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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification [6] :
H04N 1/23, 1/40, H01N 1/46

A1

(11) International Publication Number: WO 95/11565

(43) International Publication Date: 27 April 1995 (27.04.95)

(21) International Application Number: PCT/US94/11920

(22) International Filing Date: 19 October 1994 (19.10.94)

(30) Priority Data:
08/139,792 22 October 1993 (22.10.93) US

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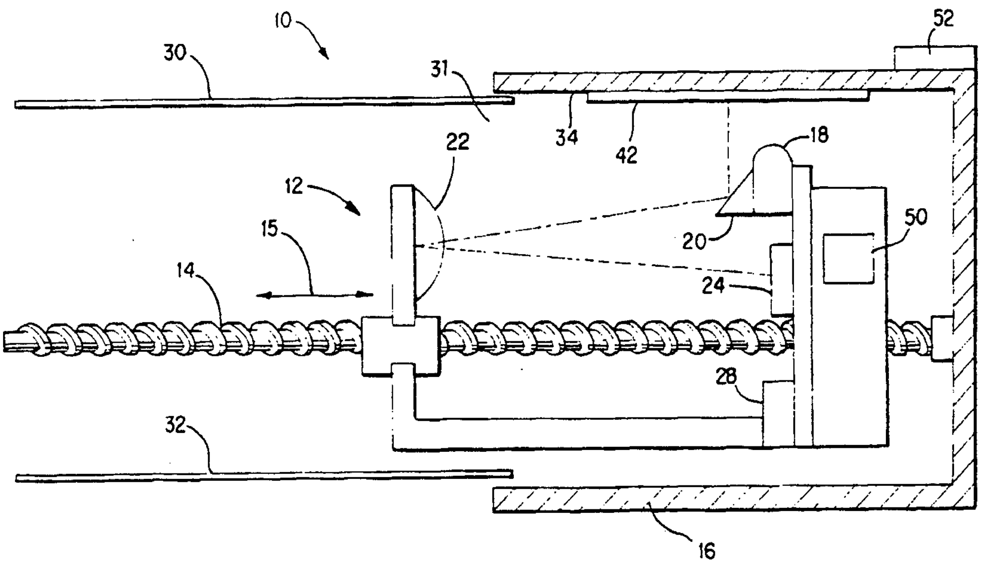
(81) Designated States: JP, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: METHOD AND APPARATUS FOR ELECTRONIC IMAGE DENSITY ADJUSTMENT



(57) Abstract

A method and apparatus of varying an image density of a scanning system (10) uses a calibration patch (42) and a variable image density setting device. A calibration patch (42) having a known density is scanned to determine a neutral threshold for each reading element (24) of the scanner. Subsequently, a user varies an image density setting device to increase or decrease the image density. In such calibration, a desired threshold of each reading element (24) is determined based on a desired image density setting and a neutral image density setting of each reading element (24). When the document (30) is subsequently scanned, the scanned response is compared to the desired threshold for each reading element (24) to determine if a dot should be printed.

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METHOD AND APPARATUS FOR ELECTRONIC IMAGE DENSITY ADJUSTMENT

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to a scanner or copier having a scanner. More particularly, this invention relates to a method and apparatus for adjusting the density of an image in a scanning system.

2. Description of Related Art

Historically, copies of document originals have been produced by a xerographic process wherein the document original to be copied is placed on a transparent platen, either by hand or automatically through the use of a document handler, and the document is illuminated by a relatively high intensity light. Image rays reflected from the illuminated document are focused by a suitable optical system onto a previously charged photoconductor. The image light rays function to discharge the photoconductor in accordance with the image content of the document to produce a latent electrostatic image of the document on the photoconductor. The latent electrostatic image so produced is thereafter developed by a suitable developer material. The developed image is transferred to a sheet of copy paper brought forward by a suitable feeder. The transfer image is thereafter fixed by fusing to provide a permanent copy. In order to adjust the density of the image formed on the copy sheet, various parameters such as exposure intensity, transfer voltage, and/or developer bias voltage are varied.

More recently, interest has arisen in electronic imaging where, in contrast to the above described xerographic system, the image of the document is converted to electronic signals or pixels and these signals, which may be processed, transmitted over long distances, and/or stored, are used to produce copies. In such an electronic imaging system, rather than focusing the light image onto a photoreceptor for purposes of discharging a charged surface prior to xerography development, the optical system focuses the image rays reflected from the document onto an image reading array that serves to convert the image rays into electronic signals. These signals could be used to create an image by some means such as operating a laser beam to discharge a xerography photoreceptor, or by operating some direct marking system such as an ink jet or a thermal transfer printing system. Some thermal transfer systems that use a thermal printhead and ink ribbon in a portable copier are disclosed, for example, in U.S. Patent No. 5,187,588 to Denis J. Stemmle, the disclosure of which is incorporated herein by reference, and in copending U.S. Patent Application No. 08/(Attorney Docket No. JAO 29010), entitled "PORTABLE COPIER AND METHOD OF USING A PORTABLE COPIER", filed October 22, 1993, to Denis J. Stemmle and Egon Babler, the disclosure of which is incorporated herein by reference.

In electronic imaging systems, the density of the output image can be corrected or changed by comparing the output of each reading element with a threshold to determine whether the read pixel is lighter or darker than the threshold.

U.S. Patent No. 4,602,293 to Sekine discloses an apparatus having a shading correction reference surface that is scanned prior to scanning a manuscript. The output of a photoelectric converter (i.e., an image sensor array) produced while scanning the shading correction reference surface is converted to a digital signal and stored in a memory as a reference. Subsequently, while the manuscript is scanned, the output of each cell of the photoelectric converter is applied to a comparator along with an analog version of the corresponding reference signal in memory to effect shading correction of the output.

U.S. Patent No. 4,383,275 to Sasaki et al. discloses a system for providing read-out level compensation in an optical reader system. In operation, the system first reads a white background to obtain a reference output. The reference output is reversed and stored in a memory. The actual sensor output derived from an original is multiplied by the memorized, reversed reference output to get a compensated video signal.

U.S. Patent No. 4,520,395 to Abe discloses a system for correcting shading or non-uniformity in a photosensitive element array due to light source, lens, optical transmission, and sensor characteristics. The system employs a memory having a number of cells corresponding to the number of photo elements positioned along a linear photosensitive array. The sensor output of each respective element is successively compared with data value stored in a corresponding memory cell. With each successive output of the linear array, the data stored in the memory is updated by determining the larger data value signal and then storing that signal in the corresponding memory cell. The stored data for each line is converted with a waiting factor and multiplied by the sensor output to produce a compensated output.

A difficultly with these prior art systems is often the variance in operation of the sensors or reading elements themselves. This causes non-uniformity in response, as well as a varying effect of each sensor in illumination levels caused by optics and lamp degradation. In pending U.S. Patent Application Serial No. 07/782,200, entitled "SCAN IMAGE PROCESSING" to Robert P. Robideau, the disclosure of which is incorporated herein by reference, a low cost and low memory method of changing the density of a scanned image is provided. Prior to any copying or scanning operation, the image scanner is moved to a location below a gray patch of known density. The gray patch is imaged by the image sensor in a normal fashion and the response of each photosite on the sensor chip is recorded. This is referred to as a "calibration sequence." The scanner then scans a document in a normal fashion, comparing the sensor response for each pixel on the document to the previously recorded response to the gray patch. Each document pixel is declared to be either white or black depending on whether the response is above or below the response for the gray scale reading for that particular sensor. To change the density of a captured image, the color density of the gray patch is changed prior to the calibration sequence. For a darker copy, the operator moves a lighter gray patch into position prior to the calibration sequence so that the threshold between printing black dots would be lowered.

The above described apparatus has a disadvantage in that only four different calibration patches are provided. While it is conceivable that more than four gray patches may be provided, it is limited to a small number of calibration settings. Therefore, the image density of the output print is limited to only a small number of color densities.

SUMMARY OF THE INVENTION

This invention solves the above and other problems of the prior art. In a first preferred embodiment, a method is provided for varying an image density of a scanning system having a plurality of reading elements. A calibration patch having a known image density is scanned. A neutral threshold is determined for each reading element based on a signal response of each reading element from scanning the calibration patch. The neutral threshold for each reading element is associated with a neutral image density setting for each reading element. An operator then varies an image density setting device to set a desired image density setting. Based on the desired image density setting and the neutral image density setting of each reading element, a desired threshold is determined for each reading element. Subsequently, a document is scanned by the reading elements in normal fashion. It is then determined whether to print a mark corresponding to each reading element based on a comparison between the scanning response of each reading element and the desired threshold of each reading element.

In a second preferred embodiment, a calibration patch is again scanned with the plural reading elements. A plurality of neutral thresholds (i.e., one for each reading element) are determined based on a signal response of each reading element to the calibration patch scanning. The total number of different neutral thresholds is less than the number of total reading elements, although each reading element is assigned a neutral threshold. Each neutral threshold is associated with a neutral image density setting. The neutral thresholds are stored in a first memory. An operator then varies an image density setting device to a desired image density setting. A desired threshold of each reading element is determined based on the desired image density setting, the neutral image density setting, and the neutral thresholds in the first memory. The document is then scanned with all of the reading elements in a normal manner. Subsequently, it is determined whether to print a mark corresponding to each reading element based on a comparison between the scanning response of each reading element and the respective desired threshold corresponding to each reading element.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in detail with reference to the following drawings in which like reference numerals refer to like elements and wherein:

Fig. 1 is a schematic illustration of a machine incorporating a calibration control system in accordance with the present invention;

Fig. 2 is a graph illustrating the response curves of reading elements of a scanner to 3 different gray patches;

Fig. 3 is a block diagram of a first preferred embodiment of the present invention;

Fig. 4 is a flow chart of a method performed by the first preferred embodiment;

Fig. 5 is a schematic illustration of the user operable controls of one type of image density setting device that can be used with the invention;

Fig. 6 is a circuit diagram of the image density setting device of Fig 5;

Fig. 7 is a flow chart of a method performed by a second preferred embodiment; and

Fig. 8 is a block diagram of the second preferred embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 1 illustrates a combined input/output scanner 10, such as can be used in the portable copier disclosed in the above-incorporated U.S. Patent No. 5,187,588 and U.S. Patent Application No. 07/782,200. The scanner 10 generally includes the carriage assembly 12 mounted on a lead screw 14 for reciprocal motion along the lead screw 14 in relation to the machine frame 16 as illustrated by the carriage motion arrows 15. An array of light emitting diodes 18 are mounted on carriage 12 to project light upwardly. Although the array 18 preferably comprises a number of light emitting diodes, other embodiments are similarly capable of using light sources such as a laser beam.

The projected light is reflected from an inner surface 34 of the machine frame 16 to the mirror 20. The reflected light subsequently travels to the lens 22 and finally to an array of reading elements 24. In the preferred embodiment, the array of reading elements 24 includes 3 sensor chips (not shown) with each sensor chip having 128 photosites. Accordingly, a total of 384 photosites are provided in the preferred embodiment. Each of the 384 photosites outputs a signal in response to the light it receives as is known in the art. The number of sensor chips and photosites in the scanner may vary depending on the type of scanner. Similarly, other types of reading elements may be used. Machine frame 16 also includes a suitable printing device 28 such as, for example, a thermal printhead that is usable with an ink transfer ribbon, or an ink jet printhead.

Fig. 2 illustrates the responses of the photosites to 3 different calibration patches, each having a different level of gray. In this example, three separate chips, each having 128 photosites are provided. Lines A, B and C represent the responses of the 384 photosites to calibration patches having gray level densities of 0.17, 0.37 and 0.57, respectively. As can be seen, the photosites do not all respond equally to a constant input, and the response of photosites located at ends of the chips is reduced. Additionally, differences in response are less for darker inputs (i.e., Line C).

Fig. 1 shows the carriage assembly 12 located at a home position where the scanner is aligned with a calibration patch as detailed below. When scanning a stationary document 30, the carriage assembly 12 moves to a start of scan position to suitably position the LEDs 18 and mirror 20 at the right edge 31 of the document 30. The carriage assembly 12 then moves further to the left so that the LEDs 18 project light to the document 30. The document 30 reflects the light to the mirror 20, the lens 22, and finally to the array of reading elements 24 that sense the amount of reflected light from the document 30.

Similarly, when printing onto stationary copy paper 32, the carriage 12 moves to a start of print position at the right edge of the copy paper 32. The printing device 28 moves with the machine carriage 12 across the copy paper 32 to suitably form dots on the copy paper 32. As described below, the decision whether to print a dot depends on whether the reflected document image exceeds a desired threshold calibrated for each reading element 24.

The calibration process of the preferred embodiment will now be described. A single calibration patch 42 is mounted on the inside surface 34 of the machine frame 16. The calibration patch 42 preferably is of a continuous gray color. Although the color density of the gray color can be of any level, in a preferred embodiment, it has a density of about 0.37, and thus produces a response curve similar to Line B in Fig. 2.

As illustrated by the flow chart of Fig. 4, the array of light emitting diodes 18 is suitably positioned under the calibration patch 42 in step 100. The response of each reading element 24 to the calibration patch 42 is determined in step 104. The response to the calibration patch 42 represents what will be referred to as a neutral threshold ($C_{neutral}$) for each respective reading element 24. The neutral threshold ($C_{neutral}$) of each reading element 24 corresponds to the response of that reading element to an image having a predetermined, or neutral density, and is associated with a neutral image density setting (to be explained below). The neutral threshold ($C_{neutral}$) of each reading element 24 is stored in a memory of control circuit 50 during step 106. Typically, each reading element 24 is capable of distinguishing up to 256 different densities of the color gray. Therefore, in order to store the response of each reading element 24, 8 bits of memory are required for each reading element 24. In the preferred embodiment utilizing 384 photosites, 384 8-bit sequences corresponding to 384 neutral thresholds ($C_{neutral}$) are stored in a memory in control circuit 50.

Subsequently, the operator of the scanner 10 is given the option of varying a desired image density setting in step 112. The desired image density setting represents a desired image density. The desired image density setting is varied using an image density setting device 52, as shown in Fig. 5. The image density setting device 52 can be any of several types of devices capable of producing a variable output. Preferably, the device provides an infinite number of different outputs (settings) between two extreme (minimum and maximum) outputs (settings). In one embodiment, the image density setting device 52 includes a slidable button 54, as shown in Fig. 5. Devices other than a slidable button, such as, for example, a rotating knob or separate buttons for increasing and decreasing the setting may be provided. The button 54 is suitably connected to a potentiometer in the preferred embodiment as is well known in the art in order to vary the output of the potentiometer when button 54 is moved.

The operation of the image density setting device 52 will now be described with respect to the preferred embodiment using the potentiometer P shown in Fig. 6. The output of potentiometer P is determined, preferably when button 54 is located at a neutral, for example, central position, as shown in Fig. 5. For illustration purposes, assume that the output at such a position is 50. This value is referred to as $S_{neutral}$. This value, $S_{neutral}$, is associated with the output of the reading elements 24 when scanning the calibration patch (this corresponds to a reading element output of $C_{neutral}$, which can be a different value for each reading element 24).

In step 112, the operator varies the output of the potentiometer P by moving button 54 to the left for a lighter image or to the right for a darker image. This new output (S_{new}) corresponds to the desired image density. Accordingly, the output between points A and B (Fig. 6) varies with the potentiometer's resistance as button 54 is moved. The selected output (S_{new}) falls between a maximum output value (darkest image) and a minimum output value (lightest image) of the potentiometer P. For illustration purposes, the maximum output corresponds to a 100 value (S_{max}) while the minimum output corresponds to a zero value (S_{min}). Accordingly, the selected output (S_{new}) can be of any value between 0 and 100. Although the above embodiment was described with respect to a potentiometer P having an output that varies between a 0 value and a 100 value, these values are solely for illustration purposes. Other values can be representative of the potentiometer's output. For example, in another embodiment $S_{neutral}=0$, $S_{min}= -10$ and $S_{max}=+10$.

Once a selected output (S_{new}) is obtained, a desired threshold (C_{new}) is computed for each reading element 24 in step 114 using a formula represented by either circuitry or as a program in a microprocessor. The formula relates the neutral threshold ($C_{neutral}$) of each reading element 24 with the selected output (S_{new}) of the image density setting device 52.

In the preferred embodiment described above, the formula can be the following equation (1):

$$C_{new} = C_{neutral} + K \times (S_{new} - S_{neutral}) \quad (1)$$

where K is a constant.

Other formulas also can be used to determine the desired threshold (C_{new}) of each reading element 24. For example, the following equations (2) and (3) are provided, although others are within the scope of the invention:

$$C_{new} = C_{neutral} + K \times (S_{new} \div S_{neutral}) \quad (2)$$

$$C_{new} = C_{neutral} + K \times (S_{new} - S_{neutral}) \div (S_{max} - S_{min}) \quad (3)$$

When used with 384 reading elements as described above, step 114 produces 384 desired thresholds (C_{new}). The desired threshold (C_{new}) of each reading element 24 is stored in a memory of control circuit 50 in a 8-bit sequence similar to that described above with respect to the stored neutral thresholds ($C_{neutral}$). The desired threshold (C_{new}) of each reading element 24 is associated with a desired image density (that is, the setting output by device 52). Therefore, each of the desired thresholds (C_{new}) represents a calibration of the respective reading element 24 to the desired image density. The new or desired thresholds C_{new} for each reading element 24 form a response curve that approximates the response curves of Fig. 2, except that it is possible to generate a large number of response curves from a single calibration patch.

Subsequently, the document 30 is scanned in step 116 as described above. The response of each reading element 24 to the reflected light is compared to the desired threshold (C_{new}) of the same respective reading element 24 in step 118. The comparison between the desired threshold (C_{new}) and the response of each reading element 24 is described in pending U.S. Patent Application

S.N. 07/782,200, the disclosure of which is incorporated herein by reference, and results in data representing either a mark or no mark to be stored and/or printed, depending on whether the response is greater than C_{new}. For example, when the document image signal of a respective reading element 24 is greater than the desired threshold (C_{new}) of the same respective reading element 24, then it is determined that a dot is to be formed by printing device 28. When the document signal is less than the desired threshold (C_{new}) of the same respective reading element, then it is determined that no dot is to be printed.

Accordingly, the above described method defines a threshold between black (for example) and white on a scanner. In accordance with the above described embodiment, the operator is able to adjust the output density of the scanner 10 by modifying the recorded response based on the setting of the potentiometer P (or other operator adjustable/machine readable device) to achieve a wide choice of density settings in a copier or scanner.

The control circuit 50 of the embodiment described above will now be described with reference to the block diagram of Figure 3. In block 68, a neutral threshold ($C_{neutral}$) is determined for each of the photosites (reading elements 24) based on a signal response to the calibration patch 42 as described above. Each of the neutral thresholds ($C_{neutral}$) are stored in threshold memory 70 in an 8-bit sequence for each of the respective 384 photosites. The desired image density is input with density input device 52, for example, a potentiometer P. Block 74 represents circuitry that implements any one of the respective formula (1), (2) or (3) utilized to convert the neutral threshold ($C_{neutral}$) into the desired threshold (C_{new}) based on the operator input image density setting S_{new} of the image density setting device 52, and the stored neutral density setting $S_{neutral}$, which was established in advance. The neutral threshold ($C_{neutral}$) for each of the 384 photosites also is used by circuitry 74 to determine the desired threshold (C_{new}) for each photosite. The desired threshold for each of the 384 photosites are subsequently stored in the threshold memory 70, for example, in another memory location composed of 8 bits for each of the 384 photosites. Alternatively, the values $C_{neutral}$ can be replaced with the values C_{new} in memory 70 because each time C_{new} is recalculated, the scanner can be positioned so that readings are taken from calibration patch 42 to obtain $C_{neutral}$.

The 8-bit digital signal stored in the threshold memory 70 for each reading element 24 is converted by the digital to analog converter 78 and input into the negative input of comparator 80. The response of each of the reading elements when the document 30 is scanned is determined in block 76. The analog readings of each of the respective reading elements 24 are input from block 76 into the positive input of the comparator 80. The output of the comparator 80 is determinative of whether the desired threshold (C_{new}) has been exceeded by the respective reading element 24. The results of comparator 80 can be used immediately for printing, or can be stored for later use.

A second embodiment will now be described with reference to Figs. 7 and 8. This second embodiment requires less memory and can determine the desired threshold values (C_{new}) faster than the first embodiment. This is advantageous, especially when implemented in the portable copier disclosed, for example, in the above-incorporated U.S. Patent No. 5,187,588, which prints in bands on a copy sheet, because the output image density can be changed with each band, and without the scan carriage having to pause between bands to redetermine the threshold values C_{new}.

A preliminary neutral threshold of each reading element 24 is obtained in a similar manner to that described above by positioning the array of light emitting diodes 18 over a calibration patch 42 in steps 120 and 122. However, rather than storing 384 8-bit sequences representing the response of each reading element as in the first preferred embodiment, only 16 8-bit sequences are ultimately stored and updated in the second preferred embodiment.

Based on the preliminary neutral thresholds determined in step 122 for each of the 384 reading elements, 16 neutral thresholds ($C_{neutral}$) are selected to represent the outputs of all 384 of the reading elements 24 in step 124. This is possible because, although 256 different outputs are possible, the outputs of the 384 reading elements usually span a relatively narrow portion of the entire possible range of response. Thus, the highest and the lowest outputs of the 384 reading elements are obtained, and then this range is divided into 16 different possible $C_{neutral}$ values. The $C_{neutral}$ values of the 384 reading elements are then assigned one of the 16 different $C_{neutral}$ values, based on which one of the 16 $C_{neutral}$ values is closest to the actual output for that reading element when it scans the calibration patch 42. Accordingly, the selected neutral threshold ($C_{neutral}$) of each reading element 24 does not always correspond exactly with the preliminary neutral threshold actually measured for each reading element 24. Therefore, the calibration method of the second preferred embodiment may result in some small rounding errors. Other methods of selecting the 16 neutral thresholds (C_{new}) are also possible and are within the scope of this invention. Of course, a number of neutral thresholds other than 16 also can be determined.

The 16 selected neutral thresholds ($C_{neutral}$) are stored in both a gray palette 64 and a new palette 66 in step 125. Each of the 16 selected neutral thresholds ($C_{neutral}$) is represented by an 8-bit sequence. Rather than storing an 8-bit sequence for all 384 reading elements, a 4-bit pointer is stored in step 126 for each reading element 24. The 4-bit pointers are stored in threshold memory 62. Each pointer corresponds to one of 16 locations in the new palette 66. Because only 16 neutral thresholds ($C_{neutral}$) are stored, only 4 bits are needed to represent the pointer for each reading element 24.

In step 128, the desired image density setting is obtained from the image density setting device 52 in a manner similar to that of the first preferred embodiment. Rather than computing a desired threshold for all 384 reading elements as in the first embodiment, the second embodiment only obtains 16 desired thresholds (C_{new}) in step 130 using the formula circuitry 74, which uses data relating to the desired image density setting (S_{new} from device 52), the predetermined value $S_{neutral}$, and the 16 neutral image density settings ($C_{neutral}$) stored in the gray palette 64. The new 16 desired thresholds (C_{new}) are stored in the new palette 66 during step 132 in the same memory locations corresponding to the original 16 neutral thresholds. Accordingly, the 16 desired thresholds (C_{new}) are written over the thresholds previously stored in the new palette 66. Therefore, in the second embodiment, when the operator desires to change the image density by varying the image density setting device 52, only the values in the new palette 66 are modified. Therefore, only 16 8-bit sequences are modified, rather than 384 8-bit sequences in the first embodiment. This results in a quicker update of the desired threshold.

In one embodiment, the scanner 10 recalibrates the desired threshold after each scan line of the document. According to that embodiment, steps 128, 130, and 132 are performed after each scan line of the printer. Therefore, the operator is able to adjust the output density while the scanner is in operation.

Because each of the reading elements 24 is only referenced by a 4-bit pointer stored in memory 62, each one of the reading elements 24 corresponds to one of the 16 desired thresholds (C_{new}).

In step 134, the document 30 is scanned in a manner similar to that described above. Comparator 80 compares the scanning response of each reading element 24 with the respective desired threshold (C_{new}) for each reading element in step 136. As previously described, each reading element 24 is represented by a pointer that points to one of the 16 desired thresholds (C_{new}). Therefore, the scanning response of each respective reading element 24 is compared with one of the 16 desired thresholds (C_{new})in the new palette 66. A print operation is determined based on whether the scanning response of each printing element 24 exceeds the respective desired threshold (C_{new}).

While this invention has been described in conjunction with a specific apparatus, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Additionally, while various preferred embodiments of this invention are described, it is understood that this invention is not limited to the preferred embodiments. Rather, this invention is intended to cover all alternatives, modifications and equivalents within the spirit and scope of the present invention as defined by the appended claims.

For example, the embodiments described above vary the image density by increasing or decreasing the number of dots printed (and/or stored). The image density also can be varied by increasing or decreasing the size of the dots that are printed (and/or stored).

What we claim is:

1. A method of calibrating a scanning system comprising the steps of:

scanning a calibration patch with a reading element;

determining a first threshold for said reading element based on a signal response of said reading element to said scanning, said first threshold associated with a first image density setting;

receiving a second image density setting from a variable image density setting device;

determining a second threshold for said reading element based upon the second image density setting and the first image density setting, said second threshold associated with a desired image density.

2. The method of claim 1, wherein said variable image density setting device includes a potentiometer, and the first image density setting represents a first potential level and the second image density setting represents a second potential level corresponding to the desired image density.

3. The method of claim 1, wherein said first threshold is stored in a first memory of said scanning system.

4. The method of claim 3, wherein said second threshold is stored in a second memory of said scanning system.

5. The method of claim 3, wherein said second threshold overwrites said first threshold stored in said first memory.

6. The method of claim 1, wherein the step of determining said second threshold includes subtracting said first image density setting from said second image density setting.

7. The method of claim 6, wherein the step of determining said second threshold further includes dividing a result of subtracting the first image density setting from the second image density setting by the

result of the difference between a maximum image density setting and a minimum image density setting.

8. The method of claim 1, wherein the step of determining said second threshold includes dividing said second image density setting by said first image density setting.

9. The method of claim 1, wherein said second threshold also is determined based upon said first threshold.

10. The method of claim 1, wherein said scanning system includes a plurality of said reading elements, and said first threshold and said second threshold are determined for all of said reading elements.

11. A method of varying an image density using a scanning system having a plurality of reading elements comprising the steps of:

scanning a calibration patch with said reading elements, the calibration patch having a known image density;

determining a neutral threshold of each reading element based on a signal response of each reading element to said scanning, said neutral threshold of each reading element associated with a neutral image density setting of the scanning system;

receiving a desired image density setting from a variable image density setting device;

determining a desired threshold of each reading element based upon the desired image density setting and the neutral image density setting, said desired threshold associated with a desired image density;

scanning a document with said reading elements; and

generating data indicating whether to print a mark corresponding to each reading element based on a comparison between the response of each reading element to said scanning of said document and the desired threshold of each reading element.

12. The method of claim 11, wherein the desired image density setting is a setting between a maximum setting and a minimum setting.

13. The method of claim 12, wherein the desired image density setting can be selected from an infinite number of settings between said maximum setting and said minimum setting.

14. The method of claim 11, wherein the step of determining said desired threshold includes subtracting said neutral image density setting from said desired image density setting.

15. The method of claim 14, wherein the step of determining said desired threshold further includes dividing a result of subtracting the neutral image density setting from the desired image density setting by the result of the difference between the maximum setting and the minimum setting.

16. The method of claim 11, wherein the step of determining said desired threshold includes dividing said desired image density setting by said neutral image density setting.

17. The method of claim 11, wherein the neutral threshold of each reading element is stored in a first memory.

18. The method of claim 17, wherein the desired threshold of each reading element is stored in a second memory.

19. The method of claim 17, wherein said desired threshold overwrites said neutral threshold stored in said first memory.

20. The method of claim 11, wherein the calibration patch is of a continuous gray color.

21. The method of claim 11, wherein said varying of the image density is accomplished by varying a number of dots that are printed.

22. The method of claim 11, wherein said varying of the image density is accomplished by varying a number of dots that are stored.

23. The method of claim 11, wherein said varying of the image density is accomplished by varying a size of dots that are printed.

24. The method of claim 11, wherein said varying of the image density is accomplished by varying a size of dots that are stored.

25. A method of calibrating a scanning system having a plurality of reading elements comprising the steps of:

scanning a calibration patch with said reading elements, the calibration patch having a known image density;

determining a plurality of neutral thresholds based on a signal response of each reading element to said scanning, a total number of the neutral thresholds being less than a total number of reading elements, each neutral threshold associated with a neutral image density setting, each reading element associated with one of the neutral thresholds;

storing said plurality of neutral thresholds in a first memory;

receiving a desired image density setting from an image density setting device;

determining a plurality of desired thresholds based upon the desired image density setting, the neutral image density setting, and the plurality of neutral thresholds, the number of desired thresholds equalling the number of neutral thresholds, each reading element associated with one of the desired thresholds.

26. The method of claim 25, wherein the plurality of desired thresholds are stored in said first memory, replacing said plurality of neutral thresholds.

27. The method of claim 25, wherein the plurality of desired thresholds are stored in a second memory.

28. The method of claim 27, wherein each reading element is associated with one of said plural desired thresholds by assigning a pointer to each reading element,

wherein the pointer points to a respective memory location of the second memory.

29. The method of claim 25, wherein each reading element is associated with one of said plural neutral thresholds by assigning a pointer to each reading element, wherein the pointer points to a respective memory location of the first memory.

30. The method of claim 25, wherein the step of receiving a desired image density setting and the step of determining a plurality of desired thresholds are performed each time the reading elements are aligned with the calibration patch.

31. An image scanning apparatus comprising:

a calibration patch having a known image density;

a scanner having a plurality of reading elements, said scanner being movable into alignment with said calibration patch for scanning the calibration patch, said plurality of reading elements outputting a signal in response to scanning said calibration patch;

a storage device, coupled to said scanner, for storing said signal output by said reading elements as a neutral threshold of each reading element, each neutral threshold being associated with a neutral image density setting of the scanning apparatus;

a variable image density setting device that outputs a desired image density setting selected by an operator; and

a threshold setting device that sets a desired threshold for each of the reading elements based upon the desired image density setting, the neutral image density setting, and the neutral threshold stored in said storage device for each of said reading elements.

32. The apparatus of claim 31, further comprising a printing device that prints a mark corresponding to each reading element based on a comparison between the desired threshold set for each respective reading element and a

scanning signal output by each reading element when a document is scanned by said scanner.

33. The apparatus of claim 31, wherein the variable image density setting device includes a potentiometer.

34. The apparatus of claim 31, wherein the calibration patch is of a continuous gray color.

35. The apparatus of claim 31, wherein said desired thresholds are stored in said storage device by overwriting said neutral thresholds.

36. The apparatus of claim 31, further comprising a second storage device for storing said desired thresholds.

37. The apparatus of claim 31, wherein said threshold setting device sets said desired thresholds by subtracting said neutral image density setting from said desired image density setting.

38. The apparatus of claim 31, wherein said threshold setting device sets said desired thresholds by dividing a result of subtracting the neutral image density setting from the desired image density setting by the result of the difference between a maximum image density setting and a minimum image density setting.

39. The apparatus of claim 31, wherein said threshold setting device sets said desired thresholds by dividing said desired image density setting by said neutral image density setting.

40. An image scanning apparatus comprising:

a calibration patch having a known image density;

a scanner having a plurality of reading elements, said scanner being movable into alignment with said calibration patch for scanning the calibration patch, said plurality of reading elements outputting a signal in response to scanning said calibration patch;

a preliminary threshold storage device, coupled to said scanner, for storing said signal output by said reading elements as a preliminary neutral threshold;

a first storage device for storing a plurality of neutral thresholds based on the plurality of preliminary neutral thresholds, a total number of said neutral thresholds being less than a total number of said reading elements, each reading element associated with one of the plurality of neutral thresholds, each neutral threshold being associated with a neutral image density setting;

a variable image density setting device that outputs a desired image density setting selected by an operator; and

a threshold setting device that sets a desired threshold for each of the reading elements based upon the desired image density setting, the neutral image density setting, and the neutral threshold stored in said first storage device for each of said reading elements.

41. The apparatus of claim 40, further comprising a printing device that prints a mark corresponding to each reading element based on a comparison between the desired threshold set for each respective reading element and a scanning signal output by each reading element when a document is scanned by said scanner.

42. The apparatus of claim 40, wherein the plurality of desired thresholds are stored in said first storage device, replacing said plurality of neutral thresholds.

43. The apparatus of claim 40, wherein the plurality of desired thresholds are stored in a second storage device.

44. The apparatus of claim 40, further comprising a pointer memory that stores a pointer for each of said reading elements said pointer associating each reading element with one of said plural neutral thresholds and with one of said plural desired thresholds.

45. The apparatus of claim 40, wherein said pointer points to a respective memory location of the first storage device.

46. The apparatus of claim 40, wherein said threshold setting device sets the plurality of desired

thresholds each time the reading elements are aligned with the calibration patch.

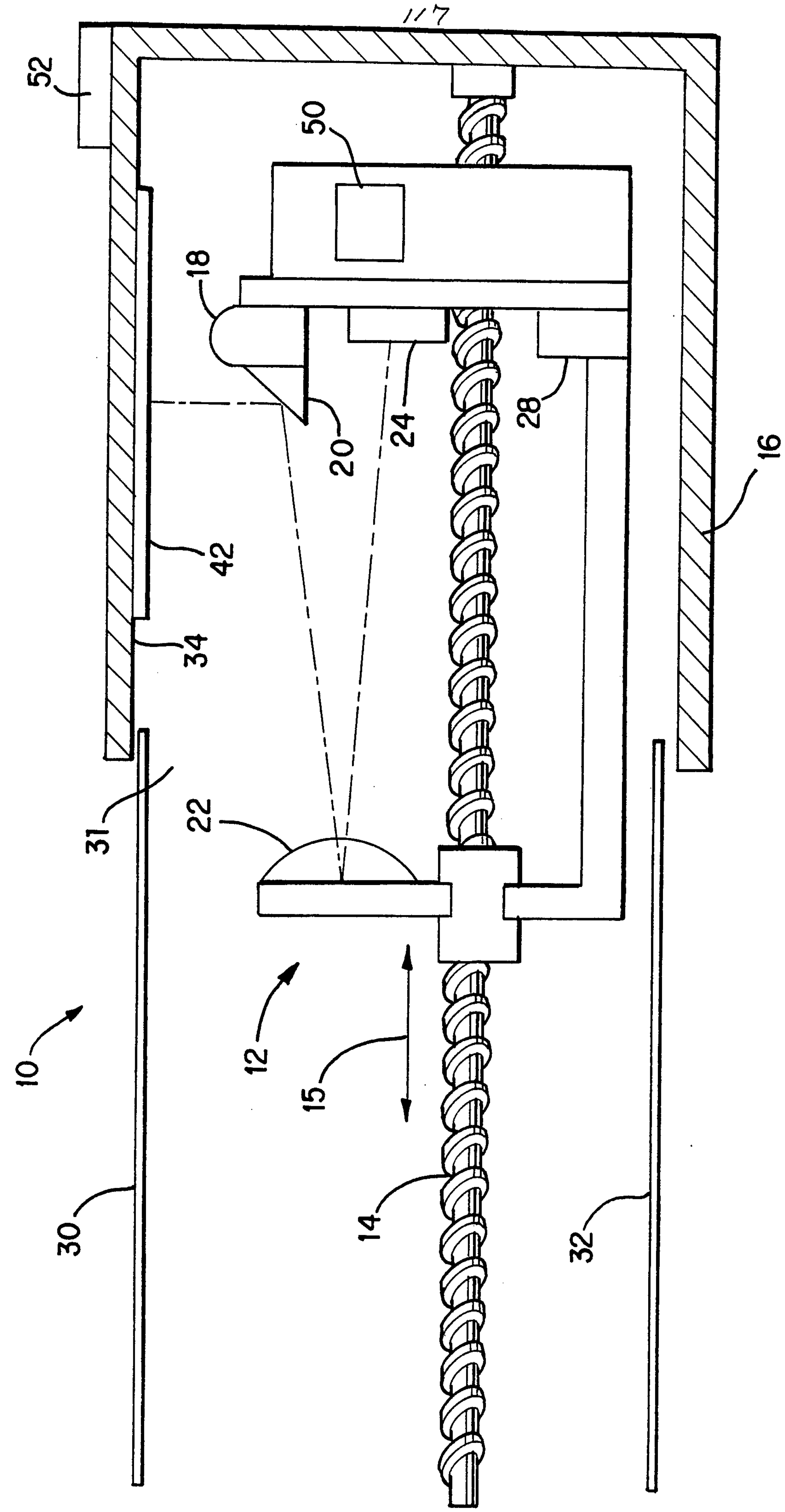

FIG. 1

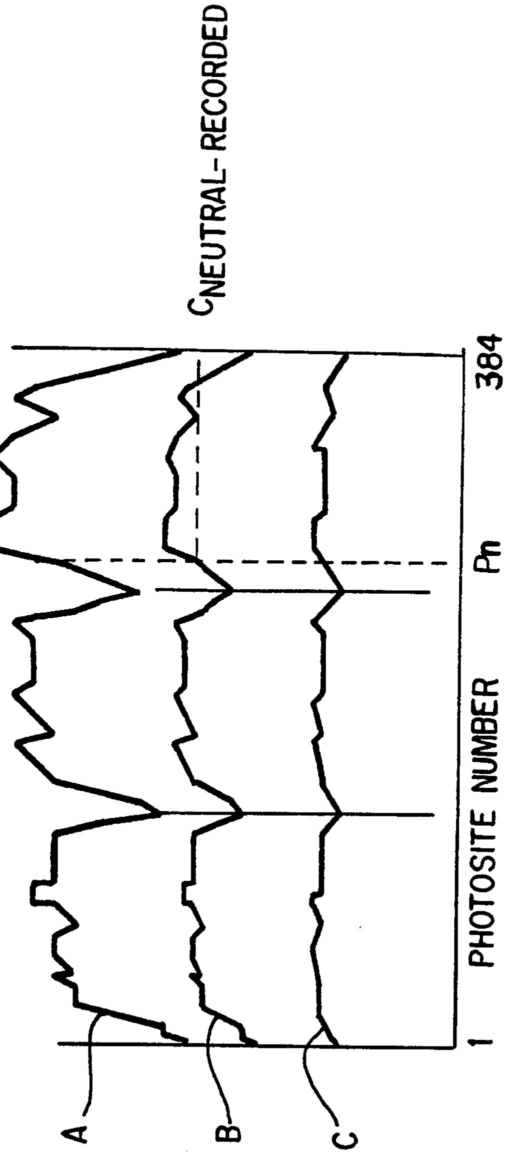
CNEUTRAL-RECORDED
A
B
C
1
Pn
384
PHOTOSITE NUMBER

FIG.2

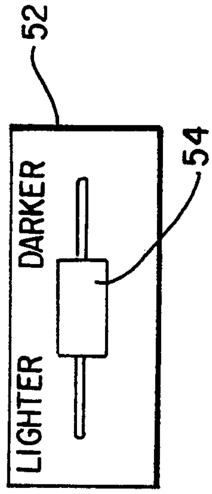
52
54
LIGHTER
DARKER

FIG.5

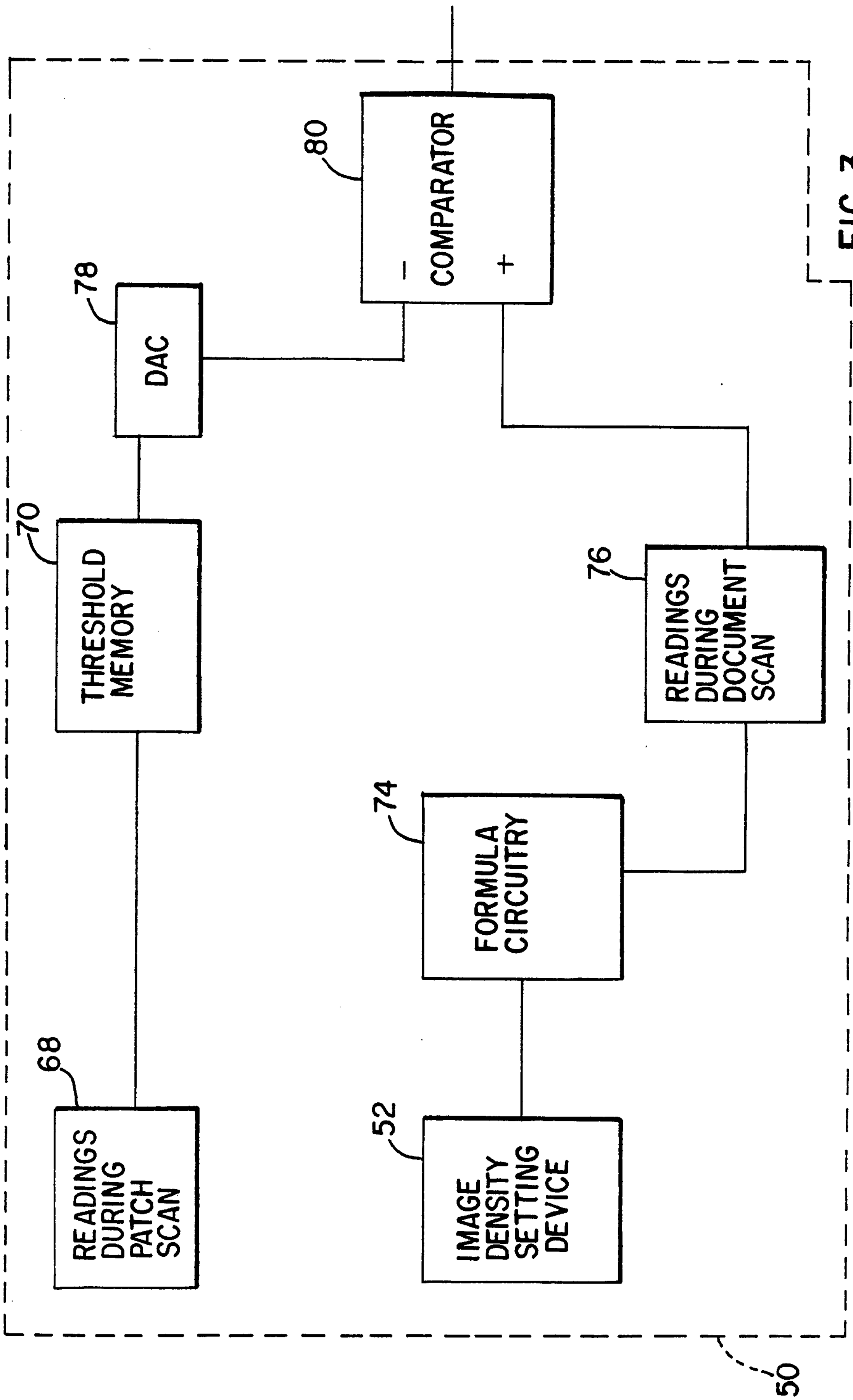
COMPARATOR
80
DAC
78
THRESHOLD MEMORY
70
READINGS DURING DOCUMENT SCAN
76
FORMULA CIRCUITRY
74
READINGS DURING PATCH SCAN
68
IMAGE DENSITY SETTING DEVICE
52
50

FIG. 3

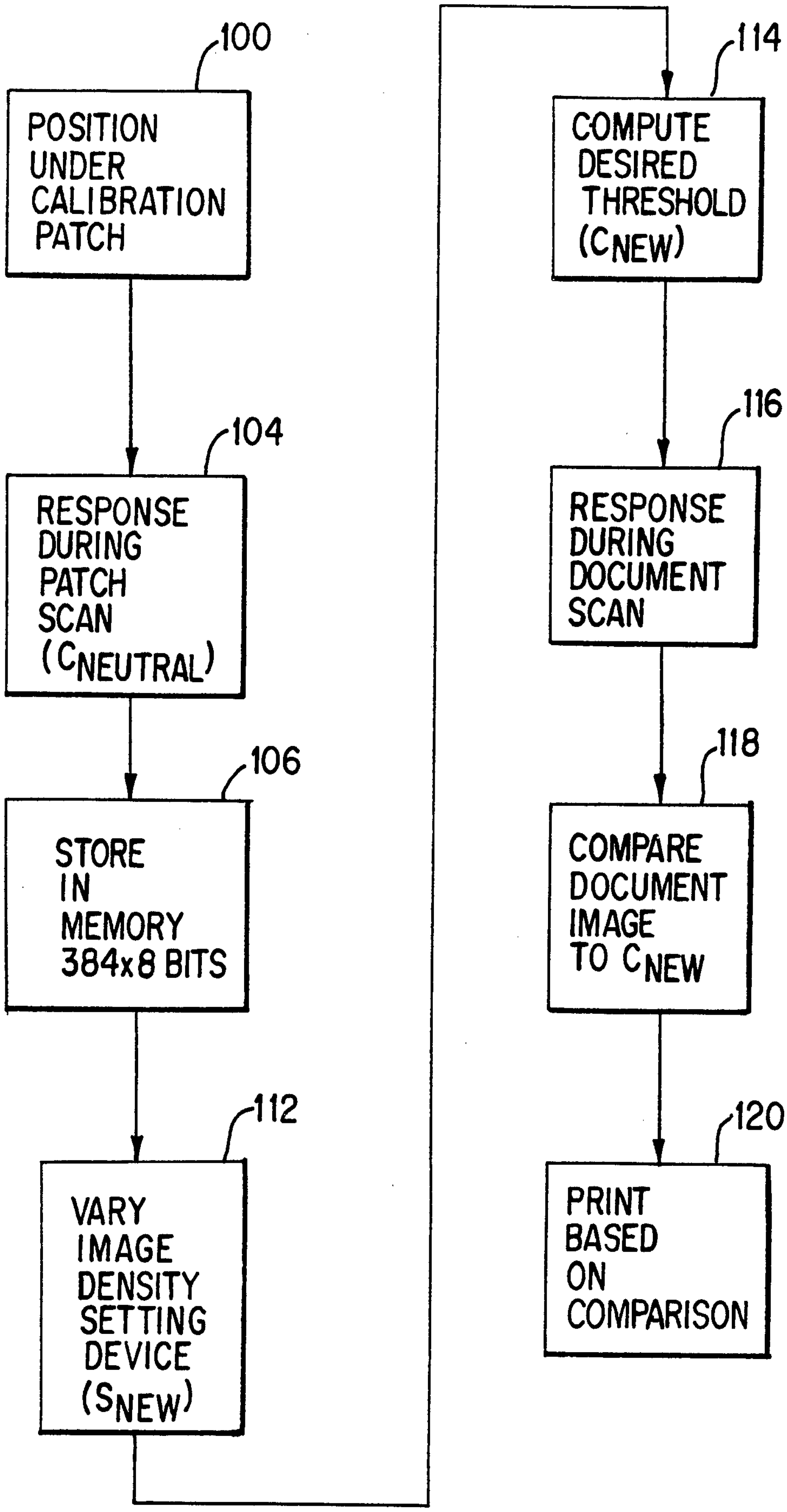
100
POSITION UNDER CALIBRATION PATCH
104
RESPONSE DURING PATCH SCAN (CNEUTRAL)
106
STORE IN MEMORY 384x8 BITS
112
VARY IMAGE DENSITY SETTING DEVICE (SNEW)
114
COMPUTE DESIRED THRESHOLD (CNEW)
116
RESPONSE DURING DOCUMENT SCAN
118
COMPARE DOCUMENT IMAGE TO CNEW
120
PRINT BASED ON COMPARISON

FIG. 4

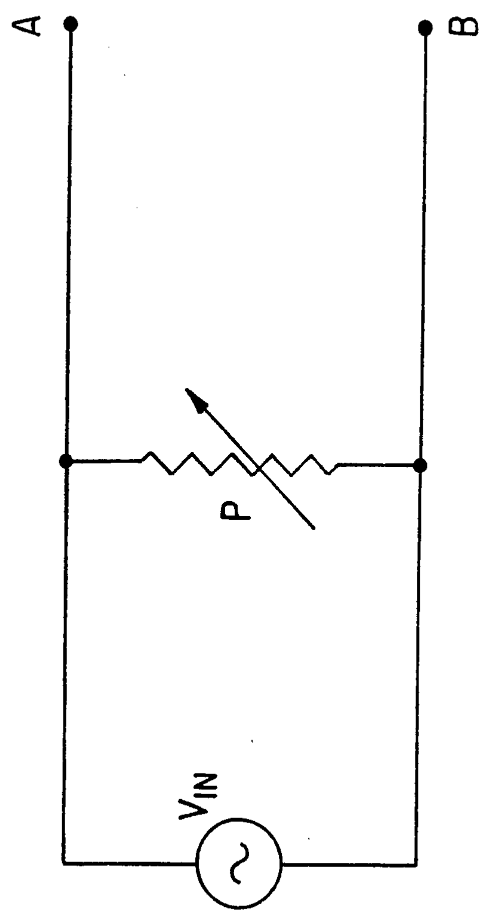

FIG.6

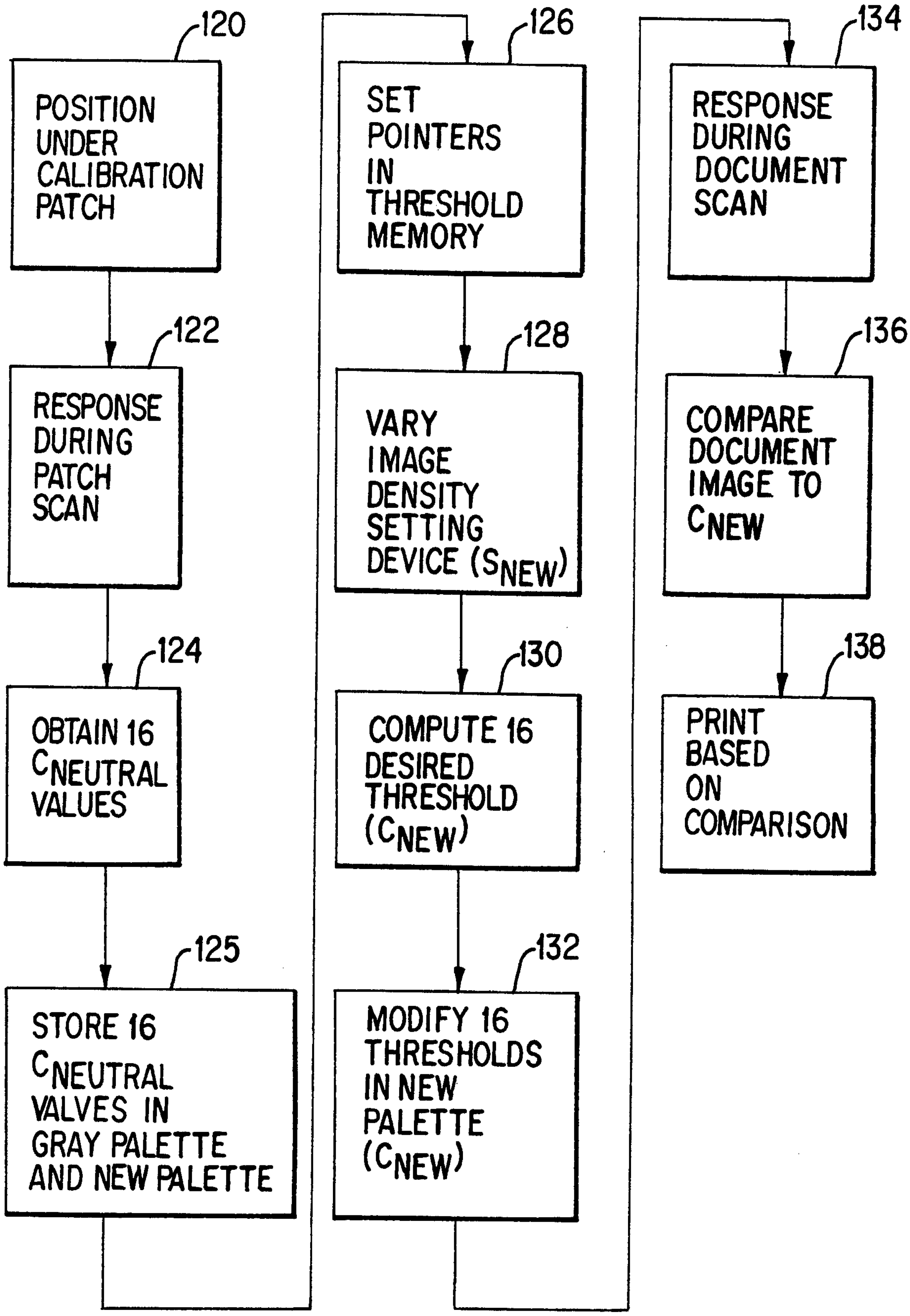
120
POSITION UNDER CALIBRATION PATCH
122
RESPONSE DURING PATCH SCAN
124
OBTAIN 16 CNEUTRAL VALUES
125
STORE 16 CNEUTRAL VALVES IN GRAY PALETTE AND NEW PALETTE
126
SET POINTERS IN THRESHOLD MEMORY
128
VARY IMAGE DENSITY SETTING DEVICE (SNEW)
130
COMPUTE 16 DESIRED THRESHOLD (CNEW)
132
MODIFY 16 THRESHOLDS IN NEW PALETTE (CNEW)
134
RESPONSE DURING DOCUMENT SCAN
136
COMPARE DOCUMENT IMAGE TO CNEW
138
PRINT BASED ON COMPARISON

FIG.7

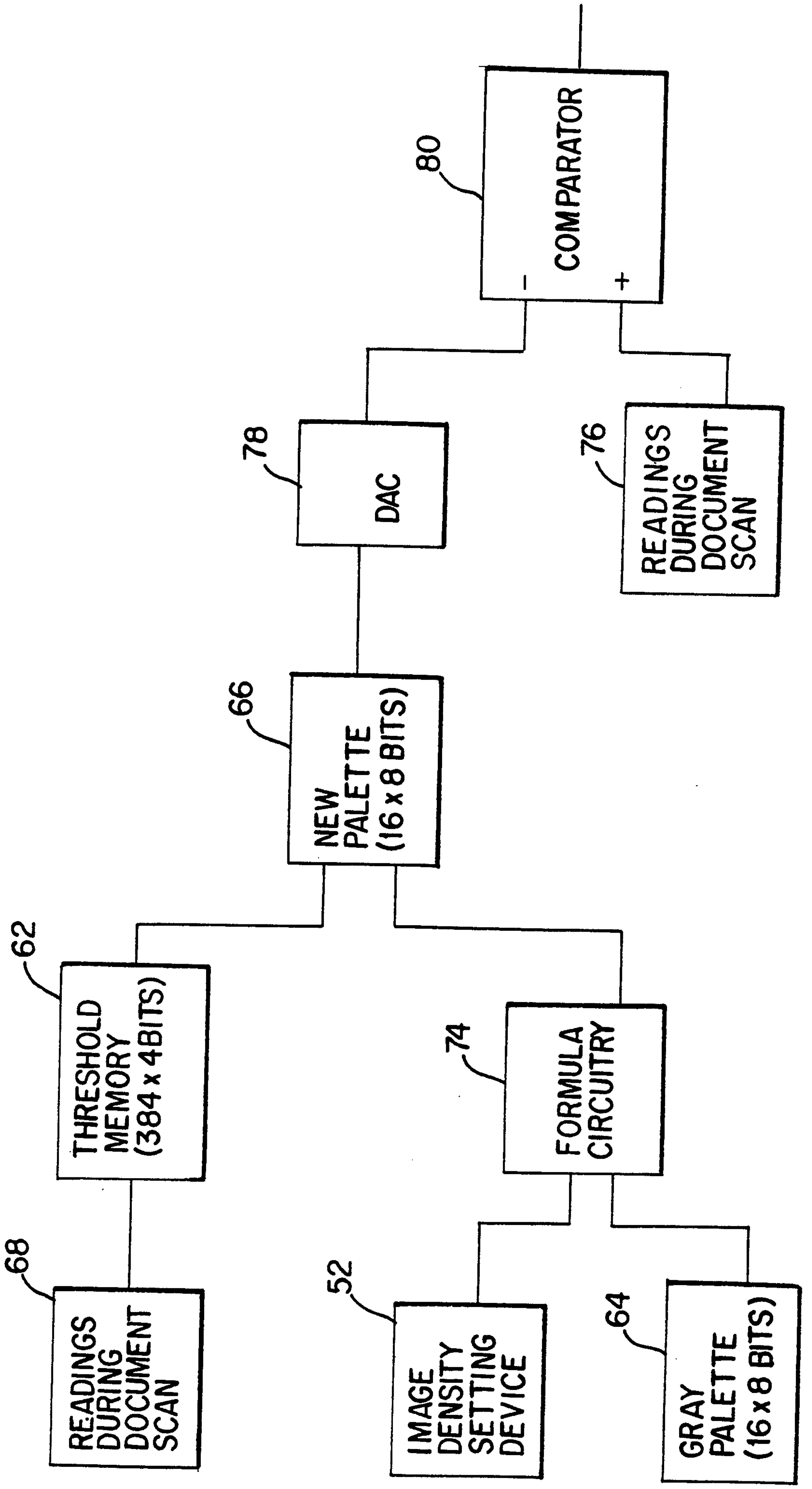
80
COMPARATOR
-
+
78
DAC
76
READINGS DURING DOCUMENT SCAN
66
NEW PALETTE (16 x 8 BITS)
62
THRESHOLD MEMORY (384 x 4BITS)
74
FORMULA CIRCUITRY
68
READINGS DURING DOCUMENT SCAN
52
IMAGE DENSITY SETTING DEVICE
64
GRAY PALETTE (16 x 8 BITS)

FIG.8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/11920

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :HO4N 1/23, 1/40, 1/46
US CL :358/296, 298, 406, 461, 504
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 358/296, 298, 406, 461, 504

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 3,723,649 (PITEGOFF ET AL) 27 March 1973, entire document	1-46
A	US, A, 4,342,047 (NIEMCZYK ET AL) 27 JUNE 1982, entire document	1-46
A	US, A, 4,383,275 (SASAKI ET AL) 10 MAY 1983, entire document	1-46
A	US, A, 4,520,395 (ABE) 28 MAY 1985, entire document	1-46
A	US, A, 4,602,293 (SEKINE) 22 JULY 1986, entire document	1-46
A	US, A, 4,647,981 (FROELICH) 03 MARCH 1987, entire document	1-46

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published 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; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 JANUARY 1995	17 FEB 1995

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/11920

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4,651,287 (TSAO) 17 MARCH 1987, entire document	1-46
A	US, A, 4,660,082 (TOMOHISA ET AL) 21 APRIL 1987, entire document	1-46
A	US, A, 4,845,551 (MATSUMOTO) 04 JULY 1989, entire document	1-46
A	US, A, 4,974,098 (MIYAKAWA ET AL) 27 NOVEMBER 1990, entire document	1-46
A	US, A, 5,187,588 (STEMMLE) 16 FEBRUARY 1993, entire document	1-46
Y --,P A	US, A, 5,282,053 (ROBIDEAU) 25 JANUARY 1994, figure 1, columns 2-6, and claims 1-7	1-10 ----- 1-46
A,P	US, A, 5,345,315 (SHALIT) 06 SEPTEMBER 1994, entire document	1-46

B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

APS
search terms: calibration, calibration patch, density, image, scan####, threshold#, neutral threshold#, document, reading element#