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(54) **Title**: DYNAMIC CONTOURED-SOUND/SUBWOOFER-SYNTHESIS AUDIO SYSTEM

(57) **Abstract**: A dynamic contoured-sound/subwoofer-synthesis system including an adjustable high pass filter coupled to the input terminal, the high pass filter being designed to provide a variety of frequency response shapes in response to adjustments thereof. A primary amplifier is coupled to receive one of the variety of frequency response shapes from the adjustable high pass filter and includes a main operational amplifier (op-amp) with the inverting input coupled to the adjustable high pass filter through a series connected input capacitor and input resistor. The primary amplifier provides low frequency signal gain and shaping of the received frequency response shape. A high frequency signal shaping circuit includes a feedback op-amp coupled to the inverting input of the main op-amp through a feedback resistor and a feedback capacitor.

DYNAMIC CONTOURED-SOUND/SUBWOOFER-SYNTHESIS AUDIO SYSTEM

Field of the Invention

This invention generally relates to analog signal conditioning in audio systems.

Background of the Invention

Research has shown that the response of the human ear is very dependent on the frequency content of the sound. The ear has peak response around 2,000 Hz to 4,000 Hz and significantly less response at lower and higher frequencies. In other words, a sound with a frequency between 2,000 Hz and 4,000 Hz will be perceived as louder to the ear than sounds below and above this range. Additionally, the ear’s ability to perceive low and high frequencies varies with sound intensity (i.e., volume) level. This explains why soft music seems to sound less rich than music played at higher volume. Turning to FIG. 1, each curve represents a different volume level from a sound source, such as a stereo system. Curves on the bottom represent quieter volume levels and curves on the top represent louder volume levels. By examining these curves it will be observed that the quieter a volume level the greater the difference in sound intensity level (sound energy) required for the ear to hear low and high frequencies. Thus, it is desirable for a sound system to compensate for the natural inadequacies of the ear.

Furthermore, the ability of a typical speaker to reproduce sound diminishes (rolls-off) at low and high frequencies resulting in a reduction of sound content conveyed to the ear. A significant reduction of sound intensity occurs as the signal frequency decreases from 700 Hz down to 20 Hz and again as the frequency increases from 4,000 Hz to 20,000 Hz. See for example the typical speaker frequency response illustrated graphically in FIG. 2. This roll-off results in diminished loudness and thus audibility as perceived by the human ear.

One method/apparatus of solving the low frequency problem in the prior art, is to provide a subwoofer system. Subwoofer systems, specifically designed to accentuate lower frequencies, are incorporated with standard stereo systems to compensate for the low frequency roll-off. A major problem is that commonly obtainable audio subwoofer systems for reproducing low frequency sound are constructed in such an embodiment that their form is bulky and therefore cannot be easily transported for personal use, for example with an MP3 player when walking or exercising. Additionally, commercially obtainable subwoofer systems consume sizeable electrical current, require ventilation for heat removal, can be complex and difficult to connect and operate, are costly to obtain, present a potential for electrical shock when exposed in damp or wet environments, and as a result are not able to be proliferated widely or easily.

To date, audio engineers have been unable to produce extreme low frequency sound (i.e., in the subwoofer range) from all speaker and earpiece types of sound devices. In fact, it is commonly believed by audio engineers that it is physically impossible to produce extreme low frequency sound with small speakers and other audio sound devices.

It would be highly advantageous, therefore, to remedy the foregoing and other deficiencies inherent in the prior art.

Accordingly, it is an object of the present invention to provide a new and improved subwoofer sound synthesizer.

It is a further object of the present invention to provide a new and improved dynamic contoured sound system that substantially compensates for the natural inadequacy of the human ear at either or both the low frequencies and the high frequencies.

It is a further object of the present invention to provide a new and improved dynamic contoured sound system that substantially compensates for the roll-off effects of standard speakers and other sound producing devices.

It is a further object of the present invention to provide a new and improved subwoofer sound synthesizer that is capable of being used with substantially any sound producing devices, including speakers, small speakers, earpieces, hearing aids, etc.

Summary of the Invention

Briefly, to achieve the desired objects of the instant invention in accordance with a preferred embodiment thereof, provided is a dynamic contoured-sound/subwoofer-synthesis system including an adjustable high pass filter coupled to the input terminal of the system and an adjustable feedback amplifier coupled to the primary amplifier. The high pass filter is designed to provide a variety of frequency response shapes in response to adjustments of an adjustable component. A primary amplifier is coupled to receive a frequency response shape of the variety of frequency response shapes from the adjustable high pass filter. The primary amplifier includes a plurality of feedback components designed and connected to produce low and high frequency signal gain and shaping. The primary amplifier provides low and high frequency signal gain and shaping of the received frequency response shape to the output terminal.

The desired objects of the instant invention are further realized in accordance with another embodiment thereof, in which a dynamic contoured-sound/subwoofer-synthesis system includes an input terminal designed to receive an audio signal and an output terminal designed to supply an output signal to an external load. An adjustable high pass filter is coupled to the input terminal and includes an adjustable component. The high pass filter is designed to provide a variety of frequency response shapes in response to adjustments of the adjustable component. A primary amplifier is coupled to receive a frequency response shape of the variety of frequency response shapes from the adjustable high pass filter. The primary amplifier includes a main operational amplifier having an inverting input, a non-inverting input, and a signal output. The inverting input is coupled to the adjustable high pass filter through a series connected input capacitor and input resistor to receive the frequency response shape of the variety of frequency response shapes. The primary amplifier further includes a first feedback resistor coupled between the signal output of the main operational amplifier and the inverting input. The primary amplifier provides low and high frequency signal gain and shaping of the received frequency response shape to the output terminal. A high frequency signal shaping circuit includes a feedback operational amplifier having an inverting input, a non-inverting input, and a signal output. The high frequency signal shaping circuit further includes a second feedback resistor and a feedback capacitor with the feedback operational amplifier coupled to the inverting input of the main operational amplifier through the second feedback resistor and the feedback capacitor. The inverting input of the feedback operational amplifier is coupled to the signal output of the main operational amplifier through a first differential gain resistor, and the non-inverting input of the feedback operational amplifier is coupled to the signal output of the main operational amplifier through a second differential gain resistor with a resistance value different than a resistance value of the first differential gain resistor. A capacitor, resistor, and adjustable component, coupled with the non-inverting input of the feedback operational amplifier and output of the second differential gain resistor forms an adjustable simulated inductor.

The desired objects of the instant invention are further realized in accordance with a method of contouring sound and synthesizing subwoofer sound in a sound producing device including the step of providing an adjustable high pass filter having a plurality of step settings and constructed with each setting having a different frequency of emphasis and the frequency of emphasis for each setting occurring at a lower frequency than a prior setting and each setting having a different magnitude of gain change, for each setting the magnitude of gain change is greater than a prior setting. The method further includes the step of applying audio signals to the adjustable high pass filter for controlling the amount of subwoofer synthesis of the audio signals, each step setting providing a different frequency response shape, and selecting a step setting of the high pass filter to provide a preferred frequency response shape of the different frequency response shapes. The method further includes the step of receiving the preferred frequency response shape of the different frequency response shapes from the adjustable high pass filter and amplifying the preferred frequency response shape to provide low frequency signal gain and shaping of the preferred frequency response shape.

The desired objects of the instant invention are further realized in accordance with a method of contouring sound in a sound producing device including the step of providing an adjustable simulated inductor having a plurality of step settings and constructed with each setting having a different frequency of emphasis and the frequency of emphasis for each setting occurring at a higher frequency than a prior setting and each setting having a different magnitude of gain change, for each setting the magnitude of gain change is greater than a prior setting. The method further includes the step of applying audio signals from the output of the primary amplifier to the adjustable simulated inductor for controlling the amount of high frequency contoured sound of the audio signals, each step setting providing a different frequency response shape, and selecting a step setting of the simulated inductor to provide a preferred frequency response shape of the different frequency response shapes. The method further includes the step of receiving the preferred frequency response shape of the different frequency response shapes from the output of the primary amplifier and amplifying the preferred frequency response shape to provide high frequency signal gain and shaping of the preferred frequency response shape.

The method thereby controls the amount of contoured sound, subwoofer synthesis, and high frequency signal shaping that substantially compensates for the roll-off effects of sound producing devices at low audio frequencies and at high audio frequencies. Furthermore, the method counterbalances the natural inadequacies of the human ear and significantly compensates the ear's ability to perceive low and high frequency sounds.

Brief Description of the Drawings

The foregoing and further and more specific objects and advantages of the instant invention will become readily apparent to those skilled in the art from the following detailed description of a preferred embodiment thereof taken in conjunction with the drawings, in which:

FIG. 1 is a graphical representation of the natural response of the human ear, each curve in the graph representing a different volume level from a sound source such as a stereo system;

FIG. 2 is a graphical representation of the frequency response of a typical speaker;

FIG. 3 is a schematic representation of one embodiment of a dynamic contoured-sound/subwoofer-synthesis sound system in accordance with the present invention;

FIG. 4 is a graphical representation of audio signal shaping produced by the circuitry of FIG. 3;

FIG. 5 is a graphical representation of the audio signal shaping illustrating the frequency of emphasis and magnitude of gain change by controller settings;

FIG. 6 is a schematic representation similar to FIG. 3 illustrating functional sections of the circuitry;

FIG. 7 is a breakaway view of section A of the circuitry illustrated in FIG. 6;

FIG. 8 is a graphical representation of the low frequency response of the circuitry of FIG. 6, illustrating the adjustability and response provided by section A;

FIG. 9 is a graphical representation of the low frequency response of the circuitry of FIG. 6, without section A;

FIG. 10 is a breakaway view of section B of the circuitry illustrated in FIG. 6;

FIG. 11 is a breakaway view of section C of the circuitry illustrated in FIG. 6;

FIG. 12 is a graphical representation of the high frequency response of the circuitry of FIG. 6, substantially as produced by the operational amplifiers;

FIG. 13 is a graphical representation of the high frequency response of the circuitry of FIG. 6, substantially as produced by the various coupling components;

FIG. 14 is a breakaway view of section D of the circuitry illustrated in FIG. 6;

FIG. 15 is a graphical representation of the high frequency response of the circuitry of FIG. 6, illustrating the adjustability and response provided by section D; and

FIGS. 16 and 17 are views in top plan and side elevation, respectively, of the sound system, illustrating the approximate size thereof.

Detailed Description of a Preferred Embodiment

Turning now to FIG. 3, a schematic representation is illustrated of one embodiment of a dynamic contoured-sound/subwoofer-synthesis sound system, designated 20, in accordance with the present invention. Sound system 20 includes passive and active electronic components formulated and configured to filter input signal frequency and contour output signal magnitude in calculated proportion with frequency characteristics of the input signal. As will be understood from the description below, sound system 20 further includes circuitry providing adjustable filtering of the input signal frequencies and thus the signal content acted upon by the contouring stage resulting in the desired contoured-sound/subwoofer-synthesis characteristics. It should be noted that FIG. 3 is a single channel representation only and in application sound system 20 would be duplicated for each independent signal channel (e.g. two channels for stereo application).

Referring additionally to FIG. 4, exemplary modulation contours are illustrated extending from below 100 Hz on the left side to above 10,000 Hz on the right side. While approximately 12 contours are illustrated for this example, the specific embodiment of sound system 20 is constructed to provide 32 unique low frequency shapes or contours and 32 independent high frequency shapes or contours, resulting in a total of 1024 (32^2) unique controller response shapes. It will of course be understood that 32 shapes is simply for purposes of explanation and more or less low frequency and high frequency contours can be provided if desired.

Referring additionally to FIG. 5, it can be seen that each contour or controller setting, has a different frequency of emphasis, i.e. for each succeeding contour or shape (beginning with the lower shape and proceeding upward) the frequency of emphasis, or highest amplitude, occurs at a little lower frequency. Also, it can be seen that each contour or controller setting, has a different magnitude of gain change, i.e. for each succeeding contour or shape (beginning with the lower shape and proceeding upward) the magnitude of gain change is slightly greater. This is true for both the unique low frequency shapes or contours and the independent high frequency shapes or contours. It should also be noted that the low frequency contours have a much greater effect on the overall response and are a primary subject of the present invention. While high frequencies are affected by both the human ear and speakers, as illustrated in FIGS. 1 and 2, the effect is less and therefore the high frequency shapes or contours illustrated in FIG. 5 may be implemented in a sound system or may be optionally left out if desired.

Turning now to FIG. 6, sound system 20 as illustrated is partitioned into sections A through D, each of which will be taken up in order. It will of course be understood that each section influences each of the other sections but for purposes of understanding the overall operation or function of the sections will be discussed individually. Also, throughout this disclosure it should be understood that components referred to as 'a resistor' or 'a capacitor' include any component or components combining to form a resistance or a capacitance, respectively, such as a plurality of interconnected resistors or a plurality of interconnected capacitors and any other devices providing an equivalent impedance.

Referring specifically to FIG. 7, the schematic representation of section A is illustrated. Section A includes an audio signal input device, designated V2, connected between a common (in this instance ground) and one end of an isolation/divider resistor R7. The opposite end of resistor R7 is connected to one side of a filter input capacitor C5. The opposite side of capacitor C5 represents the output of section A and is also connected to one end of a 32 step digital potentiometer A1. The adjustable tap of potentiometer A1 is also connected to the output side of capacitor C1 and the opposite side is connected through an isolation/divider/filter resistor R10 to the common or ground. Resistor R7 creates a voltage divider with potentiometer A1 and resistor R10. Capacitor C5, potentiometer A1, and resistor R10 form a high pass filter.

Section A is a high pass filter configuration responsible for controlling the amplitude of audio signals passed-thru to the primary amplifier (section B). By changing the value setting of digital potentiometer A1, a variety of frequency response shapes are obtained, as illustrated in FIG. 8. Without section A, the low frequency response of sound system 20 would appear as shown in FIG. 9.

Referring specifically to FIG. 10, the schematic representation of section B is illustrated. Section B includes an input capacitor C1, the input side of which is connected to receive the output signals from section A. The opposite side of capacitor C1 is connected to one side of an input resistor R1. The opposite side of resistor R1 is connected to the inverting input of an operational amplifier X2. The positive or non-inverting input of operational amplifier X2 is connected to an amplifier bias supply V3. Power is provided to the positive terminal of operational amplifier X2 by a DC voltage supply V1 and the negative terminal is connected to the common or ground. It will be understood that bias supply V3 and DC voltage supply V1 (along with other bias supplies included herein) may be simply batteries or might be connections through a voltage divider network to a common supply source, as will be understood by those skilled in the art. The output of operational amplifier X2 is the signal output of section B.

Section B is the primary amplifier including feedback components producing low frequency signal gain and shaping. The feedback components include a feedback resistor R4 an input end of which receives a signal from the output of operational amplifier X2 (see FIG. 6) and series connected feedback capacitor C3 and feedback resistor R3. The input end of resistor R3 is connected to an output of section C and the output ends of resistor R4 and capacitor C3 are connected to the inverting input of operational amplifier X2. Capacitor C1 and resistor R1 form a band pass filter that sets the bandwidth of frequencies passed to operational amplifier X2. Resistors R1, R3, R4 and capacitor C3 form a high pass filter that sets the voltage gain of operational amplifier X2. Capacitor C3 reacts in proportion to signal frequency and dynamically changes the combined impedance of components forming the voltage feedback loop. The circuit included in section B, by itself, produces the signal shape illustrated in FIG. 9.

Referring specifically to FIG. 11, the schematic representation of section C is illustrated. Section C includes an operational amplifier X1 the inverting input of which has an output terminal of a differential gain resistor R5 connected thereto and the non-inverting or positive input of which has an output terminal of a second differential gain resistor R6 connected thereto. The input ends of resistors R5 and R6 are connected to the output of operational amplifier X2 (see FIG. 6). The input side of a differential gain capacitor C4 is connected to the non-inverting or positive input of operational amplifier X1 and the output end is connected to the input of section D. Power is provided to the positive terminal of operational amplifier X1 by a DC voltage supply V4 and the negative terminal is connected to the common or ground. The output of operational amplifier X1 is connected directly to the inverting input thereof and is also connected through a high frequency shaping capacitor C6 to the junction of series connected capacitor C3 and resistor R3 in section B.

Section C is a feedback servo amplifier, further simulating the electrical characteristics of an inductor, that produces high frequency signal shaping. The impedance of capacitor C4 changes in proportion to the applied signal frequency from the output of operational amplifier X2. Resistor R6 and capacitor C4 form a dynamic voltage divider at the non-inverting input of operational amplifier X1. Operational amplifier X1 changes the output voltage thereof in proportion to the difference voltage between the inverting and non-inverting inputs thereof. The output voltage from operational amplifier X1 is applied to the inverting input of operational amplifier X2 to produce the frequency response shape illustrated in FIG. 12. The impedance of capacitor C6 changes in proportion to the applied frequency from the output of operational amplifier X1. Combined in parallel with resistor R3 of section B, capacitor C6 dynamically adjusts the feedback impedance of operational amplifier X2 shaping/limiting the high frequency gain. Basically, the inputs of operational amplifier X1 are connected to maintain operation at a mid point between upper and lower limits to ensure that no clipping and the consequent sound aberrations occurs. The effect of this high frequency shaping/limiting is illustrated in FIG. 13.

Referring specifically to FIG. 14, the schematic representation of section D is illustrated. Section D includes a 32 step digital potentiometer A2 and an isolation/voltage divider resistor R11 connected in series between common or ground and the output side of capacitor C4 in section C. The variable tap of potentiometer A2 is connected to the input end thereof (i.e. the output side of capacitor C4). Basically, potentiometer A2 and resistor R11 are added to the dynamic voltage divider (i.e. capacitor C4 and resistor R6) of section C. Resistor R11 provides a fixed resistance to the dynamic side of the voltage divider and sets the attainable high frequency gain. Capacitor C4, potentiometer A2, and resistor R11 form an adjustable simulated inductor. The adjustable simulated inductor has a plurality of step settings and is constructed with each step setting having a different frequency of emphasis, the frequency of emphasis for each step setting occurring at a higher frequency than a prior step setting and each step setting having a different magnitude of gain change, for each step setting the magnitude of gain change is greater than a prior step setting. By changing the value setting of digital potentiometer A2, a variety of frequency response shapes are obtained, as illustrated in FIG. 15.

Referring again to FIG. 6, it can be seen that the output from operational amplifier X2 is supplied through a DC blocking capacitor C2 to an external load represented by a fixed resistor R2. As will be understood by those skilled in the art, the external load can be virtually any type of sound producing device including speakers, small speakers, earpieces, etc. or it can include subsequent amplifier stages. Operation occurs when a low voltage signal is applied at the input V2 of sound system 20. The subwoofer synthesis signal conditioning circuitry controls the filtering and contouring of the applied frequencies to provide intensified low frequency signal content and increase the corresponding output magnitude. In the preferred embodiment, high frequency signal shaping and conditioning circuitry is also included to control the filtering and contouring of the applied frequencies and provide intensified high frequency signal content and increase the corresponding output magnitude.

Turning to FIGS. 16 and 17, top plan and side elevation views, respectively, are illustrated of the preferred embodiment of sound system 20, illustrating the approximate physical size thereof. It will be understood that the sizes are strictly for example and different sizes and numbers of components will result in different sizes and shapes. In this example, the length (designated L) is approximately 1.65 inches, the width (designated W) is approximately 1.22 inches, and the height (designated H) is approximately 0.200 inches. The example is provided to indicate the relatively small size that can be achieved and further accentuates the difference between the present invention and prior art subwoofer systems.

Thus, a new and improved dynamic contoured-sound/subwoofer-synthesis system has been disclosed that substantially compensates for the natural inadequacy of the human ear at either or both the low frequencies and the high frequencies. The dynamic contoured-sound/subwoofer-synthesis system includes a new and improved subwoofer sound synthesizer and preferably includes high frequency signal shaping and conditioning circuitry that substantially compensates for the roll-off effects of standard speakers and other sound producing devices at the low end and at the high end. Further a new and improved dynamic contoured-sound/subwoofer-synthesis system has been disclosed that is capable of being used with substantially any sound producing devices, including speakers, small speakers, earpieces, etc. The dynamic contoured-sound/subwoofer-synthesis system produces extreme deep low frequency sound (i.e. subwoofer) from all speaker and earpiece types and does so without inducing noticeable sound aberrations or adversely affecting/diminishing higher frequency sounds. The dynamic contoured-sound/subwoofer-synthesis system replaces the need for a separate subwoofer speaker and associated amplification systems. Also, the dynamic contoured sound system tailors audio intensity to compensate for non-linearity of the human auditory system, producing a balanced frequency-loudness listening experience. Further, the preferred embodiment provides 1024 (or more) unique loudness compensation shapes or contours to match the hearing needs of various listeners and for non-ideal characteristics of sound reproduction systems.

Various changes and modifications to the embodiment herein chosen for purposes of illustration will readily occur to those skilled in the art. To the extent that such modifications and variations do not depart from the spirit of the invention, they are intended to be included within the scope of the invention which is assessed only by a fair interpretation of the following claims.

DYNAMIC CONTOURED-SOUND/SUBWOOFER-SYNTHESIS AUDIO SYSTEM

What is claimed is:

1. A dynamic contoured-sound/subwoofer-synthesis system comprising:

an input terminal designed to receive an audio signal and an output terminal designed to supply an output signal to an external load;

an adjustable high pass filter coupled to the input terminal and including an adjustable component, the high pass filter being designed to provide a variety of frequency response shapes in response to adjustments of the adjustable component; and

a primary amplifier coupled to receive a frequency response shape of the variety of frequency response shapes from the adjustable high pass filter, the primary amplifier including a plurality of feedback components designed and connected to produce low frequency signal gain and shaping, the primary amplifier providing low frequency signal gain and shaping of the received frequency response shape to the output terminal.

2. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 1 wherein the adjustable high pass filter includes an isolation resistor, a multi-step digital potentiometer, and a divider resistor connected to the input terminal to form a voltage divider, a junction between the isolation resistor and the multi-step digital potentiometer providing the variety of frequency response shapes.

3. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 2 wherein the adjustable high pass filter further includes a filter input capacitor, the filter input capacitor in circuit with the multi-step digital potentiometer and the divider resistor forming a high pass filter.

4. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 1 wherein the primary amplifier includes a main operational amplifier having an inverting input, a non-inverting input, and a signal output, the inverting input being coupled to the adjustable high pass filter through a series connected input capacitor and input resistor to receive the frequency response shape of the variety of frequency response shapes, the input capacitor and input resistor forming a band pass filter connected to set a bandwidth of frequencies passed from the adjustable high pass filter to the main operational amplifier.

5. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 4 wherein at least one feedback component of the plurality of feedback components of the primary amplifier includes a first feedback resistor coupled between the signal output and the inverting input of the main operational amplifier.

6. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 5 wherein the plurality of feedback components further includes a second feedback

resistor and a feedback capacitor, the input resistor, the first feedback resistor, the second feedback resistor, and the feedback capacitor being connected to form a high pass filter connected to set the voltage gain of the main operational amplifier.

7. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 4 further including a high frequency signal shaping circuit coupled between the signal output and the inverting input of the main operational amplifier.

8. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 7 wherein the plurality of feedback components further includes a second feedback resistor and a feedback capacitor and the high frequency signal shaping circuit is coupled to the inverting input of the main operational amplifier through the second feedback resistor and the feedback capacitor.

9. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 8 wherein the high frequency signal shaping circuit includes a feedback operational amplifier having an inverting input, a non-inverting input, and a signal output.

10. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 9 wherein the inverting input of the feedback operational amplifier is coupled to the signal output of the main operational amplifier through a first differential gain resistor, and the non-inverting input of the feedback operational amplifier is coupled to the signal output of the main operational amplifier through a second differential gain resistor with a resistance value different than a resistance value of the first differential gain resistor.

11. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 10 wherein the plurality of feedback components further includes a second feedback resistor and a feedback capacitor, the signal output of the feedback operational amplifier being coupled to the

inverting input of the main operational amplifier through a series connection of the second feedback resistor and a feedback capacitor.

12. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 11 further including a high frequency shaping capacitor coupled in parallel with the second feedback resistor.

13. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 12 further including a differential gain capacitor coupled to the non-inverting input of the feedback operational amplifier.

14. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 13 further including a multi step digital potentiometer and an isolation/divider resistor connected in series to the differential gain capacitor, the multi step digital potentiometer and the isolation/divider resistor being connected to provide a different high frequency response shape at the output

terminal in response to changes of steps in the multi step digital potentiometer.

15. A dynamic contoured-sound/subwoofer-synthesis system comprising:

an input terminal designed to receive an audio signal and an output terminal designed to supply an output signal to an external load;

an adjustable high pass filter coupled to the input terminal and including an isolation resistor, a multi-step digital potentiometer, and a divider resistor connected to the input terminal to form a voltage divider, the adjustable high pass filter further including a filter input capacitor coupled in circuit with the multi-step digital potentiometer and the divider resistor to form a high pass filter, the high pass filter being designed to provide a variety of frequency response shapes in response to adjustments of the adjustable component;

a primary amplifier coupled to receive a frequency response shape of the variety of frequency response shapes from the adjustable high pass filter, the primary amplifier including a main operational amplifier having an inverting input, a non-inverting input, and a signal output, the inverting input being coupled to the adjustable high pass filter through a series connected input capacitor and input resistor to receive the frequency response shape of the variety of frequency response shapes, the input capacitor and input resistor forming a band pass filter connected to set a bandwidth of frequencies passed from the adjustable high pass filter to the main operational amplifier; and

the primary amplifier further including a first feedback resistor coupled between the signal output and the inverting input of the main operational amplifier, and a second feedback resistor and a feedback capacitor, the input resistor, the first feedback resistor, the second feedback resistor, and the feedback capacitor being connected to form a high pass filter connected to set the voltage gain of the main operational amplifier.

16. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 15 further including a high frequency signal shaping circuit coupled between the signal output and the inverting input of the main operational amplifier.

17. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 16 further including a second feedback resistor and a feedback capacitor and the high frequency signal shaping circuit is coupled to the inverting input of the main operational amplifier through the second feedback resistor and the feedback capacitor.

18. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 17 wherein the high frequency signal shaping circuit includes a feedback operational amplifier having an inverting input, a non-inverting input, and a signal output.

19. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 18 wherein the inverting input of the feedback operational amplifier is coupled to the signal output of the main operational amplifier through a first differential gain resistor, and the non-inverting input of the feedback operational amplifier is coupled to the signal output of the main operational amplifier through a second differential gain resistor with a resistance value different than a resistance value of the first differential gain resistor.

20. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 19 wherein the plurality of feedback components further includes a second feedback resistor and a feedback capacitor, the signal output of the feedback operational amplifier being coupled to the inverting input of the main operational amplifier through a series connection of the second feedback resistor and the feedback capacitor.

21. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 20 further including a high

frequency shaping capacitor coupled in parallel with the second feedback resistor.

22. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 21 further including a differential gain capacitor coupled to the non-inverting input of the feedback operational amplifier.

23. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 22 further including a multi step digital potentiometer and an isolation/divider resistor connected in series to the differential gain capacitor, the multi step digital potentiometer and the isolation/divider resistor being connected to provide a different high frequency response shape at the output terminal in response to changes of steps in the multi step digital potentiometer.

24. A dynamic contoured-sound/subwoofer-synthesis system comprising:

an input terminal designed to receive an audio signal and an output terminal designed to supply an output signal to an external load;

an adjustable high pass filter coupled to the input terminal and including an adjustable component, the high pass filter being designed to provide a variety of frequency response shapes in response to adjustments of the adjustable component;

a primary amplifier coupled to receive a frequency response shape of the variety of frequency response shapes from the adjustable high pass filter, the primary amplifier including a main operational amplifier having an inverting input, a non-inverting input, and a signal output, the inverting input being coupled to the adjustable high pass filter through a series connected input capacitor and input resistor to receive the frequency response shape of the variety of frequency response shapes, the primary amplifier further including a first feedback resistor coupled between the signal output and the inverting input of the main operational amplifier, the primary amplifier providing low frequency signal gain and shaping of the received frequency response shape to the output terminal; and

a high frequency signal shaping circuit including a feedback operational amplifier having an inverting input, a non-inverting input, and a signal output, the high frequency signal shaping circuit including a second feedback resistor and a feedback capacitor, the signal output of the feedback operational amplifier being coupled to the inverting input of the main operational amplifier through the second feedback resistor and the feedback capacitor, the inverting input of the feedback operational amplifier being coupled to the signal output of the main operational amplifier through a first differential gain resistor, and the non-inverting input of the feedback operational amplifier being coupled to the signal output of the main operational amplifier through a second differential gain resistor with a resistance value different than a resistance value of the first differential gain resistor.

25. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 24 further including a high

frequency shaping capacitor coupled in parallel with the second feedback resistor.

26. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 25 further including a differential gain capacitor coupled to the non-inverting input of the feedback operational amplifier.

27. A dynamic contoured-sound/subwoofer-synthesis system as claimed in claim 26 further including a multi step digital potentiometer and an isolation/divider resistor connected in series to the differential gain capacitor, the multi step digital potentiometer and the isolation/divider resistor being connected to provide a different high frequency response shape at the output terminal in response to changes of steps in the multi step digital potentiometer.

28. A method of synthesizing subwoofer sound in a sound producing device comprising the steps of:

providing an adjustable high pass filter having a plurality of step settings and constructed with each setting having a different frequency of emphasis and the frequency of emphasis for each setting occurring at a lower frequency than a prior setting, and each setting having a different magnitude of gain change, for each setting the magnitude of gain change is greater than a prior setting;

applying audio signals to the adjustable high pass filter for controlling the amount of subwoofer synthesis of the audio signals, each step setting providing a different frequency response shape, and selecting a step setting of the high pass filter to provide a preferred frequency response shape of the different frequency response shapes; and

receiving the preferred frequency response shape of the different frequency response shapes from the adjustable high pass filter and amplifying the preferred frequency response shape to provide low frequency signal gain and shaping of the preferred frequency response shape.

29. A method as claimed in claim 28 including the steps of high frequency signal shaping the preferred frequency response shape during the amplifying step to compensate for non-linearity of the human auditory system at both the auditory low frequencies and high frequencies.

30. A method as claimed in claim 28 including the steps of high frequency signal shaping the preferred frequency response shape during the amplifying step to provide adjustable contouring of the input signal frequency characteristics and the amount of low frequency signal content, thereby controlling the amount of subwoofer synthesis and high frequency signal shaping that substantially compensates for the roll-off effects of sound producing devices at low audio frequencies and at high audio frequencies.

31. A method of contouring sound in a sound producing device comprising the steps of:

providing a primary amplifier;

providing an adjustable simulated inductor having a plurality of step settings and constructed with each step setting of the plurality of step settings having a different frequency of emphasis and the frequency of emphasis for each step setting occurring at a higher frequency than a prior step setting and each step setting having a different magnitude of gain change, for each step setting the magnitude of gain change is greater than a prior step setting;

applying audio signals from the output of the primary amplifier to the adjustable simulated inductor for controlling the amount of high frequency contoured sound of the audio signals, each step setting of the plurality of step settings providing a different frequency response shape; and

selecting a step setting of the simulated inductor to provide a preferred frequency response shape of the different frequency response shapes.

32. A method as claimed in claim 31 further including a step of receiving the preferred frequency response shape of the different frequency response shapes, amplifying the preferred frequency response shape, and applying the amplified preferred frequency response shape to an input of the primary amplifier to provide high frequency signal gain and shaping of the preferred frequency response shape.

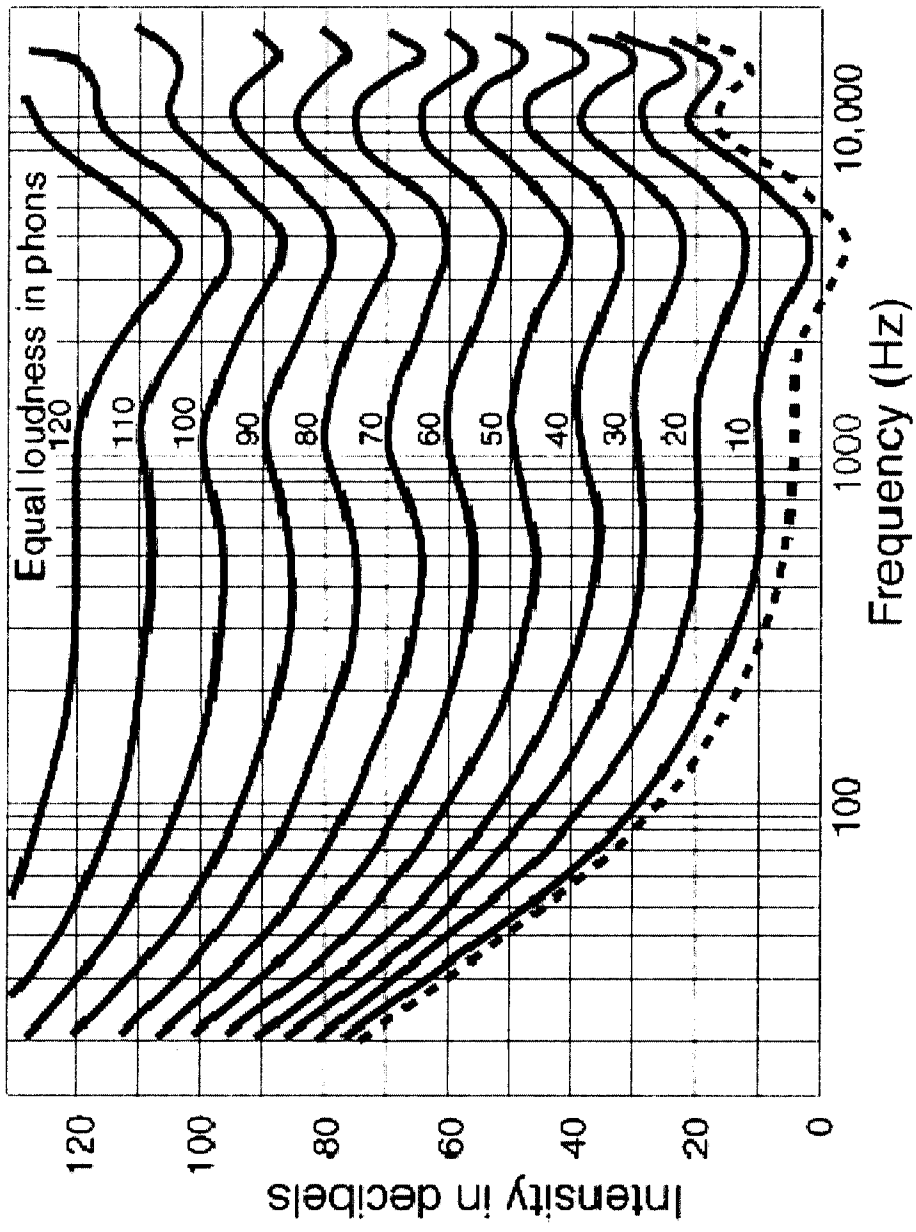

Equal loudness in phons
120
110
100
90
80
70
60
50
40
30
20
10
Intensity in decibels
0
20
40
60
80
100
120
Frequency (Hz)
100
1000
10,000

FIG. 1

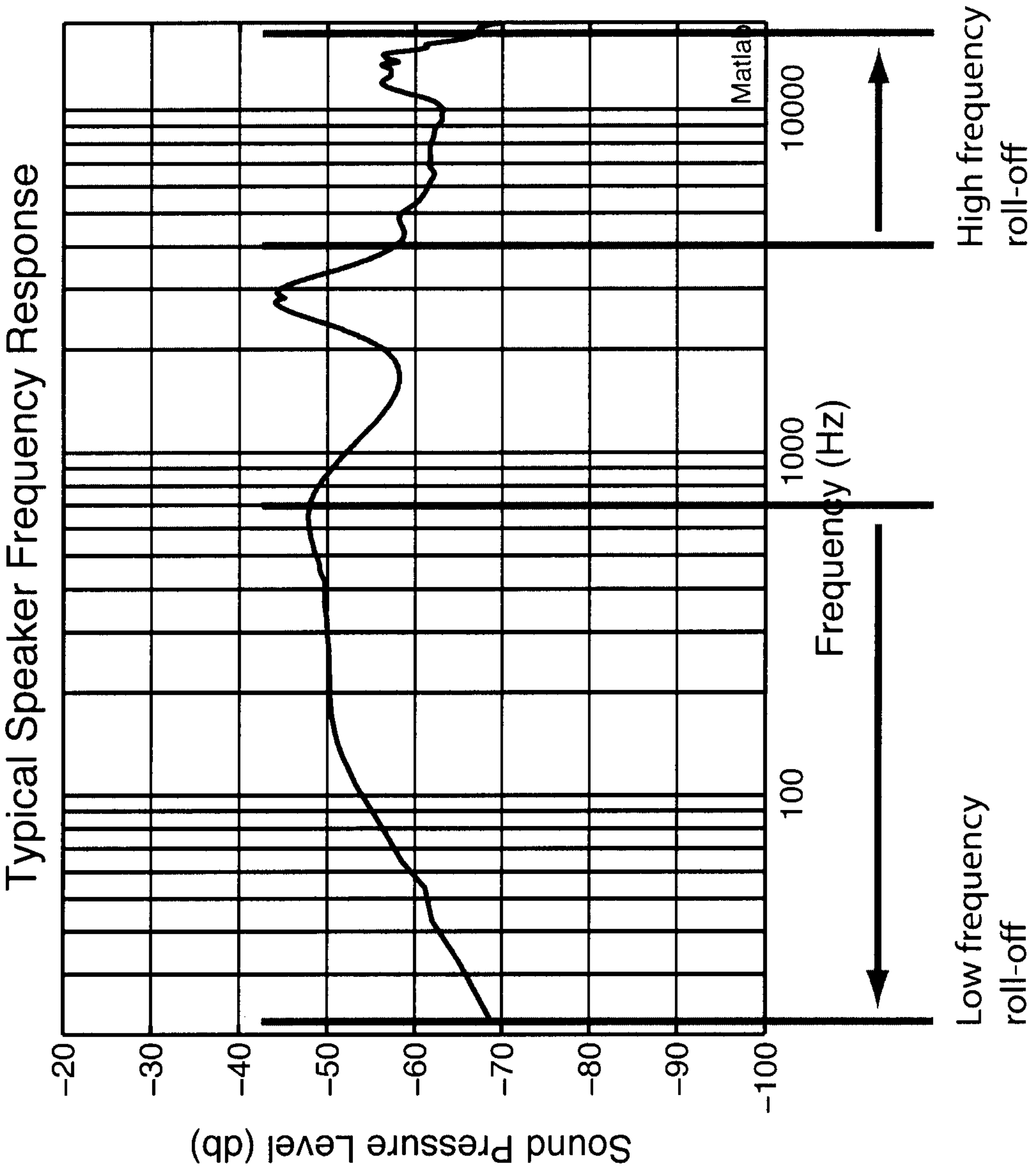

Typical Speaker Frequency Response
Sound Pressure Level (db)
−20
−30
−40
−50
−60
−70
−80
−90
−100
100
1000
10000
Frequency (Hz)
Matlab
Low frequency roll-off
High frequency roll-off

FIG. 2

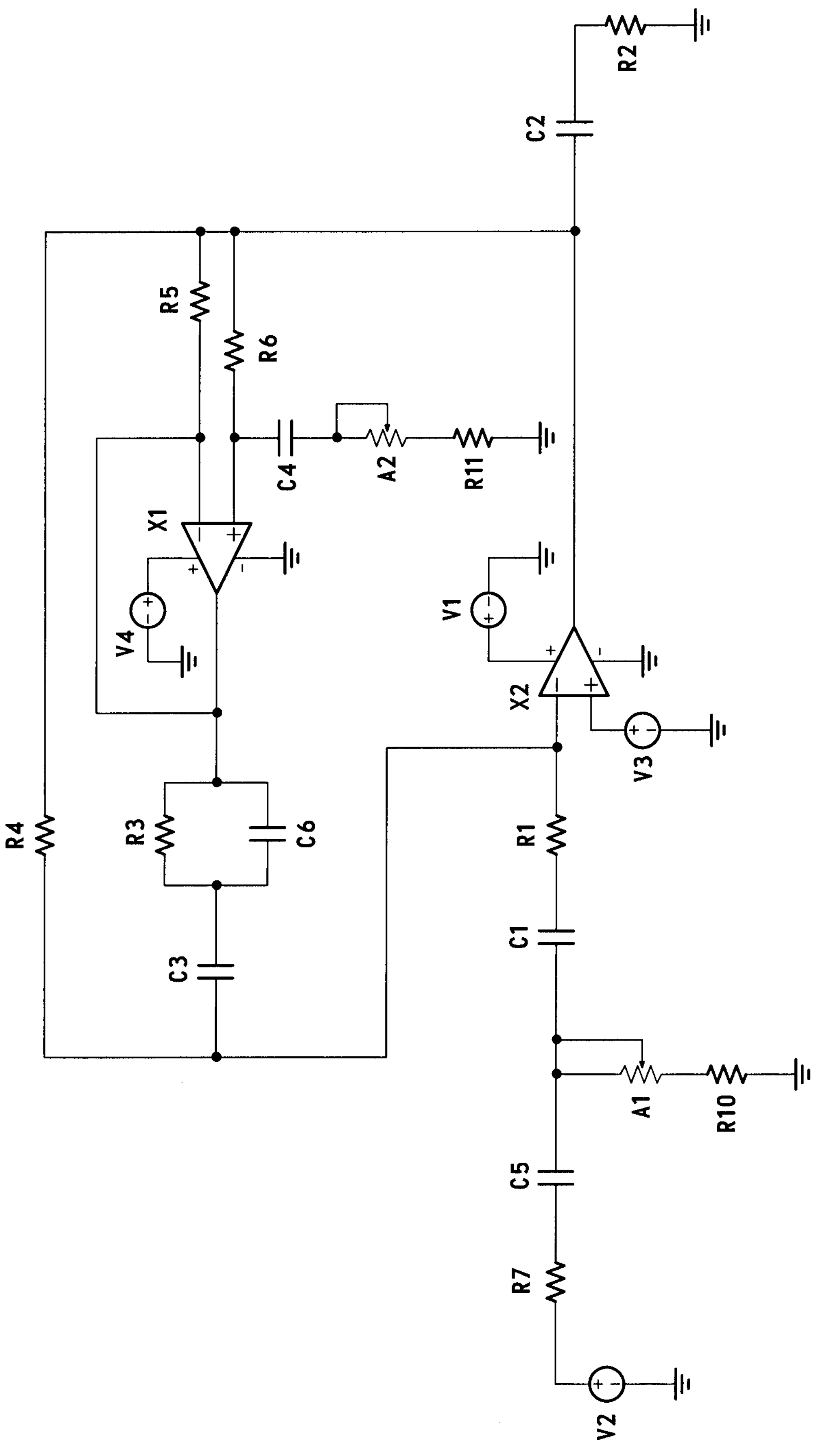


FIG. 3

FIG. 4

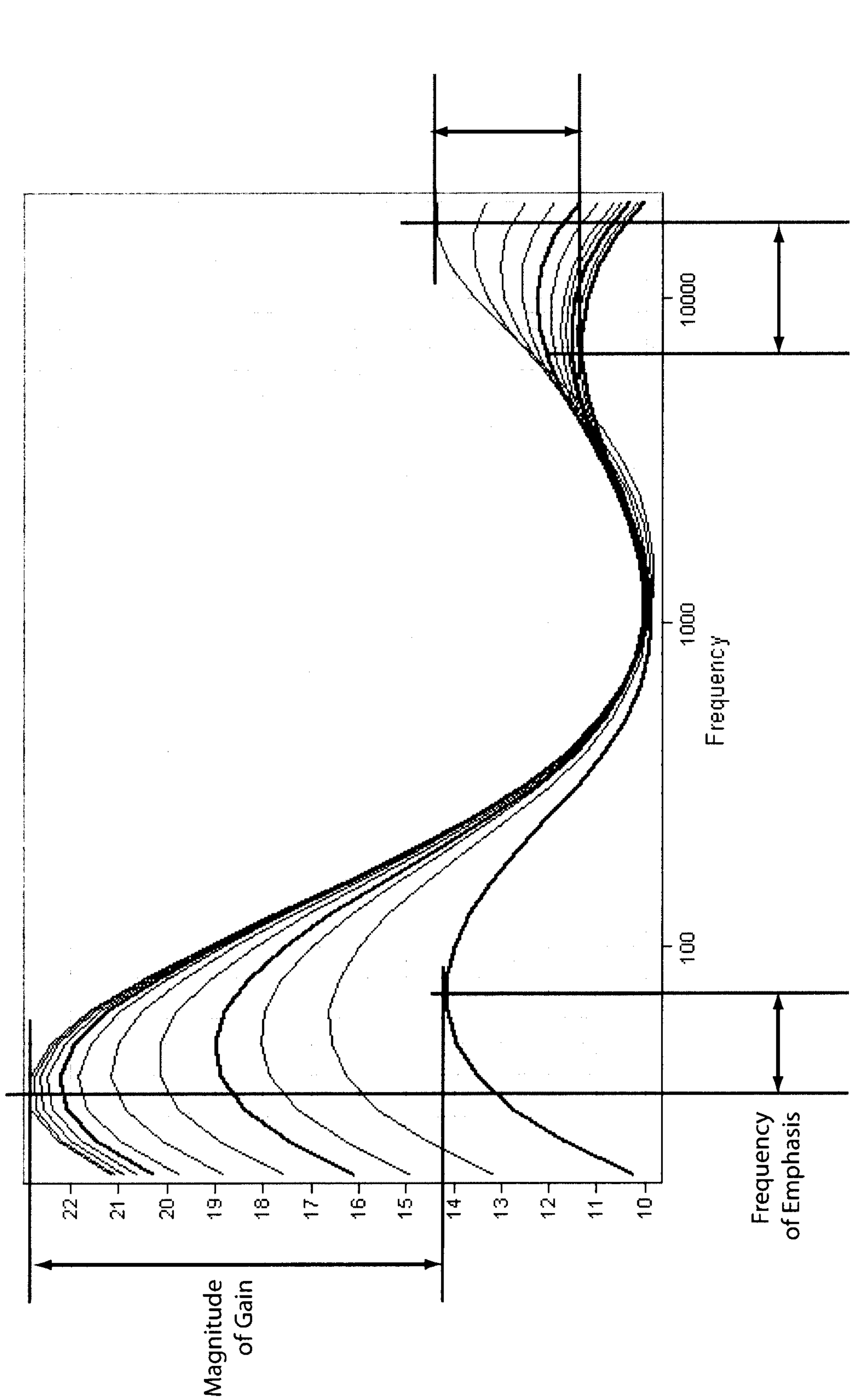

Magnitude of Gain
22
21
20
19
18
17
16
15
14
13
12
11
10
100
1000
10000
Frequency
Frequency of Emphasis

FIG. 5

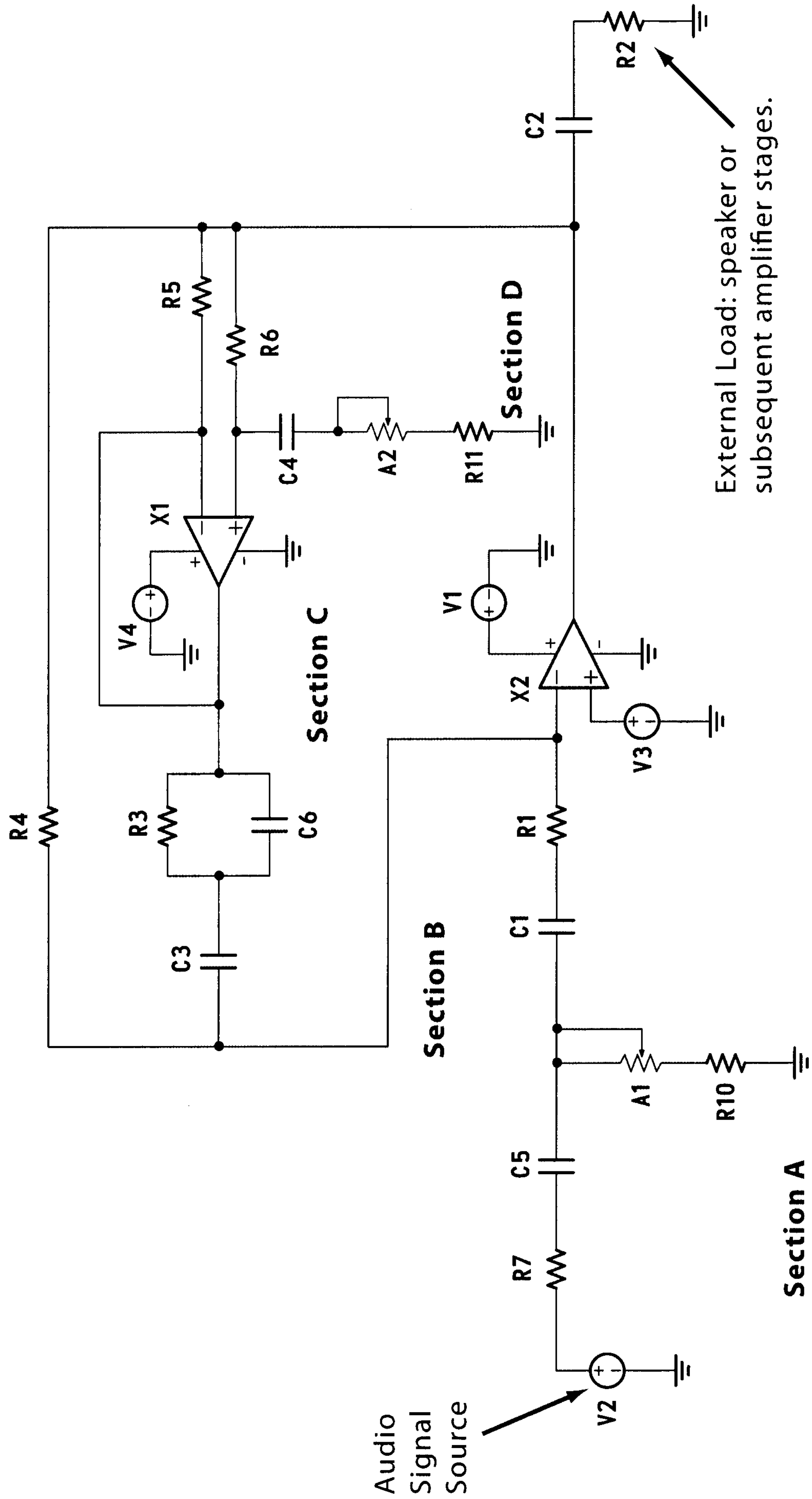

External Load: speaker or subsequent amplifier stages.
R2
C2
R5
R6
Section D
C4
A2
R11
X1
V4
Section C
V1
X2
V3
R4
R3
C6
R1
C3
C1
Section B
A1
R10
C5
Section A
R7
V2
Audio Signal Source

FIG. 6

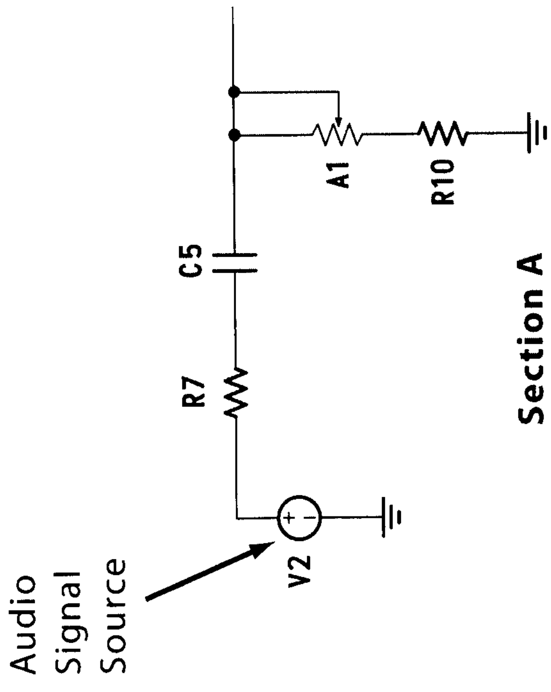


FIG. 7

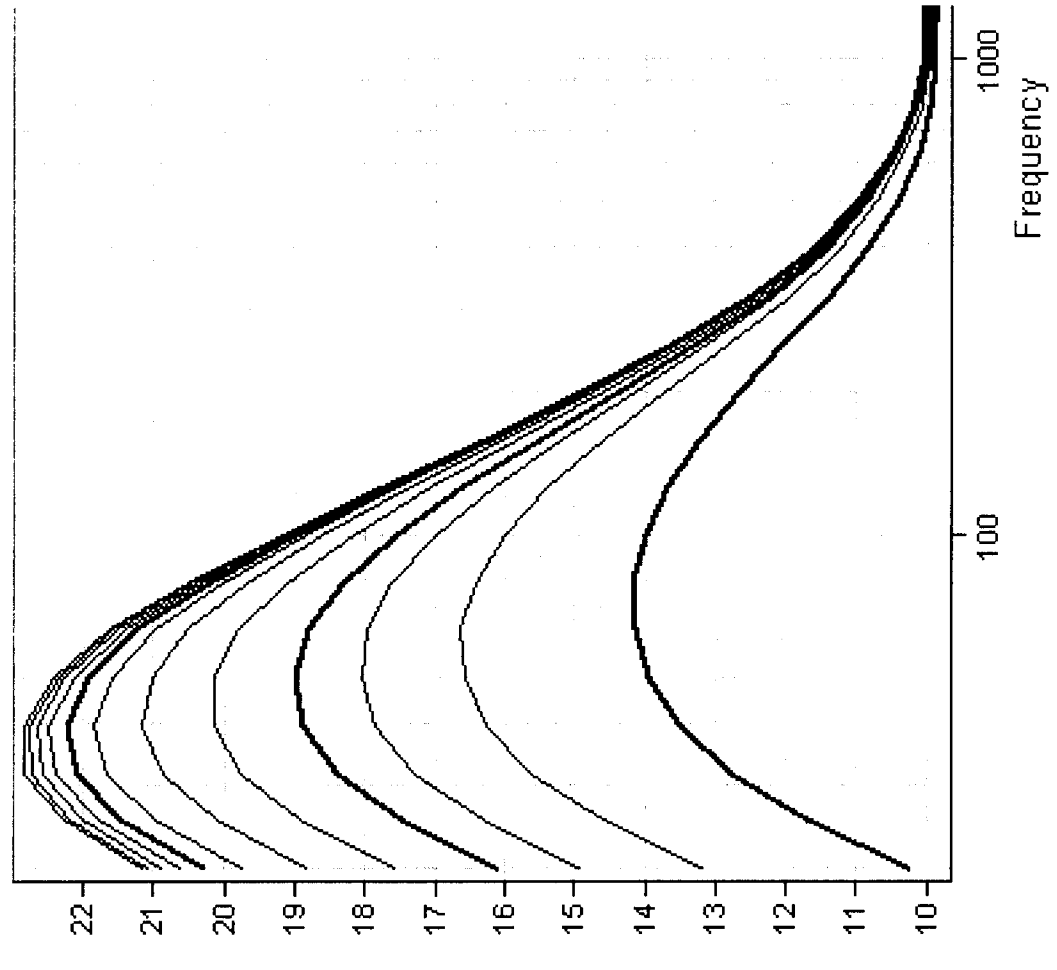


FIG. 8

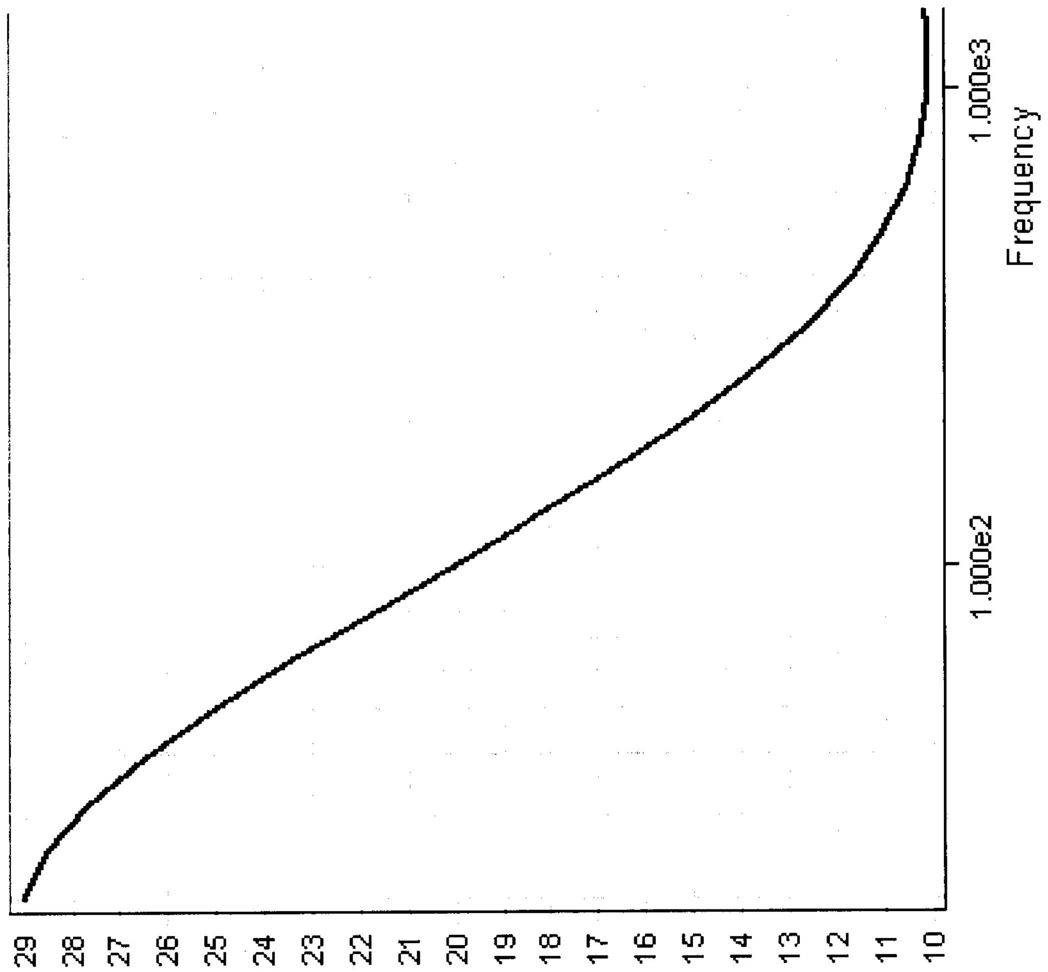

29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
1.000e2
1.000e3
Frequency

FIG. 9

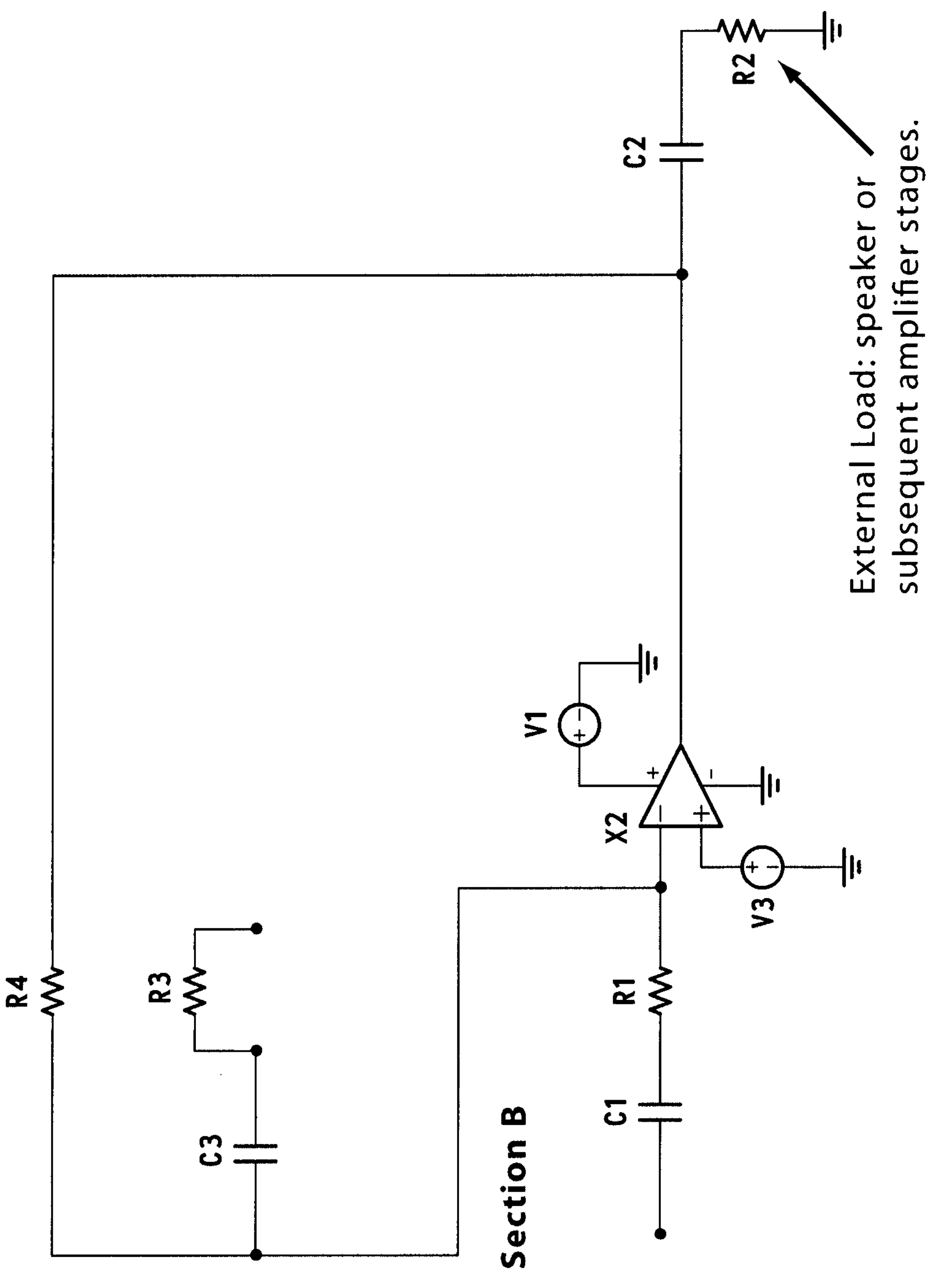

R4
R3
C3
Section B
C1
R1
X2
V1
V3
C2
R2
External Load: speaker or subsequent amplifier stages.

FIG. 10

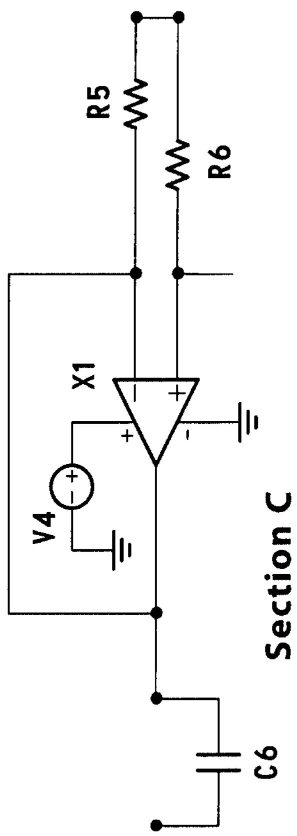


FIG. 11

FIG. 12

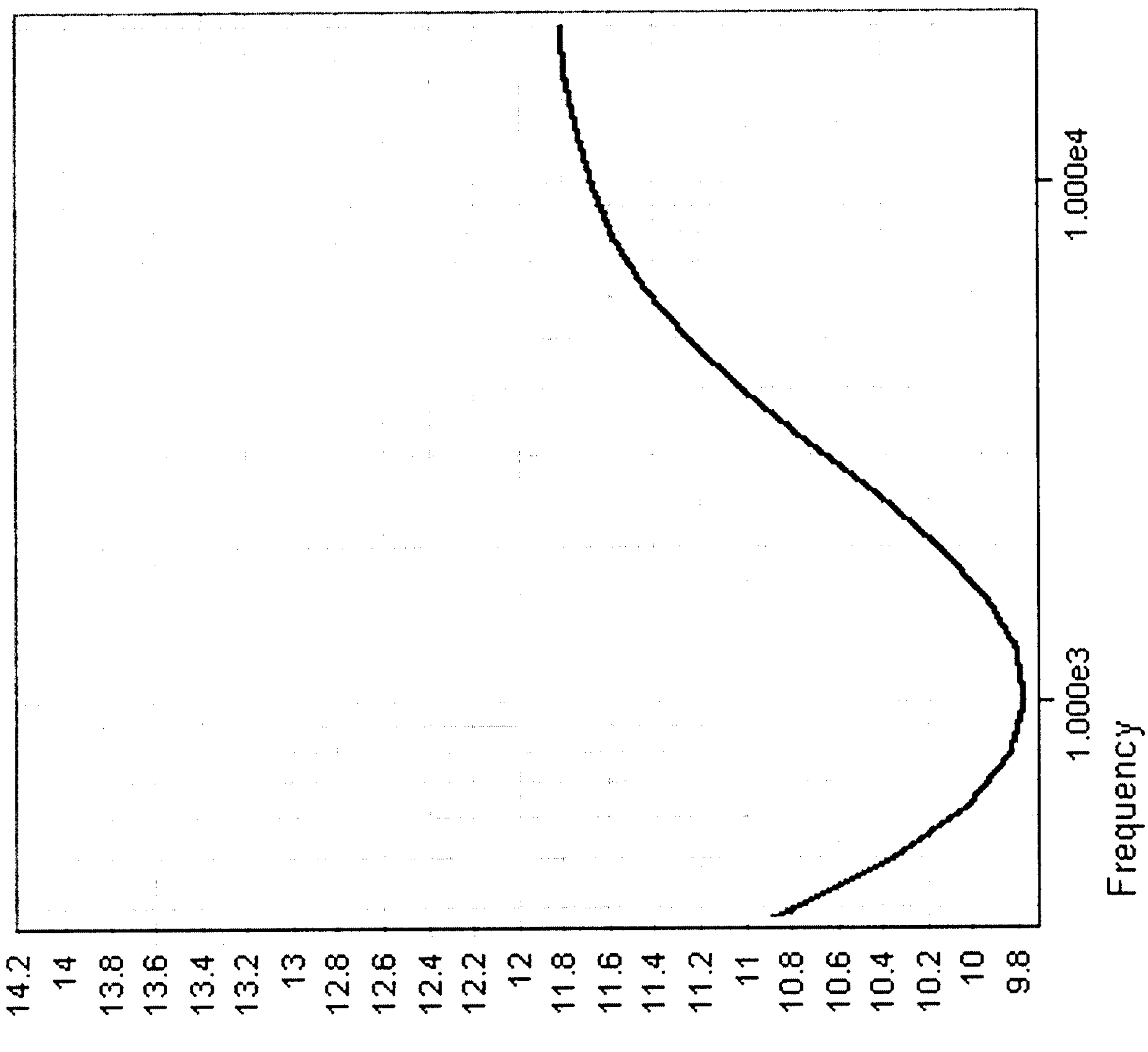

14.2
14
13.8
13.6
13.4
13.2
13
12.8
12.6
12.4
12.2
12
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
10.2
10
9.8
1.000e3
1.000e4
Frequency

FIG. 13

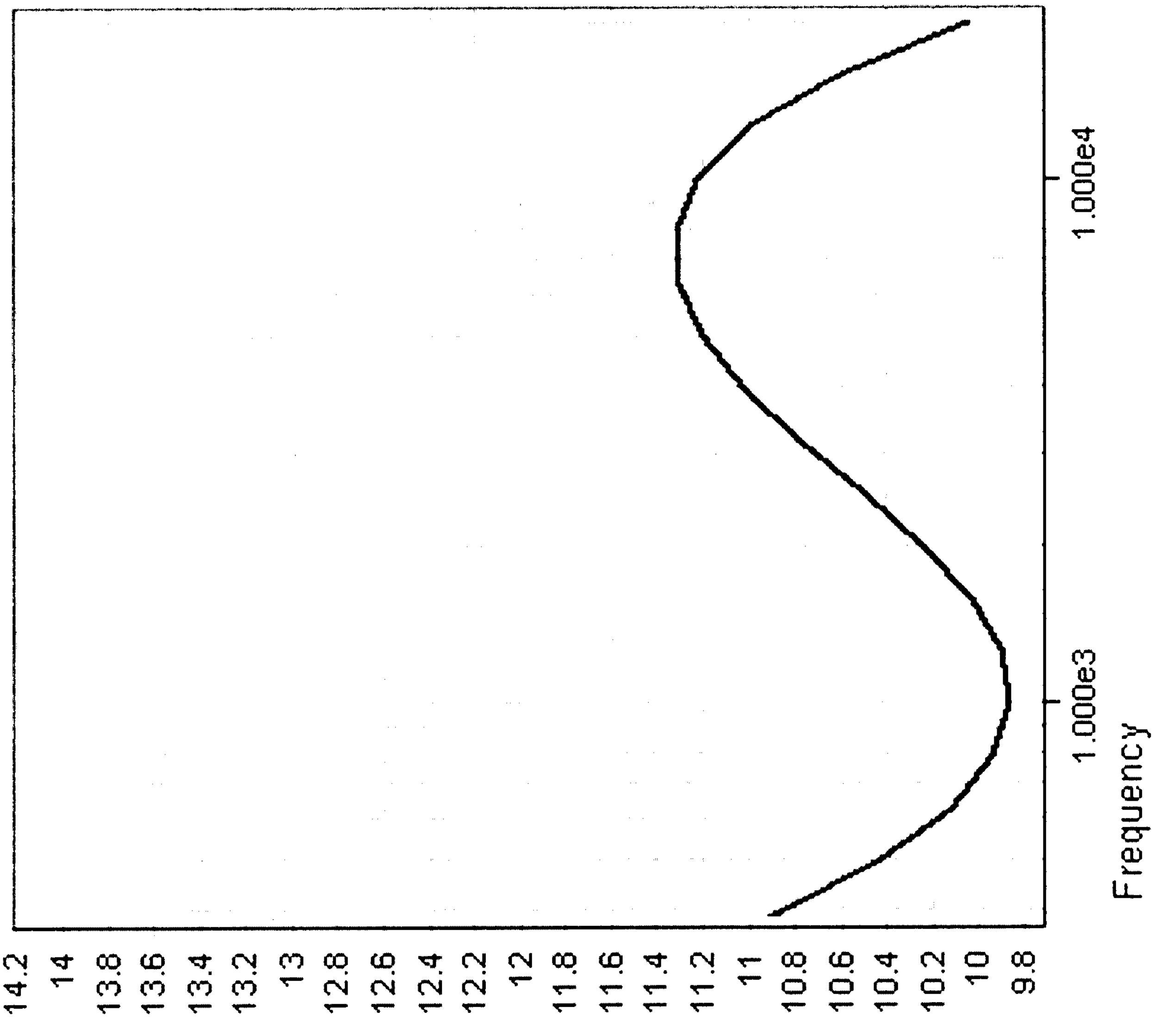

14.2
14
13.8
13.6
13.4
13.2
13
12.8
12.6
12.4
12.2
12
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
10.2
10
9.8
1.000e3
1.000e4
Frequency

FIG. 14

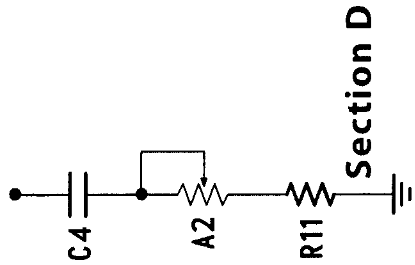
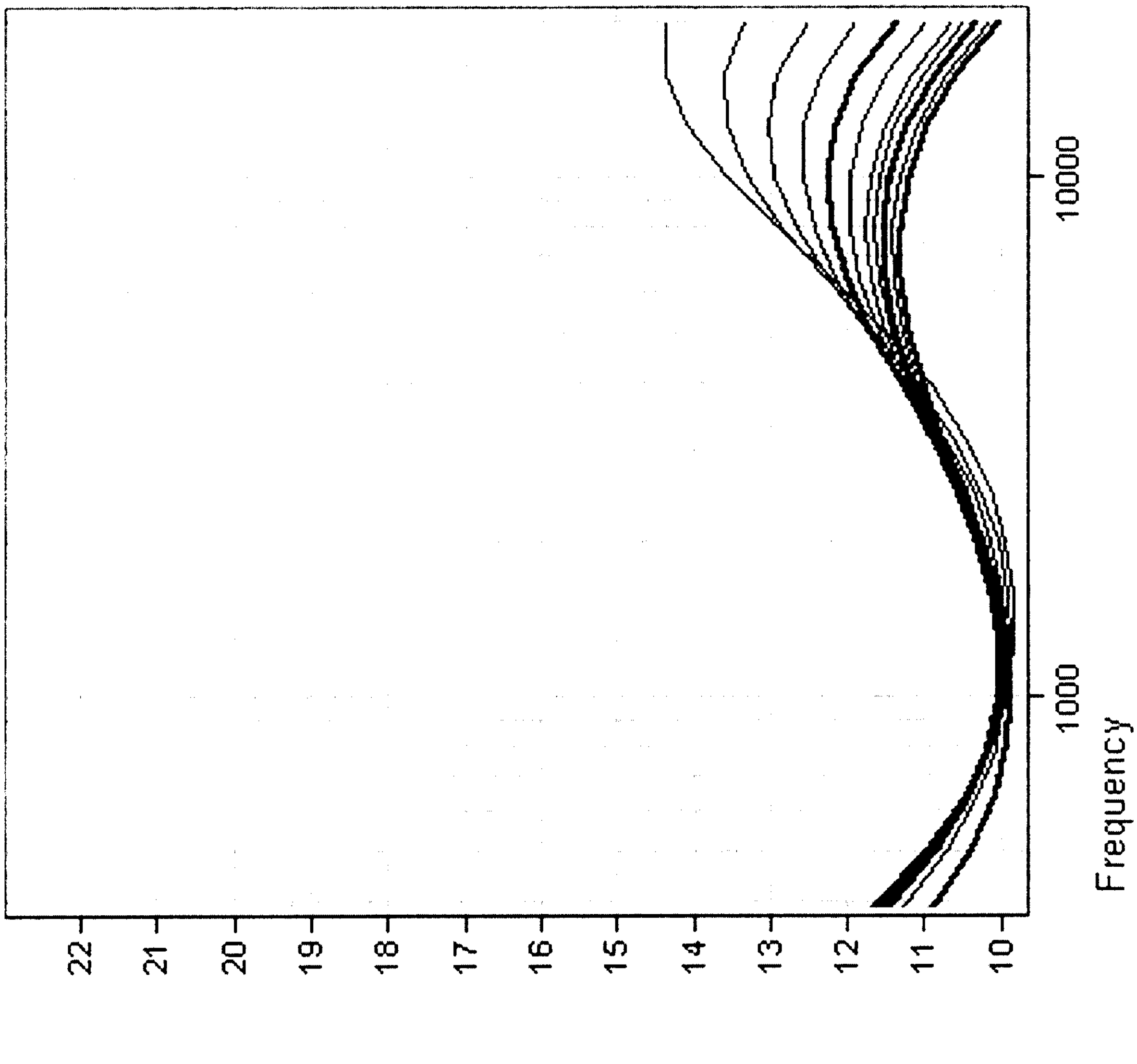


FIG. 15



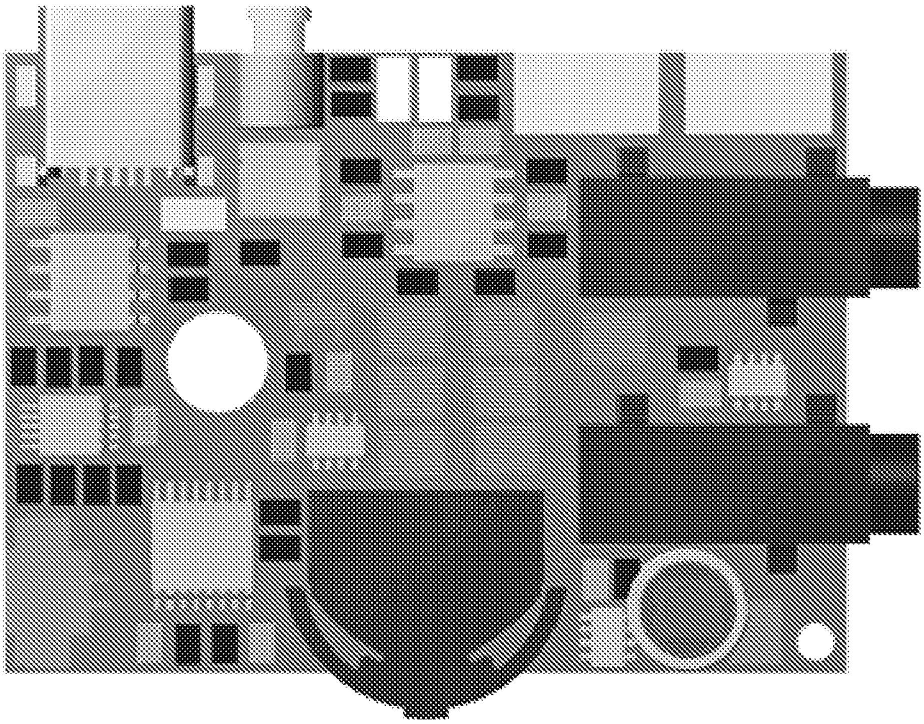


FIG. 16

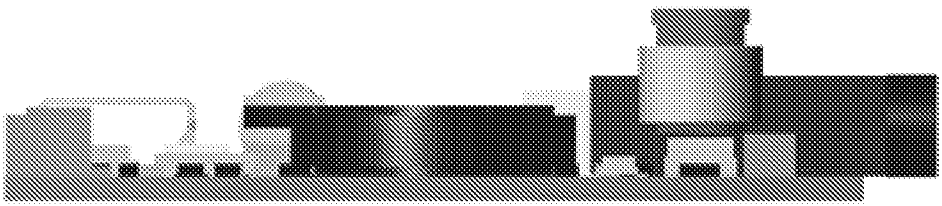


FIG. 17