United States Patent

[11] **3,549,939**

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[54] **CATHODE RAY TUBE SYSTEM FOR PRODUCING HALF-TONE IMAGES**
16 Claims, 9 Drawing Figs.

[52] **U.S. Cl.** **315/18,** 340/324; 313/85
[51] **Int. Cl.** **H01j 29/76**
[50] **Field of Search** 340/324.1; 315/18, 30, 85, 86

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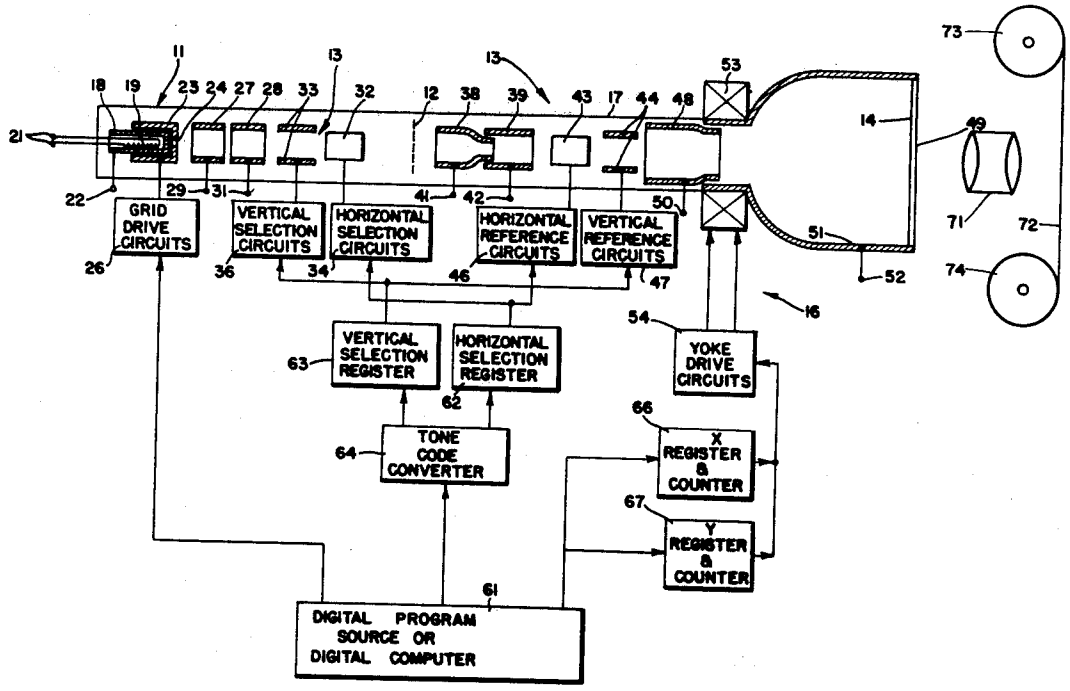
ABSTRACT: A cathode ray tube (CRT) system is described for producing a graphic image having areas of different tone levels. The image is produced by a plurality of uniformly spaced dots of different sizes, each size corresponding to one of the tone levels. The sizes of the dots are regulated by controlling the cross-sectional size of the electron beam. Beam size is determined by an apertured beam shaping plate within the tube having a plurality of apertures of graduated sizes. Beams shaped to appropriate sizes by selected apertures are positioned in succession on the uniformly spaced elemental areas of the tube screen to produce a pictorial image.



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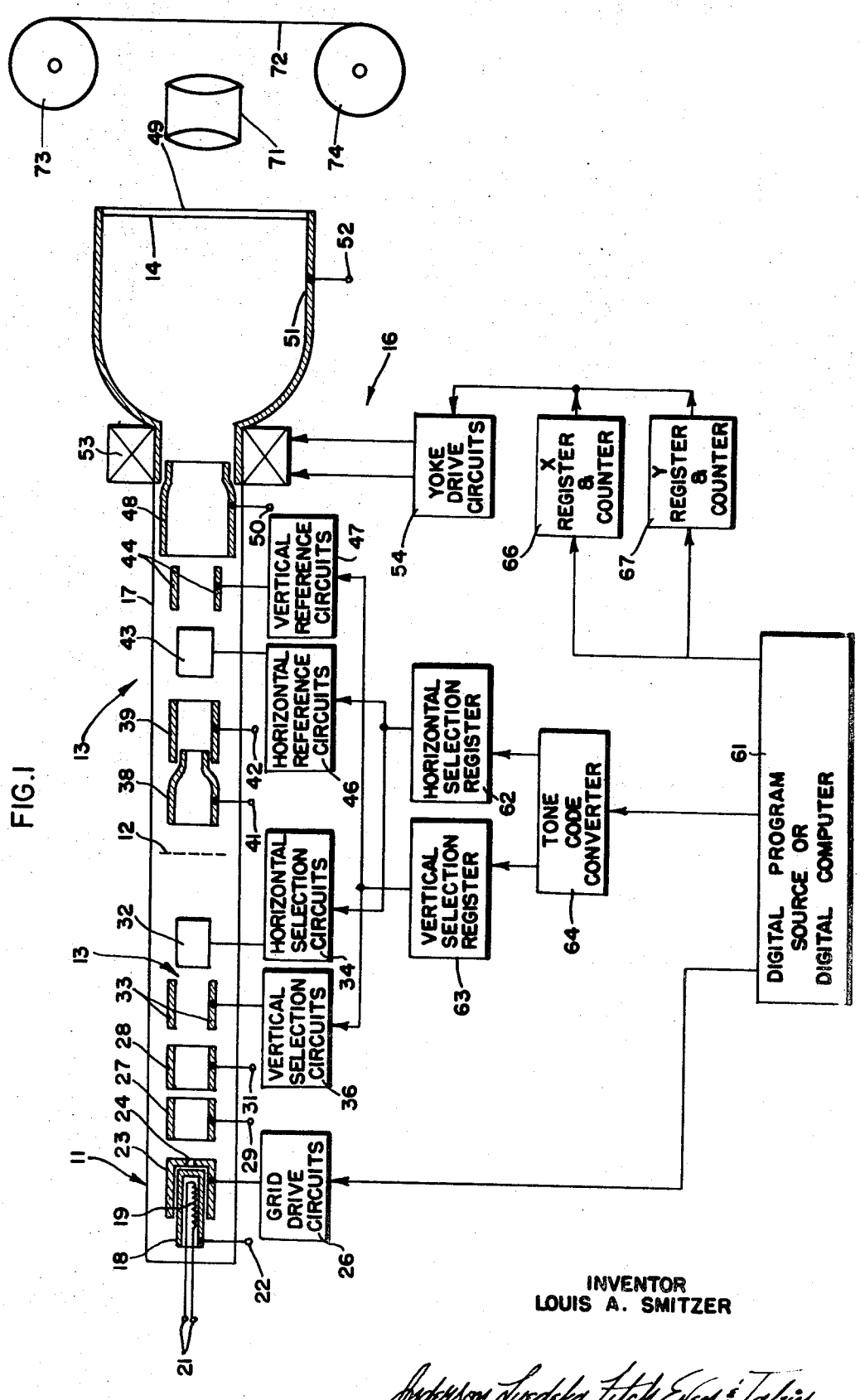

FIG. 1

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FIG.2

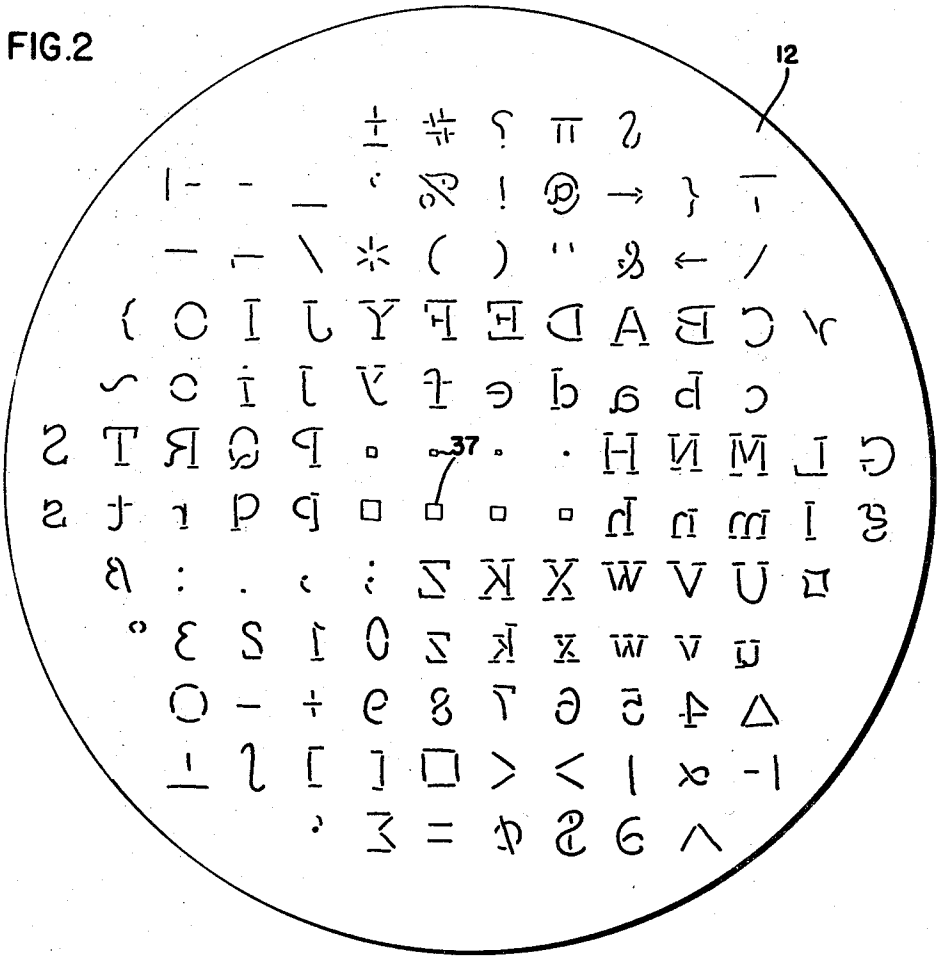

FIG.3

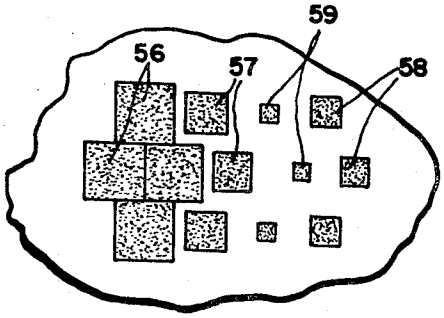

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FIG.4

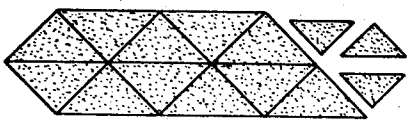


FIG.5

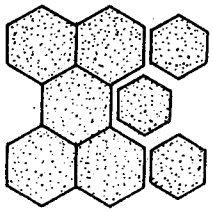


FIG.6

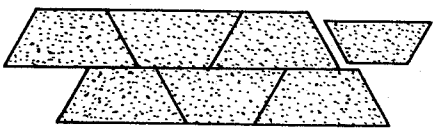


FIG.7

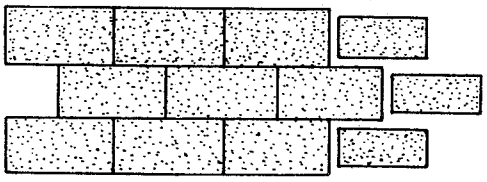


FIG.8

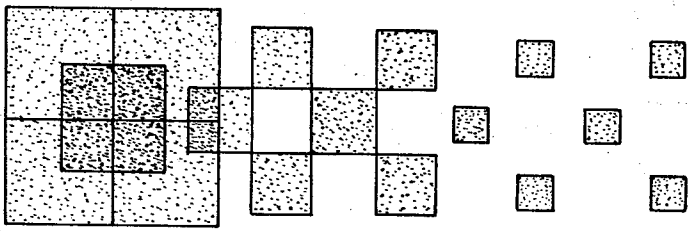
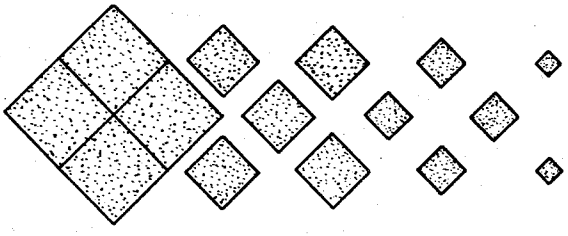


FIG.9



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CATHODE RAY TUBE SYSTEM FOR PRODUCING HALFTONE IMAGES

This invention relates generally to cathode ray tubes and, more particularly, to an improved cathode ray tube for producing a graphic image having areas of different tone levels.

Cathode ray tubes may be employed in some circumstances for providing a visual representation of information stored in an electronic information storage system or of information produced by operation of a computer. Frequently, electronic information storage systems or electronic computers provide output information in digital form. Such an output form readily lends itself to the production of alphanumeric visual data through the use of a suitable data printout system. Cathode ray tube displays of electronic digital information may be produced by various forms of tubes, including the so-called shaped beam tubes. The display may be for direct visual observation, or may be for exposing microfilm. In the latter case, the display may be formed as a negative, (i.e. white on black background rather than black on white background) to produce a positive image directly on the microfilm.

In character generating tubes of the shaped beam type, one or more electron beams are shaped as they pass from an electron gun to a target such that the resulting cross section of each shaped beam is of predetermined configuration. The area of the target energized by impingement of each beam thereon therefore corresponds in shape to the resulting cross section of the beams.

The desired beam cross section is attained by passing the beam through a shaping aperture in an electron opaque plate. The plate generally contains a plurality of apertures of various types. In tubes of the so-called aperture selection type, the apertures are all flooded by a large beam to produce a plurality of shaped beams. Another electron opaque plate having a single selection aperture therein is positioned downstream from the first plate. The beams are deflected together in a desired manner so that one of the shaped beams is selected by passing through the selection aperture and on to the target screen. The unselected beams are blocked and do not reach the target. In the beam selection type of shaped beam tube, a smaller beam is deflected to select only one of the plurality of apertures, and is subsequently deflected to a desired position on the target screen.

Cathode ray tubes of the shaped beam type are highly satisfactory for producing information in the form of alphanumeric characters, mathematical symbols, or other convenient visible symbols. Occasionally, however, it may be desireable to record a graphic image having areas of different tone levels, such as a pictorial image. The recording of pictorial information places additional requirements on the cathode ray tube recording system, since pictorial information contains a variety of areas with different tone levels, and the various tone levels must be reproduced for a satisfactory image. As used herein, the term "tone" refers to the shade (i.e., darkness or lightness) of an area of the image. For example, the tone of a given area of an image may be black, white, or one of a variety of intermediate grays.

Many printing processes including the offset printing process and some electrostatic printing processes, when adapted for the reproduction of images generated on a cathode ray tube, are inherently incapable of reproducing intermediate grays. When such printing processes are used, therefore, the pictorial image is divided into a multiplicity of elemental areas of uniform size. Each elemental area of the pictorial image contains a tiny dot, and the size of each dot relative to the size of the elemental area is varied to produce variations in tone. In such processes the individual dots are either entirely white or entirely black, and tone variations are produced when the dots do not completely occupy an elemental area. Pictorial images reproduced in this manner are called "halftone images." It is characteristic of the printing processes which utilize the halftone principle that the best copies are obtained when the dots on the printing master are all of the same density, as the printing process can then be optimized for the common dot density. When an image to be reproduced is continuous and of varying tone, it must be converted into a halftone image by a screening process which divides the continuous image into a multiplicity of dots. The screening process may be eliminated if the original image is in the form of discrete dots. It is thus advantageous to produce halftone records which are initially recorded as a sequence of dots so that screening is not required and in which the recorded dots are all of the same density so that optimum quality is obtained in the printed copies.

It is known to reproduce pictorial information by beam intensity modulation in cathode ray tubes for television and facsimile applications. When recorded images are produced by intensity modulation, the images have corresponding variations in tone. Such images must be screened to break them into dots, and an attempt must be made to equalize the densities of the dots insofar as possible. It has been proposed that halftone images be recorded from a cathode ray tube as a multiplicity of spaced dots, where the dot center-to-center spacing is variable, but the implementation of this method requires complex electronic deflection circuits. It has also been proposed that spaced dots be produced by a cathode ray tube which is intensity modulated so that the spreading of the beam as the intensity is increased will produce a variation in the recorded spot size. The latter method produces dots which are not all of the same density on the record. Both proposed methods produce dots for which the boundaries are vaguely defined.

For the reasons above, the quality and definition of graphic images produced by such prior art cathode ray tubes have sometimes been unsatisfactory. Furthermore, known cathode ray tubes have not offered sufficient versatility as to be able to produce alphanumeric information, graphical information, and graphic images with a high quality for all types of information.

Accordingly, it is an object of the present invention to provide an improved cathode ray tube system for producing a graphic image having areas of different tone levels.

Another object of the invention is to provide a cathode ray tube system for producing graphic images wherein variation in image tone may be achieved without variation in beam intensity.

A further object of the invention is to provide a cathode ray tube system for producing graphic images and which is low in cost and of simple construction.

It is another object of the invention to provide a cathode ray tube system for producing both graphic images and alphanumeric information.

Other objects of the invention will become apparent to those skilled in the art from the following description, taken in connection with the accompanying drawings wherein:

FIG. 1 is a schematic diagram of a cathode ray tube system constructed in accordance with the invention;

FIG. 2 is a plan view of a beam forming matrix plate utilized in the cathode ray tube of FIG. 1;

FIG. 3 is a plan view of a portion of the target screen of the cathode ray tube of FIG. 1 illustrating various dot sizes and a dot pattern which may be reproduced thereon when the system is operated in a preferred mode; and

FIGS. 4, 5, 6, 7, 8 and 9 are plan views of a portion of the target screen of the cathode ray tube of FIG. 1, illustrating dot patterns which may be produced in alternate embodiments of the invention.

Very generally, the cathode ray tube system of the invention comprises an electron beam source 11 and means 12 and 13 for forming at least a portion of the cross section of the beam into a predetermined shape of selectable size, each size corresponding to a different image tone level. The forming means are operable to select a beam cross section size in accordance with a desired tone level in an area of the image being reproduced. The tube system further includes an electron responsive target screen 14 for displaying the image. Means 16 are provided for directing the shaped portion of the beam

to a succession of predetermined areas on the target screen to define the graphic image by means of a plurality of dots of a size corresponding to the respective image tone levels.

In certain preferred commercial applications an optical imaging system **71** projects the image on the target screen **14** onto a photosensitive recording medium **72**.

Referring now more particularly to FIG. **1**, the specific embodiment of the invention illustrated therein comprises a shaped beam tube of the beam selection type having an evacuated envelope **17** of glass, metal or other suitable material. The envelope is shaped in the typical manner of such tubes, having a bell-shaped portion at one end and a narrow neck portion extending therefrom. Mounting of the various elements described below within the envelope **17** may be accomplished in any suitable manner in accordance with known techniques in the cathode ray tube manufacturing art.

The electron beam source **11** includes a cup-shaped cathode **18** and a heating filament **19** disposed within the cathode. Current is passed through the filament **19** from a pair of filament power supply terminals **21** located exteriorly of the glass envelope **17**. The leads from the terminals **21** pass through the end of the glass envelope as is well known in the art. The cathode may be comprised of nickel coated with barium oxide on its outer surface and is maintained at a suitable cathode potential by connection to a cathode potential terminal **22**.

In order to control blanking and unblanking of the beam and regulate the intensity thereof, a cup-shaped grid **23** is provided surrounding one end of the cathode **18**. The grid is provided with an opening **24** therein on the axis of the tube, through which the electron beam produced by the cathode is accelerated. The grid **23** is connected to grid drive circuits **26** located exteriorly of the glass envelope **17**, and such drive circuits operate to regulate the grid potential in a desired manner, as will be explained more fully below. The electron beam produced by the cathode **18**, when passed through the opening **24**, is accelerated and focused by means of a pair of electron beam lens elements **27** and **28** maintained at suitable potentials by connection to terminals **29** and **31**, respectively.

The forming means **12** and **13** include a shaping member **12** and a selecting system **13**. The latter includes one or more pairs of vertical plates **32** for deflecting the beam from its initial path a desired amount in the horizontal plane. The selecting system also includes a pair of horizontal plates **33** for deflecting the beam from its initial path an amount in the vertical plane. Horizontal selection circuits **34** are connected to the plates **32**, and vertical selection circuits **36** are connected to the plates **33**. In accordance with the potential developed across the plates by the appropriate selection circuits, the beam is deflected from its initial path a precisely regulated amount in order to select one of the apertures in the shaping member **12**. The cross section of the beam is controlled by the lens elements **27** and **28** to just flood the selected aperture only, and to avoid covering adjacent apertures.

The shaping member **12** comprises an electron opaque plate which is disposed perpendicular to the axis of the tube in the path of the electron beam. Referring to FIG. **2**, the electron opaque member or plate **12** may be seen in a plan view in which the various apertures are illustrated. The apertures comprise stencillike openings for defining upper and lower case alphanumeric characters and various other symbols such as abbreviations, mathematical notations, and line segments for producing such things as graphs and charts. The various characters and symbols are arranged in a matrix, and the horizontal and vertical selection circuits **34** and **36** operate to deflect the beam to flood a selected one of the apertures. The cross section of the beam is thus formed in accordance with the shape of a desired symbol.

For purposes which will be explained more fully below, eight square apertures **37** of graduated size are provided in the center of the matrix of characters and symbols on the electron opaque plate **12**. For clarity of illustration, the largest of the square apertures is illustrated as being one-half the height of the largest character. In actual operation of the specific embodiment described herein, however, the size of the square apertures **37** is, in each case, half that illustrated. Thus, by selecting one of the eight square apertures **37**, the cross section of the beam may be shaped into a square corresponding to the size of the selected square aperture.

Returning now to FIG. **1**, the selecting system **13** further includes a pair of convergence lens elements **38** and **39** located downstream from the matrix plate **12**. The lens elements **38** and **39** are connected to a pair of potential sources **41** and **42** for maintaining the lens elements at a potential which causes the electron beam to be focused and to be returned to the axis of the tube from the off axis deviation position of the particular selected aperture. In the region where the beam intersects the axis of the tube, it is returned to a path coincident with the axis by a pair of vertical plates **43** and a pair of horizontal plates **44**. The plates **43** are driven by horizontal reference circuits **46**, and the plates **44** are driven by vertical reference circuits **47**. The plates are driven by voltages which complement the voltages driving the plates **32** and **33** so that the vertical and horizontal deviation of the beam direction from the axial direction is corrected precisely, thereby aligning the beam on the axis of the tube once more. Final focusing of the beam to achieve a sharp image on the screen is accomplished by an accelerating and focusing element **48** positioned downstream from the plates **43** and **44**. The element **48** is maintained at a suitable potential by connection to a potential source **50**.

The large end of the envelope **17** is closed by a glass face plate **49**, the interior of which supports the target screen **14**. The target screen may be of any electron responsive material. Suitable materials include phosphors, to emit visible light when bombarded with electrons, and scotophors, to absorb light when struck by electrons.

The interior of the enlarged section or bulb portion of the envelope **17** is provided with an aquadag coating **51**, as is known in the art. The aquadag coating **51** is maintained at a suitable accelerating potential by electrical connection thereof to a potential source of high voltage **52**. The high positive potential of the aquadag coating **51** aids in accelerating the beam to the target screen **14**. Moreover, the discontinuity in potential between the aquadag coating **51** and the element **48** effects a focusing action on the electron beam to sharply image the selected aperture on the target screen at a desired degree of magnification.

The directing means **16** include a yoke **53** which surrounds the neck of the envelope **17** adjacent the larger bulb portion thereof and which provides electromagnetic deflection fields to direct the beam to a particular spot on the target screen **14**. Driving currents are supplied to the yoke **53** from the yoke drive circuits **54**, and the yoke drive circuits are controlled in a manner which will be described below in connection with the particular controlling means employed.

The visible image produced on the target screen **14** may be a pattern of luminescent spots on a dark background, if the screen is a phosphor. The image on the screen **14** is projected onto a photosensitive recording material **72** by an objective lens **71**. The recording material **72** is in the form of a strip of photographic film which is unwound from a supply reel **73** before exposure to the image of the screen **14**, and is wound up on a takeup reel **74** after exposure. A fiber optics bundle set into the faceplate **49** may be used in place of the objective lens **71**, if desired.

Referring to FIG. **3**, a particular manner of operating the cathode ray tube apparatus of the invention to produce graphic images having areas of different tone levels will be described. In order to produce a graphic image, the tube apparatus of the invention is operated in a manner which causes the yoke drive circuits **54** to produce deflecting currents in the yoke **54** to produce deflecting fields which scan the beam across the target screen **14** in a raster pattern. As the beam is scanned across each row of the raster, it is moved incrementally, i.e., in steps, to define a plurality of beam positions for each row. An image having areas of different tone levels is

produced by a plurality of dots, the beam being unblanked in each of a series of positions. These positions are uniformly spaced so that the image is formed of a plurality of elemental areas, each corresponding to a respective beam position. Tone variation is governed by the size of each dot. Assuming that the material of the target screen **14** has a white background and darkens when struck by electrons, or assuming that the image is to be produced on microfilm and a negative of the image is produced on the target screen, lighter image tones are produced by utilizing smaller dot sizes, so that less of each elemental area is darkened.

The size of the dots utilized is determined by selecting an appropriate size aperture **37** in the electron opaque plate **12**. The squares produced by the electron beam at each image position in a row are of uniform center-to-center spacing. The scan pattern, however, is selected so that the squares in adjacent rows are offset from each other by one-half the maximum square width. This is illustrated in FIG. 3. It may be seen that the largest squares **56** are of a size which is equal to the spacing of the rows and to the spacing of the incremental beam positions. The largest squares therefore fit flush against each other to completely fill the area, making it of maximum darkness. The smaller the square, the less a particular elemental area is darkened, as indicated by the progressively smaller square sizes **57**, **58** and **59**, respectively, in FIG. 3. The intensity levels available vary from solid black with the largest size square, to nearly white with the smallest size square. Where the smallest square is one-eighth the width of the largest, it occupies only one-sixty-fourth of the elemental area for a particular beam position. Thus, a graphic image, in an area where all squares are of the smallest size, is 98.4 percent white or transparent and 1.6 percent black or opaque. If desired, a blank in the matrix of the opaque plate **12** may be used in place of or in addition to the smallest square. The apparatus utilizing such a construction is capable of producing eight or nine gray levels, all of which are at least subjectively distinguishable from each other. It may be noted that a difference of 12.5 percent in the linear dimensions between the second largest size square and the largest size square produces a difference of 23.5 percent in their areas, so that even the two regions of darkest tone are subjectively distinguishable. A more preferable arrangement of square sizes is one in which the variation corresponds to equal increments of area, rather than linear dimensions. In this way, a more uniform variation in tone may be achievable.

By utilizing image producing dots of square shape, it is possible to maximize the range of tones achievable with a minimum range of aperture sizes in the plate **12**. A similar result may be obtained by using other geometric shapes capable of being mated in a complementary manner to completely cover a desired area. For example, triangles (FIG. **4**), hexagons (FIG. **5**), trapezoids (FIG. **6**) or rectangles (FIG. **7**) may be utilized, rather than squares. If triangles or trapezoids are used, it is necessary to have two sets of apertures, one with points or short sides up and the other with points or short sides down, as illustrated in FIG. **4** and FIG. **6**, respectively. If points up triangles or short-sides-up trapezoids are used in all the odd positions of a row, then points down triangles or short-sides-down trapezoids are used in the even positions of a row, thereby achieving complete coverage of the area. If hexagons are used oriented so as to have two vertical sides, then the odd rows in an image should be staggered with respect to the even rows, as is done with the squares, to achieve complete darkening of an area without overlap when the largest size hexagons are used.

If complete darkening in an area is not essential, other geometric shapes, including circles, may be utilized. Moreover, complete darkening of an area even in the case of nonmating geometric configurations or arrangements may be achieved if sufficient overlap is utilized. When the shape or arrangement is such that overlap is required in some areas to achieve complete darkening in others, the range of sizes required in the cathode ray tube to produce a full range of image tones is increased. Furthermore, the overlapped areas may have a different density than nonoverlapped areas. The shapes which require no overlap are thus used in the preferred embodiment.

Returning now to FIG. 1, a particular operating technique and apparatus for carrying the technique out will be described in connection with the apparatus of the invention. The displayed image is produced from the output of a digital program source or digital computer **61**. The horizontal selection circuits and the horizontal reference circuits are controlled by a horizontal selection register **62** which may comprise a suitable series of flip-flops. Similarly, the vertical selection circuits **36** and the vertical reference circuits **47** are controlled by a vertical selection register **63**, which may consist of a plurality of suitably connected flip-flops. The horizontal and vertical selection registers are connected to a tone code converter **64** which translates signals from the digital program source or digital computer **61** into appropriate signals for operating the selection registers. The yoke drive circuits **54** are controlled by an X-register and-counter **66** and a Y-register and-counter **67**, both operated by appropriate signals from the output of the digital program source or digital computer **61**. The beam therefore can be positioned by digital signals to any one of a number of positions, each defined by a digital address in the X-axis and a digital address in the Y-axis. The source **61** is also connected to the grid drive circuits **26** for blanking and unblanking the electron beam at appropriate beam positions.

The operation of the apparatus may best be described by way of example in producing an image comparable to a 7 inch × 7 inch halftone newspaper photo made with a 72-line per inch screen, or to a 5 inch × 5 inch magazine photo screened at 100 lines per inch. An image of such a quality may be produced by utilizing 512 horizontal lines, each line having 512 incremental beam positions. Assuming the X-register and-counter **66** and the Y-register and-counter **67** are each comprised of 12 flip-flops providing 12 binary bits, there are 4,096 available digital addresses in each axis. The desired 512 beam positions in each axis are obtained by spacing the centers of the squares in each row at intervals of eight address units in the X-axis, and spacing the centers of the rows at intervals of eight address units in the Y-axis. The largest squares **56** are made eight address units in height and width so any elemental area of the image on the screen **14** may be completely filled by a square **56**.

At the beginning of an image scan, the register and the counter **66** and the register and counter **67** may each be set to 000,000,000,100 binary or 0004 decimal by the digital program source or digital computer **61**. These two conditions of the register establish yoke currents to direct the beam to the center of the first elemental position of the image.

The source or computer **61** also operates to set the horizontal and vertical selection registers **62** and **63** to suitable four-bit binary codes which will select a square of the proper size (from the square apertures **37** in the matrix plate **12**, FIG. 2) in accordance with the tone desired at that part of the image. This may be done by sending a three-bit code to the tone code converter **64** which may be designed to then generate the proper eight-bit code from it. Alternatively, the source or computer **61** may send eight binary bits directly to the selection registers. The grid drive circuits **28** are then operated to unblank the beam and produce the first image element. The X-register **66** is then reloaded or counted up to an address which is greater by eight address units, in this case to 000,001,100 binary, or 0012 decimal, while the Y-register is unchanged. A square aperture appropriate to the tone of the second image element is then selected and unblanked. This process of increasing the X-register by eight units, selecting a square size, and unblanking the beam, continues until one entire row is completed.

In a 12-bit system, a row is a maximum of 4,096 address units, or 512 element positions. The second row is started by setting the Y-register and-counter **67** to 000,000,001,100 binary or 0012 decimal, either by reloading it from the com-

puter or source 61, or by increasing its count by eight address units. The X-register is set to 000,000,000,000 binary or 0000 decimal, for the first element in the second row. This staggers the second row by one-half an element interval, or four address units with respect to the first row, as shown in FIG. 3. The second row is then produced by successive selection, unblanking and stepping of the X-register and-counter in increments of eight address units, as before. The second X-address in the second row will be 000,000,001,000 binary or 0008 decimal, etc. The third row starts at Y-0020 decimal and X=0004 decimal. The process continues until the entire image is completed.

The X- or Y-counter can be easily increased by eight counts, by injecting a single pulse into the fourth flip-flop from the least significant end of the string of flip-flops in the counter. The least significant flip-flop has a weighting value of one and the fourth flip-flop a value of eight. This technique for incrementing a binary counter is well known in the art.

In the operation of the preferred embodiment of the invention described herein, two images are generated by each complete scan of the image area. One image is generated on the screen 14 of the cathode ray tube, typically appearing as a pattern of tiny luminescent squares on a nonluminescent background, if the screen is a phosphor. The intensities of all of the squares are nominally equal. The incremental areas of the image on the screen 14 appear to have different intensity levels, depending on the sizes of the bright squares. The second image is a corresponding image recorded on recording material 72. The recorded image typically appears as a pattern of tiny opaque squares on a clear background, if the recording material is conventional microfilm. The optical densities of all the dots are nominally equal, but the incremental areas of the image appear to have varying densities, depending on dot size. The apparent intensity in the first image, and the apparent density in the second, are both intended to be included in the term "tone" as used herein.

As an alternative to the previously described scheme, it is possible to produce an image 512 × 512 elements by utilizing digital addressing of only 10 bits per axis (1,024 addressable points or raster units). Moreover, if staggering between adjacent rows is not utilized, nine bits are sufficient for a 512 ×512 element image.

As an alternative mode of operation, the center-to-center spacing of the elemental positions in a row may be made equal to the maximum square width, while the center-to-center spacing of the rows is made one-half the square height. This is illustrated in FIG. 8. The centers of the elemental positions in the odd numbered rows are staggered with respect to even numbered rows by one-half the maximum square width, as in FIG. 3. As indicated by the left portion of FIG. 8, overlap of the squares at the corners is required to achieve full coverage of the image area. The alternate mode of FIG. 8 has the disadvantage that the range of sizes required in the cathode ray tube is greater, but has the advantage that the recorded image may appear to have greater resolution than the image produced by the mode of FIG. 3 since both the rows and columns are staggered with respect to adjacent rows and columns, respectively. The alternate mode of FIG. 8 is particularly advantageous when the succeeding steps in the printing of the image provide insufficient resolving capability to reproduce the narrow lines separating the squares in FIG. 3. In the alternative of FIG. 8, the near-white areas are comprised of tiny white dots on a black background, and the near-black areas by tiny black dots on a white background, so the subsequent process need not be capable of resolving fine lines.

FIG. 9 illustrates an alternate embodiment of the invention. The squares in the shaping plate 12 are rotated until their sides are at a 45° angle to the rows and columns of the matrix. The squares then appear on the screen 14 to be "diamond-shaped." In this embodiment, the center-to-center spacing of the rows is one-half the center-to-center spacing of the squares in a row. The diagonal of the largest square is made equal in length to the center-to-center spacing within each row, so that incremental areas of the image can be completely filled by the squares without overlap. The advantage of the alternate embodiment of FIG. 9 is that the recorded image may appear to have greater resolution, since both rows and columns are staggered with respect to adjacent rows and columns, as in FIG. 8, but the squares in FIG. 9 do not overlap, unlike the squares in FIG. 8. FIG. 9 thus achieves the advantages of staggering in both axes, while avoiding the disadvantages attendant upon overlapping.

It may therefore be seen that the invention provides an improved cathode ray tube for producing graphic images having areas of different tone levels. The apparatus of the invention operates on digital information, and thereby may be utilized to produce a visible output of information derived from a digital program source or digital computer. By utilizing uniform center-to-center element spacing in producing the image, variation in image tone may be readily achieved by variation in the size of a spot produced by the electron beam at each element position. Size variation is readily accomplished by utilizing an apertured plate having apertures of appropriately varying sizes and of appropriate shape. Accordingly, the apparatus of the invention is of relatively simple construction and correspondingly low in cost. Moreover, in view of the simple manner in which spot size variation is achieved, the apparatus is of improved reliability. Variation in image tone is achieved without variation in beam intensity, and a wide variation in image tone is available. Although described in connection with a shaped beam tube of the beam selection type, the system of the invention may utilize a tube of the aperture selection type as well.

It will be obvious to those skilled in the art that the instant invention may be used to produce halftone images by electron beam recording directly on electron sensitive film. Upon appropriate modification of the cathode ray tube envelope 17, the film 72 may be placed inside the envelope 17, replacing the target screen 14. A latent image is then produced on the film by impingement of the electron beam thereon. The film may then be removed and developed to make the latent image visible.

Various modifications of the invention in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description and accompanying drawings. Such modifications are intended to fall within the scope of the appendant claims.

I claim:

1. A cathode ray tube system for producing a graphic image having predetermined areas of different tone levels, comprising, an electron beam source, an electron opaque member having a plurality of apertures therein for forming at least a portion of the cross section of the electron beam produced by said source into predetermined shapes of different sizes, each size corresponding to a different image tone level, means for selecting a succession of beam cross section sizes, each determined by one of said apertures in accordance with the desired tone level in a predetermined area of the image being reproduced, an electron responsive target screen for displaying the image, and means for directing the shaped portion of the beam to a succession of predetermined areas on the target screen to define the graphic image by means of a plurality of dots each of a size corresponding to the image tone level of the respective predetermined area.

2. A cathode ray tube system according to claim 1 wherein the electron beam is of a substantially constant intensity.

3. A cathode ray tube system according to claim 1 wherein said selecting means include means for deflecting the beam to pass through one selected aperture of a desired size.

4. A cathode ray tube system according to claim 1 wherein the largest of said apertures is of a polygonal shape capable of being distributed in a pattern in which the shapes complement each other to leave no space therebetween and to provide no overlapped areas.

5. A cathode ray tube system according to claim 1 wherein said electron opaque member includes a plurality of further

apertures shaped to define characters, whereby said tube may be operated to display written information as well as graphic images.

6. A cathode ray tube system according to claim 1 wherein said beam directing means are adapted to distribute the dots with uniform center-to-center spacing.

7. A cathode ray tube system according to claim 6 wherein said beam directing means is adapted to distribute the dots in a raster pattern in which the dots in each horizontal row are offset from the dots in the immediately adjacent horizontal rows.

8. A cathode ray tube system for producing a graphic image having regions of different tone levels, comprising, an electron beam source, means including a plate having apertures of graduated sizes for forming at least a portion of the cross section of the electron beam produced by said source into a predetermined shape with a plurality of selectable sizes, each selectable size corresponding to a different tone level, said beam forming means being controllable to select a cross-sectional shape size in accordance with a desired tone level in each region of the image being reproduced, an electron responsive target screen for displaying the image, and means for directing the shaped beam of selected size to predetermined regions on the target screen to define the graphic image thereon by means of a plurality of shapes each of a size corresponding to the tone level of the respective region.

9. A cathode ray tube system according to claim 8 wherein said directing means is adapted to distribute the shapes with uniform center-to-center spacing.

10. A cathode ray tube system for recording graphic images having areas of varying tone comprising: an electron gun at one end of the tube for producing an electron beam; an electron responsive target at the other end of the tube for producing a graphic image; means to shape the cross section of the electron beam to a selected one of a plurality of predetermined sizes, said shaping means including an electron opaque shaping plate perforated with a plurality of shaping apertures of graduated sizes, said shaping apertures corresponding in size to the predetermined beam sizes, and said plate being mounted transverse to the axis of the tube intermediate said gun and said target; means for positioning the shaped beam in sequence upon elemental areas of said target; means for controlling the shaping means to select a shaped beam size representative of the image tone at each elemental area upon which the shaped beam is positioned; and means for recording the image produced on the target, whereby an image is recorded as a plurality of dots of greater and lesser size.

11. A cathode ray tube system according to claim 10 wherein the recorded dots are of substantially the same optical density.

12. A cathode ray tube system according to claim 10 wherein the largest of said shaping apertures is of a polygonal shape capable of being distributed in a pattern in which the shapes complement each other to leave no space therebetween and to provide no overlapped areas.

13. A cathode ray tube system according to claim 10 wherein said electron opaque shaping plate includes a plurality of further apertures shaped to define characters whereby said system may be operated to record alphanumeric information as well as graphic images.

14. A cathode ray tube system according to claim 10 wherein said shaped beam positioning means are adapted to position the dots in rows with uniform center-to-center spacing between dots in the same row.

15. A cathode ray tube system according to claim 14 wherein said shaped beam positioning means are adapted to position the dots in a raster pattern comprising a number of rows, and the dots in the odd numbered rows are staggered with respect to the dots in the even numbered rows.

16. A cathode ray tube system according to claim 10 wherein: the electron beam from said electron gun is of a size in cross section to flood any one of the shaping apertures, without flooding the other shaping apertures; and wherein said control means is adapted to deflect the electron beam to the shaping aperture having the size corresponding to the selected beam size.