United States Patent

Kolb

[15] **3,702,949**

[45] **Nov. 14, 1972**

[54] COMPENSATION SYSTEMS FOR CATHODE RAY TUBE DISPLAY SYSTEMS

[72] Inventor: **Edwin R. Kolb,** University Heights, Ohio

[73] Assignee: **Harris-Intertype Corporation,** Cleveland, Ohio

[22] Filed: **Jan. 7, 1970**

[21] Appl. No.: **1,124**

[52] **U.S. Cl.** .....**315/22,** 315/18, 315/27 GB

[51] **Int. Cl.** **H01j 29/70**

[58] **Field of Search**.....315/27 TD, 27 GD, 22, 18

[56] **References Cited**

UNITED STATES PATENTS

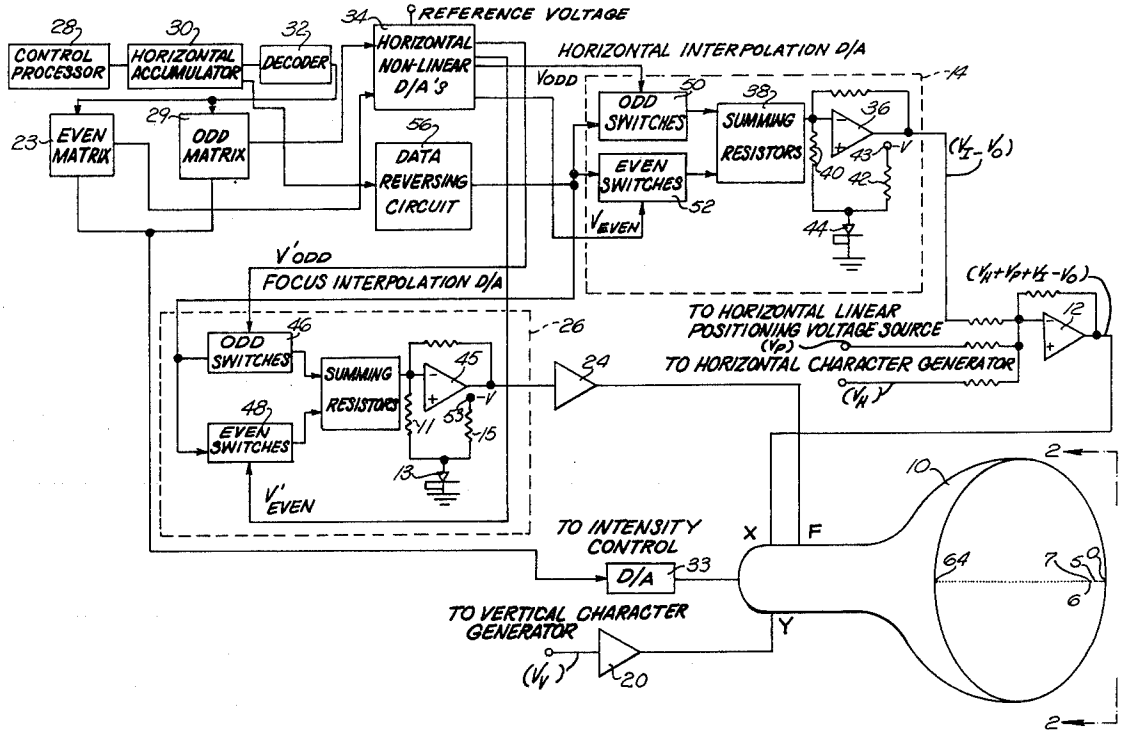
3,435,278	3/1969	Carlock et al.	315/27 GD
3,309,560	3/1967	Popodi	315/27 GD
3,544,835	12/1970	Nielsen	315/22

Primary Examiner—Carl D. Quarforth
Assistant Examiner—J. M. Potenza
Attorney—Young and Tarolli

[57] **ABSTRACT**

A phototypesetting system employs a cathode ray tube to display characters sequentially on a cathode ray tube so that they may be photographed. A horizontal electron beam positioning voltage, a horizontal character generating voltage and a horizontal position correction voltage, which compensates for horizontal positioning non-linearities of the electron beam, are coupled through a summing amplifier to the horizontal deflection plates of the cathode ray tube. A focus voltage is supplied through another amplifier to the focus electrode of the cathode ray tube to compensate for undesired focus variations of the cathode ray tube which occur as the position of the electron beam changes. An intensity control voltage which is coupled to the intensity control element of the cathode ray tube is also compensated for undesired intensity variations in accordance with a selected zone position of the visual spot that is formed by energization of the electron beam of the tube at a desired location on the screen of the cathode ray tube.

21 Claims, 7 Drawing Figures



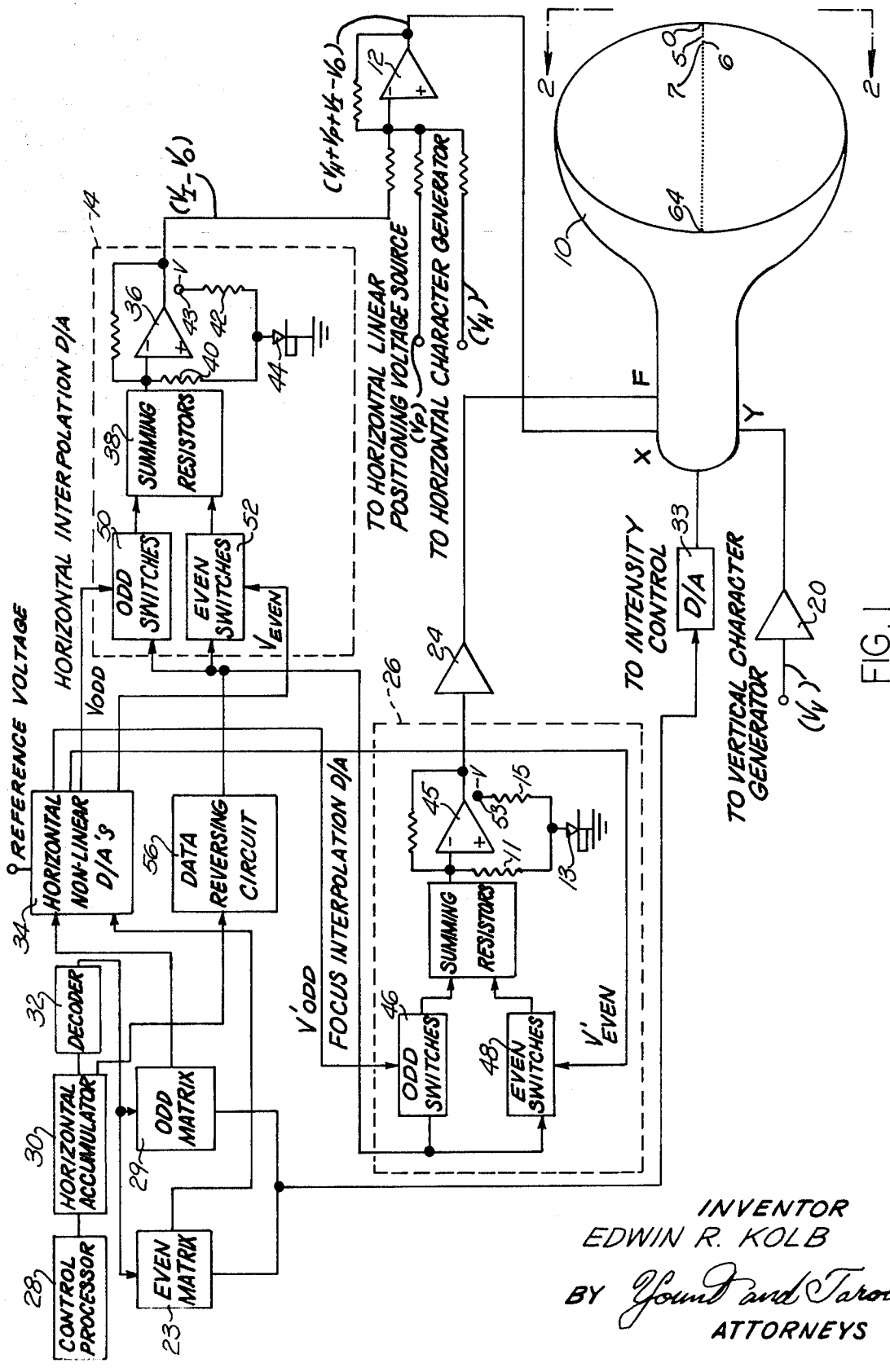

REFERENCE VOLTAGE
HORIZONTAL INTERPOLATION D/A
HORIZONTAL NON-LINEAR D/A's
DECODER
HORIZONTAL ACCUMULATOR
CONTROL PROCESSOR
ODD MATRIX
EVEN MATRIX
DATA REVERSING CIRCUIT
ODD SWITCHES
EVEN SWITCHES
SUMMING RESISTORS
TO HORIZONTAL LINEAR POSITIONING VOLTAGE SOURCE
TO HORIZONTAL CHARACTER GENERATOR
FOCUS INTERPOLATION D/A
TO INTENSITY CONTROL
D/A
TO VERTICAL CHARACTER GENERATOR
INVENTOR
EDWIN R. KOLB
BY Yount and Tarolli
ATTORNEYS

FIG. 1

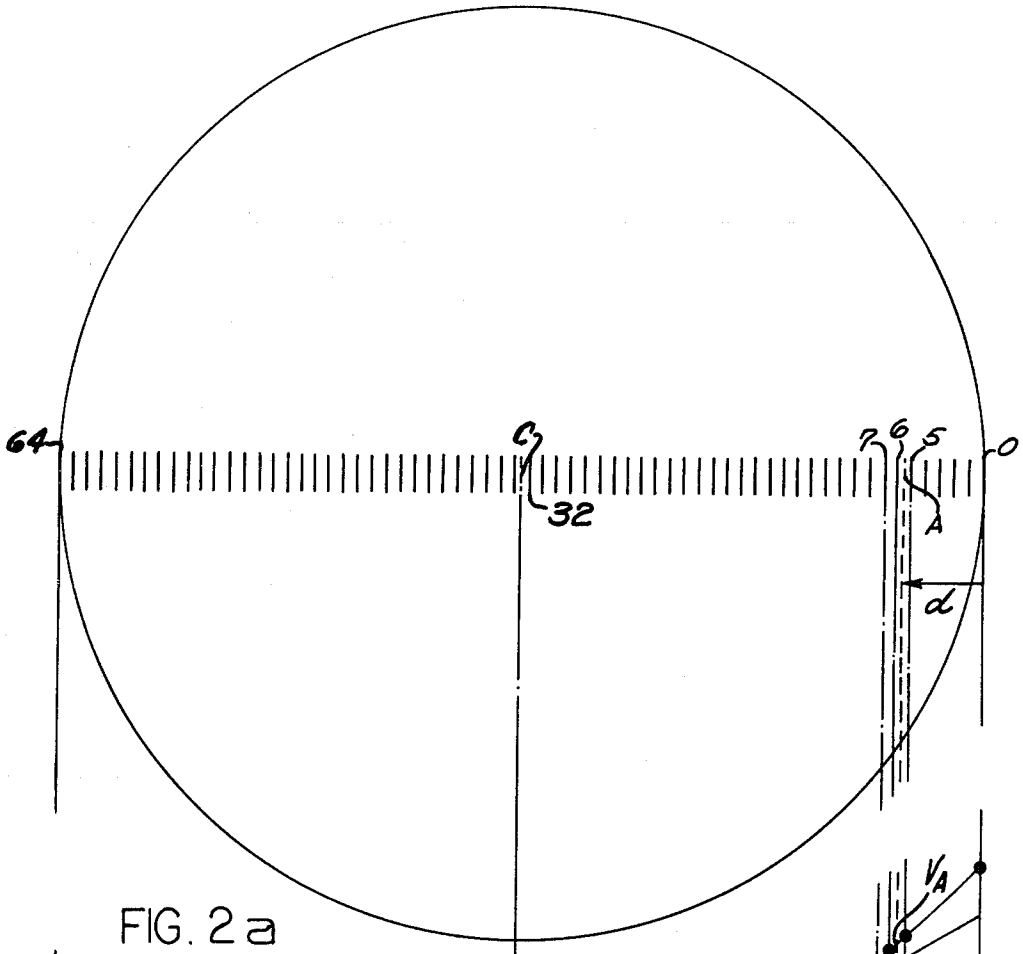


FIG. 2a

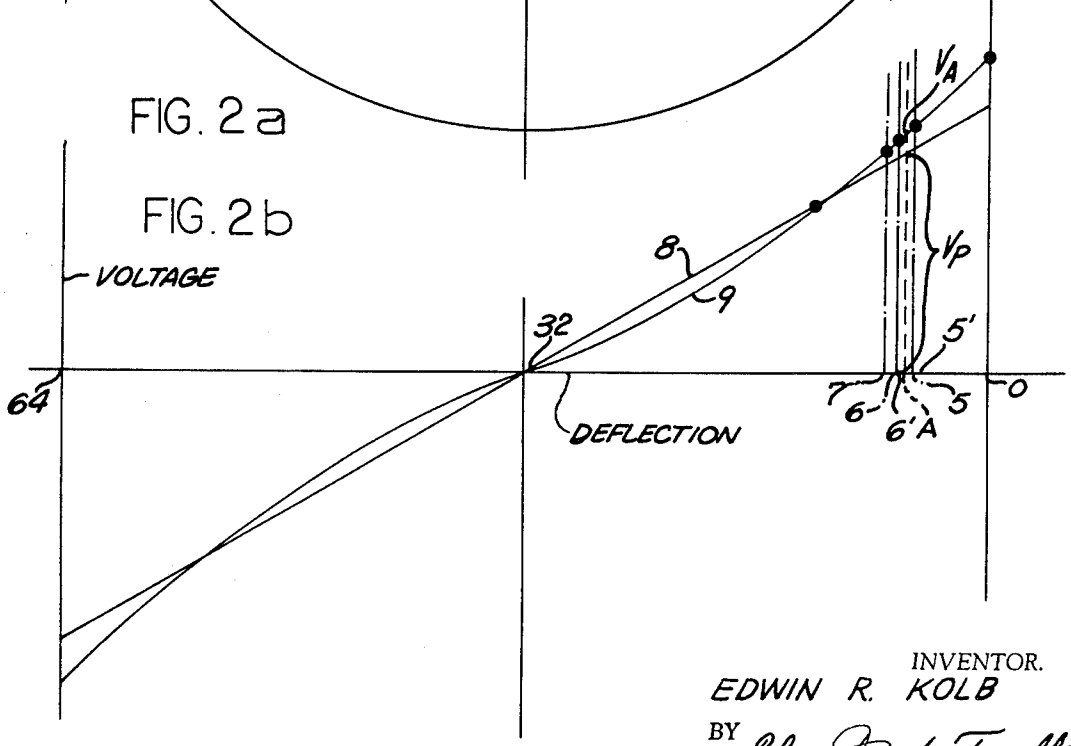


FIG. 2b

INVENTOR.
EDWIN R. KOLB
BY Yount and Tarolli
ATTORNEYS

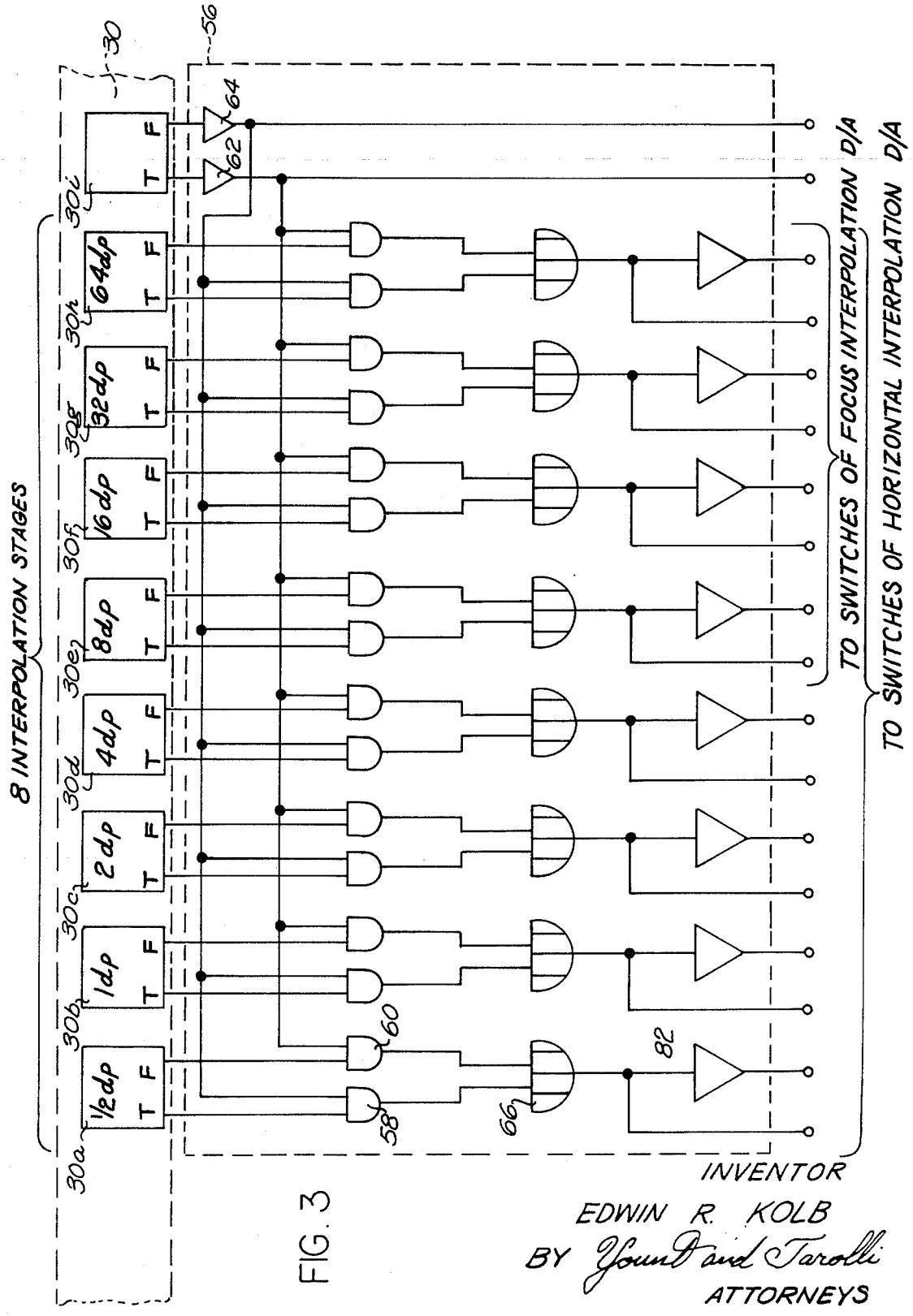


FIG. 3

INVENTOR
EDWIN R. KOLB
BY Young and Tarolli
ATTORNEYS

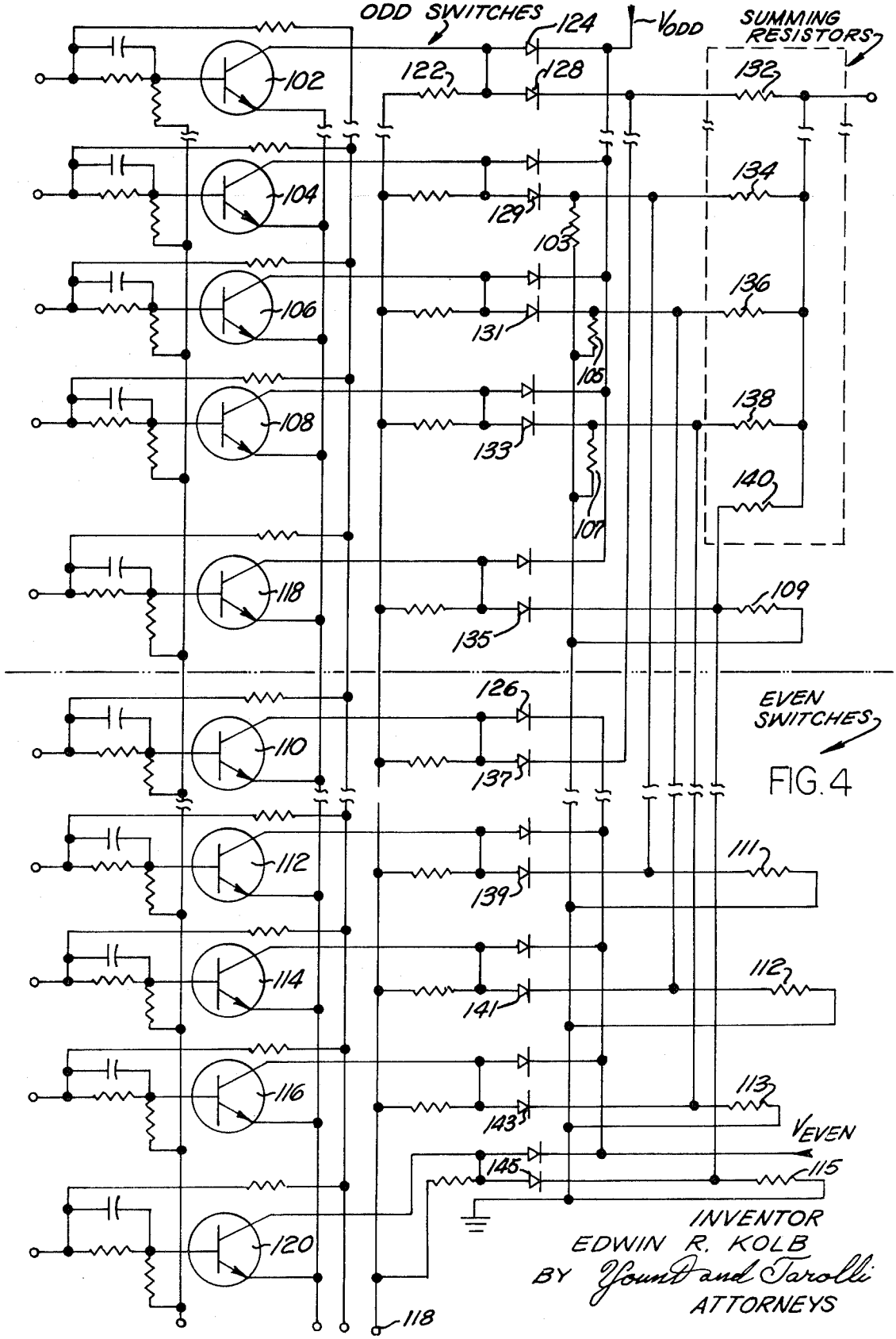


FIG. 4

INVENTOR
EDWIN R. KOLB
BY Young and Tarolli
ATTORNEYS

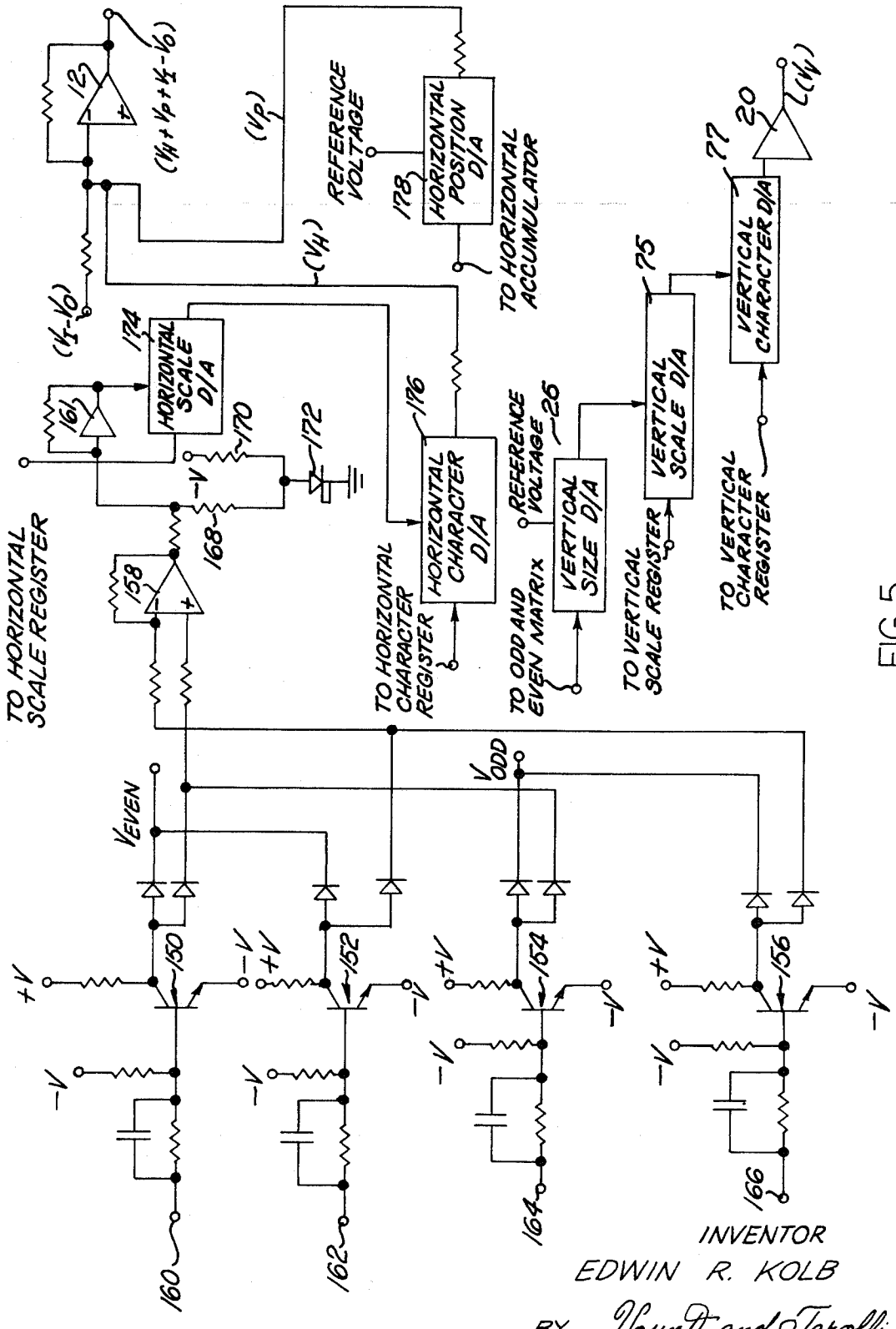


FIG. 5

INVENTOR
EDWIN R. KOLB
BY Yount and Tarolli
ATTORNEYS

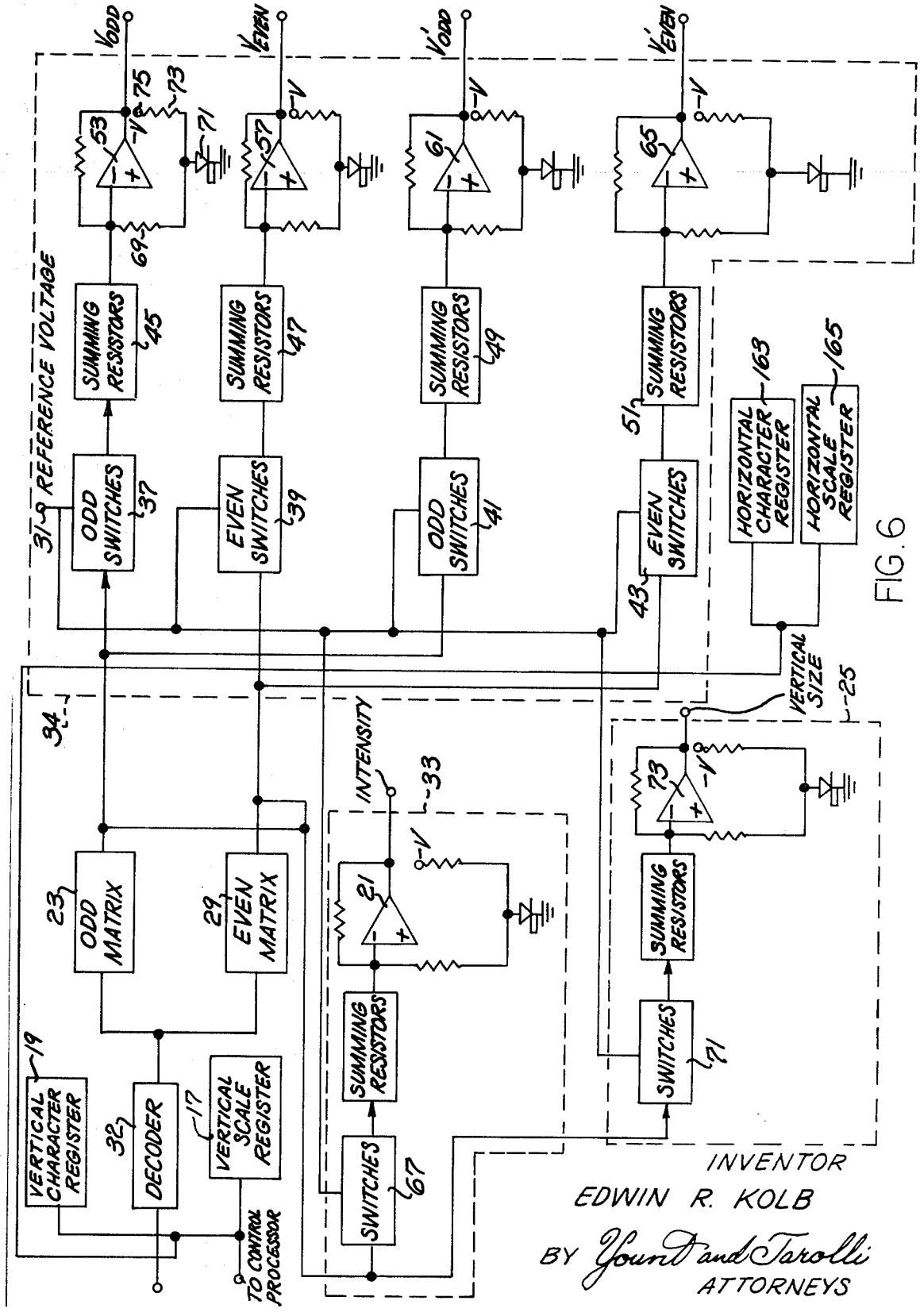


FIG. 6

INVENTOR
EDWIN R. KOLB
BY Yount and Tarolli
ATTORNEYS

COMPENSATION SYSTEMS FOR CATHODE RAY TUBE DISPLAY SYSTEMS

Reference is hereby made to the following related U.S. Pat. applications: Ser. No. 591,734, filed Nov. 3, 1966, entitled "Typesetting System"; Ser. No. 710,350, filed Mar. 4, 1968, entitled "Phototypesetting Apparatus"; and Ser. No. 710,351, filed Mar. 4, 1968, entitled "Point Size Computations and Exposure Control Device for PHototypesetting Apparatus," all assigned to the assignee of this application.

In a cathode ray tube display the voltage required to deflect the electron beam of the cathode ray tube is not a linear function of the position of the visual spot produced on the screen of the cathode ray tube by the electron beam. In many applications the non-linearities of the cathode ray tube in response to deflection voltages are of no significance, however, in phototypesetting systems where characters being generated are to be positioned on the tube and are to be defined with extreme precision the non-linearities of the cathode ray tube become of critical importance.

In addition to positioning inaccuracies, which result from the non-linear response of the cathode ray tube to applied deflection voltages, the visual spot presented on the screeen of the tube will blur as a result of focus variations of the tube and the intensity of the spot will also vary as the spot moves across the screen of the tube. In a display system employing a cathode ray tube in which these undesired variations and non-linearities are not corrected the resulting printed page will have non-uniform intensity, character size and shape and non-uniform definition. Such a display system is not suitable for high quality phototypesetting systems.

The screen of a cathode ray tube which is employed in a phototypesetting system, in accordance with the disclosed embodiment of the present invention, may be considered as being divided into a number of non-linear coarse positioning zones which extend across the screen in a horizontal direction. Some of the variable and non-linear responses of the cathode ray tube may be corrected by associating predetermined compensating voltages with each of the zones. For example, character size, intensity, focus and positioning compensation may be provided in this manner. However, the production of a focus correction voltage for focus variation and the production of a positioning correction voltage for horizontal positioning non-linearities in this manner will not provide a system which has the high degree of precision of the disclosed embodiment of the display system of the present invention.

In the disclosed embodiment of the present invention each of the various non-linear coarse positioning zones of the cathode ray may be considered as corresponding to a linear coarse positioning zone. The end points of the linear zone correspond to the end points of the respective non-linear zone after they have been corrected to compensate for the non-linear positioning response of the electron beam of the cathode ray tube to the command signal.

The linear coarse positioning zones or interpolation zones may be considered as being again subdivided into still smaller zones. In the disclosed embodiment of the present invention the spot is located at a desired point by a voltage signal which has a first positioning voltage component and a position correction voltage component which corrects for the horizontal positioning

non-linearity of the cathode ray tube. These two voltage components locate the visual spot at a desired point in response to a command signal.

An object of the present invention is to provide for a desired response to a command signal by a device normally having an undesired response to control signals by providing an active control signal which is a function of reference signals which represent the boundaries of a selected response interpolation zone of said device to obtain said desired response of said device within said selected response interpolation zone.

It is another object of the present invention to provide for compensation of undesired variations of characteristics of a cathode ray tube, such as horizontal positioning non-linearities and undesired focusing variations for example, at a desired location in an interpolation zone in which the electron beam is to be located by a positioning means in response to a command signal and two reference signals representing the boundaries of the interpolation zone, the intensity of the cathode ray tube also preferably being correspondingly compensated for undesired intensity variations with respect to the position of the electron beam.

Other objects and advantages of the present invention will be apparent from the accompanying description and drawings in which:

FIG. **1** is a block diagram showing the horizontal positioning and focus compensation sections of a cathode ray tube display.

FIG. **2***a* is a diagram showing an expanded view of the screen of the cathode ray tube of FIG. **1**.

FIG. **2***b* is a graph of the positioning correction voltages that are produced for various zones of the tube.

FIG. **3** is a block diagram of the data-reversing circuit of FIG. **1**.

FIG. **4** is a schematic of a group of transistor switches employed in FIG. **1**.

FIG. **5** is a block diagram and schematic view of the character generating portion of the display system.

FIG. **6** is a block diagram and schematic view of various digital-to-analog converters employed in the disclosed system.

The cathode ray tube **10** of FIG. **1** is the display tube of a phototypesetting system. Shown diagrammatically on the screen of the cathode ray tube **10** are **64** marks which extend horizontally across the screen of the cathode ray tube **10**, each of these marks represent a boundary of a positioning zone. The visual spot is initially positioned at the right-hand side of the screen of the cathode ray tube **10**, at the mark **0** in a manner to be subsequently described.

The control elements of the cathode ray tube **10** of the phototypesetting system may be plates, electrodes, deflection yokes or any other suitable element since it will be recognized by those skilled in the art that the principles of the present invention may be employed either with electromagnetically deflected cathode ray tubes or with electrostatically deflected cathode ray tubes. The tube that is used preferably will be one with a resolution of a 1,000–10,000, or more, lines per inch.

Instructions for controlling the display of characters or symbols at desired locations on the screen of the cathode ray tube **10** are obtained from a control processor **28** which may include one or more memories

including optical memories, magnetic core memories, paper tape memories, a magnetic tape memory or other type of memory device. The control processor **28** includes appropriate control circuitry to supply control information in a digital form to the horizontal control register or horizontal accumulator **30**.

In the illustrated embodiment, a multi-digit binary number is registered in the accumulator **30** to define the desired position of the beam along the horizontal deflection axis. The most significant six digits of the number registered in the accumulator **30** define the coarse positions of a linear geometric scale shown in FIG. **2***a* extending along the horizontal deflection axis while the lesser significant digits locate the fine position intermediate adjacent coarse positions. The coarse positions represent the end points of a coarse interpolation zone. As will be well understood by those skilled in the art, if the response of the tube were linear, the proper horizontal deflection voltage for deflecting the cathode ray tube beam to a desired position could be obtained by a single linear digital-to-analog conversion of the binary position number. The graph in FIG. **2**b has an ordinate which represents deflection voltage and an abscissa which represents the position of the beam along the horizontal axis. Curve **8** illustrates the deflection voltages which would be required and which could be obtained by a straight linear conversion of the number in the accumulator **30** if the beam of the tube deflected linearly along the axis in accordance with applied voltage. The tube, however, does not have a linear response to the horizontal deflection voltage and curve **9** of FIG. **2***b* illustrates the voltage necessary to deflect the beam horizontally to positions along the horizontal deflection axis, i.e., the abscissa of the graph in FIG. **2**b. For any position along the horizontal deflection axis, the difference between curve **8** and curve **9** represents the magnitude of the voltage which must be algebraically added to the voltage on curve **8**, which is a linear function of the position along the horizontal axis, to compensate for the non-linear response of the tube and to position the cathode ray tube beam at the desired point.

In the illustrated embodiment, the more significant digits of the number registered in the accumulator **30** represents the coarse position for the beam and the digits of lesser significance indicate the number of fine subdivisions which the desired position is displaced from the coarse position. For purposes of explanation, it will be assumed that the position registered in the accumulator **30** is position A located between the coarse position **5** and the coarse position **6** in FIG. **2***a* and the fine digits of the number represent the number of subdivisions from the coarse position **5** of the desired beam location.

To effect a positioning of the horizontal beam between coarse positions, the system of the illustrated embodiment first establishes signals which have a magnitude dependent on the differences in the voltages on curves **8** and **9** at the adjacent coarse positions, i.e., the end points of the interpolation zone. To this end, the more significant digits in the accumulator are decoded by a decoder **32** which activates odd and even matrices **23**, **29**, respectively, to provide logic signals which define the magnitudes of the compensations required at the coarse positions between which the desired position is located to reach curve **9** from curve **8**. One of these coarse positions will be an even numbered position and the other an odd numbered position and the lower numbered position will be that defined by the six most significant digits in the accumulator. In the illustrated case where the desired position is in the interpolation zone between coarse positions **5** and **6**, the odd matrix will have a logic signal output which indicates the magnitude of the compensating control signal which must be algebraically added to curve **8** at coarse position **5** while the even matrix will have logic output signals which indicate the magnitude of the compensating control signal which must be added to the voltage of curve **8** at the coarse position **6**.

The logic signals from the even and odd matrices are applied to a respective one of a plurality of D/A converter circuits **34** to convert the logic signals to an analog voltage to provide the even and odd analog control voltages (V_{odd} and V_{even}) which are used as reference voltages to an interpolator D/A converting circuit which effects an interpolation between the voltages in accordance with the lesser significant digits of the position number.

The output of the interpolation circuit is a correction voltage V_a which is to be applied to a voltage V_p which is derived in accordance with graph **8** as a straight linear conversion of the position number in an accumulator **30**. The conversion circuit for V_p is not illustrated but it may be any conventional D/A converter. In the discussion hereinafter, V_5 and V_6 will be used to refer to the compensation voltage which must be added to the voltage on the curve **8** to correct the curve to curve **9** at the coarse positions **5** and **6**, respectively.

In the disclosed embodiment of the present invention, the status of the horizontal accumulator **30** is decoded to provide the first voltage (V_p) which corresponds to the voltage on graph **8** corresponding to the position A. This voltage, as noted above, would not position the electron beam at the desired position point A on the CRT screen in the positioning zone defined by the marks **5** and **6**. In order to achieve this in the embodiment thus far described, **14** stages of the horizontal accumulator are decoded to provide for the positioning zone. An alternate embodiment of the present invention may be practiced, is desired, in which fewer stages of the horizontal accumulator **30** may be decoded when the first positioning voltage (V_p) is provided. For example, six stages of the horizontal accumulator **30** may be decoded to provide a horizontal positioning voltage (V_p) in accordance with curve **8** for the coarse position **5** when it is desired to position the beam at the point A. Then the odd reference voltage to the D/A converter **34** will still correspond to the compensating voltage V_5 as defined in accordance with the previous embodiment, but the even reference voltage will correspond to the amount of voltage which would be actually required to deflect the electron beam from the uncompensated non-linear position of the beam for coarse position **5** to the compensated linear coarse position **6**. Interpolation may be performed in the interpolation zone and the interpolated compensated voltage will then be added to the first positioning voltage (V_p) so as to obtain deflection of the electron beam to the desired point A. It will be recognized, therefore, that modifications of the present invention will be ap-

parent to those skilled in the art wherein these modifications are appropriately considered as falling within the scope of the present invention.

The reference voltage (V_{odd}), which is supplied to the odd switches **50** of the horizontal position interpolation converter **14**,and the reference voltage (V_{even}), which is supplied to the even switches **52** of the converter **14**,and a pair of corresponding reference voltages (V'_{odd}) and (V'_{even}), which are supplied to the focus interpolation converter **26**, are all produced by the digital-to-analog converters **34**, which are shown in detail in FIG. **6**.

As previously mentioned, the decoder **32** supplied the decoded information from the horizontal accumulator **30** to the odd gating matrix **29** and to the even gating matrix **23**. The output of the odd gating matrix **29** supplies switching signals to the odd switches **37** of FIG. **6**, which are a group of transistor switches that are coupled to the terminal **31** to receive a fixed reference voltage. The switching of the transistor switches **37** controls the amount of current that flows through the summing resistors **45** to the inverting input terminal of the operational summing amplifier **53**.

In the disclosed embodiment, the visual spot is initially positioned at the right-hand edge of the cathode ray tube **10** at the point **0**. An offset component is, therefore, supplied to the inverting input terminal of the amplifier **53** (FIG. **6**) by the circuit consisting of the resistors **69** and **73**, the Zener diode **71** and the negative voltage supply which is coupled to the terminal **75**. The amplifier **53**, therefore, produces the voltage (V_{odd}) which is supplied as a reference voltage to the odd switches **50** of the converter **14**.

In a similar manner, the even transistor switches **39**, which are coupled to the even gating matrix **29** and to the reference voltage which is coupled to the terminal **31**, control the amount of current that flows through the summing resistors **47** thereby controlling the output of the summing amplifier **57**. The amplifier **57** produces the voltage (V_{even}) which is supplied as a reference signal to the even transistor switches **52** of the converter **14**. A corresponding offset component is also supplied at the inverting input terminal of the amplifier **57**.

The reference voltages V'_{odd} and the V'_{even}, which are coupled to the odd switches **46** and to the even switches **48**, respectively, of the focus interpolation digital-to-analog converter **26** of FIG. **1** are produced by the odd switches **41**, the summing resistors **49** and the summing amplifier **61** and by the even switches **43**, the summing resistors **51** and the summing amplifier **65** of FIG. **6**, respectively.

The intensity interpolation digital-to-analog converter **33** of FIG. **1** is shown in greater detail in FIG. **6**. This converter is similar to the other digital-to-analog converters which were previously described. It includes digital switching transistors, input summing resistors, a summing amplifier, and an offset circuit. A reference voltage for the transistor switches **67** of the converter **33** is supplied from the reference voltage coupled to the terminal **31**.

The intensity control digital-to-analog converter **33** provides an appropriate intensity control voltage to the intensity control element to compensate for undesired intensity variations as the visual spot moves across the screen of the cathode ray tube **10** from one interpolation zone to another so as to maintain the intensity of the spot substantially constant regardless of its position on the face of the cathode ray tube. Each interpolation zone is associated with a unique voltage output from the intensity control digital-to-analog converter **33** in accordance with the signal received from the odd gating matrix **27** or the even gating matrix **29** which controls the switching of the transistor switches **67** and the output of the summing amplifier **21**.

It is also desirable to correct the character generating voltages which are produced in the phototypesetting system so that size non-linearities are not introduced into the characters which are displayed on the screen of the cathode ray tube **10**. The vertical size digital-to-analog converter **25** which provides size compensation in the vertical direction is similar to the intensity control digital-to-analog converter **33**. The gating matrices **23**, **29** are employed to selectively control the switching of the transistor switches **71** so that an appropriate vertical size compensating voltage is produced by the summing amplifier **73**.

The output of the vertical size digital-to-analog converter **25** is coupled as a reference signal to the vertical scale digital-to-analog converter **75** as shown in FIG. **5**. The vertical scale digital-to-analog converter **75** may be constructed in the same manner as the digital-to-analog converters of FIG. **6**. The digital switching signals for the vertical scale digital-to-analog converter **75** are derived from a vertical scale register **17** (FIG. **6**). The vertical scale register **17** is set according to information derived from the control processor **28** of FIG. **1**. The information in the vertical scale register **17** is representative of the point size of the character which is to be displayed on the screen of the cathode ray tube **10**.

The analog output signal from the vertical scale digital-to-analog converter **75** is coupled as a reference signal to the vertical character digital-to-analog converter **77**. The digital switching signals for the vertical character digital-to-analog converter **77**, which is similar to the other described converters, are derived from the vertical character register **19** of FIG. **6**. The information stored in the vertical character register **19** is controlled by the control processor **28** and this information controls the generation of the desired character on the screen of the cathode ray tube **10**. The analog output signal from the vertical character digital-to-analog converter **77** is coupled through the amplifier **20** to the vertical or the Y deflection elements of the cathode ray tube **10**. The output signal from the amplifier **20** is the vertical component of the character generating voltage which directs the visual spot to various locations so as to generate the desired character on the screen of the cathode ray tube **10**. The horizontal character generating voltage is developed in a similar manner, but the analog voltage which is representative of the horizontal size compensation that is required, and which is employed as a reference voltage by the horizontal scale digital-to-analog converter **174**, is developed in a substantially different manner as will be subsequently described.

The outputs of the seventh through the fourteenth most significant stages of the horizontal accumulator **30** are coupled to the data-reversing circuit **56**. The

data-reversing circuit **56** is a circuit which may assume one of two states depending upon the particular zone in which it is desired to locate the visual spot. The data-reversing circuit **56** will be in one state when the right-hand boundary of the zone corresponds to an odd reference mark and the left-hand boundary of the zone of the positioning zone corresponds to an even reference mark. For example, referring to FIGS. **1** and **2**, if the left-hand reference mark is the mark **6** and the right-hand reference mark is the mark **5** the data-reversing circuit **56** will be in its first state. If it is desired to locate the spot in the positioning zone between the reference mark **6** and the reference mark **7** then the data-reversing circuit **56** will be in its second state.

The distance between one subreference point to another is a length of 0.5 decipoint which is 0.05 point. A decipoint is a measure of size which is employed in the printing industry and it is equal to 0.00138375 inches and, therefore, the visual spot on the screen of the cathode ray tube **10** may be located at any point on the screen of the cathode ray tube **10** within a range of ± 0.00035 inches, which illustrates the resolution of the phototypesetting system of the present invention. Moreover, the resolution of the system may be improved merely by adding transistor switches to the disclosed digital-to-analog converters since each added transistor switch will reduce the tolerance with which the spot may be positioned by one-half, so long as the accuracy of the positioning is greater than the 0.5 decipoint resolution.

The deflection voltage that is required to deflect the visual spot to the desired point A is some fraction, N, of the deflection voltage that would be required to deflect the spot from the linear boundary mark **5'** to the linear boundary mark **6'**. The horizontal accumulator **30** supplies a signal representative of a number proportional to this fractional number N in binary form through the data-reversing circuit **56** to the even transistor switches **52** of the horizontal interpolation digital-to-analog converter **14** of FIG. **2** as switching signals. (The desired fractional number is multiplied by a whole number in a conventional manner in the horizontal accumulator **30** for ease of implementation although a binary number directly representing the fractional number could be employed, if desired.) Each bit of the binary number N is complemented and the signal representing the bit-by-bit complement, $\overline{N}$, is coupled from the horizontal accumulator **30** through the data-reversing circuit **56** to the odd transistor switches **50** as switching signals.

The odd transistor switches **50** and the even transistor switches **52** are coupled to the input summing resistors **38** of the summing amplifier **36**, one end of each of the summing resistors **38** being connected to transistors of the switches **50** and **52** and the other end being coupled to the inverting input terminal of the amplifier **36**. When the desired location for the visual spot is at the point A of FIG. **2**, for example, the horizontal interpolation digital-to-analog converter **14** of FIG. **1** produces a positioning voltage component, V_I, which is defined by the equation:

$$V_I = NV_6 + \overline{N}V_5 + V_5/256.$$

In other words, the voltage component, V_I, from the output of the horizontal interpolation digital-to-analog converter **14** consists of a portion which is obtained by multiplying the fractional number N, which indicates the position of the point A in the zone defined by the linear boundary marks **5'** and **6'**, by the reference voltage which corresponds to the compensation voltage for the left-hand mark **6'** of the linear interpolation zone, a second portion which corresponds to the multiplication of the bit-by-bit complement $\overline{N}$ of the binary fractional number N with the reference voltage which corresponds to the compensation voltage for the right-hand mark **5'** of the linear interpolation zone and a third portion which corresponds to the compensation voltage for the right-hand mark **5'** of the linear interpolation zone divided by the number of subreference marks (256) which are associated with the interpolation zone. The voltage V_I, which is provided by the horizontal interpolation digital-to-analog converter **14** will accurately position the electron beam at a desired mark (for example, at the point A) in the associated interpolation zone which is in accordance with the command signal that is stored in the horizontal accumulator **30**.

The voltage required to deflect the visual spot from the center of the tube **10** to the right-hand reference mark **0** is conveniently added into the output voltage of the amplifier **36** by the offset circuit consisting of the resistors **40** and **42** and the Zener diode **44**. The resistor **40** is connected to the inverting input terminal of the amplifier **36** and to the Zener diode **44**, and the resistor **42** is connected to a negative voltage power supply which is coupled to the terminal **43**.

The visual spot is accurately located at the point A by adding the compensating and offsetting voltage components, $(V_I - V_o)$, from the converter **14** with the horizontal positioning voltage (V_p) in the summing amplifier **12**. The amplifier **12** supplies the combined voltages to the X, or horizontal deflection elements, of the tube **10**. A horizontal character generating voltage (V_H) voltage component is also added to the output signal of the summing amplifier **12** during character generation. The vertical character generating voltage (V_V) is coupled to the input of the amplifier **20**, the output of which is connected to the Y, or vertical deflection elements of the tube **10**.

The data-reversing circuit **56** is shown in detail in FIG. **3**, which also shows a portion of the horizontal accumulator **30**. The true side, T, of each of the flip-flops **30*a*** through **30*h*** is connected to one input of an AND gate of the data-reversing circuit **56** and the false output side, F, of each of these flip-flops is connected to another AND gate of the data-reversing circuit **56**. For example, the true output side, T, of the flip-flop **30*a***, which represents an interpolation interval of 0.5 decipoints, is connected to an input of the AND gate **58** and the false output side, F, of the flip-flop **30*a*** is connected to an input of the AND gate **60**. The flip-flops **30*a*** through **30*h*** represent increasing interpolation intervals, in the interpolation zone with each flip-flop to the right representing an interpolation interval which is twice that represented by the flip-flop on its left. Thus, the flip-flop **30*h*** represents a horizontal position interpolation interval of 64 decipoints which is equal to one half of the interval that exists between a pair of linear reference marks at the ends of an interpolation zone.

The flip-flop **30***i* controls the state of the data-reversing circuit **56**. The true output, T, of the flip-flop **30***i* is coupled to the inverter **62** and the false output, F, of the flip-flop **30***i* is coupled to the inverter **64**. The inverter **62** produces a logic level "1" when the right-hand boundary of the region that is occupied is odd numbered. The output of the inverter **64** is a logic level "0" when the output of the inverter **62** is a logic level "1."

The output of the inverter **64** is at a logic level "1" when the right-hand boundary is even numbered. The output of the inverter **62** will then be at a logic level "0" when the output of the inverter **64** is at a logic level "1."

Therefore, if the output of the inverter **64** is at a logic level "1" the AND gate **58** will produce a logic level "1" output signal when the flip-flop **30***a* is in a true state and this will cause the output of the "OR" gate **66**, which is coupled to the outputs of the AND gates **58** and **60**, to be at a logic level "1." The output of the OR gate **66** is coupled to the input of the inverter **82** which produces a logic level "0" when the output of the OR gate **66** is at a logic level "1." On the other hand, when the flip-flop **30***a* is in a false state and the output of the inverter **62** is at a logic level "1," the output of the AND gate **60** is at a logic level "1," and the output of the OR gate **66** will then also be at a logic level "1."

The flip-flops **30***b* through **30***h*, and the associated stages of the data-reversing circuit **56**, operate in a manner identical to that described for the flip-flop **30***a*. All of the flip-flops **30***a* through **30***h* are employed in conjunction with the horizontal interpolation digital-to-analog converter **14**, but only the flip-flops **30***e* through **30***h* are employed with the focus interpolation digital-to-analog converter **36**.

It is also desirable to provide focus compensation to correct for undesired focusing variations that result in the cathode ray tube **10** as the visual spot moves across the screen of the cathode ray tube **10** in a horizontal direction. The focusing correction voltage (V_F) which is produced by the focus interpolation digital-to-analog converter **26** is supplied to the focus control element of the tube **10** through the amplifier **24**. The voltage (V_F) is developed in a manner which is similar to the manner in which the horizontal positioning correction voltage (V_I) is developed by the horizontal interpolation digital-to-analog converter **14**. However, in the disclosed embodiment a separate linear focusing voltage is not developed and summed with the correction or compensating focusing voltage since the focus compensating voltage which must be supplied to maintain the focus of the tube substantially constant as the position of the electron beam on the face of the cathode ray tube varies need not be as precise as the compensation voltage which must be supplied to correct for horizontal positioning non-linearities.

The voltages V'_{odd} and V'_{even} which are produced by the horizontal non-linear digital-to-analog converters **34** in response to the decoded digital signal from the decoder **32**, respectively, correspond to the focusing voltages which are desired reference marks **5'** and **6'**. The odd transistor switches **46** and the even transistor switches **48** correspond respectively to the odd transistor switches **50** and the even transistor switches **52**. However, due to the lower precision requirements of the focus interpolation digital-to-analog converter **26**, the odd transistor switches **46** and the even transistor switches switches **48** contain fewer transistor switches than do the odd transistor switches **50** and the even transistor switches **52** of the horizontal positioning interpolation converter **14**. The corresponding switching signal which is representative of a binary number and the corresponding switching signal which represents its bit-by-bit complement are coupled through the data-reversing circuit **56**. These signals are derived from the seventh through twelfth most significant digits of the output stages of the horizontal accumulator **30**.

Initial offsetting focus voltage is supplied to the focus electrode, F, by the summing amplifier **45** due to the offsetting circuit consisting of the resistors **11**, **15** and the Zener diode **13**. The resistor **13** is connected to the non-inverting input terminal of the differential amplifier **45** and the resistor **13** is coupled at one end to a negative voltage supply which is coupled to the terminal **55**, and to the junction of the Zener diode **13** and the resistor **11** at its other end. This offsetting focus voltage centers the range of focusing voltage for the visual spot.

Although it has been disclosed that the horizontal compensating voltage for horizontal positioning non-linearities is developed in one manner and that the horizontal compensating voltage for undesired focusing variations is developed in another manner, it is apparent that both ways of developing a compensating voltage may be employed interchangeably for either application in a display system in accordance with the present invention. Thus, the horizontal positioning compensating voltage may be developed by an interpolation digital-to-analog converter which is similar to the focus interpolation digital-to-analog converter **26** and the focus compensating voltage may be alternately developed by a digital-to-analog converter which is similar to the horizontal interpolation digital-to-analog converter **14**, if desired.

These alternative systems are intended to be included within the scope of the invention, but it is to be noted that a horizontal compensating voltage developed in this manner would be less precise than that of the disclosed embodiment of the invention, and more components would be employed in such an alternate focus interpolation digital-to-analog converter than are required to achieve a satisfactory system.

The intensity of the visual spot also varies as it moves across the screen of the tube **10** in a horizontal direction. The intensity control digital-to-analog converter **33** of FIG. **6**, which is coupled to the intensity control grid or electrode of the tube **10**, is employed to compensate for undesired intensity variation. The digital-to-analog converter **33** is coupled to the decoder **32** to receive a unique digital switching signal for each course positioning zone of the tube **10**. The reference voltage which is supplied to the digital-to-analog converter **33** is a constant reference voltage since intensity compensation need not be controlled as precisely as horizontal positioning compensation or focus compensation.

In addition to intensity control such as that provided by the digital-to-analog converter **33**, it may be desira-

ble to control the duration of time that the electron beam forming the visual spot is energized. For example, when a character is to be displayed on the screen of the tube which has fewer dots than does a nominal reference character, it may be desirable to increase the duration of energization of the electron beam as it forms each of the dots so that the character is formed by the same energy as is the reference character to insure that both characters have the same density. One example of a suitable intensity duration control system which may be employed in conjunction with the disclosed invention is shown in the above referred to application entitled "Point Size Computation and Exposure Control Device for Phototypesetting Apparatus." The intensity control grid for the tube **10** may also be keyed off and on by conventional circuitry in accordance with the desired energization and de-energization of the electron beam under the control of the character generating portion of the display system.

The interpolation control circuits of the disclosed invention may be applied to control intensity or character size or any other characteristic of the display system in accordance with the disclosed invention, if desired. In addition, the character generating voltages and the horizontal course positioning voltage may be supplied by conventional circuits, or by circuits of the previously cited applications, according to the desired application of the display system of the disclosed invention.

The transistor switches shown in the schematic of FIG. **4** may be employed for the transistor switches **46**, **48**, **50** and **52** of FIG. **1**. The NPN transistors of FIG. **4** each correspond to various interpolation intervals. Some of the switching transistors and corresponding circuitry required by the transistor switches have been omitted to simplify FIG. **4**, as indicated by the broken lines in the drawing. When the circuit of FIG. **4** is employed to represent the transistor switches **50** and **52**, the transistors **102**, **104**, **106**, and **108** correspond to 64 decipoints, 2 decipoints, 1 decipoint, and one-half decipoint, respectively. The transistors **110**, **112**, **114**, and **116** also respectively correspond to these same respective decipoint values.

The transistor **118** and **120** correspond to the same decipoint values as do the transistors **106** and **116**, respectively, and these transistors control the development of the voltage component corresponding to the reference voltage associated with the right-hand boundary of the desired interpolation zone interval divided by the number of subreference marks in the interpolation zone, for example $V_5/256$).

The output of the inverter **62** is coupled to the input terminal associated with the transistor **118** and when it is at a logic level "1," the transistor **118** is turned on and the transistor **120** is turned off by the inverter **64** which is coupled to its input terminal. When the inverter **64** is at a logic level "1," the transistor **120** is turned on and the transistor **118** is turned off. The transistors **118** and **120** may be removed and an improved interpolation control system may still be provided. However, for extremely accurate cathode ray tube display systems, the transistors **118** and **120** are preferably included, unless the number of interpolation stages is increased such that the smallest interpolation interval becomes insignificantly small.

The collector of each of the transistors of FIG. **4** is coupled to the positive voltage supply which is coupled to the terminal **118** through a load resistor. For example, the transistor **102** is coupled to the terminal **118** through the load resistor **122**. The collector of each of the transistors of FIG. **4** is also coupled through a diode to receive either the even reference voltage or the odd reference voltage from the converters **34**. For example, the transistor **102** is coupled through the diode **124** to receive a positive polarity even reference voltage, (for example, V_6) and the collector of the transistor **110** is coupled through the diode **126** to receive a positive polarity odd reference voltage, (for example V_5). The collectors of the transistors **104**, **106**, **108** and **118** are also coupled to receive the even reference voltage, while the collectors of the transistors **112**, **114**, **116** and **120** are coupled to receive the odd reference voltage.

One transistor from the odd transistor switches and one transistor from the even transistor switches of FIG. **4** are coupled in parallel to each of the summing resistors with which they are associated. For example, the transistor **102** is coupled through the diode **128** to the summing resistor **132** and the transistor **110** is coupled through the diode **137** to he summing resistor **132**. The values of the resistors **132** through **138** represent an interpolation interval and each of the resistors **132** through **138** has a value of one-half the value of the resistor located immediately above it in FIG. **4**.

The values of the resistors **138** and **140** are equal since the transistors **118** and **120** are alternately used to generate the voltage component which corresponds to the reference voltage associated with the right-hand boundary of the desired interpolation zone divided by the number of subreference points that are present in the zone. For example, if the desired interpolation zone lies between the linear marks **5'** and **6'**, then this voltage component of the horizontal correction voltage is $V_5/256$. If the desired zone lies between the linear marks **6'** and **7'**, then this voltage component is $V_6/256$. Analogous voltage components are produced for the corresponding focus compensation voltage in a similar manner.

When a transistor of the transistor switches of FIG. **4** is driven on by a positive voltage on its input terminal from the horizontal control register **30** its collector is clamped at its positive polarity reference voltage. A current is then supplied to the summing resistor which is coupled to the collector of the transistor through the associated coupling diode, and the amount of current flowing through this summing resistor influences the output voltage of the associated summing amplifier.

If the right-hand boundary associated with a particular interpolation zone is even-numbered, a digital code signal proportional to the binary fractional number N is coupled to the transistors **102** through **108** through the data-reversing circuit **56**, as previously described. A signal representing the bit-by-bit complement $\overline{N}$ of this digital code is coupled to the input terminals associated with the transistors **110** through **116** from the horizontal control register **30** through the data-reversing circuit **56**. On the other hand, if the right-hand boundary is odd-numbered, the digital signal representing the binary fractional number will be coupled through the data-reversing circuit **56** to the transistors **110** through **116**. The signal representing the bit-by-bit complement

of this number will then be coupled to the transistors **102** through **108** through the data-reversing circuit **56**.

The resistors **103** through **115** of FIG. **4** are provided to insure that the diodes **128** through **145** all carry the same current when their associated transistors are turned on. To achieve this resistor **103** has a value such that the parallel value of the resistor **103** and of the resistor **134** is equal to the value of resistor **132**. The other resistors **105** through **115** have corresponding values.

In the phototypesetting systems of the type described it is desirable to derive a voltage that is representative of the selected interpolation zone. This voltage is employed as a reference signal in the horizontal character generating section of the phototypesetting system for adjusting the size of the character or symbol to be displayed. A voltage representing the interval between the reference position marks of a selected interpolation zone is obtained from the circuit shown in FIG. **5** which consists of four pairs of transistors **150**, **152**, **154** and **156** which comprise a reversing switch.

Transistors **150** and **152** are coupled to receive the same positive polarity even reference signal that is received by the transistor switches **52**. The transistors **154** and **156** are coupled to receive the same positive polarity odd reference signal that is received by the transistor switches **50**. The collectors of the transistors **152** and **156** are coupled to the inverting input terminal of a differential amplifier **158** and the collectors of the transistors **150** and **154** are coupled to the non-inverting input terminal of the differential amplifier **158**.

The input terminals **160** and **166** of the transistors **150** and **152**, respectively, are coupled to the inverter **62** of FIG. **3** which produces a positive polarity logic level "1" signal when the right-hand reference mark of the positioning zone is odd (for example, mark **5**). The input terminals **162** and **164** are coupled to the inverter **64** of FIG. **3** which produces a positive polarity logic level "1" when the right-hand reference mark of the positioning zone is even (for example, mark **6**). Only one of the transistors **150** and **152**, and, simultaneously on one of the transistors **154** and **156** which are coupled to the odd and even reference voltages, are turned on for a given interpolation zone according to whether or not the right-hand boundary is odd or even. The output voltage from the differential amplifier **158** then represents the difference between the two departures from linearity at the two end marks of the corresponding linear interpolation zone.

The resistors **168** and **176** and the Zener diode **172** provide an offset voltage which allows the amplifier **158** to provide a reference voltage to the horizontal scale digital-to-analog converter **174** through the amplifier **161**. The voltage at the output of the amplifier **158**, represents a change of voltage corresponding to the non-linearity of the cathode ray tube **10** between the end points of a positioning zone.

The horizontal scale digital-to-analog converter **174** is similar in construction to the other digital-to-analog converters of the system and it may be constructed in a manner similar to that shown in the circuit of FIG. **4**. The digital switching signals for the horizontal scale digital-to-analog converter **174** are supplied from a horizontal scale register **165** (FIG. **6**) which is supplied information under the control of the control processor **28**. The information in the horizontal scale register **168** corresponds to the information in the vertical scale register in that it is representative of the desired point size of the displayed character.

The analog voltage output from the horizontal scale digital-to-analog converter **174** is coupled as a reference signal to the horizontal character digital-to-analog converter **176**. The digital switching signals for the horizontal character digital-to-analog converter **176** are received from the horizontal character register **163** (FIG. **6**). The information in the horizontal character register is established by the control processor **28**. The information in the horizontal character register controls the generation of the horizontal voltage component of the character generating voltage (V_H) which is coupled to the summing amplifier **12**.

The horizontal position digital-to-analog converter **178** has a fixed reference voltage and digital switching signals are supplied to this converter from the fourteen most significant digits of the horizontal accumulator **30** of FIG. **1**. The horizontal accumulator **30** is under the control of the control processor **28** and it supplies the positioning voltage (V_P) to the summing amplifier **12**. The horizontal accumulator **30** may be controlled by the control processor **28** so that the positioning voltage (V_P) which is supplied to the summing amplifier **12** increases in equal increments as the count in the horizontal accumulator **30** increases and the visual spot is positioned from one point to the next across the face of the cathode ray tube **10**. The positioning voltage (V_P) is linear with respect to the status of the horizontal accumulator **30** and, therefore, it results in a non-linear positioning of the electron beam, as previously described.

Although the present invention has been described with reference to an embodiment thereof, it is to be understood that other embodiments and variations of the present invention will be apparent to those skilled in the art and it is intended that these be included within the scope of the appended claims.

What is claimed is:

1. In a system in which a responsive means is to effect a desired response to a control signal which is derived from a command signal which dictates that said desired response be a fractional part of a selected zone bounded by first and second responses of predetermined magnitudes, command means for establishing an active command signal that defines said desired fractional part of said selected zone, control means for effecting said desired fractional part of within said selected zone comprising first means responsive to said command means for establishing first and second reference signals having values for evoking said first and second responses of said responsive means and second means responsive to said active command signal and to said first and second reference signals for deriving an active control signal for said responsive means having a value for effecting said desired fractional part in said selected zone.

2. In a system as set forth in claim **1** wherein the system is a display system, the responsive means is a cathode ray tube, the desired response is a substantially constant focusing response of said cathode ray tube regardless of the position of the electron beam of said cathode ray tube and the control signal is a focusing signal.

3. In a system as set forth in claim 1 wherein said system is a display system, the responsive means is a cathode ray tube, the desired response is a substantially linear positioning response of the electron beam of the tube and the control signal is a positioning signal.

4. In a system as set forth in claim 1 wherein said command signal comprises a selectable digital signal which uniquely represents one of said zones and said control means further comprises digital-to-analog converting means for converting a selected digital signal associated with said selected zone to an analog signal which when added to said active control signal will effect said desired fractional part of the response of said responsive means in said selected zone.

5. In a system as set forth in claim 1 wherein the system is a display system, the responsive means is a cathode ray tube, the desired response is a substantially constant focusing response of said cathode ray tube regardless of the position of the electron beam of said cathode ray tube and the control signal is a focusing signal.

6. In a system as set forth in claim 4 wherein said system is a display system, the responsive means is a cathode ray tube, the desired response is a substantially linear positioning response of the electron beam of the tube and the control signal is a positioning signal.

7. In a system as set forth in claim 6 further comprising means responsive to the command signal for compensating the intensity response of the cathode ray tube to obtain an intensity response which is appropriate for said desired fractional positioning response of said electron beam in said selected zone.

8. In a system in which a cathode ray tube having a non-linear positioning response of the electron beam and an undesired variable focusing response with respect to uncompensated positioning and focusing control signals is to have a linear positioning response of the electron beam and a predetermined focusing response with respect to a command signal which dictates that said desired positioning response of the electron beam be a fractional part of a selected positioning zone bounded by first and second positioning responses of the electron beam of predetermined magnitudes and that said desired focusing response be a fractional focusing response which is appropriate for said fractional part of said positioning response, command means for establishing an active command signal that defines said desired fractional part of said selected positioning zone, first control means for effecting said desired fractional part of said positioning response within said selected positioning zone comprising first means responsive to said command means for establishing first and second reference signals having values for evoking said first and second positioning responses of said cathode ray tube, second means responsive to said active command signal and to said first and second reference signals for deriving a compensated positioning control signal for said cathode ray tube having a value for effecting said desired fractional part of said positioning response of said electron beam within said selected positioning zone, second control means for effecting said desired fractional focusing response which is appropriate for said fractional positioning response of said electron beam in said selected zone comprising third means responsive to said command means for establishing third and fourth reference signals having values suitable for evoking first and second focusing responses of said cathode ray tube which appropriately correspond to said first and second positioning responses of said electron beam and fourth means responsive to said active command signal and to said third and fourth reference signals to derive a compensated focusing control signal having a value suitable for effecting said desired fractional focusing response of said cathode ray tube.

9. In a system as set forth in claim 8 further comprising means responsive to the command signal for compensating the intensity response of the cathode ray tube to obtain an intensity response which is appropriate for said desired fractional positioning response of said electron beam in said selected zone.

10. In a system as set forth in claim 9 wherein said command signal comprises a selectable digital signal which uniquely represents one of said zones and said control means further comprises digital-to-analog converting means for converting a selected digital signal associated with said selected zone to an analog signal which added to said active control signal will effect said desired fractional response of said responsive means in said selected zone.

11. In a system as set forth in claim 10 further comprising means responsive to the command signal for compensating the intensity response of the cathode ray tube to obtain an intensity response which is appropriate for said desired fractional positioning response of said electron beam in said selected zone.

12. In a system in which a cathode ray tube having an undesired intensity response with respect to an uncompensated intensity control signal is to have a desired appropriate intensity response with respect to a command signal which dictates a desired positioning response of the electron beam of said cathode ray tube, command means for establishing an active command signal that defines said desired positioning response of said electron beam and means responsive to said active command signal for deriving a compensated intensity control signal for said cathode ray tube having a valve which is suitable for effecting said desired intensity response of said cathode ray tube.

13. In a system as set forth in claim 12 wherein said command means establishes an active command signal which defines a desired fractional positioning response within a selected positioning zone bounded by first and second positioning responses of predetermined magnitudes.

14. In a system in which graphical configurations are displayed on a cathode ray tube having deflection elements for positioning the electron beam of the cathode ray tube, comprising configuration generating means for generating graphical configurations to be displayed on the cathode ray tube, configuration positioning means for locating each of the displayed configurations on the face of the tube comprising accumulator means for controlling the position of the displayed configurations according to the desired display characteristics of said displayed configurations, first output means for providing a first positioning signal, first control means for sensing the status of said accumulator means, said first control means being operably connected to said first output means for controlling the value of said first positioning signal from said first output means, means

for compensating for the non-linear positioning response characteristics of the cathode ray tube to said first positioning signal comprising second output means for providing a second positioning signal, second control means for sensing the status of said accumulator means, said second control means being operably connected to said second output means for controlling the value of said second positioning signal from said second output means, said second control means comprising command means for establishing an active command signal that defines a selected fractional part of a selected zone of said face of said tube which is bounded by first and second positioning responses of predetermined magnitudes and means for effecting a response within said zone comprising means responsive to said command means for establishing first and second reference signals having values for evoking said first and second positioning responses of said cathode ray tube and means responsive to said active command signal and to said first and second reference signals for deriving an active control signal for controlling said second output means to provide a second positioning signal for said cathode ray tube that has a value for effecting said desired fractional positioning response in said selected zone and means to combine the first positioning signal and the second positioning signal and to supply said combined signals to the deflection elements of said cathode ray tube to effect said desired fractional positioning response of said electron beam on the face of said tube in accordance with the status of said accumulator means.

15. In a system as set forth in claim **14** further comprising means responsive to the command signal for compensating the intensity response of the cathode ray tube to obtain an intensity response which is appropriate for said desired fractional positioning response of said electron beam in said selected zone.

16. In a system as defined in claim **14** wherein the improvement further comprises compensating means for providing a compensated focusing control signal to said cathode ray tube, comprising means responsive to said command means for establishing third and fourth reference signals having values suitable for evoking a first and second focusing response of said cathode ray tube which appropriately respectively correspond to said first and second positioning responses of said electron beam and means responsive to said active command signal and to said third and fourth reference signals for deriving said compensated focusing control signal and for supplying said compensated focusing control signal to said cathode ray tube, said focusing control signal having a value which is appropriate for effecting fractional focusing response of said cathode ray tube which corresponds to said desired fractional positioning response of said electron beam in said selected zone.

17. In a system as set forth in claim **16** further comprising means responsive to the command signal for compensating the intensity response of the cathode ray tube to obtain an intensity response which is appropriate for said desired fractional positioning response of said electron beam in said selected zone.

18. In a system in which a control signal is provided for evoking a response in a device which signal is to be compensated in dependency on the magnitude of a condition which varies over a range, the range being divided into a plurality of zones having end points, first circuit means for establishing first and second signals which have respective magnitudes dependent on the compensation required for said control signal for the end points of a selected zone and second circuit means responsive to said first and second signals for supplying a compensated control signal to said device, said device being a cathode ray tube and said condition is a desired position for the cathode ray beam along one deflection axis, the end points of said zones defining coarse positions of said beam along said axis, said control signal being a deflection signal for deflecting said beam along said axis and said system includes means for providing a linearly variable deflection signal for positioning said beam between said end points and said second circuit means includes interpolating means for interpolating between said first and second signals to provide a compensated deflection signal for positioning said beam between said end points.

19. In a control system according to claim **18** in which said control signal is a signal for controlling the focus of said beam, said second circuit means comprising interpolating means for interpolating between said signals in accordance with the position of the beam between said end points to provide a compensated focusing signal.

20. In a system in which a control signal is provided for evoking a response in a device which signal is to be compensated in dependency on the magnitude of a condition which varies over a range, the range being divided into a plurality of zones having end points, first circuit means for establishing first and second signals which have respective magnitudes dependent on the compensation required for said control signal for the end points of a selected zone and second circuit means responsive to said first and second signals for supplying a compensated control signal to said device, said device being a cathode ray tube beam along one deflection axis, the end points of said zones defining coarse positions of said beam along said axis, there being a predetermined number of fine positions between adjacent coarse positions and the desired position is displaced from a coarse position by a fractional number N of said fine positions, said second circuit means comprising means for multiplying one of said signals by N and the other of said signals by $\overline{N}$ where $\overline{N}$ is the bit-by-bit complement of N.

21. In a control system according to claim **20** wherein said system includes a multi-digit binary number having fine digits specifying said fractional number and coarse digits which define the end points of said zones as coarse positions numbered with respect to a reference whereby each zone has odd numbered and even numbered end points with the lower numbered end points of said zones alternating between even and odd when proceeding from the reference, and wherein said first circuit means comprises an odd circuit means establishing the one of said first and second signals for the odd numbered coarse position and even numbered circuit means for establishing the one of said first and second signals corresponding to the even numbered coarse position, said second circuit means comprising a first and second digital-to-analog converters for multiplying the signals by N and $\overline{N}$, one of said con-

verters being connected to said odd circuit means and one being connected to said even circuit means, and means responsive to said coarse digits to set the converters to multiply by N or $\overline{N}$ selectively depending upon whether the odd or even end point is the higher numbered end point from the reference.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,702,949 Dated November 14, 1972

Inventor(s) Edwin R. Kolb

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 18, line 39, after "tube" insert -- and said condition is a desired position for the cathode ray tube --.

Signed and sealed this 10th day of April 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
☆ U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,702,949 Dated November 14, 1972

Inventor(s) Edwin R. Kolb

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 18, line 39, after "tube" insert -- and said condition is a desired position for the cathode ray tube --.

Signed and sealed this 10th day of April 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
☆ U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334