

[54] **AUDIO RESPONSIVE COLOR DISPLAY  
SYSTEM**

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**Related U.S. Application Data**

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1971, Pat. No. 3,815,128.

[52] U.S. Cl. .... **340/366 B; 340/148**

[51] Int. Cl.<sup>2</sup> .... **G08B 5/36**

[58] Field of Search ..... 340/148, 261, 366 B;  
84/464

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*Primary Examiner*—Harold I. Pitts

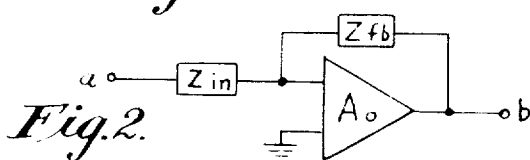
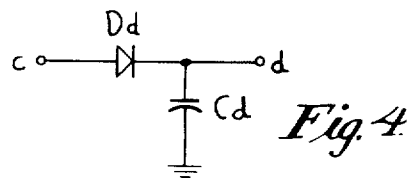
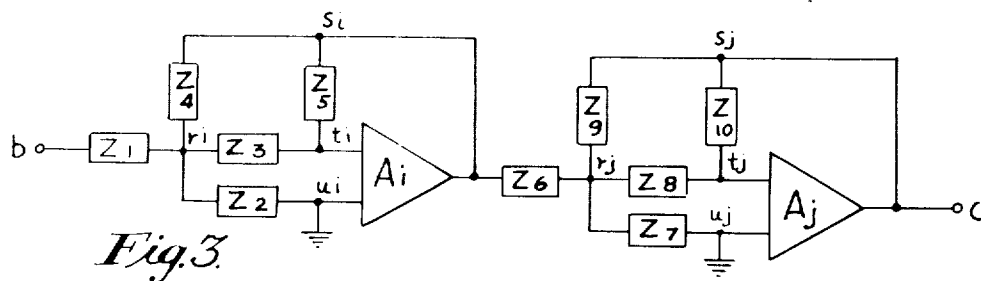
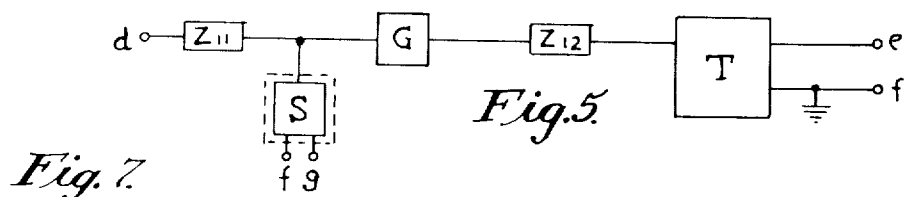
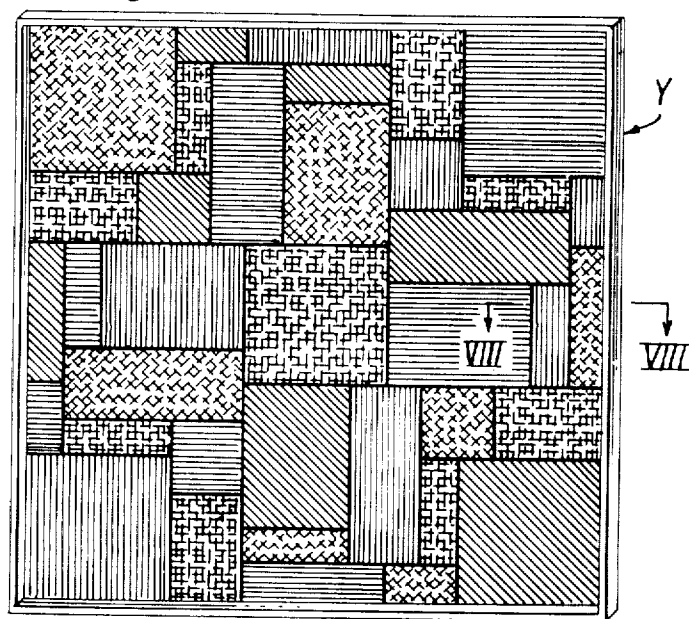
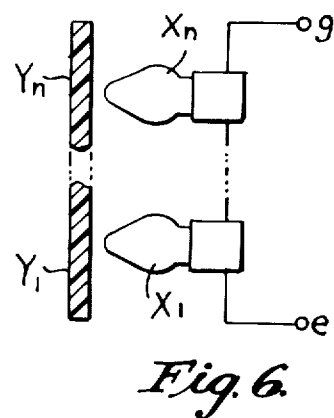
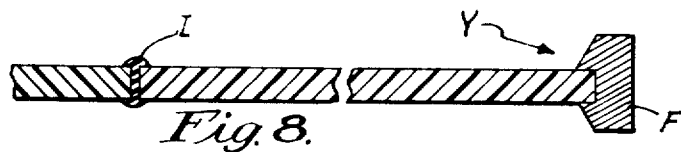
*Attorney, Agent, or Firm*—Charles A. McClure

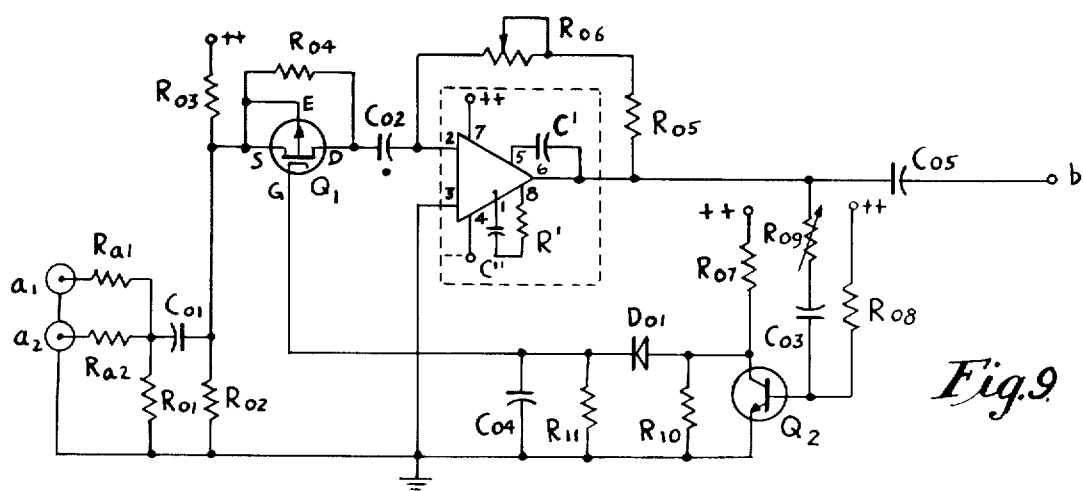
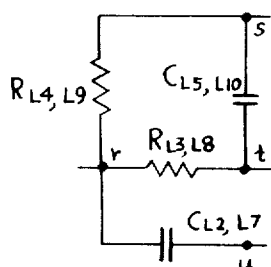
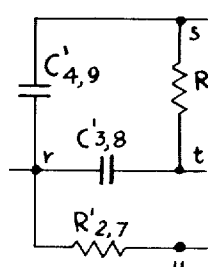
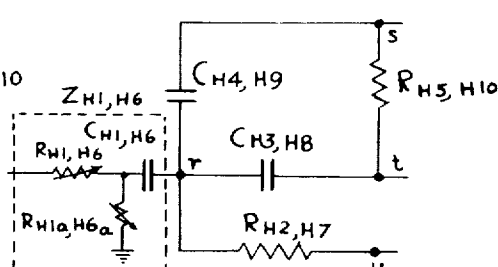
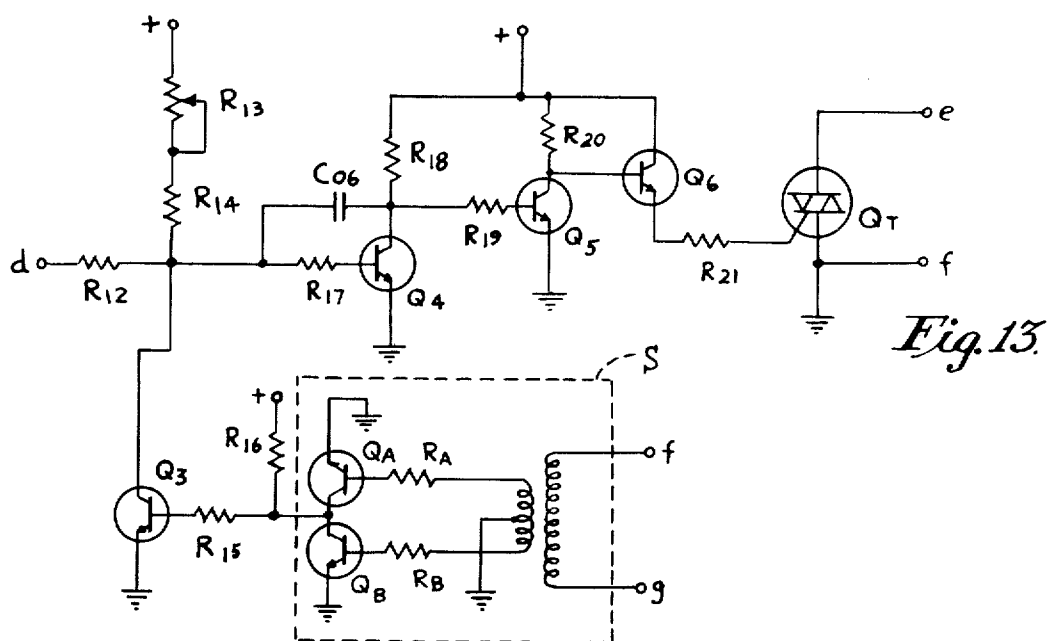
[57] **ABSTRACT**

An electronically controlled audio-responsive color display is provided by a system wherein audio signals of various frequencies are utilized to effect illumination in various colors. Signal processing amplifies and limits total audio signal strength while substantially maintaining relative signal strength. The audio signals are segregated into a plurality of frequency bands, and the detected signal magnitude from each band is applied in pulse form to effect illumination in corresponding colors.

**10 Claims, 20 Drawing Figures**





*Fig. 9**Fig. 10**Fig. 11**Fig. 12**Fig. 13*

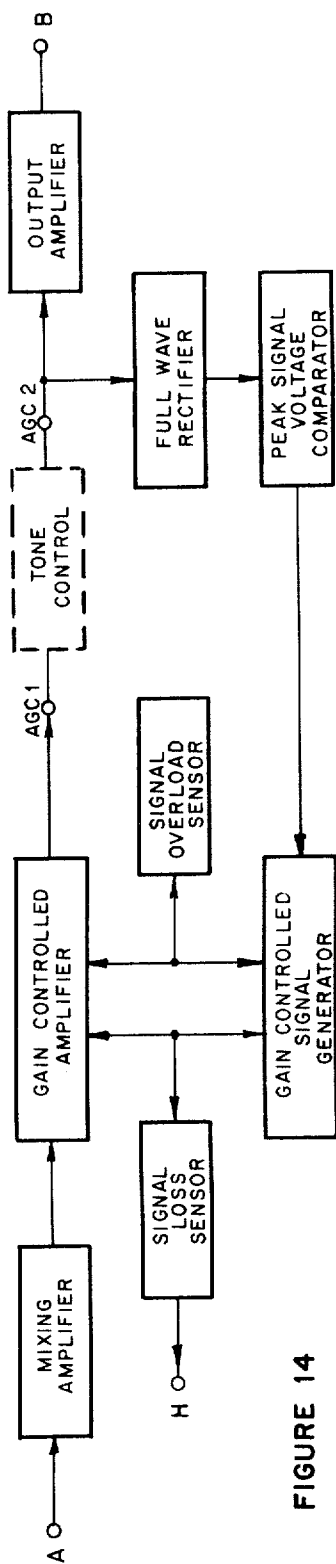


FIGURE 14

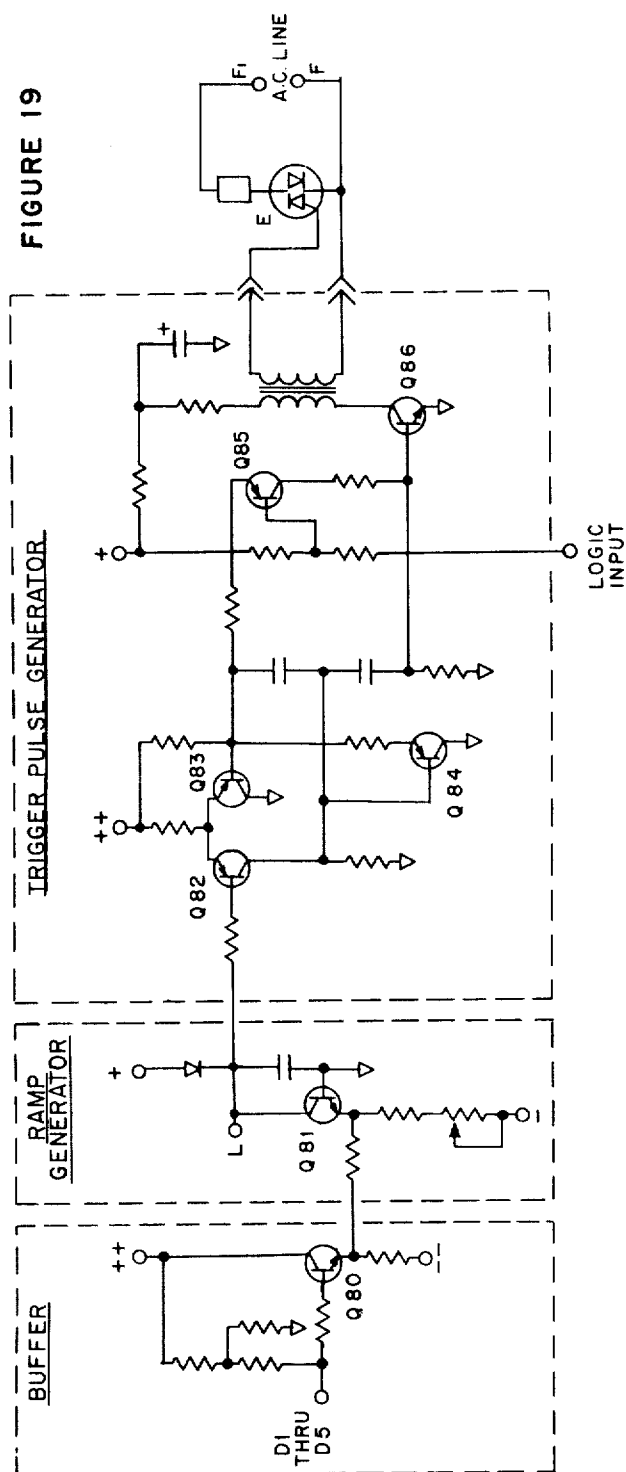


FIGURE 19

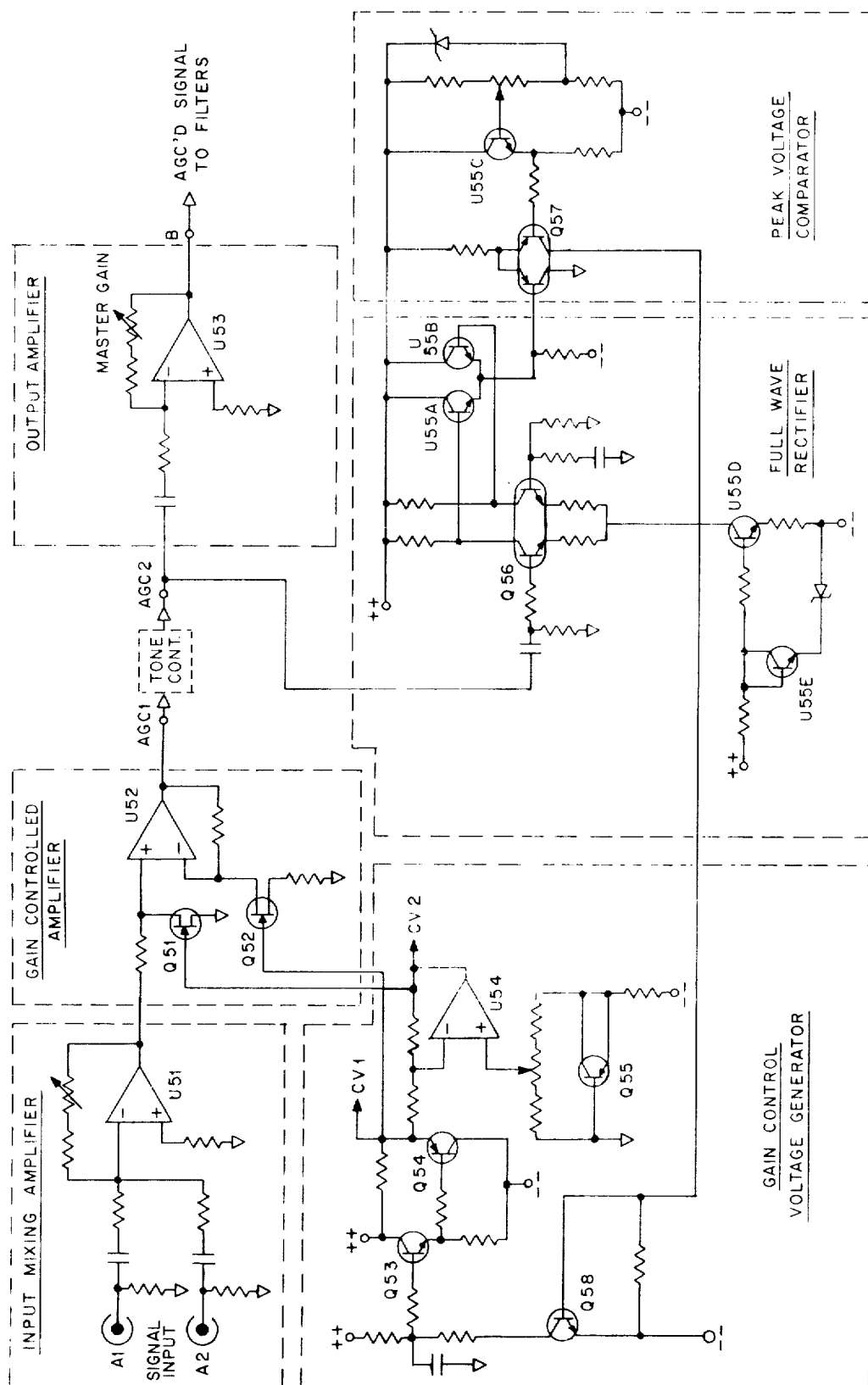
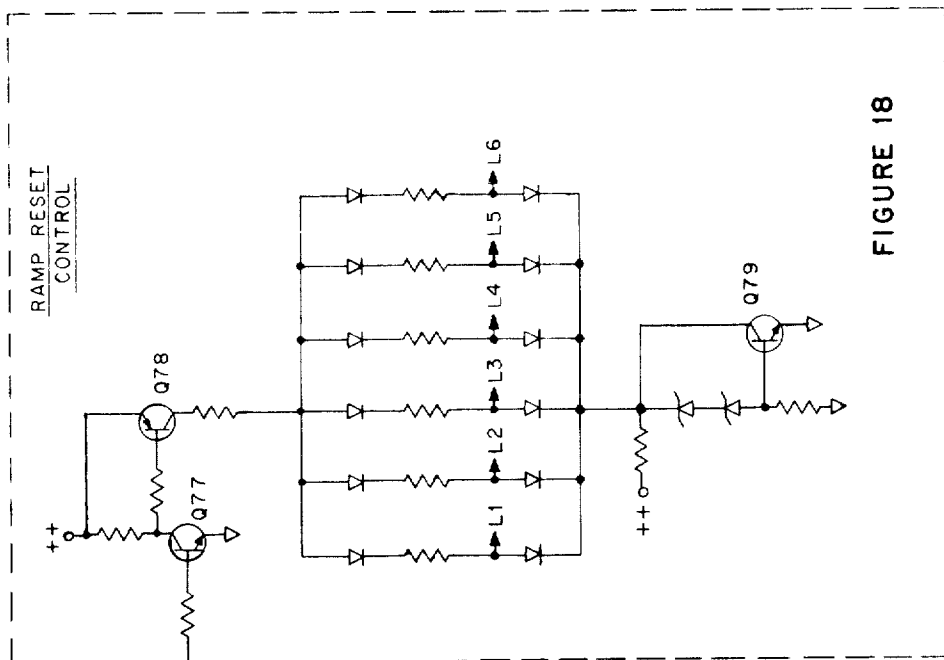
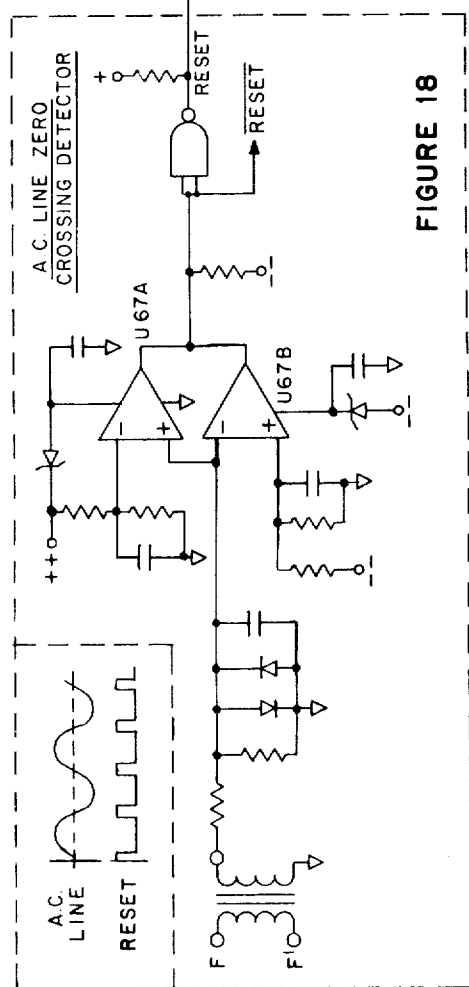
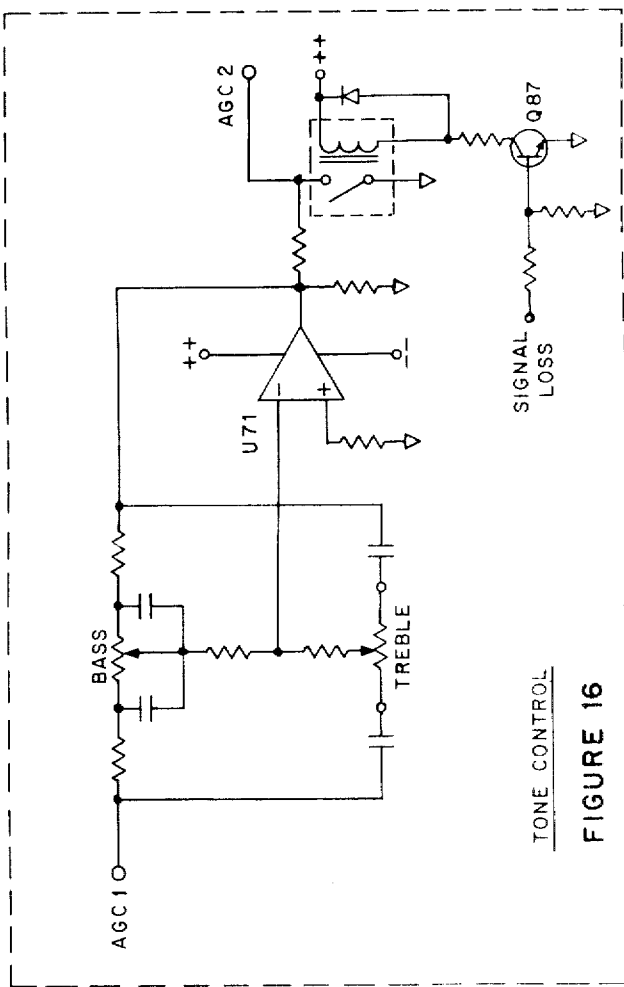
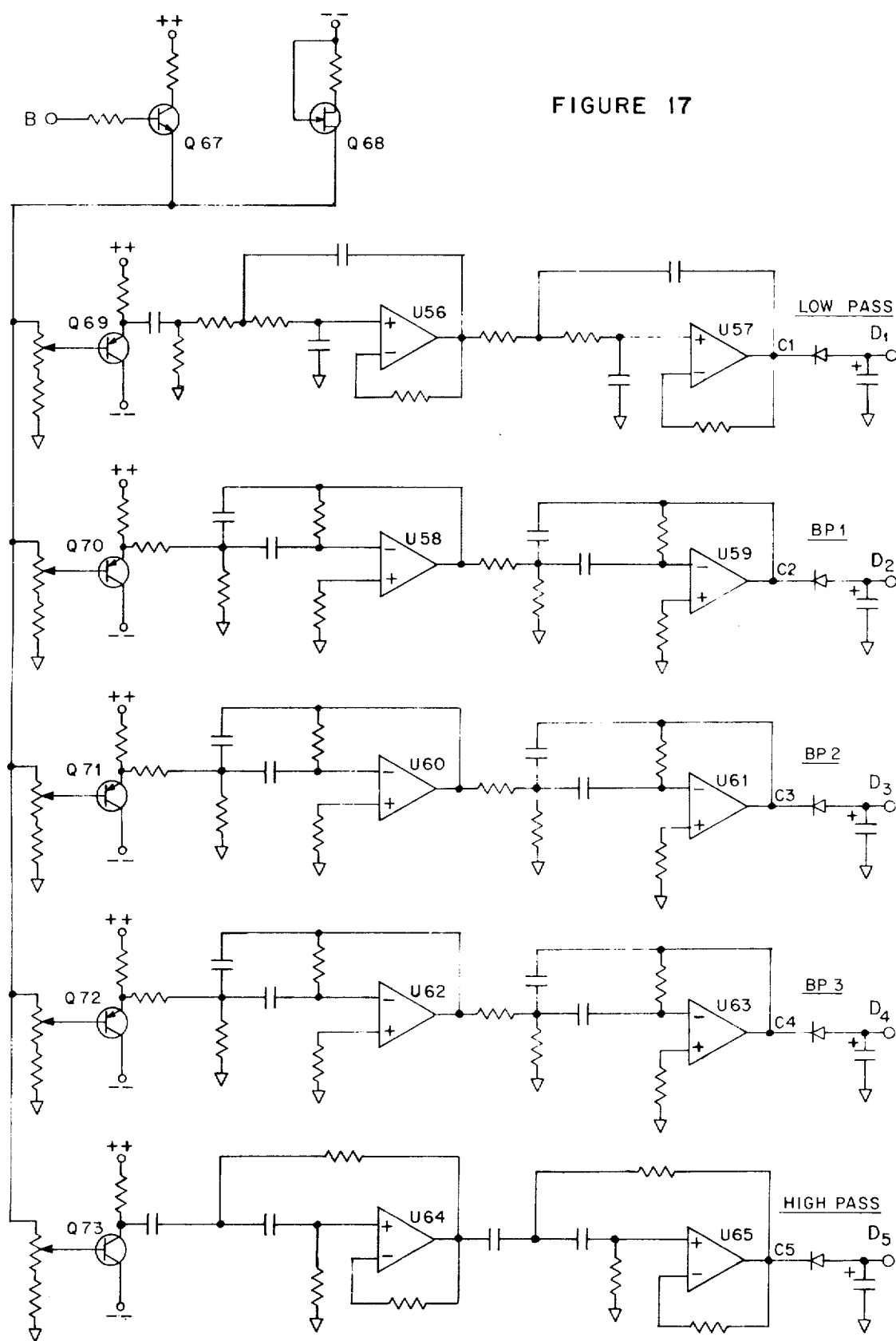


FIGURE 15





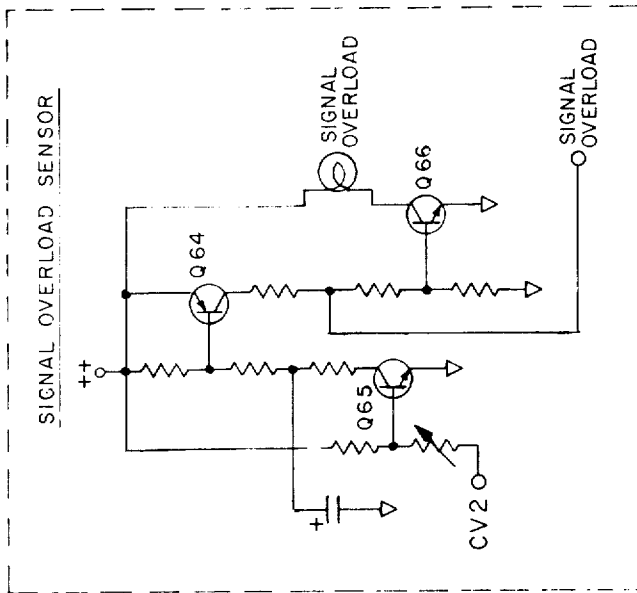
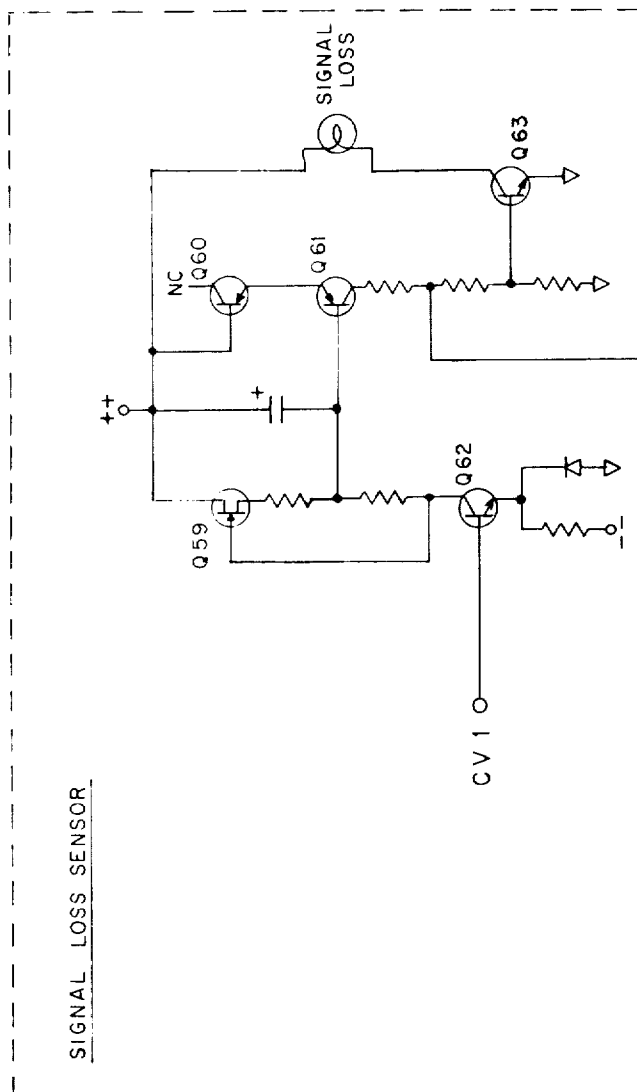
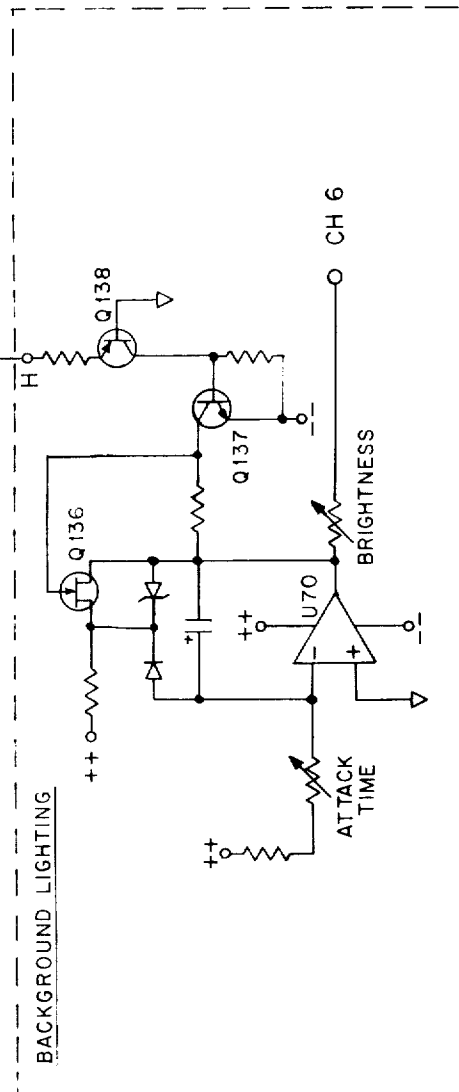


FIGURE 20



# AUDIO RESPONSIVE COLOR DISPLAY SYSTEM

## REFERENCE TO RELATED APPLICATION

This is a continuation-in-part of my copending application, Ser. No. 188,339 filed Oct. 12, 1971 and issued as U.S. Pat. No. 3,815,128.

## BACKGROUND OF THE INVENTION

This invention relates to production of color displays derived from signals of audio or sonic frequency and provides novel methods and apparatus for doing so, collectively referred to herein as a sonic-color system.

It is known to produce light displays in various colors dependent upon an input of audio-frequency signals derived from the output stage of a radio receiver, record player, tape recorder-reproducer, or the like. Interesting illumination effects are obtainable when the colors thereof are coordinated in some way with the sonic or audio frequencies. However, existing systems for doing so are deficient in a number of respects, including frequency separation, response control, and visual effect.

A primary object of the present invention is a sonic-color system having improved response to input audio-frequency signals.

Another object is a multiple-channel sonic-color system having excellent separation between channels.

A further object is a sonic-color system having novel display characteristics.

Other objects of this invention, together with means and methods for attaining the various objects, will be apparent from the following description and the accompanying diagrams thereof shown by way of example rather than limitation.

## BREIF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of components of the invention whether considered as method or apparatus;

FIG. 2 is a schematic diagram of an apparatus component corresponding to the first (extreme left) block of FIG. 1;

FIG. 3 is a schematic diagram of an apparatus component useful according to the second block of FIG. 1;

FIG. 4 is a circuit diagram of an apparatus component useful according to the third (middle) block of FIG. 1;

FIG. 5 is a schematic diagram of an apparatus component useful according to the fourth block of FIG. 1;

FIG. 6 is a schematic diagram of an apparatus component useful according to the fifth (extreme right) block of FIG. 1;

FIG. 7 is a perspective view of a display screen useful in the component of FIG. 6; and

FIG. 8 is a fragmentary sectional plan view, taken at VIII—VIII on FIG. 7.

FIG. 9 is a circuit diagram of the component shown more schematically in FIG. 2;

FIG. 10 is a circuit diagram of part of a low-pass component corresponding to that shown more schematically in FIG. 3;

FIG. 11 is a circuit diagram of part of an intermediate-band component corresponding to that shown more schematically in FIG. 3;

FIG. 12 is a circuit diagram of part of a high-pass component corresponding to that shown more schematically in FIG. 3; and

FIG. 13 is a circuit diagram of the component shown more schematically in FIG. 5.

FIG. 14 is a block diagram of components of a modified embodiment of AGC component, corresponding to the first block in FIG. 1 and generally to FIG. 2;

FIG. 15 is a circuit diagram of the modified AGC component shown in block form in FIG. 14;

FIG. 16 is a circuit diagram of an optional tone control component indicated in broken lines in FIG. 14;

FIG. 17 is a circuit diagram of a modified embodiment of active filter components, corresponding to the second and third blocks in FIG. 1 and generally to FIGS. 3 and 4;

FIG. 18 is a circuit diagram of a modified embodiment of synchronizer, corresponding generally to block S in FIG. 5;

FIG. 19 is a circuit diagram of a modified embodiment of power output component, corresponding to the fourth block in FIG. 1 and generally to FIG. 5, together with the S component of FIG. 18; and

FIG. 20 is a circuit diagram of signal loss sensor means shown in block form in FIG. 14, together with background lighting means actuatable thereby, and signal over-load sensor means.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

In general, the objects of the present invention are accomplished, in an electronically controlled audio-responsive color display system, wherein audio signals of various frequencies are utilized to effect illumination in various colors, by the method combination of amplifying the signals and limiting the total audio signal strength to a desired level while substantially maintaining relative signal strength, segregating the signals into a plurality of frequency bands, then for each band detecting the signals therein, producing pulses whose duration is dependent upon the detected signal magnitude for such band, and applying the pulses from the respective bands to effect illumination in corresponding colors.

In its apparatus aspect this invention contemplates means for accomplishing such method in conjunction with chromophoric display means responsive to such pulses to be illuminated in colors corresponding to the respective bands.

FIG. 1 shows that audio signals from any suitable source, such as aforementioned in connection with existing sonic-color systems, as subjected to automatic gain control (AGC), whereupon the system acts to Filter, Detect, Power, and Display the signals as successively acted upon by the method steps and apparatus components of this invention. The method is described, and the apparatus shown, in more detail as follows.

FIG. 2 shows the AGC component schematically as made up of operational amplifier (op-amp)  $A_0$  having input impedance  $Z_{in}$  through which the audio input is applied from input terminal "a" to the upper left side or inverting input terminal of the amplifier, with the lower left side or non-inverting terminal grounded. The amplifier output appears at the right or apex terminal of the amplifier, which connects via feedback impedance  $Z_{fb}$  to the input terminal and also connects via output terminal "b" to the component shown in the next view. Details of a preferred embodiment of the component of the present view appear in FIG. 9, considered hereinafter.

FIG. 3 shows schematically a single channel of active filter means having input terminal "b" corresponding to the output terminal of FIG. 2. The illustrated circuit constitutes one of a plurality of such channels: viz., a low-pass channel, a high-pass channel, and one or more (preferably three) intermediate-band channels. Each channel comprises a pair of operational amplifiers, designated generally as  $A_i$  and  $A_j$ , together with appropriate input and feedback impedance networks:  $Z_1$  through  $Z_5$  for  $A_i$  and  $Z_6$  through  $Z_{10}$  for  $A_j$  for which corresponding circuit elements appear in FIG. 10 (low-pass), FIG. 11 (intermediate or band-pass), and FIG. 12 (high-pass). Each amplifier is like that of FIG. 2, as outlined in broken lines in FIG. 9. The amplifier stages are connected in cascade, and the circuit elements providing impedances  $Z_1$  and  $Z_6$  are preferably adjustable to facilitate balancing of the sensitivity or gain of the cascaded stages and to assure the desired response. As with the amplifier in the preceding view, the non-inverting input (each stage) is grounded. The respective channels have separate output terminals, designated generally by "c" in this view, to corresponding detectors (one of which is shown in the next view).

FIG. 4 shows the circuit of a detector stage for a representative one of the filter channels. Diode  $D_d$  is connected in the forward direction from input terminal "c" to output terminal "d" while capacitor  $C_d$  is connected between the output terminal and ground. The output (now DC) passes to a power control channel such as is shown in the next view.

FIG. 5 shows schematically that last component before the display stage. Input impedance  $Z_{11}$  is connected between terminal "d" and ramp generator G. Also connected to the generator input is synchronizer S, itself connected to AC terminals "f, g" such as a conventional power line or equivalent source. The same synchronizer is useful in synchronizing the ramp generators of a plurality of like power control channels, one per filter channel, and optionally one or more others to control one or more additional display features. Accordingly, the block for synchronizer S is surrounded by broken lines as a reminder of its status distinct from an individual power control channel. Output impedance  $Z_{12}$  is connected between its ramp generator and triac stage T, which has output terminals "e, f" to display means (shown in the next view) and one side (grounded) of the AC source. Circuit details for the apparatus of this view appear in FIG. 13.

FIG. 6 shows the display means schematically, including plurality of lamps  $X_1 \dots X_n$  interconnected between terminal "e" (FIG. 5) and AC source terminal "g". The lamps are adjacent a display screen comprising a plurality of portions  $Y_1 \dots Y_n$ , at least one (and preferably more than one) such portion per lamp. Shown are only the extreme or end members of the series of lamps and of screen portions. Intervening parts are broken away to simplify the illustration. Either or both the lamps and the screen are colored appropriately, and opaque spacers (not shown) are useful: between lamps of diverse colors and adjacent to the divisions between diversely colored screen portions. The screen, which is shaded to indicate plastic composition, may be quite simple in design, as suggested in this view, or more elaborate, as in the next view.

FIG. 7 shows in perspective, on a greatly reduced scale, color display screen Y comprising rectilinear mosaic-like colored portions (so shaded) and frame F. The rear face (not shown) is a mirror image of the visi-

ble front face. Spacer means I, which intervenes between adjacent screen portions (of different colors) appears more clearly in FIG. 8, which shows a horizontal section therethrough and through the intervening spacer means and the frame.

Operation of the disclosed apparatus to practice the disclosed process is readily understood. Of course, although not shown, suitable DC sources are used to provide positive and negative potentials to various of the apparatus components.

Audio-frequency signals at the AGC input are amplified and the total audio signal strength is limited by suitable gain control adjustment to a desired level in that component (FIGS. 2 and 9) without substantially disturbing relative signal strength. The amplified audio input from the AGC component is fed to each (FIG. 3) in a bank of frequency filters, at least three and preferably five in number, including a low-pass, a high-pass, and one or more (preferably three) intermediate band-pass channels. These filters are active, rather than passive, and include two operational amplifiers (each like that outlined in broken lines in FIG. 9) with input and feedback networks therefor (FIGS. 10, 11, and 12 for the low-pass, band-pass, and high-pass channels, respectively), which are connected in cascade. The intermediate or band-pass op-amps (FIG. 11) are stagger-tuned (preferably approximately 0.7 octave) to square off the frequency response. Each intermediate band so produced is substantially an octave wide.

The amplified and filtered audio-frequency signals are detected conventionally (FIG. 4), and the resulting DC signals are fed through high input impedance to respective power control channels (FIGS. 5, 13), one per filter channel. The ramp generator is synchronized to the AC source frequency by synchronizer S, which conveniently controls several power control channels similarly. The input DC signal from the detector stage determines the decay of the ramp. The triac receives through the output impedance network a succession of pulses whose duration (i.e., the summed duration of individual pulses) also corresponds to the input signal, and such pulses control conduction through the triac and, thus, through the display means, which is connected to the triac output and thereby across the AC source (one side of which is grounded). In this way the channels are isolated effectively from one another, and the brightness response of the display means accurately reflects relative band strength. Controls for brightness and threshold provide a full range of response so as to minimize full-on and full-off periods.

It will be understood that each band effects illumination in a different color, preferably ranging from low to high frequency of color in accordance with low to high frequency of sound, thus: red for low-pass; orange, yellow, and green for the successively higher band-pass; and blue for the high-pass. It is preferable that a plurality of portions of the display screen be illuminated in each of the given colors and that the total area or apparent area of the portions for each color be the same as for every other one of the colors. The prepared color display screen of FIGS. 6 and 7 has these attributes and also aspects of symmetry and other esthetically desirable attributes, and its design is the subject of my design patent application, Ser. No. D-161,371 filed July 12, 1971 and now issued as Des. Pat. 226,777. Although shown herein in the form of transparent plastic composition (e.g., methyl methacrylate or other acrylic or similar material, such as that called "Plexiglas" and

available from Rohm & Haas Co., Philadelphia) for use with adjacent lamps actuated by the described electronic apparatus, the screen may comprise suitable chromophoric (e.g., phosphor) materials and be actuated directly by such apparatus. Thus, cathode ray tubes may be so driven, if desired.

The electronic apparatus of this invention is suited for use with any low-impedance source of audio-frequency signals within the range of 0.1 to 5 volts peak-to-peak (pp) without objectionable loading of the source. It is adapted to produce an output of up to 500 watts per channel. Advantages and benefits of its structural and functional features have been mentioned above and, together with others, will become apparent and accrue to persons undertaking to practice this invention in the light of the foregoing disclosure and the following more detailed consideration of the apparatus components.

FIG. 9 shows the AGC circuit, which is provided with two input terminals "a<sub>1</sub>, a<sub>2</sub>" (rather than simply "a" as in FIG. 2) to accommodate stereo input, if desired. With input from 8 ohm speakers a separation of 70 db is maintained. Input resistors R<sub>a1</sub> and R<sub>a2</sub> (4.7 k each) lead from the respective input terminals to the junction of resistor R<sub>01</sub> (560 ohms) and electrolytic capacitor C<sub>01</sub> (5  $\mu$ f). The other side of C<sub>01</sub> connects to the junction of R<sub>02</sub> (2.2 Meg) and R<sub>03</sub> (1 Meg), which together form a voltage divider from ground to positive (15 v) DC potential.

Interposed between the AGC op-amp is MOSFET (metal oxide semiconductor field effect transistor) Q<sub>1</sub> and associated circuit elements. Its Source (S) and emitter (E) electrodes are tied to the junction of R<sub>02</sub> and R<sub>03</sub> just mentioned, and its drain electrode D connects thereto through feedback resistor R<sub>04</sub> (470 k) and to the non-inverting input terminals of the op-amp through DC blocking electrolytic capacitor (C<sub>02</sub> (5  $\mu$ f). Its gate electrode receives positive feedback from a further stage after the op-amp.

The AGC op-amp is conveniently of 709C type and includes (outlined in broken lines) associated circuit elements: first capacitor C' (20 pf) connected across terminals 5 and 6 (output), second capacitor C'' (500 pf) connected in series with resistor R' (1.5 k) across terminals 1 and 8. Terminals 4 and 7 go to sources of negative (-15 v) and positive (15 v) DC potentials "++" and "--" respectively. Terminals 2 and 3 are the inverting and non-inverting input terminals, respectively, the latter of which is grounded. The same operational amplifier circuitry (and values of circuit elements) is used in both stages of each filter channel with appropriate feedback networks. The AGC op-amp has respective fixed and adjustable feedback resistors R<sub>05</sub> (33 k) and R<sub>06</sub> (0.75 Meg) from output terminal 6 to input terminal 2. The setting of adjustable resistor R<sub>06</sub> determines the "maximum gain state" voltage gain, thereby determining at what input signal level the output comes under control.

The further stage in the AGC component comprises transistor Q<sub>2</sub> (2N5135 type) with its emitter electrode grounded and its collector and base electrodes supplied with positive (15 v) DC potential through resistors R<sub>07</sub> (1.1 k) and R<sub>08</sub> (220 k) respectively. The op-amp output is injected at the Q<sub>2</sub> base through adjustable resistor R<sub>09</sub> (100 k) and electrolytic capacitor C<sub>03</sub> (10  $\mu$ f) connected in series. The Q<sub>2</sub> collector connects to Q<sub>1</sub> gate electrode G through diode D<sub>01</sub> (IN98 type). Connected between the diode lead and ground on the transistor

side is resistor R<sub>10</sub> (15 k), and on the MOSFET side R<sub>11</sub> (1.8 Meg) and (in parallel) electrolytic capacitor C<sub>04</sub> (1  $\mu$ f).

When there is no audio signal input to the AGC component and, consequently, no output, transistor Q<sub>2</sub> is normally saturated by reason of the positive bias of its base through R<sub>08</sub>. This occasions a minimum bias potential (ca. 0.3 v) applied to the Q<sub>1</sub> gate, whereupon the source-to-drain resistance is at a minimum, corresponding to maximum gain state of the op-amp. An input to the AGC component produces an output coupled through R<sub>09</sub> and C<sub>03</sub> to pulse Q<sub>2</sub> to its non-conducting state, thereby causing a positive peak detected bias to the Q<sub>1</sub> gate, whereupon the resulting increase in source-to-drain resistance reduces the overall gain, which is adjustable by the setting of R<sub>09</sub> as the master gain control. The audio signal so amplified and limited (voltage gain of about ten times) is applied through electrolytic DC blocking capacitor C<sub>05</sub> to the diverse filter channels at terminal "b".

As already mentioned, the filter channels (shown generically in FIG. 3) each comprise a pair of op-amps A<sub>i</sub> and A<sub>j</sub> (like A<sub>0</sub> of the AGC component), each with its own feedback network and associated circuit elements. The feedback circuit elements are identified in FIGS. 10, 11, and 12 for the low-pass, intermediate or band-pass, and high-pass channels, respectively, using the same subscripts as in the impedance blocks of FIG. 3. Prefixed are added subscript L for low-pass, primed (singly, double, and triply) for the band-pass, and with added subscript H for the high-pass. It will be understood that the circuitry intersections designated as "r, s, t, and u" in FIGS. 10, 11, and 12 guide the substitution of their circuits at correspondingly designated intersections in the respective stages (with subscript designations "i" and "j") in accordance with FIG. 3. The circuit elements making up impedances Z<sub>i</sub> and Z<sub>j</sub> (FIG. 3) are added within a block shown in broken lines and so designated in FIG. 12 for the high-pass channel portion. Appropriate values for these and the associated elements of the filter channels appear in Table I of my aforementioned patent.

The output from each filter channel is fed to a corresponding detector component (FIG. 4) in which the diodes are of IN98 type and the capacitors have the values shown in Table II of that patent. Of course, in each instance the detector output is DC, varying in accordance with the channel or band signal strength. Such output is used as a control potential in the respective power control units, as shown in the final view.

FIG. 13 shows the circuitry for one of the power control units together with that of a synchronizer (S, outlined in broken lines, as in FIG. 5) useful with more than one such unit. Detector potential from "d" through resistor R<sub>12</sub> (4.3 k) is furnished to the input elements, where it is superimposed upon the voltage supply from positive source "+" (4.5v) through adjustable background control resistor R<sub>13</sub> (50k) and fixed resistor R<sub>14</sub> (4.7k) to the collector of transistor Q<sub>3</sub>. Synchronizer S comprises transformer T-1 whose primary is connected across AC terminals "f,g" and whose secondary is center-tapped to ground and furnishes a low AC potential (6.3 v) to the bases of transistors Q<sub>4</sub> and Q<sub>5</sub> through like resistors R<sub>A</sub> and R<sub>B</sub> (450 ohms). Q<sub>4</sub> and Q<sub>5</sub>, whose connectors are tied together and whose emitters are grounded, constitute together with the mentioned resistors a double-ended expander (e.g., Motorola MC 785 P type). Resistor R<sub>16</sub> (680 ohms) is

connected from the positive DC potential source to the common connector terminal of the synchronizer and also to a similar but single-ended expander stage through its base resistor  $R_{15}$  (450 ohms).

The synchronizer, operating through  $Q_3$ , determines the input impedance to transistor  $Q_4$  of the ramp generator by alternately saturating  $Q_4$  and  $Q_5$  except for recurrent brief (e.g., 0.5 msec) periods. When the applied AC potential is in the vicinity of zero (less than about 0.5 v), then  $Q_3$  receives a saturating positive pulse. At each such recurrence the ramp generator is reset by the charging of capacitor  $C_{16}$ , which parallels base resistor  $R_{17}$  (450 ohms), through collector resistor  $R_{18}$  (640 ohms). Between such recurrences  $C_{16}$  discharges through  $Q_4$  and  $R_{18}$  at a rate dependent upon the input control potential from the detector, the rate of discharge increasing with such positive potential. Both  $Q_4$  with its associated resistors and the following stage,  $Q_5$  with corresponding base and collector resistors  $R_{19}$  (450 ohms) and  $R_{20}$  (640 ohms), are inverters (e.g., Motorola MC 789 P type).

Reduction of the  $Q_4$  collector potential below about 0.6v cuts off  $Q_5$ , which otherwise is saturated. This applies a positive pulse to the gate electrode of triac  $Q_7$  in triac stage T through an emitter follower stage formed of transistor  $Q_6$  (2N5135 type) which has emitter resistor  $R_{21}$  (47 ohms) connected to the triac gate electrode. Thus, the period of conduction of the triac is dependent upon detector output at the input to the power control unit, and otherwise the gate electrode is grounded. Gate interconnection between channels is precluded by the clamping of the gate electrode either to ground or to substantial positive potential. Of course, during triac conduction the interconnected chromophoric display means, such as the lamps of FIG. 1, are actuated from the AC potential source.

Experience has shown that brightness change in lamps of the usual Christmas - tree variety, which may be used in such display means if desired, is apparent over a range of about 0.5 to 2.3 v. Below the lower value no visible light is apparent, and  $R_{13}$  can be adjusted to eliminate that portion of the response curve by adding compensating positive bias. The response is quite linear over the visible range and, of course, the larger the input the longer the lamps are actuated as well as the brighter they are.

A sixth power control unit is useful to actuate other display features, such as background lighting (as described below) or to superimpose other effects (e.g., noise) upon an illuminated display screen. When six such units are used, it is convenient to use two synchronizers, synchronizing three units each.

Another embodiment of the apparatus of this invention is shown in FIGS. 14 to 20. So modified, the apparatus is somewhat more complex, in the interest of improved operation and control in the conversion of input audio signals to equivalent sonic-color display. In this modified embodiment the inter-component terminals identified in the previous embodiment as *a, b, c, d, e, f*, and *g* have their respective counterparts designated as *A, B, C, D, E, F*, and *F'*.

FIG. 14 shows the modified AGC component in block form, comprising an Input Mixing Amplifier having generalized input terminal A and, in sequence, a Gain-Controlled Amplifier, optional Tone Control (indicated in broken lines), and Output Amplifier having output terminal B. The feedback loop includes a Full-Wave Rectifier from the input of the Output Amplifier,

a Peak Signal Voltage Comparator, and a Gain-Control Voltage Generator. The latter component has a pair of outputs to the Gain-Controlled Amplifier, and a Loss Sensor is interconnected between one of these output leads and terminal H to the background lighting component, while an Overload Sensor is connected to the other output lead from the Gain-Control Voltage Generator. Terminals AGC<sub>1</sub> and AGC<sub>2</sub> flanking the Tone Control component are to be connected together in the absence of such component, which itself is shown in detail in a subsequent view.

FIG. 15 shows the circuit elements and interconnections of the AGC components of the preceding view, from input terminals  $A_1$ ,  $A_2$  to output terminal B and including control voltage outputs  $CV_1$  and  $CV_2$  to the Signal Loss and Signal Overload Sensors (shown in further detail below) as well as internally to the Gain-Controlled Amplifier. Operation of this AGC component is similar to that described previously but is more effective as a consequence of the more elaborate structure of this modified version.

The Input Mixing Amplifier mixes input signals from terminals  $A_1$ ,  $A_2$  and provides a gain, manually adjustable by means of the range adjust control, of -0.1 to -1.1. The gain of the Gain-Controlled Amplifier is electronically adjusted over a 60 db range. FETS  $Q_{51}$  and  $Q_{52}$  are used, in effect, as voltage-controlled resistors to adjust the gain of this stage and are controlled in turn by control voltages  $CV_1$  and  $CV_2$ . The Output Amplifier supplies the AGC's signal, with amplitude manually adjustable from 3 volts peak-to-peak to 10 v.p.p. by the master gain control, to the active filters. The input to the Output Amplifier is also supplied to the Full-Wave Rectifier component, in which it is amplified and full-wave rectified, and from which the resultant signal is applied to the Peak Signal Voltage Comparator, in which both peaks of the rectified signal are compared to a DC reference signal. When the peak signal exceeds the reference, an output current is supplied to the Gain-Control Voltage Generator, which integrates it and converts it to a first control voltage  $CV_1$  and then inverts the latter and produces a second control voltage  $CV_2$ , related to the reference signal voltage VCR, such that  $CV_2 = (VCR - CV_1) + VCR$ . The Full Wave Rectifier and Peak Signal Voltage Comparator are temperature compensated in the interest of high AGC stability.

Features of this AGC embodiment include 20  $\mu$  sec attack time and 5 sec decay time, 60 db AGC range with less than 2% distortion, 20 db input signal adjust for input signal ranges: minimum 0.01 v pp to 10 v pp and maximum 0.1 v pp to 100 v pp.

FIG. 16 shows the circuit of the Tone Control component, interconnected between AGC1 and AGC2 terminals of FIG. 15. Linear 100k ohm potentiometers are provided to compensate, respectively, for treble and bass predistortion, such as from corresponding controls of a stereo system whose output is being converted by the present system from sonic to color display. This component features 20 db boost and cut with turnover at 1 kHz.

FIG. 17 shows the active filters for the low-pass, high-pass, and three intermediate pass bands. In each the input signal is buffered and is supplied to adjustable attenuator stages, one for each filter. The variable attenuator stages are adjusted to provide equal-amplitude input signals in their respective frequency bands. Each filter exhibits approximately 0.5 db amplitude variation in the pass band and -35 db per octave attenuation in

the side bands. This is sharper and more level than in the previous filter embodiment. The filter frequency ranges are as follows.

TABLE III

| Band            | -10 db low side<br>(approx 20 H <sub>z</sub> ) | -db high side       |
|-----------------|------------------------------------------------|---------------------|
| LP              |                                                | 140 H <sub>z</sub>  |
| BP <sub>1</sub> | 140 H <sub>z</sub>                             | 300 H <sub>z</sub>  |
| BP <sub>2</sub> | 300 H <sub>z</sub>                             | 600 H <sub>z</sub>  |
| BP <sub>3</sub> | 600 H <sub>z</sub>                             | 1400 H <sub>z</sub> |
| HP              | 1400 H <sub>z</sub>                            | (approx 20 kHz)     |

Also shown in FIG. 17, at the extreme right between terminals C<sub>1</sub> to C<sub>5</sub> at the filter output, are the corresponding detector stages, whose respective output terminals are designated D<sub>1</sub> to D<sub>5</sub>.

FIG. 18 shows the circuit of the modified Synchronizer component, comprising AC Line Crossing Detector and Ramp Reset Control components. A 7.5 v. rms signal derived via a transformer from the AC power line is supplied to the first of these components, which produces a reset pulse of width approximating 160  $\mu$  sec. The reset pulse straddles the zero crossing of the AC line, going high about 80  $\mu$  sec before and low about 80  $\mu$  sec after such zero crossing. The reset pulse drives the other component to set and hold each ramp generator of the Voltage-Controlled Triac Trigger component (in the next view) which corresponds generally to component T of the power stage of the earlier embodiment (in FIG. 5).

FIG. 19 shows, in addition to the component just mentioned, preceding Buffer Amplifier and Ramp Generator components of the Voltage-Controlled Triac Trigger stages (one for each of the five frequency bands), corresponding generally to impedance Z<sub>11</sub> and block G of FIG. 5. The modified synchronizer (S) component has been considered last above in connection with FIG. 18. Also included in FIG. 19 are elements of the Power block and the Display load of FIG. 1 to illustrate that in this modified embodiment the output coupling to the triac is inductive, thereby isolating the load from the rest of the apparatus.

The negative DC control voltages from the respective filter outputs C<sub>1</sub> through C<sub>5</sub> in FIG. 17 are buffered and then supplied to the Ramp Generator. The latter component produces a linear negative-going ramp starting at +10v (each time the line voltage goes through zero) and falling to 4.5 v, at which level it stops falling. The time taken for the ramp to fall to +5 is proportional to the DC control voltage from the filters and the background control setting. A more negative control voltage from the filters causes the ramp voltage to drop the same amount in a shorter time. A lower resistance setting of the background control has a like effect.

When the ramp voltage passes through +5 v the Trigger Pulse Generator produces a positive pulse of about 75  $\mu$ a with 5  $\mu$  sec duration. Such pulse turns the triac on and thereby supplies power to the load until the line voltage passes through zero. At zero voltage the triac turns off and remains non-conductive until again turned on by such a trigger pulse generated when the ramp passes through +5v. The time of occurrence of such pulse relative to the AC phasing determines the duration of triac conduction and, thus, of illumination of chromophoric means in the load. An approximately -3.75 DC control voltage provides about 90% average power to the load with background control set to minimum resistance. Actuation of the triac trigger by sepa-

rate logic input is provided for, as in the absence of such audio input or in addition thereto.

FIG. 20 shows the circuit diagram for the Signal Overload and Signal Loss Sensors and the Background Lighting Component actuated by the latter. The Signal Overload component, which is fed by the second control voltage from the AGC Gain-Control Signal Generator, CV<sub>2</sub>, merely lights a lamp to show that the acceptable range has been exceeded at the audio input. The Signal Loss Sensor, however, operates through the Background Lighting component to bring up the background lighting through a sixth power control channel at a rate and to a level controllable by manual adjustment of potentiometers therein. The AGC Gain-Controlled Amplifier is cut off simultaneously to prevent transient signals, noise, etc. from actuating the frequency-sensitive load components in the absence of significant audio input. As soon as such signal reappears the Signal Loss Sensor acts to discontinue the background lighting, and enable AGC output, relatively rapidly.

The modifications shown in FIGS. 14 to 20 and described above extend the teaching and range of application of the present invention to greater sophistication and effectiveness. Whereas the earlier embodiment establishes the superior performance of my improvement in a sonic-color system over conventional equipment, the latter embodiment represents a further advance where added complexity and expense are not objectionable. Its additional advantages and benefits can be fully appreciated best in actual practice.

Other modifications of the present invention, such as may be provided by addition, combination, or subdivision of parts or steps, or substitution of equivalents, may be made while retaining significant advantages and benefits of the invention, which is defined in the following claims.

I claim:

1. In an electronically controlled audio-responsive color display system, wherein audio signals of various frequencies are utilized to effect illumination in various colors, including the steps of amplifying the signals and limiting the total audio signal strength to a desired level while substantially maintaining relative signal strength, segregating the signals into a plurality of frequency bands, then for each band detecting the signals therein, producing periodic pulses of substantially constant amplitude whose duration is dependent upon the detected signal magnitude for such band, and applying the pulses from the respective bands to effect illumination in corresponding colors, the improvement comprising: producing momentary triggering pulses of uniform duration whose position relative to an AC reference signal determines the duration of such pulses.

2. Color display system according to claim 1, including the step of coupling such momentary triggering pulses inductively to a load circuit and reproducing therein such periodic pulses of variable duration.

3. Color display system according to claim 1, including the step of providing tone control in the amplification and limitation stage so as to compensate for amplitude vs. frequency distortion from pretreatment of the input signals to accentuate signals in certain frequency ranges over others.

4. Color display system according to claim 1, including the step of cutting off such sonic-color conversion process whenever input audio signal strength falls below a predetermined level.

5. Color display system according to claim 4, including the steps of augmenting background illumination whenever the sonic-color conversion process is cut off and reducing the background illumination upon restoration of input audio signal strength above the sonic-color conversion cut-off level.

6. In an electronically controlled audio-responsive color display system, including automatic gain control means (AGC) for amplifying input audio-frequency signals from a source thereof and limiting total audio signal strength to a desired level while substantially maintaining relative signal strength, filter means interconnected thereto for segregating the signals into a plurality of frequency bands, detector means for each band connected to receive the signals therefrom, pulse means associated with the respective detector means, and connected chromophoric display means responsive to such pulse means to be illuminated in colors corresponding to the respective bands, the improvement wherein the pulse means includes triggering means adapted to produce series of momentary triggering pulses whose position relative to phasing of an AC reference signal determines the duration of such illumination.

7. Color display means according to claim 6, wherein the AGC means comprises a mixing amplifier at the

input end, a gain-controlled amplifier connected to the output of the mixing amplifier, an output amplifier connected to the output of the gain-controlled amplifier, a peak-to-reference voltage comparator connected to the rectifier output, a gain-control signal generator connected to the comparator output, the output from the gain-control signal generator being fed back to the gain-controlled amplifier so as to control the gain thereof.

8. Color display system according to claim 7, wherein the gain-control signal generator has two control signal outputs, one being produced by inverting the other, such that the inverted control signal minus a reference signal equals the reference signal minus the first control signal.

9. Color display according to claim 8, including a signal-loss sensor connected to one output of the gain-control signal generator, and background lighting means connected to the sensor output and adapted to be illuminated when the sensor determines the signal strength has fallen below a predetermined level.

10. Color display means according to claim 9, including a signal-overload sensor connected to the other output of the gain-control signal generator.

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