

1 TITLE OF THE INVENTION

Image Processing Apparatus

BACKGROUND OF THE INVENTION

5 Field of the Invention

The present invention relates to an image processing apparatus for digitizing image data to binary values or multi-levels and, more particularly, to an image processing apparatus for half-tone processing input image data.

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Related Background Art

Hitherto, in image processing apparatuses such as facsimile apparatus, digital copying machine, and the like, an error diffusion method and an average density approximating method have been proposed as a half-tone processing system.

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The former error diffusion method has been disclosed in the literature by R. Floyd & L. Steinberg, "AN ADAPTIVE ALGORITHM FOR SPATIAL GRAY SCALE", SID 75 DIGEST, pp 36 to 37. According to the error diffusion method, multi-level image data of a target pixel is binarized (converted into a highest density level or a lowest density level) and a difference between the binary level and the multi-value image data before the binarization is added with a predetermined weight and the resultant data is added to the data of the pixel near the target pixel.

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1 The applicant of the present invention has
already filed U.S. Patent Application S. N. 137,439,
S. N. 140,029, S. N. 145,593, S. N. 192,601, S. N.
203,880, S. N. 270,809, S. N. 284,603, S. N. 289,017
5 and S. N. 319,057 as techniques for half-tone processing
image data by the error diffusion method.

 On the other hand, as disclosed in Japanese
Unexamined Patent Publication (Kokai) No. 57-104369,
according to the latter average density approximating
10 method, the target pixel is binarized to black or white
by using the already binarized data of pixels near the
target pixel, the weighting average values with the
respective pixels near the target pixel are obtained,
the average of the two average values is set to a
15 threshold value, and the image data of the target
pixel is binarized on the basis of the threshold
value.

 Since the above error diffusion method is of
the type in which the difference between the input image
data and the output image data is corrected, the densities
20 of the input image and the output image can be preserved,
so that an image having excellent resolution and gradation
can be provided.

 However, in the error diffusion method, when
the difference between the input image data and the
25 output image data is corrected, many two-dimensional
calculations must be executed, so that there is a

1 drawback such that a hardware construction is very
complicated because of a very large processing amount.

On the other hand, in the average density
approximating method, since the calculations are per-
5 formed by using the binary data after completion of
the binarization, a hardware construction can be
simplified and a high processing speed can be realized
because of a very small processing amount.

However, in the average density approximating
10 method, the target pixel is merely approximated to the
average value of the region including the target pixel
and is binarized. Therefore, there are drawbacks such
that the number of gradations is limited, a texture
of a low frequency which is peculiar to the image having
15 a gentle density change occurs, and the picture quality
deteriorates.

SUMMARY OF THE INVENTION

It is an object of the present invention to
20 eliminate the drawbacks of the conventional techniques
as mentioned above and to provide an image processing
apparatus in which an image having excellent gradation
and resolution can be obtained in a short time by a
simple hardware construction.

25 To accomplish the above object, an image
processing apparatus according to the invention comprises:
input means for inputting data of a target pixel;

1 calculating means for obtaining an average density value
of a predetermined region; digitizing means for digitizing
the data of the target pixel on the basis of the average
density value obtained by the calculating means; and
5 correcting means for correcting a difference which
occurs upon digitization by the digitizing means.

Another object of the invention is to provide
an image processing apparatus in which an average density
value which was calculated from binarized data is set
10 to a threshold value and data of a target pixel is
binarized on the basis of the threshold value.

Still another object of the invention is to
provide an image processing apparatus in which when
a difference between the data of a target pixel and
the average density value is set to a predetermined
15 value or less, by correcting the difference, an image
having an excellent gradation can be reproduced.

Still another object of the invention is to
provide an image processing apparatus in which when
a difference between the data of a target pixel and
20 the average density value is set to a predetermined
value or more, the error is not corrected, so that the
resolution of a character portion can be improved.

The above and other objects and features of
the present invention will become apparent from the
25 following detailed description and the appended claims
with reference to the accompanying drawings.

1 BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1 and 14 are diagrams showing a multi-level image, a binary image, and a weighting mask of each pixel;

5 Figs. 2 and 15 are diagrams showing a difference which occurs upon binarization;

Figs. 3, 13, 17A, and 17B are diagrams showing examples of weighting masks;

10 Fig. 4 is a block diagram showing a construction of an image processing apparatus in an embodiment;

Fig. 5 is a block diagram showing the details of a binarizing circuit in the embodiment 1;

Fig. 6 is a diagram showing an example of a table stored in an ROM 12 in Fig. 5;

15 Fig. 7 is a diagram showing the case where a weighting mask 1 was converted into 6-bit data;

Figs. 8, 9, and 10 are block diagrams of binarizing circuits of embodiments in the case where the binarizing circuit of Fig. 5 is partially modified;

20 Fig. 11 is a diagram showing an example of a table stored in an ROM 100 in Fig. 10;

Fig. 12 is a diagram for explaining the embodiment 4;

25 Figs. 16 and 18 are block diagrams showing the details of the binarizing circuit in the embodiment 7;

Fig. 19 is a block diagram showing a binarizing

1 circuit of the embodiment 8;

Fig. 20 is a diagram for explaining the embodiment
9; and

Fig. 21 is a block diagram showing binarizing
5 circuits in the embodiments 9 and 10.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention will be
described in detail hereinbelow with reference to the
10 drawings.

Embodiment 1

The principle of the present system will be
first described.

Fig. 1(1) is a diagram showing multi-level data
15 of each pixel of an input image.

In Fig. 1(1), $f(i, j)$ denotes multi-level density
data of an input image at the position of a target pixel
to be binarized and is set to a normalized value of
0 to 1. On the other hand, the binarizing process has
20 already been finished at pixel positions above a broken
line. After the target pixel was binarized, the similar
processes are sequentially executed such that $f(i, j+1)$,
 $f(i, j+2)$,

Fig. 1(2) is a diagram showing binary image
data. $B(i, j)$ denotes a density (having a value of
25 0 or 1) after the target pixel was binarized. The
portion surrounded by a broken line relates to the

1 pixel data which has already been binarized when the
target pixel is processed. Those binarized pixel data
are used when the target pixel is binarized.

Fig. 1(3) is a diagram showing weighting masks.
5 R denotes an example of a weighting mask to obtain an
average density and is expressed by a matrix of a size
of 3 x 3. The weight at the position corresponding
to the target pixel is set to R(0, 0) and R(0, -1) =
0 is used.

10 According to the system, the average densities
of the output images near the target pixel in the case
where the target pixel was binarized into either black
or white are set to $m_1(i, j)$ and $m_0(i, j)$ and are
obtained by the following equation.

15
$$m_1(i, j) = \frac{1}{S} \sum_{x=0}^2 \sum_{y=-1}^1 R(x, y) \cdot B(i-x, j-y) \dots \textcircled{1}$$

(where, this equation relates to the case where $B(i, j) = 1$, that is, the target pixel is binarized to
black)

20
$$m_0(i, j) = \frac{1}{S} \sum_{x=0}^2 \sum_{y=-1}^1 R(x, y) \cdot B(i-x, j-y) \dots \textcircled{2}$$

(where, this equation relates to the case where $B(i, j) = 0$, that is, the target pixel is binarized to
white)

25 S denotes the sum of weights R. For instance,
in the case of using the weighting mask 1 in Fig. 3,
S = 29. In the case of using the weighting mask 2,

1 S = 58.

The multi-level density $f(i,j)$ of the target pixel is binarized by using the average densities m_1 and m_0 is binarized by the following equations.

$$\left. \begin{aligned} 5 \quad & \text{When } f(i,j) + E(i,j) > (m_1(i,j) + m_0(i,j))/2, \\ & B(i,j) = 1, \\ & E(i,j+1) = f(i,j) + E(i,j) - m_1(i,j) \\ & \text{When } f(i,j) + E(i,j) \leq (m_1(i,j) + m_0(i,j))/2, \\ & B(i,j) = 0, \\ 10 \quad & E(i,j+1) = f(i,j) + E(i,j) - m_0(i,j) \end{aligned} \right\} \quad (3)$$

In the equation (3), $E(i,j)$ denotes a difference which occurs when a multi-level density $f(i,j-1)$ of the pixel $(i,j-1)$ which is precedent to the target pixel (i,j) by one pixel was binarized to a binary density $B(i,j-1)$. That is, the process such that the input pixel density $f(i,j-1)$ was binarized to 1 or 0 means that the pixel $(i,j-1)$ was approximated to either $m_1(i,j-1)$ or $m_0(i,j-1)$ as an average density near the pixel $(i,j-1)$. In each case, the difference of $f(i,j-1) - m_1$ or $f(i,j-1) - m_0$ occurs with the multi-level density $f(i,j-1)$ of the input image. Therefore, the value corrected by adding the binary difference $E(i,j)$ to the target pixel $f(i,j)$ is binarized, so that density on the image after completion of the binarization can be completely preserved with respect to the whole input image region. The present system has the maximum feature with respect to a point that the processes are

1 executed in consideration of such a binarization difference.
As compared with the above average density approximating
method, the half-tone reproducing capability is remarkably
improved.

5 In the equation (3), $E(i, j+1)$ denotes a difference
which is distributed to the pixel $(i, j+1)$ which is
subsequent to the target pixel (i, j) by one pixel.
As shown in Fig. 2, $E(i, j+1)$ is set to a value which
is obtained by subtracting m_1 from $f(i, j) + E(i, j)$ in
10 the case where $f(i, j) + E(i, j) > (m_1 + m_0)/2$.
 $E(i, j+1)$ is set to a value which is obtained by
subtracting m_0 from $f(i, j) + E(i, j)$ in the case
where $f(i, j) + E(i, j) \leq (m_1 + m_0)/2$.

As mentioned above, the reason why in spite
15 of the fact that a processing amount in the case of
the average density preserving method in the embodiment
is extremely smaller than that in the error diffusion
method, the image reproducing capability which is equal
to or higher than that in the error diffusion method
can be obtained is because in spite of the fact that
20 the difference is merely corrected by using one pixel
adjacent to the target pixel, by obtaining the average
densities by using a plurality of data after completion
of the binarization, the effect similar to that in the
case of correcting by distributing the differences to
25 a plurality of pixels is equivalently obtained.

In terms of this point, it will be obviously

1 understood that the above average density approximating
method does not consider the differences as in the
present system and the image reproducing capability
of the present system is fairly better than that of
5 the average density approximating method.

Fig. 4 is a block diagram of an image processing
apparatus showing an embodiment of the invention. An
input sensor unit A comprises a photoelectric converting
element such as a CCD or the like and a drive apparatus
10 for scanning the photoelectric converting element.
The input sensor unit A reads and scans an original.
The image data of the original which was read by the
input sensor unit A is successively transmitted to an
A/D converter B. The A/D converter B converts the
15 data of each pixel into 6-bit digital data, thereby
digitizing into the data having the gradations of 64
levels. Next, a shading correction and the like to
correct a sensitivity variation of the CCD sensor and
an illuminance variation by an illuminating light source
20 are executed by digital calculating processes in a
correction circuit C. Next, the corrected data is
sent to a binarization circuit D. In the binarization
circuit D, the 6-bit multi-level image data which was
input is digitized into the 1-bit binary data by the
25 foregoing system. A printer E is constructed by a
laser beam system or an ink jet system. On the basis
of the binary data sent from the binarization circuit

1 D, the printer E on/off controls the dots and reproduces
an image onto a recording paper.

Fig. 5 is a block diagram showing the details
of the binarizing circuit D in Fig. 4.

5 In Fig. 5, reference numerals 1 and 2 denote
delay RAMs each for storing the binary data which was
binarized by an amount of one line; 3 to 7 and 11
indicate D F/F (D flip-flops) each for delaying the
binary data by one pixel; 8 an average density calcula-
10 tion ROM for calculating an average density of the
pixels around the target pixel and outputting a
threshold value; 9 a subtracter for calculating the
difference between the multi-level data of the target
pixel which was input and the threshold value; 10 a
15 comparator for comparing the threshold value which is
output from the ROM 8 with the multi-level data of the
target pixel; 11 the D F/F; 12 an ROM for calculating
difference data to be added to the multi-level data
which is input subsequently to the target pixel; and
20 13 an adder for adding the input data and the difference
data which is output from the ROM 12.

In the above construction, the comparator 10
outputs data $B(i,j)$ of one-bit which was binarized on
the basis of the equation (3) to the D F/F 7 and the
printer E. The binary data is input to the RAMs 2 and
25 1 for delaying every line. The binary data $B(i-1,j+1)$
which was delayed by one line by the RAM 2 and the

1 binary data $B(i-2, j+1)$ which was delayed by two lines
by the RAM 1 are output to the ROM 8.

Further, the D F/F 3 outputs the binary data
 $B(i-2, j)$ to the ROM 8; the D F/F 4 outputs the $B(i-2,$
5 $j-1)$; the D F/F 5 outputs the $B(i-1, j)$; D F/F 6 outputs
the $B(i-1, j-1)$; and the D F/F 7 outputs the $B(i, j-1)$,
respectively, to the ROM 8.

As shown in Fig. 1, the binary data relates
to binary images of the peripheral pixel for the input
10 image $f(i, j)$. If the binary images are connected to
input addresses in the ROM 8, the binary threshold
value can be obtained at a high speed because the
binary threshold value $(m_1(i, j) + m_0(i, j))/2$ shown
in the equation (3) has previously been stored in the
15 ROM 8 on the basis of the equations (1) and (2).

The binary threshold value is input to the
subtractor 9 and comparator 10. On the other hand,
 $f(i, j) + E(i, j)$ is input from the D F/F 11 to the
subtractor 9 and comparator 10.

20 On the basis of those two inputs, the
subtractor 9 calculates the difference

$$f(i, j) + E(i, j) - (m_1(i, j) + m_0(i, j))/2$$

between both sides of the inequality in the equation

25 (3). The difference value is input to the ROM 12.
When the above equation is modified by using the
equations (1) to (3), we have

$$\begin{aligned}
 & f(i,j) + E(i,j) - [m_1(i,j) - \frac{1}{2S}R(0,0)] \\
 & = f(i,j) + E(i,j) - [m_0(i,j) + \frac{1}{2S}R(0,0)] \\
 & = \left\{ \begin{array}{ll} E(i,j+1) + \frac{1}{2S}R(0,0) & (\text{when } B(i,j)=1) \\ E(i,j+1) - \frac{1}{2S}R(0,0) & (\text{when } B(i,j) = 0) \end{array} \right\} \quad (4)
 \end{aligned}$$

On the other hand, on the basis of the above two inputs, the comparator 10 compares $f(i,j) + E(i,j)$ and $(m_1(i,j) + m_0(i,j))/2$ and outputs the binary data $B(i,j)$.

That is, in the ROM 12, the $E(i,j+1)$ shown in the equation (4) is calculated on the basis of the value of $B(i,j)$ from the comparator 10 and $f(i,j) + E(i,j) - (m_1(i,j) + m_0(i,j))/2$ from the subtracter 9.

In the above equation (4), since the weight $R(0,0)$ and S have already been known, by previously calculating the difference $E(i,j+1)$ from the average density value and storing into the difference calculation ROM 12, if the binary data $B(i,j)$ and

$$f(i,j) + E(i,j) - (m_1(i,j) + m_0(i,j))/2$$

as the output of the subtracter 9 are input to the ROM 12, $E(i,j+1)$ can be obtained by the table conversion.

Fig. 6 shows an example of the table stored in the ROM 12.

In the embodiment, since the weight mask 1 shown in Fig. 3 has been used, in order to normalize

1 to the 6-bit image density levels (0 to 63) which are
actually input, the values obtained by the equations
① and ② are increased by 63 times and the resultant
value is stored as the value which was converted into
5 the 6-bit value into the average density calculation
ROM table. In this case, the weight mask 1 is set as
shown in Fig. 7.

The output

$$f(i,j) + E(i,j) - (m_1(i,j) + m_0(i,j))/2$$

10 of the subtracter 9 is input as an absolute value into
the ROM 12 and the positive/negative sign is determined
in accordance with the value of B(i,j). The difference
E(i,j+1) obtained by the ROM 12 is added to the input
image data f(i,j+1) by the adder 13. The D F/F 11
15 delays the addition value by a period of time of the
data of one clock.

As mentioned above, the embodiment can be
easily realized by merely adding calculation ICs of
a few chips as compared with the average density
20 approximating method. Moreover, the gradations can
be extremely improved.

As mentioned above, according to the above
first embodiment, the average density is calculated
on the basis of the binary data and the binarization
25 is executed on the basis of the average density.
Thus, a processing amount for binarization can be

1 fairly reduced. In addition, the gradations can be
remarkably improved by correcting the difference
between the average density which is generated upon
binarization and the input multi-level data.

5 In the embodiment, the binary difference E has
been distributed to only the next pixel and corrected
in the equation (3). However, if the binary difference
 E is distributed to a plurality of pixels in a manner
such that $3E(i,j+1)/4$ is distributed to the pixel
10 $(i,j+1)$ and $E(i,j+1)/4$ is distributed to the pixel
 $(i,j+2)$ in Fig. 1, even if the average processing
mask is small, the gradation reproducing capability
is improved.

The binary difference E can be also two-
15 dimensionally distributed to a plurality of pixels
near the target pixel at a predetermined distribution
ratio. In this case, although a hardware construction
is slightly complicated, the uniform image can be also
obtained with respect to the sub scanning direction
as well as in the main scanning direction and the
20 reproducibility is improved.

In the case of two-dimensionally distributing
the binary difference E in two directions (one adjacent
pixel and one pixel existing under the target pixel
by one line), the equation (3) is as follows.
25

$$\begin{array}{l}
 1 \quad \text{When } f(i,j) + E(i,j) > \{m_1(i,j) + m_0(i,j)\} / 2 \\
 \quad B(i,j) = 1 \\
 \quad E_1(i,j+1) = \frac{1}{2} [f(i,j) + E(i,j) - m_1(i,j)] \\
 \quad E_2(i+1,j) = \frac{1}{2} [f(i,j) + E(i,j) - m_1(i,j)] \\
 5 \quad \text{When } f(i,j) + E(i,j) \leq \{m_1(i,j) + m_0(i,j)\} / 2 \\
 \quad B(i,j) = 0 \\
 \quad E_1(i,j+1) = \frac{1}{2} [f(i,j) + E(i,j) - m_0(i,j)] \\
 10 \quad E_2(i+1,j) = \frac{1}{2} [f(i,j) + E(i,j) - m_0(i,j)] \\
 \text{where, } E(i,j) = E_1(i,j) + E_2(i,j)
 \end{array}
 \quad \left. \vphantom{\begin{array}{l} 1 \\ 5 \\ 10 \end{array}} \right\} (3)$$

The difference transfer pixels are set to two pixel positions which are neighboring to the target pixel in two orthogonal directions, that is, two points of $(i,j+1)$ and $(i+1,j)$. The difference value $[f(i,j) + E(i,j) - m(i,j)]$ which is obtained in the embodiment is divided into two values of $E_1(i,j+1)$ and $E_2(i+1,j)$ and they are respectively added to the input density value, thereby executing the correction.

Fig. 8 is a block diagram of a binarizing circuit in the case of two-dimensionally distributing the binary difference E. In Fig. 8, the same parts and elements as those in Fig. 5 are designated by the same reference numerals and their descriptions are omitted.

Reference numeral 14 denotes a distributor for

1 distributing the binary difference E which was sent
from the ROM 12 into the half portions in order to
distribute them to the $f(i,j+1)$ pixel and $f(i+1,j)$ pixel.

Reference numeral 15 indicates an adder for
5 adding $f(i+1,j)$ sent from the correction circuit C and
 $E_2(i+1,j)$ sent from the distributor 14.

Reference numeral 16 represents an RAM for
delaying the data sent from the adder 15 by a period
of time corresponding to one line - one pixel. By
10 providing the RAM 16, the difference generated at the
previous line can be added to the target pixel $f(i,j)$.

As mentioned above, by two-dimensionally dis-
tributing the difference between the average density
which is generated upon binarization and the input
15 density, the regularity can be lightened as compared
with the case of distributing the difference to one
adjacent pixel and the generation of a periodic pattern
can be prevented. On the other hand, even when an edge
portion of a character, a diagram, or the like is
20 reproduced, the directivity does not appear and the
edge portion can be clearly reproduced.

In the above embodiment, the weighting mask
1 shown in Fig. 3 has been used as a weighting mask
to obtain the average density. However, by enlarging
25 a region to obtain the average density like a weighting
mask 2, the reproducibility of the gradations can be
also further improved and the reproducibility of the

1 resolution information which is required in a character
original or the like is also improved. The weighting
mask is not limited to the above masks, but any mask
of a similar form can be also used.

5 On the other hand, although the weighting mask
has been set to increase as the pixel to be processed
is near the target pixel, its gradient and distribution
are not limited. Pixels at discrete positions which
are not neighboring can be also used.

10 In the embodiment, when the difference which
is distributed to peripheral pixels is obtained by the
error diffusion method, the inevitably dividing process
is unnecessary. The difference generated in such a
case is eliminated and the densities of the input image
15 and output image can be completely preserved.

Embodiment 2

 In the embodiment 1, the value which was corrected
by adding the difference $E(i,j)$ generated when the
previous pixel $(i,j-1)$ of the target pixel (i,j) is
binarized to $f(i,j)$ of the target pixel is compared
20 with the average density, thereby executing the
binarization. However, in the embodiment, the
difference $E(i,j)$ is corrected upon calculation of
the average value when the target pixel is binarized,
thereby executing the binarization.

25 That is, in the embodiment 2, $m_1(i,j)$ and $m_0(i,j)$
obtained by the equations (1) and (2) in the embodiment

1 are set as follows.

$$m_1'(i,j) = \frac{1}{S} \sum_{x=0}^2 \sum_{y=-1}^1 R(x,y) \cdot B(i-x,j-y) - E(i,j)$$

(where, $B(i,j) = 1$) ... (5)

$$m_0'(i,j) = \frac{1}{S} \sum_{x=0}^2 \sum_{y=-1}^1 R(x,y) \cdot B(i-x,j-y) - E(i,j)$$

(where, $B(i,j) = 0$) ... (6)

The multi-level density $f(i,j)$ of the target pixel is binarized by the following equations.

$$\left. \begin{array}{l} \text{When } f(i,j) > (m_1'(i,j) + m_0'(i,j))/2, \\ \quad B(i,j) = 1, \\ \quad E(i,j+1) = f(i,j) + E(i,j) - m_1'(i,j) \\ \text{When } f(i,j) \leq (m_1'(i,j) + m_0'(i,j))/2 \\ \quad B(i,j) = 0, \\ \quad E(i,j+1) = f(i,j) + E(i,j) - m_0'(i,j) \end{array} \right\} (7)$$

Fig. 9 is a block diagram of an image processing apparatus which realizes the embodiment 2.

In Fig. 9, reference numerals 1 to 12 indicate the same component elements as those in the embodiment 1 and their descriptions are omitted. Reference numeral 20 denotes a subtracter to subtract the difference $E(i,j)$ generated at the previous pixel from the average density value sent from the average density calculation ROM 8.

In the above construction, the threshold value $(m_1'(i,j) + m_0'(i,j))/2$ obtained by correcting the binary difference E by the subtracter 20 for the average density which

1 was output from the ROM 8 is input to the subtracter
9 and comparator 10. On the other hand, the multi-level
data $f(i,j)$ of the input image is input to the subtracter
9 and comparator 10.

5 On the basis of those two inputs, the subtracter
9 calculates the difference

$$f(i,j) - (m_1'(i,j) + m_0'(i,j))/2$$

between both sides of the inequality in the equation

10 (7). When the above equation is modified by using the
equations (5) and (6), we have

$$\begin{aligned} & f(i,j) - [m_1'(i,j) - \frac{1}{2S} R(0,0)] \\ & = f(i,j) - [m_0'(i,j) + \frac{1}{2S} R(0,0)] \\ & \begin{aligned} & E(i,j+1) + \frac{1}{2S} R(0,0) \quad (\text{when } B(i,j) = 1) \\ & E(i,j+1) - \frac{1}{2S} R(0,0) \quad (\text{when } B(i,j) = 0) \end{aligned} \end{aligned} \quad \left. \vphantom{\begin{aligned} & E(i,j+1) + \frac{1}{2S} R(0,0) \\ & E(i,j+1) - \frac{1}{2S} R(0,0) \end{aligned}} \right\} \textcircled{8}$$

On the other hand, the comparator 10 compares
 $f(i,j)$ with $(m_1'(i,j) + m_0'(i,j))/2$ and outputs the
binary data $B(i,j)$.

20 In the above equation (8), since the weight
 $R(0, 0)$ and S have already been known, the binary
difference $E(i,j+1)$ is derived by the ROM 12. The
difference $E(i,j+1)$ is delayed by the D F/F 11 and is
input to the subtracter 20. By repeating the above
25 processes, the input multi-level data can be sequentially
binarized. Although the embodiments 1 and 2 have been

$$\begin{array}{lcl}
 1 & E(i,j+1) = f(i,j) + E(i,j) - m_1(i,j) & \\
 & \text{(when } B(i,j) = 1\text{)} & \\
 & \text{or} & \\
 & E(i,j+1) = f(i,j) + E(i,j) - m_0(i,j) & \\
 5 & \text{(when } B(i,j) = 0\text{)} &
 \end{array}
 \left. \vphantom{\begin{array}{l} E(i,j+1) = f(i,j) + E(i,j) - m_1(i,j) \\ E(i,j+1) = f(i,j) + E(i,j) - m_0(i,j) \end{array}} \right\} \textcircled{10}$$

That is, the characteristic processes of the present system are as follows. As shown in the equations $\textcircled{9}$ and $\textcircled{10}$, in the comparison of the target pixel correction values and the average values m_1 and m_0 upon binarization, if the target pixel correction value lies within a predetermined (according to the value of α) region (namely, the difference $E(i,j+1)$ lies within a predetermined region) in which it has a value near the selected average value m_1 or m_0 , the difference between the selected average value and the target pixel correction value is assigned as the correction value upon binarization of the next pixel in accordance with the equation $\textcircled{10}$. On the other hand, when such a difference is out of the predetermined region, that is, when the difference between the target pixel correction values m_1 and m_0 is sufficiently large, the correction value is set to 0 and the correction upon binarization of the next pixel is not executed.

In other words, in the former case, the density change of the image near the target pixel is small, so that it is determined such that the image relates to the image area having a half tone. Therefore, the

1 difference between the image density and the average
density value generated by binarizing is corrected by
the next pixel, thereby enabling the gentle density
change of the image to be false half-tone processed
5 with a high fidelity. Namely, the gradations can be
improved. On the other hand, in the latter case, it
is determined that the edge portion of a character,
a diagram, or the like, namely, the target pixel density
contrarily suddenly changes as compared with the density
10 of the image near the target pixel. Therefore, the
correction value is set to 0 for the pixel in such a
case and the deterioration in resolution due to the
preservation of the density is suppressed, thereby
binarizing and reproducing. Due to this, the
15 resolution in the edge portion can be improved.

As mentioned above, according to the character-
istic processing system of the third embodiment, in
the half-tone image region, the density is preserved
on the binary image by using the binary difference in
20 accordance with the image density change and in a
resolution image portion of a character or the like,
in order to prevent the fading of the image due to the
preservation of the density, the binary difference is
not corrected but is approximated to the average density
values m_1 and m_0 .
25

Since the schematic circuit construction of
the embodiment 3 is similar to that shown in Fig. 4,

1 its description is omitted.

Fig. 10 is a block diagram showing the details of the binarizing circuit D in the embodiment 3.

In the diagram, the same parts and components
5 as those in Fig. 5 are designated by the same reference numerals.

In Fig. 10, reference numerals 1 and 2 denote the delay RAMs each for storing the binarized binary data by an amount corresponding to one line; 3 to 7
10 and 11 indicate the D F/F (D flip-flops) each for delaying the binary data by a period of time corresponding to one line; 8 the average density calculation ROM for calculating the average densities of the pixels around a target pixel and for outputting a threshold
15 value; 9 a subtracter for calculating the difference between the input multi-level data of the target pixel and the threshold value; 10 the comparator for comparing the threshold value which is output from the ROM 8 with the multi-level data of the target pixel; 11 the D F/F;
20 100 an ROM for calculating difference data to be added to the multi-level data which is input next to the target pixel; and 13 the adder for adding the input data and the difference data which is output from the ROM 100.

25 In the above construction, the comparator 10 outputs the data $B(i,j)$ of one-bit which was binarized on the basis of the equation (3) to the D F/F 7 and

1 the printer E. The binary data is input to the RAMs
2 and 1 each for delaying every line. The binary data
B(i-1, j+1) which was delayed by one line by the RAM
2 is output to the ROM 8. The binary data B(i-2, j+1)
5 which was delayed by two lines by the RAM 1 is output
to the ROM 8.

Further, the D F/F 3 outputs the B(i-2,j), the
D F/F 4 outputs the B(i-2,j-1), the D F/F 5 outputs
the B(i-1,j), the D F/F 6 outputs the B(i-1,j-1), and
10 the D F/F 7 outputs the B(i,j-1), respectively, to the
ROM 8.

For the input image f(i,j), the binary data
relates to the binary images of the peripheral pixels
as shown in Fig. 1. If the binary images are connected
to input addresses in the ROM 8, the binary threshold
15 value can be obtained at a high speed because the binary
threshold value $(m_1(i,j) + m_0(i,j))/2$ shown in the
equation (3) has previously been stored in the ROM 8
on the basis of the equations (1) and (2).

20 The threshold value is input to the subtracter
9 and comparator 10. On the other hand, $f(i,j) +$
 $E(i,j)$ is input from the D F/F 11 to the subtracter
9 and comparator 10.

On the basis of those two inputs, the subtracter
25 9 calculates the difference

$$f(i,j) + E(i,j) - (m_1(i,j) + m_0(i,j))/2$$

1 between both sides of the inequality in the equation
 (3). When the above equation is modified by using the
 equations (1) and (2), we have

$$\begin{aligned}
 & f(i,j) + E(i,j) - [m_1(i,j) - \frac{1}{2S} R(0,0)] \\
 & = f(i,j) + E(i,j) - [m_0(i,j) + \frac{1}{2S} R(0,0)] \\
 & = \begin{cases} E(i,j+1) + \frac{1}{2S} R(0,0) & (\text{when } B(i,j) = 1) \\ E(i,j+1) - \frac{1}{2S} R(0,0) & (\text{when } B(i,j) = 0) \end{cases} \quad (11)
 \end{aligned}$$

On the other hand, on the basis of the above
 two inputs, the comparator 10 compares $f(i,j) + E(i,j)$
 and $(m_1(i,j) + m_0(i,j))/2$ and outputs the binary data
 $B(i,j)$.

15 That is, in the ROM 100, the $E(i,j+1)$ shown
 in the equation (9) or (10) is calculated on the basis
 of the value of $B(i,j)$ from the comparator 10 and $f(i,j)$
 + $E(i,j) - (m_1(i,j) + m_0(i,j))/2$ from the subtracter 0.

In the equation (11), since the weight $R(0,0)$
 and S have already been known, the binary difference
 20 $E(i,j+1)$ according to the equations (4) and (5) is
 previously calculated and stored into the difference
 calculation ROM 100. Due to this, the $E(i,j+1)$ is
 obtained by the table conversion by inputting the
 25 binary data $B(i,j)$ and

$$f(i,j) + E(i,j) - (m_1(i,j) + m_0(i,j))/2$$

1 as an output of the subtracter 9 into the ROM 12.

Fig. 11 shows an example of the table stored in the ROM 100.

In the embodiment, the weight mask 1 shown in
5 Fig. 3 has been used. Therefore, in order to normalize to the image density levels (0 to 63) of six bits which are actually input, the value obtained by the equations (1) and (2) is increased by 63 times and the resultant values are stored into the average density calculation
10 ROM table as the values which were converted into 6-bit values. In this case, the weight mask 1 is set as shown in Fig. 7.

Fig. 11 shows the table in the case where $\alpha = 1$ in the equation (6). When $E(i,j+1)$ is larger
15 than $R(0,0) = 18$, $E(i,j+1)$ is set to 0.

The output $f(i,j) + E(i,j) - (m_1(i,j) + m_0(i,j))/2$ of the subtracter 9 is input as an absolute value into the ROM 100. The positive/negative sign is determined in accordance with the value of $B(i,j)$.

20 The difference $E(i,j+1)$ obtained in the ROM 100 is added to the input image data $f(i,j+1)$ by the adder 13. The D F/F 11 delays the addition value by a period of time of one clock of the data.

As mentioned above, as compared with the
25 average density approximating method, the embodiment 3 can be easily realized by merely adding calculation ICs of a few chips.

1 As described above, according to the embodiment
3 of the invention, the average density is calculated
on the basis of the data which has already been binarized
and the binarization is executed on the basis of the
5 average density, so that a processing amount for binarization can be remarkably reduced. Moreover, when
the difference between the average density which is
generated upon binarization and the input multi-level
data lies within a predetermined range, the difference
10 is corrected, so that the half-tone process having the
excellent gradations can be executed.

 Further, in the embodiment, when the difference
between the average density and the input multi-level
data is larger than the predetermined value, the difference
15 is not corrected. Thus, the deterioration in resolution
due to the preservation of the densities is prevented
and the edge portion can be clearly reproduced.

 In the embodiment, the binary difference E has
been distributed to only the next pixel and the correction
20 has been executed in the equation (3). However,
the binary difference E can be also two-dimensionally
distributed to a plurality of pixels near the target
pixel at a predetermined distribution ratio. In this
case, although a hardware construction is slightly
25 complicated, the uniform image can be also obtained
with respect to the sub scanning direction as well as
the main scanning direction and the reproducibility

1 is improved.

On the other hand, for instance, in Fig. 1,
if the binary difference E is distributed to a plurality
of pixels in a manner such that $3E(i,j+1)/4$ is distri-
5 buted to the pixel $(i,j+1)$ and $E(i,j+1)/4$ is distributed
to the pixel $(i,j+2)$, the reproducing capability of
the gradations is improved even if the average processing
mask is small.

On the other hand, although the weighting mask
10 is increased as the pixel is near the target pixel,
its gradient and distribution are not limited. The
pixels existing at discrete positions which are not
neighboring can be also used.

On the other hand, the invention can be widely
15 used in image processing apparatuses such as facsimile
apparatus, copying machine, and the like.

Embodiment 4

In the embodiment 3, the binary difference E
has been divided to the cases shown by the equations
20 (9) and (10) and when the difference E is equal to or
larger than a predetermined value using the constant
 α , the difference E is set to 0 and is not distributed
to the next pixel. However, the value of the constant
 α can be also changed in accordance with the average
density value or target pixel density value.
25

For instance, as shown in Fig. 12, if the value
of α is set so as to decrease as the average density

1 approaches 0 or 1, the edge portion of a black character
in the white background, a blank character in the black
background, or the like can be more finely binarized.

Embodiment 5

5 The following equation (12) is used in place
of the equation (9) in the embodiment 3.

In the case where

$$\left. \begin{array}{l} (m_1(i,j) + m_0(i,j))/2 < K, \text{ and} \\ m_1(i,j) < f(i,j) + E(i,j) \\ \text{or} \\ (m_1(i,j) + m_0(i,j))/2 > 1-K, \text{ and} \\ m_0(i,j) > f(i,j) + E(i,j) \end{array} \right\} \quad (12)$$

Where, K is a constant and if it is set to about
0 or 1 ($K = 0, 1$), the good result can be obtained.

15 According to the embodiment 5, by setting the
difference E to 0 in the case where the average density
value approached 0 or 1, the character portion can be
highly finely binarized in a manner similar to the
embodiment 2.

20 In the embodiments 4 and 5, as shown in Fig.
10, if the output $(m_1(i,j) + m_0(i,j))/2$ of the average
density calculation ROM 8 is input in place of the
binary data $B(i,j)$ to an address terminal of the
difference calculation ROM 100, those embodiments
25 can be easily realized by the table converting
processes based on the data which has previously
been written in a manner similar to the embodiment 3.

1 Embodiment 6

 In the embodiment 3, the weighting mask of the
matrix of 3 x 3 shown in Fig. 3 has been used. However,
generally, in order to smoothly binarize the half-tone
5 portion, it is desirable to set the weight $R(0,0)$ of
the target pixel to a small value. In addition, as
the weight $R(0,0)$ is small for a density change of the
data to be binarized, the edge portion shown by the
equation (9) can be accurately detected. Therefore,
10 in the case of using the weighting mask of 4 x 5 shown
in Fig. 14, $R(0,0)$ in Fig. 3 in the embodiment 3 is
set to $8/28 = 0.29$, while that in Fig. 13 is set to
 $11/96 = 0.11$. Thus, the half-tone portion can be more
smoothly binarized and the edge portion of a character
15 portion or the like can be more finely binarized and
reproduced.

 In the embodiments 3 to 6, the calculation of
the correction value E for preservation of all densities
during the processing has been executed by using the
20 average values m_0 and m_1 . However, for instance, the
discrimination or the like to see if the value of E
is set to 0 or not in the edge portion or the like
can be realized by a well-known technique. For
example, a two-dimensional Laplacian is obtained
25 from the image data to be binarized, this value is
processed on the basis of the threshold value, the
edge portion is determined on the basis of the result

1 of the discrimination of such a threshold value processing,
and E is set to 0 in the edge portion. Even by this
method, the similar effect is derived. On the other
hand, the edge portion is designated in a wide region
5 on the basis of a command obtained by an area designating
operation of the operator without switching the processes
every pixel and E can be also set to 0 in such a region.

In the above embodiments 1 to 6, assuming that
the average value when the target pixel was binarized
10 to 0 is set to m_1 and the average value when the target
pixel was binarized to 1 is set to m_0 , the data of the
target pixel is binarized by using $(m_1 + m_0)/2$ as a
threshold value.

In the embodiment which will be explained
15 hereinlater, explanation will now be made with respect
to an example in the case where the average value of
the binary data (the data which has previously been
binarized before the target pixel) including no target
pixel is set to a threshold value and the data of the
20 target pixel is binarized.

Embodiment 7

The principle of the above system will be first
described.

Fig. 14(1) is a diagram showing a multi-level
25 density of each pixel of the input image.

In Fig. 14(1), $f(i,j)$ denotes multi-level
density data of the input image at the position of

1 the target pixel to be binarized and is set to a normalized
value of 0 to 1. On the other hand, the binarization
has already been finished at the pixel positions above
a broken line. After the target pixel was binarized,
5 the similar binarization is sequentially executed in
a manner such that $f(i,j+1)$, $f(i,j+2)$,

Fig. 14(2) is a diagram showing binary image
data. $B(i,j)$ shows the density (having the value of
0 or 1) after the target pixel was binarized. The portion
10 surrounded by a broken line denote the pixel data which
has already been binarized upon processing of the target
pixel. Those pixel data are used to binarize the target
pixel.

Fig. 14(3) is a diagram showing weighting masks.
15 R denotes an example of the weighting mask to obtain
the average density and is expressed by a matrix of
a size of 3×3 . The weight $R(0,0)$ for the pixels
which are not binarized yet is used by setting such
that $R(0,0) = R(0,-1) = 0$.

20 In the system, the weighted average density
of the binary images near the target pixel is set to
 $m(i,j)$ and is obtained by the following equation.

$$m(i,j) = \sum_{x=0}^2 \sum_{y=-1}^1 R(x,y) \cdot B(i-x,j-y) \quad \dots \quad (13)$$

25 The target pixel $f(i,j)$ is binarized by using
the average density $m(i,j)$ and the binary correction
value $E(i,j)$ which has already been assigned in

1 accordance with the following equation.

$$\left. \begin{array}{l} \text{When } f(i,j) + E(i,j) > m(i,j), \\ \quad B(i,j) = 1 \\ \quad E(i,j+1) = f(i,j) + E(i,j) - m(i,j) \\ 5 \quad \text{When } f(i,j) + E(i,j) \leq m(i,j), \\ \quad B(i,j) = 0 \\ \quad E(i,j+1) = f(i,j) + E(i,j) - m(i,j) \\ \text{However, when } f(i,j) + E(i,j) = m(i,j) = 1, \\ \quad B(i,j) = 1 \end{array} \right\} (14)$$

10 Fig. 15 is a diagram showing the equation (14).

In the equation (14), $E(i,j)$ denotes a difference which is generated when the multi-level density $f(i,j-1)$ of the pixel which is precedent to the target pixel (i,j) by one pixel, that is, of the pixel $(i,j-1)$ was
15 binarized to the binary density $B(i,j-1)$. Namely, $E(i,j)$ corresponds to the difference value between the multi-level density $f(i,j-1)$ and the average density $m(i,j-1)$ of the pixel near the target pixel. By binarizing the corrected value which is obtained
20 by adding the binary difference $E(i,j)$ to the target pixel $f(i,j)$, the image density after completion of the binarization can be completely preserved as an average density in the whole input image region.

By executing the processes in consideration
25 of the binary difference, the reproducing capability of the half tone is remarkably improved as compared with that in the average density approximating method.

1 On the other hand, in the equation (14), $E(i,j+1)$
denotes a difference which is distributed to the pixel
 $f(i,j+1)$ which is located behind the target pixel (i,j)
by one pixel.

5 The reason why in spite of the fact that a
processing amount in the binarization system in the
embodiment is extremely smaller than that in the error
diffusion method, the image reproducing capability which
is equal to or higher than that in the error diffusion
10 method is obtained is because in spite of the fact that
the difference is merely corrected by one adjacent pixel,
by obtaining the average density by using a plurality
of data after completion of the binarization, the effect
similar to that in the case of distributing the difference
15 to a plurality of pixels and correcting is equivalently
obtained.

 Since a schematic circuit construction in the
embodiment is similar to that shown in Fig. 4, its
description is omitted.

20 Fig. 16 is a block diagram showing the details
of the binarizing circuit D in the embodiment 7.

 In Fig. 16, reference numerals 101 and 102
denote delay RAMs each for storing the binarized data
by an amount of one line; 103 to 107 and 111 indicate
D F/F (D flip-flops) each for delaying the binary data
25 by a period of time of one pixel; 108 an average density
calculation ROM for calculating the average density of

1 a predetermined region from the binary data of the pixels
around the target pixel and for outputting the average
density as a threshold value when the data of the target
pixel is binarized; 109 a subtracter for calculating
5 the difference between the input multi-level data of
the target pixel and the threshold value which is output
from the ROM 108; 110 a comparator for comparing the
threshold value which is output from the ROM 108 with
the multi-level data of the target pixel; and 112 an
10 adder for adding the difference data which is output
from the subtracter 109 and the 6-bit multi-level
data sent from the correction circuit.

In the above construction, the comparator 110
outputs the 1-bit data $B(i,j)$ which was binarized on
15 the basis of the equation (14). The binary data is
input to the RAMs 102 and 101 for delaying it every
line. The binary data $B(i-1,j+1)$ which was delayed
by one line by the RAM 102 is output to the ROM 108.
The binary data $B(i-2,j+1)$ which was delayed by two
20 lines by the RAM 101 is output to the ROM 108.

Further, the D F/F 103 outputs the $B(i-2,j)$,
the D F/F 104 outputs the $B(i-2,j-1)$, the D F/F 105
outputs the $B(i-1,j)$, the D F/F 106 outputs the
 $B(i-1,j-1)$, and the D F/F 107 outputs the $B(i,j-1)$,
25 respectively, to the ROM 108.

The binary data denote the binary images of
the peripheral pixels for the input image $f(i,j)$ as

1 shown in Fig. 14. By connecting the binary images to
input addresses in the ROM 108, the binarization threshold
value can be obtained at a high speed because the binari-
zation threshold value $m(i,j)$ shown in the equation (14)
5 has previously been stored in the ROM 108 on the basis
of the equation (13).

The threshold value is input to the subtracter
109 and comparator 110. On the other hand, $f(i,j) +$
 $E(i,j)$ is input from the D F/F 111 to the subtracter
10 109 and comparator 110.

On the basis of those two inputs, the subtracter
109 calculates the difference

$$f(i,j) + E(i,j) - m(i,j) \quad \dots \quad (15)$$

15 between both sides of the inequality in the equation (14),
that is, the difference between the average density
value $m(i,j)$ and the input data.

On the other hand, the comparator 110 compares
 $f(i,j) + E(i,j)$ and $m(i,j)$ on the basis of the two inputs
and outputs the binary data $B(i,j)$. On the other hand,
20 on the basis of the equation (15), the difference
 $E(i,j+1)$ which is output from the subtracter 109 is
added to the input image data $f(i,j+1)$ by the adder
112. The D F/F 111 delays the addition value by a
25 period of time of one clock of the data.

Fig. 17 shows examples of the weighting masks.
The weighting mask of Fig. 17A is used to obtain the

1 average value from the binary data of seven pixels.
The weighting mask of Fig. 17B is used to obtain the
average value from the binary data of twelve pixels.
In the embodiment, since the weighting mask shown in
5 Fig. 17A is used, in order to normalize to the image
density levels (0 to 63) of six bits which are actually
input, the values obtained by the equation (13) are
increased by 63 times and the resultant values are stored
into the average density calculation ROM table as the
10 values which were converted into the 6-bit values.

As described above, according to the embodiment
7, the average density is calculated by using only the
binary data which was binarized and the input multi-
level data is binarized by using the average density
15 as a threshold value. Therefore, a processing amount
for binarization can be reduced as compared with that
in the average density approximating method. Moreover,
since the difference between the input multi-level data
and the average density which is generated when the
input multi-level data was binarized is corrected the
20 gradations can be extremely improved.

In the embodiment, although the binary difference
E has been distributed to only the next pixel and corrected,
if the binary difference E is distributed to a plurality
of pixels in the main scanning direction in a manner
25 such that, for instance, in Fig. 14, $3E(i,j+1)/4$ is
distributed to the pixel $(i,j+1)$ and $E(i,j+1)/4$ is

1 distributed to the pixel $(i,j+2)$, the reproducing
capability of the gradations is improved even when
the average processing mask is small.

On the other hand, the binary difference E can
5 be also two-dimensionally distributed to a plurality
of pixels near the target pixel at a predetermined
distribution ratio in a manner similar to the case of
the error diffusion method. In this case, although
a hardware construction is slightly complicated, the
10 uniform image can be obtained in the sub scanning
direction as well as the main scanning direction and
the reproducibility is improved.

On the other hand, although the weighting mask
has been increased as the pixel is close to the target
15 pixel, its gradient and distribution are not limited.
The pixels at the discrete positions which are not
neighboring can be also used.

In the embodiment 7, the weighting mask of a
matrix of 3×3 such as shown in an example of Fig.
17A has been used. However, generally, in order to
20 smoothly binarize the half-tone portion, it is
desirable to set the weight of the pixel adjacent
to the target pixel to a small value.

Therefore, in the case of using the weighting
25 matrix of a matrix of 3×5 shown in Fig. 17B, $R(i-1,j)$
and $R(i,j-1)$ are set to $7/48 = 0.15$ as compared with
 $5/21 = 0.24$ in the matrix of Fig. 17A, so that the

1 half-tone portion can be smoothly binarized and reproduced.

In the embodiment, the calculation of the average density m has easily been realized by the ROM table.

5 However, such a calculation can be also realized even by using seven AND gates and a plurality of adders.

In this case, the processing speed can be further made high. On the other hand, by assembling such a processing circuit into a gate array or the like, a hardware scale can be remarkably reduced.

10 In the embodiment, the correction has been performed by directly adding the binary difference $E(i,j)$ to the target pixel density $f(i,j)$. However, as shown in Fig. 18, even when the difference $E(i,j)$ is corrected by subtracting it from the average density by using
15 a subtracter 113, the similar effect can be also obtained.

Embodiment 9

The embodiment 8 relates to a partially modified form of the embodiment 7.

20 That is, in the embodiment 8, the difference $E(i,j+1)$ when the next pixel is binarized is expressed by the following equation. In the case where

$$\left. \begin{array}{l} |f(i,j) + E(i,j) - m(i,j)| > \alpha, \\ (\alpha \text{ is a constant}) \end{array} \right\} \dots \quad (16)$$
$$E(i,j+1) = 0$$

25 In the cases other than the above case,

$$E(i,j+1) = f(i,j) + E(i,j) - m(i,j) \quad \dots \quad (17)$$

1 Therefore, as shown in the equations (16) and
 (17), in the comparison between the average density
 m upon binarization and the corrected target pixel
 density in which the difference was corrected, if the
5 corrected target pixel density lies within a predeter-
 mined range of a value near the average density m (that
 is, when the difference between the average density
 m and the corrected target pixel density lies within
 a predetermined range), the difference between the
10 corrected target pixel density and the average density
 is assigned as a correction value when the next pixel
 is binarized in accordance with the equation (17).
 On the other hand, if it is out of the predetermined
 range, that is, when the difference between the corrected
15 target pixel density and the average density is suffici-
 ently large, the correction value is set to 0 and the
 correction upon binarization of the next pixel is not
 executed. Namely, in the case of correcting the
 difference, the density change of the image near the
20 target pixel is small, so that it is determined that
 such as image is in the image area having a half-tone.
 Therefore, the difference between the image density
 and the average density which occurs due to the
 binarization is corrected by the next pixel, so
25 that the gentle density change of the image can be
 false half-tone processed with a high fidelity.
 That is, the gradations can be improved. On the

1 other hand, in the case where the difference is not
corrected, the edge portion in a character, a diagram,
or the like, that is, the target pixel is contrarily
determined to be suddenly changed as compared with the
5 density of the image near the target pixel. Thus, the
correction value is set to 0 for the pixel in such a
case and the deterioration in resolution due to the
preservation of the density is suppressed, thereby
binarizing and reproducing. Consequently, the resolu-
10 tion in the edge portion can be improved.

As mentioned above, according to the character-
istic processing system of the embodiment 8, in the
half-tone image area, the density is preserved on the
binary image by using the binary difference in
15 accordance with the image density change. In the
resolution image portion such as a character or the
like, in order to prevent the fading of the image due
to the preservation of the density, the correction of
the binary difference is not executed by the density
20 is approximated to the average density m .

Since a schematic circuit construction in
the embodiment 8 is similar to that shown in Fig. 4,
its description is omitted.

Fig. 19 is a block diagram showing the details
of the binarizing circuit D in the embodiment 8.
25

In Fig. 19, the same parts and elements as
those shown in Fig. 16 are designated by the same

1 reference numerals and their descriptions are omitted.

Reference numeral 115 denotes a comparator for comparing the difference between the multi-level data of the target pixel which is sent from the subtracter
5 109 and the threshold value with a predetermined value (α). Reference numeral 116 indicates a selector for selecting either 0 or an output of the subtracter 109 on the basis of a select signal from the comparator.

In Fig. 19, the comparator 110 outputs the
10 1-bit data $B(i,j)$ which was binarized on the basis of the equation (14). The binary data is input to the RAMs 102 and 101 each for delaying it every line. The binary data $B(i-1,j+1)$ which was delayed by one line by the RAM 102 is output to the ROM 108. The binary
15 data $B(i-2,j+1)$ which was delayed by two lines by the RAM 101 is output to the ROM 108.

Further, the D F/F 103 outputs the $B(i-2,j)$, the D F/F 104 outputs the $B(i-2,j-1)$, the D F/F 105 outputs the $B(i-1,j)$, the D F/F 106 outputs the $B(i-1,j-1)$, and the D F/F 107 outputs the $B(i,j-1)$, respectively,
20 to the ROM 108.

As shown in Fig. 14, the binary data denotes the binary images of the peripheral pixels for the input image $f(i,j)$. By connecting the binary images to input addresses in the ROM 108, the binarization
25 threshold value can be obtained at a high speed because the binarization threshold value $m(i,j)$

1 shown in the equation (14) has previously been stored
in the ROM 108 on the basis of the equation (13).

The threshold value is input to the subtracter
109 and comparator 110. On the other hand, $f(i,j) +$
5 $E(i,j)$ is input from the D F/F 111 to the subtracter
109 and comparator 110.

On the basis of the two inputs, the subtracter
109 calculates the difference

$$E(i,j+1) = f(i,j) + E(i,j) - m(i,j) \quad \dots \quad (18)$$

10

between both sides of the inequality in the equation
(14).

On the other hand, the comparator 110 compares
 $f(i,j) + E(i,j)$ with $m(i,j)$ on the basis of the two
15 inputs and outputs the binary data $B(i,j)$. On the
other hand, the difference $E(i,j+1)$ which is output
from the subtracter 109 is input to the selector 116
and the comparator 115 on the basis of the equation
(18).

20

The comparator 115 compares the difference
 $E(i,j+1)$ with the constant α by the equation (16) and
outputs the select signal to the selector 116 on the
basis of the result of the comparison.

As a result of the select signal sent from the
25 comparator 115, when the absolute value of the difference
 $E(i,j+1)$ is larger than α the selector 116 selects and
outputs $E(i,j+1) = 0$. If it is equal to or less than

1 α , the selector 116 directly selects and outputs the
output signal of the subtracter 109.

 The difference $E(i,j+1)$ is added to the input
image data $f(i,j+1)$ by the adder 112. The D F/F 111
5 delays the addition value by a period of time of one
clock of the data.

 In a manner similar to the above, by repeating
the above processes, the binarization is sequentially
executed.

10 The weighting mask shown in Fig. 17 is used.

 As described above, according to the embodiment
8, the average density is calculated by using only the
binary data which was binarized and the input multi-
level data is binarized by using the average density
15 as a threshold value. Therefore, a processing amount
for binarization can be reduced as compared with that
in the average density approximating method. Moreover,
when the difference between the input multi-level data
which is generated upon binarization of the input multi-
20 level data and the average density lies within a pre-
determined range, the difference is corrected, so that
the gradations can be remarkably improved.

 Further, in the embodiment, when the difference
between the average density and the input multi-level
data is larger than a predetermined value, the difference
25 is not corrected. Thus, the deterioration in resolution
due to the preservation of the density is prevented

1 and the edge portion can be clearly reproduced.

In the embodiment, the binary difference E has been distributed to only the next pixel and corrected. However, if the binary difference E is distributed to a plurality of pixels in the main scanning direction in a manner such that, for instance, in Fig. 14, $3E(i,j+1)/4$ is distributed to the pixel (i,j+1) and $E(i,j+1)/4$ is distributed to the pixel (i,j+2), the reproducing capability of the gradations is improved even if the average processing mask is small.

On the other hand, the binary difference can be also two-dimensionally distributed to a plurality of pixels near the target pixel at a predetermined distribution ratio in a manner similar to the case of the error diffusion method. In this case, although a hardware construction is slightly complicated, the uniform image can be obtained in the sub scanning direction as well as the main scanning direction and the reproducibility is improved.

On the other hand, although the weighting mask has been increased as the pixel is close to the target pixel, its gradient and distribution are not limited. The pixels existing at the discrete positions which are not neighboring can be also used.

25 Embodiment 9

In the embodiment 8, the binary difference E has been divided into two cases shown by the equations

1 (16) and (17) and when the difference E is equal to or
larger than a predetermined value using the constant
 α , the difference E is set to 0 and is not distributed
to the next pixel. However, the value of the constant
5 α can be also changed in accordance with the average
density value or target pixel density value.

For instance, as shown in Fig. 20, if the value
of α is set to be reduced as the average density approaches
0 or 1, the edge portion of a black character in the
10 white background, a blank character in the black back-
ground, or the like can be more finely binarized.

Embodiment 10

The following equation (19) can be also used
in place of the equation (16) in the embodiment 8.

$$\left. \begin{array}{l} \text{In the case where } m(i,j) < k \text{ and} \\ f(i,j) + e(i,j) - m(i,j) > \alpha \\ \text{or } m(i,j) > 1 - k \text{ and} \\ f(i,j) + E(i,j) - m(i,j) < -\alpha, \\ E(i,j+1) = 0 \end{array} \right\} \quad (19)$$

20 where, k is a constant and if k is set to about 0 or
1, the good result can be derived.

According to the embodiment, by setting the
difference E to 0 in the case where the average density
value approached 0 or 1, the character portion can be
finely binarized in a manner similar to the embodiment
25 9.

As shown in Fig. 21, in the embodiments 9 and

1 10, by inputting the output $m(i,j)$ of the average
density calculation ROM 108 to an address terminal in
a difference calculation ROM 120, those embodiments
can be easily realized by the table converting processes
5 based on the data which has previously been written.

Embodiment 11

In the embodiment 8, the weighting mask of a
matrix of 3×3 as shown in an example of Fig. 17A has
been used. However, generally, to smoothly binarize
10 the half-tone portion, it is desirable to set the
weight of the pixel adjacent to the target pixel to
a small value.

Therefore, in the case of using the weighting
mask of a matrix of 3×5 shown in Fig. 17B, $R(i-1,j)$
15 and $R(i,j-1)$ in Fig. 17B are set to $7/48 = 0.15$ while
those in Fig. 17A in the embodiment 8 are set to $5/21$
 $= 0.24$, so that the half-tone portion can be more
smoothly binarized and reproduced.

In the embodiment 8, the calculation of the
20 average density m has easily been realized by the ROM
table. However, such calculation can be also realized
by using seven AND gates and a plurality of adders.
In this case, the processing speed can be further
made high. On the other hand, by assembling such a
processing circuit into a gate array or the like, a
25 hardware scale can be remarkably reduced.

In the embodiment, the average density m which

1 is used in the present system has been used in the
calculation of the correction value E for preservation
of all densities during the processing. However, the
determination or the like to see if E is set to 0 or
5 not in the edge portion or the like can be also
realized by the well-known technique. For instance,
a two-dimensional Laplacian is obtained from the image
data to be binarized, this value is processed to a
threshold value, the edge portion is discriminated on
10 the basis of the result of the discrimination of such
a threshold value process, and E is set to 0 in the
edge portion. The similar result is also obtained
even by such a method. On the other hand, the edge
portion is designated in a wide area on the basis of
15 a command obtained by the area designating operation
by the operator without switching the process every
pixel and E can be also set to 0 in such an area.

On the other hand, although the embodiment
has been described with respect to the case where the
20 number of kind of the input data is one (one color),
the invention can be also applied to a color image by
setting the input data to three colors of R, G, and
B.

As described above, according to the invention,
25 an image having excellent gradation and resolution can
be obtained in a short time by a simple hardware
construction.

1 The present invention is not limited to the
foregoing embodiments but many modifications and
variations are possible within the spirit and scope
of the appended claims of the invention.

5 Attention is drawn to concurrently filed related
application (EP-A-), agents'
reference 2120530, which is incorporated herein by
reference and a copy of which is filed herewith.

10

15

20

25

CLAIMS:

1. An image processing apparatus comprising:
input means for inputting data of a target pixel;
5 calculating means for obtaining an average
density value of a predetermined region;
digitizing means for digitizing the data of the
target pixel on the basis of the average density
value obtained by the calculating means; and
10 correcting means for correcting a difference
which occurs when the digitization is executed by the
digitizing means.

2. An image processing apparatus comprising:
15 input means for inputting data of a target
pixel;
calculating means for obtaining an average
density value of a predetermined region;
digitizing means for digitizing the data of the
20 target pixel on the basis of the average density value
obtained by the calculating means; and
correcting means for correcting a difference
which occurs upon said digitization when the
difference is equal to or less than a predetermined
25 value.



3. An apparatus according to claim 1 or claim 2,
wherein said calculating means calculates an average
density value m_1 of the predetermined region when the
data of the target pixel was digitized to 1 and an
5 average density value m_2 of the predetermined region
when the data of the target pixel was digitized to
0.

4. An apparatus according to claim 3, wherein
10 said calculating means calculates the average density
value of the predetermined region by using a
predetermined weighting mask.

5. An apparatus according to claim 3, wherein
15 said digitizing means binarizes the data of the target
pixel by using $(m_1 + m_2)/2$ as a threshold value.

6. An apparatus according to claim 5, wherein
said correcting means corrects the difference between
20 the data of the target pixel and m_1 when the
digitizing means digitized the data of the target
pixel to 1.



7. An apparatus according to claim 5, wherein said correcting means corrects the difference between the data of the target pixel and m_0 when the digitizing means digitized the data of the target pixel to 0.

8. An apparatus according to claim 1 or claim 2, wherein said input means inputs data to which difference data which had been generated upon digitization of a previous pixel was added to the data of the target pixel.

9. An apparatus according to claim 1 or claim 2, wherein said calculating means calculates an average density value m from the data of the predetermined region which has already been digitized before the target pixel.

10. An apparatus according to claim 9, wherein said calculating means comprises an ROM in which the digitized data of the predetermined area is set to an address value and which outputs the average density value m .



11. An apparatus according to claim 9, wherein said digitizing means binarizes the data of the target pixel by using the average density value m as a threshold value.

5

12. An image processing apparatus comprising:
input means for inputting data of a target pixel;

calculating means for obtaining an average
10 density value of a predetermined region by using binary data which has already been binarized with respect to a pixel before the target pixel; and

binarizing means for binarizing the data of the target pixel on the basis of the average density value
15 obtained by the calculating means.

13. An apparatus according to claim 12, further having correcting means for correcting a difference which occurs when the binarization is executed by the
20 binarizing means.

14. An image processing apparatus comprising:
input means for inputting data of a target
pixel;
25 calculating means for obtaining an average density value of a predetermined region by using data



which was binarized;

binarizing means for binarizing the data of the target pixel on the basis of the average density value obtained by the calculating means; and

5 correcting means for correcting a difference which occurs when the data of the target pixel was binarized.

15. An image processing apparatus comprising:

10 input means for inputting data of a target pixel;

calculating means for obtaining an average density value of a predetermined region by using data which was binarized;

15 binarizing means for binarizing the data of the target pixel on the basis of the average density value obtained by the calculating means; and

correcting means for correcting a difference which occurs when the data of the target pixel was
20 digitized when the difference lies within a predetermined value.

16. An apparatus according to any one of claims 12, 14 and 15, wherein said calculating means
25 calculates the average density value by using a



weighting mask from binary data of the predetermined region.

17. An apparatus according to claim 15, wherein
5 said binarizing means binarizes the data of the target pixel by using the average density value as a threshold value.

18. An apparatus according to any one of claims
10 1, 13 and 14, wherein said correcting means corrects the difference so as to improve gradation when the difference which occurs upon said digitization or binarization exists within a predetermined value.

19. An apparatus according to any one of claims
15 2, 15 and 18, wherein said correcting means does not correct the difference so as to improve a resolution when the difference which occurs upon digitization or binarization is equal to or larger than the
20 predetermined value.

20. An image processing method or apparatus in
which the value of an optical characteristic of a pixel is determined, and the characteristic of the
25 pixel is quantized using the determined value of the optical characteristic, a correction value, and a



- 57 -

threshold value, and an error arising from the quantization is used in the generation of the correction value for use in the quantization of another nearby pixel.



FIG. 1

(1) MULTI-LEVEL IMAGE

	$f(i-2, j-1)$	$f(i-2, j)$	$f(i-2, j+1)$	
	$f(i-1, j-1)$	$f(i-1, j)$	$f(i-1, j+1)$	
	$f(i, j-1)$	$f(i, j)$	$f(i, j+1)$	

(2) BINARY IMAGE

	$B(i-2, j-1)$	$B(i-2, j)$	$B(i-2, j+1)$	
	$B(i-1, j-1)$	$B(i-1, j)$	$B(i-1, j+1)$	
	$B(i, j-1)$	$B(i, j)$		

(3) WEIGHTING MASK

$R(2, 1)$	$R(2, 0)$	$R(2, -1)$
$R(1, 1)$	$R(1, 0)$	$R(1, -1)$
$R(0, 1)$	$R(0, 0)$	$R(0, -1)$

$$R=R(0, -1)=0$$



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FIG. 2

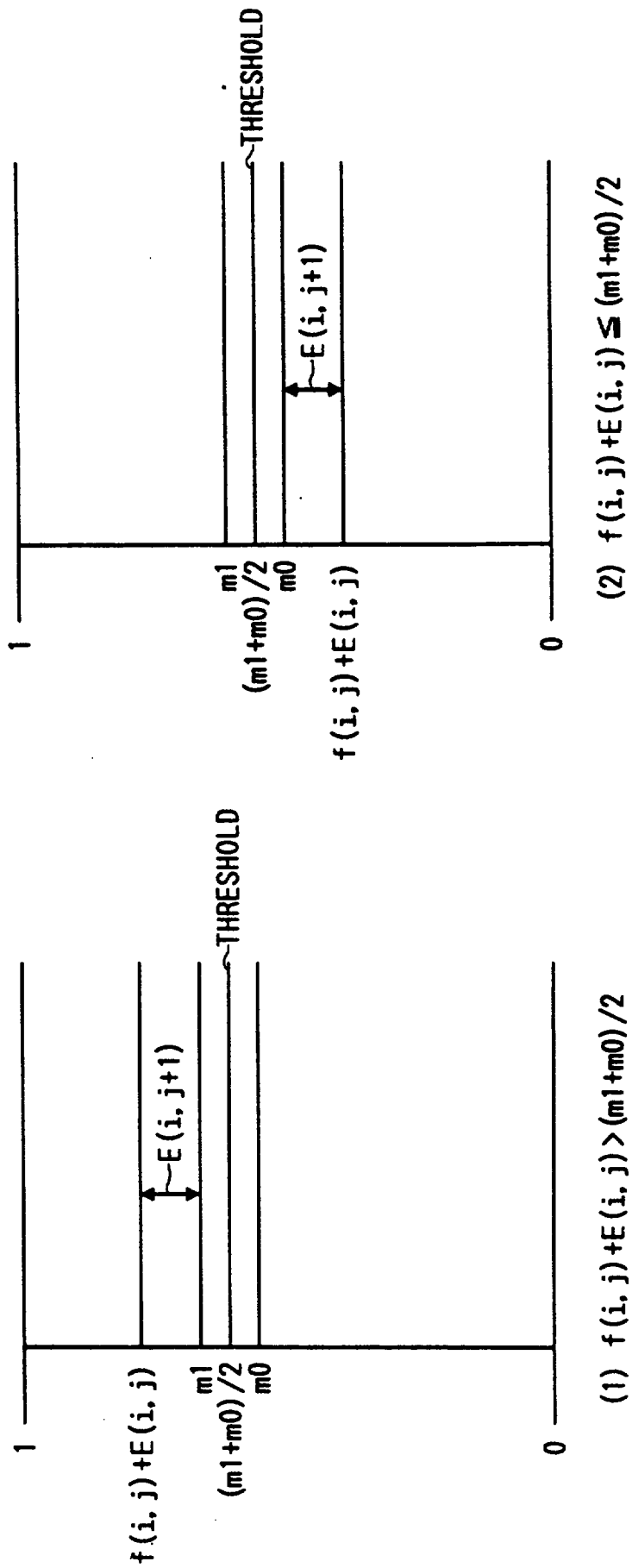


FIG. 3

1	3	1
3	5	3
5	8	0

S=29

WEIGHTING MASK 1

1	3	5	3	1
3	5	7	5	3
5	7	10		

S=58

WEIGHTING MASK 2

FIG. 4

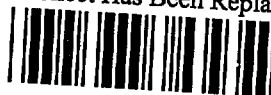
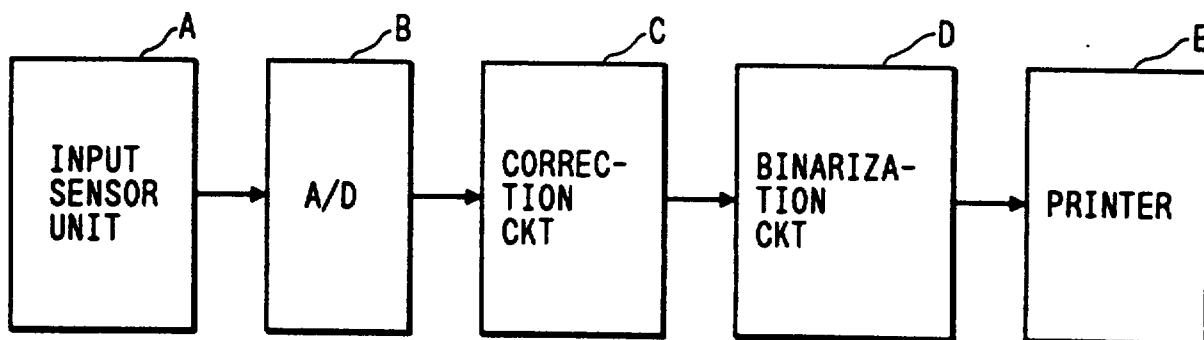
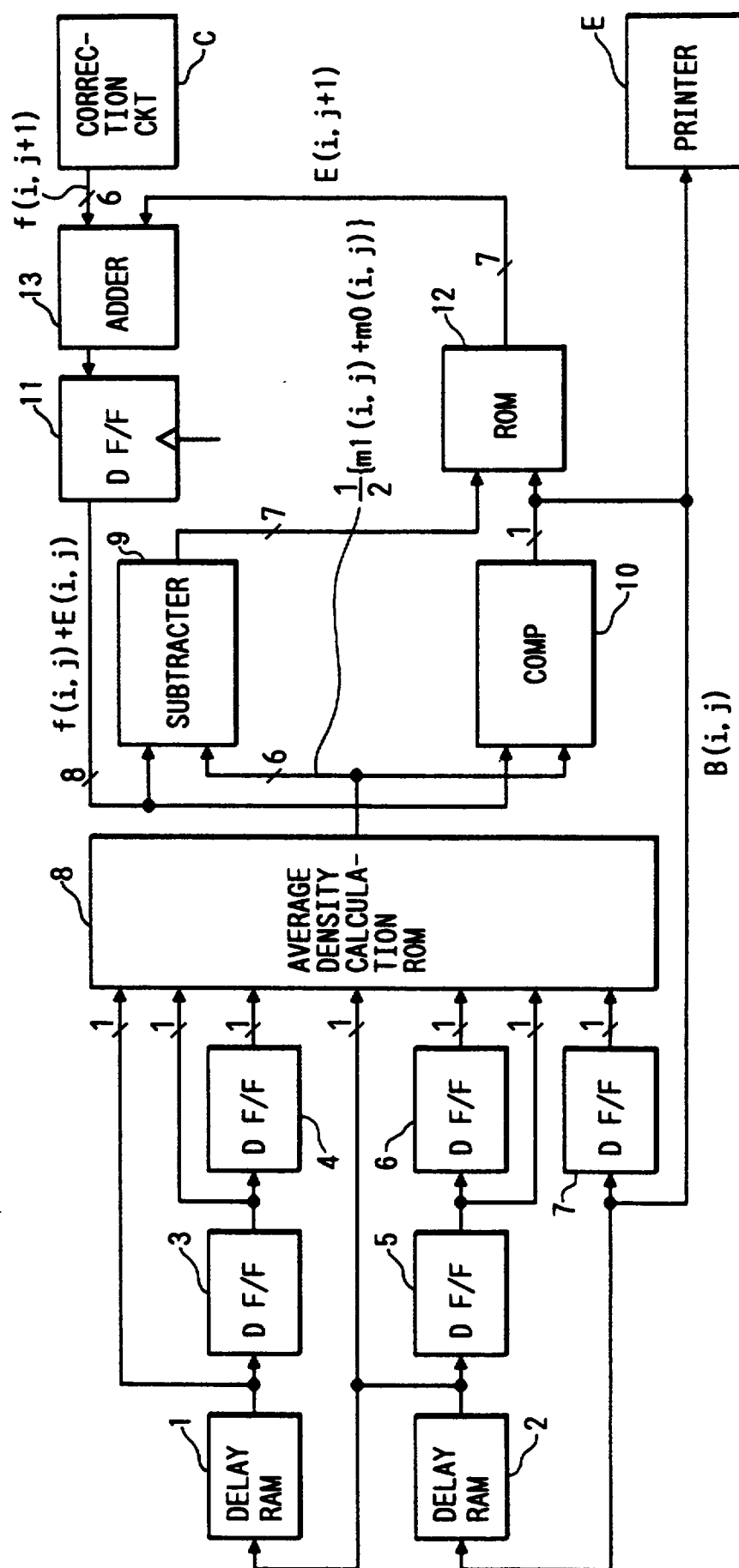


FIG. 5



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FIG. 6

B(i, j)		
7 BIT	B=1	B=0
0	-9	+9
1	-8	+8
⋮		
8	-1	+1
9	0	0
10	+1	-1
⋮		
26	+17	-17
27	+18	-18
28	+19	-19
29	+20	-20
⋮		
127	+118	-118

$$|f(i, j) + E(i, j) - (m1(i, j) + m0(i, j))/2|$$

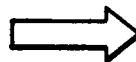
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FIG. 7

WEIGHTING MASK 1

1	3	1
3	5	3
5	8	

 $\times \frac{1}{29}$ 

6BIT (0~63)

3	6	4
6	10	6
10	18	

 $R(0.0) = 18$

FIG. 12

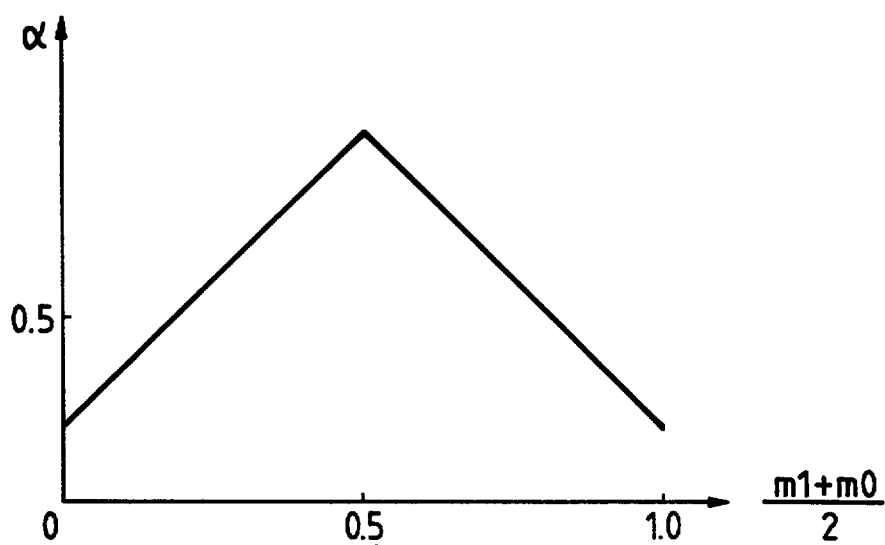


FIG. 13

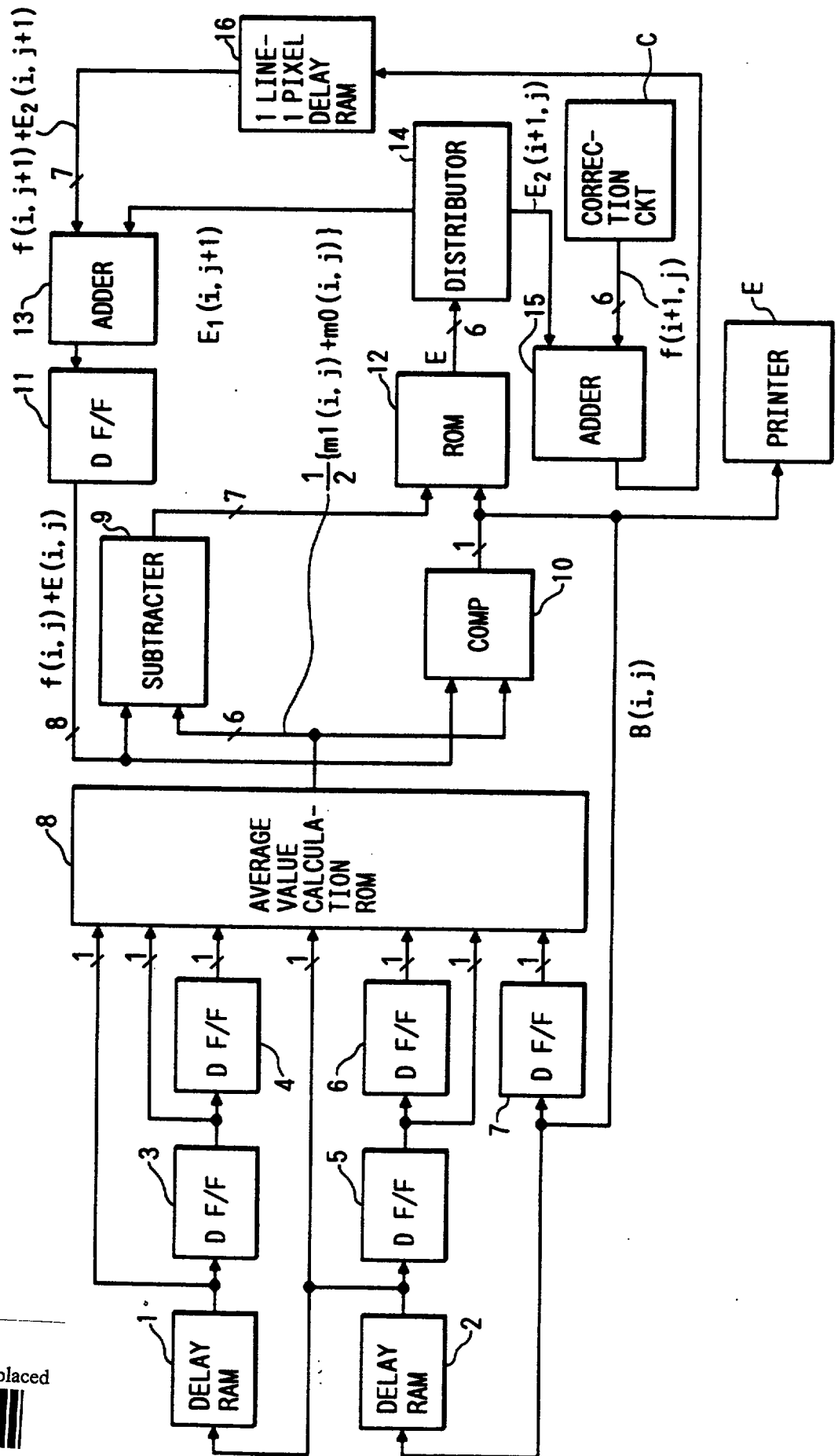
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1	3	5	3	1
3	5	7	5	3
5	7	9	7	5
7	9	11	0	0

 $S=96$ $[\times \frac{1}{S}]$

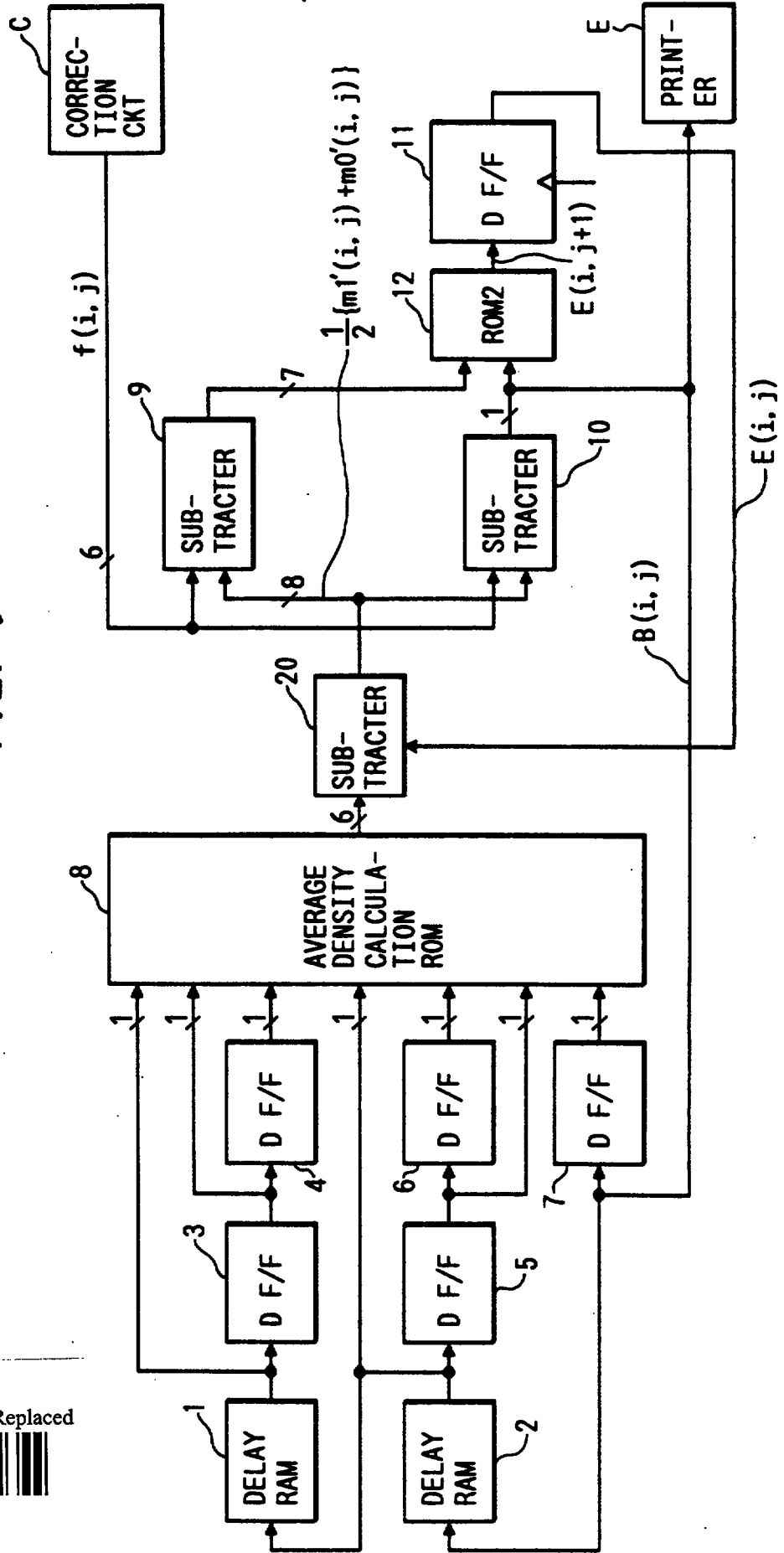
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8/17

FIG. 9

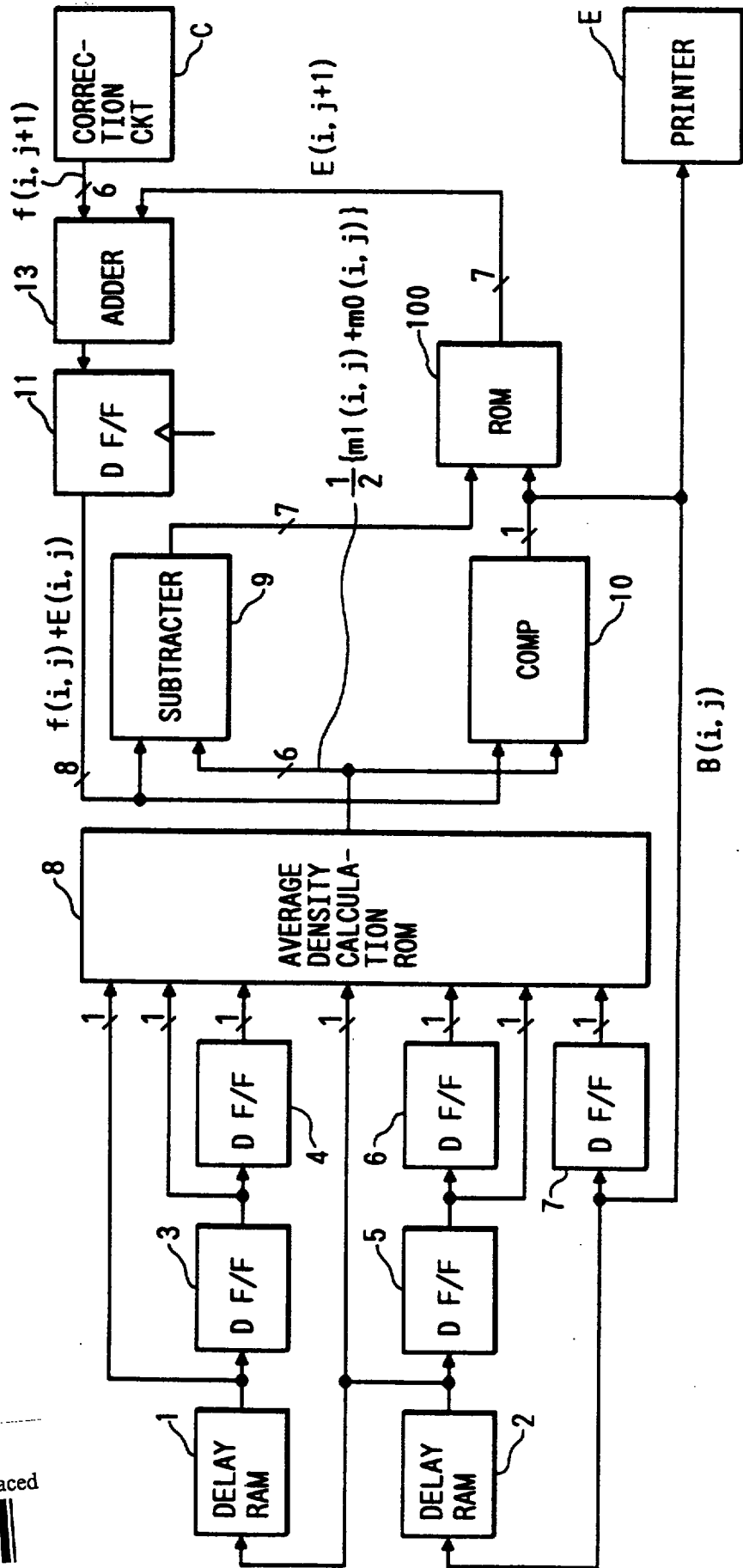


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9/17

FIG. 10



10/17

FIG. 11

B		
7 BIT	B=1	B=0
0	-9	+9
1	-8	+8
⋮		
8	-1	+1
9	0	0
10	+1	-1
⋮		
26	+17	-17
27	+18	-18
28	0	0
29	0	0
⋮		
127	0	0

$|f(i, j) + E(i, j) - (m1(i, j) + m0(i, j))/2|$

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FIG. 14

(1) MULTI-LEVEL IMAGE

	$f(i-2, j-1)$	$f(i-2, j)$	$f(i-2, j+1)$
	$f(i-1, j-1)$	$f(i-1, j)$	$f(i-1, j+1)$
	$f(i, j-1)$	$f(i, j)$	$f(i, j+1)$

(2) BINARY IMAGE

	$B(i-2, j-1)$	$B(i-2, j)$	$B(i-2, j+1)$
	$B(i-1, j-1)$	$B(i-1, j)$	$B(i-1, j+1)$
	$B(i, j-1)$	$B(i, j)$	

(3) WEIGHTING MASK

$R(2, 1)$	$R(2, 0)$	$R(2, -1)$
$R(1, 1)$	$R(1, 0)$	$R(1, -1)$
$R(0, 1)$	$R(0, 0)$	$R(0, -1)$

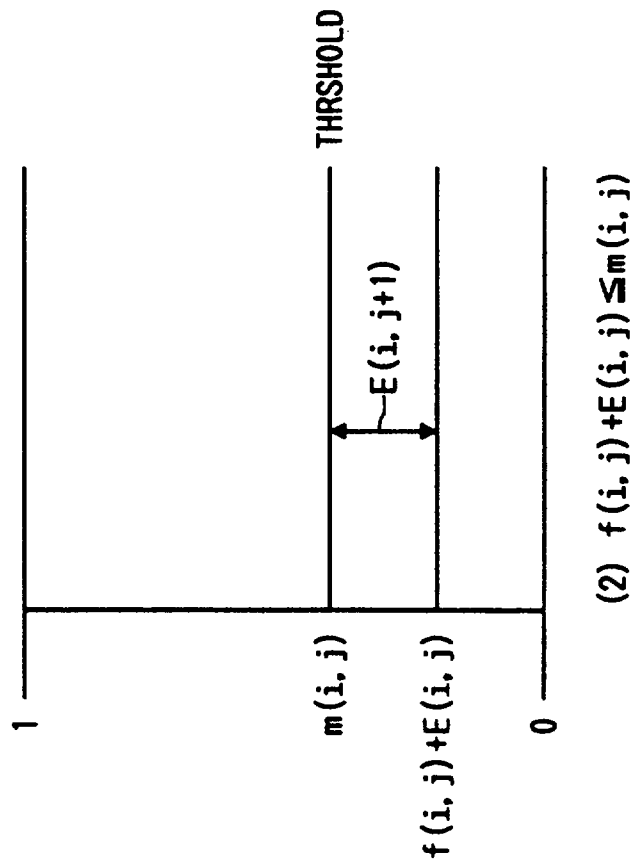
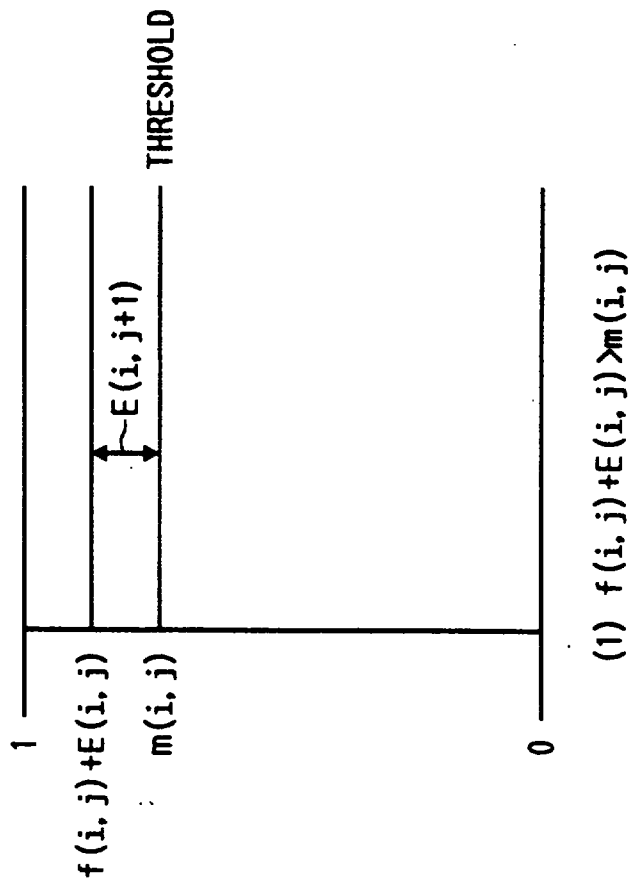
$$R(0, 0) = R(0, -1) = 0$$



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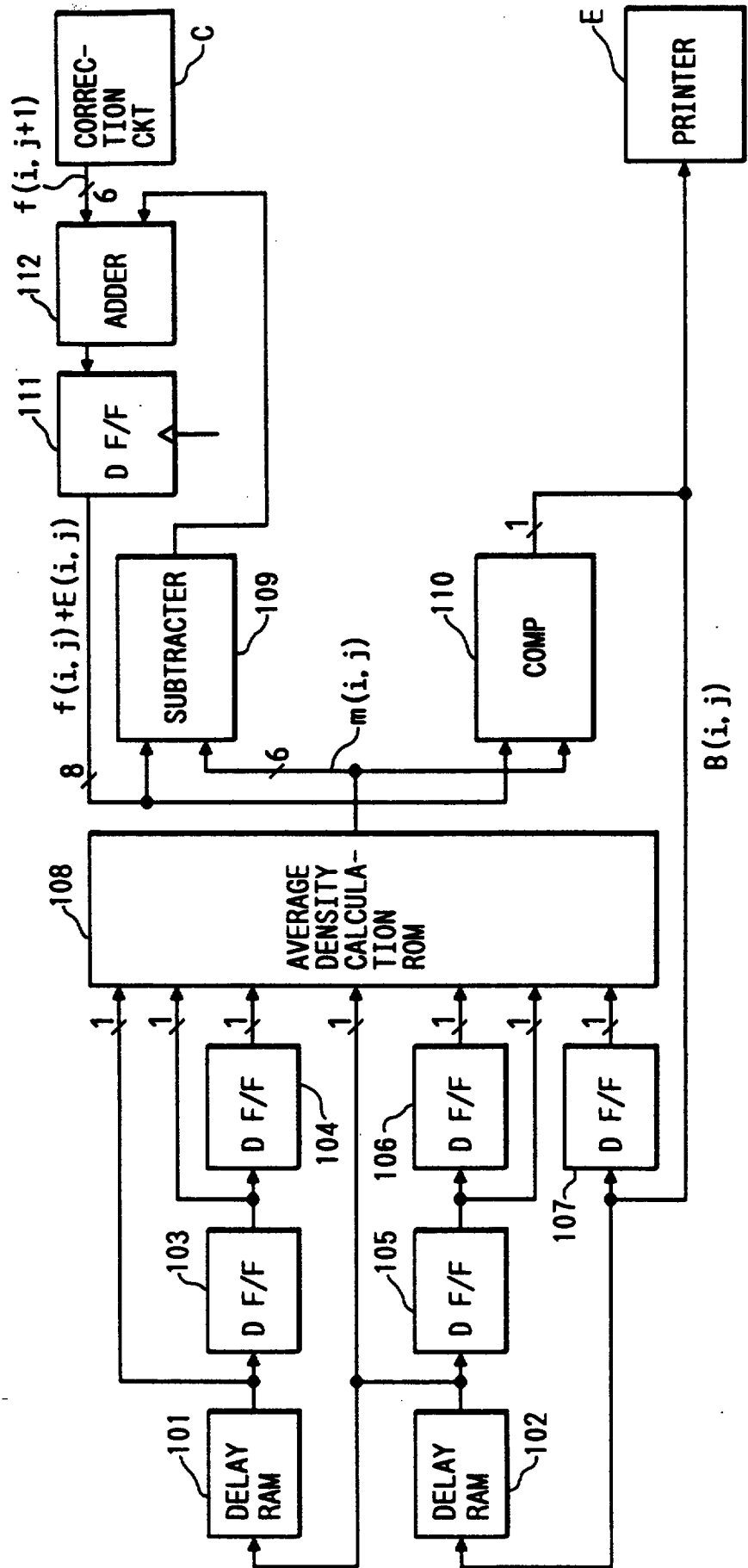


FIG. 15



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FIG. 16



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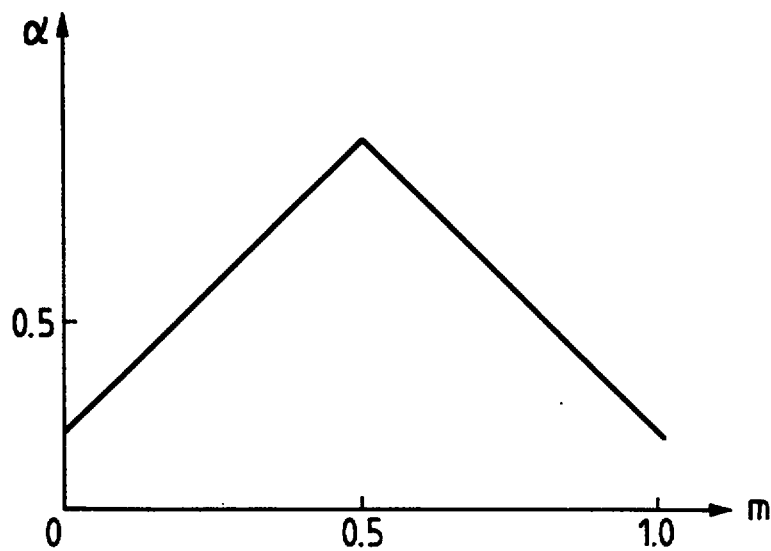
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FIG. 17A

1/21	3/21	1/21
3/21	5/21	3/21
5/21	0	0

FIG. 17B

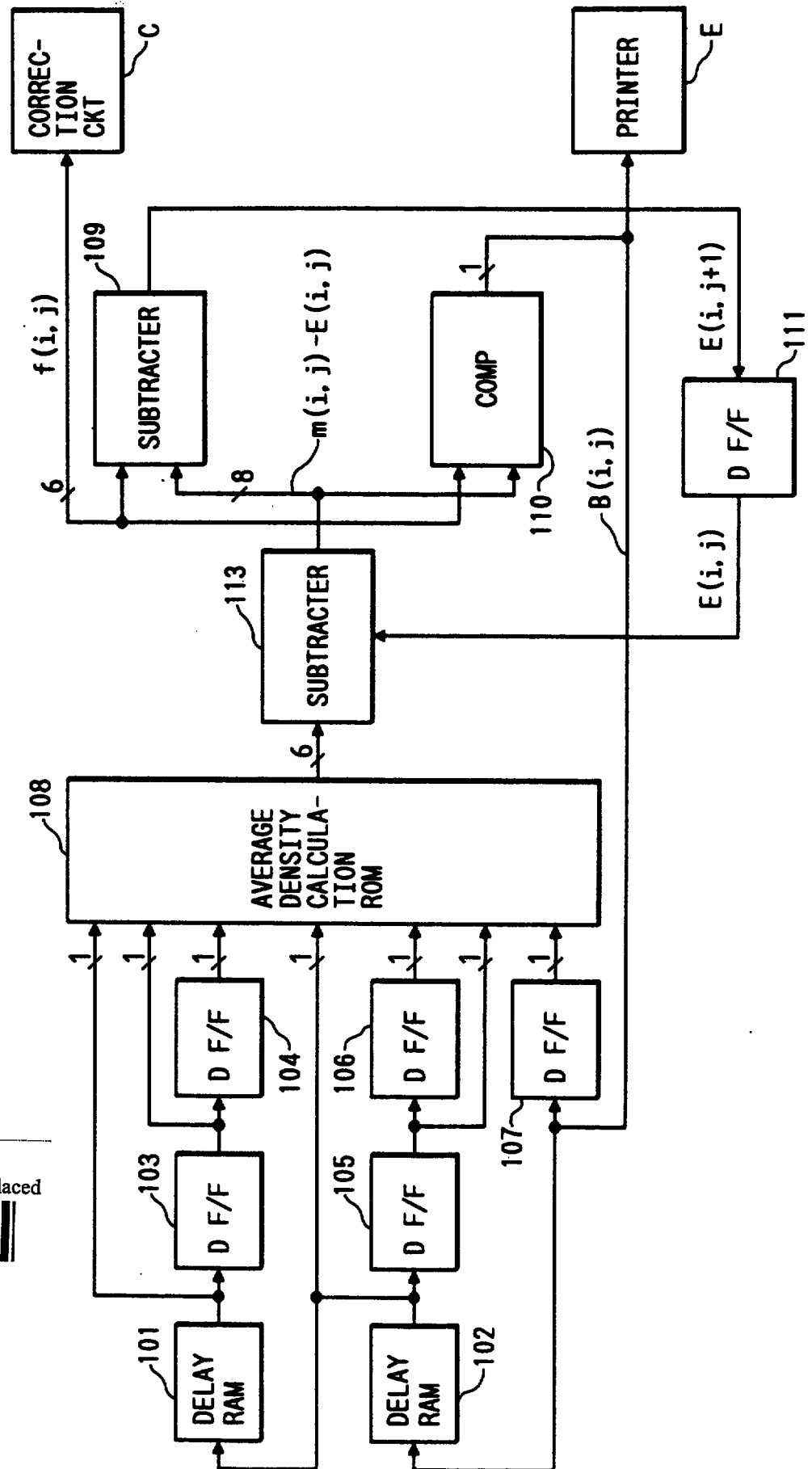
1/48	3/48	5/48	3/48	1/48
3/48	5/48	7/48	5/48	3/48
5/48	7/48	0	0	0

FIG. 20

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FIG. 18



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FIG. 19

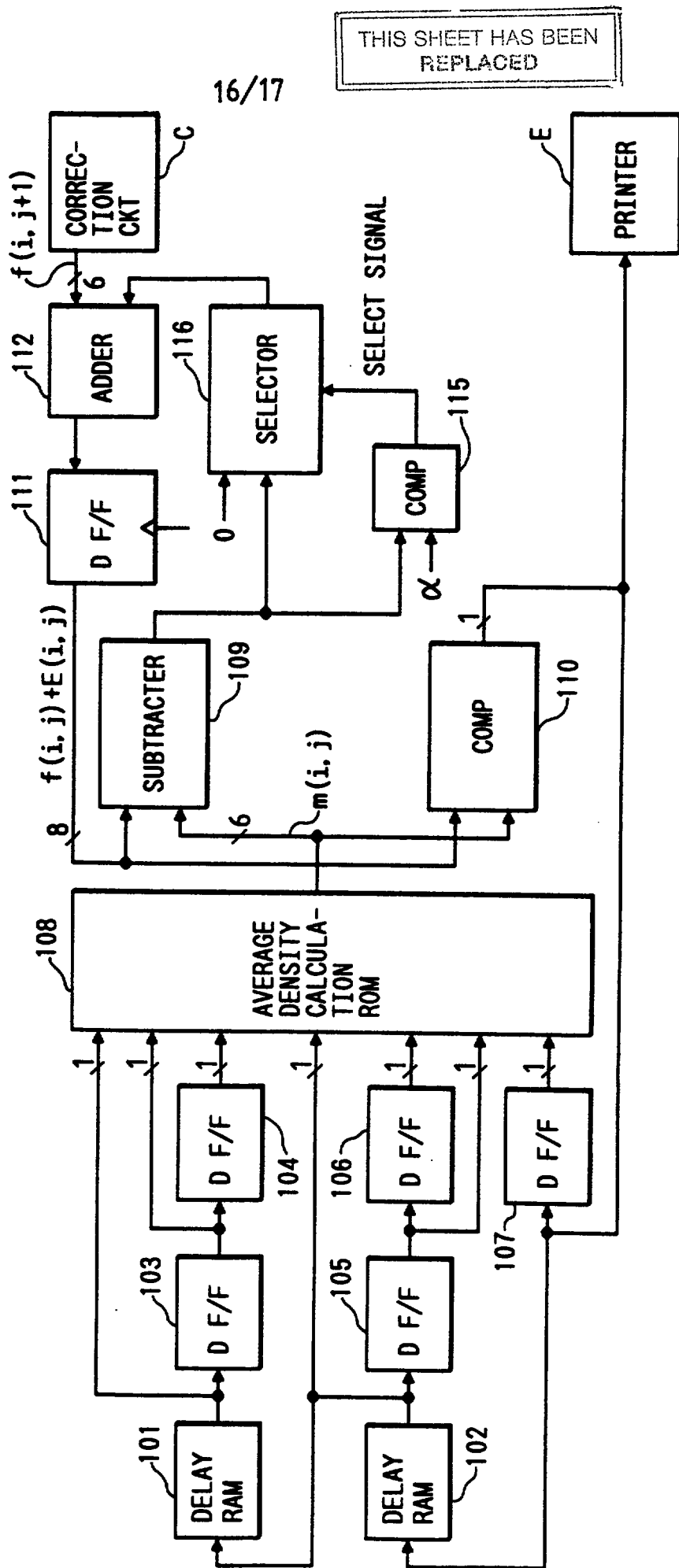
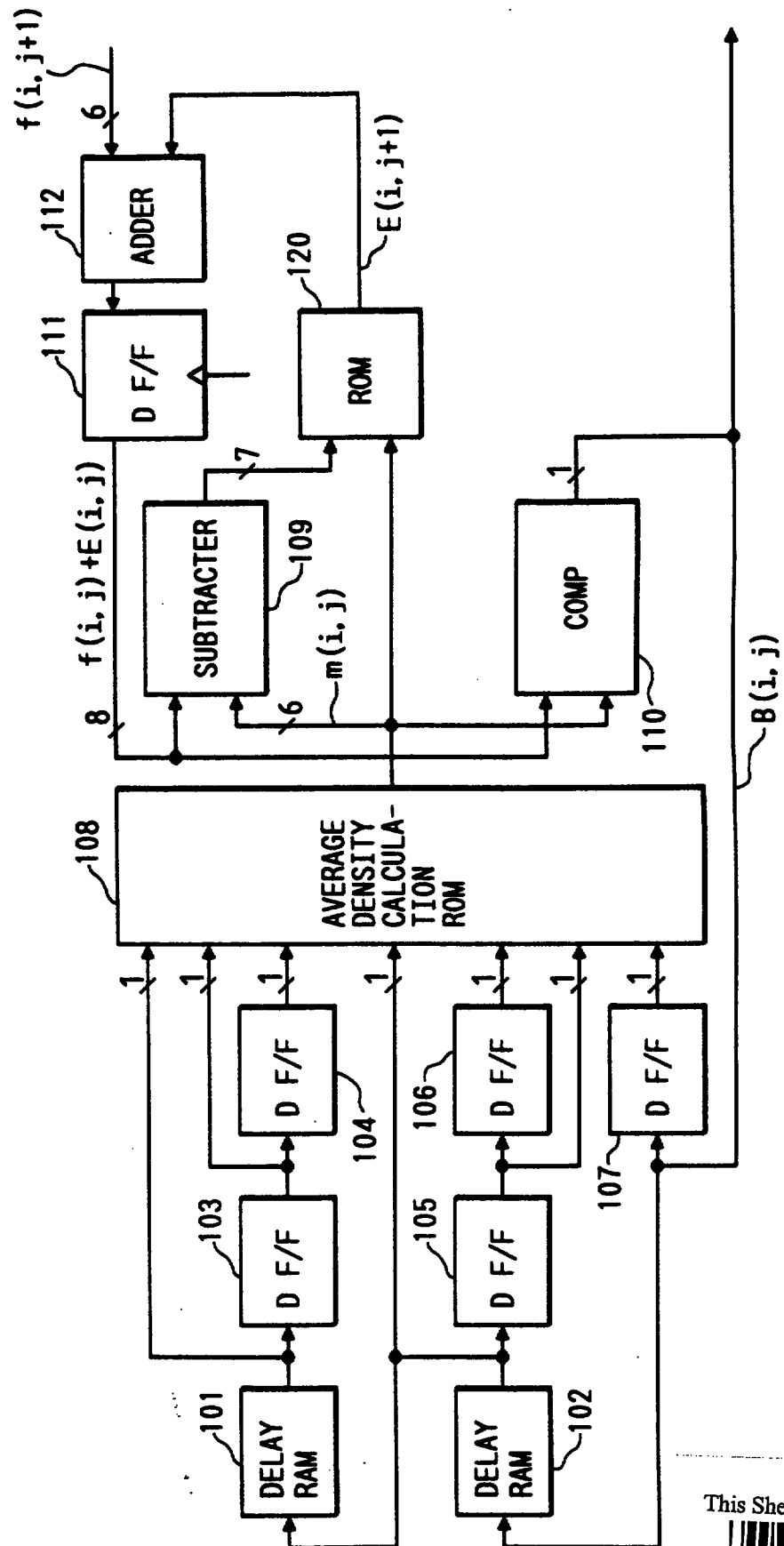


FIG. 21



ABSTRACTIMAGE PROCESSING APPARATUS

There is provided an image processing apparatus such as facsimile apparatus or digital copying machine for digitizing image data into two values or multi-values. The apparatus comprises: an input device to input data of a target pixel to be digitized; a calculating circuit to obtain an average density value of a predetermined region; a digitizing circuit such as a binarizing circuit for digitizing or binarizing the target pixel data on the basis of the average density value obtained by the calculating circuit; and a correction circuit to correct a difference which occurs upon digitization by the digitizing circuit. The calculating circuit calculates the average density value m_1 of the predetermined region when the target pixel data was binarized to 1 and the average density value m_2 of the predetermined region when the target pixel data was binarized to 0 by using a predetermined weighting mask. The digitizing circuit binarizes the target pixel data by using $(m_1 + m_2)/2$ as a threshold value. When the difference between the target pixel data and the average density value is within a predetermined value, the difference is corrected, so that an image of excellent gradation can be reproduced. When it is equal to or larger than the predetermined value, the difference is not corrected so that the resolution of a character portion such as an edge portion can be improved.

(FIGURE 1)

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1.

FIG. 1**(1) MULTI-LEVEL IMAGE**

	$f(i-2, j-1)$	$f(i-2, j)$	$f(i-2, j+1)$	
	$f(i-1, j-1)$	$f(i-1, j)$	$f(i-1, j+1)$	
	$f(i, j-1)$	$f(i, j)$	$f(i, j+1)$	

(2) BINARY IMAGE

	$B(i-2, j-1)$	$B(i-2, j)$	$B(i-2, j+1)$	
	$B(i-1, j-1)$	$B(i-1, j)$	$B(i-1, j+1)$	
	$B(i, j-1)$	$B(i, j)$		

(3) WEIGHTING MASK

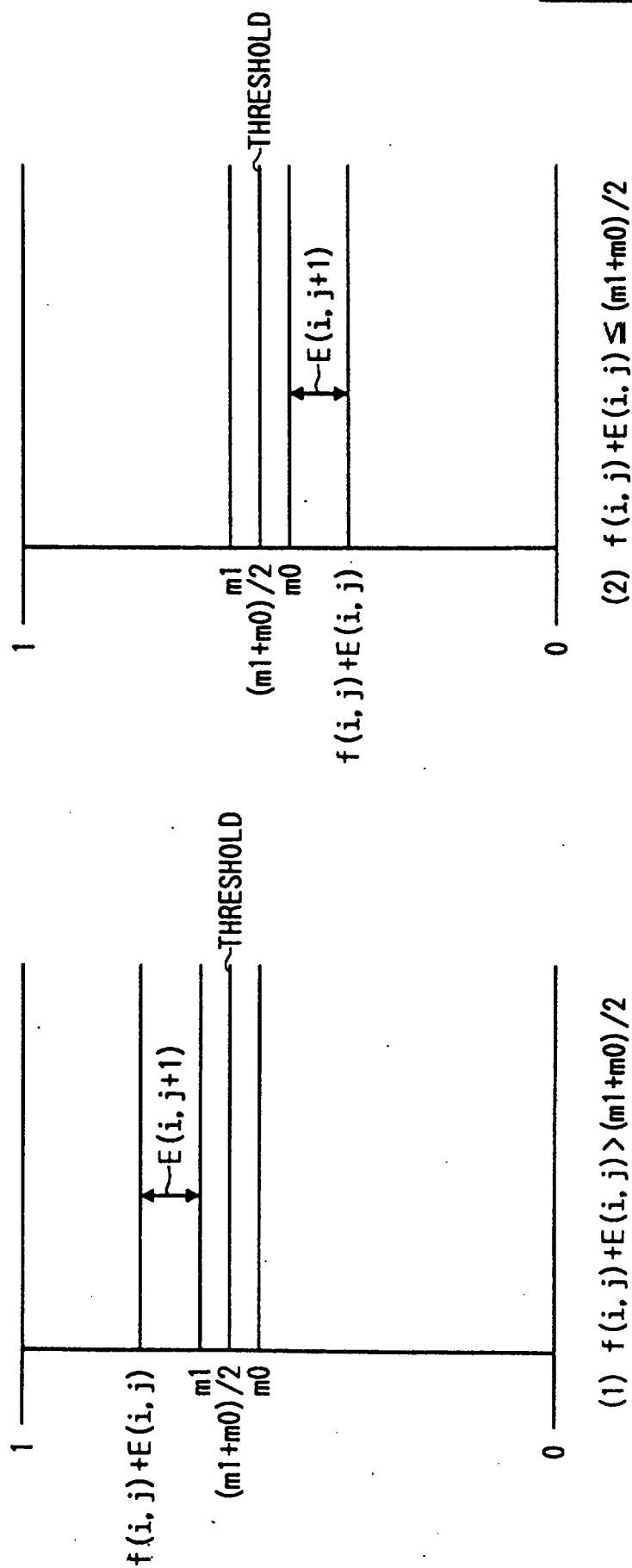
$R(2, 1)$	$R(2, 0)$	$R(2, -1)$
$R(1, 1)$	$R(1, 0)$	$R(1, -1)$
$R(0, 1)$	$R(0, 0)$	$R(0, -1)$

$$R = R(0, -1) = 0$$

05 MAR 1997

2

FIG. 2



05 MAR 1997

3.

FIG. 3

1	3	1
3	5	3
5	8	0

S=29

WEIGHTING MASK 1

1	3	5	3	1
3	5	7	5	3
5	7	10		

S=58

WEIGHTING MASK 2

FIG. 4

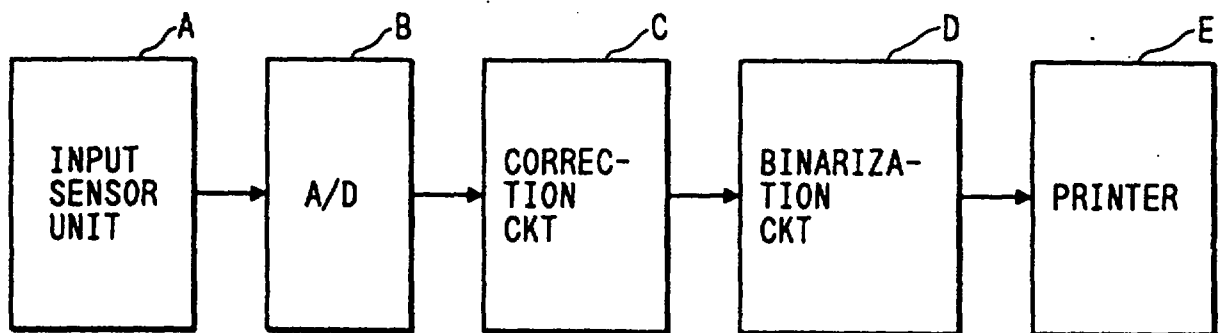
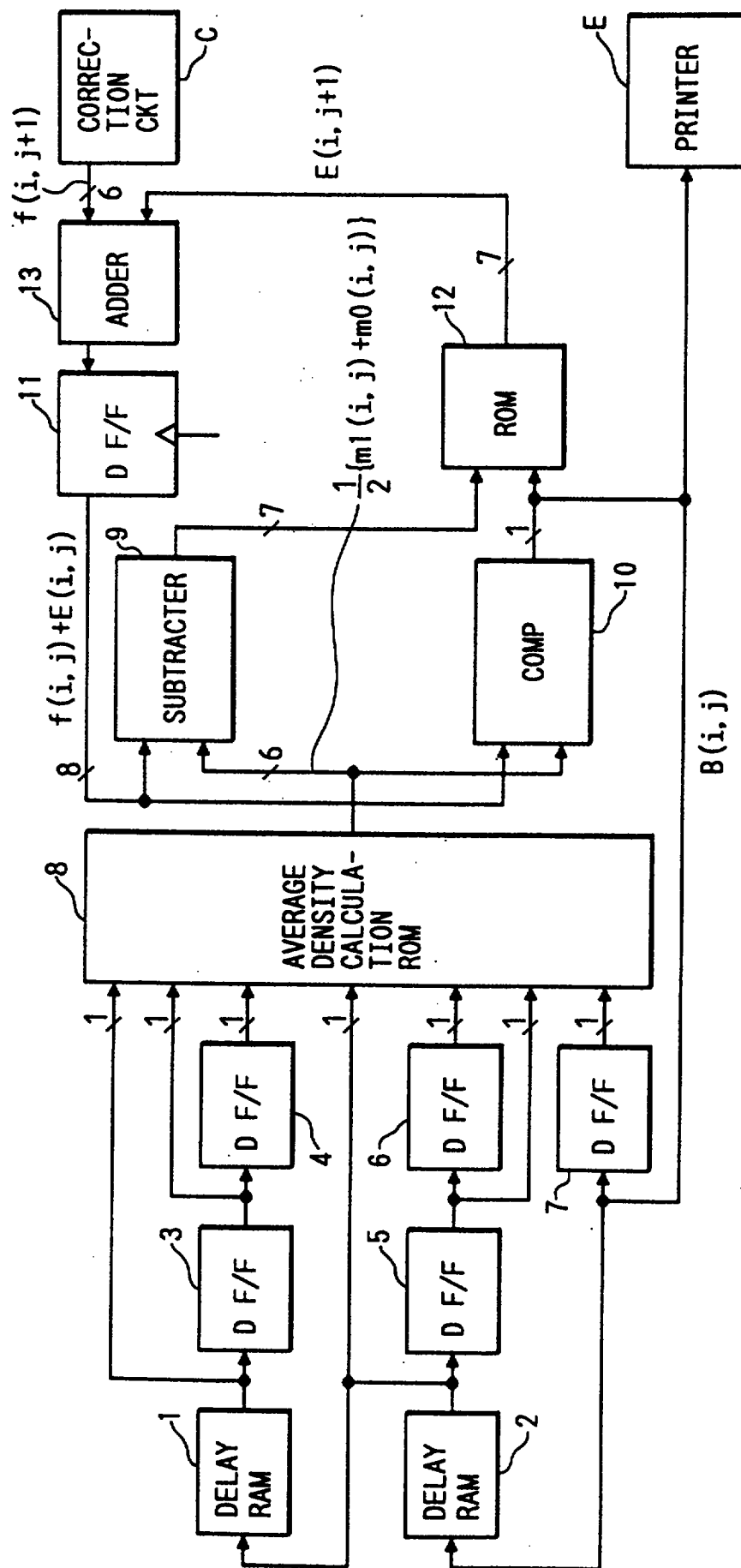


FIG. 5



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5

FIG. 6

B(i, j)		
7 BIT	B=1	B=0
0	-9	+9
1	-8	+8
⋮		
8	-1	+1
9	0	0
10	+1	-1
⋮		
26	+17	-17
27	+18	-18
28	+19	-19
29	+20	-20
⋮		
127	+118	-118

$$|f(i, j) + E(i, j) - (m1(i, j) + m0(i, j))/2|$$

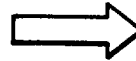
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6

FIG. 7

WEIGHTING MASK 1

1	3	1
3	5	3
5	8	

 $\times \frac{1}{29}$ 

6BIT (0~63)

3	6	4
6	10	6
10	18	

 $R(0.0) = 18$

FIG. 12

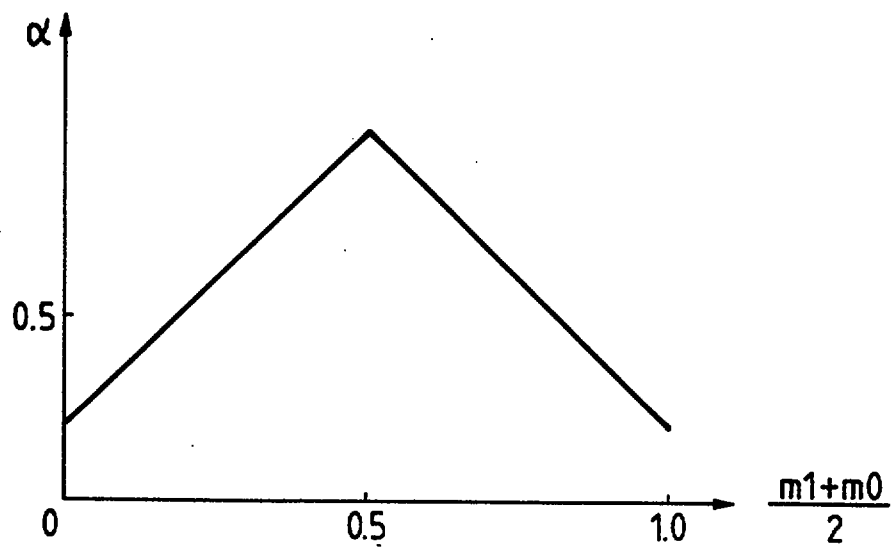


FIG. 13

1	3	5	3	1
3	5	7	5	3
5	7	9	7	5
7	9	11	0	0

 $S=96$ $[\times \frac{1}{S}]$

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FIG. 8

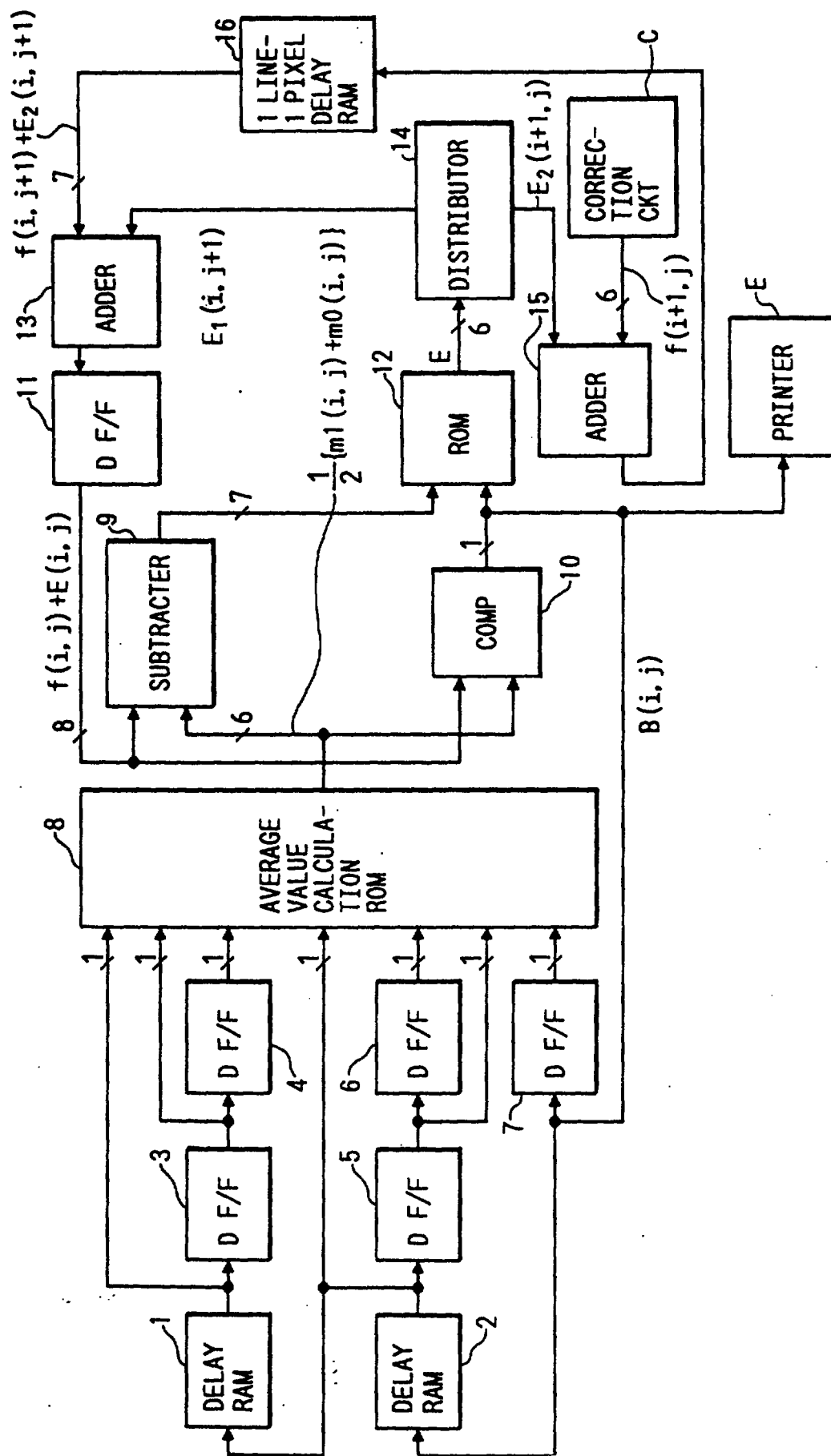
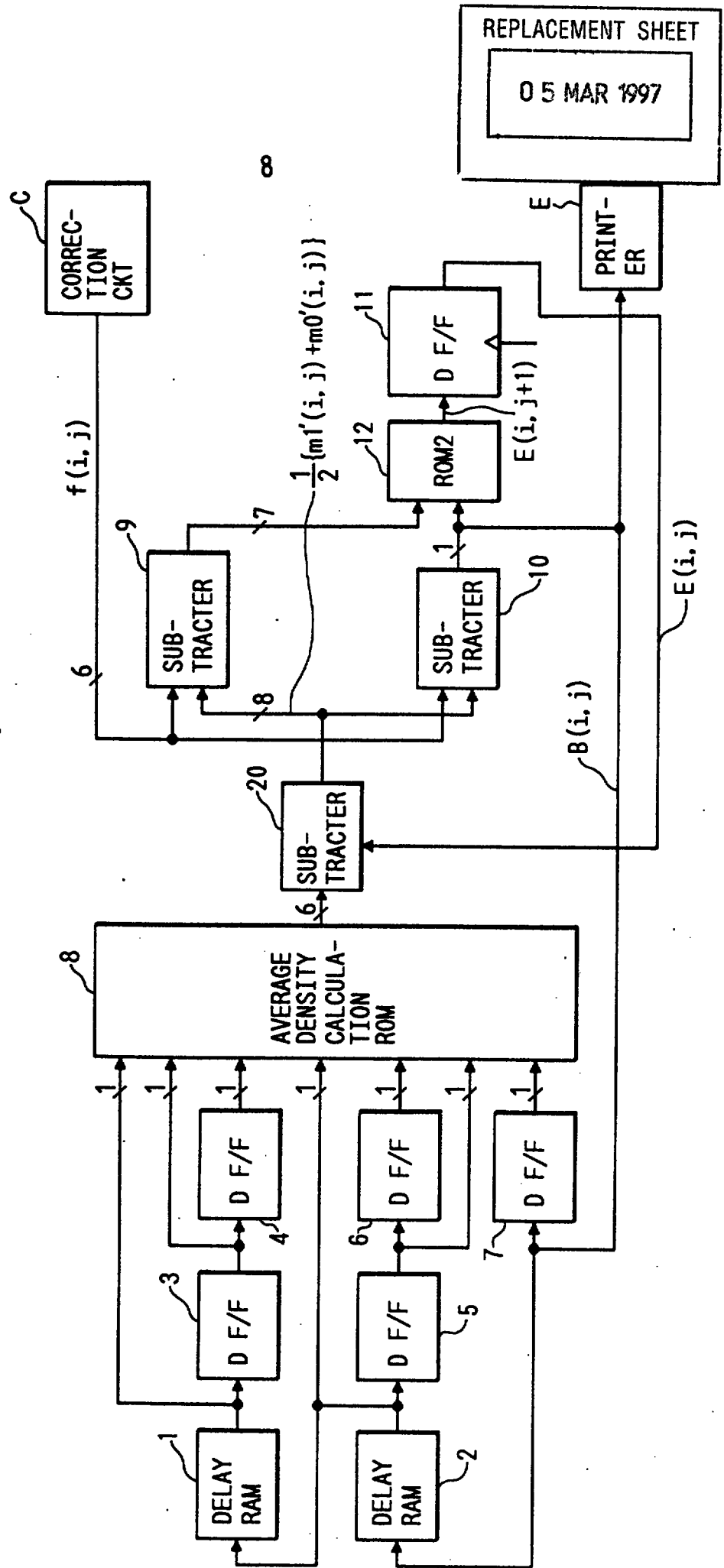
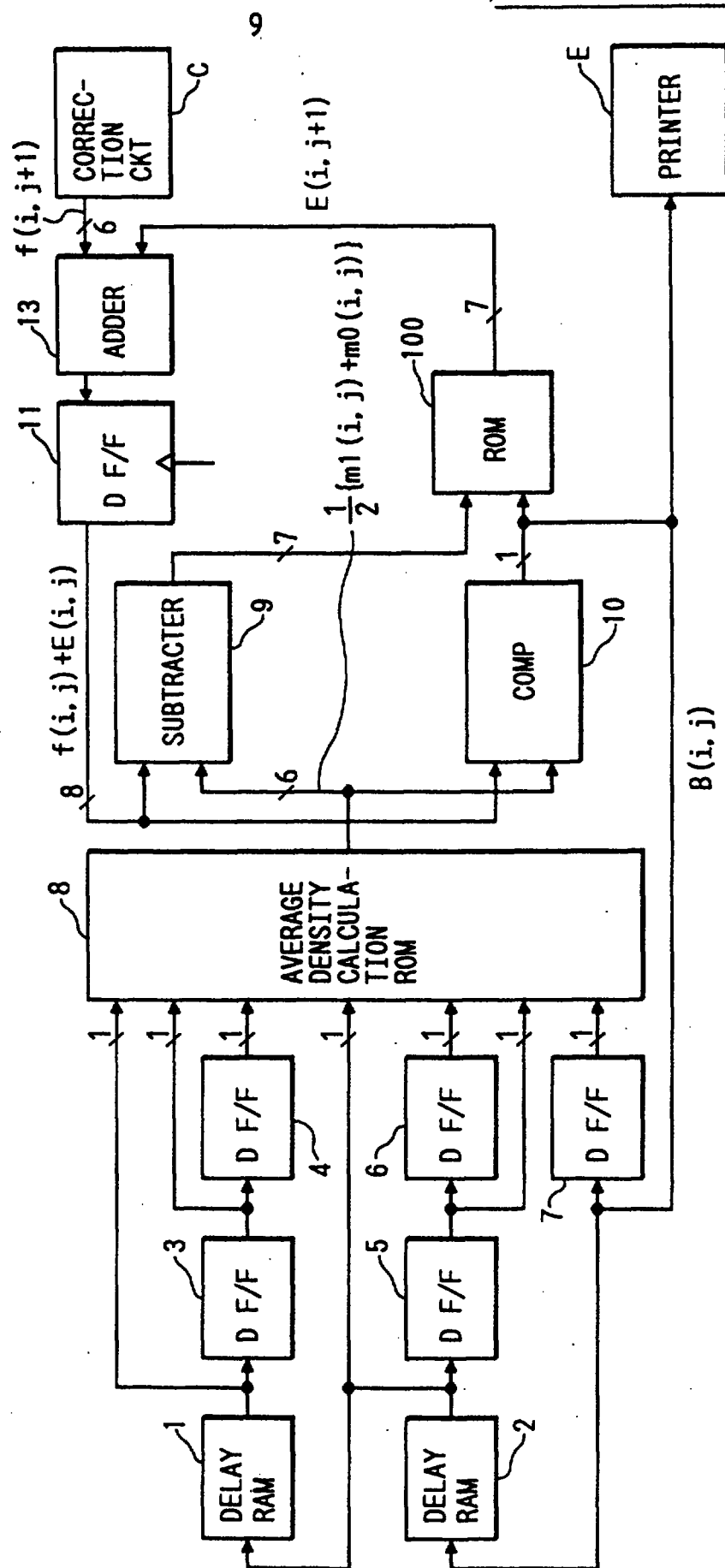


FIG. 9



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FIG. 10



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FIG. 11

$$|f(i, j) + E(i, j) - (m1(i, j) + m0(i, j))/2|$$

7 BIT	B	
	B=1	B=0
0	-9	+9
1	-8	+8
⋮		
8	-1	+1
9	0	0
10	+1	-1
⋮		
26	+17	-17
27	+18	-18
28	0	0
29	0	0
⋮		
127	0	0

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FIG. 14

(1) MULTI-LEVEL IMAGE

	$f(i-2, j-1)$	$f(i-2, j)$	$f(i-2, j+1)$	
	$f(i-1, j-1)$	$f(i-1, j)$	$f(i-1, j+1)$	
	$f(i, j-1)$	$f(i, j)$	$f(i, j+1)$	

(2) BINARY IMAGE

	$B(i-2, j-1)$	$B(i-2, j)$	$B(i-2, j+1)$	
	$B(i-1, j-1)$	$B(i-1, j)$	$B(i-1, j+1)$	
	$B(i, j-1)$	$B(i, j)$		

(3) WEIGHTING MASK

$R(2, 1)$	$R(2, 0)$	$R(2, -1)$
$R(1, 1)$	$R(1, 0)$	$R(1, -1)$
$R(0, 1)$	$R(0, 0)$	$R(0, -1)$

$$R(0, 0) = R(0, -1) = 0$$

FIG. 15

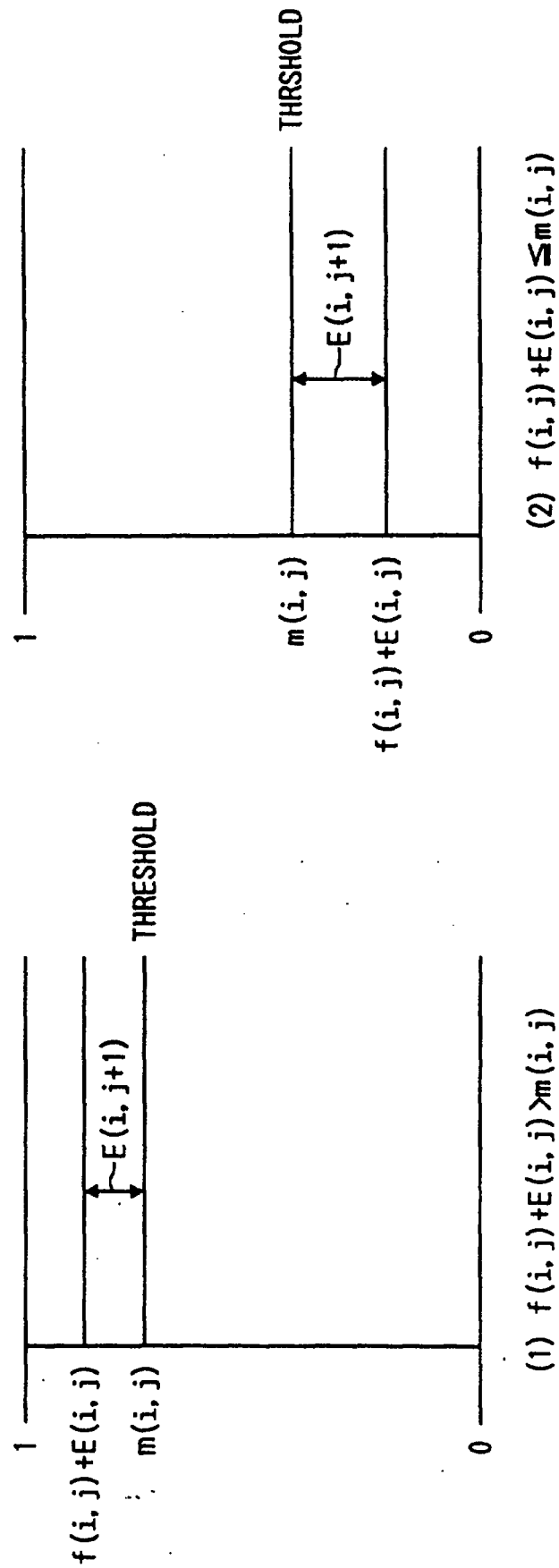
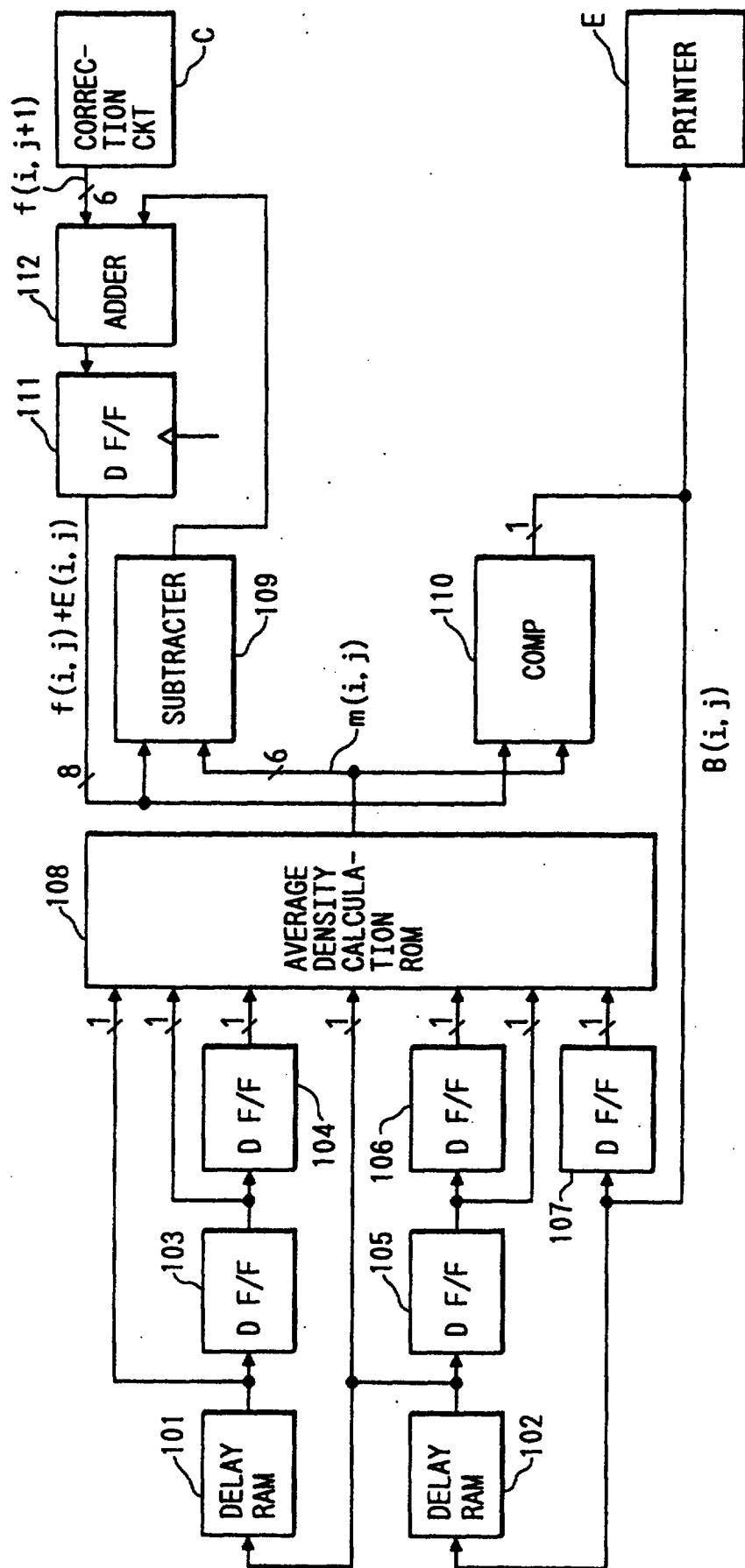


FIG. 16



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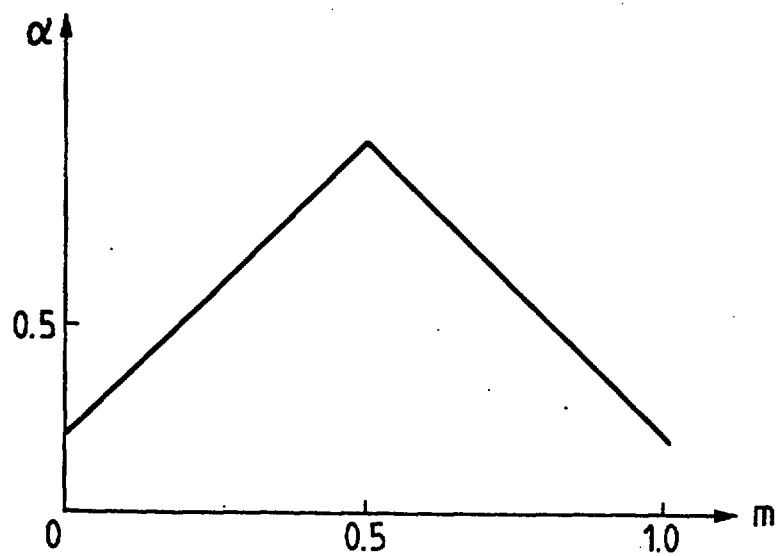
FIG. 17A

1/21	3/21	1/21
3/21	5/21	3/21
5/21	0	0

FIG. 17B

1/48	3/48	5/48	3/48	1/48
3/48	5/48	7/48	5/48	3/48
5/48	7/48	0	0	0

FIG. 20



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FIG. 18

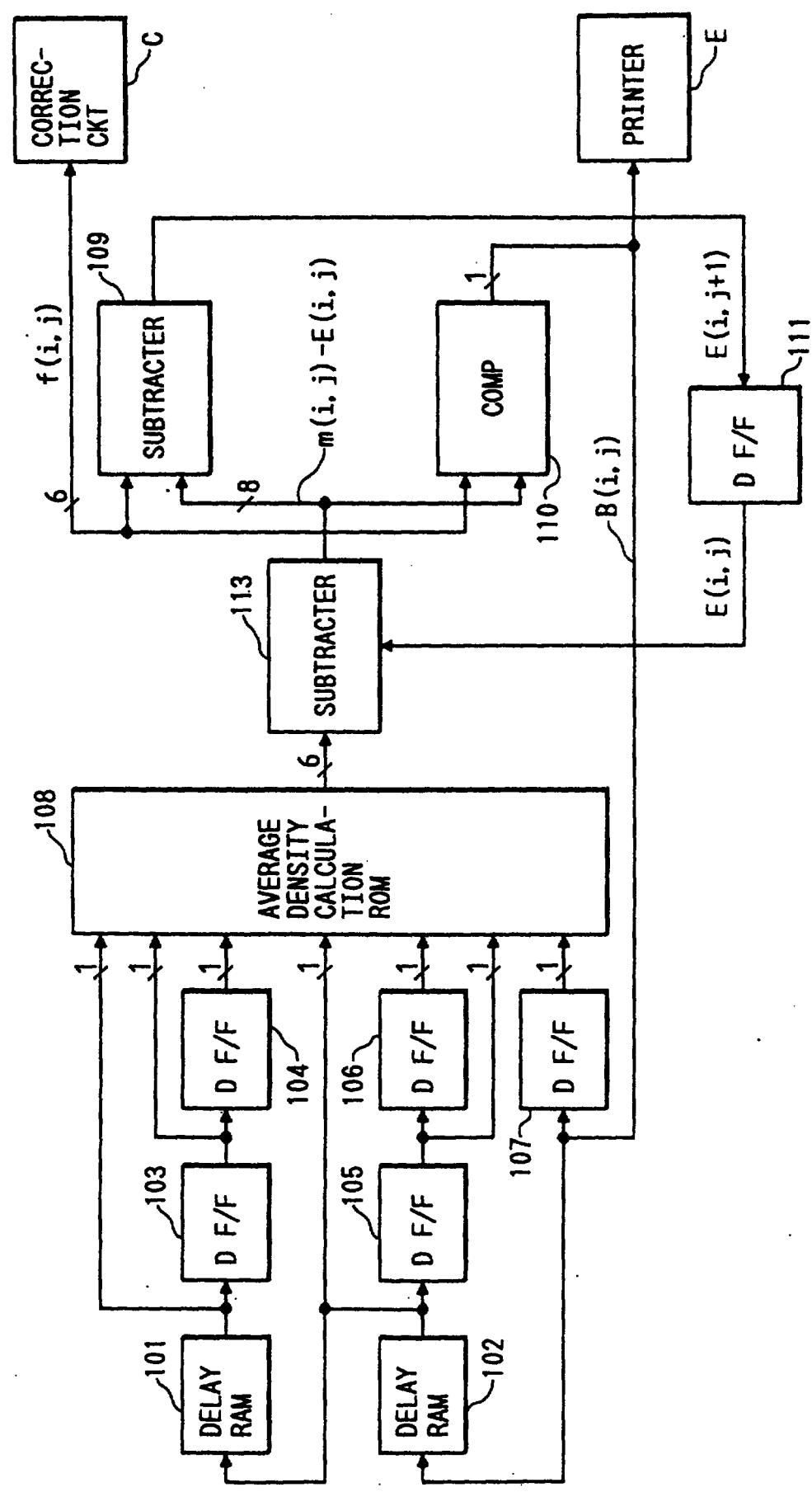
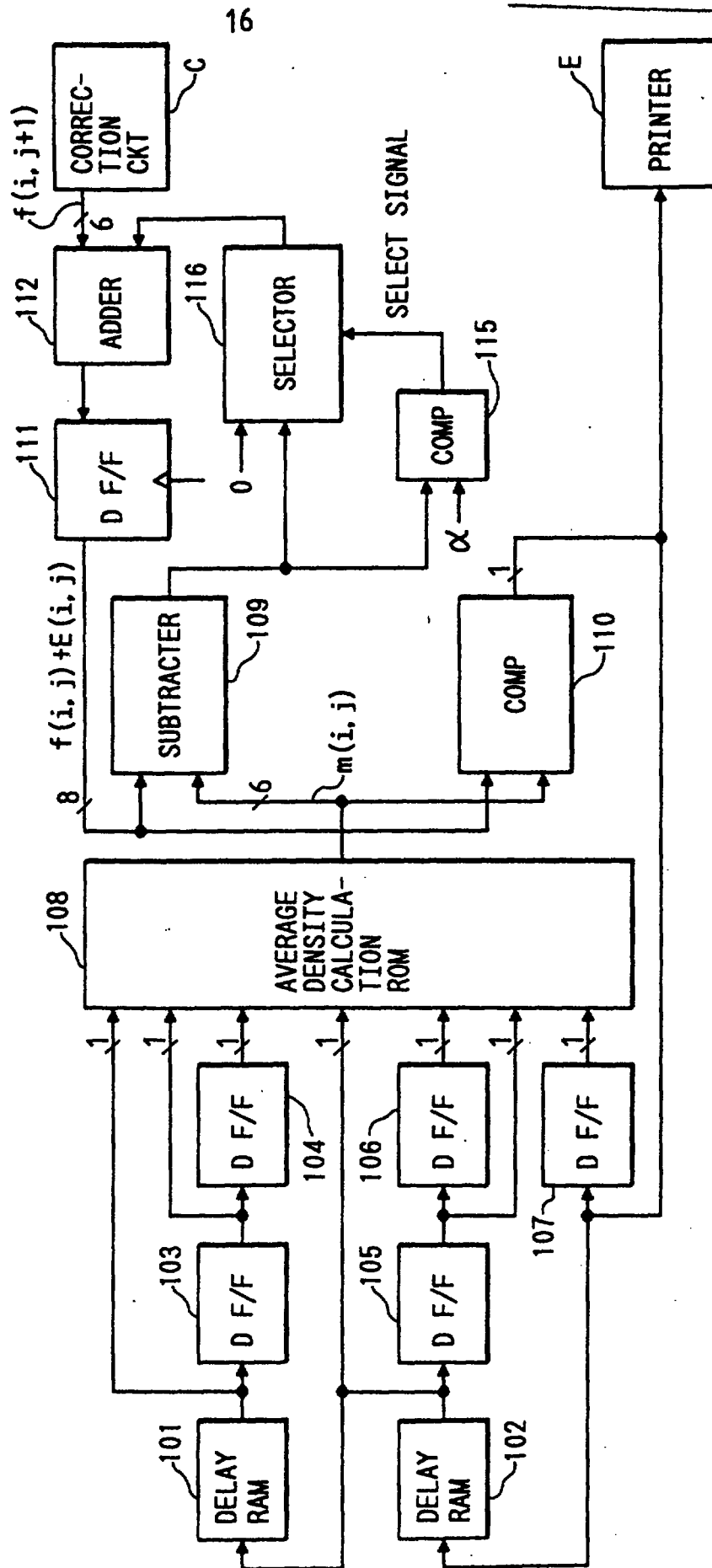


FIG. 19



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FIG. 21

