United States Patent

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[45] **Feb. 29, 1972**

[54] COMPATIBLE STEREO GENERATOR

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[22] Filed: **May 25, 1970**

[21] Appl. No.: **40,335**

Related U.S. Application Data

[63] Continuation of Ser. No. 696,249, Jan. 8, 1968, abandoned.

[52] **U.S. Cl.** ..... **179/1 G**
[51] **Int. Cl.** **H04r 5/00**
[58] **Field of Search** ..... 330/307; 179/1 G, 1 GP

[56] **References Cited**

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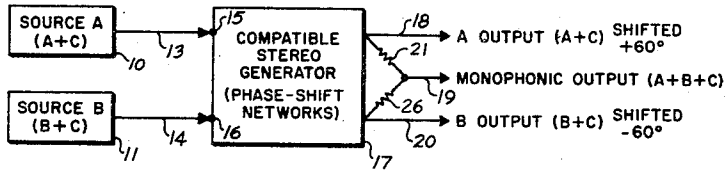
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[57] **ABSTRACT**

This invention relates to an instrument incorporating an otherwise independent pair of wide band unity gain amplifier chains of novel configuration providing in the several stages of each chain the capability of and means for shifting the phase of signals from stereophonic signal sources applied to each chain. The phase shift capability of one channel is over the range of zero phase shift related to the phase of the input signal through +90° and in the other channel over a range of from zero phase shift related to the phase of the input signal through −90°. The wide band phase shift networks are an element in the implementation of a means to apply the discovery disclosed in this invention that if the signal output of each respectively, of a pair of related stereophonic signal channels is applied to one, respectively, of said amplifier chains, one of the channels containing signals identified as *A+C*, and the other containing signals identified as *B+C* (the *C*-components of the signals being common to both channels) and the signal of the first channel shifted in phase +60° while that in the second channel is shifted in phase −60° (the difference between the two being a total of 120° centered about a zero input reference phase) then the summation of the phase shifted signals from the two channels will result in an output (summed) signal of *A+B+C*, whereas by prior art techniques the summation or mixing of two stereophonic channels produces a resultant *A+B+2C*.

14 Claims, 7 Drawing Figures



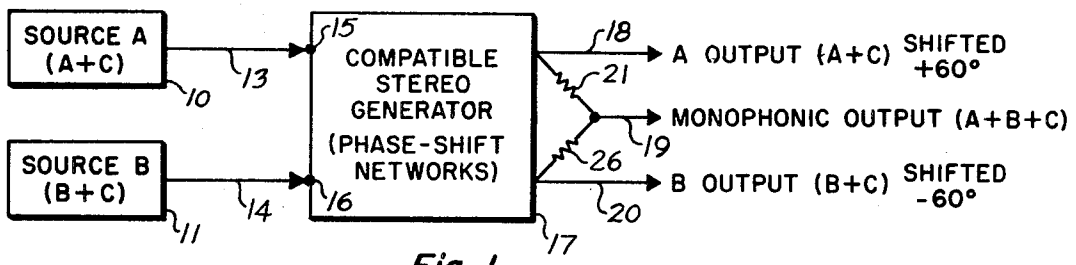


Fig. 1

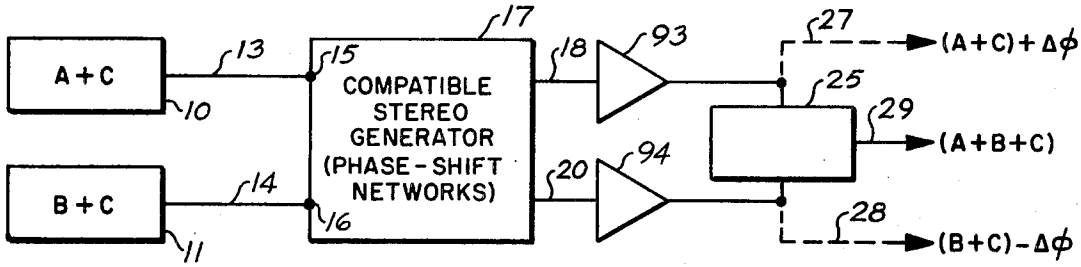


Fig. 2

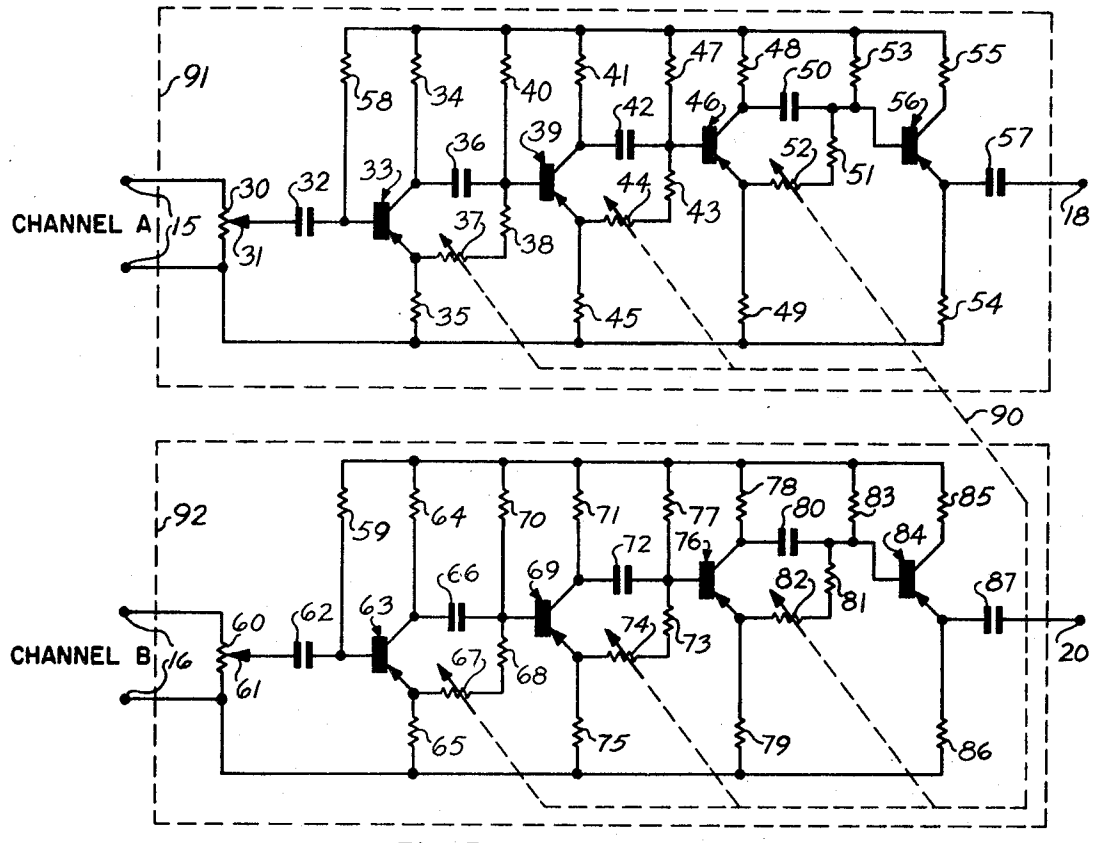


Fig. 3

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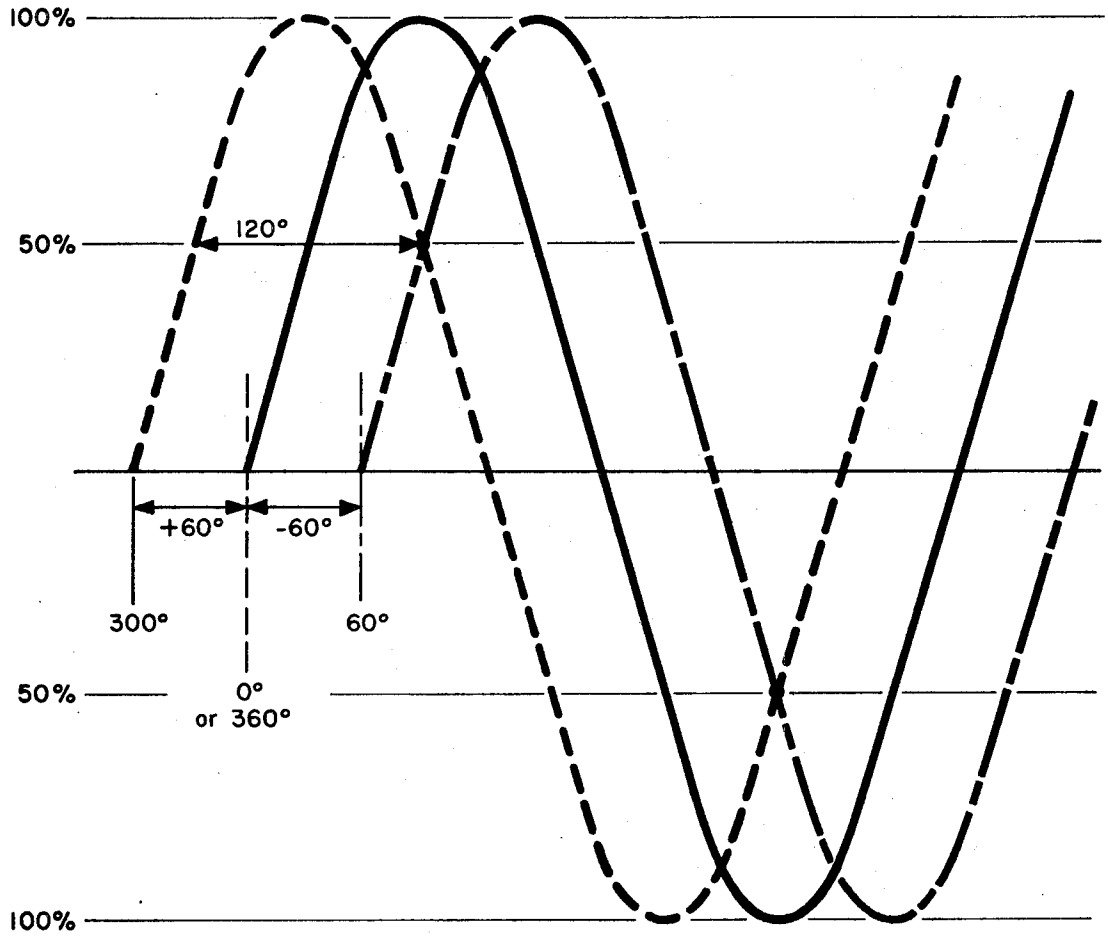


Fig. 4

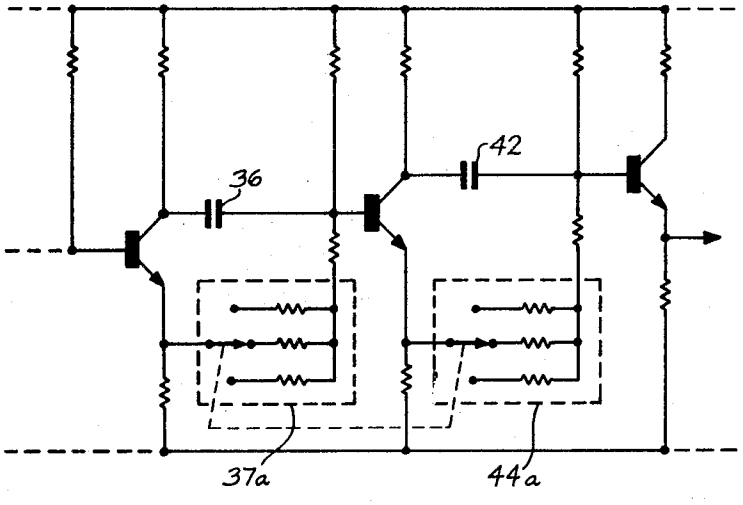


Fig. 7

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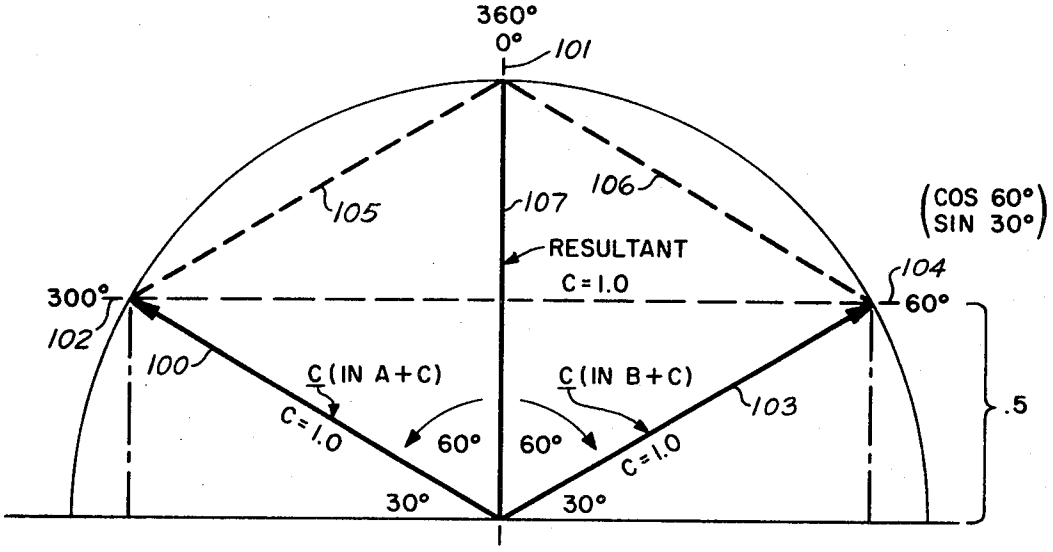


Fig. 5

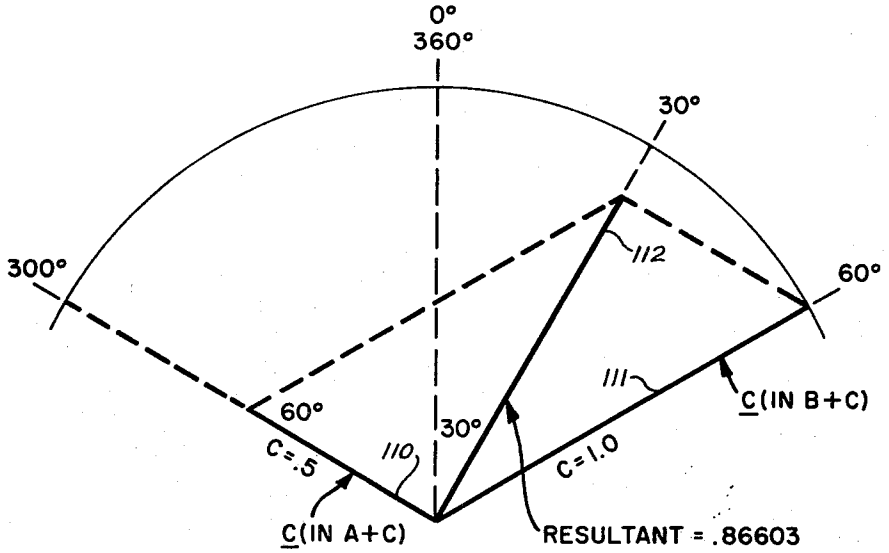


Fig. 6

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COMPATIBLE STEREO GENERATOR

This application is a continuation in part of application Ser. No. 696,249 filed Jan. 8, 1968 by this applicant under the same title and now abandoned.

BACKGROUND OF THE INVENTION

In stereophonic recording and audio amplifying systems generally, the ultimate output signals which the listener consumer of stereophonic records utilizes are divided into left and right channels. From the standpoint of the manufacturers of such records two markets must be served by the records he produces. One record must be provided for the two-channel stereophonic record playing listener consumer and another record for the monophonic equipment owner providing only a single output channel. This process necessarily doubles his manufacturing costs since in prior art systems the stereophonic recording is not compatible with the monophonic system. Therefore the need for separate stereophonic and monophonic records, at present, for any performance.

By the prior art techniques in order to be able to make monophonic as well as stereophonic forms of the same program material the initial live recording is made in three channels which can be designated as channels *A*, *B*, and *C* respectively. The *A*-channel is the "left channel" or that which receives the signals from a microphone to the listeners' left during a performance and the *B*-channel is the "right channel" or that which receives the signals from a microphone at the listeners' right during a performance. From either a third microphone, centrally placed, or, by virtue of a matrixing network electrically incorporated in the recording system, a *C*-channel is produced which contains signal components of the same performance which are common to both the left (*A*) channel and the right (*B*) channel.

Thus, when a two-channel stereophonic record is produced from the master three-channel performance record, the respective channels may be said to include in the one *A*+*C* components, and in the other *B*+*C* signal components.

When the monophonic record version of this performance is made by the prior art technique the channels are mixed so that the two channels add up as follows: *A*+*C* (left channel)+*B*+*C* (right channel). The summation resultant is *A*+*C*+*azC* which equals *A*+*B*+2*C*.

To the listener this is appreciated as a rather prominent center presence which is unnatural because the *C*-component of the signal is stronger than either the *A*- or *B*-components thereof. The monophonic recording, therefore, so made, has a character unlike the original performance in that the *C*-components of the signal information differ from their natural relationship in the original performance.

It is therefore desirable to find means for producing a stereophonic recording that will permit the resulting recorded two-channel signal when mixed together for monophonic records or when a stereophonic recording is played on monophonic playback equipment the resultant output will have equal *A*-, *B*- and *C*-components as in the original recording session. The present invention provides a means usable in the recording process or in other related stereophonic systems by which the two-channel stereophonic phonograph record resulting therefrom can be played back on monophonic equipment without the above-mentioned unnatural presence.

DESCRIPTION OF THE INVENTION

This inventor has discovered a property of phase shifting networks applied in stereophonic audio apparatus whereby the previously described signal components *A*+*C* and *B*+*C* can be summed and will only add up to *A*+*B*+*C*. A means has also been devised whereby the discovery can be implemented and applied easily and economically to two-channel systems which include the aforementioned *A*+*C* and *B*+*C* components where the *C*-component is common to both channels.

The implementation provides circuit means for phase shifting the *A*+*C* signal in one direction while the *B*+*C* signal is phase shifted in the opposite direction.

The newly discovered property is the fact that when the *A*+*C* signal channel shifts the phase of the applied signal by +60° and the *B*+*C* channel shifts the phase of the applied signal by −60° when these two channels are mixed, either electrically to produce a single channel output for a monophonic recording, or mechanically by playing back the stereophonic two-channel recording produced with phase shifted signals as above-mentioned recorded thereon, the resultant monophonic output signal adds to *A*+*B*+*C*.

The phase shifting above referred to will affect only the common *C*-components of the signal since the *A*- and *B*-signals have no counterpart in the respective opposite channels. The effective phase shift of the *A*- and *B*-signals in their respective channels is of no consequence and therefore produce absolutely no degradation of the stereophonic signals in the use of the invention.

The particular novelty achieved in the invention is the fact that the phase shifting is accomplished without distortion. It has been found that the respective equal positive and negative phase shift of the signals in the respective channels from a zero input reference phase is responsible for this. A 120° or for that matter, any total phase shift of the signals in one channel without change in the other will produce a distorted signal in the resultant when they are combined. Only the equal and opposite phase shifts from the zero reference to a maximum of +90° for one channel and −90° for the other channel produces the desired result. The system operates without adding distortion or degrading the stereophonic character of the signals.

It has been found also that when the common information signals are different in amplitude and shifted in phase over equal and opposite angles in each channel the resultant summed amplitude is never greater than the larger of the two and its apparent phase angle is shifted in proportion to the ratio between the amplitudes.

Accordingly it is an object of the invention to provide a pair of phase-shifting amplifiers each capable of shifting the phase of signals applied thereto in opposite directions equally about a zero phase reference related to the input signal to each channel.

It is another object of the invention to provide means for producing a two-channel stereophonic signal capable of being combined for monophonic reproduction without distortion and without degradation of the stereophonic character thereof, and which when combined will encompass all of the components of the original performance without amplitude change.

It is a further object of the invention to provide means by which the common component *C* of respective stereophonic audio channels *A*+*C* and *B*+*C* will, when the two channels are combined not be augmented due to summation effects.

It is still another object of the invention to implement the discovery that when stereophonic signals *A*+*C* and *B*+*C* are respectively shifted in phase in opposite directions by 60° in their respective channels, in the subsequent summation of the channels in the resultant will be *A*+*B*+*C*.

It is an even further object of the invention to provide a phase-shifting network of two independent channels which produce in respective stages thereof phase shifts for decades of frequencies in a predetermined spectrum, and the phase shifts are equal and opposite in polarity with respect to a zero reference input phase in each respective channel, the phase adjustment of all of the stages in both channels being accomplished with a single control mechanically operative for all of the stages and arranged for precise tracking in all channels. By governing the phase shift in equal angles and opposite directions for the respective channels, the common information *C* therein for selected angles between 0° and 90° can be controlled from the value of 2*C* to zero when the channels are added together by mixing.

These and other objects of the invention will become more clear from the specification which follows when taken together with the appended claims. The specification describes a preferred embodiment of the implementation of the invention shown in the drawings but should not be construed as limiting the invention to the embodiment shown since those skilled in the arts appertaining thereto will be able to devise other ways of implementing the invention in the light of the teachings herein within the ambit of the claims.

IN THE FIGURES

FIG. 1 is a basic block diagram of a system according to this invention;

FIG. 2 is a block diagram showing the mixing and amplification of signals in accordance with the invention;

FIG. 3 is a circuit schematic diagram of the opposite polarity phase shift networks devised for implementing the invention;

FIG. 4 is a waveform diagram illustrative of the discovery involved in the invention;

FIG. 5 is a vector diagram illustrative of the operation of the invention;

FIG. 6 is a vector diagram of other relationships involved in the implementation of the invention; and

FIG. 7 is a schematic circuit diagram showing details of one section of the phase shift networks of the implementation of the invention to illustrate an alternative mode of phase adjustment.

The basic principle of the invention implementation is illustrated in the block diagram of FIG. 1. In the Figure a Source *A* is indicated in block **10** and a source *B* in block **11**. These sources may be the left channel and right channel signal sources of a common stereophonic program. The program may be the result of a tape recording, a live performance, a disc recording or any other stereophonic signal source, such as an AM or FM stereophonic broadcast signalling system. In any event the source consists of a pair of channels each carrying its respective signal information related to the stereophonic program material. These source signals are applied on signal lines **13**, **14** to separate inputs **15**, **16** on the compatible stereophonic generator of this invention indicated by block **17**. From the output of the generator **17** there may be derived the A-output signal on line **18**, the B-output signal on line **20**. By adding the signals on lines **18** and **20** by any known means such as a pair of resistances **21**, **26** a monophonic compatible output may be derived on line **19**.

As is indicated in blocks **10**, **11** the signal sources *A* and *B* each include a common component C so that channel *A* as indicated in FIG. **2** has signal components *A+C* and channel *B* has signal components *B+C*. The *A*-channel "*A*" components are not found in channel *B* nor are the "*B*" components found in channel *A*.

In the compatible stereo generator block **17** are included phase shift networks to shift the phase of the respective channel signals in opposite polarity with an adjustment capability through +90° in the *A*-channel and through −90° in the *B*-channel simultaneously.

As may be seen in FIG. **2** amplifier devices **93**, **94** may be added to the outputs of channels *A* and *B* on lines **18**, **20** for any purpose such as impedance matching, power or voltage amplification or simply for isolation. The devices which perform such functions are well known in the art and can be selected from a wide variety of commercial sources of such equipment. They must each, however, be identical in circuit and performance with the other.

The outputs of amplifier or other devices **93**, **94** may be connected to a mixing network of conventional design **25** to produce the compatible signal output on line **29** identified as (*A+B+C*).

The compatible stereophonic generator **17** according to this invention and shown in a schematic circuit diagram in FIG. **3** consists of two-phase shift networks **91**, **92**. Each network includes three cascaded phase shift stages, transistors **33**, **39**, **46** in **91** and transistors **63**, **69**, **76** in **92**. Each stage produces up to a + or − 90° shift in phase for a selected decade of frequencies, by setting the controls **37**, **44**, **52** in **91** and **67**, **74**, **82** in **92** all six on a common shaft **90**. For example, the first stage of the positive going phase shift network operates to shift the phase over the frequencies from 30,000 to 3,000 Hz. The second stage produces the phase shift for frequencies from 3,000 to 300 Hz. The third stage covers the frequencies from 300 to 30 Hz. Similarly the negative going phase shift network produces a phase shift in the first stage over 30,000 to 3,000 Hz. The second stage produces a phase shift over the range 3,000 to 300 Hz. The third stage produces the negative phase shift over the frequency range 300 to 30 Hz. The phase shift in each stage is identical in each network. The resistances and capacitances such as at **36** **37**, **38** which form the feedback paths between collector and emitter of the respective transistor stage such as **33** in which they are connected, are selected in combination with the transistor impedance parameters to produce the desired phase shift range where adjustable components are used. If as may be desirable in some cases fixed value resistors as shown in FIG. **7** are to be employed the choice will be predicated upon the X_c value of the capacitor such as **36** or **66** over the frequency range of interest and the transistor amplifier parameters. While the range above-mentioned covering 30–30,000 Hz. will clearly be adequate for audio frequency stereophonic sound or broadcasting systems a unit has been produced in the process of proving the operation of the system of the invention. A four stage device was constructed in which the frequency decade separation started at 10 Hz. and continued through 100 kHz. as follows:

1st stage 100 kHz. to 10,000 Hz.
2nd stage 10,000 Hz. to 1,000 Hz.
3rd stage 1,000 Hz. to 100 Hz.
4th stage 100 Hz. to 10 Hz.

The principle enunciated above is followed in the same way in selecting the resistance and capacitance values so that the phase shift operation of the amplifier is accomplished.

It is certainly clear from the above that a wide band phase shift network similar to those shown in dashed blocks **91**, **92** is possible using the designs and principles hereinabove set forth and employing the circuit configurations shown in FIG. **3**. Such wide band networks according to the invention can be employed in video systems as in other systems where such wide range positive and negative phase shift capabilities are called for.

Each of the frequency decade amplifier phase shift units has unity gain so that the overall gain of each network chain such as **91**, **92** is unity. Stated another way, there is no insertion loss to speak of in the use of the network chain. The variable resistor such as **37**, **44**, **52** and **67**, **74** **82** in the feedback loop is chosen so that it will vary in relation to the X_c of the capacitor such as **36**, **42**, **50** or **66**, **72**, **80** for that particular loop from the lowest frequency of the decade to the highest frequency of the decade so that the X_c from the top of the decade to the bottom of the decade can either go from zero phase shift to +90° phase shift in one unit (say channel *A*) and from zero phase shift to −90° phase shift in the other (channel *B*) unit. It should be noted that the resistance units used in the adjustment of phase shift, however the network is used, that is, in fixed values, as in FIG. **7** (**37** *a*, **44***a*) or as adjustable potentiometer units, as in FIG. **3** their values must be precise and the tracking of the six potentiometers, tied to a common shaft **90**, must be exact with respect to one another to accomplish the sought for + and − 90° phase shift variation capability. On the input of each of the phase shift networks an amplitude control **30**, **31** or **60**, **61** is provided so that adjustment of the amplitude of the signals applied to each channel can be made in the event that the signal levels from the respective right and left channels of the source of the stereophonic signals should fail to be balanced, that is should not be of equal amplitude. An emitter follower amplifier at **54**, **84** provides a low-output impedance.

While in the exemplary unit an impedance of 5,000 ohms (Resistor **86**) at the output of each channel is provided other means may be employed to either step-up or stepdown the impedances to desired levels as suits the channel combining or mixing networks such as **25** or other systems to which this equipment is to be connected. Additionally integrated circuit amplifier units or other amplifiers can be added at the output of each channel before mixing to provide either power output or driver output for power stages or to produce unity gain power output conditions as desired.

The waveform diagram in FIG. **4** is illustrative of an important factor in the operation of the system of this invention, that is, that the resulting *A*+*B*+*C* is obtained upon mixing after the settings of the phase-shifting networks **91, 92** are so adjusted that a phase separation of 120° is maintained between the signals of the two channels with respect to their initial input phase, that is the right channel signal is shifted −60° in phase with respect to its input phase by the network **17** and the left channel signal is shifted −60° with respect to its input phase. Thus the 120° phase difference is created. The signals are maintained 120° apart at all times irrespective of anything else that may be taking part elsewhere in the stereophonic system. This phase difference between the two channels, once set, is invariant with respect to one another.

It should be further further noted that the advance of phase in one channel has a corresponding retardation in phase in the other channel starting from an identical zero reference phase in each channel. The system does not operate simply on the basis of a difference in phase between the two channels amounting to 120° or any other phase difference. The difference must be arranged to depart equally in a negative and positive direction from either the identical zero phase or 360° starting phase points at the input **15, 16** to the phase shift networks. For example a 120° difference all on the positive side or all on the negative side of the initial starting (zero or 360°) phase does not produce the result disclosed in this invention. Hence it is the belief of this inventor that he has discovered a phenomenon not heretofore known in this art, namely that where in a first signal channel (*A*) containing signal components *A* and *C* and a second signal channel (*B*) containing signal components *B* and *C*, the signal components *C* being common to both channels, (though the channels are otherwise independent and separate) are each respectively shifted in phase in opposite directions by 60° (the total phase difference being 120° centered over the zero phase point) and the channels thereafter added, the resultant of this summation is *A*+*B*+ with the *C*-component returning to zero phase.

Had the addition of the two channels been done by any of the known prior art techniques the resultant would have been *A*+*B*+*C* which is the expected algebraic result.

Mathematically the new result can be explained as follows:

Given the common signal *C* appearing in both channels. For the purposes of the ensuing discussion the *A*-signal and the *B*-signal can be ignored because each passes on through its respective channel without interaction with the other, albeit each goes through the same phase-shifting operation respectively applied to the cochannel *C*-signals in the channel with it.

The *C*-signal in channel *A* is phase shifted +60° which may be described as a shift of $\pi/3$ radians.

The *C*-signal in channel B is phase shifted −60° which may be described as a shift of $-\pi/3$ radians.

Upon mixing of the two signals they are summed:

$$\sin(C-\pi/3)+\sin(C+\pi/3)$$
$$=(\sin C\cdot\cos\pi/3+\cos C\cdot\sin\pi/3)+(\sin C\cdot\cos\pi/3-\cos C\cdot\sin\pi/3)$$
$$=2(\sin C\cdot\cos\pi/3)$$
$$=2\cdot\tfrac{1}{2}\sin C=\sin C$$

The *C*-signal component has therefore a value of unity rather than 2*C* which is obtained by an algebraic addition without phase shift.

In FIG. **5** there is shown a vector diagrammatic representation of the effect discovered and hereinabove disclosed. In the figure there is presented the vector or radius line **100** to represent the amplitude (value of 1 unit) of the *C*-component in the *A*+*C* channel rotated in phase counterclockwise 60° from the 360° or 0° reference line **101** to the 300° point **102** on an arbitrary reference circle. The radius line **103** represents the amplitude (value of 1) of the *C*-component in the *B*+*C* channel rotated in phase clockwise from the 360°/0° reference 60° to 60° point on the arbitrary reference circle. Forming the vector parallelogram as indicated by dashed lines **105, 106,** shows that the radius line **107** on the 0° or 360° axis is 1 unit long falling as it does on the reference circle. Radius line **107** represents the vector sum of the two vectors **100** and **103** and is equal in length to each of lines **100** and **103**.

It has been noted in the introductory remarks that when the amplitudes of the *C*-components in the respective left and right channels differ from one another, the phase-shifting operation produces, upon summation a resultant not greater than the largest amplitude and the reference phase shifts towards the side with the larger of the two *C*-component values. This is illustrated in FIG. **6** where line **110** is shown similar to line **100** of FIGS. **5** but where the amplitude of the line **110** is but 0.5 in value. The line **111** in FIG. **6** is the same as line **103** in FIG. **5**. By the parallelogram technique it can be shown that the resultant vector sum (line **112**) has a value of 0.86603 which can be computed from trigonometric tables since the angle of the line **112** is now at +30°.

From the above it can be seen that by selecting a particular phase shift angle in the negative direction for one of the channels and another angle in the positive direction for the other channel or alternatively using equal phase shifts in opposite polarities for the two channels the amplitude of the *C*-component is represented by the lines **107** in FIG. **5** and **112** in FIG. **6** may be controlled when the channels are combined. This *C*-component amplitude in the combined signal can be as little as zero where the shifts are equal and opposite at 90° giving a difference of 180° between the components. Where there is no shift and the two channels containing *C*-components are combined the *C*-components add to the sum of their values in each channel. Thus, if *C*-component has a value of 1 in each channel the summation value will be 2*C*. If the value of the nonphase shifted *C*-components are respectively 1 and 0.5 the resultant combined value will be 1.5.

The chart below indicates the combined summation values of *C*-components of equal amplitudes therein for equal and oppositely phase shifted channels according to this invention containing *A*+*C* and *B*+*C* respectively:

Equal phase shift angles	Summed value of C components
±0°	2.000
±15°	1.932
±30°	1.732
±45°	1.414
±60°	1.0
±75°	0.517
±90°	0.

It can be seen therefore that using the phase-shifting device **17** of this invention for any angle between 0° and ±90° for the respective channels *A*+*C* and *B*+*C*, the equal amplitude component *C* can be controlled in combined *A*+*B*+*NC* resultant where *N* is twice the cosine of the equal and opposite angles through which the phase is rotated. In mathematical terms *N* in this case can be described as

$$N=2\cos\pm\theta$$

where θ is the angle equal and opposite of phase shift for each channel.

The practical implication of this result is that by the use of the invention herein disclosed any desired proportionate relationship between zero and 2.0 can be imparted to the *C*-component when the two stereo channels containing the *C*-component in each are combined to produce a monophonic resultant.

One example might be given of a shift in phase of one channel counterclockwise to 270° with the other channel at 360°, the phase difference between the two phase shifted signals being a total of 90°. The amplitude of the *C*-signal component on the 270° line is 1.7. The amplitude of the *C*-component signal on the 360° line is 1.0. The diagonal, similar to that of line **112** in the arbitrary circle of FIG. **6**, for the resulting rectangular parallelogram in the above example will equal 2.0 indicating that upon mixing the two channels after the phase difference settings, the *C*-component as combined will have an amplitude value of 2.0. The angle of the above-mentioned diagonal will be at 300°. The diagonal is the vector summation line.

The principles of the invention can be expressed also in such terms that one can compute both the shift in angle of reference and the resultant amplitude or either of them for any conditions other than equal and opposite phase shift in the two channels or differences in amplitudes of the *C*-component of the two channels.

If one sets Φ to represent the lagging angle and θ, the leading angle of the shifted signals and A as the amplitude of the signal shifted by angle Φ and B the amplitude of the signal shifted by angle θ, then one can compute the new vector angle of the combined signal and the new amplitude A_x of the *C*-components in the combined signal as follows:

$$\text{Tan } X \text{ (the new vector angle)} = (A \cos \Phi + B \cos \theta)/(B \sin \theta - A \sin \Phi)$$

$$A_x \text{ (the new amplitude)} = \sin X (A \cos \Phi + B \cos \theta) + (\cos X B \sin \theta - A \sin \Phi)$$

With the above formulas one can compute the vector summation lines such as **107** of FIG. **5** or **112** in FIG. **6**. The length of lines **107** or **112** then represent A_x in the above formulas.

The system described hereinabove might be called a stereophonic signal logic device which recognizes the common signal components in the channels of a stereophonic system and permits combining the channels externally in such fashion that the amplitude of the common signal component never exceeds its original occurrence in the live program from which the stereophonic material was derived.

The significance of the invention to the recording and broadcast industries is that stereophonic program material can be broadcast, recorded or played back in such a manner that the program, as heard monophonically, from a monophonic receiver or monophonic record playback system will still have the same balance and quality as in the original live performance sans only the directional character.

This means that the identical recording can be played back with either stereophonic or monophonic equipment without compromise of the stereophonic quality or monophonic quality as related to the live performance.

The new device may be used during the original recording or in the preparation of masters for phonograph discs to produce a compatible record or tape which can be played or broadcast either stereophonically or monophonically, or if broadcast stereophonically can be received on monophonic equipment with no depreciation in quality.

It may also be used by recording studios or broadcasters to play existing stereophonic recordings to produce a compatible stereophonic signal which can be received or played back on monophonic equipment without degradation.

The device makes no change in stereophonic quality, adds no distortion nor loss in signal-to-noise ratio.

What is claimed as new is:

1. A compatible stereophonic signal generator operable from a pair of stereophonically related signal sources wherein each of said pair of sources provides a common signal component, said generator comprising:

a first cascade of phase-shift audio amplifiers for wide band phase shifting the common signal component from one of said signal sources, said first cascade having connected therein adjustable resistor capacitor networks adapted to vary the phase of signals applied thereto over a predetermined range of frequencies;

a second cascade of phase shift amplifiers for wide band phase shifting the common signal component from the other of said signal sources, said second cascade having connected therein adjustable resistor capacitor networks adapted to vary the phase of signals applied thereto over said predetermined range of frequencies;

said first and second cascades of phase shift amplifiers maintaining a substantially constant phase difference between the phase shifted common signal components, whereby upon being combined for monophonic reproduction, said phase shifted common signal components exhibit a combined signal magnitude less than the sum of the individual common signal component magnitudes.

2. The signal generator of claim **1** wherein said phase difference is 90°.

3. The signal generator of claim **1** wherein said phase difference is 120°.

4. The signal generator of claim **1** wherein each cascade of phase shift amplifiers comprises three phase shift amplifiers.

5. The signal generator of claim **1** wherein the frequency ranges for the respective cascade phase shift amplifiers are set for approximately 30 to 300 Hz., 300 to 3,000 Hz. and 3,000 to 30,000 Hz., respectively.

6. The signal generator of claim **1** wherein for each cascade all the resistors of said adjustable, resistor capacitor, phase shift networks include variable portions, said generator further including a common shaft with the variable portions being connected to said shaft so as to be commonly adjustable with a single manual operation.

7. A compatible stereophonic signal generator operable from a pair of stereophonically related audio signal sources, each of the pair having at least a signal component common to both said sources, said generator comprising:

a first wide band phase shift generator having an input circuit, a first cascade of phase shift amplifiers connected to said input circuit, each of said amplifiers in said first cascade having connected therein adjustable resistor capacitor, phase shift networks adapted to vary the phase of signals applied thereto over a predetermined range of frequencies;

a second wide band phase shift generator having an input circuit, a second cascade of phase shift amplifiers connected to said input circuit, each of said amplifiers in said second cascade having connected therein adjustable resistor capacitor, phase shift networks adapted to vary the phase of signals applied thereto over the same predetermined range of frequencies as defined for said first phase shift generator;

said first and second wide band phase shift generators producing respective phase shifted signals which differ in relative phase by a substantially constant phase difference;

said input circuit of said first wide band phase shift generator being connected to one of said pair of signal sources;

said input circuit of said second wide band phase shift generator being connected to the other of the pair of signal sources.

8. The signal generator of claim **7** wherein said first and second wide band phase shift generators shift the phase of said common signal components by equal and opposite amounts respectively independently of frequency.

9. The signal generator of claim **7** wherein said amounts are +45° and −45°, respectively.

10. The signal generator of claim **7** wherein said amounts are +60° and −60°, respectively.

11. The method of producing compatible two-channel stereophonic signals from first and second stereophonically related signals each containing at least a common signal component, said method comprising the steps of:

phase shifting the common signal component of said first signal to provide a first phase shifted common signal component;

phase shifting the common signal component of said second signal to provide a second phase shifted common signal component differing in phase from said first phase shifted common signal component by a substantially constant phase angle; and combining said phase shifted common signal components, for monophonic reproduction, to result in a combined component having an amplitude less than the sum of the amplitudes of the individual common signal components.

12. In the method defined in claim 11, the additional step of applying said first and second phase shifted components to respective impedance-matching networks.

13. In the method defined in claim 11, the additional step of combining said first and second phase shifted common signal components in a mixing arrangement, whereby a resultant summed common signal is produced which retains substantially the original composition obtained in the initial performance from which said stereophonic related signals were derived.

14. The method of producing compatible two-channel stereophonic signals from first and second stereophonically related signals, said first and second related signals containing, respectively, components $A+B$ and $B+C$ wherein the C signal components are common, said method comprising the steps of:

applying the $A+C$ component to a first phase-shifting network;

applying the $B+C$ component to a second phase-shifting network;

phase shifting the $A+C$ component applied to the first phase shift network over a predetermined phase angle to provide a phase shifted $A+C$ component;

phase shifting the $B+C$ component applied to the second phase-shift network to provide a phase shifted $B+C$ component, the phase of the C component in the $B+C$ phase shifted component differing from the phase of the C component in the $A+C$ phase shifted component by a substantially constant phase angle; and

so combining said $A+C$ and said $B+C$ components as to provide a compatible stereophonic signal wherein said C component in the combined signal is less than the algebraic sum of the C components in said $A+C$ and said $B+C$ components.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,646,574 Dated February 29, 1972

Inventor(s) Howard S. Holzer

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 46, "A+CazC" should read -- A+C+B+C -- .
Column 5, line 51, "A+B+C" should read -- A+B+2C -- .

Signed and sealed this 2nd day of January 1973 .

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

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