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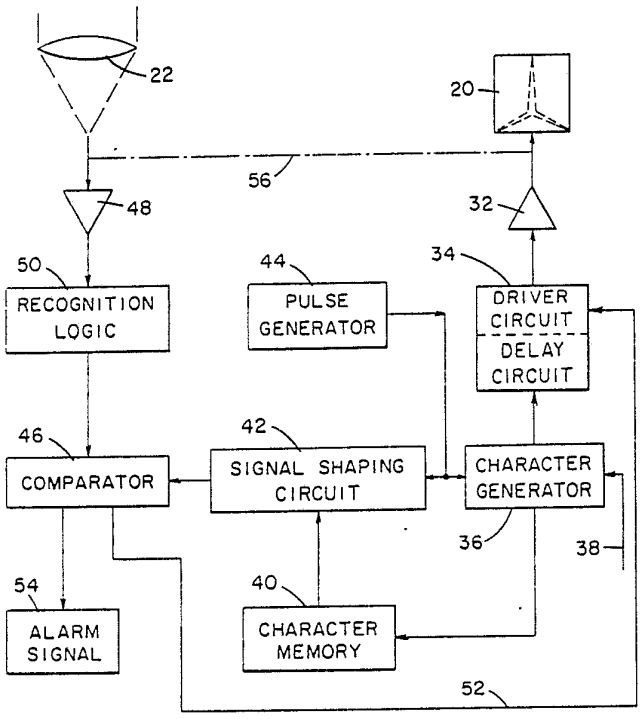
(54) Title: DOT MATRIX PRINTER

(57) Abstract

Dot matrix printer, such as an ink jet printer, wherein the dots produced by a printing element (20) are optically sensed and the existence, the position, the size and the condition of each dot are determined. The desired printing signals are produced by a character generator (36) and input in a signal shaping circuit (42) and these signals are compared with the actual signals from the optical sensing means (22, 48, 50) and the drive means (34) for the printing element (20) is altered to correct the printing or an alarm signal (54) is produced when the compared signals do not correspond with each other.



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DOT MATRIX PRINTER

Technical Field

The present invention relates to a dot matrix printer.

Background Art

In the field of non-impact printing, the most common types of printers have been the thermal printer and the ink jet printer. When the performance of a non-impact printer is compared with that of an impact printer, one of the problems in the non-impact machine has been the control of the printing operation. As is well known, the impact operation depends upon the movement of impact members such as wires or the like and which are typically moved by means of an electromechanical system which is believed to enable a more precise control of the impact members.

The advent of non-impact printing, as in the case of thermal printing, brought out the fact that the heating cycle must be controlled in a manner to obtain maximum repeated operations. Likewise, the control of ink jet printing in at least one form thereof must deal with rapid starting and stopping movement of the ink fluid from a supply of the fluid. In each case, the precise control of the thermal elements and of the ink droplets is necessary to provide for both correct and high-speed printing and to make certain that a clean printed character results from the printed dots.

Endeavors have been made to improve the print quality of dot matrix printers and accordingly arrangements have been proposed for detecting printing errors. Thus, for instance, the U.S. Patent No. 3,977,010 describes a multi-nozzle ink jet print head wherein conductive ink is propelled from the nozzles in a continuous stream caused to break up into a train of individual droplets which are selectively charged and deflected for recording or recirculation. Measurements are

made on the ink jet stream of charged droplets to sense jet alignment, drop arrival time, charge electrode operation and charge phase.

By reason of the fluid characteristics of ink and the high speed of the driven ink droplets several other problems may arise in jet printing operations. The existence of an ink mark or spot and then the non-existence of an ink spot on the paper may indicate that the nozzle plate of the ink jet print head became clogged and requires cleaning or rinsing. Secondly the actual position of the ink mark may be different from the desired position and this condition may be caused by an improper delay time or an incorrect speed of the ink droplet relative to the speed of the moving print head or like device. A third problem may be that the actual size of the ink spot or mark on the paper does not correspond with the desired ink spot size and wherein the ink droplet drive means may require an adjustment in the operation thereof. Additionally, the precise optical properties of the ink spot in regard to the contrast or reflection characteristic may not be within the scope of the specification, and the driving condition can then be altered to correct the condition or else the composition of the ink may be changed to correct for contrast or reflection quality.

Disclosure of Invention

It is an object of the present invention to provide a dot matrix printer which is capable of detecting and correcting errors resulting from the omission or misplacement and the reduced size or density of a printed dot.

Thus according to the invention, there is provided a dot matrix printer for printing characters on a record medium, including at least one printing element, character generating means for producing signals indicative of characters to be printed, and

drive means for actuating each printing element for printing said characters, characterized by optical sensing means associated with each printing element for sensing the dots printed thereby and producing signals representative of the sensed dots, signal shaping means for shaping the signals produced by said character generating means into signals comparable with the signals produced by said optical sensing means, and comparison means for comparing the signals produced by said optical sensing means with the signals produced by said signal shaping means and producing an output signal when the compared signals do not correspond with each other.

In accordance with one embodiment of the present invention, an ink jet print head or like device is caused to be moved in side-to-side manner and the ink in the print head is controlled by means of a driver circuit to cause ink droplets to be ejected through a nozzle and onto the paper or like record media. Input signals are provided to a character generator and the signal output thereof is supplied to a character memory and also to a signal shaping circuit. The shaping circuit determines the shape of the optical signal to be detected and the output signal of the shaping circuit is compared with the actual signal which is sensed or observed by the optical sensing device.

The optical sensing device is preferably a sensing unit associated with the printing element or print head and movable therewith and is capable of detecting the actual position of the ink mark or spot on the paper. While the sensing device may be mounted in horizontal manner on one side with respect to the printing element, there may be a sensing device on either side of the printing element, or the sensing device may be located in a vertical arrangement with the printing element.

When a difference or error condition in the proper printing operation exists, as for example when an

ink spot or mark does not exist, the nozzle plate may require cleaning and the optical sensing device may initiate actuation of apparatus for automatic cleaning or rinsing of the plate. Likewise, when the size, position or condition of the ink mark or spot is not correct, the optical sensor may initiate a change or alteration of the ink droplet drive means or the operation thereof to correct the printing of the characters. It is also within the scope of the present invention that, if the above-mentioned change or alteration in the printing operation is not possible to effect correction of the printed characters, an alarm or like audible tone would be generated to notify the operator of malfunction of the machine.

Embodiments of the invention will now be described by way of example, with reference to the accompanying drawings, in which:

Fig. 1 shows a diagrammatic view of a sensing device arranged to move in front of a printing element;

Fig. 2 is a view of the sensing device arranged to follow the printing element;

Fig. 3 is a view showing a sensing device arranged on each side of the printing element to move therewith;

Fig. 4 is a view showing a vertical arrangement of the sensing device and the printing element;

Fig. 5 is a block diagram of the arrangement of the supervisory system for a single ink nozzle;

Fig. 6 is a view showing the influence of the speed of the ink droplet on the ink spot position;

Fig. 7 is a block diagram of the arrangement of the supervisory system for a plurality of ink nozzles;

Fig. 8 is a view of a pattern of ink spots influenced by preceding spots;

Fig. 9 is a graph showing the influence of the drive element on the size of the ink droplet;

Fig. 10 is a graph showing the signal shapes utilized in the control logic;

Fig. 11 shows an arrangement of elements for the recognition logic;

Fig. 12 shows an arrangement of elements for the comparison of actual signals with desired signals;

Fig. 13 shows an arrangement of elements for the alarm signal; and

Fig. 14 shows an arrangement of elements for the network of the driver circuit and the delay circuit.

Best Mode for Carrying Out the Invention

As seen in schematic form in Fig. 1, paper or like record media 10 is caused to be transported from one roller 12 to another roller 14 and in a plane to receive droplets 16 of ink ejected from the nozzle 18 of a printing element or print head 20. The print head 20 is caused to be driven in well known manner from side to side in a horizontal direction along a line of printing across the printer. The paper 10 moves in a vertical direction after each line of dots is printed in the manner and process of making the characters in dot matrix form.

In the process of making such dot matrix characters it is important that the location of the point of impact of each ink droplet on the paper 10 be exactly determined or supervised so as to insure that a clean printing image is effected in forming each of the characters. The location of such impact points of the ink droplets can be sensed by means of an optical sensing device 22 for detecting the actual position of the ink spot 24 on the paper 10 and wherein the actual position may be at a different location from the desired dot position 26.

Fig. 2 shows the position of the optical sensing device 22 relative to the print head 20 after

the head has moved in the direction of the arrow for a predetermined time and at a certain speed as controlled by the printer control mechanism. In a certain time the sensing unit 22 and the print head 20 are moved a precise distance along the line of printing.

Fig. 3 shows an arrangement wherein the print head 20 ejects an ink droplet 16 onto the paper 10 and the sensing or detecting means includes the optical sensing device 22 for detecting the actual position 24 of an ink spot and includes another optical sensing device 28 for detecting the actual position 30 of an ink spot. In this manner an optical sensing device is positioned on either side of the print head 20 in leading and lagging nature for supervising or observing the printing of dots during both forward and reverse movement of the print head.

Another arrangement of the apparatus is shown in Fig. 4 wherein the ink jet print head 20 ejects an ink droplet 16 onto the paper 10 carried on rollers 12 and 14 in similar manner as for the previous figures. However, the optical sensing device 22 is positioned in a vertical arrangement above the print head 20 so that the device 22 is positioned independent of the horizontal movement of the print head 20.

The optical sensing of the actual position of the ink droplets or spots 24 on the paper 10 enables the recognizing of trouble sources of the ink jet printing and the diminishing or elimination of the troubles in a subsequent operational manner. For example, if it is desired to print an ink spot or dot at position 26 in Fig. 1, but such ink spot or dot is actually at position 24 as detected by the optical sensing device 22, the consequence of a misplaced ink spot or dot can effect the release of a cleaning agent for the nozzle plate by rinsing thereof or can effect a scraping or like cleaning of the nozzle plate. If the rinsing or scraping procedures do not correct the printing operation, an

alarm can be connected to the sensing device to indicate the trouble condition.

Fig. 5 shows the supervisory system of the present invention for one ink nozzle or spray device wherein the positions of the actual ink spots or dots on the paper 10 are recognized and are compared with desired positions to provide proper operation. The ink jet print head 20, which may be of the well known piezoelectric drive type, is controlled through a power amplifier 32 and a driver circuit 34 from a character generator 36. The input to the generator 36 is by means of a line 38 from an electronic data processing system which supplies the desired signals for printing the characters in dot matrix manner. Such desired signals from the character generator 36 are timely delayed in a character memory 40 and are then supplied to a signal shaping circuit 42. The signals may be subjected to different delay times as hereinafter shown and described. A pulse generator 44 is provided to send signals to the character generator 36 and to the signal shaping circuit 42 to establish a pulsing signal for the driver circuit 34. The signal shaping circuit 42 obtains the necessary information from the desired character signal as to the desired shape of the optical signal to be detected.

The output signal of the signal shaping circuit 42 is supplied to a comparator 46 which compares such output signal with the actual signal of the optical sensing device 22. A preamplifier 48 is provided along with suitable recognition logic 50 for determining and enabling the circuit to identify the ink dot or spot which is seen at the actual physical position. The result of the comparison causes an alteration of the energization of the piezoelectric actuated ink spraying device or print head 20 through the line 52 if there is a deviation from the desired signal. In those cases where the alteration of the energization of the print

head 20 does not provide a sufficient correction of the printing, an alarm signal 54 is indicated or sounded for the operator. In effect, the comparator 46 determines whether the signal difference is applied to affect the driver circuit 34 or the alarm signal 54. The tie line 56 indicates that the optical sensing unit 22 moves with the print head 20.

As mentioned above, one of the problems associated with ink jet printing is that the actual position 24 (Figs. 1, 2 & 3) of the ink spot or dot on the paper 10 does not correspond with the desired position 26 of the ink spot. Fig. 6 shows the ink droplet 16 moving at a velocity V_d toward the paper 10 while the print head 20 is moving at a velocity V_H in a direction parallel with the paper and along the line of printing. The resulting velocity V_R determines the point of impact of the ink droplet 16 on the paper 10 in a manner wherein it can be seen that any variation or alteration of one or both of the velocity components can influence the point of impact of the droplets 16. The desired position 26 of the ink spot is seen as being located to the right of the actual position 24. The horizontal drive of the print head 20 determines the velocity V_H whereas the ink droplet velocity V_d is controlled by the energization of the piezoelectric crystal in the print head 20.

Fig. 7 shows an arrangement of the delay network for a plurality of ink nozzles or spray devices in a print head 20 having a multi-nozzle plate or for a plurality of print heads each having a single nozzle and including an amplifier 32 connected to a driver circuit 34 for each of the nozzles. The time of ejecting ink droplets from the nozzles also aids in determining the point of impact of the droplets in forming the ink spots. In this manner it is possible to control each of the nozzles through the delay network 66 and the individual control of the delay circuit to each nozzle.

The signals of the generated characters may be timely delayed at different times through the character memory 40 so as to affect the electrical signals for energizing the piezoelectric drivers.

Fig. 8 shows a pattern of ink spots 70 with the desired positions being an equal distance from each other and showing an error condition wherein two of the ink spots 72 have been influenced by a preceding ink droplet. The position of an ink spot or dot also depends upon whether a droplet is ejected onto the paper 10 just prior to a supervised ink droplet. According to the dot sequence for making up a dot matrix character, a droplet ejection time with the delay circuits shown in Fig. 7 must be precisely controlled and the position of the influenced ink spots or dots 72 may be again or further corrected. Alterations of the deviation "d" of the influenced spots 72 can be eliminated by means of the optical measuring device 22. The right side portion of Fig. 8 shows an information pattern of the ink spots 70 and 72 on the paper 10. Another possibility for correction is to provide fixed or predetermined correction patterns in the character generator 36 of Fig. 5 for certain symbols or characters. It is seen that either the correction patterns in the character generator 36 of Fig. 5 or the delay network of Fig. 7 may be adapted to the actual state or position of the ink dots as supplied by the optical measuring device 22.

Another condition or trouble source is that the ink spot on the paper does not correspond with the desired size of the ink spot or dot. A remedy for this condition is by means of respective alteration of the driving conditions of the drive elements or piezoelectric crystals in the print heads, wherein a lesser amount or a greater amount of ink is ejected from the nozzle. Fig. 9 is a graph showing the influence of the operating voltage of the piezoelectric drive elements in relation to the size of the ink droplet. The graph

posts a range of 28 to 44 volts with an ink droplet diameter of 0.08 to 0.11 millimeters at a spray distance of 2 to 12 centimeters. The broken line of the graph represents the diameter of the ink droplet and the solid line represents the spray distance. This feature of the invention can be used to compensate for different absorbency of various types of paper at high speed printing.

Fig. 10 shows the shape of the several signals or voltage pulses relative to time t utilized in the recognition logic 50 and the comparator 46 (Fig. 5). The signal V_S is an output signal of the preamplifier 48 and indicates a digital signal size, the duration of the signal being equal to an analog value of the dot size and indicating that the signal or pulse approximates the density of print. V_{LI} is an output signal of a trigger element of the recognition logic 50 and $\frac{dV_S}{dt}$ is an output signal of an R-C circuit of the recognition logic and is an indication of signal position P. V_{L2} is an output signal of a set-reset flip-flop.

Fig. 11 illustrates an arrangement of elements for the recognition logic 50 wherein the pulse or signal V_S is received from the preamplifier 48, as seen in Figs. 5 and 7. The signal V_S is provided as an input to a schmitt trigger 80, an input to a summing operational amplifier 82 and an input to a summing operational amplifier 84, which input includes a diode 86.

The outputs of these elements are provided as inputs to the comparator 46, shown in detail in Fig. 12, and designated as signal position P, signal density D and signal size S. One output from the signal shaping circuit 42 is provided as an input to a monostable element 90 and to the set-reset flip-flop 92. A second output from the signal shaping circuit 42 is input to an AND gate 94 along with signal S. Signal P is provided as a second input to the flip-flop 92, the output of which is V_{L2} provided as one input to an AND gate 96, the other input being provided from the output of

element 90. The density signal D is provided as one input to a summing operational amplifier 98 with a second input being a fixed voltage pulse. The outputs of the elements 94, 96 and 98 are made available to the alarm signal 54 and the outputs of AND gates 94 and 96 are provided to the driver circuit 34. Summarily, the comparator 46 compares the signal from the recognition logic 50 with the desired value of the signal from the signal shaping circuit 42 and then provides the difference between these signals to the driver circuit 34 and to the alarm signal generator 54.

The alarm signal 54 is illustrated in Fig. 13 as including a pair of monostable elements 100 and 102 receiving input signals S and a pair of monostable elements 104 and 106 receiving input signals P. The outputs of elements 100 and 102 are provided as inputs to an AND gate 108 along with the signal S, and the outputs of elements 104 and 106 are provided as inputs to an AND gate 110 along with the signal P. The outputs of AND gates 108 and 110 along with a signal D are provided as inputs to an OR gate 112, the output of which is the input of an alarm 114.

Fig. 14 illustrates an arrangement of elements for the delay circuit and for the driver circuit 34. A signal output from the delay network 66 is provided through a diode 120 as an input to a field effect transistor 122 connected to a monostable element 124. An input to such element 124 is a signal from the character generator 36. The output of element 124 is connected as an input to a monostable element 126. The P signal from the comparator 46 is connected through a diode 130 and to the transistor 122, and the S signal from the comparator 46 is connected through a diode 132 to a field effect transistor 134. The output from element 126 is provided as an input to the base of a transistor 136 and a lead from transistor 134 is connected as an input to a transistor 138. The difference

between the detected signal and the desired signal controls the gate voltage of the field effect transistor 134 and this transistor controls the collector current of transistor 138, which current is directly proportional to the voltage height on the piezo element of the print head 20. The driver circuit 34 provides the pulse for driving the piezo element of the print head 20.

It should be here mentioned that the summary delay of the excitation pulse to the piezo drive element for the print head 20 is dependent upon the "multi-drop-behavior" concept and upon the error signals of the comparator 46. This behavior concept refers to irregularities in emission of ink droplets during the first 2-10 drops of a burst and prior to a uniform drop emission. Corrections for irregularities caused by this behavior, which in turn may depend upon the character to be printed, can be stored in the character generator 36 which sends a trigger signal to the monostable element 124. The pulse duration of element 124 is determined by signals from the delay network 66 and from the recognition logic 50. The individual delay is a function of the capacity of the monostable element 124 and the electrical resistance between the source and the drain of the transistor 134 which resistance is controlled by the gate voltage.

The logic design for signal shapes as shown in Fig. 10 and for the required information as to the height, width and the delay of the electrical pulse from the preamplifier 48 is illustrated in one manner and method by Figs. 11-14. An alternative manner and method for extraction of the desired information is by means of an analog/digital converter which supplies digital data to a microprocessor running on a software program.

In certain cases the optical properties of the ink spots or dots relative to the contrast or reflection characteristics in a certain part of the light spectrum are not sufficient to require the parameters for precise

correction. In other cases the contrast of the ink spots can be effected and advantageously corrected by alteration of the driving conditions of the drive elements to control the quantity of ink ejected from the nozzles. Another means of effecting contrast or reflection of the ink spots or dots is to regulate the composition of the ink with a solvent so as to change the concentration of the ink ejected onto the paper 10 and thereby influence the reflection characteristic of the ink relative to a desired spectrum range.

The ink jet printer just described enables the accomplishment of the objects and advantages mentioned above; however, it should be clear that the detection system can be equally well applied to a wire matrix printer or a thermal printer for supervising the quality of the printed characters.

CLAIMS:

1. A dot matrix printer for printing characters on a record medium (10), including at least one printing element (20), character generating means (36) for producing signals indicative of characters to be printed, and drive means (34) for actuating each printing element (20) for printing said characters, characterized by optical sensing means (22, 48, 50) associated with each printing element (20) for sensing the dots printed thereby and producing signals representative of the sensed dots, signal shaping means (42) for shaping the signals produced by said character generating means (36) into signals comparable with the signals produced by said optical sensing means (22, 48, 50), and comparison means (46) for comparing the signals produced by said optical sensing means (22, 48, 50) with the signals produced by said signal shaping means (42) and producing an output signal (52) when the compared signals do not correspond with each other.

2. A printer according to claim 1, characterized in that said output signal (52) is effective to alter the operation of said drive means (34).

3. A printer according to claim 1, characterized in that said output signal is effective to operate alarm signal means (54).

4. A printer according to claim 1, characterized by memory means (40) for delaying the signals supplied by said character generating means (36) to said signal shaping means (42) in dependence on the distance between each printing element (20) and an associated optical sensing element (22) and on the speed of each printing element (20) relative to the record medium (10).

5. A printer according to claim 1, characterized by a pulse generator (44) for providing signals to said character generating means (36) to establish a pulsing signal for said drive means.

6. A printer according to claim 1, characterized by a plurality of printing elements (20) disposed in a linear array and each having an optical sensing means (22, 48, 50) associated therewith.

7. A printer according to claim 1, characterized in that each printing element (20) is included in an ink jet print head moveable along a line of printing and that the associated optical sensing means (22, 48, 50) includes a sensing element (22) carried on said print head for movement therewith.

8. A printer according to claim 1, characterized in that each printing element (20) is included in an ink jet print head moveable along a line of printing and that the associated optical sensing means (22, 48, 50) includes a sensing element (22, 28) on each side of said print head for movement therewith.

9. A printer according to claim 1, characterized in that each sensing means (22, 48, 50) includes logic means (50) for recognising the signals representing the sensed dots.

10. A printer according to claim 1, characterized in that each printing element (20) is included in an ink jet print head and is driven by a piezoelectric crystal element.

FIG. 1

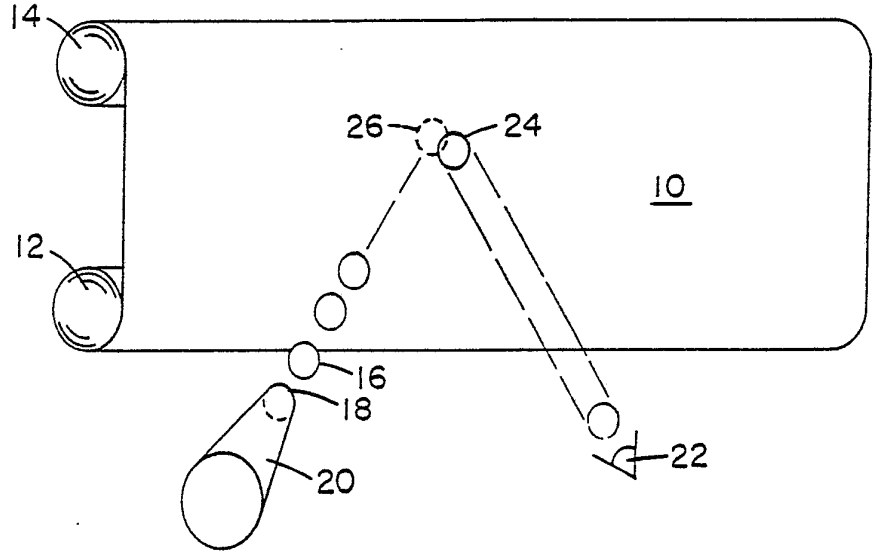


FIG. 2

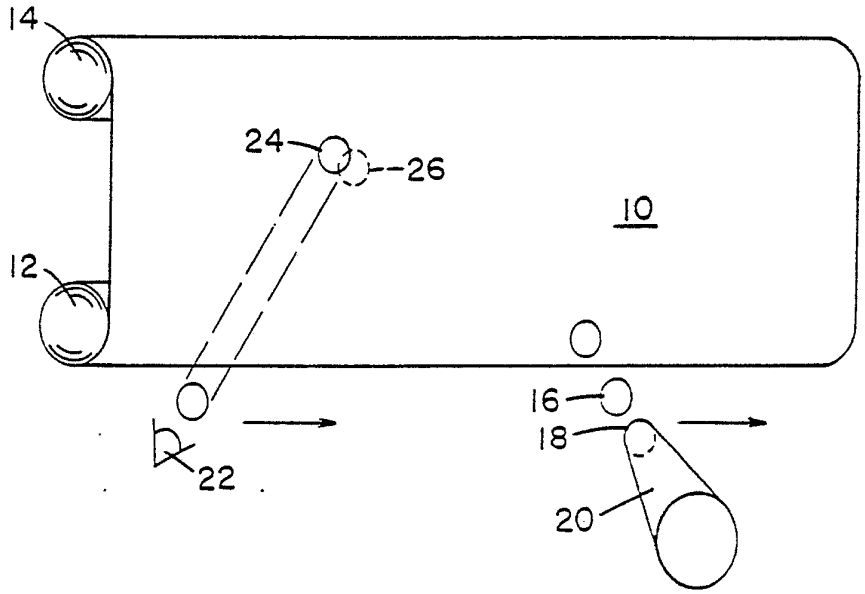


FIG. 3

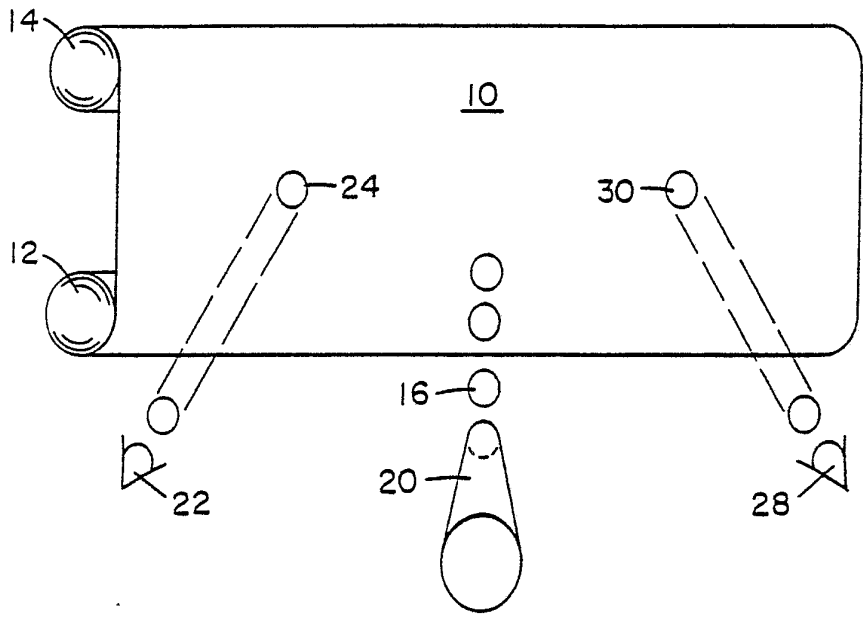


FIG. 4

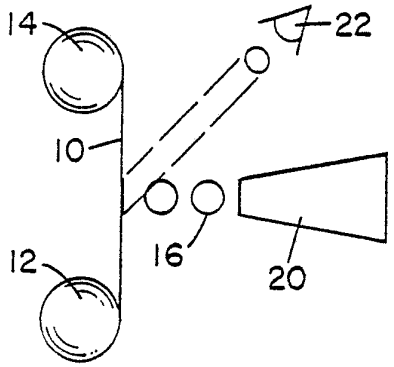


FIG. 6

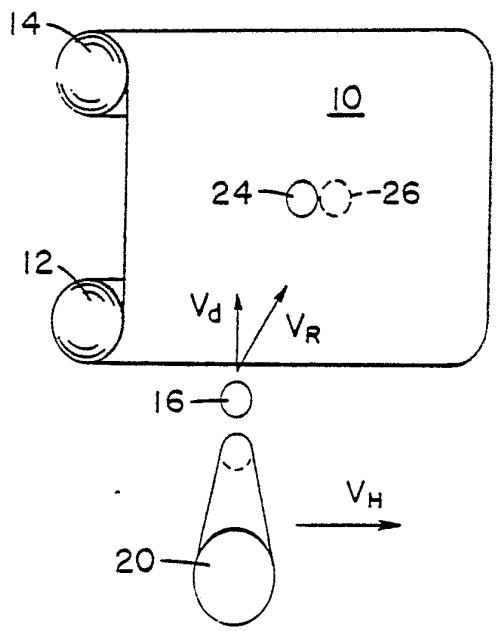
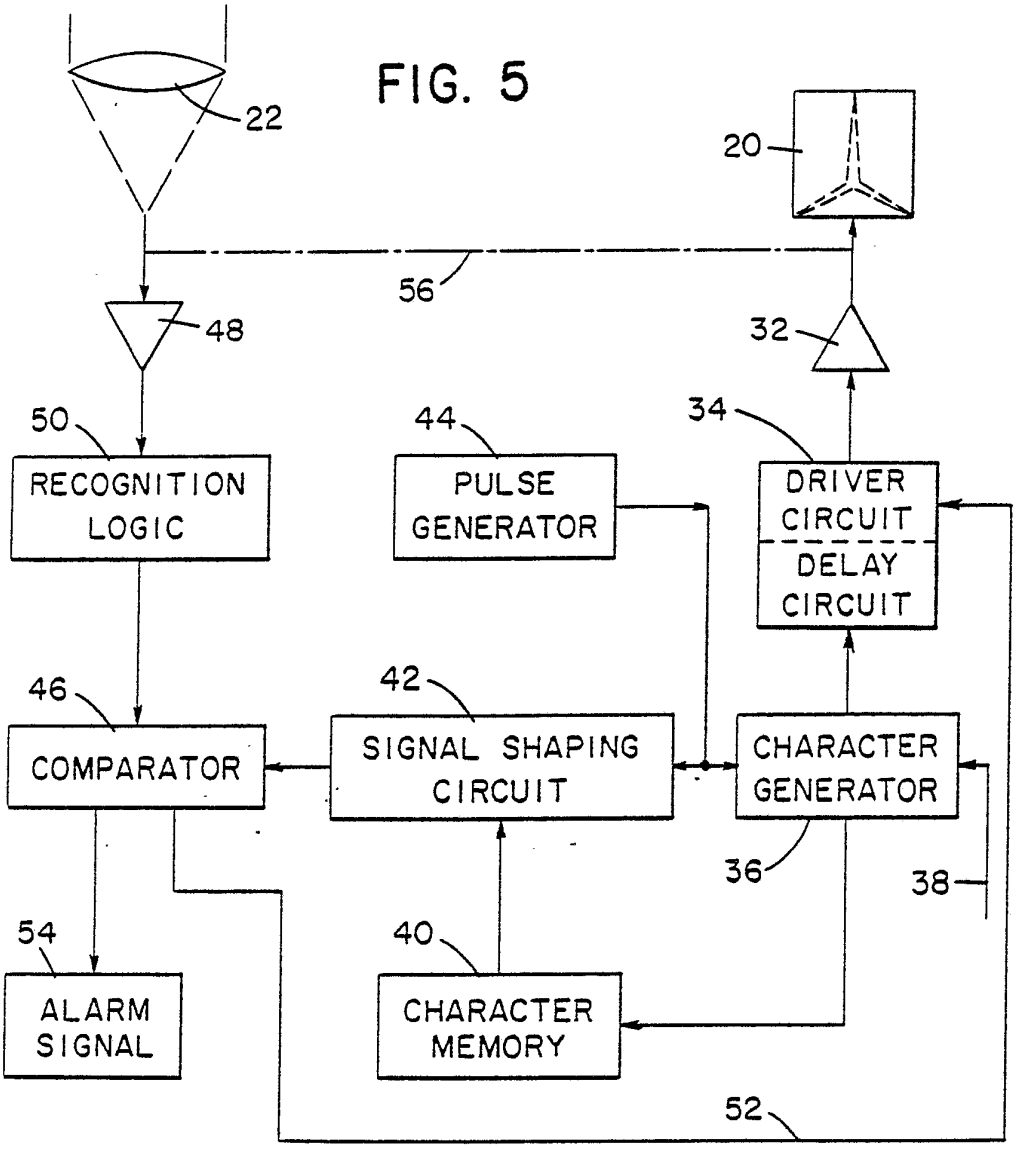


FIG. 5



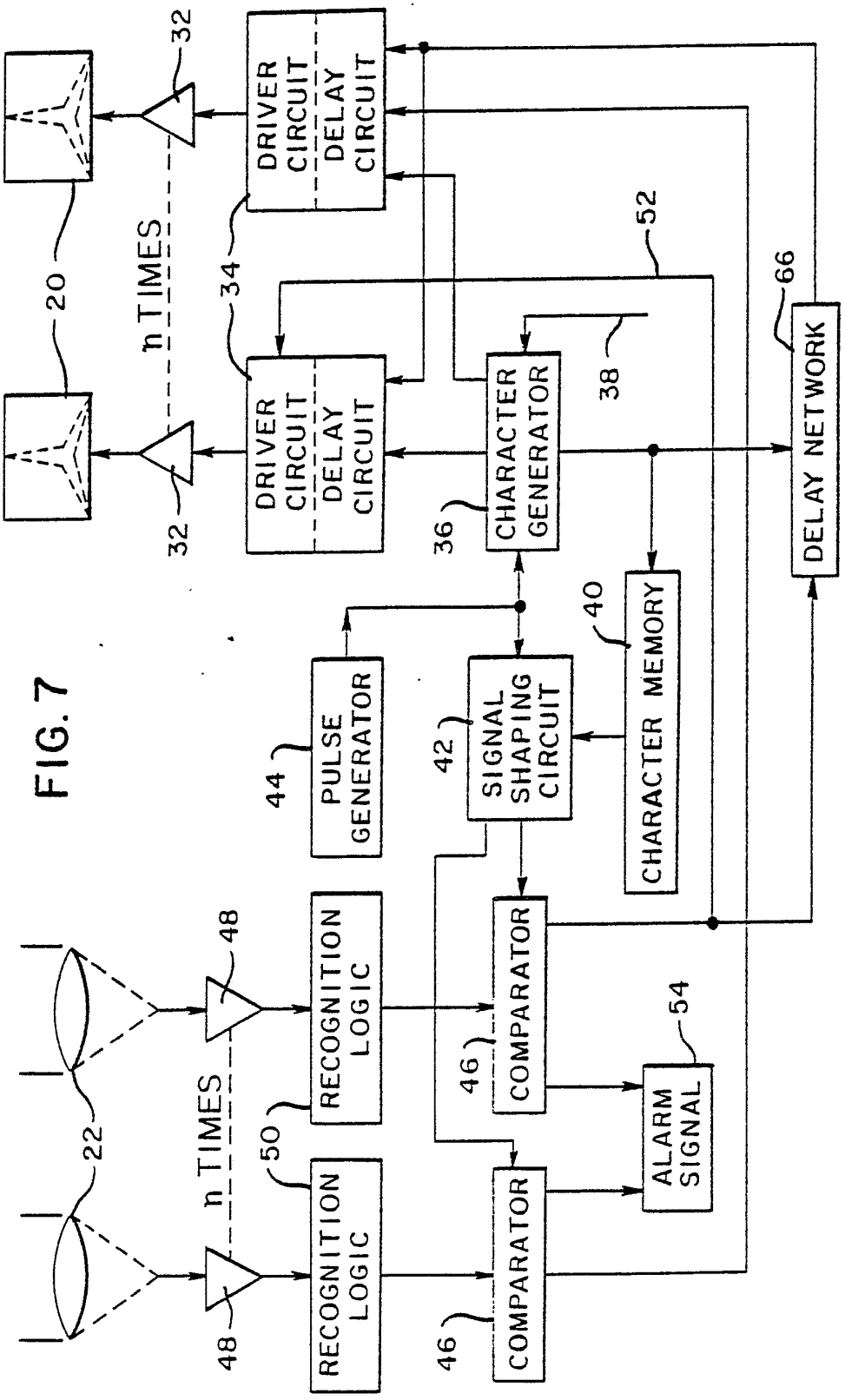


FIG. 7

FIG. 9

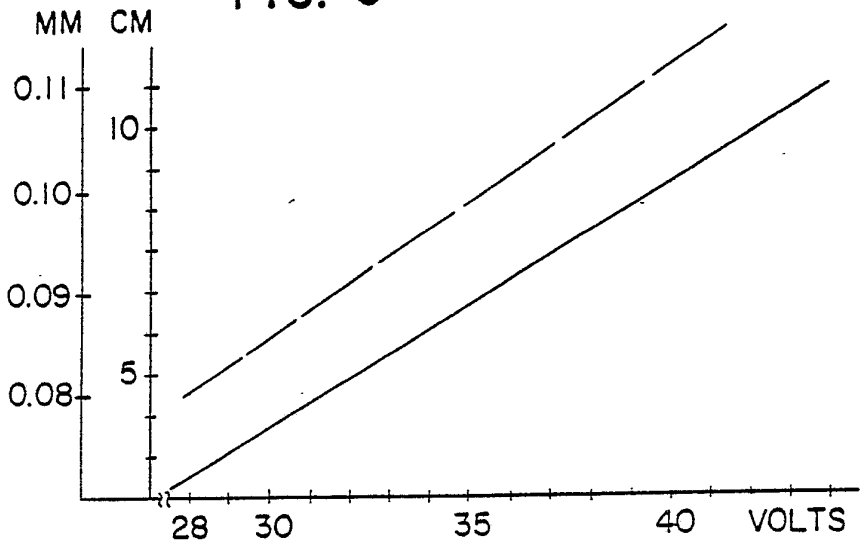
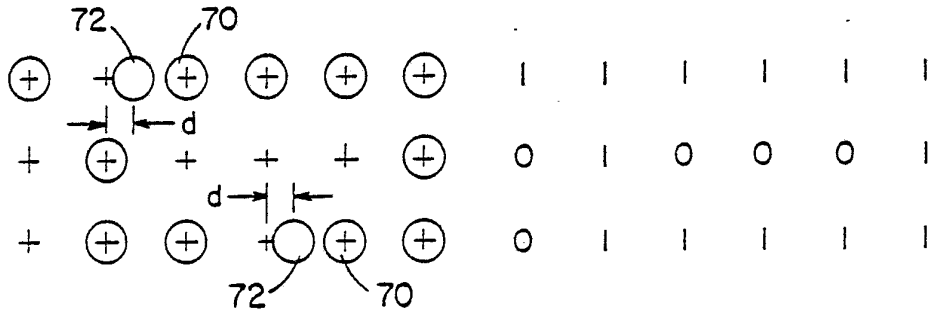


FIG. 8



PRINTING IMAGE INFORMATION PATTERN

FIG. 10

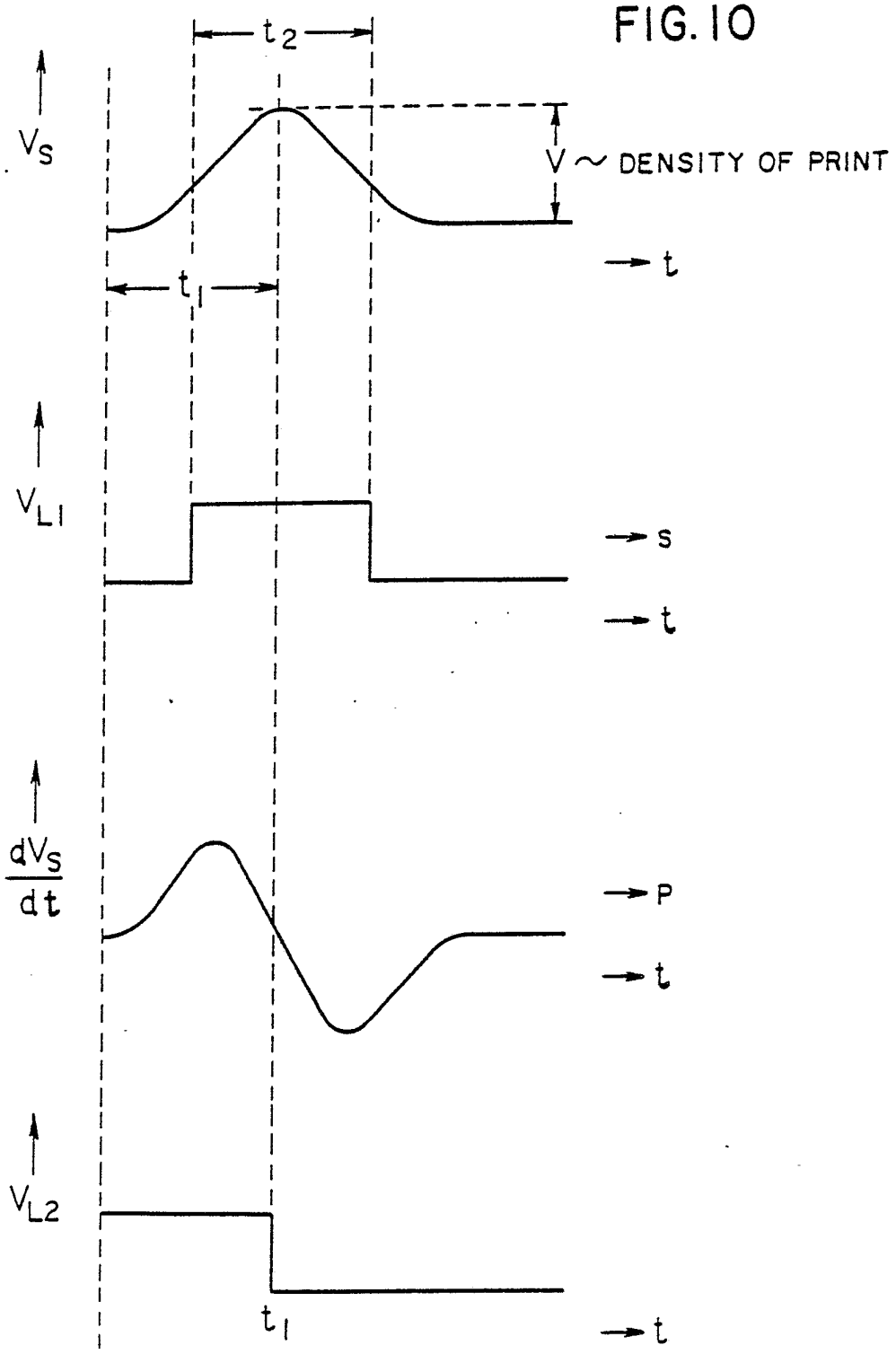


FIG. 11

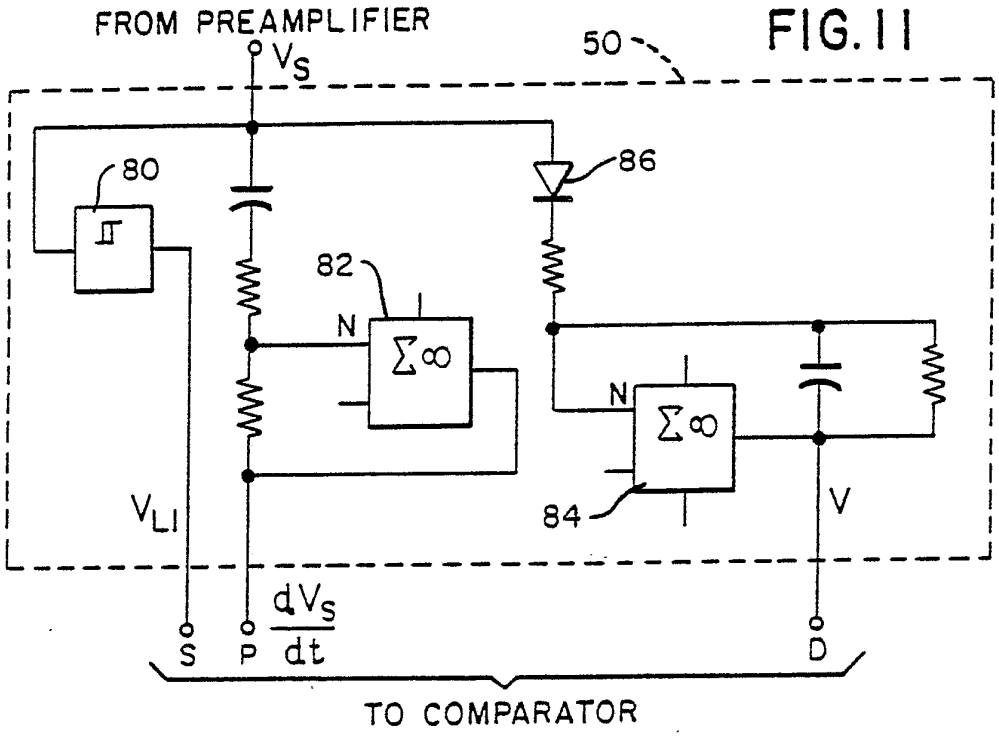


FIG. 12

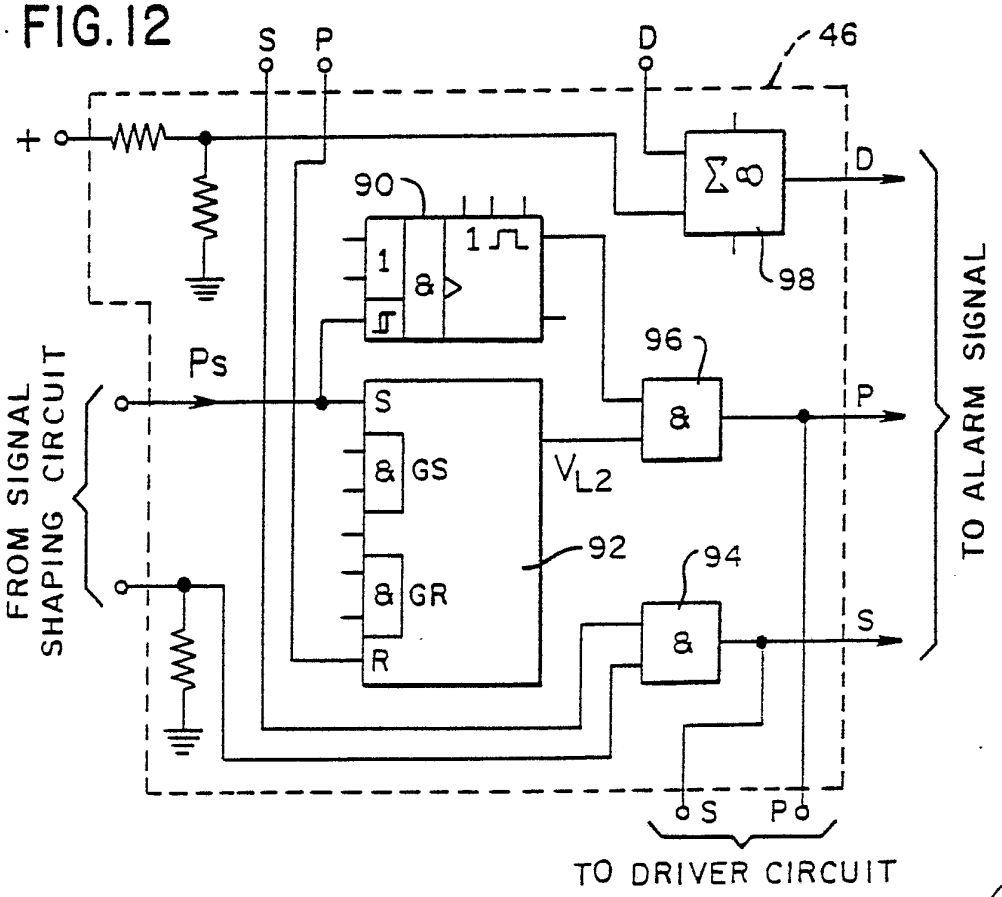
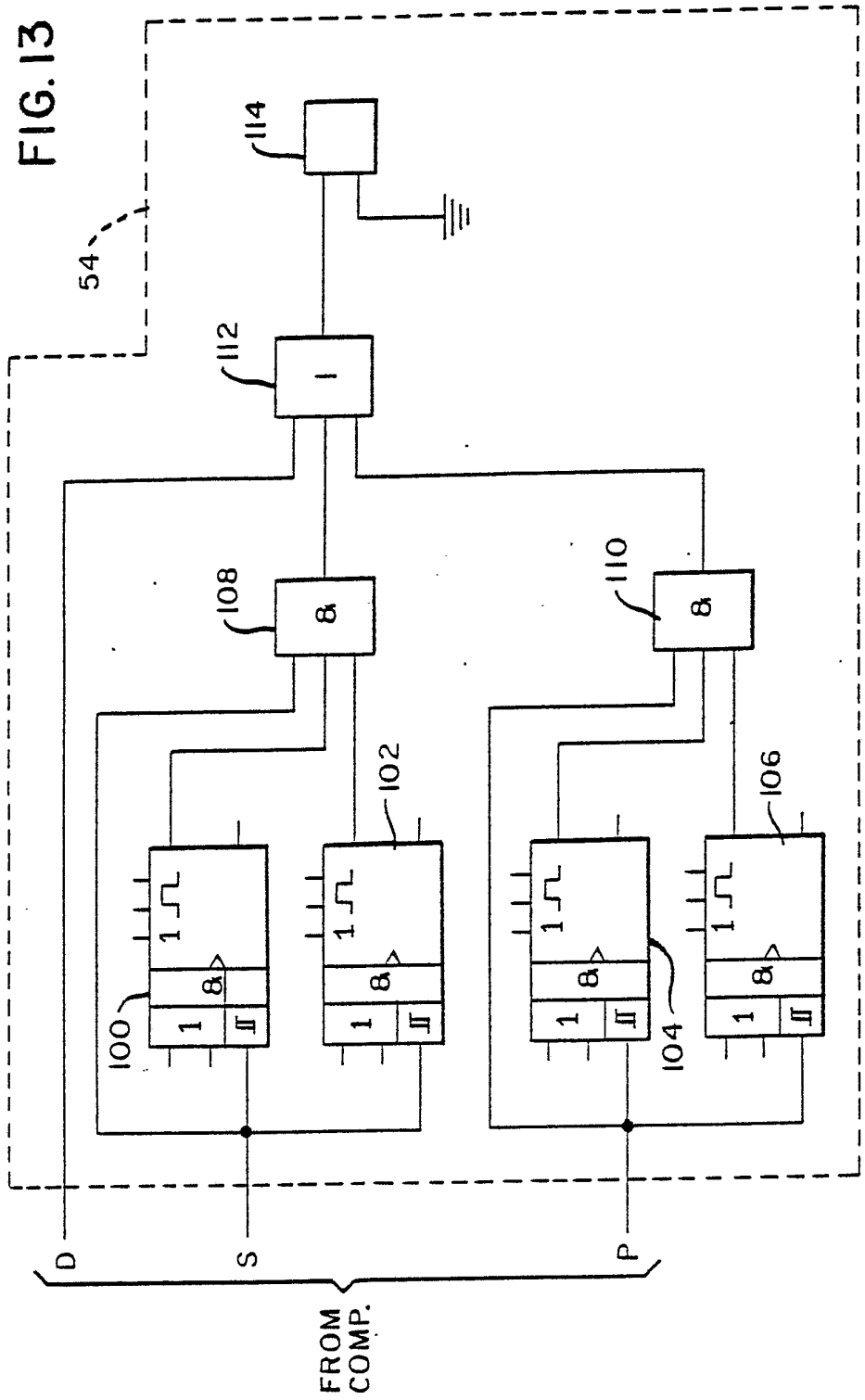


FIG. 13



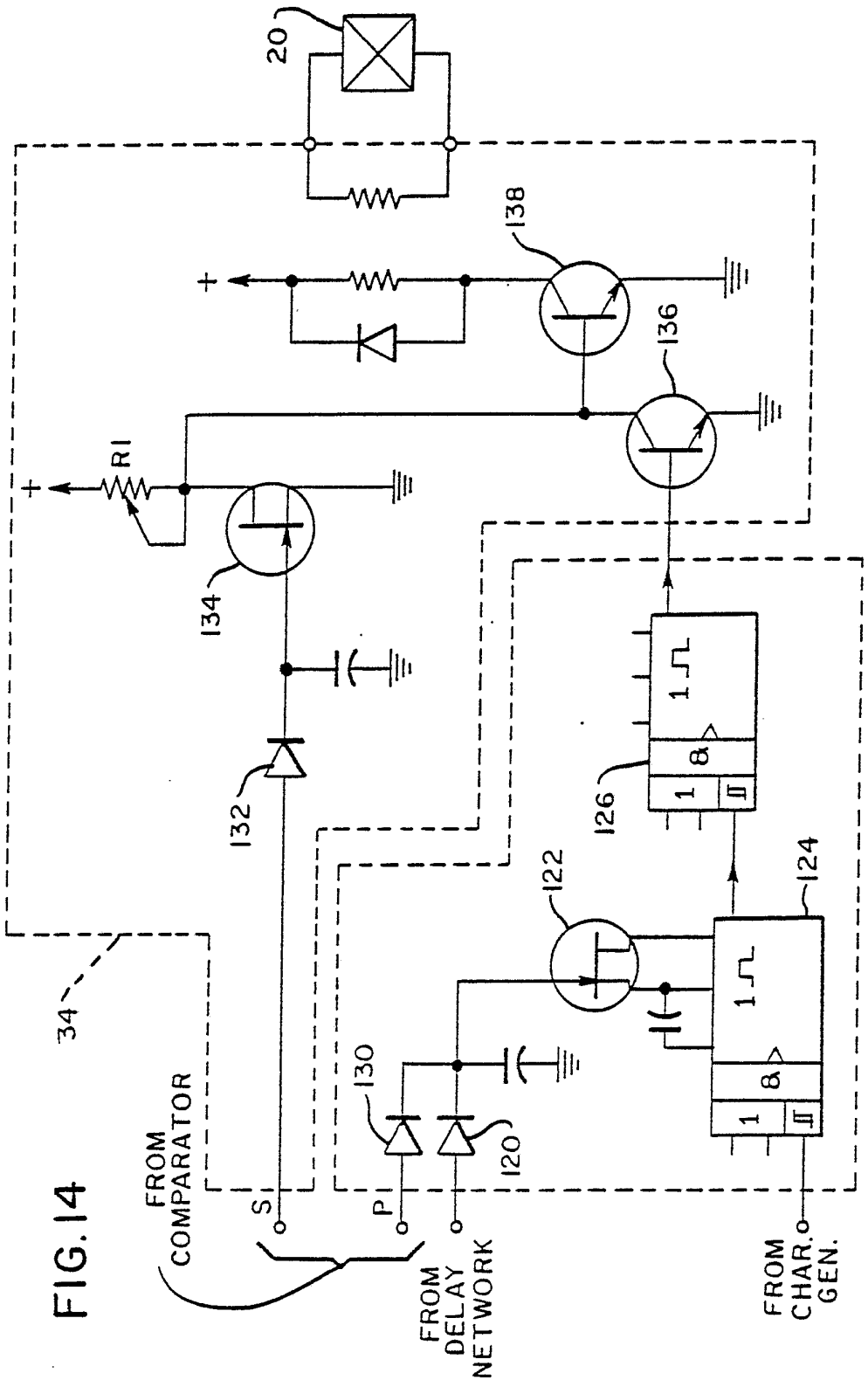


FIG. 14

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 81/01367

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. Cl.[3] G01D 15/18, 18/00
U.S.Cl. 346/75

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	346/75,140R,140PD,76PH 400/120-126

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
P,A	US,A, 4,255,754, Published 10 March 1981, Crean et al.	1-10
A	US,A, 4,136,345, Published 23 January 1979, Neville et al.	1-10
A	US,A, 4,060,813, Published 29 November 1977, Yamada et al.	1-10
A	US,A, 4,067,019, Published 3 January 1978, Fleischer et al.	1-10
A	US,A, 4,063,253, Published 13 December 1977, Ito et al.	1-10

* Special categories of cited documents: [15]

"A" document defining the general state of the art

"E" earlier document but published on or after the international filing date

"L" document cited for special reason other than those referred to in the other categories

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but on or after the priority date claimed

"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention

"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
25 November 1981	12 JAN 1982
International Searching Authority [1]	**Signature of Authorized Officer** [20]
ISA/US	R. J. Brady

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