

Dec. 9, 1969

M. C. HENDERSON

3,483,547

DISPLAY APPARATUS

Filed Sept. 20, 1965

7 Sheets-Sheet 1

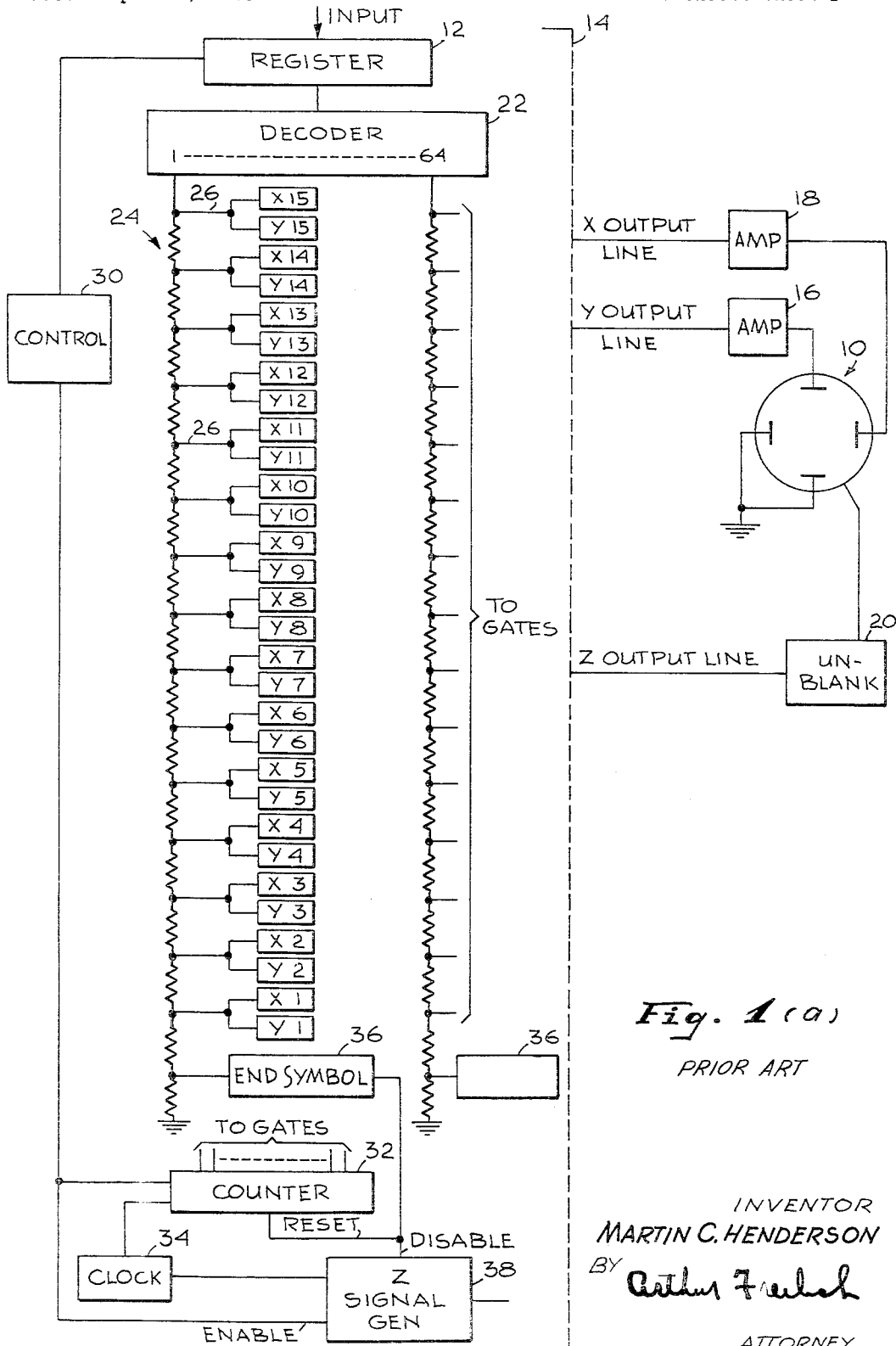


Fig. 1(a)

PRIOR ART

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7 Sheets-Sheet 2

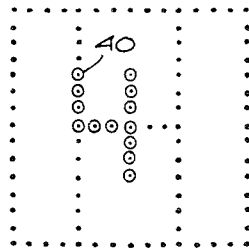


Fig. 1(b)

CL Pd	X	Y	Z
t ₁	5	11	ON
t ₂	5	10	"
t ₃	5	9	"
t ₄	5	8	"
t ₅	6	8	"
t ₆	7	8	"
t ₇	8	8	"
t ₈	8	9	"
t ₉	8	10	"
t ₁₀	8	11	"
t ₁₁	8	7	"
t ₁₂	8	6	"
t ₁₃	8	5	"
t ₁₄			OFF
t ₁₅			

Fig. 1(c)

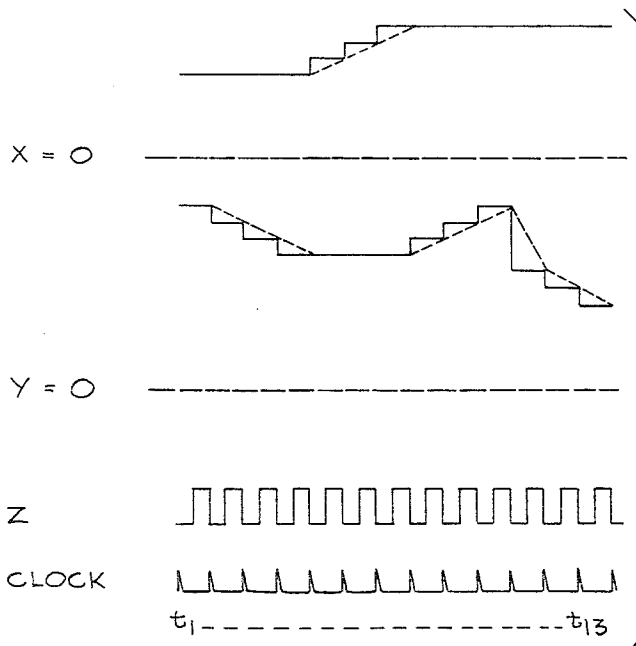


Fig. 1(d)

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Fig. 2(a)

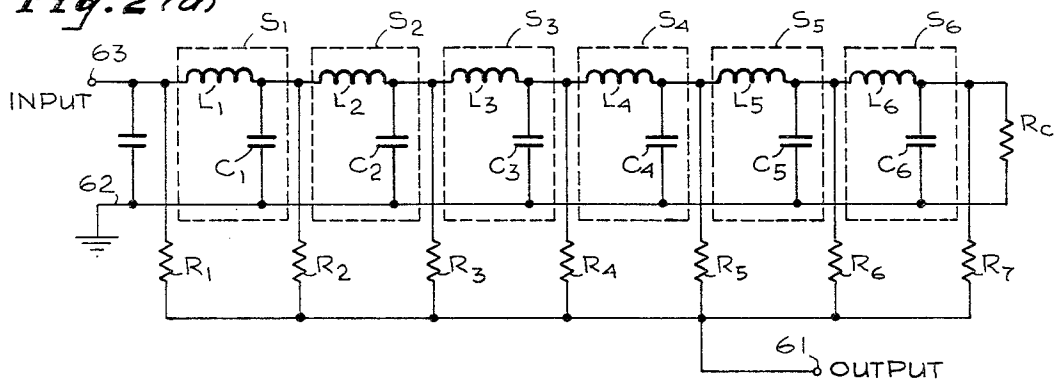


Fig. 2(b)

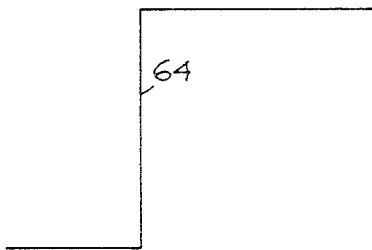


Fig. 2(c)

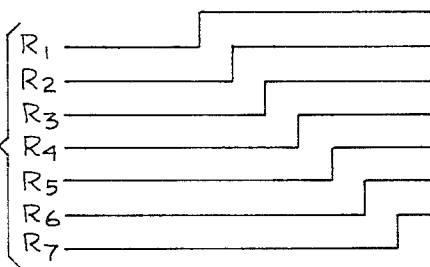


Fig. 2(d)

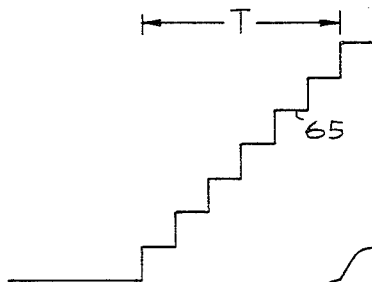
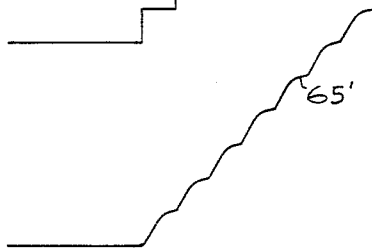


Fig. 2(e)



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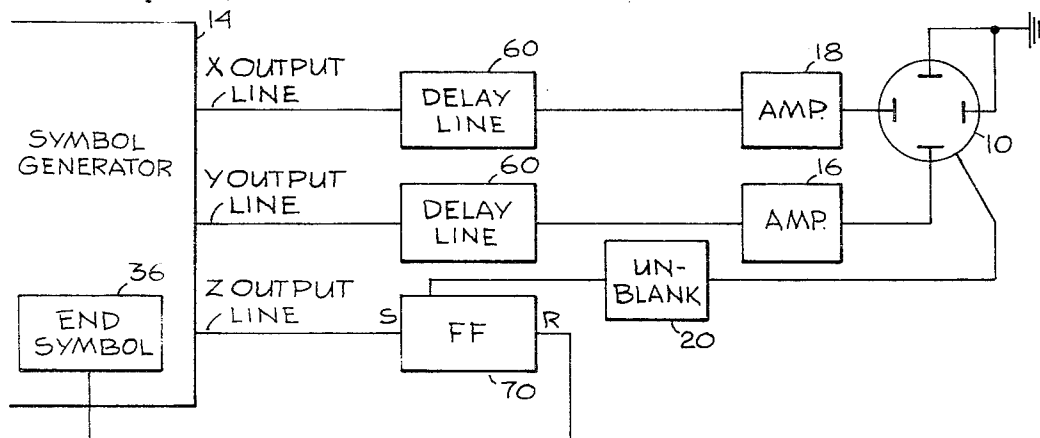


Fig. 3

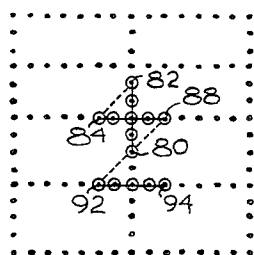


Fig. 4(a)

	X	Y	Z
t ₁	8	7	OFF-ON
t ₂	8	8	ON
t ₃	8	9	"
t ₄	8	10	"
t ₅	8	11	"
t ₆	6	9	OFF-ON
t ₇	7	9	ON
t ₈	8	9	"
t ₉	9	9	"
t ₁₀	10	9	"
t ₁₁	6	5	OFF-ON
t ₁₂	7	5	ON
t ₁₃	8	5	"
t ₁₄	9	5	"
t ₁₅	10	5	"
t ₁₆			OFF

Fig. 4(b)

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Fig. 5

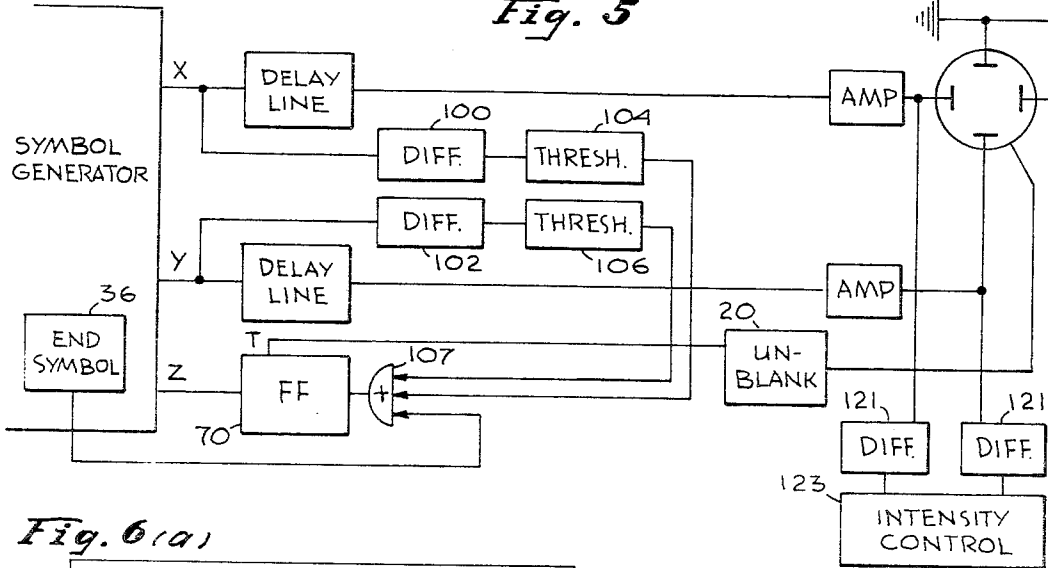
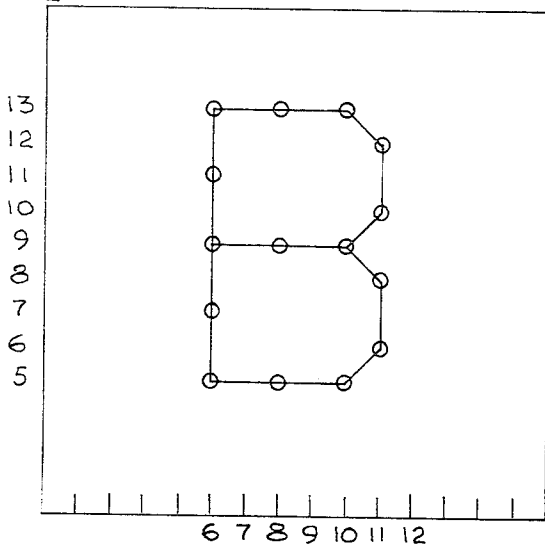


Fig. 6(a)



CLP ₀	X	Y	Z
t ₁	6	9	OFF-ON
t ₂	6	7	ON
t ₃	6	5	"
t ₄	8	5	"
t ₅	10	5	"
t ₆	11	6	"
t ₇	11	8	"
t ₈	10	9	"
t ₉	8	9	"
t ₁₀	6	9	"
t ₁₁	6	11	"
t ₁₂	6	13	"
t ₁₃	8	13	"
t ₁₄	10	13	"
t ₁₅	11	12	"
t ₁₆	11	10	"
t ₁₇	10	9	"
t ₁₈			OFF

Fig. 6(b)

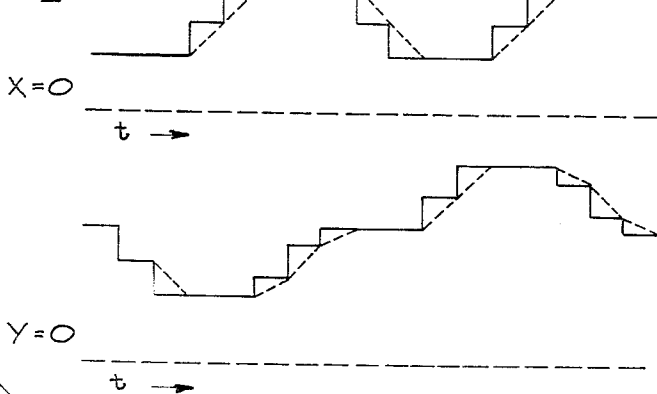
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Fig. 6(c)



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Fig. 7(a)

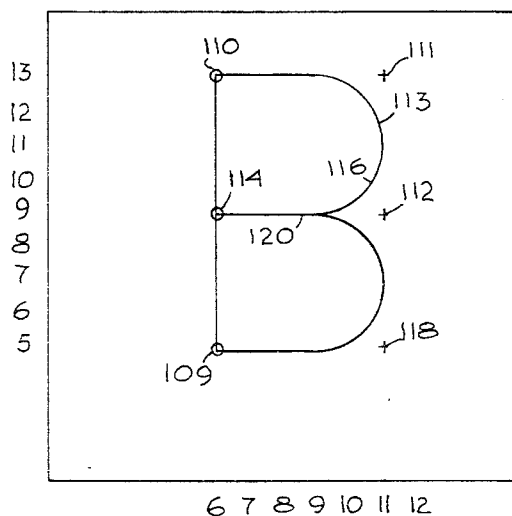


Fig. 7(b)

cl Pd	X	Y	Z
t ₁	6	5	ON
t ₂	6	13	"
t ₃	6	13	"
t ₄	11	13	"
t ₅	11	9	"
t ₆	6	9	"
t ₇	6	9	"
t ₈	11	9	"
t ₉	11	5	"
t ₁₀	6	5	"
t ₁₁	6	5	"
t ₁₂			OFF

Fig. 7(c)

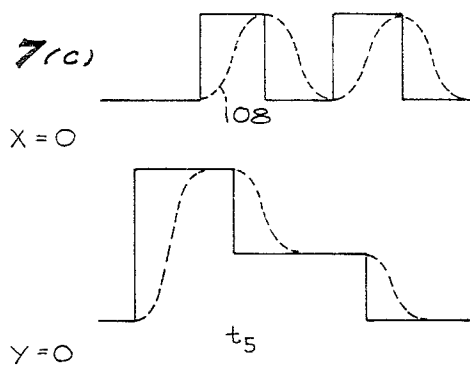


Fig. 8(b)

cl Pd	X	Y	Z
t ₁	6	5	ON
t ₂	6	13	"
t ₃	6	13	"
t ₄	11	13	"
t ₅	11	9	"
t ₆	6	9	"
t ₇	6	9	"
t ₈	13	13	OFF
t ₉	6	9	"
t ₁₀	6	9	"
t ₁₁	11	9	"
t ₁₂	11	5	ON
t ₁₃	6	5	"
t ₁₄	6	5	"
t ₁₅			OFF

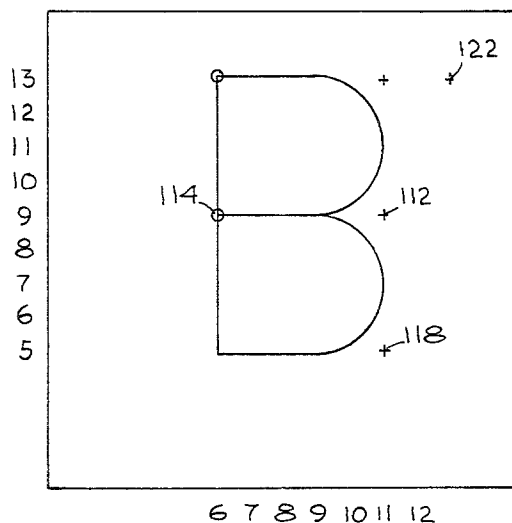


Fig. 8(a)

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DISPLAY APPARATUS

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U.S. Cl. 340—324

15 Claims

ABSTRACT OF THE DISCLOSURE

A system for displaying symbols, as for example, on the screen of a cathode ray tube. The system includes means defining one of a plurality of discrete screen points during each of a plurality of successive dot intervals. Vertical and horizontal deflection signals are developed for deflecting the beam along a path defined by the successively defined discrete points. The deflection signals change gradually, rather than sharply, to thereby extend the beam transition time between successive screen points to one or more substantially full dot intervals and reduce the dwell time at each defined screen point to substantially zero. The beam is continuously unblanked during the successive dot intervals to thus draw a visible line pattern. By extending the beam transition time to more than one full dot interval, the beam direction can be modified between successively defined screen points to thus draw a curved line. Means are also provided for introducing discontinuities in the drawn symbols.

This invention relates generally to display apparatus and more particularly to apparatus for generating and displaying alphanumeric and other symbols.

It is often desirable that display devices be provided for use with digital data processing equipment for displaying output data. Most such known display devices include a cathode ray tube in which the beam is controlled to selectively draw any one of several alphanumeric or other symbols. In the design of such display devices, several characteristics are significant. For example, the symbols displayed should be pleasing in appearance, clear and unambiguous. It is also important that the restrictions on symbol design be minimal, and that it be relatively easy to modify the shape of a symbol when desired. In addition, symbols should be produced rapidly to allow a display of many symbols to be refreshed at a flicker-free rate. The bandwidth of the signals used in displaying the symbols should be kept low to thus allow relatively simple deflection and video amplifiers to be employed. Further, the writing beam should be unblanked for a large fraction of the time, i.e. a high duty factor to thus provide a bright display.

Although several different types of symbol generation and display apparatus are known in the prior art, no specific type is the best in all respects. For example, raster type symbol generators allow great flexibility in symbol design, but however require high video bandwidth and for typical alphanumeric symbols have a low duty factor. Typical raster type symbol generators also are inflexible in that symbols cannot easily be modified after the devices have been constructed.

Dot type symbol generators on the other hand are quite flexible in original symbol design and allow easy alteration of symbols to meet changed needs. However, the limited number of discrete dots used to define a symbol is found less pleasing by many viewers. The video bandwidth requirements tend to be less than in a raster type generator of equivalent speed and resolution, but the deflection amplifier bandwidth tends to be greater.

Stroke or line type generators produce symbols by trac-

ing out standard patterns by unblanking appropriate lines. For a given font of symbols, only a comparatively few patterns are used. Some modification of the straight strokes are provided in some types of generators but the symbols generally tend to be displeasingly angular. Bandwidth requirements are comparable to those of the dot type generator.

In accordance with the present invention, display apparatus is provided which has attributes normally characteristic of the dot type generator, i.e., flexibility in original symbol design and relatively easy alterability of symbols thereafter, and yet which also has the ability to draw lines to thus permit the formation of symbols having a more pleasing appearance than is provided by conventional dot type generators. Briefly, in accordance with one aspect of the present invention, it is recognized that more pleasing symbols can be produced by substantially conventional dot type generators by sweeping the beam from dot to dot while leaving the beam unblanked to thus draw lines between the dots.

In accordance with a further aspect of the present invention, discontinuities can be selectively introduced in symbols either in response to characteristics of the symbols' deflection signals, or by directly controlling the unblanking of the beam.

In accordance with a still further aspect of the invention, the rate of movement of the beam is varied as it is deflected along a straight line between two end points such that the beam is moving relatively rapidly between the end points but relatively slowly in the vicinity of the end points thus reducing the deflection amplifiers bandwidth requirements.

In accordance with a still further aspect of the invention, curved lines can be selectively drawn by changing one of the forces deflecting the beam while it is moving between first and second end points.

More particularly, in a first embodiment of the invention, the X and Y output signals available from a dot type generator are respectively coupled to the horizontal and vertical deflection plates of a cathode ray tube through wave shaping circuits which convert signal steps into substantially linear ramps whose rise time is equal to a dot period. As a consequence, the beam is swept at a uniform velocity between first and second end points identified by the X and Y output signals. By keeping the beam unblanked while it is being deflected to successive points, straight lines will be drawn to thus define the symbol. The successive dots are so chosen that a discontinuity will be introduced, i.e., the beam will be blanked in the event that one dot is spaced from the immediately preceding dot by more than a certain distance.

In a second embodiment of the invention, in lieu of converting the deflection signal steps into a substantially linear ramp, they are converted into signals approximating 180° of a sine wave, i.e., from $-\pi/2$ to $+\pi/2$ having a period equal to two dot periods. Thus, the beam moves slowly close to the end points of a line and relatively rapidly therebetween. Curved lines are defined by modifying the direction of beam movement prior to its reaching an end point defined by the deflection signals. A discontinuity can be introduced in response to the definition of a particular, otherwise unused, dot position.

In a third embodiment of the invention, discontinuities are selectively introduced by directly controlling the blanking of the beam instead of in response to the characteristics of the X and Y deflection signals.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be

understood from the following description when read in connection with the accompanying drawings, in which:

FIGURE 1(a) is a schematic diagram of a substantially conventional display system employing a dot type symbol generator;

FIG. 1(b) illustrates a dot type symbol formed by the apparatus of FIG. 1(a);

FIGS. 1(c) and 1(d) are respectively a table and a waveform chart describing the deflection signals used in the apparatus of FIG. 1(a) to form the symbol of FIG. 1(b);

FIG. 2(a) illustrates apparatus for modifying the waveforms of FIGS. 1(d) in order to form more pleasing symbols;

FIGS. 2(b), 2(c), 2(d), and 2(e) illustrate in greater detail the operation of the apparatus of FIG. 2(a);

FIG. 3 is a schematic diagram illustrating how the apparatus of FIG. 1(a) is modified to improve the appearance of symbols formed thereby;

FIG. 4(a) illustrates an additional symbol which can be formed by the apparatus of FIG. 3 which symbol includes a discontinuity;

FIG. 4(b) is a table describing the signals which are applied to a cathode ray tube to form the symbol of FIG. 4(a);

FIG. 5 is a schematic diagram illustrating the manner in which the apparatus of FIG. 3 is modified to introduce discontinuities within displayed symbols;

FIG. 6(a) illustrates a symbol which can be drawn by the apparatus of FIG. 5 employing the information signals respectively described in tabular and graphical form in FIGS. 6(b) and 6(c);

FIG. 7(a) illustrates the same symbol as in FIG. 6(a) but having a more pleasing appearance as a consequence of modifying and differently operating the apparatus of FIG. 5 to form the information signals respectively illustrated in tabular and graphical form in FIGS. 7(b) and 7(c);

FIG. 8 illustrates how the symbol of FIG. 7(a) can be further improved by introducing a discontinuity employing the information signals described in tabular form in FIG. 8(b);

FIG. 9 illustrates a schematic diagram of apparatus which can be used alternatively with the apparatus of FIG. 5 to introduce a discontinuity in a symbol;

FIG. 10(a) is a schematic diagram of apparatus illustrating how the apparatus of FIG. 1(a) can be modified to directly control the introduction of symbol discontinuities; and

FIG. 10(b) describes in tabular form information signals which are provided and utilized by the apparatus of FIG. 10(a) to form the symbol of FIG. 8(a).

Attention is now called to FIG. 1(a) of the drawings which illustrates a substantially conventional dot type symbol generator system in which symbols are displayed on the face of a cathode ray tube 10 in response to input data codes applied to an input register 12 of a symbol generator 14.

The cathode ray tube 10 includes sets of vertical and horizontal deflection plates which are respectively driven by the outputs of amplifiers 16 and 18. In addition, the beam of the cathode ray tube 10 can be selectively blanked or unblanked by an unblank enabling means 20. The substantially conventional symbol generator 14 is provided with X, Y, and Z output signal lines which are respectively coupled to the inputs of amplifiers 18 and 16 and unblank enabling means 20.

The symbol generator 14 usually includes a decoder device 22 which is responsive to the output of the register 12. Let it be arbitrarily assumed that the register 12 has a six-bit capacity and that any one of 64 different six-bit data codes can be entered therein each code identifying a different symbol. The decoder device 22 is provided with 64 output terminals and includes

means therein for applying a potential to a particular one of the terminals corresponding to the data code entered into the register 12.

Each of the decoder device output terminals is connected to a source of reference potential, herein ground, through a series string of impedances 24. A tap 26 is connected to the upper terminal of each of the impedances 24. Thus, when the decoder device applies a potential to a selected output terminal, a different potential will appear at each of the taps 26 coupled thereto.

Connected to each tap 26 is a pair of switches comprised of an X switch and a Y switch. Thus, switches X15 and Y15 are connected to the uppermost tap coupled to output line 1 of the decoder device 22. Similarly, a pair of X and Y switches are connected to each of the other taps 26. The outputs of all of the Y switches are connected together through an OR circuit (not shown) whose output in turn is connected to the symbol generator Y output line. Similarly, the outputs of all of the X switches are connected together and coupled through an OR circuit (not shown) to the symbol generator X output line.

A control means 30 controls the entry of data codes into the register 12. In addition, the control means 30 enables a counter 32, which when enabled, is incremented in response to each pulse provided by clock pulse source 34. Counter 32 has a plurality of output terminals which are sequentially energized, and each of the counter output terminals can control one X switch and one Y switch. Thus, when one of the counter output terminals is energized, it can close one X and one Y switch to respectively apply horizontal and vertical deflection signals to the amplifiers 18 and 16 to thus position the beam in the cathode ray tube 10. By unblanking the beam, a dot can thus be formed at this position. Thus, the energization of each of the counter output terminals can cause a dot to be displayed on the cathode ray tube. Inasmuch as certain symbols require the utilization of more dots in their formation than other symbols, different numbers of counter output terminals are connected to the various decoder device output terminals, or rather switches thereof. For example, if seven dots are required to form a symbol, then each of the first seven counter output terminals operate to close switches connected to the decoder output terminal corresponding to that symbol. It should be recognized that any one X or Y switch can be controlled by more than one counter output terminal.

In addition to the X and Y switches, an end symbol switch 36 is also connected to each of the series impedance strings. One of the counter output terminals is connected to and controls each of the end symbol switches 36 in the same manner as it is connected to and controls each of the X and Y switches. Thus, after the cathode ray tube beam has been moved to form all of the dots required in the formation of a symbol, the end symbol switch will be closed to thereby provide a reset pulse to the counter 32 to prepare it for the next symbol to be drawn. The output from the end of symbol switch 36 is also utilized to disable the Z signal generator 38. More particularly, the output from the control means 30 is connected to the enable line of the Z signal generator and thus enables the Z signal generator to provide an output pulse in response to, but slightly delayed from, each of the clock pulses provided from source 34. The output of the Z signal generator 38 is connected to the Z output line of the symbol generator 14. Thus, it should be appreciated that the Z signal generator unblanks the cathode ray tube beam as the beam is successively moved to each of the defined dot positions. After all of the dots have been drawn and the end symbol switch 36 disables the Z signal generator 38, the beam will remain blanked until the control means 30 again enables the Z signal generator.

Attention is now called to FIGS. 1(b), 1(c), and 1(d). Let it be assumed that it is desired to draw the symbol

"4" on the face of the cathode ray tube as shown in FIG. 1(b). Let it further be assumed that the symbol will be drawn within a 15 x 15 matrix around a gross position defined by positioning means which are not a subject of the present invention and are not treated herein. In order to draw the symbol "4," the appropriate one of the decoder device output terminals is of course energized to therefore apply different potentials to each of the taps 26 connected thereto. As shown in the table of FIG. 1(c), at clock period t_1 as defined by counter 32, switches X5 and Y11 are closed to deflect the beam to point 40 on the face of the cathode ray tube. At this position, the Z output signal unblanks the beam to form the dot illustrated in FIG. 1(b). Similarly, during the succeeding clock periods t_2 through t_{13} , the beam is deflected to each of the illustrated dot positions by closing the switches designated in the table of FIG. 1(c) and by unblanking the beam when it is properly positioned. Thus, the Z signal represented in the table of FIG. 1(c) is shown in full line in FIG. 1(d) and consists of pulses causing the beam to be periodically unblanked. The waveshapes of the signals appearing on the X, Y, and Z output lines of the symbol generator 14 to form the symbol "4" of FIG. 1(b), are shown in FIG. 1(d). Note for example that during clock period t_1 the level of the X signal is five units and the level of the Y signal is eleven units. After allowing for settling time of the beam, i.e., toward the end of clock period t_1 , a Z signal pulse is provided to unblank the beam. At the beginning of clock period t_2 , the level of the X signal remains constant but the Y signal drops to a level of ten units. Thus, from the nature of the waveshapes of FIG. 1(d), it is apparent that each of the X and Y output signals is comprised of a series of signal levels which are coupled by sharp relatively instantaneous transitions from one level to another. In other words, the X and Y output signals provided by a dot type symbol generator are comprised of a series of signal steps. After all of the dots necessary to define the symbol have been drawn, the end of symbol switch 36 provides a disabling signal to the Z signal generator to thereafter inhibit the application of the Z signal pulses to the unblanking means 20.

In accordance with one aspect of the present invention, in order to give the symbols defined by the output signals provided by dot type generators of the type shown in FIG. 1(a) a more pleasing appearance, straight lines can be drawn between the dots. More particularly, whereas the signals provided to the deflection amplifiers by the symbol generator will move the cathode ray tube beam nearly instantaneously between dot positions and will then define a long dwell time at each dot position, in accordance with the present invention the dwell time of the beam at each dot position is reduced to substantially zero while the transition time of the beam between dot positions is extended to a full unit interval or dot period. In order to do this, as shown in dotted line in FIG. 1(d), the instantaneous transitions in the X and Y signals are converted to ramp signals so that the beam will have a long transition time, i.e., the full dot period and a short or nonexistent dwell time. Thus, utilizing the dotted line deflection signals shown in FIG. 1(d), straight lines can be drawn through the dots, which can be defined by conventional apparatus, by modifying the Z signal so that it is unblanked from the end of the first dot period and then continuously throughout all of the succeeding dot periods utilized to define the symbol until the end of the last dot period. Inasmuch as use of the invention eliminates any settling time problems, the initial Z signal pulse can be utilized to turn the unblanking means, as will be hereinafter described in greater detail, and the output of the end of symbol switch 36 can later be used to turn the unblanking means off.

In order to convert the instantaneous signal transitions or steps to ramps as shown in dotted line in FIG. 1(d), different types of waveshaping devices can be employed. One such type comprises delay line devices as disclosed

in detail in U.S. patent application Ser. No. 298,881, filed on July 31, 1963 (now U.S. Patent No. 3,364,479) and assigned to the same assignee as the present application. For example, a delay line device 60 as shown in FIG. 2(a) herein can be employed. The delay line 60 comprises a number of sections which, for explanatory purposes only, are represented as six and designated respectively as S_1 through S_6 . As shown, the delay line 60 includes six serially connected, substantially equal value inductors designated L_1 through L_6 , and six substantially equal value capacitors designated C_1 through C_6 . One side of each capacitor is connected to a common grounded lead 62 and the other side of each capacitor C_1 through C_5 is connected to a junction point between two inductors, with the other side of capacitor C_6 connected to the far side of inductor L_6 . Each delay line section comprises one inductor L and one capacitor C with sampling resistors R_2 through R_6 connected to the junction points between inductors L_1 through L_6 , respectively. One end of a sampling resistor R_1 is connected to an input terminal 63 to which the inductor L_1 is also connected. Another sampling resistor R_7 has one end connected to the far side of inductor L_6 . The opposite ends of the resistors R_1 through R_7 are connected to an output terminal 61. The relative values of the resistors R_1 through R_7 control the overall rise time linearity of the signal at the output terminal 61, the linearity being selected on response characteristics of other circuits in the system such as the deflection amplifiers 16 and 18. The resistors R_1 through R_7 may all be of substantially equal value in order to convert a signal step into substantially a linear ramp as shown in FIG. 1(d). As will be discussed hereinafter, the resistors can be chosen to have different values to form other than linear ramps.

The delay line 60 is terminated in its characteristic impedance, designated as R_C , so that any wave propagated down the delay line from input terminals 62, 63 terminates therein and is not reflected. With an input signal having step function characteristics, as shown by a line 64 in FIG. 2(b), introduced at the input terminals 62, 63 the signal propagates through the delay line with each sampling resistor contributing an increment of signal change to the output signal. FIG. 2(c) represents the individual output signal contributions of each of the sampling resistors R_1 through R_7 . As shown therein, the contributions of the various sampling resistors are equal in amplitude, since, as assumed above, all of the resistors are equal. Further, the time delays between contributing output increments are the same since it is assumed that all the inductors L and all of the capacitors C are identical to one another resulting in equal incremental time delays produced by each of the substantially identical sections of the delay line 60.

In FIG. 2(d), a line, generally designated by a numeral 65, represents the total output signal at terminal 61 as a function of an input step function signal 64 as shown in FIG. 2(b), the total rise time being equal to the total time delay T of the delay line 60. It is apparent to those familiar in the art that each incremental output step contributed by each sampling resistor will not be in practice a sharp step function as shown in FIGS. 2(c) and 2(d) but rather will have its own incremental rise time which is a function of the characteristics of each delay line section, the true output signal more closely resembling the signal shown in FIG. 2(e). The incremental rise times may effectively blend the steps together thereby shaping the input step function of FIG. 2(b) to approach a straight line 65' as shown in FIG. 2(e), so that when such signals are applied to deflection amplifiers 16 and 18 (FIG. 1), the deflection amplifiers do not saturate but rather deflect the cathode ray tube beam in a desired straight line as explained above. Although an increasing step or signal transition has been shown in FIG. 2, it should, of course, be appreciated that the delay line 60 of FIG. 2(a) will operate on a decreasing or negative

step to form a decreasing ramp signal in substantially the same manner. It should thus be appreciated that the delay line functions to extend the substantially instantaneous signal transition of FIG. 2(b) into a relatively slowly changing signal which has a total rise time T equal to the delay of the delay line 60. This rise time T can be made equal to a single dot interval or can be made equal to two or more dot intervals for purposes which will be better appreciated hereinafter.

Attention is now called to FIG 3 which illustrates the manner in which the delay lines 60 of FIG. 2(a) can be incorporated between the X and Y output lines of the symbol generator 14 and the deflection amplifiers 16 and 18. As a consequence of the action of the delay line 60, the dotted line ramp signals rather than the instantaneous step transitions, as shown in FIG. 1(d), will be applied to the vertical and horizontal deflection plates of the cathode ray tube 10. Of course, if continuous lines are to be drawn between the dot positions defined by the symbol generator, the beam must be unblanked continuously from the initial to the terminal dot position. In order to continually activate the unblanking means 20, a set-reset flip-flop 70 is provided. The Z output signal line is connected to the set input terminal of the flip-flop and the end of symbol switch 36 is connected to the reset input terminal. The true output terminal of the flip-flop 70 is connected to the input of the unblanking means 20.

In the operation of the system, the initial pulse appearing on the Z output line from the symbol generator 14 will set the flip-flop 70 to thus provide an enabling signal to the unblanking means to thereby unblank the cathode ray tube beam. The flip-flop 70 will remain in a true state for so long as pulses appear on the Z output line. As soon as the end of symbol switch 36 is closed the flip-flop 70 will be reset to thus disable the unblanking means 20 and blank the cathode ray tube beam. Accordingly, utilization of the system of FIG. 3 enables lines to be drawn interconnecting dots defining a symbol.

Some symbols cannot be drawn by a continuously unblanked beam inasmuch as they contain some discontinuities. For example, consider the symbol $\pm$ illustrated in FIG. 4(a). Although this symbol can be easily represented by dots, it cannot be suitably drawn by the apparatus of FIG. 3 which must be modified in order to draw symbols having discontinuities. FIG. 4(b) describes in tabular form the signals which can be applied to the deflection means of the cathode ray tube for drawing the symbol of FIG. 4(a) and teaches a first technique for blanking the beam to introduce discontinuities. Notice that during clock period t_1 , the beam is unblanked after it moves into position at point 80 on the cathode ray tube face and that during the succeeding four clock periods, i.e., t_2 through t_5 , it remains unblanked as it is moved upward one position so that at the end of clock period t_5 it resides at point 82. It is desired then to move the beam to point 84 but, of course, it is necessary to blank the beam during its movement from point 82 to point 84. In accordance with the embodiment of FIG. 4, the beam is blanked whenever the distance between a defined dot position and an immediately subsequent dot position exceeds a certain predetermined threshold level. Thus, during clock period t_6 , the point 84 is defined which is spaced from point 82 by a distance greater than that threshold level and accordingly the beam can be moved to point 84 while blanked. When the threshold level is exceeded, the beam is preferably blanked for an interval equal to approximately a single dot interval during which it is moved to point 84 and is thereafter unblanked through the succeeding four clock periods until it arrives at point 88. Then, inasmuch as the distance between point 88 and the next defined point 92 again exceeds the threshold level, the beam is again blanked for approximately a dot period so that no visible line is formed by the movement of the beam between the points 88 and 92. At the end of clock period t_{11} , the beam is again unblanked and then remains

unblanked until it arrives at point 94 when it is blanked by the end of symbol signal.

The apparatus for introducing the discontinuities illustrated in FIG. 4(a) is shown in FIG. 5 which comprises a modified form of the apparatus of FIG. 3. In order to determine the distance from one point to a succeeding point, the transition from one signal level to the next can be differentiated. Thus, differentiating circuits 100 and 102 are respectively connected to the X and Y symbol generator output lines. The outputs of the differentiator circuits 100 and 102 are respectively connected to threshold circuits 104 and 106 which provide a true signal to OR gate 107 when the signal provided by either of the differentiator circuits exceeds a predetermined level set by the threshold circuits. When a true input signal is applied to the OR gate 107, a corresponding true output signal is provided thereby to the reset input terminal of flip-flop 70. Thus, a true signal applied to OR gate 107 will reset flip-flop 70 and unblank the beam until a subsequent pulse appears on the Z output line.

Accordingly, it should be appreciated that the apparatus of FIG. 5 operates identically to the apparatus of FIG. 3 except however that discontinuities in the symbol are created in response to the characteristics of the deflection signals by blanking the beam while it is in transition between points separated by greater than a predetermined distance. Although it has been shown that discontinuities are introduced in response to the characteristics of either the X or Y signals, it should be appreciated that discontinuities can be made to depend on only one, or alternatively both of these signals, if the system requirements make this desirable. It is also pointed out that although the beam has been shown as being blanked for approximately a single period to introduce a discontinuity, the beam can be blanked a longer interval, e.g., two periods, by defining some unused points in between. This may be desirable where the beam has to be moved a very great distance.

Attention is now called to FIG. 6(a) which illustrates still another symbol which can be drawn by the apparatus of either FIGS. 3 or 5. FIG. 6(b) illustrates in tabular form the deflection signals required to successively define the dots which together comprise the symbol illustrated in FIG. 6(a). FIG. 6(c) illustrates in solid line the waveform of the deflection signals applied to the cathode ray tube in order to successively deflect the beam to each of the indicated dot positions. The dotted line waveform in FIG. 6(c) illustrates how the solid line waveform can be modified to draw straight lines interconnecting the various dots.

Although the symbol of FIG. 6(a) definitely has a more pleasing appearance than it would have if formed by the apparatus of FIG. 1(a) and merely consisted of a plurality of dots as shown in FIG. 1(b), it is still somewhat displeasing in that it is comprised solely of straight lines which interconnect positioned dots. A still more pleasing symbol, as shown in FIG. 7(a), can be provided by introducing the facility in the apparatus of FIG. 5 for drawing curved lines.

Briefly, it will be demonstrated that the apparatus of FIG. 5 can be utilized to draw curved lines as shown in FIG. 7(a) by altering the directional movement of the beam prior to its reaching its destination point. For example, deflection signals can be applied to a cathode ray tube to cause the beam to move from its position at a first point in a straight line toward a defined second point. While in transition between the first and second points, the signals applied to the deflecting means can be altered to thereby appropriately change the velocity and direction of the beam to cause it to follow a smooth curve. It will, however, be appreciated that merely changing the course of movement while the beam is in transition will cause the generation of a smooth curve but rather will merely form an angle between a pair of straight lines. In accordance with the present invention, the beam is

moved in a smooth curve by varying its velocity so that in response to each new set of deflection signals applied to the cathode ray tube, the beam initially moves away from the first point at a relatively slow velocity and picks up speed intermediate the points and then is slowed down prior to arriving at its destination point. By introducing deflection signals defining a different destination point while the beam is moving at maximum velocity on its original path, the beam will be deflected to the new path along a smooth curve. In order to impart relatively low initial and terminal velocities and a relatively high intermediate velocity to the beam, the ramp signals developed by the delay line device 60 of FIG. 2 can be modified so that in lieu of having a constant slope for its full rise time, it initially and ultimately has a small slope and therebetween has a relatively large slope. In other words, the instantaneous signal transitions or steps can be converted into modified ramp signals 108, which approximate 180° of a sine wave, i.e., from $-\pi/2$ to $+\pi/2$ or from $+\pi/2$ to $-\pi/2$ as shown in FIG. 7(c).

Now considering FIG. 7 in more detail, it will be noted that during clock period t_1 , the beam is initially positioned at point 109 whose X and Y coordinates respectively equal 6 and 5 within the assumed 15×15 matrix. At clock period t_2 , the point 110 having X and Y coordinates respectively equal to 6 and 13 is defined by the deflection signals. For reasons which will become more apparent, the rise time of the modified ramp signals of FIG. 7(c) are chosen to equal two, rather than one dot interval. Thus, at clock period t_3 , the point 110 is also defined and at the end of clock periods t_2 and t_3 , the beam should have arrived at point 110. At clock period t_4 , the point 111 having X and Y coordinates respectively equal to 11 and 13 is defined. Thus, the beam will start to move in a straight line from point 110 to point 111 but inasmuch as the modified ramp signal 108 will not arrive at its final destination until the end of clock period t_5 , at the end of clock period t_4 , the beam will be intermediate the points 110 and 111 and moving at its maximum velocity inasmuch as the slope of the modified ramp deflection signal is greatest at this time.

By then changing the Y deflection signal during clock period t_5 , the beam will curve downwardly heading toward point 112 having X and Y coordinates respectively equal to 11 and 9 as defined by the deflection signals. Since at the beginning of clock period t_5 , the beam will be moving at a maximum velocity in the X direction and will be moving at a minimum velocity in the Y direction, and further since at the end of clock period t_5 the beam will be moving in a maximum velocity in the Y direction and will have terminated movement in the X direction, it will move in a substantially smooth curve 113. Similarly, during clock time t_6 , the X deflection signal can be changed to thus direct the beam toward point 114 having X and Y coordinates respectively equal to 6 and 9. The beam will thus turn around and be directed toward this point but however will still be moving in a maximum velocity in the Y direction while movement in the X direction is increasing. Thus, the beam will move along the curve 116 during clock period t_6 . At the end of clock period t_7 , which defines the same destination point as is defined during clock period t_6 , the beam will in fact arrive at point 114. During clock period t_8 the beam can then be directed again toward point 112 but its direction of movement can be modified during clock period t_9 when it has only moved about half the distance toward point 112. At clock period t_9 , the beam can be directed toward point 118 whose X and Y coordinates are respectively 11 and 5. However, by changing the deflection signals during clock period t_{10} , the beam will not in fact arrive at point 118 but after it is halfway there will be deflected toward point 109 having X and Y coordinates respectively equal to 6 and 5. The beam will arrive at point 109 at the end of clock period t_{11} by permitting the deflection signals to maintain the definition of this

point for two dot intervals. The end of symbol switch can then cause the beam to be blanked at clock period t_{12} .

The modified ramp signal shown in FIG. 7(c) can be developed by delay line devices of the type similar to that shown in FIG. 2 herein. However, certain modifications of the delay line of FIG. 2(a) are required to initially increase its rise time from one to two dot intervals and to modify its shape so that instead of having a uniform slope it has a small slope at the beginning and end thereof, and a relatively large slope therebetween. The rise time of the delay line can be doubled by choosing different valued inductors and capacitors in the delay line 60 to thereby double the delay of each stage or the characteristic resistance R_C can be deleted and use can be made of the signal which would thus be reflected back to the input terminals from the end of the line. In this latter form of delay line, it would require one full dot interval for the signal to traverse the delay line each way. Propagation of the signal in the first direction would raise the output signal level from its initial level to substantially half of its ultimate level and propagation in the opposite direction would increase the output signal to the ultimate level. Utilization of equal valued resistors as shown in FIG. 2(a) will generate a substantially linear ramp signal of course having a uniform slope. By choosing the resistors such that the signal contributions made by the resistors at the beginning and end of the total rise time are less than the contributions made by the resistors during the middle of the rise time, a modified ramp signal approximating 180° of a sine wave can be formed. For example, utilizing the delay line of FIG. 2(a), resistors R1 and R7 can have a value of 10 units, resistors R2 and R6 can have a value of 6 units, resistors R3 and R5 can have a value of 3 units, and resistor R4 can have a value of 2 units. Thus, resistor R4 would, of course, contribute most significantly to the output signal.

Accordingly, it has been shown in FIG. 7 that information provided by a substantially conventional dot type symbol generator can be modified to draw symbols comprised of continuous straight and curved lines. As mentioned, the beam in the embodiment of FIG. 7 will move with a varying speed and as a result the intensity of the beam will vary in inverse proportion thereto. In order to eliminate this intensity variation, a signal related to the speed of the beam can be developed and used to control the beam intensity. More particularly, differentiator circuits 121, responsive to the deflection signals applied to the CRT can be provided for developing signals related to the rate of change of deflection, i.e., speed. As the speed increases the beam intensity is increased via the intensity control circuit 123.

In FIGS. 4 and 5, it was shown how discontinuities can be introduced in a symbol by monitoring the change from each dot position to a succeeding dot position and when this change exceeds a certain amount, the beam is blanked. An alternative approach is to define one coordinate or point on the 15×15 matrix as being illegal so far as display purposes is concerned and utilizing the designation of this point as a signal to blank the beam for several dot intervals. Thus, let it be assumed that it is desired to appropriately blank the beam to avoid twice drawing the portion 120 of the symbol shown in FIG. 7(a). That is, as can be determined from FIG. 7(b), the beam will retrace during clock period t_8 , substantially the same path as it took during clock period t_7 . Inasmuch as these paths may be not exactly identical, a certain sloppiness in the symbol may be visible. This sloppiness can be avoided by effectively blanking the beam during clock period t_8 of FIG. 7(b). This is accomplished as shown in the table of FIG. 8(b) wherein during clock period t_8 an illegal point 122 (arbitrarily $X=13$, $Y=13$) is identified. A comparator 124 shown in FIG. 9 is capable of recognizing the designation of this point and as a consequence thereof switches a mono-

stable multivibrator 126 to its unstable state to thereby disable AND gate 128 and the previously mentioned unblanking means 20. The unstable period of the multivibrator 126 will be assumed to be approximately four dot intervals. During clock period t_8 as expressed in FIG. 8(b), the beam will be blanked but will move toward point 122. Prior to reaching point 122 during clock period t_9 , it will be directed back toward point 114 respectively having X and Y coordinates equal to 6 and 9. At the end of clock period t_{10} , the beam will arrive at point 114 and at time t_{11} while the beam is still blanked, it will be directed toward point 112 having X and Y coordinates respectively equal to 11 and 9. After the four dot interval unstable period of the multivibrator 126, the beam will be unblanked and will be directed toward point 118. The remainder of the symbol will be drawn in the same manner as discussed with respect to FIG. 7. Although for the sake of simplicity the multivibrator 126 has been assumed to introduce blanking for four periods, three periods, will actually suffice since it is not necessary to actually return the beam to point 114 during clock period t_{10} . That is, period t_{10} can be used to deflect the beam toward point 112. At time t_{11} the beam will then have reached the same point as at t_{12} in the previously described sequence.

Accordingly, two techniques, as shown in FIGS. 5 and 9, have been employed for introducing discontinuities in a symbol. Each of these techniques has used as a criteria, the characteristics of the X and Y deflection signals. A still further approach is exemplified in FIGS. 10(a) and 10(b). As shown in FIG. 10(a), a Z signal control circuit 200 can be connected to each of the decoder circuit 22 output lines. That is, a different Z signal control circuit will be provided for each symbol and each of these circuits can have certain ones of the output terminals of counter 32 connected thereto. Thus, if the beam is to be blanked during a particular clock period for particular symbol, the corresponding counter output terminal will be connected to the Z signal control circuit 200 corresponding to that symbol. When that symbol is being drawn, the discontinuity will be introduced during the appropriate clock period as a consequence of the control circuit 200 disabling the gate 112 and unblanking means 20.

It has been assumed throughout the foregoing that at time period t_1 , the beam has reached equilibrium in its initial position. Depending upon the actual hardware employed, it may be necessary to introduce some delay after the position of the initial point is defined and prior to period t_1 .

From the foregoing, it should be appreciated that several embodiments of a display system have been disclosed herein which enable signals provided by substantially conventional dot type symbol generators to be used to draw much more pleasing characters comprised of continuous, or selectively discontinuous, straight and curved lines.

Although primary attention has been paid herein to the utilization of the invention with cathode ray tubes, it should be readily appreciated that the invention is equally as applicable to other X-Y deflection systems which employ writing elements and targets analogous to the cathode ray tube beam and face. Thus, the writing element could, for example, comprise a stylus and the target could comprise a piece of paper.

What is claimed is:

1. In a symbol display system including a cathode ray tube for displaying symbols in the form of a plurality of dots and wherein a symbol generator controls the cathode ray tube beam responsive to input data identifying a symbol by providing horizontal and vertical deflection signals respectively having, during each successive dot period, a signal level defining the deflection of the beam during that period adjacent signal levels being coupled by sharp signal transitions, and further including

means for unblanking said beam during a portion of each dot period, the improvement comprising:

means for converting each of said sharp signal transitions into relatively slowly changing transitions to thereby increase the transition time of the beam and reduce the dwell time during each dot period;

unblanking means for maintaining said beam unblanked throughout all of said dot periods; and

means responsive to characteristics of said deflection signals for disabling said unblanking means.

2. In a symbol display system including a cathode ray tube for displaying symbols in the form of a plurality of dots and wherein a symbol generator controls the cathode ray tube beam responsive to input data identifying a symbol by providing horizontal and vertical deflection signals respectively having, during each successive dot period, a signal level defining the deflection of the beam during that period adjacent signal levels being coupled by sharp signal transitions, and further including means for unblanking said beam during a portion of each dot period, the improvement comprising:

means for converting each of said sharp signal transitions into a modified ramp signal having a relatively small slope at each end thereof and a relatively large slope therebetween; and

means for maintaining said beam unblanked throughout all of said dot periods.

3. In a symbol display system including a cathode ray tube for displaying symbols in the forms of a plurality of dots and wherein a symbol generator controls the cathode ray tube beam responsive to input data identifying a symbol by providing horizontal and vertical deflection signals respectively having, during each successive dot period, a signal level defining the deflection of the beam during that period adjacent signal levels being coupled by sharp signal transitions, and further including means for unblanking said beam during a portion of each dot period, the improvement comprising:

means for converting each of said sharp signal transitions into a modified ramp signal having a relatively small slope at each end thereof and a relatively large slope therebetween;

said modified ramp signal having a rise time equal to at least two dot periods; and

unblanking means for maintaining said beam unblanked throughout all of said dot periods.

4. In a symbol display system including a cathode ray tube for displaying symbols in the form of a plurality of dots and wherein a symbol generator controls the cathode ray tube beam responsive to input data identifying a symbol by providing horizontal and vertical deflection signals respectively having, during each successive dot period, a signal level defining the deflection of the beam during that period adjacent signal levels being coupled by sharp signal transitions, and further including means for unblanking said beam during a portion of each dot period, the improvement comprising:

means for converting each of said sharp signal transitions into a modified ramp signal having a relatively small slope at each end thereof and a relatively large slope therebetween;

said modified ramp signal having a rise time equal to at least two dot periods;

unblanking means for maintaining said beam unblanked throughout all of said dot periods; and

means responsive to characteristics of said deflection signals for disabling said unblanking means.

5. A symbol display system comprising:

a cathode ray tube device having a target and including vertical and horizontal beam deflection means and a beam unblanking means;

a source of data codes, each code identifying one of a plurality of symbols;

symbol generator means responsive to each of said data codes for defining M successive dot intervals, said

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symbol generator means providing vertical and horizontal output signals during each of said M dot intervals defining a target position either the same as or different from the position defined during a prior dot interval, each of said output signals comprised of a series of successive signal levels coupled by substantially instantaneous transitions;

first and second wave shaping means respectively coupling said vertical and horizontal output signals to said vertical and horizontal deflection means for selectively extending the duration of each of said transitions to substantially one or more dot intervals; and

means for continually actuating said unblanking means throughout said M dot intervals.

6. The system of claim 5 including means responsive to said vertical and horizontal output signals for deactuating said unblanking means.

7. The system of claim 5 wherein said extended transitions between first and second signal levels have small slopes adjacent said first and second signal levels and a relatively large slope therebetween.

8. The system of claim 5 including means responsive to said signals coupled to said deflection means for varying the intensity of the cathode ray tube beam.

9. A symbol display system comprising:

a cathode ray tube device having a target and including vertical and horizontal beam deflection means and a beam unblanking means;

a source of data codes, each code identifying one of a plurality of symbols;

symbol generator means responsive to each of said data codes for defining M successive dot intervals, said symbol generator means providing vertical and horizontal output signals during each of said M dot intervals defining a target position either the same as or different from the position defined during a prior dot interval, each of said output signals comprised of a series of successive signal levels coupled by substantially instantaneous transitions;

first and second wave shaping means respectively coupling said vertical and horizontal output signals to said vertical and horizontal deflection means for extending the duration of each of said transitions to substantially one or more dot intervals;

said symbol generator means including means for providing an unblanking pulse during each of said M dot intervals; and

means responsive to said unblanking pulse during the initial one of said M dot intervals for actuating said unblanking means and for maintaining said unblanking means actuated throughout said M dot intervals.

10. A symbol display system comprising:

a target;

a selectively actuatable writing means for forming a visible image on said target;

a data source providing data signals identifying one of a plurality of symbols;

symbol generator means responsive to each of said data signals for defining M successive dot intervals, said symbol generator means providing vertical and horizontal output signals during each of said M dot intervals defining a point on said target either the same as or different from the point defined during a prior dot interval, each of said output signals comprised of a series of successive signal levels coupled by substantially instantaneous transitions;

first and second wave shaping means respectively responsive to said vertical and horizontal output signals for developing vertical and horizontal deflection signals, said first and second wave shaping means

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including means for extending the duration of at least some of said transitions to two or more dot intervals; and

vertical and horizontal deflection means respectively responsive to said vertical and horizontal deflection signals for deflecting said writing means with respect to said target.

11. The system of claim 10 including means for continually actuating said writing means throughout said M dot intervals.

12. Symbol display apparatus useful in combination with a cathode ray tube having a target defining a plurality of points and including means for producing an electron beam and accelerating said beam toward said target and means for vertically and horizontally deflecting said beam, said apparatus including:

first means for producing positioning signals for application to said deflection means for initially positioning said beam at a first of said target points;

a source of data codes, each identifying one of a plurality of symbols; and

means responsive to said source of data codes for first producing a first set of deflection signals for application to said deflection means for moving said beam from said first toward a second of said points and for secondly producing a second set of deflection signals for application to said deflection means while said beam is intermediate said first and second points for moving said beam toward a third of said points.

13. The apparatus of claim 12 wherein said means responsive to said source of data codes includes means for providing output signals, each output signal comprised of a series of signal levels, each signal level being maintained for at least one unit time interval and adjacent signal levels being coupled by substantially instantaneous signal transition; and

wave shaping means for extending the duration of said signal transitions to at least one unit time interval and for correspondingly reducing the duration that each signal level is maintained to substantially instantaneous.

14. The apparatus of claim 12 wherein said deflection signals are each comprise of a series of signal levels coupled by signal transitions of substantially ramp shape having a relatively small slope adjacent the signal levels it is coupling and a relatively large slope therebetween.

15. The apparatus of claim 12 wherein said deflection signals are comprised of a vertical deflection signal and a horizontal deflection signal, each deflection signal being comprised of a series of signal levels coupled by signal transitions of substantially ramp shape, each such signal transition having a rise time equal to at least two unit time intervals; and

wherein said means responsive to said source of data codes is able to initiate a horizontal deflection signal transition during a vertical deflection signal transition and initiate a vertical deflection signal transition during a horizontal deflection signal transition.

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