April 27, 1965

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3,181,015

CONTROL SYSTEM RESPONSIVE TO AUDIO SIGNALS

Filed April 13, 1962

2 Sheets-Sheet 1

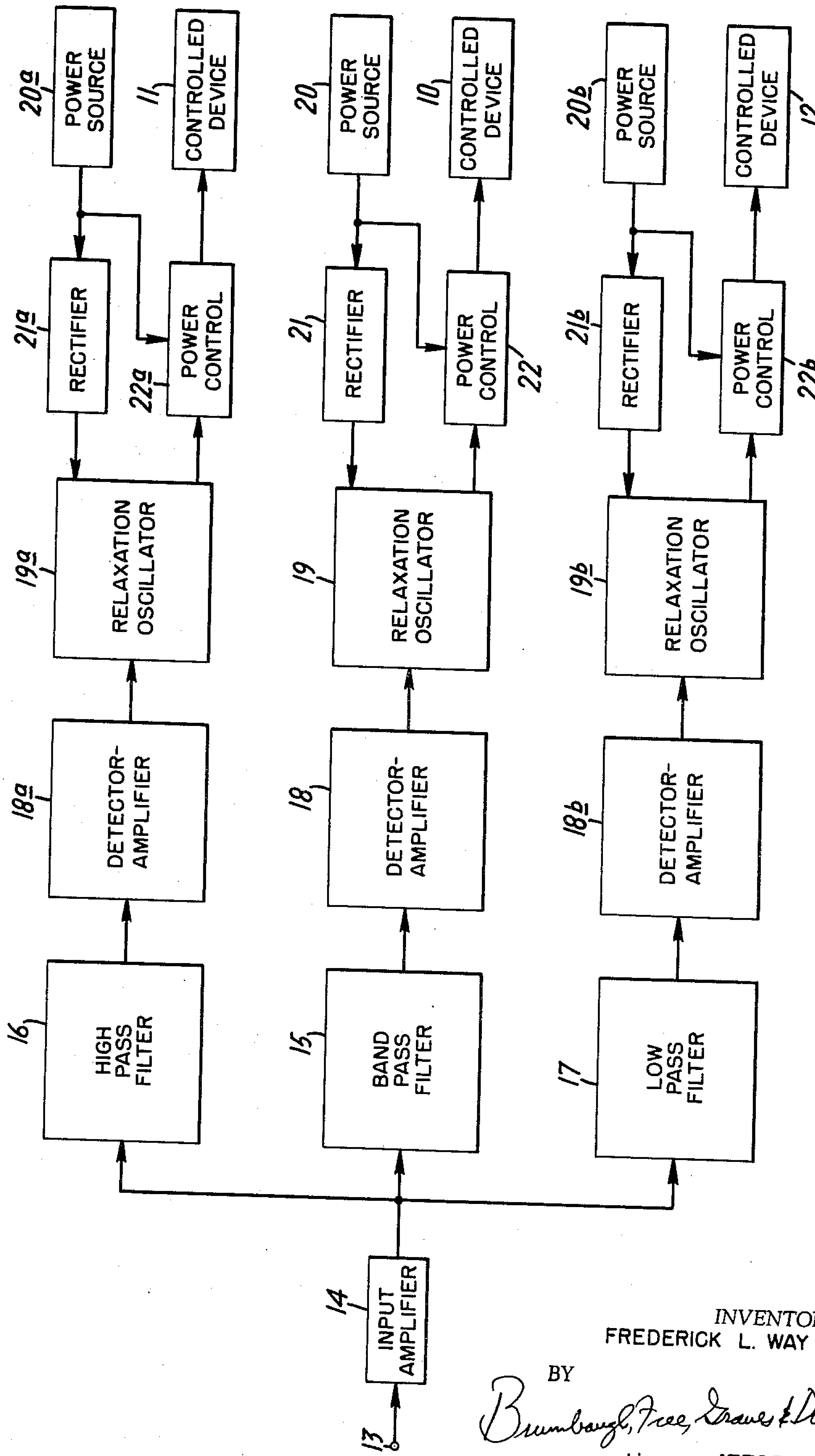

FIG. 1

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2 Sheets-Sheet 2

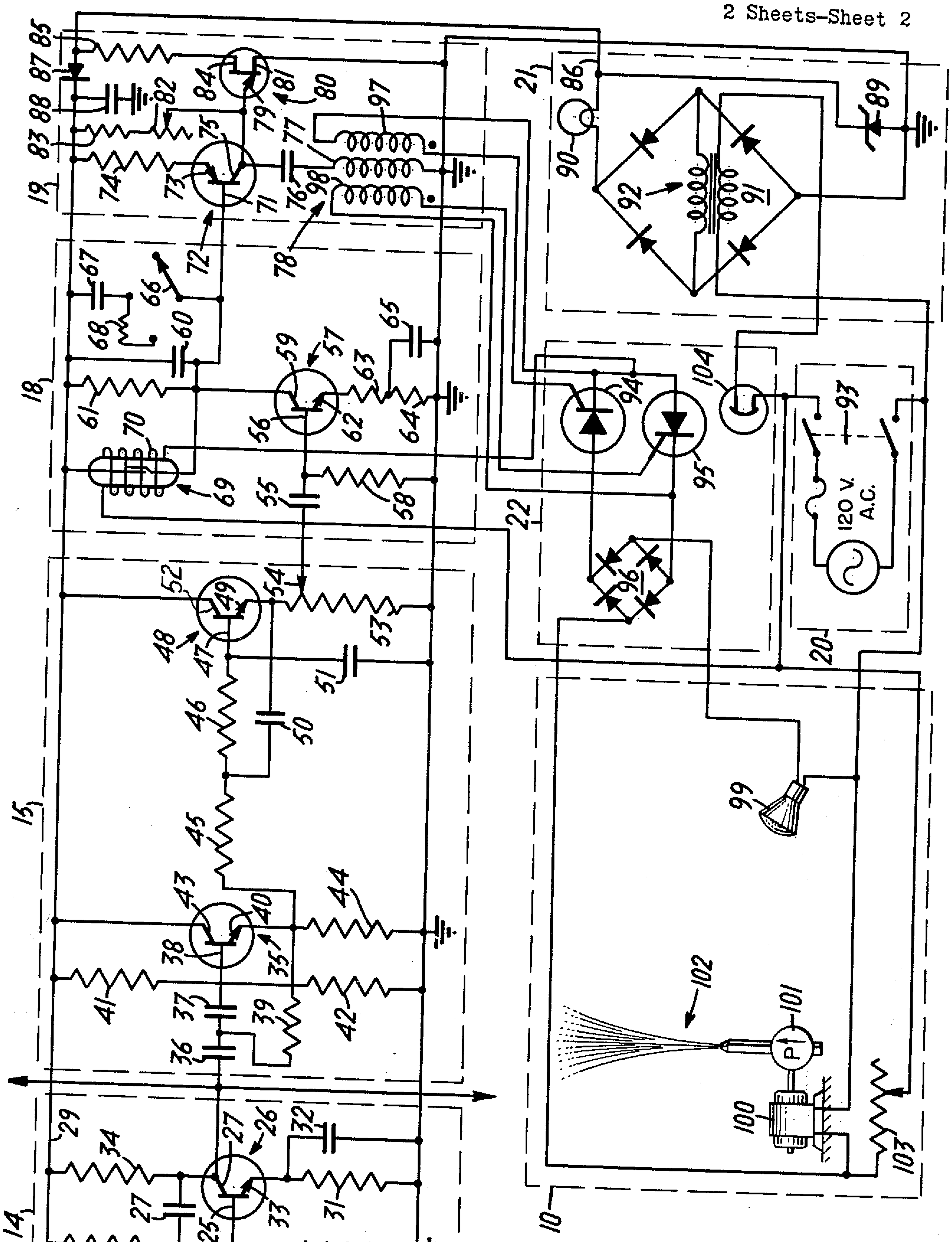

FIG. 2

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3,181,015
Patented Apr. 27, 1965

3,181,015
CONTROL SYSTEM RESPONSIVE TO AUDIO SIGNALS

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Filed Apr. 13, 1962, Ser. No. 187,311
9 Claims. (Cl. 307—155)

This invention relates to systems for controlling electrically-powered devices in response to audio signals and, more particularly, to a new and improved control system capable of monitoring large blocks of power in accordance with audio signal variations in a simple and efficient manner.

In many display arrangements, background music is supplied to enhance the esthetic appeal of the display. Moreover, considerably greater appear can be obtained if visually attractive devices such as colored lights, motor operated display elements, water fountain pumps and valves, etc. are controlled to provide a continuous variation in motion or intensity in harmony with changes in amplitude and tonal character of the music. The electrical power required to operate such devices, however, is often quite high and may, in certain cases, run to several thousand watts.

Heretofore, the audio signal responsive systems devised for such purposes have been incapable of controlling very large quantities of electrical power at the rate necessary to accomplish the desired control of variable devices either because they require moving mechanical components of substantial inertia or because the electrical circuit arrangements are inadequate and inefficient.

Accordingly, it is an object of the present invention to provide a new and improved control system responsive to audio signals which effectively overcomes the above-mentioned disadvantages of the prior art.

Another object of the invention is to provide a system of the above character capable of controlling devices which require substantial power for their operation in accordance with audio signals.

A further object of the invention is to provide a system of the above character which is effective to control simultaneously two or more devices having different electrical operating characteristics in accordance with a single audio signal.

An additional object of the invention is to provide a control system having improved efficiency for controlling simultaneously a plurality of electrically-powered devices in accordance with different characteristics of an audio signal.

These and other objects of the invention are attained by providing, in a system having an A.C. power source and an electrical device energized thereby, means effective to conduct current only during a selected portion of each A.C. oscillation in circuit with the power source and the device along with means responsive to audio signals to vary the duration of the selected portion. In a preferred embodiment of the invention, the current conducting means comprises a trigger-operated unidirectional conducting device such as a silicon control rectifier triggered by an oscillator having a phase relation to the power source which is varied by the amplitude of the audio signal. To assure synchronization of the trigger oscillator with the power source, a relaxation type oscil-

lator may be utilized which is controlled from the power line. Moreover, an audio signal may be filtered into a group of high, medium, and low frequency components to control three different devices such as colored lights and, if desired, two such groups of devices may be controlled from the two channels of a stereophonic system.

Further objects and advantages of the invention will be apparent from a reading of the following description in conjunction with the accompanying drawings, in which:

FIG. 1 is a block diagram illustrating the arrangement of the functional components of a typical system arranged according to the invention; and

FIG. 2 is a schematic circuit diagram illustrating the circuit arrangement of certain of the components illustrated in FIG. 1.

In the typical system represented in the block diagram of FIG. 1, three separate electrically-powered devices 10, 11, and 12 are controlled independently in accordance with the medium frequency, high frequency and low frequency components, respectively, of an audio signal applied to an input terminal 13. To accomplish this according to the invention, the input signal after amplification by an amplifier 14 is applied to an electrical band pass filter 15 arranged to pass only the middle range of audio frequencies and also to a high pass filter 16 and a low pass filter 17. Signals transmitted by the filter 15 are further amplified in a detector amplifier 18 and applied to a relaxation oscillator 19 which oscillates at the same frequency as an A.C. power source 20, this oscillator being synchronized with the A.C. line through a rectifier component 21.

In proportion to the amplitude of the audio signal received from the amplifier 18, however, the phase of the oscillations produced by the oscillator 19 is shifted with respect to the phase of the power source and these phase shifted signals trigger a power control component 22 to initiate conduction of current from the power source at a corresponding point during each cycle of oscillation of the power source, thereby regulating the power supplied to the controlled device 10 which may be a colored light source, a fluid pump or the like, in accordance with variations in audio signal amplitude. Similar circuit components identified by corrseponding reference numerals with letter suffixes, are included in the circuits from the high pass and low pass filters 16 and 17 to the devices 11 and 12, respectively.

Each of the components of the circuit for controlling the device 10 in accordance with variations in the middle frequency portion of the audio signal, is illustrated in detail in FIG. 2, the components of the other circuits being identical thereto or so similar that description with reference to FIG. 2 will suffice. As shown in FIG. 2, audio signals from the input terminal 13 pass through an amplitude control potentiometer 23 and an input coupling capacitor 24 to the base electrode 25 of an NPN transistor 26 in the input amplifier 14. The transistor 26 along with the other NPN transistors referred to hereinafter, may conveniently be of the type commercially known as 2N1302.

Preferably, the potentiometer 23 has an audio taper and a feedback capacitor 27 having a value of about 500 micro microfarads, is connected between the base electrode 25 and the collector electrode 27 of the transistor to attenuate frequencies above 10,000 cycles, the base electrode 25 also being connected to ground through a resistor 28 and to a 22 volt positive conductor 29 through a resistor 30. In addition, the input coupling capacitor 24 is given a relatively low value, for example, 0.5 microfarad to provide a 6 db per octave attenuation for frequencies below 270 cycles and thereby balance the audio power in the low frequency channel with that in the upper channels. If desired, the potential for the positive conductor 29 may be derived from the A.C. power source 20 in the manner described hereinafter. A parallel connected resistor 31 and capacitor 32 connect the emitter electrode 33 to ground while the amplified output signal is carried from the collector 27 which is joined to the positive conductor 29 by a resistor 34 to the middle frequency channel filter 15 as well as to the high and low frequency channel filters 16 and 17 shown in FIG. 1.

In the filter 15, the low frequencies are attenuated by a first feedback type active filter circuit comprising an NPN transistor 35 receiving signals from the amplifier 14 through two capacitors 36 and 37 connected in series to the base electrode 38, a resistor 39 being connected from the emitter electrode 40 to the junction of the two capacitors 36 and 37. Also, two resistors 41 and 42 join the base electrode 38 to the positive line 29 and to ground, respectively, while the collector electrode 43 is connected directly to the positive line and a resistor 44 joins the emitter electrode to ground. Utilizing 0.05 microfarad capacitors 36 and 37 in this arrangement, frequencies below 1,000 cycles are attenuated at a rate of 12 db per octave. Moreover, the high pass filter 16 shown in FIG. 1, may be identical to the circuit just described except that the capacitors 36 and 37 are replaced by 0.02 microfarad capacitors, thereby attenuating frequencies below 4,000 cycles at the same rate in that channel.

The second filter circuit in the filter 15 attenuates the higher frequencies in the middle range and comprises a pair of resistors 45 and 46 connected in series between the emitter electrode 40 and the base electrode 47 of another NPN transistor 48. In this case, the junction between the resistors 45 and 46 is joined to the transistor emitter electrode 49 by a capacitor 50 and another capacitor 51 connects the base electrode 47 to ground, the collector electrode 52 being joined to the positive line and a resistor 53 having a movable tap 54 being connected between the emitter 49 and ground. To attenuate frequencies below 1,000 cycles at a 12 db per octave rate in the middle frequency filter 15, the resistors 45 and 46 are given values of 5600 ohms each, while the capacitor 50 has a value of 0.1 microfarad and the element 51 is a 0.01 microfarad capacitor. In the low pass filter 17, an identical circuit is utilized except that the series resistors have values of 3300 ohms each and the capacitors are 0.5 and 0.05 microfarad, respectively, thereby attenuating frequencies below above 270 cycles at the same 12 db per octave rate. Accordingly, the three filters 15, 16, and 17 have crossover points of about 540 cycles and 1800 cycles at which the amplitudes are down by about 9 db from the peak values at the centers of the ranges.

From the movable tap 54, which along with the corresponding taps in the other filters can be used as gain controls to balance the signals in the three channels, middle frequency audio information is carried through a coupling capacitor 55 to the base electrode 56 of an unbiased transistor 57 of the NPN type which serves to detect and further amplify the signal, the base electrode 56 also being joined to ground through a resistor 58. In the middle frequency detector 18, the capacitor 55 has a value of 0.2 microfarad, whereas in the high frequency channel this may be 0.1 microfarad and in the low frequency channel, 0.5 microfarad. The detected signal appearing at the collector electrode 59 of this transistor is filtered at a fast time constant by a capacitor 60 connected in parallel with a resistor 61 to the positive line 29, while the emitter electrode 62 is joined to ground through two series resistors 63 and 64 and a capacitor 65 which shunts the resistor 64. In order to vary the time constant of the collector circuit and thereby provide medium and relatively slow response rates for the device 10 to audio signals, the collector circuit also includes a three position switch 66 arranged to join the collector 59 to the positive line 29 through a capacitor 67 at one position and a resistor 68 in series with the capacitor 67 at another position, the switch beign inactive at the third position.

Accordingly, if the controlled device 10 is an electric lamp, for example, the light can be made to flicker rapidly in response to rapid variations in the audio amplitude by keeping the switch 66 in the open position or it can be made to vary at a slower rate in harmony with the rhythm of medium tempo music by moving the switch to connect the capacitor 67 in the circuit, or the change in intensity of the lamp can be made average rate by including the resistor 68 in circuit with the capacitor. Although the fast rate of response enables the system to follow each note of a rapid tempo musical piece, the slower rates are generally found to provide a more esthetic effect.

To protect the subsequent control circuit components from damage by the high inrush currents which occur, for example, when an incandescent lamp is initially turned on, the detector 18 also includes a reed relay 69 connected between the positive line 29 and the collector 59 and comprising a pair of adjacent contacts which are normally spaced but can be moved together, surrounded by a coil 70 consisting of a few turns of wire connected in series with the device to be controlled. When the current through the coil 70 exceeds a selected value, the resulting magnetic field joins the contact momentarily, thereby discharging the capacitor 60 and disabling the subsequent control circuit 19. Thereafter, the control circuit is reactivated at a relatively gradual rate as the capacitor 60 is recharged but if the excessive current has not subsided by the time the capacitor 60 has been recharged, the reed relay 69 is actuated again and the disabling cycle is repeated.

As long as the load current is below the selected value, the amplified audio signal is applied from the collector 59 to the base electrode 71 of a PNP type transistor 72 in the relaxation oscillator 19 having its emitter electrode 73 connected through a resistor 74 to the positive line. This transistor which may be of the 2N1414 type, for example, has its collector electrode 75 connected through a series capacitor 76 and the primary winding 77 of a pulse transformer 78 to ground. In addition, this electrode is joined to the emitter electrode 79 of a unijunction transistor 80 having one base electrode 81 grounded. This transistor is of the 2N1671A type and its emitter electrode 79 is also connected to the positive line 29 through a series rheostat 82 and resistor 83, while the other base electrode 84 is connected through a resistor 85 to a conductor 86 which receives full wave rectified but unfiltered A.C. power clamped at the voltage level of the line 29 from the rectifier 21. As mentioned previously, the positive D.C. voltage on the line 29 may be derived from the A.C. power source 20 and, for this purpose, the line 29 is joined to the line 86 through a 1N536 type diode rectifier 87 and to ground through a filter capacitor 88.

In order to provide the proper voltage, the line 86 is connected in the rectifier unit 21 to ground through a zener type diode rectifier 89 having a reverse voltage breakdown level of about 22 volts, such as a 10M22Z diode. The line 86 is also connected through a 10 watt pilot lamp 90 to one corner of a full wave rectifier bridge 91 to which A.C. power is supplied from the source 20 by a transformer 92, the opposite corner of this bridge being grounded. In addition, the power source 20 includes a double pole power switch 93 connected between the A.C. terminals and the primary of the transformer 92. If the three devices to be controlled by the high, medium, and low frequency audio signals are all connected to the same power source 20 so as to have the same phase relation, only one rectifier unit 21 is necessary and the line 86 may be connected to the corresponding points in the oscillators 19*a* and 19*b* to supply power thereto. Furthermore, if three different power sources are utilized, the pilot lamp 90 may be replaced in the other rectifier units 21*a* and 21*b* by corresponding resistors, the on/off switch 93 being ganged with corresponding switches in the other power sources.

According to the present invention, the power control unit 22 comprises gated current conducting devices connected between the power source and the controlled device which pass current only during selected portions of the A.C. oscillation cycle and the duration of these conductive periods are controlled by the oscillator 19 in response to the audio signal. In the representative embodiment of the invention shown in FIG. 2, the current conducting device comprises two silicon control rectifiers 94 and 95 of the type commercially designated C35B. These rectifiers, which conduct current in one direction only, and then only after they have been triggered by a gating pulse, are both connected in opposite orientations through the reed relay coil 70 to one side of the power source 20. The other ends of these rectifiers are connected to opposite input corners of a rectifier isolation network 96 from which power may be taken at the other two corners to control two separate elements having different electrical characteristics without either element affecting the operation of the other. Trigger pulse signals for the two rectifiers 94 and 95 are derived from the relaxation oscillator through two secondary windings 97 and 98, respectively, and inasmuch as these pulses which have twice the frequency of the A.C. source, are phase shifted by the relaxation oscillator 19 with respect to the A.C. line in accordance with the audio signal applied to the oscillator, they occur at a controlled time interval after the initiation of each cycle of the A.C. power source. As a result, current is conducted by each of the silicon control rectifiers 94 and 95 only during a selected portion of the positive going half cycle of the A.C. voltage applied to it, thereby providing accurate regulation of the current transmitted to the controlled device 10 without any appreciable dissipation of power as occurs in many other types of power control systems utilizing power transformers, impedance elements, or the like.

As pointed out previously, the controlled device 10 may include one or more elements arranged for simultaneous actuation according to the audio signal and, in the example shown in FIG. 2, these elements are an electric light 99 and a motor 100 connected to drive a pump 101 so as to produce a spray of water 102 which is illuminated by the light 99. In this case, the electrical characteristics of the motor 100 which may be any conventional A.C. motor are quite different from those of the light and, in order to maintain a threshold torque on the motor and thereby provide rapid response to audio signal variations, a resistor 103 is connected in series to the other side of the A.C. line shunting the power control unit. This resistor may have an impedance approximately equal to that of the motor, the actual value depending on the rating of the motor or, if a selected minimum spray height is desired with no applied audio signal, the resistor 103 may have a lower value. Nevertheless, the operation of the light 99 remains completely independent of the characteristics of the circuit including the motor 100 by reason of the isolation network 96. Moreover, if further elements are to be controlled in accordance with the same audio signal, they may be connected in a similar manner to another isolation network (not shown) joined to the control rectifiers 94 and 95 in parallel with the network 96. Also, a thermal switch 104 preferably of the snap type mounted closely adjacent to the control rectifiers 94 and 95 is connected in the power line to prevent overheating of these elements and, if desired, a noise filter (not shown) comprising chokes and capacitors arranged in a conventional manner may be connected between the power source 20 and the power control unit to prevent radio noise from being conducted out of the control system by the power lines.

In a typical control system of the above-described type, representative values for the various circuit components not previously specified are as follows:

Resistors 23 and 82	ohms	50,000
Resistor 28	do	15,000
Resistor 30	do	100,000
Resistors 31 and 35	do	390
Resistor 34	do	1,800
Resistor 39	do	1,200
Resistor 41	do	12,000
Resistor 42	do	22,000
Resistors 44 and 53	do	1,000
Resistor 58	do	4,700
Resistors 61 and 74	do	470
Resistors 63, 64 and 68	do	220
Resistor 83	do	10,000
Capacitors 32 and 67	microfarads	100
Capacitors 60 and 65	do	10
Capacitor 76	do	0.2
Capacitor 88	do	500

In operation, an audio signal representing music, a human voice, or the like, applied at the terminal 13 is amplified in the unit 14 and the middle frequency range is selected by the filter 15, while the upper and lower ranges are passed by the filters 16 and 17, respectively. The movable contact 54 along with the corresponding contacts in the other filters preferably is adjusted to balance the three signals. The amplifier 18 in turn supplies a corresponding signal to the relaxation oscillator 19 having a response time which is controlled by the switch 66. When the A.C. source 20 is turned on, the rectifier 21 supplies full wave rectified current through the conductor 86 to the unijunction transistor 80 and as the rectified current drops to zero during each cycle, the capacitor 76 discharges generating trigger pulses in the secondary coils 97 and 98 of the pulse transformer 78. The exact point in the A.C. cycle at which the capacitor discharges, however, is controlled by the potential at the electrode 79 of the unijunction transistor 80 and this, in turn, depends on the setting of the rheostat 82 and on the amplitude of the audio signal applied to the transistor 72. Usually, the rheostat 82 which controls the minimum current conducted by the power control 22 is set so that the lamp 99 operates just below the visual threshold with no applied audio signal. After this, the resistor 103 is adjusted so that the minimum desired spray of water is obtained in the absence of any audio signal. Accordingly, audio signals applied to the oscillator 19 will raise the potential of the electrode 79 causing the relaxation oscillator to fire earlier in the decreasing current portion of the rectified A.C. cycle, and this in turn, triggers the control rectifiers 94 and 95 to conduct current for a longer portion of the cycle, thereby increasing the average current supplied to the device 10.

When the power switch 93 is initially turned on, a strong surge of current is drawn by the reduced resistance of the cold filament in the lamp 99. To prevent this and any other excessive current condition from injuring the rectifiers 94 and 95, the coil 70 in the reed relay 69 responds to such current surges by closing the relay contact and momentarily discharging the capacitor 60. This capacitor recharges slowly during about 10 cycles of the A.C. line permitting the current passed by the power control unit to the device 10 to increase gradually. If, at the end of that time, the current is still too high the relay operates again. The operation of the high frequency and low frequency channels is identical to that of the middle channel but the adjustable elements therein may, of course, have different settings. Preferably, the lamp 99 is covered with a green filter while the corresponding lamp in the high frequency channel is covered with a red filter and the low frequency lamp produces blue light.

It will be readily apparent from the foregoing that the present invention provides a new and highly effective control system for controlling high powered devices in faithful response to rapid variations in audio signals with substantially no power losses. For example, the total maximum power controlled by each power control unit 22 may be as high as 2400 watts which is sufficient for the operation of all the electrical components in relatively large outdoor displays.

Although the invention has been described herein with reference to a specific embodiment, many modifications and variations therein will readily occur to those skilled in the art. For example, instead of controlling the pump motor 100, the system might be arranged to vary the setting of a control valve in a fluid line or the position of a deflector mounted at the end of the nozzle. Moreover, if desired, two systems of the type described herein may be connected to receive the two components of a stereo audio signal and the devices controlled thereby may be placed in appropriate locations to emphasize the three-dimensional effect produced by stereo systems. Accordingly, all such variations and modifications are included within the intended scope of the invention as defined by the following claims.

I claim:

1. A system for controlling an electrical device in response to audio signals comprising variable power control means adapted to be connected in circuit with an A.C. power source and a device to be controlled, said variable power control means having a control input and being effective to conduct current in a circuit from the power source to a device only during at least one selected portion of each A.C. oscillation cycle, and means responsive to audio signals connected to the control input of the variable power control means to control the operation thereof so as to vary the duration of the selected portion with respect to the period of the A.C. cycle.

2. A system for controlling an electrical device in response to audio signals comprising variable power control means adapted to be connected in circuit with an A.C. power source and a device to be controlled, said variable power control means having a control input and including unidirectional conducting means effective to conduct current in a circuit from the power source to a device only after actuation by a trigger signal applied to the input, oscillator means connected to the unidirectional conducting means and the power source for supplying trigger signals to the input at a rate dependent upon the A.C. oscillation frequency and having a phase control input, and means responsive to audio signals connected to the phase control input of the oscillator means to control the operation thereof so as to vary the phase of the trigger signals with respect to the oscillations of the A.C. power source.

3. A system for controlling an electrical device in response to audio signals comprising variable power control means adapted to be connected in circuit with an A.C. power source and a device to be controlled, said variable power control means having a control input and and including unidirectional conducting means effective to conduct current in a circuit from the power source to a device only after actuation by a trigger signal applied to the input, relaxation oscillator means connected to the variable power control means and the power source for applying trigger signals to the input, means connected to the oscillator means and the power source for controlling the operation of the relaxation oscillator means in controllable phase relation with the oscillation of the A.C. power source, and means responsive to the amplitude of an audio signal and connected to the oscillator control means for controlling the oscillator in accordance therewith so as to vary the phase of the trigger signals with respect to the oscillations of the A.C. power source.

4. A system for controlling simultaneously at least two electrical devices having different characteristics in response to variations in an audio signal comprising variable power control means adapted to be connected in circuit with an A.C. power source and the devices to be controlled, said variable power control means having a control input and being effective to conduct current in a circuit from the power source to a device only during at least one selected portion of each A.C. oscillation cycle, means responsive to audio signals connected to the control input of the variable power control means to control the operation thereof so as to vary the duration of the selected portion with respect to the period of the A.C. cycle, and isolation network means linking the power control means with the devices to be controlled to supply power thereto but prevent the operation of each device from affecting the operation of the other device.

5. A system for controlling an electrical device in response to audio signals comprising variable power control means adapted to be connected in circuit with an A.C. power source and a device to be controlled, said variable power control means having a control input and being effective to conduct current in a circuit from the power source to a device only during at least one selected portion of each A.C. oscillation cycle, means responsive to audio signals connected to the control input of the variable power control means to control the operation thereof so as to vary the duration of the selected portion with respect to the period of the A.C. cycle, and filter means for controlling the rate of response of the system to audio signal variations.

6. A system for controlling an electrical device in response to audio signals comprising variable power control means adapted to be connected in circuit with an A.C. power source and a device to be controlled, said variable power control means having a control input and including unidirectional conducting means effective to conduct current in a circuit from the power source to a device only after actuation by a trigger signal applied to the input, oscillator means connected to the unidirectional conducting means and the power source for supplying trigger signals to the input at a rate dependent upon the A.C. oscillation frequency and having a phase control input, means responsive to audio signals connected to the phase control input of the oscillator means to control the operation thereof so as to vary the phase of the trigger signals with respect to the oscillations of the A.C. power source, and means connected in circuit with the power control means and responsive to excess current drawn through the power control means to control the phase relation of the trigger signals with respect to the A.C. oscillations so as to reduce the current to a minimum value and thereafter to permit increased current during successive A.C. oscillation cycles.

7. A system for controlling the rate of flow of fluid in response to audio signals comprising electrical fluid flow control means, means for supplying a minimum current to the fluid flow control means to produce a threshold fluid flow condition, variable power control means adapted to be connected in circuit with an A.C. power source and the fluid flow control means, said variable power control means having a control input and being effective to conduct current in a circuit from the power source to the fluid flow control means only during at least one selected portion of each A.C. oscillation cycle, and means responsive to audio signals connected to the control input of the variable power control means to control the operation thereof so as to vary the duration of the selected portion with respect to the period of the A.C. cycle.

8. A system for controlling the intensity of illumina-

tion from an electric light source and the rate of flow of fluid simultaneously in response to audio signal variations comprising electrical fluid flow control means, means for supplying a minimum current to the fluid flow control means to produce a threshold fluid flow condition, electric light source means, variable power control means adapted to be connected to an A.C. power source, said variable power control means having a control input and being effective to conduct current in a circuit from the power source to the light source and the fluid flow control means only during at least one selected portion of each A.C. oscillation cycle, means responsive to audio signals connected to the control input of the variable power control means to control the operation thereof so as to vary the duration of the selected portion with respect to the period of the A.C. cycle, and isolation network means linking the electric light source means and the fluid flow control means to the variable power control means.

9. A system for controlling a plurality of electrical devices separately in accordance with variations in selected frequency ranges of an audio signal comprising a plurality of variable power control means each adapted to be connected in circuit with an A.C. power source and a corresponding one of a plurality of electrical devices to be controlled, each variable power control means having a control input and being effective to conduct current in a circuit from the power source to a device only during at least one selected portion of each A.C. oscillation cycle, a corresponding plurality of means responsive to audio signals connected to the control input of the variable power control means to control the operation thereof so as to vary the duration of the selected portion in each of the variable power control means in response to audio signals, and filter means connected to the plurality of means responsive to audio signals for supplying thereto a plurality of audio signals representing information in a corresponding plurality of restricted portions of the audio frequency range.

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