

- [54] METHOD AND APPARATUS FOR FORMING
HALFTONE IMAGES**

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178/6.8

- [51] Int. Cl...... **H04n 1/22**, **G06f 3/14**, **B41b 27/00**

- [58] **Field of Search** 340/172.5, 324; 95/4.5;
178/6.6, 6.7, 6.8

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Primary Examiner—Paul J. Henon

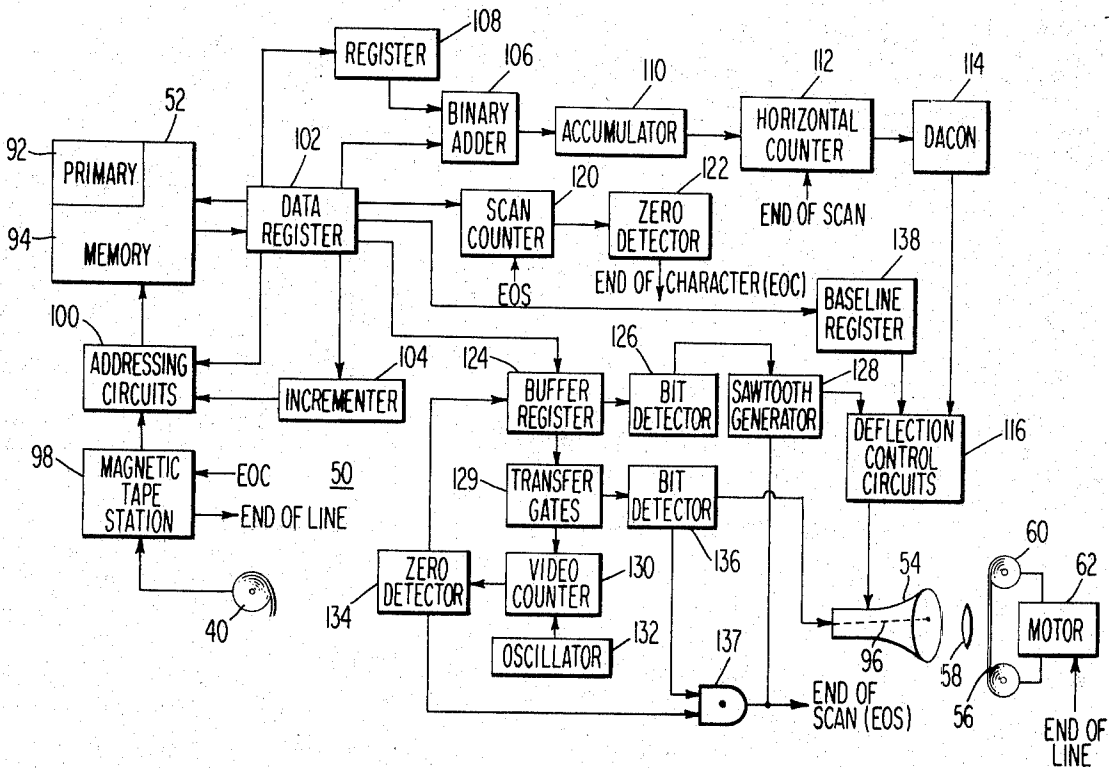
Assistant Examiner—Paul R. Woods

Attorney, Agent, or Firm—Lindenberg, Freilich & Wasserman

[57] **ABSTRACT**

Halftone images of an original scene are formed from halftone dots which are derived from a halftone dot character font. The halftone dot characters in the font comprise halftone dots of different sizes that correspond to different gray scale tones. The original scene to be reproduced is first dissected by taking a plurality of gray scale tonal measurements thereof. The tonal measurements are then utilized to call out from the halftone font the halftone dot characters that correspond to the tones measured. The halftone dot characters produced on a surface area a tonal density that is substantially equivalent to the density of the corresponding area in the original scene or photograph thereof.

4 Claims, 5 Drawing Figures



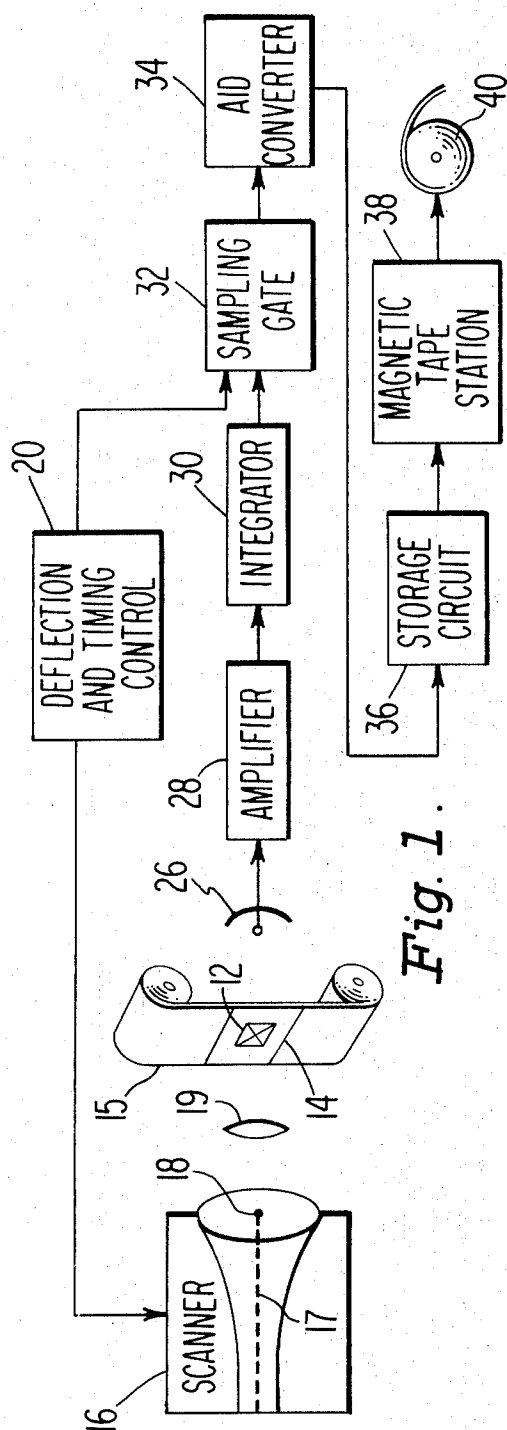


Fig. 1.

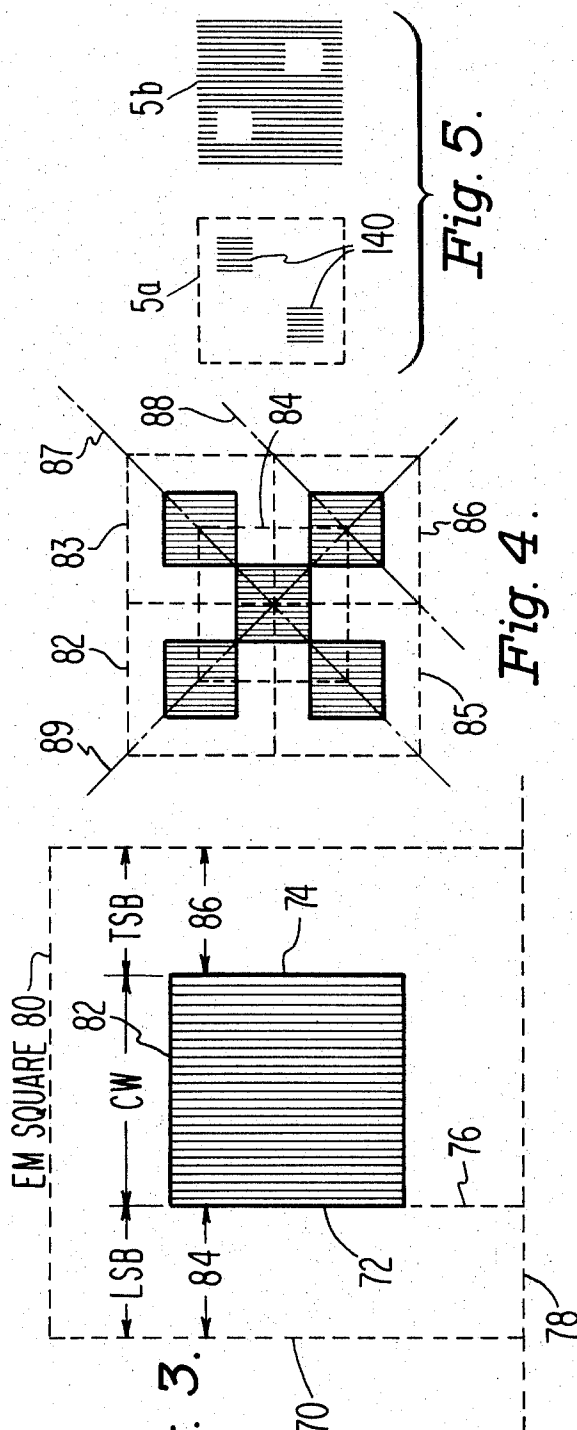


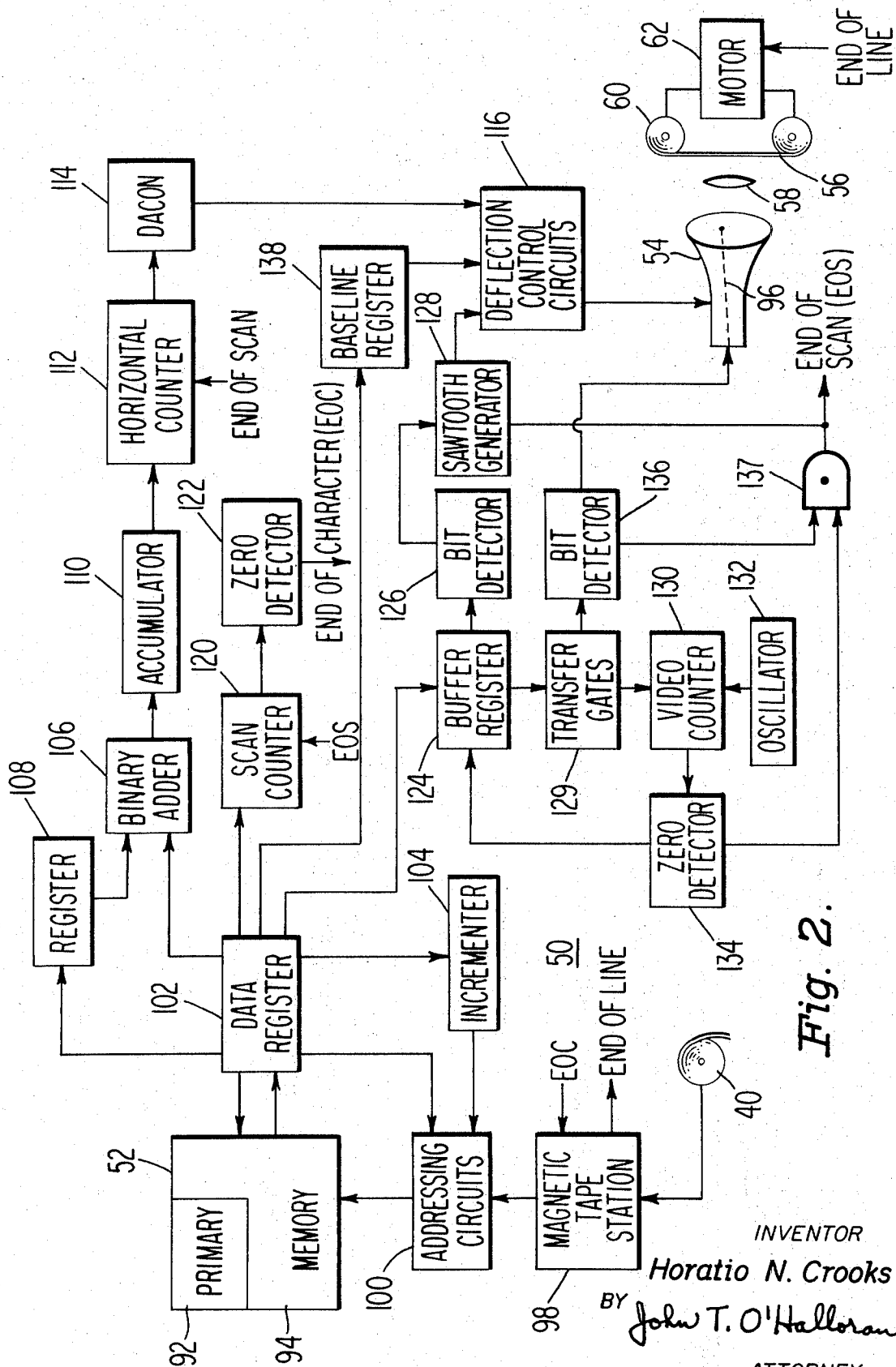
Fig. 3.

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METHOD AND APPARATUS FOR FORMING HALFTONE IMAGES

BACKGROUND OF THE INVENTION

The printing processes commonly used in the graphic arts industry, i.e. newspapers, books, magazines, etc., deposit a dot of ink on paper whenever it is desired to print all or a portion of an image and deposit no ink when the absence of an image is desired. This all-or-nothing process poses no problem when alphabetic or other characters are printed. However, when pictures such as photographs are printed, the problem of representing the continuous tones, i.e. light gradations, arises. This problem is solved by transforming the continuous tones of the original image into halftone images. Halftone images are typically produced by a large number of inked dots of various sizes. The size of the inked dots correspond to the shades or tones to be reproduced. When the largest dots, and the spaces on the paper between the dots, are made small compared with the visual acuity of the human eye, i.e. they are subliminal to the eye, the dots and the paper fuse visually and trick the eye into believing it is seeing various shades of continuous tones.

Recently, there have been developed electronic photocomposing apparatus. The transformation of type composition into an electronic art greatly increases the speed of type composition. One such electronic photocomposition system produces character images on the face of a cathode ray tube by building up each character from a plurality of substantially linear and vertical scan lines that form slices of a character. The character images are photographed and the photograph is then processed into a printing plate, such as an offset printing plate.

Commercial electronic photocomposition systems do not, at present, produce halftone images. It is desirable to provide an electronic halftone image printing capability that is compatible with existing electronic alphanumeric character photocomposing systems so that such systems are capable of producing both text and pictures for newspapers, magazines and other such publications.

SUMMARY OF THE INVENTION

A halftone image is formed of a plurality of halftone dot characters. Each halftone dot character may be represented by first digitally coded signals that define a plurality of linear zones or slices of the halftone character and second digitally coded signals that define the leading and trailing side bearings of the halftone character. The first digitally coded signals for different halftone characters correspond to different tonal gradations. A plurality of such halftone dot characters are grouped together to form a halftone character font that is utilized to create a halftone image reproduction of the various tones in an original scene.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic block diagram of a scanner subsystem for scanning an original image;

FIG. 2 is a schematic block diagram of an electronic photocomposing system embodying the invention;

FIG. 3 is a graphical illustration of a halftone dot character;

FIG. 4 is a graphical illustration of a fragment of a halftone dot character screening pattern; and

FIG. 5 is a graphical illustration of another type of halftone dot character contemplated within the invention.

DETAILED DESCRIPTION

Referring to FIG. 1, a scanner subsystem initiates the conversion of a continuous tone image 12 on a transparency 14 into a halftone reproduction thereof. The transparency 14 may, for example, comprise one frame of a microfilm strip 15. A scanner 16, which may, for example, include a cathode ray tube having an electron beam 17, produces a light spot 18 for scanning the transparency 14. The scanning spot 18 is focused by a lens 19 onto the transparency 14. The scanning spot is deflected from left to right in a series of vertical scans of a predetermined height under the control of a deflection and timing control circuit 20. The predetermined height may, for example, be equal to an alphanumeric character height or character line. The transparency 14 on the film strip 15 may be stepped to the next line at the end of scanning one line to produce an orthogonal scanning of the transparency 14. Alternatively the scanning spot 18 may be deflected to scan the next line. When one horizontal line or slice of the transparency 14 has been scanned, the scanning spot 18 is also retraced to the left of the transparency to scan another slice thereof.

The light penetrating through the transparency 14 is detected by a light sensor such as a photomultiplier tube 26. It is, of course, apparent that opaque film, or the like, may also be scanned by the scanner 16, with the reflected light from the image on the film comprising the image signal.

The amount or amplitude of light penetrating through the transparency 14 depends on the density of the tones in the image contained on the transparency 14. The tonal gradations of the transparency 14 cause variation in the amount of light in the image signal. The light in the image signal is converted into a varying electronic signal by the photomultiplier tube 26 and then amplified in an amplifier 28. The amplified image signal is integrated in an integrator 30 to derive the tonal content of a discrete area of the transparency 14. The integrator 30 output is sampled periodically by a sampling gate 32 which is activated by sampling pulses derived from the deflection and timing control circuit 20. The output of the sampling gate 32 is digitized in an analog-to-digital (A/D) converter 34 and a succession of digital numerals corresponding to the tones on the transparency 14 is applied to an output storage circuit 36. The storage circuit 36 stores a succession of binary numbers that specifies the tonal gradations in the image on the transparency 14. The binary numbers may be entered on magnetic tape 40 by means of a magnetic tape station 38.

In the photocomposing system 50 of FIG. 2, the binary numbers are utilized to call out corresponding halftone dot characters stored in a utilization storage device or memory 52. The halftone dot characters are displayed on a display or imaging device 54. The displayed halftone dot characters are focused onto photographic film or stabilization paper 56 by a focusing lens 58. The filmstrip 56 is mounted on rollers 60, whose motion is controlled by a stepping motor 62 or other incremental advance mechanism.

The imaging device 54 may, for example, also function as the CRT scanner 16 (FIG. 1) in which case the rollers 60 and motor 62 would also control the motion of the microfilm 15.

An enlarged view of a halftone dot character 70 from a halftone dot character font that is stored in the storage device 52 is shown in FIG. 3. The character 70 includes a plurality of adjacent linear zones 72 or character slices of first and/or second visual states. The first visual state may, for example, be black and the second one white as reproduced on photographic film. The different visual states define different zonal segments in the zones. Black segments 74 are portions of scanlines where the electron beam in the imaging device is unblanked. Those portions of the scans wherein the electron beam is blanked are white segments 76 and a representative one is shown dashed in FIG. 3. Of course, in the imaging device itself, the black segments 74 are actually white on a dark background. The black segments 74 overlap each other and are selected to be sufficiently numerous so that a halftone dot character of a uniform density is formed on the photographic film. For the purposes of clarity and simplicity, such overlapping is not shown in FIG. 3. The halftone dot character 70 is seated on a character baseline 78.

Each character in a halftone font of characters is defined by a set of parameters that includes an EM square 80 shown dashed in FIG. 3. The body size or overall set width of the halftone dot character is equal to the sum of the halftone dot character width (CW) 82 and the leading 84 and trailing 86 side bearings. The leading side bearing 84 (LSB) is defined as the distance from the leading or left outer periphery of the halftone dot character to the leading end of the character width. Similarly, the trailing side bearing 86 (TSB) is defined as the distance from the right edge of the halftone dot character to the trailing end of the character width. One halftone dot character is spaced from another halftone dot character by the sum of the trailing and leading side bearings, respectively, of the successive characters.

A plurality of halftone dot characters are grouped together to form a halftone character font. Each character in the font is selected to exhibit the same sized EM square. One character in the font differs from another character by the length of the black segments 74 in the linear zones 72. The totality of the linear zones in a character creates a substantially square halftone dot. Of course, curvilinear zones may also be utilized and shapes other than square may be formed if desired.

The halftone dot occupies a portion of the EM square such that the proportion of black to white area produces a desired tone. The halftone dot characters in a font vary from a character wherein the EM square is 100 percent black to one wherein the EM square is less than 10 percent black. There may, for example be 64 halftone dot characters in a font. Such characters vary from lightest to the darkest to give a desired tonal range. Of course, any other number of characters that gives the desired tonal range in a font may be utilized. The scanner 16 in FIG. 1 scans a vertical height substantially equal to an EM square 80.

In halftone reproductions, the halftone dots of successive lines preferably are oriented at an angle of 45° in relation to each other, i.e. the centers of the halftone dots in one line are horizontally displaced by EM/2 relative to the centers of halftone dots in the two adjacent

lines. In FIG. 4, there are shown portions of three successive lines of halftone dot characters derived from a character font. The characters 82 through 86 all exhibit 25 percent black regions or dots. It is to be noticed that the EM square, shown dashed, of the halftone character 84 is positioned intermediate the characters 82 and 83 and intermediate the rows or lines containing the characters 82 and 83 and 85 and 86. This causes the halftone dots of the characters 82 through 86 to exhibit the usual 45° screening pattern or orientation to each other as shown by the screening lines 87, 88 and 89.

The sizes of the EM squares of all of the halftone dot characters in a font may be selected to be substantially equal to one point. Thus, there are 72 halftone dot characters in one inch of a line of halftone characters. This creates 102 screening lines per inch, which is a high graphic quality screening.

The parameters of a halftone character, as well as other data to be described below, are stored in the memory 52 shown in FIG. 2. The memory 52 may, for example, comprise a magnetic core random access memory that is divided into two main portions, a primary portion 92 and a secondary portion 94. The primary portion 92 includes a plurality of successive storage locations that correspond one-to-one with the characters in a halftone font. A second primary portion is allocated to alphanumeric fonts. Thus, for a 64 character halftone font, there will be 64 storage locations in the primary portion 92 allocated to the halftone font. Each multibit storage location in the primary portion 92 is addressed by a character identity code which comprises one of the digitized numbers derived from the analog-to-digital converter 34 (FIG. 1). Thus, a digitized tonal gradation is the character identity code of the corresponding halftone dot character. The sequence of the addresses in the memory 52 may begin with the address for the smallest character dot in the halftone font and continue successively up to the largest character dot. The contents in each one of the multibit storage locations of the primary portion 92 of the memory 52 is actually an address for the storage location in the secondary portion 94 of the memory wherein is stored the data that define the corresponding halftone characters. Thus, when an identity code is utilized to address a halftone dot character in the primary portion 92 of the memory 52, the binary number read from this memory storage location comprises an address in the secondary portion 94 of the memory 52 that begins a block of secondary storage locations wherein the coded parameters of the halftone dot character is stored successively.

The secondary portion 94 of the memory 52 stores in sequence the blocks of information necessary to create a halftone dot character pattern on the cathode ray tube 54. The contents of the first memory location for a block of data in the secondary portion 94 relating to one halftone dot character in the memory may be a coded representation of the number of scans in the leading side bearing (LSB) 84. The format data stored in the next storage location may be the sum of the number of scans in the character width (CW) 82 (FIG. 3) and the trailing side bearing (TSB) 86 of the character. The next parameter stored is the character width (CW). The next parameter stored is the vertical displacement that defines the displacement of the black scans from the base line 78 of the halftone dot character. The remaining data stored for a halftone dot char-

acter is not format data but is rather the segment data, which are the successive coded representations of the lengths of the individual black segments and the individual white segments in each scan of a halftone dot character.

To attain synchronism between the scanning beam reproducing the halftone image in the cathode ray tube 54 and the reading of the memory 52, the stored segment words also include data relating to the starting and retracing of the scanning beam 96 in the cathode ray tube 54, as well as data relating to blanking and unblanking it. The least significant bit in a binary number defining a black segment, i.e. the 2⁰ bit, may be selected to designate the end of a scan or retrace. No white segments terminate a scan because the scanning beam is retraced after finishing the last black segment in a scanline. A binary "1" occurring in the 2⁰ bit position indicates that the scan retraces whereas a binary "0" indicates that the scan continues.

The next least significant bit in a segment word, i.e. the 2¹ bit, indicates when the scanning beam should be turned on, i.e. unblanked, and when the beam should be turned off, i.e. blanked. When a binary "1" is stored in this position, the beam is turned on whereas the beam is turned off when a binary "0" is stored in this position. Thus, the black segment words are differentiated from the white segment words by the binary bit, i.e. the color bit, stored in this 2¹ bit position. It is therefore apparent that the segment words themselves control the formation of the zones or slices of the halftone dot characters.

In FIG. 2 a magnetic tape 40 that contains text material and halftone image material is read in a magnetic tape station 98 and the character identity codes of both the alphanumeric and halftone dot characters are utilized by the addressing circuits 100 to address the memory 52. For a halftone dot character, the identity code addresses the memory 52 and the contents of the addressed storage location are read into a data register 102. The data read into the data register 102 is read back into the memory 52 to prevent destruction thereof and is also read from the register 102 into the addressing circuit 100. This is because the first data read from the memory 52 is the first address in the secondary portion 94 of the memory 52 that begins the block of data that defines the character parameters needed to create the halftone dot character. Each secondary address is then incremented by an incrementer 104 so that each secondary address is incremented by one as the data in the block is read from the memory 52. The first data read from the memory 52 in the block of character parameters is the binary number representing the leading side bearing (LSB) of the character. This data is coupled through the data register 102 to a binary adder 106. The binary adder 106 adds the contents of the data register 102 to the contents of a register 108. The register 108 stores the sum of the character width (CW) and the trailing side bearing (TSB) from the previous character. The sum of the data in the register 102 and in the register 108 is the horizontal position in the cathode ray tube 54 of the start of the new character to be created. At the beginning of a line, the contents of the register 108 is zero. The summed number in the binary adder 106 is added to the contents of an accumulator 110 so that the accumulative position of the beginning of the scans of each character is indicated.

The data contained at the next successive secondary address is a binary number representing the sum of the character width (CW) and the trailing side bearing (TSB) of the halftone dot character and this data is fed through the data register 102 into the register 108. The new contents of the register 108 remain therein until the next character is read. At the next character, the binary adder 106 adds the contents of the register 108 (the character width and the trailing side bearing of the previous character) to the leading side bearing (LSB) of that next character. This addition specifies the position to which the scanning beam is moved at the end of scanning one halftone dot character so that the beam is properly positioned to scan the next halftone dot character.

The accumulated total in the accumulator 110 is transferred to a horizontal counter 112. The count in the counter 112 is coupled to a horizontal digital-to-analog converter (DACON) 114 where the digital or binary data is transformed to an analog voltage so as to horizontally position the scanning beam 96. The output of the DACON 114 is coupled to the deflection circuit 116 of the tube 54 to so deflect the scanning beam 96.

The horizontal counter 112 may, for example, comprise a binary counter for stepping the scanning beam in the imaging device 54 across the face thereof as a line of halftone dot characters is printed.

The next data read out of the memory 52 is the number of scans in the character width (CW). This number is coupled into a scan counter 120. The scan counter 120 is decremented by a count of one at the end of each scanline so that when a count of zero is reached, a zero detector 122, coupled to the scan counter, signals that the end of the character has been reached. The vertical displacement is read into the baseline register 138.

The next data read from the memory 52 is the segment data that actually causes the halftone dot character patterns, or dots, to be written on the cathode ray tube 54. The segment data is read into a buffer register 124 which register stores segment data relating to a plurality of scanlines and may be operated in a simultaneous read-write mode, i.e. push-pull, wherein one section of the buffer register 124 is being written into whereas another section is being read. Such operation prevents delay in forming the dot patterns. A bit detector 126 is coupled to detect a binary "1" in the 2⁰ bit position of the binary numbers entering the buffer register 124 to detect that information relating to an entire scan. The bit detector 126 activates a sawtooth generator 128 when a binary "1" is detected to begin the vertical deflection of the scanning beam. The segment data in the buffer register 124 is jam transferred through transfer gates 129 into a video counter 130 and the video counter 130 is downcounted by an oscillator 132. When the count at the video counter 130 goes to zero, a zero detector 134 transfers another segment from the buffer register into the video counter.

Also coupled to the output of gates 129 is a dual bit detector 136 which functions to decode the 2¹ and 2⁰ bit positions in each segment. When a binary "1" occurs in the 2¹ bit position, the bit detector 136 turns on the scanning beam 96 of the cathode of cathode ray tube 54. When a binary "0" is detected in this bit position, the scanning beam is biased off. When a binary "1" is detected in the 2⁰ bit position, this signifies that

the end of a scan has been reached. This signal is gated with the output of the zero detector 134 in an AND gate 137 to signify the end of a scan when activated. The output of the gate 137 turns off the sawtooth generator 128 and retraces the scanning beam 96. The sawtooth signal generator 128 causes the scanning beam 96 to scan upwardly in a vertical scanning pattern. When the sawtooth signal generator 128 is reset, the scanning beam 96 is retraced back to the character baseline as specified by a baseline register 138, into which the vertical displacement or baseline position is read and stored during the creation of a halftone dot character. The end of scan signal is also coupled to up-count the count in the horizontal counter 112 to move the beam to a new horizontal position for the next scan.

OPERATION

The photocomposition system 50 produces both alphanumeric and halftone dot character patterns on the imaging device or cathode ray tube 54. These patterns are projected onto photosensitive film 56 to provide both text and pictures. The compatibility illustrated by the system 50 in producing both text and pictures in the same device, and in a similar manner, has not heretofore been achieved.

The operation of a photocomposition system such as the system 50 in FIG. 2 in creating alphanumeric characters is explained in greater detail in U.S. Pat. No. 3,568,178, for Robert F. Day, entitled "Electronic Photocomposition System" and assigned to the same assignee as the present application.

The production of pictures by means of halftone dot characters differs from the production of text because, of course, pictures cannot be specified as text can, but rather must be read into the system. Thus, the scanner subsystem 10 of FIG. 1 is needed for pictures, but not for text. Of course, in actuality the scanner 16 may be identical to the imaging device 54 and the subsystem 10 may be a part of the system 50.

To create a halftone replica of an image 12, the image 12 is first dissected by scanning it by means of the scanner 16 and sampling the integrated light output of the film 14. Such a sampled output provides discrete measurements of the tones in the image 12. The sampled tones are converted into binary numbers by the analog-to-digital converter 34, and the storage circuit 36 merges each converted binary number into any one of 64 halftone dot character identity codes corresponding most closely to the binary number. Thus, the large number of tonal numbers are mapped into 64 dot character identity codes. This limits the size of the halftone font that must be stored in the photocomposition system.

The character identity codes specifying the image 12 are written onto magnetic tape 40, and the tape 40 may be merged with text data to create a complete newspaper page of text and pictures or the like.

Instructions specifying the location of the picture on a page are also put onto the tape by means, not shown in the drawings. For simplicity in explanation, it is assumed that the picture begins at one side of a page and ends at the other side. The fragment of a halftone image shown in FIG. 4 is assumed to be the image to be reproduced.

The first identity code read from the tape 40 produces the halftone dot character or tonal region 82 on

the film 56. The leading side bearing (LSB) of the character 82 is read into the binary adder 106 where it is summed with the contents of the register 108. Since this is the first halftone dot character in a line, the contents of the register 108 is zero. Consequently, the leading side bearing of the character is accumulated unchanged in the accumulator 110 and stored in the horizontal counter 112. The converter (DACON) 114 converts the binary number to an analog signal that is coupled to the deflection circuits 116 to position the scanning beam 96 horizontally.

The combined character width (CW) and trailing side bearing (TSB) of this first halftone character is transferred to the register 108. The character width (CW) alone is transferred to the scan counter 120. The vertical displacement or baseline is transferred to the register 138.

The segment data that creates the halftone dot is then transferred sequentially into the buffer register 124. The bit detector 126 detects a binary "1" in the 2⁰ bit position of the last segment in the first scan of the halftone dot. Consequently, information relating to an entire scan is stored in the register 124. The detector 126 therefore turns on the sawtooth generator 128 as well as transfers the first zonal segment into the video counter 130. Since the first zonal segment is white, the detector 136 detects the binary "0" in the 2¹ bit position and does not turn on the scanning beam 96. Consequently, the video counter 130 is counted down by the oscillator 132 while the scanning beam 96 is sweeping vertically but the beam is blanked.

At the end of scanning the first white zonal segment, the zero detector 134 detects the end of the downcount of the video counter 130 and initiates the transfer of the next zonal segment, which is a black segment, into the video counter 130. The bit detector 136 detects the binary "1" in the 2¹ bit position of the black segment word and turns on the scanning beam 96. The detector 136 also detects the binary "1" in the 2⁰ bit position, i.e. the retrace bit, and applies an enabling signal to the AND gate 137. The scanning beam 96 scans out the black segment while the video counter 130 is counted down. When the detector 134 detects the end of the black segment, the AND gate 137 is actuated to turn off the sawtooth generator 128 and retrace the scanning beam 96. The end of scan signal also advances the horizontal counter 112 by a count of one and counts down the scan counter 120. The first segment of the next scan is transferred into the video counter 130 and a set of events similar to the first scan occur.

By the end of scanning the zonal segment data, the scan counter 120 is downcounted to zero and the zero detector 122 signals the end of a character. The end of character signal (EOC) is applied to the tape station 98 to read the next character identity code. The leading side bearing (LSB) of this second halftone character is added in the binary adder 106 to the sum of the character width (CW) and the trailing side bearing (TSB) of the previous character. This sum is added in the accumulator 110 to the previous number stored therein, i.e. the beginning of the character width of the first character, and this initial scanning position of the new character is transferred into the counter 112. The scanning beam is moved to this new position and the second halftone dot character is created.

At the end of scanning a line of halftone dot characters, the motor 62 is activated by a signal (end of line)

from the tape station 98 to move the film 56 an increment to the next line. The tape station 98 also provides an even line offset signal to start the next line of halftone characters offset so as to produce a 45° screening pattern as shown in FIG. 4. Each line of halftone dot characters is therefore laid down in a 45° screening pattern until a halftone replica of the original image has been created.

It is to be noted that the EM squares or character regions overlap each other so as to insure that when 100 percent black regions are specified, there are no white areas within these regions. Such overlapping also renders the system 50 relatively insensitive to slight incorrect positionings of the scanning beam or film.

In FIG. 5 there are shown halftone characters that include two halftone dots positioned at a 45° angle to each other. Such a configuration permits halftone replicas to be reproduced without offsetting every other line. In FIG. 5a the halftone dots 140 create a tone less dense than the character in FIG. 5b.

Thus, there has been described apparatus for creating halftone reproductions of an original scene. The method of creating halftone replicas of an original scene includes the steps of storing a font of halftone dot character signals in a storage device or memory. The tones on an original scene are extracted from the scene and the halftone characters that correspond to these tones are extracted from the memory and laid down on a surface to reproduce the original scene.

What is claimed is:

1. The method of creating on a surface a halftone reproduction of an original scene comprising the steps of

providing a font of electronic halftone dot character signals in digital form

storing said halftone dot character signals in a digital storage device

providing an indication of the tonal gradations of said original scene that are to be reproduced on said surface

extracting from said storage device said halftone dot character signals that correspond to said tonal gradations, and

utilizing said extracted halftone dot character signals to create corresponding halftone dots of various sizes on said surface so as to reproduce the tonal gradations of said original scene.

2. The method of claim 1 wherein said step of providing an indication of the tonal gradations of said original scene includes providing a sequence of multibit identity codes, each different identity code representative of a particular tonal gradation.

3. The method of claim 2 wherein said step of storing includes storing said halftone dot character signals in addressable storage locations in a first section of said storage device and storing the addresses of said addressable storage locations in locations in a second section of said storage device, each location in said second section being addressable by a different one of said identity codes.

4. A photocomposing system for producing a halftone replica of an original scene comprising in combination

means for scanning said original scene to derive tonal representations thereof

digitizing means responsive to said scanning means for producing digital signals corresponding to the density of said tonal representations

an imaging device

means providing a font of halftone dot characters, each consisting of a plurality of signals that create halftone dots on said imaging device

a storage device for storing said signals of said font, and

means responsive to said digitizing means for extracting from said storage device a plurality of said halftone characters corresponding to said digitized tonal representations to provide a substantial replica of said original scene on said imaging device.

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