July 7, 1970 J. E. MURRAY 3,519,876

ALPHANMERIC CHARACTER DISPLAY

Filed July 26, 1968 3 Sheets-Sheet 1

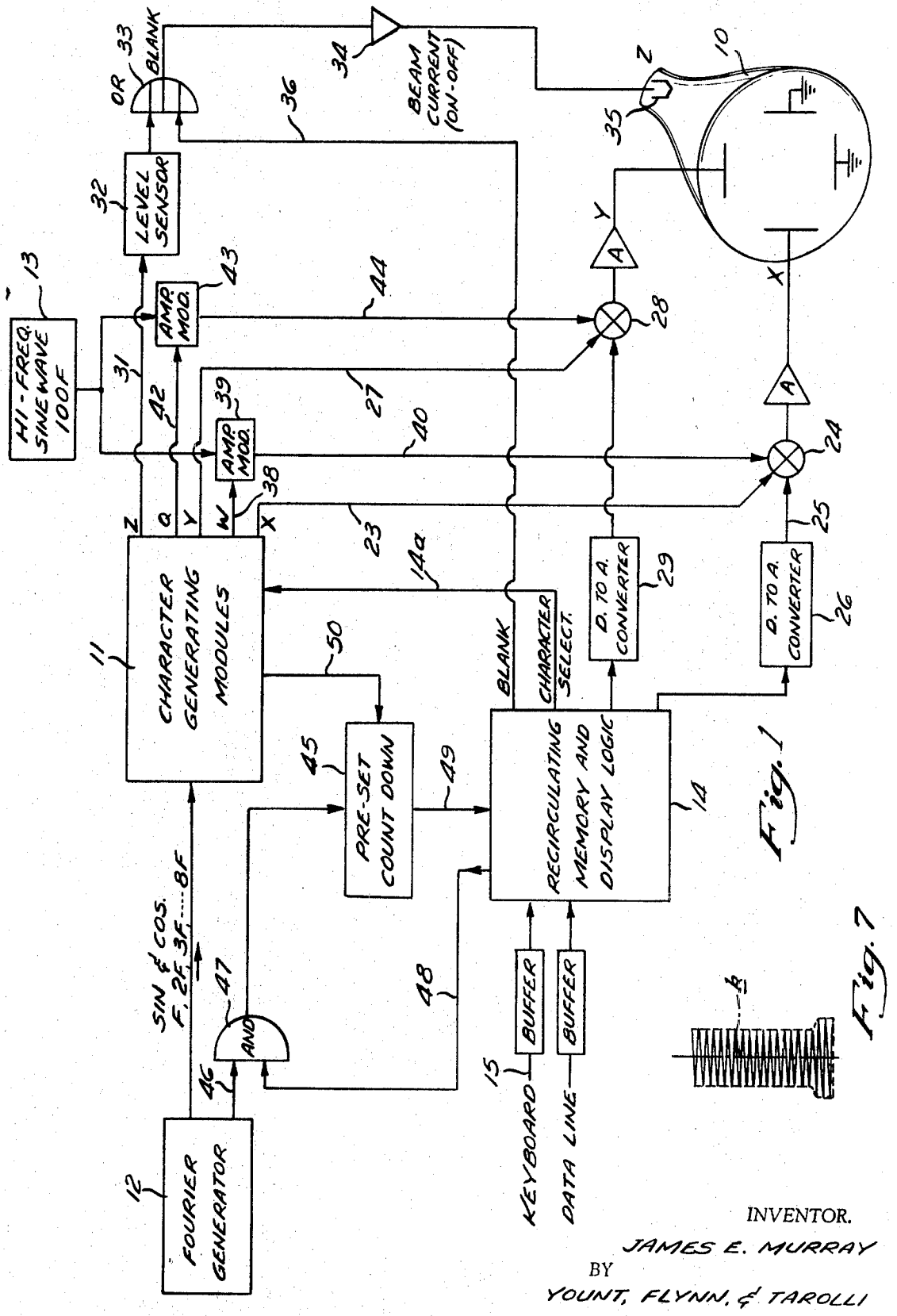



Fig. 1

Fig. 7

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ALPHANMERIC CHARACTER DISPLAY

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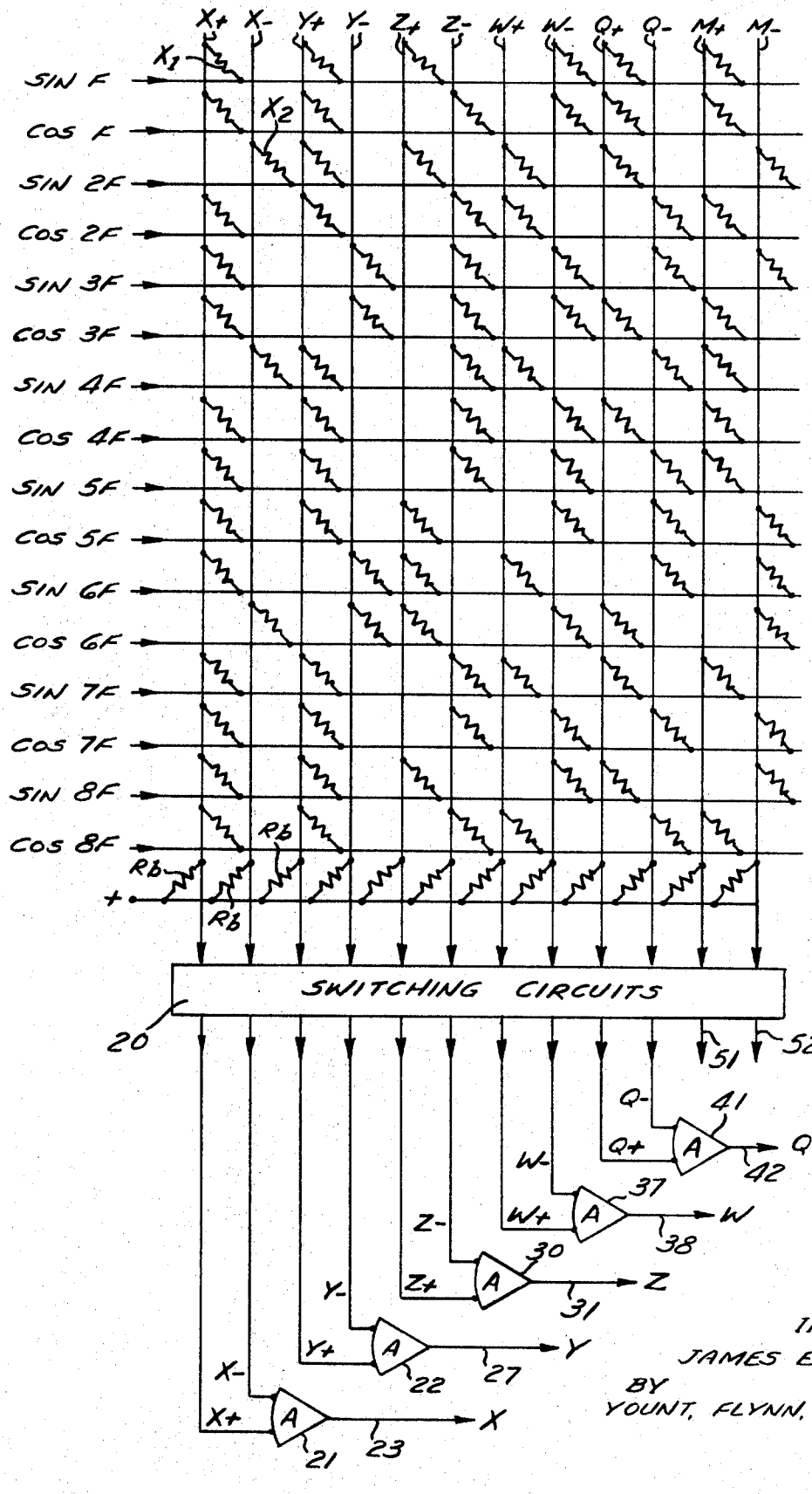



Fig. 2

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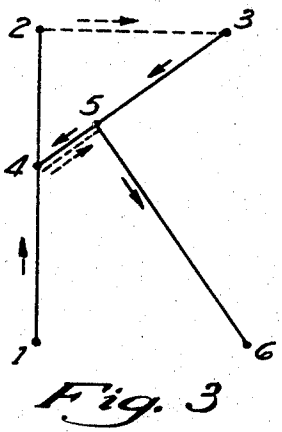



Fig. 3

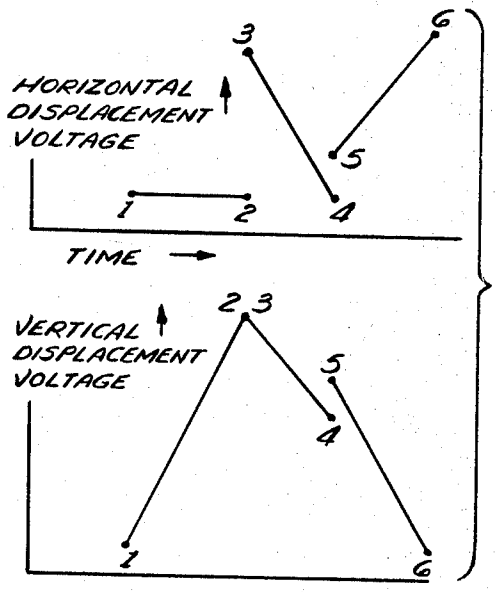



Fig. 4

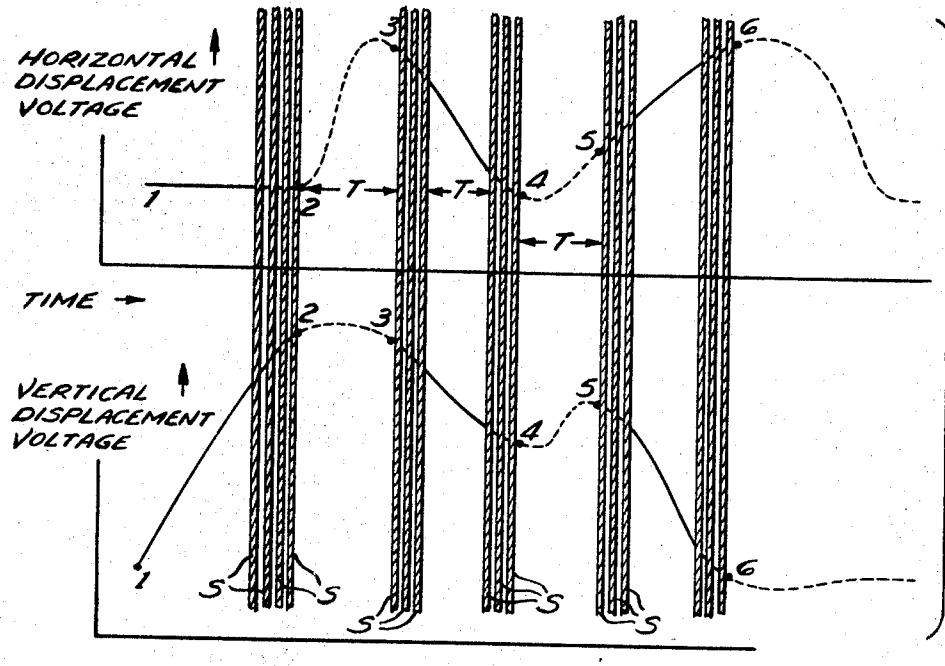



Fig. 5

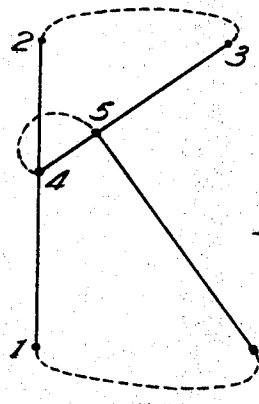



Fig. 6

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United States Patent Office

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Patented July 7, 1970



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# ALPHANUMERIC CHARACTER DISPLAY

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Int. Cl. H01v 29/70

U.S. Cl. 315—18

15 Claims

## ABSTRACT OF THE DISCLOSURE

System and method for displaying alphanumeric characters on the face of a cathode ray tube. The horizontal and vertical deflection voltages for the cathode ray beam are developed from a Fourier series generator acting through resistance matrices to provide the coefficients of the terms in the Fourier series expressions for the different characters. The beam current is turned on and off by the Fourier series generator in synchronism with the instantaneous beam position. The beam deflection velocity is reduced near discontinuities in the beam trace to eliminate high frequency harmonics in the Fourier series expressions for the horizontal and vertical deflection voltages. A high frequency wobble is superimposed on the deflection voltages to impart a variable thickness to the beam trace laterally of the general direction of its deflection across the face of the tube, so that the character traces will be of typographic quality.

The present invention is directed to a system and method for generating alphanumeric characters, such as on the face of a cathode ray tube, by providing analog horizontal and vertical deflection voltages, each of which may be defined by a Fourier series expression.

Various systems have been proposed heretofore for generating alphanumeric characters on the face of a cathode ray tube by applying deflection voltages which determine the instantaneous position of the beam trace on the face of the tube. In general, such systems fall into three categories:

(1) Relatively crude systems in which the character is composed of narrow-line segments displaying merely the approximate outline of the character and omitting any details contributing to typographic quality;

(2) Relatively expensive systems in which digital control of a raster scan determines the length of a line; and

(3) Relatively expensive and complicated systems in which digital control signals displace the beam from point-to-point across the face of the cathode ray tube to provide a display character of typographic quality.

The present invention is directed to a system and method which avoids the expense and complexity of the point-to-point and digitally controlled raster scan systems, while at the same time enabling the generation of alphanumeric characters of sufficient typographic quality that they may be read without the strain or annoyance associated with the reading of narrow-line segment characters of the type produced by certain of the prior art systems.

The present system generates a set of synchronized sine waves and cosine waves which are operated on by character module impedances to produce appropriate Fourier series horizontal and vertical voltages for generating the characters in analog fashion. Preferably, an amplitude-modulated high frequency "wobble" is superimposed on these deflection voltages to displace the beam trace laterally of its instantaneous general direction of movement across the face of the cathode ray tube by the deflection voltages, so as to impart to the beam trace a "thickness" which may be varied at different parts of the character trace to enhance its typographic quality and



readability. The beam current is turned on and off during the different portions of the deflection voltage wave forms where the beam trace is to be visible and invisible, respectively, so that the beam trace will display only those segments which are part of the character itself, with the connecting segments being blanked out. The turning on and off of the beam current is under the control of the Fourier generator so that the condition of the beam current will correspond precisely to the instantaneous beam position, regardless of variations in the beam deflection velocity across the face of the cathode ray tube. Preferably, the beam deflection velocity is reduced in the vicinity of discontinuities or direction changes in the deflection voltage wave forms so as to minimize the number of harmonics required to provide an adequate Fourier series expression of these deflection voltage wave forms.

It is a principal object of this invention to provide a novel and improved system and method for displaying alphanumeric characters under the control of analog signals.

Another object of this invention is to provide such a system and method employing a Fourier series generator to provide analog deflection voltages for a cathode ray beam and to turn the beam current off during those portions of the beam trace which do not form part of the character itself.

Another object of this invention is to provide such a system and method in which the deflection velocity of the beam trace is reduced in the vicinity of discontinuities or changes of direction, so as to minimize the harmonics required of the Fourier series generator to provide the desired deflection voltage wave forms.

Another object of this invention is to provide such a system and method having novel provision for imparting line thickness and typographic quality to the cathode ray beam trace which provides the character display.

Further objects and advantages of this invention will be apparent from the following detailed description of a presently-preferred embodiment, with reference to the accompanying drawings in which:

FIG. 1 is a schematic block diagram of a system in accordance with the present invention;

FIG. 2 is a circuit diagram showing the resistance matrix to be connected to the Fourier series generator for generating a particular alphanumeric character on the face of a cathode ray tube in accordance with the present invention;

FIG. 3 shows a thin line trace of a letter, capital K, having abrupt discontinuities;

FIG. 4 shows the horizontal and vertical deflection voltages, plotted against time, for generating this capital K with the abrupt discontinuities being present and allowing no time for the beam-off segments of the trace which join successive spaced-apart visible segments of the letter;

FIG. 5 is a view similar to FIG. 4, but with the deflection voltages modified in accordance with the present invention to provide a beam deflection slow-down near each discontinuity in one or both deflection voltages and to provide adequate beam-off time periods between successive spaced-apart visible segments of the letter;

FIG. 6 is a view similar to FIG. 3 and showing the beam trace produced by the modified deflection voltages of FIG. 5; and

FIG. 7 is a fragmentary view showing the effect on the beam trace of the wobble signal.

## GENERAL DESCRIPTION

The present invention is based in part upon the principle that a repetitive wave form may be expressed as a Fourier series:

$$A_0 \pm A_1 \sin F \pm B_1 \cos F \pm A_2 \cos 2F \pm B_2 \cos 2F \ldots \pm A_n \sin nF \pm B_n \cos nF$$

Referring to FIG. 1, the present system has a cathode ray tube **10** for displaying analog-generated cathode ray beam traces of alphanumeric characters, such as letters, numbers, punctuation symbols, and the like. The horizontal and vertical deflection voltages for the cathode ray beam are produced by a character-generating module network **11**. A Fourier series generator **12** is connected to provide to the input of the character-generating module network a sine wave and a cosine wave of a predetermined fundamental frequency F, and also a certain number of sine and cosine harmonics, such as the second through the eighth harmonics, of this fundamental frequency. The character-generating module network **11** includes a plurality of resistance matrices, one for each alphanumeric character to be generated Each resistance matrix also provides the D.C. term, $A_0$, in the Fourier series expression of the repetitive closed wave form which includes that character. This much of the system would produce alphanumeric characters on the face of the cathode ray tube composed of narrow, uniform width lines, with the beam being blanked during those segments of the repetitive closed wave form which connect the visible segments which make up the character itself.

For the purpose of providing characters of typographic quality, or approaching such quality, a high frequency "wobble" signal from a sine wave source **13** is superimposed upon the horizontal and vertical deflection voltages. This superimposed "wobble" signal rapidly displaces the beam a short distance back and forth substantially perpendicular to the general direction in which it is then being deflected across the face of the cathode ray tube, so as to add thickness to the beam trace. The instantaneous amplitude and the direction in which this wobble signal displaces the beam are controlled by the Fourier generator **12** acting through character-generating module network **11**, so that the displayed character trace may have different line thicknesses at different portions of its extent, in accordance with accepted typographic principles.

The beam current for the cathode ray tube **10** is turned on and off under the control of the Fourier generator **12** acting through the character-generating module network **11**, so that the beam will be on when it is being deflected along a segment of the selected alphanumeric character which is to be visible and it is turned off while it is being deflected from one such segment of the character to the next segment.

The gross beam position (i.e., the starting position of the beam on the face of the cathode ray tube just before a character is to be generated) is controlled by a recirculating memory and display logic circuit **14**. This circuit **14** also controls the selection of the character to be generated in accordance with the instructions from a keyboard input **15**. Circuit **14** also turns off the beam circuit during intervals when the gross beam position is being changed.

## CHARACTER GENERATION

Referring to FIG. 2, in the particular example shown, the Fourier series generator produces synchronized sine and cosine signals of the fundamental frequency, F, and each harmonic, 2F, 3F . . . etc. up to and including the eighth harmonic, 8F. As they come out of the Fourier series generator these fundamental and harmonic sine and cosine signals all have the same amplitude. The fundamental frequency may be about 10 kilocycles per second in one practical embodiment.

Each of the character-generating modules in the network **11** includes a resistance matrix of the type shown in FIG. 2, there being one resistance matrix for each character which may be generated This resistance matrix is composed of individual resistors having resistance values which determine the coefficients of the respective fundamental and harmonic sine and cosine components of the X (horizontal) and Y (vertical) deflection voltages for the corresponding alphanumeric character. Each of these



deflection voltages for a particular character consists of a Fourier series of the following general type:

$$V_d = A_0 \pm A_1 \sin F \pm B_1 \cos F \pm A_2 \sin 2F \pm B_2 \cos 2F \ldots \pm A_8 \sin 8F \pm B_8 \cos 8F$$

The ohmic value of each resistor for a particular sine or cosine component, fundamental or harmonic, is inversely proportional to the magnitude of the coefficient of that sine or cosine component. For example, in the resistance matrix shown partially in FIG. 2, the ohmic value of resistor $X_1$, which is connected between the sin F input from the Fourier generator and the X+ line in the resistance matrix, is inversely proportional to the magnitude of the $+A_1$ coefficient in the Fourier series expression for the X deflection voltage of the corresponding alphanumeric character. Similarly, the ohmic valve of resistor $X_2$, which is connected between the sin 2F input from the Fourier generator and the X— line in the resistance matrix, is inversely proportional to the magnitude of the $-A_2$ coefficient in the Fourier series expression for this X deflection voltage. In like manner, for each of the other coefficients which appears in the Fourier series expression for the X or Y deflection voltage for this character, a resistor is connected between the corresponding output of the Fourier generator and the respective X+, X—, Y+, or Y— line of the resistance matrix for this character.

At the lower end of the resistance matrix, bias resistors $R_b$ are connected between a positive input terminal and each of the lines X+, X—, etc to produce a predetermined D.C. bias on the latter which provides the term, $A_0$, in the Fourier series expression of the deflection voltage wave form.

The character-generating module network **11** also includes switching circuits **20** (FIG. 2) connected between the X+, X—, Y+ and Y— lines of all the resistance matrices for the difference individual characters and the respective X+, X—, Y+ and Y— inputs to respective operational amplifiers **21** and **22**. These switching circuits **20** are controlled by a character selection output signal on line **14***a* in FIG. 1 from the recirculating memory and display logic network **14**, such that only one resistance matrix at a time will be connected to the amplifiers **21** and **22**. The particular resistance matrix thus connected will correspond to the particular alphanumeric character which is then to be generated.

The X deflection operational amplifier **21** in the character generating module network **11** has an output line **23** leading to a summing network **24** (FIG. 1). This summing network **24** also receives an input signal via line **25** from a digital-to-analog converter **26** which is connected to the recirculating memory and display logic network **14** to receive from the latter a gross positioning signal which determines the X deflection signal for the cathode ray tube **10** in the absence of an X deflection output signal on line **23** from the character-generating module network **11**. That is the gross positioning signal on line **25** determines the general horizontal location of the cathode ray beam on the face of the cathode ray tube, and the character-generating X deflection signal on line **23** is superimposed upon this gross positioning signal to vary the beam position in accordance with the particular portion of the alphanumeric character then being generated.

Similarly, the Y deflection amplifier **22** in the character-generating module network **11** has an output line **27** leading to a summing network **28** (FIG. 1), which superimposes the character-generating Y deflection signal (on line **27**) on a gross positioning vertical deflection signal coming from a digital-to-analog converter **29** connected to the recirculating memory and display logic network **14**.

The horizontal and vertical gross positioning signals coming out of the network **14** are in digital form, and the respective D.-to-A. converters **26** and **29** convert these digital signals to analog voltages in a known manner.

## BEAM CURRENT CONTROL

As shown in FIG. 2, the resistance matrix for the generating of each character includes Z+ and Z— lines, which are connected to the sine and cosine fundamental and harmonic inputs to the matrix from the Fourier generator through resistors in the same manner as the connections of the X+, X— Y+ and Y— lines. The purpose of these resistance connections of the Z+ and Z— lines to the Fourier generator inputs is to turn the beam current for the cathode ray tube **10** on and off in accordance with the instantaneous beam position. That is, instead of having fixed beam-on and beam-off periods, the beam-on and beam-off periods are under the direct control of the Fourier generator. This enables the system to have a variable beam velocity while still providing exact synchronism or correspondence between the instantaneous beam position and the beam current condition (i.e., on or off).

Lines Z+ and Z— in the resistance matrix are connected through the switching circuits **20** to the positive and negative inputs of an operational amplifier **30**. The net input to amplifier **30** follows a Fourier series expression having fundamental and harmonic sine and cosine terms whose coefficients are determined by the respective resistors connected between the inputs from the Fourier generator and the Z+ and Z— lines in the resistance matrix such that the difference between the Z+ input to the operational amplifier **30** and the Z— input exceeds a predetermined level at every instantaneous beam position where the beam is to be on, and the difference between the Z+ signal and the Z— signal is below this level at every instantaneous beam position where the beam is to be off. Because the X and Y deflection voltages and the Z+ and Z— output signals from the resistance matrix are all under the control of the same Fourier generator, the beam current on and off conditions correspond precisely to the beam position, as determined by the X and Y deflection voltages coming out of the respective operational amplifiers **21** and **22**, regardless of the beam velocity. That is, changes in the beam velocity do not result in erroneous timing of the beam-on and beam-off conditions.

The output from the beam current control amplifier **30** in the character-generating module network **11** is connected via line **31** to a level sensor **32** (FIG. 1), which either passes or does not a beam current turn-off signal into an OR gate **33**, depending upon the difference between the Z+ and Z— signals going into the differential amplifier **30**. If this beam current turn-off signal is produced by the level sensor **32**, it passes through the OR gate **33** to an amplifier **34** connected in the energization circuit for the cathode **35** of the cathode ray tube **10**.

The OR gate **33** has a second input line **36** connected to the recirculating memory and display logic network **14**, which provides a beam current turn-off signal while the gross position of the beam is being changed.

In the absence of a turn-off signal on either of its inputs, the OR gate **33** permits the amplifier **34** to pass beam current to the cathode ray tube. If a beam turn-off signal is present on line **36**, the OR gate **33** causes the amplifier to block the beam current until beam has been moved to its new gross position. Also, if a beam turn-off signal is received from the level sensor **32** while a character is being generated, the OR gate **33** causes the amplifier to block the beam current until the beam has been displaced to a point where the character trace is to be visible again.

## BEAM TRACE THICKNESS CONTROL

In the preferred embodiment of this invention, a high frequency, variable amplitude "wobble" signal is superimposed on the horizontal and vertical deflection control signal inputs to the cathode ray tube **10** so as to impart the desired instantaneous thickness to the beam trace on the face of the tube. To achieve this effect, the wobble signal displaces the beam rapidly back and forth substantially perpendicular to the general direction in which it is then being moved by the X and Y displacement signals on lines **23** and **27**. This effect is illustrated in FIG. 7 for the lower end of the vertical segment of the letter, capital K. The general direction of the beam deflection is designated by the centerline *k*, and the high frequency wobble signal causes the actual beam trace to move back and forth laterally across this centerline substantially perpendicular to the centerline.

Referring to FIG. 2, the resistance matrix for each alphanumeric character to be generated has four lines designated W+, W—, Q+ and Q—, respectively. The W+ and W— lines provide the positive and negative amplitude modulation for the high frequency wobble signal, which is then super-imposed on the horizontal deflection voltage. The Q+ and Q— lines provide the positive and negative amplitude modulation for the high frequency wobble signal, which is then superimposed on the vertical deflection voltage.

Each of these lines W+, W—, Q+ and Q— is connected to the fundamental and harmonic sine and cosine inputs from the Fourier generator through individual resistors in the same manner as the other lines X+, X—, Y+, Y—, Z+ and Z— in the resistance matrix.

The W+ and W— lines in this resistance matrix are connected through the switching circuits **20** to the W+ and W— inputs of an operational amplifier **37**. The output signal from this operational amplifier has an instantaneous amplitude proportional to the difference in magnitude between its W+ and W— input signals. This differential output signal on line **38** (FIG. 1) is applied to the control terminal of a modulator **39**, in which its amplitude modulates a high frequency sinusoidal input signal from the wobble signal source **13**, which operates at a frequency of approximately 100 times the fundamental frequency of the Fourier generator **12**. This amplitude modulated wobble signal output from modulator **39** is applied via line **40** to the summing network **24** which also receives the horizontal gross positioning signal on line **25** and the character-generating horizontal deflection signal on line **23**.

Similarly, the Q+ and Q— lines in the FIG. 2 resistance matrix are connected through the switching circuits **20** to the Q+ and Q— inputs of an operational amplifier **41**. The output signal from this amplifier on line **42** (FIG. 1) is applied to the control terminal of a modulator **43**, in which the high frequency wobble signal from the source **13** is amplitude modulated by the wobble-modulating signal on line **42**. The amplitude modulated wobble signal coming out of modulator **43** is applied via line **44** to the summing network **28** which also receives the vertical gross positioning signal output from the D.-to-A. converter **29** and the character-generating vertical deflection signal on line **27**.

In this manner, the character-generating displacement voltages are displaced back and forth at high frequency by the wobble signals in accordance with the predetermined desired instantaneous line thickness of the character trace on the face of the cathode ray tube **10**. The instantaneous amplitude of this wobble signal and the direction of the wobble signal, as applied to the principal character-generating horizontal and vertical displacement voltages, are both controlled by the same Fourier generator as provides these principal displacement voltages. Consequently, the wobble signal will corresepond to the actual position of the beam throughout its movement when a character is being generated, regardless of differences in the velocity of the beam's movement across the face of the cathode ray tube **10** at different points along the character.

## CHARACTER RE-TRACING

The FIG. 1 system also includes a pre-set count-down circuit **45** which controls the number of times a character

is traced and re-traced at a given gross position on the face of the cathode ray tube **10**.

One of the fundamental wave output signals from the Fourier generator, either the sin F wave or the cos F wave, is connected by line **46** to one input of an AND gate **47**. This AND gate is held open by an output signal on line **48** from the recirculating memory and display logic network **14** which begins after the beam has been gross-positioned for a new character and lasts until the character trace has been re-traced a certain number of times. Each cycle of the fundamental wave input on line **46** passes through the AND gate **47** to reduce by one the count stored in the pre-set count-down circuit **45** until the stored count is down to zero. At that time, the count-down circuit delivers a signal via line **49** to the recirculating memory and display logic network **14** to cause the latter to stop the signal on line **48** which has been holding the AND gate **47** open and also to deliver a signal via line **14***a* to the switching circuits **20** in the character-generating module network **11** to cause the latter to connect to its output lines **23, 27, 31, 38** and **42** to the resistance matrix for the next character to be generated. After this switching has occurred, the switching circuits **20** deliver a signal via line **50** which restores the pre-set original count in the count-down circuit **45** to begin the next count down of the number of repetitive beam traces of this next character.

## BANDWIDTH COMPRESSION DURING CHARACTER GENERATION

As an illustrative example, FIG. 3 shows in straight-line form the capital letter K, which may be formed on the face of a cathode ray tube by displacing the beam vertically from point **1** to point **2** while the beam is on, then turning the beam off while displacing it horizontally to the right to point **3**, then turning on the beam and moving it diagonally downward to the left from point **3** to point **4**, then turning the beam off while displacing it upward and to the right to point **5**, and then turning on the beam and moving it diagonally downward to the right from point **5** to point **6**.

FIG. 4 shows, plotted against time, the horizontal and vertical displacement voltages for generating this capital K with a constant beam velocity, these displacement voltages being shown only for the character strokes when the beam is on. Obviously, a finite time is required to move the beam while it is turned off from point **2** to point **3**, and later from point **4** to point **5**. These beam-off times may be visualized by interposing a horizontal (time axis) displacement between points **2** and **3**, and between points **4** and **5**, in FIG. 4.

It will be evident from a visual inspection of the capital K in FIG. 3 that if the cathode ray beams were to be commanded by the deflection voltages to follow the shortest path between points **2** and **3** and between points **4** and **5**, there would be an abrupt discontinuity in the beam's direction of movement at each of points **2, 3, 4** and **5**. Sharp discontinuities of this type would involve an abrupt change in slope in either or both the horizontal and vertical deflection voltages. Such abrupt slope changes would require high frequency harmonics of the Fourier series wave generator which provides the horizontal and vertical deflection voltages. It is one of the purposes of the present invention to avoid the use of such high harmonics by reducing the velocity of the cathode ray beam while the beam is on in the vicinity of the discontinuity points **2, 3, 4** and **5** and by providing horizontal and vertical displacement voltages during the beam-off periods (e.g., from point **2** to point **3**, and from point **4** to point **5**) which blend smoothly with displacement voltages in the immediately preceding and following portions of the beam-on periods.

This may be conveniently done in an empirical fashion, in accordance with the present invention, by taking narrow vertical slices of both the displacement voltage curve traces of FIG. 4 and separating the adjoining slices horizontally (that is, along the time axis), particularly in the vicinity of the discontinuity points **2, 3, 4** and **5**. FIG. 5 shows the manner in which this may be done, but for simplicity the time separation S between adjoining slices are shown only for the most critical portions, which are near the discontinuity points just mentioned. It will be noted that since each vertical slice extends through the same time segments of both the horizontal and the vertical displacement voltage curves, each time separation will be the same for both the horizontal and the vertical displacement voltages. Also, it should be understood that the time separation between each pair of vertical slices may be different from that between any other pair of slices, if that is considered necessary to achieve the desired elimination of high frequency harmonics from the Fourier series expressions of the horizontal and vertical deflection voltages for the character in question.

In addition, during the interval between each pair of points, such as points **2** and **3**, when the beam is to be off, the user inserts a sufficient horizontal separation T to provide the desired period of time for the beam deflection during this period. These beam-off periods are provided by horizontally separating the different groups of vertical slices, such as the group from point **1** to point **2**, the group from point **2** to point **3**, etc.

In this fashion, the user may lengthen the time base from what is shown in FIG. 4 in two distinct respects:

(1) By inserting the beam-off time periods T between successive character strokes when the beam is on; and

(2) By separating the vertical slices in the different beam-on periods, particularly in the vicinity of the discontinuity points.

Having done this, the user may join the separated, narrow beam-on segments of each displacement voltage curve and then draw smooth, continuous curve segments in the beam-off periods T which have no abrupt changes of slope and which merge smoothly with the adjacent beam-on curve segments so as to avoid the necessity for high frequency harmonics to produce any of these curve segments. In general, the longer these beam-off time periods, the lower will be the high harmonic content of the deflection voltages.

From these modified, time-stretched horizontal and vertical displacement voltage curves, as shown in FIG. 5, the user may determine the Fourier series expressions of these curves and insert in the resistance matrix (FIG. 2) for this character a plurality of resistors having ohmic values which are inversely proportional to the coefficients of the different terms of this Fourier series expression.

The significant advantage of the present bandwidth compression technique is that it substantially eliminates the need for high frequency harmonics in the Fourier series expressions for the horizontal and vertical beam-deflection voltages.

By the just-described technique of "stretching" time in certain portions of the beam-on periods, particularly near the discontinuity points, it necessarily follows that the beam velocity is reduced in these portions of its travel. As a result, if the beam current were constant, the brightness or intensity of the beam trace might be noticeably higher in the slow velocity portions of its travel. In that case, if desired, the beam current may be regulated in accordance with the beam velocity so as to reduce the amplitude of the beam current where the beam velocity is lower, so that the beam trace on the face of the cathode ray tube will be substantially uniform over the entire character.

This may be done by providing additional beam current modulating lines M+ and M— in the individual resistance matrix (FIG. 2) for each character to be generated. These modulating lines M+ and M— are connected to the sine and cosine fundamental and harmonic

inputs to the resistance matrix from the Fourier generator **12** through resistors in the same manner as the connections to the X+, X−, Y+, Y− and other lines in the matrix. The purpose of these resistance connections of the M+ and M− lines to the Fourier generator inputs is to increase or decrease the beam current in accordance with the instantaneous beam position during each beam-on period, so that the beam trace brightness on the face of the cathode ray tube will remain substantially constant despite differences in the beam velocity at different portions of the character trace. These beam current modulating voltages are under the control of the same Fourier generators **12** as control the horizontal and vertical deflection voltages, the beam velocity and the wobble amplitude-modulating signals. Consequently, the beam modulating voltages will be precisely synchronized with the instantaneous beam position and velocity.

The beam current modulating signals from the resistance matrix pass through the switching circuits **20** (FIG. 2) to respective output lines **51** and **52** leading to the output side of the level sensor **32**. Consequently, the beam current modulating signals do not have any effect on whether the beam current is on or off, but they do affect the magnitude of the beam current during the beam-on periods.

FIG. 6 shows schematically the beam trajectory for producing the letter, capital K, in accordance with the present invention, from time-stretched horizontal and vertical deflection voltage curves as shown in FIG. 5. The beam trace proceeds vertically from point **1** to point **2** while the beam is on. The beam slows down as it approaches and leaves point **2**. At point **2** it is turned off and it undergoes a gradual and smooth change of direction, moving generally horizontally over to point **3**. As it approaches point **3** the beam is slowed down and it undergoes a gradual change of direction to merge smoothly with the straight-line beam-on trace from point **3** to point **4**. As it approaches and leaves point **4**, the beam velocity is again reduced, and during the beam-off period between points **4** and **5** it undergoes a gradual change of direction. The beam is turned on again for the straight-line segment between points **5** and **6**. As it approaches and leaves point **6** its velocity is reduced again, and in the beam-off period after point **6** it undergoes a gradual change of direction as it returns to point **1** to begin the re-trace of the character, capital K, on the face of the cathode ray tube.

The same principles may be applied to the generation of any other alphanumeric character, using the beam slow-down technique near any discontinuity points in the beam trace necessary to generate the character and providing a sufficiently long time for each beam-off period between successive visible segments of the beam trace to enable a gradual and smooth transition between the adjoining beam-on and beam-off segments of the trace.

In this system it does not matter when the beam is first turned on during a particular cycle of the Fourier generator for that character. That is, the trace may be begun anywhere on the character. Once the gross positioning horizontal and vertical deflection signals have positioned the beam to provide the general position of a new character, the switching circuits **20** may connect the outputs from the resistance matrix for that character immediately to the respective output lines **23** and **27** to begin immediately the generation of that character without waiting for the beginning of the next cycle of the fundamental, F, of the Fourier generator.

From the foregoing description it will be evident that the present system has a modular character-generating memory **11** with one resistance matrix per character and no theoretical upper limit on the number of individual characters which may be generated. The memory **11** is of the read-only type and is composed of resistors, so that it may be embodied in integrated circuits, with no moving parts and without requiring typography storage in a computer. In this system, the digital information transfer is minimized because only enough bits are required to select the proper character matrix. Because all of the wave inputs from the Fourier generator are sinusoidal, they may be readily adjusted in amplitude or phase-shifted without destroying fidelity. Also, higher information transfer rates can be achieved because there is no rise-time phenomenon, as in digital circuitry. If desired, a single Fourier series generator may operate several different character display stations simultaneously, thereby reducing the cost of a multiple display station installation.

While a presently-preferred embodiment of this invention has been described in detail with reference to the accompanying drawings, it is to be understood that various modifications, omissions and adaptations which differ from the disclosed arrangement may be adopted without departing from the scope of the invention, as defined in the appended claims.

Having described my invention, I claim:

**1.** In a system for displaying on a cathode ray tube having horizontal and vertical deflection means alphanumeric characters or the like which may have discontinuities therein, comprising:

Fourier series generator means for generating fundamental and harmonic sine and cosine waves;

means for imparting selected amplitudes to said waves individually to provide respective Fourier series expressions for horizontal and vertical deflection voltages which, when applied respectively to said horizontal and vertical deflection means of the cathode ray tube, deflect the cathode ray beam along a path which includes a trace of the corresponding character and to reduce the beam deflection velocity in the vicinity of discontinuities in the character;

means for combining the amplitude-selected waves which provide the terms of the Fourier series expression for the horizontal deflection voltage;

means for combining the amplitude-selected waves which provide the terms of the Fourier series expression for the vertical deflection voltage;

means for applying said horizontal and vertical deflection voltages to said horizontal and vertical deflection means of the cathode ray tube, the improvement comprising;

means responsive to the Fourier series generator constructed to cause the beam trace to vibrate with respect to the instantaneous general direction in which the beam is deflected by said deflection voltages with an amplitude that is dependent upon the Fourier generated wave forms.

**2.** In a system for displaying on a cathode ray tube having horizontal and vertical deflection means alphanumeric characters or the like which may have discontinuities therein, comprising:

Fourier series generator means for generating fundamental and harmonic sine and cosine waves;

means for imparting selected amplitudes to said waves individually to provide respective Fourier series expressions for horizontal and vertical deflection voltages which, when applied respectively to said horizontal and vertical deflection means of the cathode ray tube, deflect the cathode ray beam along a path which includes a trace of the corresponding character and to reduce the beam deflection velocity in the vicinity of discontinuities in the character;

means for combining the amplitude-selected waves which provide the terms of the Fourier series expression for the horizontal deflection voltage;

means for combining the amplitude-selected waves which provide the terms of the Fourier series expression for the vertical deflection voltage;

means for applying said horizontal and vertical deflection voltages to said horizontal and vertical deflection

means of the cathode ray tube, the improvement comprising;

means responsive to the Fourier series generator constructed to turn the cathode ray beam on and off in accordance with the Fourier generated wave forms.

3. In a character display system having a display device with deflection means for displacing a spot across a display surface, Fourier generator means for generating fundamental and harmonic sine and cosine waves, means for imparting selected amplitudes to said waves and for then combining the waves to provide respective deflection voltages which follow Fourier series expressions, and means for applying said deflection voltages to said deflection means to displace the spot across the display surface to trace the corresponding character, the improvement which comprises;

means responsive to the Fourier series generator constructed to cause the beam trace to vibrate with respect to the instantaneous general direction in which the beam is being deflected by said deflection voltages, with an amplitude that is dependent upon the Fourier generated wave forms.

4. A system for displaying on the face of a cathode ray tube having horizontal and vertical deflection means alphanumeric characters or the like which may have discontinuities therein, said system comprising:

Fourier series generator means for generating fundamental and harmonic sine and cosine waves;

a plurality of impedance matrices, one for each character to be displayed;

each said impedance matrix presenting impedances which are inversely proportional respectively to the coefficients of the terms of respective Fourier series expressions for the horizontal and vertical deflection voltage wave forms for deflecting the cathode ray beam across the face of the tube to trace a path which includes the character corresponding to said matrix, said impedances having impedance values effective to reduce the beam deflection velocity near discontinuities in said character so as to avoid the need for high frequency harmonic terms in said Fourier series expression;

means for simultaneously applying said fundamental and harmonic sine and cosine waves from said Fourier series generator means to the respective impedances in a selected matrix;

means for combining the outputs of said impedances to provide said horizontal and vertical deflection voltage wave forms;

and means for simultaneously applying said horizontal and vertical deflection voltage wave forms to said horizontal and vertical deflection means.

5. A system according to claim 4 wherein:

each impedance matrix including additional impedances connected to be energized respectively by said fundamental and harmonic waves, and means for combining the outputs from said additional impedances to provide two amplitude control signals, each of which follows a Fourier series expression having sine and cosine terms whose coefficients are determined by said additional impedances;

and further comprising:

wobble signal generator means producing a pair of high frequency wobble signals;

means for amplitude-modulating said wobble signals separately with said amplitude control signals;

and means for superimposing said amplitude-modulated wobble signals on said horizontal and vertical deflection voltage wave forms, respectively, to deflect the cathode ray beam rapidly back and forth laterally of the instantaneous general direction of its deflection by said horizontal and vertical deflection voltage wave forms so as to impart line thickness to the beam trace which varies with the amplitude modulation provided by said amplitude control signals.

6. A system according to claim 4 wherein:

each impedance matrix includes beam current-control impedances which are effective, when energized by the respective fundamental and harmonic sine and cosine waves, to control the turning on and off of the beam current in the cathode ray tube;

and further comprising:

means connected to the output of said beam current-control impedances for turning the beam current on and off in accordance with the beam position as defined by said Fourier series expressions for said horizontal and vertical deflection voltage wave forms for the corresponding character.

7. A system according to claim 6, wherein:

each impedance matrix including additional impedances connected to be energized respectively by said fundamental and harmonic waves, and means for combining the outputs from said additional impedances to provide two amplitude control signals, each of which follows a Fourier series expression having sine and cosine terms whose coefficients are determined by said additional impedances;

and further comprising:

wobble signal generator means producing a pair of high frequency wobble signals;

means for amplitude-modulating said wobble signals separately with said amplitude control signals;

and means for superimposing said amplitude-modulated wobble signals on said horizontal and vertical deflection voltage wave forms, respectively, to deflect the cathode ray beam rapidly back and forth laterally of the instantaneous general direction of its deflection by said horizontal and vertical deflection voltage wave forms so as to impart line thickness to the beam trace which varies with the amplitude modulation provided by said amplitude control signals.

8. In a character display system having a display device energized by beam current and having deflection means for displacing a spot across a display surface, Fourier generator means for generating fundamental and harmonic sine and cosine waves, means for imparting selected amplitudes to the fundamental and harmonic waves produced by said Fourier generator means in accordance with the desired displacement of said spot to display a corresponding character on said display surface, and means for applying said waves having said amplitudes to said deflection means to displace the spot across the display surface to display said character thereat, the improvement which comprises:

means operated in response to said Fourier generator means to turn the beam current on and off, to thereby make said spot visible and invisible in accordance with the instantaneous position of said spot on said display surface.

9. A system according to claim 8, wherein said means to turn the beam current on and off comprises a plurality of beam curent-controlling impedances connected to be energized respectively by said sine and cosine waves, means for combining the individual currents through said beam current-controlling impedances to provide a control current which follows a Fourier series expression having sine and cosine wave terms whose coefficients are determined by the respective beam current-controlling impedances, a level sensor connected to receive said control current and to respond to the latter's instantaneous amplitude to either provide or not provide an output signal, and a beam current amplifier connected to the output of said level sensor to turn the beam current on and off in accordance with the instantaneous amplitude of said control current input to the level sensor.

10. A system for displaying alphanumeric characters or the like on the face of a cathode ray tube having horizontal and vertical deflection means, said system comprising:

Fourier series generator means for generating sine and cosine waves of a fundamental frequency and a plurality of harmonics of said fundamental frequency;

a plurality of impedance matrices, one for each character to be displayed;

each said impedance matrix presenting a first group of impedances which are inversely proportional respectively to the coefficients of the terms of the respective Fourier series expressions for the horizontal and vertical deflection voltages which, when applied to said horizontal and vertical deflection means, cause the cathode ray beam to trace a path which includes the corresponding character;

each said impedance matrix also including a plurality of beam current-control impedances which are effective, when energized by the respective fundamental and harmonic sine and cosine waves from said generator means, to control the turning on and off of the beam current in the cathode ray tube;

means for simultaneously applying said fundamental and harmonic sine and cosine waves to the respective impedances of said first group in a selected matrix and to the respective beam current-controlling impedances in said selected matrix;

means for connecting the first group of impedances in the selected matrix to said horizontal and vertical deflection means in the cathode ray tube to apply to the latter horizontal and vertical deflection voltages which follow said Fourier series expressions for the corresponding character;

and means connected to said beam current-controlling impedances in the selected matrix for turning the beam current on and off in accordance with the instantaneous beam position as defined by said Fourier series expressions for the horizontal and vertical deflection voltages for the corresponding character.

11. A system for displaying alphanumeric characters or the like on the face of a cathode ray tube having horizontal and vertical deflection means, said system comprising:

Fourier series generator means for generating sine and cosine waves of a fundamental frequency and a plurality of harmonics of said fundamental frequency;

a plurality of impedance matrices, one for each character to be displayed;

each said impedance matrix presenting a first group of impedances which are inversely proportional respectively to the coefficients of the terms of the respective Fourier series expressions for the horizontal and vertical deflection voltages for deflecting the cathode ray beam to trace a path which includes the alphanumeric character corresponding to the matrix;

wobble signal generator means which produces a pair of wobble signals of substantially higher frequency than the harmonic waves produced by said Fourier series generator means;

each said impedance matrix also including two additional groups of impedances connected to be energized respectively by said fundamental and harmonic waves, and means for combining the currents through the impedances of each said additional group to provide two amplitude control signals, each of which follows a Fourier series expression having sine and cosine terms whose coefficients are determined by the impedances in the respective last-mentioned group;

means for amplitude-modulating said wobble signals separately with said amplitude control signals;

means for superimposing said amplitude-modulated wobble signals on said horizontal and vertical deflection voltages, respectively, to deflect the cathode ray beam laterally of the instantaneous direction of its deflection by said horizontal and vertical deflection voltages alone so as to impart line thickness to the beam trace on the face of the cathode ray tube.

12. A method of displaying alphanumeric characters or the like which may have discontinuities therein comprising the steps of:

deflecting a cathode ray beam to providea trace of the character to be displayed;

and reducing the beam deflection velocity in the vicinity of discontinuities in the character trace.

13. A method of displaying on the face of a cathode ray tube which has horizontal and vertical deflection means alphanumeric characters which may have discontinuities therein comprising the steps of:

producing horizontal and vertical deflection voltages which follow respective Fourier series expressions of the horizontal and vertical deflections of the cathode ray beam along a path including the desired character trace and which have provision for reducing the beam deflection velocity near the discontinuities in the respective character;

and applying said horizontal and vertical deflection voltages simultaneously to said horizontal and vertical deflection means of the cathode ray tube.

14. A method according to claim 13, and further comprising turning the beam current for the cathode ray tube on and off in synchronism with said deflection voltages to provide the visible and invisible segments of the beam trace.

15. A method of displaying on the face of a cathode ray tube alphanumeric characters which may have discontinuities therein comprising the steps of:

determining the beam-on horizontal and vertical deflection voltage wave forms for deflecting a cathode ray beam to display a beam trace of a particular character;

extending the time periods of both the horizontal and the vertical deflection voltage wave forms in the vicinity of discontinuities in the character;

inserting beam-off time periods between successive segments of both the beam-on horizontal and vertical deflection wave forms where there is abrupt change of position in either;

inserting in each beam-off time period a beam-off wave form segment which joins and merges smoothly with the adjoining beam-on segments of the respective wave form;

applying to the cathode ray tube the horizontal and vertical deflection wave forms having the time-extended beam-on segments joined by the beam-off segments;

turning on the beam current for the cathode ray tube during said beam-on segments of the deflection voltage wave forms;

and turning off the beam current during said beam-off segments of the deflection voltage wave forms.

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