

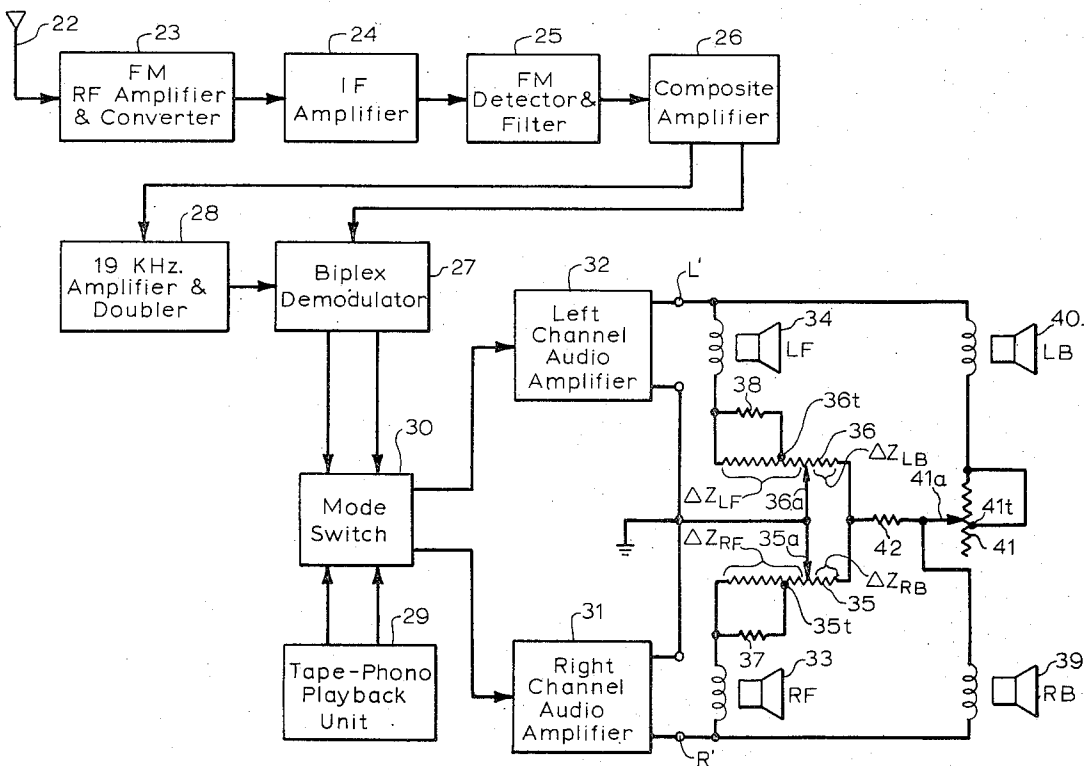
[54] **FOUR-CHANNEL FRONT-TO-BACK
BALANCE CONTROL**
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Ill.
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[51] **Int. Cl. H04n 5/00**
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179/100.1 TD, 1 GA, 1 GP, 1 D**

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[57] **ABSTRACT**

A front-to-back balance control circuit in a quadra-
phonic playback system for adjusting the sound output
levels of a front pair of speakers relative to a back pair
while simultaneously varying the phase differential be-
tween the back speakers. The balance control utilizes a
ganged potentiometer arrangement wherein a poteni-
ometer is serially-connected with each front speaker
to concurrently adjust the sound output of each
speaker to corresponding levels. The ganged poteni-
ometer arrangement also provides a variable impe-
dance signal path common to the back speakers for
varying their sound output levels inversely in response
to adjustments in the sound output level of the front
speakers. The common signal path is further effective
to serve as a variable coefficient matrixing means for
applying portions of a first and a second input signal
to each of the back speakers.

4 Claims, 3 Drawing Figures



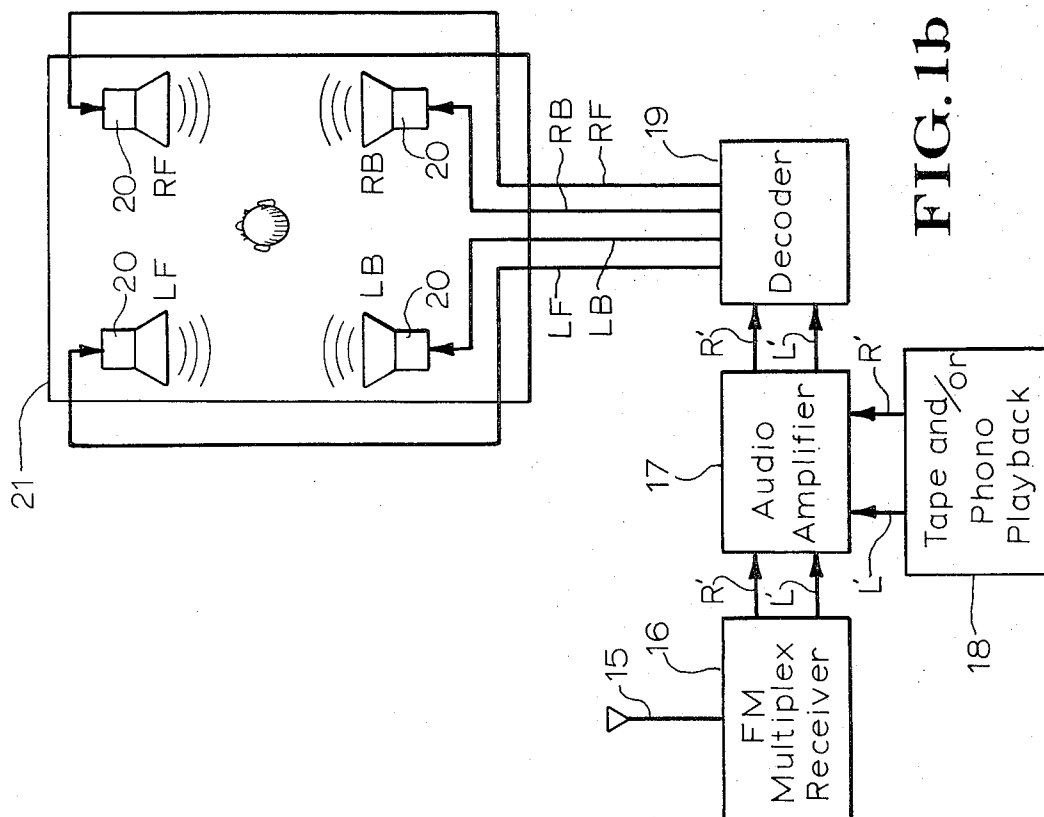


FIG. 1b

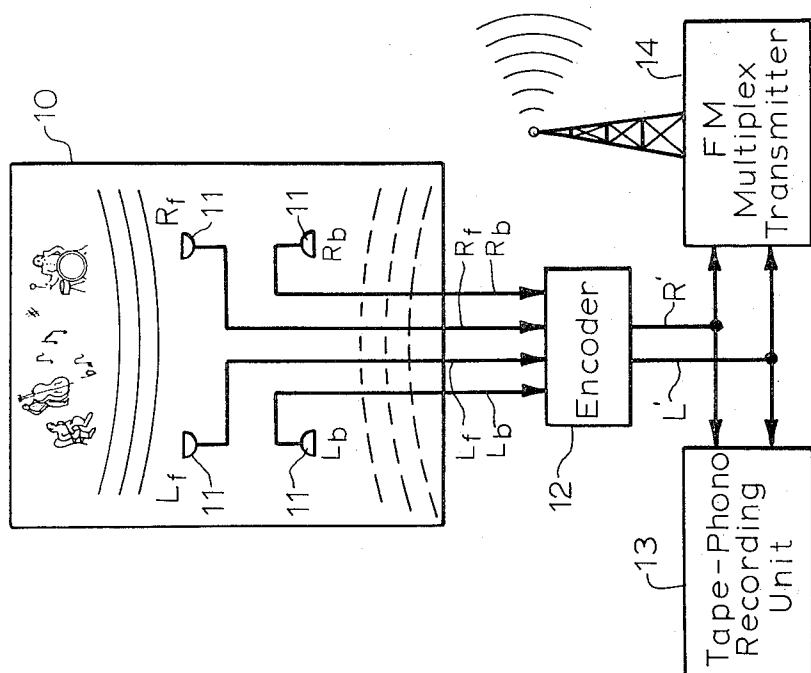


FIG. 1d

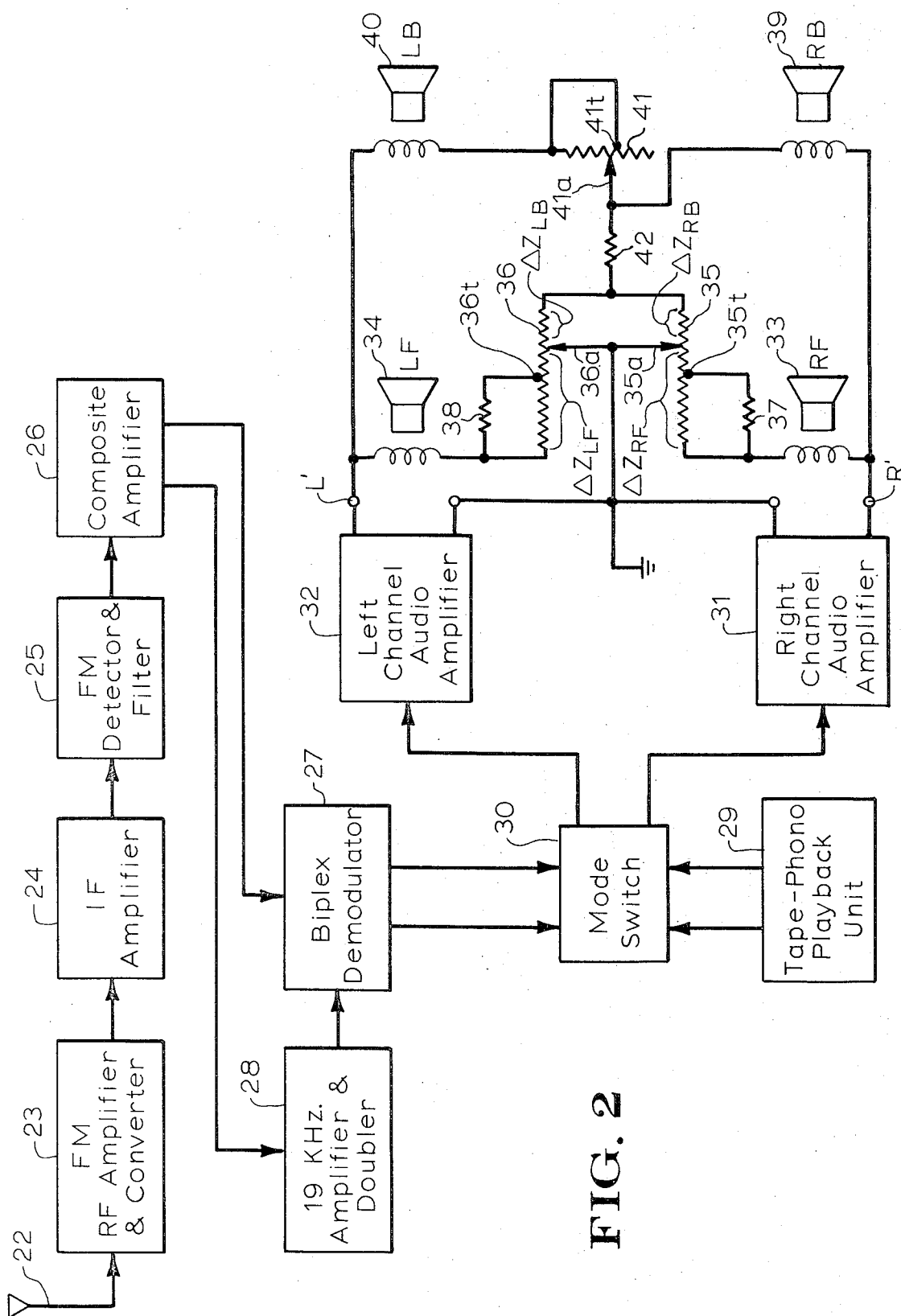


FIG. 2

FOUR-CHANNEL FRONT-TO-BACK BALANCE CONTROL

BACKGROUND OF THE INVENTION

The present invention relates generally to quadraphonic sound reproduction systems and more particularly to a front-to-back balance control circuit for adjusting the sound output level of the "front" sound reproducers relative to that of the "rear" sound reproducers while simultaneously varying the phase differential between the "left-rear" and "right-rear" sound reproducers in a predetermined manner.

It is well known that the human auditory system can distinguish between sounds emanating from points (i.e., front, back, left and/or right) on an imaginary 360° circle of variable radius surrounding the listener. Furthermore, the listener can also detect ambient sounds having a reduced amplitude, differential phase shift, and time delay resulting from sound reflections which are dependent on the acoustical characteristics of the room in which the sound source is located. Recorded ambient sound, when part of, or added to stereo records or tape can result in greatly enhanced sound reproduction to the listener.

Heretofore, stereophonic sound reproduction systems have provided means for coupling two channels of signal information representing "right-front" and "left-front" sound sources to a pair of sound reproducers, or speakers, resulting in a more realistic sound image to the listener. With such a system, however, the listener is able to distinguish only between sounds coming from the "right-front" or the "left-front." Any ambient or so-called reverberation sound effect will depend on sound reflections from the rear and side walls of the room. Accordingly, the manner in which the room is furnished can greatly affect what the listener hears; for example, in a carpeted room having drapes and a great deal of furniture, the sound is dispersed and absorbed, thereby minimizing the reverberation effect. Thus, even though the original recording may have been that of an orchestra performing in a large concert hall, it will not be apparent when reproduced on the listener's stereophonic system. The opposite may be true, however, in a room having bare walls, no carpeting and little furniture where the sound it almost totally reflected by the walls to effect reverberation.

A logical extension of the stereophonic concept is to provide a quadraphonic sound reproduction system having one speaker positioned in each quadrant of the room. Thus, a true "concert hall" effect may be obtained by reproducing the ambient sound or reverberation from the "rear" speakers. While conceptually a discrete four-channel system would appear to be the most desirable means of accomplishing this, the integration of such a system with existing phonographs, tape players and FM stereo tuners would be difficult if not impossible. For example, most present-day tape recorders provide only two recording and two playback heads thereby rendering them useless for quadraphonic purposes, while most phonographs are likewise capable of reproducing only two channels of sound. Furthermore, the FM stereo multiplex broadcasting techniques currently in widespread use are subject to rules promulgated by the Federal Communications Commission which provide for only two discrete channels. Although the design of new four-channel equipment may not be

difficult, the fact remains that such revisions would make most of today's stereophonic systems obsolete.

Accordingly, some emphasis has shifted to psuedo four-channel systems which recover quadraphonic signals from matrixed two-channel information and are therefore compatible with presently available phonographs, tape players and FM stereo tuners. These systems are generally based on the encoding or matrixing of four discrete sound channels into two composite signals which may then be stored on records and tape or broadcast to an FM multiplex tuner. Upon application to a quadraphonic playback system, the signals are amplified and then coupled to a matrixing network wherein the original four discrete signals are reconstituted for application to the sound reproducers. Prior art quadraphonic sound reproduction systems, unfortunately, have generally required an expensive, specially-designed transformer to "matrix" the composite signals.

As in conventional stereophonic systems, it is desirable to include a balance control for adjusting the sound output levels of the "right-front" and "left-front" speakers relative to one another. In addition, the quadraphonic system adds a further dimension; that is, besides maintaining balance between the two "front" speakers, proper balance should be maintained between the sound output levels of the "front" speakers and the "rear" pair. If, however, the "front" speakers are reduced to zero sound output, the 180° phase differential between the "right-rear" and "left-rear" speakers required to reproduce the reverberation effect of the concert hall is harsh and displeasing to the listener.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the invention to provide a novel front-to-back balance control circuit for a quadraphonic sound reproduction system.

A more particular object of the invention is to provide a front-to-back balance control circuit which may be used to adjust the sound output levels of the "front" and "rear" pair of sound reproducers relative to one another.

A further object of the invention is to provide a front-to-back balance control circuit which varies the phase differential between the rear sound reproducers in accordance with the relative sound output levels of the "front" and "rear" sound reproducers.

Another object of the invention is to provide a front-to-back balance control circuit incorporating an inexpensive simplified matrixing network for reconstructing four channels of audio information from two input signals.

In accordance with the present invention, a control circuit in a quadraphonic sound reproduction system is provided for adjusting the sound output levels of a primary pair of sound reproducers relative to an auxiliary pair. The control circuit of the present invention contemplates the application of first and second input signals to the amplifier stage of an audio playback system. The amplifier stage has a primary sound reproducer with an associated series resistance coupled between each output and a plane of reference potential and an auxiliary sound reproducer coupled to each output. A resistive network couples the auxiliary sound reproducers to the plane of reference potential providing each of them with a signal path common to the other auxili-

ary sound reproducers. The common signal path is effective to serve as a matrixing means for applying portions of the first and second input signals to each of the auxiliary sound reproducers. Further, front-to-back balance means are also provided for simultaneously varying the impedances of the common signal path and the series resistances of the primary sound reproducers to control the sound output level of the auxiliary sound reproducers.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of this invention which are believed to be novel are set forth with particularity in the appended claims. The invention together with its further objects and advantages thereof, may be best understood, however, by reference to the following description taken in conjunction with the accompanying drawings, which like reference numerals refer to like elements in the several figures and in which:

FIG. 1a is an illustrative block diagram of a quadrasonic sound reproduction system;

FIG. 1b is an illustrative block diagram of a quadrasonic playback system; and

FIG. 2 is a combined schematic and block diagram of an FM multiplex receiver which includes a front-to-back balance control in accordance with the present invention.

PREFERRED EMBODIMENT OF THE INVENTION

The quadrasonic sound reproduction system shown in FIG. 1a employs a matrixing network to encode four discrete channels of sound information into two composite signals for purposes of information storage and/or FM multiplex broadcast transmissions. A room 10 (e.g., a concert hall) having a sound source located therein is depicted to have four microphones 11, i.e., right-front (R_f), left-front (L_f), right-back (R_b), and left-back (L_b), positioned to "pick-up" sounds emanating from the corresponding quadrant of the room. Accordingly, if the sound source (e.g., an orchestra) is positioned in the front-center of the room, as illustrated in FIG. 1a, the front pair of microphones, (R_f) and (L_f), may be directed toward the sound source to receive sound waves directly therefrom. The rear microphones, R_b and L_b , face away from the sound source to "pick-up" reflected sound waves from the rear and side walls.

The sound waves detected by the four microphones 11 are, in turn, converted into corresponding electrical signals, designated here for convenience as R_f , L_f , R_b and L_b and applied to an encoder network 12. In a typical quadrasonic system, the encoder 12 matrixes the four input signals into two composite signals, R' and L' , with the following amplitude and phase relationships;

$$1. R' = +1.22 R_f + 0.38 L_f + 1.22 R_b - 0.62 L_b$$

$$2. L' = +0.38 R_f + 1.22 L_f - 0.62 R_b + 1.22 L_b$$

The composite signals, R' and L' , may then be coupled to a tape/phono recording unit 13 where they are stored on conventional stereophonic records or recorded on stereophonic tapes. Alternatively, since the four discrete channels are encoded into two composite signals, the R' and L' composite signals may be broadcast by an FM multiplex transmitter 14 for reception by a conventional FM stereo multiplex receiver such as that shown in FIG. 1b.

The quadrasonic playback system, shown in FIG. 1b, is effective to dematrix the R' and L' composite signals developed by the quadrasonic transmission system of FIG. 1a into four channels of audio information.

Operationally, broadcast signals from the FM multiplex transmitter 14 are intercepted by the antenna 15 of an FM multiplex receiver 16 wherein the received radio-frequency signals are processed and converted into the respective R' and L' composite signals. The R' and L' signals are then applied to an audio amplifier 17 where they are further amplified. In the alternative, when the composite signals have been stored on stereophonic tapes or records, as previously mentioned, a conventional stereophonic phonograph or tape player may be used to reproduce the R' and L' composite signals which are then, in turn, applied to the audio amplifier 17. There is provision in the audio amplifier 17 for manual switching, as desired by the listener, between input composite signals derived from the FM multiplex receiver 16 or the tape and/or phono playback system 18.

The R' and L' composite signals are then coupled to a decoder 19 where they are matrixed. While it is feasible to matrix the composite signals into four decoded output signals, it has been empirically determined that decoding of the composite signals for application to right-front (RF) and left-front (LF) speakers 20, respectively, provides no significant advantages under most conditions. Thus, the signals applied to the right-front and left-front speakers 20 are:

$$1. RF = R' = +1.22 R_f + 0.38 L_f + 1.22 R_b - 0.62 L_b$$

$$2. LF = L' = +0.38 R_f + 1.22 L_f - 0.62 R_b + 1.22 L_b$$

For this reason, the composite signals are matrixed to provide only the RB and LB signals applied to the right-back (RB) and left-back (LB) speakers 20, respectively. This is accomplished when the R' and L' signals are matrixed according to the equations:

$$3. RB = +0.68 R' - 0.53 L'$$

$$4. LB = -0.53 R' + 0.68 L'$$

Combining the matrixing equations (1) and (2) with composite signal equations (3) and (4) it is found that the signals applied to the right-back and left-back speakers 20 are:

$$5. RB = 0.63 R_f - 0.39 L_f + 1.16 R_b - 1.07 L_b$$

$$6. LB = 0.39 R_f + 0.63 L_f - 1.07 R_b + 1.16 L_b$$

Subsequently, the four derived output signals (i.e., RF, LF, RB and LB) available at the output terminals of decoder 19 are applied to the corresponding speakers 20, designated RF, LF, RB and LB, positioned in the quadrants of listening room 21. The speakers 20 reproduce the audio information from the signals applied thereto, simulating the "concert hall" effect.

One advantage of this type of quadrasonic playback system is that conventional stereophonic records, tapes and FM multiplex transmissions may be reproduced with some "enhancement" thereby producing an acceptable illusion of four channel stereo when, in fact, encoded signals are not being used. The degree of enhancement, however, will vary between the various materials being reproduced, but this does mean that not all present stereophonic audio information storage techniques and hardware are obsolete.

Referring now to FIG. 2, shown therein is an FM multiplex receiver which is adaptable as a quadrasonic

playback system incorporating a front-to-back balance control in accordance with the present invention. The receiver includes an antenna 22 which intercepts frequency-modulated (FM) signals and couples them in a conventional manner to a radio-frequency (RF) amplifier and converter stage 23 wherein the signals are amplified and translated to an intermediate-frequency. The resultant IF signal is then coupled to an intermediate-frequency (IF) amplifier stage 24, which may comprise a plurality of individual tuned amplifier and limiting circuits for subsequent amplification.

The IF output signal from IF amplifier 12 is coupled to an FM detector and filter 25 wherein the received carrier transmission is demodulated to obtain a modulation signal at the detector output. The signal from FM detector 25 consists of three components: an audio frequency component representing the sum ($L' + R'$) of the left and right composite audio signals, a 38 kHz suppressed-carrier subcarrier component representing the difference ($L' - R'$) of the two composite audio signals, and a 19 kHz pilot-carrier component. The output signal from FM detector 25 is amplified by an amplifier 26 and applied to the biphase demodulator 27. In order to detect the suppressed-carrier amplitude-modulated subcarrier, it is necessary to apply to the biphase demodulator 27 a 38 kHz demodulation or switching signal which corresponds to the carrier component of the suppressed-carrier subcarrier signal. The 19 kHz pilot-carrier is amplified by a 19 kHz amplifier and doubler 28 wherein the amplified 38 kHz switching signal is generated. The regenerated 38 kHz demodulating signal is then applied to the biphase demodulator 27. The biphase demodulator 27 reinserts the 38 kHz subcarrier switching signal into the ($L' - R'$) 38 kHz suppressed-carrier subcarrier component from amplifier 26 and demodulates this signal into the ($L' - R'$) audio signal. Demodulator 27 further matrixes the ($L' + R'$) audio signal from amplifier 26 and the ($L' - R'$) audio signal to produce audio signals of the form L' and R' , which correspond to the desired left and right composite signals. The R' and L' composite signals are then applied through a switching network 30 to a right channel audio amplifier 31 and a left-channel audio amplifier 32, respectively. The right and left channel audio amplifiers 31 and 32, in turn, drive the right-front (RF) and left-front (LF) speakers, 33 and 34, respectively.

Similarly, the R' and L' composite signals may be recovered from the tape-phonograph playback unit 29 and coupled to a switching network 30 having composite signals from biphase demodulator 27 also applied thereto. Accordingly, the listener may manually select his source of listening material, i.e., records, tapes, or FM multiplex broadcast transmissions.

As thus far described, the receiver is conventional in general construction and operation such that further and more particular consideration may now be given to that portion of the receiver which relates to the preferred embodiment of the present invention, and in general constitutes a front-to-back balance control.

In accordance with the present invention, the amplified R' composite signal is coupled directly from the right channel audio amplifier 31 to a right-front (RF) speaker 33 where it is converted into sound waves emanating therefrom. The other terminal of the RF speaker 33 is coupled to ground through a variable impedance, identified as ΔZ_{RF} in FIG. 2, comprising a portion of the

potentiometer 35 determined by the positioning of its wiper arm 35a. Similarly, the amplified L' composite signal is coupled from the left channel audio amplifier 32 to a leftfront (LF) speaker 34 having a resistive network identical to that just described interposed between its other terminal and ground. That is, the LF speaker 34 is coupled to ground through a variable impedance, ΔZ_{LF} , determined by the positioning of wiper arm 36a of potentiometer 36. In the embodiment shown in FIG. 2, the potentiometers 35, 36 are ganged such that corresponding adjustments of wiper arms 35a and 36a are accomplished simultaneously. Thus, the variable impedance (ΔZ_{RF}) interposed between the RF speaker 33 and ground is identical to that (ΔZ_{LF}) interposed between the LF speaker 34 and ground. Accordingly, the relative sound output levels of the two front speakers 33, 34 are correspondingly increased or decreased. A resistor 37 is coupled between the RF speaker 33 and a tap 35t on the potentiometer 35 to effect differing tapers over two predetermined impedance ranges. Likewise, a resistor 38 spans the portion of potentiometer 36 between a tap 36t and the LF speaker 34.

The R' composite signal is further coupled from the right channel audio amplifier 31 to the right-back (RB) speaker 39, while the L' composite signal is also coupled from the left channel audio amplifier 32 to the left-back (LB) speaker 40. Potentiometer 41, which is ganged with potentiometers 35, 36, is connected to the other terminal of the LB speaker 40. Its wiper arm 41a is coupled to the second terminal of the RB speaker 39 interconnecting the two back speakers to complete the $L' - R'$ signal path. The variable impedance interposed between the two back speakers 39, 40 by potentiometer 41 controls the level of $L' - R'$ signals coupled to each of the back speakers. That is, when potentiometer 41 is adjusted to its "maximum impedance" the $L' - R'$ signal path is essentially an open circuit and $L' - R'$ signals will not be coupled to the back speakers 39, 40.

A resistor 42 connected to the wiper arm 41a also couples the back speakers 39, 40 to ground through a variable impedance, ΔZ_{BACK} , comprising the parallel impedances, ΔZ_{RB} and ΔZ_{LB} , which are determined by the positioning of wiper arms 35a and 36a, respectively. The common signal path to ground provided by the variable impedance ΔZ_{BACK} and resistor 42 provides the back speakers 39, 40 with an $L' + R'$ sum-type signal having the desired matrixing coefficients required for decoding the R' and L' composite signals into the RB and LB signals applied to the RB speaker 39 and the LB speaker 40, respectively. When the variable impedance ΔZ_{BACK} is varied by the repositioning of wiper arms 35a, 36a the resistance of the common signal path interposed between the back speakers 39, 40 and ground is adjusted to correspondingly change the relative sound output levels of the two back speakers. Furthermore, by varying the impedance of the common signal path the matrixing coefficients are similarly changed such that there is nearly zero phase difference between the signals applied to the RB and LB speakers 39, 40, respectively, when the variable impedance ΔZ_{BACK} is minimized.

Operationally, the three ganged potentiometers 35, 36, and 41 may be simultaneously adjusted by a single manual control to adjust the sound output levels of the front speakers 33, 34 relative to the back speakers 39,

40 while varying the phase differential between the back speakers. For example, when the wiper arms 35a, 36a and 41a are moved to their extreme counterclockwise positions, and variable impedances ΔZ_{RF} and ΔZ_{LF} in series with the RF and the LF speakers 33, 34, respectively, will be small. Accordingly, the R' and L' composite signals applied across the front speakers will be minimally attenuated. The variable impedance ΔZ_{BACK} , however, will be maximized due to the variable impedances ΔZ_{RB} and ΔZ_{LB} such that there will be minimal sound output from the back speakers 39, 40 resulting from the matrixing of the R' and L' composite signals through the common signal path to ground. Also, the series impedance provided by potentiometer 41 and serially connected between the back speakers 39, 40 will effectively present an open circuit to any L' - R' difference signals.

As the wiper arms 35a, 36a, and 41a are moved to an optimum position defined by the taps 35t, 36t on potentiometers 35, 36 the impedances ΔZ_{RF} and ΔZ_{LF} are correspondingly increased thus decreasing the sound output level of the front speakers 33, 34. Simultaneously, the resistance of potentiometer 41 is decreased as wiper arm 41a is moved to tap 41t to allow reproduction by the back speakers 39, 40 of the decoded signals, RB and LB, applied thereto. The impedance ΔZ_{BACK} provides a common signal path to ground to matrix the R' and L' composite signals.

Finally, when the potentiometers 35, 36 and 41 are adjusted to their extreme clockwise position, the impedances ΔZ_{RF} and ΔZ_{LF} are maximized to attenuate the R' and L' composite signals applied to the RF and LF speakers 33, 34, respectively, attenuating greatly the sound output from the front speakers. The impedance ΔZ_{BACK} is minimized such that the back speakers 39, 40 are, in essence, coupled closely to ground through resistor 42. Accordingly, the matrixing coefficients are changed such that decoding of the R' and L' composite signals will not be effected. Accordingly, for the most part, R' composite signal will be applied to the RB speaker 39 while L' composite signal will be applied to the LB speaker 40. This reduces the phase differential between the back speakers to nearly zero.

Accordingly, there has been shown a means for adjusting the sound output levels of the two front speakers relative to a pair of back speakers so that a proper balance may be maintained. Further provision has been made for automatically reducing the phase differential between the back speakers to nearly zero when the front speakers are effectively "shut-off" thereby eliminating any harsh or displeasing sounds to the listener. Also, the present invention provides an inexpensive matrixing network for reconstructing the four channels of audio information from the two composite input signals.

While a particular embodiment of the present invention has been shown and described, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from the invention in its broader aspects. The aim in the appended claims is to cover all such changes and modifications as may fall within the true spirit and scope of the invention.

I claim:

1. A control circuit for use in an audio playback system which includes an amplifier stage having right and left outputs issuing respective right and left output sig-

nals, a right front sound reproducer and a right back sound reproducer each having a first terminal coupled to said right output, a left front sound reproducer and a left back sound reproducer each having a first terminal coupled to said second output, said control circuit comprising:

a pair of potentiometers individually associated with an assigned one of said front sound reproducers, each of said potentiometers having a first terminal coupled to a second terminal of its assigned front sound reproducers,

each potentiometer also having a second terminal coupled to a junction and each potentiometer further having a wiper arm coupled to a plane of reference potential to constitute a first segment of each potentiometer between its first terminal and its wiper arm as a series impedance for coupling its assigned front sound reproducer to reference potential;

impedance means intercoupling a second terminal of said right back sound reproducer and a second terminal of said left back sound reproducer;

a matrix network comprising second segments of said potentiometers disposed between their wiper arms and said junction and a matrixing impedance coupled between said junction and said intercoupling impedance means,

said potentiometer second segments, said matrixing impedance and said intercoupling impedance means establishing a common signal path coupling said second terminals of said back sound reproducers to reference potential to permit application of portions of said first and second output signals to each of said back sound reproducers;

and control means coupled to said potentiometer wiper arms for varying the impedance of said potentiometer second segments included in said matrix network to adjust the output levels of said back sound reproducers as well as the magnitude of said first and second output signals applied to said left back and right back sound reproducers, respectively, while simultaneously varying the impedance of said potentiometer first segments forming said series impedances to adjust the output level of said front sound reproducers relative to the output level of said back sound reproducers.

2. A control circuit as set forth in claim 1 in which said wiper arms are interconnected through said control means so that when the impedance of said matrix segments is increased, the impedance of said series segments is decreased, and vice versa.

3. A control circuit as set forth in claim 1 in which said matrix segments of said potentiometers are effectively connected in parallel.

4. A control circuit as set forth in claim 1 in which said impedance means intercoupling said right back and left back sound reproducers comprises an adjustable resistor having one terminal coupled to said second terminal of one of said back sound reproducers and a wiper arm coupled to said second terminal of said other back sound reproducer and, through said matrixing impedance, to said junction, for changing the phase difference between said first and second output signals applied to said rear sound reproducers to substantially zero as the output level of said rear sound reproducers approaches a maximum,

and in which said wiper arm of said intercoupling impedance is mechanically coupled to said wiper arms of said potentiometers for conjoint displacement therewith.

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