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Takahashi

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[54] **ENCODING SYSTEM FOR FORMING TWO-CHANNEL SIGNALS FROM A PLURALITY OF SOUND SIGNALS**

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[52] **U.S. Cl.** .... **179/1 GQ,** 179/100.4 ST

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

[58] **Field of Search** .... 179/1 GQ, 100.4 ST, 1 G

[56] **References Cited**

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Attorney, Agent, or Firm—Harris, Kern, Wallen & Tinsley

[57] **ABSTRACT**

In an encoding system in which front-left and right audio input signals are coupled to left and right channels with a reference phase-shift angle, and back-left and right audio input signals are coupled to the left channel with the reference phase-shift angle plus 90° and to the right channel with the reference phase-shift angle minus 90°, a left-center audio input signal is coupled in a large proportion to the left channel with the reference phase-shift angle and in a small proportion to the right channel with the reference phase-shift angle minus 90° and a right-center signal is coupled in a large proportion to the right channel with the reference phase-shift angle and in a small proportion to the left channel with the reference phase-shift angle plus 90°.

6 Claims, 2 Drawing Figures

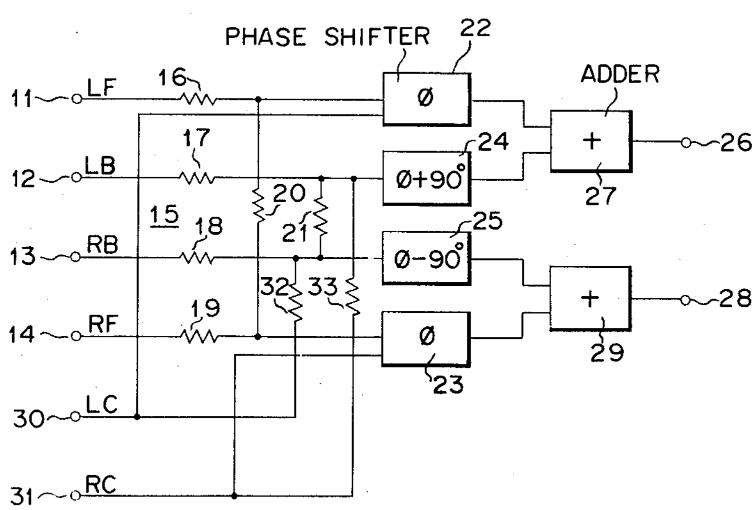


FIG. 1

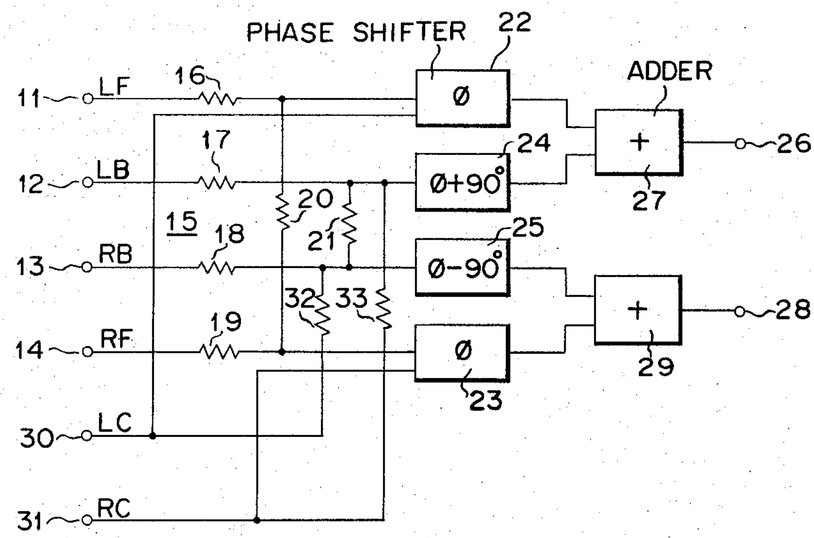
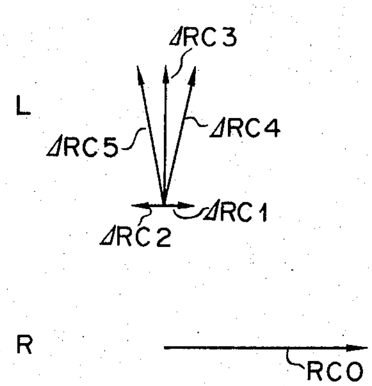

PHASE SHIFTER
22
ADDER
11
LF
16
Ø
12
LB
17
Ø+90°
24
+
26
27
15
20
21
13
RB
18
Ø-90°
25
32
33
14
RF
19
Ø
+
28
29
23
30
LC
31
RC

FIG. 2


ΔRC3
L
ΔRC5
ΔRC4
ΔRC1
ΔRC2
R
RCO

ENCODING SYSTEM FOR FORMING TWO-CHANNEL SIGNALS FROM A PLURALITY OF SOUND SIGNALS

This invention relates to a four-channel matrix encoding system for forming two-channel signals from a plurality of sound signals.

Already known is an encoding system which couples a left-front signal (LF) and a right-front signal (RF) in large and small proportions respectively to the left channel L with a reference phase shift amount; couples the RF signal and the LF signal in large and small proportions respectively to the right channel R with the reference phase shift amount; couples a left-back signal (LB) and a right-back signal (RB) in large and small proportions respectively to the left channel L with the reference phase shift amount plus 90°; and couples the RB signal and the LB signal in large and small proportion respectively to the right channel R with the reference phase shift amount minus 90°.

Signals of the left and right channels L and R generated by the prior art encoding system arranged as described above may be expressed by the following equation:

$$\left.\begin{aligned} L &= LF + \Delta RF + jLB + j\Delta RB \\ R &= RF + \Delta LF - jRB - j\Delta LB \end{aligned}\right\} \quad (1)$$

where Δ denotes a matrix coefficient whose typical value is 0.414.

To attain the most distinct separation of left and right signals obtained on the reproduction side, the customary practice is to couple a left-center signal LC and right-center signal RC to the left and right channels L and R respectively with the reference phase shift amount.

Where the two-channel signals L and R shown in the above equation (1) are reproduced into four-channel signals by the known decoder, separation between two adjacent channels is −3db. Separation between diagonally opposite channels is −∞.

To improve such indistinct separation of channels on the reproduction side, there has already been proposed a separation enhancing decoder for momentarily changing the mixing ratio of two-channel signals or a matrix coefficient according to the condition of the two-channel signals. For details of the decoder, refer to the copending U.S. Pat. application Ser. No. 298,933, filed on Oct. 19, 1972, with the title "DECODER FOR USE IN "4–2–4" MATRIX PLAYBACK SYSTEM."

The decoder is provided with a control unit for detecting the level relationship of front and back signals and generating a first and a second control output.

The equation (1) above shows that where the back signals LB and RB have a negligible amplitude as compared with that of the front signals LF and RF the two-channel signals are substantially in phase, and that conversely where the front signals LF and RF have a negligible amplitude as compared with that of the back signals LB and RR, the two-channel signals are substantially 180° out of phase. In case of LF = RF = LB = RB, the two-channel signals are 90° out of phase.

Where the two-channel signals L and R are in phase, the first control output takes a positive maximum value with respect to the referential voltage level whereas the second control output assumes a negative maximum value, or vice versa where the two-channel signals L and R are 180° out of phase. Where the two-channel

signals L and R are 90° out of phase, the first and second control outputs have a voltage level equal to the referential voltage level.

Where the two-channel signals L and R have the same phase, one type of prior art decoder enhances separation between front-left and right reproduced signals, but reduces separation between back-left and right reproduced signals and also increases the voltage level of the front signals and decreases that of the back signals, thereby promoting separation between the front and back reproduced signals. Where the two-channel signals L and R are 180° out of phase, the prior art decoder carries out an opposite operation to that mentioned above. Where the two-channel signals L and R are 90° out of phase, the decoder is operated in the same manner as the other conventional decoders without changing the matrix coefficients.

Where a decoder carrying out the above-mentioned operation is supplied with, for example, a right signal R and a left signal L including a left-center signal LC, the control unit does not act on the left-center signal LC. Therefore, this signal LC is reproduced by the left-front loudspeaker and left-back loudspeaker with an equal level. Since, however, two-channel signals are supplied to the decoder generally after being reproduced through a pickup cartridge from a phonographic record, it is difficult to prevent the left-center signal from necessarily appearing in the right signal R as a crosstalk component. In this case, it is also difficult to determine whether the crosstalk component has the same or opposite phase with respect to the original signal or the left-center signal. In either case, existence of the left-center signal causes the decoder to take the erroneous action of controlling the front and back signals.

It is accordingly an object of this invention to provide an encoding system capable of preventing two-channel signals reproduced through a recording medium from presenting the same or opposite phase relative to the left or right-center signal.

Another object of the invention is to provide an encoding system capable of producing two-channel signals in the form adapted for a decoder to reproduce separation enhanced output signals.

According to an aspect to this invention, there is provided an encoding system in which at least first to fourth sound signals desired to be coupled mainly to first to fourth loudspeakers surrounding a listener are utilized in forming first and second channel signals, and first and second sound signals are coupled to the first channel in large and small proportions respectively with a reference phase shift amount, second and first sound signals are coupled to the second channel in large and small proportions respectively with the reference phase shift amount, third and fourth sound signals are coupled to the first channel in large and small proportions respectively with a phase shift amount of the reference phase shift amount plus 90°, and the fourth and third sound signals are coupled to the second channel in large and small proportions with a phase shift amount of the reference phase shift amount minus 90°, the improvement comprising means for coupling a fifth sound signal desired to have its sound image localized between the first and third loudspeakers to the first channel in a large proportion with the reference phase shift amount; means for coupling the fifth sound signal to the second channel in a small proportion with a phase shift amount having substantially 90° phase difference with respect to the reference phase shift amount; means for coupling a sixth sound signal desired to have its sound image localized between the second and fourth loudspeakers to the second channel in a large proportion with the reference phase shift amount; and means for coupling the sixth sound signal to the first channel in a small proportion with a phase shift amount having substantially 90° phase difference with respect to the reference phase shift amount.

This invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawing, in which:

FIG. 1 is a circuit diagram of an encoding system according to one embodiment of this invention; and

FIG. 2 is vector diagrams given for better understanding of the invention.

Referring to FIG. 1 reference numerals **11** to **14** denote input terminals supplied with LF, LB, RB and RF audio input signals respectively. These input terminals are connected to a resistance matrix circuit **15** containing resistors **16** to **21.** A sum output of an LF signal having a large proportion and an RF signal having a small proportion is drawn out from the junction of the resistor **16** and blend resistor **20.** This output is coupled to a first phase shifter **22.** Further, a sum output of an RF signal having a large proportion and an LF signal having a small proportion is delivered from the junction of the resistor **19** and blend resistor **20.** This output is coupled to a second phase shifter **23.** A sum output of an LB signal having a large proportion and an RB signal having a small proportion is obtained from the junction of the resistor **17** and blend resistor **21.** This output is coupled to a third phase shifter **24.** Further, a sum output of an RB signal having a large proportion and an LB signal having a small proportion is taken out of the junction of the resistor **18** and blend resistor **21.** This output is coupled to a fourth phase shifter **25.**

Output signals from the first and third phase shifters **22** and **24** are coupled to an output terminal **26** through an adder **27** to produce a left-channel signal L. Output signals from the second and fourth phase shifters **23** and **25** are coupled to an output terminal **28** through an adder **29** to produce a right-channel signal R.

The first and second phase shifters **22** and **23** have substantially the same phase-shifting characteristic over entire audible frequency range, so as to shift the phase of input signal thereto by an reference angle ϕ. On the other hand, the third phase shifter **24** has a phase-shifting characteristic so as to shift the phase of input signal thereto by the reference angle ϕ plus 90° and the fourth phase shifter has a phase shifting characteristic so as to the phase of input signals by the reference angle ϕ minus 90°. Accordingly, left and right channel signals L and R obtained at the output terminals **26** and **28** can obviously be indicated by the aforementioned equation (1).

Reference numerals **30** and **31** show input terminals supplied with a left-center signal LC and a right-center signal RC respectively. The LC signal is coupled to the first phase shifter **22** in a large proportion and to the fourth phase shifter **25** through a resistor **32** in a small portion. The RC signal is coupled to the second phase shifter **23** in a large proportion and to the third phase shifter **24** through a resistor **33** in a small portion.

The resistors constituting the resistor matrix circuit **15** are chosen to have such resistance values as to cause the ratio of the small proportion to the large proportion of the LF, LB, RB and RF to indicate a value of 0.414. On the other hand, the small and large proportions of the LC and RC signals may be so chosen as to have a ratio of, for example, 0.01 to 0.1 (or −40 db to −20db).

There will now be described the appearance of a crosstalk. If, in case two-channel signals R and L are reproduced from a phonographic disk, the right-channel signal R contains a right-center signal RCO, then the reproduced left-channel signal L will be contaminated by a crosstalk component **ΔRC1** (about −30db) having the same phase as that of the **RC0** signal or another crosstalk component **ΔRC2** having an opposite phase from that of the **RC0** signal. Further, the left signal L is contaminated by a third crosstalk component **ΔRC3** (about −20db) which was carried into the left signal L on the encoder side in quadrature with the **RC0** signal. As the result, the reproduced left-channel signal L contains a resultant crosstalk component **ΔRC4** formed of crosstalk components **ΔRC3** and **ΔRC1** or a resultant crosstalk component **ΔRC5** formed of crosstalk components **ΔRC3** and **ΔRC2.** Since the crosstalk component **ΔRC1** or **ΔRC2** has a smaller proportion than the crosstalk component **ΔRC3,** the resultant crosstalk **ΔRC4** or **ΔRC5** is approximately in quadrature with the aforesaid RC0 component. Accordingly, the reproduced two-channels L and R are in quadrature with each other with respect to the left-center signal LC or right-center signal RC. Where, therefor, such two-channel signals are supplied to the previously described separation enhancing decoder, then the existence of the LC or RC signal can substantially prevent the front and back signals from being controlled by mistake.

Though, in FIG. **1,** the left-center signal LC and the right-center signal RC of a small proportion are coupled to the right and left channels with phase-shifts of ϕ−90° and ϕ+90° respectively, the left-center signal LC of a small proportion may be coupled to the right channel with a phase-shift of ϕ+90° and the right-center signal RC to the left channel with a phase-shift of ϕ−90°.

What is claimed is:

1. An encoding system in which at least first to fourth sound signals desired to be coupled mainly to first to fourth loudspeakers surrounding a listener are utilized in forming first and second channel signals, and first and second sound signals are coupled to the first channel in large and small proportions respectively with a reference phase shift amount, second and first sound signals are coupled to the second channel in large and small proportions respectively with the reference phase shift amount, third and fourth sound signals are coupled to the first channel in large and small proportions respectively with a phase shift amount of the reference phase shift amount plus 90°, and the fourth and third sound signals are coupled to the second channel in large and small proportions with a phase shift amount of the reference phase shift amount minus 90°, the improvement comprising means for coupling a fifth sound signal desired to have its sound image localized between said first and third loudspeakers to the first channel in a large proportion with the reference phase shift amount; means for coupling said fifth sound signal to the second channel in a small proportion with a phase shift amount having substantially 90° phase difference with respect to the reference phase shift amount; means for coupling a sixth sound signal desired to have its sound image localized between the second and fourth loudspeakers to the second channel in a large proportion with the reference phase shift amount; and means for coupling said sixth sound signal to the first channel in a small proportion with a phase shift amount having substantially 90° phase difference with respect to the reference phase shift amount.

2. An encoding system for encoding at least first to fourth sound signals desired to be coupled mainly to first to fourth loudspeakers surrounding a listener into first and second channel signals, comprising first means for mixing the first sound signal in a large proportion and the second sound signal in a small proportion; second means for mixing the second sound signal in a large proportion and the first sound signal in a small proportion; third means for mixing the third sound signal in a large proportion and a fourth sound signal in a small proportion; fourth means for mixing the fourth sound signal in a large proportion and the third sound signal in a small proportion; a first phase shifter coupled to the output of said first means; a second phase shifter coupled to the output of said second means and having substantially the same phase shifting characteristic as said first phase shifter over the entire audible frequency range; a third phase shifter coupled to the output of said third means and having a phase shifting characteristic of plus 90° difference with respect to those of said first and second phase shifters; a fourth phase shifter coupled to the output of said fourth means and having a phase shifting characteristic of minus 90° difference with respect to those of said first and second phase shifters; means for coupling a fifth sound signal desired to have its sound image localized between the first and third loudspeakers to the input of said first phase shifter in a large proportion; means for coupling said fifth sound signal to the input of said fourth phase shifter in a small proportion; means for coupling a sixth sound signal desired to have its sound image localized between the second and fourth loudspeakers to the input of said second phase shifter in a large proportion; means for coupling said sixth sound signal to the input of said third phase shifter in a small proportion; means for mixing output signals from said first and third phase shifters; and means for mixing output signals from said second and fourth phase shifters.

3. An encoding system for coupling to the first and second channels first to fourth sound signals desired to be coupled mainly to first to fourth loudspeakers surrounding a listener comprising: means for coupling the first and second sound signal to the first channel in large and small proportions respectively with a reference phase shift amount; means for coupling the second and first sound signals to the second channel in large and small proportions respectively with the reference phase shift amount; means for coupling the third and fourth sound signals to the first channel in large and small proportions respectively with the reference phase shift amount plus 90°; means for coupling the fourth and third sound signals to the second channel in large and small proportions with the reference phase shift amount minus 90°; means for coupling a fifth sound signal desired to have its sound image localized between the first and third loudspeakers to the first channel in a large proportion with the reference phase shift amount; means for coupling the fifth sound signal to the second channel in a small proportion with a phase shift amount having substantially 90° phase difference with respect to the reference phase shift amount; means for coupling a sixth sound signal desired to have its sound image localized between the second and fourth loudspeakers to the second channel in a large proportion with the reference phase shift amount; and means for coupling the sixth sound signal to the first channel in a small proportion with a phase shift amount having substantially 90° phase difference with respect to the reference phase shift amount.

4. An encoding system according to claim 3 wherein the small proportion of the first to fourth sound signals bears a ratio of about 0.414 to the large proportion thereof.

5. An encoding system according to claim 3 wherein the small proportion of the fifth and sixth sound signals bears a ratio of 0.01 to 0.1 to the large proportion thereof.

6. An encoding system for encoding first to fourth sound signals desired to be coupled mainly to first to fourth loudspeakers surrounding a listener into first and second channel signals comprising: first to fourth input terminals adapted to receive the first to fourth sound signals respectively; a fifth input terminal adapted to receive a fifth sound signal desired to have its sound image localized between the first and third loudspeakers; a sixth input terminal adapted to receive a sixth sound signal desired to have its sound image localized between the second and fourth loudspeakers; first and second output terminals; matrix means connected to said first to fourth input terminals so as to form first, second, third and fourth output signals, said first output signal being a sum of the first sound signal having a large amplitude and the second sound signal having a small amplitude, said second output signal being a sum of the first sound signal having a small amplitude and the second sound signal having a large amplitude, said third output signal being a sum of the third sound signal having a large amplitude and the fourth sound signal having a small amplitude, and said fourth output signal being a sum of the third sound signal having a small amplitude and the fourth sound signal having a large amplitude; a first phase shifter connected to receive said first output signal and having a reference phase shifting characteristic; a second phase shifter connected to receive said second output signal and having the reference phase shifting characteristic; a third phase shifter connected to receive said third output signal and having a phase shifting characteristic of plus 90° difference with respect to the reference phase shifting characteristic; a fourth phase shifter connected to receive said fourth output signal and having a phase shifting characteristic of minus 90° difference with respect to the reference phase shifting characteristic; means for coupling output signals from said first and third phase shifters to said first output terminal; means for coupling output signals from said second and third phase shifters to said second output terminal; means for coupling a fifth sound signal to said first phase shifter with a large amplitude; means for coupling the fifth sound signal to said third phase shifter with a small amplitude; means for coupling a sixth sound signal to said second phase shifter with a large amplitude; and means for coupling the sixth sound signal to said fourth phase shifter with a small amplitude.

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