

- [54] **PHASE CONTROL FOR INK JET PRINTER**
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[73] Assignee: **International Business Machines Corporation**, Armonk, N.Y.
[22] Filed: **July 19, 1973**
[21] Appl. No.: **380,641**

Related U.S. Application Data

- [63] Continuation of Ser. No. 253,065, May 15, 1972, abandoned.
[52] U.S. Cl. **346/140**
[51] Int. Cl. **G01d 18/00**
[58] Field of Search **346/75**

[56] **References Cited**

UNITED STATES PATENTS

- 3,596,276 7/1971 Lovelady 346/75 X
3,681,778 8/1972 Keur 346/75

OTHER PUBLICATIONS

Haskell et al.; Variable Delay for Ink Jet Printer; IBM

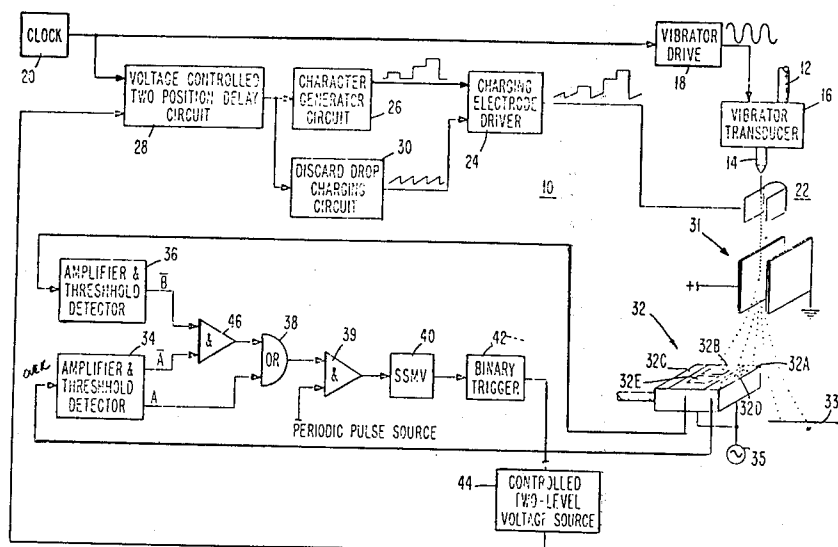
Tech. Disc. Bulletin; Vol. 14, No. 9, February 1972, pp. 2796.

Primary Examiner—Joseph W. Hartary
Attorney, Agent, or Firm—Francis V. Giolma

[57] **ABSTRACT**

A gutter structure for catching discarded ink drops from an ink jet nozzle comprises a multisection electrode structure to separate drops having different phase relations. A relatively low calibrating voltage is applied to the drop charging electrode in conjunction with a character generation signal so that the calibrating voltage prevails to deflect drops whenever a drop is to be discarded. Circuitry connected to the different electrode sections controls the phase relation of the drop charging voltage and the drop formation in accordance with detection of the calibrating voltage drops to maintain the proper phase relations.

20 Claims, 20 Drawing Figures



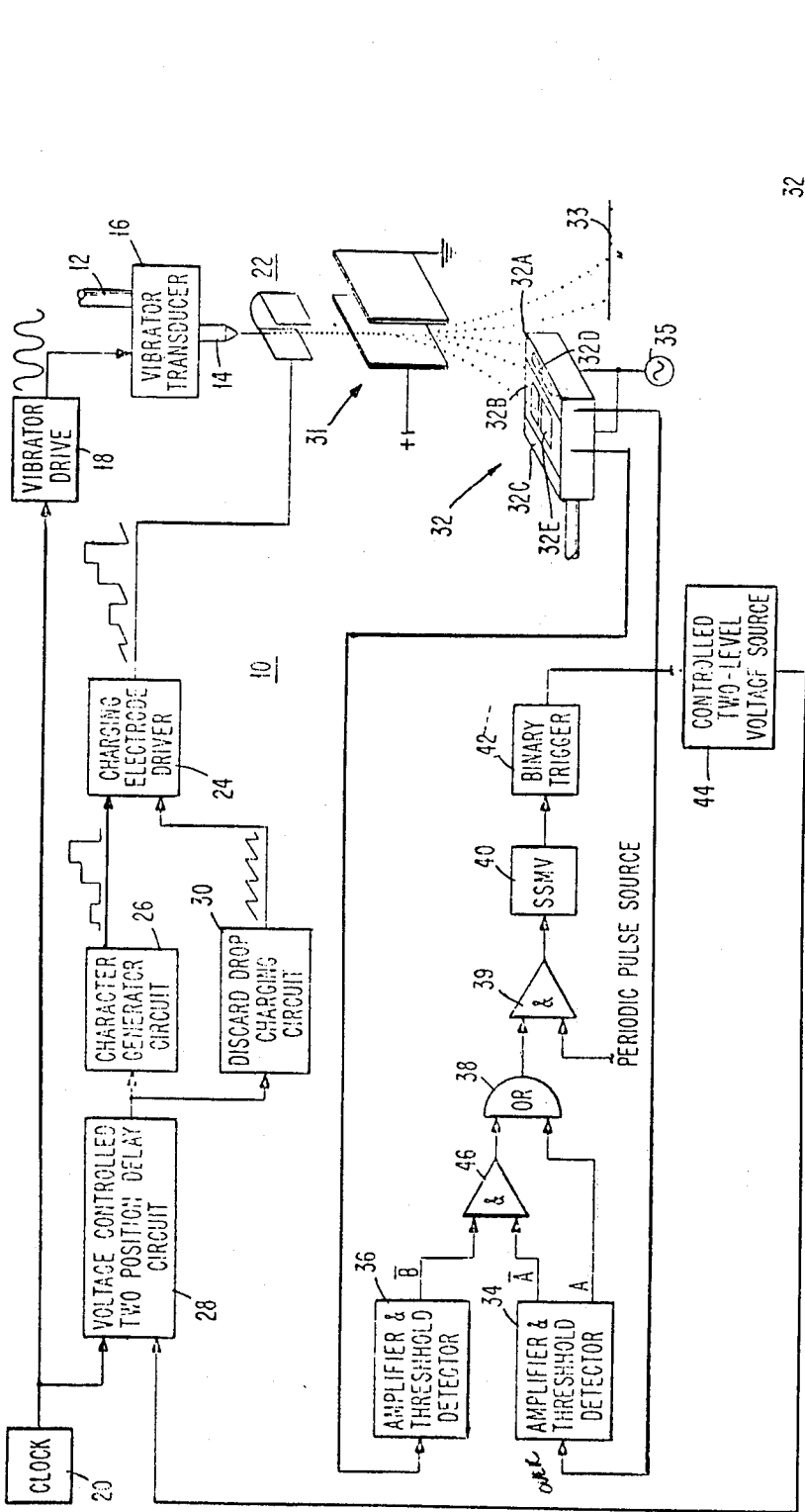


FIG. 1

FIG. 1a

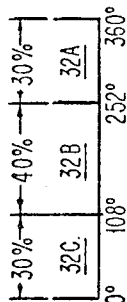


FIG. 2a

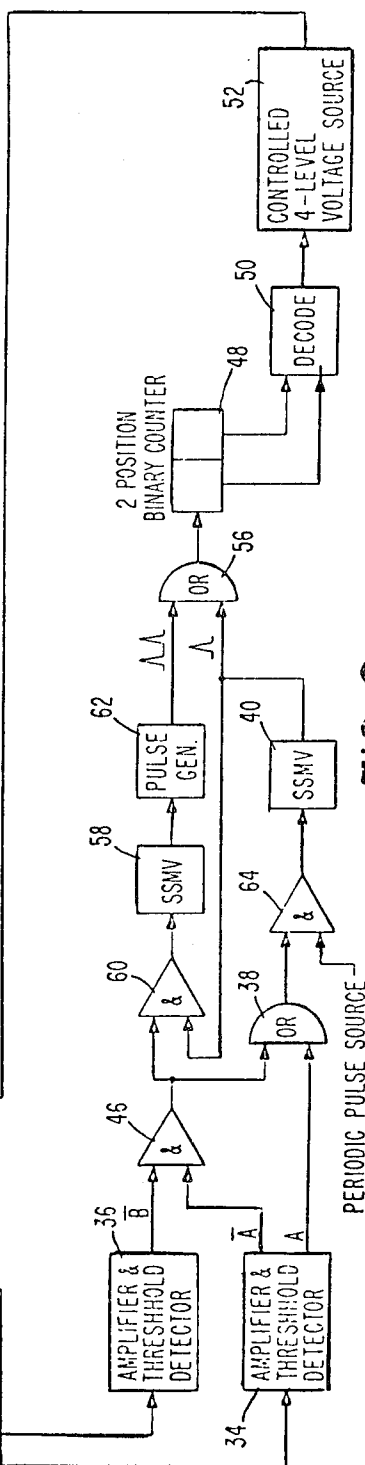
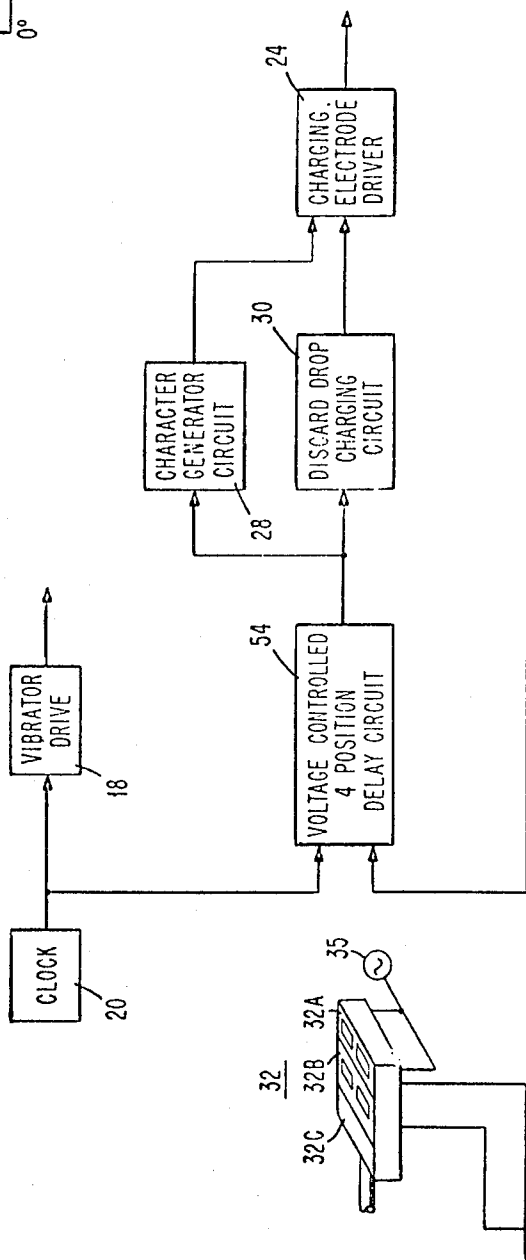


FIG. 2

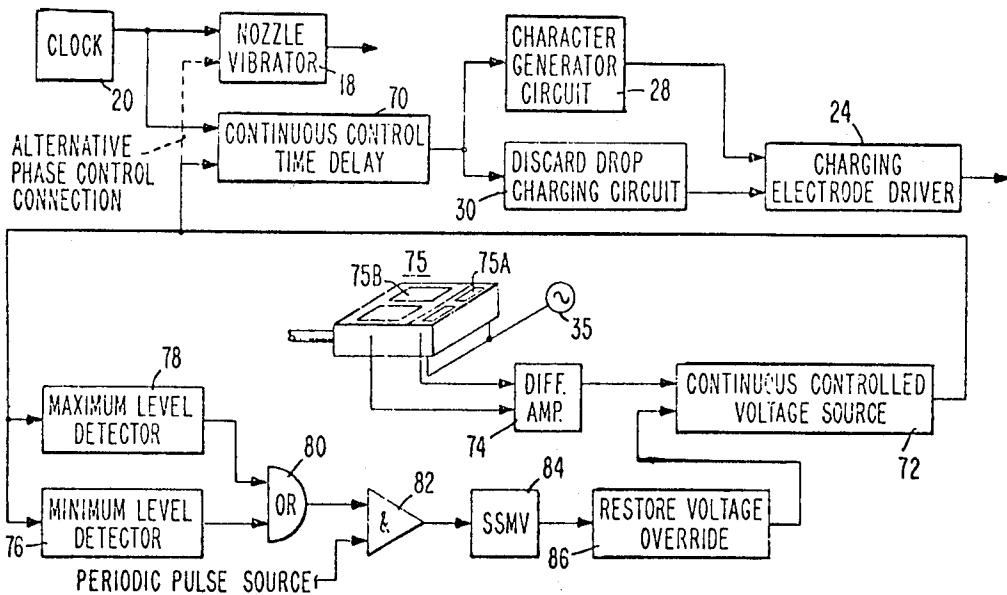


FIG. 3

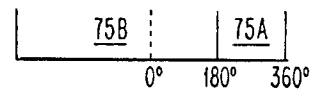


FIG. 3a

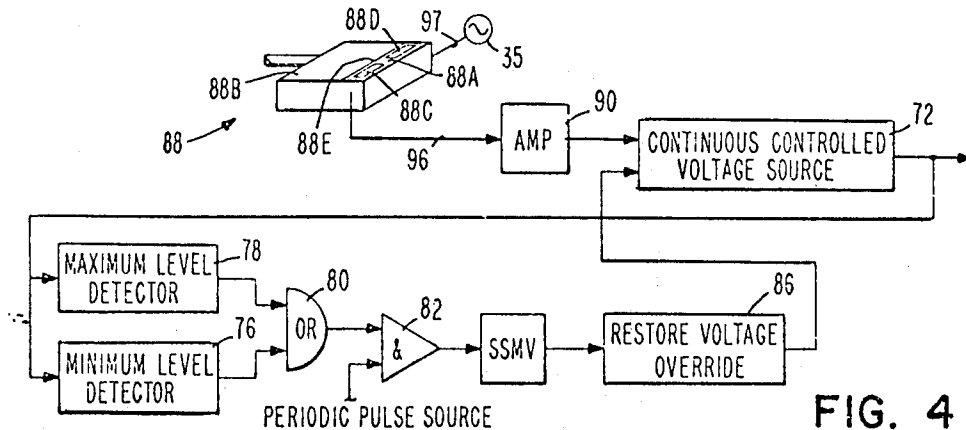


FIG. 4

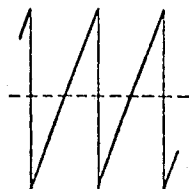


FIG. 5a

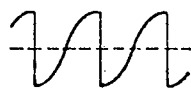


FIG. 5b

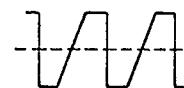


FIG. 5c

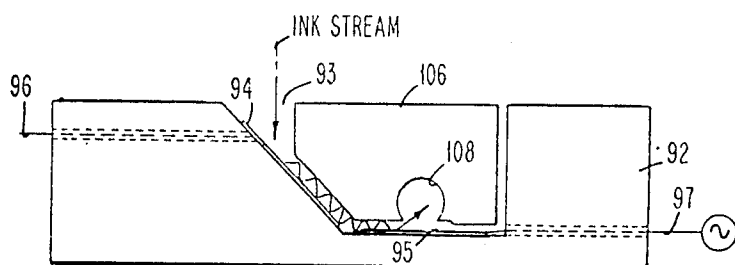


FIG. 6

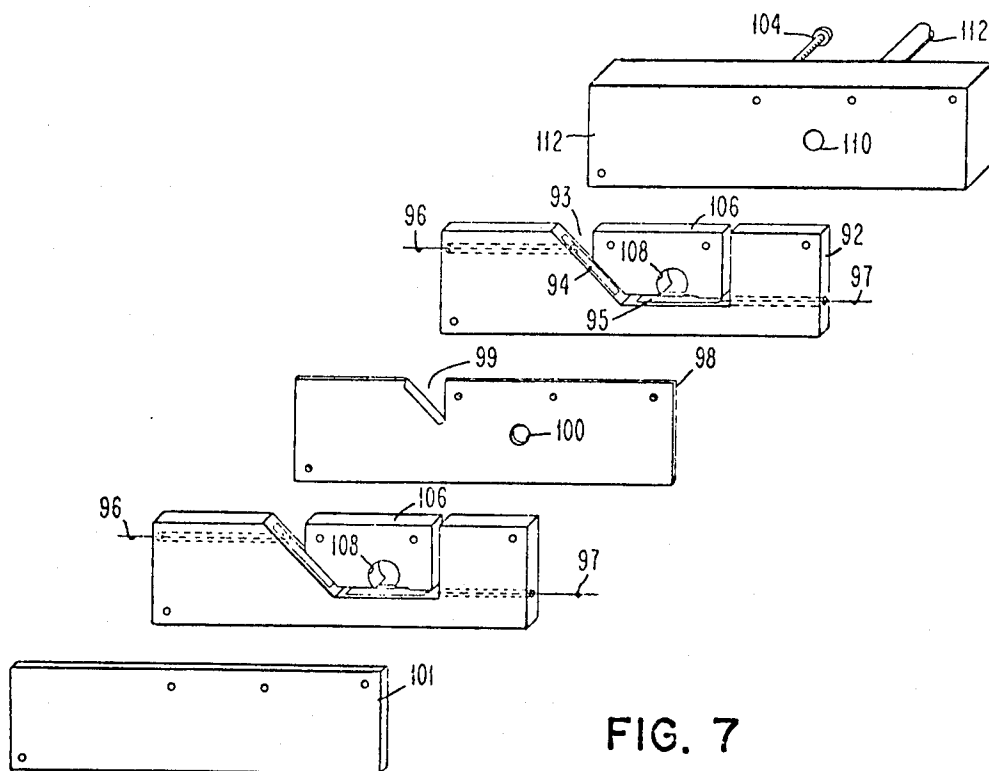


FIG. 7

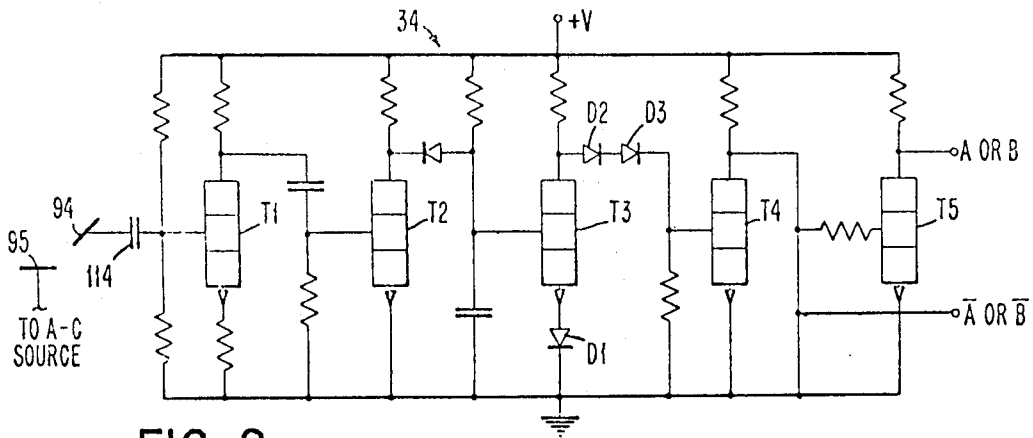


FIG. 8

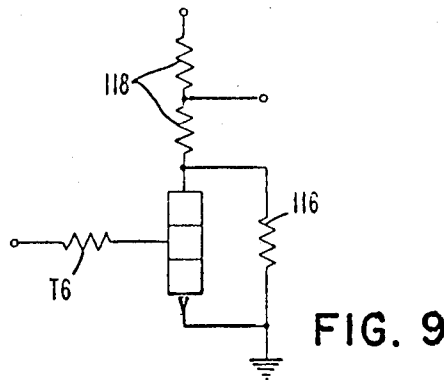


FIG. 9

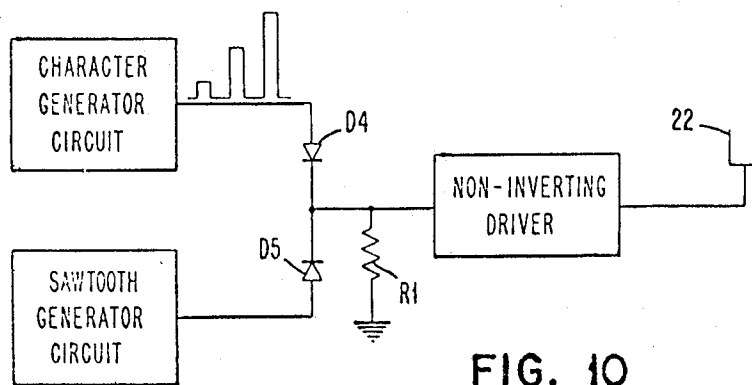


FIG. 10

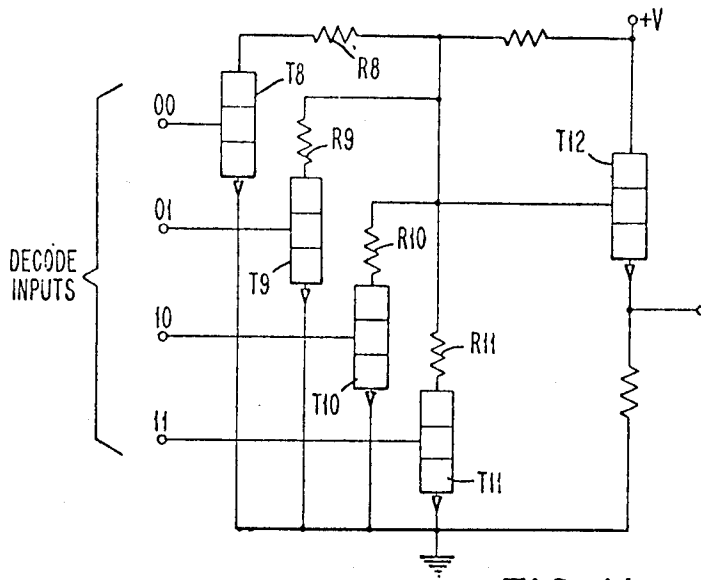


FIG. 11

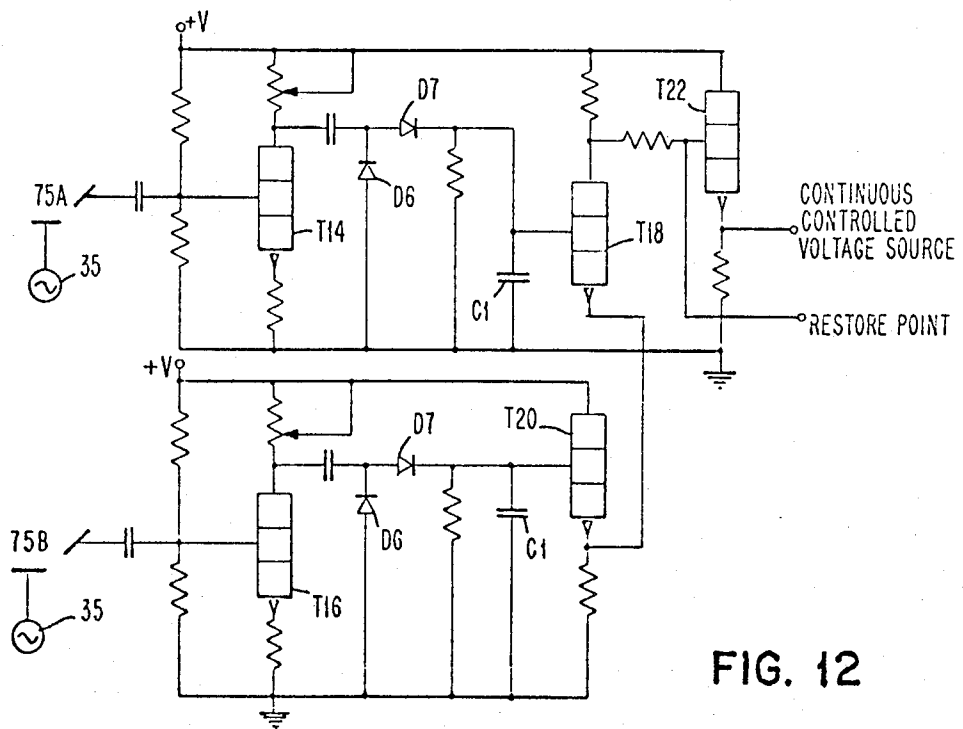
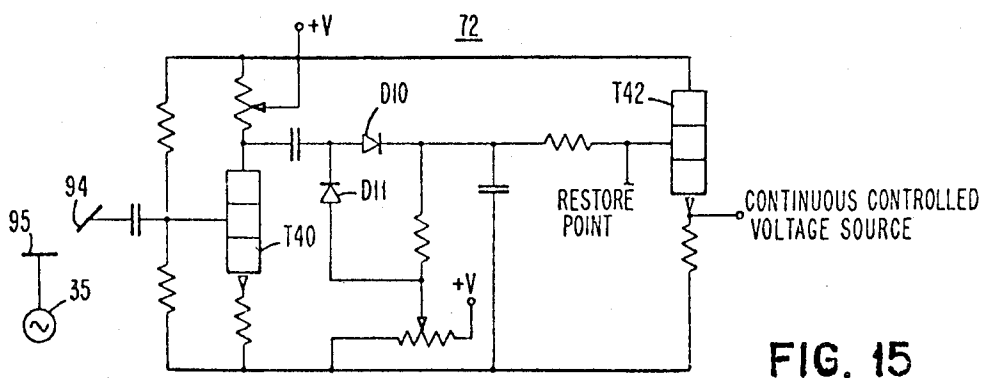
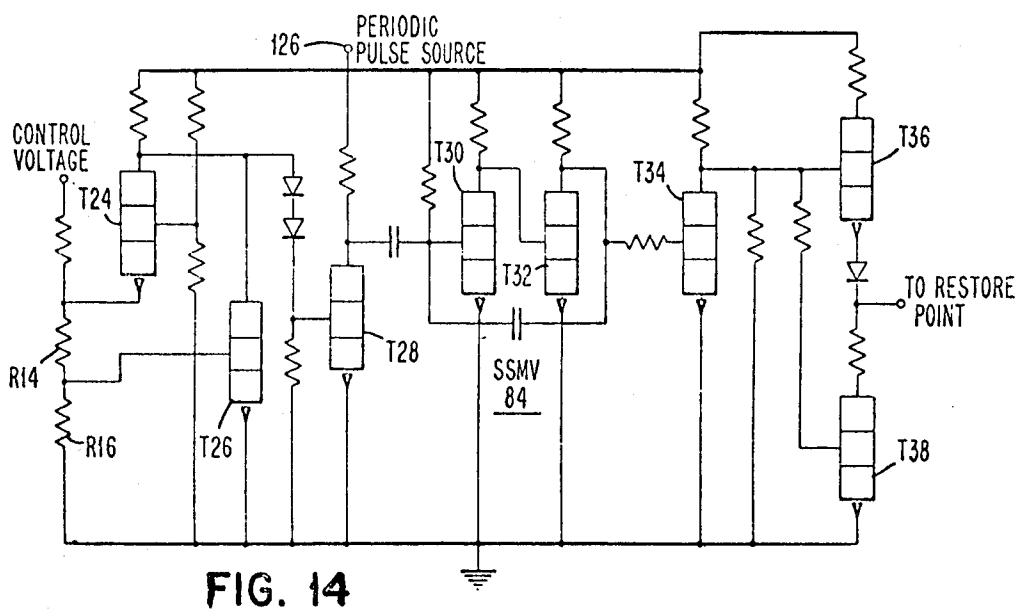
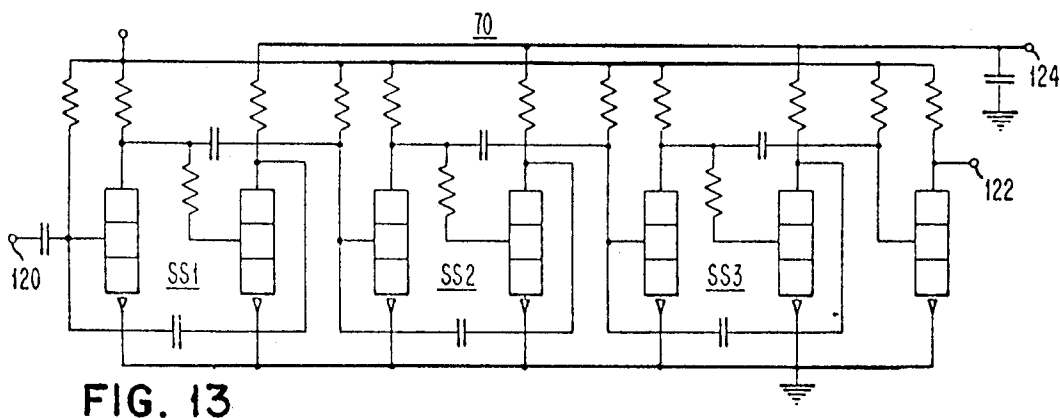


FIG. 12



PHASE CONTROL FOR INK JET PRINTER

This is a continuation of application Ser. No. 253,065 filed May 15, 1972, now abandoned.

FIELD OF THE INVENTION

The invention relates generally to ink jet printers and it has reference in particular to means for maintaining the proper phase relation between the drop charging voltage and the drop forming means.

DESCRIPTION OF THE PRIOR ART

Heretofore, phase control has been effected by a detection electrode adjacent the charging electrode which is effective only in the home position of a printer and which is impacted by all the drops after applying a fixed frequency signal to the charging electrode as described in U.S. Pat. No. 3,465,351, entitled "Ink Drop Writing Apparatus," which issued on Sept. 2, 1969, to R. I. Keur et al, by a detection electrode position near the deflecting electrodes which is impacted only by drops subjected to a predetermined signal as described in U.S. Pat. No. 3,465,351, entitled "Ink Drop Writing Apparatus," which issued on Sept. 2, 1969, to R. I. Keur et al, or by the use of separate Print and Calibrate cycles during which the outputs of a staircase character generator and a ramp calibration generator are selectively gated to the charging electrode as disclosed in U.S. Pat. No. 3,596,276, entitled "Ink Jet Printer with Droplet Phase Control Means," which issued on July 28, 1971, to K. T. Lovelady et al.

SUMMARY OF THE INVENTION

Generally stated, it is an object of this invention to provide a new and novel phase control system for an ink jet printer.

More specifically, it is an object of this invention to provide for using drops not used during a printing operation in an ink jet printer for continually correcting the phase relations of the drop formation and the charging voltage.

Another object of the invention is to provide for monitoring and correcting the phase relations of the drop formation and the charging voltage actually during, as well as between, printing operations in an ink printer.

Yet another object of the invention is to provide for using all ink drops in an ink jet printer which are discarded during the printing of a character for correcting the phase relation of the drop formation and the drop charging voltage.

It is an important object of this invention to provide for correcting the phase relations in an ink jet printer anytime a drop is not being used to form a character or a graphic.

Still another object of the invention is to provide in an ink drop printer for continuously applying a phase detection signal to a selection circuit to which the signal voltage is also applied, so that whenever the signal voltage drops below a predetermined value the phase detection signal becomes effective.

It is also an object of the invention to provide for using a multisection gutter for catching unused or discarded ink drops, with different sections comprising electrodes positioned to sense different degrees of deflection of the unused ink drops and connected to pro-

vide a corresponding change of phase relation between the drop forming means and the charging voltage.

Another important object of the invention is to provide for using a multisection gutter structure with spaced electrode elements which are connected by logic circuitry to selectively control phase reversing means for changing the phase relations between the drop formation voltage and the drop charging voltage in an ink jet printer.

It is also an important object of the invention to provide for applying a fixed frequency saw-tooth calibrating voltage and a variable drop deflection voltage to a charging electrode through logic circuitry which permits the higher of the two voltages to override the other and charge drops being formed, and for collecting the sawtooth charged drops in different sections of a multisection gutter for controlling the phase relations between the drop charging and the drop formation.

Still another important object of the invention is to provide for substantially continuously monitoring and correcting the phase relations of the drop formation and the drop charging in an ink drop printer during printing.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more detailed description of preferred embodiments of the invention, as illustrated in the accompanying drawing.

DESCRIPTION OF THE DRAWING

In the drawing:

FIG. 1 is a schematic circuit diagram of a phase control system for an ink jet printer embodying the invention in one of its forms;

FIG. 1a is a schematic showing of a multisection gutter used in the system of FIG. 1, illustrating the proportions of the different sections;

FIG. 2 is a schematic circuit diagram in part of a phase control system for an ink jet printer embodying the invention in another form;

FIG. 2a is a schematic showing of the multisection gutter used in the system of FIG. 2;

FIG. 3 is a schematic circuit diagram in part of a phase control system for an ink jet printer embodying the invention in yet another form;

FIG. 3a is a schematic showing of a multisection gutter used in the system of FIG. 3;

FIG. 4 is a schematic circuit diagram in part of a phase control system for an ink jet printer embodying the invention in still another form;

FIGS. 5a, b and c are charts showing typical waveforms which may be applied to the charging electrode for phase detection in the system of FIGS. 3 and 4 for phase correction;

FIG. 6 is a cross-sectional view of a multisection gutter such as may be used in the system of FIGS. 1-4;

FIG. 7 is an exploded isometric view of a two-section gutter construction representative of the multisection gutters used in the systems of FIGS. 1-4;

FIG. 8 is a schematic circuit diagram of an amplifier and threshold circuit used in the system of FIGS. 1 and 2;

FIG. 9 is a schematic circuit diagram of a two-level voltage source used in the systems of FIGS. 1 and 2;

FIG. 10 is a schematic circuit diagram showing the relations between the character generator, sawtooth

generator and the charging electrode driver in the system of FIGS. 1 and 2;

FIG. 11 is a schematic diagram of a four-level voltage source used in the system of FIG. 2;

FIG. 12 is a schematic circuit diagram of the differential amplifier and the continuous controlled voltage source used in the system of FIG. 3;

FIG. 13 is a schematic circuit diagram of a variable time delay circuit used in the system of FIG. 3;

FIG. 14 is a schematic circuit diagram of a restoration circuit used with the systems of FIGS. 3 and 4; and

FIG. 15 is a schematic circuit diagram of an amplifier and controlled voltage source used in the system of FIG. 4.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIG. 1, the reference numeral 10 denotes generally a schematic diagram of an ink drop printer system. As shown, ink is supplied from a pressurized ink supply (not shown) through a conduit 12 to a nozzle 14. A nozzle vibrator transducer 16 mechanically vibrates the nozzle 14 or introduces vibrations into the ink flow to insure the ink stream issuing therefrom breaks up uniformly into uniformly-spaced and sized drops of ink. The transducer 16 may be energized from a nozzle vibrator drive 18 which provides, for example, a sine wave on the order of 100 KHz in response to clock signals from a system clock or oscillator 20.

To provide for selectively deflecting ink drops for printing characters or graphics on a document droplet charging electrodes 22 are positioned adjacent the nozzle 14, preferably at the point where the stream of ink issuing from the electrode begins to break up into drops 23. The electrodes 22 are connected to a charging electrode driver 24, which is in turn connected to a character generator drop charging circuit 26 which provides a drop charging voltage output characteristic of predetermined characters or graphics which are to be printed, so as to deflect the ink drops in accordance with the charges placed on the drops by the charging electrodes 22. Deflecting electrodes 31 connected to a high voltage source provide a constant electric field through which the charged drops pass to produce the desired deflection for locating the drop on a Document 33.

In order to provide for maintaining the proper phase relation between the nozzle vibrating signal from the nozzle vibrator drive 18 and the drop charging signals applied to the charging electrodes 22, so as to properly position ink drops 23 on the document 33, phase shift means comprising a voltage-controlled two-position time delay circuit 28 may be connected between the system clock 20 and the character generation drop charging circuit 26 for changing the phase relation of the charging signals relative to the ink drop forming signals.

Control of the time delay circuit 28 is effected by utilizing a discard drop charging circuit 30, which is connected to the charging electrode driver 24 for applying a calibrating signal thereto, such as, for example, a sawtooth voltage for charging drops discarded or not used with the character generation drop charging function. A multisection gutter 32 having, for example, three sections 32A, 32B and 32C, is used for catching the drops charged by the discard drop charging function circuit. Sections 32A and 32B are provided with sensors or electrodes 32D and 32E which are connected

to an a-c source 35 and to amplifiers 34 and 36 for providing A, $\bar{A}$ and B signals. The A output of amplifier 34 is connected through OR 38 and AND 39 to a single shot multivibrator 40, which controls a binary trigger 42 for controlling a two-level Voltage Source 44, which is connected to the voltage-controlled two-position time delay circuit 28 for changing the time delay of the circuit. The $\bar{A}$ output of amplifier 34 and the B output of amplifier 36 are connected through AND 46 to the OR 38 to provide a signal when there is no output from the sensor in the 32A section or the 32B section of the gutter 32.

A sawtooth waveform from the charging circuit 30 is impressed on the drop charging electrode 22 whenever discard drops are required. As a result, the point of impact of the discard stream in the gutter 32 is a function of the amplitude of the sawtooth waveform at the instant of drop breakoff from the jet. It is therefore possible to determine the state of system phasing by observing where the discard stream is striking the different sections of the gutter 32. To utilize the information on system phasing the gutter 32 is partitioned into three sections 32A, 32B and 32C and pairs of sensor electrodes 32D and 32E are placed in two of these sections and connected to a-c Source 35 to detect the presence or absence of the discard drops. These sections are labeled 32A, 32B and 32C in FIGS. 1 and 1a. It should be clear that if the discard stream is going into the 32B section, then system phasing is correct since the drops are breaking off at or near the middle of the sawtooth waveform. If the discard stream is going into section 32A or section 32C, then the phasing is approaching an incorrect condition and some phase correction is required. There is an exception to this rule as follows: During printing some of the discard drops may be overthrown towards discard if no charge correction scheme is used. In this case these discard drops will land in section 32C as well as section 32B. In summary, phase correction is required if the discard drops land in section 32A, or if no discard drops land in section 32A and section 32B. In Boolean algebra this phase correction situation is represented by the expression: $A + \bar{A} \bar{B}$

The circuitry of FIG. 1 utilizes the information provided by the sensors 32D and 32E in sections 32A and 32B to shift the phase of the character generation drop charging function and the discard drop charging circuit 30 when required. The output of this circuit controls the system delay circuit 28 to provide the correct phasing. In the present ink jet system the drop formation period is on the order of 10 microseconds. The delay of circuit 28 is therefore switched 5 microseconds when phase correction is required.

Referring to FIG. 1a, which shows the relative proportions of the three gutter sections 32A, 32B and 32C, it can be seen that if the drop separation time is in the 72°-288° range of the charging cycle, then the desired stream will impact in section 32B. During printing some drops may land in section 32C. No phase correction occurs for this condition. If the separation time should increase to greater than 288°, the discard stream will impact in section 32A, producing an A sensor signal which activates by way of the amplifier and threshold detector 34 and OR 38, the phase correction repetition rate control single shot multivibrator 40, the binary trigger 42, and the two-level voltage source 44, the voltage-controlled two-position circuit time delay 28. This action shifts the charging signal timing 180°,

which in turn shifts the discard stream impact point back to 108° in section 32B. It does not matter in which direction this 180° shift occurs provided the shift is completed within one drop formation cycle.

If the separation time decreases to less than 72° the discard stream will impact in section 32C. The lack of a signal from the A sensor and the B sensor activates the phase correction sequence as before, this time and $\bar{B}$ and $\bar{A}$ signals being gated in AND 46 to operate the single short multivibrator 40 through OR 38, shifting the discard stream impact point 180° to the 252° point in section 32B.

Since the circuit time delay can be shifted between its two values within a few microseconds, printing can continue without interruption during a phase correction sequence with the possible loss of not more than one drop during the shift. The ON cycle of the repetition rate control signal shot multivibrator 40 is selected to allow sufficient time for the jet stream and the gutter sensor to accommodate to the shifted timing condition before permitting another phase correction sequence to take place. This time includes the drop air-flight plus sensor signal transition time.

Referring to FIG. 2, a further embodiment of the invention is disclosed in which the character generation drop circuit 26 and the discard drop charging circuit 30 are connected to a charging electrode driver 24, as previously described in connection with the system of FIG. 1. A nozzle vibrator drive 18 is likewise connected to effect vibration of the nozzle under the control of the System Clock 20, as described in connection with the system of FIG. drop charging

A three-section Gutter 32 is likewise utilized having 32A and 32B sensors which are connected to Amplifier and Threshold Detectors 34 and 36, respectively. The Amplifiers and Threshold Detectors 34 and 36 are connected to an OR 38 with the Amplifier and Threshold Detector 36 being connected to the OR 38 through AND 46.

Instead of utilizing a Single Shot Multivibrator 40 and a Binary Trigger 42 controlling a two-level Voltage Source 44, as described in connection with the system of FIG. 1, a two-position Binary Counter 48 is connected through a Decode Circuit 50 to control a four-level Voltage Source 52 for controlling a voltage-controlled four-position Time Delay Circuit 54, which shifts the phase of the Character Generator 28 and the Discard Drop Generator 30. Control of the two-position Binary Counter 48 is effected through OR 56 in response to the operation of a pulse train control Single Shot Multivibrator 58 controlled by AND 60 through a Pulse Generator 62, and a repetition rate control Single Shot Multivibrator 40 through AND 64.

This is an expansion of the system shown in FIG. 1, in which the phase correction sequence can shift the phase in four steps of 90° instead of two steps of 180°, as described in connection with the system of FIG. 1. In addition, the direction of the phase shift is controlled to avoid stepping the system through an out-of-phase condition while seeking the best in-phase condition. The advantages gained are greater latitude in aligning the discard stream with the Gutter 32, in proportioning the gutter sections, 32A, 32B and 32C, and in maintaining the drop separation time closer to the center of the charging cycle. This last advantage is of importance when it is necessary to use an ink formulation which has a substantial randomness in drop separation time.

The operation of the circuit of FIG. 2 is as follows:

When the separation time is in the 108°-252° range of the charging cycle, the discard stream impacts in Section 32B and no phase correction occurs. If the separation time increases to greater than 252°, Sensor 32A generates a signal which activates the repetition rate control Single Shot Multivibrator 40 which advances the two-position Binary Counter 48 one step, drops the four-level Controlled Voltage Source 52 one step, and increases the circuit delay 90° through the four-position Time Delay Circuit 54. This effectively reduces the separation time 90° back to 162° in the charging cycle.

If the separation time decreases to less than 108°, the lack of a signal from Sensor 32A and Sensor 32B activates the repetition rate control Single Shot Multivibrator 40 and also activates the Pulse Train Control 58 so that a total of three pulses advance the binary counter three steps, which is equivalent to reversing one step, decreasing the circuit delay 90°, which effectively shifts the separation time to 198° in Section 32B.

Referring to FIG. 3, it will be seen that a Nozzle Vibrator 18 operates in response to a System Clock 20 to vibrate the nozzle for producing drops, while a Character Generator Drop Charging Circuit 26 and a Discard Drop Charging Circuit 30 operate from the system clock through a continuous Control Time Delay Circuit 70 for operating the Charging Electrode Driver 24. Control of the Time Delay Circuit 70 is obtained through a continuous controlled Voltage Source 72 under the control of a Differential Amplifier 74 connected to the 75A sensor and the 75B sensor of a two-section Gutter 75.

In this system at start-up an override circuit is required to momentarily place the control voltage in the center of the operating range required by the control parameter. The control voltage is then released to the feedback system where the gutter sensor outputs cause the control voltage to seek the level required to split the discard stream between the 75A and 75B sections. As shown, a Minimum Level Detector 76 and a Maximum Level Detector 78 are connected to the output of the controlled voltage source and are connected through OR 80 and AND 82 to a restore repetition rate control Single Shot Multivibrator 84, which activates a Restore Voltage Override Circuit 86, connected to the continuous controlled Voltage Source 72 for driving the output of the source to the middle of its operating range. While the phase correction control has been shown as applied to the Character Generator Drop Charging Circuit 26 and the Discard Drop Charging Circuit 30, it will be realized that the continuous control Time Delay Circuit 70 may be connected in circuit with the Nozzle Vibrator Driver 18 instead, and used to control the phase or amplitude of the Nozzle Vibrator 18 relative to the phase of the character generator Circuit 28 and the Discard Drop Charging Circuit 30.

Referring to FIG. 4, it will be seen that a two-section Gutter 88 may be used in connection with an a-c Source 35 and Amplifier 90 and a single pair of sensor Electrodes 88 C-D in the 88A section of the gutter for controlling the continuous controlled Voltage Source 72. In an optimum condition the discard stream is still split by a knife-edge Separator 88E between the A and B sections, however, the stream division is typically 15% to the A section and 85% to the B section. Exact division is determined by the response characteristics

of the gutter sensor and the amount of system open loop gain. This system possesses all the advantages of the system shown in FIG. 3, but is somewhat simpler and should be of lower cost.

Referring to FIGS. 6 and 7, one form of multi-gutter construction is shown, which may be used with the systems of FIGS. 1-4. As shown, each of the Sensors A and B may comprise a relatively flat Sensor or Signal Plate 92 having a cutaway edge portion defining a Notch or Gutter Section 93 intermediate the ends on one side. Spaced apart Signal Plates or Electrodes 94 and 95 are provided adjacent each other in the cutaway portion having connections made thereto by means of Conductors 96 and 97, which pass out through openings in the signal plates. A relatively thin Separator 98 having a Notch 99 and an Opening 100 is positioned between the A sensor and B sensor so that the notches of the two sensors provide substantially separate gutter sections for receiving discard ink drops. Front and back Support Plates 100 and 102 are placed on opposite sides of the sensor plates so as to sandwich them therebetween. The assembly may be secured by means of Bolts 104. Baffles 106 may be positioned in the cutaway portions having Openings 108 therethrough to provide a connecting drain passage for discarded ink drops, being in alignment with an Opening 110 in the Back Plate 102, which has a Drain Tube 112 connected thereto for returning discarded ink drops to the source. The Baffle 106 is maintained in spaced relation with the Electrodes 94 and 95 so as to provide an adequate passage for the ink drops to the Drain Tube 112, which may be connected to a vacuum source for collecting the discard drops. In a typical application the Electrodes 94 and 95 are separated by a 0.50 in. gap. The A Sensor plate is .015 in. wide and the B Sensor plate is .040 in. wide. The Separator 98 is .007 in. thick and has a substantially knife edge. A 20 volt a-c source can be with an ink having a resistance on the order of 200 ohm centimeters.

Referring to FIG. 8, a circuit diagram is shown of one form of Amplifier and Threshold Detector 34 or 36 which may be used with the systems of FIGS. 1 and 2. Transistors T1 and T2 comprise an amplifier section which is connected to the Sensor Electrode 94 through a Capacitor 114 for detecting how much of an a-c input signal applied to the Electrode 95 is passed by discard ink drops. Transistor T3 with an Emitter Diode D1 and Diodes D2 and D3 provides a threshold detector the output of which is selectively detected by the Transistors T4 and T5 to provide A and A output signals.

Referring to FIG. 9, the Transistor T6 provides a switch for shunting an Impedance 116, which in conjunction with an Impedance 118 provides two output voltage levels for the transistor depending on whether the Transistor T6 is turned on or off.

Referring to FIG. 10, one mode of operation with a Character Generator Circuit 26 and Sawtooth Generator Circuit 30 is illustrated in which the Character Generator 26 and the Discard Drop Charging Sawtooth Generator 30 are connected through an OR circuit comprising Diodes D4 and D5 with a bias Resistor R1 connected to a non-inverting Driver 24, which may be connected to the Charging Electrode 22. This arrangement provides for applying the character generator output signal through the Diode D4 to the Charging Electrodes 22 whenever such signal is available. When the character generator signal is at a zero level, or

below the level of the character generator signal, the output of the Sawtooth Generator 30 will be supplied through the Diode D5 to the Charging Electrodes 22 for producing a phase correction charging signal any-time that drops are being discarded.

Referring to FIG. 11, a typical four-level voltage source is represented in which Transistors T8, T9, T10 and T11 are connected to a +V source through Collector Resistors R8, R9, R10 and R11 having different values so that selective control of the Transistors T8 through T11 provide different output voltages through the Emitter Follower Transistor T12.

Referring to FIG. 12, a typical differential amplifier circuit is shown which may be used in the system of FIG. 3. As shown, the 75A and 75B sensors are connected to an a-c source and through Amplifier Transistors T14 and T16, respectively, to rectifier circuits of Diodes D6 and D7 with filter Capacitors C1, for operating a Transistor T18 as a differential amplifier. The output from the Sensor A is connected to the base of the Transistor T18 while the output of the Sensor B is connected to the emitter of the Transistor T18 through an equalizing Transistor T20. Transistor T22 operates as an emitter follower to provide a continuous controlled voltage output.

Referring to FIG. 13, a typical circuit diagram of a variable time delay circuit 70 is shown which may be used in the system of FIG. 3. As shown, the delay circuit 70 comprises three Single Shots SS1, SS2, and SS3 connected in cascade. The input signal is applied at Terminal 120 and a delayed output is provided at Terminal 122 with a variable control voltage applied to Terminal 124 for controlling the delay times of the individual single shots.

Referring to FIG. 14, a typical restoration circuit is shown which may be used with the systems of FIGS. 3 and 4. As shown, minimum and maximum level detection Transistors T24 and T26 are connected to the control voltage through a voltage divider of Resistors R12, R14 and R16. Both transistors are normally off and Transistor T24 turns on when its emitter becomes more negative, while the Transistor T26 turns on when its base detects a relatively high voltage. Transistor T28 amplifies the signal and is normally on and will kill a periodic pulse signal applied at Terminal 126 to its collector when it is on. Transistors T30 and T32 provide a multivibrator combination which is connected through a Transistor T34 to a pair of Transistors T36 and T38, which function to pull up the control voltage and pull down the control voltage, respectively. Both Transistors T36 and T38 are normally off and a pulse from the Multivibrator 84 turns both of them on, so that the control voltage is restored to a normal intermediate value whether it is high or low.

Referring to FIG. 15, a typical amplifier and controlled voltage source implementation is shown such as is used in the system of FIG. 4. Transistor T40 provides a stage of amplification while Diodes D10 and D11 rectify the alternating current signal used with the Sensors 94 and 95. Transistor T42 operating as an emitter follower provides a continuous controlled voltage output dependent on the input signal from the Sensor Electrodes 88C and 88D.

From the above description and the accompanying drawing it will be apparent that I have provided in a simple and effective manner for controlling the phase relations in an ink drop printer during the printing op-

eration. It is not necessary for the printer to wait for a non-printing mode for correcting the phase relation, since all discard drops, even during the printing of a character, may be used for phase correction. In other words, drops discarded or not used for printing are used for phase correction.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

I claim:

1. In an ink jet printer system wherein ink under pressure is delivered to a nozzle which is vibrated by a transducer connected to a source of synchronizing signals and driven by said synchronizing signals to produce a stream of drops, and a charging electrode is positioned adjacent said nozzle to charge some of said drops in accordance with variable value information input signals from input information signal means applied to said electrode for deflecting said drops to print data in accordance with said information input signals as said drops move in an electric field between a pair of deflecting electrodes; all other of said drops not being so charged being discard drops not used to print data;

the improvement in the phase of formation of said ink drops relative to the occurrence of said information input signals comprising means producing a continuous fixed frequency calibration signal having an amplitude less than the minimum information input signal value;

circuit means including means responsive to the relative values of said information input signals and said calibration signal connecting said input information signal means and said calibration signal means to said charging electrode to selectively apply said fixed frequency signal and said information input signals to said charging electrode so that all of said discard drops not charged by information input signals even during the printing of data are charged by said fixed frequency signal;

phase control circuit means connected to said circuit means and said source of synchronizing signals to vary the phase relation between said input information signals and said synchronizing signals, and a single means positioned to catch all said discard drops and having electrode means positioned to be responsive to said charge on said discard drops connected to said phase control means to control the phase relation between said information input signals and said synchronizing signals, and thereby control the phase relation of said input information signals relative to the formation of said ink drops.

2. The invention as defined in claim 1 characterized by said means producing said fixed frequency calibration signal comprising a positive sawtooth waveform generator.

3. The invention as defined in claim 2 characterized by said catching means responsive to the charge on all discard drops comprising a multisection discard drop gutter having said electrode means positioned in at least one of said sections to detect charged discard drops, said electrode means being connected to said phase control means to control the phase relations of

said information input signals and said synchronizing signals.

4. The invention as defined in claim 3 characterized by said multisection gutter comprising a three-section gutter with said electrode means comprising spaced electrodes in two of said sections and a two-position time delay device which is connected to said phase control means and to said spaced electrodes to control the phase relations of said fixed frequency signal and said information input signal relative to said synchronizing signals.

5. The invention as defined in claim 3 characterized by said multisection gutter comprising a two-section gutter having a divider therebetween and said electrode means comprising spaced sensing electrodes in one only of said sections, said spaced sensing electrodes being connected to said phase control means to vary the phase relations of said information input signals and said synchronizing signals.

6. The invention as defined in claim 5 characterized by said catching means including a continuous controlled voltage source connected to be energized from said electrode means, said electrode means comprising a pair of spaced electrodes in said one section of said gutter and connected to said phase control means which comprises a variable delay circuit controlling the phase relations of said information input signals and said fixed frequency signal relative to said synchronizing signals.

7. The invention as defined in claim 3 characterized by a differential amplifier connected between said electrode means and said phase control means, said multisection gutter comprising a two-section gutter with each section having said electrode means connected to said differential amplifier for controlling said phase control means which includes a variable time delay circuit to change the phase relations of said input information signals and said fixed frequency signals with said synchronizing signals.

8. The invention as defined in claim 3 characterized by a binary counter and a multilevel voltage source, said multisection gutter comprising a three-section gutter with said electrode means positioned in two sections and connected to control said binary counter and said multilevel voltage source being connected to said phase control means which comprises a multiposition time delay device connected in circuit relation with said information input signal and said fixed frequency signal means.

9. A discard drop catching gutter for in ink drop printer comprising a sensor plate having a cut-away edge portion defining an ink drop receiving groove and having front and back sides,

electrode means positioned on the cut-away edge portion,

a front plate positioned on one side of said sensor plate, and

a back plate positioned on the other side of said sensor plate, said front and back plates at least partially enclosing said cut-away edge portion on the front and back sides, at least one of said front and back plates having an opening therethrough providing access to drain ink from said cut-away portion.

10. A discard drop catching gutter as defined in claim 9 characterized by a plurality of sensor plates positioned in side-by-side relation, and separators sand-

wiched between said sensor plates to substantially separate said cut-away portions of said sensor plates.

11. In an ink jet printer system wherein ink under pressure is delivered to a nozzle which is vibrated by a transducer connected to a source of synchronizing signals to be driven by synchronizing signals to produce a stream of drops, and a charging electrode is positioned adjacent said nozzle to charge some of said drops in accordance with variable value information input signals from input information signal means applied to said electrode for deflecting said drops to print data in accordance with said information input signals as said drops move in an electric field between a pair of deflecting electrodes, all others of said drops not being charged in accordance with said variable value information input signals being discard drops, and said information input signals having a preferred phase relation with said synchronizing signals so as to maintain said information input signals in phase with said ink drop formation;

the improvement in the phase of formation of said ink drops relative to the occurrence of said information input signals comprising means producing a continuous fixed frequency calibration signal in phase with said information input signal but having an amplitude less than the minimum information input signal value;

circuit means including means responsive to the relative values of said information input signals and said calibration signal connecting said input information signal means and said calibration signal means to said charging electrode to selectively apply said fixed frequency signal and said information input signals to said charging electrode so that all said discard drops not charged by information input signals during at least a portion of cycle for printing of data are charged by said fixed frequency signal;

phase control circuit means connected to said source of synchronizing signals and one of said transducer and said input information signal means to vary the phase relation between said input information signals and said synchronizing signals and maintain said phase relation between said information input signals and said ink drop formation, and

means positioned to sense the charge on all of said discard drops deflected by said electric field in response to said fixed frequency signal charge on said discard drops, said sensing means being connected to said phase control means to operate said phase control means to control the phase relation between said information input signals and said synchronizing signals applied to said transducer.

12. The invention as defined in claim 11 characterized by said sensing means comprising a multisection discard drop gutter having drop sensing means positioned in at least one of said sections to detect charged discard drops, said drop sensing means being connected to said phase control means to control the phase relations of said information input signals and said syn-

chronizing signals and maintain said phase relation between said input information signals and said drop formation.

13. The invention as defined in claim 12 characterized by said multisection gutter comprising a two-section gutter means having said drop sensing means in one of said sections, said drop sensing means being connected to said phase control means to vary the phase relations of said information input signals and said synchronizing signals in accordance with the charge on said discard drops sensed by said drop sensing means.

14. The invention as defined in claim 11 characterized by said means producing said fixed frequency signal comprising a generator producing a waveform which changes amplitude throughout the interval in which discard drops may be formed so that the charge on said discard drops varies with and is a measure of the phase relation between said fixed frequency signal and said drop formation.

15. The invention as defined in claim 14 in which said waveform of said means producing said fixed frequency signal changes gradually during said interval so as to provide a charge on discard drops which changes gradually in accordance with different phase relations between said drop formation and said fixed frequency signal.

16. The invention as defined in claim 15 in which said waveform of said means producing said fixed frequency signal changes in a straight line manner during said interval so that there is a linear relation between the charge on said discard drops and the phase relation of said drop formation and said fixed frequency signal.

17. The invention as defined in claim 12 characterized by counter means connecting said drop sensing means to said phase control means for selectively effecting operation of said phase control means in response to the charge on said discard drops.

18. The invention as defined in claim 17 characterized by said counter means comprising a binary counter which operates the phase control means to correct an out-of-phase relation between said drop formation and said fixed frequency signal.

19. The invention as defined in claim 17 characterized by said counter means connecting said drop sensing means and said phase control means comprising a two-position binary counter operable to vary the phase relations of said information input signals and said synchronizing signals on plural steps and said phase control means comprising a four-position delay circuit.

20. The invention as defined in claim 11 characterized by said means connecting said sensing means to said phase control means including a controlled voltage source having a plurality of voltage levels connected between said sensing means and said phase control means to vary said phase relations with each level of voltage and restore means connected to said source operable to place the voltage of said source in the middle of its operating range during start up.

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