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STEREOPHONIC SOUND SYSTEM

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2 Sheets-Sheet 1

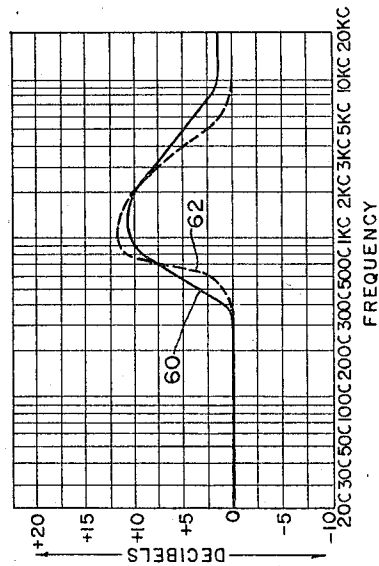
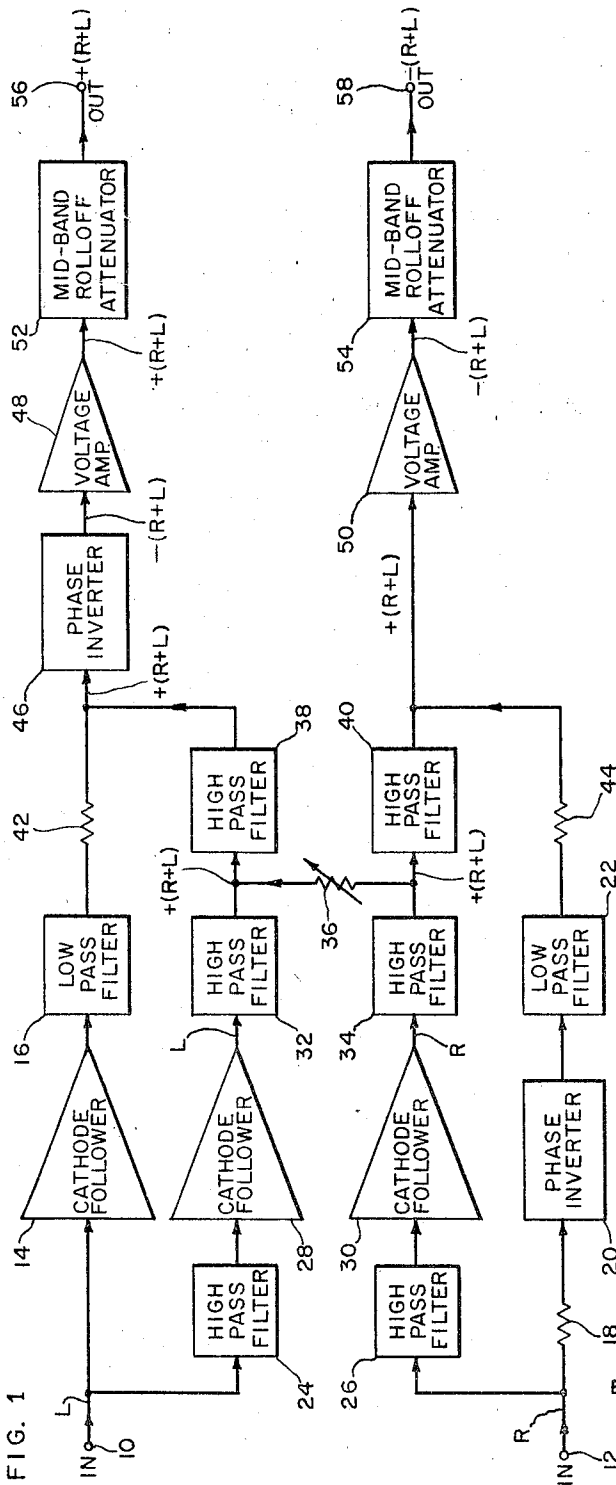


FIG. 3

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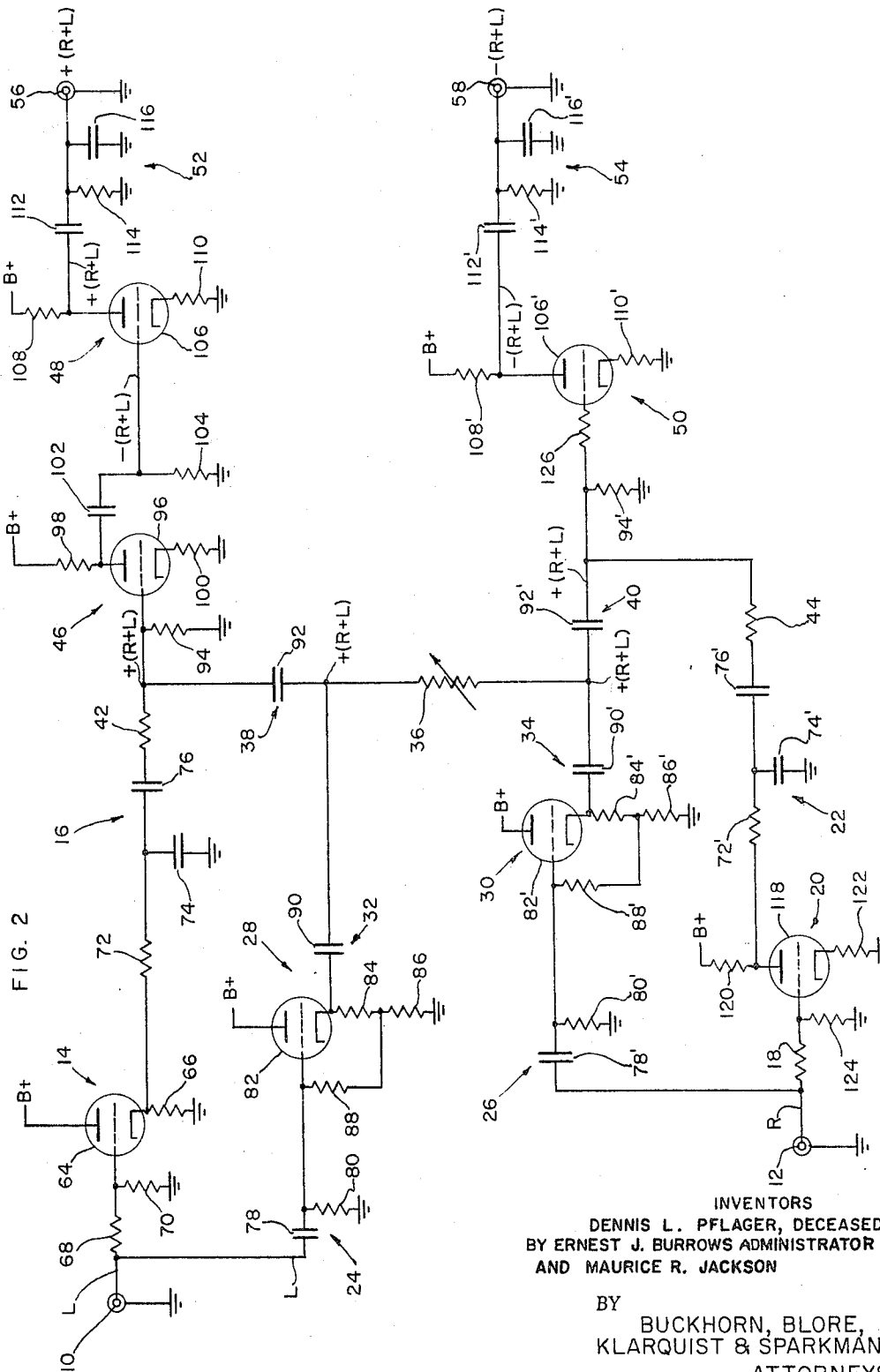
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STEREOPHONIC SOUND SYSTEM

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6 Claims. (Cl. 179—1)

The subject matter of the present invention relates generally to audio reproduction apparatus, and in particular to a stereophonic sound system which employs an electrical circuit to mix at least two different audio input signals together to produce a combined signal containing frequencies within a midband range of frequencies between 800 and 4,000 cycles per second and to transmit a portion of such combined signal to each of the two output terminals of such circuit after reversing the phase of one such signal portion. The stereophonic sound system of the present invention is an improvement on the system disclosed in co-pending U.S. patent application, Serial No. 114,979, now Patent No. 3,124,649, filed on June 5, 1961, by the present inventors and entitled Method and Apparatus for Audio Reproduction.

The sound system of the present invention is particularly useful in the reproduction of stereophonic sound recorded on magnetic tape or phonograph records, transmitted from radio stations, or as part of public address systems. However, the present stereophonic system may also be used in the reproduction of monaural sound signals as sound signals of greater dimension and dynamic range similar to stereophonic sound, and in the recording of stereophonic sound on magnetic tape, phonograph records or any other recording medium.

By employing phase reversed mixture signals of midband audio frequencies, the present stereophonic system has all the advantages over conventional stereophonic systems discussed in the co-pending patent application mentioned previously. In addition, the system of the present invention does not require the use of band pass filters but instead employs a combination of high pass and low pass filters to separate each of the input signals applied to the different channels of the circuit into a pair of signals of different frequencies. A signal containing frequencies above the cut-off frequency of the high pass filter which may be about 800 cycles per second is mixed with a corresponding filtered signal from the other channel of the circuit to produce a combined signal. Separate portions of the combined signal are then added to low frequency signals below about 800 cycles per second in each channel and then one of the resultant signals is inverted in phase so that the two output signals of the circuit contain mixture signals of midband frequencies between 800 and 4,000 cycles per second which are approximately 180 degrees out of phase. Thus, the midband range of frequencies is not separated from the high frequencies in the stereophonic system of the present invention as it is in the system of our copending application. This enables the use of a more simplified circuit to accomplish phase inversion of the critical midband frequencies.

Still another advantage of the circuit of the present invention is that the right and left channels of such circuit are connected so that they are isolated from one another except for a single variable coupling resistor which controls the amount of mixing of the signal from high pass filters in such two channels. This makes the two channels essentially functionally independent of one another and enables the use of a much simpler circuit having fewer components than that previously employed. A further improvement over the circuit described in the

above co-pending application is the use of cathode follower amplifiers to maintain a high input impedance for the circuit and to isolate the filter sections employed therein. These cathode followers help to reduce the distortion of the circuit to an exceedingly low level without the use of complicated and power consuming feedback loops.

It is, therefore, one object of the present invention to provide an improved audio reproduction system which enables the production of a more realistic sounding output signal.

Another object of the invention is to provide an improved stereophonic sound system which mixes together portions of at least two different audio signals above a lower limit frequency to produce at least two combined signals containing frequencies in the midband range between 800 and 4,000 cycles per second, and which inverts one of such combined signals before transmitting them to the output terminals of such system in order to produce a more realistic stereophonic sound output.

A further object of the present invention is to provide an improved stereophonic sound system of simplified construction having at least two channels which are isolated from each other except for a single variable coupling resistor so that such channels are essentially functionally independent from each other.

An additional object of the present invention is to provide an improved stereophonic circuit in which high pass filters and low pass filters are employed to separate each of the input signals of such circuit into a signal which contains only low audio frequencies and another signal containing midband and high audio frequencies, in order to simplify the mixing of the midband frequencies of different signals.

Still another object of the present invention is to provide a stereophonic circuit with very low distortion by employing cathode follower amplifiers to isolate the filter sections in such circuit, and to enable a high input impedance for such circuit.

Other objects and advantages of the present invention will be apparent from the following detailed description of a preferred embodiment thereof and from the attached drawings of which:

FIG. 1 is a block diagram of a stereophonic system in accordance with the present invention;

FIG. 2 is a schematic diagram of one embodiment of an electrical circuit of the system of FIG. 1; and

FIG. 3 is a graph of the response curve of the circuit of FIG. 2 compared with the theoretically ideal curve of the amplification characteristic of the critical midband range of frequencies.

As shown in FIG. 1, the stereophonic system of the present invention may include two circuits forming left and right channels having input terminals 10 and 12, respectively, connected to the outputs of suitable sources of left and right stereophonic signals. The input terminal 10 is connected through a cathode follower amplifier 14 to a first low frequency pass filter 16, while input terminal 12 is connected through a high impedance coupling resistor 18 and a phase inversion amplifier 20 to a second low pass filter 22. These low pass filters may have different characteristics in order to compensate for the presence of the coupling resistor 18 and the phase inversion amplifier 20 in the right channel so that both of these filters transmit similar signals having frequencies below about 800 cycles per second. A first pair of high pass filters 24 and 26 are connected to input terminals 10 and 12, respectively, in order to separate a signal portion from each of the input signals applied to such input terminals which has a frequency above a lower limit of about 800 cycles per second. The outputs of the first high pass fil-

ters 24 and 26 are connected through cathode follower amplifiers 28 and 30, respectively, to the inputs of a second pair of high pass filters 32 and 34, respectively. Each of these second filters 32 and 34 may have slightly different characteristics than the first pair of high pass filters 24 and 26 so that the cut off frequency of the second pair of filters is about 700 cycles per second. The outputs of the second pair of high pass filters 32 and 34 are connected together by a variable coupling resistor 36 in order to mix together the left and right signals (L and R) transmitted through such high pass filters. Thus, the setting of the coupling resistor 36 controls the amount of signal mixture. These combined or mixed signals ($L+R$) are then transmitted to a third pair of high pass filters 38 and 40 having their outputs connected respectively to the outputs of low pass filters 16 and 22. These third high pass filters are designed to attenuate the low frequencies even more than the other two pairs of high pass filters so that the low frequency output signals of low pass filters 16 and 22 are not transmitted through coupling resistor 36 as part of the mixture signal. Thus, the third filters 38 and 40 may have a turn over point of about 1,000 cycles per second.

The outputs of the low pass filters 16 and 22 are connected through coupling resistors 42 and 44, respectively, to the outputs of the third high pass filters 38 and 40, respectively. Thus, the low frequency signals transmitted through the low pass filters are added to the midband and high frequencies transmitted through the high pass filters as mixture signals $+(R+L)$. The input of a phase inversion amplifier 46 is connected to the common connection of the coupling resistor 42 and the high pass filter 38 in order to reverse the phase of the entire left channel signal present at that point. Thus, the bass or low frequencies below 800 c.p.s. in the signal at the output of the phase inverter 46 are in phase with the bass frequencies transmitted from the output of the low pass filter 22 in the right channel, but the midband and high frequencies above 800 c.p.s. in the signal at the output of such phase inverter, indicated by $-(R+L)$, are about 180 degrees out of phase with the signal at the output of the high pass filter 40 in the right channel. These combined signals are then transmitted through a pair of voltage amplifiers 48 and 50, respectively, which reverse their phase to produce output signals containing midband mixture signals of the polarity $+(R+L)$ and $-(R+L)$, respectively. The signals are then transmitted through midband rolloff attenuators 52 and 54, respectively, to the output terminals 56 and 58, respectively, of the left and right channels. Thus, the output signals transmitted from output terminals 56 and 58 are 180 degrees out of phase in the midband and high frequencies of the combined signals. This is indicated by the expression $+(R+L)$ adjacent output terminal 56 and the expression $-(R+L)$ adjacent output terminal 58. The output terminals are connected through power amplifiers (not shown) to electro-acoustical transducers, such as loudspeakers or tape recording heads.

As stated in co-pending U.S. patent application Serial No. 114,979, the mixture of midband frequencies in the output signals at output terminals 56 and 58 is amplified in a particular manner to a voltage greater than that of the bass and treble frequencies in order to produce a more realistic stereophonic effect. This is shown in FIG. 3 which includes a response curve 60 of one of the output signals of the circuit of FIG. 2 compared with the ideal characteristic curve 62 of the stereophonic theory of the present invention.

As shown in FIG. 2, one embodiment of the stereophonic circuit of the present invention includes an electron tube 64 of the triode type connected as a cathode follower amplifier with its anode connected to a source of positive D.C. supply voltage and its cathode connected to ground through a load resistor 66. The input signal applied to the input terminal 10 of the left channel is transmitted through a coupling resistor 68 to the grid of

tube 64 which is connected to ground through a bias resistor 70. The cathode of tube 64 is connected to a resistor 72 which forms the low pass filter 16 of FIG. 1 with a bypass capacitor 74 connected to ground at the output terminal of such resistor. Such low pass filter may have a cutoff frequency of 800 c.p.s. The output of the low pass filter 16 is connected through a coupling capacitor 76 to the coupling resistor 42.

The high pass filter 24 of the left channel may be formed by a capacitor 78 connected to input terminal 10, and a shunt resistor 80 connected to ground at the output of such capacitor. A triode vacuum tube 82 is connected as the cathode follower amplifier 28 with its anode connected to a source of positive D.C. supply voltage and its cathode connected to ground through a pair of series connected load resistors 84 and 86. A coupling resistor 88 is connected from the grid of tube 82 to the common connection between load resistors 84 and 86. Thus, the signal (L) transmitted through the high pass filter 24 which may have a cutoff frequency of 800 c.p.s., is applied to the grid of tube 82 and transmitted as a similar signal $+L$ from the cathode of such tube to the input of the second high pass filter 32 including a capacitor 90 which may have a cutoff frequency of 700 c.p.s. As a result, the cathode follower amplifier 28 isolates the two high pass filters 24 and 32 from each other and reduces signal distortion. The output of the second high pass filter 32 is connected to one terminal of the variable resistance potentiometer 36 connected as a coupling resistance between the left and right channels. As discussed above, the setting of this potentiometer determines the amplitude of the signals transmitted through the potentiometer and mixed at the end terminals of such potentiometer. The combined midband and high frequency signals $+(R+L)$ of the left and right channels are then transmitted through a capacitor 92 which forms the third high pass filter 38 with a shunt resistor 94 connected to ground at the output of such capacitor to the input of the phase inversion amplifier 46.

The phase inversion amplifier 46 includes a triode vacuum tube 96 having its anode connected to a source of positive D.C. supply voltage through a load resistor 98, and its cathode connected to ground through a cathode bias resistor 100. The grid of tube 96 is connected to the output terminals of coupling resistor 42 and filter capacitor 92 so that the low frequency bass signal transmitted through the low pass filter 16 is added to the midband and high frequencies of the combined signal $+(R+L)$ transmitted through high pass filter 38 as the input signal of such tube. This input signal is inverted and transmitted from the anode of tube 96 as an output signal containing a midband mixture signal of the polarity $-(R+L)$ through a coupling capacitor 102 which may form a phase correcting filter section with a shunt resistor 104 connected to ground at the output of such capacitor. The output signal of the phase correcting filter is applied to the grid of a triode vacuum tube 106 which is connected as a common cathode type of voltage amplifier with its anode connected through a load resistor 108 to a source of positive D.C. supply voltage, and its cathode connected to ground through a bias resistor 110. It should be noted that the voltage amplifier 48 including tube 106, also reverses the phase of the signal applied thereto so that the combined midband signal $+(R+L)$ is back in phase with the midband frequencies of the input signals applied to the input terminals 10 and 12. The anode of tube 106 is connected through a coupling capacitor 112 to the output terminal 56 of the left channel which is connected across a shunt resistor 114 in parallel with a bypass capacitor 116, such resistor and capacitors forming the midband rolloff attenuator 52 with the coupling capacitor and shunt resistor acting as a rumble filter. Thus, capacitor 112 and resistor 114 reduce the amplitude of the low frequencies while capacitor 116 attenuates the high frequencies.

The right channel of the circuit of FIG. 2 is similar to the left channel so that only the differences between these two will be discussed. Components in the right channel performing the same function as similar components in the left channel will be given the same number but distinguished by a prime on such number. Thus, the right channel employs the inverter amplifier 20 connected to input terminal 12 in place of the cathode follower amplifier 14 of the left channel. This inverter amplifier includes a triode vacuum tube 118 connected as a common cathode amplifier having its anode connected to a source of positive D.C. voltage through a load resistor 120 and its cathode connected to ground through a bias resistor 122. The grid of tube 118 is connected to the high impedance coupling resistance 18 and across a grid bias resistor 124 connected to ground. The inverted output signal developed across the load resistor 120 is transmitted through the first low pass filter 22 formed by resistor 72' and capacitor 74' which may have a different transmission characteristic than the low pass filter 16 of the left channel in order to compensate for the effect of the inverter amplifier 20 so that the low frequency output signals from such filters are substantially the same. The third high pass filter 40 of the right channel may also be provided with a different transmission characteristic than the third high pass filter 38 of the left channel merely by providing the shunt resistor 94' with a different resistance value than that of resistor 94. Thus, the combined midband signal $+(R+L)$ transmitted through a coupling resistor 126 to the grid of the voltage amplifier tube 106' is substantially the same as the combined midband signal $-(R+L)$ applied to the grid of the voltage amplifier tube 106 of the left channel except that such signals are of opposite phase due to the fact that the phase inverter amplifier 46 connected to the input of the voltage amplifier has been eliminated in the right channel. As a result, the output signal transmitted to output terminal 58 of the right channel is approximately 180 degrees out of phase with the output signal transmitted to output terminal 56 of the left channel in the midband and high frequency range including the combined or mixed signal $-(R+L)$, as indicated above.

Typical values of the components which may be used in the circuit of FIG. 2 are listed below:

Resistors 18, 70, 80, 80' and 94	1.2 megohms.	45
Resistors 36, 108, 108', 114 and 114'	100 kilohms.	
Resistors 42 and 44	150 kilohms.	
Resistor 66	47 kilohms.	
Resistor 68	680 kilohms.	50
Resistor 72	68 kilohms.	
Resistors 72' and 120	10 kilohms.	
Capacitors 74 and 74'	.05 microfarad.	
Capacitors 76 and 76'	.68 microfarad.	
Capacitors 78 and 78'	200 micromicrofarads.	55
Resistors 84, 84', 100 and 104	2.2 kilohms.	
Resistors 86 and 86'	4.7 kilohms.	
Resistors 88 and 88'	1 megohm.	
Capacitors 90 and 90'	.02 microfarad.	
Capacitors 92 and 92'	.001 microfarad.	60
Resistor 94'	470 kilohms.	
Resistor 98	220 kilohms.	
Capacitor 102	.04 microfarad.	
Resistors 110 and 110'	1.5 kilohms.	65
Capacitors 112 and 112'	.1 microfarad.	
Capacitors 116 and 116'	.001 microfarad.	
Resistor 122	5.6 kilohms.	
Resistor 124	220 kilohms.	
Tubes 64, 82, 82' and 118	Type 12AU7-A.	70
Tube 96	Type 6C4.	
Tubes 106 and 106'	Type 12AX7-A.	

It will be obvious to those having ordinary skill in the art that various changes may be made in the details of the above described preferred embodiment of the present

invention without departing from the spirit of the invention. Therefore, the scope of the present invention should only be determined by the following claims.

What is claimed is:

1. An audio reproduction system comprising:
 - a plurality of electrical circuits each having input and output terminals;
 - means for applying audio input signals to the input terminals of said circuits;
 - means for separating a portion of each said input signals from the remainder of said input signals to provide separated signals containing frequencies above a lower limit frequency and including a midband range of audio frequencies;
 - means for mixing said separated signals together to produce a combined signal containing said midband frequencies;
 - means for substantially reversing the phase of a portion of said combined signal and for transmitting the phase reversed portion of said combined signal to the output terminal of one of said circuits; and
 - means for transmitting another portion of said combined signal to the output terminal of another of said circuits so that the output signals of said one circuit and said another circuit are substantially reversed in phase in said midband range of frequencies.
2. An audio reproduction system comprising:
 - a plurality of electrical circuits each having input and output terminals;
 - means for applying audio input signals to the input terminals of said circuits;
 - filter means for separating a portion of each said input signals from the remainder of said input signals to provide separated signals containing frequencies above a lower limit frequency and including those in the midband range of frequencies between 800 and 4,000 cycles per second;
 - means for mixing at least two of said separated signals together to produce at least a pair of combined signals containing said midband frequencies;
 - inverter means for substantially reversing the phase of one of said combined signals and for transmitting the phase reversed combined signal to the output terminal of one of said circuits; and
 - means for transmitting the other combined signal to the output terminal of another of said circuits so that the output signals of said one circuit and said another circuit are substantially reversed in phase in said midband range.
3. An audio reproduction system comprising:
 - a pair of electrical circuits each having input and output terminals;
 - means for applying different audio input signals to the input terminals of said circuits;
 - high pass filter means for separating a portion of each said input signals from the remainder of said input signals to provide a pair of separated signals containing frequencies above a lower limit frequency and including midband frequencies in the range approximately from 800 to 4,000 cycles per second;
 - low pass filter means for obtaining a pair of low frequency signals from said remainder of said input signals, said low frequency signals having an upper limit frequency of about 800 cycles per second;
 - means for mixing at least two of said separated signals together to produce a pair of combined signals containing said midband frequencies;
 - means for adding a different one of said combined signals to each of said low frequency signals;
 - inverter means for substantially reversing the phase of one of said combined signals and for transmitting the phase reversed combined signal to the output terminal of one of said circuits; and
 - means for transmitting the other combined signal to the output terminal of another of said circuits so

- that the output signals of said one circuit and said another circuit are substantially reversed in phase in said midband range.
4. An audio reproduction system comprising:
 - a pair of first and second input terminals;
 - a pair of first and second low frequency pass filters having their inputs connected, respectively, to said first and second input terminals, said low pass filters being capable of transmitting signals having frequencies below about 800 cycles per second;
 - a pair of first and second high frequency pass filters having their inputs connected, respectively, to said first and second input terminals, said high pass filters being capable of transmitting signals having frequencies above about 800 cycles per second;
 - a variable coupling resistor connected between the outputs of said pair of high pass filters to mix together the signals transmitted through said high pass filters in order to obtain a pair of mixture signals containing frequencies in the midband audio range between 800 and 4,000 cycles per second;
 - a pair of first and second inverter amplifiers, said first inverter amplifier having its input connected to the outputs of said first high pass filter and to said first low pass filter and having its output connected to said first output terminal, and said second inverter amplifier being connected between said second input terminal and the input of said second low pass filter; and
 - a pair of first and second voltage amplifiers, said first voltage amplifier being connected between said first inverter amplifier and said first output terminal, and said second voltage amplifier having its input connected to the outputs of said second low pass filter and said second high pass filter and having its output connected to said second output terminal.
 5. An audio reproduction system comprising:
 - a pair of first and second input terminals;
 - a pair of first and second low frequency pass filters having their inputs connected, respectively, to said first and second input terminals, said low pass filters being capable of transmitting signals having frequencies below about 800 cycles per second;
 - a pair of first and second high frequency pass filters having their inputs connected, respectively, to said first and second input terminals, said high pass filters being capable of transmitting signals having frequencies above about 800 cycles per second;
 - a variable coupling resistor connected between the outputs of said pair of high pass filters to mix together the signals transmitted through said high pass filters in order to obtain a pair of mixture signals containing frequencies in the midband audio range between 800 and 4,000 cycles per second;
 - a pair of first and second inverter amplifiers, said first inverter amplifier having its input connected to the outputs of said first high pass filter and to said first low pass filter and having its output connected to said first output terminal, and said second inverter amplifier being connected between said second input terminal and the input of said second low pass filter;

- a pair of first and second voltage amplifiers, said first voltage amplifier being connected between said first inverter amplifier and said first output terminal, and said second voltage amplifier having its input connected to the outputs of said second low pass filter and said second high pass filter, and having its output connected to said second output terminal; and
 - a pair of first and second midband audio frequency roll-off attenuators connected between said voltage amplifiers and said output terminals to enable the gain of the output signals transmitted to said output terminals to be greater for the midband range of frequencies of said mixture signals.
6. An audio reproduction system comprising:
 - a pair of first and second input terminals;
 - a pair of first and second low frequency pass filters having their inputs connected, respectively, to said first and second input terminals, said low pass filters being capable of transmitting signals having frequencies below about 800 cycles per second;
 - a first pair of high frequency pass filters having their inputs connected, respectively, to said first and second input terminals, said high pass filters being capable of transmitting signals having frequencies above about 800 cycles per second.
 - a second pair of high pass filters capable of transmitting signals above 700 cycles per second;
 - a pair of cathode follower amplifiers connected between said first and second high pass filters;
 - a variable coupling resistor connected between the outputs of said second pair of high pass filters to mix together the signals transmitted through said high pass filters in order to obtain a pair of mixture signals containing frequencies in the midband range between 800 and 4,000 cycles per second;
 - a third pair of high pass filters connected to the outputs of said second pair of high pass filters;
 - a pair of first and second inverter amplifiers, said first inverter amplifier having its input connected to the outputs of one of said third pair of high pass filters and to said first low pass filter and having its output connected to said first output terminal, and said second inverter amplifier being connected between said second input terminal and the input of said second low pass filter;
 - a pair of first and second voltage amplifiers, said first voltage amplifier being connected between said first inverter amplifier and said first output terminal, and said second voltage amplifier having its input connected to the outputs of said second low pass filter and the other of said third pair of high pass filters, and having its output connected to said second output terminal; and
 - a pair of first and second midband audio frequency roll-off attenuators connected between said voltage amplifiers and said output terminals.

No references cited.

- 60 KATHLEEN H. CLAFFY, *Primary Examiner*.
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