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DROP PHASING IN INK DROP  
WRITING APPARATUS  
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ABSTRACT OF THE DISCLOSURE

In an apparatus of the type wherein ink under pressure is applied to a nozzle which is vibrated, and the ink emitted by the nozzle thereafter breaks down into ink drops which are charged in a charging tunnel in response to video signals, means are provided, in accordance with this invention, for sensing whether or not the ink drops are properly charged. If the ink drop phase is not correct, the phase of the vibration of the nozzle whereby the ink drop phasing and charging are corrected.

BACKGROUND OF THE INVENTION

This invention relates to apparatus for writing with ink drops which are charged by a video signal and directed through an electric field to be deflected in accordance with the charge, and more particularly to improvements therein.

An ink drop writing apparatus has been developed wherein ink is applied under pressure to a nozzle. The nozzle is vibrated in response to a synchronizing signal which is also used for synchronizing video signals. The vibrated nozzle causes an ink jet, which is emitted thereto from to break up into uniform drops at a distance away from the tip of the nozzle. The rate of such drop formation is determined by the vibration rate. A means for charging each drop is provided at the location at which the ink stream begins to break into drops. This means usually is a conductive tube or cylinder. Video signals are applied between the nozzle and the cylinder in response to which a drop assumes a charge determined by the amplitude of the video signal at the time that the drop breaks away from the jet stream.

The drop thereafter passes through a fixed electric field, as a result of which it is deflected by an amount determined by the amplitude of the charge on the drop. At the boundary of the electric field there is positioned a writing medium upon which the drop falls. Since the deflection of the drop is determined by the charge on the drop, the arrangement enables one to write information with the ink which is carried by the video signal.

As previously stated, at the time that a drop separates from the fluid stream, the drops are charged by electrostatic means. If the drop is maintained in this charged condition while it remains in the electric field, the drop will carry a charge determined by this video signal. Obviously, if the video signal is in the process of rising or falling or is not present at the time the drops separate, the charge on the drop will not be that of the video signal. In order to place specific charges on given drops, one must know when drop separation is occurring or the phasing of the drop formation relative to the video signal. In the absence of control over drop separation time, because of unpredictable phase changes in the ink drop formation, the uniformity and the fidelity of the printing are affected adversely.

In an application by Keur and Vorne, Ser. No. 712,808 filed Mar. 13, 1968, now Pat. No. 3,465,350, and also assigned to this assignee, another arrangement for phase detection and correction of ink drop formation is described. Here, the frequency of the video signal relative to the frequency of the generation of the ink drops is made such that, if the phasing is correct, alternate ink drops receive a charge. During the transit time between the charging tunnel and the detector, there is a tendency for a charged ink drop to merge with the adjacent uncharged ink drop. As a result a frequency detector may be employed. If the drops are generated in the proper phase, the frequency of the drops arriving at the drop detector is half the frequency at which the drops are generated. If the phase relationships are incorrect then the drops which are received by the detector will have a somewhat random frequency.

While the technique just described for detecting the phasing of the ink drops operates satisfactorily, the clumping or gathering of the adjacent ink drops requires a rather long time of flight of the ink drops in order to make absolutely certain that this occurs. It was also found that the charge on the drops had to be substantial. Upon analysis it was found that the reason for the gathering of the adjacent ink drops was because the dropping process imparted a slight velocity change to the charged droplets as compared to the uncharged droplets. The charged droplet approaches the uncharged droplet the attractive force between them accelerates the clumping. Without the velocity modulation the forces between droplets are balanced and no tendency to clump would occur.

OBJECTS AND SUMMARY OF THE INVENTION

An object of this invention is the provision of an improved system for enabling detection and correction of ink drop phasing. This is achieved by providing test video signals for charging ink drops which operate to charge two adjacent ink drops and then do not charge the succeeding two ink drops. As a result the two adjacent charged ink drops are positively driven in opposite directions due to the repelling effects of their charges whereby they clump with the adjacent uncharged drops. As a result, if the phasing of the drops is proper, they generate a strong fixed frequency signal at the detector. If the phasing of the drops is improper the fixed frequency is no longer present. The phasing of the drop formation may then be changed to provide the proper phasing.

The novel features of the invention are set forth with particularity in the appended claims. The invention will best be understood from the following description, when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block schematic drawing of a prior art ink drop writing system.

FIG. 2 is a schematic drawing of a mechanical arrangement for an ink drop printing system in which this invention may be employed.

FIG. 3 illustrates a series of wave shapes to assist in an understanding of this invention.

FIG. 4 is a block schematic diagram illustrating the electrical arrangement required for this invention.
FIG. 5 is a block schematic diagram of the details of the detector and video test signal circuits which are referred to in FIG. 4, and FIG. 6 illustrates the circuit details of the video logic required with this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is a schematic drawing of the presently known arrangement which is shown to afford a better understanding of the invention. An ink reservoir 10 provides ink under pressure to tubing 12 which is flexible. An electromagnetic transducer 14 is usually placed adjacent to or around the tubing. The transducer is driven in response to signals from a source 16. The transducer serves to vibrate and/or compress the tubing 12 in the region of the nozzle 18. This results in an ink jet 20 being emitted which at a short distance downstream breaks up into drops 22 which are formed at a rate determined by the frequency of the vibration. In the region where the stream of drops 22 breaks down into drops, a charging tunnel 24 is provided. This comprises a conductive cylinder to which video signals from a video signal source 26 are applied. The video signals establish a field within the charging tunnel so that the ink drops which are formed therein assume a charge characteristic of the video signal present at the time the drop separates from the ink jet 20.

Downstream of the charging tunnel there are usually placed a pair of electrodes 28 which are connected to a field bias source 30. As a result, there is established between the electrodes a constant electric field. The ink drops, which bear charges in accordance with the video signal, enter this field and are deflected by an amount which is proportional to the amplitude of the charge. This enables intelligent writing to occur on a writing medium 32, which is moved at some synchronous rate past the electrodes. Drops which do not bear a video charge are captured by a tube or trough 34 which is judiciously placed at one side so as to capture these drops. It then leads to a waste reservoir 36. The paper 32 moves into the plane of the drawing whereby its motion, together with the deflection of the drops, may be used for forming intelligible characters.

In order to write lines of information across a wide sheet of paper, an arrangement such as is schematically represented in FIG. 2 may be employed. Here, the ink drop writer 40 is attached to a traveling nut 42 which is free to move on a journal supported lead screw 44. At the top of the ink drop writer is a nut 46 which is free to slide along a rod 48. Accordingly, as the lead screw 44 is rotated in one direction or the other, the ink drop writer will move in a direction dictated by this rotation along a path parallel to the lead screw.

By "ink drop writer" is meant a housing which supports the ink reservoir 10, tubing 12, transducer 14, nozzle 20, and charging tunnel 24. The video and sync signal sources are placed elsewhere and are connected to the ink drop writer by wires. The function of the deflection electrodes 28 is performed by a pair of spaced plates 41 which extend the path of travel of the ink drop writer and are placed so that the stream of drops pass there through on their way to the paper. A trough (not shown) identical to the tube 34 is provided which extends adjacent the bottom plate.

The paper 50 upon which writing is to occur moves in a direction vertical to the direction of the path of motion of the ink drop writer. A motor 52 has a first shaft 54 extending therefrom to a ½ sector gear 56. The motor has a second shaft 58 extending therefrom to a gear box 60, which functions to reverse the direction of rotation of the shaft 58. This reverse motion is communicated through a shaft 62 to another ½ sector gear 64 in which it terminates. The sector gears are cut so that as the motor rotates the sector gear 56 engages a sector gear 66 attached to one end of the lead screw to rotate the lead screw 44 so that the ink drop writer is moved from left to right. When the ink drop writer reaches the right-hand end of the lead screw, the sector gear 56 is disengaged from the gear 66 and the sector gear 64 engages a gear 68 on the other end of the lead screw. This results in the lead screw being rotated in the opposite direction thereby returning the ink drop writer 40 to its home position on the left-hand side of the lead screw. Motor control apparatus 70 serves the function of energizing the motor to rotate over the interval required for the ink drop writer to make one round trip path along the lead screw. The motor control then waits until it receives a signal from a gate, shown in FIG. 4, which enables the motor to again function to cause the ink drop writer to make a round trip path.

A sensing switch circuit 72 has a feeler 74 which tripped the sensing switch circuit when the ink drop writer returns to the home position. The sensing switch circuit may be any well known arrangement for generating a signal when the feeler 74 is tripped. For example, an arrangement for connecting a battery to the terminal 71 until the feeler 74 is out of contact with the ink drop writer.

It should be noted that when the ink drop writer is in the home position the deflection plates 41 are not present.

In accordance with this invention the video signal is applied with the test video signal to two adjacent drops, skip the next two drops, then apply a charge to the two adjacent drops that follow. To do this, a video signal having the wave form 80, as shown in FIG. 3, is required. This wave form is achieved by generating a 33 kHz, rectangular pulse train and inhibiting each succeeding two pulses, as indicated by the dotted lines 82 in the wave train. Drops 84, which are generated in phase with the video signal, will assume a charge-uncharge pattern as represented by the drops bearing pulses, indicative of the charged drops and the ones without any sign indicative of no charge.

In accordance with this invention, two adjacent drops have charges. Accordingly, they will repel each other with a rather strong force, one of the drops being pushed back toward the preceding uncharged drop while the other drop is pushed forward toward the succeeding uncharged drop. Since there are no shielding drops between the charged drops, the operation occurs rather quickly and within a short distance from the charging tunnel.

As a result, the drop pattern obtained from the combined drops is shown by the drop representations 86. The wave form 88, illustrates the signal which is generated by a transducer receiving these drops. This represents a wave train having a 16.5 kHz frequency.

When the drops are not formed in phase with the video signal, an uncharged drop pattern arises which produces a signal pulse train 90. The frequency of this signal pulse train is much higher than that of the signal train 88 thus detection between proper phasing of the formation of the drops and improved charging of the drops is rendered very easy. It should also be noted that the width of the video signal pulse employed for charging is made rather narrow, being on the order of 7.5 microseconds, so that the likelihood of the charging of drops which are not in phase with the video signal is considerably reduced.

FIG. 4 is a schematic drawing illustrative of the circuitry required in conjunction with the ink drop forming and charging apparatus. Those structures which are shown in FIGS. 1 and 2 and which perform the same functions as are described in connection with the description of these figures have the same reference numerals applied thereto. The 66 kHz sync signals are applied from the generator 16 to the phase change network 92, and to the video test signal circuit 94. The phase change network, under control of a phase control network 96, applies 66 kHz signals in one or the other of two phases to the transducer 14, which vibrates the nozzle.
The ink stream which is emitted from the nozzle 18 breaks down into drops within the charging tunnel 24 and receives the video signals, which by induction apply charge to the phase of a 66 kc signal which is applied to a succeeding OR gate 122, is reversed. The output of the OR gate 122 is applied to the transducer 14 to be used to vibrate the nozzle and thus determine the phase of drop formation.

The output of the delay circuit 106 can also be used to instruct the sotot control 70 (shown in FIG. 2) that the end of a sampling period has occurred, and that it is time to initiate another writing line. However, to insure that the phase detecting circuitry has operated, the output of the integrator 106 and the output of the AND gate 110 are applied to an OR gate 124, the output of which is applied to an AND gate 126. The other input to the AND gate is the output delay circuit 106. Accordingly, in the presence of a delay circuit output together with an output from either the Schmitt trigger or the AND gate indicative of the fact that the phase detecting network is operated, the signal is applied to the motor control circuit 70 to instruct it to cause the motor to proceed to another cycle of operation.

The test video signal, as shown in FIG. 3, is generated by applying the output of the 66 kc signal generator 16 to a divider circuit 130, which may comprise a flip-flop, which divides the signal by one-half. The output of the divider circuit 130 is applied to an AND gate 132. This AND gate is enabled in the presence of a signal from the sensing switch. Its output, consisting of a 33 kc signal is applied to video logic circuits 134. The output of the video logic circuits constitutes the video signal having a requisite waveform.

FIG. 6 is a block diagram of the video logic circuit. The 33 kc pulse was applied to a delay circuit 134 which provides a short delay to enable the circuits to attain steady state after the sensing switch has operated. The output of the delay circuit is applied to a dividing flip-flop 136, which in response to the 33 kc input provides a 16.5 kc output. This is applied to a 15 microsecond one shot circuit 138, and to a 7.5 microsecond one shot circuit 140. The output of the 15 microsecond one shot circuit is also applied to a second 7.5 microsecond one shot circuit 142. The outputs of the two 7.5 microsecond one shot circuits are applied to an OR gate 144. The output of the OR gate 144 is a video signal.

The 7.5 microsecond one shot circuit is a multivibrator circuit which in response to receiving an input pulse produces an output signal pulse which is 7.5 microseconds wide. The 15 microsecond one shot circuit also is a multivibrator which, in response to its input provides a 15 microsecond output which is delayed 15 microseconds from its input. This output triggers the second 7.5 microsecond one shot circuit 142 which provides a second 7.5 microsecond pulse 15 microseconds after the commencement of the first 7.5 microsecond pulse.

The operation of the circuit just described is to provide two 7.5 microsecond pulses whose leading edges are spaced apart 15 microseconds for every 16.5 kc pulse which is received. This results in the wave train which is shown in FIG. 3.

From the foregoing description, it should be appreciated that this invention, by charging two adjacent drops and then not charging the following two drops provides a mechanism whereby the adjacent charge drops positively repel each other to join with the uncharged drops on either side of these charge drops. This serves to make the detection of whether or not the drops have been generated with the proper phase to receive the charges, a simple, and binary operation. That is, if the drop generation is out of phase with the video signal and thus are charged properly, the phasing of the generation of the drops is left unaffected. If the detection shows the improper drop phasing by the absence of a 16.5 kc signal, then the phasing of the drop generation is shifted to correct for this. This text
is made upon the completion of every round trip of the ink drop writer and thus proper operation of the ink drop writer is maintained.

There has accordingly been described and shown herein, a novel and useful arrangement for insuring that the detection of the phase of formation of ink drops is positive and reliable.

What is claimed is:

1. In an ink drop writing system of the type wherein ink under pressure is delivered to a nozzle, an electromotive transducer vibrates the nozzle, synchronizing signals from a source drive the transducer, the nozzle emits an ink jet which breaks into drops in synchronism with the vibration of the nozzle, a charging tunnel is positioned in the region at which the ink jet breaks down into drops, a video signal source synchronized by sync signals applies its signals to the charging tunnel for charging each drop formed therein, said charged ink drops passing out from the charging tunnel, the improvement for establishing correct phase of formation of said ink drops relative to the application of a video signal in said charging tunnel comprising:

   video signal means for inhibiting every other two drop charging signals applied to said charging tunnel from said video signal source for charging the first two of each four drops and not charging the last two of each four drops, detecting means positioned adjacent said charging tunnel for intercepting all of the ink drops passing therethrough, said detecting means including transducer means for generating a signal in response to each drop received by said detecting means, means connected to said transducing means for detecting when the frequency of each two signals from said transducer means has a predetermined value and for producing an output indicative thereof, and means responsive to the absence of said output for changing the phase of the sync signals applied to said electromotive transducer to correct the phase of the drops which are formed to be in synchronism with signals from said video signal source.

2. In a system for testing the phase of formation of drops in an ink drop writing system by applying video signals at a predetermined frequency to a charging tunnel through which there passes an ink jet which is emitted from a nozzle vibrated at a frequency synchronized with the frequency of said video signals for causing the ink jet to break into drops within said charging tunnel, and there are means positioned downstream of the exit from said charging tunnel for receiving said ink drops, detecting from the frequency of said ink drops whether or not they have been formed in phase with said video signals, the improvement comprising:

   means for generating video signals comprising a train of pulses having the same frequency as the frequency of the formation of said drops with every other two pulses omitted from said train, means for applying said video signals to said charging tunnel, and a filter in said means for detecting having a pass frequency equal to the frequency of the occurrence of said two adjacent pulses in said video signal wave train.

3. In a system as recited in claim 2 wherein said means for generating a video signal includes divider means connected to said sync signal source providing a pulse train at one-fourth the frequency of said sync signals, and means responsive to said dividing means for producing a pulse train comprising two adjacent pulses for each pulse in a wave train output of said dividing means which are spaced from the succeeding two pulses by the interval required for two adjacent pulses.

4. In an ink drop writing system as recited in claim 3 wherein said video signal means includes means connected to said source of sync signals for producing video signals having a frequency which is one-fourth of said sync signals, and means connected to said dividing means output for producing a video signal pulse train wherein there are successive pairs of pulses generated in response to each pulse received, which successive pairs of pulses are spaced by an interval having the duration of a pair of said pulses.

5. Apparatus as recited in claim 2 wherein said filter means is tuned to the frequency of the repetition of the occurrence of each two charged drops.

References Cited

UNITED STATES PATENTS
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317—3; 178—6.6