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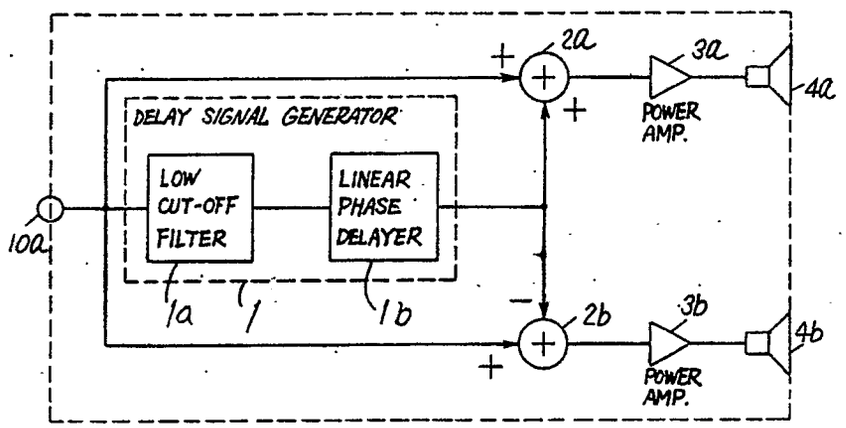
(54) Sound reproduction apparatus.

(57) During the reproduction of two central positioned signal by a pair of loudspeakers in a sound reproduction apparatus, the characteristic of sound propagation is leveled so that the perception of reproduced sound is possible without distortion at any location off the center line between the two loudspeakers. An input audio signal is passed through a filter for removing its low-band component and delayed by a delayer. The delay signal is then added to the input audio signal in approximately opposite-phase relationship to obtain two sum signals. The two sum signals are amplified by power amplifiers and reproduced by their respective loudspeakers.

FIG. 1



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SOUND REPRODUCTION APPARATUS

The present invention relates to an apparatus for reproducing sound with the use of left and right or upper or lower loudspeakers, e.g. a car audio system, a stereo-sound audio system such as a portable cassette player, and a video/sound reproduction system having upper and lower loudspeakers disposed upper and lower sides of the center of a video screen for reproduction of a center channel signal, and more particularly, a sound reproduction apparatus for use in a TV receiver having left and right loudspeakers provided on the left and right of a TV screen.

2.Description of the Prior Art

There have lately been introduced television receivers provided with built-in sound reproduction systems, in which the TV screen is enlarged and the quality of reproduced sound is improved. As the audio signals in television broadcasting and other video systems are separated into two channels, today's TV receivers incorporate left and right built-in loudspeakers mounted at both the sides of a TV screen for stereo-sound reproduction.

It is known that a prior art television receiver with a built-in loudspeaker system comprises, as shown in Fig.3, an audio signal input terminal 10a, power amplifiers 3a and 3b for amplifying the input signals, left and right loudspeak ers 4a and 4b arranged to be actuated by the amplified input signals, a TV tube 11 for reproduction of a TV image, and a cabinet 12 accommodating the loudspeakers, TV tube, and other audio and video signal circuit boards. The video signal to be reproduced may be a TV picture signal modulated from a normal broadcasting signal or a video signal supplied from the outside, and the audio signal supplied to the built-in sound reproduction apparatus may be an audio signal modulated in synchronization with the TV picture signal or an audio signal supplied from the outside. The video and audio signals are to be reproduced simultaneously or separately.

When the audio signal which generates mono- or stereophonic sound exhibiting a sweet spot or stereo image at the center is reproduced by a conventional TV receiver, left and right sound pressure levels thereof and corresponding sound propagation durations will be equal to each other at the point A shown in Fig.3, which is just in the center front of the TV receiver and equally spaced from the left and right loudspeakers. However, at any off-center point, e.g. the point B shown in Fig.3, the sound propagation duration from the nearer loudspeaker becomes shorter and thus, there will be caused a difference between the two reproduced sound pressure levels. Figs.3-c and 4-d show the characteristics of impulse response at the point A and Figs.3-b and 4-b at the point B. Fig.4 illustrates how two impulse reproduced waveforms generated from the left and right loudspeakers are combined at the points A and B respectively. The characteristic of propagation at the point A is shown in Fig.4-c and at the point B in Fig.4-d, in which a form of distortion is present resulting from a time lag. More particularly, the distortion is associated with the fact that sounds from the two loudspeakers reach the listening point with time lag, i.e. a comb filter is developed in the sound space. When the listening point is located off the center line, a distortion in the propagation is generated by the comb filter, so that quality sound for listening cannot be reproduced.

The use of upper and lower extra loudspeakers for having a stereo image at the center of the TV screen may enable to give a sweet spot when the listening point is equally spaced from both the upper and lower loudspeakers. However, if the listening point is either higher or lower like dislocated leftwardly or rightwardly, a distortion in the propagation also occurs and causes the reproduced sound to be degraded in quality.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a sound reproduction apparatus which offers such a wide listening area that the propagation characteristic remains appreciable when the listening point is off-centered in any left-, right-, up-, or down-ward direction.

To accomplish the foregoing object, a sound reproduction apparatus according to the present invention comprises a signal input terminal for receiving an input audio signal, a delay signal generator consisting mainly of a filter for blocking a low-tone component of the input audio signal and a delay means for delaying the output signal from the filter, an in-phase adder for summing an output signal of the delay signal generator and the input audio signal, an opposite-phase adder for summing the output signal of the delay signal generator in reverse phase and the input audio signal, power amplifiers for amplifying output signals of the in-phase and opposite-phase adders respectively, and a pair of left and right or upper and lower loudspeakers for being actuated by the amplified signals.

Accordingly, the delay signals from the left and right loudspeakers are offset by each other at a listening point lying on the center line of a TV receiver thus not to appear in the form of sound. Sounds derived from the signals which have not passed through the delay signal generator will propagate by the same time from the left and right loudspeakers, causing no distortion in the propagation. At an off-center listening point lying off the center line, the delay signal is actuated so that the distortion of propagation caused by a difference in the propagation time of sound can be compensated for improvement. As the result, the flat range of propagation characteristics will be extended from the center line to both the left and right sides, thus increasing the audible area of reproduced sound at acceptable quality.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 is a block diagram of one embodiment of a sound reproduction apparatus according to the present invention;

Fig.2 is a schematic diagram showing the impulse response and propagation characteristic of the sound reproduction apparatus according to the present invention;

Fig.3 is a schematic diagram showing a prior art television receiver equipped with a built-in sound reproduction system and its impulse response with respect to a listening position;

Fig.4 is a schematic diagram showing the impulse response and propagation characteristic of the prior art television receiver with the built-in sound reproduction system;

Fig.5 is a block diagram of another embodiment of a sound reproduction apparatus according to the present invention;

Fig.6 is a block diagram of a further embodiment of a sound reproduction apparatus according to the present invention;

Fig.7 is a block diagram of a still further embodiment of a sound reproduction apparatus according to the present invention;

Fig.8 is a block diagram of a still further embodiment of a sound reproduction apparatus according to the present invention;

Fig.9 is a diagram showing one embodiment of a delayer for generating a delay time varying depending on the fre quency;

Fig.10 shows an example of the characteristic of a delay time generated varying depending on the frequency;

Fig.11 is a schematic diagram showing impulse response waveforms of the delayer, in which the higher the frequency, the shorter the delay time, and when an input audio signal and a delay signal are summed;

Figs.12, 13, and 14 are block diagrams showing a further embodiment of a sound reproduction apparatus according to the present invention;

Figs.15 and 16 are block diagrams showing a still further embodiment of a sound reproduction apparatus according to the present invention; and

Fig.17 is a block diagram of a still further embodiment of a sound reproduction apparatus according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

(Embodiment 1)

Fig.1 illustrates a sound reproduction apparatus according to one embodiment of the present invention.

An object of this embodiment is to increase an audible area of quality sound.

As shown in Fig.1, there are provided a signal input terminal 10a for input of an audio signal, a low cut-off filter 1a for blocking the low-tone level of the input audio signal, a linear phase delayer 1b for giving a time delay in every frequency of an output signal from the low cut-off filter, a delay signal generator 1, an in-phase adder 2a for summing an output signal of the delay signal generator 1 and the input audio signal from the signal input terminal 10a, an opposite-phase adder 2b for summing the output signal of the delay signal generator 1 in reverse phase and the isniut audio pgnal from the signal input terminal 10a, power amplifiers 3a and 3b for amplifying the output signals of the in-phase and opposite-phase adders 2a, 2b, respectively, and left and right loud-speakers 4a and 4b provided for being actuated by the amplified signals from the amplifiers 3a and 3b, respectively.

The operation of the audible area increasing apparatus having the aforementioned arrangement will be described referring to Fig.2.

Figs.2-a and 2-b schematically illustrate the impulse response of sounds generated from the right and left loudspeakers 4a and 4b, in which like Fig.4, the impulses reproduced by the left and right loudspeakers are combined in the waveform at each of the points A and B explained in Fig.3, exhibiting a form of impulse response. Fig.2-c shows the propagation characteristic at the point A while Fig.2-d at the point B. At the point A lying on the center axis of the television receiver, no sound from delay signals is involved because the delay signals reproduced by the left and right loudspeakers are offset by each other and also, no distortion in the propagation characteristic is devel-

oped because the sounds from the left and right loudspeakers, of which signals have passed no delay signal generator, are equal to each other in the propagation time. At the point B lying off the center line, a delay signal is actuated to compensate for the distortion of propagation caused by a difference in the propagation time, eliminating such a distortion as shown in Fig.4-d which results from the existence of the comb filter. More particularly, when the delay signal is added to a simple impulse response developed by the comb filter for response elaboration, peak and dip in the frequency characteristic will appear more often. As the propagation characteristic resides in the average of different bands, the peak and dip are complemented to each other in each band thus ensuring equilibration throughout the range of propagation characteristic. This results in the reduction of propagating distortion.

The signal reproduced by the left loudspeaker 4b is fed from the opposite-phase adder 2b where a signal passing the low cut-off filter 1a is added and thus, remains undecayed in the low band. Accordingly, the reproduction of low-tone sound is ensured and no difference in the energy of sound between the left and right loudspeakers will be sensed. This means that the flat range of propagation characteristic is extended from the center line to both the left and right sides, increasing the audible area of reproduced sound with acceptable quality.

It is understood that the delay time and the cut-off setting frequency of the low cut-off filter 1a are deter mined by the distance between the left and right loudspeakers, the listening distance, and the listening angle. If the delay is too long, the direct sound and the delayed sound are heard separately and if too short, the propagation characteristic will be less improved. Preferably, when the distance between the two loudspeakers is about 0.2 to 2 meters, the delay time may be within a range from 1 to 20 mm/sec. Also, if the low cut-off frequency is too high, the improvement will decline and if too low, the low band of an output signal from the opposite-phase adder means 2b will be decreased, causing a difference in the reception of sound energy between left and right. Preferably, the low cut-off frequency may be about 50 to 500 Hz.

Either analog or digital signal processing is possible in any apparatus of the present invention. Also, the delay signal generator 1 may have the two components 1a and 1b substituted in the order of arrangement with equal success.

As described previously, the low cut-off signals are delayed and then, reproduced in both the normal and reverse phase by the left and right loudspeakers together with the direct signals, whereby the flat range of propagation characteristic can be extended from the center line to both the left and right sides, increasing the audible area of reproduced sound with acceptable quality.

(Embodiment 2)

Fig.5 illustrates a sound reproduction apparatus showing another embodiment of the present invention.

An object of this embodiment is to increase the audible area of quality sound derived from a central normal-position signal during the reproduction of 2-channel stereo signals.

As shown in Fig.5, there are additionally provided an input signal adder 2c for summing input stereo signals supplied from two signal input terminals 10a and 10b and an attenuator 2d for attenuating the output signal of the adder 2c to a half.

According to the sound reproduction apparatus having such an arrangement, the common signals existing in both the left and right channels are normal-position signals to be reproduced in the center, offering the same effect as of monophonic signals when reproduced by the left and right loud speakers. In reproduction, the center sound when received at a location off the center line exhibits a distortion in the propagation and will thus be declined in quality. However, when the monophonic signal generated by summing signals with the input signal adder 2c is delayed by a delay signal generator 1 and after reversed in phase, added to left and right signals by an in-phase adder 2a and an opposite-phase adder 2b respectively, the receipt of quality sound will be feasible at an off-center location during the reproduction of stereo signals, as well as the previous embodiment.

The central normal-position signal of the output of the input signal adder 2c which is generated by summing the left and right signals has an amplitude of 2 times the center signal component of the left or right signal. Hence, the output of the input signal adder 2c is preferably reduced by the signal attenuator 2d to about 1/2 in the amplitude.

(Embodiment 3)

Fig.6 illustrates a sound reproduction apparatus showing a further embodiment of the present invention.

An object of this embodiment is to increase the audible area of quality sound derived from a central normal-position false-source signal, which is associated with the allocation of center-channel signal to the left and right loudspeakers, during the reproduction of front 3-channel audio signals.

As shown in Fig.6, there are additionally provided a demodulator 5 for converting input stereo signals fed from two signal input terminals 10a and 10b into 4-channel stereophonic signals, a power amplifier 3c for amplifying a signal to be reproduced at the rear, and a loudspeaker drive signal output terminal 4c for delivering a drive signal to a rear loudspeaker 4d.

According to the sound reproduction apparatus having such an arrangement, the center-channel signal is fed to a delay signal generator 1 and also, to both in-phase and opposite-phase adders 2a and 2b where the signals are added together with the outputs of the delay signal generator 1 to the left- and right-channel signals respectively prior to amplification.

As the result, the receipt of quality sound from the center-channel signal will also be possible at a location off the center line between two main loudspeakers, ensuring a wide audible area of stereo sound.

(Embodiment 4)

Fig.7 illustrates a sound reproduction apparatus showing a still further embodiment of the present invention.

An object of this embodiment is to decrease the reverse-phase effect of sound which is encountered during the reproduction of two delay signals in opposite phase with their respective left and right loudspeakers.

As shown in Fig.7, represented by 1aO is a band-pass filter. The signal generated by a delay signal generator 1 is added to the input audio signal in opposite phase relationship, whereby a listener will suffer from the opposite-phase effect of sound from a delay signal. Meanwhile, the high tone range in the propagation characteristic exhibiting the average of 1/3 octave involves no distortion during off-center listening, as shown in Fig.4-d. Hence, no problem arises in the sense of bare listening when the compensation for leveling a high band in the propagation characteristic is not executed. Accordingly, the low cut-off filter 1a can be replaced with equal success by a band-pass filter adapted for rejecting a high band signal. It is preferred to have the high cut-off frequency ranging from 1 to 10 KHz.

(Embodiment 5)

Fig.8 illustrates a sound reproduction apparatus showing a still further embodiment of the present invention.

An object of this embodiment is to carry out the repro duction of sound throughout a wide rage of frequencies in which no separation between direct sound and delayed sound is caused in the entire frequency band.

As shown in Fig.8, represented by 1c is a non-linear phase delayer for providing a delay time varying with frequency.

The operation of the sound reproduction apparatus having such an arrangement will now be described referring to Fig.9.

Fig.9-a shows an analog circuit of a basic component of the non-linear phase delayer 1c provided in the form of a primary full-wave pass filter. Its delay time is shown in Fig.9-b which will be decreased when the frequency is high and increased when low. A number of the circuits having different time constant (CR) from each other are coupled in series forming an array so that the delay frequency characteristic is properly determined providing a delay as shown in Fig.10-a. Fig.11-a illustrates a waveform of impulse response in the non-linear phase delayer 1c, in which the lower the frequency, the longer the delay time. The non-linear phase delayer 1c may be composed of secondary full-wave pass filters so that the natural angular frequency ωo becomes greater in the delay time characteristic introducing a time delay shown in Fig.10-b.

Fig.12 illustrates a sound reproduction apparatus showing a still further embodiment of the present invention, in which a linear phase delayer 1b and a nonlinear phase delayer 1c are coupled to each other in series. Hence, the impulse response after an in-phase adder 2a involves the sum of time delays of the two delayers as a time delay of the delay signal which follows the input audio signal.

Figs.13 and 14 show sound reproduction apparatuses explaining further embodiments of the present invention in which denoted by 1aO to 1aN are bandpass filters for separating an input audio signal into an N-number of frequency bands. The band signals are delayed by linear phase delayers 1bO to 1bN (Fig.13) or linear phase delayers 1b0 to 1bN and non-linear phase delayers 1cO to 1cN (Fig.14). The characteristic of time delay in the embodiment of Fig.13 is shown in Fig.10-c and that of Fig.14 in Fig.10-d.

The separation between the direct sound and the delayed sound is reduced by decreasing the time delay, as described in Embodiment 1. However, a proper time delay is needed for a distortion in the propagation to be corrected. To correct the propagating distortion by adding a delay signal, the delay should be small when the frequency is high and large when low. According to the embodiments in which a time delay is determined in the frequency characteristic by a non-linear phase de-

layer or a plurality of delayers, the delay time can be set short when the frequency is high and long when low. Thus, the separation between the direct sound and the delayed sound will be avoided throughout the frequency band for reproduction of more natural sound. The delay is determined in length and frequency by the distance between the left and right loudspeakers, the listening distance, and the listening angle. When the distance between the left and right or upper and lower loudspeakers is 0.2 to 2 meters, the delay may be preferably 2 to 20 mm/sec at a frequency of about 200 Hz, 1 to 10 mm/sec at about 500 Hz, 0.5 to 5 mm/sec at about 1 KHz, 0.3 to 3 at about 2 KHz, 0.1 to 1 mm/sec at about 5 KHz, and 0.05 to 0.5 mm/sec at about 10 KHz.

(Embodiment 6)

Figs.15 and 16 illustrate sound reproduction apparatuses showing still further embodiments of the present invention.

An object of this embodiment is to decrease the reverse-phase effect of sound which is encountered during the reproduction of two delay signals in opposite phase with their respective left and right loudspeakers.

As shown in Figs.15 and 16, there are provided a linear phase delayer 1bO and a non-linear phase delayer 1cO.

According to each sound reproduction apparatus having such an arrangement, two signals in opposite phase from the delay signal generator 1 are not directly reproduced by the left and right loudspeakers. More particularly, one of the two signals is further delayed a bit by the delayer 1bO or 1cO, so that the reverse-phase effect of sound can be reduced during reproduction.

(Embodiment 7)

Fig.17 illustrates a sound reproduction apparatus showing a still further embodiment of the present invention.

An object of this embodiment is to ensure the optimum receipt of sound by selectively determining a difference in the propagation time from the left and right loudspeakers to the listening position with relation to the listening position and the distance between the two loudspeakers.

As shown in Fig.17, there are provided linear phase delayers 1b0 and 1b1 having different delay characteristics from each other, a delay signal selector 1d for selecting an output signal from either the first delayer 1b0 or the second delayer 1b1, and a delay selector control terminal 13 for receiving a signal for control of the delay signal selector 1d.

According to the sound reproduction apparatus having such an arrangement, the introduction of a control signal to the delay signal selector control terminal 13 is selectively carried out by a listener so that the delay signal from the first delayer 1b0 or the second delayer 1b1 can be accepted at the listening position more naturally and effectively.

Claims

1. A sound reproduction apparatus comprising: a signal input terminal for receiving an input audio signal;
a delay signal generator consisting mainly of a filter for rejecting a low-tone component of the input audio signal and a delay means for delaying an output signal of the filter;
an in-phase adder for summing an output signal of the delay signal generator and the input audio signal;
an opposite-phase adder for summing the output signal of the delay signal generator in reverse phase and the input audio signal;
power amplifiers for amplifying output signals of the in-phase and opposite-phase adders, respectively; and
a pair of left and right or upper and lower loudspeakers for being actuated by amplified signals from the power amplifiers.

2. A sound reproduction apparatus according to Claim 1, wherein the filter in the delay signal generator is a low cut-off filter or a bandpass filter.

3. A sound reproduction apparatus according to Claim 1, wherein the delay means provides a different time delay depending on the frequency.

4. A sound reproduction apparatus according to Claim 1, wherein the in-phase or opposite-phase adder means includes a delay means for further introducing a time delay independ ently in the delay signal supplied from the delay signal generator.

5. A sound reproduction apparatus according to Claim 1, wherein the delay signal generator includes a plurality of delay means which have different time delay characteristics from each other and a selector for selecting an output signal of one of the plurality of delay means.

6. A sound reproduction apparatus comprising:
a signal input means for receiving input left- and right-channel audio signals;
an input signal adder for summing the input left- and right-channel audio signals;
a delay signal generator consisting mainly of a filter and a delay means for delaying an output signal of the input signal adder;

an in-phase adder for summing an output signal of the delay signal generator and one of the input left- and right-channel audio signals;
an opposite phase adder for summing the output signal of the delay signal generator in reverse phase and the other of the input left- and right-channel audio signals;
power amplifiers for amplifying output signals of the in-phase and opposite-phase adders, respectively; and a pair of left and right loudspeakers for being actuated by the amplified signals from the power amplifiers.

7. A sound reproduction apparatus according to Claim 6, wherein the filter in the delay signal generator is a low cut off filter or a bandpass filter.

8. A sound reproduction apparatus according to Claim 6, wherein the delay means provides a different time delay depending on the frequency.

9. A sound reproduction apparatus according to Claim 6, wherein the in-phase or opposite-phase adder means includes a delay means for further introducing a time delay independently in the delay signal supplied from the delay signal generator.

10. A sound reproduction apparatus according to Claim 6, wherein the delay signal generator further includes a plurality of delay means which have different time delay characteristics from each other, and a selector for selecting an output signal of one of the plurality of delay means.

11. A sound reproduction apparatus comprising:
a signal demodulator for modulating input two channel signals to output three left-, right-, and center-channel signals;
a delay signal generator consisting mainly of a filter for rejecting a low-tone component of the center-channel signal from the signal demodulator and a delay means for delaying an output signal of the filter;
an in-phase adder for summing a delay signal generated by the delay signal generator, one of the left- and right-channel signals, and the center-channel signal;
a first power amplifier for amplifying an output signal of the in-phase adder;
an opposite-phase adder for summing the delay signal in reverse phase, the order of the left- and right-channel signals, and the center-channel signal;
a second power amplifier for amplifying an output signal of the opposite-phase adder; and
a pair of left and right or upper and lower loudspeakers for being actuated by amplified signals from the respective first and second power amplifiers.

12. A sound reproduction apparatus according to Claim 11, wherein the filter in the delay signal generator is a low cut-off filter or a bandpass filter.

13. A sound reproduction apparatus according to Claim 11, wherein the delay means provides a different time delay depending on the frequency.

14. A sound reproduction apparatus according to Claim 11, wherein the in-phase or opposite-phase adder means includes a delay means for further introducing a time delay independently in the delay signal supplied from the delay signal generator.

15. A sound reproduction apparatus according to Claim 11, wherein the delay signal generator means further includes a plurality of delay means which have different time delay characteristics from each other, and a selector for selecting an output signal of one of the plurality of delay means.

FIG. 1

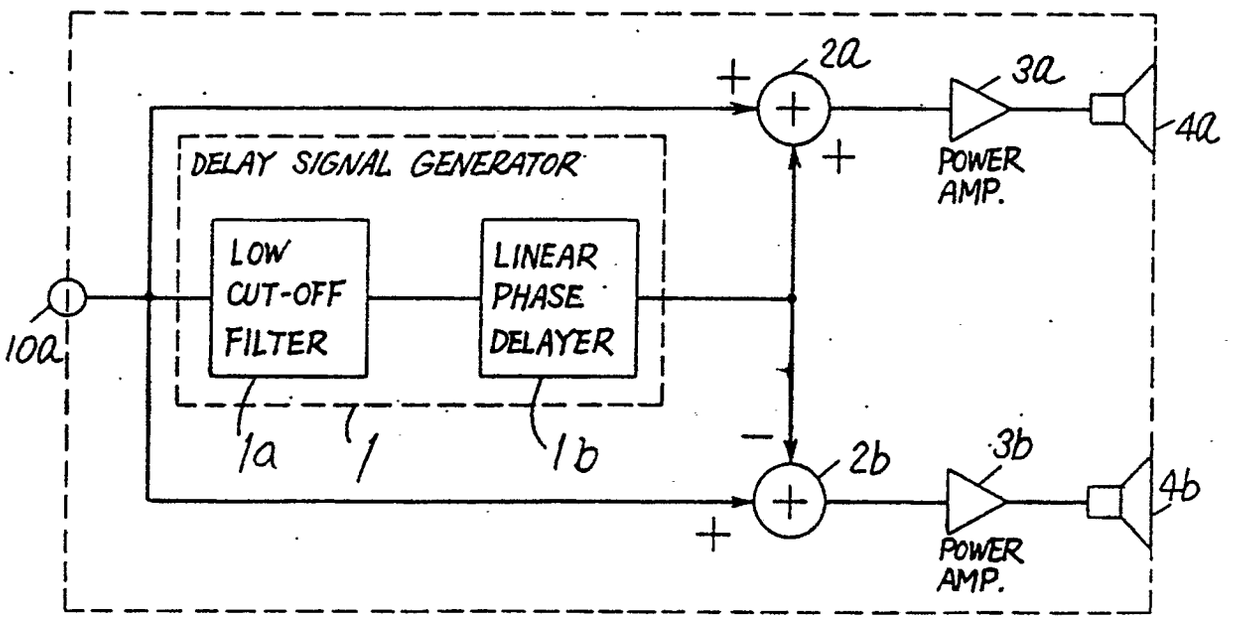
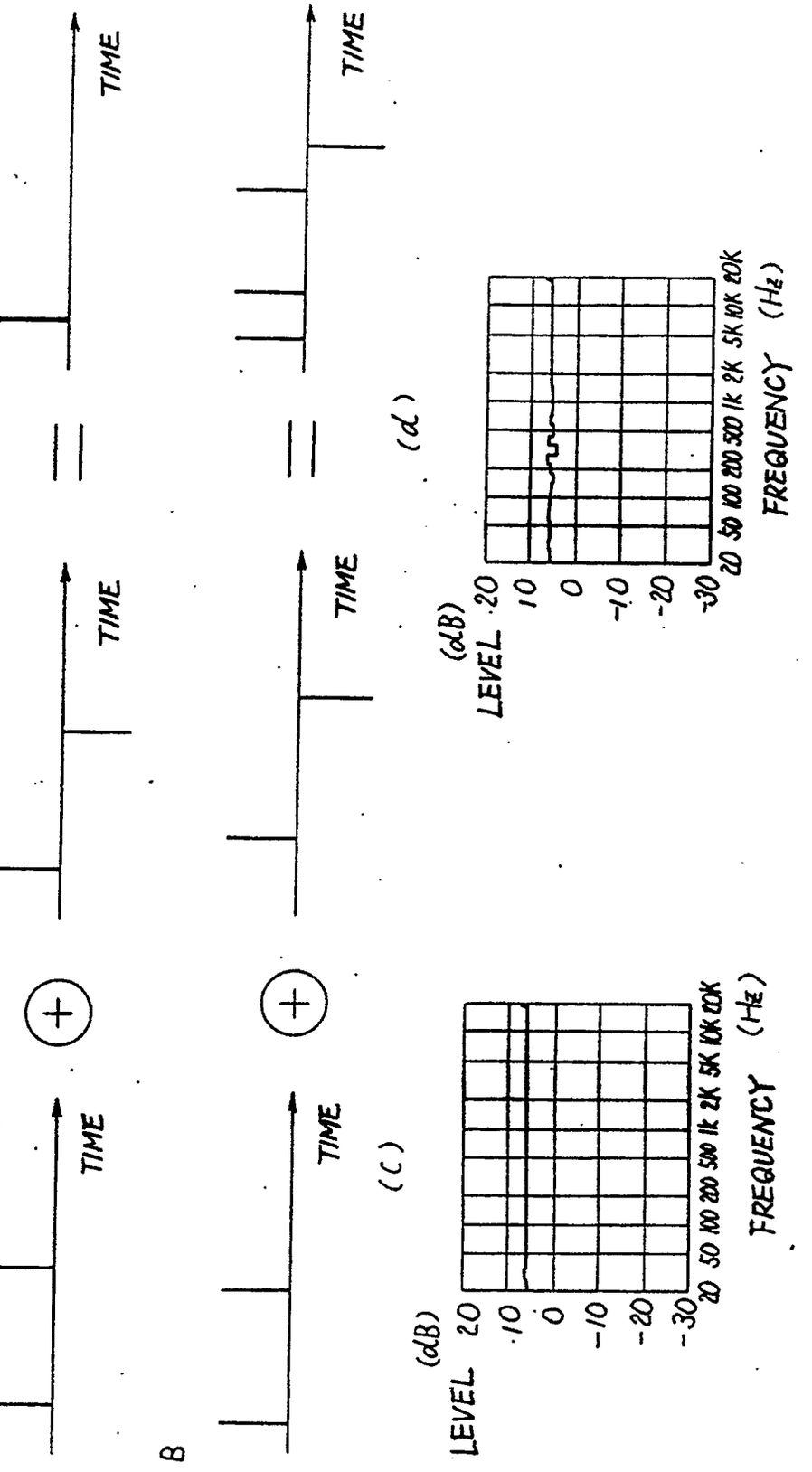

DELAY SIGNAL GENERATOR
LOW CUT-OFF FILTER
LINEAR PHASE DELAYER
1a
1
1b
10a
2a
2b
3a
3b
4a
4b
POWER AMP.
POWER AMP.
+
+
+
−

FIG. 2


(a)
A
TIME
(b)
B
TIME
(c)
LEVEL (dB)
20
10
0
-10
-20
-30
20 50 100 200 500 1K 2K 5K 10K 20K
FREQUENCY (Hz)
(d)
TIME
LEVEL (dB)
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FREQUENCY (Hz)

FIG. 3

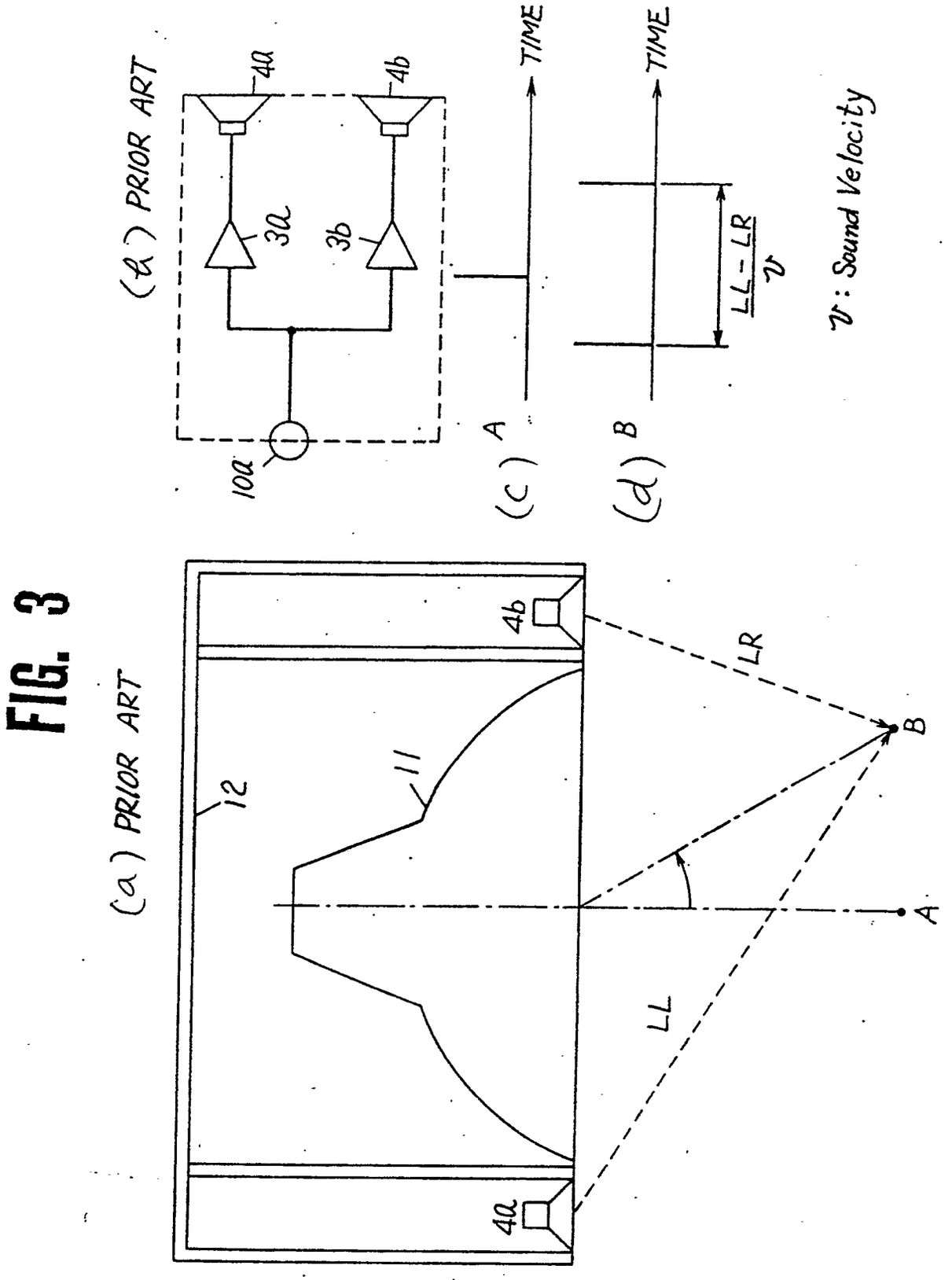
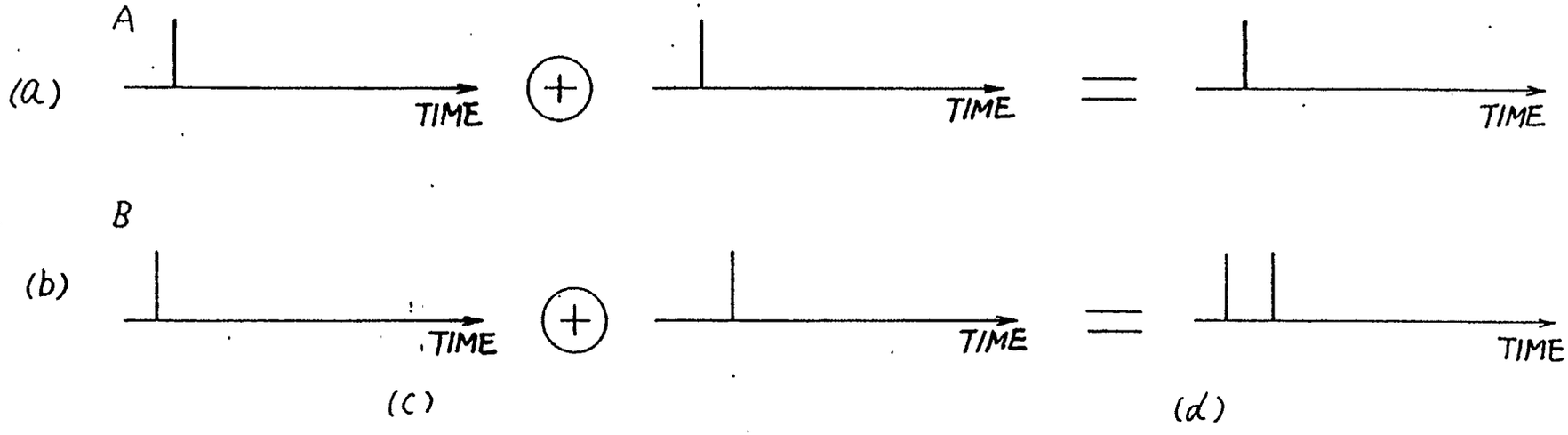
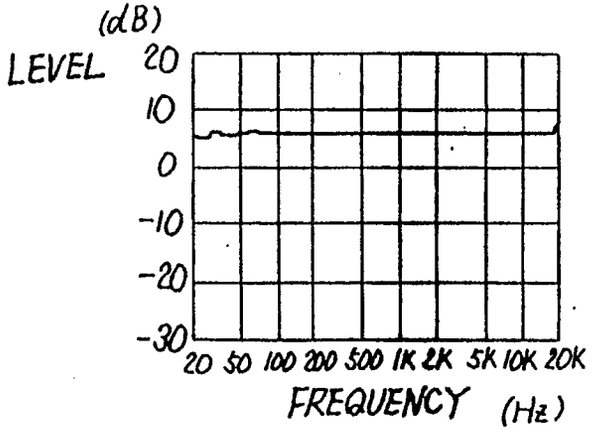
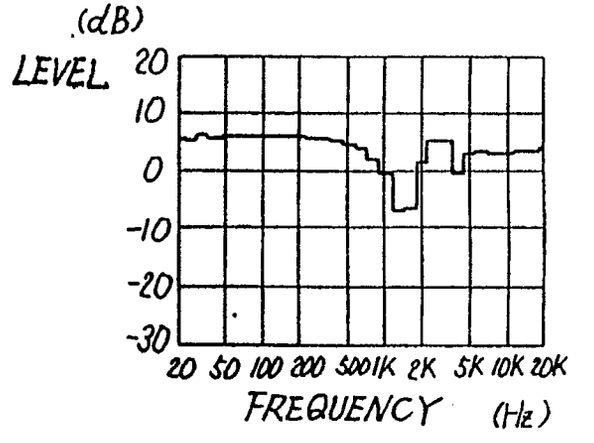

(a) PRIOR ART
12
11
4b
4a
LR
LL
A
B
(b) PRIOR ART
4a
4b
3a
3b
10a
(c)
A
TIME
(d)
B
TIME
LL - LR
v
v : Sound Velocity

FIG. 4





Transmission Characteristic at Point A



Transmission Characteristic at Point B

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FIG. 5

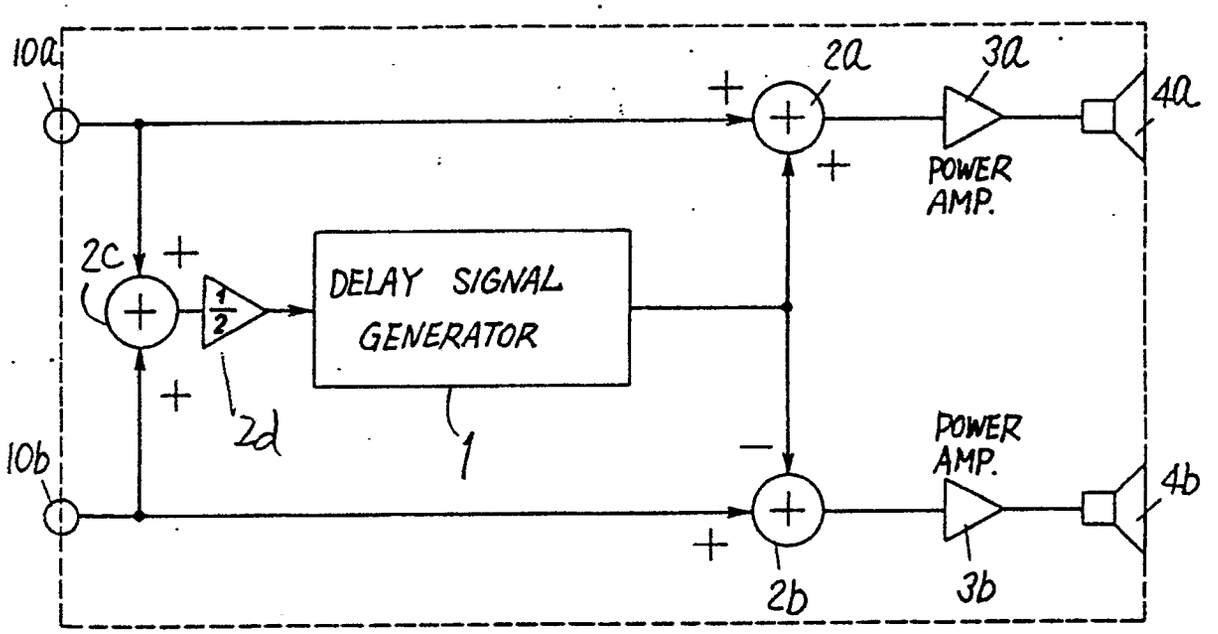

10a
10b
2a
2b
2c
2d
3a
3b
4a
4b
1/2
DELAY SIGNAL GENERATOR
POWER AMP.
POWER AMP.
1
+
+
+
+
+
−

FIG. 6

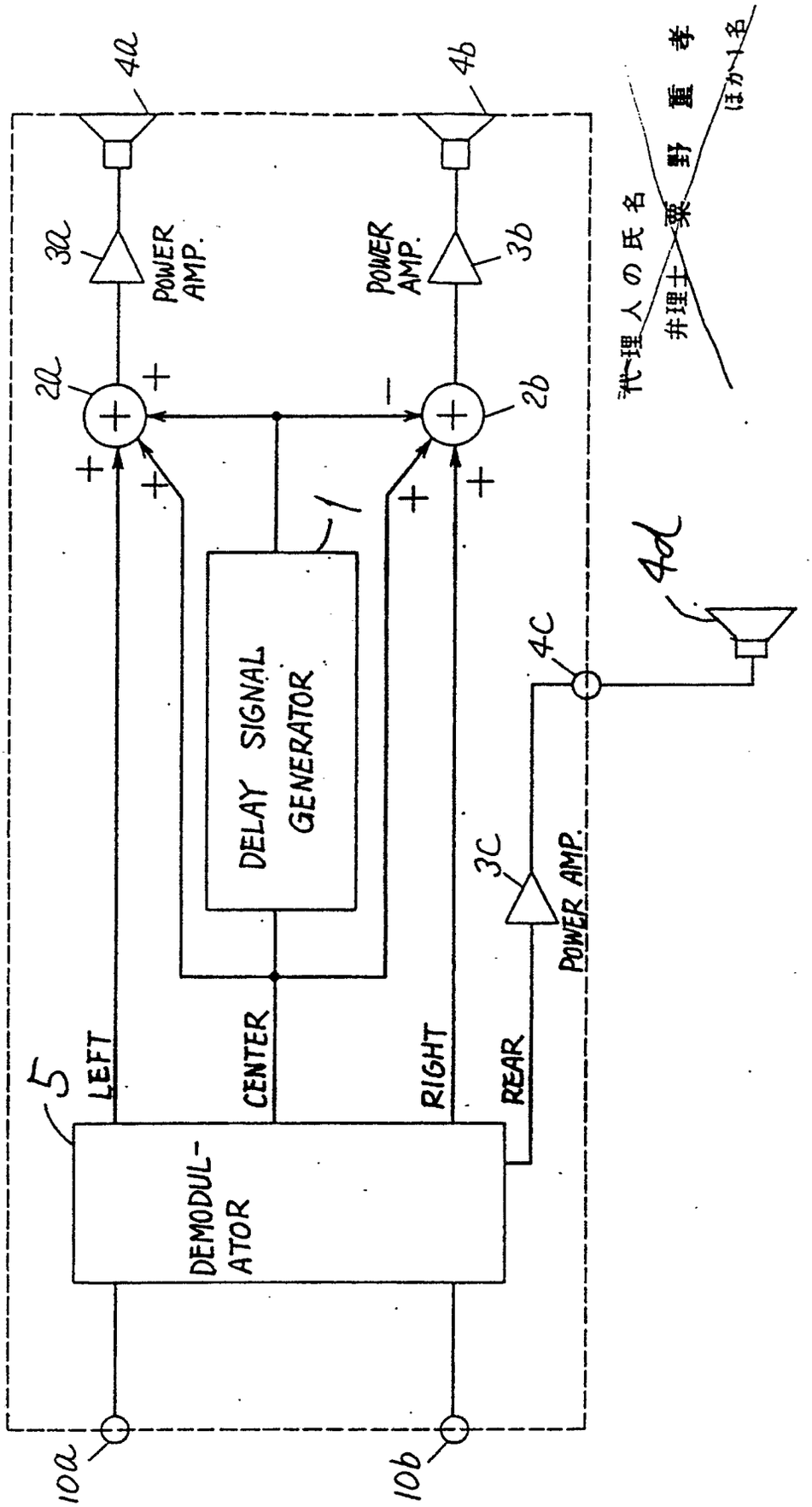

4a
4b
3a
POWER AMP.
3b
POWER AMP.
2a
2b
1
DELAY SIGNAL GENERATOR
4d
4c
3C
POWER AMP.
5
LEFT
CENTER
RIGHT
REAR
DEMODUL-ATOR
10a
10b
代理人の氏名
弁理士 栗野 重孝
ほか1名

FIG. 7

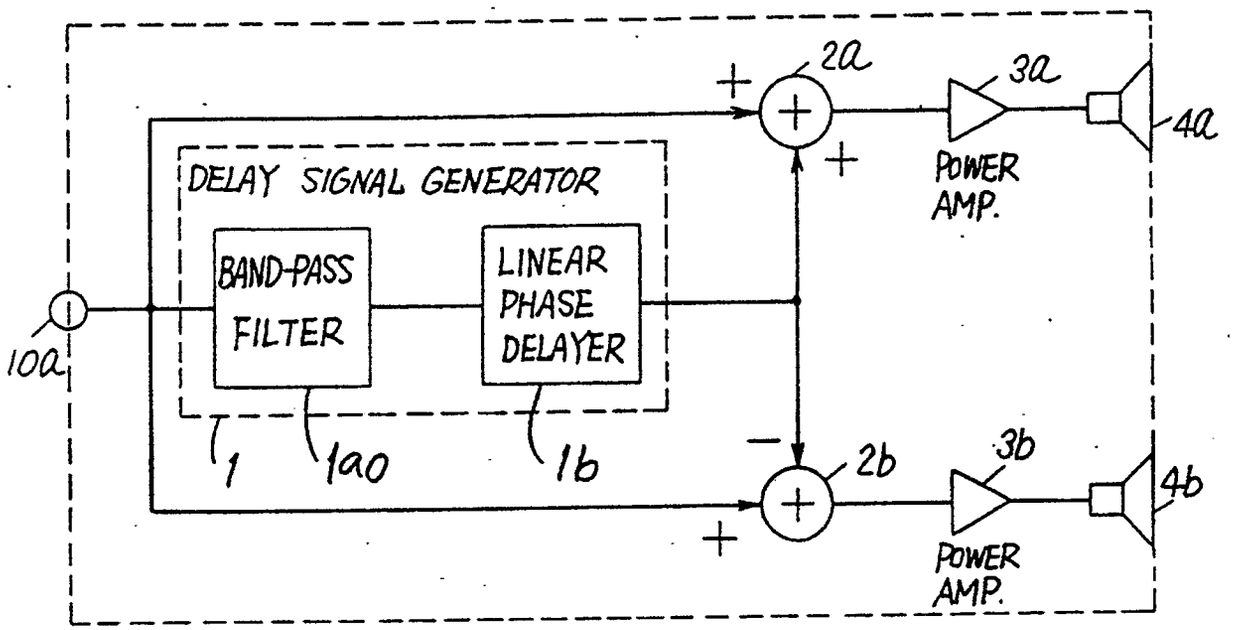

DELAY SIGNAL GENERATOR
BAND-PASS FILTER
LINEAR PHASE DELAYER
POWER AMP.
POWER AMP.
10a
1
1a0
1b
2a
2b
3a
3b
4a
4b
+
+
+
−

FIG. 8

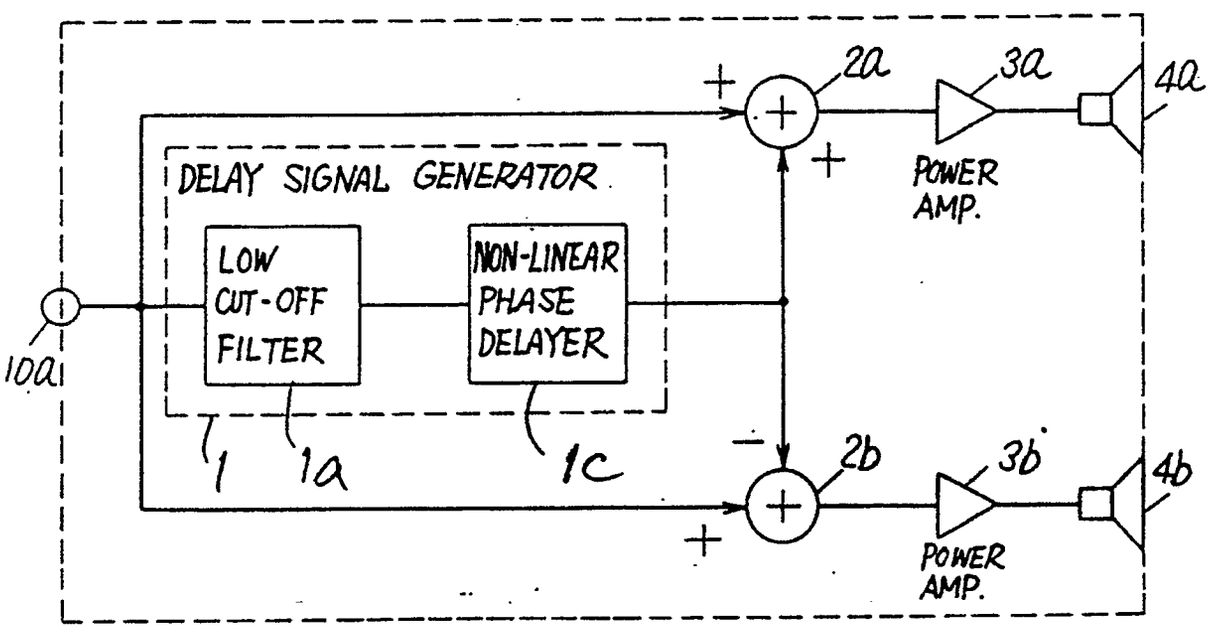

DELAY SIGNAL GENERATOR
LOW CUT-OFF FILTER
NON-LINEAR PHASE DELAYER
10a
1
1a
1c
2a
2b
3a
3b
4a
4b
POWER AMP.
POWER AMP.
+
+
+
−

FIG. 9

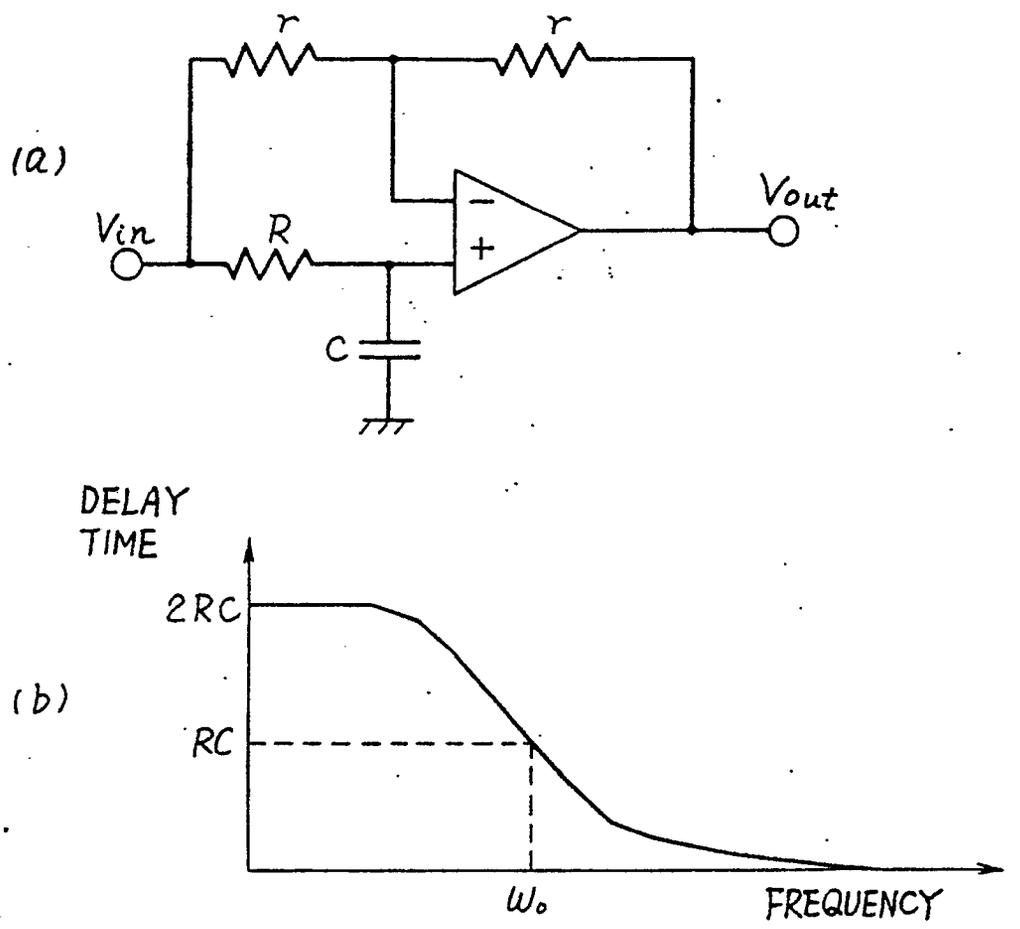


FIG.10

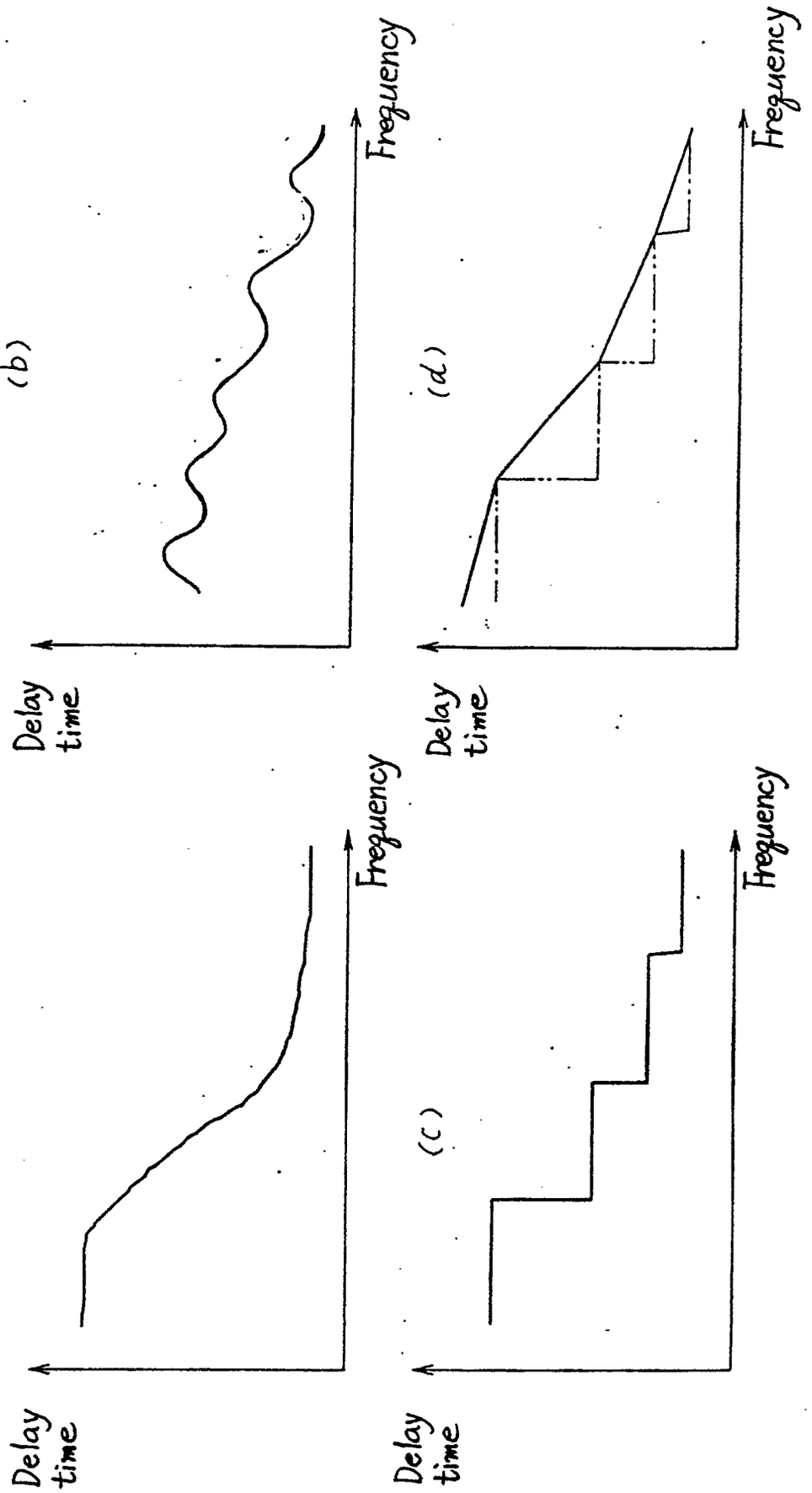

(a)
Delay time
Frequency
(b)
Delay time
Frequency
(c)
Delay time
Frequency
(d)
Delay time
Frequency

FIG.11

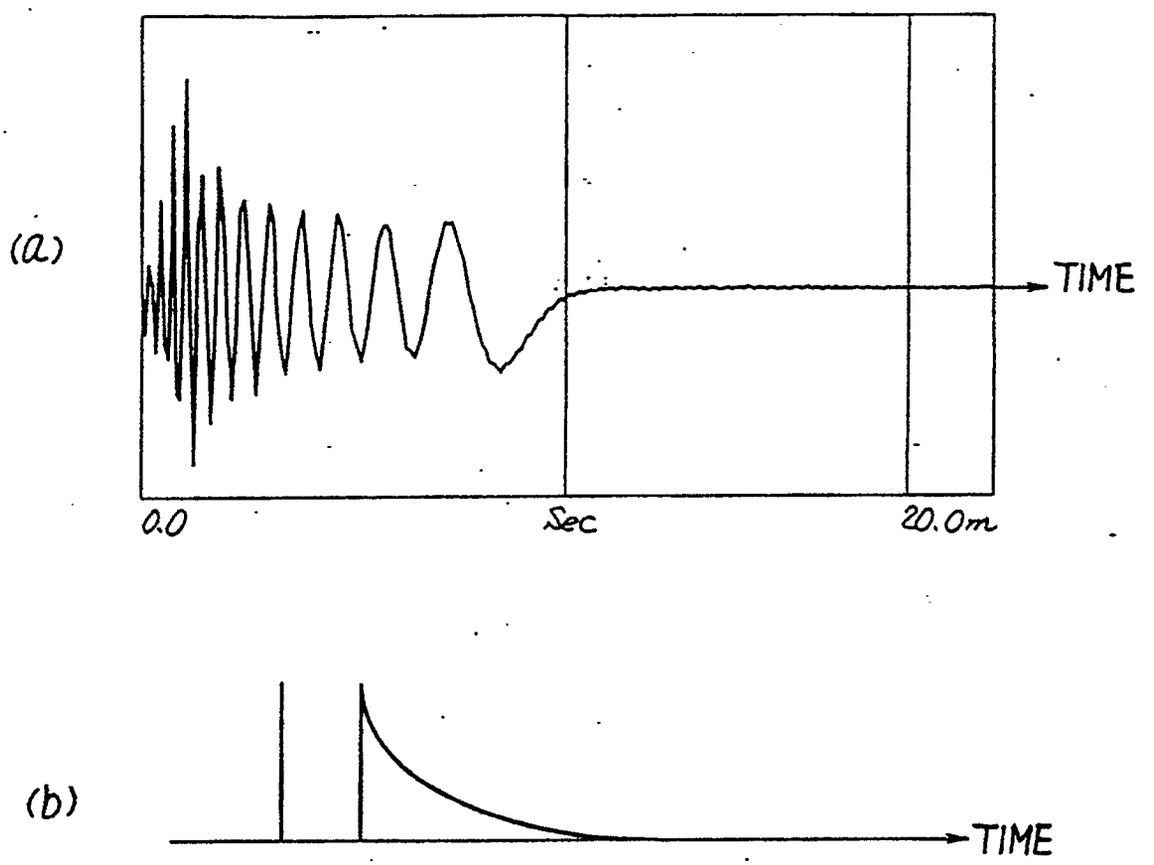


FIG.12

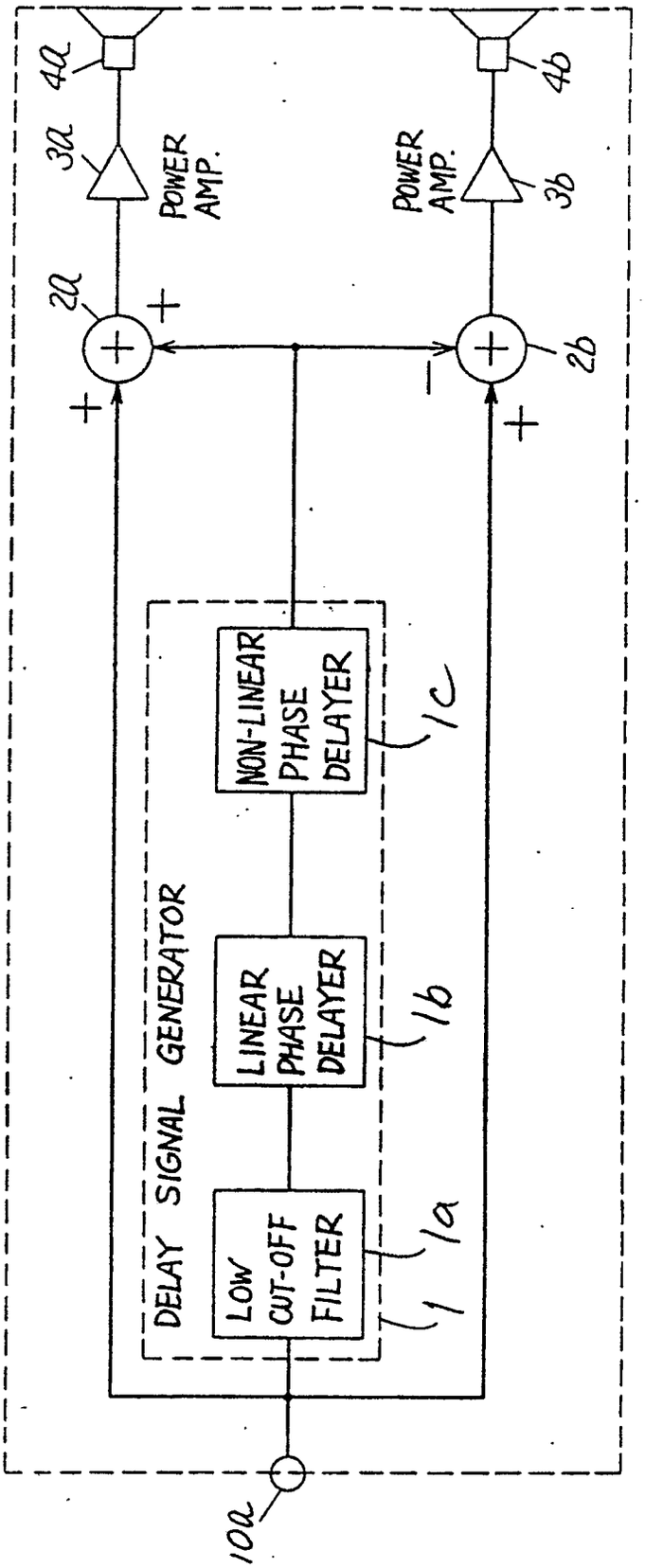

4a
4b
3a
POWER AMP.
3b
POWER AMP.
2a
2b
+
+
+
−
+
DELAY SIGNAL GENERATOR
NON-LINEAR PHASE DELAYER
1c
LINEAR PHASE DELAYER
1b
LOW CUT-OFF FILTER
1a
1
10a

FIG.13

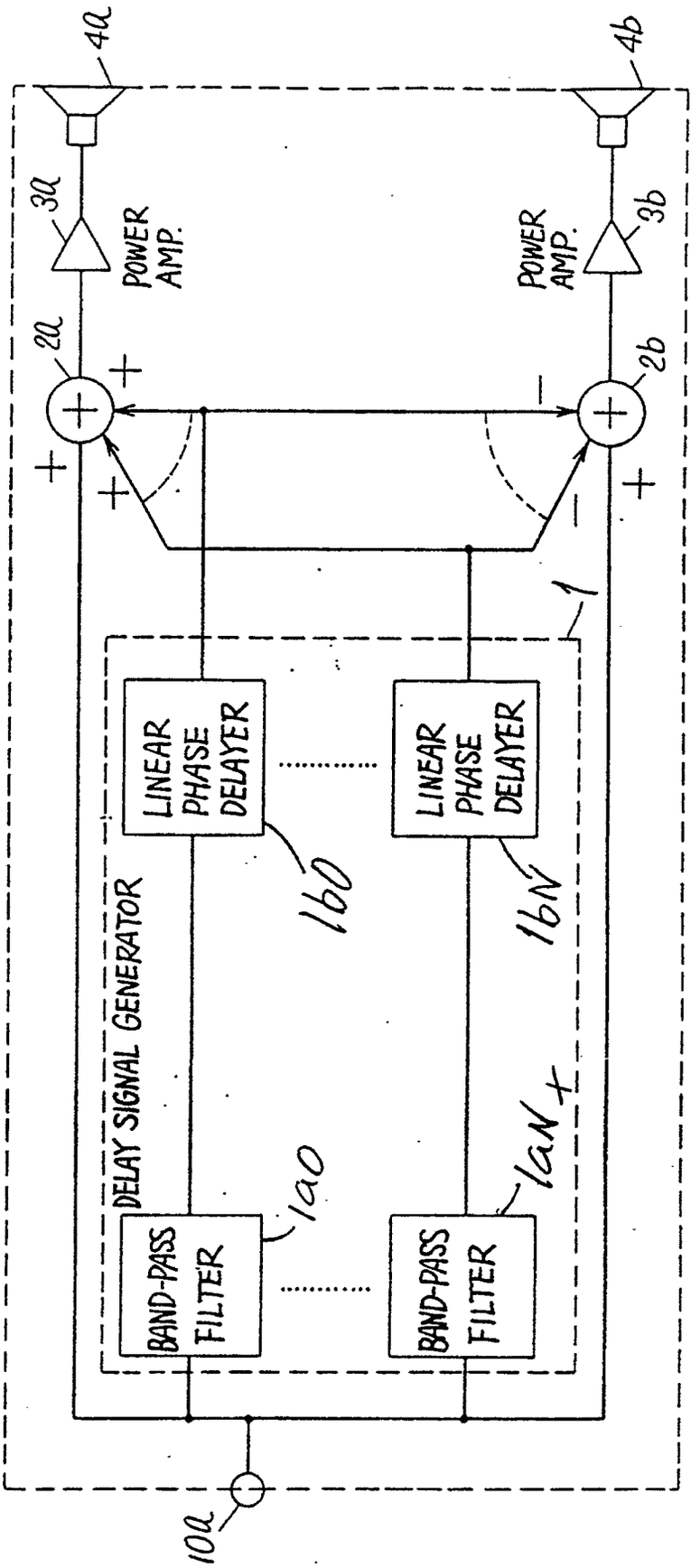

4a
4b
3a
POWER AMP.
3b
POWER AMP.
2a
2b
+
+
+
+
−
−
+
1
DELAY SIGNAL GENERATOR
LINEAR PHASE DELAYER
LINEAR PHASE DELAYER
16O
16N
BAND-PASS FILTER
BAND-PASS FILTER
14O
14N
10a

FIG.14

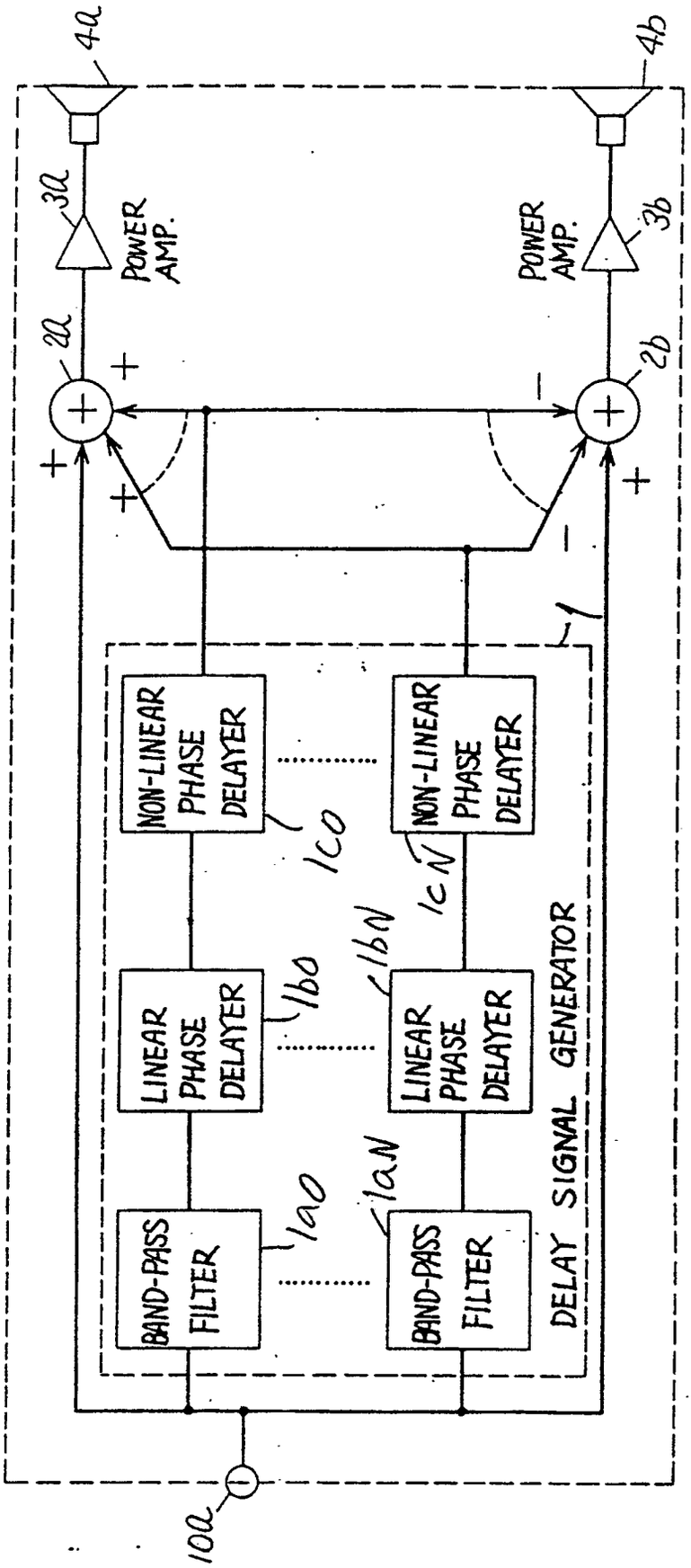

4a
4b
3a
POWER AMP.
3b
POWER AMP.
2a
2b
+
+
+
+
−
−
+
1
NON-LINEAR PHASE DELAYER
NON-LINEAR PHASE DELAYER
LINEAR PHASE DELAYER
LINEAR PHASE DELAYER
BAND-PASS FILTER
BAND-PASS FILTER
DELAY SIGNAL GENERATOR
10a

FIG.15

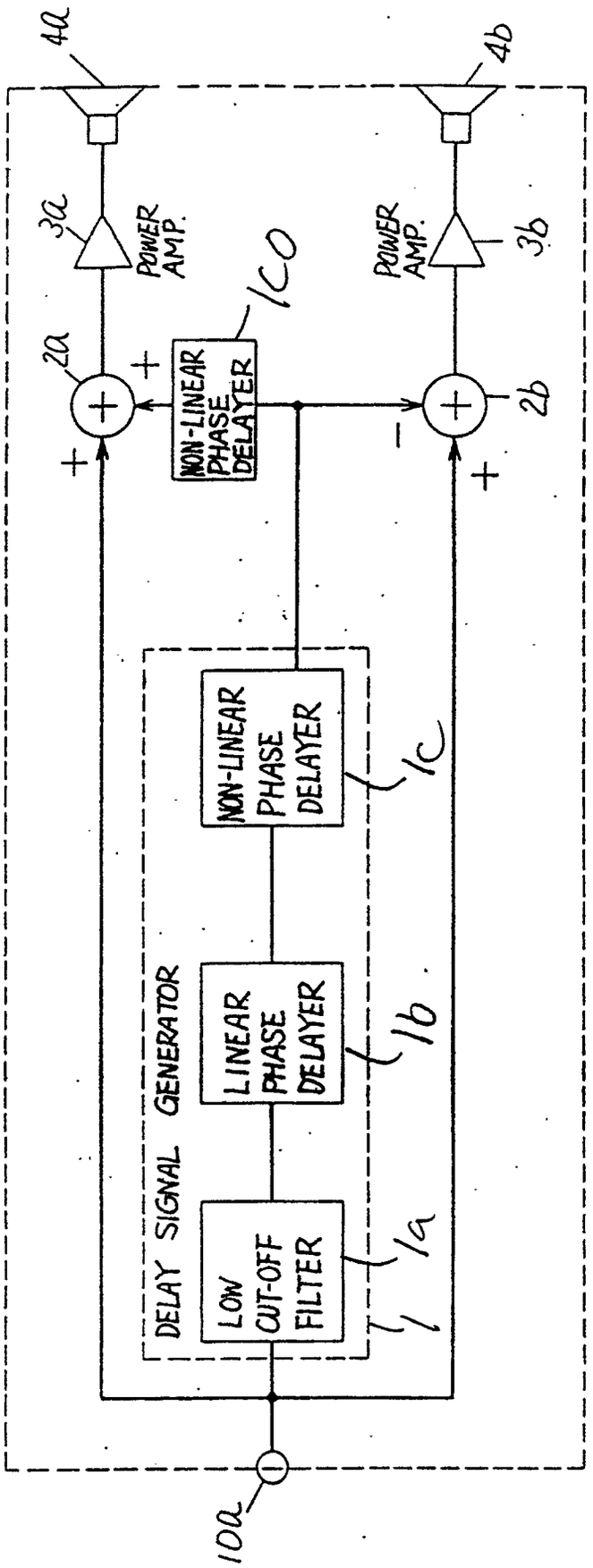

4a
4b
3a
POWER AMP.
POWER AMP.
3b
10
2a
2b
NON-LINEAR PHASE DELAYER
DELAY SIGNAL GENERATOR
NON-LINEAR PHASE DELAYER
LINEAR PHASE DELAYER
LOW CUT-OFF FILTER
1c
1b
1a
1
10a

FIG.16

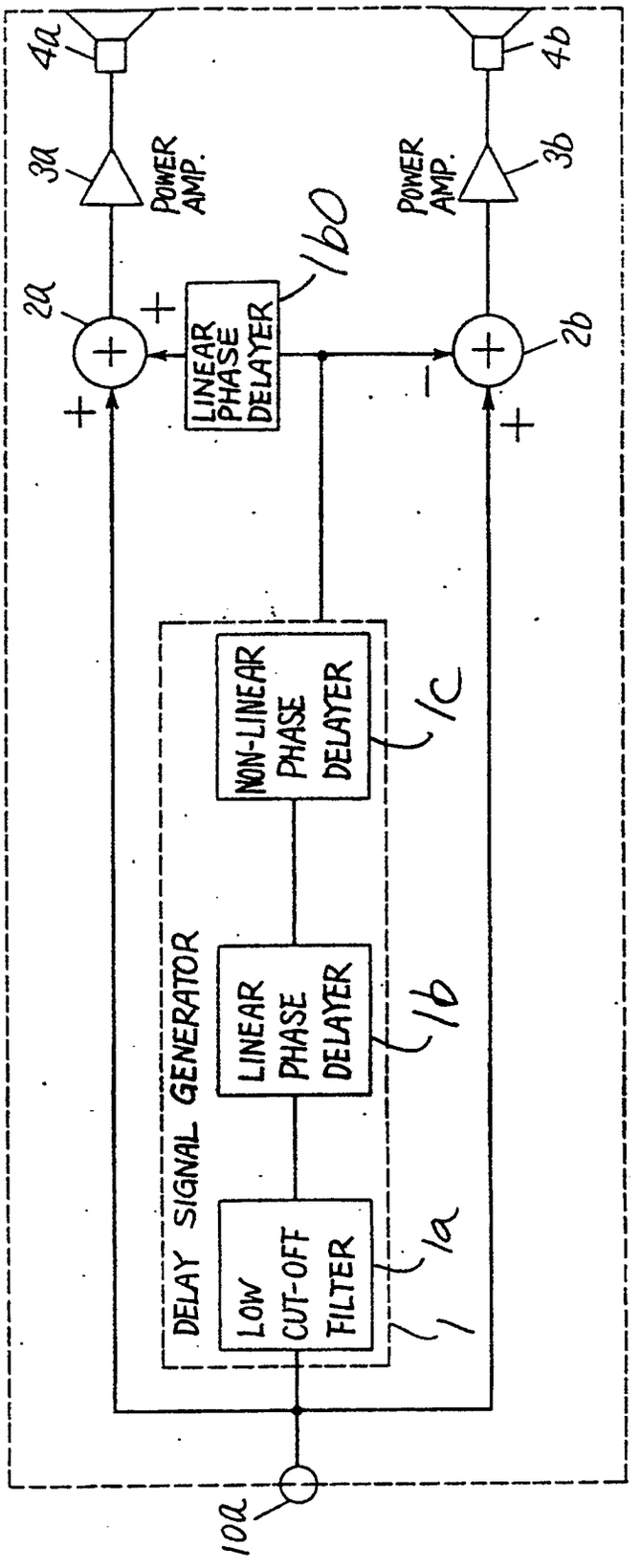
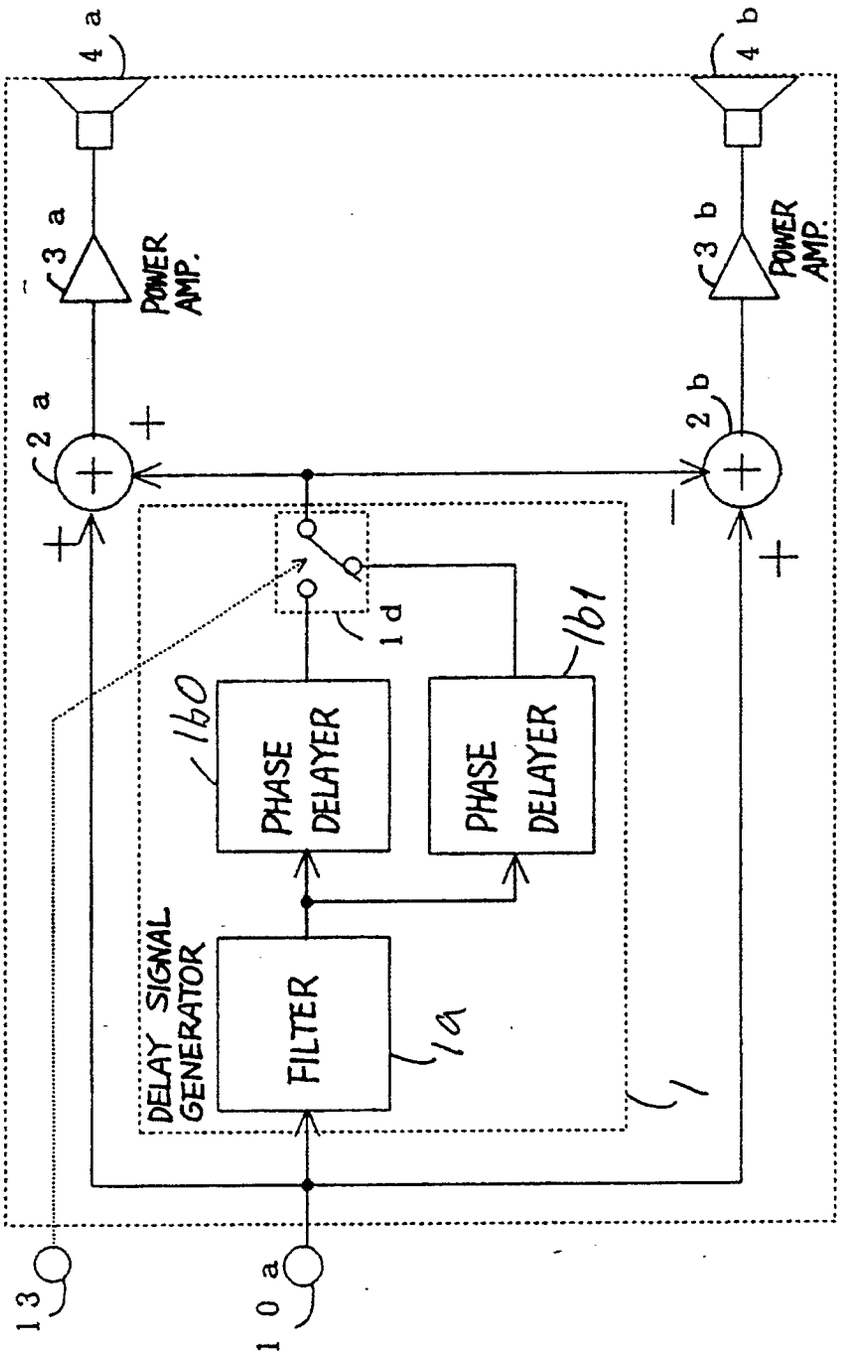

4a
4b
3a
POWER AMP.
3b
POWER AMP.
2a
+
+
+
LINEAR PHASE DELAYER
16
−
2b
+
DELAY SIGNAL GENERATOR
NON-LINEAR PHASE DELAYER
1c
LINEAR PHASE DELAYER
1b
LOW CUT-OFF FILTER
1a
1
10a

FIG.17


4 a
4 b
3 a
POWER AMP.
3 b
POWER AMP.
2 a
2 b
+
+
−
+
1 d
160
PHASE DELAYER
161
PHASE DELAYER
DELAY SIGNAL GENERATOR
FILTER
1a
1
13
10 a