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(54) **Ink jet printer.**

(57) An ink jet printer includes circuitry for controlling the alignment and deflection of droplets produced by nozzles and changed by charging and deflection electrodes which control the trajectory of droplets. A charging signal is generated for each droplet by control circuitry and routed to the appropriate charging electrode. The charging signal is adjusted to take into account nozzle aim as well as the operating characteristics of the charging and/or deflection circuitry for that nozzle. The preferred adjustment includes application of a gain and/or an offset factor to uncompensated charging signals. These gain and offset factors are periodically updated to compensate for changes in nozzle directionality and circuitry gain with time.

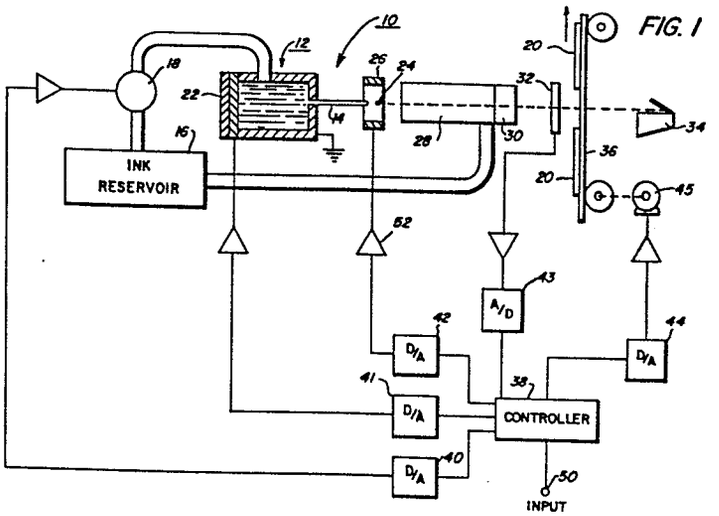


FIG. 1

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INK JET PRINTER

The present invention relates to ink jet printing and more particularly relates to an improved printer calibration method and apparatus to position ink droplets accurately on a record medium.

U.S. patent No. 4,238,804 to Warren discloses ink jet printer for recording information on a record member. The printer utilizes a linear array of nozzles each of which records a segment of a row of picture elements (or pixels) in a desired raster pattern. A pixel is recorded by an ink drop from a nozzle through the process of first selectively charging the ink drop and then deflecting the charged droplet away from its initial trajectory to a desired location on the record medium.

The droplets from adjacent nozzles are "stitched" together to ensure an entire row of picture elements is printed without gaps or overlaps in printing coverage. The stitching process is performed by first observing printer operation during a calibration step. In particular, the charging voltages necessary to deflect the droplets along a specific calibration path are noted and used to determine appropriate charging voltages for droplets deflected along other paths.

Copending U.S. patent application Serial No.296,922, filed August 27, '81 discloses a modification of the Warren architecture. According to this modification, as the droplets break off from the ink jet column they are charged either positively or negatively, hence the bipolar designation. The choice of a bipolar charging scheme in combination with application of an interlace algorithm for separating the droplets in their path to the medium causes less drop to drop interaction and enchanced drop placement accuracy.

The multiple nozzles in the Warren or Crean et al architecture have varied operating characteristics with the result that each nozzle and its associated charging and deflecting apparatus must be individually calibrated. The correct charge on a droplet from one nozzle to cause the droplet to be

deflected to a certain pixel will typically be different from the correct charge for other nozzles. This difference may be due to a slight nozzle mis-direction or a variation in deflecting field strength. Whatever the cause, it is important that an accurate method be provided for monitoring nozzle performance and using the information gathered to correct charging voltages so that the ink droplets properly stitch together and strike intended positions on the recording medium.

The present invention provides a mechanism for taking into account nozzle non-uniformity of operation. The preferred correction technique is applied to each nozzle periodically as updated correction information is obtained so that each nozzle directs the drops to their intended positions.

Apparatus constructed in accordance with the invention includes an ink jet generator for directing one or more ink jet streams toward a record medium such as paper or the like. As the droplets break off from these one or more streams they are charged by one or more charging electrodes with a charge corresponding to an intended droplet trajectory. The charged droplets pass through deflection electrodes which create an electric field to deflect the droplets from their initial trajectory to the intended trajectory. Most important in terms of defining the invention is the circuitry coupled to the charging electrodes which modify the charges to take into account nozzle performance.

This circuitry includes a section for determining a charge signal for each ink droplet. A second portion of the circuitry modifies this charging signal by an amount dictated by the operation of the nozzle which generates the droplet. The modification is accomplished by scaling the charge signal by a first correction factor and adding or subtracting a second correction factor to the scaled value. The rationalefor modifying the charging signal in this way will become clear as a specific example of the technique is disclosed.

The preferred modification circuit operates on digital data signals which are converted to analog charging voltages by a digital-to-analog circuit. An optimum charging signal is first calculated from a memory look-up table which stores charging signals as a function of the desired pixel location and the charge characteristics of other droplets generated by the same nozzle both before and after the droplet under consideration. This first digital charging signal is then scaled and offset to create the modified charging signal in

digital format. In a preferred embodiment this modifying step is performed in dedicated hard wired circuitry which will be described in conjunction with a preferred embodiment of the invention.

From the above it is clear that one object of the invention is the generation of charging signals which take into account the performance characteristics of each ink jet nozzle in an ink jet printer as those characteristics vary with time and/or position along an ink jet array. Other objects, features and advantages of the invention will become clear when a preferred embodiment of the invention is considered in conjunction with the accompanying drawings, in which :

Figure 1 is a schematic elevation view of an ink jet printer of the invention;

Figure 2 is schematic plan view of a portion of the Figure 1 printer wherein representative deflection paths for ink drops have been shown in dotted line.

Figure 3 is a flow chart showing a methodology for charging individual ink droplets as they break off from the ink jet columns generated by the printer, and

Figures 4, 5a, 5b, and 6 illustrate exemplary circuitry for generating the charging voltages.

Refer now to the drawings and in particular Figure 1, wherein there is depicted a schematic representation of an ink jet printer 10 comprising an ink jet generator 12 having a manifold for generating a plurality of jet columns 14. The generator 12 is coupled to an ink reservoir 16 from which ink is pumped by a pump 18 to the generator 12. The pump 18 maintains ink inside the generator 12 at a pressure sufficient to cause ink to be squirted through orifices in the manifold toward a recording member 20 moving along a print plane 21 (Fig. 2) in relation to the ink jet generator 12. Also coupled to the generator 12 is an acoustic exciter 22 which causes the columns 14 to break up into ink droplets 24 at a specific distance from the generator 12. As the columns 14 are breaking up into individual droplets 24, a charging electrode 26 induces a net electric charge on each droplet in accordance with a scheme related to a desired subsequent droplet trajectory.

Downstream from the charging electrode 26 are located a number of field creating electrodes 28 which are energized to voltages which create

an electric field through which the charged droplets 24 must pass. As is well known, a charged particle passing through an electric field will experience a force related to both the magnitude and polarity of the charge on the particle and the electric field strength through which it is passing. An uncharged droplet, therefore, will pass unimpeded through the electrodes 28 toward the recording member 20. A charged particle will be diverted in its initial trajectory depending upon its charge magnitude and polarity. By transmitting appropriate charging potentials to the charging electrode 26 as each droplet passes that electrode, it is possible to selectively bend or redirect those droplets to a desired portion of the recording medium. Certain highly charged droplets are directed to a gutter 30 for recirculation to the ink reservoir.

Droplets which are either uncharged or charged to a level insufficient to cause their trajectory to lead to the gutter 30, are directed past a droplet sensor 32 to the recording medium 20. The drop sensor 32 is used to sense passage of ink droplets toward the recording media and modify printer operation to ensure that ink droplets from the plurality of columns are properly stitched together to allow each incremental region on the recording medium to be accessed by droplets from one of the manifold nozzles. An example of the use and application of a typical drop sensor 32 is disclosed in U.S. Patent 4,255,754 to Crean et al. The functioning of the drop sensor 32 is to calibrate the printer by observing droplet trajectories during a calibrate mode of operation.

A second gutter 34 for recirculating ink droplets is used to intercept droplets generated while calibrating the system with the aid of the drop sensor 32. One application to which the present invention has particular applicability is a high speed ink jet device wherein successive sheets of paper are transmitted past the ink jet printer and encoded with information. Experience has indicated that it is desirable to recalibrate the printer at periodic intervals to ensure that the droplets 24 are directed to desired regions on the recording member 20. To accomplish this calibration, ink droplets are generated and caused to travel past the sensors 32 when no recording member 20 is in position to receive those droplets. In the calibrate mode of operation, it is therefore necessary that a gutter 34 be positioned to intercept droplets when no recording member is present.

A transport mechanism 36 is also shown in Figure 1. The transport 36 is used to move individual sheets of paper or the like past the printer 10 at a controlled speed. Since the present printer is a high speed device, a mechanism must be included in the transport 36 for delivering unmarked paper to the transport and for stripping marked paper away from the transport once it has been encoded by the printer 10. These features of the transport 36 have not been illustrated in Figure 1.

Ink droplet generation, charging and recording medium transport are all controlled by a central processor or controller 38 which interfaces to the various components of the printer 10 by digital-to-analog and analog-to-digital converters 40-44.

As seen in Figure 2, the sensing array 32 is positioned close to the print plane 21 on the recording medium. Liquid drops 24 in a drop stream represented by the dashed lines fly toward the target to strike a given pixel within a print line or to be deflected into the print gutter 30.

During a printing operation, voltages are applied to the charging electrodes 26 to affect a sweep of the drop stream the length of the segments within the scan line. The points 54 and 56 represent adjacent pixels in the scan plane 21. Pixel 54 is addressed by a drop trajectory 58 from the rightmost drop stream and pixel 56 is addressed by a drop following a trajectory 60 from the neighboring stream to the left. In a raster image printing system like that of Figure 1, it is essential that the drops from adjacent streams are "stitched", that is, aligned to the ideal pixel locations within the print plane 21. Drops not intended for the target during a printing operation are charged to a level causing them to follow a trajectory intersecting a print gutter 30. The trajectories 62 and 64 are those followed by gutter drops in the two leftmost streams and are typical for other streams. Zero charge level drops flys a path to the trajectory unaffected by the deflection field between plates 28. However, the zero charge level is not used unless it results in placement of a drop at one of the evenly spaced pixels within print plane 21.

The sensor array 32 is used to calibrate drop charging. The array is an assembly including a plurality of drop sensor sites 66a-e spaced apart a fixed distance along the sensor array. The sensor spacing is equal to that of the nozzle-to-nozzle spacing. The sensor positioning is chosen so that each drop stream can have drops deflected to trajectories over two sensor sites.

This is important for the stitching operation. A drop is charged, for example, to a voltage causingit to fly through a trajectory 67 over sensor 66c. Then a drop is charged to cause it to follow a path 69 over sensor 66b.

The field generating electrodes 28 are alternately grounded and energized to a positive voltage +B across the width of the printer array. By causing the droplets to enter the center of the deflecting electrodes the side-to-side droplet definition entails both positively and negatively charging the droplets at their formation point. This bipolar charging procedure has advantages pointed out in the above referenced Crean et al patent application.

The generation of digital charging signals related to the charging voltages coupled to the charging electrodes 26 is performed in the controller 38 by the combination of a programmable processor 110 and hard wired circuitry comprising a sequence of custom designed integrated circuits which perform a sequence or series of data manipulation steps 112-117 (Fig. 3). The product of these data manipulation steps 112-117 is an N bit (in the preferred embodiment a 12 bit) voltage representation which is converted to an analog signal, amplified, and coupled to the charging electrodes 26.

A video input 120 to the circuitry is shown at the left-hand portion of Figure 3. The video signals at this input 120 comprise a series of print/no print commands representative of a desired information scheme to be encoded on the recording medium 20. The video data is transmitted in bit fashion where, for example, a set or high bit indicates a particular drop is to be printed on the paper and a reset or zero bit indicates the particular drop corresponding to that bit is to be transmitted to the gutter 30.

The disclosed technique for converting these video signals to analog charging voltages utilizes a so-called "pipelining" technique wherein digital holding registers are series coupled between the video input and the digital-to-analog converter 42 coupled to the charging electrode 26.. By controlled clocking of these registers, digital dataare moved stepwise through the processing path from one register to the next. As the data proceed through the pipeline, theyare processed according to the format to be described. After a discrete number of controller generated clock pulses, data in the pipeline have passed through all processing stations and reached a stage where they are output tothe digital-to-analog converter. The actual physical implementation of the pipelining can be accomplished in a variety of ways dependent upon the capabilities of the circuitry comprising the controller 38.

Each block in Figure 3 corresponds to a particular function rather than a particular circuit.

As a first step in the pipelining process, the video bit data are stored in a buffer 112 so that print or no print information for a multitude of pixels is available for processing. The size of the particular buffer or storage can vary with the application and in one embodiment, the buffer has storage capacity large enough to store four consecutive lines of pixels at a given time. During each controller clock interval or drop interval, a pixel bit for each jet or nozzle comprising the printing system 10 is read from the buffer to the pipeline.

The buffered or stored information is a sequence of binary bits corresponding to the desired print or no print information for each pixel in sequence across a given nozzle's paper segment. As the data are read from the buffer, however, they are interlaced at the next step 113 so that the serial data stored in the data buffers are scrambled as they enter the pipeline. This scrambling or interlacing of bit information is accomplished with the use of an interlace look-up table which dictates the pattern by which the bits buffered in the controller enter the pipeline. According to one embodiment, the look-up table is implemented in a portion of controller memory.

Once a particular interlaced drop signal exits the buffer region, a charging signal is generated for that droplet. This signal is related to the charging sequence on those droplets both preceding and following that particular drop as well as the desired pixel location for the drop. In the preferred embodiment of the invention, this information is used to generate a bit pattern which corresponds to a unique address in the controller's address space.

By way of example in the illustrated embodiment of the invention each nozzle addresses 12 pixels across the width of the paper. Thus, four bit locations in the address space will uniquely designate the pixel location for a given droplet. If eleven drop histories (10 other droplets in addition to the droplet under consideration) are taken into account in computing the correct charge for the droplet under consideration these eleven bits of information (print or no print) are combined with the four pixel designating bits to create a 15 bit sequence related to charging history and pixel location. One additional bit is needed to distinguish between odd and even nozzles since the direction of the deflecting field alternates across the array width. This combination of

factors results in a 16 bit sequence of bits corresponding to an address in the controller memory space. Once this address is generated at step 114 a 64K x 10 bit memory look-up table is accessed at step 115 to provide a unique 10 bit drop charge voltage. If fewer than eleven drop histories are used, a smaller look-up table can be used to produce the correct drop charge.

The drop history look-up table compensates for instances in which a particular sequence or series of droplet charging would cause a slight drop misplacement. The look-up table improves drop placement in the situation, for example, where a series of gutter droplets which are highly charged both precede and follow a droplet which is not to be guttered but is scheduled to strike the recording medium at a location not far removed from the gutter 30. In this situation, drop-to-drop interaction is significant and the look-up table provides a means for taking this interaction into account to provide accurate drop placement.

The actual values stored in the look-up table are derived from both theoretical modeling of the ink jet printing process and experience derived from observing actual drop-to-drop interactions and their effect on drop placement. The most straight forward technique is to image patterns corresponding to each sequence of drops (the print and no print pattern) and adjust the voltage in the look-up table until the drop strikes the correct location. A less time consuming method is to experimentally determine some voltage value and mathematically interpolate the remaining look-up table values. The look-up table generation process is simplified by computer models of the droplet coulombic and aerodynamic interactions.

The next step 116 in the pipeline process modifies the data from the voltage signal look-up table to take into account induced charging effects at the charging electrode 26. It is known that as an ink jet droplet is formed, the charge on the droplet is determined by the voltage on the charging electrode 26 but also by the charge on the immediately preceding droplets. These charged droplets create an electric field in the vicinity of the droplet breakoff and therefore induce charges in combination with the charges induced by the electrode 26. Since the charge on droplets immediately preceding the droplet under consideration are known (or at least approximately so since their 12 bit charging signals are known), a modification in charging signal is made to correct for this additional charging effect. The charge compensation step 116 accomplishes a transversal filtering according to the formula

$$D_{compensated} = D_t + \underline{a}^* D_{t-1} + \underline{b}^* D_{t-2} + \underline{c}^* D_{t-3}$$

where $\underline{a}$, $\underline{b}$, $\underline{c}$ are constants determined from the operating characteristics of the printer and the nozzle from which the droplet of interest is emitted. The speed of droplet travel and frequency of droplet production would be two printing characteristics needed to determine these constants since those factors would dictate the spacing between the droplet and its predecessors. The D_t, D_{t-1}, etc., values are the data values for the droplets immediately preceding the droplet whose signal is being compensated.

The kernel of the present invention is found in the next step 117 where so-called gain and offset factors are applied to the charging signals to take into account variations in nozzle performance as well as variations in the performance of the charging and deflecting electronics. The offset and gain step is accomplished by a VLSI NMOS signal processor 122, a block diagram of which is shown in Figure 4.

Central to the processor 122 is a 12 bit multiplier/adder 124 which modifies data from the previous pipeline register. The multiplier/adder 124 generates modified data D_m given by the relation $D_m = D_c \underline{m} + \underline{a}$, where D_c is the 12 bit data value as charge compensated at step 116. The $\underline{m}$ and $\underline{a}$ factors are unique for each nozzle and can vary with time during printer operation. In the preferred embodiment, the multiplier/adder 124 operates on data inputs from 32 different channels, where a channel is defined as a nozzle and its accompanying charging and deflecting apparatus. As a result, the multiplier/-adder 124 must be capable of applying 32 different sets of $\underline{m}$ and $\underline{a}$ constants to the data input to it. To accomplish this task the 32 sets of $\underline{m}$ and $\underline{a}$ constants are stored in two 32 bit long and 12 bit wide recirculating shift registers 126, 128 which act on data as they are clocked through the multiplier/adder 124. The data as modified by the multiplier/adder 124 aretransmitted to one of thirty two digital-to-analog converters 42 each of which is coupled to an output amplifier 52 for generating a voltage coupled to a charging electrode.

The format for modifying the data inputs with the $\underline{m}$ and $\underline{a}$ constants or modifiers can be seen by referring to Figure 5a and 5b. Although a preferred multiplier/adder comprises circuitry for modifying 12 bit data, those Figures show circuitry for modifying 3 bits of data. The principals of operation are directly extendable to 12 bit data but have been simplified for ease in illustration.

The multiplier/adder 124 is of a pipelined configuration. The 3 bit illustration (Fig. 5a) includes 3 data inputs D_0, D_1, D_2 from the charge compensation circuitry which are clocked through the multiplier/adder 124 at the controller clock frequency. The $\underline{m}$ and $\underline{a}$ constants which operate on these data are stored in the shift registers 126,128 and are clocked through the registers at the same frequency as the charge data. The shift registers 126, 128 comprise a sequence of series connected amplifiers and switches 126a, 126b, 126c and 128a, 128b, 128c, etc., selected outputs of which are connected to the multiplier/adder 124. In this way, once the data for a given charge electrode enter the processor 122, the same $\underline{m}$ and $\underline{a}$ modifiers act on that data as they pass through the multiplier/adder 124. Each of the first three stages of the multiplier/adder 124 comprise three full adders 130, 132, 134 and three data latches 136, 138, 140. During each clock cycle the input data D_0, D_1, D_2 are added to an accumulated sum and this sum is transferred to the next stage. Before summing, the data are gated with an appropriate multiplicand bit from the multiplier shift register 126. Thus, during the first stage operation the least significant bit from the multiplier shift register 126 is gated to an and inlet 142 on the full adder 134. The constants from the adder shift register 128 are added through the most significant bit of the adder so in the first stage, the least significant adder constant is added to the result. The modified data next pass through a carry propagate matrix comprising a number of half adders 144, 146, 148 and data latches 150, 152, 154. The output from the multiplier/adder is a sequence of twelve modified data bits D_{m0}, D_{m1}, D_{m2} . . . which are transmitted to a data bus. The modified data now conform to the above referenced relation, i.e. $D_m = D_c \underline{m} + \underline{a}$.

The $\underline{m}$ and $\underline{a}$ constants are loaded into the shift registers 126, 128 through two way multiplexers 156,158. When a load input 160 to these two multiplixers is high, new data are loaded into the recirculating shift register. When the load input 160 is low, the $\underline{m}$ or $\underline{a}$ data are recirculated from the last register (126i and 128i in Figure 5b) in the shift register sequence back to the first shift register. Since during typical printer operation the $\underline{m}$ and $\underline{a}$ modifiers are only occasionally updated, the input 160 is typically low as the modifiers are recirculated. When they are updated the $\underline{m}$ and $\underline{a}$ modifiers are computed and gated into the recirculating shift register 126, 128 by the controller110.

Calculation of the m and a modifiers is performed during a calibrate mode of operation in which the printer performance is monitored with the sensor array 32. The charging voltage needed to direct ink droplets across each of its two sensors is obtained for each nozzle in the ink jet printer. The multiplier/adder 124 modifies data from the data look-up table according to the format $V_m = V_c\ m + a$. According to one technique V_m is first set equal to the voltage signal required to send droplets over the sensors. But the charge modified data signals V_c are known from the data look-up table. As a result, the controller 110 is faced with task of solving two equations for two unknowns. The form of the equations is as follows:

V_m (sensor 1) = V_{c1} (known) m + a

V_m (sensor 2) = V_{c2} (known) m + a

Once the controller 110 calculates the m and a modifiers for a given channel, this information is input into the recirculating shift register 126 so that it can be applied to the data as they are transferred to the data pipeline. It should be appreciated that although this technique for calculating the m and a modifiers is the preferred technique, other sensing and/or iteration calculations might be performed to arrive at the m and a values.

The modified output data are transmitted to a data bus which in turn is coupled to each of 32 different digital-to-analog converters 42 used to change the digital charging data to analog voltage signals. The circuitry coupled to a typical digital-to-analog converter 42 is shown in Figure 6. As seen in that figure, an input latch 164 for each digital-to-analog converter is coupled to the data bus 165. This data latch 164 latches on to data on the data bus only when a chip select input 166 from a controller 110 sends an indication that the data on the bus were generated for that particular digital-to-analog converter. The simultaneous occurrence of a chip select 166 and data strobe signal 168 from the controller 110 causes the data on the data bus to be strobed into the first latch circuit 164. After a certain number of controller clock pulses, the digital signal from this first latch 164 is strobed to a second latch 170 which transfers these digital input data to the analog converter 42.

A delay between receipt of data by the first latch 164 and transmittal of that data to the second 170 is accomplished by a programmable register 172 which comprises a series of flip-flops which form a down counter. Each flip-flop has an input from a latch 176 which is programmed by the controller 110 with a series of inputs 178a-e which dictates the amount of delay

between receipt of the data input by the first and second latches coupled to the analog-to-digital converter. Data are input into this countdown register by receipt of a phase strobe signal 180 from the controller. Subsequent clock pulses from the controller cause the countdown register 172 to count out and generate a clock pulse 182 to the second data latch. This data delay ensures that the charging signal which appears at the output 184 of the digital to analog converter 42 appears at an appropriate time in relation to the droplet breakoff from the printer.

The analog signal from the digital-to-analog converter 42 is a relatively low level signal which must be amplified by a power amplifier 52 and transmitted to its associated charging electrode. Both the digital-to-analog converter 42 and amplifier 52 must be fast acting since the drop generation frequency of a typical ink jet printer is on the order of 200 kHz.

The m and a modifiers, which alter the charging voltage in accordance with the sensed operation of the ink jet printer, correct for variations in the directionality of droplet generation and changes in the gain of the charging circuitry. Changes in alignment or directionality are performed by changing the a modifier, and changes in the gain are performed by changing the m modifier. The exemplary m and a modifiers are binary 12 bit numbers so they comprise numbers from 0 to 4095. A slightly misdirected jet with too narrow a spread to completely cover its assigned ink jet segment might, for example, result from the use of m and a modifiers of 2000 and 1900 respectively. The spread of drop coverage might be increased by changing the m modifier from 2000 to 2500, and the misdirection might be corrected by changing the a modifier from 1900 to 2300. These changes would alter all charging signals sent to the digital-to-analog converter such that the desired ink jet performance (i.e. proper direction and spread of the ink droplets from a given nozzle) is obtained. One method for updating these m and a values is discussed above where the method of solving two equations and two unknowns is discussed. An iteration scheme might also be devised for systematically varying the m and a modifiers until the "right" values are determined.

The disclosed gain and offset modifiers have utility in any type ink jet printer where the drop position on the recording medium is changed by changing the magnitude of charge placed on a droplet. Thus, although the invention has been described in a preferred bi-polar environment, it is the intent that all modifications and/or alterations falling within the spirit or scope of the appended claims be covered by the invention.

CLAIMS

1. An ink jet printer comprising:

means (12, 22) for directing one or more ink jet streams (14) in the direction of a recording medium (20),

means (26) for charging individual ink droplets which break off said one or more jet streams to a charge level related to an intended droplet trajectory, and

means (28) for creating an electric field in the vicinity of said droplets to deflect said droplets away from their initial trajectory to said intended trajectory, characterised by

means (32) coupled to said charging means for determining an appropriate charge for each ink droplet and generating a charging signal related to said charge, said means (32) including means (38) for modifying said charging signal by an amount dictated by the operating characteristics of the jet stream directing means said charging means, and said field-creating means to ensure that said droplets follow their intended trajectory, said means for modifying including means for both adding a correction factor, to, and scaling, said charging signal.

2. The printer of Claim 1, wherein said means (32) generates an initial N-bit digital representation of an optimum charging voltage, and said signal-modifying means includes circuitry for multiplying said initial N-bit representation by a scaling factor (m) and adding an offset factor (a) to provide a corrected N-bit representation, said gain and offset factors being calculated from observed performance of said printer during a calibration procedure.

3. The printer of Claim 1 or 2, wherein said stream-directing means comprises a multiple nozzle ink source, ink from each nozzle providing coverage of a specific portion of said record medium, and wherein said signal-modifying means comprises circuitry for operating a gain and offset factor for each nozzle, and further comprises means for directing an appropriate charging signal to the respective droplet-charging means.

4. A printer as claimed in claim 3, in which the droplet charging apparatus comprises:

a plurality of voltage amplifiers equal in number to said charging electrodes for applying charge-inducing voltages to said charging electrodes;

means for generating a digital charging signal for each droplet dependent on both the desired droplet position on said record medium and the charging histories of preceding droplets from the same nozzle;

means for monitoring droplet flight during a droplet calibration procedure;

means for modifying said digital charging signal to take into account the operating characteristics of a particular nozzle sensed by said means for monitoring; and

means for coupling an appropriate corrected charging signal to an appropriate voltage amplifier.

5. The printer of Claim 4, wherein the nozzles direct said droplets through uniform deflecting fields, and the voltage amplifiers selectively charge droplets both positively and negatively to deflect said droplets away from an initial trajectory.

6. A method for charging ink droplets as they form to ensure that said droplets are deflected along an intended trajectory by a uniform electric field, said method comprising the steps of:

determining the charge needed to cause said droplets to be deflected from an initial trajectory past a droplet sensor;

calculating a charging signal corresponding to a desired charge on each droplet;

modifying said charging signal by an offset and/or scaling factor related to the charge sensed in said determining step;

converting said modified charging signal to a voltage; and

applying said voltage to a charging electrode in the vicinity of droplet formation to induce an appropriate charge on said droplet.

7. The method of Claim 6, wherein said calculating step is performed by a programmable processor which determines said charging signal by accessing an appropriate address in a processor look-up table and where said

charging signal is modified by a hard wired circuit which adds said offset factor to and multiplies said scaling factor by said charging signal.

8. An ink jet printer having a number of spaced ink jet nozzles for directing parallel ink streams to a recording medium moving with respect to said nozzles, a number of charging electrodes equal in number to said nozzles positioned next to a point of droplet breakoff for inducing a net charge on each droplet related to a desired droplet trajectory, electrodes for generating electric fields through which said charged droplets pass on their way to said recording medium for controllably deflecting said charged ink droplet, means for intercepting certain highly charged droplets, and control circuitry coupled to said charging electrodes for generating charging voltages to induce said net charge on the droplets, said control circuitry comprising:

an input buffer for storing a pattern of print or no print signals for each nozzle based upon a series of print or no print indications for ink droplets emitted by that nozzle;

means for creating a first charging signal for each droplet based on the pattern of print or no print signals

means for generating a second modified charging signal related to said first signal by the relation:

V (2nd) = V (1st) $\underline{m}$ + $\underline{a}$, where the values of $\underline{m}$ and $\underline{a}$ are binary numbers;

means for monitoring printer operation to determine said second modified charging signals for specific droplet trajectories to allow calculation of said $\underline{m}$ and $\underline{a}$ values from said first charging signals for those same specific droplet trajectories; and

means for converting said second modified charging signals to charging voltages for transmission to an appropriate charging electrode.

9. The printer of Claim 8, wherein said means for generating the first charging signal comprises a look-up table in a programmable controller memory space for generating an N bit signal, and said means for gnerating said second modified charging signal comprises an N bit multiplier/adder for applying said $\underline{m}$ and $\underline{a}$ values to said N bit signal prior to conversion to a charging voltage.

FIG. 1

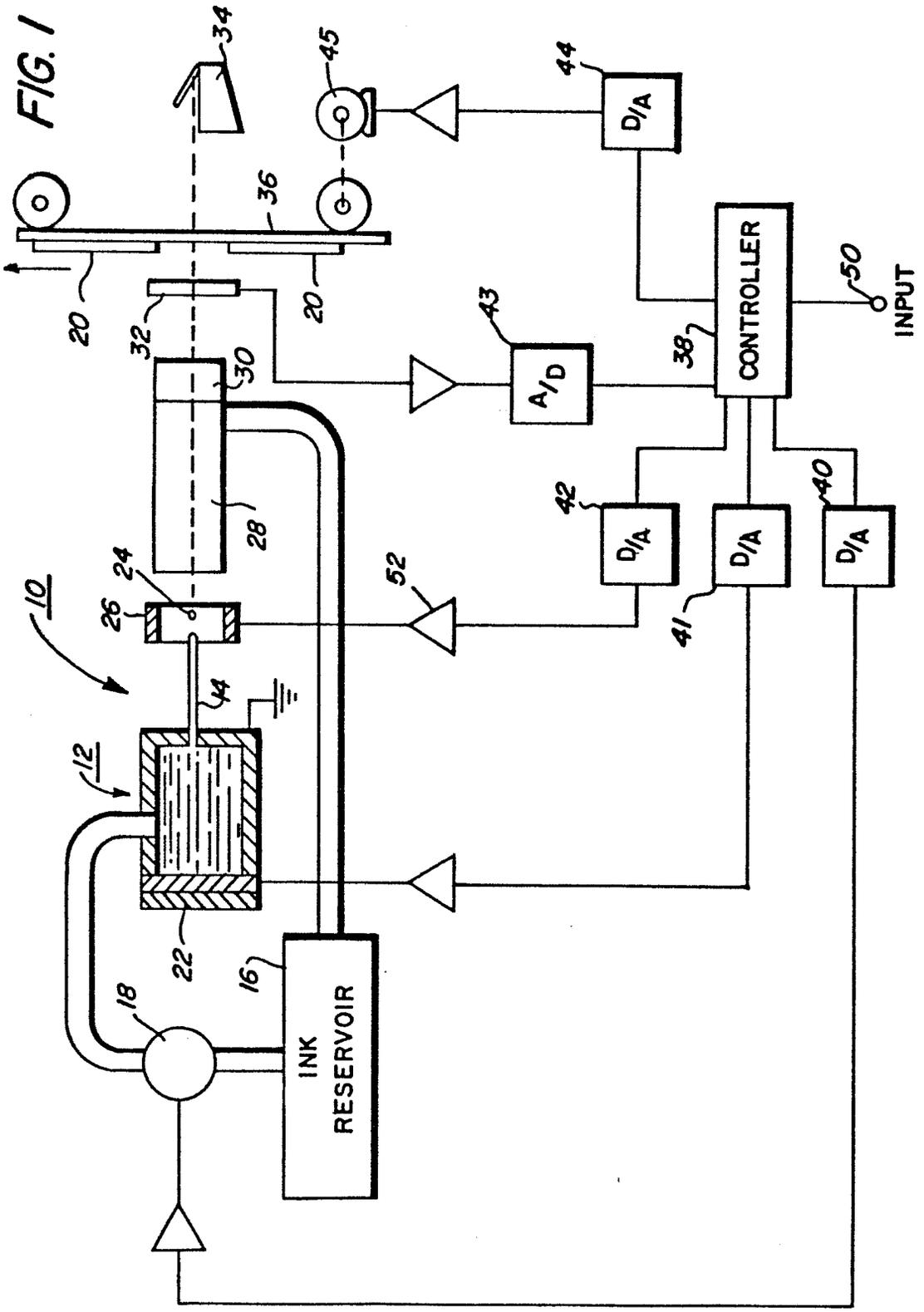

34
45
44
D/A
36
20
20
32
30
43
A/D
38
CONTROLLER
50
INPUT
28
42
D/A
40
D/A
D/A
24
52
10
26
41
14
12
22
16
18
INK
RESERVOIR

FIG. 2

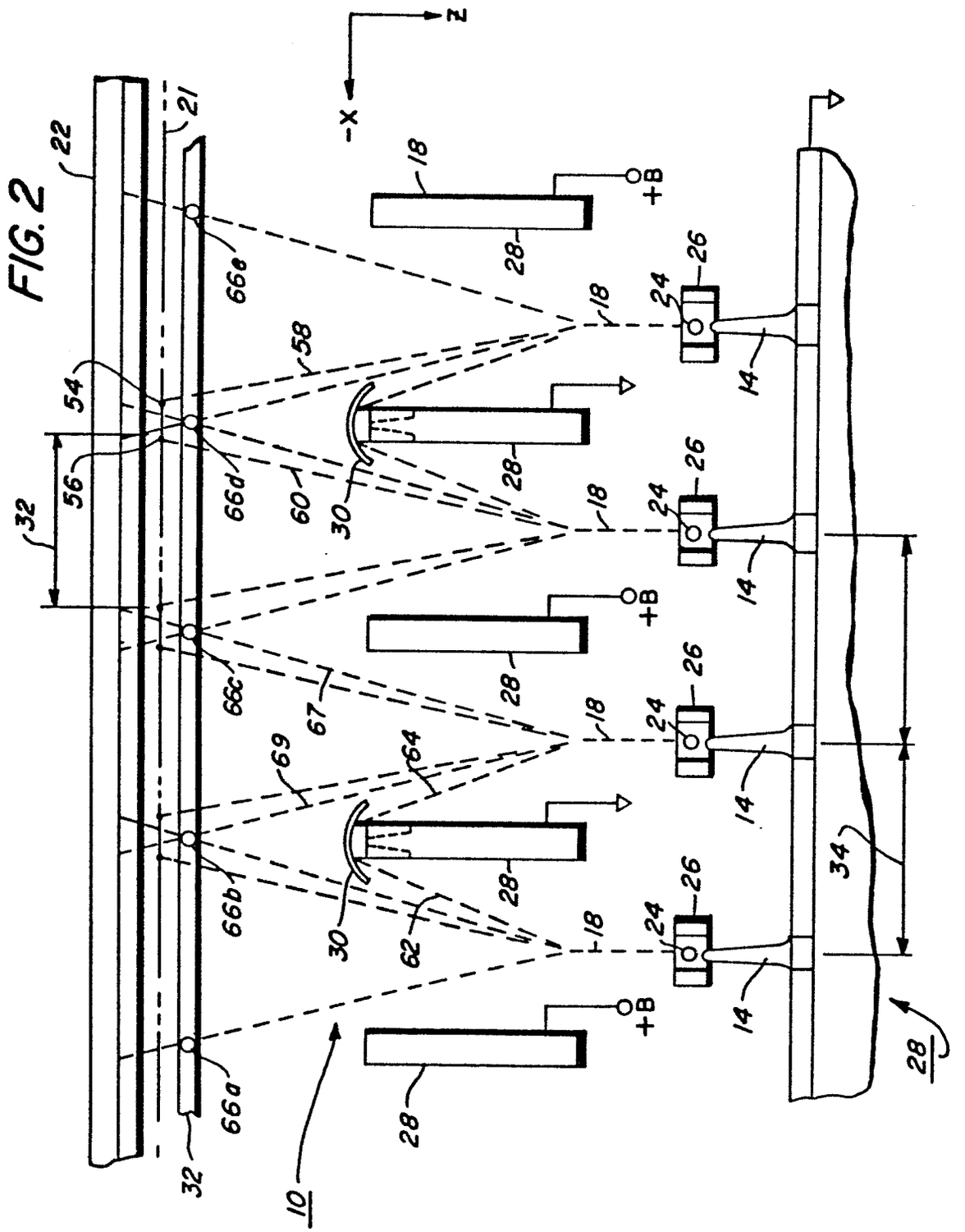

Z
-X
22
21
18
+B
28
26
24
14
58
54
56
32
66a
66d
60
30
66c
67
69
64
66b
62
34
10

FIG. 3

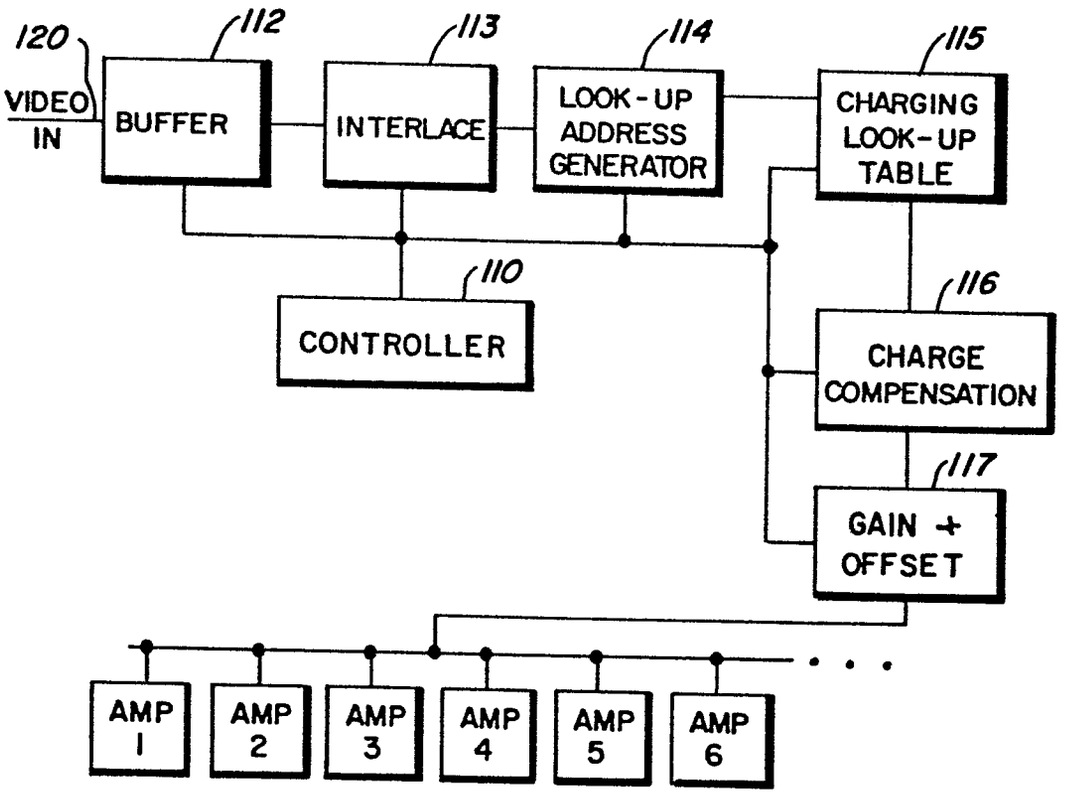

120
VIDEO IN
112
BUFFER
113
INTERLACE
114
LOOK-UP ADDRESS GENERATOR
115
CHARGING LOOK-UP TABLE
110
CONTROLLER
116
CHARGE COMPENSATION
117
GAIN + OFFSET
AMP 1
AMP 2
AMP 3
AMP 4
AMP 5
AMP 6

FIG. 4

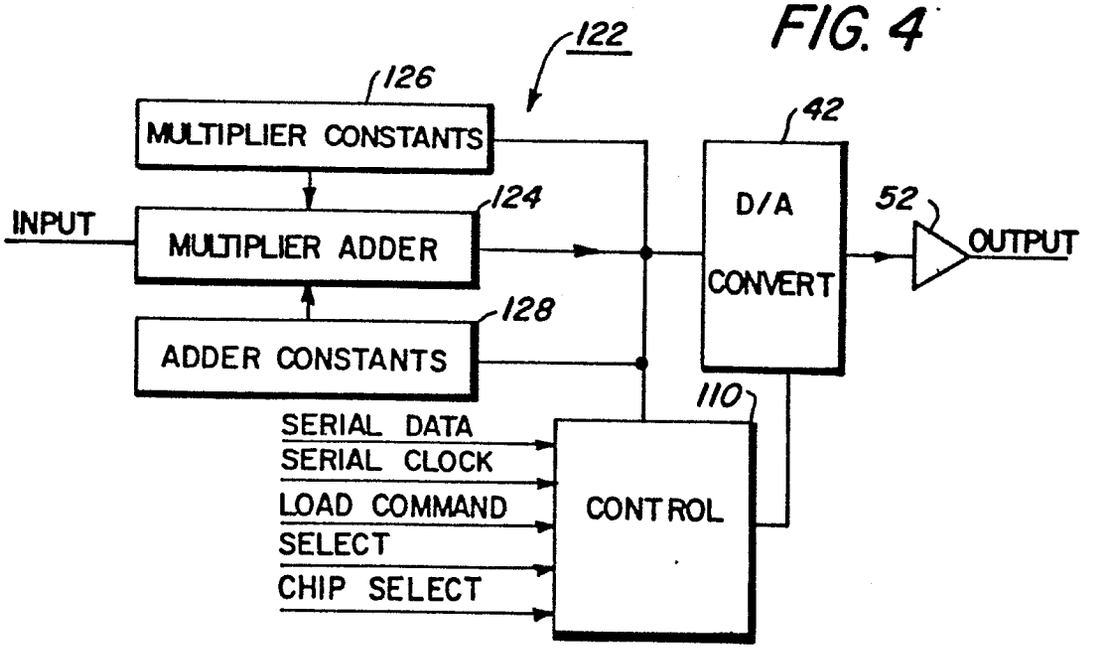

122
126
MULTIPLIER CONSTANTS
INPUT
124
MULTIPLIER ADDER
128
ADDER CONSTANTS
42
D/A CONVERT
52
OUTPUT
110
SERIAL DATA
SERIAL CLOCK
LOAD COMMAND
SELECT
CHIP SELECT
CONTROL

FIG. 5a

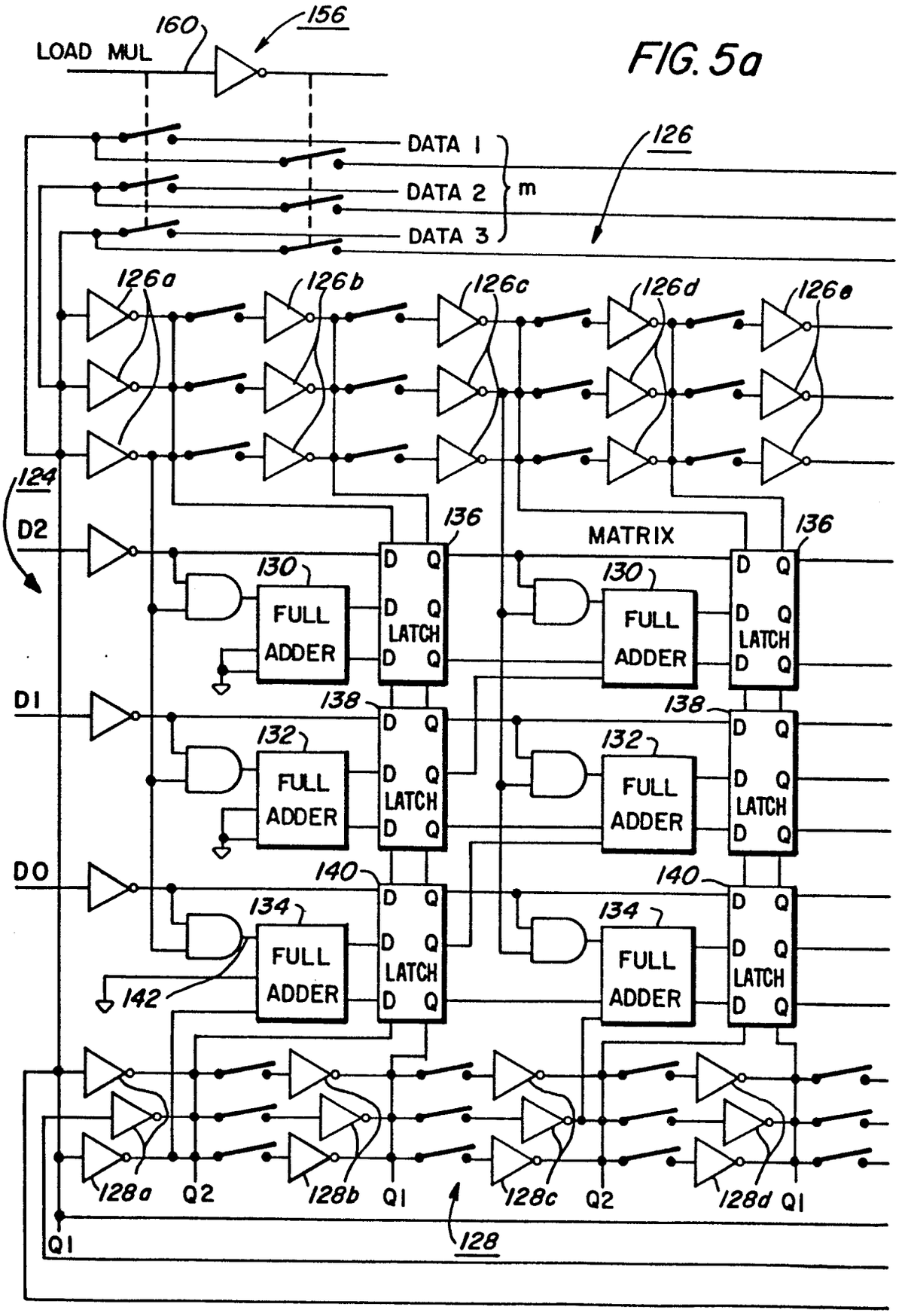

LOAD MUL
160
156
DATA 1
DATA 2
DATA 3
m
126
126a
126b
126c
126d
126e
124
D2
D1
D0
MATRIX
136
130
132
134
138
140
FULL ADDER
D Q
LATCH
142
128a
128b
128c
128d
Q2
Q1
128

FIG. 5b

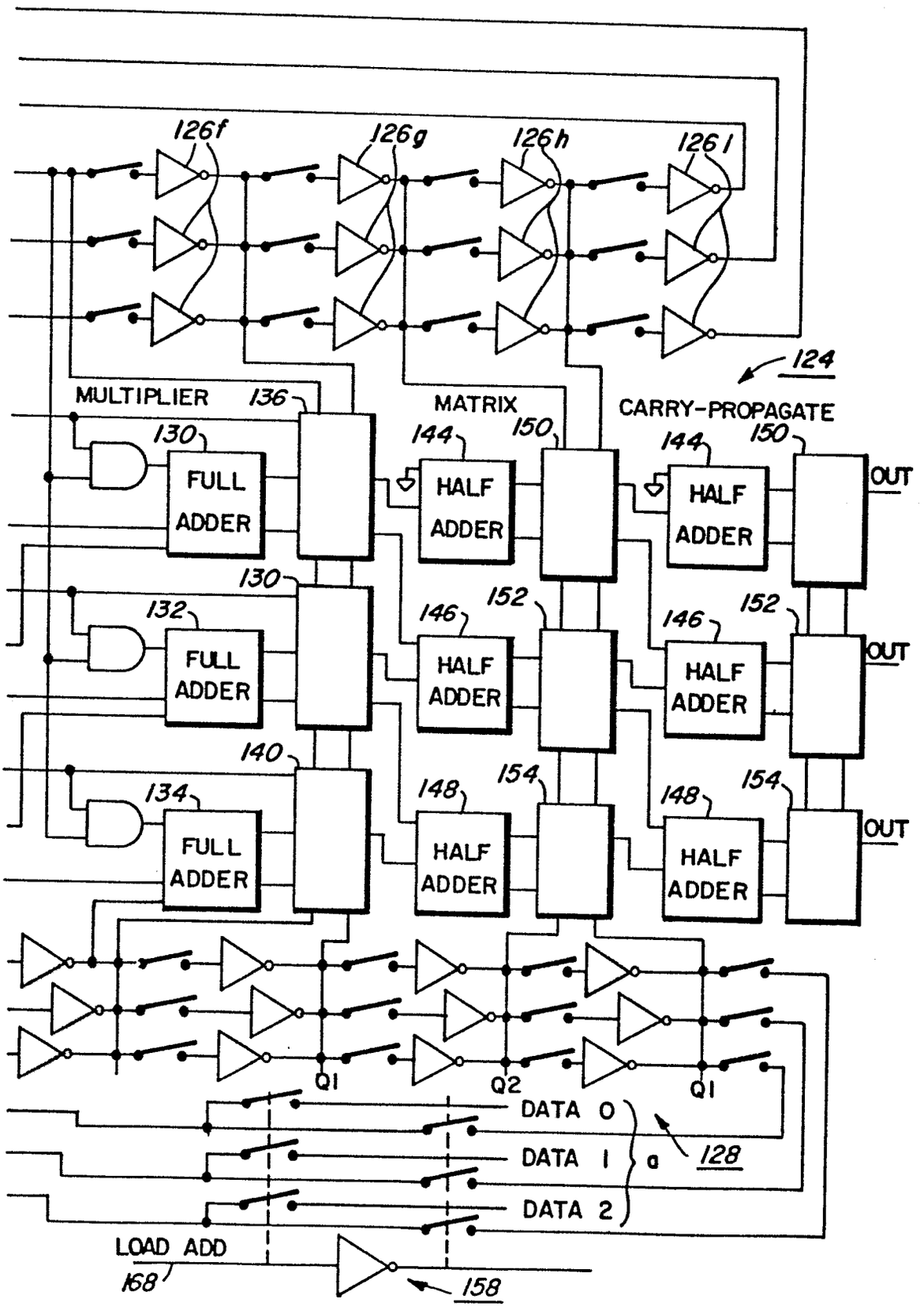
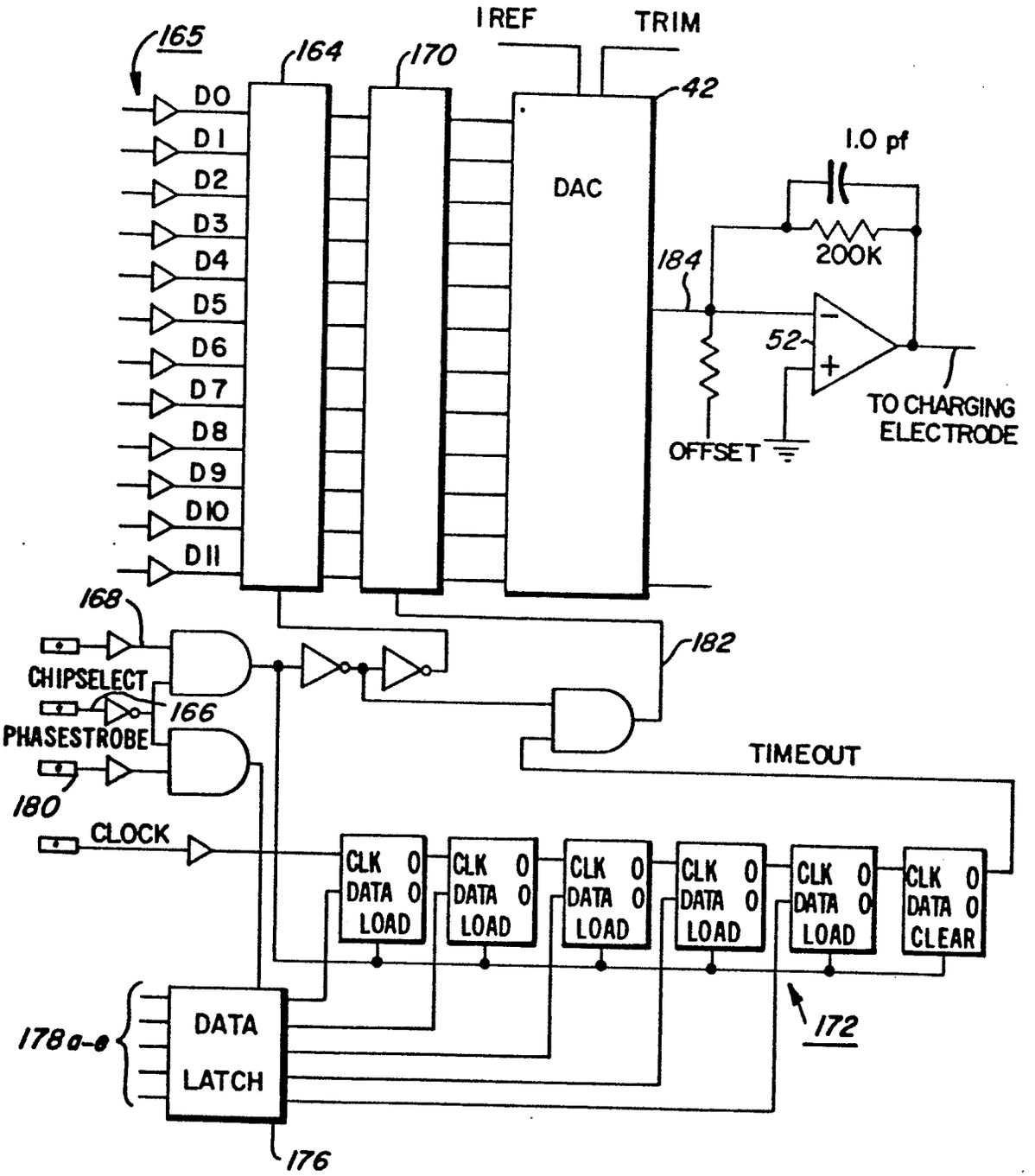

126f
126g
126h
126i
124
MULTIPLIER
136
MATRIX
CARRY-PROPAGATE
130
FULL ADDER
144
HALF ADDER
150
OUT
132
146
152
134
148
154
140
Q1
Q2
DATA 0
DATA 1
DATA 2
128
LOAD ADD
168
158

FIG.6


IREF
TRIM
165
164
170
42
DAC
D0
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
1.0 pf
200K
184
52
TO CHARGING ELECTRODE
OFFSET
168
182
CHIPSELECT
166
PHASESTROBE
180
TIMEOUT
CLOCK
CLK 0
DATA 0
LOAD
CLEAR
178a-e
DATA
LATCH
172
176

European Patent Office

EUROPEAN SEARCH REPORT

0080900
Application number

DOCUMENTS CONSIDERED TO BE RELEVANT

EP 82306379.7

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
D,A	US - A - 4 238 804 (WARREN)		B 41 J 3/04
A	DE - B2 - 2 611 282 (HITACHI) * Totality *	1,4	
A	EP - A1 - 0 036 788 (CAMBRIDGE CONSULTANTS LTD.) * Totality *	1,4,6	

TECHNICAL FIELDS SEARCHED (Int. Cl. ³)

B 41 J 3/00
G 01 D 15/00
G 06 K 15/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	18-02-1983	WITTMANN

CATEGORY OF CITED DOCUMENTS

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