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[54] **FOUR CHANNEL SOUND REPRODUCTION SYSTEM**

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July 16, 1970	Japan	45/61980
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[52] **U.S. Cl.** .... **179/1 GQ,** 179/1 GP

[51] **Int. Cl.** **H04r 5/00**

[58] **Field of Search** .... 179/1 G, 1 GP, 1 GA, 179/15 BT, 100.4 ST, 100.1 TP

[56] **References Cited**

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[57] **ABSTRACT**

A sound reproduction system comprising a stereophonic source for generating right and left audio signals, signal combining means for combining said right and left signals to obtain four composite audio signals, phase shifting means for shifting the phases of said composite signals to prevent any of said composite signals from being substantially reversed in phase from the others, and four electroacoustic transducers located so as to define a listening area and supplied with said four composite signals respectively.

11 Claims, 8 Drawing Figures

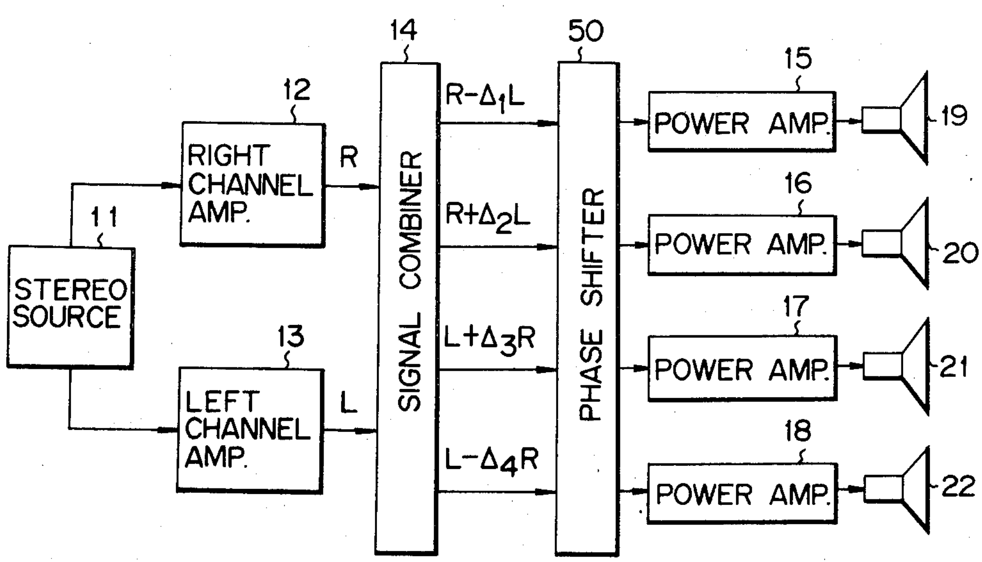

FIG. 1

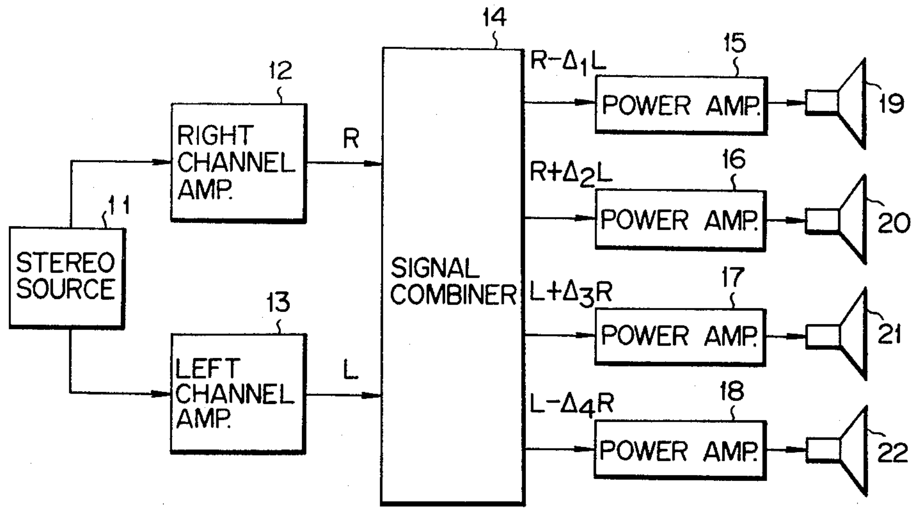

FIG. 2

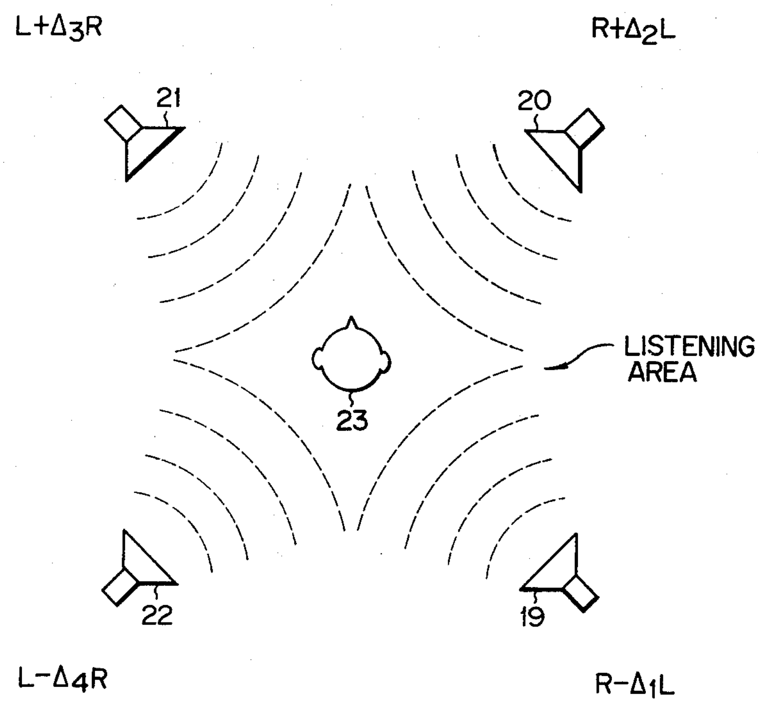

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FIG. 3

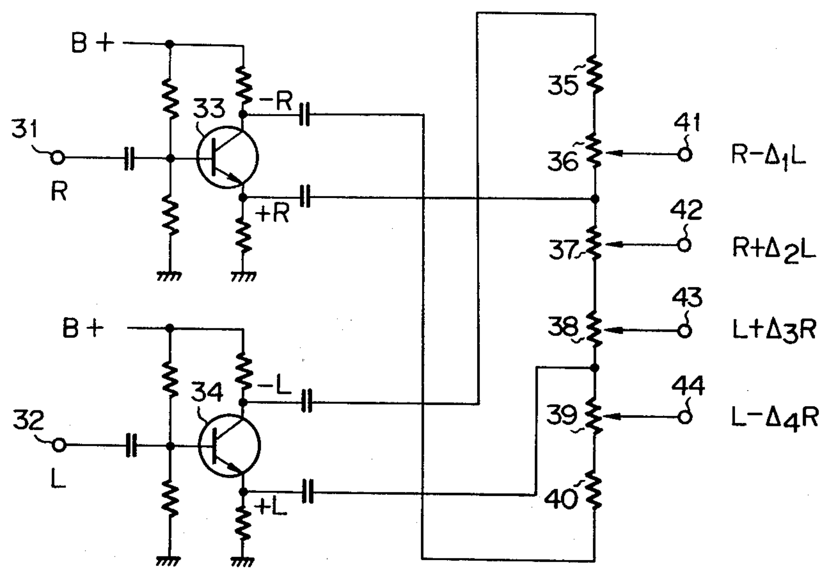

FIG. 4

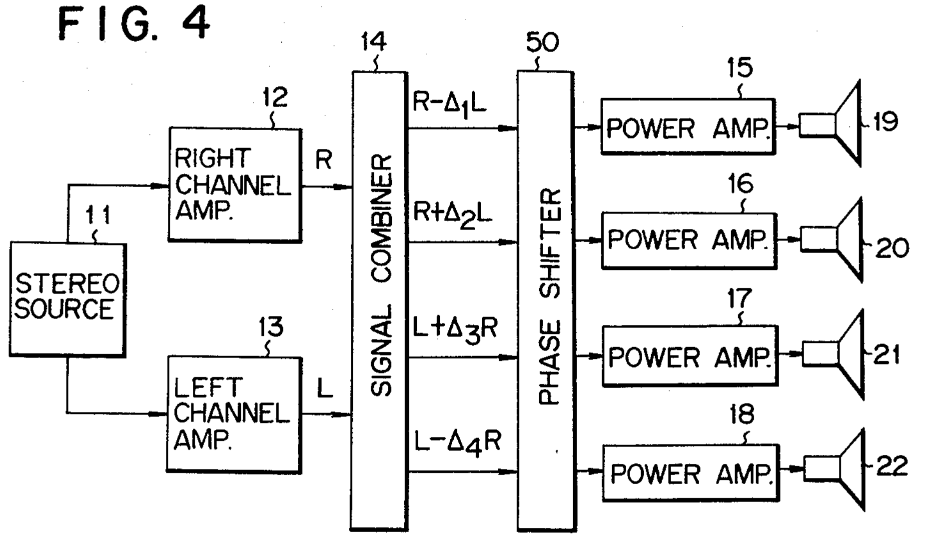

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FIG. 5

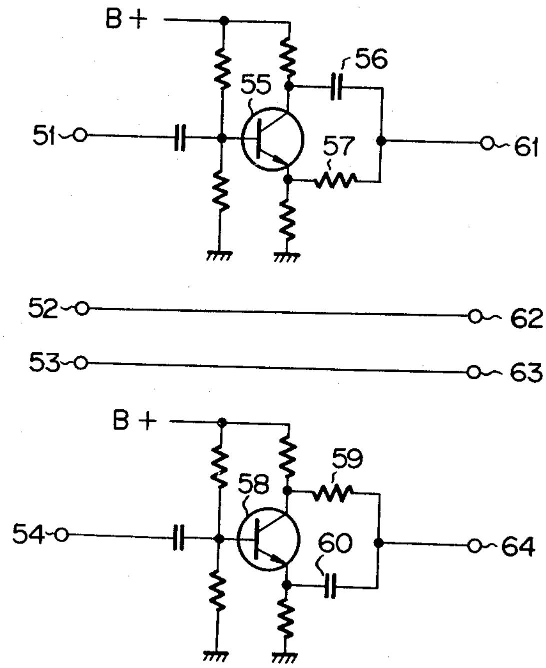

FIG. 6

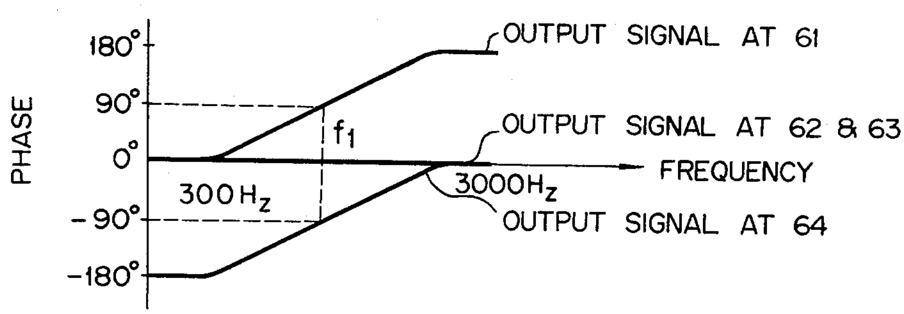

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FIG. 7

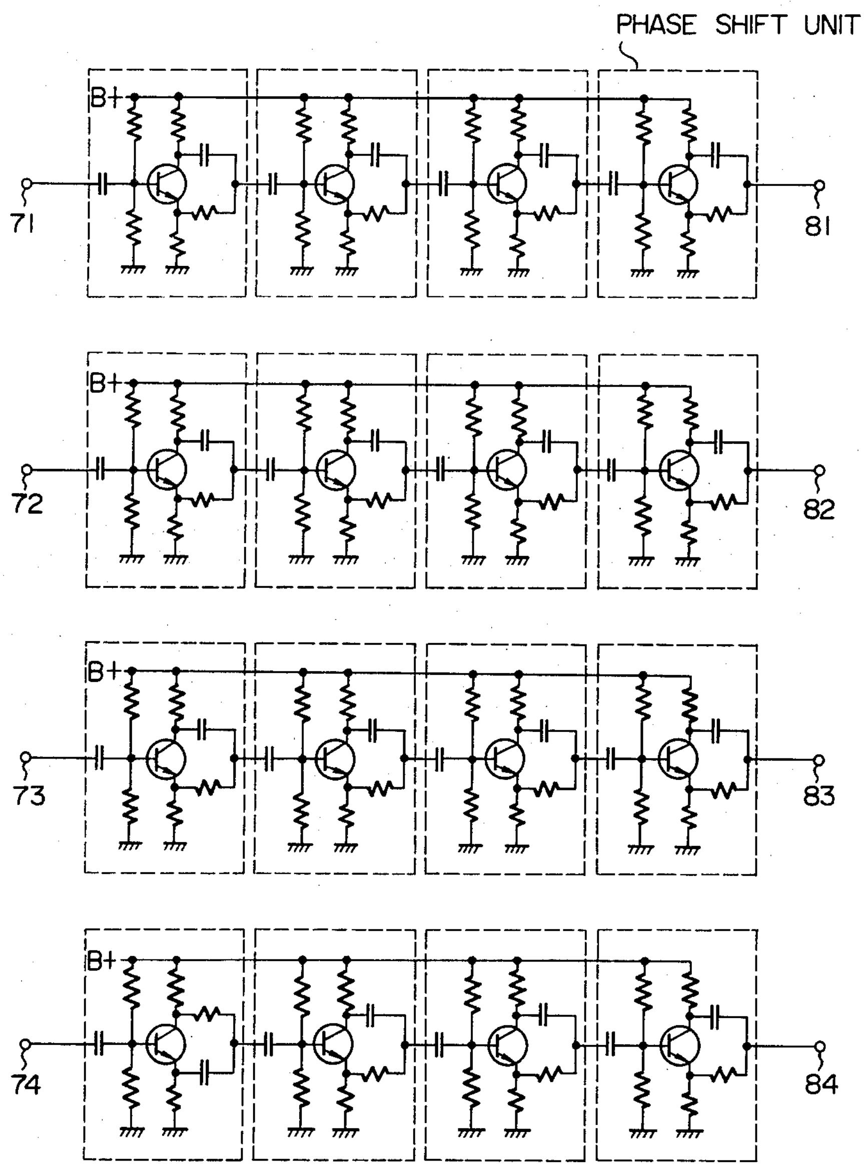

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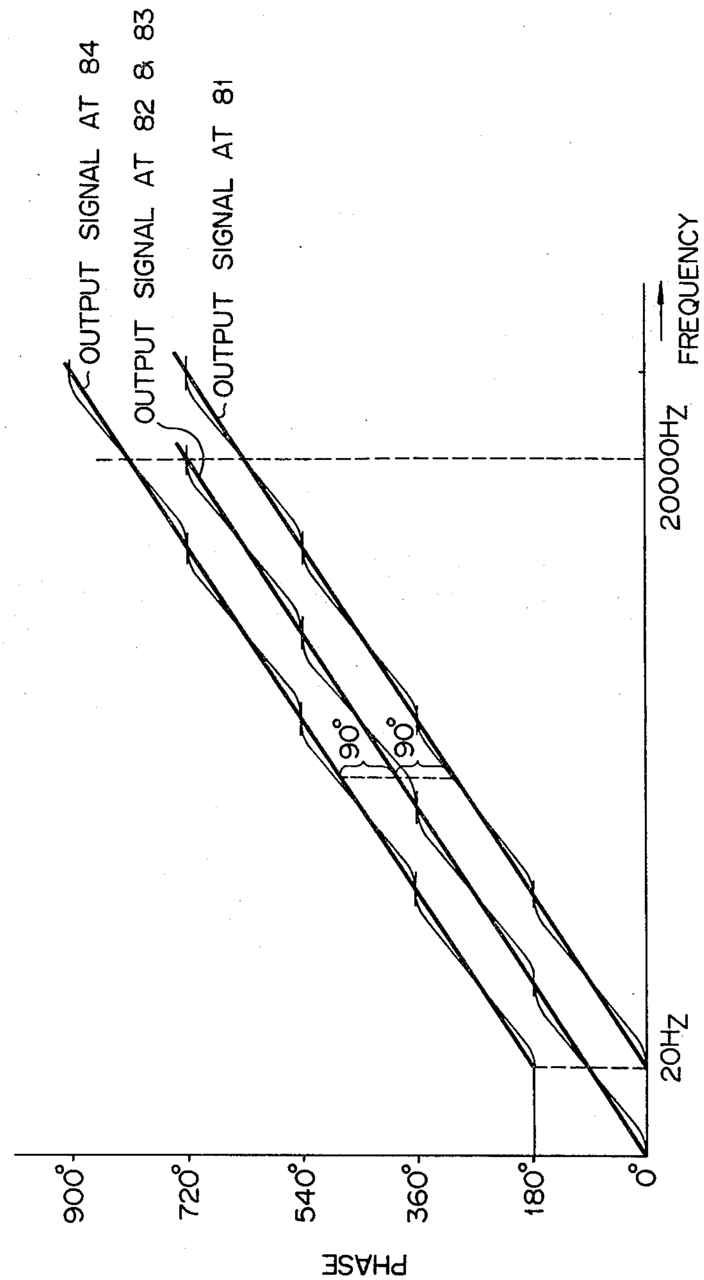
FIG. 8



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FOUR CHANNEL SOUND REPRODUCTION SYSTEM

This invention relates to a sound reproduction system and more particularly to a stereophonic sound reproduction system which consists in combining right and left stereophonic signals to draw out four composite signals representing the sum of and balance between the right and left signals and supplying said composite signals to loud-speakers respectively.

The conventional so-called two-channel type stereophonic sound reproduction system generates sounds corresponding to right and left stereophonic signals from two loud-speakers disposed on the right and left sides slantwise ahead of a listener in the same listening area, so as to make the listener feel that there are produced sounds at a certain point within a region defined by the two right and left loud-speakers. Since the point at which the listener feels sounds are produced is limited to an area defined by the two-loud-speakers, he can not sense the presence of any sound at other points, that is, aside or behind him. This prior art system, therefore, fails to display a satisfactory effect with respect to the so-called "feeling of the presence of sounds." This term as used herein means the feeling by which, for example, the audience in a concert hall senses the sounds actually played therein. In the concert hall, the audience receives sounds directly brought from a source of sounds ahead (direct sounds) and other sounds arriving from all sides by being reflected from the walls and ceiling of the concert hall (indirect sounds). In other words, the aforesaid term " a feeling of the presence of sounds" denotes the sound effect brought about only by the direct sounds and the indirect sound arriving in every direction from the actual sound source in the concert hall.

The object of this invention is to provide a sound reproduction system which enables the listener to have a better feeling of the presence of sounds using right and left audio signals produced by the prior art stereophonic sound reproduction system.

According to this invention, right and left stereophonic sound signals are combined by a signal combiner into two composite signals formed by adding up right and left signals and two other composite signals representing balances between right and left signals, and these four composite signals are supplied to four loud-speakers respectively. Said loud-speakers are disposed at the apices of a tetragon, enabling the listener in a listening room simultaneously to hear sounds produced by the loud-speakers in said quadrilateral listening area. The two composite signals respectively representing the sums of right and left signals are supplied to the loud-speakers placed on the right and left sides ahead of the listener and the two other composite signals respectively representing the balances between right and left signals are conducted to the two other loud-speakers disposed on the right and left sides behind the listener. The two composite signals formed of said sums correspond to the aforementioned direct sounds and the two other composite signals consisting of said balances correspond to the indirect sounds. Accordingly, reception of sounds given forth by the four loud-speakers enables the listener to have the same feeling of the presence of sounds as if he were in a concert hall.

The present invention can be more fully understood from the following detailed description when taken in conjunction with reference to the appended drawings, in which:

FIG. 1 is a block circuit diagram of a sound reproduction system according to an embodiment of this invention;

FIG. 2 illustrates the arrangement of the electro-acoustic transducers included in the sound reproduction system of FIG. 1;

FIG. 3 shows a concrete circuit of the block 14 of FIG. 1;

FIG. 4 is a block circuit diagram of a sound reproduction system according to another embodiment of the invention;

FIG. 5 indicates a concrete circuit of the block 50 of FIG. 4;

FIG. 6 graphically presents the phase-shifting properties of the circuit of FIG. 5 with respect to frequency;

FIG. 7 is another concrete circuit of the block 50 of FIG. 4; and

FIG. 8 graphically shows the phase-shifting properties of the circuit of FIG. 7 with respect to frequency.

There will now be described by reference to FIG. 1 a sound reproduction system according to an embodiment of this invention. Right and left audio signals from a source 11 of stereophonic audio signals, for example, a disk or magnetic tape, are amplified by amplifiers 12 and 13 respectively, and supplied to a signal combiner 14. With right channel signals supplied to the signal combiner 14 designated as R and left channel signals supplied thereto as L, then output signals from said signal combiner 14 may be expressed by $R-\Delta_1L$, $R+\Delta_2L$, $L+\Delta_3R$ and $L-\Delta_4R$ respectively (where Δ_1, Δ_2, Δ_3 and Δ_4 represent proportion constants each having a proper value of $0<\Delta_1, \Delta_2, \Delta_3, \Delta_4<1$).

The four loud-speakers 19, 20, 21 and 22 are arranged as shown in FIG. 2, that is, at the apices of a tetragon so as to face the interior of a substantially quadrilateral listening area. As viewed from a listener located substantially at the center of said listening area, the loud-speaker 19 is disposed on the right rear side, the loud-speaker 20 on the right front side, the loud-speaker 21 on the left front side and the loud-speaker 22 on the left rear side.

The stereophonically related right and left signals are normally picked up by two microphones respectively positioned on the right and left sides of a sound source. Accordingly, said right and left signals include components representing direct sounds and those representing indirect sounds reflected from the walls and ceiling of, for example, a concert hall. The right and left direct sound signal components have substantially the same wave forms, levels and phases. On the other hand, the indirect sound signal components are a sum total of those representing indirect sounds reflected from the walls and ceiling of the concert hall and brought to the microphones through many routes, so that they vary in wave form, level and phase. Therefore, direct sound signal components are extinguished in composite signals representing balances between right and left signals, resulting in the inclusion of large proportions of indirect sound signal components. Other composite signals representing sums of right and left signals contain larger amounts of direct sound signal components than the original right or left audio signal.

Thus as illustrated in FIG. 2, the listener 23 receives from the loud-speaker 20 on the right front side sounds containing large amounts of direct sound components and corresponding to signals [$R+\Delta_2L$] containing large proportions of the right signal; from the left front loud-speaker 21 sounds containing large amounts of direct sound components and corresponding to signals [$L+\Delta_3R$] containing large proportions of the left component signal; from the right rear loud-speaker 19 sounds containing large amounts of indirect sound components and corresponding to signals [$R-\Delta_1L$] containing large proportions of the right signal; and from the left rear loud-speaker 22 sounds containing large amounts of indirect sound components and corresponding to signals [$L-\Delta_4R$] containing large proportions of the left signal. Accordingly, the listener 23 sitting in a quadrilateral listening area defined by the four loud-speakers 19, 20, 21 and 22 is surrounded with sounds arriving from all sides as if he were present in a concert hall, that is, the listener is fully impressed with the presence of sounds.

FIG. 3 is a concrete circuit of the signal combiner 14 of FIG. 1. The right signal (R) supplied to the input terminal 31 of said combiner 14 is impressed on the base of an NPN transistor 33 to produce signals of reverse phase (−R) in the collector thereof and signals of the same phase (R) in the emitter thereof. The left signal (L) conducted to the input terminal 32 of said combiner 14 is impressed on the base of an NPN transistor 34 to produce signals of reverse phase (−L) in the collector thereof and signals of the same phase (L) in the emitter thereof. The collector of the first mentioned NPN transistor 33 is connected to one end of a resistor 40 through a coupling capacitor. A resistor 35, variable resistors 36, 37, 38 and 39 and resistor 40 are connected in series to constitute a voltage dividing circuit. The collector of the latter NPN transistor 34 is connected through a coupling capacitor to one end of the voltage dividing circuit, that is, one end of the resistor 35. The emitter of the transistor 33 is connected through a coupling capacitor to the contact of the variable resistors 36 and 37 and the emitter of the transistor 34 is connected through a coupling capacitor to the contact of the variable resistors 38 and 39. The variable contacts of the variable resistors 36, 37, 38 and 39 are connected to the output terminals 41, 42, 43 and 44 respectively of the aforementioned signal combiner 14. Resistance between the resistors 35 and 40 and resistance across the fixed terminals of the variable resistors 36, 37, 38 and 39 have an equal value. At the output terminals 41, and 44, therefore, are obtained composite signals $R-\Delta_1L$ and $L-\Delta_4R$ representing balances between right and left signals. At the output terminals 42 and 43 are obtained composite signals $R+\Delta_2L$ and $L+\Delta_3R$ representing sums of right and left signals. The proportion constants Δ_1, Δ_2, Δ_3 and Δ_4 may be chosen to have an arbitrary value ranging from zero to 1. It has been experimentally confirmed that if Δ_1, Δ_2, Δ_3 and Δ_4 are respectively set at a value generally ranging between 0.3 and 0.5, then there will be obtained good results. In some cases, however, there is not obtained a satisfactory sound effect with such values, depending on the stereophonic relationship of right and left signals generated from a source of stereophonic audio signals. In such case, the variable contacts of the variable resistors 36, 37, 38 and 39 are operated so as to determine such values of the proportion constants Δ_1, Δ_2, Δ_3 and Δ_4 are as capable of displaying the best stereophonic effect.

FIG. 4 is a block circuit diagram of a sound reproduction system according to another embodiment of this invention. As seen from the figure, this embodiment only differs from that of FIG. 1 in that there is additionally provided a phase shifter 50 between the output side of the signal combiner 14 and power amplifiers. Accordingly, the same parts of FIG. 4 as those of FIG. 1 are denoted by the same numerals and description thereof is omitted. In the embodiment of FIG. 4, the electroacoustic transducers 19, 20, 21 and 22 are arranged in the same way as in FIG. 2.

Referring again to FIGS. 1 and 2, the loud-speakers 19 and 22 placed behind a listener 23 give forth sounds corresponding to the composite signals $R-\Delta_1L$ and $L-\Delta_1R$. As can be inferred from the relationship of said signals, these output sounds are reversed in phase from each other and cause the listener in the listening area to feel the untruthfulness of said sounds to those originally played. Accordingly, the embodiment of FIG. 4 additionally uses the phase shifter 50 to remove such difficulties by substantially eliminating the reverse phase relationship of the aforemen-tioned composite signals representing the balances between the right and left signals. The phase shifter 50 shifts the phase of the composite signal $R-\Delta_1L$ substantially by +90° and that of the composite signal $L-\Delta_1R$ substantially by −90° to cause sounds obtained from the rear loud-speakers 19 and 22 to have the same phase, thereby allowing the sounds produced by the rear and front loud-speakers 19 and 20 to be differentiated in phase substantially by 90° and the sounds generated by the front and rear loud-speakers 21 and 22 to be differential in phase substantially by 90°. Under such arrangement, any two of the four loud-speakers 19, 20, 21 and 22 defining a quadrilateral listening area do not substantially give forth sounds having a mutually reverse phase, thus enabling the listener to be relieved of unpleasantness resulting from the untruthfulness of sounds to those originally played.

The phase shifter 50 may consist of concrete circuits shown in FIGS. 5 and 7. The circuit of FIG. 5 carries out phase shifting substantially by 90° with respect to certain audio frequencies f_1, and the circuit of FIG. 7 performs phase shifting substantially by 90° over the entire audio frequency range. While the arrangement of FIG. 7 is more preferred, that of FIG. 5 well serves practical applications. Referring to FIG. 5, the input terminals 51, 52, 53 and 54 of the phase shifter 50 which are connected to the corresponding output terminals 41, 42, 43 and 44 of the signal combiner 14 are supplied with composite signals expressed by $R-\Delta_1L$, $R+\Delta_2L$, $L+\Delta_3R$ and $L-\Delta_4R$. The input terminal 51 is connected to the base of an NPN transistor 55, the collector of which is connected to one end of a capacitor 56 and the emitter of which is connected to one end of a resistor 57. The other ends of said capacitor 56 and resistor 57 are jointly connected to a common output terminal 61. The input terminals 52 and 53 are connected directly to output terminals 62 and 63 respectively. The input terminal 54 is connected to the base of an NPN transistor 58, the collector of which is connected to one end of a resistor 59, and the emitter of which is connected to one end of a capacitor 60. The other ends of said resistor 59 and capacitor 60 are jointly connected to a common output terminal 64. The phase-shifting properties of the phase shifter of FIG. 5 relative to frequency are presented in FIG. 6, which indicates the phase shifting properties of the phase shifter of FIG. 5 with respect to the frequencies of signals obtained at the output terminals **61, 62, 63** and **64** when the input terminals **51, 52, 53** and **54** are supplied with signals having the same phase. It has been experimentally proved that when the frequency f_1 shown in FIG. 6 is chosen to have a value of 300 to 3,000 Hz, then there will be obtained greater conveninece from the standpoint of a listener's sense of hearing. It will be apparent that to obtain the aforesaid phase-shifting properties to frequency, it is only required that the capacitors **56** and **60** and resistors **57** and **58** be set at a proper value.

FIG. 7 is another concrete circuit of the phase shifter **50.** This circuit has four series-connected phase shifting units disposed between input terminals **71, 72, 73** and **74** and the corresponding output terminals **81, 82, 83** and **84** respectively. FIG. 8 presents the phase-shifting properties of the circuit of FIG. 7 with respect to the frequencies of signals obtained at the output terminals **81, 82, 83** and **84** when the input terminals **71, 72, 73** and **74** are supplied with signals having the same phase. To obtain a phase shifter having such phase shifting properties relative to frequency, it will be apparent that with a circuit consisting of several groups of phase-shifting units connected in series in a proper number as shown in FIG. 7, the capacitors and resistors connected to the collectors and emitters of the transistors used in said circuit be chosen to have a proper constant. Accordingly, detailed description of said circuit is omitted.

When the input terminals **71, 72, 73** and **74** of the phase shifter **50** are connected to the corresponding output terminals **41, 42, 43** and **44** of the signal combiner **14** and the output terminals **81, 82, 83** and **84** of the phase shifter **50** are connected to the input terminals of the power amplifiers **15, 16, 17** and **18,** then over the entire audio frequency range of **20** to 20,000 Hz, sounds produced by the rear loud-speakers **19** and **22** have substantially the same phase; sounds obtained from the rear and front loud-speakers **19** and **20** are differentiated in phase substantially by 90°; and sounds given forth by the front and rear loud-speakers **21** and **22** are differentiated in phase substantially by 90°. Accordingly, sounds generated by the loud-speakers **19, 20, 21** and **22** are not reversed in phase from each other, thus relieving the listener of unpleasantness resulting from the untruthfulness of sounds to those originally played.

What we claim is:

1. A sound reproduction system comprising:

means for generating stereophonically related right and left audio signals;

means for combining said right and left signals to form at least four composite signals, a first composite signal being a differential signal formed by subtracting the left signal from the right signal, a second composite signal being a sum signal formed by adding the left signal to the right signal, a third composite signal being a sum signal formed by adding the right signal to the left signal and a fourth composite signal being a differential signal formed by subtracting the right signal from the left signal;

phase shifting means operating over a predetermined frequency range for shifting phase of at least two of said composite signals to cause the first and fourth composite signals to have substantially the same phase and prevent any of said composite signals from being substantially 180° out of phase from the others; and

at least four electroacoustic transducers so arranged as to define a listening area and supplied with said at least four composite signals respectively.

2. A sound reproduction system according to claim **1** wherein the electroacoustic transducers are substantially positioned at the apices of a tetragon and directed to the interior thereof.

3. A sound reproduction system according to claim **2** wherein, with the right and left signals designated as R and L respectively, the first of said four composite signals may be expressed by $R-\Delta_1L$, the second composite signal by $R+\Delta_2L$, the third composite signal by $L+\Delta_3R$ and the fourth composite signal by $L-\Delta_4R$ where Δ_1, Δ_2, Δ_3 and Δ_4 represent proportion constants each having a prescribed value falling within the range of zero to 1, the electroacoustic transducer placed on the right side behind the listener sitting in a quadrilateral listening area defined by said four electroacoustic transducers being supplied with the first composite signal, the electroacoustic transducer disposed on the right side ahead of the listener being supplied with the second composite signal, the electroacoustic transducer located on the left side ahead of the listener being supplied with the third composite signal, and the electroacoustic transducer positioned on the left side behind the listener being supplied with the fourth composite signal.

4. A sound reproduction system according to claim **3** wherein the phase shifting means shifts over a prescribed frequency range of 300 to 3,000 Hertz the phase of the first composite signal substantially by 90° in a prescribed direction and the phase of the fourth composite signal substantial-ly by 90° in the opposite direction, thereby preventing any of the sounds produced by the electroacoustic transducers from being substantially reversed in phase from the others.

5. A sound reproduction system according to claim **3** wherein the phase shifting means causes over the entire audio frequency range the first and fourth composite signals to have substantially the same phase, the first and second composite signals to be differentiated in phase substantially by 90°, the second and third composite signals to have substantially the same phase, the third and fourth composite signals to be differentiated in phase substantially by 90°, thereby preventing any of the sounds generated by the electro-acoustic transducers from being substantially reversed in phase from the others.

6. A sound reproduction system for use with a two channel source producing first and second audio signals and at least first, second, third and fourth electroacoustic transducers about a listener, with said first and second transducers being adapted to position at the front side of the listener and said third and fourth transducers at the rear side thereof, the combination comprising:

first means connected to receive said first and second audio signals for combining said first audio signal with an amplitude portion of said second audio signal;

second means connected to receive said first and second audio signals for combining said second audio signal with a portion of said first audio signal;

third means connected to receive said first and second audio signals for combining said first audio signal with an out-of-phase amplitude portion of said second audio signal;

fourth means connected to receive said first and second audio signals for combining said second audio signal with an out-of-phase amplitude portion of said first audio signal;

fifth means for coupling the output of said first means to said first transducer;

sixth means for coupling the output of said second means to said second transducer;

seventh means for coupling the output of said third means to said third transducer;

eighth means for coupling the output of said fourth means to said fourth transducer; and

phase shifter means connected between at least one of said third and seventh means and said fourth and eighth means to provide a predetermined phase difference between the outputs of said third and fourth means to thereby decrease the opposite phase relationship between the inputs of said third and fourth transducers.

7. The combination according to claim 6 including first phase shifter means connected between said third and seventh means and second phase shifter means connected between said fourth and eighth means, with said first and second phase shifter means having phase shifting characteristics for providing across a predetermined frequency range between the inputs thereof, a phase difference of about 180°.

8. The combination according to claim 7 wherein said predetermined frequency range is about 300 Hz to 3,000 Hz.

9. The combination according to claim 7 wherein said first and second phase shifter means phase-shifts the inputs thereof at a predetermined frequency by +90° and −90° respectively.

10. The combination according to claim 6 including first phase shifter means connected between said third and seventh means and second phase shifter means connected between said fourth and eighth means, and including third and fourth phase shifter means respectively connected between said first and fifth means and between said second and sixth means, and wherein said first to fourth phase shifter means have phase shifting characteristics for providing over the entire audible frequency range between the inputs of said first and second phase shifter means a phase difference of about 180°.

11. The combination according to claim 6 wherein said first to fourth means include at least first, second, third and fourth potentiometers connected in series and each having a slidable arm, and wherein one terminal of said series connection adjacent to said first potentiometer is connected to receive the out-of-phase signal of first audio signal, the other terminal thereof adjacent to said fourth potentiometer is connected to receive the out-of-phase signal of said second audio signal, the junction of said first and second potentiometers is connected to receive said second audio signal, and the junction of said third and fourth potentiometers is connected to receive said first audio signal.

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