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Barrett et al.

[11] **3,784,874**

[45] **Jan. 8, 1974**

[54] **LIGHTING CONTROL SYSTEMS**

[75] Inventors: **James Howard Barrett,** London; **Jack Kelleher,** Wembley, both of England

[73] Assignee: **Dynamic Technology Limited,** Wembley, England

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[52] **U.S. Cl.** **315/294,** 313/297, 313/316, 313/320

[51] **Int. Cl.** **H05b 37/02,** H05b 39/06

[58] **Field of Search** 315/292-301, 316, 311-315, 315/320

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Primary Examiner—Alfred L. Brody

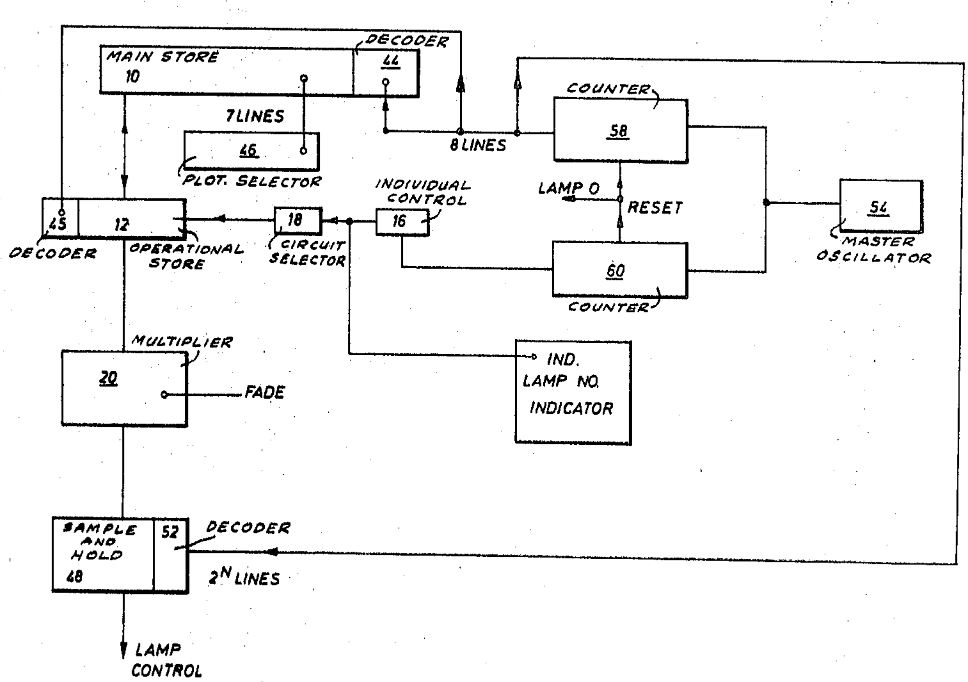
Attorney—William E. Schuyler, Jr. et al.

[57] **ABSTRACT**

Lighting control apparatus for controlling the brightness of a group of (typically 256) lamps in which a number of (typically 128) lighting plots comprising brightness control information are transferred in turn from a main store to an operational store and which includes time-division-multiplex means for controlling the brightness of the lamps in the group in accordance with a lighting plot in the operational store. Embodiments are described which include an "action" operational store and a "standby" operational store and means which may be manual or automatic for cross-fading control of the brightness of lamps from the action to the standby store, which is then designated the action store.

Lighting plots are built up in an operational store by storing brightness information for each individual lamp and transferring light plots to the main store.

16 Claims, 8 Drawing Figures



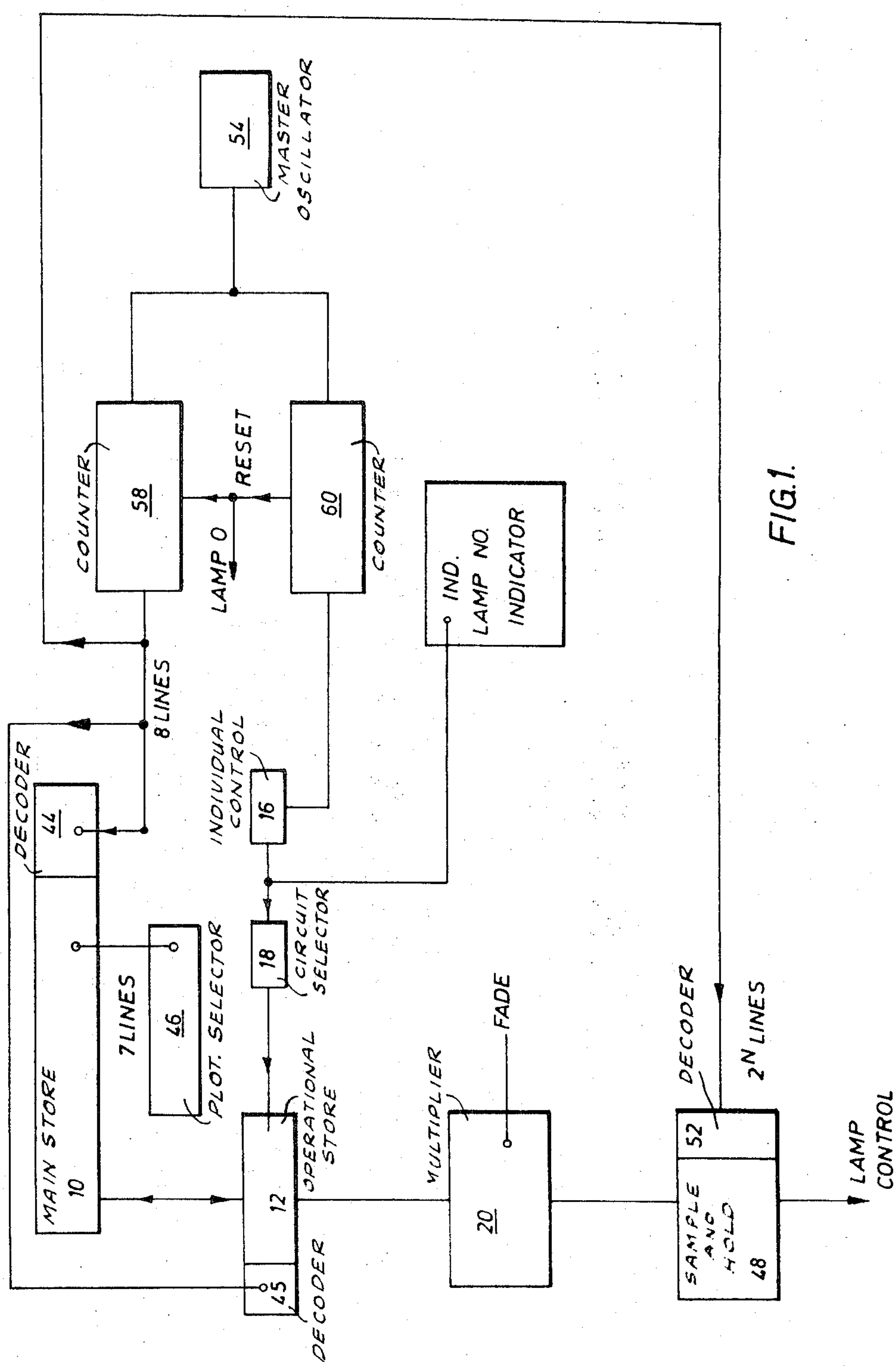

54
MASTER OSCILLATOR
58
COUNTER
60
COUNTER
RESET
LAMP 0
IND. LAMP NO. INDICATOR
8 LINES
44
DECODER
MAIN STORE 10
7 LINES
46
PLOT. SELECTOR
16
INDIVIDUAL CONTROL
18
CIRCUIT SELECTOR
12
OPERATIONAL STORE
45
DECODER
20
MULTIPLIER
FADE
52
DECODER
2^N LINES
SAMPLE AND HOLD 48
LAMP CONTROL

FIG.1.

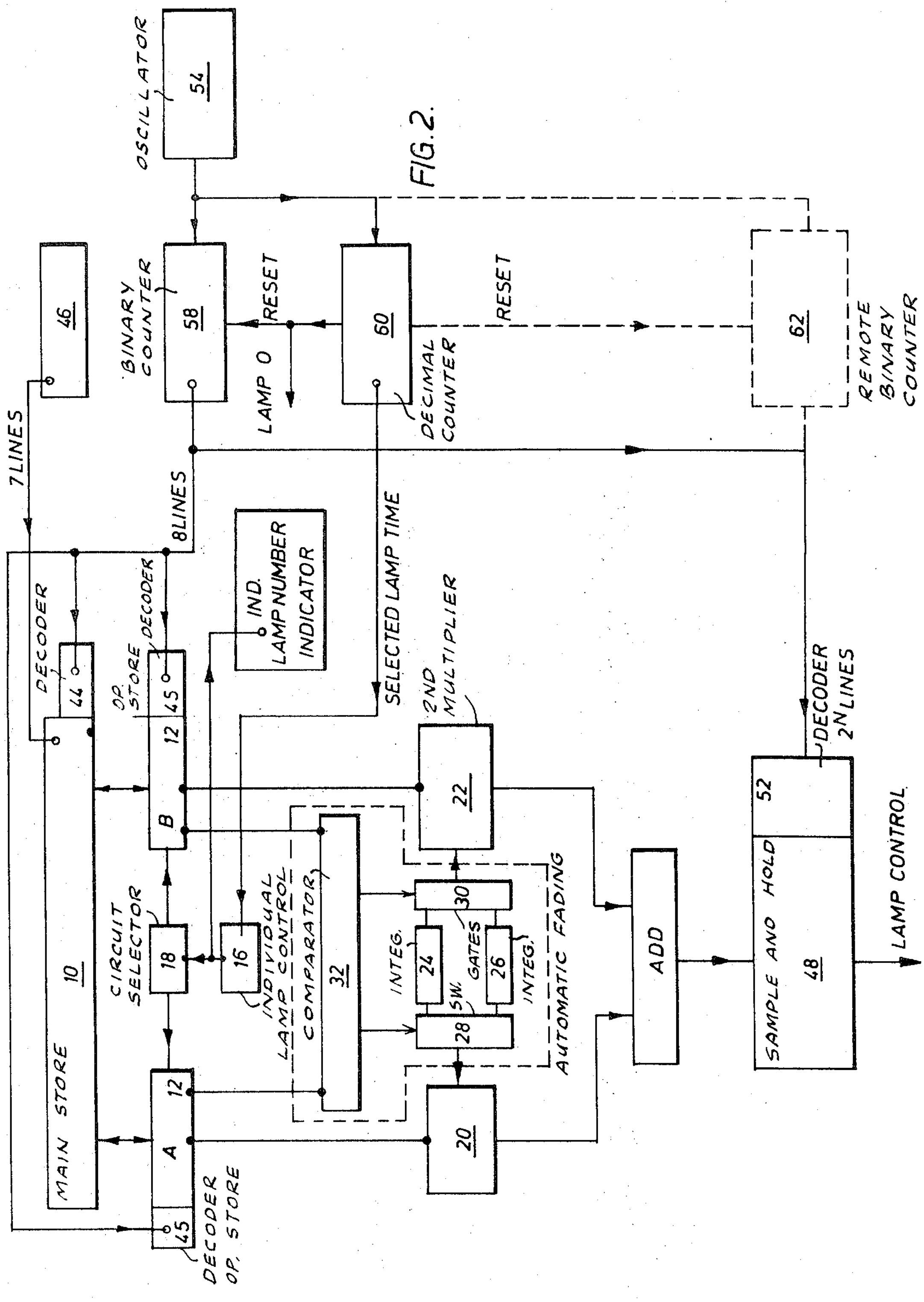

OSCILLATOR
54
BINARY COUNTER
58
RESET
LAMP 0
60
DECIMAL COUNTER
RESET
62
REMOTE BINARY COUNTER
46
7 LINES
8 LINES
DECODER
44
OP STORE
DECODER
45
12
B
IND. LAMP NUMBER INDICATOR
SELECTED LAMP TIME
2ND MULTIPLIER
22
DECODER 2N LINES
52
SAMPLE AND HOLD
48
LAMP CONTROL
ADD
AUTOMATIC FADING
30
INTEG.
24
SW. GATES
26
INTEG.
28
20
COMPARATOR
32
INDIVIDUAL LAMP CONTROL
16
CIRCUIT SELECTOR
18
MAIN STORE
10
A
12
45
DECODER OP. STORE

FIG. 2.

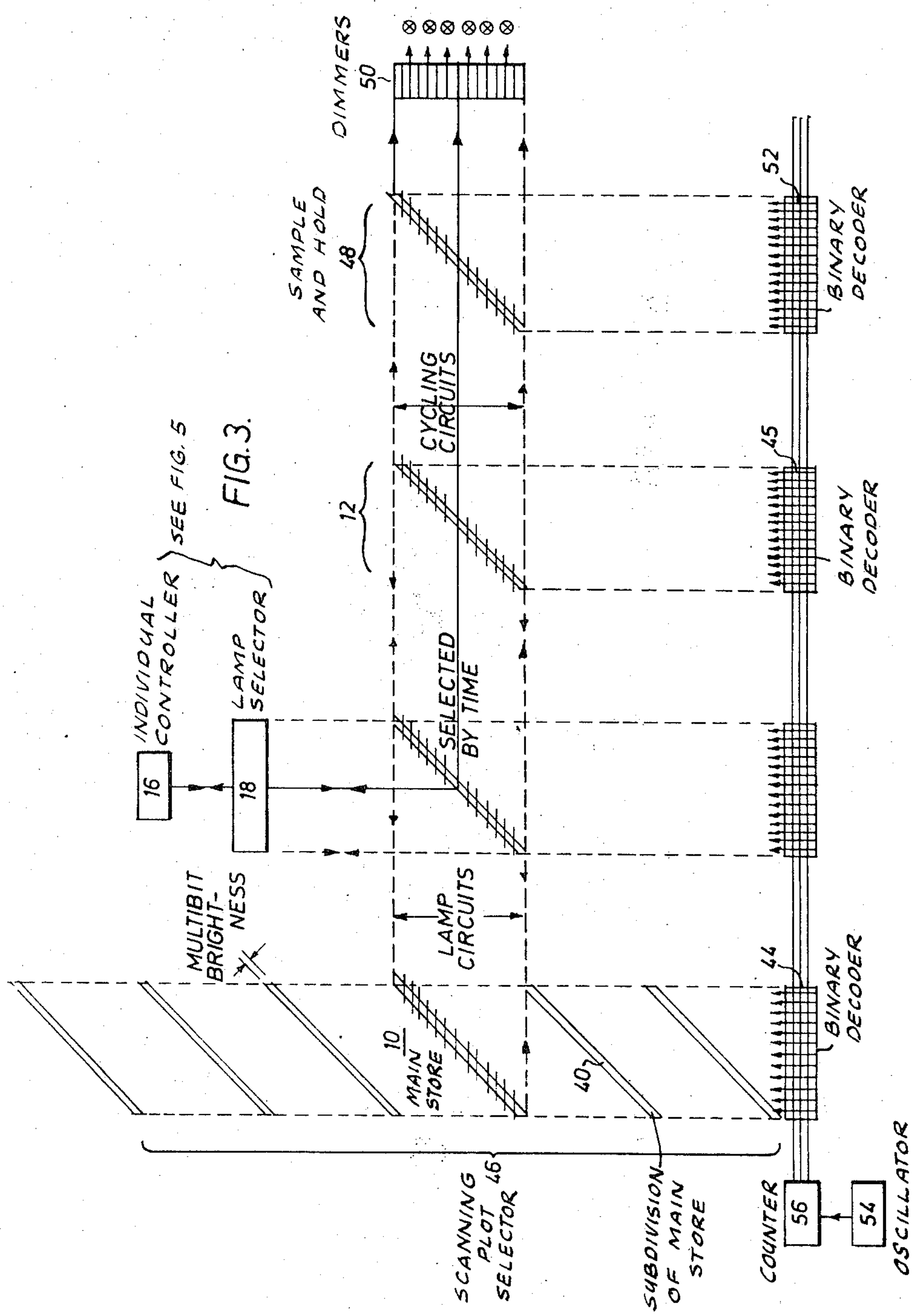
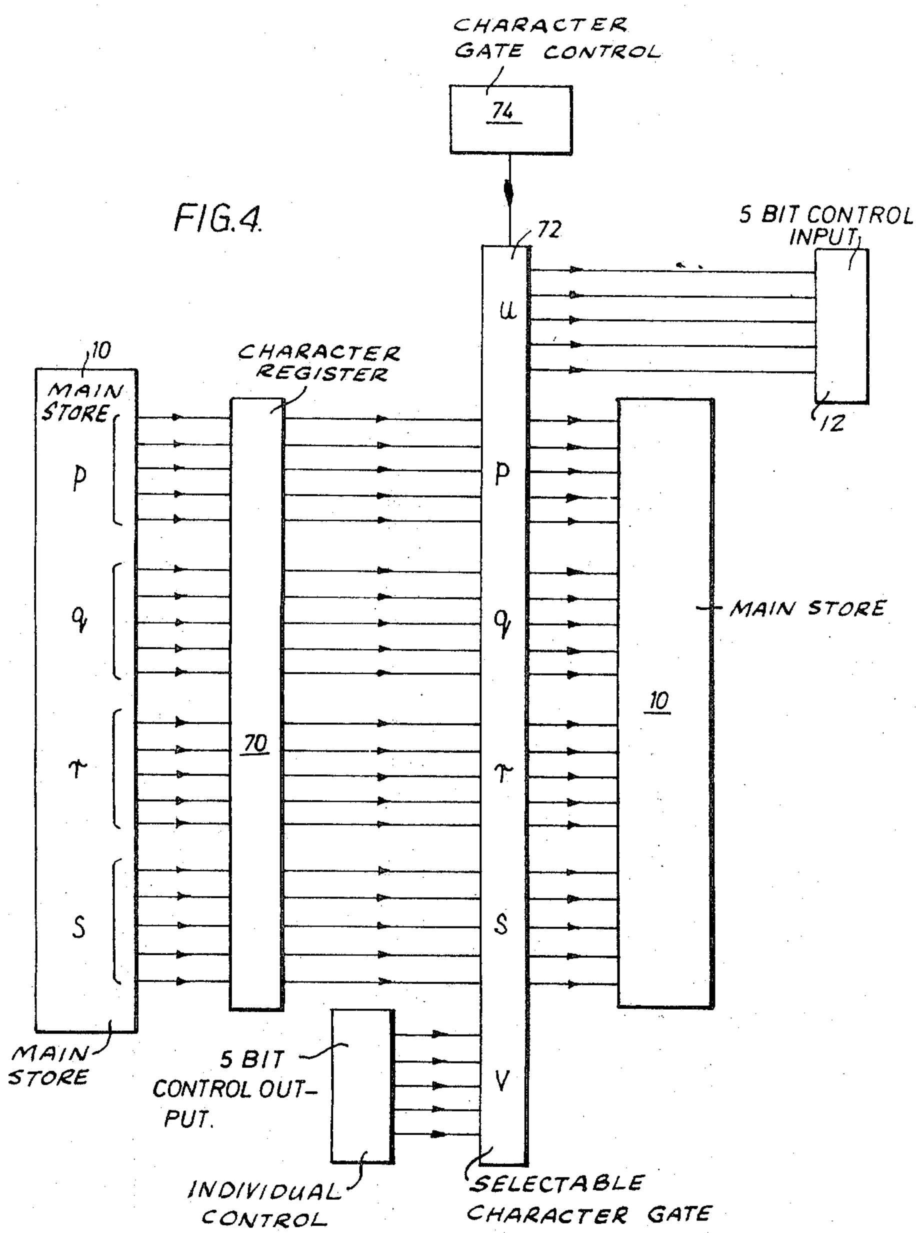

INDIVIDUAL CONTROLLER
16
LAMP SELECTOR
18
SEE FIG. 5
MULTIBIT BRIGHTNESS
10
MAIN STORE
40
LAMP CIRCUITS
SELECTED BY TIME
12
CYCLING CIRCUITS
48
SAMPLE AND HOLD
50
DIMMERS
44
BINARY DECODER
45
BINARY DECODER
52
BINARY DECODER
SCANNING PLOT SELECTOR 46
SUBDIVISION OF MAIN STORE
COUNTER
56
54
OSCILLATOR

FIG. 3.

FIG.4.


CHARACTER
GATE CONTROL
74
72
5 BIT CONTROL
INPUT
u
10
MAIN
STORE
CHARACTER
REGISTER
12
p
p
q
q
MAIN STORE
10
70
r
r
s
s
MAIN
STORE
5 BIT
CONTROL OUT-
PUT.
v
INDIVIDUAL
CONTROL
SELECTABLE
CHARACTER GATE

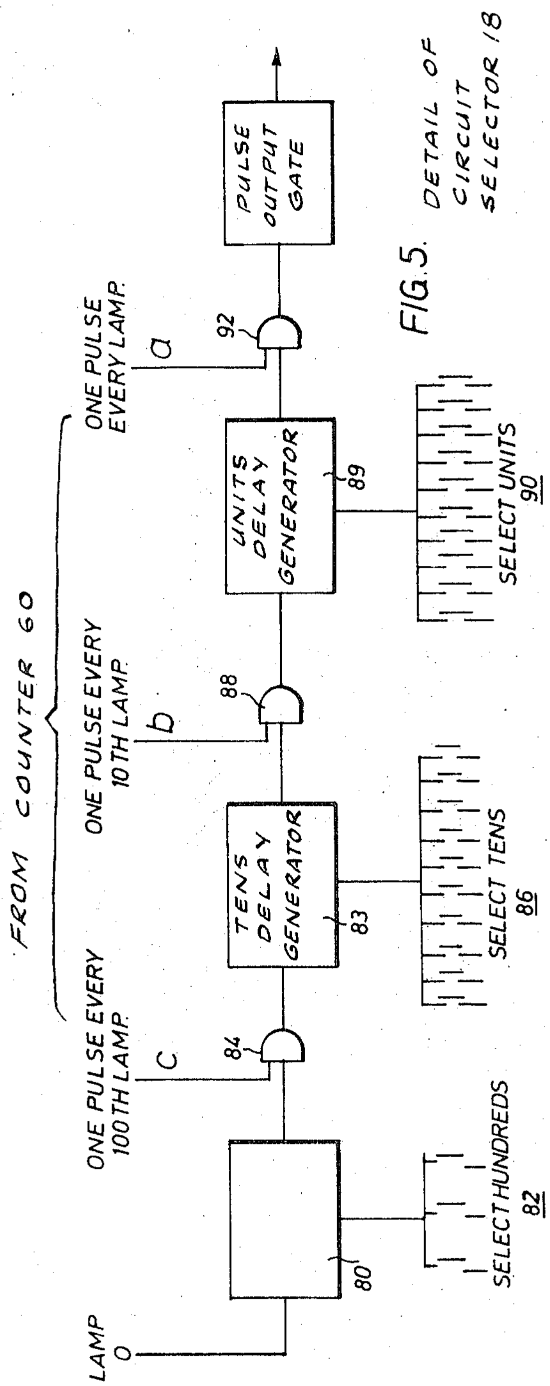


FIG.5. DETAIL OF CIRCUIT SELECTOR 18

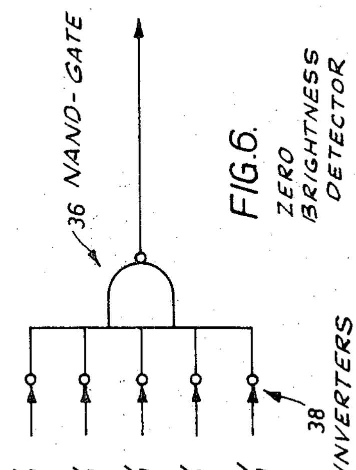


FIG.6. ZERO BRIGHTNESS DETECTOR

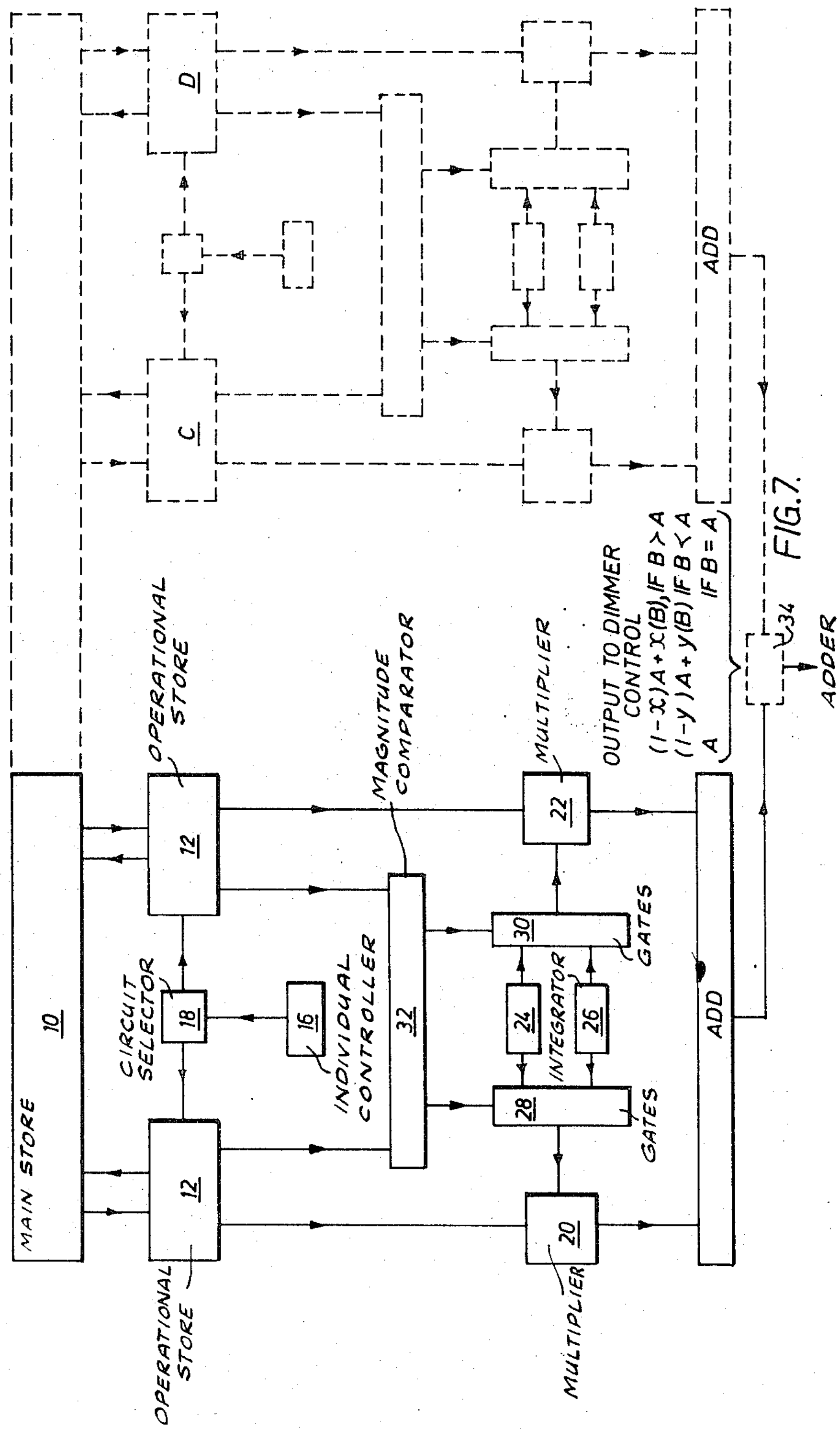

MAIN STORE
10
OPERATIONAL STORE
12
OPERATIONAL STORE
12
CIRCUIT SELECTOR
18
INDIVIDUAL CONTROLLER
16
MAGNITUDE COMPARATOR
32
MULTIPLIER
22
MULTIPLIER
20
INTEGRATOR
24
26
GATES
30
GATES
28
ADD
D
C
ADD
OUTPUT TO DIMMER CONTROL
(1-x)A+x(B), IF B>A
(1-y)A+y(B) IF B<A
A IF B=A
34
ADDER

FIG.7.

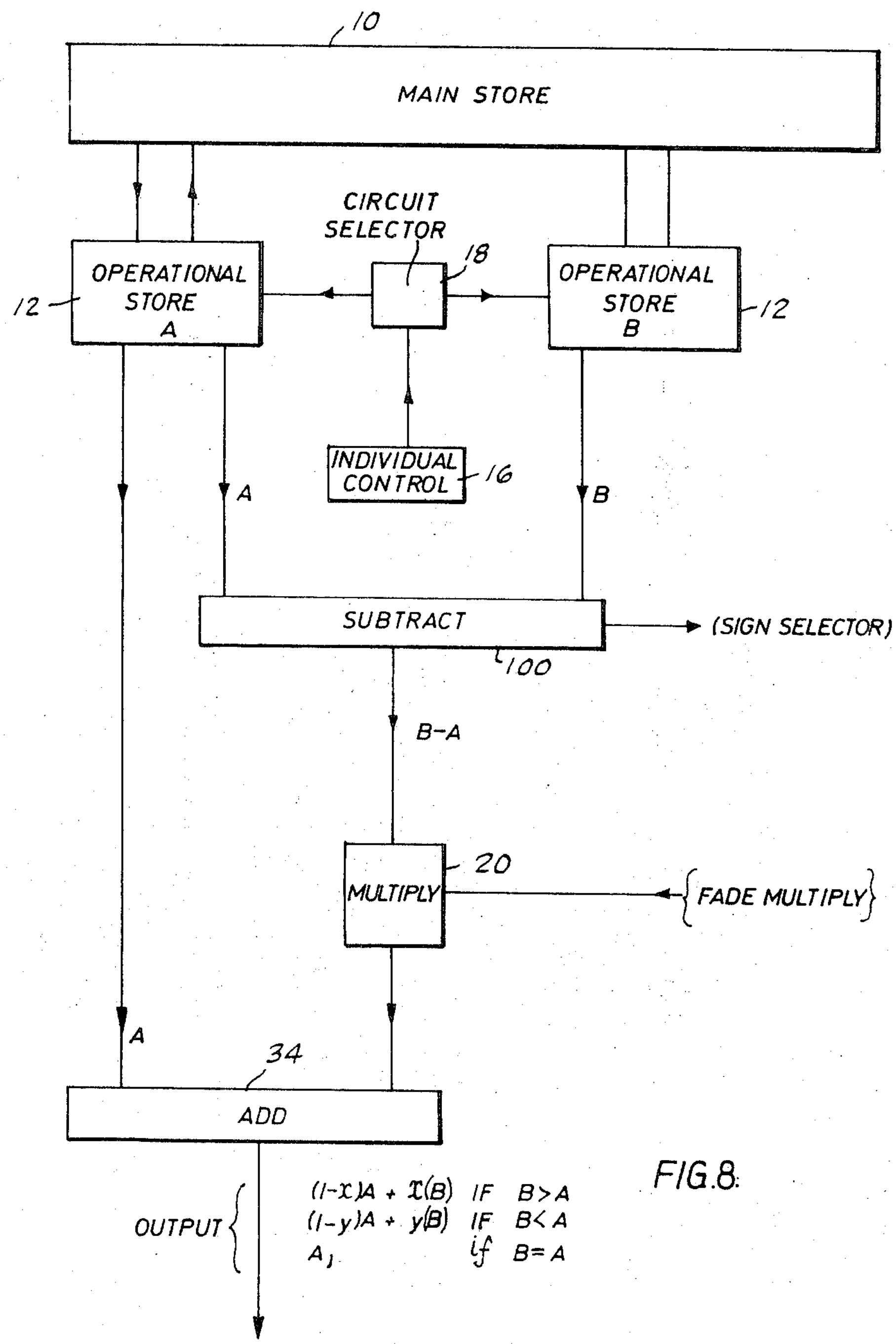

10
MAIN STORE
CIRCUIT SELECTOR
18
OPERATIONAL STORE A
12
OPERATIONAL STORE B
12
INDIVIDUAL CONTROL
16
A
B
SUBTRACT
(SIGN SELECTOR)
100
B−A
MULTIPLY
20
{FADE MULTIPLY}
A
34
ADD
OUTPUT
(1−x)A + x(B) IF B>A
(1−y)A + y(B) IF B<A
A, if B=A

FIG.8.

LIGHTING CONTROL SYSTEMS

The invention relates to lighting control apparatus for stage and film or television studio lighting.

The lighting conditions required for any particular scene or set may be defined by dividing the available increments in brightness of each lamp into a number of discrete steps. A lighting plot or cue is then defined as the information necessary to reproduce the required lighting conditions corresponding to a large number of lamps and this information may be stored in a central core or memory for recall as and when required.

The required conditions would normally be determined during rehearsals and stored for recall during a performance. It is an object of this invention to provide a control system which permits the speedy recall of a whole sequence of lighting plots and automatic control of lamp dimmers which is flexible for example, in so far that lighting plots may easily be modified even during a performance, without recourse to re-recording the whole plot and which is adapted to accommodate sophisticated stage lighting techniques.

According to one aspect of this invention a lighting control apparatus for controlling the brightness of a group of lamps comprises a main store for storing a plurality of lighting plots or cues including brightness control information for lamps within the group, at least one operational digital store, means for transferring a lighting plot from or to the main store respectively to or from an operational store, means for controlling the brightness of a lamp within the group in accordance with the control information stored in that operational store and means for changing the information relating to an individual lamp in that operational store. Preferably the apparatus comprises selecting means for producing a pulse at a time appropriate to an individual lamp after the start of a scanning cycle during which the information corresponding to all the lamps in the operational store is scanned and the means for changing the information in the operational store is enabled by said pulse relating to that individual lamp.

Conveniently the pulse is derived from the time-division-multiplex system clock and further selection of a particular lamp is achieved by means of a decimal selector, the selection of each digit of a lamp number introducing a delay appropriate to that lamp and measured from the beginning of the time-multiplex cycle.

In one form the lighting control apparatus includes two or more operational digital stores, means for transferring one lighting plot to each of the operational stores, and the control means for controlling the brightness of a lamp within the group in accordance with a predetermined and variable combination of the lighting plots contained in the operational stores in such a way that each lighting plot stored in an operational store remains unchanged.

Conveniently a lighting control system includes two operational stores and said control is adapted to fade at a predetermined and variable rate from control of the lamps within the group in accordance with one lighting plot to control in accordance with the other lighting plot.

If desirable, a cathode ray tube display of which lamps are switched on in the studio and/or which lamps have non-zero brightness information in an operational store may be produced. The display preferably includes individual lamp brightness information and lamp numbers. Conveniently, the numbers appear in numerical order or in positions corres-ponding to their studio positions.

Further, the C.R.T. display facility may be extended to include alternative means for selecting an individual lamp, said means having a photo-cell for producing a pulse at the time in a cycle corresponding to that lamp, the cell being positioned adjacent the area on the C.R.T. in which information relating to an individual lamp is displayed.

The invention will now be described by way of example with reference to the accompanying drawings of which:

FIG. 1 shows a block diagram of a lighting control system including one operational store;

FIG. 2 shows a block diagram of a lighting control system including two operational stores;

FIG. 3 shows a diagram representing the operation of a lighting system employing time division multiplex;

FIG. 4 shows a block diagram representing a method of character selections;

FIG. 5 shows a time-delay selector circuit diagram;

FIG. 6 shows a circuit diagram of a zero brightness detector;

FIG. 7 shows a lighting control system having four operational stores, and

FIG. 8 shows an alternative form of an automatic cross-fade sub-system.

The main store **10** shown in FIG. **1** is a large capacity store capable of holding multi-brightness information for (typically) 128 lighting plots each involving the use of (typically) 256 lamps. Each lighting plot or cue may be recalled from the main store **10** to an operational store **12** by means of an appropriate main store address. The nature of this address is a binary number referred to as a lighting plot or cue number. The operational store **12** may form part of the main store **10** but preferably is quite separate. The reason for this preference is that any information retained in the main store is an important operational investment; it needs to be free from hazards involved in carrying out operations on the various memories. Magnetic core-stores are preferred because they are compact and robust in operation, they have good access time and the storage is non-volatile but other forms of storage such as registers or circulating or delay line type storage media may be used. The main store unit **10** is "addressed" by a fixed address from plot selector **46** and a variable "address" from counter **58** via decoder **44**: The counter **58** is controlled from a master oscillator **54**. The plot selector is a counter which gives a binary output and may be automatically sequenced to the next number required or held at a desired number by depression of the decimal plot selector keys. The output of the main store **10**, representing the desired plot can be transferred into the operational store **12**, (not necessarily a core store). This is also addressed by the binary counter **58**, which is decoded by decoder **45**, allowing each lamp in the plot to be located in its correct slot.

The nature of a lighting plot has been defined and the "discrete steps" referred to in that definition are encoded by an analogue to digital converter or other means into the multi-digit binary code which can be stored by a core store.

The outputs of the operational store **12** is multiplied by multiplier **20** before actually controlling the lamp brightness and the multiplier serves as a master fade for the lighting plot. This provides fading of the plot from maximum to zero, as the multiplicand is changed from one to zero. This method ensures that all lamps are faded together, maintaining the desired balance, irrespective of their initial levels. After multiplication, the signal is applied to a number of sample and hold circuits **48**, which are sampled by the binary decoder **52**, supplied with pulses from circuits **58**. The information which is supplied to the sample and hold circuits is cyclic, in that it is only present for each lamp for some **64** microseconds in turn. The sample and hold circuit is basically an array of capacitors which are charged up sequentially by gating the input to the capacitor with the required output of decoder **52**. Each capacitor is thus charged up in turn through the complete sweep of lamps. The charge on the capacitor cannot decay when the sampling pulse is removed, and is therefore maintained until the next sampling pulse. This transforms the incoming serial information into the required parallel control signals for the dimmers.

The operational store may be fed with brightness information for all the lamps involved in one plot by addressing and reading the main store. Further, the operational store may feed information back to the main store by using the same main store address.

New information may be added to the operational store by means of an individual control **16** and a circuit selector **18**. The function of selector **18** is to select the lamp required for brightness adjustment from among the total complement of lamps. The individual controller **16**, in conjunction with circuit selector **18** allows the brightness information for a single lamp to be changed in the main store. This is done instantaneously and not over a period of time. A detailed description of selector **18** will be given with reference to FIG. **5**.

The individual control **16** consists of a brightness facility for the single selected lamp and may take the form of an analogue signal whose level is varied by means of a manually-controlled lever, the signal being subsequently converted into multi-bit binary code compatible with information already contained within the operational store. Alternatively the lever may directly operate on the operational store by means of a digital output shaft encoder.

The control system briefly described above can be significantly improved by employing two or more small operational stores. In the modified system the main store would store **128** (e.g.,) plots and each of the operational stores one plot. The modification provides facility for cross-fades and other more sophisticated lighting control techniques.

In a system having two operational stores one is designated an action store A containing a 'studio plot' viz. a plot corresponding to the lamps and brightness actually in use on a set and the other is designated a standby store B, containing either a reference plot for producing cross-fades for example, or the next plot in a sequence. The latter would, as will become evident later, enable a smooth transition between plots. In addition a second multiplier **22** is added, with integrators **24** and **26**, and switching gates **28** and **30** controlled by comparator **32**. The multipliers have as one input the output of an operational store. The second input, or multiplicand can be either directly from a fader for manual control, or from the sub-system, shown in the dotted lines, which provides automatic fading. Either signal may be analogue or digital in form, the multiplier being analogue, digital, or hybrid (combination). The output of the fader is varied from zero to one and is used as a multiplicand allowing zero output at minimum and exact output of the operational store at maximum, thus providing manual fading.

The automatic fading system consists of a multiplicand supplied by a fade up integrator and a fade down integrator. These are devices which produce an output which is automatically varied from zero to one and vice versa at the rate determined by an external control. Only one integrator need be used if up and down fades of identical duration are required. Provision of two integrators allows the up fade time and down fade time to be different.

The outputs of the two stores A and B are compared in a digital comparator, and provides signals for each lamp which represent A > B or A < B. (If equal no fading takes place). If the brightness for a given lamp is greater in store A than it is in store B, then an A > B signal is produced which switches the output of gates **28** and **30** to the fade down integrator **26**. The output can be considered as $(1-y)$ and y, where y is varying from 0 to 1 at the fade down rate.

Conversely, if the signal produced by store B is greater than the equivalent signal from store A, an A < B signal is produced in the comparator **32**, which selects the up fade integrator **24**, which provides signal to the multiplier in the form $(1-x)$ and x, where x is varying from 0–1 at the fade up rate.

If the signals from A and B are identical, then no control signal is produced and no fade takes place for the lamp concerned.

Before a fade commences, store A is controlling the studio lighting, and store B provides a holding store. Multiplier **20** is used to fade up store B. The outputs of the two multipliers are added together in algebraic form to give control of the lamp during a fade.

FIG. 2 is a block diagram of a control system having two operational stores A and B and a main store **10**, a circuit selector **18** and an individual lamp control **16** by means of which new information may be added to either of the two operational stores. The output of each operational store A and B is multiplied; in the mathematical sense by multipliers **20** and **22** respectively before the outputs actually control any lamps. One input to each multiplier consists of the stored brightness information in either analogue or digital form. The multiplier that is to say the factor by which each output is multiplied is derived either directly in analogue or digital form from a set of levers (not shown) which replace that section of the figure enclosed by a dotted line and which are called the manual fade or cross-fade controls or obtained indirectly again in analogue or digital form from an automatic cross-fade sub-system as shown in the figure. It will therefore be appreciated that the multipliers may be either analogue digital or hybrid multipliers.

Multipliers **20** and **22** each have inputs from either a fade-up integrator **24** or a fade-down integrator **26** depending on the conditions of the gates **28** and **30** which are controlled by a magnitude comparator **32**. The comparator compares the relative magnitude of the outputs from operational stores A and B. If the brightness information for an individual lamp in store A is greater than the corresponding information in B then the switched output from gates **30** and **28** comes from the fade-down integrator **26** and the multipliers are of the form y and $(1-y)$ respectively.

Conversely, if the stored brightness in B is greater than that in A the magnitude comparator **32** switches the gates to permit the fade-up integrator to provide signals to the multipliers **22** and **20** in the form x and $(1-x)$ respectively. When the stored brightness in A for an individual lamp equals the corresponding brightness in B no cross-fade occurs.

The multiplier **20** normally fades out the lighting plot in A whereas multiplier **22** normally fades in the lighting plot stored in B. Before a fade begins the lighting plot in A controls the studio lighting by means of the stored information and the store B provides a holding facility for the incoming lighting plot.

The outputs of multipliers **20** and **22** are then added together before control of the lamp circuits occurs. Thus the quantities derived at this stage may be represented as:

a. $(1-x)A + xB$ if B brighter than A

b. $(1-y)A + yB$ if A brighter than B

c. A if A as bright as B.

The factor x or y varies during a fade from 0 to 1 at a preselected rate and therefore at the end of a fade the information in a plot controlling the lamps for:

a. would be — B

b. would be — B

c. would be — A.

It is important to note that the information stored in each of the operational stores at the end of a cross-fade is identical with that stored before the cross-fade and it is in this respect that one distinction between the new type of control system and other known systems is manifest.

At the end of the cross-fade the integrator(s) is re-set and the addresses of the operational stores are changed so that the operational store B is now designated operational store A since the information stored therein governs lighting conditions in the studio. The old operational store A assumes the role of "standby."

An alternative form of an automatic cross-fade system is shown in **FIG. 8.**

The information contained in A is first subtracted in a unit 100 from the information contained in B. The result, $(B - A)$, is then tested for sign in a comparator (not shown), to determine whether a "fade-up" or a "fade-down" is required, before being multiplied by x or y as appropriate.

The (B–A) signal is fed to a single multiplier, the multiplicand being provided by integrators **24** or **26** or manual faders in the normal way. The sign selector selects the desired integrator which provides only x or y signals, giving an output from the multiplier **20** of (B–A) x or (B–A) y. This is then simply added to A to provide: A+(B–A)x or A+(B–A)y. By simple mathematical manipulation it is obvious that:
similarly

$$A+(B-A)x=A+Bx-Ax=(1-x)\ A+xB$$

$$A+(B-Z)y=(1-y)A+yB$$

These of course are identical to the expressions originally used in **FIG. 2.**

In complex lighting systems it may be desirable to provide more than two operational stores. **FIG. 7** shows a system where four stores A, B, C and D are used. In practice as many stores as desired may be added, either in pairs for cross fading, or singly.

A control system having more than one operational store/multiplier combination may include a combining circuit **34.** Such a circuit may, for example, add together all the multiplied component operational store brightness levels for an individual lamp or may combine them in a special way. It is useful to arrange the circuit **34** (FIG. 7) so that, when one lamp is being controlled from two or more operational stores, the brightest component level for that lamp is used. This technique is called "Highest Taking Procedence."

The output from combining circuit **34** may be either digital or analogue in form and is fed, if required, through a digital to analogue converter, to control the lamp dimmers.

The mechanism whereby control of the lamps is effected in accordance with the stored information employs time-division-multiplex. An access period of typically 64 micro seconds is allowed for each lamp in a plot. Therefore the total cycle time is (No. of lamps/-plot) × 64 μ secs. In the example quoted the cycle time would be 256 × 64 = 16 m.seconds.

This proves to be a perfectly practicable period. It is worth noting that studio lamps require at least 100 m.secs. to turn on and 500 m.secs. to turn off due to their inherent thermal inertia.

Core storage systems of long word length make savings in overall physical volume required as well as in the economics of their application. The ideal stored word length requirement for lamp brightness is inherently a short one and in this case five bits since there are to be 32 discrete increments of brightness.

By deciding that if lamps contain stored brightness they are therefore required to be switched on; and if lamps contain no stored brightness they are therefore required to be switched off, there becomes possible an operational basis for not storing lamp on/off information; thereby saving considerable storage space.

The detector necessary for zero or non-zero brightness information may perform digitally as shown in **FIG. 6.**

The NAND gate **36** only produces an output when the brightness information character is 00000 corresponding to a logical zero at input to each inverter **38** and to zero brightness. The NAND gate **36** will only give a "low" output when all five of the inputs are "high." If inverters **38** are fitted to each input, the output of **36** is only "low" when all inputs are "low." If the inputs to inverters **38** are the five bits representing the brightness of a lamp, then when it is off, all inputs are low and the output of gate **36** is low. This can be used as an artificial sixth bit, representing on/off information, but not using any storage capacity. Therefore the need to store on/off information is obviated.

For 128 plots incorporating 256 lamps and using a 20 bit word within which the brightness information becomes a five bit character an 8K store would be required.

The lighting plots are stored in sub-divisions **40** of the main store **10** and these are further sub-divided into lamp characters **42** which are cycled or scanned by a binary decoder **44** as indicated in **FIG. 3.** The subdivision **40,** holding one lighting plot, is addressed in its entirety by the plot selector **46** described previously. In summary, the subdivision is scanned cyclically by oscillator **54** divided by counter **56,** and decoded in unit **44.** The desired signals are routed through gates, which allow the substitution of the individual signal if required, in the operational store, addressed by a further binary decoder **45.** The output of the operational store is routed to the sample and hold circuits **48,** addressed by decoder **52,** where staticised parallel signals are produced to control the dimmers **59.**

The lighting plot sub-divisions **40** are addressed by an external selector **46** (see also FIGS. **1** and **2**). This latter selection forms the lighting cue or plot memory numbers and is made by depressing decimal keys on a control console. For the lamps, as well as for the plot memory numbers, an illuminated display of selection is preferably decimal. However, by retaining the binary address code form for storage the core store required becomes a standard purchasable item. Thus the address required for a particular lamp in one plot memory may consist of, for example, an eight bit number for selecting any lamp between 0 – 255 and a seven bit number for selecting any plot between 1 – 128. These 15 bits are provided, for example, by one bit selecting one of two 4096 (2^{12}) word stores, 12 bits corresponding to the 4096 words and two bits selecting one character from a word. In this case two **4K** rather than one **8K** store is to be used.

A lighting plot is transferred from the main store to an operational store **12** (either A or B) which is scanned by a binary decoder **45** by a mechanism to be described later with reference to FIG. **4.** The information is eventually transferred cyclically in digital form to sample and hold circuits **48,** normally situated remote from the central system console, before proceeding to control the dimmers **50.** The sample and hold unit **48** which basically consists of an array of capacitors is scanned synchronously by a binary decoder **52** and the sampled brightness information is held for staticized control of the lamp dimmers **50** which require d.c. volts. That is to say the time sequence of states representing digits is converted into a space distribution of simultaneous states.

The individual controller **16** and lamp selector **18** shown in FIG. **3** enable information to be added into the operational store or information already within the operational store to be modified by gating the individual controller **16** appropriately to the input of the operational store to effect the necessary changes. This is an important feature of this invention and will be described at a later stage with reference to FIG. **5.**

The counter **56** and oscillator **54** shown diagrammatically in FIG. **2** represent the drive for the decoding and selector circuits. However, the drive is shown more clearly in FIG. **1.**

The time division intervals, typically **64** μ secs. as mentioned above, are kept in synchronism throughout the system by means of a common clock oscillator **54.** The frequency of this oscillator drives two counters **58** and **60,** counter **58** being a binary counter and counter **60** being a decimal counter. Each counter counts from 0.255 amd the zero count of the decimal counter resets the binary counter to zero in order to maintain both counters in step. The binary counter **58** drives the decoders **44, 45** and **52** and the decimal counter drives the individual lamp selector **18** and actuates a display for the selected individual lamp number.

A useful modification, shown dotted in FIG. **2,** is to include a further binary counter **62** to be situated remote from the control system in the dimmer room. In this case the sample and hold circuits may be kept in complete synchronism with the main system. By further encoding this information, a single conductor with return is all that need connect the sample and hold circuits to the main control electronics. One form of such encoding may conveniently become a series of pulses for the clock frequency with a different pulse added for the re-set signal. The brightness information for each lamp could then become a superimposed sub-carrier modulator for the brightness for each lamp.

FIG. **4** is a block diagram representing the process by which a plot is transferred to/from the main store from/to the operational store. The process of transferring information to the main store will be considered first of all.

The longer word of 20 bits and subdivided into four characters p. q. r and s is read into a register **70** from the main store and is applied along with a five bit individual control output *v* to a 25 bit input/25 bit output character selectable gate **72.** The input and output control of this gate is by means of a character gate control **74.** An input character *v* can be substituted for any character *p, q, r* or *s* from the main store and the result fed back in again to the main store for recording, the other characters being re-recorded unchanged.

Alternatively, the character gate control **74** can select any character *p, q, r* or *s* for feeding to the operational store.

As described above the basis of operation of this system is time division multiplex. Each lamp is sequentially allowed a definite time interval, in this instance 64 .secs. during which the brightness information in an operational store may be recalled or changed. FIG. 5 shows a diagram of a circuit by means of which it is possible to locate any lamp in a plot during the cycle. This is achieved by shifting a pulse of the requisite (64 μ.secs.) along the time scale using controllable time delays.

The decimal counter **60** shown in FIG. **1** produces three pulses; one pulse *a* corresponding to every lamp, a second pulse *b* corresponding to every tenth lamp and a third pulse c corresponding to every one hundredth lamp.

The other pulse produced by counter **60** (viz. that produced at lamp **0** to re-set the binary counter) is also used to initiate a time delay **80,** the duration of which is determined by a series of "select hundreds" **82** forming part of a decimal lamp selector on the control console. Thus the AND gate **84** enabled by pulse train *c* is opened after the required delay corresponding to (e.g.) the 200^{th} lamp. Similarly the output of AND gate **84** initiates a second time delay **83** the duration of which is determined by a series of "select tens" **86** forming part of the same decimal lamp selector and, in the same way, AND gate **88** which is enabled by pulse train *b* is opened after a delay corresponding to (e.g.) the 240^{th} lamp. Finally, after a further delay, **89** determined by "select units" **90** the AND gate **92** enabled by pulse train *c* is opened at a point in time corresponding to the (e.g.) 243^{rd} lamp. The time of this delay, as determined by the select units buttons represents the start of the deserved lamp time, and gate **92** enabled by pulse train *a* initiates the output circuit which produces a pulse equal to the desired time slot.

Alternatively a delay which is naturally slightly longer than that corresponding to 100, 200, 300 lamps is used and the precise delay is locked to 100, 200 or 300 lamps by the addition of one pulse every 100 lamps to the timing wave form. Other delays are used in a similar way to select the lamp tens and units and finally a pulse is generated of length corresponding to one lamp time.

The selection of the lamp for individual control from the complement of lamps of the operational store allows the original brightness of that lamp to be displayed for reference. In particular the brightness display may take the form of an actual displacement, over a calibrated scale, of the control lever by means of a positional servo-mechanism. The control lever can be used manually to set levels of brightness as well, when the servo action is not operating.

A prototype device has been developed in which the brightness information contained in the operational stores A and B is displayed on the control console by means of a plurality, corresponding to the number of lamps involved, of pairs of bulbs, the bulbs in a pair being of a different colour. The two displays are called the studio and mimic displays.

It will be appreciated that this provision can account for a substantial proportion of the cost of a control system and therefore a cheaper and more elegant system has been devised.

It may be necessary to have an indication (mimic) of which lamps are switched on in a memory plot, or in the studio, perhaps with some indication of brightness. It is convenient either for the lamps to appear in numerical order, or in positions corresponding to their positions in the theatre or studio.

Such a display can be produced on the face of a cathode ray tube. In order to do this the x and y deflections are each composed of the sum of two waveforms.

a. waveform which brings the beam to the correct area of the face which corresponds to the lamp. These areas are selected sequentially at the same time as the lamps are selected in the lighting system.
b. another deflection, depending on the display to be shown.

These may be sawtooth or sinewave or special waveforms to generate a character.

Some possibilities are:

1. Displaying a bright lamp number on a dark background. This may be generated with a monoscope, read-only memory or character generator.
2. Displaying a dark lamp number on a bright background. This is most easily generated with a monoscope.
3. Displaying a bright patch. A graticule over the tube can show the lamp number.
4. Displaying a line, the length of which depends on the brightness to be indicated
5. Combining (1) and (4), or (2) and (4).

In (1), (2) and (3) the brightness may be changed to indicate lamp brightness.

By the use of a colour cathode ray tube, displays of different colours for different stores could be provided.

Such a system could be extended to include individual lamp selection employing a cathode ray tube.

1. When the display is being produced as above, if a photoelectric cell is placed over the area corresponding to a particular lamp, it will produce a pulse of current at the time corresponding to that lamp. This can be used for lamp selection.
2. Using the time delay method of selection described in FIG. 5 a joystick control can be provided, with deflection in one direction according to the tens number of lamps, and in the other direction according to the units. The lamp selected for control can be indicated by means such as underlining its number.

Finally, FIG. 7 shows a system having four operational stores. The four stores are divided into two pairs A and B and C and D; each pair being arranged as shown in FIG. 2.

In order to appreciate the usefulness of this arrangement it is worthwhile to consider an example.

The two pairs are able to operate independently of each other and the time taken for a cross-fade between the two plots in each pair may be different since the rates of change of the factors x and y are variable as required. Thus, in a play one pair may be set for a long cross-fade, for example at sunset and another pair may be set for a relatively short cross-fade as an actor makes to switch on say the lights in a room.

The output from the two independent systems are combined according to the "highest takes precedence" technique described earlier.

We claim:

1. Lighting control apparatus for controlling the brightness of a group of lamps, comprising a main store for storing a plurality of lighting plots or cues including brightness control information for the group of lamps, at least one operational digital store, means for transferring one of said plurality of lighting plots between said main store and said operational store, and time-division-multiplex means for controlling the brightness of the group of lamps in accordance with the one plot stored in the operational store, including means for producing a sequence of output signals corresponding to the brightness control information of the one plot for the group of lamps, multiplier means for multiplying said output signals by a multiplicand factor, variable between unity and zero, and supplying said multiplied output signals to means for controlling dimmers for the group of lamps, and means coupled to said operational store for changing the brightness control information relating to an individual lamp of the group of lamps in said operational store.

2. Lighting control apparatus according to claim 1 wherein the information in the operational store corresponding to all the lamps in the group of lamps is cyclically scanned in a time division mode, and comprising selecting means for producing a pulse at a time appropriate to said individual lamp of the group of lamps after the start of a scanning cycle, said means for changing the information in said operational store relating to said individual lamp being enabled by said selecting pulse.

3. Lighting control apparatus according to claim 2, wherein the time-division-multiplex means comprises a clock for providing said selecting pulse and wherein the selecting means comprises a decimal selector in which the selection of each digit of a lamp number delays the production of said selecting pulse for a time appropriate to said individual lamp as measured from the beginning of the time-division-multiplex cycle.

4. Lighting control apparatus according to claim 3, wherein the means for producing the sequence of output signals comprises a decoder for scanning the operational store and wherein said means for controlling the lamp dimmers comprises a sample and hold unit scanned by a second decoder, said sample and hold unit comprising an array of capacitors which store

brightness control information for staticised control of the lamp dimmers associated with the group of lamps.

5. Lighting control apparatus according to claim **4** including fading means coupled to the multiplier for adjusting the factor between zero and unity by which the outputs are multiplied.

6. Lighting control apparatus according to claim **5**, wherein the fading means is manually operable.

7. Lighting control apparatus according to claim **1** comprising at least two digital operational stores wherein the control means controls the brightness of each of the lamps within the group in accordance with a predetermined and variable combination of the portions of the lighting plots contained in each of the operational stores relative to said brightness controlled lamp, each lighting plot stored in an operational store remaining unchanged.

8. Lighting control apparatus according to claim **7**, wherein said control means includes automatic fading means cooperating with said multiplier for fading at a predetermined and variable rate from control of the lamps within the group in accordance with a lighting plot in one of said operational stores to control in accordance with the lighting plot in another of said operational stores.

9. Lighting control apparatus according to claim **8**, wherein said fading means fade out control of the brightness of lamps in accordance with information stored in the first operational store and fade-in control of the brightness of lamps in accordance with information stored in the second operational store.

10. Lighting control apparatus according to claim **9**, wherein said multiplier means includes first and second multipliers associated with said first and second operational stores and controlled by said fading means.

11. Lighting control apparatus according to claim **10**, wherein said fading means is manually operable.

12. Lighting control apparatus according to claim **10**, wherein said fading means include integrator means connected to said first and second multipliers for modifying the factor by which the outputs from the first and second operational store are multiplied respectively by $(1-z)$ and z where z varies from 0 to 1 during a fade.

13. Lighting control apparatus according to claim **10** wherein said integrator means comprise a fade up integrator and a fade down integrator, and comprising a comparator for comparing the individual outputs of the first and second operational store and for connecting the first and second multipliers to said fade up integrator or said fade down integrator when the magnitude of an individual output from the first operational store is respectively less than or greater than the magnitude of a corresponding individual output from the second operational store, wherein the fade up integrator and the fade down integrator modify the factors to a form $(1-x)$ and x and $(1-y)$ and y where x and y vary respectively from 0 to 1 during a fade up or a fade down.

14. Lighting control apparatus according to claim **1** including means for displaying which lamps of said group of lamps are switched on in the studio and/or which of said lamps have non-zero brightness information in said operational store.

15. Lighting control apparatus according to claim **14** wherein the said display means comprises a cathode ray tube display.

16. Lighting control apparatus according to claim **14** wherein the display includes individual lamp brightness information and lamp numbers for each of the lamps of said group of lamps.

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