

[54] **ELECTRONIC DISPLAY CONTROLLED STAGE LIGHTING SYSTEM**

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[21] Appl. No.: **391,481**

**Related U.S. Application Data**

[63] Continuation-in-part of Ser. No. 134,979, April 18, 1971, abandoned.

[52] U.S. Cl. .... **340/324 A; 240/9**

[51] Int. Cl. .... **G06f 3/14**

[58] Field of Search .... **340/324 A, 324 AD, 166 R, 340/175, 332; 240/9; 315/312, 316, 318, 325**

[56] **References Cited**

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Primary Examiner—John W. Caldwell  
 Assistant Examiner—Marshall M. Curtis  
 Attorney, Agent, or Firm—Darby & Darby

[57] **ABSTRACT**

An electronic display controlled lighting system and method for controlling a large number of theatrical stage lights including data storage apparatus for storing information representing sequences of stage lighting cues, data processing apparatus for modifying, re-arranging and executing the stored stage lighting cues under control of an electronic display control apparatus such as a cathode ray tube monitor for displaying, in the form of a character matrix display, information representing the operating status of the system and information representing the circuit values to be applied to each lighting circuit to be controlled in accordance with the stored lighting cues and a light pen selecting device for activating system functions according to the portion of the character matrix display designated by the operator.

21 Claims, 40 Drawing Figures

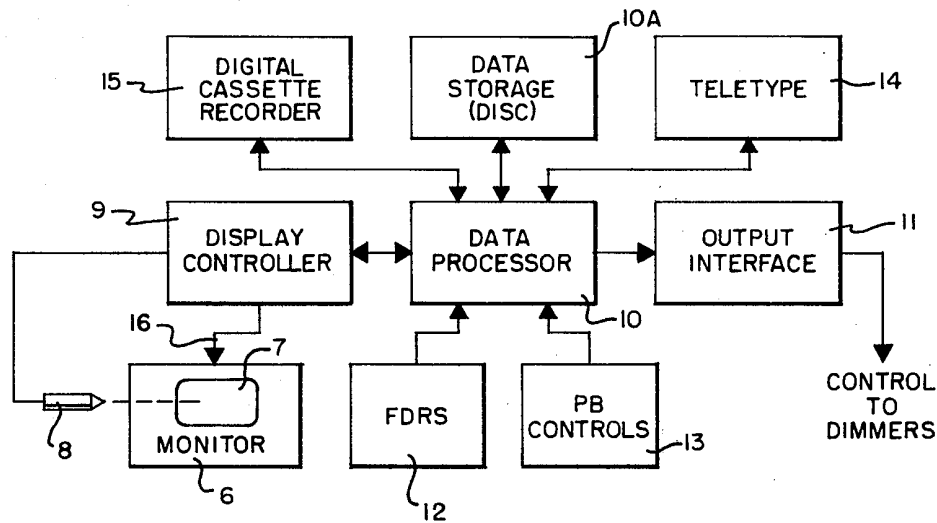


FIG. 1

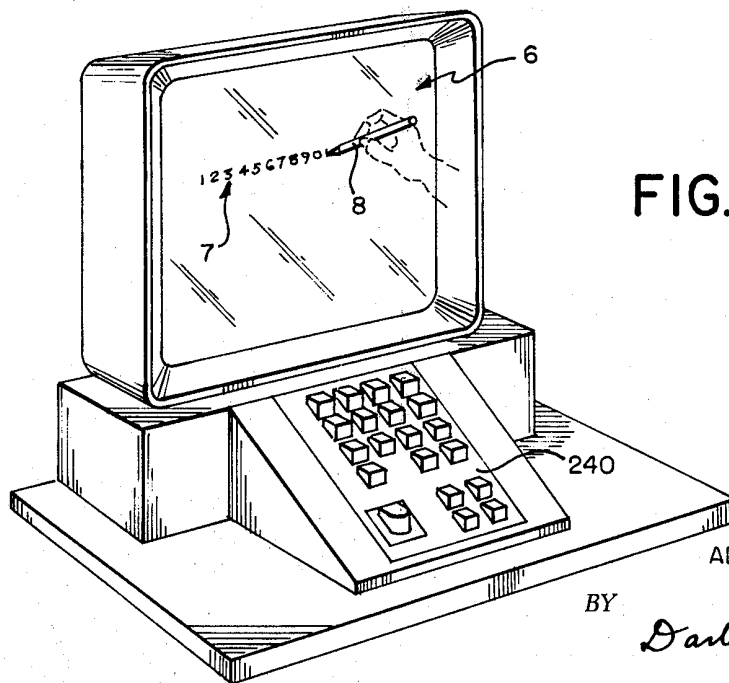
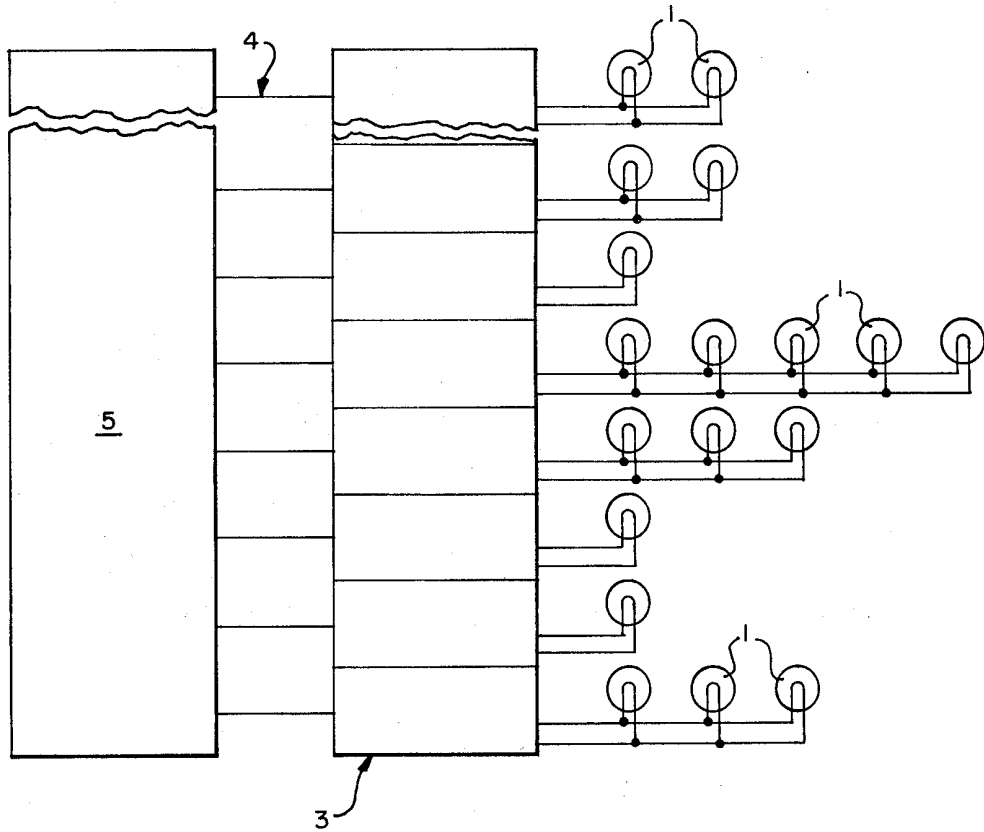


FIG. 2

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FIG. 3

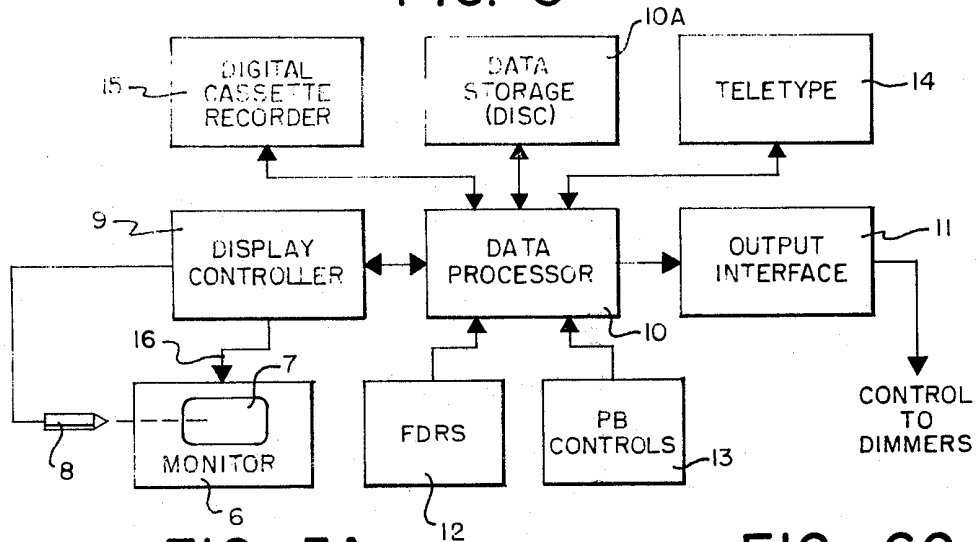


FIG. 5A

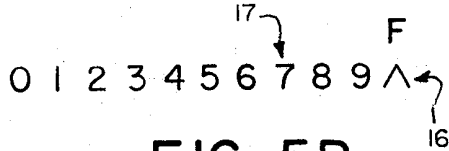


FIG. 5B

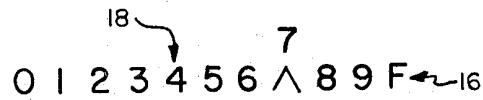


FIG. 5C

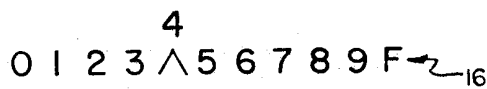


FIG. 6A

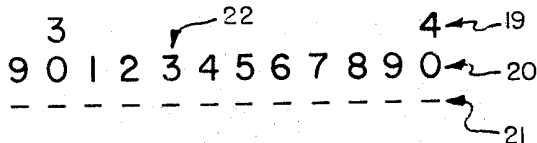


FIG. 6B

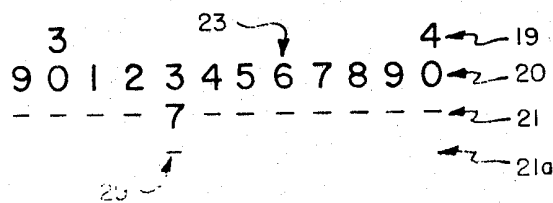


FIG. 6C

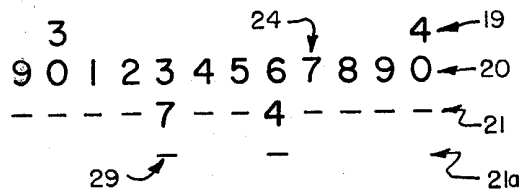


FIG. 6D

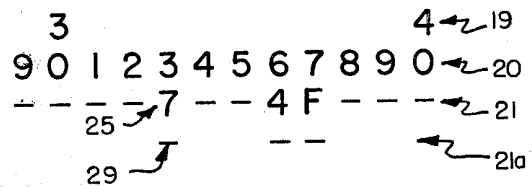


FIG. 6E

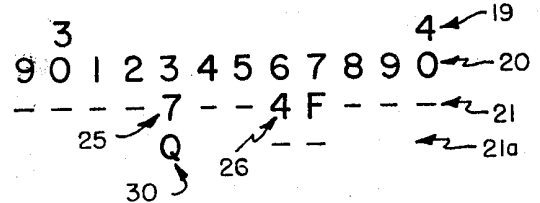


FIG. 6F

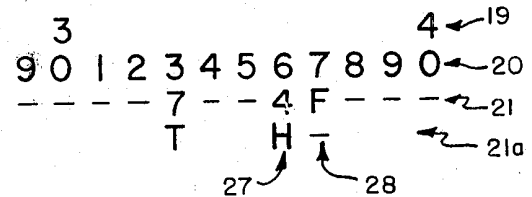




FIG. 6G

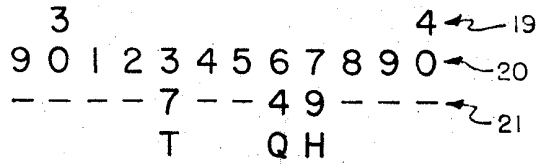


FIG. 7D

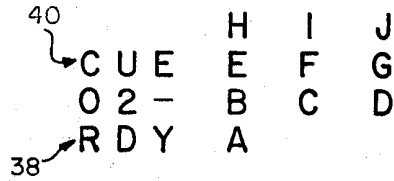
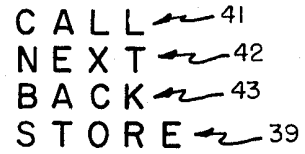
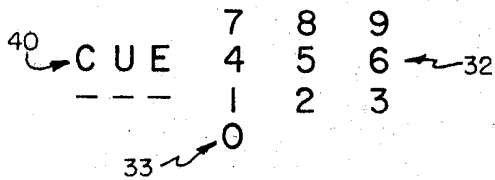


FIG. 7A



44 → CANCEL

FIG. 7B

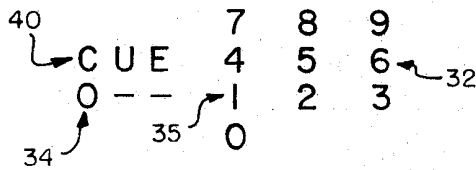


FIG. 8A

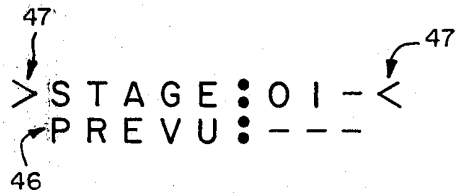


FIG. 7C

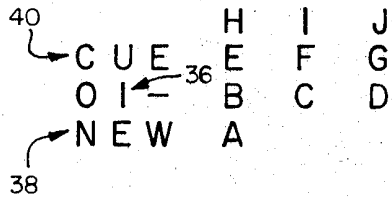
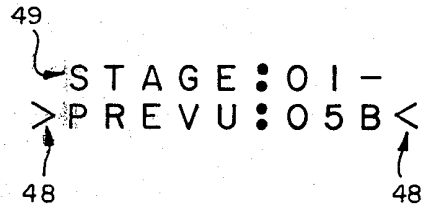


FIG. 8B



39 → STORE

FIG. 9A

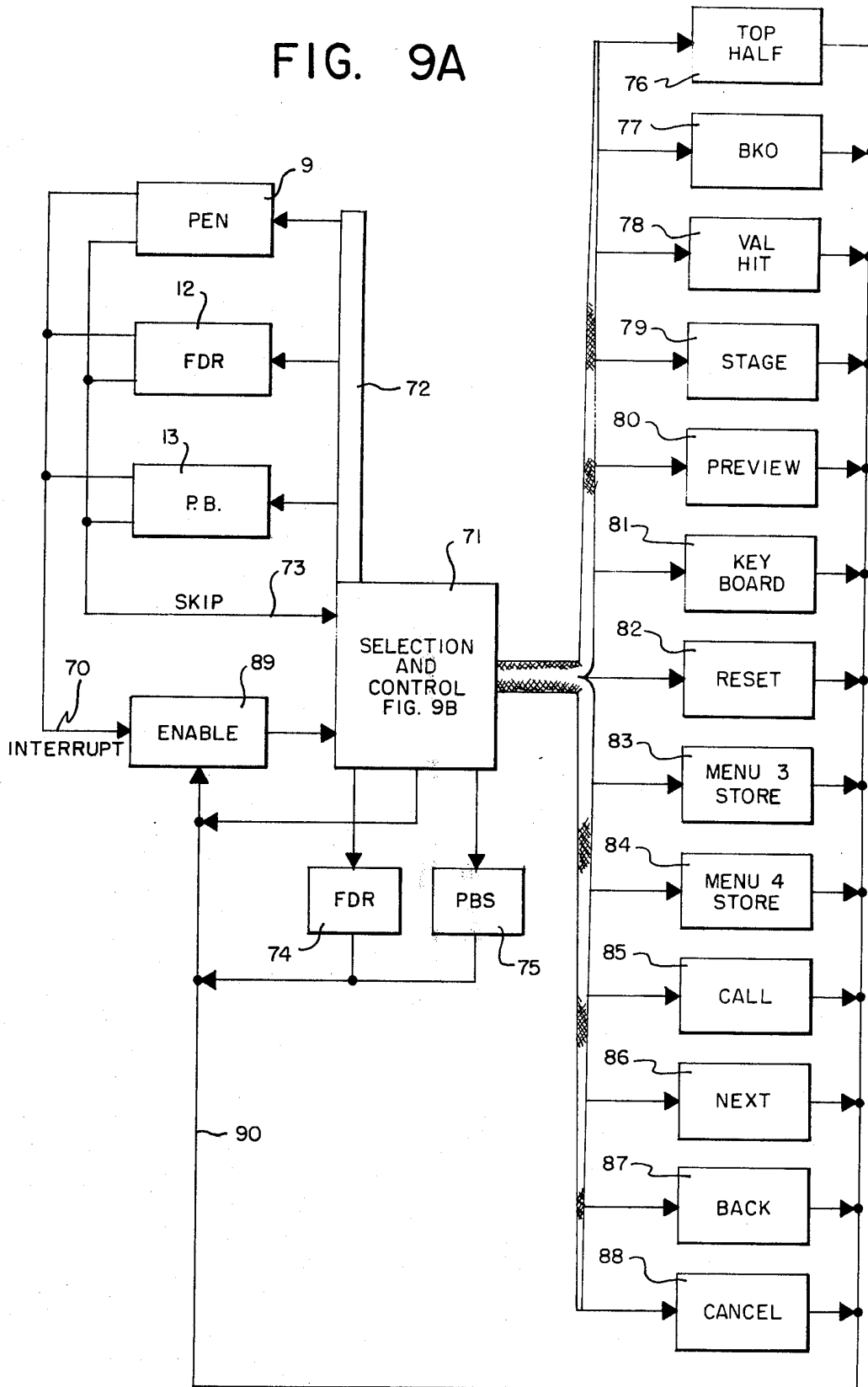


FIG. 9B

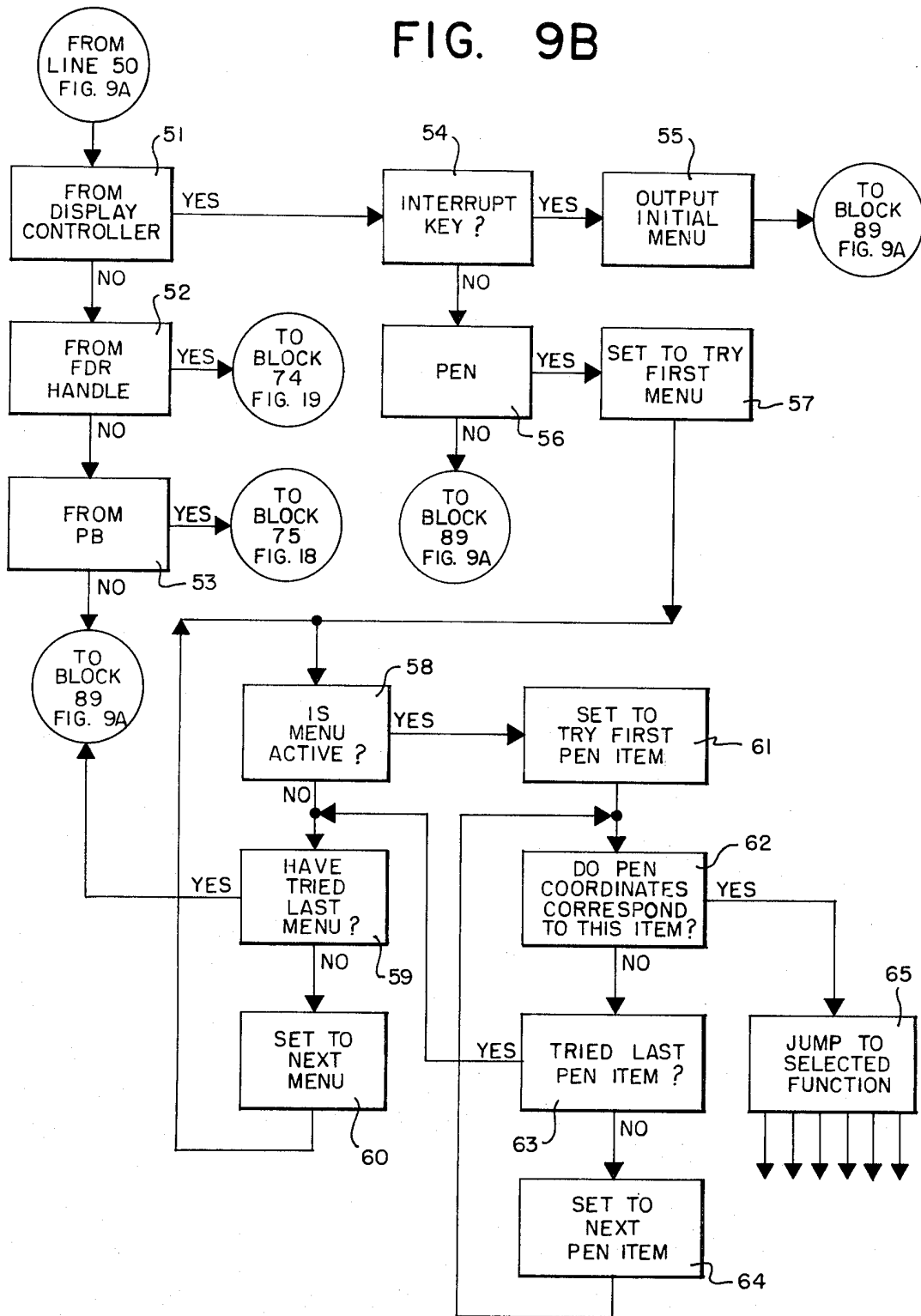


FIG. 10A

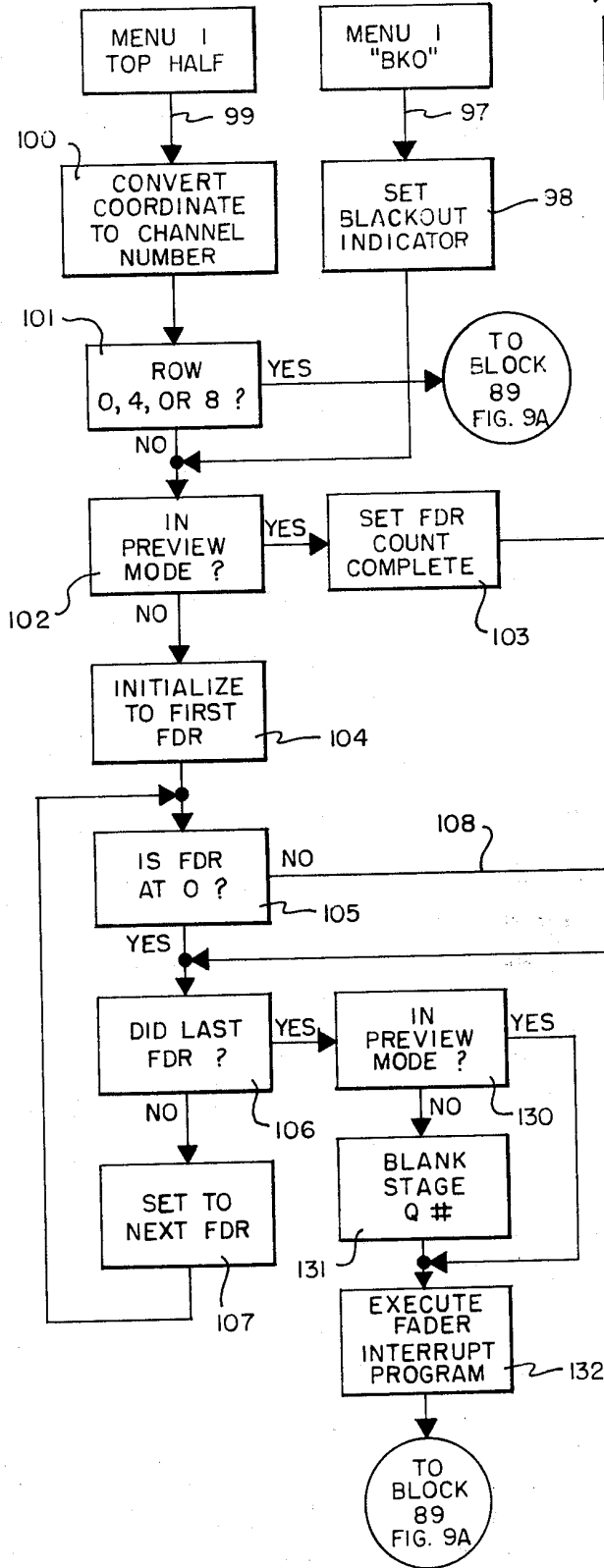


FIG. 11

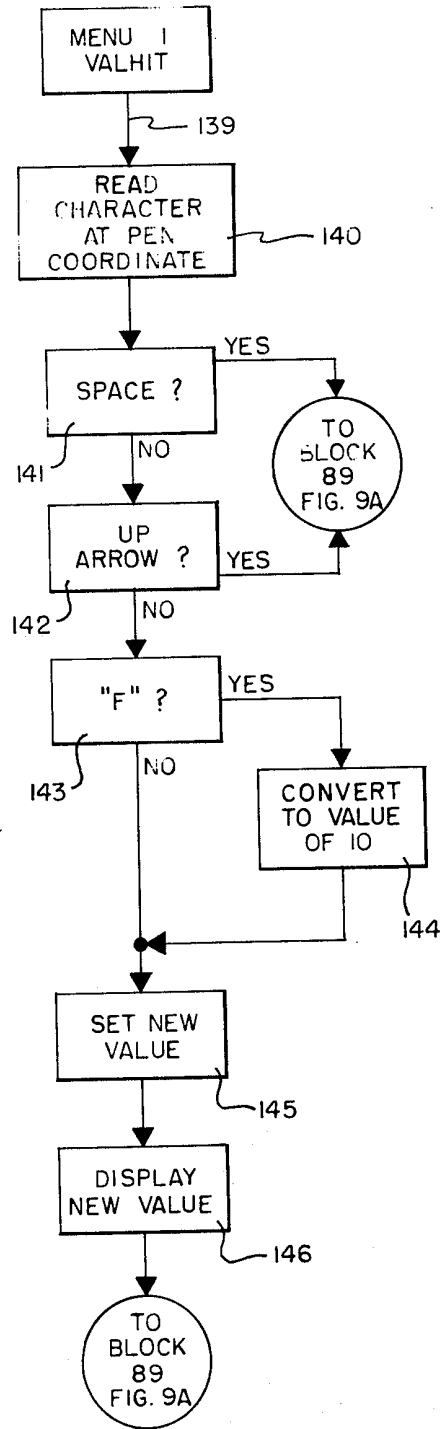


FIG. 10B

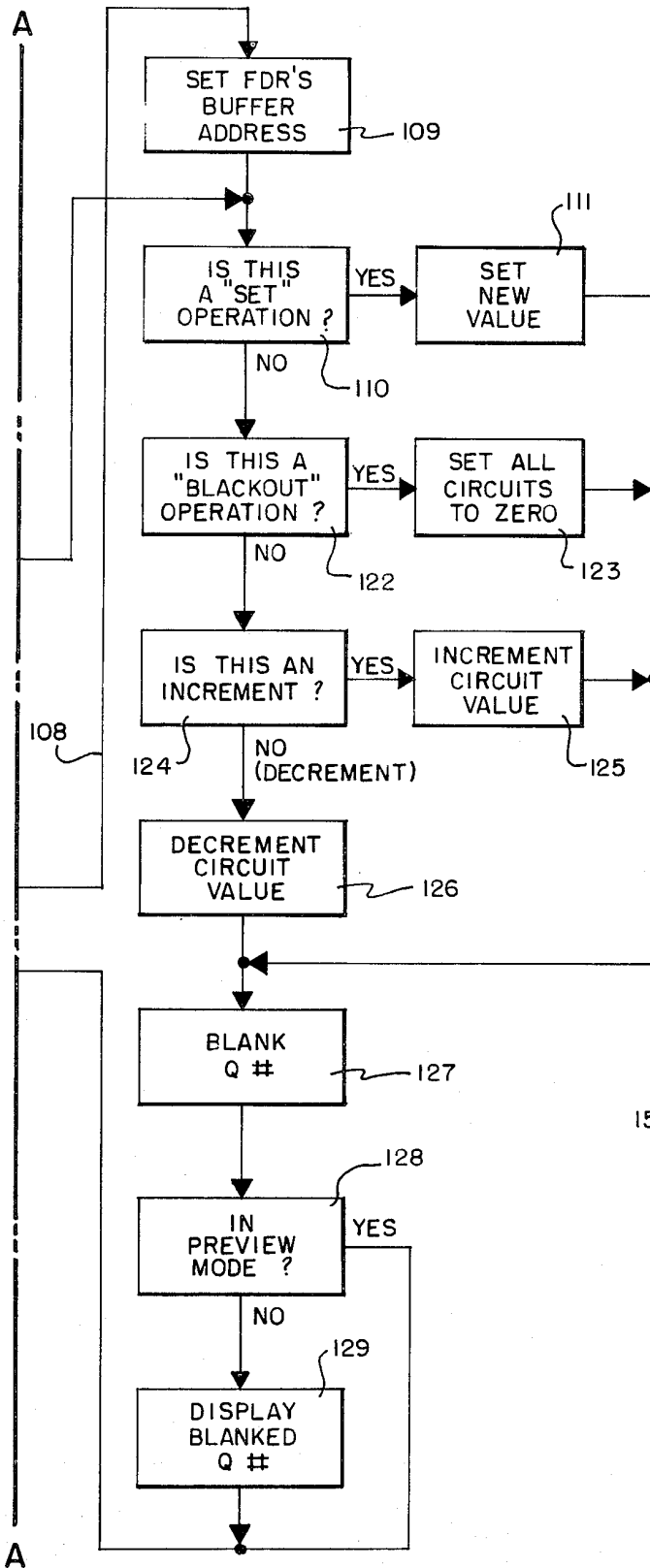


FIG. 12

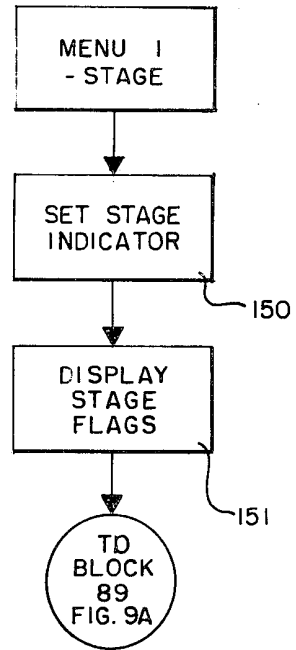


FIG. 13

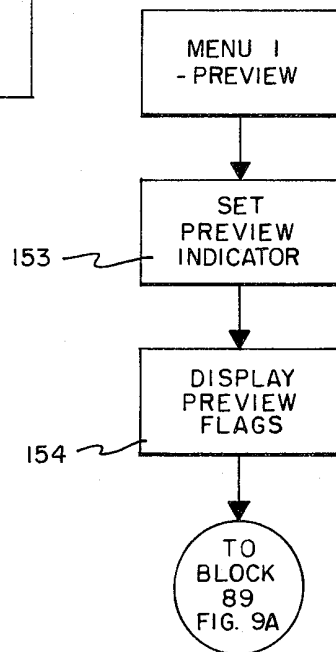


FIG. 14

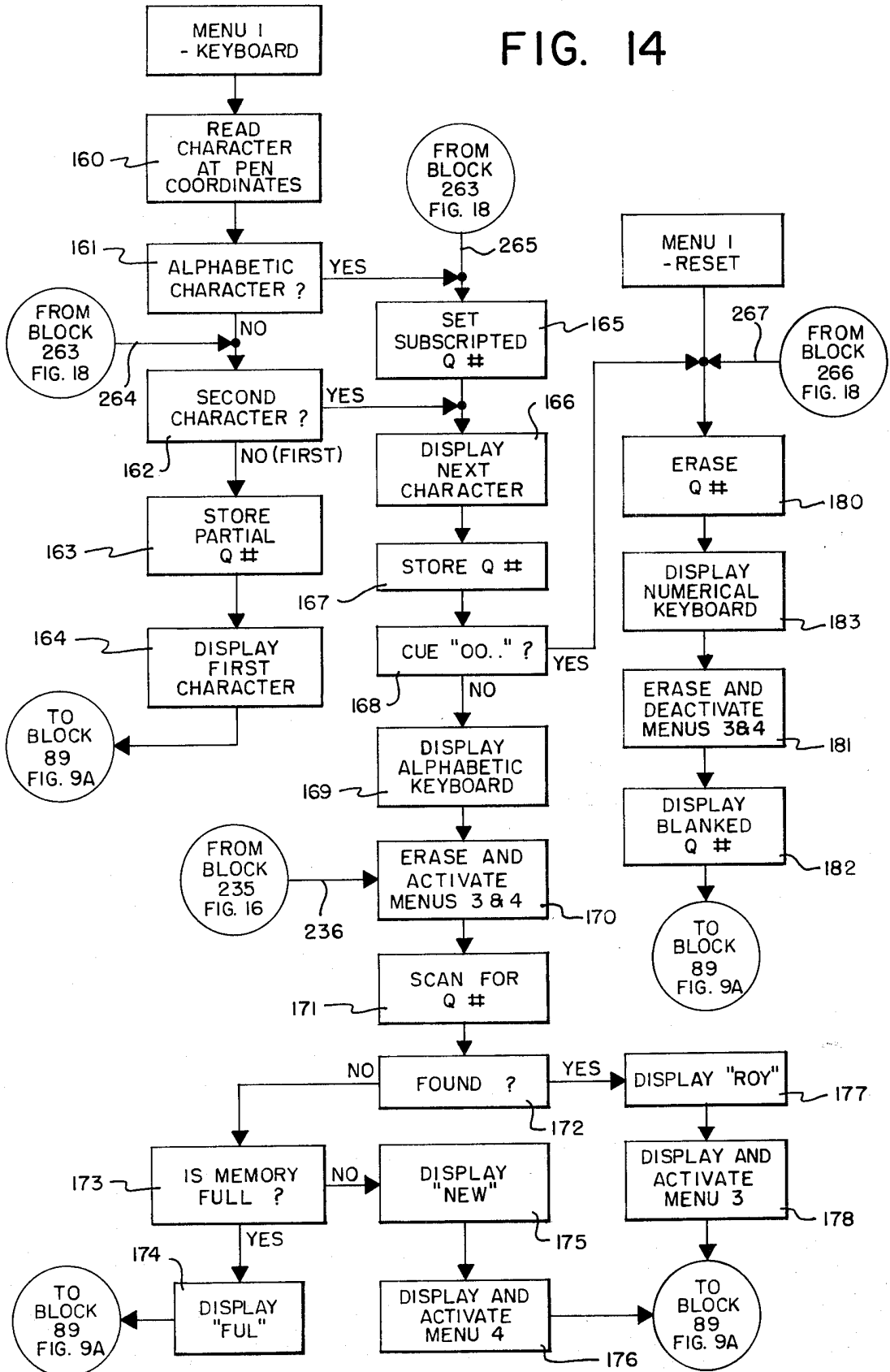


FIG. 15

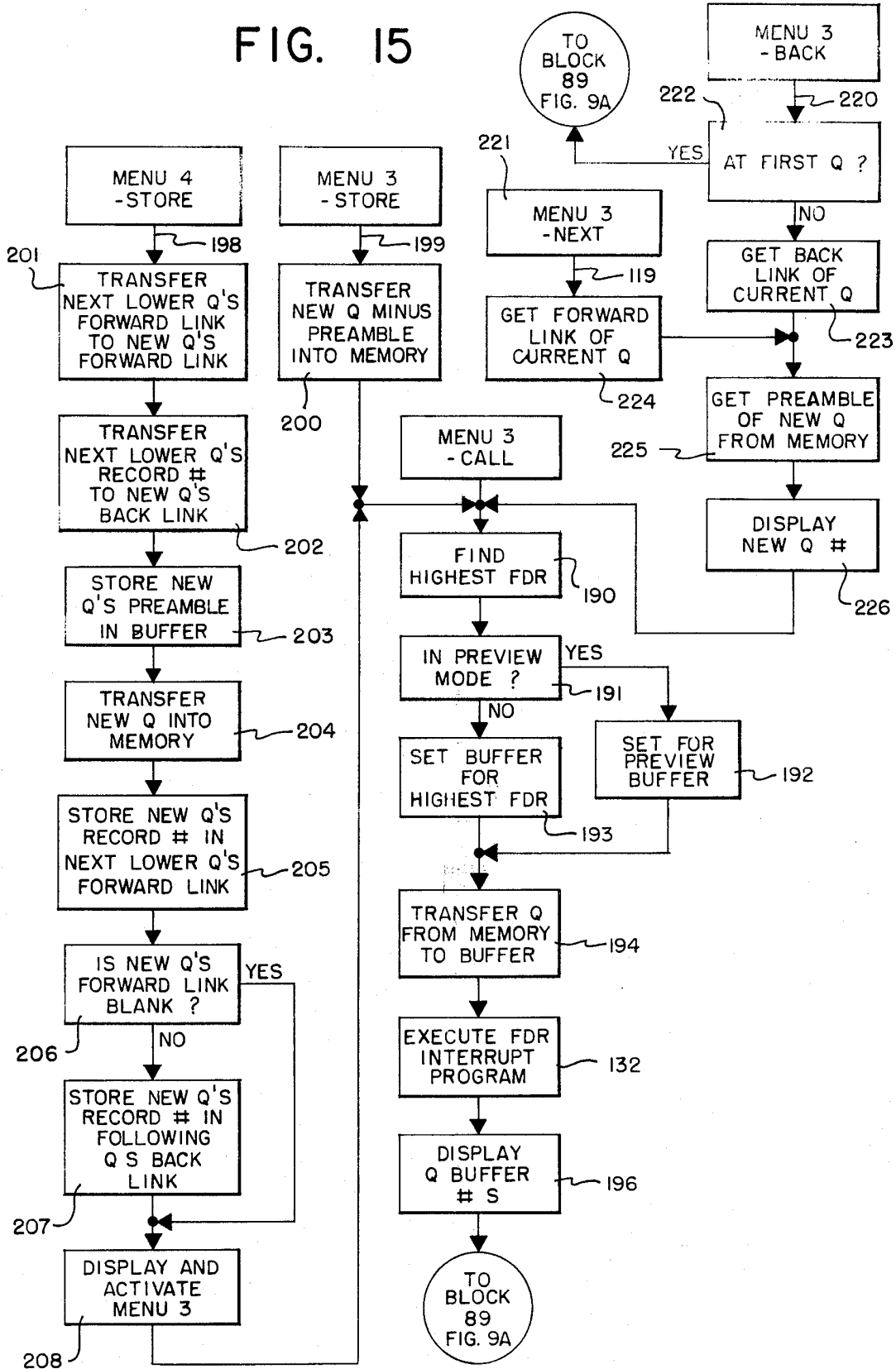


FIG. 16

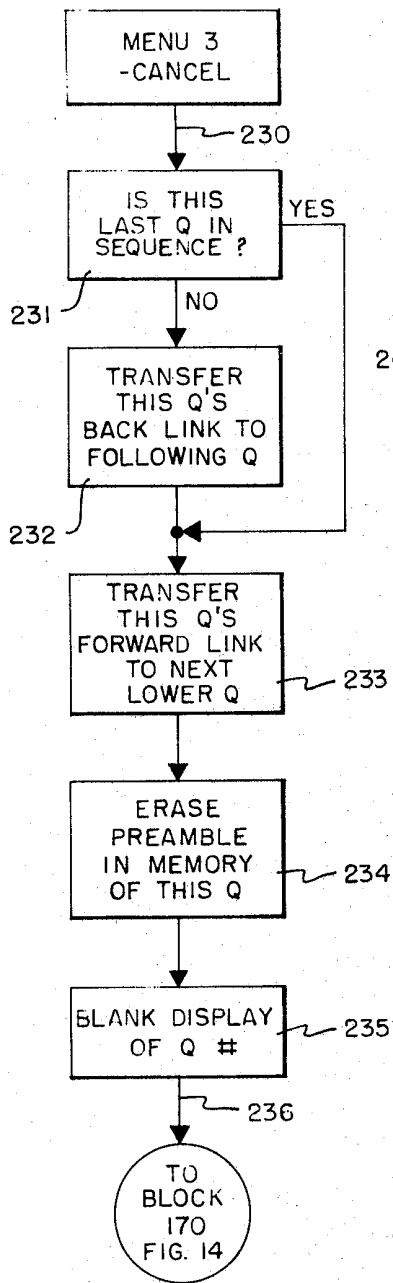


FIG. 17

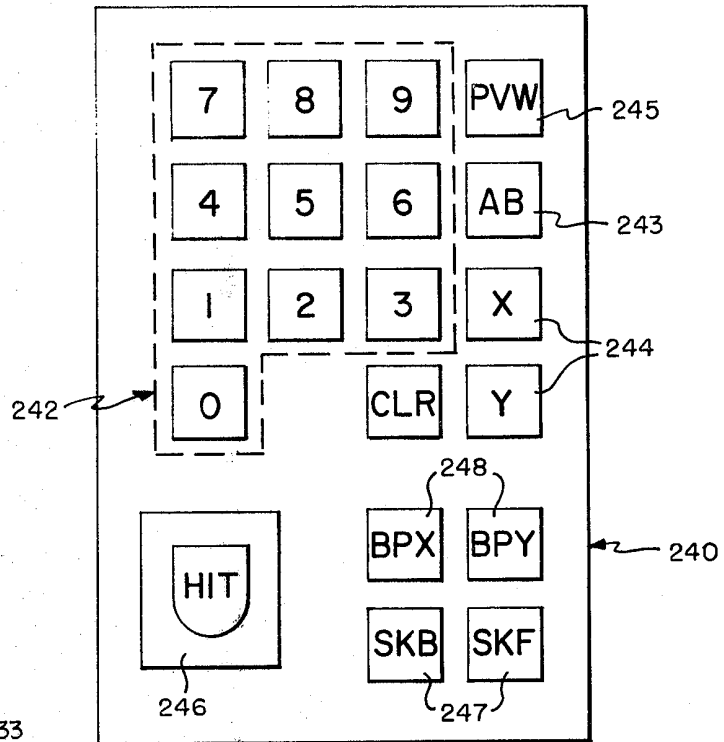


FIG. 19

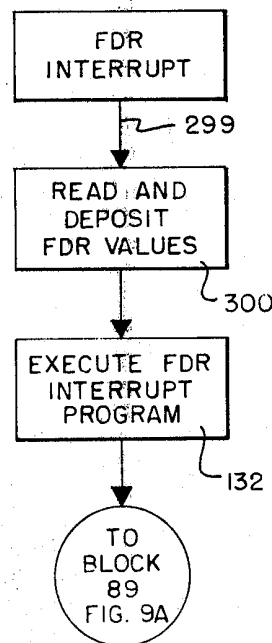




FIG. 20A

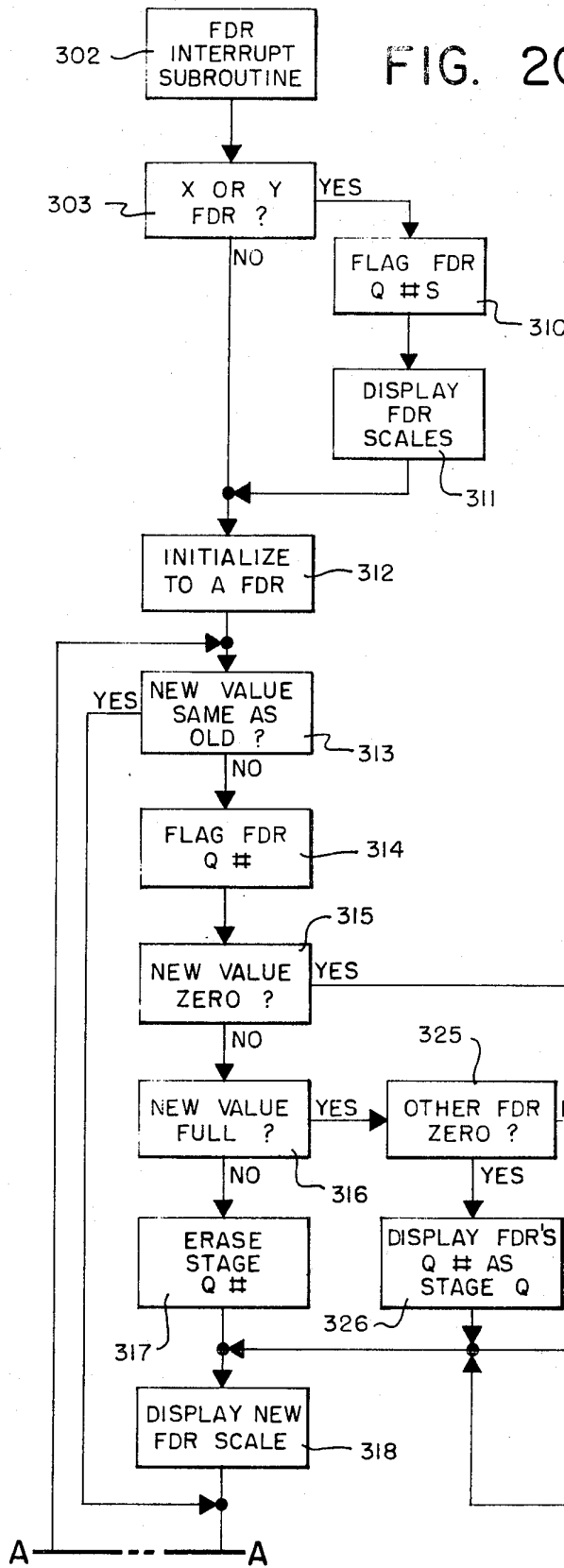


FIG. 20C

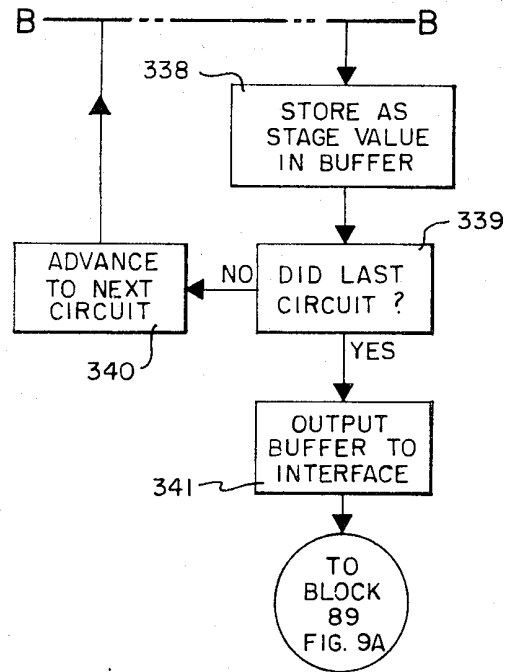


FIG. 20B

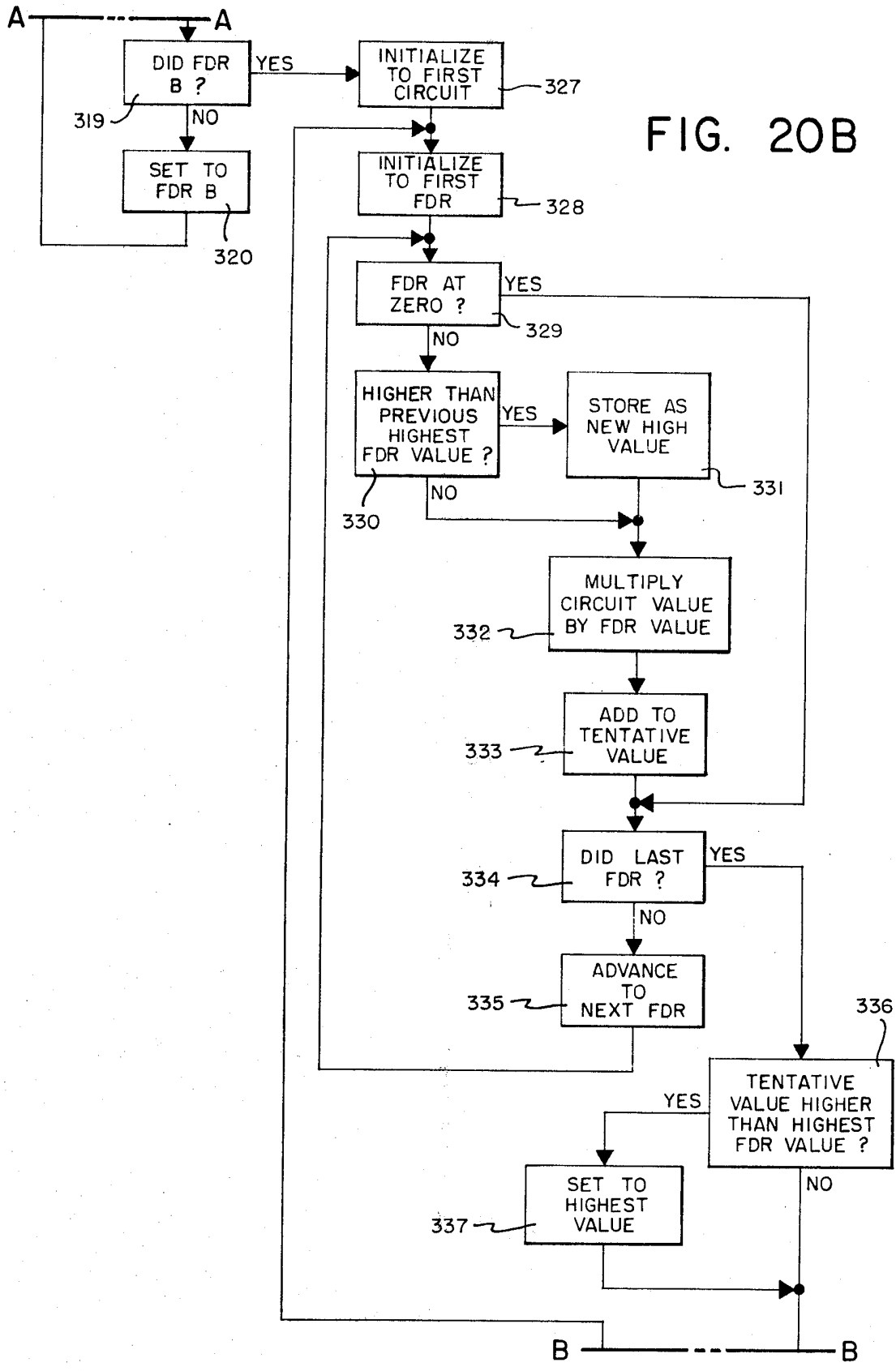


FIG. 21

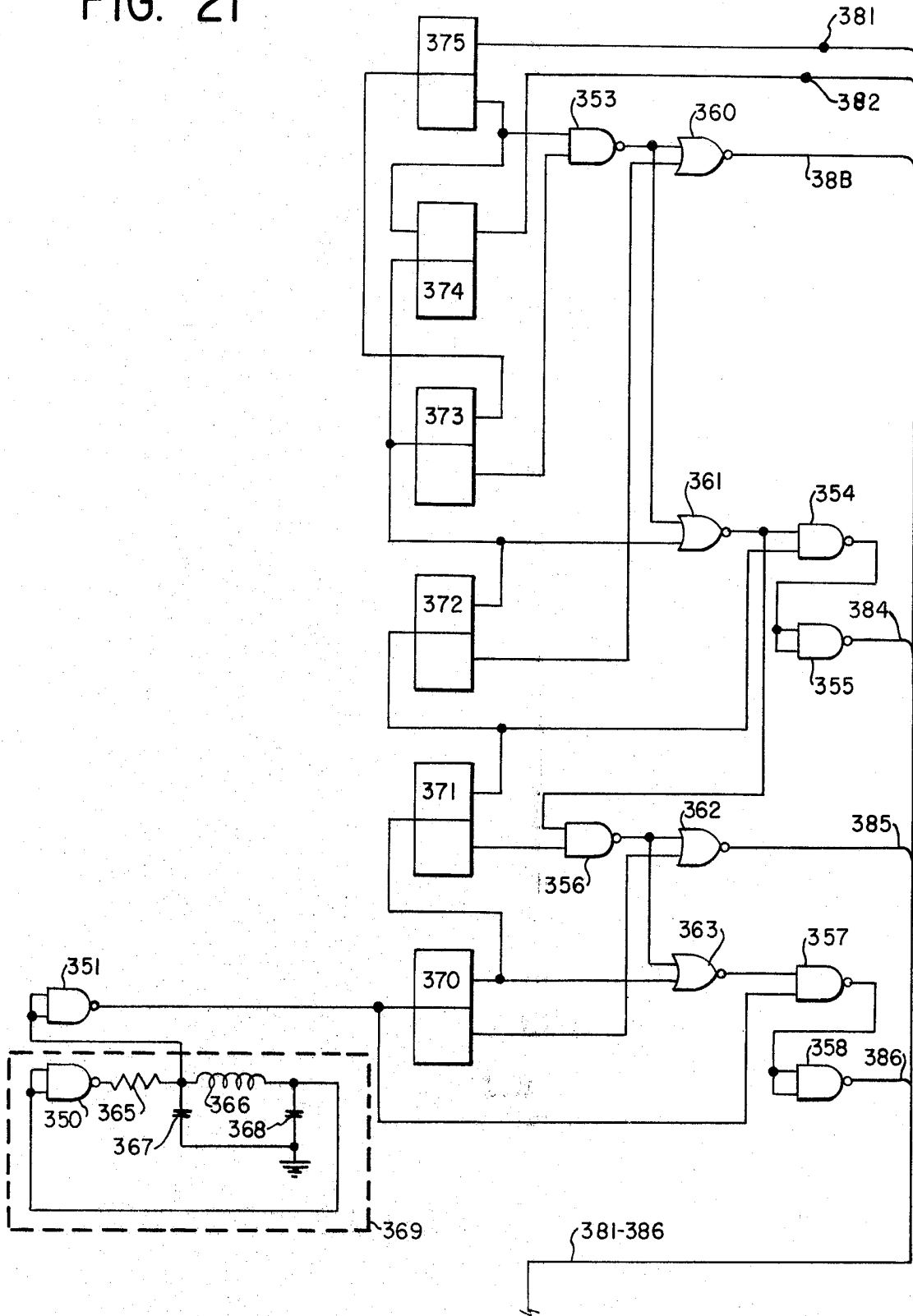


FIG. 22

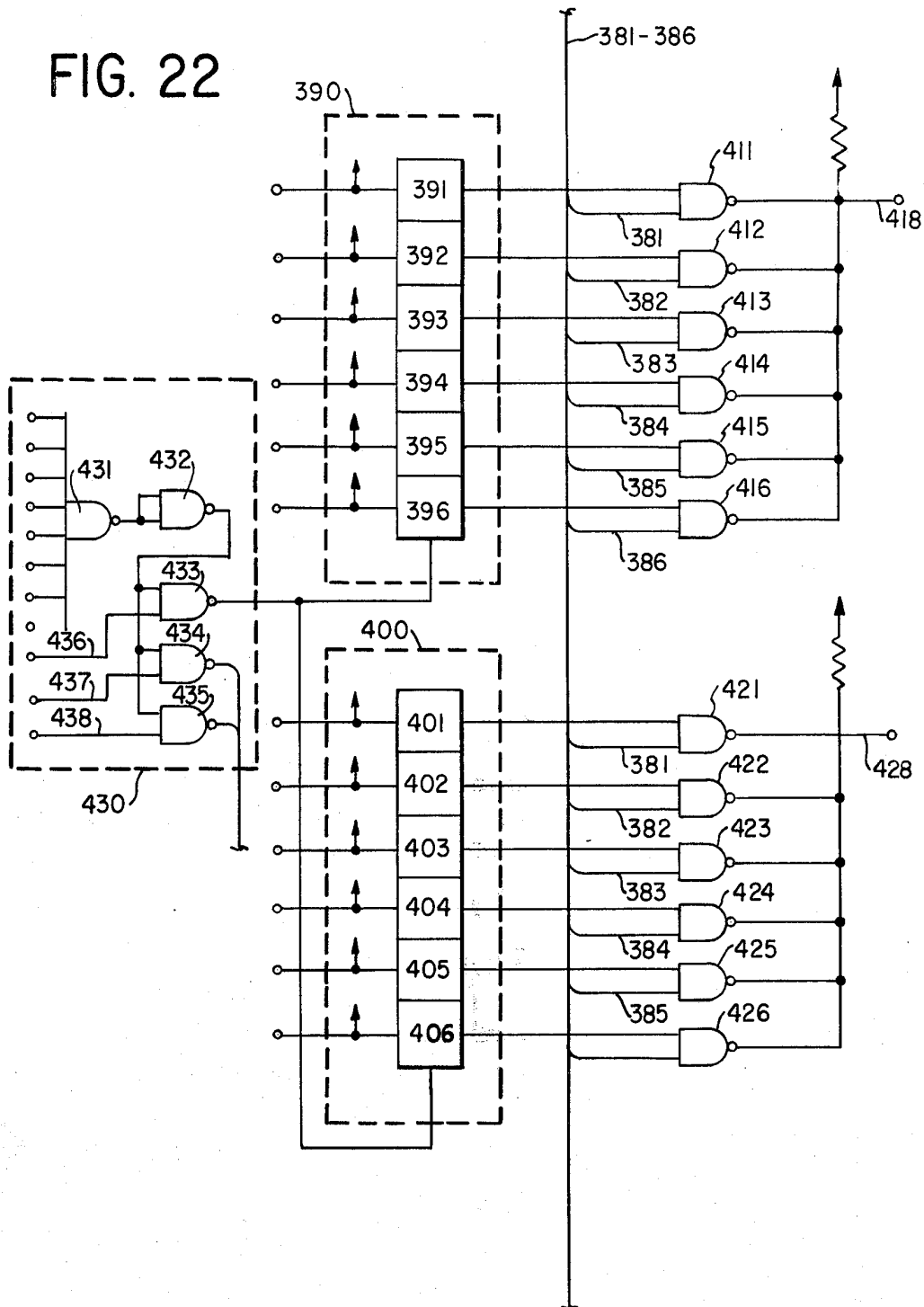


FIG. 23

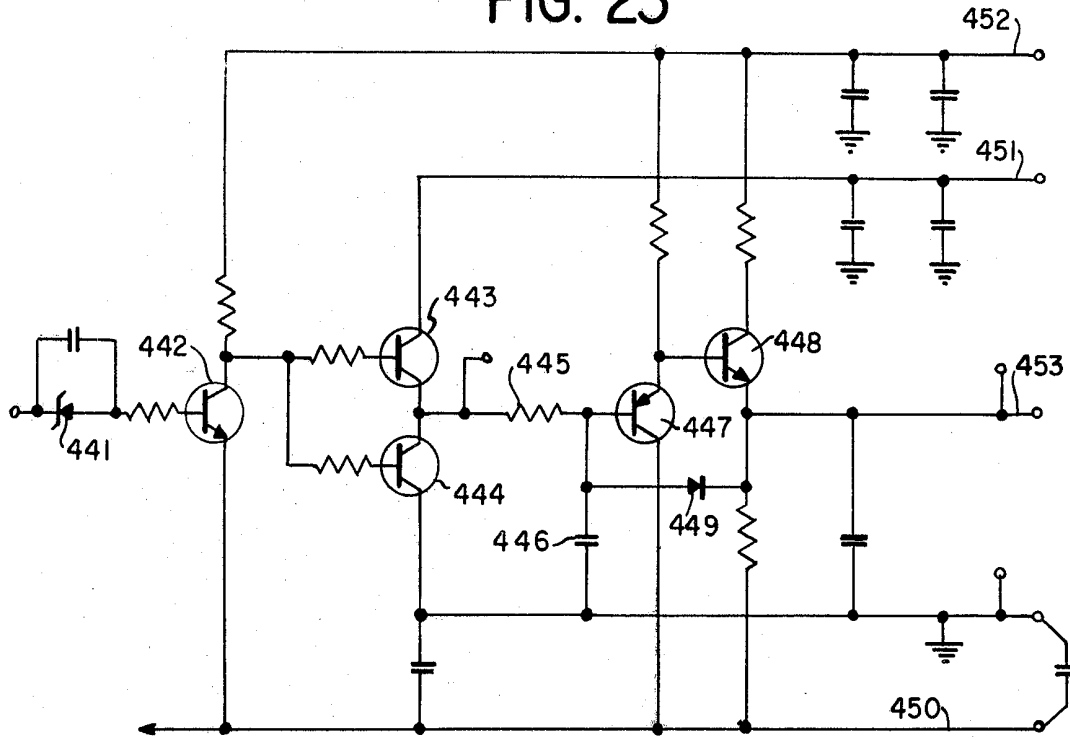
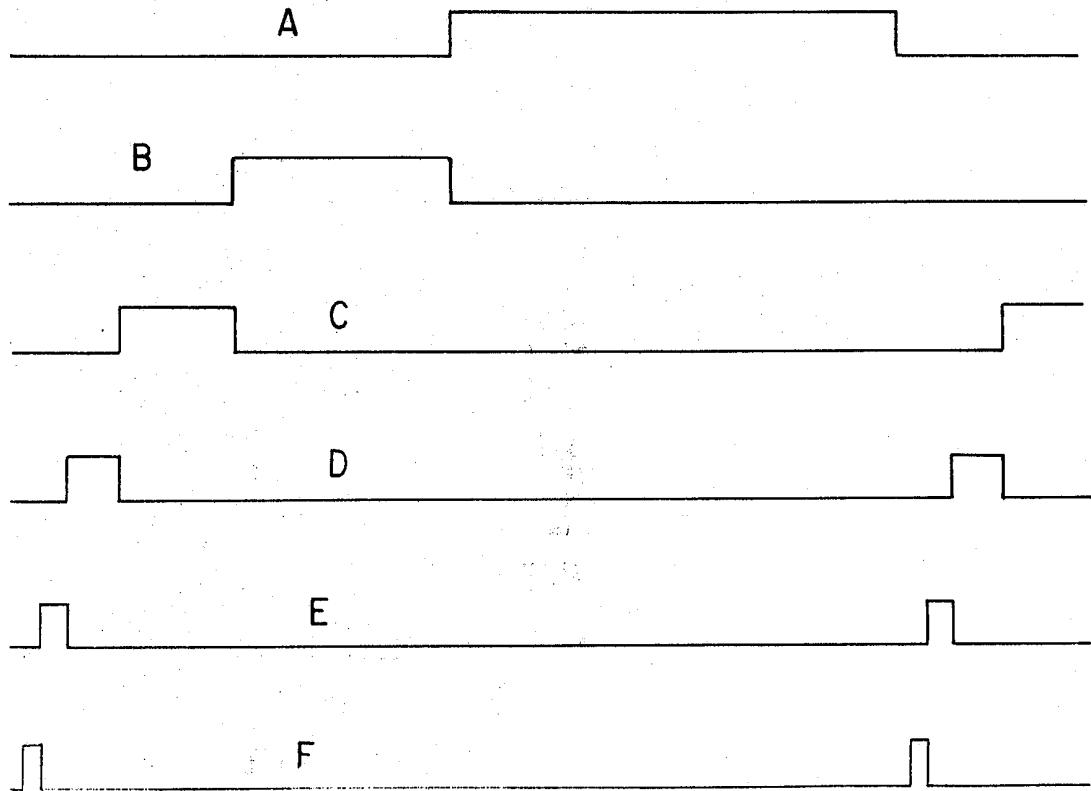


FIG. 24



## ELECTRONIC DISPLAY CONTROLLED STAGE LIGHTING SYSTEM

This application is a continuation-in-part of my co-pending application Ser. No. 134,979 filed Apr. 18, 1971, now abandoned.

This invention relates to apparatus and a method for controlling theatrical stage lamps, and, more particularly to a stage lighting system in which the stage lights are controlled by an operator through an electronic display controller and associated data processing apparatus.

### BACKGROUND OF THE INVENTION

In the control of theatrical or television stage lighting, a sequence of lighting effects are activated in synchronism with the dramatic action on the stage. Each individual lighting effect in the sequence is commonly called a "cue". Each individual lighting cue is created by activating a plurality of stage lights according to a predetermined plan. For some types of theatrical presentations, there may be as many as 300 individual lighting circuits and as many as 200 lighting cues which must be activated in sequence.

Electrical stage lighting technology has progressed through a number of stages of development. The earliest form of electrical stage lighting system used individual manual controls. In the early manually controlled systems, an individual manually-operated electrical voltage controller, such as a rheostat or an autotransformer, was directly connected to each lighting circuit. For theatrical presentations other than very simple ones, such manually-controlled systems required the employment of a number of human operators, since the manual control devices were of such size that a large number of them could not be situated within reach of a single operator, and also because the number of separate manipulations which had to be executed simultaneously was typically more than a single operator can perform.

In the next stage of development, there was introduced into stage lighting technology the lighting "dimmer", which is essentially a power amplifier for converting a low-power control signal to a high-power output signal for operating a stage lamp. This development permitted the use of an array of small-sized controllers, such as low-power potentiometers, to control the dimmers which then, in turn, controlled the stage lamps. It also made practical the use of several arrays of controllers which could be manually preset and then selectively activated to produce a sequence of lighting effects or cues.

For example, in a "ten-scene preset", there would be ten arrays of controllers, each array or "scene" having one controller per lighting circuit and a master controller, sometimes called a "fader", for applying the entire array of controller settings to the dimmers. Thus, a single operator, by manipulating the master controllers or faders, could control transitions between any two or more of the 10 complex lighting cues or "scenes".

Although the use of multiple arrays of preset lighting controllers permits complex lighting cue transitions which would not be feasible in direct manual control, the function of manually presetting lighting cues or scenes typically requires the employment of one or more human operators in addition to the operator who controls the transitions between lighting cues by manipulating the fader controls.

In the next stage of development, electrical and electronic data storage techniques were introduced for storing sequences of stage lighting cues. In this type of system, the predetermined lighting control information is stored as a matrix or array of voltage values from which the individual lighting cues may be called forth in sequence. Such systems have the advantage of being able to economically store larger numbers of individual lighting cues than the older manually preset systems.

However, one problem of existing systems using electrical or electronic data storage techniques is that there is a fixed correspondence between the position at which each designated lighting cue will appear in the automated sequence of cues and the physical position of that lighting cue within the storage device. Thus, in the prior art systems, it is not possible to modify the sequence of cues by inserting an additional cue into a previously-stored sequence, or to eliminate a cue from a previously-stored sequence, without re-writing and re-storing some of the other cues, or without making less than full use of available storage space.

Another problem of the prior art systems using electronic data storage is that the apparatus for displaying the array of lighting circuit levels in effect at a particular moment when the system is under control of the electronic memory is separate and distinct from the apparatus used to adjust the lighting circuit levels by immediate access to any individual circuit or group or circuits. Instead, it is necessary to manually set a control lever to a position which matches the level at which the lighting circuit is currently set by the electronic memory control, and then to transfer control of the lighting circuit to the manual control lever to make the adjustment.

All electronic memory systems in the prior art are of the "hand-wired" control system type, that is, they do not include a stored-program digital computer as part of the system.

Further, the more modern prior art theatre lighting systems whether of the manually preset or electronic data storage type use large numbers of physically large and expensive conventional electrical components, such as lever-controlled potentiometers and electrical indicating meters. This creates a problem with respect to the physical size and cost of any theatre lighting control system having a large number of lighting circuits. In fact, the technological advantages of the manually preset and electronic data storage types of theatre lighting control systems described above have not been of sufficient impact to replace the earliest manually operated systems in a large sector of the theatre industry. Most theatrical productions in the major world centers of the live dramatic stage still carry on lighting operations with manually operated lighting systems, using equipment sometimes dating to the earliest years of incandescent stage illumination.

It is therefore an object of the present invention to provide an improved stage lighting system which obviates the problems of prior stage lighting systems.

More particularly, it is an object of this invention to provide a stage lighting system which permits sequences of stage lighting cues to be quickly and easily designed and executed by a single operator.

It is also an object of this invention to provide a stage lighting system which permits individual stage lighting cues to be designed, stored, retrieved, modified, rear-

ranged and inserted into or deleted from previously stored sequences of lighting cues.

It is another object of this invention to provide a stage lighting system including a device for displaying any stored stage lighting cue or cues under control of the operator.

It is a further object of this invention to provide a stage lighting system including a device for continuously displaying the operating status of the system to the operator.

In accordance with the above and other objects, the present invention provides an improved stage lighting system including data storage apparatus for storing information representing sequences of stage lighting cues, data processing apparatus for creating, storing, retrieving, modifying, rearranging, and otherwise manipulating information representing stage lighting cues, display apparatus, such as a cathode ray tube monitor, for simultaneously displaying information representing the operating status of the data processing apparatus and information representing stage lighting cues stored in the data storage apparatus, a selecting device, such as a light pen, for designating selected portions of the displayed information under control of the operator and a device for activating the data processing apparatus to perform selected functions in accordance with the portion of the display designated by the selecting device.

The stage lighting system of the present invention, called electronic display controlled stage lighting for convenience, is capable of controlling large numbers of high-voltage stage lamps through suitable low voltage-controlled power amplifiers known as dimmers. A practical advantage of the present electronic display controlled stage lighting system is that it enables a single operator to control larger numbers of dimmer circuits than has been possible in prior art systems.

A related advantage of the present electronic display controlled stage lighting system is that, because it enables a single operator to control larger numbers of dimmer circuits, it eliminates the need for "power patching" several stage lamps or other lighting effects for control by a single dimmer circuit.

Another advantage of the present electronic display controlled stage lighting system is that it enables the voltage values applied to the lamps on stage to be quickly and easily modified at any time regardless of the status of the system.

Still another advantage of the present electronic display controlled lighting system is that the structure and content of the information presented to the operator by the display device can be changed under control of the operator in order to more clearly present the range of decision options available to the operator depending on the status of the system.

Other objects and advantages of the present invention will be apparent from the following detailed description and accompanying drawings which set forth the principle of the present invention and, by way of example the preferred mode contemplated for carrying out that principle.

In the drawings:

FIG. 1 is a block diagram of the general layout of a stage lighting system suitable for electronic display control according to the present invention.

FIG. 2 is a perspective view of the cathode ray tube monitor and light pen of the preferred form of the present invention.

FIG. 3 is a block diagram showing the interrelationship of the major components of the electronic display controlled stage lighting system of the present invention.

FIG. 4 shows the layout of the information displayed on the cathode ray tube monitor of the preferred form of the present invention.

FIGS. 5A, B and C show the "setting value" portion of the display illustrating various changes accompanying system operations initiated by light pen activation of this portion of the display.

FIGS. 6A through 6G show a section of the "status display" portion of the display illustrating various settings of dimmer control circuits.

FIGS. 7A through 7D show the "cue designating" section of the display illustrating changes accompanying various system operations initiated by light pen activation of this portion of the display.

FIGS. 8A and B show the "stage/preview" mode selecting portion of the display illustrating changes accompanying light pen activation of this portion.

FIG. 9A is a block diagram of the preferred form of the present invention showing the interrelationship of the system controls and portions of the data processing apparatus for carrying out various functions of the present electronic display controlled stage lighting system.

FIG. 9B is a detailed block diagram of the selection and control section of the data processing apparatus of the system according to the present invention.

FIGS. 10A and 10B are a detailed block diagram of the portion of the data processing apparatus for carrying out functions initiated by light pen activation of the portion of the display which shows the individual lighting channel settings and for carrying out the blackout function.

FIG. 11 is a detailed block diagram of the portion of the data processing apparatus for carrying out functions initiated by light pen activation of the setting value portion of the display shown in FIGS. 4 and 5 A-C.

FIG. 12 is a detailed block diagram of the portion of the data processing apparatus for carrying out functions initiated by light pen activation of the "stage" portion of the display shown in FIGS. 4 and 8A, B.

FIG. 13 is a detailed block diagram of the portion of the data processing apparatus for carrying out functions initiated by light pen activation of the "preview" portion of the display shown in FIGS. 4 and 8A, B.

FIG. 14 is a detailed block diagram of the portion of the data processing apparatus for carrying out functions initiated by light pen activation of the cue designating portion of the display shown in FIGS. 4 and 7A-D.

FIG. 15 is a detailed block diagram of the portion of the data processing apparatus for carrying out functions initiated by light pen activation of the "store" portion of the display shown in FIGS. 7C and 7D and the "call", "next", and "back" portions of the display shown in FIG. 7D.

FIG. 16 is a detailed block diagram of the portion of the data processing apparatus for carrying out functions initiated by light pen activation of the "cancel" portion of the display shown in FIG. 7D.

FIG. 17 is a plan view of the layout of the panel of push buttons for activating certain functions of the data processing system.

FIG. 18 is a detailed block diagram of the portion of the data processing apparatus for carrying out functions initiated by the push buttons.

FIG. 19 is a block diagram of the portions of the data processing apparatus for carrying out functions initiated by the faders.

FIGS. 20A, B and C are a detailed block diagram of the portions of the data processing apparatus for carrying out functions initiated by the faders.

FIG. 21 is a logic diagram of the central logic section of the preferred form of digital to analog converter used in the output interface of the present electronic display controlled by stage lighting system.

FIG. 22 is a logic diagram of the register-gate section of the preferred form of digital to analog converter used in the present invention.

FIG. 23 is a schematic diagram of the integrator output section of the preferred form of digital to analog converter used in the present invention.

FIG. 24 is a timing diagram showing the output wave forms produced by the central logic section shown in FIG. 21.

Referring in greater detail to the drawings, FIG. 1 is a block diagram showing the general layout of a stage lighting system suitable for electronic display control according to the present invention. The stage lamps 1 are connected individually or in groups as required by the specific dramatic production to a set of dimmers 3 known as the "dimmer bank" by conductors 2 which are of high current carrying capacity as required by the lamps. The dimmers 3 are preferably power amplifiers which are capable of producing a large amount of a.c. output power at a voltage which is determined by the low voltage control signals supplied to their input terminals via conductors 4. The control signals to the dimmers 3 may be either a.c. or d.c. and are supplied from a control system 5 which is commonly known in the trade as a "front end". According to the present invention the front end 5 includes electronic data storage and data processing apparatus and an electronic display controller as described in greater detail in connection with FIGS. 2 and 3.

FIG. 3 is a block diagram showing the relationship of the major components of the front end 5 shown in FIG. 1. The cathode ray tube (CRT) monitor unit 6 preferably has the characteristics of a standard television monitor of the type known to those skilled in the art. For example the CRT monitor unit 6 may be a type CZB video monitor manufactured by Conrac Corp. of Covina, California.

Video signals are supplied to the CRT monitor unit 6 from the display controller 9 via cable 16. The display controller 9 may be of a type well known to those skilled in the art such as for example the Type CC-30 display controller manufactured by Computer Communication Inc. of Culver City, California.

The light pen 8 is used to designate portions of the display which appear on the screen 7 of CRT monitor unit 6. The light pen 8 may be of a type well known to those skilled in the art such as, for example, the type CC-304 Light Pen manufactured by Computer Communications Inc.

FIG. 2 is a perspective view of the CRT monitor unit 6 the light pen 8 and push button panel 240. It will be

appreciated that other forms of electronic character display might be used to display the required information within the spirit and scope of the present invention. It will be appreciated also that the light pen 8 is only one form of selecting device that might be used to identify a specific coordinate position in the character matrix displayed on screen 7. Other selecting devices, such as for example a joystick controlled cursor might also be used.

Referring again to FIG. 3, the display controller 9 is connected to a digital data processor 10 which may be of a type well known to those skilled in the art such as for example the Type PDP-8/L manufactured by the Digital Equipment Corp. of Maynard, Massachusetts. The interconnection of the display controller 9 and the data processor 10 is such that the data processor 10 receives information signals on its Input/Output (I/O) bus as to the position in the character matrix which has been designated by the light pen 8 to specify a particular system function to be activated. The data processor 10 is also capable of transmitting information signals on its I/O bus to the display controller 9 to cause the character matrix displayed on screen 7 to change in composition.

The I/O bus of data processor 10 is also connected to an interface unit 11 which includes a set of digital data registers coupled to a set of digital-to-analog converters. Each digital-to-analog converter provides an analog d.c. output signal which is fed to the input of one of the dimmers 3 shown in FIG. 1. Thus, lighting cue information in the form of voltage representing digital signals is transferred via the I/O bus of the data processor 10 in proper sequence to the digital registers of the interface 11 and is then connected by the digital-to-analog converters of interface 11 to become the array of low voltage control signals which are fed to the dimmers 3 via lines 4 shown in FIG. 1.

A data storage device 10A is connected to the data processor 10 to provide storage for long sequence of lighting cues which are to be sequenced automatically during the performance of a show or modified, rearranged or otherwise manipulated at random during rehearsal. In the preferred form of the present invention the data storage device 10A is a random access storage device such as core storage or disc storage. Such random access data storage devices are well known to those skilled in the art such as, for example the Type DF32 Disc File unit manufactured by the Digital Equipment Corporation of Maynard, Massachusetts.

The preferred form of the present invention also includes one or more faders 12 which may resemble the faders used in conventional lighting control systems. In the preferred form of the present invention each fader 12 includes a small control handle for controlling a shaft position encoder or a standard potentiometer connected to an analog-to-digital converter which is connected to the I/O bus of the data processor 10 so as to transmit information to the data processor 10 describing the physical position of each fader handle as it is moved. Stage lighting cue transitions can thus be manipulated by the faders 12 in a manner identical to that with which lighting control operators are accustomed in conventional systems. The data processor 10 performs the function of determining the positions of the fader handles and transmitting to the output interface 11 the corresponding information defining the voltage values to be fed to the dimmers 3 shown in FIG. 1.

As another aid to operational control, a number of push buttons 13 may be connected to the data processor 10 through its I/O bus. The push buttons 13 may be used to activate functions which could also be activated by the light pen 8, but may be more conveniently activated with precise timing, such as may be needed in the actual performance of a theatrical presentation, by a push button 13 which does not require such close attention of the operator to its use as does the light pen 8.

Also shown in FIG. 3 are two units which provide auxiliary features useful in the overall theatrical lighting function. A teletype terminal 14 or other electrically operated printing device may be connected to the data processor 10 and may be operated by the data processor 10 in such a way as to provide page printed copy describing the stage lighting cue information which has been stored in the system. Such data in printed form can be of value to theatrical personnel in planning for changes to the lighting pattern between actual rehearsal periods. A digital magnetic tape cassette recorder 15, or other digital magnetic data storage device, may be connected to the data processor 10 to provide the function of storing stage lighting cue data in a permanent form that can be re-entered into the system at any later date. This feature can be useful for a repertory theatre which may repeatedly cycle through a series of different dramatic productions, for which the lighting effects must be continually re-created.

FIG. 4 is a diagram showing the character matrix displayed on the viewing screen 7 of the CRT monitor unit 6 in the preferred form of the present invention. The character matrix shown in FIG. 4 consists of 24 lines of 40 characters each, or a total of 960 characters and represents the initial status of the system with all lighting circuit values set to zero and no lighting cues having been placed in an active status. Particular sections of the display shown in FIG. 4 will be further illustrated in FIGS. 6 through 8 to show the changes which occur in response to activation by the light pen 8 shown in FIGS. 2 and 3.

The "setting value" portion 16 of the display shown in FIG. 4 is used to preset a voltage value to be applied to lighting circuits designated by the operator. The voltage may be set to any value on an arbitrary scale from 0 to 10 according to conventional practice in stage lighting control systems. The letter F is used to indicate a value of 10, or "full". The voltage actually fed to the stage lamps by way of dimmers 3 shown in FIG. 1 may be directly proportional to the scale of 10 value or it may follow a non-linear relationship.

FIGS. 5A to 5C represents the appearance of the setting value portion 16 of the display shown in FIG. 4 when the value is changed, successively, from F, or full, to 7, then to 4. Referring to FIG. 5A, the change to the value of 7 is accomplished by pointing the light pen 8 to the character 7 at coordinate position 17 of the display and then either pressing the point of the light pen 8 against the screen 7 or pressing a separate button, depending upon the type of light pen used, to activate the appropriate portion of the data processor 10. The information as to the coordinate position of the light pen 8 at the moment that its point is pressed against the screen 7 is determined in the display controller 9 shown in FIG. 3 based on the correlation of a signal from a light sensitive element in the light pen 8 and the raster scanning signal for the CRT monitor unit 6. The cir-

uits for accomplishing this purpose are well known to those skilled in the art and will not be described in further detail here.

The information as to the coordinate position 17 of the light pen 8 is transmitted from the display controller 9 to the data processor 10 to activate the particular hardware or program for changing the setting value as will be described in greater detail in connection with FIG. 11.

FIG. 5B shows the appearance of area 16 of the display after the setting value has been changed to 7. The setting value may further be changed to 4 by pressing the point of the light pen 8 against the character 4 at coordinate position 18 on the display. FIG. 5C shows the appearance of the display after the setting value has been changed to 4. The display is changed by the computer virtually instantaneously when the light pen activation is made.

The top half of the display shown in FIG. 4 includes, lines 19, 20 and 21 and is used to display the status of the dimmer circuits. In the particular embodiment illustrated in FIG. 4, 120 dimmer circuits are displayed in three rows of 40 circuits each. Four character line positions are used for each row of 40 circuits. The top line 19 indicates the decade designation of the dimmer circuit number. The next line 20 indicates the units designation of the dimmer circuit number. The next line 21 indicates the voltage value of the designated dimmer circuit. In FIG. 4, all dimmer circuits are shown at a voltage value of zero or "off" as designated by the "dash" characters on line 21.

FIGS. 6A-G illustrate the display changes which occur when various voltage values are set into selected dimmer circuits by light pen activations on selected character positions in a portion of the "status display" section of the character matrix shown in FIG. 4. FIGS. 6A through G show the portion of the status display section for dimmer circuits 29-40.

A light pen activation on the character 3 at coordinate position 22 in FIG. 6A will, if the setting value is 7 as illustrated in FIG. 5B, change the display to the status shown in FIG. 6B, and also change the voltage value of dimmer circuit 33 to the voltage value corresponding to the scale of 10 value of 7.

Similarly, a light pen activation on the character 6 at coordinate position 23 in FIG. 6B will, if the setting value is 4 as shown in FIG. 5C, change the display to the status shown in FIG. 6C, and also change the voltage value of dimmer circuit 36 to the voltage value corresponding to a scale of 10 value of 4. A further light pen activation on the character 7 at coordinate position 24 in FIG. 6C will, if the setting value is F or full as shown in FIG. 5A, change the display to the status shown in FIG. 6D, and also change the voltage value of dimmer circuit 37 to its maximum, or full, value.

The foregoing description of FIGS. 6A, B and C has described the procedure for setting the voltage values of the dimmer circuits to integer values according to the present invention. In FIGS. 6B, 6C, and 6D, the dash 29 below the character 7 is an indicator that the dimmer circuit setting is to an exact integer value. However, in practical stage lighting operations, dimmer circuit settings are typically specified to quarterpoint increments on the conventional scale of 10. If the character 7 at coordinate position 25 in FIG. 6D is given a light pen activation, the display will change to the status shown in FIG. 6E, in which the letter Q at coordi-

nate position 30 on line 21a signifies that dimmer circuits 33 is set to a voltage value of  $7\frac{1}{4}$ .

As the letter Q is used to indicate "Quarter", the letters H and T on line 21a are used for "Half" and "Three-quarters", respectively. For example, if two more light pen activations are made on the character 7 at coordinate position 25 and two light pen activations are made on the character 4 at coordinate positions 26 in FIG. 6E, the display will change to the status shown in FIG. 6F, in which voltage value of dimmer circuit 33 has been raised to a value of  $4\frac{1}{2}$ .

While each light pen activation on line 21 causes the voltage value of the respective dimmer circuit to be increased one-quarter point, light pen activations on line 21a will reduce the voltage value of the dimmer circuit by one-quarter point. Thus, one light pen activation on the character H at coordinate position 27 in FIG. 6F and two light pen activations on the - at coordinate position 28 will change the display to the status shown in FIG. 6G, in which the voltage value of dimmer circuit 36 has been reduced to  $4\frac{1}{4}$  and the voltage value of circuit 37 has been reduced to  $9\frac{1}{2}$ .

It will be appreciated that, in accordance with the principles of the present invention the "top half" or status display portion of the display shown in FIG. 4 is, during all normal operating situations, continually active and available for light pen activations to change the voltage value of any dimmer circuit.

Referring again to FIG. 4, another feature relating to the setting of circuit values is the "blackout" feature which is initiated by light pen activation of the legend BKO at coordinate position 31 to cause all circuits to go to zero voltage value.

The portion 32 of the display shown in FIG. 4 is used for the purpose of designating lighting cues for storage, or recalling stored lighting cues. As shown in FIG. 4 and in FIG. 7A, the portion 32 of the display is in the "reset" state, awaiting the designation of a lighting cue number by the operator.

The cue numbering system used in the preferred form of the present invention designates each cue by two numerical digits followed by an optional letter subscript within the range from A to J. A light pen activation on the character 0 (zero) at coordinate position 33 in FIG. 7A, will cause 0 to be displayed as the first digit of the cue number at coordinate position 34 in FIG. 7B. A light pen activation on the character 1 at coordinate position 35 in FIG. 7B will cause the display to change to the status shown in FIG. 7C in which the character 1 appears at coordinate position 36. Since this completes the specification of the numerical portion of a possible cue number, the number field is replaced by a letter field 37 shown in FIG. 7C to permit selection of the optional letter subscript.

The specification of the numerical portion of a cue number causes the data processor to search data storage for the specified cue. In this example, it is assumed that lighting cue number 01- has not been previously stored. Therefore cue 01- does not exist in storage, and the word NEW is displayed at position 38 in FIG. 7C. Also, the word STORE is displayed at position 39. If, on the other hand, the specified cue number had been previously stored, such as, for example cue number 02- for purposes of illustration, the display would change to the status shown in FIG. 7D. Instead of the word NEW, the legend RDY would appear at position 38 to signify that the specified cue is "ready", and can be subjected

to a number of functions initiated by light pen activation of the word, STORE at position 39, CALL at position 41, NEXT at position 42, BACK at position 43, and CANCEL at position 44.

Referring to FIG. 7C, a light pen activation on the word STORE at position 39 will cause the new cue, designated cue 01-, to be stored in memory. After cue 01- is stored, which, from the viewpoint of the operator, appears to occur instantaneously, the display will change to the status shown in FIG. 7D, except that the cue number will be 01- instead of 02-. The appearance and condition of the display would thus be exactly as if a previously stored cue 01- had been specified, and the dimmer circuit voltage values shown in lines 21 and 21a of the overall display of FIG. 4 will have become stored in data storage together with the identifying cue number 01-.

The specification of a previously stored cue such as cue 02-, in FIG. 7D does not affect the dimmer circuit status display on lines 21 and 21a of FIG. 4, but a light pen activation on the word CALL at position 41 in FIG. 7D, will cause the contents of the previously stored cue 02- to be displayed on the dimmer circuit status display, and the illumination of the stage lamps will abruptly change accordingly.

The words NEXT at position 42 and BACK at position 43 of FIG. 7D may be subject to light pen activations for the purpose of progressing through the list of stored cues in sequential order. After a number of cues have been stored under various numbers, some with and some without letter subscripts, the set of stored cues will be treated by the data processor as a sequence in ascending order of numerical value, with letter-subscripted cues following unsubscripted numerical cues in ascending order of the letter's position in the alphabet. The cue numbers actually used will be treated as a sequence regardless of whether any gaps have been left in the normal progression of numerical values. A light pen activation on the word NEXT at position 42 will produce the same effect as a CALL of the next higher cue number in storage. Conversely, a light pen activation on the word BACK at position 43 will produce the equivalent effect to calling the next lower numbered cue in storage.

To remove a previously stored cue from storage a light pen activation on the word CANCEL at position 44 will cause the specified cue to be cancelled from memory as if it had never been stored.

To specify a new cue number other than by means of sequential accessing by use of the NEXT and BACK features, the cue number designating area 32 of the display shown in FIG. 4 can be reset from the statuses shown in FIGS. 7B, 7C or 7D, by a light pen activation anywhere on the word CUE at position 40, on the cue number itself at coordinates 34 and 36, or on the legend NEW or RDY at position 38. The display will then assume the status shown in FIG. 7a, and the system will be prepared for the specification of a new cue number.

To this point in the description, it may be assumed that the display shown on the screen 7 of CRT monitor 6 of FIGS. 2 and 3 has at all times exhibited the pattern of voltage values that is actually fed to the dimmer circuits 3 shown in FIG. 1. In this circumstance, any change in voltage value setting made on the dimmer circuit status display, lines 21 and 21a in FIG. 4, is transferred directly to change the voltage value fed to the corresponding dimmer circuit, and any cue called

either directly by the CALL feature or by the NEXT or BACK features causes an abrupt change in the pattern of dimmer circuit voltage values so that the stage lamps immediately assume the pattern of the called lighting cue. However, the present electronic display controlled stage lighting system also includes features which permit the composition, storage, and recalling of cues without affecting stage lights. This feature is implemented by a choice between the stage and the preview modes. This choice is made by light pen activation on the portion 45 of the display shown in FIG. 4.

FIG. 8A shows the appearance of display after cue 01- has been called with the system in the stage mode. A shift to the preview mode can be made by a light pen activation on the word PREVU at position 46. The pointers 47 which indicated that the system was in the stage mode disappear and pointers 48 appear as in FIG. 8B to provide indication that the system is in the preview mode. FIG. 8B also illustrates the effect of calling cue 05B after shifting to the preview mode. Shifting back to the stage mode is achieved by a light pen activation on the word STAGE at position 49 in FIG. 8B.

FIG. 9A is a block diagram of the preferred form of electronic display controlled stage lighting system according to the present invention. FIG. 9A shows the interrelationship between the system controls, such as the display controller 9 faders 12 and push buttons 13, and certain portions of the data processor 10, shown in FIG. 3, which serve to carry out the various operational functions of the system. In the preferred form of the present invention, the operational functions of the system are carried out by suitable programs in a general purpose data processor such as for example the Type PDP-8/L manufactured by the Digital Equipment Corp. It will be appreciated, however, that the operational functions of the present system might alternatively be carried out by special purpose data processing hardware. It will be appreciated further that the operational functions of the present system might be carried out by a combination of special purpose hardware and programmed general purpose data processor.

Basically, the system of FIG. 9A is activated by "interrupts" from the display controller 9, faders 12 or push buttons 13 all of which are connected to the same interrupt line 70 which feeds into the selection and control apparatus or program 71 through enabling block 89. Enabling block 89 is disabled immediately after transmitting the interrupt signal to selection and control apparatus 71 so that no further interrupts will activate the system until the current interrupt has been processed.

Upon receipt of an interrupt, selection and control program 71 interrogates the display controller 9, faders 12 and push buttons 13 on the addressing bus 72 to determine the source of the interrupt. The display controller 9, faders 12 or push buttons 13, whichever has caused the interrupt, will then respond on the skip line 73 to shift control of the system to the appropriate operational programs 74-88 or operational hardware in the case of a special purpose data processor. The operational programs include the fader operational program 74, the push button operational program 75, and the following display controller activated programs: top half 76, blackout 77, value hit 78, STAGE 79, PREVIEW 80, KEYBOARD 81, RESET 82, MENU 3 STORE 83, MENU 4 STORE 84, CALL 85, NEXT 86, BACK 87, and CANCEL 88. After a particular opera-

tional program has executed its function, control is returned to the interrupt mechanism via line 90 which enables block 89 to transmit the next interrupt to the selection and control program 71. In the preferred form enable block 89 is simply an idle loop program which makes the selection and control program 71 available to be activated by the next interrupt.

FIG. 9B is a detailed block diagram of the selection and control section 71 shown in FIG. 9A illustrating the manner in which a specific function is selected to be performed by the data processor 8 depending upon the coordinate position within the character matrix display at which the light pen 8 is activated and also depending upon the status of the display at the instant of the light pen activation.

When an interrupt is received by the data processor from the display controller 9 push buttons 13 or fader handles 12 shown in FIG. 9A the interrupt line 50 of FIG. 9B is activated to test the source of the interrupt. Interrupt line 50 feeds into decision block 51 which tests whether the interrupt originated from the display controller 9. If the interrupt did originate from the display controller, the YES branch of decision block 51 is activated thus transferring control to decision block 54 for subsequent processing as will be explained in greater detail hereinafter. If the interrupt did not originate from the display controller, the NO branch of decision block 51 is activated, thus transferring control to decision block 52 which tests whether the interrupt originated from the fader handles 12. If the interrupt originated from the fader handles, the YES branch of the decision block 52 is activated thus transferring control to line 299 of FIG. 19. If the interrupt did not originate from the fader handles, the NO branch of decision block 52 is activated thus transferring control to decision block 53 which tests whether the interrupt originated from the push buttons 13. If the interrupt did originate from the push buttons, the YES branch of the decision block 53 is activated thus transferring control to line 260 of FIG. 18. If the interrupt did not originate from the push buttons, the NO branch of block 53 is activated to return control to enabling gate 89 of FIG. 9A. The NO branch of block 53 thus provides a safe program exit for accidental interrupts due to spurious electrical transients.

It will be appreciated that the decision blocks 51-53 may be of a type well known to those skilled in the art. For example, one type of decision block suitable for use in the present system accomplishes its function by testing for the presence of a selected status bit and transfers control to the YES branch if the status bit is present and to the NO branch if the status bit is not present.

The YES branch from the display controller decision block 51 feeds to the INTERRUPT KEY decision block 54. The interrupt key, not shown, is a feature of the display controller 9 shown in FIG. 3. The YES branch from decision block 54 leads to a function block 55 labeled OUTPUT INITIAL MENU which serves to set up the system in its normal operating condition when power is initially supplied to it and then returns control of the system to the interrupt enabling gate 89 in FIG. 9A. The NO branch from the light pen decision block 56 leads to the program exit which returns control of the system to the interrupt enabling gate 89 in FIG. 9A. This control path or program

branch is followed only when a keyboard key of no functional purpose is operated.

In order to better understand the manner in which the light pen 8 serves to activate selected functions of the present system, it will be understood that the operator has available several "menus" of possible functions from which to choose. The term menu is commonly used in data processing and applies to a display format, such as might be displayed on a CRT monitor unit, which serves to present to the operator a choice of functions which he may selectively activate. For purposes of the present invention, a menu may consist of the entire contents of the character matrix displayed on the CRT monitor unit 6 of FIGS. 2 and 3 or only a portion of the entire character matrix. In the preferred form of the present invention the data processor 10 contains a list of menus, and indicators for indicating whether each menu is active or inactive. More than one menu can be active at the same time. When more than one menu is active, each active menu occupies a different specific area of the character matrix displayed on the screen 7 of CRT monitor unit 6 in FIGS. 2 and 3.

In the data processor, a list of light pen coordinates and corresponding data storage addresses are associated with each menu. These data storage addresses provide the entrance points to the program routines or hardware sub-combinations intended to be activated by light pen activation of the corresponding coordinate positions on the character matrix display. Additionally, the list of light pen coordinates in the data processor 10 may include entries which specify a range of coordinate positions in either the horizontal or vertical (or both) directions. Thus, a given data storage address may be entered by a light pen activation within a rectangular area of the displayed character matrix as well as by light pen activation of single individual coordinate positions.

Returning to FIG. 9B of the drawings, the YES branch from light pen decision block 56 leads to the program routine or hardware sub-combinations identifying and transferring control to the system functions corresponding to particular light pen activations. The YES branch from decision block 56 leads to function block 57 which is labeled SET TO TRY FIRST MENU and thence to decision block 58 which tests whether the first menu is active. If the first menu is not active, the NO branch from block 58 leads to decision block 59 the YES branch of which exits from the program and returns control to interrupt enabling gate 89 in FIG. 9A if all menus have been tested. Such an exit will occur if the light pen 8 is activated on a coordinate position of the character matrix display which does not represent an active coordinate position of an active menu. When an active menu is found, the YES branch of decision block 58 transfers control to function block 61, labeled SET TO TRY FIRST LIGHT PEN ITEM, which initiates a processing of the light pen coordinate list associated with the active menu. In decision block 62, a comparison is made to determine whether the coordinates of the light pen activation which has caused the current interrupt correspond to a specific item of the light pen coordinate list. If not, the NO branch of decision block 62 leads to decision block 63, which determines whether the last item on the light pen coordinate list of this particular active menu has been tested. If it has, the YES branch of decision block 63 returns control to decision block 59 of the menu list testing

loop so as to test the remaining menus. If the specific light pen coordinates tested are not the last item on the particular light pen coordinate list function block 64 causes the system to advance to the next item on the light pen coordinate list which is then tested in decision block 62.

When the correct light pen coordinates are found the YES branch of decision block 62 transfers control to block 65 which is in effect a jump sub-routine which transfers control to the data storage address corresponding to the light pen coordinates so as to enter the selected functional program or hardware subcombination. The multiple exits from this block 65 lead to the various functional programs described below.

FIGS. 10A and 10B are a detailed block diagram of the TOP HALF block 76 shown in FIG. 9A. More particularly, FIGS. 10A and 10B are a detailed block diagram of the portion of the data processing apparatus for carrying out functions initiated by light pen activation of the top half of the character matrix display shown in FIG. 4 a portion of which is shown in greater detail in FIGS. 6A through 6G.

The top half program or hardware subcombinations shown in FIGS. 10A and 10B is entered on line 99 from block 65 in FIG. 9A. Line 99 feeds into function block 100 which converts the light pen coordinates to a dimmer channel number. This is a conventional arithmetical operation which uses the horizontal and vertical coordinate positions of the light pen activation point on the character matrix display to obtain the dimmer channel number which may range from 1 to 120 in the preferred form illustrated in FIG. 4. Control then passes to decision block 101 which determines whether row number 0, 4 or 8 has been activated by the light pen. These are the rows 19a, b and c are not legitimate light pen activation coordinates and no system response is produced by attempted light pen activation of them. Therefore, the YES branch from decision block 101 leads directly to the program exit to block 89 via line 90 in FIG. 9A. The NO branch from decision block 101 leads to a decision block 102 which determines whether the system is in the preview mode. If the system is in the preview mode, a substantial part of the logic is bypassed via the YES branch from block 102 which leads to the function block 103 which sets the fader count complete because it is not necessary to process fader settings if the system is in the preview mode. After the fader count has been set complete, control passes from block 103 to decision block 110 in FIG. 10B.

If the system is not in the preview mode each fader setting must be examined because the actual function of setting a dimmer channel voltage value depends upon the configuration of the faders. In the normal operation of the system, one fader would be at "full" and all other faders would be at "zero", but the system of the present invention provides means for setting the correct voltage values for each dimmer channel even if the faders are not in the normal configuration.

The NO branch from decision block 102 leads to function block 104 which serves to initialize the system to examine the setting of the first fader and then transfer control to decision block 105 which determines whether the first fader is set at zero. If the fader is at zero the YES branch from block 105 leads to decision block 106 which determines whether the last fader has been examined. If the last fader has not been examined,

the NO branch from block 106 leads to function block 107 which sets the system to examine the next fader and returns control to decision block 105. This procedure continues until a fader is found which is not at zero which causes control to pass via the NO branch 5 108 from decision block or box 105 to function box 109 in FIG. 10B.

Function box 109 serves to set the buffer address of the non-zero fader. Each fader has an associated data storage area which is set aside to contain a complete array of voltage values for each of the 120 dimmer circuits controlled by the system. After the fader buffer address is set, control passes to decision box 110, which determines whether the current interrupt is to initiate "set" operation. This determination depends upon the specific line of the character matrix display shown in FIG. 4 activated by the light pen. If the light pen activation was on one of the three lines 20a, b or c in FIG. 4, a set operation is indicated and the YES branch from decision box 110 leads to function box 111 which sets the new voltage value for the particular dimmer channel determined by function box 100. The new voltage value would be the "setting value" which had been set into display area 16 in FIG. 4 as described in connection with FIGS. 5A, B and C. The new voltage value is also stored in the position reserved for the particular dimmer channel in the area of data storage set aside for the particular non-zero fader as determined by decision block 108 in FIG. 10A.

If it is determined that this is not a set operation, control proceeds via the NO branch of decision box 110 to decision box 122 which determines whether this is a "blackout" operation. This is determined by checking the blackout indicator which, in the case of a blackout operation, will have been set by function block 98 in FIG. 10A which is entered via line 97 from block 65 in FIG. 9B if there has been a light pen activation on the legend BKO at position 31 shown in FIG. 4. If this is a blackout operation control proceeds via the YES branch of decision block 122 to function box 123 which sets the voltage values of all 120 dimmer channels to zero in the data storage area associated with the particular non-zero fader determined by decision block 108 in FIG. 10A.

If decision box 122 determines that this is not a blackout operation, the NO branch from box 122 leads to decision box 124 which determines whether this light pen activation is an "increment". This determination depends on whether the vertical coordinate of the light pen activation point is on line 21 shown in FIGS. 4 and 6B through G.

If it is determined that this interrupt is an increment, the control proceeds via the YES branch from decision box 124 to function box 125 which increments the voltage value of the particular dimmer channel by one-fourth point. If decision box 124 determines that the interrupt is not an increment, then the interrupt must be a decrement initiated by a light pen activation on line 21a shown in FIGS. 4 and 6B through G, and control proceeds via the NO branch of decision box 124 to function box 126 which decrements the voltage value of the dimmer channel by one-fourth point.

Function boxes 111, 123, 125 and 126, each of which brings about a specific change in the structure of a lighting cue depending on the coordinates of the light pen activation point, all proceed to function box 127 which blanks the cue number displayed in area 45 of

FIG. 4 so as to indicate to the operator that a change has been made to the array of dimmer channel voltage values and that the cue number that formerly displayed in area 45 of the display shown in FIG. 4 no longer applies to the new array of values shown in the top half of the display of FIG. 4 and that the new array of values no longer corresponds to the array of values stored under the old cue number. It will be noted that the letter Q is substituted for the word cue at certain places in the drawings for purposes of brevity.

After the cue number display is blanked by function box 127, control proceeds to decision box 128 which determines whether the system is in the preview mode. If the system is not in the preview mode, control proceeds to function box 129 which displays three blanks (" - - ") in space formerly occupied by the cue number in area 45 of FIG. 4.

If the system is in the preview mode the top half program is not actually processing the dimmer channel voltage values stored in a fader buffer but is instead processing the values stored in the preview buffer. Therefore, there is no need to display blanks ( - - - ) in the cue number space in area 45 of FIG. 4 and the YES branch from decision box 128 leads back to decision box 106 (FIG. 10A) in the loop which examines each fader.

In normal operation of the system the portion of the sequence between function box 109 and function box 129 will normally be passed through just once for one fader, or, if in the preview mode, will be passed through just once to process the preview buffer. Although it would be the normal process to pass through this branch of the program just once, if in fact more than one fader were not at zero, the branch would be passed through once for each fader that was not set to zero and the same setting operation would be performed for each such fader.

When the branch of the program ending at function box 129 is completed, the sequence of control re-enters at decision box 106 which determines whether the last fader has been processed. After the last fader has been processed, the YES branch from decision box 106 is followed to decision box 130 which determines once again whether the system is in the preview mode. If the system is not in the preview mode, control proceeds via the NO branch from decision box 130 to function box 131 which serves to display blanks ( - - - ) in the cue number space adjacent the word STAGE in area 45 of FIG. 4.

Control then proceeds from the function box 131 or via the YES branch of decision block 130 to major function box 132 which executes the "fader interrupt" program which is described in detail below. The fader interrupt program which, as will be hereinafter described, reads the values of the fader handles and activates the output registers which determine the actual voltage values that are fed to the dimmer channels. After executing the fader interrupt program, control proceeds from function box 132 via line 90 to the enabling gate 89 shown in FIG. 9A so as to enable the selection and control block 71 to receive the next interrupt.

Referring now to FIG. 11 of the drawings, there is shown a detailed block diagram of block 78 shown in FIG. 9A which is the portion of the data processing apparatus for carrying out functions initiated by light pen

activation of the setting value portion 16 of the character matrix display shown in FIG. 4.

The program or hardware subcombination of FIG. 11 is entered from box 65 in FIG. 9B via line 139 to function box 140 in FIG. 11. Function box 140 reads the character at the coordinates of the light pen activation point. In this case, rather than making actual use of the light pen coordinates, the data processor 10 (FIG. 3) reads from the display controller 9 the actual character which is contained in the core storage of the display controller corresponding to this particular coordinate position. Control then proceeds to decision box 141 which determines whether the character which has just been read is a space. This test is simply for safety purposes to guard against the possibility that the light pen activation may have occurred outside of the proper boundaries for activation in area 16 of the display shown in FIG. 4.

If it is determined that the character read is a space, the YES branch of decision box 141 is followed to the program exit which proceeds via line 90 to enable block 89 in FIG. 9A.

If the character is not a space the NO branch of function box 141 is followed to decision box 142 which determines whether the character which has been hit is an "up arrow" ( $\wedge$ ). This character would be detected if the light pen activation were made at the position corresponding to the voltage value already set (cf. value F in FIG. 4).

If it is determined that an "up arrow" was activated by the light pen, then no function need be performed and the YES branch from decision box 142 leads to the program exit which proceeds back to block 89 in FIG. 9A. The NO branch from decision box 142 leads to decision box 143 which determines whether the character activated by the light pen is F. If it is an F, the YES branch from decision box 143 proceeds to function box 144 which arbitrarily converts the character to a voltage value of 10 and then proceeds to function box 145. If the character selected by the light pen is not F, control proceeds via the NO branch of decision box 143 to the function box 145 where the new voltage value is set into an appropriate location in the storage facility of the data processor so that upon subsequent light pen activation of the top half of the display shown in FIG. 4, the new voltage value will be transferred to the particular lighting control channel activated. After setting the new value the sequence proceeds to function box 146 which displays the new voltage value in the appropriate position in area 16 of the character matrix display of FIG. 4 as illustrated by example in FIGS. 5A-C.

Referring now to FIG. 12 of the drawings, there is shown a detailed block diagram of the stage program (block 79 in FIG. 9A) which is initiated by a light pen activation on the word STAGE in area 45 of the display shown in FIGS. 4, 8A and 8B. The STAGE program is entered from box 65 in FIG. 9B via line 149 to function box 150 which sets the "stage indicator" which is simply an internal scratch pad memory location or register within the data processor which may be interrogated by other sections of the program when it is necessary to determine whether or not the system is in the stage mode.

Control proceeds from function box 150 to function box 151 which displays the stage flags 47 shown in FIGS. 4 and 8A to indicate to the operator that the system is in the stage mode.

Referring to FIG. 13, there is shown a detailed block diagram of the preview program (block 80 of FIG. 9A) which is initiated by a light pen activation on the word PREVU in area 45 of the display shown in FIGS. 4, 8A and 8B. The preview program is entered from box 65 in FIG. 9B via line 152 to function box 153 which sets the "preview indicator" which is another internal scratch pad memory location or register in the data processor which can be interrogated by other sections of the program to determine whether the system is in the preview mode. Control proceeds from function box 153 to function box 154 which displays the preview flags 48 shown in FIG. 8B to indicate to the operator that the system is in the preview mode.

FIG. 14 is a detailed block diagram of the program initiated by light pen activation on the "keyboard" within the area 32 of the display shown in FIG. 4 and also shown in FIGS. 7A-7D. This program is called the keyboard program and is indicated by block 81 in FIG. 9A. The keyboard program is entered from block 65 in FIG. 9B via line 159 to function box 160 which reads the character displayed at the coordinates of the light pen activation point. This operation is similar to that performed in the value setting program described above in connection with FIG. 11 in that the data processor 10 (FIG. 3) reads the actual character stored in the core storage of the display controller 9. Control proceeds from function box 160 to decision box 161 which determines whether the character read is alphabetic or numeric. If the character is numeric it is deduced that it must be one of the first two digits in the cue number being specified and the NO branch from decision box 161 is followed to decision box 162 which determines whether it is the second character or the first character that is being specified. This determination is made by testing a special character which is inserted into an internal register of the data processor when the first digit of the cue number is stored. If it is the first digit, the NO branch of decision box 162 is followed to function box 163 which stores the first digit as a partial cue number in a register in the data processor and also stores a special character which may later be tested by function box 162 to determine whether it is the first or second character that is being designated by a subsequent light pen activation. After function box 163, the sequence proceeds to function box 164 which displays the first character of the cue number at position 34 shown in FIG. 7B. The sequence then proceeds to the exit point which returns to function box 89 in FIG. 9A.

After the first character has been entered and the system is in the status indicated by the display shown in FIG. 7B, another light pen activation on the keyboard within area 32 of FIG. 4 re-enters the keyboard program at function box 160 shown in FIG. 14, but now when decision box 162 is reached the YES branch will be followed to function box 166 which displays the next character of the cue number at position 36 shown in FIG. 7C. After function box 166, the system proceeds to function box 167 which stores the full unsubscripted cue number in an internal register of the data processor.

After function box 167 the system proceeds to decision box 168 which determines whether the cue number "00" has been specified. Cue number "00" is illegal and, if it has been specified, the YES branch from decision box 168 proceeds to the "reset" program

which is described in detail below. If cue number "OO" has not been specified, the NO branch from decision box 168 is followed to function box 169 which displays the alphabetic keyboard 37 as shown in FIG. 7C for the purpose of the later optional designation of a subscript for the specified cue number.

If after specification of an un-subscripted cue number, a light pen activation occurs on the alphabetic keyboard 37 shown in FIG. 7C, the keyboard program is entered at function box 160, but then decision box 161 will determine that an alphabetic character has been activated by the light pen, and the YES branch will be followed from decision box 161 to function box 165 which will set the subscripted cue number. The system will then proceed in the same path as previously described from function box 166 onward.

After function box 169 the system proceeds to function box 170 which erases and deactivates menus 3 and 4 which are the words STORE, CALL, NEXT, BACK and CANCEL, as illustrated in FIG. 7C and 7D. This portion of the display must be erased so that it may be properly re-established depending upon whether or not the cue number is associated with a lighting cue that exists in storage.

Function box 171 scans the main data storage facility 10A of the data processor 10 to find the specified cue number. In the preferred embodiment of the present invention the main data storage facility 10A is a disc memory unit.

After function box 171, the system proceeds to decision box 172 which determines whether the specified cue number has been found.

If the specified cue number is not found, the NO branch from decision box 172 is followed to decision box 173 which determines whether the main data storage facility of the system is full. This must be determined so that, if the memory is in fact full and there is no space remaining to store a new lighting cue, the system can inhibit the operator from attempting to store a cue under the newly specified cue number.

If it is determined that the main data storage facility is full, the YES branch of decision box 173 is followed to function box 174 which displays the word FUL in position 38 shown in FIGS. 7C and 7D and then proceeds to the program exit which returns control of the system to enabling gate 89 shown in FIG. 9A.

The NO branch from decision box 173 leads to function box 175 which displays the word NEW in position 38 as illustrated in FIG. 7C. After function box 175 the system proceeds to function box 176 which displays and activates menu 4 which consists solely of the word STORE in position 39 as shown in FIG. 7C.

Returning to decision box 172, if the specified cue number is found in the main data storage facility, the YES branch from decision box 172 is followed to function box 177 which displays the word RDY in position 38 as illustrated in FIG. 7D. The sequence then proceeds to function box 178 which displays and activates menu 3 which includes the words CALL 41, NEXT 42, BACK 43, STORE 39 and CANCEL 44 as illustrated in FIG. 7D. At the same time, an internal register within the data processor is set to indicate that menu 3 has become active so that upon receipt of a light pen interrupt the selection and control program of FIG. 9B will examine the light pen coordinate list for menu 3 as described above in order to find the addresses of the entrance points for the menu 3 programs.

Referring again to FIG. 14, a light pen activation in any portion of the display shown in FIGS. 7C or 7D which includes the word CUE at position 40, the cue number itself, or the words NEW or RDY at position 38 will cause the reset part of the program to be entered at function box 180. (It will be remembered that the YES branch from decision box 168, indicating that cue number 00 has been specified, also causes the reset part of the program to be entered at function box 180.)

Function box 180 erases the cue number from the internal cue number register within the data processor. This provides an indication that the cue number has been erased and that there is no current active cue number. The system then proceeds to function box 183 which displays the numerical keyboard 37 within the area 32 as shown in FIGS. 4 and 7A and 7B. The system then proceeds to function box 181 which erases and deactivates menus 3 and 4, so that the area 32 of the display returns to the status shown in FIG. 4, in which neither menu 3 nor menu 4 is displayed. The system then proceeds to function box 182 which displays three blanks ( - - - ) in the space for the cue number below the word CUE shown in FIG. 4. Control then proceeds to the program exit which returns via line 90 to enabling gate 89 in FIG. 9A.

Generally, the reset program serves to clear the cue number space in area 32 of FIG. 4 so as to prepare it to receive the first digit of another cue number. The reset program is normally used in rehearsal operations when the operating personnel require general random access to different stored cues in order to change the data or activate then on the stage. It also has a function during performance of a show where there is an unexpected development which requires shifting from the normal expected sequence of lighting cues to some cue not in the normal sequence.

Referring now to FIG. 15 of the drawings, there is shown a detailed block diagram of the MENU 3 STORE, MENU 4 STORE, CALL, NEXT and BACK programs indicated respectively by blocks 83-87 shown in FIG. 9A.

The "call" program is initiated by a light pen activation on the word CALL at position 41 within area 32 of the character matrix display as shown in FIG. 7D. The block diagram shown in FIG. 15 is entered from the jump block 65 in FIG. 9B via line 189 to function box 190 which performs the operation of finding the fader having the highest setting. During normal use of the system for random access and storage and retrieval and composition of lighting cues, one would expect to find one fader at a full setting and all other faders at zero settings. The call function is so arranged that the lighting cue which has been specified and called is placed on the fader having the highest setting.

After function box 190 locates the fader with the highest setting, the sequence proceeds to decision box 191 which determines whether the system is in the preview mode. The purpose of this determination is to set the address of the internal buffer into which the specified cue will be transferred. If the system is in the preview mode, the YES branch from decision box 191 proceeds to function box 192 which sets the buffer address for the preview buffer. If the system is not in the preview mode, the NO branch from decision box 191 leads to function box 193 which sets the buffer address for the fader which has been found by function box 190 to have the highest setting.

The system then proceeds to function box 194 which transfers the specified cue from memory to the proper buffer. The system then proceeds to major function box 132 which executes the fader interrupt program which sets the external registers which determine the voltages which are fed to the dimmer bank in accordance with the lighting cue information and the fader settings.

After executing the fader interrupt program, the system proceeds to function box 196 which serves to display the called cue number in the area 45 of the character matrix display shown in FIGS. 4, 8A and 8B adjacent the word STAGE or PREVU depending on whether the system is in the stage or preview mode. Control is then returned via line 90 to the enabling gate 89 shown in FIG. 9A.

The effect of light pen activations on the word STORE shown in FIG. 7C and 7D differs depending upon whether the word STORE is activated in menu 3 as shown in FIG. 7D, that is, to store a cue that already exists in storage, or whether the word STORE is activated in menu 4 as shown in FIG. 7C, that is, to store a newly-numbered cue. If the cue that is to be stored is one that already exists in storage (menu 3), the store program is entered from jump box 65 in FIG. 9A via line 199 to function box 200 which transfers the new cue minus its "preamble" into storage, and then enters the call program at function box 190, in order to recall and reestablish the cue from storage after it has been stored. The entrance into the call program is to avoid unnecessary duplication of many of the functions in the call program for the sake of economy.

In the electronic display controlled stage lighting system of the present invention, each lighting cue stored in the main data storage facility of the system includes a preamble in addition to an array of voltage values for the 120 dimmer channels of the system. The preamble includes (a) the cue number itself, (b) a "back link" which is the record number of the preceding next lower cue in the sequence, and (c) a "forward link" which is the record number of the following next higher numbered cue in sequence. The term "record number", refers to the actual physical location of the particular lighting cue within the main data storage facility which, in the preferred embodiment, is a disc storage device. The record number bears no relation to the cue number, and any cue number might be stored at any record number position in the main data storage facility. It is by means of the preamble that the system is able to link one cue to next cue so as to provide a sequence of lighting cues for controlling the stage lamps.

Light pen activation on the word STORE at position 39 shown in FIG. 7C enters the menu 4 store program from jump box 65 of FIG. 9B via line 198 to function box 201. This indicates that a newly numbered cue is to be stored. Function box 201 transfers the forward link of the next lower cue to the forward link of the newly specified cue.

Referring back to FIG. 14, it will be remembered that when the new cue number was specified, the main data storage was scanned by function box 171. This scanning operation also locates the cue number in storage which is next immediately lower than a newly specified cue number. Function box 201 takes the forward link of this next lower numbered cue and transfers it to a temporary storage location so that it will become the forward link of the newly specified cue. It will be appreciated that the forward link in the next lower numbered

cue in the record number of the next higher numbered cue and that the forward link of the new cue should now point to the record number of the next higher numbered cue.

After function box 201, the sequence proceeds to function box 202 which transfers the record number of the next lower numbered cue to the back link of the newly specified cue. It will be appreciated that the next lower numbered cue will be the cue preceding the new cue in sequence and that the back link in the new cue's preamble should therefore point to it. Thus, function boxes 201 and 202 serve to compose the preamble for the new cue.

The sequence then proceeds to function box 203 which stores the preamble for the new cue in the buffer area in proper position relative to the data specifying the array of dimmer channel voltage values for the new cue. The sequence then proceeds to function box 204 which transfers the new cue into storage.

The system then proceeds to function box 205 where is begun the process of adjusting the preambles of both the next lower and the next higher cues, in order that their respective links will point to the new cue's record number. Function box 205 stores the new cue's record number and the next lower cue's forward link. The sequence then proceeds to decision box 206 which determines whether the new cue's forward link is blank. This would be the case if the number of the new cue is the highest in the sequence.

If the new cue's forward link is blank, the YES branch of decision box 206 is followed directly to function box 208 which displays and activates menu 3, as shown in FIG. 7D, and then enters the call program at function box 190, to redisplay the cue which has just been stored. If the new cue's forward link is not blank, the NO branch from decision box 206 is followed to function box 207, which stores the new cue's record number in the next higher numbered cue's back link. The sequence then proceeds to function box 208 as previously described.

Light pen activation of the word BACK at position 43 on menu 3 shown in FIG. 7D enters the "back" program from jump box 65 in FIG. 9B via line 220 to decision block 222 which determines whether the system is at the first cue of the sequence. If it is, then no function should be performed, and the YES branch from block 222 is followed to the program exit which leads to enabling gate 89 in FIG. 9A. The NO branch from decision box 222 leads to function box 223 which acquires the back link of the cue which is currently specified in area 32 of the character matrix display of FIG. 4 and stores it in a register in the data processor.

A light pen activation of the word NEXT at position 42 on menu 3 shown in FIG. 7D enters the "next" program from jump block 65 in FIG. 9B via line 119 to function box 224 which acquires the forward link of the cue which is currently specified in area 32 of FIG. 4 and stores it in the same register in the data processor.

At this point the back and next programs merge at function block 225 which retrieves the lighting cue found at the storage location referenced by the link acquired by block 223 or block 224. After the retrieval of the cue from storage by function box 225, the system proceeds to function box 226 which displays the retrieved cue number. The system then proceeds to function box 190 in the call program and thence through

the remaining function and decision blocks of that program to the program exit.

It will be appreciated by those skilled in the art that various sub-routines or, in the case of a special purpose data processor, that various hardware sub-combinations may be used to perform the same function in a number of different places in the system. For example, the function of box 226, which displays the cue number, may be performed by a single sequence of logical instructions or sub-routines which is used by various parts of the program whenever it is necessary to perform this particular display function. Similarly the functions of box 129 in FIG. 103 and box 182 in FIG. 14 may be performed by the same sub-routine for displaying blanks in the cue number space.

Referring to FIG. 16, there is shown a detailed block diagram of the "cancel" program (block 88 in FIG. 9A) which is initiated by a light pen activation on the word CANCEL at position 44 on menu 3 shown in FIG. 7D. The block diagram shown in FIG. 16 is entered from jump block 65 in FIG. 9B via line 230 to decision block 231 which determines whether the cue being cancelled is the last cue in the sequence. If it is the last cue in the sequence, the YES branch from box 231 leads directly to function box 233. The NO branch from decision box 231 leads to function box 232 which transfers and stores the specified cue's back link to the following cue's back link. Control then proceeds to function box 233 which transfers and stores the specified cue's forward link to the next lower cue's forward link. The effect of function boxes 232 and 233 is to cause the various links to bypass the specified cue as if it had never been stored.

Function box 234 then erases the preamble of the specified cue. This is necessary to prevent the specified cue from being found if main storage is scanned by the scanning program of function box 171 in FIG. 14. Function box 235, which then follows, blanks out the display of the cue number which has been cancelled. The system then proceeds via link 236 to function box 170 in FIG. 14 in order to establish display conditions corresponding to those produced when main storage is scanned for a non-existent cue.

FIG. 17 is a plan view of a control panel 240 which may be used by the operator for certain required functions during the performance of a show using the stage lighting system of the present invention. More particularly, the purpose of the control panel 240 shown in FIG. 17 is to implement certain functions which must be carried out with precise timing for which the light pen is not well adapted. Certain of the pushbuttons on control panel 240 accomplish functions which may also be accomplished by the light pen. The panel 240 is connected to the data processor through an appropriate interface. The operation of any push button on the panel 240 causes the "push button" program to be entered via line 260 which leads to decision box 261 shown in FIG. 18. Decision box 261 determines whether the push button that caused the interrupt was in the alpha-numeric keyboard 242 shown in FIG. 17. The YES branch from decision box 261 proceeds to function box 262 which reads the character by determining which specific one of the ten alpha-numeric push buttons 242 was operated. Control then passes from function box 262 to function box 263 which determines whether the system is in the status awaiting a third character. If the system is not awaiting a third

character, it is deduced that it is awaiting a first or second character, and the NO branch of decision box 263 is followed via line 264 to decision box 162 on FIG. 14 which then continues the same processing as if the light pen keyboard had been operated for the first or second character. The YES branch from decision box 263 proceeds via line 265 to function box 165 on FIG. 14, which then continues the same processing as if an alphabetical character had been selected by the light pen.

The next key to be tested on the push button panel 240 in FIG. 17 is the clear key 242. Function box 266 determines whether this key has been operated, and if so, the YES branch is followed via path 267 to function box 180 on FIG. 14, which then follows the same processing as if a light pen clear function had been activated.

The AB push button 243 in FIG. 17 is then tested in decision box 268 on FIG. 18. If this key has been operated, the YES branch of decision box 268 leads to decision box 269, which determines whether fader A is at zero. If fader A is not at zero, the NO branch of decision block 269 is followed to decision box 270 which determines whether fader B is at zero. If fader B is not at zero, the NO branch of decision box 270 is followed to the program exit which leads to enabling gate 89 in FIG. 9. The purpose of this program exit is to prevent the loading of a fader buffer and consequent sudden change of stage lighting by accidental operation of the AB push button.

The intended function of the AB push button is to load the pending cue onto whichever fader of the AB pair is at zero. This function is accomplished by function box 271, which transfers the pending cue to the proper buffer and activates the stage lights accordingly. The sequence proceeds from function box 271 to function box 226, which displays the new cue number in area 45 on the character display of FIG. 4 and thence to enabling gate 89 shown in FIG. 9A.

The next push buttons to be tested on push button panel 240 are push buttons X and Y 244. Decision block 272 determines whether either of these two buttons X or Y are operated. The YES branch from decision block 272 leads to decision box 273 which determines whether the specified fader is at zero. If the fader is not at zero, the NO branch is followed to the exit which leads to block 89 in FIG. 9A. If the fader is at zero, which is the proper condition to permit loading the specified cue onto the fader, the YES branch of block 273 is followed to function box 271, which carries out the same functions as previously described for loading the A or B faders.

The next push button to be tested on push button panel 240 is the preview button 245, which is tested in decision box 274, in FIG. 18. If this button has been operated the YES branch from decision box 274 is followed directly to function box 271, which transfers the cue specified in area 32 of the display shown in FIG. 4 to the preview buffer and consequently displays the cue in the top half of the display shown in FIG. 4.

The next push button to be tested is the HIT button 246 which is tested in decision box 280. If the HIT button 246 has been operated, the YES branch from decision box 280 leads to function box 281 which determines the highest valued fader of the AB pair. Then, function box 282 transfers the cue presently in the buffer of the lower valued fader of the AB pair to the buf-

fer of the highest valued fader. And then, function box 283 loads the next cue in sequence from data storage into the buffer of the lowest valued fader.

In normal operation, it would be expected that the lowest valued fader would actually be at a zero value and the highest valued fader would actually be at full value, but it is not essential that the faders be so arranged.

Following the loading of cues which has been accomplished by function boxes 282 and 283, function box 132 executes the fader interrupt program, which causes the newly loaded cue on the highest valued fader to abruptly change the intensity configuration of the stage lamps.

The next push buttons to be tested are the skip-back (SKB) and skip-forward (SKF) buttons 247 which are tested by decision box 285. If either of the two buttons 247 has been operated, the YES branch of decision box 285 is followed to decision boxes 286 and 287 which determine whether neither fader A nor fader B is at zero. If neither fader A nor fader B is at zero control is returned to enabling gate 89 in FIG. 9A. If either fader A or fader B is at zero, control passes to function box 288 which loads the next cue, in the case of skip-forward, or the previous cue, in the case of skip-back, into the buffer of the fader at zero.

This causes no change to the stage lights, but simply bypasses the cue which had been pending on the zero fader for later activation and replaces it with either the next cue in the sequence or the previous cue in the sequence. This is to provide an alternate method for specifying a new cue, out of the normal sequence, to be activated on the AB fader pair. After function box 288 loads the next cue or previous cue into the buffer of the zeroed fader, function box 226 displays the new cue number in area 45 on the character matrix display of FIG. 4.

Lastly, the bypass to X, and bypass to Y push buttons 248 are tested in decision box 289. If either of these push buttons 248 have been operated, the YES branch of decision box 289 is followed to function box 290, where the cue from the buffer of the lowest valued of the AB fader pair is transferred to the buffer of either the X or the Y fader, as selected. Function box 291 then loads the next cue in sequence into the buffer of the lowest valued fader of the AB fader pair. The purpose of this function is to provide a convenient method to separate out a specific cue from the normal sequence and to assign it conveniently to either the X or Y fader for separate and independent manipulation, while the normal sequence is allowed to continue on the AB fader pair.

Following the loading of cues by function boxes 290 and 291, function box 226 displays the new cue numbers, after which the sequence proceeds to the exit which leads back to enabling gate 89 in FIG. 9A. The NO branch from decision box 289 also proceeds to enabling gate 89 in FIG. 9A. This branch is simply a safety device which would be followed only in the case of a transient hardware failure in which a push button interrupt occurred but the specific push button operated was not identified.

FIG. 19 is a block diagram of the fader interrupt program which is entered, from the decision box 52 of FIG. 9B via line 299 to function box 300 in FIG. 19 which reads the fader values by means of an interface system and deposits them in internal registers within

the data processor. Control then passes to major function box 132 which executes the fader interrupt program, and thence to the program exit, which leads to enabling gate 89 in FIG. 9a.

FIGS. 20A, B and C show a detailed block diagram of the fader interrupt program represented by block 132 in FIGS. 10, 15, 18 and 19. The fader interrupt program is entered on line 302 which leads to decision box 303 in FIG. 20A which determines whether the X or Y fader caused the interrupt. The purpose of this determination is to allow for up-dating the display with new values for the X or Y fader, which is not otherwise accomplished in the remainder of the fader interrupt program.

As shown in FIG. 4, each of faders A, B, X and Y has a vertical array of characters 304A, B, X and Y which are used to represent to the operator the relative physical position of the fader. As illustrated in FIG. 4, the fader scales 304Y and 304B for faders Y and B are both shown as they would appear with the faders at their zero settings. The X fader scale 304X is shown as it appears when the X fader is at a value of 4. The A fader scale 304A is shown as it appears when set to its full value.

It will also be noted that, as a further aid to the operator, the portions of the display 307A, B, X and Y on which are shown the cue numbers which are assigned to the A, B, X and Y faders respectively are "flagged", that is, flanked by symbols to serve as a reminder to the operator as to which faders are at partial or full level. The cue number positions 307B and 307Y for the faders B and Y are not flagged since these faders are set to zero. The cue number position 307X for the X fader is flagged with reverse brackets 308 and the cue number position 307A for the A fader is flagged with pointers 309 to show that the X fader is at a partial level, and the A fader is at full level.

The YES branch from decision box 303 in FIG. 20A leads to function box 310 which sets the appropriate flags 308, 309 flanking the cue number positions 307A, B, X and Y for each of the faders A, B, X and Y. From function box 310, the system proceeds to function box 311 which brings fader scales 304X and 304Y for the X and Y faders up to date in accordance with the new value that has been read from the shaft of the X or Y fader. After function box 311, the system proceeds to function box 312 to which the NO branch from decision box 303 also leads. Function box 312 initializes the fader interrupt program for processing the A fader.

The A and B faders are intended for automatic sequencing of lighting cues, that is, a new cue may be loaded from storage under certain conditions when either the A or B fader reaches a zero value. The logical network beginning at decision box 313 is passed through twice, once for the A fader and once for the B fader.

Decision box 313 determines whether the new value for the fader being processed is different or whether it is the same as the old value. The value may be the same if it was the other fader that was moved so as to cause the interrupt. If the new value is the same as the old, the YES branch from decision box 313 bypasses all of the processing functions for that particular fader and proceeds directly to decision box 319. The NO branch from decision box 313 leads to function box 314 which flags the fader's cue number with the symbols 308, 309 as described above.

After function box 314, control passes to decision box 315 which determines whether the new value for the fader being processed is "zero". The YES branch of decision box 315 leads to a series of steps to be activated to determine the posting of cue numbers and the loading of following cues. The NO branch proceeds to decision box 316 which determines whether the new value is full. The YES branch from decision box 316 also leads to logic related to the display of fader cue numbers as the STAGE cue numbers. The NO branch from decision box 316 leads to function box 317 which erases the STAGE cue number from the display. The purpose of this step is to insure that the cue number will be displayed as the STAGE cue number only if the information shown in the top half of the character matrix display of FIG. 4 actually corresponds exactly to the stored cue of that number. This is to avoid confusion as to whether or not the information which is presented to the operator as the array of dimmer circuit values on the top half of the display actually represents the contents of a specific stored lighting cue. The system proceeds from function box 317 to function box 318 which displays the new fader scale 304A or 304B.

The system then proceeds to decision box 319 in FIG. 20B which determines whether fader B has been processed. If fader B has not been processed, the NO branch from decision box 319 leads to function box 320 which sets the system to process fader B, and then returns to decision box 313 to go through the same functions for fader B as have been completed for fader A. The YES branch from decision box 319 leads to further processing.

Returning to decision box 315 in FIG. 2A, if the new value for the fader is zero, the YES branch is followed to decision box 321 which determines whether the opposite fader, that is fader B if fader A is being processed or vice versa, is at full. If the other fader is at full, the YES branch from decision box 321 proceeds to function box 322 which displays the other fader's cue number as the STAGE cue. The NO branch from decision box 321 simply bypasses function box 322 and continues on to function box 323 which loads the next cue in sequence from data storage. The sequence then continues to function box 324 which displays the cue number of the next cue in the portion of the display 307A, B, X and Y where cue numbers assigned to faders are displayed. Following function box 324, the system reenters the main loop at the function box 318.

Returning now to decision box 316, if it is determined that the new fader value is full, the YES branch from decision box 316 is followed to decision box 325 which determines whether the other fader is at zero. If the other fader is not at zero, the NO branch from decision box 325 returns directly to function box 318 in the main loop. If the other fader was at zero, the YES branch is followed to function box 326, since conditions are now proper for displaying the fader's cue number as the STAGE cue number and this function is accomplished by function box 326.

Returning to FIG. 20B decision box 319 tests for the conclusion of processing faders A and B for the loading of new cues from memory, if appropriate, or the display of STAGE cue numbers. The YES branch from decision box 319 leads to function box 327 which begins the process of determining and temporarily storing in a buffer memory area the actual circuit values which

are to be transferred to the interface system for a final output as analog voltages to the dimmer circuits.

Function box 327 initializes to the first dimmer circuit, and then proceeds to function box 328, which initializes to the first fader for processing all four faders. The system control then proceeds to decision box 329, which determines whether the fader being processed is at zero. If the fader is at zero, the YES branch proceeds to bypass the processing of the particular fader. If the fader is not at zero, the NO branch of decision box 329 leads to decision box 330 which determines whether the value specified for this particular circuit in the cue that is assigned to this particular fader is higher than the value specified for this particular circuit in the cue stored for any previously processed fader. This determination is required to ensure that it is not possible for any circuit to be given an output voltage value higher than the highest voltage value specified for it within any cue assigned to any fader. Such a high voltage output could result from straight arithmetic processing under a condition where more than one fader specifying a given value for this particular circuit were manually set to values averaging higher than mid-scale.

If the value specified for this particular circuit in the cue assigned to this particular fader is higher than any previous such value, the YES branch from decision box 330 leads to function box 331 which stores the new high value and transfers control to function box 332. The NO branch from decision box 330 also leads to function box 332 which multiplies the circuit value specified in the cue assigned to this particular fader by the value of the fader itself. The product of this multiplication represents the appropriate contribution by this particular fader to the voltage value that should be transmitted to this particular dimmer.

The sequence then proceeds to function box 333 which adds this value to a previously stored tentative value. The sequence then proceeds to decision box 334 which determines whether the last fader has been processed. If the last fader has not been processed, the NO branch from decision box 334 is followed to function box 335, which advances the system to process the next fader and then returns control to decision box 329 so as to repeat the same processing until the last fader is processed. After the last fader is processed, the tentative value stored will be the sum of the products of the circuit value specified under the cues assigned to various faders, and the values of the various faders.

The YES branch from decision box 334 proceeds to decision box 336 which determines whether the tentative value stored is higher than the highest possible contribution by any one of the faders. If the tentative value is higher, the YES branch is followed to function box 337 which arbitrarily sets the value for this particular circuit to the highest previously stored acceptable contribution by any one fader and then transfers control to function box 338. The NO branch from decision box 336 also leads to function box 338 which stores the new value which has been determined by function box 337 as the stage value for this particular dimmer circuit in a buffer storage area within the data processing system. The sequence then proceeds to decision box 339 which determines whether or not the last circuit has been processed. If the last circuit has not been processed, the NO branch from decision box 339 proceeds to function box 340 which advances the system to process the next

circuit, and then returns control to function box 328 to initialize the loop to process all faders once again.

The YES branch from decision box 339 proceeds to function box 341 which transfers the contents of the newly formed buffer, containing the proper voltage values for all dimmer circuits, via the interface to the dimmers 3 thus controlling the stage lamps 1 shown in FIG. 1.

Referring to FIG. 21 of the drawings, there is shown a logic diagram of the central logic section of the preferred form of digital to analog converter used in the output interface 11 of the system block diagram shown in FIG. 3. The central logic section shown in FIG. 21 generates six repetitive pulse waveforms each having one pulse per cycle, the pulses of the six waveforms being non-overlapping in time and having pulse widths related in the ratio of 1:2:4:8:16:32. The six waveforms produced by the central logic section shown in FIG. 21 are illustrated in FIG. 24.

Elements 350-358 of the central logic section shown in FIG. 21 are NAND gates, the outputs of which are down (negative) only when both inputs are up (positive). Elements 360-363 are NOR gates, the outputs of which are up (positive) only when both inputs are down (negative). Elements 370-375 are J-K flip-flops which operate in a manner well-known to those skilled in the art.

NAND gate 350 serves as the active element for the oscillator circuit 369 which includes resistor 365, inductor 366 and capacitors 367 and 368. The frequency of oscillation is determined by the LC time constant of the combination of inductor 366 and capacitors 367 and 368. The oscillator frequency is preferably high enough to avoid ripple at the output of the integrator section shown in FIG. 23. For example, the oscillator frequency may be in the neighborhood of 250 KHz. NAND gate 351 serves as an inverter-buffer between oscillator 369 and flip-flop 370.

Flip-flops 370, 371, 372, 373 and 375 are connected in a counter-chain. That is, each successive flip-flop serves to divide the switching rate of the previous flip-flop by a factor of two. The outputs of oscillator 369 and flip flops 370-373 and 375 are converted by flip-flop 374, NAND gates 350-358 and NOR gates 360-363 into six output waveforms of the type shown in FIG. 24. More specifically, the output on line 381 of FIG. 21 corresponds to waveform A of FIG. 24. The signal on line 382 of FIG. 21 corresponds to waveform B of FIG. 24. The signal on line 383 of FIG. 21 corresponds to waveform C of FIG. 24. The signal on line 384 of FIG. 21 corresponds to waveform D of FIG. 24. The signal on line 385 of FIG. 21 corresponds to waveform E of FIG. 24 and the signal on line 386 of FIG. 21 corresponds to waveform F of FIG. 24.

The signals on lines 381-386 comprise the building blocks from which the analog output signals for controlling the dimmers for the stage lights are constructed. By combining the signals on line 381-386 in various ways in the register gate section shown in FIG. 22 and integrating the combination in the integrator output section in FIG. 23, any of 64 possible levels of output voltage can be produced.

Referring now to FIG. 22, there is shown a logic diagram of the register-gate section of the preferred form of digital to analog converter used in the output interface of the subject electronic display controlled stage lighting system. In the preferred form of the present in-

vention, the register-gate section includes six latches arranged as a 6-bit register and six NAND gates associated with each dimmer in the output of the stage lighting system. FIG. 22 illustrates two 6-bit registers 390 and 400 and sets of six NAND gates 411-416 and 421-426 associated with two of the output dimmers of the system. It will be appreciated, however, that the present invention contemplates the operation of large numbers of dimmers, for example 200 or more.

Referring to FIG. 22, 6-bit register 390, comprising latch circuits 391-396 is associated with one output dimmer while 6-bit register 400 comprising latch circuits 401-406 is associated with another output dimmer. The outputs of latches 391-396 are each connected, respectively, to an input of the NAND gates 411-416. The other inputs of NAND gates 411-416 are connected, respectively, to the output lines 381-386 from the central logic section shown in FIG. 22. Similarly, the outputs of each of the latches 401-406 are connected, respectively, to an input of the NAND gates 421-426 while the other inputs of NAND gates 421-426 are connected, respectively, to the lines 381-386. The outputs from NAND gates 411-416 are ANDed, or tied together as are the outputs of NAND gates 421-426. It will be appreciated that this arrangement provides an output signal on line 418 having a duty cycle which corresponds to the 6-bit binary code stored in register 390. Similarly, the output signal on line 428 has a duty cycle corresponding to the 6-bit binary code stored in register 400.

For example, if register 390 contains the binary number 100101 corresponding to decimal 37, the signals on lines 381, 384 and 386 will be gated through NAND gates 411, 414 and 416 to be combined at the output 418 while the signals on lines 382, 383 and 385 will be inhibited. Referring to FIG. 24, it will be seen that if waveforms A, D and F, corresponding to the signals on lines 381, 384 and 386, are combined, the combined signal will have a duty cycle of thirty-seven sixty-fourths. If such a combined signal is integrated over a large number of cycles, a d.c. analog output signal having a voltage level corresponding to thirty-seven sixty-fourths of the full value of the waveforms shown in FIG. 24 will result. The integration function will be described in greater detail in connection with FIG. 23.

Referring again to FIG. 22, a selection circuit 430 is used to select the particular 6-bit registers to receive binary digital information from the data processor 10 of the system shown in FIG. 3. The selection circuit in 430 includes a multiple input NAND gate 431 that is used to select a particular group of 6-bit registers. For example, a six input NAND gate 431 could be used to select one of 64 groups of six 6-bit registers each if, for example, the registers happen to be mounted six to a card. The output of NAND gate 431 is applied to an inverter 432, the output of which is applied to one input of each of the three NAND gates 433, 434 and 435. The signals on lines 436, 437 and 438 are applied to the other inputs of NAND gates 433-435, respectively, and serve to strobe the binary information from the data processor into each of three pairs of 6-bit registers within the group selected by multiple input NAND gate 431. For example, a positive signal on line 436 causes NAND gate 433 to strobe 12 bits of information from the data processor into the two 6-bit registers 390 and 400. It will be appreciated that the 6-bit registers 390 and 400 are arranged in a pair so that, together, they

are capable of accepting a full 12-bit word from a data processor such as the PDP-8/L manufactured by the Digital Equipment Corp. It will be apparent that various other arrangements could be made in the case of data processors having different word sizes and in cases where a greater or lesser resolution is desired in the analog output signals.

Referring to FIG. 23 of the drawings, there is shown a schematic diagram of the integrator-output section of the digital to analog converter used in the preferred form of output interface. An integrator output circuit such as that shown in FIG. 23 is connected to each of the register-gate outputs such as, for example, outputs 418 and 428 shown in FIG. 22. The output from the register gate section is applied through a zener diode 441, which performs a level translation function, to transistor 442 which serves as an amplifier. The output from transistor 442 is applied to a pair of transistors 443 and 444 which act as complementary saturated switches. The combination including transistors 443 and 444 is sometimes called a chopper. The output from complementary saturated switches 443 and 444 is applied to the RC integrating network including resistor 445 and capacitor 446. The output from the RC integrating network is applied to transistors 447 and 448 which are connected as a complementary emitter follower pair. Diode 449 provides short circuit protection for the transistors. Line 450 is held below ground, -5v. for example. Line 451 is at a reference voltage related to the full scale value of the analog d.c. control voltage to be applied to the dimmer circuits. For example, if the full scale dimmer control voltage is 28v., the reference voltage on line 451 will be 28.4 volts so that sixty-three sixty-fourths of the reference voltage will give the full scale dimmer control voltage. The peak value of the rectangular waveforms shown in FIG. 24 also correspond to the 28.4v. reference voltage. Line 452 is at a voltage above the reference level, 35v. for example. The output line 453 has a range from zero to 28 volts d.c. and may be connected to a conventional dimmer circuit.

An advantage of the digital to analog converter described in connection with FIGS. 21-24 is that it provides reasonable analog resolution for stage lights at relatively low cost. In particular, cost savings are achieved by the fact that the central logic section shown in FIG. 21 is shared between several output channels. In principle, all output channels could be served by a single central logic section, but, for reasons of reliability, it is preferable to use several central logic sections.

Although the principles of the present electronic display controlled stage lighting system and method have been illustrated by reference to a preferred embodiment, it will be appreciated by those skilled in the art that certain modifications and adaptations of the apparatus may be made without departing from the spirit and scope of the invention as defined with particularity in the appended claims.

What is claimed is:

1. Display-controlled apparatus for controlling a plurality of stage lighting circuits, comprising:

display means for displaying data in the form of a character matrix;

selecting means for selectively designating portions of the displayed character matrix;

a data processor connectable to said display means and said selecting means, said data processor including:

first data storage means for storing a plurality of digital data records, each data record including data representing a plurality of lighting circuit values, each circuit value being associated with one of the lighting circuits to be controlled;

second data storage means for storing a single digital data record representing a plurality of lighting circuit values;

selective retrieving means connectable to said first and second data storage means for transferring selected data records from said first data storage means to said second data storage means;

means for causing said display means to display characters identifying the lighting circuits controlled in a first portion of said character matrix;

means connectable to said second data storage means and said display means for causing said display means to display characters representing the circuit values stored in said second data storage means in said first portion of said character matrix adjacent said characters identifying the lighting circuits with which said circuit values are associated;

circuit value changing means connectable to said second data storage means and said selecting means for changing the circuit values of the data record stored in said second data storage means in response to the designation by said selecting means of the associated lighting circuit identifying characters in said first portion of said character matrix display; and

a digital-to-analog converter means connectable to said second data storage means for converting the digital data record stored in said second data storage means to a plurality of voltages for controlling the stage lighting circuits.

2. The display controlled apparatus of claim 1 wherein said digital-to-analog converter means comprises:

means for generating a set of synchronized periodic pulse waveforms, each of said waveforms having one pulse per cycle, said pulses being non-overlapping in time and having pulse widths related as powers of the base 2;

means responsive to the digital data record stored in said second data storage means for combining selected ones of said set of waveforms to provide a composite pulse waveform having a duty cycle corresponding to the circuit value associated with a lighting circuit to be controlled; and

means for integrating said composite pulse waveform to provide an analog d.c. voltage for controlling a lighting circuit.

3. The display controlled apparatus of claim 2 wherein said means for combining selected ones of said set of waveforms comprises:

a plurality of registers, each of said registers being associated with one of the lighting circuits to be controlled and each of said registers being connectable to said second data storage means to receive the data representing the circuit value of the lighting circuit with which said register is associated;

a plurality of sets of gate circuits, each set of gate circuits being associated with one of said registers, each gate circuit having one input connected to

one stage of said associated register and another input connected to receive one of said waveforms from said waveform generating means so that selected ones of said set of waveforms appear at the outputs of said set of gate circuits in accordance with the data stored in said associated register; and means for combining the outputs of each set of gate circuits so as to provide a plurality of composite pulse waveforms, each said composite pulse waveform having a duty cycle corresponding to the circuit value associated with a lighting circuit to be controlled.

4. The display controlled apparatus of claim 2 wherein said waveform generating means generates a set of six waveforms having pulse widths related as 1:2:4:8:16:32.

5. The display-controlled apparatus of claim 1 wherein said circuit value changing means comprises: means for causing said display means to display, in a second portion of said character matrix, characters representing a range of circuit values for the circuits controlled;

means for specifying a circuit value in response to the designation by said selecting means of the character representing said circuit value in said second portion of said character matrix display; and means for changing the circuit values of the data record stored in said second data storage means to correspond to said specified circuit value in response to the designation by said selecting means of the associated circuit identifying characters in said first portion of said character matrix display.

6. The display-controlled apparatus of claim 1 further comprising:

third data storage means for storing a single data record representing a plurality of circuit values;

means for causing said display means to display characters representing the circuit values stored in said third data storage means in said first portion of said character matrix adjacent said characters identifying the electrical circuits with which said circuit values are associated; and

mode selecting means for causing said selective retrieving means to transfer selected data records from said first storage means to said third storage means and for causing said circuit value changing means to change the circuit values of the data record stored in said third storage means so as to enable selected data records to be displayed and changed without affecting the circuit values of the circuits controlled.

7. The display controlled apparatus of claim 6 wherein said mode selecting means comprises:

means for causing said display means to display, in a third portion of said character matrix, characters representing each of the possible operating modes of the apparatus;

means for specifying an operating mode of the apparatus in response to the designation by said selecting means of the characters representing said operating mode; and

means for causing said display means to display, adjacent the characters representing said specified operating mode, a code identifying the data record displayed in said first portion of said character matrix display.

8. The display controlled apparatus of claim 6 further comprising:

storing means for transferring data records from said second storage means and said third storage means to said second storage means.

9. The display-controlled apparatus of claim 1 wherein each of said data records stored in said first data storage means is associated with a data record identifying code, said apparatus further comprising:

means for causing said display means to display data record identifying characters in a fourth portion of said character matrix;

means for specifying a data record identifying code in response to the designation by said selecting means of data record identifying characters; and means for causing said display means to display the specified data record identifying code in said fourth portion of said character matrix.

10. The display-controlled apparatus of claim 9 further comprising:

means for determining whether there is stored in said first data storage means a data record associated with said specified data record identifying code;

means responsive to said determining means for causing said display means to display a first character near said specified record identifying code in said fourth portion of said character matrix if there is a data record associated with said specified record identifying code stored in said first data storage means and for causing said display means to display a second character near said specified record identifying code if there is no data record associated with said specified record identifying code stored in said first storage means.

11. The display-controlled apparatus of claim 10 further comprising:

means responsive to said determining means for causing said display means to display in said fourth portion of said character matrix, a first set of codes representing operations to be selectively activated if there is a data record associated with said specified record identification code stored in said first storage means, and for causing said display means to display a second set of codes representing operations to be selectively activated if there is no data record associated with said specified record identification code stored in said first storage means.

12. The display controlled apparatus of claim 11 further comprising:

means responsive to the designation by said selecting means of one code of said first set of codes to activate said selective retrieving means to transfer from said first data storage means to said second data storage means the data record associated with said specified record identification code.

13. The display-controlled apparatus of claim 12 further comprising:

means responsive to the designation by said selecting means of a second code of said first set of codes to activate said selective retrieving means to transfer from said first data storage means to said second data storage means the data record associated with the record identification code next higher than said specified record identification code.

14. The display-controlled apparatus of claim 12 further comprising:

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means responsive to the designation by said selecting means of a third code of said first set of codes to activate said selective retrieving means to transfer from said first data storage means to said second data storage means the data record associated with the record identification code next lower than said specified record identification code.

15. The display-controlled apparatus of claim 11 further comprising:

canceling means for selectively canceling data records stored in said first storage means and for linking the data record having the next higher record identification code than the canceled record to the data record having the next lower record identification code than the canceled record; and

means responsive to the designation by said selecting means of a fourth code of said first set of codes for activating said canceling means to cancel the data record associated with said specified record identification code.

16. The display controlled apparatus of claim 11 further comprising:

first storing means for transferring the data record stored in said second data storage means to the location in said first storage means which is occupied by the data record associated with said specified record identification code, and;

means responsive to the designation by said selecting means of a fifth code of said first set of codes to activate said first storing means.

17. The display-controlled apparatus of claim 11 further comprising:

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second storing means for transferring the data record stored in said second data storage means to said first storage means and for linking said data record to the data record having the next higher record identification code than said specified record identification code and to the data record having the next lower record identification code than said specified record identification code; and

means responsive to the designation by said selecting means of one code of said second set of codes for activating said second storing means.

18. The display-controlled apparatus of claim 1 wherein said display means comprises a cathode ray tube monitor unit.

19. The display-controlled apparatus of claim 18 wherein said selecting means comprises a light pen.

20. The display-controlled apparatus of claim 1 further comprising:

control means for simultaneously and proportionally increasing or decreasing all circuit values in said second data storage means between zero and full value for the data record stored in said second storage means.

21. The display-controlled apparatus of claim 20 further comprising:

means responsive to said control means for causing said display means to display, in a fifth portion of said character matrix, characters representing the status of said control means between zero and full value.

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