having the printing functions, the switches 18, 54 are turned to the terminals 17, 53, respectively. In this instance the manual operation of the intermittent input device 16 equipped with a keyboard produces the low velocity control signals X which are introduced to the control circuit 31 to output the intermittent drive control signals W. They are inputted to the intermittent drive circuit 34. The outputs of the intermittent drive circuit 34 applied to the servomotor 40 causes the printing head 1 to move to the position just before the first character printing position. Then, the information from the intermittent input device 16 is applied to the delivery memory 22 and the video counter 28 starts counting in response to the control signals from the control circuit 30. Thus, printing is initiated.

At this time the signals applied to the video counter 28 are ones provided by a considerable frequency reduction of the 25kHz ultrasonic transducer exciting signals derived from the oscillator 42. This procedure is accomplished by both the first and second frequency dividers 50, 52. Therefore, the number of the ink drops 4 directly relating to the record printing (charged ink drops) decreases to a product (1/40) of the frequency division rate (one/half) of the first divider 50 and that (1/20) of the second divider 52. The intermittent drive control signals W are dependant upon the product of the frequency division. Accordingly, the rate of travel of the printing head 1 is reduced during the intermittent printing mode and the acceleration thereof also is reduced to facilitate control of the head advancement operation.

After completion of printing of a single row of characters the printing head 1 is prevented from travelling, depending upon the intermittent drive control signals W. The head 1 is then caused to return to the original position by the signals from the position detector 36.

It should be noted that the rates of the frequency division in the first and second frequency dividers 50, 52 are determined by various factors such as the oscillating frequency of the oscillator 42, the repulsion force exerted between the charged ink drops, and the printing velocity proper to the intermittent type printing procedure and thus are not necessarily limited to one/half and one/twentieth as briefly described above. Although the printing head 1 carrying the nozzle 2 and the charging electrode 6 is advanced in a horizontal direction in the above embodiments, it may be fixed and, the drum carrying the record receiving member be moved in the horizontal direction to provide the relative horizontal displacement therebetween.

We claim:

1. An ink jet system printer of a charge amplitude controlling type comprising a nozzle, an ultrasonic transducer exciting the nozzle for issuing a stream of ink drops, a charging electrode for charging the ink drops from the nozzle, a charging signal generator for providing charging signals to be applied to the charging electrode in accordance with input information to be recorded, a pair of deflection electrodes for deflecting the charged ink drops into selective trajectories in accordance with the amplitudes of charges on the ink drops by means of a fixed field potential between said electrodes, a record receiving member for forming images indicative of the input information by means of deposition of the charged and deflected ink drops, a head carrying the nozzle and the charging electrode, drive means for moving the head transversely of said trajectories, an oscillator providing an output signal of a predetermined frequency for activating the ultrasonic transducer, a high velocity input device for continuously introducing the input information to the charging signal generator at a high rate and providing a high velocity control signal, a low velocity input device for intermittently introducing the input information to the charging signal generator at a lower rate and providing a low velocity control signal, a first selection circuit for selecting any one of the input devices to selectively convert said printing unit to a high velocity printing unit and a low velocity printing unit, control means connected with said input devices and responsive to said high and low velocity control signals to provide high and low rate control signals and high and low velocity drive signals in correlation with the selective energization of said input devices, a frequency divider connected with said control means and the output of said oscillator responsive to said high and low rate control signals to effect a variable rate of frequency division, and means for applying the output from said oscillator to the
charging signal generator through the variable frequency divider to modify the frequency of occurrence of said charging signals and the resulting ratio of charged ink drops to the total ink drops in the stream by adjustment of the frequency division rate of the frequency divider in response to said rate control signals.

said drive means connected with said control means and responsive to said high and low velocity drive signals to modify the velocity of movement of said head in correlation with said ratio to thereby control the printing velocity of said printer.