TWO-CHANNEL STEREO SYSTEM WITH DERIVED CENTER CHANNEL

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FIG. 1

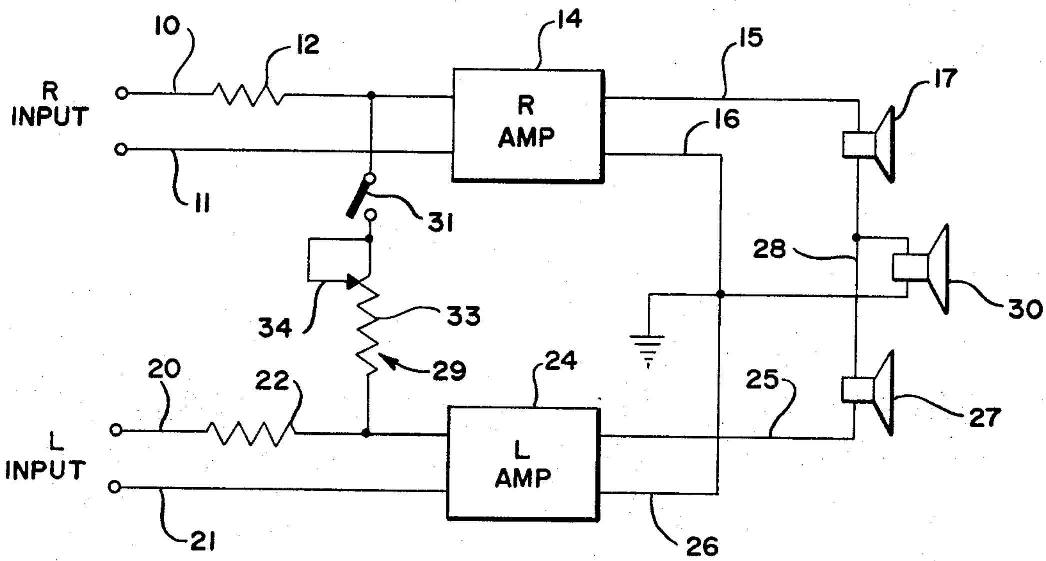
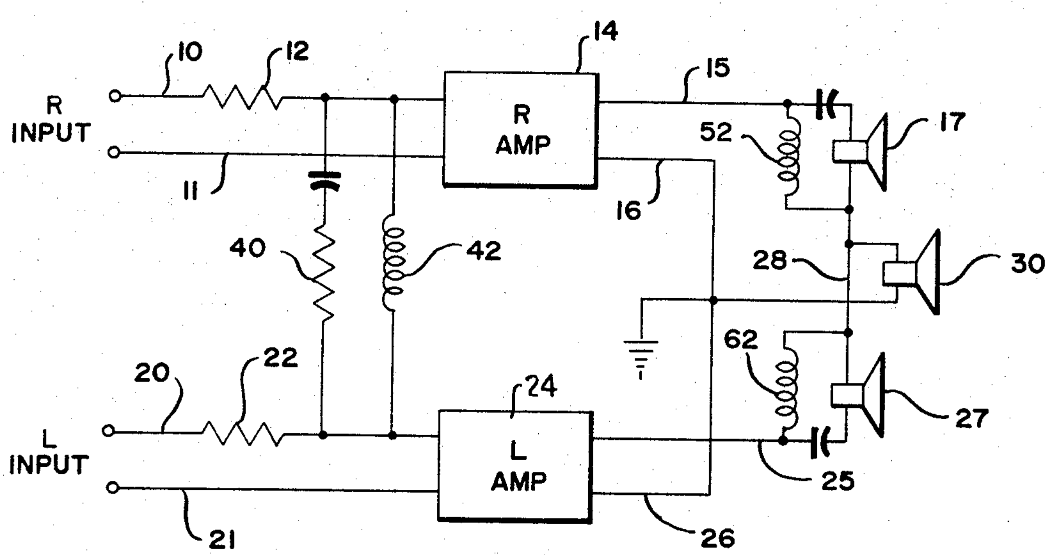


FIG. 2



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ABSTRACT OF THE DISCLOSURE

A derived center channel stereo reproduction system wherein the signal appearing in one of the left and right channels is reproduced by its corresponding transducer and is also reproduced by the opposite transducer out-of-phase. A blend circuit is included before the amplification stage to introduce a signal from one channel to the other, such that the out-of-phase component is cancelled.

The present invention relates generally to sound reproducing systems and, more particularly, to stereophonic sound reproducing systems wherein a center channel is derived from existing "left" and "right" channels.

Many variations of circuitry for adding a third channel to a basic two-channel stereophonic sound system have been proposed in the prior art. As is well known, a three-channel system may be simulated by the inclusion of a third speaker and associated components centrally located relative to the speakers associated respectively with the left and right channels, the third speaker being fed by a mixture of the left and right channel signals. In general, such systems have required, among other things, an additional amplifier for the third channel, or special matrixing transformers and/or signal deriving apparatus to provide suitable composite signal to the third channel speaker. The various advantages to be obtained from the addition or simulation of a center channel have, depending on the complexity of the required added structure, often been outweighed by the economic factor of increased system expense in the view of the average home listener.

The principal advantages of the derived center channel are (1) substantial elimination of the so-called "hole in the middle" present in the basic two-channel system, (2) improved reproduction of location and magnitude of the original centrally located sound sources, and (3) minimization of apparent shift in sound source magnitude when the listener turns his head or moves away from his on-center-axis position. However, such systems also have certain disadvantages in addition to the added cost factor, principal among which is the loss in stereophonic effect; that is to say, in the dimensional perspective or spatial distribution of the sound sources. The latter is caused primarily by a pronounced decrease in the apparent spread, i.e. reduction in apparent distance, between sources flanking the center.

The prior art also contains numerous proposals intended to overcome the latter disadvantage in the simulated three-channel system, such as by decreasing the sum to difference ratio of the two channels, by phase reversal of left or right channel amplifier or speaker, by controlled variation of the impedance of the center speaker, by use of positive and/or negative feedback in the channels, and so forth. None of these proposals has proved entirely successful and each has required the inclusion of several additional components to the basic two-channel system, thus increasing the system cost factor.

It is accordingly a principal object of the present invention to overcome the aforementioned disadvantages of prior art three-channel stereo systems.

In accordance with an embodiment of the present invention, a third channel is derived from existing "left" and "right" channels of a two-channel stereo system by connecting a center speaker to the left and right speakers in the so-called three-speaker, two-amplifier series circuit. In this circuit arrangement, the left and right speakers are serially connected across the amplifier output circuits of the two channels, and the center speaker is connected between the junction of the two speakers and a point of reference potential. Hence, each side speaker is effectively connected in series with the center speaker across its respective channel output circuit. Equal in-phase signals feeding left and right channel speakers will therefore tend to cancel each other out to produce a reduced signal level at those speakers, while the center speaker is driven by the sum of the two signals. This corresponds to the condition in which the signals are derived from central or near-central sound sources, and in such a situation the center speaker will predominate. For those signals which are purely or predominantly left or right, i.e. pure stereo of one channel only, the respective side speaker predominates and an in-phase signal of somewhat diminished amplitude will be applied to the center speaker. In this situation, furthermore, the signal will be cross-fed through the speaker system circuit to the opposite side speaker in reverse phase, the amplitude of the signal depending in part on amplifier output impedance and speaker impedance. To compensate for this undesirable effect; that is, to improve the distribution of signals to the speaker system array, a symmetrical impedance circuit is connected between the two channels antecedent to the amplifiers therein to permit controlled blending of signals from channel to channel. By proper selection of impedance circuit values, an in-phase signal is fed from one channel to the other in precise amount to eliminate, i.e. to balance out, the unwanted out-of-phase signal in the opposite channel speaker. Because of system symmetry, the compensation will occur irrespective of which channel is energized at any given instant. Therefore, the center channel speaker predominates on centrally derived information, while each side and center speaker share the information deriving from the respective flanking sound sources; and no undesired signal from one side appears on the opposite side.

It is, therefore, a more specific object of the present invention to provide a simulated three-channel stereophonic sound reproducing system which fills the central void in sound which existed in prior art systems without substantially detracting from the distinct separation of the flanking sound sources.

It is a further object of the present invention to provide a stereophonic sound reproducing system wherein a center speaker is provided for predominance on centrally derived information and wherein flanking sound source information retains its apparent spread by virtue of an improved distribution of signals to the speaker system array.

It is another object of the present invention to provide an improved three-channel stereophonic sound system by the novel modification of existing two-channel systems with a minimum of additive expense.

The above and still further objects, features and attendant advantages of the present invention will become apparent from a consideration of the following detailed description of specific embodiments thereof, especially when taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a partially schematic and partially block diagrammatic representation of one embodiment of a stereophonic sound system in accordance with the present invention; and

FIGURE 2 is a diagram of a further embodiment of the present invention.

Referring now to the drawings wherein like reference numerals are used to refer to like components, FIGURE 1 represents a simplified illustration, for purposes of clarity in describing the novel features of the present invention, of a stereophonic sound reproducing system. The left and right channels may be of conventional form and are substantial duplicates of each other. Therefore, a description of one channel is presumed sufficient to persons of ordinary skill in the art except in those areas of novelty to be hereinafter discussed. The right channel comprises an amplifier **14** having a suitable input circuit designated by input leads **10** and **11** which may include conventional components (not shown). The source impedance, Z_1, of the right channel is designated by reference numeral **12**. Right and left electroacoustic transducers, such as loud speakers **17** and **27**, respectively, are coupled in suitable manner to amplifiers **14** and **24**, as through an output transformer (not shown) in the amplifier output circuit via conductors **15** and **25**, respectively. The two speakers **17** and **27** are interconnected via conductor **28**. Reference potential connections in the two amplifier output circuits are provided in a conventional manner through conductors **16** and **26**.

In the speaker system thus far described, equal in-phase signals in each channel will be balanced out at the speakers to produce a null in sound therefrom. Moreover, the system may readily be balanced at this point by adjusting for a sound null with a monophonic input to the two channels.

A center speaker **30** is connected between the electrical junction of speakers **17** and **27** and a point of reference potential, in this case, ground potential. By virtue of this arrangement, the center speaker **30** will be driven by the sum of the signals present in each channel so that it will predominate when each channel has equal in-phase signals. For pure stereo of one channel only, the speaker system array will permit the cross-feeding of signals from the energized channel to the opposite channel speaker, and will thus diminish the stereophonic effect. If, for example, an output signal is obtained from right amplifier **14** only, this signal will appear across the right speaker **17**, with reduced amplitude across center speaker **30**, and oppositely phased across left speaker **27**.

To improve the distribution of signals to the speaker system array, an impedance circuit, generally designated at **29**, is coupled between the left and right channels to permit controlled blending of signal from one channel to the other. Impedance circuit **29** may comprise, for example, a variable resistor **33** having a movable tap or slider **34**, the resistor being connected via a switch **31** between leads **10** and **20** of the right and left channels respectively. Switch **31** may be employed for inclusion or removal of blend resistance **33**, but is not otherwise essential since it will generally be desired to provide signal blending at all times for three-channel stereo.

When properly adjusted, the blend resistor will feed an in-phase signal from one channel to the other with sufficiently reduced amplitude to precisely eliminate the oppositely phased signal which is cross-fed into the speaker of the non-energized channel. Since the system is symmetrical, undesired signals appearing at the left of speaker **27**, in the presence of a right channel signal only will be elminated, as will signals at the right speaker **17** in the presence of a left channel signal only.

Impedance circuit **29** may alternatively comprise a fixed resistance of preselected value to provide a null at the opposite speaker when signal is present in only one of the channels. In general, the fixed resistance is preferred because once the system has been balanced in the above-described manner no further adjustment is required.

The proper value of blend resistance to provide the

aforementioned effect may be determined by adjustment (if variable) or by selection (if fixed) to produce a null at one side loud speaker with a signal applied to the opposite channel. If the three speakers are of equal impedance, as will normally be the case, the proper value of blend resistance will be that which provides approximately 50 percent cross-feeding of signals between channels. More specifically, the proportion of blend, which is 50 percent in the above example, is set at approximately the ratio of the impedance value of the center speaker to the sum of the impedance values of the center speaker and one side speaker, or algebraically

$$E_x = E_o \left(\frac{Z_c}{Z_c + Z_f} \right)$$

where E_x is the cross-fed signal, E_o is the signal from which E_x is derived, Z_c is the center speaker impedance and Z_f is the impedance of each of the flanking or side speakers.

By virtue of this controlled signal blending, the side speaker associated with that channel which is energized at any given instant of time and the center speaker will share the signal in proportion to the ratio of side and center speaker impedance. The oppositely phase signal, which is cross-fed from the speaker system to the opposite side speaker, will be completely cancelled by the in-phase signal which proceeds from the energized channel via the impedance circuit **29** to that speaker.

Systems in accordance with the present invention will eliminate the "hole-in-the-middle" effect present in previously existing systems in a region along the central axis of the side speakers, and the apparent location of sound sources becomes virtually independent of the listener's position. Listening tests have confirmed that changes in listener position along a line parallel to the line of speakers produces insignificant shift in the sound sources. Since central or near-central sound sources will result in an essentially monophonic input to the two channels, the equal in-phase signals will produce a reduced output at left and right speakers and a predominant output at the center speaker. Moreover, because of the compensation introduced by the blend control impedance circuit, stereophonic separation is distinctly maintained for a wide variety of positions within the listening area. Sharing of the signal between side speaker and center speaker diminishes the apparent spread of the sound to some extent. However, this effect is controllable by increasing the spacing between side speakers.

Even in the extremely unusual situation of equal out-of-phase signals in the two channels, system performance is unaffected since the signals will cancel at the center speaker.

A further advantage of the present invention resides in the capability of impedance matching without undesirable losses. If all speakers are of equal impedance, proper matching is provided by selection of an impedance tap in each amplifier output circuit (for example, the output transformer tap) of a value double that of the normally required impedance for a like speaker connected only to that channel in the basic two-channel system. Thus, for example, if side and center speakers are each 8 ohm speakers, a 16 ohm output circuit tap will be selected for each circuit. For pure stereo of one channel only, the center speaker and side speaker of the energized channel are series coupled while the output circuit of the unused channel is "floating." The unused channel is consequently unloaded and dissipates no power. For signals common to both channels, i.e. monophonic input, additional power is provided because both amplifiers are operating, and hence, any possibility of less than optimum impedance match is effectively compensated.

Referring now to FIGURE 2, there is illustrated another embodiment of the present invention involving only slight modification of the circuit of FIGURE 1. Here, the blend resistance is fixed resistor **40**, which is preselected to provide the required blending, as previously discussed. Alternatively, the blend resistor may be variable, as illustrated in FIGURE 1, and adjusted to the required value for blending.

Center speaker **30** is a full range unit while right and left speakers **17** and **27** each provide audio output at middle and high frequencies only. Choke coils **52** and **62** are connected in shunt circuit with side speakers **17** and **27**, respectively, to provide low impedance paths for low frequency components of the signal. In the limiting case of lowest signal frequencies, complete shunting of the side speakers occurs. A choke coil **42** is connected in parallel with blend resistance **40** between the two channels to correct for impedance shifts as the side speakers are shunted out. In the above-mentioned limiting case; that is, at the lowest frequencies, the proportion of blend is 100 percent, or nearly so, and the input circuits are effectively connected together, as are the output circuits of each channel. This corresponds to a circuit arranged for monophonic low frequency signal use. However, the lower frequency components are essentially non-directional to the listener and will therefore not detract from the full stereophonic effect, while a significant advantage in decreased system cost is obtained by use of tweeters, for example, as side speakers. An appropriate capacitor may be connected in series circuit with blend resistor **40** to provide additional impedance shift correction, and with each of the left and right speakers **17** and **27**, to further inhibit the passage of lower frequency components through those paths.

Systems in accordance with the present invention may also be employed to provide remote monaural speakers (combining left plus right channel signals) without loss of stereophonic effect at positions within the main listening region.

While I have described and illustrated one specific embodiment of my invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined by the appended claims.

I claim:

1. In a sound system for reproducing the magnitude and location of sound sources via electroacoustic transducers, first and second channels for transmitting stereophonically related signals derived from said sound sources; each of said channels including means for amplifying said signals, and output circuit means for coupling respective ones of said electroacoustic transducers to each of said amplifying means and for coupling another electroacoustic transducer to said first and second channels via said respective electroacoustic transducers, so that signals from either or both of said first and second channels are applied to said another electroacoustic transducer and are converted thereby to audible sound while signal from one of said first and second channels is applied in oppositely phased relation to the respective electroacoustic transducer coupled to the other of said channels; and impedance means interconnecting said first and second channels for feeding signal from said one of said channels to said other of said channels in predetermined amplitude proportionality and substantially in-phase relation to cancel said oppositely phased signal; whereby signals of equal amplitude and phase coincidence transmitted concurrently by both of said channels are converted to audible sound predominantly by said another electroacoustic transducer, and signal transmitted by one channel only is converted to audible sound by both the respective electroacoustic transducer associated with that channel and said another electroacoustic transducer.

2. The combination according to claim **1** wherein said impedance means interconnects said first and second channels antecedent to said amplifying means therein, and includes resistance means having a value selected to provide said predetermined proportionality of signal feeding in the ratio

$$\frac{Z_c}{Z_c+Z_f}$$

wherein Z_c is the impedance of said another electroacoustic transducer and Z_f is the impedance of each of said respective electroacoustic transducers.

3. The combination according to claim **2** including reactance means coupled to all of said electroacoustic transducers to prevent application of relatively low frequency signals to said respective electroacoustic transducers and to feed said relatively low frequency signals to said another electroacoustic transducer, whereby impedance shifts occur in signals applied to said transducers as said respective electroacoustic transducers are shunted by said reactance means at said relatively low signal frequencies; and wherein said impedance means includes further reactance means for increasing the proportionality of signal fed from one of said channels to said other of said channels and for canceling said impedance shifts at said relatively low signal frequencies.

4. A two-channel stereophonic sound system comprising means in each channel for amplifying signals applied thereto, first and second electroacoustic transducer means coupled to each other and to respective ones of said amplifying means for converting said amplified signals to audible sound, third electroacoustic transducer means series-connected separately to each of said first and second electroacoustic transducer means to convert amplified signals either common to both channels or peculiar to one channel to audible sound, said amplified signals peculiar to one channel being also converted to audible sound by that one of said first and second electroacoustic transducer means associated respectively with said one channel and being applied thereby via said coupling to the other of said first and second electroacoustic transducer means, and electrical impedance means interconnecting said channels antecedent to said amplifying means therein to feed signal from said one channel to the other channel in predetermined proportion for nulling the amplified signals applied to said other of said first and second electroacoustic transducer means from said one channel via its respective electroacoustic transducer means.

5. Signal transmission apparatus for cooperating with loud speakers to reproduce audible sound from stereophonically related signals, said apparatus including a first channel, a second channel, means for applying signal to said first channel, means for applying signal to said second channel, said signals being stereophonically related, means in each channel for amplifying said signals, each of said amplifying means including an input circuit and an output circuit, said output circuits including means for connecting a pair of series coupled loud speakers therebetween and for connecting another loud speaker to a point of reference potential from the junction of said pair of series coupled loud speakers, whereby each of said pair of loud speakers is connected in a separate series circuit with said another loud speaker across the output circuit of its respective channel, and an electrical impedance interconnecting said input circuits of said amplifying means of both channels for introducing signal transmitted by one channel into the other channel in predetermined amplitude and phase relationship to cancel signal applied from said one channel via said series coupling to the loud speaker respectively associated with said other channel.

6. The combination according to claim **5** wherein said electrical impedance includes a resistive component for maintaining said introduced signal amplitude in the proportion of

$$\frac{Z_c}{Z_c+Z_f}$$

relative to the amplitude of said one channel, where Z_f is the impedance of each of said pair of loud speakers and Z_c is the impedance of said another loud speaker.

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