April 7, 1970 J. R. BROWN, JR 3,505,650

VISUAL CHARACTER DISPLAY DEVICE

Filed Jan. 17, 1967 5 Sheets-Sheet 1

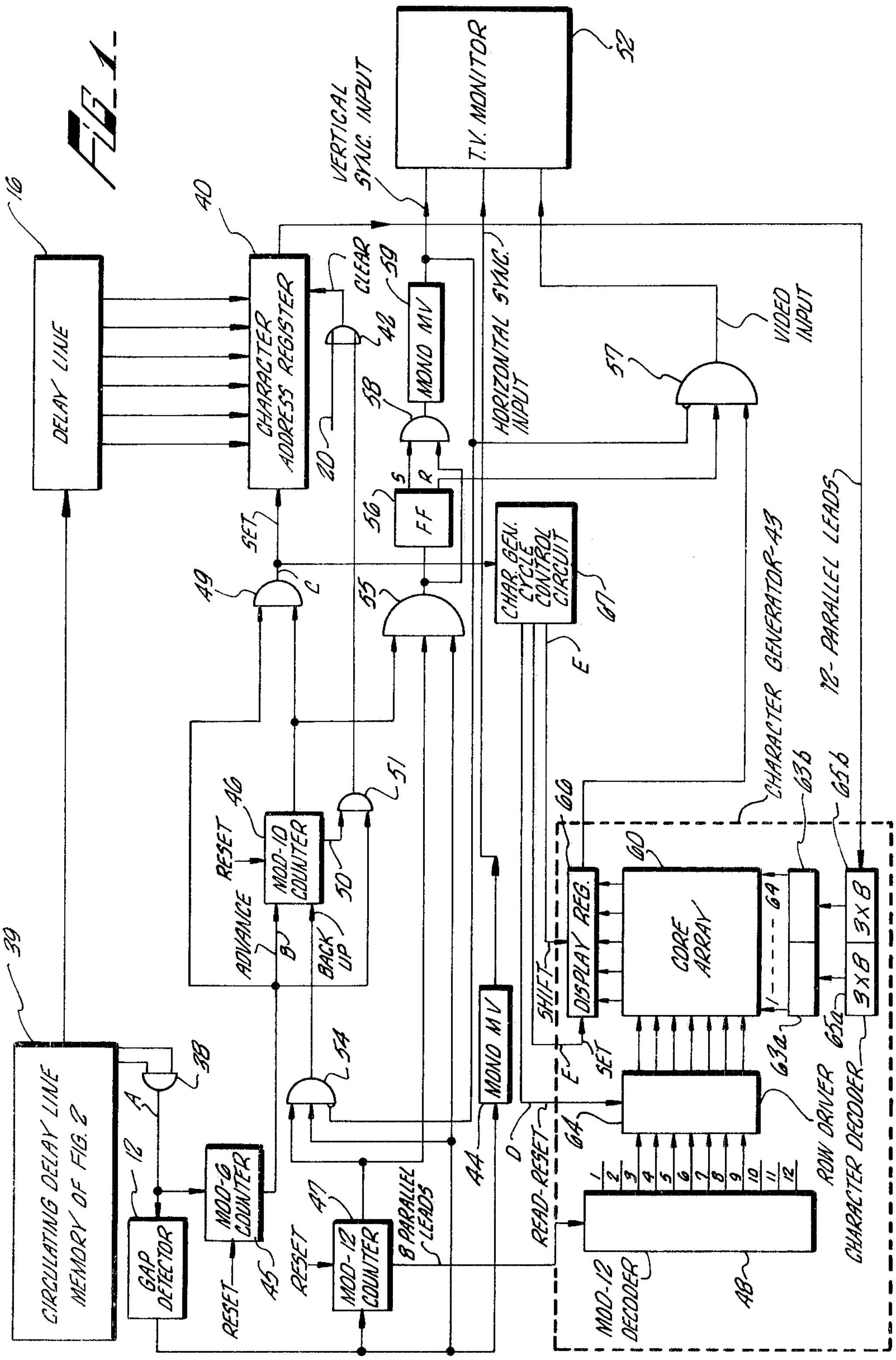


FIG. 1

VISUAL CHARACTER DISPLAY DEVICE

Filed Jan. 17, 1967 5 Sheets-Sheet 2

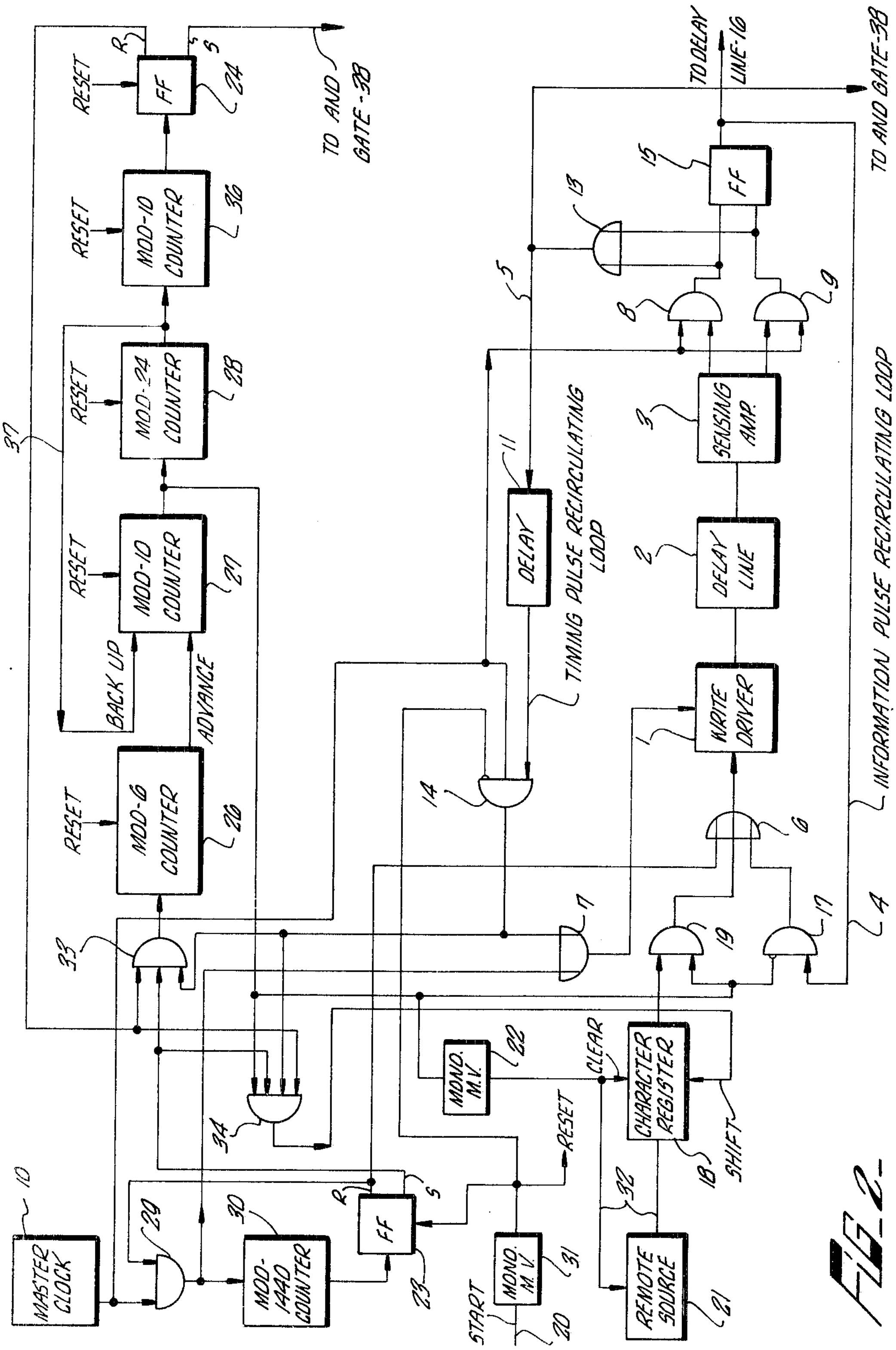


FIG. 2

FIG. 3

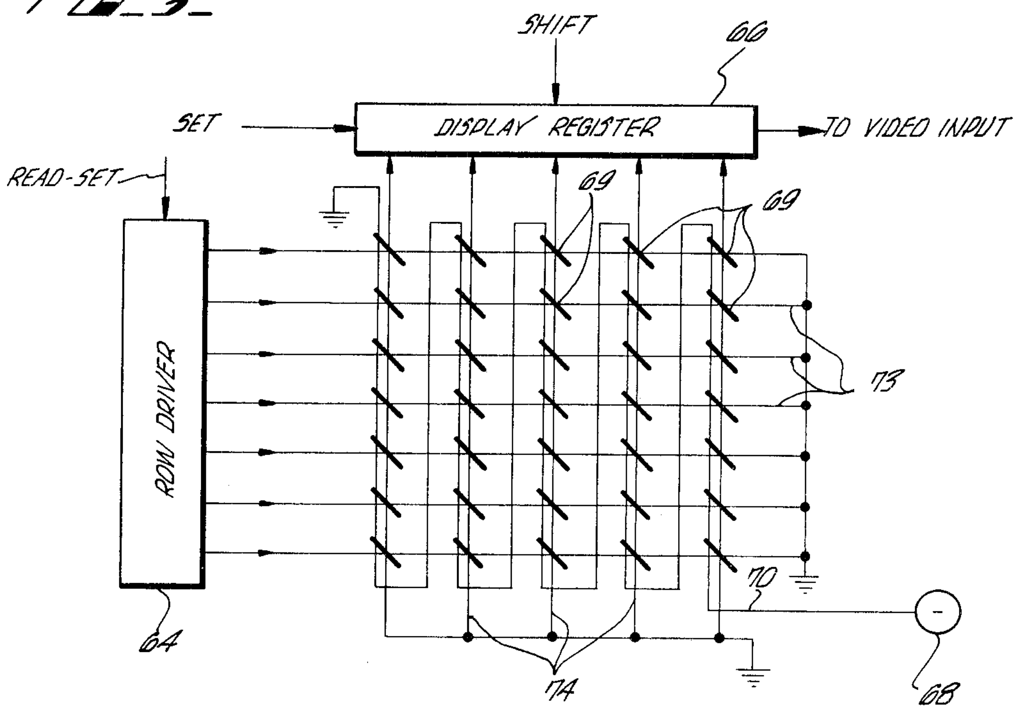
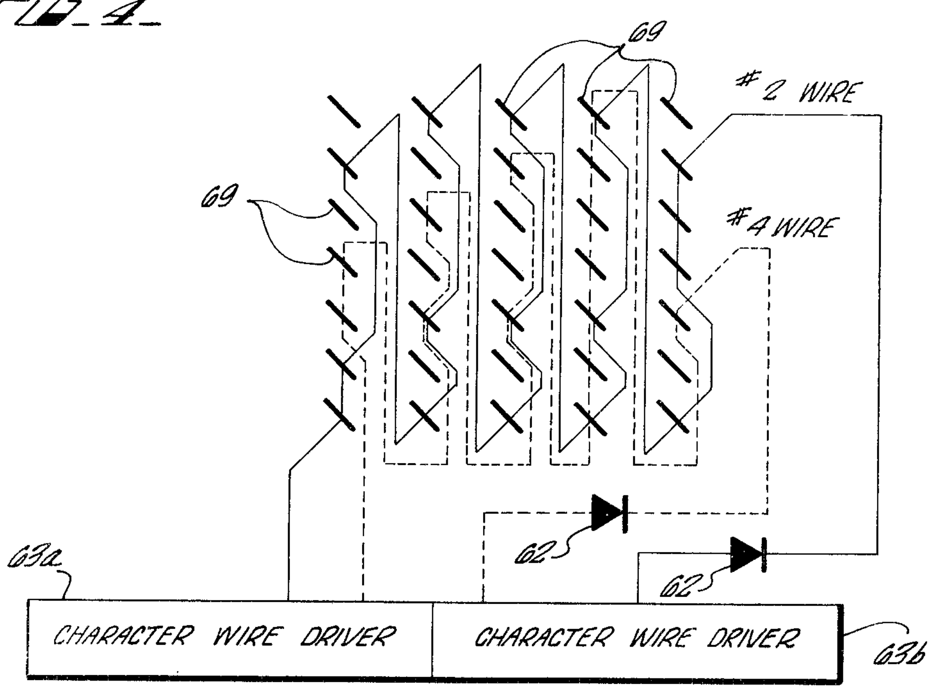

SHIFT
66
SET
DISPLAY REGISTER
TO VIDEO INPUT
READ-SET
69
69
ROW DRIVER
73
70
64
74
68

FIG. 4


69
#2 WIRE
69
#4 WIRE
62
62
63a
CHARACTER WIRE DRIVER
CHARACTER WIRE DRIVER
63b

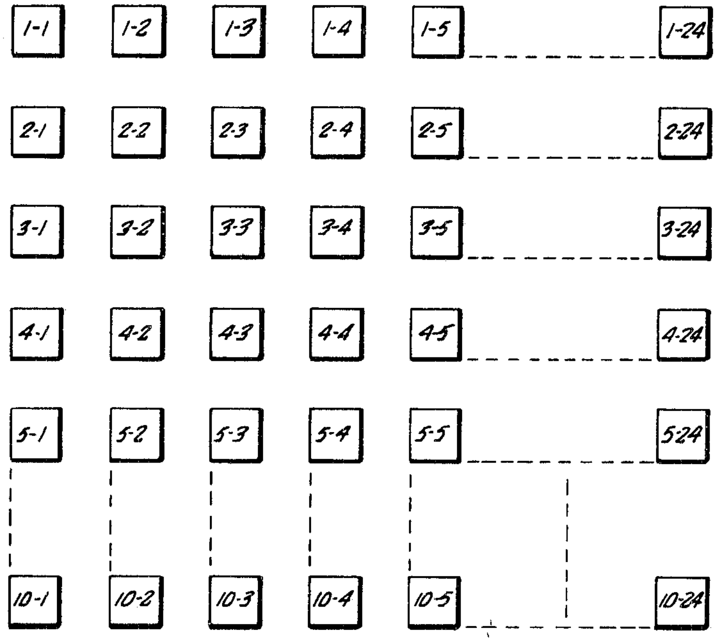


FIG. 6

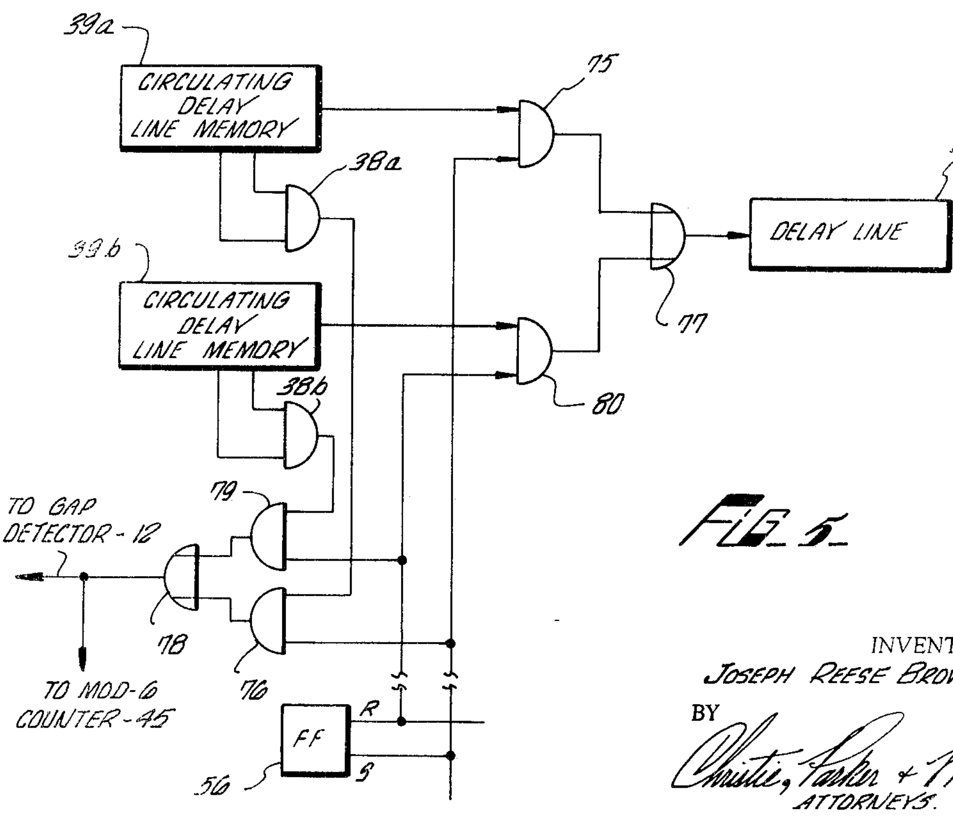


FIG. 5

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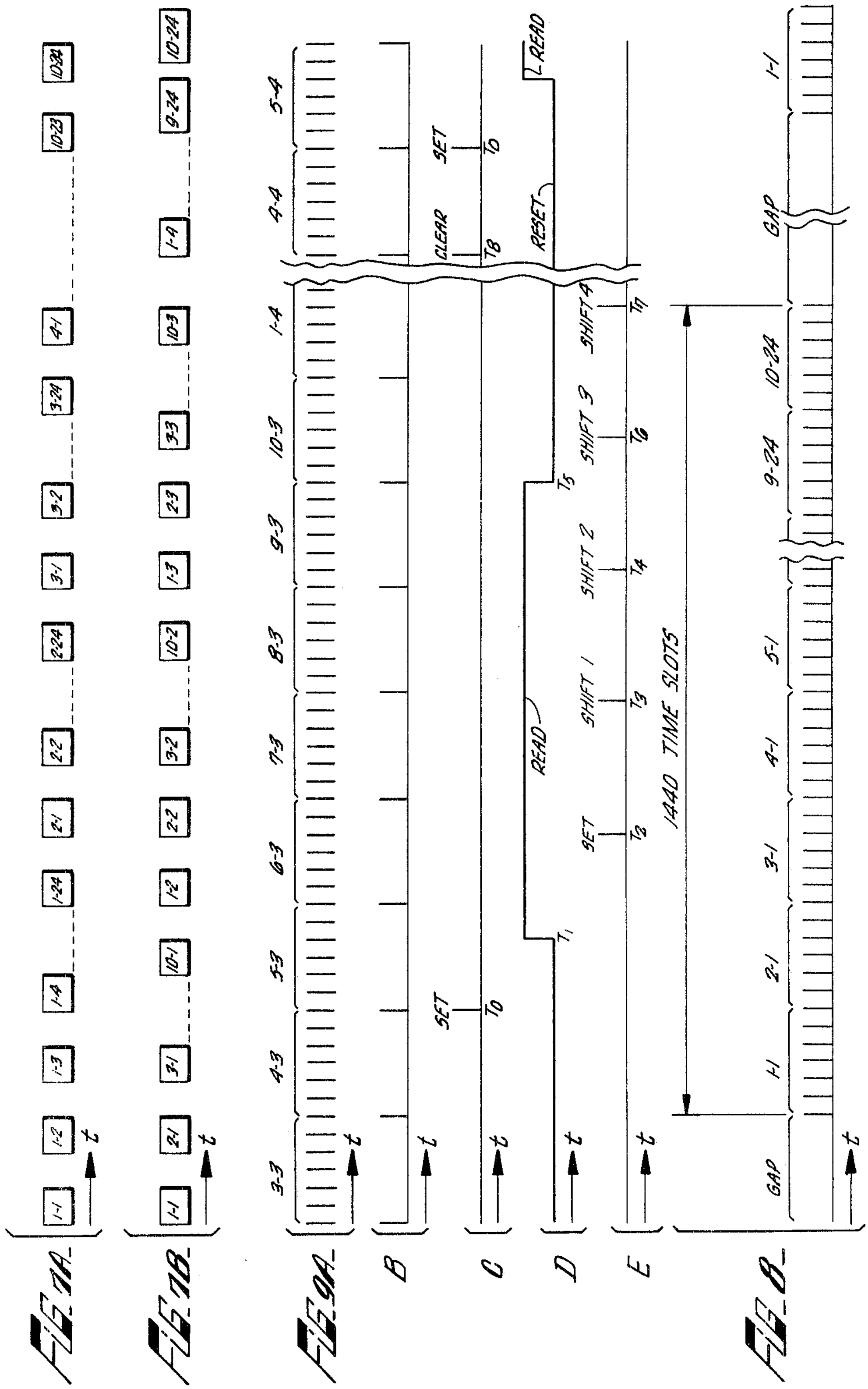
April 7, 1970 J. R. BROWN, JR 3,505,650

VISUAL CHARACTER DISPLAY DEVICE

Filed Jan. 17, 1967 5 Sheets-Sheet 5



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1

3,505,650
VISUAL CHARACTER DISPLAY DEVICE

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U.S. Cl. 340—172.5 20 Claims

ABSTRACT OF THE DISCLOSURE

A circulating memory device serves to store character information while it is being displayed on a cathode ray tube. Apparatus is disclosed for introducing the character information into the circulating memory in a predetermined sequence such that it can be retrieved from the memory at constant time intervals. The horizontal beam sweeps of the cathode ray tube are synchronized to the circulation of the character information in the memory. Circuitry is also disclosed for retrieving the character information from the memory in the sequence required to modulate the beam of the cathode ray tube as it produces a raster.

This invention relates to the visual display of information in the form of characters and, more particularly, to apparatus for controlling a visual display device, such as a cathode ray tube, so as to produce an arrangement of characters on its screen.

In many information processing systems, such as digital computers, it has been found useful and pleasing to the eye to display the output information as alphanumeric characters on the screen of a cathode ray tube. It has been recognized that the cost of producing such a visual display device can be substantially reduced by employing as the cathode ray tube a standard television monitor, i.e., a television set without the radio-frequency and intermediate-frequency receiver sections. Even when a standard television monitor forms part of a visual character display, however, its total cost remains high as compared to many other types of output devices used in information processing systems.

A major factor for the high cost of cathode ray tube visual character displays stems from the difficulty encountered in storing the character information during its display and retrieving the stored character information in a time sequence coordinated with the movement of the beam of the tube across the screen so as to produce the desired arrangement of characters on the screen. In general, a character generator is provided comprising a matrix of cross points corresponding to the picture elements on the screen that form a character. As the beam of the tube traverses the screen, coded information representing each character to be displayed in a row is in turn retrieved from a storage device and applied to the character generator which generates the appropriate signals for modulating the beam in the proper time sequence to produce the picture elements forming one line of a row of characters. With each traverse of the beam the procedure of entering the same character information into the character generator is repeated until all the lines of a row of characters are formed. Then, coded information representing each character to be displayed in the next row is repeatedly retrieved until all the lines in it are formed. To form one complete image or frame on the screen, this procedure is repeated for each row of characters in the arrangement.

According to the invention, a storage medium, in which the stored information is accessible in a repetitive time series coordinated with the motion of the beam, is

2

exploited to store character information to be displaced on the screen of a cathode ray tube or other display device during display. Particularly well suited is a circulating memory device. The circulating memory and the associated circuitry for gaining access to the character information stored therein are less complex, and can therefore be implemented for a lower cost, than the storage devices for the character information heretofore employed in cathode ray tube visual character display devices. To permit access to the character information in a time sequence compatible with the motion of the cathode ray tube beam on the screen, the character information is circulated in predetermined time relationship to the motion of the beam and is stored in the circulating memory in a special sequence.

Specifically, the character information circulates in synchronism with the sweeps of the beam across the screen, one complete circulation of the information taking place, while the beam makes one sweep cycle. The characters are interleaved in the circulating memory, such that the information needed to modulate the beam is obtained by addressing the circulating memory at uniform time intervals. Assuming the character positions are arrange on the screen in straight horizontal rows and straight vertical columns, forming a rectangle and the beam makes horizontal sweeps, the character information is stored in the circulating memory in a time series column by column of character positions. On the other hand, the character information is retrieved in a time series row by row, of character positions, since the beam makes horizontal sweeps. In retrieving the character information, the circulating memory is addressed at uniform time intervals equal to the time required for the character information in one vertical column of character positions to circulate. As the circulating memory is addressed, successive characters in the same horizontal row of character positions are accordingly retrieved, one entire row of characters for each complete circulation. To retrieve the next horizontal row of characters, the addressing interval is simply shifted one character position.

According to a feature of the invention, the character information is stored in the circulating memory by first introducing a series of dummy pulses predetermined in number and spacing into the circulating memory and then replacing the series of dummy pulses by the character information in coded form. Specifically, the series of dummy pulses equals in number the pulses representing the character information, and is spaced such that the entire series of dummy pulses circulates in the time interval the beam sweeps across the screen and a gap in the series occurs during the flyback interval of the beam. During display of the character information, the gap serves to indicate the completion of each circulation. The character information is fed to the circulating memory in a time series row by row. The pulses representing successive characters, however, do not replace successive dummy pulses. As pointed out above, the character information is actually circulated in a time series column by column. Thus, the pulses circulate repeatedly until all the dummy pulses are replaced by character information.

These and other features of the invention are considered further in the following detailed description taken in conjunction with the drawings, in which:

FIG. 1 is a schematic circuit diagram in block form of apparatus in accordance with the principles of the invention that controls a cathode ray tube so as to generate an arrangement of characters on its screen;

FIG. 2 is a schematic circuit diagram in block form of the circulating delay line memory employed in an arrangement of FIG. 1, together with apparatus for introducing the character information into the circulating memory in a predetermined time series;

FIG. 3 is a schematic diagram of part of the character generator employed in FIG. 1;

FIG. 4 is a schematic diagram of part of the character generator of FIG. 1;

FIG. 5 is a schematic diagram in block form of a modification of the apparatus of FIG. 1, in which a plurality of circulating memories is employed to store the character information;

FIG. 6 is a diagram depicting a typical arrangement of character positions on a cathode ray tube screen;

FIGS. 7A and 7B are diagrams depicting respectively the time series, in which the characters to be displayed in the positions are fed to the circulating memory, and the time series, in which these characters actually appear in the circulating memory;

FIG. 8 is a diagram illustrating the distribution of the pulses representing the character information in the circulating memory; and

FIGS. 9A through 9E are timing diagrams illustrating a typical timing sequence in a character generation cycle.

Reference is first made to FIG. 6, in which a rectangular arrangement of blocks is shown, each representing a character position on a cathode ray tube screen. Two numbers are contained in each block. The first number signifies one of ten horizontal rows counting from top to bottom, and the second number signifies one of twenty-four vertical columns counting from left to right. It is assumed that the beam of the cathode ray tube used to display characters moves across the screen in successive horizontal sweeps one beneath the other, as is the case in the standard television raster. Thus, character information to generate the video signal that modulates the cathode ray tube beam so that it produces the desired characters in each character position must be retrieved in a time series horizontal row by row. The characters to be displayed in one horizontal row are retrieved a given number of times, depending upon how many horizontal sweep lines constitute a horizontal row of character positions before the characters to be displayed in the next row are retrieved. A complete frame of characters is produced on the screen after the characters to be displayed in each horizontal row have thus been retrieved the given number of times. In terms of the specific arrangement of character positions in FIG. 6, the character to be displayed in character position **1–1** is first retrieved, followed by the character to be displayed in position **1–2**, the character to be displayed in position **1–3**, etc., up to the character to be displayed in position **1–24**. This provides the information to generate a modulating signal for one horioznta1 sweep of the cathode ray tube beam. For each horizontal sweep line of the beam assigned to the same row of character positions, the same character information is again retrieved. Thereafter, the character to be displayed in position **2–1** is retrieved, followed by the character to be displayed in position **2–2**, the character to be displayed in position **2–3**, etc., up to the character to be displayed in position **2–24**. This character information is also retrieved once for each horizontal sweep line assigned to the row of positions in which the retrieved information is to be displayed. The character information to be displayed in each of the other eight rows is similarly retrieved in turn. If, for example, twelve horizontal sweep lines are assigned to a row of character positions, each series of characters is retrieved twelve times and a complete picture comprises 120 horizontal sweeps.

According to the invention, the characters to be displayed on a screen of a cathode ray tube are stored in a circulating memory during their display. As shown in FIG. 7A, the character information would generally be fed, e.g., by the output of a computer, to the circulating memory for storage in a time series row by row, i.e., all the characters of row **1**, followed by all the characters of row **2**, all the characters of row **3**, etc. To adapt the circulating memory to the application at hand which calls for the character information to be retrieved at uniform time intervals and in a predetermined time series, the time series of information fed to the circulating memory, shown in FIG. 7A, is transformed in the course of the storage operation.

FIG. 7B represents the time series, in which the character information is stored in the circulating memory to achieve compatibility with the information demands of a cathode ray tube. Specifically, the character information circulates in a time series vertical column by column, beginning with column **1** and ending with column **24**. Furthermore, the character information circulates through the circulating memory in synchronism with the horizontal sweep of the cathode ray tube. In displaying the characters on th screen of the cathode ray tube, every tenth character is retrieved from the circulating memory. Thus, as the beam starts its first horizontal sweep, the character displayed in position **1–1** is retrieved first, followed by the character to be displayed in position **1–2**, etc., up to the character to be displayed in position **1–24**. At this point, the beam is at the end of its horizontal sweep and returns to its initial position during the horizontal flyback time. During this flyback time, a gap exists in which no character information circulates. To retrieve the character information to be displayed in the next horizontal row of positions, a shift of one character in the circulating memory takes place and every tenth character is again retrieved.

Reference is now made to FIG. 2, in which a circulating memory and the circuitry to control the operation of storing the character information in the circulating memory in the proper time series are shown in detail. In this illustrative embodiment of the invention, the character information is stored in the circulating memory in the form of a binary code. The circulating memory comprises a main signal path including a write driver **1**, a delay line **2**, and a sensing amplifier **3**, an information pulse recirculating loop **4**, and a timing pulse recirculating loop **5**. Write driver **1** produces at its output bipolar pulses depending on the state of the output of an OR gate **6** when timing pulses appear at the output of an OR gate **7**. Thus, the output of write driver **1** is normally at a base level, for example ground, moving positive of the base level to designate one binary state and moving negative of the base level to designate the other binary state. Instead of this bipolar pulse system, the Ferranti system of pulse coding could also be used. Sensing amplifier **3** detects the delayed bipolar pulses after propagation through delay line **2**. An AND gate **8** is enabled when a pulse of one polarity is detected by amplifier **3** and an AND gate **9** is enabled when a pulse of the other polarity is detected by amplifier **3**. While write driver **1**, delay line **2**, and sensing amplifier **3** accommodate bipolar pulses, the remainder of the system including the inputs of write driver **1** and the outputs of sensing amplifier **3** accommodate unipolar pulses. The master clock pulses produced by a source **10** serve to synchronize the phase of the entire system. The master clock pulses are applied to one input of each of AND gates **8** and **9** and, depending upon the polarity of the output of delay line **2** at the time, are transmitted through either AND gate **8** or **9**. The outputs of AND gates **8** and **9** are coupled by an OR gate **13** to timing pulse ricirculating loop **5** and a gap detector **12** (shown in FIG. 1). Thus, a timing pulse is generated at the output of OR gate **13** for each pulse propagating through delay line **2** irrespective of polarity. The timing pulses and the master clock pulses are applied to the inputs of an inhibit gate **14**. Timing pulses synchronized in phase to the master clock pulses therefore appear at the output of inhibit gate **14** and are applied to one input of OR gate **7** for timing the circulating memory.

The outputs of gates **8** and **9**, respectively, are also applied to two inputs of a flip-flop **15**. The state of flip-flop **15** depends upon which AND gate, **8** or **9**, has last transmitted a pulse, and therefore, upon the polarity of the bipolar pulses propagated through delay line **2**. Flip-flop **15** serves to convert the bipolar pulses to unipolar pulses. The output of flip-flop **15** is connected to a delay line **16** (shown in FIG. 1) and by information pulse recirculating loop **4** to one input of an inhibit gate **17**. Normally, no signal is applied to the inhibit terminal of gate **17**. Thus, recirculating information pulses are coupled by gate **17** and an OR gate **6** to write driver **1**. New character display information is transferred to a character register **18** one character at a time from a remote source **21**, which could be, for example, the output of a digital computer. The equipment is coupled to remote source **21** by a communication link **32**, which could be data communication lines presently in commercial operation. The transfer of character information occurs responsive to pulses generated by a monostable multivibrator **22**, the operation of which is described below. The output of register **18** is coupled to one input of an AND gate **19**. The output of AND gate **19** is also coupled by OR gate **6** to the input of write driver **1**. When a new character of display information is to be introduced into the circulating memory, AND gate **19** becomes enabled and gate **17** becomes inhibited by means described below, so that the character of display information stored in register **18** is substituted for the recirculating pulses as the input signal to write driver **1**. A delay device **11** in loop **5** retards the timing pulses sufficiently to be in phase on the average with the pulses from master clock **10**.

The procedure for storing character display information in the circulating memory will now be described. First, a start signal is applied to a lead **20** to actuate a monostable multivibrator **31**. Multivibrator **31** generates a pulse of fixed duration that serves to reset a flip-flop **24** and counters **26**, **27**, **28**, and **36** and to inhibit transmission through gate **14**. In addition, certain counters and a register discussed in connection with FIG. 1 are reset by the start signal. Gate **14** is inhibited for a time interval equal to or greater than the delay time of the circulating memory, during which time no bipolar pulses are applied to delay line **2**. Thus, the circulating memory is cleared of all information. The trailing edge of the pulse generated by multivibrator **31** resets a flip-flop **23**. Multivibrator **31** does not produce another pulse until another start signal is applied to lead **20**.

Before the character display information is actually introduced into the circulating memory, a series of dummy pulses equal in number to the total number of binary bits of character information is introduced into the circulating memory to mark the positions or time slots that the binary coded character information bits will occupy and to serve temporarily as the source of recirculating timing pulses. Then the binary coded character information bits gradually replace the series of dummy pulses as they circulate. Assuming that it is desired to display **64** different characters, each character to be displayed is represented by six binary bits, and the vertical and horizontal circuits of a standard television monitor are to be employed, a series of 1440 dummy pulses occupying a time interval of 53.3 microseconds (nominal horizontal beam sweep time in a television raster) is introduced into the circulating memory. This operation is initiated when flip-flop **23** is reset by multivibrator **31**. At this time, output R of flip-flop **23** is energized and thereby enables an AND gate **29**. Thus, master clock pulses from source **10** pass through AND gate **29** to a modulo–1440 counter **30** and to an input of OR gate **7** for application to write driver **1**. Output N of flip-flop **23** is also coupled through OR gate **6** to the other input of write driver **1**. As a result, all the master clock pulses passing through gates **29** and **7** to write driver **1** result in dummy pulses of the same polarity at the output of write driver **1**. After 1440 dummy pulses pass through AND gate **29**, the output of counter **30** becomes energized and sets flip-flop **23**. Output R of flip-flop **23** thus becomes deenergized and AND gate **29** stops transmitting master clock pulses. For the assumed example of 1440 binary bits of character information, a horizontal beam sweep time of 53.3 microseconds, a horizontal beam flyback time of 10.2 microseconds (nominal time periods in a television raster), master clock **10** would operate at a repetition rate of 27 mega-Hertz and the circulating memory would have a delay of 63.5 microseconds. Between successive occurrences of the series of dummy pulses, a time gap of 10.2 microseconds exists in which no pulses appear. FIG. 8 represents the distribution of the series of dummy pulses stored in the circulating memory. The time required for each dummy pulse of the series to occur once is equal to the horizontal sweep time of the beam and the time gap between the last dummy pulse of one occurrence of the series and the first dummy pulse of the next occurrence of the series is equal to the horizontal flyback time of the beam.

Next, each group of six dummy pulses of the series is replaced by the binary bits of a character as the pulses circulate. The numbers **1–1**, **2–1**, **3–1**, etc., in FIG. 8 designate the bracketed groups of time slots, in which the coded character bits are substituted. As explained below in connection with FIG. 1, during display of the character information, the horizontal beam sweep and flyback are synchronized to the operation of the circulating memory. Thus, as the beam moves through one horizontal sweep, all the binary bits of character information successively appear at the output of flip-flop **15** and during beam flyback, due to the gap, no bits of character information appear at the output of flip-flop **15**, i.e., flip-flop **15** does not change state.

When counter **30** sets flip-flop **23**, AND gate **33** is enabled to initiate substitution of character information for dummy pulses. The recirculating timing pulses, which at this point are entirely produced by the series of dummy pulses, control the introduction of the character information into the circulating memory. As previously discussed in connection with FIGS. 7A and 7B, although the character information is fed to the circulating memory row by row, it is stored in the circulating memory column by column. This transformation is carried out under the control of counters **26**, **27**, **28**, and **36**, which are advanced by the recirculating timing pulses coupled through AND gate **33** from the output of AND gate **14**.

After being reset at the beginning of the operation by the start signal on lead **20**, the output of counters **26**, **27**, and **28** are all energized. These counters are designed so that they are advanced only when their inputs change from an unenergized to an energized state. When counter **27** is reset, it actuates monostable multivibrator **22**. As a result, register **18** is cleared and the first display character, **1–1**, is called from remote source **21**. This character is stored in register **18** until shifted into the circulating memory.

The first six timing pulses emanating from inhibit gate **14** after AND gate **33** becomes enabled represent the pulse positions in which character **1–1** is to be stored in the circulating memory, as shown in FIG. 8. The output of counter **27**, the S output of flip-flop **23**, the R output of flip-flop **24**, and the output of inhibit gate **14** are all coupled to the inputs of an AND gate **34**. As a result, AND gate **34** is immediately prepared to transmit timing pulses after flip-flop **23** is set. After the gap in the recirculating timing pulses, the first six timing pulses representing the positions or time slots in the circulating memory, in which character **1–1** (actually the character to be displayed in position **1–1** on the screen) is to be stored, pass through AND gate **34** to the shift input of register **18**. The energized output of counter **27** also enables gate **19** and inhibits gate **17** so that six binary bits of character information are shifted out of register **18** and introduced into the circulating memory, while information recirculating loop **4** is inoperative. These six timing pulses are also coupled through AND gate **33** to advance modulo-6 counter **26** one complete cycle until its output is again reenergized. The output of counter **26** is connected to the advance input of modulo-10 counter **27**. When counter **26** becomes reenergized, the state of counter **27** is advanced one count, as a result of which its output becomes deenergized. Thus, AND gate **34** stops transmitting pulses to the shift input of register **18**, AND gate **19** becomes disabled, and information pulse recirculating loop **4** is reestablished through gate **17**.

As indicated by FIG. 7A, the next retrievable character in register **18** is character **1–2**. Furthermore, as indicated in FIG. 7B, nine characters, characters **2–1** through **10–1**, are to be stored in the circulating memory between characters **1–1** and **1–2**. Therefore, the time slots for nine characters must circulate through the memory before character **1–2** is stored. The timing pulses representing these time slots are counted by counters **26** and **27**. Each group of six timing pulses moves counter **26** through one cycle and thereby advances counter **27** by one count. Thus, after 54 timing pulses pass through gate **33**, the output of counter **27** becomes reactivated again, multivibrator **22** generates a pulse to clear register **18** and calls character **1–2** from source **21**, and the character is tansmitted over link **32** to register **18**. The six binary bits representing character **1–2** are immediately shifted out of register **18** and introduced into the circulating memory, in the manner described in connection with character **1–1**. It is assumed that the transmission time over link **32** is negligible. If this is in fact not the case, the operation of the circulating memory must be delayed accordingly, so a character is available in register **18** when the appropriate time slots in the circulating memory are in position to accept it. The output of counter **27** is connected to the input of modulo-24 counter **28**. Each time the output of counter **27** becomes reenergized, counter **28** is consequently advanced one count and another character is stored in the circulating memory. In this way, the characters are transferred from source **21** to the circulating memory in the time slots for every tenth character until modulo-24 counter **28** has stepped through an entire cycle. At this point, the character display information in the circulating memory has completely circulated once and the characters to be displayed in one complete row have been stored in the circulating memory. When the output of counter **28** becomes energized, a signal is generated that is coupled over a lead **37** to the backup input of counter **27**, so as to reduce the count by one. As a result, during the second circulation of pulses in the circulating memory, a character is transferred from register **18** to the circulating memory in the time slots of every tenth character beginning with the character adjacent to character **1–1**. Thus, character **2–1** is stored adjacent to character **1–1**, character **2–2** is stored adjacent to character **1–2**, etc. After the entire row of 24 characters is introduced into the circulating memory, counter **28** has passed through an entire cycle, again causing counter **27** to back up and counter **36** to advance. Each time the pulses stored in the circulating memory circulate once, another horizontal row of display characters is stored in the circulating memory in the time slots of every tenth character. After ten complete circulations of the pulses stored in the circulating memory, all the character display information is stored in the circulating memory in the sequence illustrated in FIG. 7B. Counter **36** has moved through an entire cycle at this point, and its output is energized thereby setting flip-flop **24**. As a result, the R output of flip-flop **24** becomes deenergized and further transmission through AND gates **3 3**and **34**, which transmit the pulses to control the counting and shifting operations, respectively, is inhibited. The S output of flip-flop **24**, which is coupled to the input of an AND gate **38** (shown in FIG. 1), becomes energized. This initiates retrieval of the character information and generation of the control signals applied to the inputs of a standard television monitor for display of the character arrangement on its screen.

Other arrangements for transmitting the character display information and storing it in the circulating memory are possible, depending upon the rate at which this information is transmitted by source **21**.

Reference is now made to FIG. 1, which shows the circuitry for retrieving character display information from the circulating memory and generating the signals applied to the inputs of a standard television monitor **52**. The circuitry of FIG. 2 is represented in FIG. 1 by a block **39**. The output of flip-flop **15** (FIG. 2) is connected to delay line **16**, which has six equally spaced taps along its length so that the binary bits comprising a character to be displayed can be retrieved simultaneously, i.e., in parallel. The six taps on delay line **16** are coupled to a six bit binary character address register **40**. Twelve parallel leads, shown in FIG. 1 as a single line, are coupled from character address **40** to a character generator **43**. One pair of leads corresponds to each bit of a character, the value of the bit being determined by which lead of the pair is energized. On application of a set signal produced at predetermined time intervals in a fashion described below, character address register **40** transfers the character it then contains to character generator **43**. As described in detail below, character generator **43** produces a modulating signal for the beam of television monitor **52** as it makes its horizontal sweeps in order to produce the characters on the screen. This modulating signal is coupled through an inhibit gate **57** to the video input of television monitor **52**.

Although many different formats on the screen are possible, it will be assumed for the purpose of illustration that each horizontal row of characters on the screen is composed of twelve horizontal sweep lines of the beam, seven sweep lines actually being occupied by the characters and five sweep lines being empty as space between horizontal rows of characters. Thus, 120 horizontal sweep lines are employed in forming the arrangement of FIG. 6 on the screen. Nominally 525 horizontal sweep lines are contained in a television raster, i.e., one frame, which is repeated 30 times per second. Each raster is broken down into two interlaced fields, each with 262½ horizontal sweep lines which are repeated 60 times per second. Since 120 lines are used in producing the arrangement of FIG. 6, 120 lines of each field are unused, and the rest of the lines are used for the vertical flyback of the beam. As a result, in this particular format one-half of the screen (either the upper or lower half) remains blanked out. The vertical sync input of the television monitor is controlled so that a constant and whole number of lines occurs in each field with the lines of successive fields being essentially in registration with one another. Thus, each field occurs 60 times per second without interlace. In order that the vertical sweep oscillator of the television monitor operates near its nominal frequency, the number of horizontal lines in a field is fixed to near 262½, for example, either 262 or 263 lines.

As explained in connection with FIG. 2, the pulses in the circulating memory circulate ten or more complete times during the storage operation, after which flip-flop **24** is set and output S is energized. As the pulses begin to circulate the eleventh time, the timing pulses are transmitted by AND gate **38** to a gap detector **12** and a modulo-6 counter **45**. Gap detector **12** produces a pulse at its output each time the gap in the timing pulses occurs. Gap detector **12** could be an integrator circuit coupled to a level detector, so that a pulse is produced when the integrated output falls below a predetermined value, i.e., when the time duration between successive pulses becomes large. The output of gap detector **12** is coupled to a monostable multivibrator **44**, which produces a pulse for application to the horizontal sync input of television monitor **52** each time a gap occurs in the pulses circulating in the memory. Consequently, the horizontal beam sweep of television monitor **52** is synchronized to the operation of the circulating memory, i.e., one horizontal sweep cycle of the beam, including flyback, occurs each time the information stored in the memory makes a complete circulation.

Counter **45**, as well as a modulo-10 counter **46** and a modulo-12 counter **47**, is reset by the start signal on lead **20** (FIG. 2), so that its output is initially energized. Character address register **40** is also cleared by the start signal on lead **20** as coupled through an OR gate **42**. As in the case of the counters of FIG. 2, counters **45**, **46**, and **47** are designed so their state will advance only when their input changes from an unenergized to an energized state. Similarly, character address register **40** only transfers character information from delay line **16** to character generator **43**, when its set lead changes from an unenergized to an energized state. The first six pulses transmitted through AND gate **38** advance counter **45** through one complete cycle. These are the timing pulses corresponding to the binary bits representing the character to be displayed in position **1–1**, which are propagating through delay line **16** as counter **45** is completing its cycle. The output of counter **45** is coupled to the advance input of counter **46**. The outputs of counters **45** and **46** are applied to the inputs of an AND gate **49**, whose output is applied to the set lead of character address register **40**. After counter **45** has advanced through one complete cycle, and its output becomes energized, a set signal is produced at the output of AND gate **49** to transfer character **1–1** from delay line **16** to character generator **43**. At the same time, the state of counter **46** is advanced one count. As each group of six timing pulses corresponding to a character stored in the circulating memory is applied to the input of counter **45**, counter **46** is advanced by one count. After counter **46** advances through eight counts, an output lead **50**, which is connected to the input of an AND gate **51**, becomes energized. The next time the output of counter **45** becomes energized, counter **46** advances to the ninth count and a signal is produced at the output of AND gate **51**, which is coupled through OR gate **42** to character address register **40** clearing it preparatory to transferring the next character from delay line **16** to character generator **43**. After the next six timing pulses are applied to the input of counter **45**, the output of counter **46**, which has now advanced through one complete cycle, becomes energized and a signal to set character address register **40** appears at the output of gate **49**. The six binary bits representing character **1–2**, which are propagating through delay line **16** at this instant, are transferred by character address register **40** to character generator **43**.

This procedure continues as the character display information circulates through the circulating memory. Each tenth character circulating through the memory is transferred by character address register **40** to character generator **43**. During one complete circulation of the character information, each of the twenty-four characters to be displayed in the first horizontal row of character positions on the screen is transferred in turn to character generator **43**. As previously mentioned, one complete horizontal sweep also occurs during this time. When the gap before the next series of timing pulses appears at the output of AND gate **38**, the output of gap detector **12** is energized to advance counter **47**. As the next series of timing pulses is applied to the input of counter **45**, the characters to be displayed in the first horizontal row of character positions are again each transferred in turn from character address register **40** to character generator **43**. This continues for twelve circulations of the character display information through the circulating memory, each advancing the state of counter **47**. The state of counter **47**, which designates the horizontal sweep line within a row of character positions being produced by the beam, is communicated by four parallel leads, shown in FIG. 2 as a single line, to a modulo-12 decoder **48** that forms part of character generator **43**, described in detail below.

The outputs of counter **47** and gap detector **12** are connected to the inputs of an inhibit gate **54**, to which no inhibiting signal is normally applied. After counter **47** has advanced through a complete cycle to indicate that one horizontal row of characters is completely produced, its output, which is coupled through gate **54** to the backup input of counter **46**, becomes energized. Thus, the state of counter **46** is reduced by one count. During the next twelve complete circulations of the character information through the circulating memory, the outputs of counters **45** and **46** actuate character address register **40**, so as to transfer to character generator **43** in turn every tenth character occupying positions in the circulating memory adjacent to the characters previously transferred. As illustrated in FIG. 7B, the characters to be displayed in the positions of the second horizontal row are respectively stored in the circulating memory adjacent to the characters displayed in the first horizontal row. Thus, the second horizontal row of characters is produced on the screen in the proper location. Each time counter **47** completes a cycle, which indicates that the horizontal sweep lines of the beam have formed one complete row of characters, the state of counter **46** is reduced by one count, and the next horizontal row of characters is retrieved. This is repeated ten times so that all the horizontal rows of characters are produced on the screen.

At the beginning of the display operation, the outputs of counters **46** and **47** are energized simultaneously. After the timing pulses begin to appear at the output of AND gate **38**, the outputs of counters **46** and **47** are not energized simultaneously again until counter **47** has reduced the state of counter **46** ten times, i.e., until 120 horizontal sweep lines have been produced on the screen. At this point, an AND gate **55** becomes energized in synchronism with the gap in the timing pulses, thereby setting a flip-flop **56**. The R output of flip-flop **56**, which is connected to an input of AND gate **57**, thus becomes deenergized. As a result, further transmission of the modulating signal for the beam from character generator **43** through AND gate **57** to the video input of television monitor **52** is cut off. The beam remains blanked for the 120 horizontal sweeps across the bottom half of the screen. Nevertheless, the circuitry operates during this time as described above. At the end of 120 complete circulations of the character information through the circulating memory, the output of AND gate **55** becomes energized again. The output of AND gate **55** and the S output of flip-flop **56** are connected to the inputs of an AND gate **58**. When the output of AND gate **55** becomes energized, a trigger signal for a monostable multivibrator **59** is produced at the output of AND gate **58** and then flip-flop **56** is reset. The output of monostable multivibrator **59** is applied to the vertical sync input of television monitor **52** to synchronize the repetition of the fields on the screen to the character information in the circulating memory. The output of multivibrator **59** is connected to the inhibit input of gate **57** to blank the video input during the vertical flyback time and to the inhibit input of gate **54** to prevent reducing the state of counter **46** during the vertical flyback time.

Character generator **43** comprises a core array **60** controlled by a character wire driver **63** and a row driver **64**. In succession, the rows of core array **60** are energized by row driver **64** synchronously with the horizontal beam sweeps under the control of modulo-12 decoder **48**. Likewise, character wires strung through the elements of core array **60** are individually energized by character wire drivers **63*a*** and **63*b*** under the control of character decoders **65*a*** and **65*b***, respectively. Decoders **65*a*** and **65*b*** each have eight output leads, one of which is energized depending upon the state of the three binary bits applied thereto. The character information for modulating the beam is transferred by a display register **66** through gate **57** to the video input of television monitor **52**. The entire operation is controlled by a character generator cycle control circuit represented as a block **67**.

For the purpose of illustration, it is assumed that eight discrete picture elements are allocated to each character position in a horizontal sweep line. Of these eight discrete picture elements, five actually form a character to be displayed while three serve as space between characters. During one horizontal sweep of the beam, the modulating signal applied to the video input of television monitor 52 from character generator 43 has 192 time slots or picture elements, each of a duration of .277 microsecond, for the asumed example. Character generator 43 controls the formation of characters on the screen by providing pulses in selected ones of these time slots in accordance with the character transferred thereto and the horizontal line count indicated by decoder 48.

Reference is now made to FIGS. 3 and 4 for a detailed description of how core array 60 generates the modulating signals for the beam. FIG. 3 shows an array of cores, such as those labeled 69, each of which is fabricated from a ferromagnetic material that exhibits a square-loop hysteresis characteristic. The array comprises seven horizontal rows, one for each horizontal sweep line actually forming a row of characters, and five vertical columns, one for each discrete picture element actually forming a character. A single wire connected to ground at one end and to a source 68 of negative potential at the other end is wound through each core of the array. Individually energizable wires, such as those labeled 73, are connected from row driver 64 through each horizontal row of cores to ground. Individually energizable wires, such as those labeled 74, are connected from display register 66 through each vertical column of cores to ground.

FIG. 4 depicts the same array of cores 69 with several wires wound through selected cores, which form the outline of several characters. A wire for producing the character "4" and a wire for producing the character "2," which are shown strung through the selected cores required to form their outline, are connected to character wire drivers 63*a* and 63*b* at the other end. Although only two wires are actually shown, 64 different wires, one for each available character to be displayed on the screen, would be strung through selected cores of the array according to the form of the character. The outputs of drivers 63*a* and 63*b* are arranged in an 8 x 8 matrix. A different one of the 64 character wires is connected between outputs of drivers 63*a* and 63*b* at each cross point of the matrix. Each character wire is connected in series with a diode 62 to provide isolation. All the wires shown in FIGS. 3 and 4 are in fact wound through the same core array.

In operation, all the cores are initially biased into negative saturation due to source 68. A positive current sufficient to drive a core from negative saturation up to the point of negative remanence is applied by character wire drivers 63*a* and 63*b* to the wire corresponding to the character to be displayed. All cores linked by the energized character wire are thus brought up to the point of negative remanence on their characteristic curve. Upon energization of one of wires 73 by row driver 64, all the cores in that row through which the energized character wire is wound change state, moving into positive saturation. By applying a set signal to display register 66, wires 74 then sense and transfer to register 66 the states of the cores in the row selected by row driver 64.

Reference is again made to FIG. 1 for a description of a typical time sequence in which the modulating signal for the beam is produced. In FIG. 9, curves A through E represent the signals at the points in the circuit of FIG. 1 bearing the corresponding letter.

Curve A represents the timing pulses produced at the output of AND gate 38 during the time interval in which the characters of slightly more than one vertical colum circulate through the circulating memory. Groups of six timing pulses are shown bracketed in curve A and designated according to the corresponding characters. The output of counter 45 is represented by waveform B. It is assumed that the state of counter 46 is such that the characters to be displayed in the positions of the fourth horizontal row are at the time being transferred to character generator 43. Thus, at the end of the six timing pulses corresponding to character 4–3, designated in curve C as time T_0, a pulse is produced at the output of AND gate 49 to set character address register 40. As a result, the character information to be displayed in position 4–3 is transferred by character address register 40 to character decoders 65*a* and 65*b*. Decoders 65*a* and 65*b* each accommodate three binary bits of character information. Each character decoder could comprise eight AND gates, to the inputs of which various combinations of the twelve parallel leads from character address register 40 are connected so that a different AND gate conducts for each combination of values of the binary bits. The leads from decoders 65*a* and 65*b* are connected in an 8 x 8 matrix, which results in one of the sixty-four character wires being energized.

Similarly, eight parallel leads are connected from the various stages of counter 47 to decoder 48. Each pair of leads represents the state of one of the four binary stages of counter 47. Decoder 48 could comprise seven AND gates, to the inputs of which various combinations of the eight parallel leads are connected, so as to energize the AND gates in sequence as counter 47 advances from state to state. The output of each AND gate would be connected to actuate a different output of row driver 64.

The output of AND gate 49 is coupled to character generator cycle control circuit 67. When the set signal is generated at time T_0, circuit 67 also begins its cycle to produce control pulses at predetermined time intervals after T_0. These control pulses could be generated in circuit 67 by monostable multivibrators each triggered simultaneously at time T_0 and having different time delays, depending upon the time at which the particular control pulse is to be produced.

As represented in curve D, circuit 67 produces a read signal starting at a time T_1. The time interval between T_1 and T_0 is sufficient to permit the character information to be decoded and to energize one of the 64 character wires of core array 60. Upon application of the read signal to row driver 64, one of the rows of the core array is prepared to be read, depending upon which output of decoder 48 is energized. Thereafter, at time T_2, a set input of display register 66 is energized by circuit 67 as shown in curve E. This causes the state of the five cores of the selected row of the array to be stored in register 66 and at the same time causes a signal representing the state of the first of the five cores to be shifted out of register 66 as the first picture element in the character and transmitted through gate 57 to the video input. Similarly, at times T_3, T_4, T_6, and T_7, each separated by intervals of .277 microsecond, the input of display register 66 is energized by circuit 67 to move an element of the character of register 66 to the video input. As shown by curve D, the read signal is removed from row driver 64 at a time T_5. When lead 50 connected to an auxiliary output of counter 46 is energized one count before the output of counter 46, and when the output of counter 45 is then energized, a pulse is transmitted by gates 51 and 48 to register 40 to clear it. As shown by curve C, this occurs at a time T_8. As a result of register 40 being cleared, the twelve parallel leads connecting register 40 and decoders 65*a* and 65*b* are all deenergized and none of the sixty-four character wires is energized. Since the leads from row driver 64 through the cores are also deenergized, the cores of array 60 become reset. Thereafter, the cycle is repeated with respect to the character information to be displayed in position 4–4. After each horizontal sweep line is produced, counter 47 advances and another horizontal row of cores of array 60 is read.

Although the described embodiment of the invention utilizes only half of the screen, it would be a simple matter to modify the circuitry to produce an arrangement of characters occupying the whole screen. In general, counter **45** represents the number of binary bits in each character to be displayed, counter **46** represents the number of horizontal rows of character positions on the screen, and counter **47** represents the number of horizontal sweep lines forming a horizontal row of character positions on the screen.

To increase the number of characters stored in the circulating memory and displayed on the screen of a television monitor, the frequency of operation of the entire system must be raised proportionately, because one complete circulation of the character information stored in the circulating memory must occur for each horizontal sweep of the beam. The modification of FIG. 5, in which two circulating memories, **39***a* and **39***b*, are employed, permits an increase in the number of characters to be displayed without increasing the frequency of operation. This configuration could be substituted directly into FIG. 1 for block **39**. For the first 120 horizontal sweep lines, output R of flip-flop **56** (FIG. 1) is energized. This enables AND gates **75** and **86**. As a result, circulating memory **39***a* is operative, supplying binary character bits to be displayed on the upper half of the screen through an OR gate **77** to delay line **16** and timing pulses through an AND gate **38***a*, AND gate **76**, and an OR gate **78** to gap detector **12** and counter **45**. During the second 120 horizontal sweep lines of the field, output S of flip-flop **56** is energized. This enables AND gates **79** and **80**. As a result, circulating memory **39***b* is operative, supplying binary character bits to be displayed on the lower half of the screen through OR gate **77** to delay line **16** and timing pulses through an AND gate **38***b*, AND gate **79**, and OR gate **78** to gap detector **12** and counter **45**. Similarly, more circulating memories could be added to increase the capacity even further.

Any number of modifications of the described embodiment are possible. For one thing, the character information can be stored in the circulating memory in a sequence different from that described, so long as the sequence is such that character information can be retrieved at substantially constant intervals of time in the proper time sequence to produce the desired arrangement of characters on the screen of a cathode ray tube. Likewise any memory in which the stored information is repetitively available in a time series is to be understood as a circulating memory adaptable to operate according to the invention. Furthermore, although particularly advantageous in connection with a standard television monitor to form a low-cost visual character display, the principles of the invention apply equally well to other types of display devices, including one covering the screen with successive vertical sweeps instead of horizontal.

What is claimed is:

1. Apparatus for generating a modulating signal for a beam that produces an arrangement of characters on a surface by sweeping across the surface in substantially parallel paths successively displaced from each other to form a raster, the apparatus comprising:

(a) means for storing information representing the characters to be displayed on the surface so that such character information is accessible in a repetitive predetermined time series, the storing means including means for controlling the period of repetition of the information such that all the information is accessible at least once during each sweep of the beam across the surface;

(b) means for retrieving the information representing each character from the storing means as the beam sweeps across the position on the surface at which such character is to be displayed in accordance with the arrangement of characters; and

(c) a character generator responsive to the retrieved information representing each character for generating a modulating signal for the beam that produces on the screen the portion of the character required in the area of the surface momentarily in contact with the beam to produce the arrangement of characters.

2. The apparatus of claim **1**, in which the controlling means makes all the information in the storing means accessible only once during each sweep of the beam across the surface.

3. The apparatus of claim **1**, in which the controlling means comprises means for generating an indication each time the series of character information in the storage means is repeated and means for synchronizing the beam sweeps to the indications.

4. The apparatus of claim **2**, in which the character information in the storage means is accessible in a repetitive time series with a gap in the information occurring between successive series, the controlling means comprises means for sensing the gaps in the character information and means responsive to the sensing means for generating synchronizing pulses for controlling the beam sweep.

5. The apparatus of claim **1**, in which the character information is stored in the storing means such that the information to be retrieved by the retrieving means is accessible at uniform time intervals.

6. The apparatus of claim **1**, in which the arrangement of characters on the surface forms rows and columns perpendicular to one another, the beam sweeps across the surface in paths essentially parallel to the rows of characters such that the character information is to be retrieved successively row by row, and the character information is stored in the storing means successively column by column.

7. The apparatus of claim **6**, in which the retrieving means retrieves character information from the storing means at uniform time intervals.

8. Apparatus for producing a visual display of an arrangement of characters comprising:

(a) a cathode ray tube having a screen on which the characters are to be displayed and a beam that sweeps across the screen in substantially parallel paths successively displaced from each other to produce visual images on the screen;

(b) a circulating storage medium adapted to hold information representing all the characters to be displayed on the screen at one time;

(c) means for retrieving the character information in the circulating storage medium in a time sequence coordinated with the sweep of the beam across the screen so as to provide continuously the information representing the character to be displayed in the area of the screen momentarily occupied by the beam;

(d) means responsive to the retrieved information representing each character for modulating the beam in accordance with the form of the character so that the portion of the character to be displayed in the area of the screen momentarily occupied by the beam is produced on the screen; and

(e) the improvement comprising means for controlling the circulation of the character information in the storage medium so the sweep period of the beam is a multiple of the period of circulation of the character information.

9. The apparatus of claim **8**, in which means are provided for generating an indication each time the character information completes a circulation in the storage medium, the indications serving as a synchronizing source for the parallel beam sweeps.

10. The apparatus of claim **8**, in which the character information is stored in the storage medium such that the information to be retrieved by the retrieving means is accessible at uniform time intervals.

11. The apparatus of claim **10**, in which the character information in the storage medium circulates in a time period equal to the period of the parallel sweeps of the beam.

12. The apparatus of clam **8**, in which the arrangement of characters on the screen forms rows and columns perpendicular to one another, the beam sweeps across the screen in paths essentially parallel to the rows of characters such that the character information is to be retrieved successively row by row, and the character information is stored in the storage medium successively column by column.

13. The apparatus of claim **12**, in which the retrieving means retrieves character information from the storage medium at uniform time intervals.

14. The apparatus of claim **8**, in which the retrieving means comprises: means for generating timing pulses representing the time of occurrence of the pulses in the storage medium; first and second counters connected in tandem such that the second counter advances by one count each time the first counter completes a cycle, the first counter having a cycle equal to the number of pulses representing a character and the second counter having a cycle equal to the number of rows of characters; means for advancing the first counter one count responsive to each timing pulse; means for retrieving information representing a character from the storage medium upon each completion of a cycle by the second counter; a third counter having a cycle equal to the number of parallel sweeps of the beam assigned to a row of characters, the state of the second counter being reduced by one count each time the third counter completes a cycle; and means for advancing the state of the third counter upon completion of each parallel sweep of the beam.

15. The apparatus of claim **14**, in which means are provided responsive to the simultaneous completion of the cycles of the second and third counters for generating a synchronizing pulse to control the motion of the beam perpendicular to the parallel sweeps.

16. The apparatus of claim **8**, in which a plurality of individual circulating storage mediums are provided, to which the retrieving means has access in succession during production of one complete image on the screen.

17. The apparatus of claim **16**, in which the character information is equally divided among the individual storage mediums and the information in all the storage mediums circulates in synchronism with the beam sweep.

18. The apparatus of claim **8**, in which plural circulating storage mediums are connected in parallel to operate one at a time in supplying character information to the retrieving means during the production of a complete image on the screen.

19. The apparatus of claim **8**, in which the means for modulating the beam comprises: an array of square loop ferromagnetic cores, the number of rows in the array being equal to the number of parallel sweeps of the beam actually forming a row of characters and the number of columns in the array being equal to the number of picture elements of the beam actually forming a character; a character wire for each character to be displayed wound through selective cores of the array in accordance with the form of the character; row driver wires individual to each row of the array wound through the rows of the array; means for biasing each core of the array so that upon the simultaneous energization of a character wire and a row driver wire wound through a core, the core changes state; means for individually energizing the character wires in accordance with the retrieved information; means for energizing the row driver wires in succession in synchronism with the beam sweeps across the screen; and means for modulating the beam as a function of the state of the cores in the row having an energized row driver wire.

20. The apparatus of claim **8**, in which the beam is blanked during the parallel sweeps on part of the screen and the characters are entirely displayed on the other part of the screen.

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