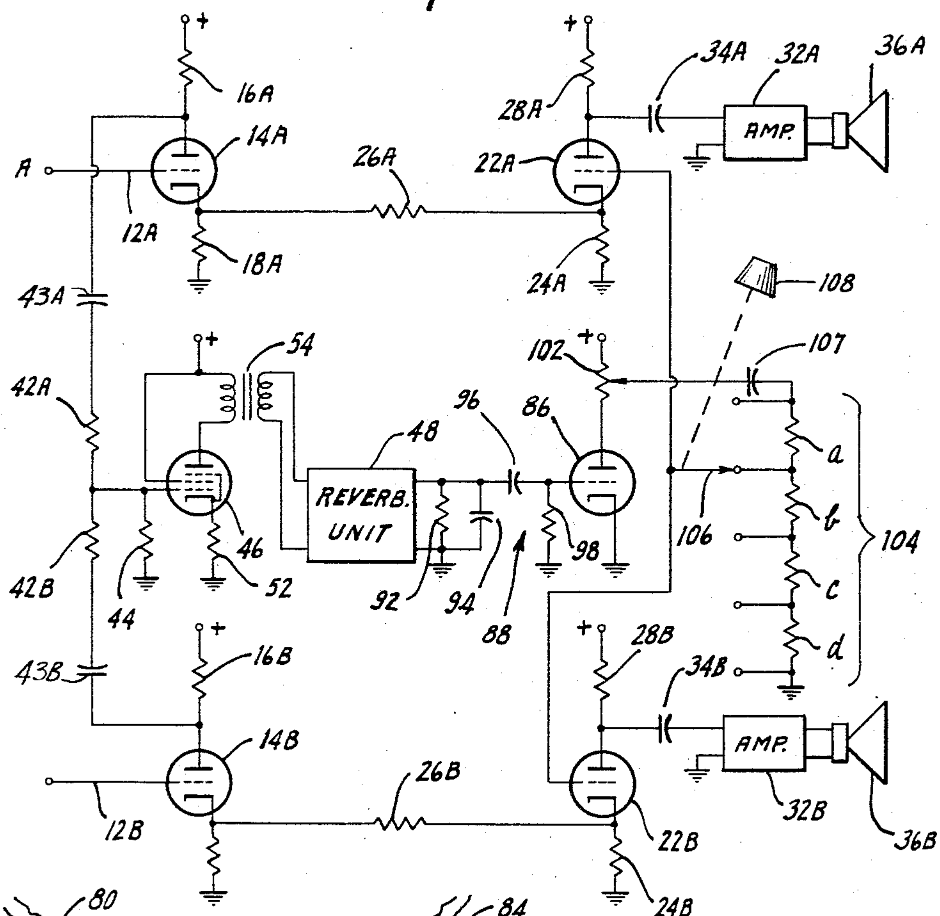
July 25, 1967 H. E. DOW **3,333,061**

REVERBERATION CIRCUIT FOR DUAL-CHANNEL AUDIO REPRODUCER

Filed June 27, 1960

FIG. 1.



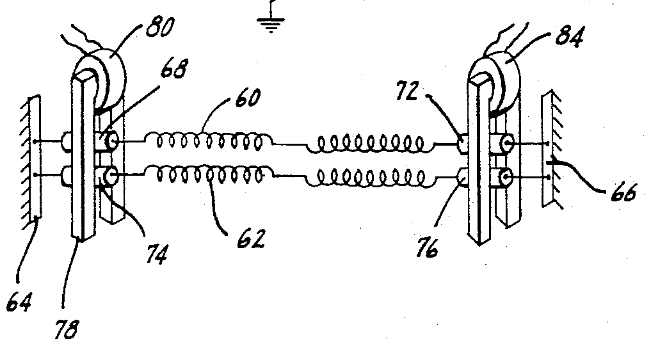


FIG. 2.

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REVERBERATION CIRCUIT FOR DUAL-CHANNEL AUDIO REPRODUCER

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The present invention relates to audio reproduction systems and more particularly to stereophonic audio reproduction systems.

In recent years, it has been the aim of workers in the audio reproduction art to give to reproduced music the life-like quality enjoyed by the listener at the concert hall. Great improvements have been made in the frequency response of system components such as phonographic pickups, audio amplifiers, speakers, etc. Added realism has been achieved by employing two stereophonically related reproduction channels in order to reproduce at a distance the effect of the slight phase differences in the signals reaching the two ears of the listener in a concert hall. However, even the stereophonic reproduction at a distance of a "live" concert cannot provide the distant listener with the same effect as that experienced by a direct listener. This is so whether or not the program signals are broadcast directly by means of appropriate radio circuits or are first recorded and then reproduced at the distant location. One reason for this is that the microphones, which pick up the sound for transmission or recording, are usually located adjacent the orchestra pit or stage and not at the points in the audience which correspond to the ears of the listener. This placement of the microphone makes it impossible to capture the reverberant effect produced by the reflection of the music from the walls, ceilings, etc. of the concert hall. Therefore there is need even in the reproduction at a distance of music picked up before a "live" audience to introduce some form of reverberant effect.

Recording of music before a "live" audience has additional disadvantages. Audience noises such as talking, shuffling of feet or coughing, etc. are usually picked up by the microphones. For these and other reasons, it is desirable to record in specially equipped studios which have neither an audience nor an auditorium. Some attempts may be made to match the acoustics of the studio to those of the concert hall but this is usually impossible of achievement.

Means are known for adding, in an artificial manner, the reverberant effect of concert hall music to recorded or broadcast music. However the amount of reverberation that should be added depends to a large extent on the acoustical properties of the room in which the ultimate audio reproducer is located. Since this cannot be known in advance and will vary greatly from reproducer to reproducer, it is the general practice to add only very little or no reverberation at the radio transmitter or recording studio. Therefore it is necessary to provide at each audio reproducer means for adding a controllable amount of reverberation to the reproduced signal. The means for adding the controllable amount of reverberation should be relatively inexpensive so that it does not add greatly to the cost of the radio receiver or audio reproducer. It should be relatively flexible in its operation so that the degree of reverberant effect, which is optimum for a particular room and a particular passage of music, may be selected. It should be capable of embodiment in a substantially self-contained unit which has signal input and output levels such that it may be inserted in existing equipment with a minimum of modification.

Various systems have been proposed for introducing a reverberant effect in the output signal of a stereophonic

reproducer. It has been proposed, for example, to place a delay line in each channel for high frequencies only. Another proposal is to supply to one speaker signals representing unreverberated high frequency components and reverberated low frequency components and to supply to another speaker signals representing reverberated high frequency components and unreverberated low frequency components. Still other proposals involve delay means for cross-connecting the two channels.

Systems of the type described which require dual delay means or dual reverberating means are generally rather inflexible in their operation, complex and expensive to construct and not wholly satisfactory in the reverberant effect produced. Economy systems have been proposed which add a reverberation signal to one channel only of a stereophonic system. However, both the stereophonic effect and the reverberation effect produced by such systems are far from optimum.

Therefore it is an object of the present invention to provide a relatively simple and inexpensive system for adding a reverberant signal to both channels of the stereophonic audio reproducer.

It is a further object to provide a system for adding a readily controllable amount of reverberant signal to the two channels of a stereophonic audio reproducer.

An additional object of the present invention is to provide a system which requires only a single reverberator unit for applying a reverberated signal to the two channels of a stereophonic audio reproducer.

Still another object of the invention is to provide a simple and economical dual channel reverberator unit having substantially the same input and output signal levels.

A further object of the invention is to provide a reverberator unit which is readily adaptable to either single-channel or dual-channel operation.

In general, these and other objects of the present invention are achieved by providing means for combining signals from each of the two stereophonically related channels to form a sum signal. This sum signal is then passed through a single reverberator unit. Signal amplitude control means are provided at the output of the reverberator unit. The reverberated signal is then added equally to the two channels of the stereophonic reproducer. Thus the present system makes use of the fact that in a concert hall or the like, the reverberant signal is the composite of the reflection of sound from many surfaces of the hall so that little, if any, stereophonic effect is present in the reverberant signal per se.

In the preferred embodiment of the invention an amplifier circuit is employed for supplying an amplified sum signal to the input of the reverberator unit and for combining the output of the reverberator unit with the two stereophonic channels without introducing cross-talk paths between the two channels.

For a better understanding of the present invention together with other and further objects thereof, reference should now be made to the following detailed description which is to be read in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic drawing partially in block form of a preferred embodiment of the present invention; and

FIG. 2 is a diagrammatic showing of one preferred form of reverberator unit which may be employed in the circuit of FIG. 1.

In the system of FIG. 1, the signal from one output, hereinafter referred to as the "A" output, of a stereophonic program signal source (not shown), is supplied to input lead 12A which connects directly to the grid of vacuum tube 14A. The stereophonic program signal source may be, for example, a dual channel (or single channel multiplex) stereophonic radio receiver or a stereophonic disc or tape reproducer. Tube **14A** is provided with a relatively large anode load resistor **16A** and a relatively small, unbypassed, cathode load resistor **18A**. Typical values for the circuit elements shown in FIG. 1 are given in a table at the end of this description. The source of anode supply potential is represented schematically by the plus sign adjacent the upper terminal of resistor **16A**. This same convention is employed in all of the amplifier stages of FIG. 1.

The cathode of a second tube **22A** is connected to the junction of resistors **24A** and **26A** which together form a signal divider network connected between the cathode of tube **14A** and a point of reference potential. Preferably resistor **26A** has a value several times that of resistor **24A**. Cathode load resistor **24A** is made quite small compared to the anode load resistor **28A** of tube **22A**.

The circuit just described provides a signal channel which couples the lead **12A** to the input of one amplifier **32A** of the stereophonic reproducer with which the reverberator unit of FIG. 1 is associated. In FIG. 1, amplifier **32A** is shown in block form since it may be of conventional construction. The capacitor **34A**, which connects the anode of tube **22A** to the input of amplifier **32A**, is a conventional coupling capacitor.

The output of amplifier **32A** is shown connected to a speaker **36A**. Speaker **36A** represents schematically the electro-acoustical transducer system associated with the "A" channel of the stereophonic reproducer.

A second channel, identical to the one just described, is provided for connecting the second output, hereinafter called the "B" output of the program source to the second amplifier **32B** and speaker **36B**. For convenience of reference, parts in the second channel corresponding to like parts in the first channel are identified by the same reference numeral followed by the letter B rather than the letter A.

Resistors **42A**, **42B** and **44** form a resistive adder network which couples to the grid of an amplifier tube **46** a signal representative of the sum of the signals present at the anodes of tubes **14A** and **14B**. Capacitors **43A** and **43B** are direct current blocking capacitors. Tube **46** is part of a power amplifier stage which drives a reverberator unit **48**. Tube **46** is provided with a cathode bias resistor **52** which is unbypassed to provide some linearizing negative feedback. The anode of tube **46** is coupled by means of transformer **54** to the input of a reverberator unit **48**.

Reverberator unit **48** is preferably a form of acoustic or mechanical delay device having a mismatched termination so that signals introduced by transformer **54** make several passages through the delay device before they are completely attenuated. One form of reverberator unit is shown in FIG. 2. This reverberator comprises two springs **60** and **62** which are fastened under slight tension between rigid supports **64** and **66**. A magnet or rotor **68** is secured to spring **60** at a point sufficiently distant from support **64** to permit torsional motion of spring **60** under the influence of the torque applied thereto by rotor **68**. A second magnet or rotor **72** is secured to the other end of spring **60** at a sufficient distance from support **66** so that it may be rotated by torsional motion of the end portion of spring **60**. Similarly, rotors **74** and **76** are provided at the two ends of the spring **62**. For reasons which will become clear presently, rotors **68**, **72**, **74** and **76** are magnetized along a diameter.

Rotors **68** and **74** are positioned between the two arms of a U-shaped magnetic core **78**. A driving coil **80** is wound on the base of the U-shaped core **78**. Rotors **72** and **76** are disposed between the two arms of a second U-shaped member **82** which has a pickup coil **84** wound on the base thereof.

Audio signal energy applied to driving coil **80** from transformer **54** of FIG. 1, for example, sets up a magnetic field between two arms of the U-shaped core **78**. The secondary of transformer **54** may have a relatively

high resistance so that the field strength is substantially proportional to signal amplitude at any frequency within the audio frequency band. The magnetized rotors **68** and **74** are caused to rotate by the magnetic field thus produced. This imparts a corresponding rotation to the springs **60** and **62** to which they are secured. The rotational displacement impressed at one end of springs **60** and **62** is propagated in a torsional mode along the springs **60** and **62** to rotors **72** and **76**, respectively. Rotation of magnetized rotors **72** and **76** between the two arms of core **82** induce in coil **84** audio signals which correspond to the signals initially applied to coil **80** but delayed by a time determined by the constants of springs **60** and **62**. In one preferred embodiment of the invention spring **60** produces a time delay of .029 second and spring **62** produces a time delay of .037 second. Repeated reflections of the energy in springs **60** and **62** will occur at the supports **64** and **66** due to the mismatched terminations of the springs **60** and **62**. As a result, a series of echo signals will be picked up by coil **84**. The amplitude of successive echo signals will decay logarithmically. This corresponds very closely to the logarithmic decay of signals in a reverberant hall.

No claim is made to the reverberator unit of FIG. 2 per se. A unit corresponding substantially to the one shown in FIG. 2 is marketed commercially by the Hammond Organ Company, Chicago, Illinois.

Returning now to the description of FIG. 1, it will be seen that the output of reverberator unit **48**, which corresponds to pickup coil **84** of FIG. 2, is coupled to the grid of vacuum tube **86** by way of a resistor-capacitor coupling network **88** which controls the high frequency roll-off characteristic of the reverberated signal. Network **88** comprises resistor **92** and capacitor **94** connected in shunt with the output of unit **48**, a second capacitor **96** coupling one output terminal of unit **48** to the grid of tube **86** and a resistor **98** connected between this grid and ground. The second output terminal of coil **84** is also connected to ground.

The anode load impedance of tube **86** is an adjustable potentiometer **102**. A tapped potentiometer **104** is coupled between the movable tap of potentiometer **102** and a point of reference potential schematically represented by the ground symbol. In the table of values which follows this description, the sections of tapped potentiometer **104** are identified by the letters *a, b, c,* and *d*.

The movable contact **106** on potentiometer **104** is connected directly to the control grids of tubes **22A** and **22B**, respectively. A control, schematically represented at **108** in FIG. 1, is provided for selecting the desired position of movable contact **106**. Control **108** may be a suitable knob on the control panel of the stereophonic reproducer.

The following table of values for a typical circuit is given by way of example only and it is to be understood that the invention is not in any way limited to the particular values given.

TABLE

R16A, 16B		47K
R28A, 28B		39K
R18A, 18B		3.3K
R24A, 24B		2.2K
R26A, 26B		10K
R42A, 42B	meg	1
C34A, 34B	μf	0.001
R44	meg	0.5
R52	ohms	270
R92		22K
R98	meg	10
C94	μf	0.0033
C96	μf	0.01
C107	μf	0.0047
R104a		33K
R104b		27K

R104c	27K
R104d	18K
Tubes 14A, 22A, 14B, 22B	½ 12AX7
Tube 46	6AQ5
Tube 86	6AV6

The constants given above are selected so that the two channels from inputs **12A** and **12B**, respectively, to the inputs of the amplifiers **32A** and **32B**, respectively, have substantially unity gain. This permits the portion of the unit shown in schematic form in FIG. 1 to be inserted in existing stereophonic systems without changing the signal level of those systems. By way of example, a package unit may be provided with input jacks (not shown) at inputs **12A** and **12B** which are similar to jacks at the inputs of amplifiers **32A** and **32B**. The stereo source and the outputs of tubes **22A** and **22B** may be provided with identical plugs (not shown). In such a system the output of the pickup may be supplied directly to the amplifiers **32A** and **32B** or it may be supplied through the reverberation circuit of FIG. 1 merely by changing plugs. If the system shown in schematic form is to be designed as an integral part of a stereophonic reproducer, it will usually be desirable to change the values of the components to provide at least some gain from the grid of tubes **14A** and **14B** to the anodes of tubes **22A** and **22B**.

Turning once again to FIG. 1, it will be seen that, for the program signal supplied to input **12A**, tube **14A** acts as a cathode loaded amplifier having a gain less than one. Resistors **26A** and **24A** form a signal divider for coupling the signal present at the cathode of tube **14A** to the cathode of tube **22A**. Tube **22A** and associated resistors function as a grounded grid amplifier for the signals supplied at input **12A**. It will be seen that if contact **106** is in its lowermost position, the stage which includes tube **22A** is truly a grounded grid amplifier stage. The portion of the circuit associated with tubes **14B** and **22B** functions in a similar fashion to pass the program signal present at input **12B** to the input of amplifier **32B**.

Resistors **42A**, **42B** and **44** form a conventional resistive adder network for supplying to the grid of driver amplifier tube **46** a signal representative of the sum of the two amplified program signals present at the anodes of tubes **14A** and **14B**. Resistors **42A** and **42B** are made large so as to prevent coupling of a signal from the anode of tube **14A**, for example, to the cathode of tube **14B** by way of the anode-cathode path of tube **14B**. Such a signal would result in cross-talk between the two program signal channels of the stereophonic reproducer.

The operation of the reverberator unit **48** has been described above. In one particular embodiment of the invention, the amplitude versus frequency characteristic for reverberator unit **48** and coupling circuit **88** was substantially flat from 200 cycles to 4000 cycles. It dropped off at approximately the rate of 18 db per octave below 200 cycles and at approximately 54 db per octave at frequencies above 4000 cycles. It was found in practice that this characteristic together with the multiple delays provided by unit **48** and the amplitude selection permitted by potentiometer **104** permitted a very pleasing and realistic reverberant effect to be achieved at the output of the stereophonic reproducer. Different roll-off characteristics may be provided, however, if desired.

The movable tap on potentiometer **102** sets the maximum amplitude of the reverberated signal which may be combined with the two program signals at the input of amplifiers **32A** and **32B**. The provision of potentiometer **102** adds a certain degree of flexibility to the adjustment of the system. However it may be omitted in the interest of economy if desired.

Capacitor **107** is a blocking capacitor which prevents the anode bias potential of tube **86** from appearing at the grids of tubes **22A** and **22B**. Control **108** and tap **106** together provide means for selecting the appropriate amplitude of the reverberated signal for the particular location of the reproducer and the particular passage of music being played.

Since, as mentioned previously, the echoes in the reverberator unit die out in a logarithmic fashion, increasing the amplitude of the reverberated signal will increase the number of echoes which will be audible in the output of speakers **36A** and **36B**. It is to be understood that these signals do not appear as separate and distinct echoes but merely as a prolonged reverberation of the program signal. Obviously, it lies within the scope of the present invention to make potentiometer **104** continuously variable rather than tapped, but it has been found in practice that five levels of reverberation provide sufficient flexibility under most conditions.

The signal appearing at tap **106** is amplified in conventional fashion by tubes **22A** and **22B**. Tubes **22A** and **22B** and the resistors associated therewith function as two two-input signal adders. Therefore, the signal appearing at the anode of **22A**, for example, is the sum of one unreverberated program signal and the reverberated sum signal. Similarly, the signal at the anode of tube **22B** is the sum of the other program signal and the reverberated sum signal. These signals are amplified in the usual fashion by amplifiers **32A** and **32B**.

The unit shown in schematic form in FIG. 1 may be provided with its own power supply or it may share a power supply with the amplifiers **32A** and **32B**.

There is a limit as to the amount of energy which may be supplied to springs **60** and **62** by way of rotors **68** and **74**. Therefore the signal level at coil **84** may be quite low. For this reason it may be desirable to supply the heaters of tubes **86**, **22A** and **22B** with direct current to minimize hum in the signal at the anodes of tubes **22A** and **22B**.

It is to be understood that the drawings illustrate what is at present considered to be the preferred embodiment of the invention. Other forms of signal adders may be substituted for those shown. Also, a reverberator unit other than the one shown in FIG. 2 may be employed. For example, the reverberator unit may take the form of a coil of plastic pipe which is provided with a pressure chamber speaker at the transmitting end and a microphone at the receiving end.

Therefore, while the invention has been described with reference to the preferred embodiment thereof, it will be apparent that various modifications and other embodiments thereof will occur to those skilled in the art within the scope of the invention. Accordingly I desire the scope of my invention to be limited only by the appended claims.

I claim:

1. In a signal processing circuit: first and second amplifier stages, each of said amplifier stages comprising an amplifier element having first and second electrodes defining a main signal path, and a control electrode which together with said first electrode controls the current flow in said main signal path, each of said amplifier stages further comprising a first load impedance coupled to said first electrode, a second load impedance coupled to said second electrode, and a bias source coupled to the ends of said first and second load impedances remote from said amplifier element, signal coupling means coupling said first electrode of said amplifier element of said first stage to said first electrode of said amplifier element of said second stage, the impedance of said signal coupling means being large compared to the impedance of said first load impedance of said second amplifier stage, a signal modifier circuit coupling said second electrode of said amplifier element of said first stage to said control electrode of said amplifier element of said second stage, means for supplying a signal to be processed to said control electrode of said first stage, and means for deriving an output signal from said second load impedance of said second stage.

2. A signal processing circuit in accordance with claim 1 wherein said amplifier element in each stage comprises a vacuum tube and wherein said first electrode, said second electrode and said control electrode comprise the cathode, the anode and the control grid, respectively, of said vacuum tube.

3. A signal processing circuit in accordance with claim **2** wherein said signal modifier circuit comprises a signal reverberator unit.

4. A dual channel audio reproducer comprising: first and second signal channels; each of said signal channels comprising first and second amplifier stages; each of said amplifier stages comprising an amplifier element having first and second electrodes defining a main signal path, and a control electrode which together with said first electrode controls the current flow in said main signal path; each of said amplifier stages further comprising a first load impedance coupled to said first electrode and a second load impedance coupled to said second electrode; each of said signal channels further comprising signal coupling means coupling said first electrode of said amplifier element of said first stage to said first electrode of said amplifier element of said second stage, means for supplying a signal to be processed to said control electrode of said first stage, and an electroacoustical transducer coupled to said second load impedance of said second stage; said dual channel audio reproducer further comprising a bias source coupled to the ends of said first and second load impedances remote from said amplifier elements, first adder means coupled to said second load impedance of said first stage of each channel, a reverberator unit coupled to the output of said first adder means, and means coupling the output of said reverberator unit to said control electrode of said second stage in each of said two signal channels.

5. A dual channel audio reproducer in accordance with claim **4** wherein said last mentioned means includes signal attenuator means for controlling the amplitude of the signals supplied to the control electrode of said second stage in each of said two signal channels.

6. A dual channel audio reproducer comprising: first and second signal channels; each of said signal channels comprising first and second amplifier stages; each of said amplifier stages comprising an amplifier element having first and second electrodes defining a main signal path, and a control electrode which together with said first electrode controls the current flow in said main signal path; each of said amplifier stages further comprising a first load impedance coupled to said first electrode and a second load impedance coupled to said second electrode; each of said signal channels further comprising signal coupling means coupling said first electrode of said amplifier element of said first stage to said first electrode of said amplifier element of said second stage, means for supplying a signal to be processed to said control electrode of said first stage, and means for deriving an output signal from said second load impedance of said second stage; said dual channel signal processing circuit further comprising first adder means coupled to said second load impedance of said first stage of each channel, a reverberator unit coupled to the output of said first adder means, and a third signal input means coupled directly to said control electrode of said second stage in said first signal channel and said control electrode of said second stage in said second signal channel.

7. A dual channel audio reproducer in accordance with claim **6** wherein said amplifier element in each of said first and second amplifier stages of each channel comprises a vacuum tube having at least an anode, a cathode, and a control grid, and wherein said first electrode, said second electrode and said control electrode of said amplifier element comprises said cathode, said anode and said control grid of said vacuum tube.

8. In a signal processing circuit: first and second amplifier stages, each of said amplifier stages comprising a vacuum tube having an anode, a cathode and a control grid, each of said amplifier stages further comprising a first load resistor coupled to said cathode, a second load resistor coupled to said anode and a bias source coupled to the ends of said first and second load resistors remote from said vacuum tube, a third resistor coupling said cathode of said vacuum tube of said first stage to said cathode of said vacuum tube of said second stage, the impedance of said third resistor being large compared to the impedance of said first load resistor of said second amplifier stage, a signal modifier circuit coupling said anode of said vacuum tube of said first stage to said control grid of said vacuum tube of said second stage, means for supplying a signal to be processed to the control grid of said vacuum tube of said first stage and means for deriving an output signal from said second load impedance of said second stage.

9. A dual channel audio reproducer comprising: first and second signal channels, each of said signal channels comprising first and second amplifier stages; each of said amplifier stages comprising a vacuum tube having an anode, cathode and a control grid, a first load resistor coupled to said cathode and a second load resistor coupled to said anode; each of said signal channels further comprising a coupling resistor connected between said cathode of said first amplifier stage and said cathode of said second amplifier stage, means for supplying a signal to be processed to said control grid of said first stage, and an electroacoustical transducer coupled to said second load resistor of said second stage; said dual channel audio reproducer further comprising a bais source coupled to the ends of said first and second load resistors remote from said vacuum tubes, a first adder means coupled to said second load resistor of said first stage of each channel, a reverberator unit coupled to the output of said first adder means, and means coupling the output of said reverberator unit to said control grid of said second stage in each of said two signal channels.

10. In a stereo sound system: a pair of power amplifiers, the ouput of each being connected to a respective speaker, a pair of input channels for supplying independent signals to said power amplifiers, circuit means connecting said input channels to said power amplifiers, said connecting circuit means comprising: a first pair of amplifiers each having a cathode, a grid, and an anode; means connecting one of said grids to one of said input channels; means connecting the other of said grids to the other of said input channels; circuit means connected for mixing the outputs from both said anodes; means providing a reverberation mechanism having a driving unit and a driven unit; circuit means connecting said mixing circuit to said driving unit; amplifying means connected to said driven unit for amplifying the output of said driven unit; a second pair of amplifiers each having a cathode, a grid, and an anode; circuit means connecting said amplifying means to both of the last said grids; circuit means connecting one of the last said anodes to one of said power amplifiers; independent circuit means connecting the other of the last said anodes to the other of said power amplifiers; circuit means connecting one of the cathodes of said first pair of amplifiers to one of the cathodes of said last pair of amplifiers; and independent circuit means connecting the other of the cathodes of said first pair of amplifiers to the other of the cathodes of said last pair of amplifiers.

11. In a stereo sound system: a pair of power amplifiers, the output of each being connected to a respective speaker, a pair of input channels for supplying independent signals to said power amplifiers, circuit means connecting said input channels to said power amplifiers; said connecting circuit means comprising: a first pair of amplifiers each having a cathode, a grid, and an anode; means connecting one of said grids to one of said input channels; means connecting the other of said grids to the other of said input channels; circuit means connected for mixing the outputs from both said anodes; means providing a reverberation mechanism having a driving unit and a driven unit; circuit means connecting said mixing circuit to said driving unit; a second pair of amplifiers each having a cathode, a grid, and an anode; circuit means connecting said driven unit to both of the last said grids; circuit means connecting one of the last said anodes to one of said power amplifiers; independent circuit means connecting the other of the last said anodes to the other of said power amplifiers; circuit means connecting one of the cathodes of said first pair of amplifiers to one of the cathodes of said last pair of amplifiers; and independent circuit means connecting the other of the cathodes of said first pair of amplifiers to the other of the cathodes of said last pair of amplifiers.

12. In a stereo sound system: a pair of power amplifiers, the output of each being connected to a respective speaker, a pair of input channels for supplying independent signals to said power amplifiers, circuit means connecting said input channels to said power amplifiers; said connecting circuit means comprising: a first pair of amplifiers each having a cathode, a grid, and an anode; means connecting one of said grids to one of said input channels; means connecting the other of said grids to the other of said input channels; circuit means connected for mixing the outputs from said anodes; means providing a reverberation mechanism having a driving unit and a driven unit; circuit means connecting said mixing circuit to said driving unit; amplifying means connected to said driven unit for amplifying the output of said driven unit; a second pair of amplifiers each having a cathode, a grid, and an anode; circuit means connecting said amplifying means to both of the said last grids; circuit means connecting one of the said last anodes to one of said power amplifiers; independent circuit means connecting the other of the said last anodes to the other of said power amplifiers; circuit means connected for supplying one of said independent signals from one cathode of said first pair of amplifiers to one of the cathodes of the said last pair of amplifiers; and independent circuit means connected for supplying the other of said independent signals from the other cathode of said first pair of amplifiers to the other of the cathodes of the said last pair of amplifiers.

13. In a stereo sound system: a pair of power amplifiers, the output of each being connected to a respective speaker, a pair of input channels for supplying independent signals to said power amplifiers, circuit means connecting said input channels to said power amplifiers; said connecting circuit means comprising: a first pair of amplifiers each having a cathode, a grid, and an anode; means connecting one of said grids to one of said input channels; means connecting the other of said grids to the other of

said input channels; circuit means connected for mixing the outputs from said anodes; means providing a reverberation mechanism having a driving unit and a driven unit; circuit means connecting said mixing circuit to said driving unit; a second pair of amplifiers each having a cathode, a grid, and an anode; circuit means connecting said driven unit to both of the said last grids; circuit means connecting one of the said last anodes to one of said power amplifiers; independent circuit means connecting the other of the said last anodes to the other of said power amplifiers; circuit means connected for supplying one of said independent signals from one cathode of said first pair of amplifiers to one of the cathodes of the said last pair of amplifiers, and independent circuit means connected for supplying the other of said independent signals from the other cathode of said first pair of amplifiers to the other of the cathodes of the said last pair of amplifiers.

14. A reverberation circuit arrangement for a stereophonic system having at least two stereophonic signal channels, comprising: a plurality of impedance members respectively connected between a junction thereof and signal points in at least two of said signal channels to provide a sum signal at said junction, a sum signal delay circuit connected to said junction for providing a delayed sum signal, transducer means, and means for applying said delayed sum signal to said transducer means.

15. An arrangement as claimed in claim 14, in which said signal channels have a given value of signal impedance at said signal points, and in which each of said impedance members has a value of impedance relatively greater than that of said given value of signal impedance.

16. An arrangement as claimed in claim 15, in which each of said impedance members has a value of impedance at least twenty times as great as that of said given value of signal impedance.

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