

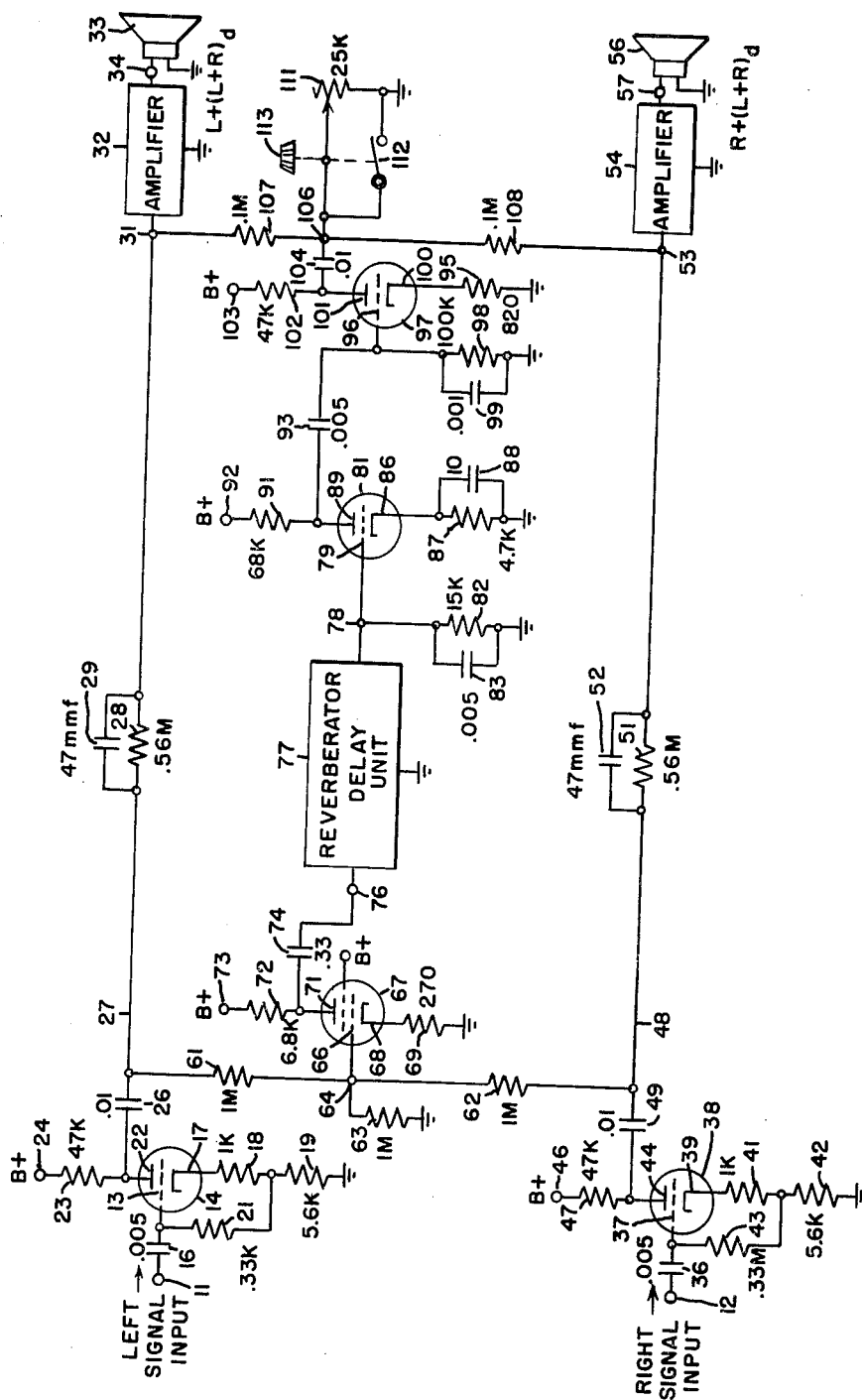
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J. BANG

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## STEREOPHONIC REVERBERATION CIRCUIT

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INVENTOR:  
JENS BANG,

BY *Norman C. Zulmer*  
HIS ATTORNEY.

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## STEREOPHONIC REVERBERATION CIRCUIT

Jens Bang, Decatur, Ill., assignor to General Electric Company, a corporation of New York

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This invention relates to stereophonic audio systems, and particularly to stereophonic audio systems provided with a reverberation effect. Such audio systems are useful in connection with stereophonic phonographs, stereophonic tape players, stereophonic radios, and the like.

Stereophonic reverberation audio systems, of the type having left and right signal channels, have been provided with a signal delay device through which the sum of the left and right signals of the two stereophonic channels are fed, the delayed sum signal being recombined with the left and right stereophonic signals in the stereophonic signal channels, so that the audible signals emitted by each of the left and right stereophonic loudspeakers contains a delayed or reverberation sum component of the left and right signals, which creates a pleasing illusion of being in a large auditorium or concert hall. In such stereophonic reverberation systems, it is necessary to obtain the sum of the left and right signals, and, after delaying this sum signal, to feed the delayed sum signal into both the left and right stereophonic signal channels, without adversely affecting the stereophonic separation between the left and right signals of the two channels, i.e., without permitting the left signal to become contaminated with the right signal and vice versa. Previously known circuits for stereophonic reverberation have employed a pair of amplifier tubes respectively connected to the stereophonic channels for isolating the left and right signals from each other when combining these signals to form the sum thereof for feeding into the delay device, and also have employed an additional pair of isolation amplifier tubes for feeding the delayed sum signal to the respective left and right stereo channels. The addition of these tubes to a stereophonic amplifier circuit adds to the cost of the circuit, not only because of the cost of the tubes, but also because of the cost of providing increased power capacity in the amplifier to provide anode and heater power for these additional tubes. Furthermore, whenever amplifier stages are thus added to channels of a stereophonic circuit in order to obtain a sum of the left and right signals, there is the possibility of incurring undesired unbalance of the sum signal components due to a difference in amplification factors of the tubes.

An object of the invention is to obviate the above-mentioned drawbacks of prior art stereophonic reverberation circuits.

Another object is to provide an improved stereophonic reverberation circuit.

A further object is to provide a relatively inexpensive stereophonic reverberation circuit having adequate stereophonic separation between the left and right stereophonic signal channels.

An additional object is to provide a stereophonic reverberation circuit having improved balance of the left and right signal components of the reverberated signal.

Still other objects will be apparent from the following description and claims, and from the drawing.

The single figure of the drawing is an electrical schematic diagram of a preferred embodiment of the invention.

The stereophonic reverberation circuit of the invention comprises, basically, and in its preferred embodiment, an input pair of electrical impedance members connected in series directly between the two signal channels of a stereophonic amplifier to provide a sum of the stereo-

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phonic signals at the junction of these impedance members, a reverberation signal delay circuit connected to the junction, an output pair of electrical impedance members connected in series directly between the two signal channels and having their junction connected to the output of the signal delay circuit, and electrical impedance members respectively interposed in the two channels between the connections thereto of the aforesaid pairs of electrical impedance members. Thus, the sum of the stereophonic signals becomes delayed or "reverberated" in the reverberator circuit and this reverberated sum signal is fed to both of the stereophonic channels, whereby each of the stereophonic signals in the channels is accompanied by a pleasing reverberation effect.

The invention further comprises certain critical ratios of values for various of the aforesaid impedance members. Each impedance member of the aforesaid input pair has an impedance value considerably greater than the impedances of the stereophonic signal channels to which these members are connected, this impedance ratio being at least 20 to 1. Still further, the invention comprises a reverberation control rheostat connected between electrical ground and the junction of the aforesaid output pair of impedance members, each of the members of the output pair of impedance members having an impedance value considerably greater than the maximum impedance of the reverberation control rheostat, this impedance ratio being at least 4 to 1. The aforesaid impedance ratios insure adequate stereophonic separation of the stereophonic signals in the two channels. Preferably, the aforesaid impedance members that are respectively interposed in the two stereophonic channels between the connections thereto of the pairs of impedance members, each has an impedance value intermediate that of each of the impedance members of the input pair of impedance members and that of each of the impedance members of the output pair of impedance members.

Now referring to the drawing, the preferred embodiment of the invention comprises a stereophonic amplifier system having a left stereophonic signal input terminal 11 and a right stereophonic signal input terminal 12. The left and right input signals may be provided by a phonograph, magnetic tape player, stereophonic radio, or the like. The left signal input terminal 11 is coupled to the grid 13 of a left signal channel amplifier tube 14, via a coupling capacitor 16. The cathode 17 of this tube is connected to electrical ground via series connected resistors 18 and 19, and the grid 13 is connected to the junction of the aforesaid resistors by means of a resistor 21, thereby providing proper grid bias. The anode 22 of this tube is connected, via a resistor 23, to a terminal 24 of suitable B+ voltage and is coupled, via a capacitor 26, to a conductor 27. A parallel combination of a resistor 28 and capacitor 29 is connected between the conductor 27 and the input terminal 31 of an amplifier 32 which may contain the usual volume control, balance control, and tone controls. A "left" loudspeaker 33 is connected to the output terminal 34 of the amplifier 32.

The right signal input terminal 12 is coupled, via a capacitor 36, to the control grid 37 of a right channel amplifier tube 38. The cathode 39 of tube 38 is connected to electrical ground via a series connected pair of resistors 41 and 42, and the grid 37 is connected to the junction of these resistors via a resistor 43 to provide suitable grid bias. The anode 44 of tube 38 is connected to a terminal 46 of B+ voltage, via a resistor 47, and also is connected to a conductor 48 via a capacitor 49. A parallel combination of a resistor 51 and capacitor 52, is connected between the conductor 48 and the input terminal 53 of a right channel amplifier 54 which may contain the usual volume control and balance control and tone

controls, the aforesaid controls of the amplifiers 32 and 54 conventionally being ganged together to provide simultaneous control of gain, balance and tone in the two amplifiers 32 and 54. A "right" loudspeaker 56 is connected to the output terminal 57 of the amplifier 54. In the circuit thus far described, the left stereophonic signal is amplified, in the amplifier tube 14 and in the amplifier 32, and fed to the loudspeaker 33. Similarly, the right stereophonic signal is amplified by the amplifier tube 38 and by the amplifier 54, and is applied to the "right" loudspeaker 56, thereby providing stereophonic sound in accordance with the left and right input signals.

The reverberation circuit comprises an input pair of resistors 61 and 62, preferably of equal value, connected in series directly across and between the conductors 27 and 48 of the left and right stereophonic channels. A resistor 63 is connected between electrical ground and the junction 64 of resistors 61 and 62, and the control grid 66 of a sum signal amplifier tube 67 is connected to the junction 64. The cathode 68 of tube 67 is connected to electrical ground via a resistor 69, and the anode 71 is connected via a resistor 72 to a terminal 73 of B+ voltage. The anode 71 also is coupled, via a capacitor 74, to the input terminal 76 of a reverberator delay unit 77. The reverberator delay unit 77 may comprise any of the various known means for delaying an electrical signal, such as an electrical delay line, or acoustical or mechanical delay means such as are described in U.S. Patent 2,318,417 issued May 4, 1943 to W. D. Phelps and assigned to the same assignee as the present invention. An output terminal 78 of the unit 77 is connected to a grid 79 of a reverberation signal amplifier tube 81. A resistor 82 and capacitor 83 are parallel connected between electrical ground and the grid 79. A cathode 86 of tube 81 is connected to electrical ground via a parallel combination of a resistor 87 and a capacitor 88. An anode 89 of tube 81 is connected, via a resistor 91 to a terminal 92 of B+ voltage, and also is connected, via a coupling capacitor 93, to the control grid 96 of a second amplifier tube 97. The grid 96 is coupled to electrical ground via the parallel combination of a resistor 98 and capacitor 99. The cathode 100 is connected to electrical ground via a resistor 95. An output anode 101 of tube 97 is connected, via a resistor 102, to a terminal 103 of B+ voltage, and also is connected, via a coupling capacitor 104, to a reverberation circuit output terminal 106. A pair of output resistors 107, 108 are connected in series directly between the input terminal 31 of amplifier 32 and the input terminal 53 of amplifier 54, the junction of these resistors 107 and 108 being connected to the reverberation circuit output terminal 106. Preferably, the resistors 107 and 108 have equal values of resistance. A rheostat 111 is connected between the junction 106 and a signal reference point such as electrical ground. A switch 112 is connected across the rheostat 111. If desired, the switch 112 may be mechanically connected to be closed when the control knob 113 of the rheostat 111 is pulled to an "outer" position.

The circuit functions as follows. As has been explained above, the left stereophonic signal passes through the amplifier tube 14, the parallel combination of resistor 28 and capacitor 29, and the amplifier 32, to the "left" loudspeaker 33. Similarly, the right stereophonic signal passes through the amplifier tube 38, the parallel combination of resistor 51 and capacitor 52, and the amplifier 54, to the "right" loudspeaker 56. The left stereophonic signal also passes, from the left channel conductor 27 and through the input resistor 61, to the reverberation circuit input terminal 64, and the right stereophonic signal passes, from the right channel conductor 48 and through the input resistor 62, to the terminal 64. Thus, there is provided at the terminal 64 a sum of the left and right stereophonic signals. This sum signal is amplified by the amplifier tube 67, and is applied to the reverberator delay unit 77, wherein the sum signal becomes delayed.

The amount of delay is chosen to give a pleasing effect. A suitable delay has been found to be about 25-50 milliseconds. The reverberator delay unit 77 may, if desired, be provided with a plurality of delay devices respectively having different amounts of delay, whereby the sum signal is delayed simultaneously by different amounts, thereby increasing the overall reverberation effect. The reverberated sum signal at the output terminal 78 of the reverberator delay unit 77 is amplified by the tubes 81 and 97, and applied to the output junction 106 from which the reverberated sum signal is respectively fed, via the resistors 107 and 108, to the input terminals 31 and 53 of the left and right channel amplifiers 32 and 54. Thus, the "left" loudspeaker 33 provides an audible signal having as components thereof the left stereophonic signal and the delayed sum of the left and right stereophonic signals, and the "right" loudspeaker 56 provides audible signals having as components thereof the right stereophonic signal and the delayed sum of the left and right signals. The rheostat 111 functions as a volume control for the amount of reverberation effect. Switch 112, when closed, turns off the reverberation effect.

The circuit of the drawing is provided with component values of the resistors (in ohms) and capacitors (in microfarads except where otherwise indicated), because the values of certain resistors are critical with respect to values of other resistors in the circuit. The value of each of the input resistors 61 and 62 of the reverberation circuit must be relatively large compared with the signal impedance of the conductors 27 and 48 of the left and right signal channels. The impedances of the left and right signal channels at the conductors 27 and 48 are primarily determined by the values of the plate load resistors 23 and 47, respectively. Thus, resistor 61 must have a relatively larger value than that of resistor 23, and resistor 62 must have a relatively larger value than that of resistor 47. A suitable ratio of these resistor values is at least 20 to 1. This ratio of impedance values insures that relatively little of the left signal can pass through the resistors 61 and 62 to the right channel conductor 48, and likewise relatively little of the right signal can flow through the resistors 61 and 62 to the left channel conductor 27. Thus, adequate stereophonic signal separation is maintained in the two channels.

To insure adequate stereo signal separation between the two channels at the output of the reverberation circuit, each of the resistors 107 and 108 should have a resistance value considerably greater than that of the rheostat 111. The ratio of resistance value of each of the resistors 107 and 108, to the maximum resistance value of the rheostat 111, should be at least 4 to 1. However, even if the resistance of the rheostat 111 is not as low in proportion to the values of resistors 107 and 108 as is required to maintain stereo separation between the two channels, the stereophonic separation will be lost only in the same degree as the reverberation is injected into the two channels, and with a higher degree of reverberation signal fed to the two channels, it is not so important to maintain a high degree of stereophonic separation, because the addition of reverberated sum signal into the two channels tends to reduce the amount of stereophonic signal separation.

The resistors 28 and 51, which respectively are connected between the channel conductors 27 and 48 and the input terminals 31 and 53 of the left and right channel amplifiers 32 and 54, are for the purpose of isolating the input and output connections of the reverberation circuit. The parallel capacitors 29 and 52 are for the purpose of boosting the amplitudes of the higher frequencies slightly, in order to compensate for a slight loss in high frequency response which the resistors 28 and 51 tend to cause. The value of each of the resistors 28 and 51 should preferably lie between the value of each of the input reverberation circuit resistors 61 and 62, and that of the reverberation circuit output resistors 107 and 108.

Other isolating means, such as amplifier stages, could be used in lieu of the resistors 28 and 51.

It has been found that the stereophonic reverberation of this invention achieves the desired objects, and provides a pleasing stereophonic reverberation effect with a simple and relatively low-cost circuit.

While a preferred embodiment of the invention has been shown and described, various other embodiments and modifications thereof will become apparent to those skilled in the art but will fall within the scope of invention as defined in the following claims. For example, while described in connection with 2-channel stereo, the invention can be applied to stereo having more than two channels, by adding together the signals of all channels by means of resistors similar to 61 and 62, and by feeding the delayed sum signal to all of the channels by means of resistors similar to 107 and 108.

What I claim is:

1. A reverberation circuit arrangement for a stereophonic system having at least two stereophonic signal channels, comprising a first plurality of impedance members respectively connected between a junction thereof and first 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 and adapted to provide a delayed sum signal at an output thereof, a second plurality of impedance members respectively connected between said output of the delay circuit and second signal points in said signal channels to apply the delayed sum signal thereto, and signal isolating means respectively interposed in said signal channels between said first and second signal points.

2. An arrangement as claimed in claim 1, in which said signal isolating means each comprises an impedance member.

3. An arrangement as claimed in claim 2, in which the impedance members of said first plurality thereof have substantially equal impedance values, in which the impedance members of said second plurality thereof have substantially equal impedance values, and in which the impedance members of said signal isolating means each has an impedance value intermediate that of said first plurality of impedance members and that of said second plurality of impedance members.

4. An arrangement as claimed in claim 1, including a reverberation control rheostat connected between said output of the delay circuit and a signal reference point.

5. An arrangement as claimed in claim 4, including a reverberation control switch connected electrically across said rheostat.

6. 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 and adapted to provide a delayed sum signal, transducer means and means for applying said delayed sum signal to said transducer means.

7. An arrangement as claimed in claim 6, 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.

8. An arrangement as claimed in claim 7, 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.

9. A reverberation circuit arrangement for a stereophonic system having at least two stereophonic signal channels, comprising means connected to at least two of said channels and adapted to provide a sum of the signals of said last named signal channels, a sum signal delay circuit connected to receive said sum of the signals and adapted to provide a delayed sum signal at an output thereof, and a plurality of impedance members respectively connected between said output of the delay circuit and signal points in at least two of said signal channels to apply the delayed sum signal thereto.

10. An arrangement as claimed in claim 9, including a reverberation control rheostat connected between said output of the delay circuit and a signal reference point.

11. An arrangement as claimed in claim 10, including a reverberation control switch connected electrically across said rheostat.

12. An arrangement as claimed in claim 10, in which each of said plurality of impedance members has an impedance value substantially greater than the maximum impedance of said rheostat.

13. An arrangement as claimed in claim 12, in which each of said plurality of impedance members has an impedance value at least four times as great as the maximum impedance of said rheostat.

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ROBERT H. ROSE, *Primary Examiner*.

THOMAS B. HABECKER, *Examiner*.