United States Patent

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[73] Assignee **RCA Corporation**

[54] **ASTIGMATISM CORRECTION FOR ELECTRON BEAM DEVICES**
12 Claims, 7 Drawing Figs.

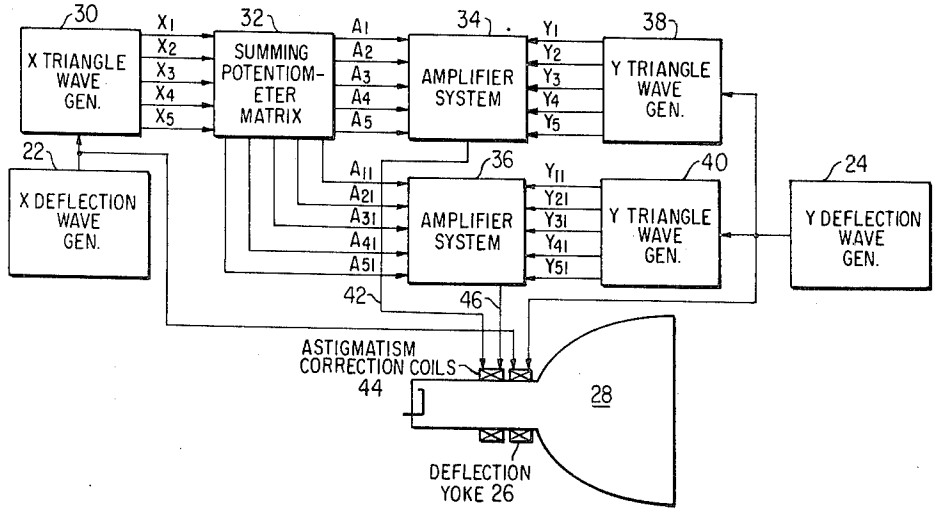
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[51] **Int. Cl.** **H01j 29/56**
[50] **Field of Search** ..... 315/24, 26, 31 TV, 31 R, 27 GD

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ABSTRACT: The correction field applied to a cathode-ray beam device substantially fully cancels astigmatism at a plurality of discrete, known in advance positions of the beam, preferably uniformly spaced over the area swept by the beam. The value of the field automatically is changed as the beam moves as a function of the relative distances of the beam from a plurality of said discrete positions to at least partially cancel astigmatism at the remaining positions of the beam.



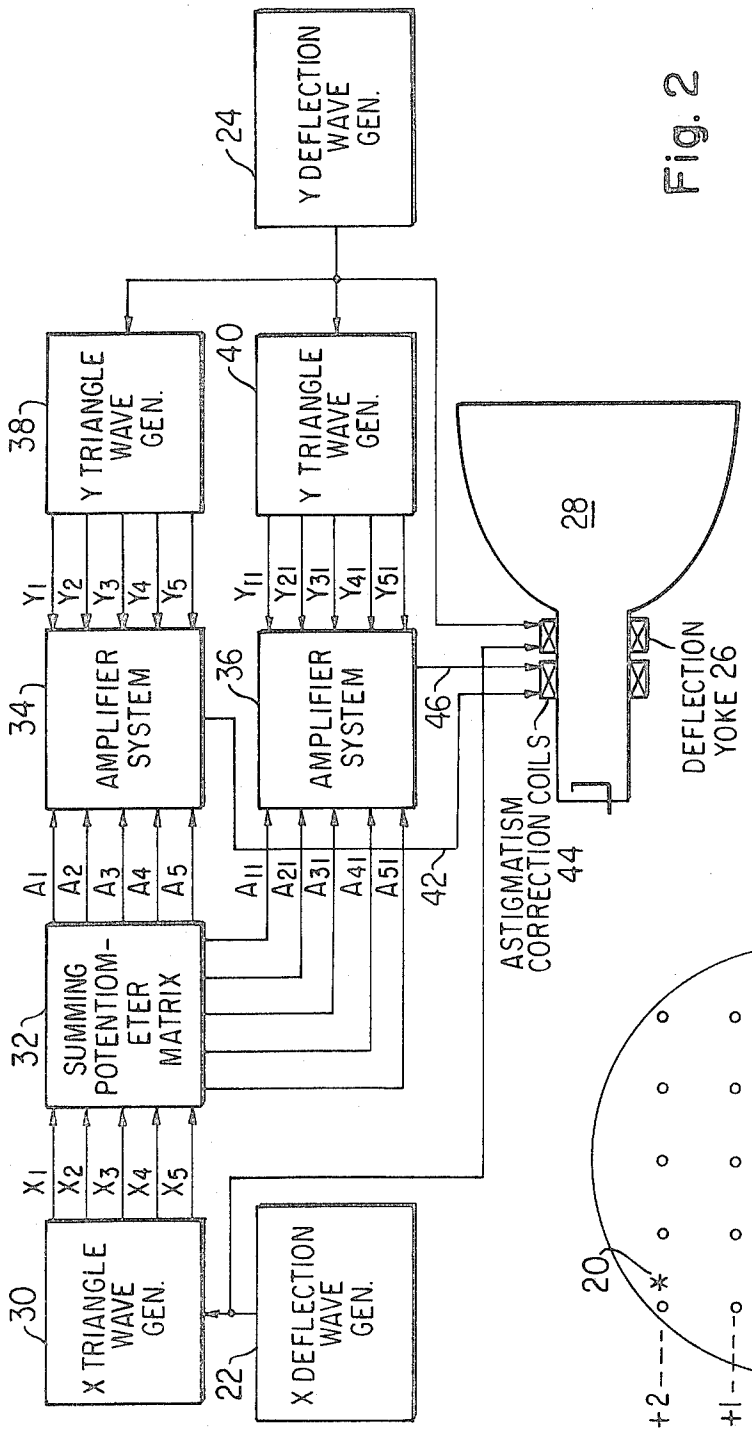


Fig. 2

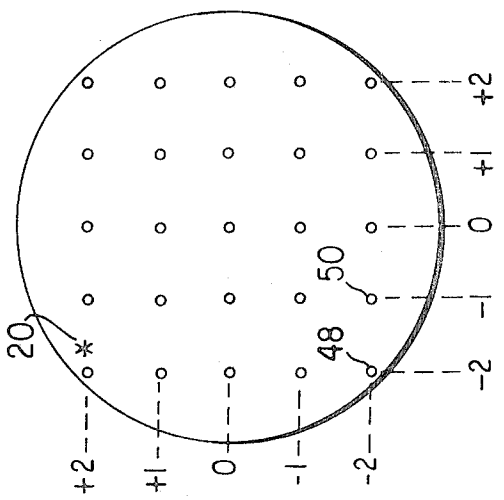


Fig. 1

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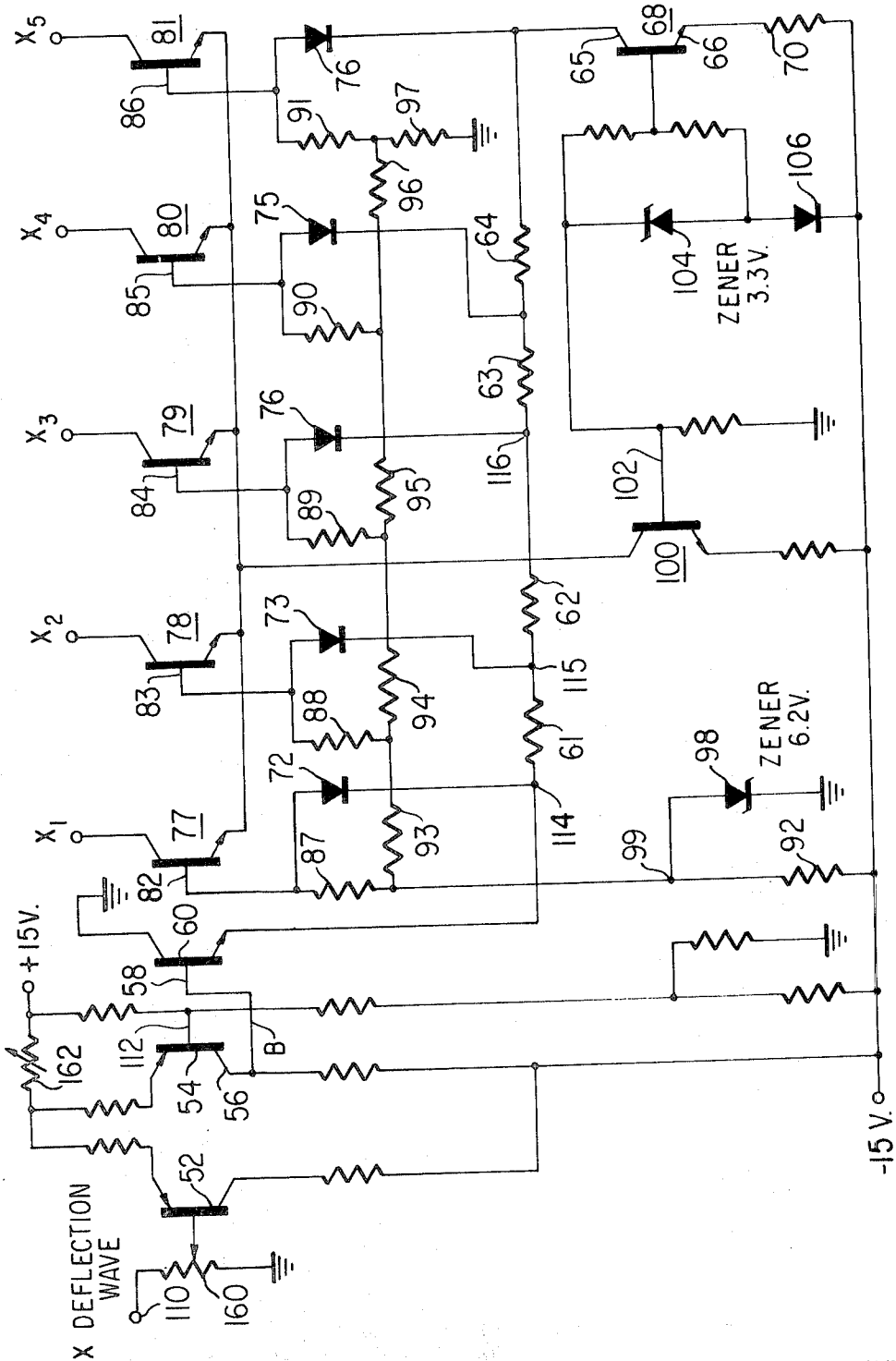


Fig. 3

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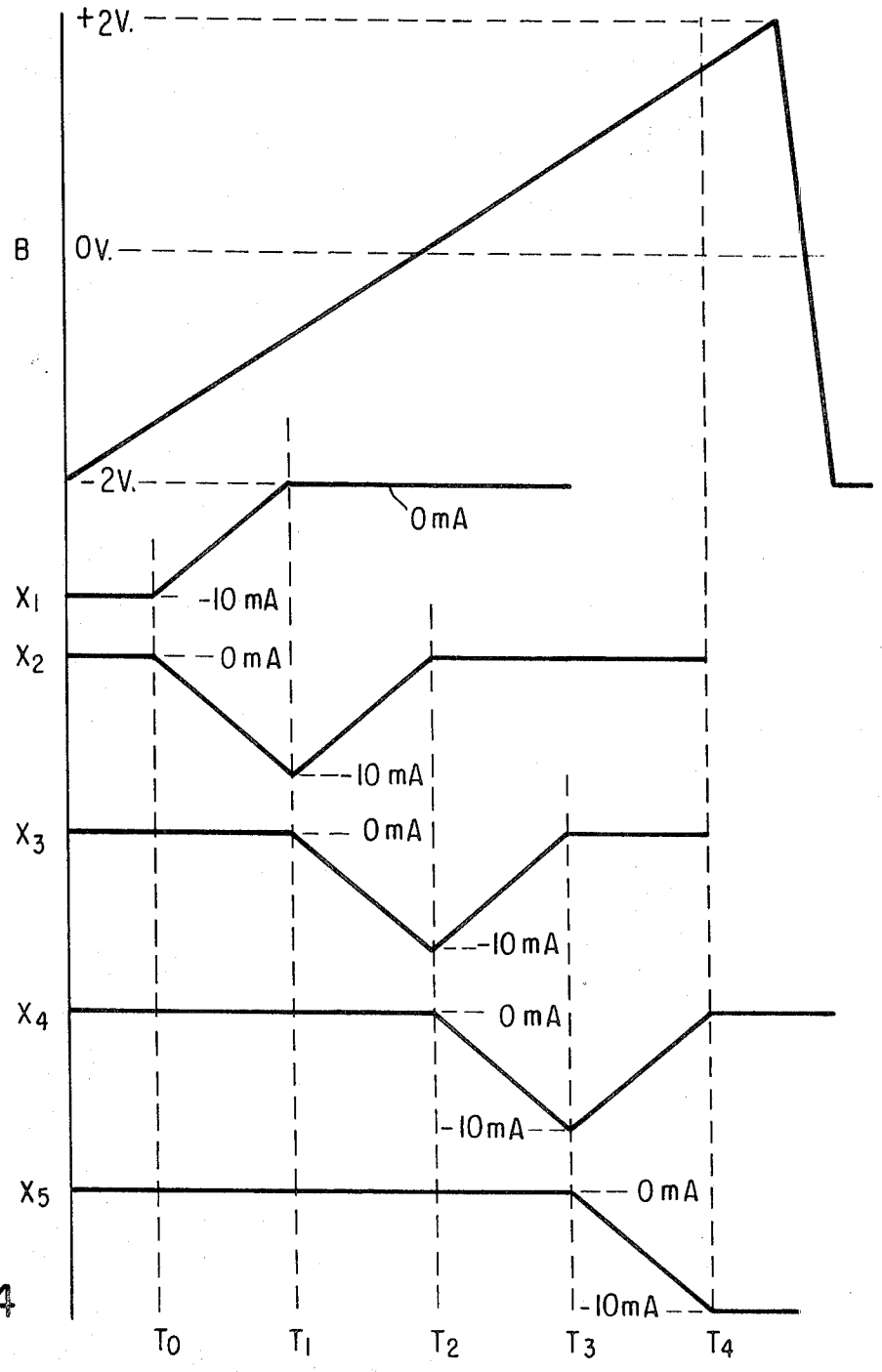


Fig.4

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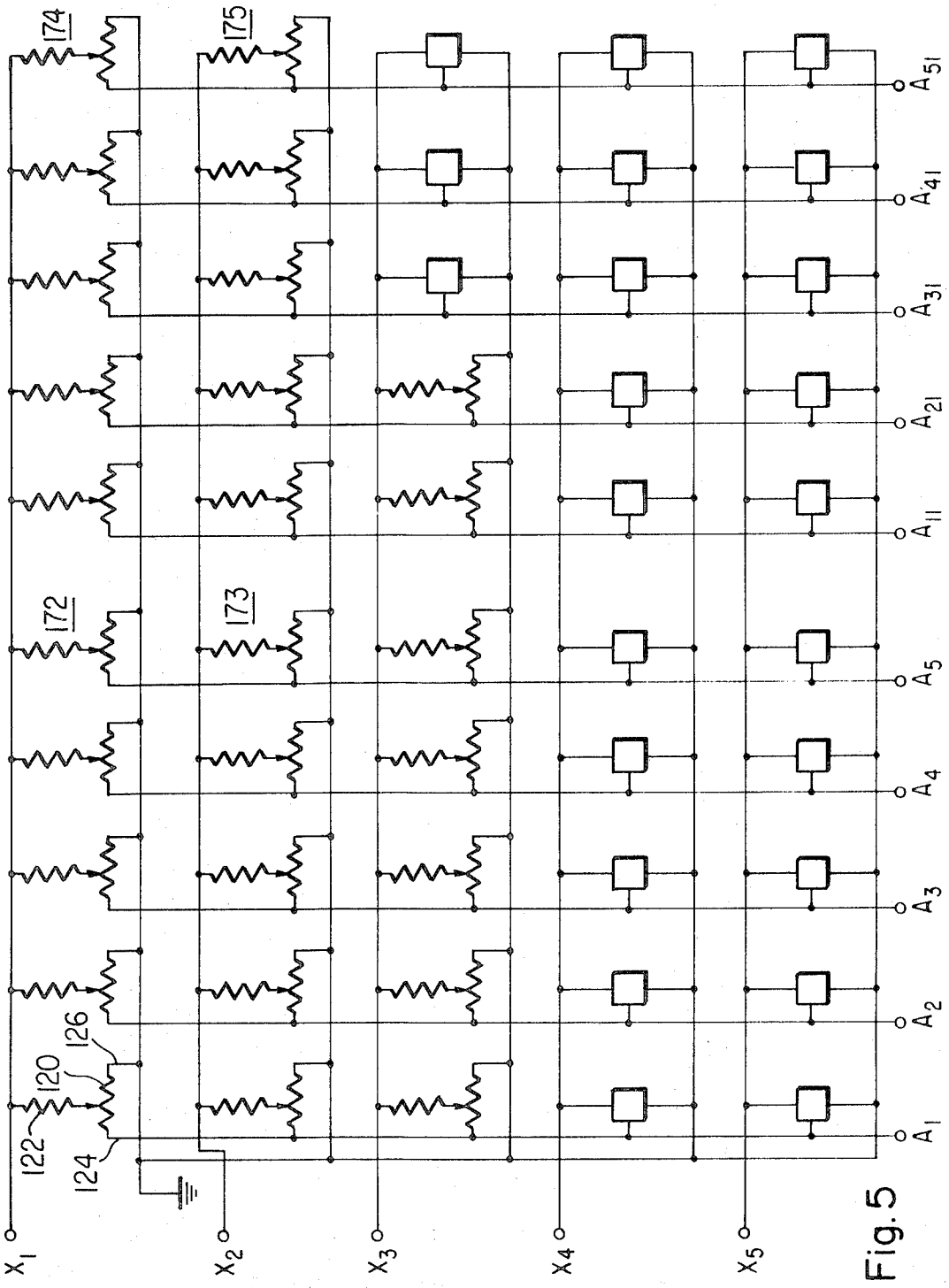


Fig. 5

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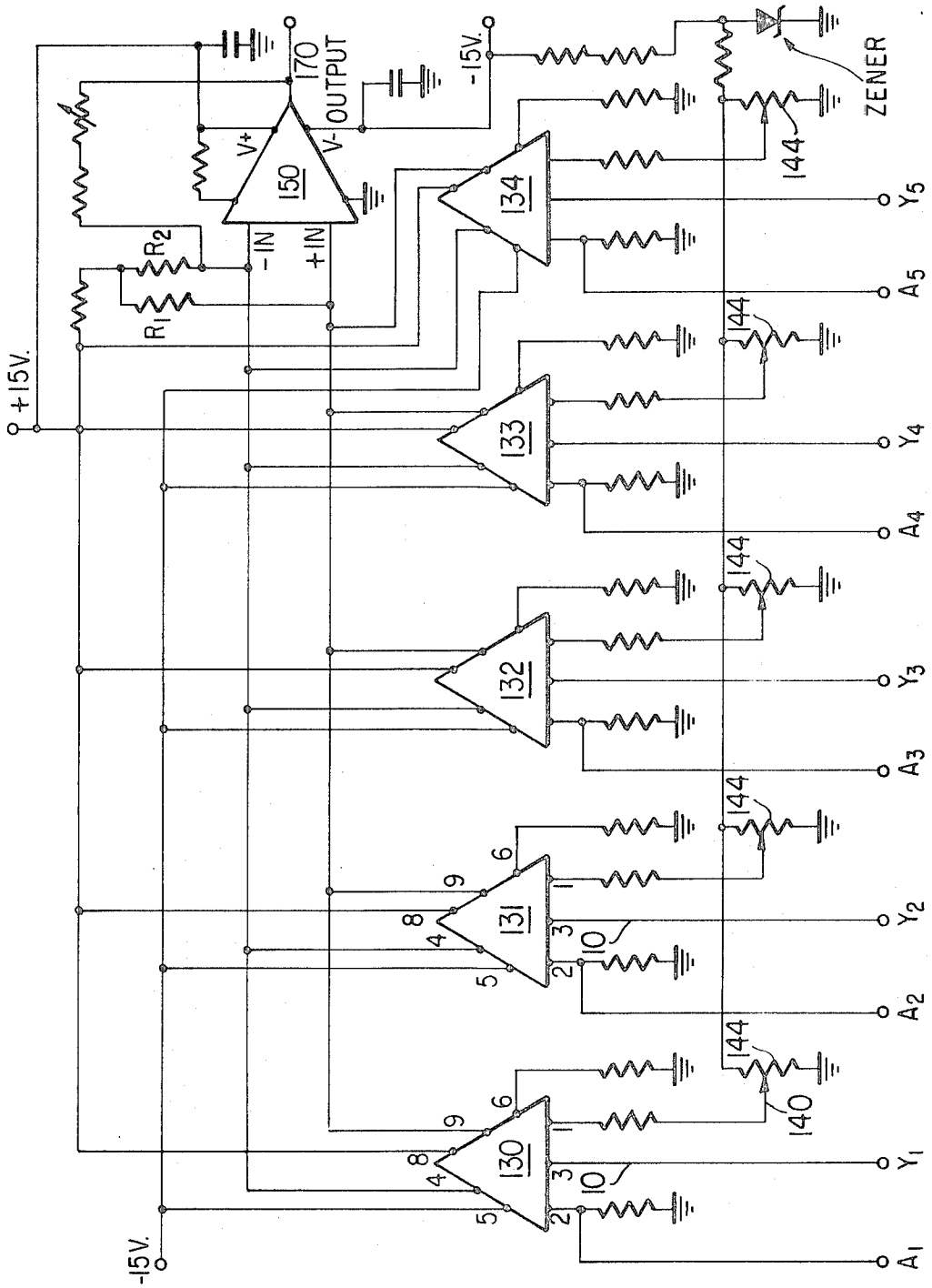


Fig. 6

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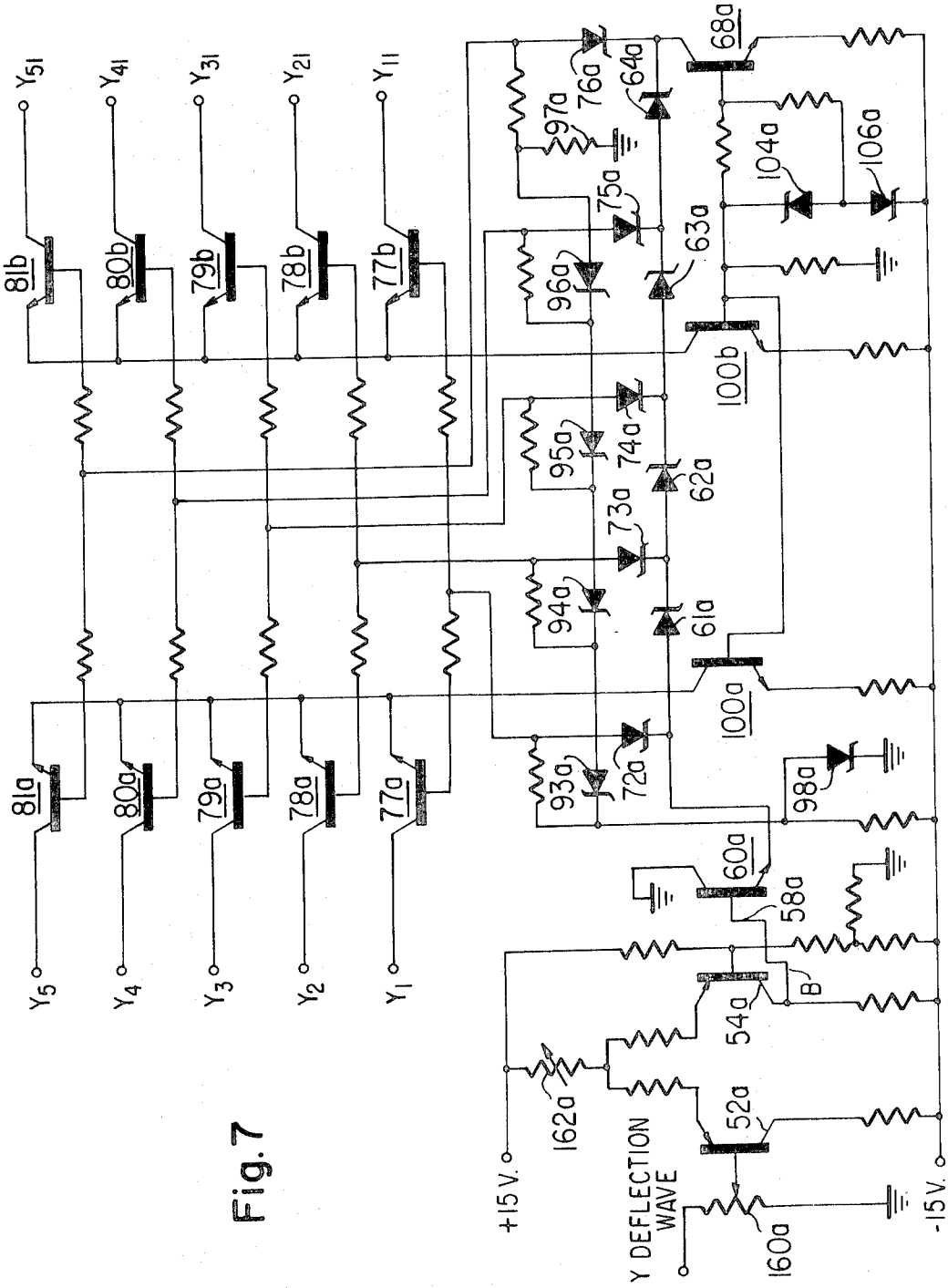


Fig. 7

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ASTIGMATISM CORRECTION FOR ELECTRON BEAM DEVICES

BACKGROUND OF THE INVENTION

In certain high-precision electron beam systems as, for example, in high-resolution, magnetically deflected and focused cathode-ray tube systems, the distortion introduced by the small deviations from roundness of the spot formed by the electron beam is a serious disadvantage. This effect, known as "astigmatism," can be partially corrected by devices known as "astigmatism coils" located on the neck of the cathode-ray tube. Such coils produce magnetic fields oriented along different axes which compensate for minor aberrations in the deflecting and focusing fields.

The amount of current required in each coil varies with the spot position. In theory, the variations of astigmatism correction current as a function of beam position are predictable but, in practice, it has been found that such things as small misalignments of the electron beam focusing coils, deflecting coils and astigmatism coils and/or variations in the cathode-ray tube dimensions, and/or small imperfections in the magnetic field due to magnetic pole piece structure defects and other factors can cause essentially unpredictable results in the astigmatism current requirements.

The object of the present invention is to provide a new and improved system for correcting astigmatism in an electron beam device.

SUMMARY OF THE INVENTION

In a system embodying the invention, a deflection field is produced which substantially fully compensates for astigmatism at a plurality of discrete, selected in advance positions of the beam. This type of field may be produced by an arbitrary function generator, the details of which are given below, Means are also provided for changing the value of the astigmatism correction field as the electron beam moves as a function of the relative distances of the beam from a plurality of said discrete positions.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a sketch to help illustrate the principle of operation of the invention;

FIG. 2 is a block diagram of a system embodying the invention;

FIG. 3 is a schematic circuit diagram of one form of triangle wave generator which may be employed in the system of FIG. 2;

FIG. 4 if a drawing of waveforms present at various points in the circuit of FIG. 3;

FIG. 5 is a block and schematic drawing of the summing potentiometer matrix of FIG. 2;

FIG. 6 is a block and schematic drawing of one of the amplifier systems of FIG. 2; and

FIG. 7 is a schematic circuit diagram of another form of triangle wave generator which may be used in the system of FIG. 2.

DETAILED DESCRIPTION

FIG. 1 illustrates 25 points on the screen of a cathode-ray tube. These correspond to deflections in the X and Y directions of the beam produced at deflection voltages of −2 volts, −1 volt, 0 volts, +1 volt and +2 volts, respectively. These voltages are measured at the outputs of the deflection wave generators of FIG. 2. At these 25 different positions, the electron beam may undergo different amounts of astigmatism. In general, the astigmatism will be greatest at the positions of the electron beam furthest from the center of the screen; however, due to the factors discussed in the introductory portion of this application, this may not necessarily be the case. Moreover, the amount of astigmatism at any one of the 25 discrete positions may not be known in advance.

In accordance with the present invention, a main deflection field is applied to the cathode-ray tube for deflecting the electron beam to each of the positions shown. A correction field is also applied to the astigmatism correction coils at each such beam position and the correction field is adjusted until any astigmatism present at that beam position is removed. In other words, the correction field is adjusted until the spot on the screen is of minimum size and most nearly round.

In the subsequent operation of the cathode-ray tube, each time the beam is of one of the 25 positions, the determined-in-advance correction field for that position is applied and the astigmatism present at that position is cancelled. In addition, the system embodying the present invention produces a correction deflection field at any position of the beam other than that shown in FIG. 1, which correcting field is a function of the distances of the beam from a plurality of the closest ones of the spots. For example, if the beam is in a position indicated by the asterisk 20, which is approximately seven-tenths of the distance from the X=−1 volt to the X=−2 volts position, the deflection current applied for astigmatism correction is $0.7I_{12}+0.3I_{11}$, where I_{12} is the astigmatism correction current at X=−2 and I_{11} is the astigmatism correcting current at X=−1. While the beam position shown by the asterisk is at the Y=+2 line, and is corrected accordingly if it were between two Y positions, the same type of process as discussed above would be employed for producing the necessary Y astigmatism correction field.

FIG. 2 is a block diagram of a system embodying the invention. The X and Y deflection wave generators 22 and 24 are conventional. They produce the X and Y deflection waves applied to the deflection yoke 26 of the cathode-ray tube illustrated schematically at 28. In the particular application chosen for illustration, the X and Y magnetic deflection fields produced by the yoke 26 in response to the X and Y deflection currents deflect the electron beam in television raster fashion.

The X deflection wave is also applied to the X triangle wave generator 30. It produces the five wave X1 through X5 illustrated in FIG. 4. These are applied to the summing potentiometer matrix 32. Five of the output waves A_1 through A_5 produced by the summing potentiometer matrix are applied to the amplifier system 34 and the other five waves A_{11} through A_{51} produced by the matrix are applied to a second amplifier system 36.

The Y deflection wave generator supplies its deflection wave to two Y triangle wave generators 38 and 40 which perform a function similar to that performed by the X triangle wave generator 30. The first triangle wave generator 38 applies its five output waves Y_1 through Y_5 to amplifier system 34 and the second Y triangle wave generator 40 applies its five output waves Y_{11} through Y_{51} to the second amplifier system 36. Amplifier system 34 produces the X astigmatism deflection current and applies it via lead 42 to the astigmatism correction coils 44. The amplifier system 36 produces the Y astigmatism deflection current and applied it via lead 46 to the astigmatism correction coils 44. The astigmatism correction coil may typically by the type DC301-5560 as manufactured by Celco Inc., Mahway, N.J. The cathode-ray tube may typically be the WX31536P11 as manufactured by Westinghouse.

In the operation of the system of FIG. 2, for the position 48 (FIG. 1) of the electron beam, the X triangle wave generator produces at output X_1 a typical current of −10 milliamperes (see FIG. 4). The other currents X_2 through X_5 are zero. In response to the current X_1, the summing potentiometer matrix 32 produces a group of output currents A_1 through A_5 and A_{11} through A_5. At the same time, the Y triangle wave generators 38 and 40 are producing maximum current outputs at leads Y_5 and Y_{51} and zero current at the remaining leads. These outputs cause one amplifier of a group of five amplifiers in system 34 to be rendered operative and one amplifier also in a group of five amplifiers of system 36 to be rendered operative (details are given later in connection with FIG. 6). These two amplifiers, one in system 34 and the other in system 36 produce the astigmatism correction currents from which are derived

the magnetic fields which are necessary for removing all the astigmatism from the spot at 48.

In a similar fashion, in response to maximum current X_2 and zero current at X_1, X_3, X_4 and X_5 and maximum current at Y_5 and Y_{51} and zero current at the remaining Y outputs, a second amplifier in system 34 and a second amplifier in system 36 are activated. These two amplifiers produce the deflection currents necessary to minimize the astigmatism of spot 50. In between the beam positions causing the spots 48 and 50, the X triangle wage generator produces currents X_1 and X_2, X_1 decreasing in the direction from 48 to 50 and X_2 increasing in the direction from 48 to 50. These cause a group of outputs to be produced by the summing potentiometer matrix. In response to this group of outputs and the outputs produced by the Y triangle wave generators 38 and 40, the value of the astigmatism correction field is varied in accordance with the beam position so that any astigmatism present between positions 48 and 50 is also corrected, to a first approximation at least.

The system of FIG. 2 includes three triangle wave generators 30, 38 and 40. As they can be substantially identical, only one of them, that is, the X triangle wave generator 30 is illustrated in FIG. 3. This generator includes a pair of PNP transistors 52 and 54 in a differential amplifier circuit. The collector 56 of transistor 54 is connected to the base 58 of transistor 60. The latter is connected as an emitter follower through series connected resistors 61, 62, 63, 64, through the collector 65 to emitter 66 path of NPN transistor 68, and through resistor 70 to the −15 volt terminal of the power supply. The voltages developed across the resistors 61–64 are applied through diodes 72 to 76 to the bases 82 to 86 of NPN transistors 77 to 81 respectively. These bases 82–86 are connected through resistors 87 to 91 respectively, to various points along a clamping circuit. The clamping circuit comprises the chain of resistors 92 to 97 connected in series between the −15 volts supply terminal and ground. A Zener diode 98 is also included in the circuit for clamping the terminal 99 of the network to −6.2 volts.

Transistor 100, whose base 102 is clamped to a fixed voltage level by the combination of Zener diode 104 and a second diode shown as a conventional diode 106, acts as a constant current source. The circuit parameters are such that it applies 10 milliamperes to the common connection 108 for the emitters of the five NPN transistors 77–81.

In the operation of the circuit of FIG. 3, the diodes 72, 73, 74, 75 and 76 initially all conduct. As the deflection wave applied to input terminal 110 increases in the positive sense, transistor 52 conducts less current and transistor 54, whose base 112 is maintained at a fixed potential, conducts more current. The wave B produced at the collector 56 is as shown in FIG. 4. This wave causes the current drawn through the emitter-to-collector path of transistor 60 to increase.

Initially, the transistor 77 passes the entire 10 milliamperes provided by the current source 100 as its base 82 is relatively more positive (actually less negative) than the bases of the other transistors 78–81. It is maintained in this condition by the conducting diode 72 as circuit point 114 is more positive than (is closer to ground than) the remaining circuit points 115, 116, and so on. However, as the wave B becomes more positive, (actually less negative) and the potential at the cathode of diode 72 reaches a value within a fraction of volt of its anode, diode 72 stops conducting. When this occurs, the base 82 of transistor 77 becomes clamped through resistor 87 to the potential of −6.2 volts present at circuit point 99. The diode 73, however, is still conducting and point 115 of the circuit is at a potential such that transistor 78 begins to draw current.

The circuit condition is that illustrated at time T_0 in FIG. 4. During the period from time T_0 to time T_1, transistor 77 draws decreasing current and transistor 78 increasing current, all as shown in FIG. 4. At time T_1, transistor 78 draws all of the current provided by the current source 100 and the current passing trough transistor 77 is reduced to zero.

The operation described above continues in response to the increasing value of voltage present at B. In other words, immediately after time T_1, when diode 73 cuts off, the current X_2 flowing through transistor 78 starts to decrease and an increasing amount of current X_3 starts to flow through transistor 79. This process continues until time T_2 when transistor 78 cuts off, transistor 79 draws maximum current and diode 74 cuts off. In a similar manner, full triangle waves X_3 and X_4 are produced by transistors 79 and 89 respectively, and half triangle wave X_5 is produced by transistor 81.

The five triangle waves X_1 through X_5 are applied to the summing potentiometer matrix as shown in FIG. 5. This matrix consists of five rows and 10 columns. At each column-row intersection, there is a potentiometer 120 connected at its slider through the fixed resistor 122 to the row lead. The second terminal 124 of the potentiometer is connected to the column lead and the third terminal 126 of the potentiometer is connected to ground. To simplify the drawing, some of these column-row intersections are shown by boxes, however, the structure is identical at each such intersection. Five of the column leads produce outputs A_1 through A_5 and the remaining five column leads produce outputs A_{11} through A_{51}.

In tee operation of the matrix of FIG. 5, when a current such as X_1 is applied to a row lead, 10 output currents A_i are produced by the matrix. If two input currents such as X_2 and X_3 are present at the same time, these currents are effectively summed in the matrix to produce the ten A_i output currents. The function of these currents will be better understood from the explanation which follows of FIG. 6.

As the two amplifier systems 34 and 36 of FIG. 2 are identical, only one of them is shown at FIG. 6. This circuit includes five amplifiers 130–134 respectively. These may be commercially available integrated circuit amplifiers such as *ua*726*c* manufactured by Fairchild Manufacturing Company. Each amplifier comprises a matched pair of transistors with special control characteristics such that the current going into the emitters 3, 10 (two emitters are connected in parallel) is divided to the collectors in proportion to the difference of voltage between the two bases 1 and 2. An output current such as A_1 of the matrix is applied to the base 2 of amplifier 130. A Y triangle wave such as Y_1 produced by a Y triangle wave generator is applied to the common connection for emitters 3 and 10. The base 1 is connected to the slider 140 of the potentiometer 144. As explained shortly, after this slider is set it remains set so that the base 1 of each amplifier remains connected to some fixed value of bias voltage.

In view of the explanation above, it is clear that not more than two of the amplifiers 130–134 are operative at any one time. If, for example, the wave Y applied to an amplifier is at a value of zero current, that amplifier is effectively out of the circuit since there is no current to be divided by the amplifier.

When there is a current such as Y_1 present at a Y input to an amplifier, it is divided proportionally between the two collectors 4 and 9. The voltages generated by these two currents flowing through R_1 and R_2 are subtracted one from the other by the differential amplifier 150. This differential amplifier also is a commercially available circuit such as amplifier model No. 149B produced by Analog Devices Company. Its purpose is to produce an output proportional to the difference in voltages applied to its input.

In operation of the system, the gain potentiometer 160 and the centering potentiometer 162 of the circuit of FIG. 3 initially are adjusted until the peaks of the X triangle waves shown in FIG. 4 occur at values of X deflection voltage equal to −2 volts, −1 volt, 0 volt, +1 volt and +2 volts, for the example shown in FIG. 1. The same adjustment is made in the Y triangle wave generators 38 and 40 for the corresponding Y deflection voltages. Next, all the potentiometers of the matrix are adjusted to midway and the centering potentiometers 144 (FIG. 6) for both amplifier systems 34 and 36 of FIG. 2 are adjusted to produce zero volts out of the summing amplifier 150 (0 volts present at output terminal 170) for any value of X or Y. This initial adjustment permits generation of both positive

and negative astigmatism correction currents and leaves the circuit ready for use.

The system may now be set up for the particular cathode-ray tube 28 of FIG. 2 to which it is connected. First, preliminary adjustments are completed for the cathode-ray tube focusing yoke (not shown), deflection yoke 26 and other elements properly to position the raster and accurately to focus the beam. With the beam focused in this way, a direct voltage is applied to terminal 110 and to the corresponding terminal 110 of the two Y triangle wave generators 38 and 40 to position the beam to one of the 25 spots. For example, the beam may be positioned so that the spot is at location 48 of FIG. 1. At this location, the current X_1 is at −10 milliamperes and the remaining currents X_2 to X_5 are zero. This means that only the potentiometers connected to the first row of the matrix are producing output currents. At this same position, only the Y deflection currents Y_5 and Y_{51} are present, the remaining Y deflection currents being zero. Therefore, only the amplifier 134 of FIG. 6, and the corresponding amplifier of the second system 36 are active. Amplifiers 130, 131, 132 and 133 produce no output currents as Y_1, Y_2, Y_3 and Y_4 are all zero, and the same holds for the corresponding four amplifiers of system 36.

The active amplifier 134 receives only a single output that is A_5, of the matrix 32 and the corresponding active amplifier of system 34 also receives only a single such output, namely A_{51}, To adjust for astigmatism at this position, therefore, it is only necessary to adjust the potentiometer networks namely 172 and 174 of FIG. 5 which produce currents A_1 and A_{51} respectively, when X_1 is present and X_2–X_5 are all equal to zero. These two potentiometers are adjusted until the spot 48, which may be observed through a magnifying lens or other optical means, is of minimum size and is most nearly round.

The same procedure as above may be repeated for the remaining 24 spots of FIG. 1. At each such spot, it is necessary to adjust only two potentiometers, one at the left side of the matrix of FIG. 5 and the other at a corresponding location at the right side of the matrix of FIG. 5. Thus, all 25 spot positions can be corrected for astigmatism independently of one another, with essentially no interaction.

With the adjustments made in the way described above, the system automatically provides approximately correct compensating astigmatism deflection currents for all electron beam positions other than the 25 shown in FIG. 1. For example, at a beam position between that indicated by spots 48 and 50, X_1 and X_2 will have same value other than zero and less than 10 milliamperes (where $X_1+X_2=10$ milliamperes). If at the same time Y=−2 so that only amplifiers 134 in systems 34 and 36 are active, the current A_5 (produced by networks 172 and 173) will be the weighted average of the currents X_1 and X_2 so that the astigmatism deflection field derived from A_5 will be proportional to the distance of the spot between points 48 and 50 of FIG. 1. The same holds for current A_{51} produced by the two networks 174 and 175 and for the correction field derived from these currents. If Y is some value intermediate say Y=−2 and Y=−1, then Y_4 and Y_5 (and Y_{41} and Y_{51}) both will have some value other than zero and less than 10 milliamperes (where $Y_4+Y_5=Y_{41}+Y_{51}=10$ milliamperes.) In this case, two amplifiers 133 and 134 will be active in each amplifier system 34 and 36. The outputs of these amplifiers, in each case, are combined in the summing amplifier 150 of each system. In each case an astigmatism deflection field is produced having a value intermediate that produced at Y=−2 and y=−1 in FIG. 1 and which, in fact, is proportional to the distance of the spot between Y=−1 and Y—2.

It is found in practice, that the approximate astigmatism corrections discussed above are adequate for an extremely high-quality picture. The quality is sufficiently high, for example, to permit high-quality photographs to be taken of the pages of a book, newspaper or the like for photocomposing.

A second form of a triangle wave generator is shown in FIG. 7. Circuit elements which perform a function in FIG. 7 corresponding to that of elements in FIG. 3 are identified by the same number followed by the letter *a*. The principle difference between the two circuits is first that the resistor chains are replaced with Zener diode chains. However, note that the Zener diodes are connected to conduct in the forward direction rather than operating in the breakdown mode. An important advantage of employing Zener diodes in this particular application is that in the forward direction their dynamic resistance at the point at which they are being operated is quite low. For this reason, variations in load current do not appreciably affect the voltage drop across the diodes.

In the circuit of FIG. 3, there are five output transistors. In the circuit of FIG. 7, there are 10 output transistors. The first five transistors are supplied by constant current source 110*a* and the second group are supplied by a second constant current source 100*b*. The circuit shown in FIG. 7 may be employed for both triangle wave generators 38 and 40. A similar circuit may be employed for the X triangle wave generator 30, however, here five of the outputs are not used.

In the circuit of FIGS. 4 and 7, it is preferred to use integrated circuit packages for certain of the elements. For example, the differential amplifier 52, 54 may be an RCA model No. 198069–1. The five transistors 77–81 may come in a single package identified as model No. CA4036 manufactured by RCA. Aside from economy, the group of five transistors integrated onto a common substrate and in a single package simplifies temperature stability and gain matching problems. In a similar manner, the transistor 68 may be two transistors of a CA4936 package connected in parallel; the diode 106 of FIG. 3 may be the emitter-to-base diode of one transistor of the same package; the constant current source 100 may be one transistor of the same package; and the transistor 60 may be the fifth transistor of the same package.

What is claimed is:

1. A circuit for correcting astigmatism in an electron beam deflection system comprising, in combination;

means for applying to said electron beam deflection system an astigmatism correction deflection field which substantially fully compensates for astigmatism at a plurality of discrete, selected in advance positions of the beam; and

means responsive to voltages indicative of the electron beam position for changing the value of the astigmatism deflection field as the electron beam moves as a function of its relative distances from a plurality of said discrete positions.

2. A circuit for correcting astigmatism in an electron beam deflection system comprising, in combination:

means for applying to said electron beam deflection system a main deflection field for deflecting the electron beam;

means for separately applying to said electron beam deflection system an astigmatism correction field which substantially fully compensates for astigmatism at a plurality of discrete, selected in advance positions of the beam, said means including a matrix of impedance means, each such means corresponding to an electron beam position; and

means including said matrix of impedance means responsive to voltages indicative of the beam position for changing the value of the deflection field as the electron beam moves as a function of its relative distances from a plurality of said discrete positions.

3. An arrangement for correcting astigmatism in a magnetically deflected cathode-ray tube comprising, in combination:

a main deflection yoke on said cathode-ray tube;

astigmatism correction coils on said cathode-ray tube;

means for applying deflection currents to said yoke for deflecting said electron beam; and

an arbitrary function generator responsive to said deflection currents for applying to said astigmatism correction coils correction currents for correcting astigmatism of said electron beam at a plurality of discrete, known in advance positions of said beam.

4. An arrangement set forth in claim 3, wherein said arbitrary function generator includes a summing matrix responsive to currents derived from said deflection currents for producing correction currents of values intermediate those produced at said discrete positions of said beam when said beam is intermediate said discrete positions.

5. A circuit for deriving from a sweep voltage a plurality of waves comprising, in combination:

a constant current source;

a plurality of active elements, each having a conduction path, said paths being connected at one end to said constant current source and the other end of each path serving as an output terminal, each such element having also a control electrode for controlling the conductivity of its conduction path;

a bias network for applying to said control electrodes successively higher values of bias;

a second network receptive of said sweep voltage for applying to said control electrodes successively lower levels of signal in a sense such that the signal tending to cause maximum current through an active element is applied to the active element receiving *a* value of bias tending to cause minimum current flow through the active element, and the signal tending to cause minimum current through an active element is applied to the active element receiving a value of bias tending to cause maximum current flow through the active element, the initial relative values of said bias and said sweep voltage being such that only said active element receiving said lowest bias initially passes said constant current; and

means in said second network responsive to said sweep voltage for successively disconnecting said control electrodes from said second network as said sweep voltage amplitude increases, beginning with the control electrode for the active element receiving the value of bias tending to cause minimum current flow, thereby, in each case, clamping the disconnected control electrode solely to said bias network, whereby each time a control electrode is disconnected, the current passing through the conduction path of its active element starts to decrease and the current passing through the conduction path of the active element receiving the next higher value of bias starts to increase and continues to increase until it draws all of the current supplied by said constant current source.

6. A circuit as set forth in claim 5, wherein said active elements comprise transistors.

7. A circuit as set forth in claim 6, wherein said transistor are all in a single integrated circuit package.

8. A circuit as set forth in claim 5, wherein said bias network comprises a plurality of impedance elements connected in series between two terminals of a direct current source.

9. A circuit as set forth in claim 8, wherein said impedance elements comprise Zener diodes connected to conduct in the forward direction.

10. A circuit as set forth in claim 5, wherein said last-named means comprises a plurality of normally conducting diodes coupling said bias network to said control electrodes.

11. A circuit for correcting astigmatism in an electron beam deflection system comprising, in combination:

means responsive to vertical and horizontal sweep waves for applying to said electron beam deflection system a main deflection field for deflecting the electron beam;

means for deriving from each horizontal sweep wave a group of successive first sweep waves, each corresponding to a different amplitude increment of the horizontal sweep wave;

means for deriving from each vertical sweep wave a group of successive second sweep waves, each corresponding to a different amplitude increment of the vertical sweep wave;

a matrix of impedance means arranged in columns and rows, each impedance means corresponding to a discrete electron beam position;

means applying the respective first sweep waves to the respective rows of said matrix; and

means responsive to voltages at the columns of said matrix and to said second sweep waves for separately applying to said electron beam deflection system an astigmatism correction field which substantially fully compensates for astigmatism at the plurality of discrete positions of said electron beam corresponding to the elements of said array and for changing the value of the deflection field as the electron beam moves, as a function of its relative distances from a plurality of said discrete positions.

12. In the combination as set forth in claim 11, said means responsive to said vertical and horizontal sweep waves comprising the main deflection means for said electron beam and the last-named means comprising a second deflection means independent of said main deflection means.

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