

March 30, 1965

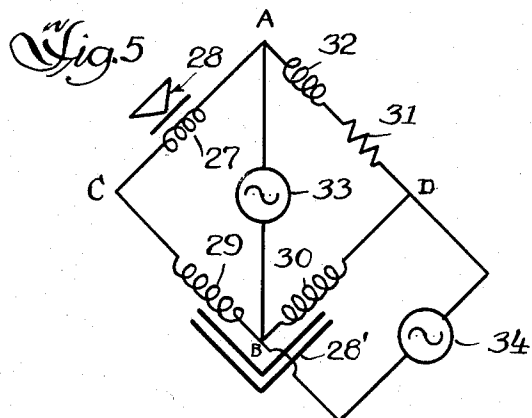
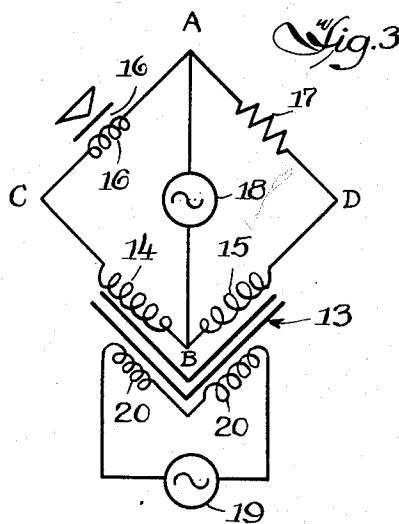
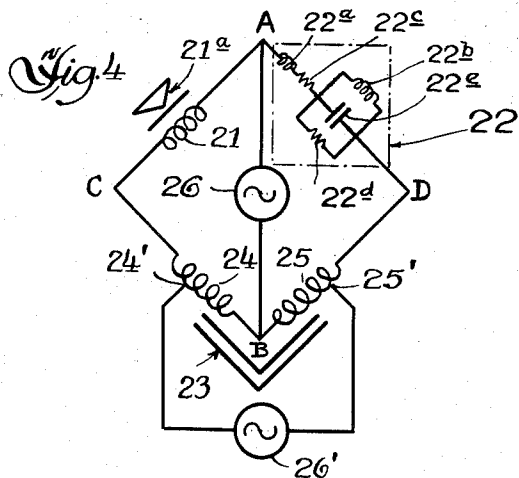
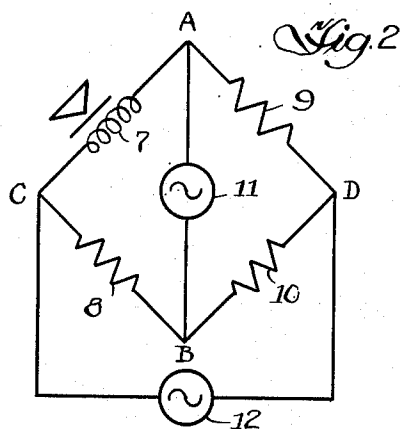
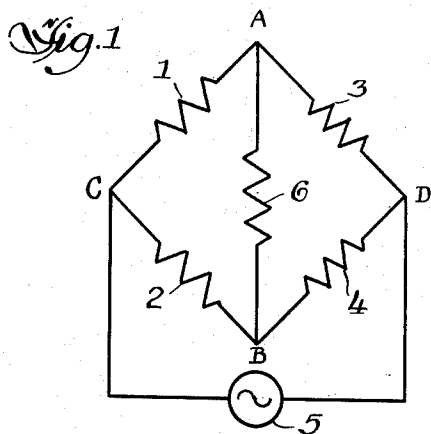
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3,176,072

STEREOPHONIC REPRODUCTION SYSTEM

Filed April 21, 1960

3 Sheets-Sheet 1



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STEREOPHONIC REPRODUCTION SYSTEM

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3 Sheets-Sheet 2

Fig. 6

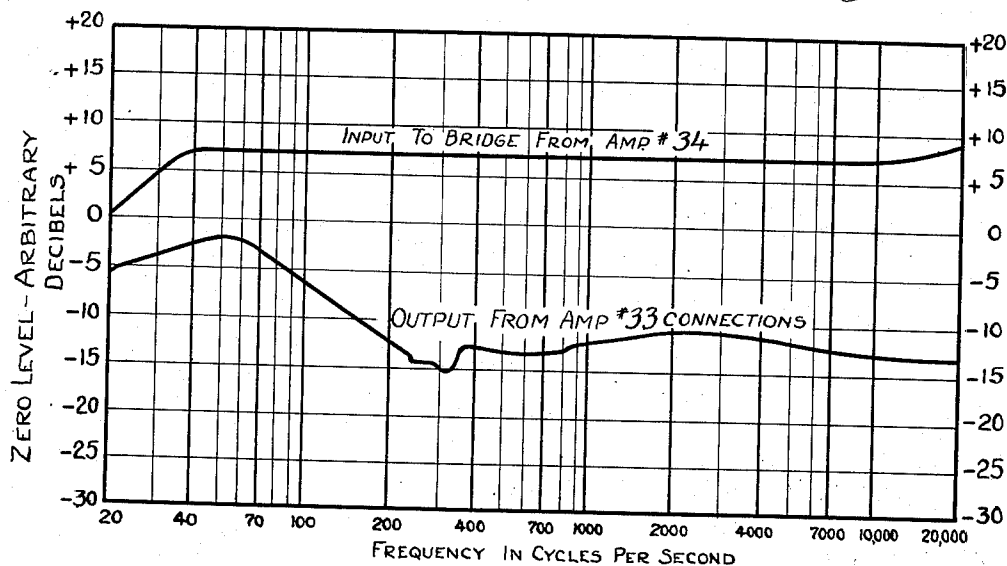
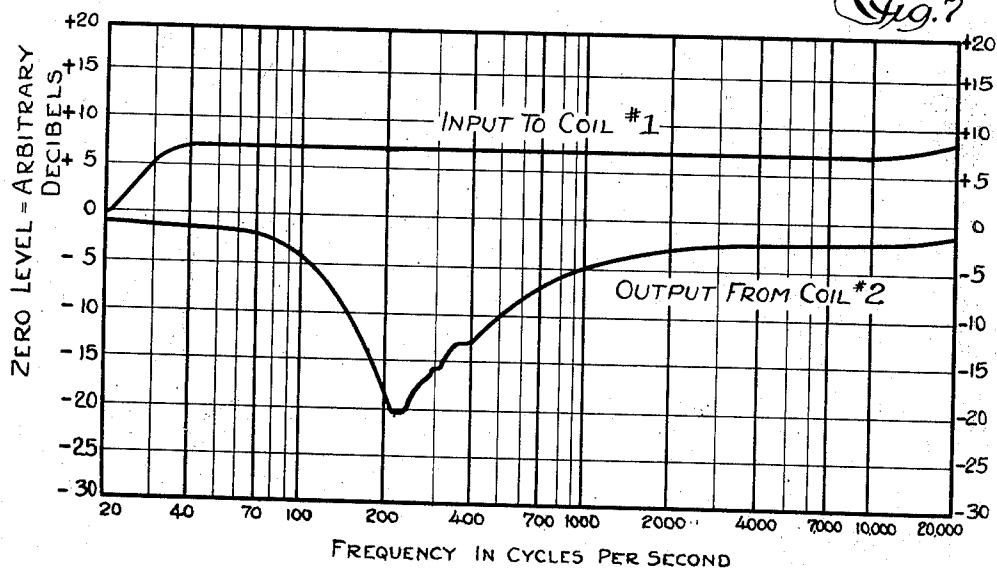


Fig. 7



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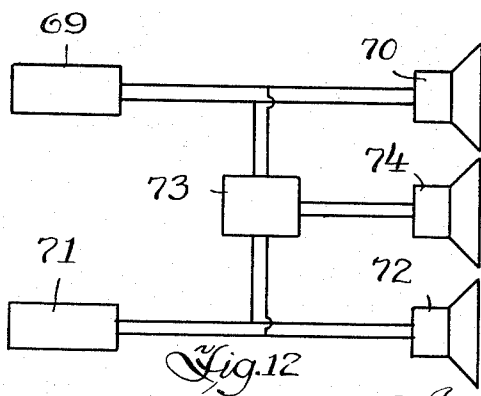
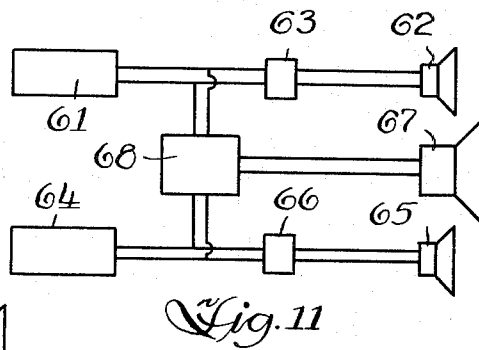
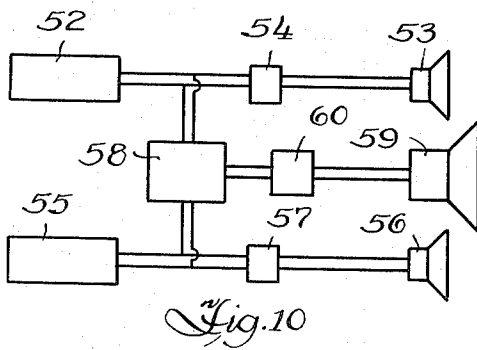
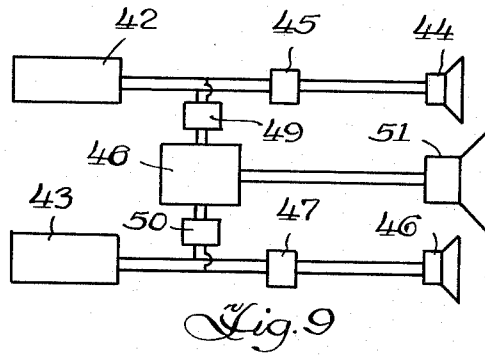
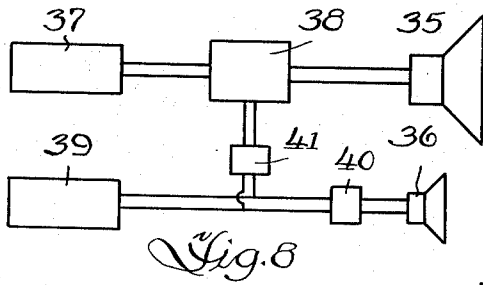
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STEREOPHONIC REPRODUCTION SYSTEM

Filed April 21, 1960

3 Sheets-Sheet 3



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STEREOPHONIC REPRODUCTION SYSTEM

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13 Claims. (Cl. 179—1)

This invention relates to the stereophonic reproduction of sound, and more particularly refers to a novel system for the reproduction of multi-channel stereophonic sound in which at least the low frequency sound portions of each channel are combined and reproduced by a single low frequency sound loudspeaker.

The development of multi-channel stereophonic recording and reproduction through the media of both magnetic tape and single groove recorded disks has ushered in a new era in the field of recorded sound. However, their development has also introduced a number of problems, one of the most serious of which is the high cost of equipment necessary for high quality reproduction of the signals from several channels. In the case of monophonic systems, only a single set of components were required including a single amplifier and a single loudspeaker system. Dual channel stereophonic sound has generally doubled these requirements, since a separate set of equipment is necessary for each channel with traditional systems.

One of the most expensive components of a high quality reproduction system is the loudspeaker and its enclosure, and especially the low frequency range loudspeaker with its required acoustical chamber for adequately reinforcing the low frequency portion of the sound spectrum. For the general public the use of two complete high quality loudspeaker system has generally been ruled out because of the great expense involved. Consequently, popularly priced stereophonic systems have been placed on the market utilizing low cost reproducing systems of generally inferior quality.

It is known in the art that sound comprised of frequencies below about three hundred cycles per second is relatively non-directional in a room having the dimensions of those found in the average home. Consequently, the stereophonic effect produced by two spaced-apart loudspeakers is almost entirely dependent upon the directivity of the middle and high frequency sound range. Since the low frequency sound reproducer is by far the most expensive component in the sound reproduction system, methods have been developed for combining the low frequency portions of the signals from both channels and reproducing the combined low frequency signal by means of a single low frequency sound reproducer. This system has permitted the elimination of one of the two low frequency reproducers formerly used.

Several requirements must be met in a system for combining the low frequency signal from both channels if high quality reproduction is desired. First, the two channels supplying the sound signal must be maintained substantially isolated from each other. Second, the two low frequency signals must be combined in such a manner that they do not adversely affect each other or interact with each other. Moreover, the entire process must be accomplished without a substantial loss in signal strength.

One of the methods currently used for combining the low frequency signals utilizes a low frequency loudspeaker having two voice coils. Each of the signals is introduced into one of the two voice coils, and when the channels are properly connected, are reproduced together. This system has several drawbacks. It introduces considerable loss in signal strength. Moreover, it is subject to cross-talk between the signals due to inadequate isolation.

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It is an object of the present invention to provide a system for the reproduction of multi-channel stereophonic sound which requires only one low frequency reproducer.

It is still further an object to provide such a stereophonic reproduction system which permits either a portion or all of the sound frequency ranges of both channels to be combined and introduced into a single loudspeaker, while still maintaining a high order of isolation between the two channels themselves.

It is still further an object to provide a system for the reproduction of multi-channel stereophonic sound which may be manufactured at a moderately low cost, and yet, which will reproduce stereophonic sound exhibiting a low order of distortion.

It is still further an object to provide a stereophonic reproduction system in which a derived third channel may be produced by combining a portion of each of the other two channels and reproducing the combined signal through a third loudspeaker to fill in the "hole" existing in the center between the spaced apart loudspeakers utilized for the two primary channels.

Other objects and advantages of the invention will become apparent from a study of the following disclosure and the drawings in which:

FIG. 1 is a schematic diagram of a traditional alternating current bridge;

FIG. 2 is a schematic diagram of a resistive bridge matrix according to the present invention;

FIG. 3 is a schematic diagram of a bridge matrix according to the present invention utilizing two inductive arms in the form of a transformer having a center-tapped secondary winding, wherein the balancing arm consists of only a resistance;

FIG. 4 is a schematic diagram of a bridge matrix according to the present invention utilizing two inductive arms formed by a center tapped autotransformer, wherein the balancing arm consists of a complex impedance;

FIG. 5 is a schematic diagram of one form of bridge according to the invention similar to that shown in FIG. 4, but wherein the balancing arm consists of a series inductance and resistance;

FIG. 6 is a graph of data obtained from a test measuring the degree of cross-talk introduced in a system utilizing the bridge matrix circuit shown in FIG. 5;

FIG. 7 is a graph of data obtained from a test measuring the degree of cross-talk introduced between the voice coils of a loudspeaker having two coaxially arranged voice coils;

FIG. 8 is a schematic diagram of a stereophonic reproduction system according to the present invention utilizing one full frequency range loudspeaker and one middle and high frequency range loudspeaker system;

FIG. 9 is a schematic diagram of a stereophonic reproducing system utilizing one centrally located low frequency loudspeaker and two middle and high frequency range loudspeaker systems placed on each side of the low frequency loudspeaker;

FIG. 10 is a schematic diagram of a stereophonic reproducing system utilizing one centrally located full range loudspeaker and two middle and high range loudspeaker systems placed one at each side;

FIG. 11 is a schematic diagram of a system according to the present invention utilizing one centrally located loudspeaker capable of reproducing low and middle range frequencies, and two loudspeaker systems capable of reproducing middle and high range frequencies placed one at each side; and

FIG. 12 is a schematic diagram of a stereophonic system according to a modified form of the present invention utilizing three full frequency range loudspeaker systems.

According to the present invention, it has been found that the amplifier output, or a portion thereof, from each of two separate channels may be combined and introduced into a single loudspeaker by means of an impedance bridge matrix. The output from one amplifier is connected to the bridge at two points of equal potential. The output from the second amplifier is connected to the bridge at two other points of equal potential. Both amplifiers remain isolated from each other, but their signal outputs are combined in one pair of opposite arms of the bridge to form signals comprising the sum of the two signal outputs, and in the other pair of opposite arms to form signals comprising the difference of the two signal outputs. The loudspeaker voice coil or its input coupling circuit is connected to form an arm in which both applied signal currents flow in the same direction and are thus additive. The combined signal currents from both channels then operate the single loud speaker with negligible interaction between the two channel amplifier circuits.

Referring to FIG. 1, a conventional alternating current bridge is shown comprised of four resistive arms 1, 2, 3 and 4, an alternating current source 5 and a load resistance 6. When the bridge is balanced, the following impedance relationship exists:

$$\frac{R_1}{R_3} = \frac{R_2}{R_4}$$

wherein the letter R represents the respective resistance values.

When the balanced relationship is thus established, points A and B are at the same potential, and consequently no current flows through the load resistance 6. If the current source is alternatively applied at points A and B, and the load resistance 6 is connected between points C and D, points C and D are at the same potential when the bridge is balanced, and consequently no current flows through the load resistance 6. Thus, a current source connected to points C and D will be isolated from another current source which is connected to points A and B.

When two current sources are applied simultaneously to such a balanced bridge, one across points A and B and the other across points C and D, the two currents flow in the same direction through one pair of opposite resistances, for example 1 and 4, while they flow in opposite directions through the other pair of opposite resistances, for example 2 and 3. Thus each resistance arm carries either a sum or a difference current. Whether a pair of resistances carries a sum current or a difference current is determined by the relative polarity of the connections of the two current sources.

FIG. 2 illustrates one form of the present invention utilizing a bridge to isolate two signal channels and to combine signal current portions of each channel into a single loudspeaker. Here the loudspeaker voice coil 7 itself, or a loudspeaker connecting network, is utilized as one of the arms of the bridge carrying a sum current. The values of the resistances 8, 9 and 10 are so chosen that the bridge is balanced, thus isolating the two input channels 11 and 12 in a manner similar to that described above.

Although the circuit shown in FIG. 2 is quite satisfactory, a more efficient circuit is shown in FIG. 3, comprising a transformer 13 having a tapped secondary winding to form two inductances 14 and 15 which serve as arms of the bridge in place of the resistances 8 and 10 of FIG. 2. The voice coil 16 of the loudspeaker 16' forms a third arm of the bridge and a resistance 17 forms the fourth arm. The bridge is balanced when the following impedance relationship is obtained:

$$\frac{Z_{14}}{Z_{15}} = \frac{Z_{16}}{Z_{17}}$$

wherein the letter Z represents the respective impedance values.

When the bridge is so balanced points A and B are at

the same potential with respect to the signal voltage applied across CB and points C and B are at the same potential with respect to the signal voltage applied across AB. One signal channel 18 is connected at points A and B. The second channel 19 instead of being connected to points C and D, is connected to the primary winding 20 of the transformer 13. Because of the mutual inductance between the transformer windings, 14, 15, and 20, signal channel 19 is effectively connected to the equipotential points C and D and is, therefore, isolated from signal channel 18. During operation, the sum of the signal 18 plus the signal 19 flows through the voice coil 16, while the channels themselves remain isolated from each other if proper polarity of the applied-signal currents is observed. The turns ratio and other characteristics of the transformer 13 should be chosen to provide the proper impedance for bridge balance.

Representative values for the components in the circuit of FIG. 3 may be as follows:

Voice coil 16	-----ohms--	32
Resistance 17	-----do----	32
Transformer primary impedance	-----do----	16
Ratio of secondary to primary windings	-----	2:1

In FIG. 4 the bridge shown is comprised of the voice coil 21 of a loudspeaker 21a, a complex impedance 22, and an autotransformer 23 having a center tap at point B which divides the winding into two inductances 24 and 25. The impedance 22 is comprised of two inductances 22a and 22b, two resistances 22c and 22d, and a condenser 22e. One channel 26 is applied between points A and B, while the other channel 25 is applied at taps 24' and 25' of the autotransformer. Due to the mutual inductance between the two halves of the winding, taps 24' and 25' are in effect at the same potential, in the same manner as if they were connected to points C and D. Consequently, the two channels 26 and 26' remain isolated from each other, while the sum of the two signals flows through the voice coil 21. Representative values for the components of the circuit of FIG. 4 are as follows:

Loudspeaker voice coil 21	-----ohms--	16
Impedance 22:		
Inductance 22a	-----mhy--	2
Inductance 22b	-----mhy--	237
Resistance 22c	-----ohms--	11
Resistance 22d	-----do----	90
Condenser 22e	-----mf--	213
Total autotransformer impedance	-----ohms--	32
Impedance across center taps 24' and 25'	-----do----	8

The balancing impedance 22 is designed to have an impedance characteristic similar to that of the speaker 21a. Since speaker impedance is a function of frequency, neither the circuit of FIG. 2 nor the circuit of FIG. 3 will remain in balance over the entire range of frequencies in the audio band.

The circuit of FIG. 4 is rather complex and expensive. In the interest of economy it may be simplified to the circuit shown in FIG. 5. Through the use of the modified circuit a good impedance balance is obtained at higher frequencies, and, although a minor amount of unbalance results at the lower frequencies, the amount is kept within an acceptable range. The bridge of FIG. 5 is comprised of a voice coil 27 in a loudspeaker 28, and autotransformer 28' having inductances 29 and 30, but differing from the previous circuit in several respects. First, the balancing arm for the voice coil 27 is comprised of the combination of a resistance 31 and an inductance 32. One channel 33 is connected across point A and B in a manner similar to that of the circuit of FIG. 4. However, the second channel is connected across only one-half of the autotransformer at point B and D. This connection eliminates the necessity for separate taps for the channel signal 34, and additionally permits both channels 33 and 34 to have a common ground at point B. Al-

though the circuit with respect to signal 34 does not appear to be symmetrical, because of the autotransformer effect, the points of application of the channel 34 are still at equal potentials with respect to the channel 33, and therefore the channel 34 is maintained isolated from the channel 33. The inductance 32 has the function of balancing out the inductance of the voice coil 27 so that a precise bridge balance may be maintained throughout a wide range of frequencies. Inspection of bridge arm AD in FIG. 4 shows that at frequencies above about 150 c.p.s. the circuit degenerates into the bridge arm AD of FIG. 5. Representative values for the components of the circuit are as follows:

Voice coil 27	-----ohms	16
Resistance 31	-----do	11
Inductance 32	-----millihenrys	2
Total impedance of autotransformer	-----ohms	32
Portion of autotransformer 30 between center tap B and end connected to points D	-----ohms	8

The bridge matrix system for combining the base or low frequency range portions of the channels from two amplifiers and introducing them into a single speaker, as presently disclosed and claimed, is far superior in many respects to the systems previously disclosed in the prior art for accomplishing the same purpose. The present system is considerably less expensive than the system utilizing a filter network in conjunction with an isolation transformer. It has greater channel separation and lower signal insertion loss than the two voice coil system another of the commonly used prior art systems. Calculated on a theoretical basis by methods known to those skilled in the art, the minimum signal loss in the two voice coil system is 3 decibels in the reproduction of two channel sound where the low frequencies are evenly distributed between the two channels. Under identical conditions, the theoretical signal loss for the bridge matrix system is 0 decibel. Under the condition where the total bass is contained solely in one channel, a recording system utilized by some professional recording organizations, the minimum signal loss for the two voice coil system is 6 decibels, while the minimum signal loss under identical conditions for the bridge matrix system is only 3 decibels.

The bridge matrix system is also superior for use in stereophonic reproduction over the two voice coil loudspeaker system in regard to channel separation.

Channel isolation in a stereophonic system is extremely important where the ultimate in reproduction is desired, although the significance of its function varies with the frequency of the sound reproduced. Channel isolation below 300 cycles per second is of importance to prevent impedance matching difficulties or to prevent any short circuiting effect that the amplifiers may have upon each other. Isolation above 300 cycles per second is of primary importance to prevent the mixing of the higher frequency component of the two signals. Such mixing would result in the destruction of the stereophonic effect. It is in this range above 300 cycles per second that the bridge matrix system shows its marked superiority over prior art systems.

The superior performance of the bridge matrix system in regard to channel separation can be readily seen by comparison of the results shown in the graph of FIG. 6 with those shown in the graph of FIG. 7. The data used in plotting the graph of FIG. 6 were obtained by utilizing a bridge matrix circuit similar to that shown in FIG. 5, and introducing a modulated electrical signal at points 29' and 30', in place of the signal 34 shown in FIG. 5. The induced output at the points A and B, the points at which the signal 33 would be normally applied, was measured by suitable measuring apparatus. The data used to plot the graph shown in FIG. 7 were obtained by introducing a modulated electrical signal into one voice coil of a dual voice coil loudspeaker similar to those used in prior art stereophonic systems. The signal induced in

the second voice coil was then measured as an index of channel separation. In both graphs the data were plotted using an arbitrary zero point. The channel separation in both graphs at any particular frequency is represented by the distance between the input and output curves at that frequency. An examination of the graphs shows that channel separation in the region below 300 cycles per second is comparable for both systems. However, in the case of the two voice coil system, channel separation falls off sharply above 300 cycles per second. On the other hand, channel separation in the bridge matrix system is retained substantially constant to a frequency of over 20,000 cycles per second.

In the system shown in FIG. 8, a single full frequency range loudspeaker 35 and a single middle and high frequency range loudspeaker system 36 are utilized. The first channel amplifier 37 is connected directly to the bridge matrix 38. The second channel amplifier 39 is connected to the middle and high frequency loudspeaker system 36 through a high pass filter 40. The second channel amplifier 39 is connected to the bridge matrix 38 through a low pass filter 41. The combined output from the bridge matrix 38, which consists of the sum of the full frequency range signal from the first channel amplifier 37, and the low frequency portion of the signal from the second channel amplifier 39, is connected to the full frequency range loudspeaker 35. Thus, the middle and high frequency portion of the signal from the first channel as well as the low frequency portion of the signals from both channels are reproduced by the full range loudspeaker 35. The middle and high frequency portion of the second channel signal reproduced by the middle and high frequency loudspeaker system 36. Since the low frequency sound is substantially non-directional, the low frequency portions of both channels may be combined and reproduced by a single loudspeaker placed at any position, without destroying the stereophonic effect created by reproducing the middle and high frequency portions of each channel by separate spaced-apart loudspeaker systems.

In FIG. 9 is shown a system comprised of a first channel amplifier 42, and a second channel amplifier 43. The first amplifier 42 is connected to a middle and high frequency range loudspeaker system 44 through a high pass filter 45. The second amplifier 43 is connected to a middle and high frequency range loudspeaker system 46 through a high pass filter 47. The first amplifier 42 is connected to the bridge matrix 48 through a low pass filter 49, while the second amplifier 43 is connected to the bridge matrix 48 through a low pass filter 50. A low frequency range loudspeaker 51 is connected to the bridge matrix 48 in such a manner that its voice coil forms an arm of the bridge in which the sum of the currents applied to the bridge flows. In operation, the middle and high frequency range portion of the signal from each amplifier is reproduced by its own middle and high frequency range loudspeaker system which is spaced apart from the middle and high frequency range loudspeaker which reproduces the equivalent portion of the signal from the other channel. The bass or low-frequency range portions of both signals, on the other hand, are combined by the bridge matrix and introduced into the low frequency range loudspeaker. Thus the stereo effect is produced by the spaced-apart loudspeakers 44 and 46, while the combined bass of both channels is reproduced by the centrally located loudspeaker 51. As a variation, the loudspeaker 51 may be one capable of reproducing the middle frequency range and even the high frequency range, or in other words a full frequency range loudspeaker. The low pass filters 49 and 50 may then be so chosen that a portion of the middle and high frequencies will be passed to the loudspeaker 51. This will tend to produce an artificial third channel which aids in eliminating the "hole-in-the-center" effect encountered when only two spaced-apart systems are used.

In the system shown in FIG. 10 the first channel amplifier 52 is connected to a middle and high frequency range loudspeaker system 53 through a high pass filter 54. The second channel amplifier 55 is connected to a middle and high frequency range loudspeaker system 56 through a high pass filter 57. The first channel amplifier is also connected to the bridge matrix 58 at two separate points of equal potential. The second channel amplifier 55 is connected to the bridge matrix at two other points of equal potential. The bridge matrix is connected to the low frequency range loudspeaker 59 through a low pass filter 60. If it is desired to introduce a derived third channel, the loudspeaker 59 may be a full frequency range loudspeaker, and the filter 60 designed to pass a portion of the middle frequencies, and even high frequencies if desired.

The circuit of FIG. 10 has an economic advantage over the circuit of FIG. 9 in that only a single low pass filter 60 is required, while all the benefits of the system are retained. The low pass filter 60 is connected into the bridge as an arm in which the sum of the two combined signals flows. The loudspeakers 53 and 56 must be oriented in spaced-apart relationship to provide the stereophonic effect. The loudspeaker 59 may be placed in any position when it is utilized to reproduce only the low frequency range, but should preferably be arranged between the spaced-apart loudspeakers when it is also used to reproduce portions of the frequency range which are also directional.

The circuit of FIG. 11 is similar to that of FIG. 10 in that the first channel amplifier 61 is connected to the middle and high frequency range loudspeaker system 62 through a high pass filter 63, and the second channel amplifier 64 is connected to the second middle and high frequency range loudspeaker system 65 through a high pass filter 66. However, this circuit differs in that combined portions of the entire bass and portions of the middle and high frequency ranges of both channel amplifiers are introduced into the full frequency range loudspeaker 67 directly through the bridge matrix 68. This system accomplishes both the derivation of a third channel and the combination of the bass from both of the channels into a single speaker system.

In FIG. 12 is shown a system in which the bridge matrix of the present invention is used solely to derive a third channel for filling in the center between the spaced apart loudspeaker systems. In this system, the first channel amplifier 69 is connected to a full frequency range loudspeaker system 70, and the second channel amplifier 71 is connected to a full frequency range loudspeaker 72. Both amplifiers are also connected to a bridge matrix 73 at different points of equal potential in the manner described above. A third full frequency range loudspeaker system 74 is connected to the bridge 73 with its voice coil forming an arm thereof in which the combined signals from both amplifiers flow in the same direction. Through the use of this arrangement, a third channel may be added to make the stereophonic effect more realistic in that a portion of the sound comes from a point between the two spaced apart loudspeakers and eliminates the "hole-in-the-center" effect while still maintaining the amplifiers 69 and 71 isolated from each other.

The presently described systems have many advantages over other systems used to combine the bass frequencies from two stereophonic channels in utilizing a single bass frequency reproducer. First, the present system provides excellent isolation between the two channels, and effectively prevents any short circuiting therebetween. The signals passing through the bridge matrix incur only negligible loss in signal strength, an important consideration especially when using the low efficiency loudspeakers which are currently in vogue. Furthermore, the present system is relatively inexpensive material-wise, and is not difficult to produce.

Many variations of the circuits and systems described

above may be made by those skilled in the art, and are to be considered as falling within the spirit and scope of the present invention as defined by the appended claims.

What is here claimed is:

1. A system for the reproduction of stereophonic sound from modulated electrical signal currents carried by two separate channels which comprises an impedance bridge having four series-connected impedance arms, the product of the impedances of one pair of opposite arms being substantially equal to the product of the impedances of the other pair of opposite arms, a first sound reproducing means connected to a first pair of points in said bridge, said first pair of points having means for connection to the first of said channels, a second sound reproducing means connected to a second pair of points in said bridge, said second pair of points having means for connection to said second channel, said first pair of points being at equal potential with respect to the signal voltage applied to said second pair of points and said second pair of points being at equal potential with respect to the signal voltage applied to said first pair of points, and a third sound reproducing means having its input circuit connected to said bridge to form one of said impedance arms in which the currents from both said channels are additive, whereby portions of both signal currents are combined and introduced into said third sound reproducing means while said channels are maintained substantially electrically isolated from each other.
2. A system according to claim 1 having a high pass filter connected between said first sound reproducing means and said bridge, and having a second high pass filter connected between said second sound reproducing means and said bridge.
3. A system according to claim 2 in which said first and said second sound reproducing means are both designed to reproduce substantially the middle and high sound frequency range.
4. A system according to claim 1 wherein three of said arms are comprised of substantially non-inductive resistances.
5. A system according to claim 1 wherein each of two adjacent arms of said bridge are comprised of inductances.
6. A system according to claim 1 wherein three of the arms of said bridge are comprised of inductances.
7. A system according to claim 1 wherein two adjacent arms of said bridge are comprised of a transformer having a center-tapped secondary winding, the portion of the secondary winding on each side of the center tap forming a separate arm, the primary of said transformer being adapted to be connected to one of said channels.
8. A system according to claim 1 wherein two of the adjacent arms of said bridge are comprised of a center-tapped autotransformer, the portion on each side of the center-tap comprising a separate bridge arm, said autotransformer having a pair of taps adapted to be connected to one of said channels.
9. A system according to claim 1 wherein two of the adjacent arms of said bridge are comprised of a center tapped autotransformer, the portion on each side of the center-tap comprising a separate bridge arm, said autotransformer being adapted to be connected to one of said channels across its bridge arms.
10. A system for the reproduction of stereophonic sound from modulated electrical signal currents carried by two separate channels which comprises an impedance bridge having four series-connected impedance arms, the product of the impedances of one pair of opposite arms being substantially equal to the product of the impedances of the other pair of opposite arms, a first low pass filter having its output circuit connected to said bridge at a first pair of points, a first sound reproducing means, the input circuit of said first low pass filter being connected to said first sound reproducing means and having means for connection to said first channel, a second low pass filter having its output circuit connected to said bridge

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at a second pair of points, a second sound reproducing means, having its input circuit connected to the input of said second low pass filter and having means for connection to said second channel, said first pair of points being at equal potential with respect to the signal voltage applied to said second pair of points and said second pair of points being at equal potential with respect to the signal voltage applied to said first pair of points, and a third sound reproducing means having its input circuit connected to said bridge to form one of said impedance arms in which the currents from both said channels are additive, whereby portions of both signal currents are combined and introduced into said third sound reproducing means while said channels are maintained substantially electrically isolated from each other.

11. A system according to claim 10 having a high pass filter connected in the circuit between said first sound reproducing means and said bridge, and a second high pass filter connected in the circuit between said second sound reproducing means and said bridge.

12. A system for the reproduction of stereophonic sound from modulated electrical signal currents carried by two separate channels which comprises an impedance bridge having four series-connected impedance arms, the product of the impedances of one pair of opposite arms being substantially equal to the product of the impedances of the other pair of opposite arms, a first sound reproducing means connected to said bridge at a first pair of points, a second sound reproducing means connected to said bridge at a second pair of points, said bridge having means for connection to one of said chan-

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nels at said first pair of points and to said second channel at said second pair of points, and a third sound reproducing means and a low pass filter connected in series therewith connected to said bridge to form one of said impedance arms in which the currents from both said channels are additive, whereby portions of both signal currents are combined and introduced into said third sound reproducing means while the channels are maintained substantially electrically isolated from each other.

13. A system according to claim 12 having a high pass filter connected in the circuit between said first sound reproducing means and said bridge, a second high pass filter being connected in the circuit between said second sound reproducing means and said bridge.

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