United States Patent

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[72] Inventors Edwin R. Kolb
University Heights;
Charles H. Grace, Becksville, Ohio
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[73] Assignee Harris Intertype Corporation
Cleveland, Ohio

[54] POINT SIZE, COMPUTATION AND EXPOSURE CONTROL DEVICE FOR A CHARACTER DISPLAY APPARATUS
10 Claims, 11 Drawing Figs.

[52] U.S. Cl. 340/324, 95/4.5, 315/18
[51] Int. Cl. H01j 29/70
[50] Field of Search 340/324.1; 95/4.5

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Primary Examiner—Thomas B Habecker
Assistant Examiner—David L Trafton
Attorney—Yount & Farolli

ABSTRACT: A character memory, including several fonts of characters each of a different point size, supplied characters generating data to form characters on an energy responsive surface, such as the face of a cathode-ray tube, in response to instructions from a control record. The control record selects the font and the character within the font to be displayed and the size of the character to be displayed independent of its size as recorded in the memory within the selected font. Each character is formed by moving a beam of energy to a plurality of predetermined locations relative to each other and energizing the beam for a predetermined duration on the energy responsive surface to form a series of spots, and each character is formed to the point size required by the control record by a circuit which analyzes the point size of the character stored in the character memory, compares this information with the point size of the character to be displayed from the control record, and provides a reference voltage to the character generator to control the spacing between adjacent spots. Thus, typesetting characters may be displayed at different speeds and of different quality, depending upon the use for which the output of the phototypesetting system is to be employed. A circuit is also provided to control the duration of the spots which form the characters so that the characters are all of the same density independent of the size of the character displayed or the point size of the character memory selected.

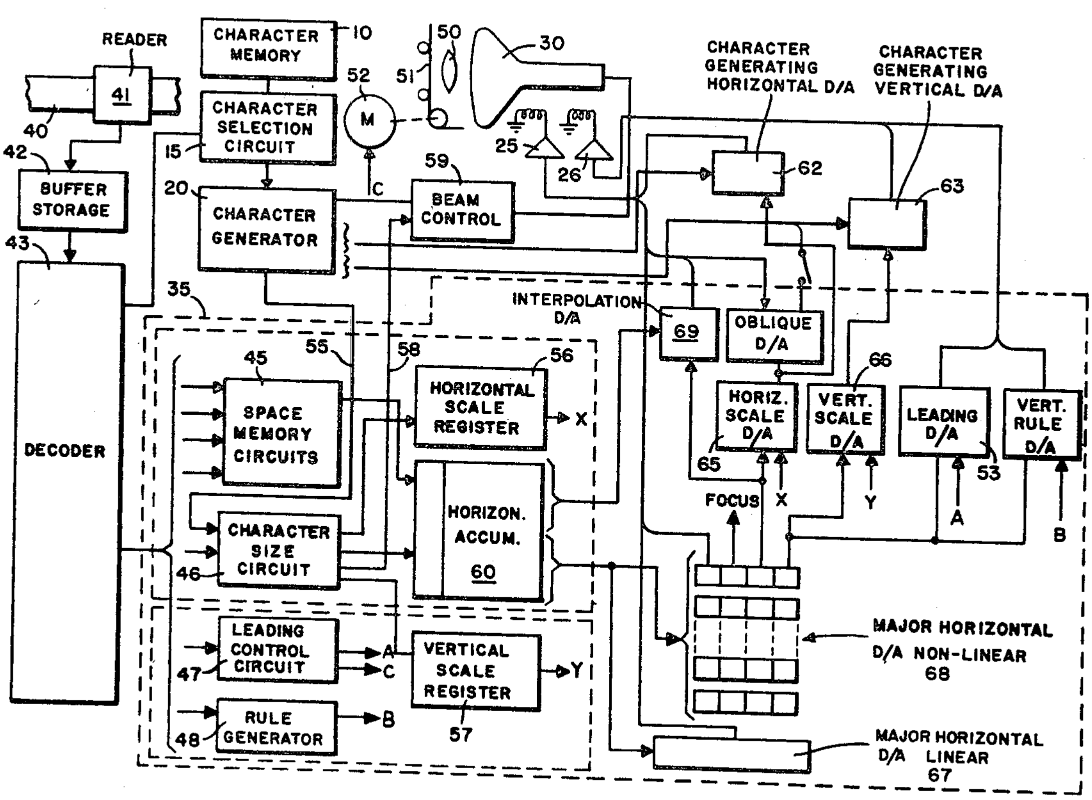
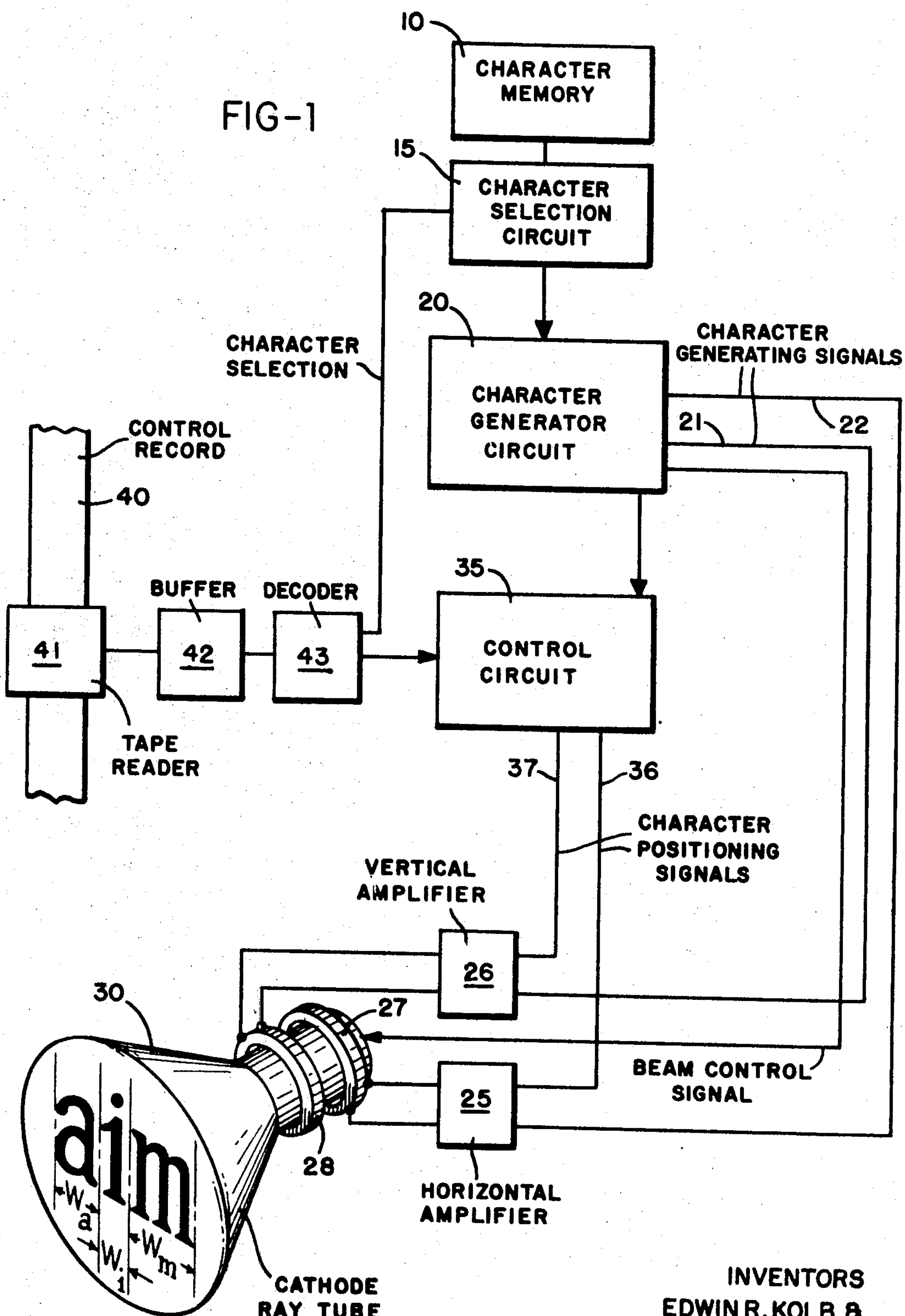


FIG-1



INVENTORS
EDWIN R. KOLB &
CHARLES H. GRACE

BY Marechal, Biebel, French & Bugg
ATTORNEYS

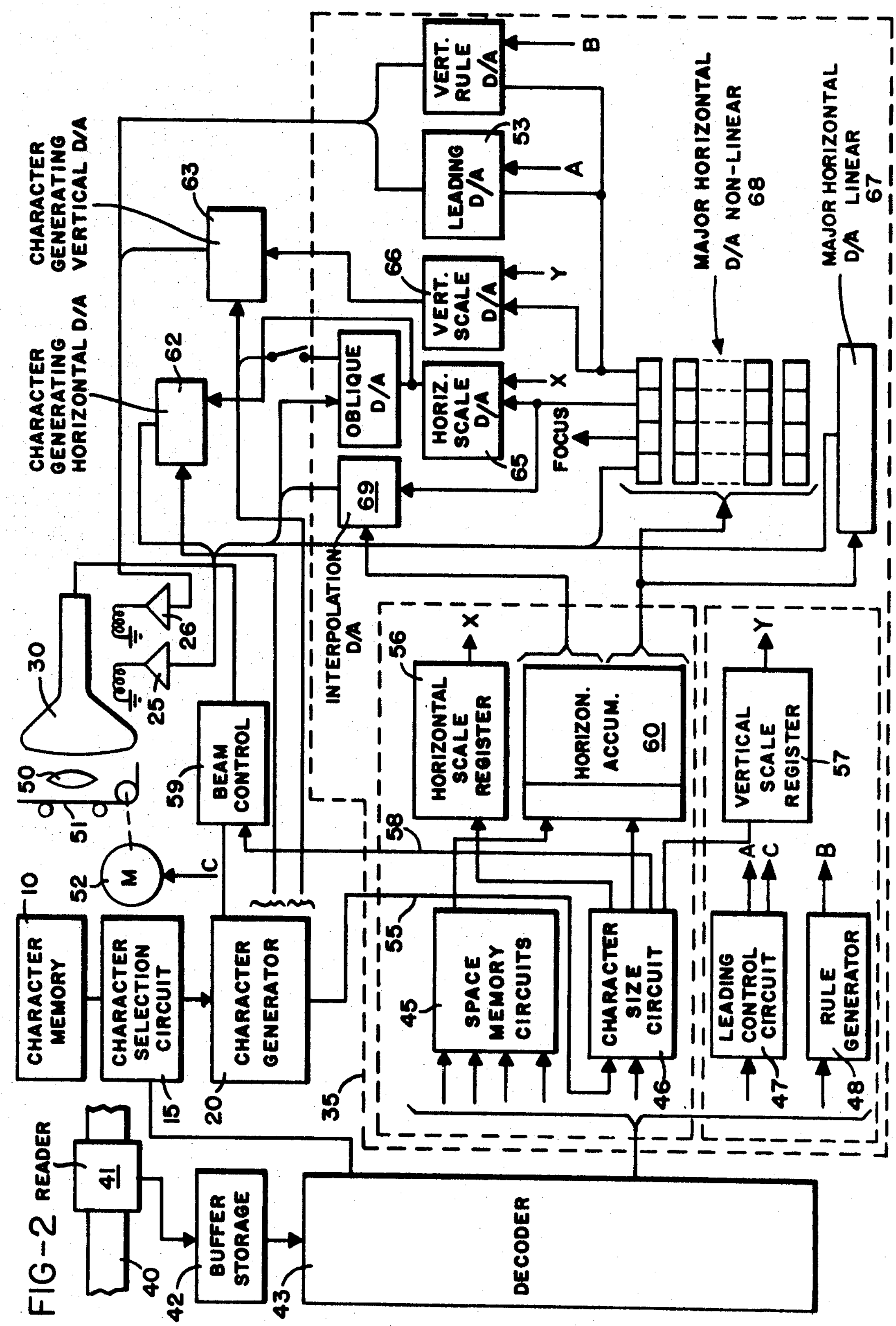


FIG-2
READER
41
40
BUFFER STORAGE
42
DECODER
43
CHARACTER MEMORY
10
CHARACTER SELECTION CIRCUIT
15
CHARACTER GENERATOR
20
35
M
52
C
51
50
30
25
26
BEAM CONTROL
59
CHARACTER GENERATING HORIZONTAL D/A
62
CHARACTER GENERATING VERTICAL D/A
63
INTERPOLATION D/A
69
OBLIQUE D/A
HORIZ. SCALE D/A
65
VERT. SCALE D/A
66
LEADING D/A
53
VERT. RULE D/A
A
B
X
Y
FOCUS
MAJOR HORIZONTAL D/A NON-LINEAR 68
MAJOR HORIZONTAL D/A LINEAR 67
HORIZONTAL SCALE REGISTER
56
HORIZON. ACCUM.
60
VERTICAL SCALE REGISTER
57
58
55
SPACE MEMORY CIRCUITS
45
CHARACTER SIZE CIRCUIT
46
LEADING CONTROL CIRCUIT
47
RULE GENERATOR
48

FIG-3

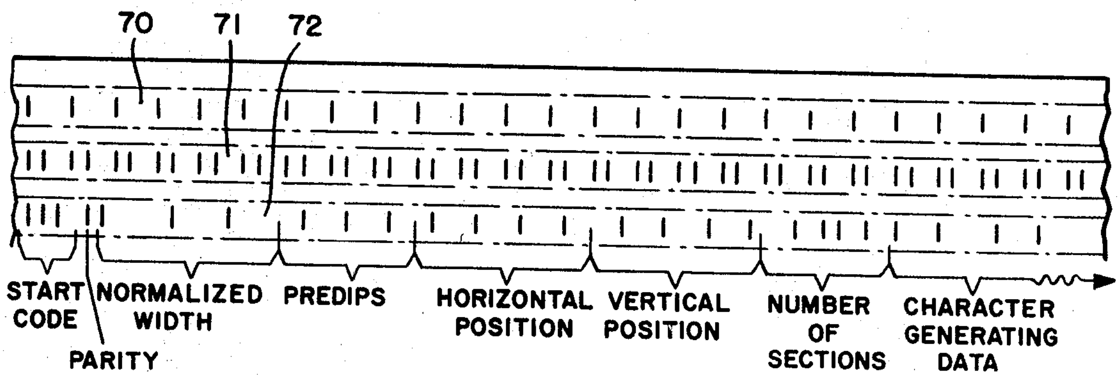


FIG-5

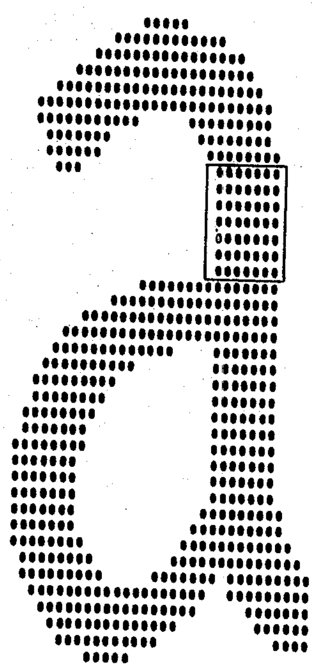
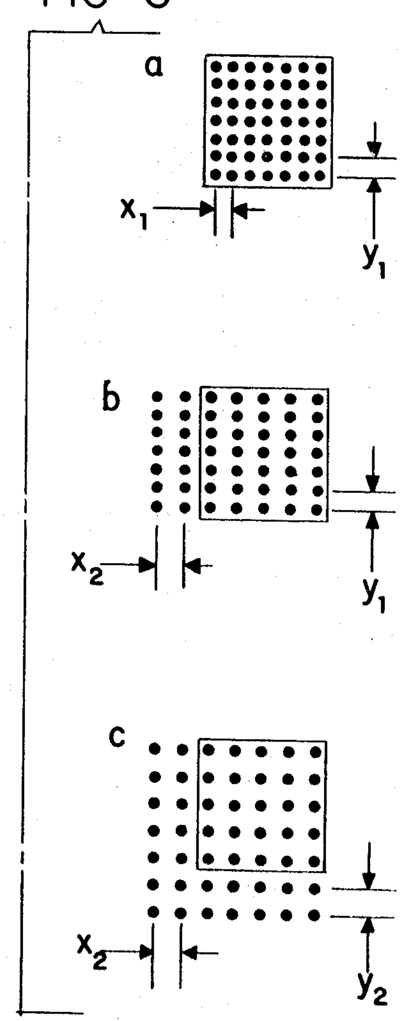


FIG-6



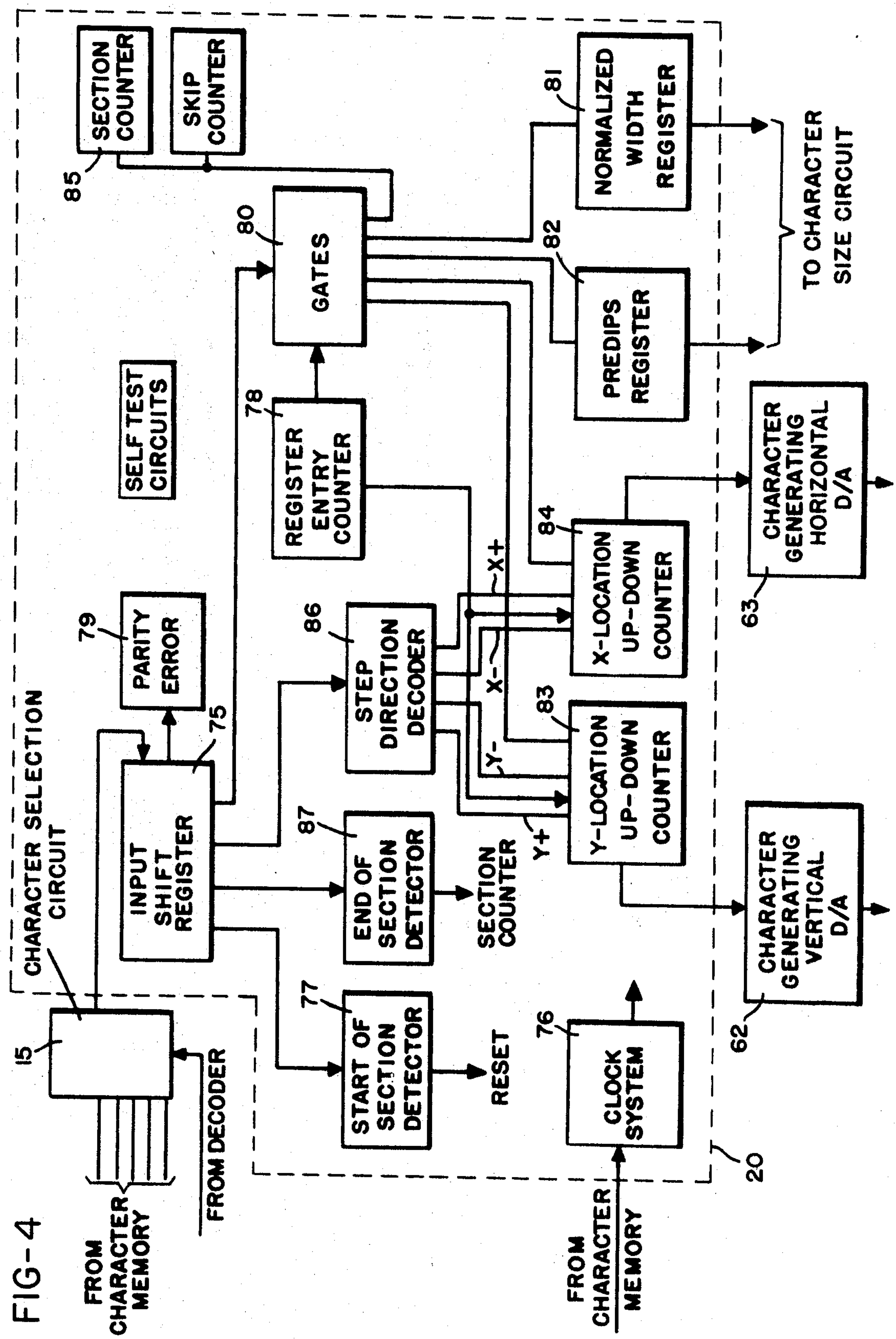

SECTION COUNTER
SKIP COUNTER
85
80
GATES
81
NORMALIZED WIDTH REGISTER
82
PREDIPS REGISTER
TO CHARACTER SIZE CIRCUIT
SELF TEST CIRCUITS
78
REGISTER ENTRY COUNTER
CHARACTER GENERATING HORIZONTAL D/A
84
X-LOCATION UP-DOWN COUNTER
X+
X-
63
79
PARITY ERROR
86
STEP DIRECTION DECODER
83
Y-LOCATION UP-DOWN COUNTER
Y-
Y+
CHARACTER SELECTION CIRCUIT
75
INPUT SHIFT REGISTER
87
END OF SECTION DETECTOR
SECTION COUNTER
CHARACTER GENERATING VERTICAL D/A
62
15
77
START OF SECTION DETECTOR
RESET
76
CLOCK SYSTEM
20
FROM DECODER
FROM CHARACTER MEMORY
FROM CHARACTER MEMORY

FIG-4

FIG-7A

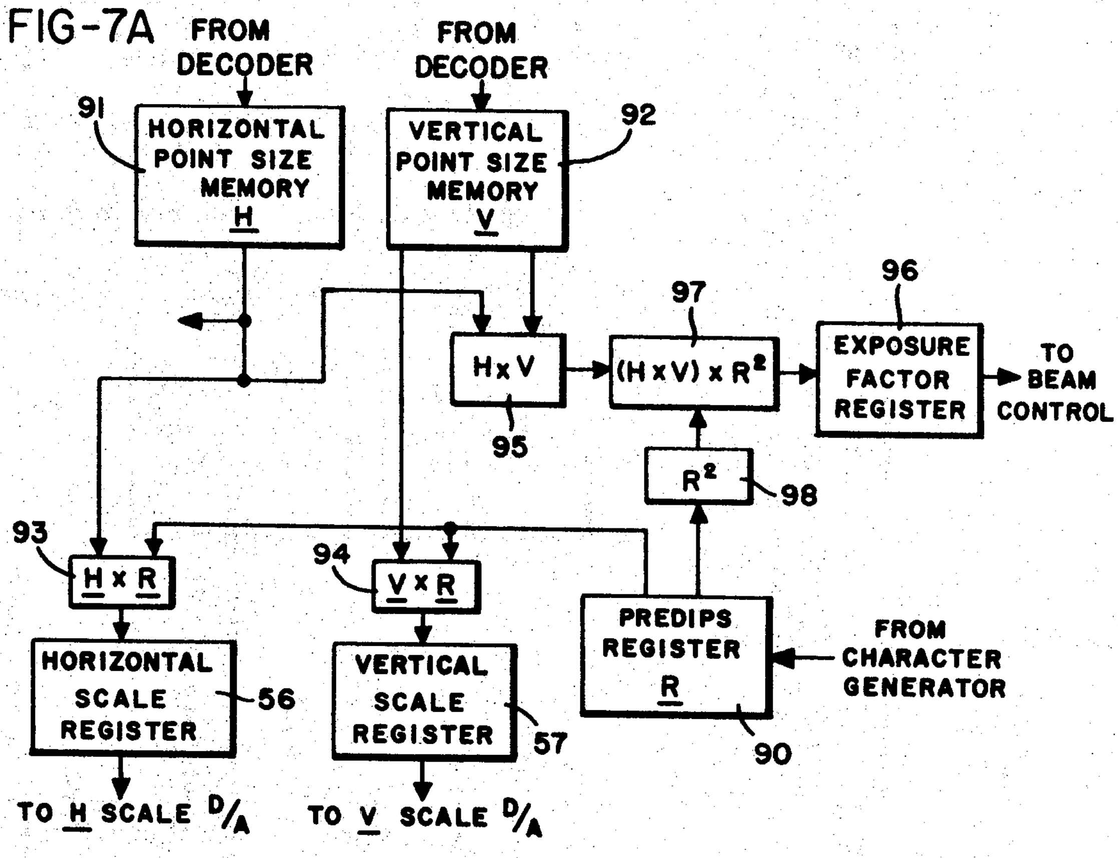
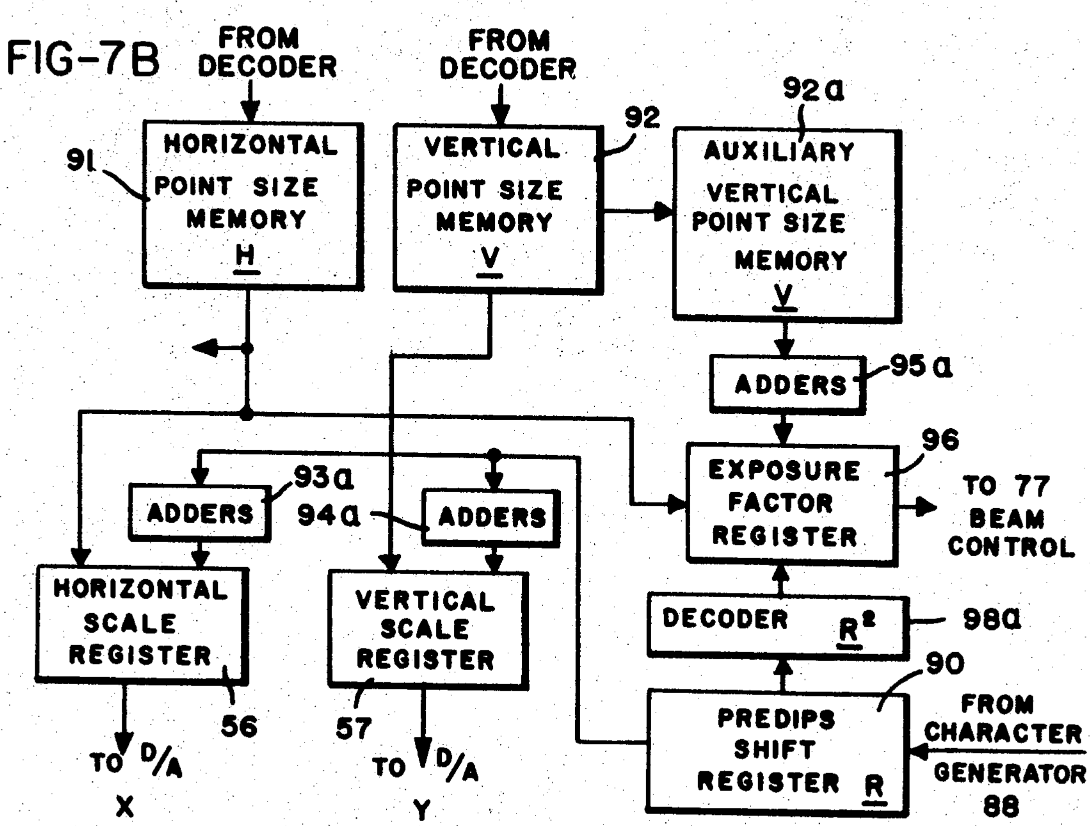

FROM DECODER
FROM DECODER
91
HORIZONTAL POINT SIZE MEMORY H
VERTICAL POINT SIZE MEMORY V
92
97
96
H x V
(H x V) x R²
EXPOSURE FACTOR REGISTER
TO BEAM CONTROL
95
R²
98
93
H x R
94
V x R
PREDIPS REGISTER R
FROM CHARACTER GENERATOR
HORIZONTAL SCALE REGISTER
56
VERTICAL SCALE REGISTER
57
90
TO H SCALE D/A
TO V SCALE D/A

FIG-7B


FROM DECODER
FROM DECODER
92a
91
HORIZONTAL POINT SIZE MEMORY H
92
VERTICAL POINT SIZE MEMORY V
AUXILIARY VERTICAL POINT SIZE MEMORY V
ADDERS
95a
96
93a
ADDERS
94a
ADDERS
EXPOSURE FACTOR REGISTER
TO 77 BEAM CONTROL
HORIZONTAL SCALE REGISTER
VERTICAL SCALE REGISTER
DECODER R²
98a
90
56
57
PREDIPS SHIFT REGISTER R
FROM CHARACTER GENERATOR 88
TO D/A X
TO D/A Y

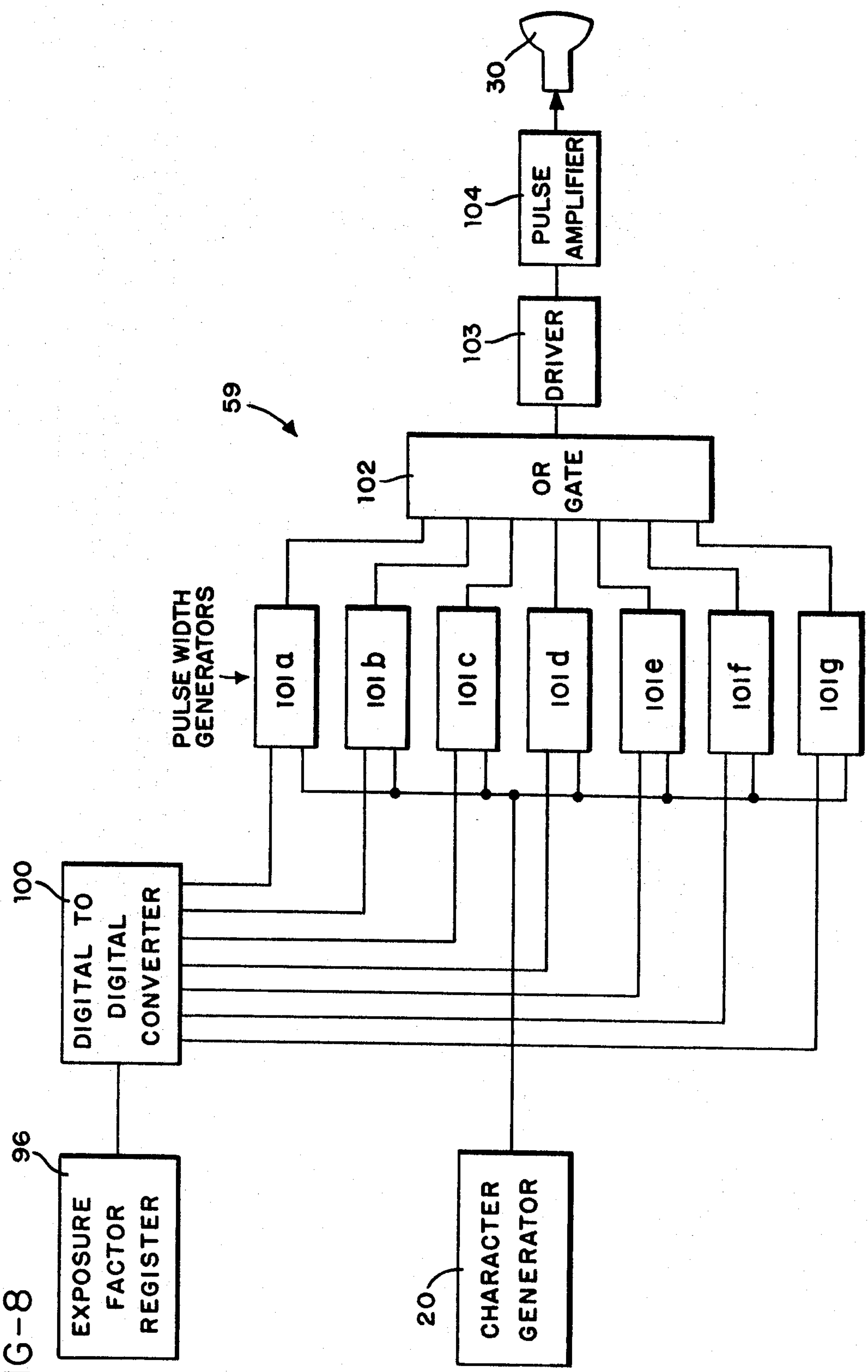

30
PULSE AMPLIFIER
104
DRIVER
103
59
OR GATE
102
PULSE WIDTH GENERATORS
101a
101b
101c
101d
101e
101f
101g
DIGITAL TO DIGITAL CONVERTER
100
EXPOSURE FACTOR REGISTER
96
CHARACTER GENERATOR
20

FIG-8

FIG-9A

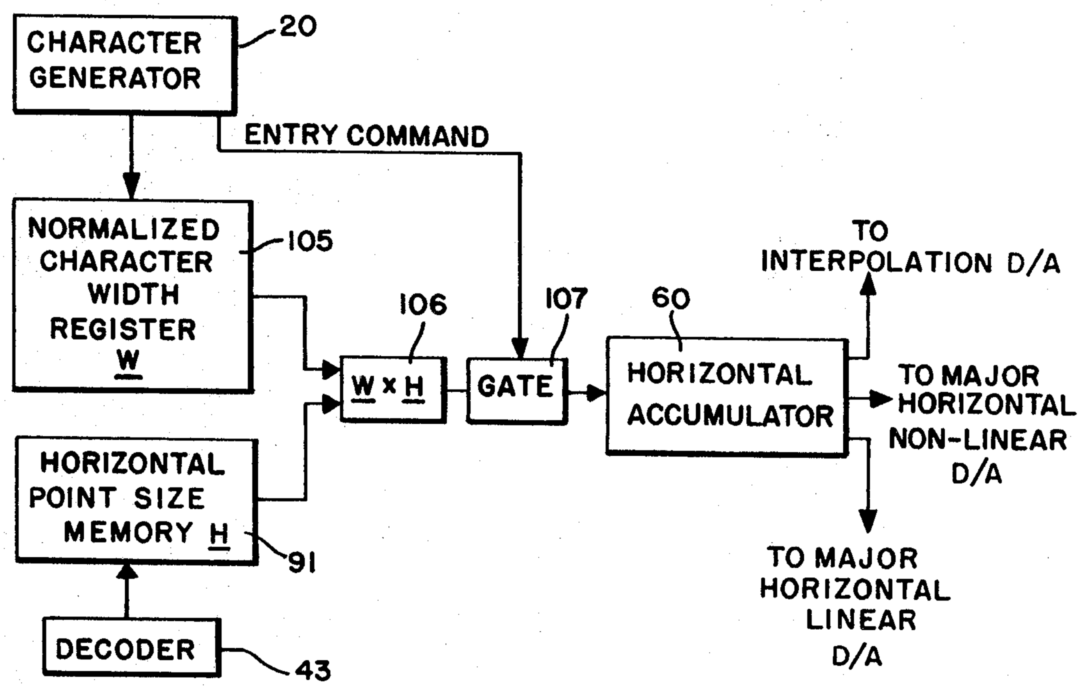
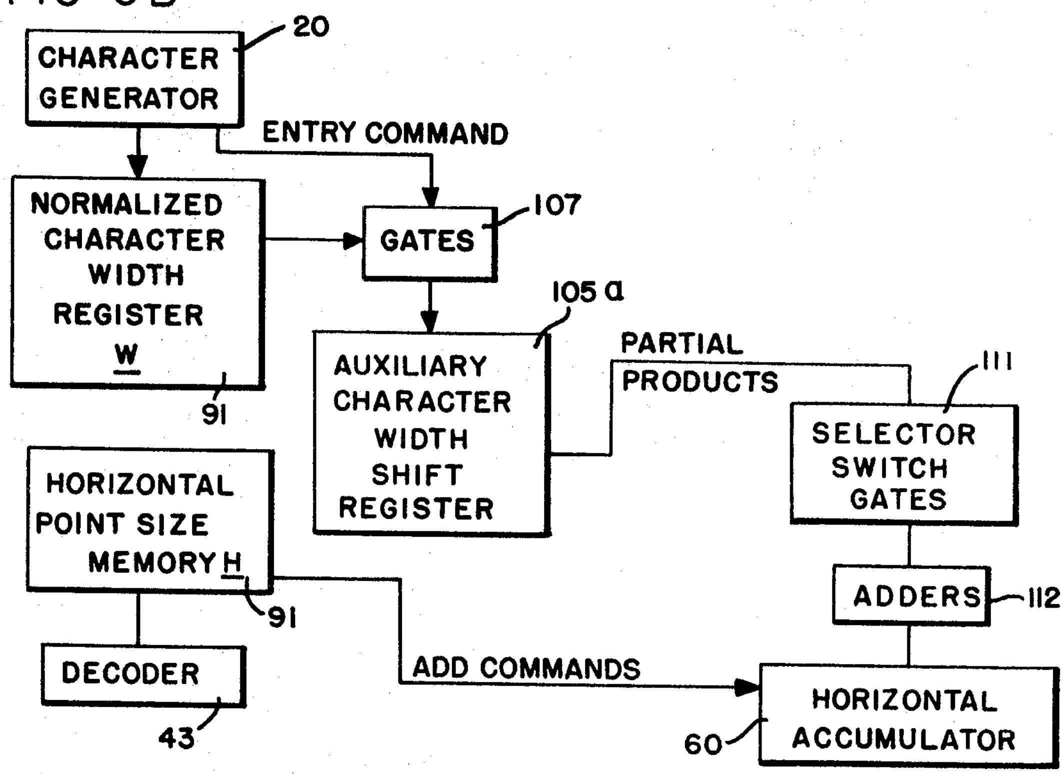

CHARACTER GENERATOR
20
ENTRY COMMAND
NORMALIZED CHARACTER WIDTH REGISTER W
105
106
107
60
W x H
GATE
HORIZONTAL ACCUMULATOR
TO INTERPOLATION D/A
TO MAJOR HORIZONTAL NON-LINEAR D/A
TO MAJOR HORIZONTAL LINEAR D/A
HORIZONTAL POINT SIZE MEMORY H
91
DECODER
43

FIG-9B


CHARACTER GENERATOR
20
ENTRY COMMAND
NORMALIZED CHARACTER WIDTH REGISTER W
91
GATES
107
105 a
AUXILIARY CHARACTER WIDTH SHIFT REGISTER
PARTIAL PRODUCTS
111
SELECTOR SWITCH GATES
ADDERS
112
HORIZONTAL POINT SIZE MEMORY H
91
DECODER
43
ADD COMMANDS
HORIZONTAL ACCUMULATOR
60

POINT SIZE, COMPUTATION AND EXPOSURE CONTROL DEVICE FOR A CHARACTER DISPLAY APPARATUS

RELATED APPLICATIONS

Reference is hereby made to copending U.S. applications Ser. No. 591,734, filed Nov. 3, 1966, entitled PHOTOTYPESETTING SYSTEM; Ser. No. 710,349 filed on even date herewith, entitled PHOTOTYPESETTING METHOD AND APPARATUS; and Serial No. 710,350, filed on even date herewith, entitled PHOTOTYPESETTING APPARATUS.

BACKGROUND OF THE INVENTION

Characters may be formed on an energy responsive surface, such as a cathode-ray tube, by moving a beam of energy from spot to spot and energizing that beam only at those spots which form part of the character to be displayed. Characters of the smallest point size font within the memory are formed from a fewer number of spots than the characters in the largest point size font, however, the spacing between the spots forming characters in these two fonts are usually spaced the same distance apart.

As a practical matter, the character memory is provided with five fonts, each of a different point size. Since only a limited number of fonts of characters are available from the character memory, some provisions must be made to interpolate between the stored point sizes to give a phototypesetting apparatus its full utility. Also, it may be desirable to use the characters from a smallest point size font to provide proof copies of the printing since the character generation speed is increased due to the reduced number of spots forming the character and since the quality of the character displayed is of secondary importance. For subsequent printouts from the phototypesetting apparatus which are to be used in the production runs, the font having the point size closest to the one desired will most often be used, and in those circumstances where extremely high resolution is required, the font of characters having a greater point size may be used. In each case, the characters may be displayed at the same size regardless of the point size stored in the memory of the font selected.

The density of a character formed in the manner described must be controlled so that each character formed will have substantially the same energy released per unit area regardless of the point size of the font selected or of the point size required to be displayed. This permits characters of typesetting quality to be displayed with consistent density at a specified point size regardless of whether the font selected is a point size smaller than or larger than the displayed character. Differing horizontal and vertical point sizes may be employed in the same displayed character using the same font, by specifying differing horizontal and vertical sizes on the control record. This increases the variety of the characters which may be displayed from a font.

BRIEF SUMMARY OF THE INVENTION

This invention therefore relates to a point size computation and exposure control device for phototypesetting apparatus utilizing a cathode-ray tube to form lines of characters on the face thereof. A point size computation circuit compares the point size of the font from which the character is selected with the point size of the character to be displayed and supplies the appropriate reference voltage to a character generator. An exposure factor control circuit determines the duration of the energized beam of energy which forms each spot making up a character so that each character is displayed with uniform density regardless of its point size.

It is an object of this invention to provide an apparatus to form characters on an energy responsive surface by directing a beam of energy to a plurality of spots with each character formed having its size and density determined solely by instructions from a control record independent of the size of the character recorded in a character memory. This is accomplished in the present invention by providing a code in the character memory. This is accomplished in the present invention by providing a code in the character memory which represents the point size of the character stored in the memory. In the preferred embodiment, this code is actually proportional to the reciprocal of the character point size command obtained from the control record. The products of these multiplications are stored in the horizontal scale register and the vertical scale register, respectively, and represent ratios of control record sizes to character memory sizes. These two scale registers control the voltage output from the horizontal scale digital to analogue circuit or D/A and a vertical scale D/A each of which supplies a reference voltage to the character generator and therefore ultimately control the spacing between the spots which form the character. Thus, for a particular point size of character to be displayed, the spots forming the character will have different spacings depending on whether the character was selected from a font having the same point size, a smaller point size, or a larger point size. The smaller character memory-recorded character will thus be displayed with the spots forming the character separated a greater distance than a character formed from a font having the same point size.

It is another object of this invention to provide an apparatus for forming characters on an energy responsive surface wherein each character is formed with the same density regardless of the point size of the selected character stored in the character memory or the point size of the character to be displayed. In the preferred embodiment of the invention, this is accomplished by multiplying the horizontal point size and the vertical point size of the character as obtained from the control record and then multiplying that product by the square of the reciprocal of the point size of the character stored in the memory to obtain an exposure factor value. This value is recorded in a register which controls the duration the beam of energy remains on in forming each spot. Thus, as the character size increases, when using characters from a font or memory having one point size, the spots forming that character will be separated by proportionately greater distances and therefore the number of spots within a unit area will decrease. In order to compensate for the loss of energy within this unit area, the beam is energized for a longer period of time for each spot thus increasing the energy by an amount equal to the loss of energy resulting from the separation of the spots. Conversely, forming two or more characters of a particular point size using two different fonts will require that the character formed from the font having the most spots per unit area be formed by a beam which remains on for a shorter duration than those characters formed from the font containing the smaller point size characters.

It is a further object of this invention to provide an improved phototypesetting apparatus wherein characters are formed automatically on an energy responsive surface and wherein the starting position of the beam of energy which forms these characters is automatically repositioned at the completion of each character generation. In the preferred embodiment of this invention this is accomplished by multiplying the horizontal point size of the character as determined by the control record by a signal representing the width of the selected character from the control memory, and by adding that product, at the completion of character generation, into a register which controls the starting position of the beam of energy, for the next character to be generated.

Another object of this invention is to provide characters of controlled energy density, for example bold or faded characters, for emphasis or deemphasis.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified block diagram of the phototypesetting system employing a cathode-ray tube to display lines of typesetting characters;

FIG. 2 is a detailed block diagram of a phototypesetting system employing means to adjust the size of the character in response to instructions from a control record and to display these characters at any point size with consistent intensity;

FIG. 3 is a view showing a portion of a character memory including the start code, a plurality of functional codes which describe the width and point size of the character as well as the starting position for the beam of energy within a character field, and a part of the character generating data;

FIG. 4 is a block diagram of one form of character generator which may be used with the present invention;

FIG. 5 is a view showing the letter *a* formed from a series of spots, each spot consistently spaced from an adjacent spot;

FIG. 6 consists of three views showing the portion of the character within the dotted lines in FIG. 5 with FIG. 6*a* illustrating the spacing between the spots when the character is formed at the same point size as the character recorded in the character memory, FIG. 6*b* illustrating the spacing between the spots when the character is expanded in the horizontal direction only, and FIG. 6*c* illustrating the spacing between spots when the character is expanded in both the horizontal and vertical directions;

FIGS. 7*a* and 7*b* are block diagrams of another portion of the character size circuit with FIG. 7*a* being a functional diagram showing the mathematical computation obtaining values to be stored in the horizontal and vertical scale registers and the exposure factor register, and with FIG. 7*b* being the actual block diagram of the circuit employed in the preferred embodiment of this invention to perform this computation;

FIG. 8 is a block diagram of the beam control circuit for maintaining a consistent density of the characters formed on the cathode-ray tube regardless of their point size; and

FIGS. 9*a* and 9*b* are block diagrams of a portion of the character size circuit for computing the distance through which the beam of energy must move in order to reposition itself prior to the generation of a subsequent character with FIG. 9*a* being a block diagram representing the mathematical computations which are made to obtain this distance, and with FIG. 9*b* being a block diagram of the actual circuit employed in the preferred embodiment of this invention to perform this computation.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1 which is a simplified block diagram of a cathode-ray tube system for displaying characters, a character memory **10**, which may be a rotating disc onto which the character information is optically recorded, a magnetic disc or drum, a core matrix memory, or other similar type of memory device, supplies the necessary information for generating a font of characters through the character selection circuit **15** to the character generator circuit **20**. Character generating signals representing a selected character are applied along lines **21** and **22** to the horizontal and vertical deflection amplifiers **25** and **26**, respectively, which amplifiers in turn modify the current through deflection coils **27** and **28** surrounding the neck of the cathode-ray tube **30** to deflect the beam to the appropriate locations and form the characters.

The individual characters are positioned relative to the face of the tube in response to a command from a control circuit **35** which supplies character positioning signals along lines **36** and **37** to the horizontal and vertical amplifiers **25** and **26**. A control record **40**, containing such information as character selection and interword spacing, is read by a tape reader **41** and that information supplied as an input to the buffer **42**. While the control record **40** is shown in FIG. 1 as a magnetic tape, other types of control means, such as the output from a computer, may be used to select and position the characters and to supply other functional data.

The buffer **42** accepts the information from the control record at its optimum readout rate and then transfers that information to the decoder circuit at a rate which can be accepted by the remainder of the phototypesetting system. Different control functions will take differing amounts of time, and even the generation of some characters in some cases will take longer than the generation of other characters. One output of the decoder circuit is therefore applied as a character selection signal to the character selection circuit **15** and other outputs are directed to the control circuit **35**.

In the preferred embodiment of this invention, the cathode-ray tube **30** displaying the characters uses electromagnetic deflection means, and both the character positioning signals and the character generating signals are variable voltages applied to the horizontal and vertical deflection amplifiers **25** and **26** which modify the current flowing through the deflection coils **27** and **28**. It has been found that supplying both the character positioning and the character generating signals to the same amplifier is preferred, especially when generating characters of typesetting quality. It is understood, however, that this invention is not limited to cathode-ray tubes having electromagnetic deflection means.

The magnitudes of the character positioning signals from control circuit **35** appearing on lines **36** and **37** are determined by the instructions from the control record **40** and also in response to information received from the character generator circuit **20**. In the present invention, the cathode-ray tube beam is first positioned by the character positioning signals and thereafter moved to various locations within a character field in response to the character generating signals. The character generator circuit **20** also functions to turn the beam of energy on and off so that it may illuminate the appropriate spots on the tube face as the beam is moved within a character field, the duration of the beam being controlled so that all characters formed have the same density.

The character generator circuit **20** supplies the necessary information to the control circuit **35** to modify the character positioning signals once the character generating operation for that character is finished in order to reposition the starting location of the cathode-ray tube beam for the next character. The point size and width of the character will, of course, determine the magnitude of the change in the character positioning signals. Interword spaces supplied by the control record **40** also function to modify the character positioning signals so that a justified line of type may be formed on the cathode-ray tube face. In the preferred embodiment of the invention, only a single line of characters at a time appears on the cathode-ray tube.

FIG. 2 is a more complete block diagram showing the general arrangement of the various circuits and structural components which make up the complete phototypesetting system. As mentioned previously, the control record is read by the reader **41** which converts the information stored thereon into electrical signals which are directed into the buffer storage device **42**.

The control record **40**, among other things, selects the point size of the characters to be displayed, the type or style of font to be displayed, interword spaces, the amount of leading, and other similar phototypesetting functional commands. The control record also selects the characters to be displayed in sequence, and when used in a phototypesetting system, the control record supplies the proper interword spaces to create justified lines of type.

One output from the decoder **43** is applied to the character generator **20** to select the information representing one of the plurality of characters supplied by the character memory **10** for display on the cathode-ray tube **30**. Another output from the decoder **43** is applied to the control circuit **35** where the proper interword spaces for justified lines of type are stored in the space memory circuit **45**, and where the size of the character to be displayed is placed into the character size circuit **46**. Also, leading instructions are stored in the leading control circuit **47**, and horizontal or vertical rule commands may be applied to the rule generator **48**.

The characters formed on the face of the tube may be photographically recorded by projecting the image of the characters through lens **50** onto photographic material **51** which is positioned relative to the face of the tube by a motor 52. The motor is controlled by one output of the leading control circuit 47. The other output of the leading control circuit is connected to the leading digital to analogue converter or D/A 53 which positions the characters vertically with respect to the face of the tube allowing interpolations between the angular positions of the stepping motor 52 and permits simultaneous leading of the film and generation of the characters.

In one embodiment of the invention, characters may be generated by moving a cathode-ray beam from spot to spot and energizing the beam to illuminate the spots and thus form the character. This character generator is more completely described in the above mentioned copending U.S. application Ser. No. 710,349. In another embodiment, the character generating means may be similar to that described in copending U.S. application Ser. No. 591,734 where the beam is moved in a raster pattern and energized only at those spots which form a part of the character.

As mentioned previously, the point size of the character is determined by an instruction from the control record 40, and when a character is selected for display, a signal representing the width and point size of the selected character is supplied by the character generator 20 to the character size circuit 46 on line 55. The character size circuit 46 supplies several outputs, one establishing a status of the horizontal scale register or accumulator 56, another establishing a status of the vertical scale register or accumulator 57, a third output is applied on line 58 to the beam control circuit 59 and determines the duration of time that the beam remains on at each spot to control the intensity of the character display, and a fourth output represents the width of the character display which is applied to modify the status of the horizontal accumulator circuit 60 at the completion of the character generating operation.

By way of illustration, assuming that the cathode-ray tube beam is initially positioned at the extreme left of the writing surface on the cathode-ray tube face, the character generator circuit 20 will supply the necessary signals to the horizontal and vertical deflection amplifiers to form the character, and once character generation has been completed, the control circuit 35 will reposition the beam to a new starting location preparatory to the generation of the next character. Since each character normally has a different width, as for example in FIG. 1 where the letter *a* has a width value W*a* and the letters *i* and *m* have width values W*i* and W*m*, respectively, the spacing of each character is determined by a signal from from the character memory 10 which, when multiplied by the point size to be displayed as stored in the character size circuit 46, results in a digital input which is applied to the horizontal accumulator 60 after completion of character generation. The horizontal accumulator 60 controls other circuits which supply the proper character positioning signals to the horizontal deflection amplifier.

Referring briefly to the generation of a character, the output of the character generator 20 is applied to the beam positioning means including a horizontal character generating digital to analogue circuit or D/A 62 (FIG. 2) and a vertical character generating D/A 63. These circuits convert the digital information supplied by the character generator into analogue voltages which are applied as inputs to the horizontal and vertical deflection amplifiers 25 and 26. The magnitudes of these analogue voltages are determined in part by reference voltages supplied to these components by the horizontal scale D/A 65 and the vertical scale D/A 66, respectively.

The reference voltages supplied by the horizontal scale D/A 65 and the vertical scale D/A 66 are determined in part by the horizontal position of the character to be generated and by the status of the horizontal scale register 56 and the vertical scale register 57, respectively, these registers having previously been set to a digital value representing the character magnification or reduction by the character size circuit 46 under the direction of the control record 40.

The horizontal position of the characters displayed on the tube face is determined by the status of the horizontal accumulator 60 consisting of 18 registers, the outputs of the 14 most significant of which, in the preferred embodiment, are connected to three circuit means for positioning the characters, including an output circuit means or major horizontal linear D/A 67, a compensating means or the major horizontal nonlinear D/A 68, and the interpolation D/A 69. The outputs from all of these D/A's are combined and supplied as a voltage input to the horizontal deflection amplifier 25.

The six registers representing the most significant digits in the horizontal accumulator 60 control both the output circuit means 67 and the compensating means 68, while the eight registers representing the next most significant digits in the accumulator 60 control the interpolation D/A 69.

FIG. 3 represents a portion of a character memory such as that described in copending U.S. application 710,349. A plurality of characters stored in the memory may have associated therewith timing tracks 70 and 71. Each character track 72 includes a unique code identifying the starting position of the character within the track, a group of codes identified as control data, and a plurality of digital codes representing the character generating data.

Nineteen bytes of information, each byte consisting of three bits, are used for the storage of the control data, as shown in FIG. 5, although interspaced at predetermined locations within each byte are fill bits which serve no other purpose than to prevent the occurrence of false start of section and end of section codes. The control data contains the following codes: a single bit parity code which is used by the control circuitry to sense whether the entire group of control data codes is properly and accurately recorded prior to permitting generation of the character; a 9-bit normalized width code indicating the width of the character which has been recorded in the character generating portion of the character track; a 5-bit PREDIPS code which is proportional to the reciprocal of the point size of the recorded character which is referred to by the control circuitry in the spacing of spots which form the character and the duration the beam of energy remains energized at each spot to permit characters having point sizes different from the recorded point size to be formed without significant variations in the density of the characters thus formed; two 8-bit codes representing the horizontal and vertical starting coordinates which identify the position of a section of the character with respect to the remaining sections forming the character; and a 6-bit code indicating the number of sections required to generate a complete character.

While the control data is shown being recorded in the same track as the character generating data, all or some of this control data may be recorded in a separate track or tracks which could be common to more than one character track. This is especially true of the PREDIPS code since most of the characters within a font have the same point size. In fact, the PREDIPS code could be supplied by the control record or by selector switches which would be set when a character memory is installed in the apparatus.

Reference is now made to the electrical block diagram in FIG. 4 showing the character generator used in the above mentioned application 710,349. The output of one of the tracks in the character memory 10 is selected in response to instructions from the control record by the character selection circuit 15, shown at the upper left, and that output is applied to the input shift register 75. A clock system 76 senses the clock tracks 70 and 71 recorded in the character memory and functions to control the sequence of operation of the character generator.

Once character selection has been made, the data is shifted through the input shift register 75 until a "start of section" code is detected. At the same time, an inhibit is placed on the remainder of the system which will remain until character generation is completed. In this embodiment of the invention, the "start of section" code is represented by the digital code 1110, and is shown at the extreme left in track 72 in FIG. 5.

When the first "start of section" code is sensed by the start of section detector 77, all of the registers in the character generating circuit are reset and the control data which follows is entered into appropriate registers under the direction of the register entry counter **78**. The register entry counter directs the first bit through a gate **80** to the parity error detector **79** to be recorded therein. The next nine bits are routed by means of the gate **80** to the normalized width register **81**. This date represents the horizontal width of the character recorded in this track of the character memory, and when multiplied by the actual point size of the character as determined by the control record, will alter the status of the horizontal accumulator **60** and assist in repositioning the cathode-ray tube beam after the entire character has been formed.

The next 5-bits of data are routed by means of gate **80** into the PREDIPS register **87** where this information will be used to control the size of the character generated and the duration the beam generating the character remains on in each location.

The register entry counter **79** thereafter directs the gate **80** to route the next 8-bits of control data information into a first reversible counter means or the X location up-down counter **83**, and the following 8-bits of control data information into a second reversible counter means or the Y location up-down counter **84**. The status of the X and Y location up-down counters controls the output of the horizontal character generating deflection D/A **62** and the vertical character generating deflection D/A **63**, respectively, and thus the location of the cathode-ray tube beam with respect to the starting position of the beam as determined by the status of the horizontal accumulator **60**. The location information stored in the X location up-down counter and the Y location up-down counter will normally be different for each of the sections which make up a complete character.

The last 6-bits of data making up the control data is directed by the register entry counter **79** into the section counter **85**. This data indicates the number of sections required to form a complete character, and when that number of sections has been generated, an end of character signal is generated which permits the decoder circuit to resume operation.

After all of the control data, which consists of a predetermined number of bytes, has been stored in the appropriate registers, the remainder of the digital information, which comprises the character information, is decoded by the step direction decoder **86** and gated into the X and Y location up-down counters to modify the status of these counters by as much as one incremental unit at a time, either positive or negative.

By moving the beam only one unit at a time, either as an increment or a decrement in the X and Y directions, or both, a complete character may be traced on the cathode-ray tube. In the preferred embodiment, the cathode-ray tube beam is energized in response to the clock system only after the beam has been positioned, and the circuit components have had time to settle. Using this technique of character generation permits characters of typesetting quality to be formed.

After a portion of the character has been created, an end of section code, represented by the digital code **1111**, is detected by the end of section detector **87** and the character generation ceases momentarily. The end of section detector **87** applies a pulse to the section counter **85** to reduce its value by one unit, indicating that one section has been completely generated. The system therefore recognizes that a specified number of sections remain to be generated and therefore character generation will continue until all the sections making up that character have been generated.

Since the control data consists of a predetermined number of digital bytes, the register entry counter **78** forms a means for counting these bytes and directing the control data to the appropriate storage registers, and after the control data is recorded, to gate the character information appearing on the input lines to the character sensing means or step direction decoder **86** and thus to the X and Y location up-down counters. Those skilled in the art will recognize that other methods of presenting the control data may be used without departing from the scope of this invention.

Reference is now made to FIG. **5** which shows the letter *a* formed from a series of spaced apart spots. The spots forming the character are consistently spaced apart, that is, the distance in the X direction between spots remains constant throughout the generation of the character, and the distance in the Y direction also remains constant, although the X and Y distances may or may not be different. Also, each of the spots within a single character is of the same size, and the spots may either occupy an area so that one spot overlaps an adjacent spot or the spacing may be adjusted so that the area covered by one spot is entirely separate from the area covered by any other spot.

Characters of differing point sizes will contain differing numbers of spots to form the characters. It is contemplated that for the range of typesetting characters to be displayed, five different point sizes may be recorded in the character memory and these expanded or contracted to form characters of intermediate point sizes. In the preferred embodiment of this invention, the character point size is represented in the character font or memory by the PREDIPS code.

FIG. **6***a* represents the number of spots falling within a unit area which form that portion of the character outlined in dotted lines in FIG. **5** when the character is formed at the same point size as it is recorded in the selected font. In this figure, the X_1 and Y_1 distances are equal. FIG. **6***b* shows the same portion of the character with only the horizontal (X_2) point size of the character expanded. In this figure, the number of spots forming the character within the unit area is reduced. In FIG. **6***c*, both the horizontal (X_2) and the vertical (Y_2) point size of the character are expanded to show even greater separation of the spots forming the character within a unit area.

The exposure time of the spots must be altered to compensate for the differences in brightness of the character images for various point sizes when formed from a single character memory. Thus, when the desired character size is larger than the stored character size, the character is expanded, as shown in FIGS. **6***b* and *c*. When the character is expanded, the larger image is not as intense because the amount of available light is spread over a larger area. Therefore, the duration of the exposure of each spot must be increased to compensate for the dimmer image.

Unless compensated in some manner, an expanded character will contain less energy per unit area than the character stored by a ratio An/Ap, where An is the normalized character area of the stored character and where Ap is the actual printed character area. The exposure factor (E.F.), which is a value used to determine the duration of the exposure of the character image to the photographic film or paper, is defined as the reciprocal of the above area ratio. Thus, $E.F.=Ap/An$.

The area of the printed character, Ap, is proportional to the product of the horizontal point size H times the vertical point size V, thus, $Ap=H\times V$. In the preferred embodiment of this invention, the characters in a single font are stored with a predetermined height and width, thus the normalized character area An may be expressed as a square of a single number, or N^2, where N is the normalized point size. However, when printing a character on the face of the cathode-ray tube, the machine operator has the option of expanding either the width or the height of the character independently. The width of the character may be expanded, for example, to provide justified lines of type in conjunction with interword spacing.

However, neither the character area nor the normalized point size is stored in the character memory since more electronic equipment is required to divide one number into another than to multiply them. Since $E.F.=Ap/An$, or $E.F.=(H\times V)/N^2$, a division is indicated. Therefore, a number proportional to the reciprocal of the character point size is stored in the character memory. In the embodiment of this invention described herein, the number R stored in the memory is equal to 140 divided by the normalized point size N. This number R is identified as the PREDIPS number, an acronym meaning Proportional REciprocal DIsc Point Size. The number **140** was arbitrarily chosen, based on the fact that fonts of characters having point sizes of 5, 7, 10, 14 and 20 are provided in the character memory. This renders the value R a small integer thereby minimizing the number of date stages required to store this number. Thus, the number R is equal to 28, 20, 14, 10, and 7 when representing point size values of 5, 7, 10, 14, and 20, respectively. Therefore, $E.F. = (H \times V) R^2 (140)^2$

The character size circuit **46** performs the mathematical computations necessary in order to present a character of the size and density required by the control record **40** independently of the size of the character stored in the character memory **10**. For example, if the control record **40** designates that an 8-point character is to be displayed, and the character is selected from a 7-point font, the stored character must be magnified by the ratio 8/7 before exposure on the energy responsive circuits. The character size circuits includes control means to compute this ratio and to supply the necessary signals to the remainder of the phototypesetting system to cause the spots which actually form the character to be properly spaced apart to form the required character.

The character size circuit **46** also includes exposure control means to compute the area of the character and to adjust the duration of exposure of the beam to the energy responsive circuit with all characters being formed with the same energy per unit area so that they appear to have the same density regardless of expansion or contraction of the stored character.

Furthermore, the character size circuit **46** includes means to compute the width of the displayed character and to provide the signal to reposition the starting point of the beam of energy automatically in preparation for the generation of the subsequent character.

Reference is now made to the block diagram of FIGS. 7*a* and 7*b* showing a portion of the character size circuit **46**, with FIG. 7*a* representing a functional block diagram to show the mathematical computations which are made and with FIG. 7*b* representing a block diagram of the actual circuitry being used in the preferred embodiment.

In operation, the character memory **10** supplies the PREDIPS register **82** in the character generator circuit **20** with a code representing the number R which is proportional to the reciprocal of the point size of the character stored in the memory. The PREDIPS register **82** is connected to a PREDIPS storage register **90**, shown at the lower right in FIG. 7*a* which is a 1-state shift register containing the number to be used as the multiplicand in the mathematical computations which follow.

Point size information from the control record is supplied through the decoder to the character size circuit **46** and stored in the horizontal point size memory **91** and in the vertical point size memory **92**, both shown at the top of FIG. 7*a*.

During the interval of time herein designated as step **1**, several multiplications are carried out simultaneously. For example, in the circuit **93**, the PREDIPS number R is multiplied by the horizontal point size H and the product (H×R) is stored in the horizontal scale register or accumulator **56**, in the circuit **94**, the PREDIPS number R is multiplied by the vertical point size Hand that produce (V×R) is stored in the vertical scale register or accumulator **57**, and in the circuit **95**, the horizontal point size H is multiplied by the vertical point size V and the product (H×V) temporarily accumulated in the exposure factor register or accumulator **96**. (One further computation must be performed before the exposure factor value is completed. This will be described in connection with step **2**).

The horizontal scale register **56** and the vertical scale register **57** are connected to the horizontal scale D/A **65** and the vertical scale D/A **66** (see FIG. 2) which modify the reference voltage to the character generator digital to analogue circuits **62** and **63**. Therefore, the spacing between adjacent spots which form a character is primarily dependent upon the value of the product stored in these two registers. The character generator in the preferred embodiment of this invention merely provides a digital signal to the character generating D/A circuits **62** and **63** to move the beam in increments from one location to another location without regard to the absolute value of the spacing between spots, the spacing being determined by the magnitude of the reference voltage applied as inputs to these digital to analogue converters. Thus, the number of spots which form any particular character will vary depending upon the point size of the character stored in the memory, and for characters generated at the point size of the selected font, the spots forming those characters will be placed the same distance apart. In other words, the spots forming a 5-point size character from a 5-point font will be the same distance apart as the spots forming a 20-point character generated from a 20-point font.

During step **2**, the product (H×V) is multiplied in the circuit **97** by the square of the PREDIPS number, or R^2 from the squaring circuit **98**. This product is also stored in the exposure factor register **96**. As will be explained in connection with FIG. **9**, a decoder circuit connected to the output of the exposure factor register **96** decodes the value stored therein, and one of seven different exposure times is selected in the beam control circuit **59**. Of course, this computation occurs prior to the generation of the character since the character is formed by moving the beam incrementally from spot to spot and exposing the beam for the time determined by the beam control circuit **59**.

All computations in the character size circuit **46** are multiplications, for the reason stated above, and since the numbers used are in binary form, a binary multiplication technique is used.

The following illustrates the binary multiplication technique of multiplying the decimal number 109×10:

Multiplicand		1101101	(109)
Multiplier		×1010	(10)
Partial products	(a)	0000000	
	(b)	1101101	
	(c)	0000000	
	(d)	1101101	
Product		10001000010	(1090)

In the binary multiplication system, the multiplicand 109 is multiplied by the multiplier 10 by computing the partial product of each digit of the multiplier separately and then summing the individual partial products. The multiplication in the binary system is somewhat simpler than multiplication in the decimal system since the digits in the multiplier are only ones and zeros. Therefore, the partial product is either zero or a number which is the same as the multiplicand, except the number is shifted to the left by the appropriate number of binary places. Hence, the first partial product (*a*) in in the example above is zero since the 2^0 digit of the multiplier is zero. The second partial product (*b*) is the same number as the multiplicand because the digit in the 2^1 position of the multiplier is a one, except it is shifted to the left one place. The third partial product (*c*) is zero, and the fourth partial product (*d*) is again the same number as the multiplicand except shifted to the left three places.

To multiply a binary number by machine requires only that the multiplier be examined one digit at a time, the least significant digit being examined first in this example, and either adding or not adding the multiplicand into an accumulator depending on whether the multiplier being examined is a one or a zero. This examination is performed by sensing the contents of the least significant digit stage of the register storing the multiplier, and then shifting the multiplier within the register to the right one digit at a time. The multiplicand, at the same time, is shifted to the left one digit at a time, and if the multiplier digit under examination is a one, the weighted multiplicand is added to an accumulator. In this embodiment of the invention, the accumulators also serve as output registers into which the partial products are added as they are computed.

Reference is now made to FIG 7*b* which is a block diagram of the actual circuitry employed in the preferred embodiment to calculate the numbers to be stored in the horizontal scale register **56**, the vertical scale register **57**, and the exposure factor register **96**. The data stored in the horizontal point size memory **91** and in the vertical point size memory **92** is placed into these memory circuits from the control record **40** through the decoder circuit **43** and retained throughout the generation of several characters, or until the character point size changes. Both of these memory circuits are 6-stage ring shift registers having a recirculating path so that the data stored in these memory circuits may be reused as the multiplier in the computations H×R and V×R which occur during the generation of each character of the same point size.

The PREDIPS register **90** is a 10-stage register which stores the multiplicand in these computations. Therefore, to obtain the product of the multiplication H×R, the first or least significant digit in the horizontal point size memory **91** is examined, and if this digit is a binary 1, the data in the PREDIPS register **90** is entered into the horizontal scale register **56** through the full adder circuit **93***a*. Thereafter, the data in the horizontal point size memory **91** is shifted to the right one place, and the data in the PREDIPS register **90** is shifted to the left one place. The second digit in the horizontal point size memory is then inspected, and if it is also a binary 1, then the shifted data from the PREDIPS register **90** is again entered into the horizontal scale register through the adder circuit **93***a*. This process is repeated until all the partial products have been computed. The multiplication V×R occurs simultaneously with the multiplication H×R as described above.

Therefore, at the completion of the multiplication, the numbers stored in the horizontal and vertical point size memories have been recirculated to their original positions to await the computation sequence for the next character. Accordingly, the horizontal and vertical scale registers **56** and **57** contain the products of these multiplications and modify the reference voltage to the character generator circuit through the horizontal and vertical scale digital to analogue circuits **65** and **66**. This computation occurs prior to the actual generation of the character on the face of the cathode-ray tube.

The computation of H×V is performed using the number H in the horizontal point size memory **91** as the multiplier and using an auxiliary vertical point size memory **92***a* to store the multiplicand V. An auxiliary member is used since the multiplicand is shifted to the left, and added into the exposure factor register **96** through the adder circuit **95***a* when the digit being inspected in the multiplier is a binary 1. The same number V is being used as a multiplier in the computation V×R, as indicated above. The number V is entered into the auxiliary point size memory from the vertical point size memory **92** for each separate computation, therefore the auxiliary point size memory **92***a* need not be a recirculating memory.

The computation of R^2 is performed in the decoder circuit **98***a*. This computation merely causes the number stored in the exposure factor register **96** to be shifted to the left one or more places. Each shift to the left corresponds to multiplication by a power of 2. In the preferred embodiment, only 5 different values of R are provided since fonts having only 5 different point sizes are available from the character memory **10**. With reference to the table below, the logarithm to the base 2 value of $R^2/50$ is either 0, 1, 2, 3, or 4. Therefore, merely shifting the contents (H×V) in the exposure factor register to the left the appropriate number of steps will accomplish the multiplication $(H\times V)\times R^2$.

The value of R^2 is approximated, as shown in parenthesis in the table below, to facilitate the mathematical computation. Since the approximated value of R^2 is within 2 percent of the actual value, the results of the computation are well within the tolerances necessary for printing characters of typesetting quality.

Stored master point size N	$R=\frac{140}{N}$	R^2	$\frac{R^2}{50}$	Logarithm$_2$ $\frac{R^2}{50}$
5	28	784(800)	16	4
7	20	400(400)	8	3
10	14	196(200)	4	2
14	10	100(100)	2	1
20	7	49(50)	1	0

Referring now to the block diagram of the beam control circuit **59** in FIG. **8**, the character generator **20** supplies signals to initiate the energization of the beam of the cathode-ray tube for each spot forming the character. Since the duration that the beam remains energized is determined by the number of spots within a unit area, all characters are formed at the same energy per unit area thus giving the characters a uniform density.

The number in the exposure factor register **96** is decoded by the circuit **100** which selects one of 7-pulse width generators **101***a*—**101***g*, each of which is a simple monostable flip-flop or single shot multivibrator triggered by the output of the character generator **20**. All seven of these generators **101** are connected to a seven input OR gate **102** and its output signal applied through the driver circuit **103** and pulse amplifier circuit **104** to the control elements of cathode-ray tube **30**.

At this point, there is a waiting time during which the character size circuit **46** is dormant while the character generating routine forms the character on the face of the cathode-ray tube **30**. After the character has been completely formed, the signal from the character generator **20** is supplied to the character size circuit **46** to initiate step **3**.

The contents of the horizontal scale register **56**, the vertical scale register **57**, and the exposure factor register **96** are erased in step 3 by setting all of these registers to zero. The normalized character width W, obtained from the character memory **20** and stored in the normalized character width register **105** (FIG. **9***a*) is multiplied in the circuit **106** by the horizontal point size H contained in the horizontal point size memory **91**, and this product (H×W) is entered into the horizontal accumulator **60** through gate **107** upon an entry command from the character generator **20** at the completion of the character generating operation.

FIG. **9***b* is a block diagram of the actual circuit used to perform this multiplication operation. The number W in the normalized character width register **81** in the character generator is the multiplicand while the number in the horizontal point size memory **91** is the multiplier. The number in the normalized character **81** circuit is entered into an auxiliary shift register **105***a* at the beginning of the character generating operation, and at the conclusion of that function, this auxiliary character width register adds the partial products through the selector gate circuit **111** and the adder circuit **112** into the horizontal accumulator **60**, in the manner previously described. Thus, the status of the horizontal accumulator **60** is changed by an amount equal to the space actually occupied by the character just generated to establish the next starting location of the beam.

A character generating system has been described wherein characters from one of several fonts, each font having differing point sizes, may be selected and displayed at any point size within the range of the apparatus. The apparatus computes the spacing required between the spots of energy forming each character and causes an appropriate voltage to be supplied to a character generator. The density of each character is maintained uniform by controlling the duration each spot of energy remains energized.

While the forms of apparatus herein described constitutes preferred embodiments of the invention, it is to be understood that the invention is not limited to those precise forms of apparatus, and that changes may be made therein without departing from the scope of the invention which is defined in the appended claims.

We claim

1. Apparatus for displaying characters on an energy responsive surface in response to commands from a control record containing character selection and point size instructions including:

character memory means containing at least a font of characters supplying first signals representing the location within a character field of each of a plurality of spots which define each character on the energy responsive surface;

means supplying second signals representing the point size of the characters stored within said character memory;

means responsive to the control record for selecting one of the characters in said character memory means to be displayed;

beam positioning means responsive to said first signals representing the selected character for positioning the beam of energy to a plurality of spots in a sequence on the energy responsive surface, as determined by said character memory means; and

control means responsive to the point size instructions from the control record and to said second signals for supplying a reference signal of such a magnitude to said beam positioning means that the spacing between adjacent spots forming the character and therefore the actual size of the character displayed on the energy responsive surface will be in response to instructions from the control record and independent of the point size of the character stored in said character memory means.

2. The apparatus as set forth in claim 1 wherein said second signals are recorded in said character memory means.

3. The apparatus as set forth in claim 1 wherein said control means comprises:

first storage means for recording the point size instructions from the control record;

second storage means for recording said second signals representing the point size of the selected character stored in said character memory means;

means for multiplying the point size instructions in said first storage means by the character point size stored in said second storage means;

third storage means connected to said multiplying means for recording the product of said multiplication; and

means for supplying a reference voltage to said beam positioning means having a magnitude proportional to the status of said third storage means to control the spacing between adjacent spots forming the character on said energy responsive surface.

4. The apparatus of claim 3 wherein said first storage means includes a horizontal point size memory and a vertical point size memory, both said point size memories being responsive to and recording the point size instructions from the control record; and

wherein said third storage means includes a horizontal scale register and a vertical scale register, said registers recording the product of the multiplication of the horizontal point size and the vertical point size instructions from the control record by the point size of the selected character as recorded in said second storage means.

5. A phototypesetting apparatus for displaying characters on an energy responsive surface in response to commands from a control record containing character selection and point size instructions, said apparatus including

a character memory means containing at least a font of characters for supplying first signals representing the location of each of a plurality of spots within a character field which define each character on the energy responsive surface;

means responsive to the control record for selecting one of the characters in said character memory means to be displayed;

means supplying second signals representing the point size of the characters stored in each font;

means for comparing the point size instructions from the control record with said second signals; and

exposure control means responsive to said comparing means for controlling the duration each of said plurality of spots remains energized on said energy responsive surface so that each character is formed with the same energy per unit area independently of the spacing between the spots forming that character.

6. The apparatus as defined in claim 5 wherein said second signals are proportional to the reciprocal of the area of the selected character, wherein said point size instructions from the control record include both the horizontal point size and the vertical point size of the character to be displayed, and wherein said comparing means includes;

first means multiplying the horizontal point size times the vertical point size to obtain a first product representing the area of the character to be displayed;

means for squaring the number representing the reciprocal of the area of the selected character; and

second means for multiplying said first product times said squared reciprocal to obtain a second product representing the ratio between the point size of the character to be displayed and its point size as recorded in said character memory means.

7. The apparatus as defined in claim 6 wherein said means squaring the number representing the area of said selected character includes a decoder sensing said second signals for producing an output which is equivalent to the square of said number.

8. The apparatus as defined in claim 5 wherein said exposure control means includes

a plurality of single shot multivibrators, each having a different pulse width to control the duration each of said plurality of spots remains energized, said multivibrators being triggered by clock signals generated in response to data from said character memory means;

means responsive to the product of said second multiplying means for selecting one of said plurality of single shot multivibrators; and

means connecting the output of the selected one of said single shot multivibrators to energize a beam of energy to form each of said spot for a time duration such that all characters are formed having the same energy per unit area.

9. Apparatus for displaying characters on an energy responsive surface in response to commands from a control record containing character selection, horizontal point size, and vertical point size instructions for the character to be displayed, said apparatus including

a character memory means containing at least a font of characters for supplying signals representing the location of each of a plurality of spots within a character field which define each character on the energy responsive surface;

means supplying signals representing the width of each character within said character memory means;

means responsive to the control record for selecting one of the characters in said character memory means to be displayed;

means for positioning each character field on the energy responsive surface;

means for multiplying the horizontal point size of the character to be displayed times said signals representing the width of the character selected for display; and

means entering the product from said multiplying means into said means positioning each character field on the energy responsive surface at the completion of character generation so that a character subsequently displayed is properly spaced from the character previously displayed.

10. Phototypesetting apparatus for displaying characters on an energy responsive circuit in response to commands from a control record containing character selection and point size instructions, said apparatus including:

character memory means containing at least a font of characters supplying first signals representing the location within a character field of each of a plurality of spots which define each character on the energy responsive surface;

means supplying second signals representing the point size of the character stored within said character memory,

means responsive to the control record for selecting one of the characters in said character memory means to be displayed;

beam positioning means responsive to said first signal representing the selected character for positioning the beam of energy to a plurality of spots in a sequence on the energy responsive surface as determined by said character memory means;

control means responsive to the point size instruction from the control record and to said second signals for supplying a reference voltage of such a magnitude to said beam positioning means that the spacing between adjacent spots forming the selected character and therefore the actual size of the character displayed on the energy responsive surface will be in response to instructions from the control record and independent of the point size of the character stored in said character memory means; and

exposure control means responsive to the point size instructions from the control record and to said second signals for controlling the duration each of said plurality of spots remains energized on the energy responsive surface so that each character is formed with the same energy per unit area independently of the spacing between the spots forming that character.