

12

**EUROPEAN PATENT APPLICATION**

21 Application number: 82300721.6

51 Int. Cl.<sup>3</sup>: H 04 S 3/00

22 Date of filing: 12.02.82

43 Date of publication of application: 24.08.83  
Bulletin 83/34

71 Applicant: **NORTECH LABORATORIES LIMITED,**  
1203 Plymouth Avenue, San Francisco California (US)

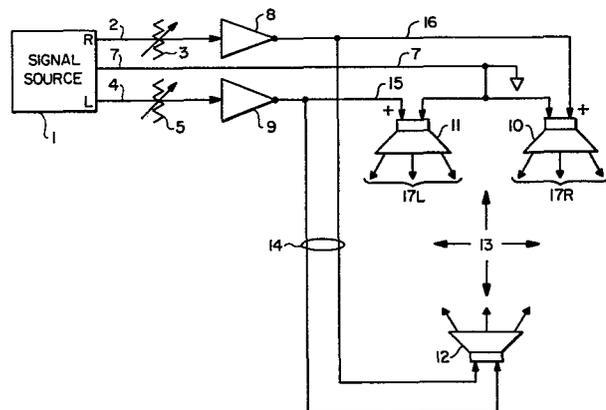
72 Inventor: **Norgaard, Donald Eugene, Deceased (US)**

64 Designated Contracting States: **CH DE FR GB IT LI NL SE**

74 Representative: **Beresford, Keith Denis Lewis et al,**  
R.G.C. Jenkins & Co. 12-15, Fetter Lane, London  
EC4A 1PL (GB)

54 **Improved acoustic apparatus and method.**

57 An improved method and means of reproducing sound includes processing the pair of signals (2, 4) representing left and right stereophonic channels to produce a signal which is the linear algebraic difference of the pair of left and right signals (2, 4) and includes acoustically radiating the left and right stereophonic signals (2, 4) toward a reception region (13) in substantially the same one direction from a pair of spaced locations (10, 11), and also acoustically radiating the difference signal toward the reception region (13) in substantially the opposite direction from a location (12) which is spaced in the one direction away from the pair of spaced locations (10, 11).



IMPROVED ACOUSTIC APPARATUS AND METHODBackground of the Invention

5 Early stereophonic techniques featured direction-  
ality or "stereo imagery" by means of exaggerated signal  
manipulation. The "ping pong" transfers of virtual sources  
from side to side bear little resemblance to musical per-  
formances ranging from a solo performer to a full symphony  
orchestra, but instead serve to misdirect attention away  
10 from reality and toward "separation" as the hallmark of  
stereophonic sound. See, for example, U.S. Patents  
3,247,321, 3,184,550, 3,478,167, 3,171,891, and 3,280,258.  
This attention to separation has served to set unrealistic  
and unattainable goals in the quest for acceptable imitation  
15 of the original sound. Primary sounds are strongly affected  
by the acoustical characteristics of the immediate surround-  
ings, whether they be a concert hall, a small studio, or  
even out-of-doors. The sense of hearing apparently involves  
a continuing space-time analysis unconsciously performed by  
20 the ear/brain combination, and it is this analysis that  
provides the unmistakable credibility of real sound in a  
real location. In the case of reproduced sound, the addi-  
tional effect of acoustical characteristics of the region  
where the sound is reproduced combines irreversibly with the  
25 sound which might otherwise be heard at the original site,  
with the result that the final effect can be interpreted by  
the highly organized hearing mechanism as synthetic rather  
than natural.

The hearing sense relies strongly upon an "ambi-  
30 ance" created by a multitude of acoustic reflections and  
absorptions always present in any site where a sound occurs,  
and it is this feature which provides authenticity to what  
is heard. The nature of the ambiance, moreover, is  
transient due to reflections and absorptions which combine  
35 differently with direct sounds in a complex manner depending  
on the sonic radiation pattern of the source, its frequency,  
timbre, and location in any physically realizable surround-

ing. A spatially-distributed source such as an orchestra compounds this intrinsic complexity to an enormous degree. Restoration of an initial ambiance at the site of acoustic reproduction is the foundation of acoustic reality as interpreted by the hearing mechanism.

#### Summary of the Invention

In accordance with this invention conventional two-channel stereophonic signals are utilized to create a third related signal channel used to provide an additional source of sound which supplements the traditional pair of stereophonic acoustic sources by the process of sonic combination at the site of sound reproduction so that an acceptable level of acoustic reality may be perceived over a relatively large portion of the region where sound is reproduced. This relieves restrictions on where listeners may be positioned for essentially optimum acoustic effect.

The present invention permits creation of acoustic ambiance in the general region of sound reproduction in order to diminish the effect of artificial sound sources which compete with each other for the listener's attention and serve to destroy the illusion of credibility or naturalness. Also, the present invention provides an apparent extension of frequency range of reproduced sound, particularly in the low frequency region of human hearing where convincing bass response essential to the illusion of reality in reproduced sound is especially difficult to achieve.

#### Description of the Drawings

Fig. 1 is a block diagram of one embodiment of the invention;

Fig. 2 is a block diagram of another embodiment of the invention;

Fig. 3 is a block diagram of another embodiment of the invention;

Fig. 4 is a block diagram of an alternative embodiment of the invention; and

Fig. 5 is a block diagram of another embodiment of the invention.

Description of the Preferred Embodiment

The block diagram of Fig. 1 illustrates a system according to the invention in which a source 1 of left- and right-channel stereophonic signals such as a stereo receiver, tape player, phonograph, or the like, supplies left-channel signal 4 and right-channel signal 2 through level controls 5 and 3 to power amplifiers 9 and 8, respectively. These level controls may be ganged together for convenience of operation, or may be operated independently. A common or ground reference conductor 7 serves to delineate the respective left- and right-channel signals for both input and output paths. Output signals from the power amplifiers 9 and 8 are supplied to respective left and right loudspeakers 11 and 10 by conductors 7 and 15 for the left loudspeaker and by conductors 7 and 16 for the right loudspeaker. As described thus far, the named elements comprise a conventional stereophonic reproducing system wherein the quality of signals provided by source 1 and the quality and power-handling capabilities of amplifiers 9 and 8 as well as loudspeakers 11 and 10 determine overall stereophonic performance. It is normal practice to separate loudspeakers 11 and 10 by several feet and to direct their principal axes of sonic radiation forward toward a preferred listening region 13, as indicated by arrow clusters 17L and 17R. It is customary for listeners to face the loudspeakers 11 and 10 in simulation of the general practice of facing performers during a live performance. It is also general practice to utilize matching front loudspeakers, which may be of multiple-transducer design, to avoid preferential treatment of either channel.

Acoustic combination of the sounds radiated independently by loudspeakers 11 and 10 produces at almost all reasonable locations within the listening region 13 a resultant acoustic field which closely resembles that which would otherwise be produced by two identical signals which represent the algebraic sum of left- and right-channel signals supplied at equivalent levels to loudspeakers 11 and 10. In accordance with the present invention, an acoustic

signal related to the linear algebraic difference between instantaneous values of left- and right-channel signals is radiated from a third loudspeaker 12 located substantially behind the listening region 13. The pair of conductors 14 serves to provide signal excitation for loudspeaker 12. The resulting sonic combination greatly enhances the credible illusion of reality in the sound perceived by listeners located generally within the listening region 13. Fig. 1 thus illustrates a system in which the third loudspeaker 12 located behind the listening region 13 is driven by a signal derived from the left- and right-channel signals and which signal represents the algebraic difference between the signals that drive loudspeakers 11 and 10.

The supplementing effect of the sound radiated from rear loudspeaker 12 takes the form of a type of derived ambiance or "phantom" acoustic energy which propagates in a general direction opposite to acoustic energy provided by the front pair of loudspeakers. This supplementary sound is instantaneously different (but not necessarily statistically different) from that produced by either or both front loudspeakers 10 and 11 and encounters totally different sets of multiple reflections and absorptions within the listening region 13. The cumulative effect as interpreted by the human hearing mechanism therefore approaches that experienced while listening at the site of the original sound as modified by the acoustical characteristics at that site.

It has been determined that the symmetry implied in Fig. 1 is not required for realization of the effect described above. Interpretation of total system performance is not significantly altered either by orientation of rear loudspeaker 12 or by the symmetry of the triangle determined by loudspeakers 10, 11 and 12 as well as orientation of a listener. Certain geometric restrictions on the preferred listening region 13 are due to the inverse square law of sound propagation, modified by the local acoustic characteristics of that site. Stated differently, a listener has a broad choice of both position and orientation in order to

achieve nearly optimum acoustic effect in much the same sense as choice of seating in a concert hall.

Fig. 2 illustrates a system as in Fig. 1 (similar elements bear the same designations) in which adjustments may be made of output of loudspeaker 12 relative to that of front loudspeakers 10 and 11. In this system, primary winding 21 of a high impedance bridging transformer 18 is excited by a signal which is the algebraic difference between the signals used to drive loudspeakers 10 and 11. A secondary winding 22 of the transformer 18 provides the difference signal through adjustable attenuator 19 to a third power amplifier 20. The output of amplifier 20 drives the third or rear loudspeaker 12. The difference signal which appears across secondary winding 22 is referenced to common conductor 7 as indicated in Fig. 2. Because the impedance level of primary winding 21 can be significantly higher than that of loudspeakers 10 and 11, the added loading effect of transformer 18 on amplifiers 8 and 9 is inconsequential. A voltage step-down ratio of about 5:1 provided by bridging transformer 18 assures sufficient signal excitation for amplifier 20 to produce the desired effect.

The design of power amplifier 20 can be identical to that of power amplifiers 8 and 9, and other circuit details such as power supply, and the like, which may be of conventional design and connection to the active elements of the illustrated circuits have been omitted for clarity.

It should be noted that since signal power required to drive loudspeaker 12 at a chosen level is supplied by the third power amplifier 20 instead of by joint action of power amplifiers 8 and 9, as in the system of Fig. 1, total power requirements for the three power amplifiers in the system of Fig. 2 are lower than for operation of the system of Fig. 1 under conditions which provide the same relative power levels to the respective loudspeakers.

In Fig. 3 (elements that are similar to those in Figs. 1 and 2 bear the same designations), a signal representing the algebraic difference between left- and right-channel signals from the stereophonic signal source 1 is

obtained by means of a high impedance bridging transformer 26 which has a primary winding 27 connected to receive left- and right-channel signals appearing on terminals 29 and 30. The secondary winding 28 of bridging transformer 26 supplies  
5 a ground-referenced difference signal to power amplifier 20 through a level-control potentiometer 23. The bridging transformer 26 should provide a voltage step-up ratio of approximately 3:1 if the voltage gains of power amplifiers 9, 8 and 20 are equal and loudspeaker input impedances and  
10 their conversion efficiencies are approximately equal.

Unity-gain, low-level, impedance-transforming amplifiers 25 and 24 are connected to the outputs of signal source 1 via the attenuators 3 and 5 to drive the power-amplifier input terminals 29 and 30 and the primary winding  
15 27 of bridging transformer 26. Amplifiers 25 and 24, which may be integrated circuits, provide very low source impedance for driving primary winding 27 of transformer 26 and the power amplifiers 9 and 8. One advantage of the system illustrated in Fig. 3 over that of Fig. 2 is that distortion, noise, and other imperfections attendant to operation  
20 of power amplifiers 9 and 8 are not applied to amplifier 20 and thus not reproduced by loudspeaker 12.

In the embodiment of the invention illustrated in Fig. 4 (elements which are similar to those in Fig. 3 bear  
25 the same designations), the function of transformer 26 in Fig. 3 is performed by operational amplifiers 33 and 34 and associated resistor network 35, 36, 37, 38 and 39. In this embodiment, amplifiers 33 and 34 each serve as phase inverters, wherein a signal voltage gain of (-1) is achieved  
30 through feedback connection of equal value resistors 35 and 36 in association with operational amplifier 33. If resistors 35, 36, 37 and 38 are of equal value, the algebraic sum of currents flowing through resistors 38 and 37 into circuit nodal point 44 represents the algebraic difference between  
35 left- and right-channel signals applied to power amplifier input points 29 and 30. Difference signal at the output 43 of operational amplifier 34, which acts as a summing amplifier having a voltage gain of  $R_{39}/R_{37}$ , is applied to adjust-

able attenuator 23 whose output serves to drive power amplifier 20 at an output level selected by the user to provide sound reproduction enhancement in accordance with the overall invention.

5           Because loudspeaker 12 primarily furnishes supplementary acoustical ambiance, this loudspeaker need not be of design similar to that of front loudspeakers 11 and 10. For example, it has been determined that reproduction of frequencies higher than 3000 to 4000 Hz. is not required for  
10 fulfillment of this function.

          In the embodiment illustrated in Fig. 5 (elements similar to those of Fig. 4 bear the same designations), a high-frequency rolloff is produced by capacitor 45 for frequencies above, say, 3000 Hz. in the signal channel which  
15 drives loudspeaker 12. In addition, bass boost of user-adjusted amount is provided by capacitor 46 and adjustable resistor 47 for this signal channel. The purpose of this bass boost is to compensate for possible response deficiency of loudspeaker 12 at low frequencies where a low-cost loud-  
20 speaker might require disproportionately higher driving power in order to fulfill its role of supplying adequate low frequency acoustic output to be compatible with the output of front loudspeakers 10 and 11. Resistor 47 need be set only once for a given installation to establish bass  
25 response compatible with that of the front loudspeakers, and, as such, serves as a system "voicing" adjustment. Power amplifiers 8, 9, and 20 may be of identical circuit design and may have power output capability, frequency response, distortion and noise characteristics suited for a  
30 given overall system application.

          Representative circuit design values applicable to Figs. 4 and 5 are:

	Resistors 35, 36, 37 and 38	10,000 ohms
	Resistor 39	27,000 ohms;
	Resistor 23	20,000 ohms;
	Resistor 47	100,000 ohms;
5	Capacitor 45	0.0018 microfarad;
	Capacitor 46	0.082 microfarad; and
	Operational Amplifiers 24, 25, 33 and 34	Type 741 (or (equivalent)).

10           The operational amplifiers 24, 25, 33 and 34 in  
 conjunction with resistors 35, 36, 37 and 38 (common to  
 Figs. 4 and 5) can be consolidated within a single special-  
 15           ized integrated circuit 60 which incorporates the eight  
 above-named elements with appropriate internal connections  
 and external terminals. Such integrated-circuit devices can  
 be mass produced at low unit cost as small self-contained  
 functional elements of high reliability. Such devices can  
 be used in the embodiments of Figs. 4 and 5 at a low total  
 system cost. It should be noted that this specialized  
 20           integrated circuit does not place restraints on overall  
 system performance parameters such as power output capabil-  
 ities of power amplifiers 8, 9 and 20, for example.

          Where desired, power amplifiers 8, 9 and 20,  
 operational amplifiers 24, 25, 33 and 34 together with  
 25           resistors 35, 36, 37 and 38 may be integrated within a  
 single large-scale integrated-circuit package as a substan-  
 tially complete functional embodiment of the invention.  
 Provision must be made for removal of relatively greater  
 amounts of heat dissipated within such a package, since the  
 30           operating power levels can be many thousands of times  
 greater than those of signal processing amplifiers 24, 25,  
 33 and 34 alone. The large-scale integration approach  
 outlined above may place restraints on power output ratings  
 and thus may not be applicable universally to every system  
 35           installation.

Claims

1. The method of acoustic reproduction of electrical signals representing left and right stereophonic signal channels, comprising:

5 radiating in substantially the same one direction toward a reception region from spaced left and right locations acoustic signals representing respective left and right stereophonic signal channels;

10 processing the left and right stereophonic signal channels to produce a third signal channel representing the instantaneous algebraic difference between the left and right stereophonic signal channels; and

15 radiating acoustic signals representing said third signal channel from a third location toward said reception region in a direction substantially opposite to said one direction.

2. The method of processing electrical signal voltages representing left and right stereophonic channels to produce a third electrical signal voltage linearly  
20 related to the instantaneous algebraic difference between respective left and right signal channel voltages, comprising in sequence:

reversing the polarity of one of the respective left and right stereophonic signal voltages;

25 summing current proportional to the resulting reverse-polarity signal channel voltage with current proportional to the other stereophonic signal channel voltage; and

30 providing a circuit path for resulting current sum through a common impedance to produce said third electrical signal voltage proportional to the product of said current sum and said common impedance.

3. Signal processing apparatus for operation with stereophonic signals representing respective left- and  
35 right-channel voltages to produce a third signal channel

voltage proportional to the instantaneous algebraic difference between said left- and right-channel voltages, comprising:

5 transformer means connected to apply respective left and right signal voltages to a primary winding thereof; and

means for applying the resulting signal voltage appearing across a secondary winding of said transformer means to signal utilization apparatus.

10 4. Signal processing apparatus for operation with stereophonic signals representing respective left- and right-channel voltages to produce a ground-referenced third signal channel voltage linearly related to the instantaneous algebraic difference between said left- and right-channel  
15 voltages, comprising:

amplifier means connected to provide a current proportional to the algebraic difference between respective left- and right-channel voltages, said current occurring at a voltage node; and

20 circuit means connected to pass said current through a common impedance to produce a ground-referenced third signal voltage proportional to the product of said current and said common impedance.

25 5. Apparatus for supplying acoustic signals to a reception region, comprising:

source means of stereophonic signals representing right and left acoustic channels;

30 signal means connected to receive the signals representing right and left acoustic channels for producing a signal representative of the linear algebraic difference thereof;

35 first and second acoustic radiating transducer means positioned in front of a reception region to radiate respective left and right acoustic signals in substantially the same direction into the region;

third acoustic radiating transducer means positioned substantially in the rear of the reception region to radiate acoustic signals into the region in a direction substantially opposite that of the first and second acoustic radiating transducer means; and

circuit means coupled to apply the signals representing left and right acoustic channels to the first and second acoustic radiating transducer means, and to apply said signal representing algebraic difference to the third acoustic radiating transducer means.

6. Signal translating apparatus for operation with stereophonic signals representing left and right acoustic channels, comprising:

circuit means coupled to receive signals which are representative of left and right acoustic channels for producing a third signal as the linear algebraic difference thereof;

a pair of acoustic radiating transducer means positioned to radiate substantially in the same direction, toward a reception region, and a third acoustic radiating transducer means positioned relative to the pair of transducer means to radiate toward the reception region in a direction substantially opposite to that of the first and second transducer means; and

means coupling the first and second transducer means to receive the signals representing left and right acoustic channels, and coupling the third transducer means to receive said third signal.

7. Signalling apparatus for operation with stereophonic signals represented by respective left and right signal voltages, the apparatus comprising:

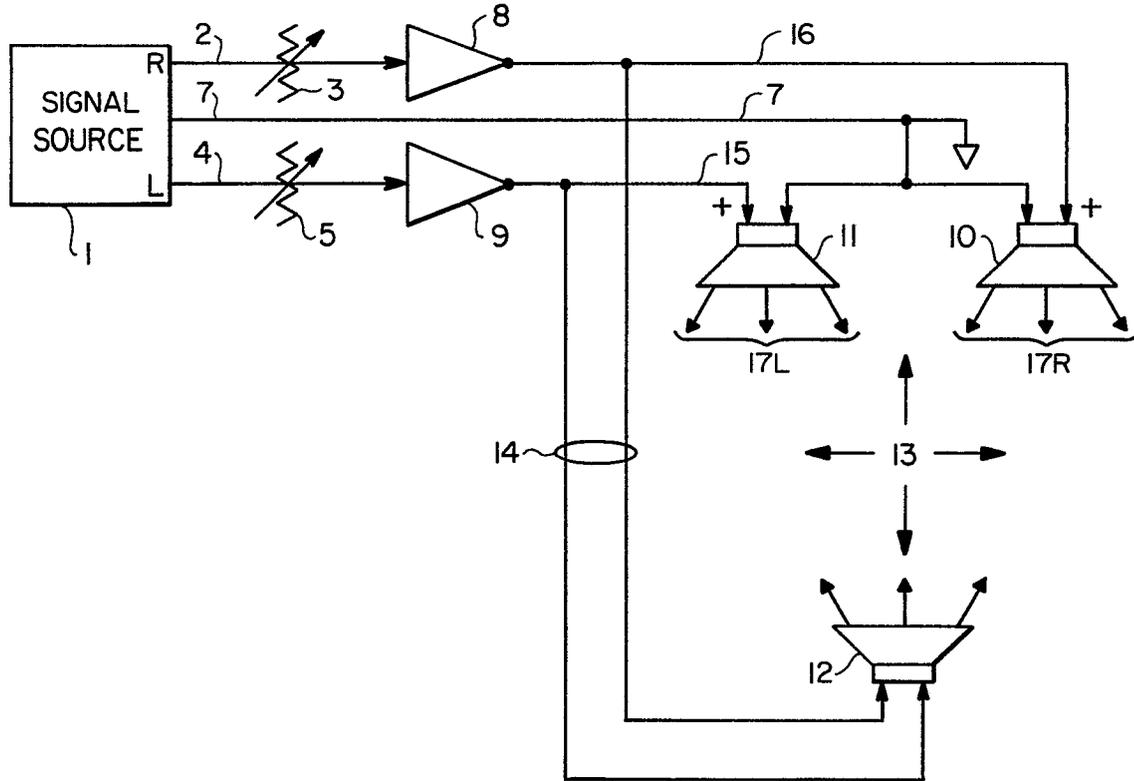
first amplifier means for reversing polarity of one of said signal voltages;

a plurality of resistor means connected to a circuit node for linearly summing current proportional to

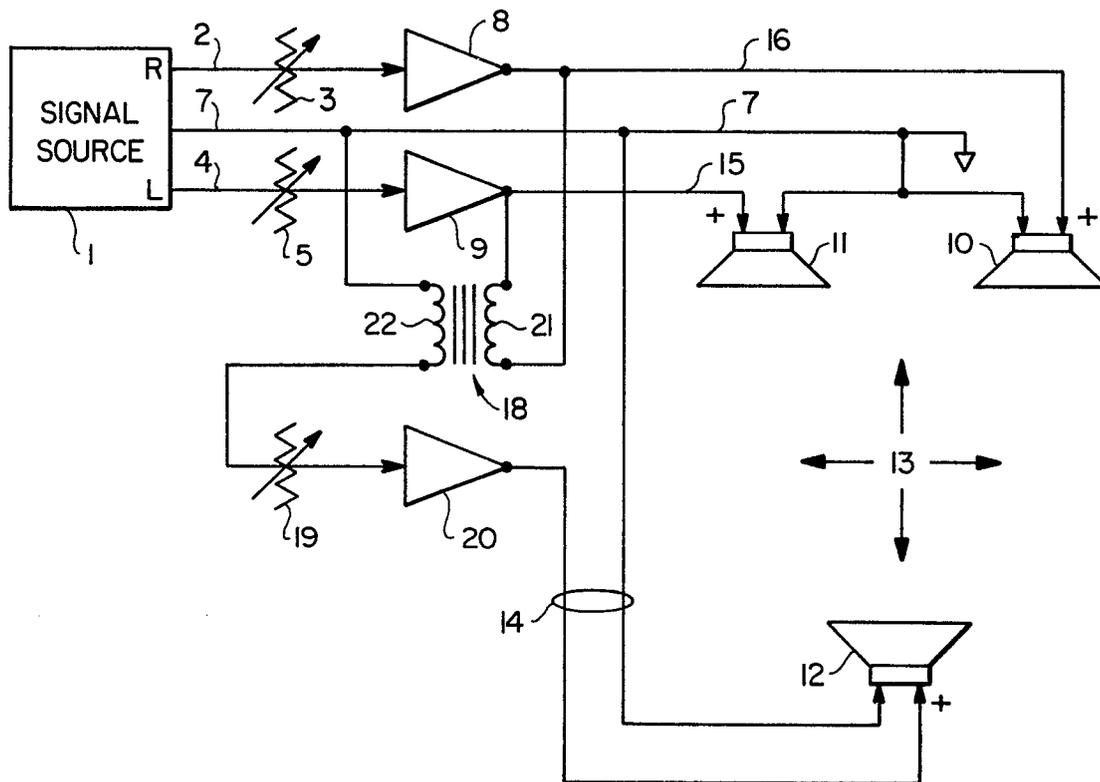
the reverse-polarity signal voltage and current proportional to the other of said signal voltages; and

second amplifier means connected to the circuit node for supplying a current proportional to the resulting  
5 current sum to a common impedance to produce a signal voltage thereacross proportional to the product of said current sum and said common impedance.

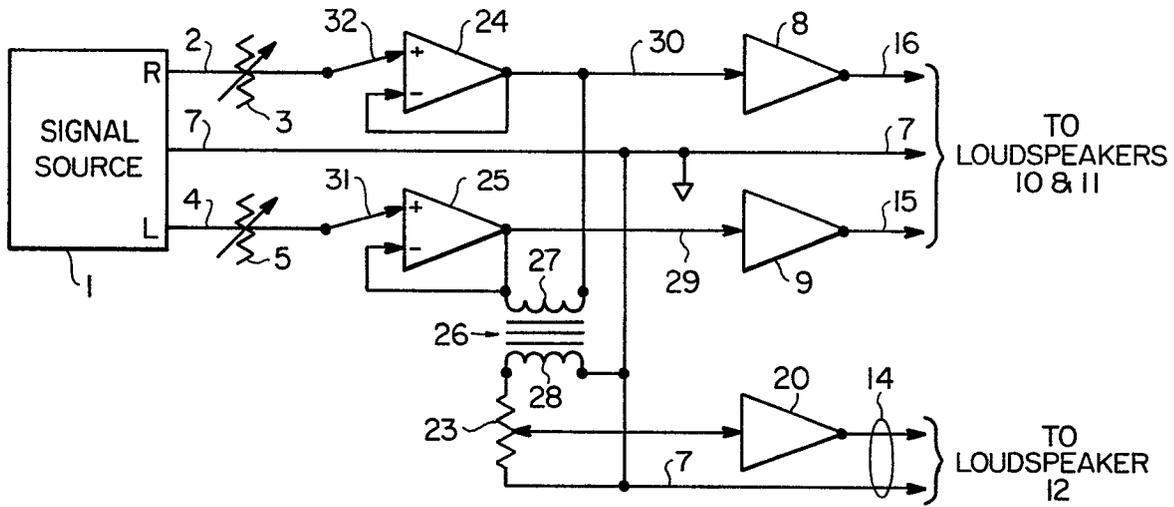
8. Stereophonic reproduction apparatus  
10 having left and right channels characterised by a third channel in which a signal dependent upon the algebraic difference between the left and right channel signals is produced.



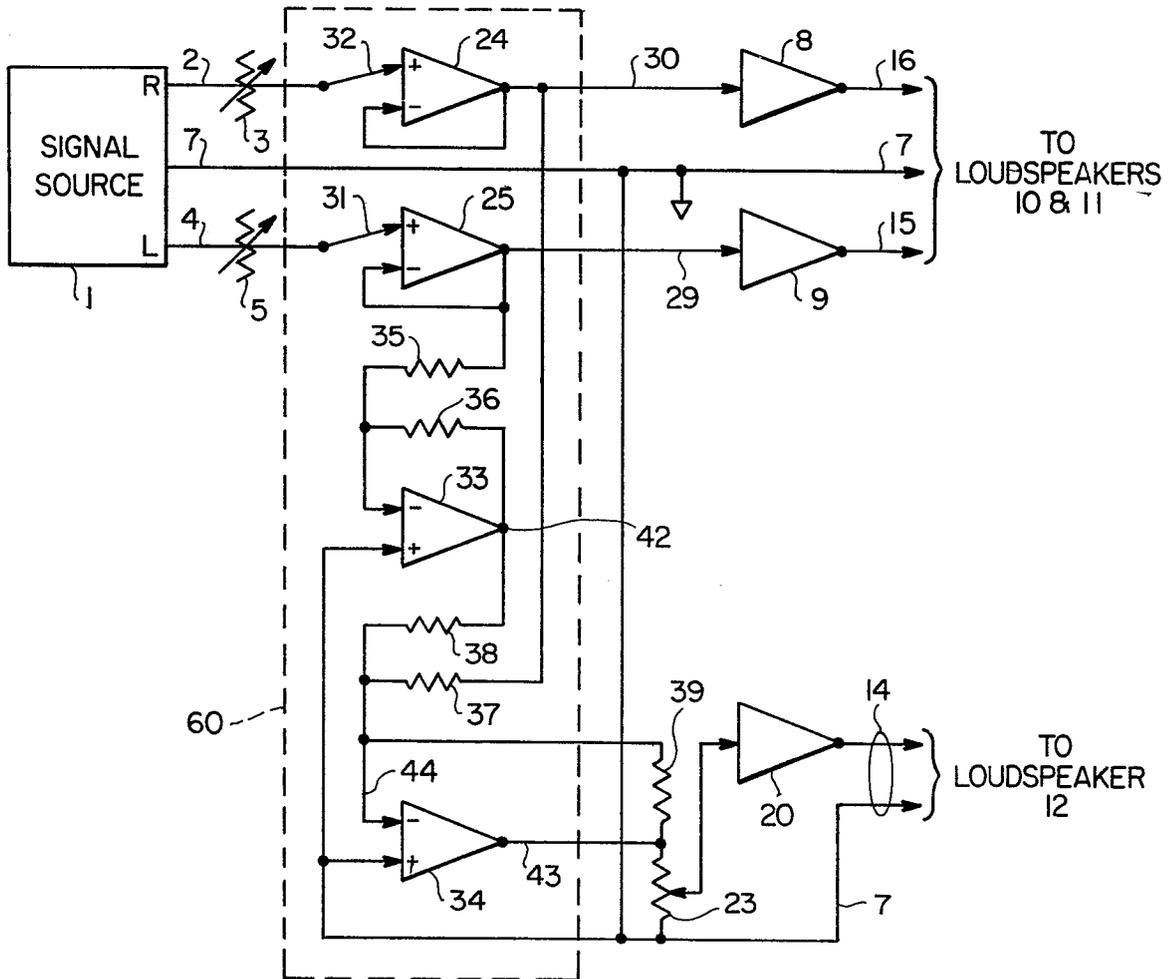
FIG\_1



FIG\_2



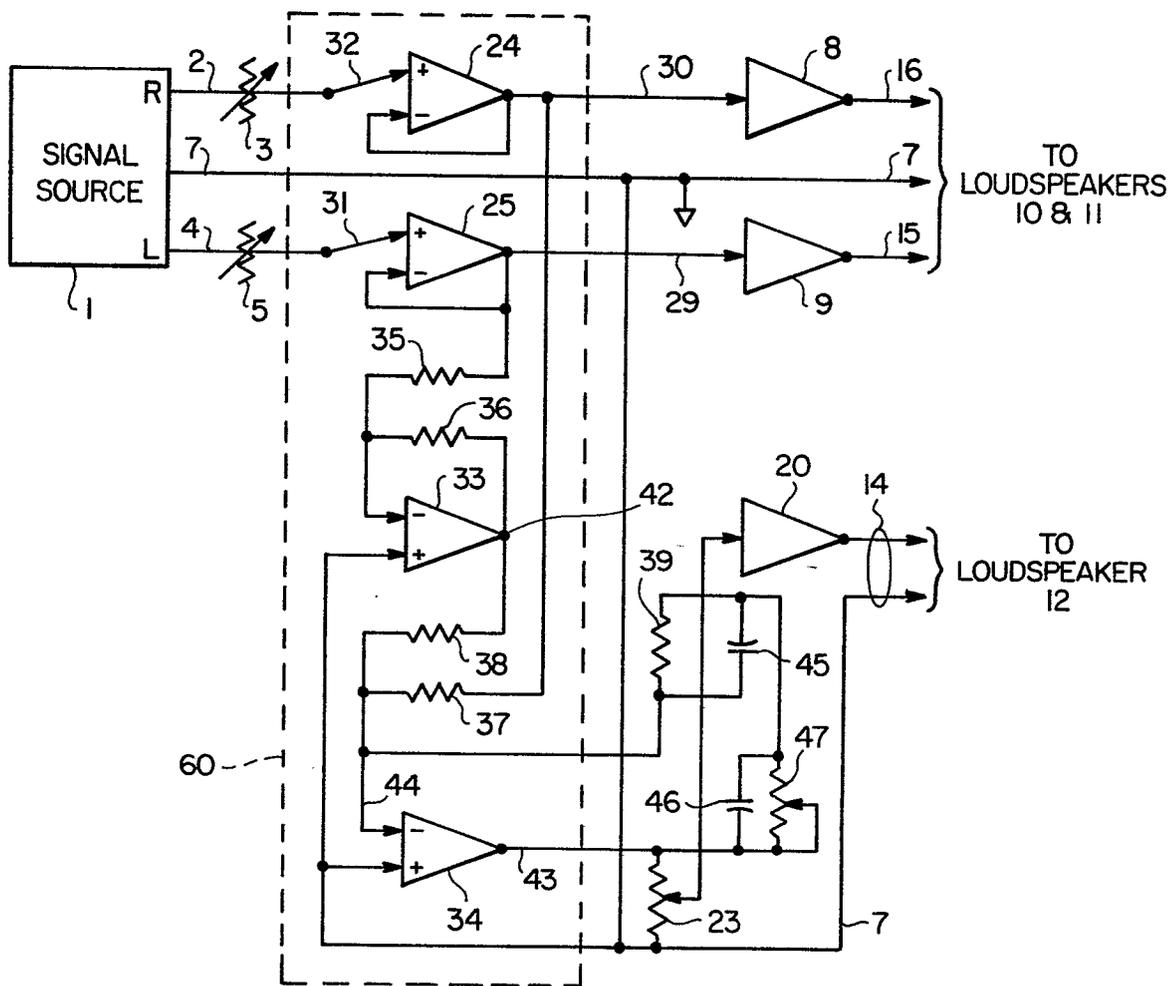
FIG\_3



FIG\_4

3/3

0086287



FIG\_5



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
X	FR-A-2 113 781 (J.C. PASCOLINI) * Claims 1,4; page 2, line 28 - page 4, line 35; figures 1,2 *	1,2,5,6,8	H 04 S 3/00
A	US-A-3 164 676 (D.H. BRUNNER) * Column 2, lines 47-68; figure 1A *	3	
A	WIRELESS WORLD, vol. 79, no. 1452, June 1973, page 284, London, G.B. "Circuit ideas" * Page 284: "Surround sound with 741s and variable crosstalk"; page 284, lower part; figure *	4	
A	FUNKSCHAU, vol. 44, no. 18, September 1972, page 672, München, DE. M. HORST: "Pseudoquadrofonie-Schaltung nach dem Matrix-Prinzip" * Page 672, right-hand column, paragraph 2; figure 2 *	7	TECHNICAL FIELDS SEARCHED (Int. Cl. 3) H 04 S 3/00 H 04 S 5/02 H 04 R 5/02
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 06-10-1982	Examiner MINNOYE G.W.
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			