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(54) **AUDIO SIGNAL PROCESSING APPARATUS AND SIGNAL PROCESSING METHOD FOR A SOUND SYSTEM, PARTICULARLY IN A VEHICLE**

AUDIOSIGNALVERARBEITUNGSVORRICHTUNG UND SIGNALVERARBEITUNGSVERFAHREN FÜR EIN TONSYSTEM, INSBESONDERE IN EINEM FAHRZEUG

APPAREIL ET PROCÉDÉ DE TRAITEMENT DE SIGNAL SONORE POUR UN SYSTÈME SONORE DE VÉHICULE

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Description

[0001] The invention relates to an audio signal processing apparatus for generating multiple output signals, particularly for a multi-way loudspeaker system. The invention further relates to a sound system and to a vehicle having such audio signal processing apparatus, and to a signal processing method for a sound system, particularly but not exclusively applicable in a vehicle.

[0002] Generally, in a typical configuration, a multi-way loudspeaker system with so-called active frequency cross-over comprises at least one low frequency (LF) loudspeaker, one or more high frequency (HF) speaker(s), multiple amplifier channels and an active analog or digital cross-over filter which has a high pass filter and a low pass filter to split the input audio signal into at least two bands, one for each speaker or speaker group. Typically, the cross-over frequency between the loudspeakers is defined during set-up or sound tuning of the system and stays fixed.

[0003] Particularly in a vehicle multi-way loudspeaker system, it is advantageous to reproduce mid and high frequencies as much as possible from the higher mounted loudspeakers (i.e. loudspeakers mounted at a higher position with respect to the floor plane of the vehicle) to achieve a high sound stage and a cross-over point below the speech band. This is currently only used in cases where high-cost large mid-band loudspeakers are used in at least a 3 way configuration.

[0004] Current known technology uses fixed cross-over frequencies or sets the cross-over frequency by volume control setting, as disclosed in WO 2010/122441 A1.

[0005] WO 2010/122441 A1 discloses a drive system which comprises a splitter which generates a low frequency signal and high frequency signal from an input signal. A first drive circuit is coupled to the splitter and generates a drive signal for an audio driver from the low frequency signal. A second drive circuit is coupled to the splitter and generates a drive signal for a second audio driver from the high frequency signal. The second drive circuit provides a bass frequency extension for the second audio driver by applying low frequency boost to the low frequency signal. A processor determines a driver excursion indication for the second audio driver and a controller performs a combined adjustment of a cross-over frequency for the high and low frequency signals and a characteristic of the low frequency boost based on the driver excursion indication.

[0006] JP 08-033093 A discloses a multi-way speaker device where rich musicality can be enjoyed even at the time of the reproduction in a low level. In this device, each filter is composed so that a cut-off frequency may be changed. The device is provided with a cross-over frequency control means outputting a variable control signal of the cut-off frequency for each filter according to an input sound signal level. When an input sound signal level is lower than a prescribed level, the cross-over frequency by each filter is made to change to a low-pass side.

[0007] Particularly in two-way active cross-over systems in vehicles, such as cars, the value of the cross-over frequency fx is a compromise between power handling of the HF speaker(s) and perceived sound stage height. The high-mounted HF speaker(s) (so-called tweeter) should play as much of the mid-band as possible to define a high sound stage, but the power handling sets a lower frequency limit, because the HF speaker(s) typically cannot handle high power.

[0008] If mid frequencies are reproduced from the LF speaker(s), the perceived sound stage is pulled down towards the bottom of the door of the vehicle, as LF speakers are typically installed in a lower area of the door. There, greater installation space is available for the LF speakers which is often necessary for good sound reproduction. In practice this means for a given mid-tweeter that the lower bandwidth limit depends on input power before the high pass filter, or the rated power handling limit depends on the high pass filter.

[0009] In a typical two-way sound system of a car, the cross-over frequency is about 2-3 kHz, inside the upper half of the human speech band. Thus, the lower end comes from the LF speaker and the intelligibility is impaired by the cross-over point, see also Figures 2 and 3.

[0010] Fig. 2 shows a standard configuration of a sound system with active cross-over between a high frequency speaker coupled to an amplifier and a low frequency speaker coupled to another amplifier and a corresponding signal diagram showing an exemplary cross-over frequency. The cross-over frequency is set in a so-called splitter to which an audio source signal as an input signal is applied. Signal components of higher frequency above the cross-over frequency fx (in this example approx. 100 Hz, see signal diagram in the lower part of Fig. 2) are supplied to the amplifier for the high frequency speaker, and signal components of lower frequency below the cross-over frequency fx are supplied to the amplifier for the low frequency speaker. As commonly known, the splitter comprises a respective low pass filter and high pass filter which are correspondingly set with the cross-over frequency fx, as shown in the diagram of Fig. 2.

[0011] Fig. 3 shows a diagram with a spectrum of audio signal components of exemplary associated audio sources in different frequency bands. Typical tweeter loudspeakers operate in a frequency range above roughly 3000 Hz and, as such, mainly reproduce signal components of higher frequencies of male speech or female speech, but other sources like trombone, violin, bass or flute are not or less reproduced. These sources are mainly reproduced by woofer speakers which operate in a frequency range below the cross-over frequency of 3000 Hz. Thus, a sound stage or image reproduced according to Fig. 3 is typically not preferable, at least in a typical loudspeaker configuration of a vehicle.

[0012] US 2014/0093096 A1 discloses methods and systems for adjusting a crossover frequency between a plurality of audio speakers. In one instance, the crossover frequency may be adjusted in response to the volume adjustment to improve the audio content rendering quality by the respective subsets of audio speakers in the plurality of audio speakers. The system may determine that at increased volume, a first zone player is capable of better rendering the lower frequency audio content distorted by the mid-range speaker, and thus determine that a crossover frequency adjustment may improve the audio content playback quality. In a further example, crossover frequency adjustments may be determined not based on playback volume per se, but rather based on detected distortion in the rendered audio content.

[0013] GB 2 181 626 A discloses an audio signal transmission system comprising an input section, an output section, and a transmission section for transmitting an audio signal between said input and output sections, said transmission section including first means for analyzing the spectrum of the audio signal input by said input section and second means for processing the audio signal on the basis of the output of said first means and in accordance with the physical characteristics of said output section.

[0014] It is an object of the invention to provide an audio signal processing apparatus and a signal processing method for a sound system which are capable of increasing the sound stage of a sound system, particularly used in a vehicle, while protecting HF speakers against overload.

[0015] The invention relates to an audio signal processing apparatus according to claim 1 and to a signal processing method for a sound system according to claim 12.

[0016] According to an aspect, there is disclosed an audio signal processing apparatus, comprising a signal input section through which in operation at least one audio signal is received, a splitting section coupled to the signal input section and configured to generate a first signal and a second signal from the received at least one audio signal, wherein the first signal comprises signal components of a first frequency range of the at least one audio signal and the second signal comprises signal components of a second frequency range of the at least one audio signal, the first frequency range comprising lower frequencies than the second frequency range and the first and second frequency ranges having a cross-over frequency, a first output section coupled to the splitting section and arranged to generate a first output signal for at least one first loudspeaker from the first signal, a second output section coupled to the splitting section and arranged to generate a second output signal for at least one second loudspeaker from the second signal. A processing section is coupled to the signal input section and receives a volume control signal which is indicative of a user volume input and which controls a volume of the first and second output signals depending on the user volume input. The processing section is configured to determine a first cross-over frequency value according to the volume control signal and to determine a second cross-over frequency value, wherein the determination of the second cross-over frequency value comprises a calculation of at least one power value of signal components over at least one frequency band of the at least one audio signal. The processing section is further configured to determine the cross-over frequency from one of the first and second cross-over frequency values.

[0017] According to another aspect, there is disclosed a signal processing method for a sound system, the method comprising the steps of receiving at least one audio signal, generating a first signal and a second signal from the received at least one audio signal, wherein the first signal comprises signal components of a first frequency range of the at least one audio signal and the second signal comprises signal components of a second frequency range of the at least one audio signal, the first frequency range comprising lower frequencies than the second frequency range and the first and second frequency ranges having a cross-over frequency, generating a first output signal for at least one first loudspeaker from the first signal and a second output signal for at least one second loudspeaker from the second signal, receiving a volume control signal which is indicative of a user volume input and controls a volume of the first and second output signals depending on the user volume input, determining a first cross-over frequency value according to the volume control signal and determining a second cross-over frequency value, wherein the determination of the second cross-over frequency value comprises a calculation of at least one power value of signal components over at least one frequency band of the at least one audio signal, and determining the cross-over frequency from one of the first and second cross-over frequency values.

[0018] According to the audio signal processing apparatus and the signal processing method for a sound system according to the invention, it is possible to increase the sound stage of a sound system and power handling capabilities of the sound system while preserving a high sound stage. Advantageously, an amount of signal components of the received audio signal that is sent to HF speaker(s) can be derived from a combination of (a) a user volume input setting and (b) a power estimation through frequency analysis, which may be employed for protecting the HF speaker(s) against overload while preserving a high sound stage. For the power estimation, the processing section particularly calculates at least one power value of signal components over at least one frequency band in the second frequency range of the at least one audio signal.

[0019] Advantageously, for a multi-way speaker system the audio signal processing apparatus may be configured such that it sends an increased or maximum amount of signal components to HF speaker(s) to keep the sound stage (also called sound image) high or as high as possible (e.g. adjusting the cross-over frequency as low as possible), but limited by maximum power (heat) and excursion (total harmonic distortion, or shortly THD) handling capabilities of the HF speaker(s).

[0020] The processing section is configured to determine the cross-over frequency as the first cross-over frequency value if the first cross-over frequency value is greater than the second cross-over frequency value, and as the second cross-over frequency value if the second cross-over frequency value is greater than the first cross-over frequency value.

[0021] According to an embodiment, the determination of the second cross-over frequency value comprises calculation of power values of signal components of the at least one audio signal along at least one frequency band from a first frequency level of the second frequency range to a lower frequency of the second frequency range, summing up the calculated power values from the first frequency level of the second frequency range down to the lower frequency of the second frequency range, and determining whether a sum of the summed up calculated power values reaches a power limit defined for the at least one second loudspeaker, and determining a frequency value that corresponds to a calculated power value at which the defined power limit is reached as the second cross-over frequency value.

[0022] According to an embodiment, the determination of the second cross-over frequency value comprises performing an n-th octave band analysis for calculating at least one power value in a respective one of multiple n-th octave bands of the second frequency range of the at least one audio signal from a first n-th octave band of the second frequency range to a lower n-th octave band of the second frequency range, summing up the respective calculated power values of the n-th octave bands from the first n-th octave band of the second frequency range down to the lower n-th octave band of the second frequency range, and determining whether a sum of the summed up calculated power values reaches a power limit defined for the at least one second loudspeaker, and determining a lowest one of the n-th octave bands at which the sum of the summed up calculated power values reaches the defined power limit, and determining a frequency of the lowest one of the n-th octave bands as the second cross-over frequency value.

[0023] According to an embodiment, the processing section is configured to determine a first and a second cross-over frequency from one of the first and second cross-over frequency values, wherein the first cross-over frequency is supplied to a low pass filter of the splitting section for generating the first signal and the second cross-over frequency is supplied to a high pass filter of the splitting section for generating the second signal.

[0024] According to an embodiment, the audio signal processing apparatus further includes a storing section for storing a table of multiple cross-over frequency values at multiple volume control signal values, wherein the processing section is configured to determine the first cross-over frequency value according to one of the stored cross-over frequency values.

[0025] According to another aspect, the invention also relates to a sound system comprising an audio signal processing apparatus according to the invention which is coupled to the at least one first and second loudspeakers.

[0026] According to an embodiment, the at least one first loudspeaker comprises at least one low frequency (LF) loudspeaker and the at least one second loudspeaker comprises at least one high frequency (HF) loudspeaker.

[0027] According to an embodiment, the at least one first loudspeaker comprises at least one of the following: a center loudspeaker, a subwoofer, an ambience loudspeaker; and the at least one second loudspeaker comprises at least one tweeter loudspeaker. Typically, a tweeter loudspeaker, or shortly tweeter, is a particular type of loudspeaker that is designed to produce high audio frequencies, typically from around 2,000 Hz to 20,000 Hz (generally considered to be the upper limit of human hearing).

[0028] According to an embodiment, the at least one first loudspeaker comprises at least one low frequency (LF) loudspeaker configured for a frequency range of 50 to 4000 Hz, and the at least one second loudspeaker comprises at least one high frequency (HF) loudspeaker (or mid-HF speaker) configured for a frequency range of 300 to 20,000 Hz.

[0029] According to another aspect, the invention also relates to a vehicle comprising an audio signal processing apparatus or sound system according to the invention which is coupled to the at least one first and second loudspeakers.

[0030] According to an embodiment, the at least one first loudspeaker comprises at least one low frequency loudspeaker and the at least one second loudspeaker comprises at least one high frequency loudspeaker, and the at least one low frequency loudspeaker is installed in the vehicle at a first position, and the at least one high frequency loudspeaker is installed in the vehicle at a second position which is at greater height than the first position relative to a floor plane of the vehicle. Such configuration is advantageous for achieving a high sound stage or image.

[0031] According to an embodiment, the at least one second loudspeaker comprises at least one of a front loudspeaker and a door loudspeaker of the vehicle.

[0032] According to aspects of the invention, as described above, preferably at low to medium volume levels the sound stage may be kept high because the audio signal processing apparatus may be configured such that most of the mid band signal components of the audio signal are sent to higher mounted mid-tweeter speaker(s). Such configuration is particularly advantageous in a vehicle where installation space for higher mounted mid-tweeter speaker(s) is limited. Due to power estimation through frequency analysis, small mid-tweeter speaker(s) with limited power may be protected from overload and heat at higher volume levels.

[0033] At higher volume levels the cross-over frequency is preferably shifted up to higher values in order to not overload any employed mid-tweeter speaker(s). The sound stage height is degraded at high power levels of the audio signal, but the power handling capability of the overall system may be increased significantly. For example, a highly compressed pop song has much more energy (or power) than quiet classical music at the same volume step, wherein this may be taken into account according to aspects of the invention.

[0034] All embodiments as described herein with respect to the apparatus, sound system or vehicle, may equally be applied in connection with the method as described herein.

[0035] Embodiments of the invention are described in greater detail below with reference to the Figures, in which:

Fig. 1 shows a perspective schematic view of an exemplary vehicle having an exemplary sound system in accordance with an embodiment of the invention installed therein,

Fig. 2 shows a standard configuration of a sound system with active cross-over between a high frequency speaker and a low frequency speaker and a corresponding signal diagram showing an exemplary cross-over frequency,

Fig. 3 shows a diagram with a spectrum of audio signal components in different frequency bands with exemplary associated audio sources,

Fig. 4 shows two diagrams with a respective spectrum of audio signal components and different cross-over frequencies,

Fig. 5 shows a block diagram of an exemplary audio signal processing apparatus in accordance with an embodiment of the invention,

Fig. 6 shows an exemplary signal diagram of the cross-over frequency values fx1, fx2 according to Fig. 5 and a cross-over frequency fxA as input for the splitting section 12 according to Fig. 5 according to an embodiment with an exemplary volume control signal 70.

[0036] Fig. 1 shows a perspective schematic diagram of a vehicle 1 provided with a sound system 2 in accordance with an exemplary embodiment of the invention.

[0037] The sound system 2 comprises a multi-way loudspeaker system with a plurality of loudspeakers 21-24. It should be noted that the invention can be applied with any number of loudspeakers, and that a typical vehicle sound system, for which the invention may be employed, includes more than the number of loudspeakers shown in Fig. 1. In particular, the exemplary sound system 2 comprises a lower left door speaker 21A, a lower right door speaker 21B, an upper left door speaker 22A, an upper right door speaker 22B, and a left front speaker 23 and right front speaker 24. The sound system may further comprise, e.g., rear speakers and a subwoofer (not shown). All of these speakers are coupled to an audio signal processing apparatus 10 by respective signal lines (shown in dashed lines in Fig. 1). It is also possible that the speakers 21-24 and the audio signal processing apparatus 10 are coupled via a bus architecture or any other means of signal communication, e.g. by wire and/or wirelessly.

[0038] According to an embodiment, the lower left door speaker 21A (and lower right door speaker 21B) is a low frequency (LF) speaker, and the upper left door speaker 22A (and upper right door speaker 22B) is a high frequency (HF) speaker. For example, the lower left door LF speaker 21A can have larger dimensions and thus has higher maximum power than the upper left door HF speaker 22A, which may be quite small and may have limited installation space, e.g. in the back region of the rear-view mirror of the door. The HF speaker 22A may be configured for reproduction at lower or mid volume levels. The speakers 23, 24 may be HF speakers with similar or different frequency band as the speaker 22A. According to an embodiment, the LF speaker 21A is configured for a frequency range of 50 to 4000 Hz, and the HF speaker (or mid-HF speaker) 22A is configured for a frequency range of 300 to 20,000 Hz.

[0039] According to an embodiment, the speaker 21A is installed in the vehicle 1 at a first position, e.g. in a lower area of the vehicle front door where more installation space is available. The speaker 22A is installed in the vehicle 1 at a second position, e.g. in an upper area of the vehicle front door, which is at a greater height than the position of the speaker 21A relative to the floor plane 3 of the vehicle. Particularly, the floor plane of the vehicle is the bottom plane where the seats of the vehicle are mounted. With such arrangement of speakers, a high sound stage may be achieved. Particularly, in a vehicle with such multi-way loudspeaker system, it is advantageous to reproduce mid and high frequencies as much as possible from higher mounted loudspeakers.

[0040] It should be noted that a sound system and an audio signal processing apparatus according to the invention, such as the sound system 2 and audio signal processing apparatus 10, are applicable in a vehicle, but may also be applied in a different environment.

[0041] Generally, a sound system according to the invention may comprise an audio signal receiving apparatus, such as a tuner, for receiving wireless audio source signals, such as radio broadcast waves or any other kind of source signal. Additionally or alternatively, it is possible that the sound system is coupled to an audio source reading apparatus, such as a CD player or a DVD player or a hard disk drive or any other kind of signal / data storage device, e.g. via a data connection such as USB. The audio signal receiving apparatus and/or the audio source reading apparatus may be coupled to the audio signal processing apparatus for providing the audio source signal(s) to the audio signal processing apparatus. No matter what the audio source is, the audio signal processing apparatus according to the invention is adapted to receive the audio source signal(s) as audio signal(s) and to generate respective output signals for the respective speakers.

[0042] Fig. 5 shows an audio signal processing apparatus 10 in accordance with an exemplary embodiment of the invention. Particularly, Fig. 5 shows an implementation with a 2-way speaker system and an embodiment of a digital sound processor (DSP) block diagram. The audio signal processing apparatus 10 comprises a signal input section 11, a splitting section 12, a first output section 41, a second output section 42, and a processing section 30. The audio signal processing apparatus 10, or one or several of its components or sections, such as the signal input section, the splitting section, the first output section, the second output section, and/or the processing section, may be implemented in any appropriate manner. They may be implemented in hardware, such as in one or more digital sound processors and/or in digital signal processing components. They may also be implemented at least in part using analog components. They may also be implemented (partly) in software in a digital sound processor, or in any appropriate combination of hardware and software.

[0043] According to the embodiment of Fig. 5, with the signal input section 11 at least one audio signal 50 is received in operation, for example from an audio source as described above. The audio signal 50 may be a stereo signal or any single or multi channel audio signal. The splitting section 12 is coupled to the signal input section 11 and configured to generate from the received audio signal 50 a first signal 61 via a respective low pass filter 121, and a second signal 62 via a respective high pass filter 122. The first signal 61 comprises signal components of a first frequency range of the audio signal 50 and the second signal 62 comprises signal components of a second frequency range of the audio signal 50. The first frequency range comprises lower frequencies than the second frequency range. For example, the first frequency range is a low frequency range, and the second frequency range is a high frequency range. The first and second frequency ranges have at least one cross-over frequency.

[0044] Such cross-over frequency is shown in Fig. 4A and 4B, respectively depicting a cross-over frequency fxA in Fig. 4A and fxB in Fig. 4B between a respective low frequency range and high frequency range (the x-axis designating increasing frequency values f, and the y-axis designating increasing volume levels V of reproduced audio signals).

[0045] The first output section 41 is coupled to the splitting section 12, particularly to the low pass filer 121, and is arranged to generate from the first signal 61 provided by the low pass filter 121 at least one first output signal 71 for at least one first loudspeaker, such as one or more LF speakers like the lower left door speaker 21A shown in Fig. 1 and/or the lower right door speaker. The second output section 42 is also coupled to the splitting section 12 and is arranged to generate from the second signal 62 provided by the high pass filter 122 at least one second output signal 72 for at least one second loudspeaker, such as one or more HF speakers like the upper left door speaker 22A shown in Fig. 1 and/or the upper right door speaker.

[0046] The processing section 30 is coupled to the signal input section 11 and receives a volume control signal 70 which is indicative of a user volume input and controls a volume of the first and second output signals 71, 72 depending on the user volume input. For example, the volume control signal 70 may be provided from an input section of a human machine interface where the user can input a volume setting for adjusting the volume of reproduced audio signals. The input section may output a volume control signal which is indicative of such volume setting. For example, the volume control signal may be provided to respective amplifiers in the output sections 41, 42.

[0047] The processing section 30 comprises a preselection section 31 and a storing section 32 with which the processing section determines a first cross-over frequency value fx1 according to the volume control signal 70 input to the preselection section 31. For example, in the storing section 32 a table of multiple cross-over frequency values (such as X, Y, Z shown in Fig. 5) at multiple volume control signal values (such as 0, 1, 2 shown in Fig. 5) is stored. Depending on the respective volume control signal value input to the preselection section 31, the preselection section 31 retrieves the corresponding values from the table in storing section 32 and determines the first cross-over frequency value fx1 according to one of the stored cross-over frequency values X, Y, Z which corresponds to the received volume control signal value at the input of preselection section 31.

[0048] For example, the high pass filter 122 may be set with a cross-over frequency value of X, Y, Z, whereas the low pass filter 121 may be set with the same cross-over frequency value X, Y, Z, or with roughly the same (i.e. a slightly different) cross-over frequency value (expressed in Fig. 5 by ~X, ~Y, ~Z). For example, X may be 1020 Hz, whereas ~X may be 970 Hz. Particularly in the latter case, the preselection section 31 sets a respective cross-over frequency value fx1 for the high pass filter 122 and the low pass filter 121, which need not be the same.

[0049] According to an embodiment, the optimal cross-over frequency is set by a set of parameters in one or several tables. This may be calculated during a system tuning by using design knowledge of speaker system and knowledge of the source and gain structure of the audio signal sources in the system (such as maximum input levels to cross-over frequency). Using the user volume input to preselect a cross-over frequency has the advantage that the changes in the cross-over frequency are normally not audible to the user, because the cross-over frequency is mostly changed at a time when there is a volume change by the user volume input.

[0050] The processing section 30 further comprises a calculation section 33 having calculation blocks 331, 332 and 333, as explained in more detail below. In calculation section 33, which works in parallel to the preselection section 31, the processing section 30 determines a second cross-over frequency value fx2. The determination of the second cross-over frequency value fx2 performed in calculation section 33 comprises a calculation of a power value of signal components over at least one frequency band of the audio signal 50, which is input into calculation section 33. From this calculation, the processing section 30 determines a cross-over frequency value fx2 for both high pass filter 122 and low pass filter 121, or a respective cross-over frequency value fx2 for the high pass filter 122 and the low pass filter 121, which need not be the same, analogously as explained above for setting the cross-over frequency value fx1.

[0051] In the selection section 34, the processing section 30 determines a cross-over frequency fxA for setting the high pass filter 122 and low pass filter 121, respectively, from one of the first and second cross-over frequency values fx1, fx2. The cross-over frequency fxA is supplied as a control value to the low pass filter 121 and high pass filter 122 for setting their respective cross-over frequency to be the cross-over frequency fxA.

[0052] For example, referring to Fig. 4A, a cross-over frequency fxA of 300 Hz may be set. According to Fig. 4B, in another scenario with a different volume control signal 70 having a higher volume level V, for example, a cross-over frequency fxB of 2500 Hz may be set instead of fxA, thus protecting the HF speaker(s) against overload.

[0053] In a case where different cross-over frequencies are set for the high pass filter 122 and low pass filter 121, respectively, the processing section 30 in the selection section 34 determines a first and a second cross-over frequency fxA1, fxA2 from the received first and second cross-over frequency values fx1, fx2. The first cross-over frequency fxA1 is supplied as a control value to the low pass filter 121 for setting its cross-over frequency to be the first cross-over frequency fxA1, and the second cross-over frequency fxA2 is supplied as a control value to the high pass filter 122 for setting its respective cross-over frequency to be the second cross-over frequency fxA2.

[0054] The processing section 30 determines the cross-over frequency fxA (or fxA1, fxA2) from the greater one of the first and second cross-over frequency values fx1, fx2. Particularly, the processing section 30 determines the cross-over frequency fxA (or fxA1, fxA2) as the first cross-over frequency value fx1 if the first cross-over frequency value fx1 is greater than the second cross-over frequency value fx2, and as the second cross-over frequency value fx2 if the second cross-over frequency value fx2 is greater than the first cross-over frequency value fx1. According to an embodiment, in blocks 331 to 333, the determination of the second cross-over frequency value fx2 is done as follows:

In block 331, power values of signal components of the audio signal 50 are calculated along at least one frequency band from a first frequency level of the second frequency range to a lower frequency of the second frequency range. Particularly, it is performed an n-th octave band analysis for calculating at least one power value in a respective one of multiple n-th octave bands of the second frequency range of the audio signal 50 from a first n-th octave band of the second frequency range to a lower n-th octave band of the second frequency range.

[0055] In block 332, the calculated power values are summed up from the first frequency level of the second frequency range down to the lower frequency of the second frequency range, and it is determined whether a sum of the summed up calculated power values reaches a power limit defined for the at least one second loudspeaker (such as speaker 22). Particularly, the respective calculated power values of the n-th octave bands from the first n-th octave band of the second frequency range down to the lower n-th octave band of the second frequency range are summed up, and it is determined whether a sum of the summed up calculated power values reaches a power limit defined for the at least one second loudspeaker (i.e. speaker 22).

[0056] In block 333, as the second cross-over frequency value fx2 a frequency value is determined that corresponds to a calculated power value at which the defined power limit is reached. Particularly, there is determined a lowest one of the n-th octave bands at which the sum of the summed up calculated power values reaches the defined power limit, and a frequency of the lowest one of the n-th octave bands is determined as the second cross-over frequency value fx2.

[0057] In other words, according to an embodiment of the invention, any steps performed by the cross-over frequency calculation section 33 comprise the following steps:

In a first step, an n-th octave band analysis is performed which calculates the power (energy) in every n-th octave band of the source audio signal 50. In a second step, from a top end (typically 20 kHz) of the second frequency range down, calculated power values (corresponds to quadrature of the signal voltages of the respective signal components) of the n-th octave bands are summed up (integrated) until the maximum total power limit of the HF loudspeaker is reached. The n-th octave bands might be weighted in this sum. In a third step, the lowest n-th octave band that is still included within the power limit calculation in the second step determines the cross-over frequency fx2.

[0058] According to an embodiment, the calculation performed in calculation section 33 (which functions as a prediction algorithm) continuously or intermittently calculates a minimum possible cross-over frequency value fx2. If the current preselected cross-over frequency value fx1 is too low due to unusually high power content in the source audio signal 50, the cross-over frequency fxA is shifted higher following the cross-over frequency value fx2 to protect the speakers. Thus, the prediction algorithm performed in calculation section 33 has always priority over preselection performed in the preselection section 31.

[0059] Referring to Fig. 4A and 4B, according to aspects of the invention, the cross-over frequency determined by the processing section 30 may be varied, e.g. between fxA of 300 Hz and fxB of 2500 Hz.

[0060] As shown in Fig. 4A, at low listening level, i.e. at low volume level of the volume control signal 70, most signal components are reproduced by the speaker(s) which reproduces signal components in the second frequency range, i.e. the higher frequency range. Thus, more signal components may be reproduced by mid-tweeter speakers or HF speakers, such as speaker 22. Since the frequency range reproduced by such mid-tweeter speakers is quite large, e.g. reaches down to cross-over frequency fxA of 300 Hz, a high sound stage may be achieved. This can save the use of a separate mid-range speaker and, thus, reduces costs.

[0061] As shown in Fig. 4B, at higher listening level, i.e. at higher volume level of the volume control signal 70, the cross-over frequency determined by the processing section 30 shifts towards a higher cross-over frequency fxB (here, e.g., 2500 Hz), thus the first frequency range is extended and more signal components are reproduced by the speaker(s) which reproduces signal components in the first frequency range, i.e. the lower frequency range, such as speaker 21A. In other words, at high listening level, the cross-over frequency is increased to protect the mid-tweeters and more signal components are reproduced by LF speakers(s) which are capable of handling higher power. In both diagrams of Fig. 4A and 4B, the areas A1 and A2, respectively, are indicative of the total power sent to the mid-tweeter speakers or HF speakers, and are roughly equal.

[0062] Fig. 6 shows an exemplary signal diagram of the cross-over frequency values fx1, fx2 according to Fig. 5 and a cross-over frequency fxA as input for the splitting section 12 according to Fig. 5 according to an embodiment of the invention with an exemplary volume control signal 70. With increasing the volume control signal 70 towards higher volume levels, the cross-over frequency value fx1 (volume based) increases accordingly (see characteristics between the two vertical lines). In a region R where the cross-over frequency value fx2 (based on power calculation) is greater than the cross-over frequency value fx1, the cross-over frequency fxA as an input to the splitting section 12 is higher than the cross-over frequency value fx1 and is based on fx2. In other regions, the cross-over frequency fxA follows the cross-over frequency value fx1 according to the user volume setting and volume control signal 70. In region R, due to high calculated power of the audio signal 50, any HF speaker(s) configured for lower or mid volume levels are protected by increasing the cross-over frequency fxA following the cross-over frequency value fx2.

[0063] Thus, according to aspects of the invention, for a multi-way speaker system, the audio signal processing apparatus can be configured to always send a maximum amount of output signal components to the HF speaker(s) to keep the sound image as high as possible (cross-over frequency as low as possible), but limited by the maximum power (heat) and excursion (THD) handling capabilities of the HF speaker(s). At low to medium volume levels, the sound stage is high because most of the mid-band signal is reproduced from the high mounted HF speaker(s). At high volume levels, the cross-over frequency is shifted up to not overload the HF speaker(s). The amount of signal components that is sent to the HF speaker(s) is derived from a combination of a user volume setting and power estimation through frequency analysis. The sound stage height at high output volume levels is degraded at high power levels, but the power handling capability of the overall system is increased significantly.

Claims

1. An audio signal processing apparatus (10), comprising

- a signal input section (11) through which in operation at least one audio signal (50) is received,
- a splitting section (12) coupled to the signal input section (11) and configured to generate a first signal (61) and a second signal (62) from the received at least one audio signal (50), wherein the first signal (61) comprises signal components of a first frequency range of the at least one audio signal and the second signal (62) comprises signal components of a second frequency range of the at least one audio signal, the first frequency range comprising lower frequencies than the second frequency range and the first and second frequency ranges having a cross-over frequency (fxA),
- a first output section (41) coupled to the splitting section (12) and arranged to generate a first output signal (71) for at least one first loudspeaker (21A) from the first signal (61),
- a second output section (42) coupled to the splitting section (12) and arranged to generate a second output signal (72) for at least one second loudspeaker (22A) from the second signal (62);
- a processing section (30) coupled to the signal input section (11) and receiving a volume control signal (70) which is indicative of a user volume input and controls a volume of the first and second output signals (71, 72) depending on the user volume input,

- **characterized in that** the processing section (30) is configured to determine a first cross-over frequency value (fx1) according to the volume control signal (70) and to determine a second cross-over frequency value (fx2), wherein the determination of the second cross-over frequency value (fx2) comprises a calculation of at least one power value of signal components over at least one frequency band of the at least one audio signal (50),
- wherein the processing section (30) is configured to determine the cross-over frequency (fxA) as the first cross-over frequency value (fx1) if the first cross-over frequency value (fx1) is greater than the second cross-over frequency value (fx2), and as the second cross-over frequency value (fx2) if the second cross-over frequency value (fx2) is greater than the first cross-over frequency value (fx1).

2. The audio signal processing apparatus (10) according to claim 1, wherein the determination of the second cross-over frequency value (fx2) comprises

- calculation of power values of signal components of the at least one audio signal (50) along at least one frequency band from a first frequency level of the second frequency range to a lower frequency of the second frequency range,
- summing up the calculated power values from the first frequency level of the second frequency range down to the lower frequency of the second frequency range, and determining whether a sum of the summed up calculated power values reaches a power limit defined for the at least one second loudspeaker (22), and
- determining a frequency value that corresponds to a calculated power value at which the defined power limit is reached as the second cross-over frequency value (fx2).

3. The audio signal processing apparatus (10) according to one of claims 1 to 2, wherein the determination of the second cross-over frequency value (fx2) comprises

- performing an n-th octave band analysis for calculating at least one power value in a respective one of multiple n-th octave bands of the second frequency range of the at least one audio signal (50) from a first n-th octave band of the second frequency range to a lower n-th octave band of the second frequency range,
- summing up the respective calculated power values of the n-th octave bands from the first n-th octave band of the second frequency range down to the lower n-th octave band of the second frequency range, and determining whether a sum of the summed up calculated power values reaches a power limit defined for the at least one second loudspeaker (22), and
- determining a lowest one of the n-th octave bands at which the sum of the summed up calculated power values reaches the defined power limit, and determining a frequency of the lowest one of the n-th octave bands as the second cross-over frequency value (fx2).

4. The audio signal processing apparatus (10) according to one of claims 1 to 3, wherein the processing section (30) is configured to determine a first and a second cross-over frequency (fxA1, fxA2) from one of the first and second cross-over frequency values (fx1, fx2), wherein the first cross-over frequency (fxA1) is supplied as a control value to a low pass filter (121) of the splitting section (12) for generating the first signal (61) and the second cross-over frequency (fxA2) is supplied as a control value to a high pass filter (122) of the splitting section (12) for generating the second signal (62).

5. The audio signal processing apparatus (10) according to one of claims 1 to 4, further including a storing section (32) for storing a table of multiple cross-over frequency values (X, Y, Z) at multiple volume control signal values, wherein the processing section (30) is configured to determine the first cross-over frequency value (fx1) according to one of the stored cross-over frequency values (X, Y, Z).

6. A sound system (2) comprising an audio signal processing apparatus (10) according to one of claims 1 to 5 coupled to the at least one first and second loudspeakers (21A, 22A).

7. The sound system (2) according to claim 6, wherein the at least one first loudspeaker (21A) comprises at least one low frequency loudspeaker and the at least one second loudspeaker (22A) comprises at least one high frequency loudspeaker.

8. The sound system (2) according to claim 6 or 7, wherein the at least one first loudspeaker (21A) comprises at least one of the following: a center loudspeaker, a subwoofer, an ambience loudspeaker; and the at least one second loudspeaker (22A) comprises at least one tweeter loudspeaker.

9. A vehicle (1) comprising an audio signal processing apparatus (10) according to one of claims 1 to 5 coupled to the at least one first and second loudspeakers (21A, 22A).

10. The vehicle (1) according to claim 9, wherein the at least one first loudspeaker (21A) comprises at least one low frequency loudspeaker which is installed in the vehicle (1) at a first position, and the at least one second loudspeaker (22A) comprises at least one high frequency loudspeaker which is installed in the vehicle (1) at a second position which is at greater height than the first position relative to a floor plane (3) of the vehicle.

11. The vehicle (1) according to claim 9 or 10, wherein the at least one second loudspeaker (22A) comprises at least one of a front loudspeaker and a door loudspeaker of the vehicle.

12. A signal processing method for a sound system (2), the method comprising the steps of:

- receiving at least one audio signal (50),
- generating a first signal (61) and a second signal (62) from the received at least one audio signal (50), wherein the first signal (61) comprises signal components of a first frequency range of the at least one audio signal and the second signal (62) comprises signal components of a second frequency range of the at least one audio signal, the first frequency range comprising lower frequencies than the second frequency range and the first and second frequency ranges having a cross-over frequency (fxA),
- generating a first output signal (71) for at least one first loudspeaker (21A) from the first signal (61) and a second output signal (72) for at least one second loudspeaker (22B) from the second signal (62);
- receiving a volume control signal (70) which is indicative of a user volume input and controls a volume of the first and second output signals (71, 72) depending on the user volume input,
- **characterized by** determining a first cross-over frequency value (fx1) according to the volume control signal (70) and determining a second cross-over frequency value (fx2), wherein the determination of the second cross-over frequency value (fx2) comprises a calculation of at least one power value of signal components over at least one frequency band of the at least one audio signal (50), and
- determining the cross-over frequency (fxA) as the first cross-over frequency value (fx1) if the first cross-over frequency value (fx1) is greater than the second cross-over frequency value (fx2), and as the second cross-over frequency value (fx2) if the second cross-over frequency value (fx2) is greater than the first cross-over frequency value (fx1).

Patentansprüche

1. Audiosignalverarbeitungsvorrichtung (10), umfassend:

- einen Signaleingangsabschnitt (11), durch den im Betrieb mindestens ein Audiosignal (50) empfangen wird,
- einen Teilungsabschnitt (12), der mit dem Signaleingangsabschnitt (11) gekoppelt ist und dazu ausgelegt ist, ein erstes Signal (61) und ein zweites Signal (62) aus dem mindestens einen empfangenen Audiosignal (50) zu erzeugen, wobei das erste Signal (61) Signalkomponenten eines ersten Frequenzbereichs des mindestens einen Audiosignals umfasst und das zweite Signal (62) Signalkomponenten eines zweiten Frequenzbereichs des mindestens einen Audiosignals umfasst, wobei der erste Frequenzbereich niedrigere Frequenzen als der zweite Frequenzbereich umfasst und der erste und der zweite Frequenzbereich eine Übergangsfrequenz (fxA) aufweisen,
- einen ersten Ausgabeabschnitt (41), der mit dem Teilungsabschnitt (12) gekoppelt ist und dazu vorgesehen ist, ein erstes Ausgangssignal (71) für mindesten einen ersten Lautsprecher (21A) aus dem ersten Signal (61) zu erzeugen,
- einen zweiten Ausgabeabschnitt (42), der mit dem Teilungsabschnitt (12) gekoppelt ist und dazu vorgesehen ist, ein zweites Ausgangssignal (72) für mindestens einen zweiten Lautsprecher (22A) aus dem zweiten Signal (62) zu erzeugen;
- einen Verarbeitungsabschnitt (30), der mit dem Signaleingangsabschnitt (11) gekoppelt ist und ein Lautstärkesteuersignal (70) empfängt, das eine Benutzerlautstärkeeingabe angibt und eine Lautstärke des ersten und des zweiten Ausgangssignals (71, 72) abhängig von der Benutzerlautstärkeeingabe steuert,
- **dadurch gekennzeichnet, dass** der Verarbeitungsabschnitt (30) dazu ausgelegt ist, einen ersten Übergangsfrequenzwert (fx1) gemäß dem Lautstärkesteuersignal (70) zu bestimmen und einen zweiten Übergangsfrequenzwert (fx2) zu bestimmen, wobei das Bestimmen des zweiten Übergangsfrequenzwerts (fx2) eine Berechnung von mindestens einem Leistungswert von Signalkomponenten über mindestens ein Frequenzband des mindestens einen Audiosignals (50) umfasst,
- wobei der Verarbeitungsabschnitt (30) dazu ausgelegt ist, die Übergangsfrequenz (fxA) als den ersten Übergangsfrequenzwert (fx1) zu bestimmen, wenn der erste Übergangsfrequenzwert (fx1) größer als der zweite Übergangsfrequenzwert (fx2) ist, und als den zweiten Übergangsfrequenzwert (fx2) zu bestimmen, wenn der zweite Übergangsfrequenzwert (fx2) größer als der erste Übergangsfrequenzwert (fx1) ist.

2. Audiosignalverarbeitungsvorrichtung (10) nach Anspruch 1, wobei das Bestimmen des zweiten Übergangsfrequenzwerts (fx2) umfasst

- Berechnen von Leistungswerten von Signalkomponenten des mindestens einen Audiosignals (50) entlang mindestens einem Frequenzband von einer ersten Frequenzebene des zweiten Frequenzbereichs zu einer niedrigeren Frequenz des zweiten Frequenzbereichs,
- Addieren der berechneten Leistungswerte von der ersten Frequenzebene des zweiten Frequenzbereichs zu der niedrigeren Frequenz des zweiten Frequenzbereichs hinunter, und Bestimmen, ob eine Summe der addierten berechneten Leistungswerte eine für den mindestens einen zweiten Lautsprecher (22) definierte Leistungsgrenze erreicht, und
- Bestimmen eines Frequenzwerts, der einem berechneten Leistungswert entspricht, bei dem die definierte Leistungsgrenze erreicht wird, als den zweiten Übergangsfrequenzwert (fx2).

3. Audiosignalverarbeitungsvorrichtung (10) nach einem der Ansprüche 1 bis 2, wobei das Bestimmen des zweiten Übergangsfrequenzwerts (fx2) umfasst

- Durchführen einer Analyse eines n-ten Oktavbands zum Berechnen mindestens eines Leistungswerts in einem entsprechenden von mehreren n-ten Oktavbändern des zweiten Frequenzbereichs des mindestens einen Audiosignals (50) von einem ersten n-ten Oktavband des zweiten Frequenzbereichs zu einem niedrigeren n-ten Oktavband des zweiten Frequenzbereichs,
- Addieren der entsprechenden berechneten Leistungswerte der n-ten Oktavbänder von dem ersten n-ten Oktavband des zweiten Frequenzbands zu dem niedrigeren n-ten Oktavband des zweiten Frequenzbands hinunter, und Bestimmen, ob eine Summe der addierten berechneten Leistungswerte eine für den mindestens einen zweiten Lautsprecher (22) definierte Leistungsgrenze erreicht, und
- Bestimmen eines niedrigsten der n-ten Oktavbänder, bei dem die Summe der addierten berechneten Leistungswerte die definierte Leistungsgrenze erreicht, und Bestimmen einer Frequenz des niedrigsten der n-ten Oktavbänder als den zweiten Übergangsfrequenzwert (fx2).

4. Audiosignalverarbeitungsvorrichtung (10) nach einem der Ansprüche 1 bis 3, wobei der Verarbeitungsabschnitt (30) dazu ausgelegt ist, eine erste und eine zweite Übergangsfrequenz (fxA1, fxA2) aus einem des ersten und des zweiten Übergangsfrequenzwerts (fx1, fx2) zu bestimmen, wobei die erste Übergangsfrequenz (fxA1) als ein Steuerwert an ein Tiefpassfilter (121) des Teilungsabschnitts (12) zum Erzeugen des ersten Signals (61) geliefert wird und die zweite Übergangsfrequenz (fxA2) als ein Steuerwert an ein Hochpassfilter (122) des Teilungsabschnitts (12) zum Erzeugen des zweiten Signals (62) geliefert wird.

5. Audiosignalverarbeitungsvorrichtung (10) nach einem der Ansprüche 1 bis 4, die ferner einen Speicherabschnitt (32) zum Speichern einer Tabelle von mehreren Übergangsfrequenzwerten (X, Y, Z) bei mehreren Lautstärkesteuersignalwerten umfasst, wobei der Verarbeitungsabschnitt (30) dazu ausgelegt ist, den ersten Übergangsfrequenzwert (fx1) gemäß einem der gespeicherten Übergangsfrequenzwerte (X, Y, Z) zu bestimmen.

6. Tonsystem (2), das eine Audiosignalverarbeitungsvorrichtung (10) nach einem der Ansprüche 1 bis 5 umfasst, die mit dem mindestens einen ersten und zweiten Lautsprecher (21A, 22A) gekoppelt ist.

7. Tonsystem (2) nach Anspruch 6, wobei der mindestens eine erste Lautsprecher (21A) mindestens einen Niedrigfrequenzlautsprecher umfasst und der mindestens eine zweite Lautsprecher (22A) mindestens einen Hochfrequenzlautsprecher umfasst.

8. Tonsystem (2) nach Anspruch 6 oder 7, wobei der mindestens eine erste Lautsprecher (21A) mindestens eines der folgenden umfasst: einen Mittellautsprecher, einen Subwoofer, einen Umgebungslautsprecher; und der mindestens eine zweite Lautsprecher (22A) mindestens einen Hochtonlautsprecher umfasst.

9. Fahrzeug (1), das eine Audiosignalverarbeitungsvorrichtung (10) nach einem der Ansprüche 1 bis 5 umfasst, die mit dem mindestens einen ersten und zweiten Lautsprecher (21A, 22A) gekoppelt ist.

10. Fahrzeug (1) nach Anspruch 9, wobei der mindestens eine erste Lautsprecher (21A) mindestens einen Niedrigfrequenzlautsprecher umfasst, der in dem Fahrzeug (1) an einer ersten Position installiert ist, und der mindestens eine zweite Lautsprecher (22A) mindestens einen Hochfrequenzlautsprecher umfasst, der in dem Fahrzeug (1) an einer zweiten Position installiert ist, die sich relativ zu einer Bodenebene (3) des Fahrzeugs höher als die erste Position befindet.

11. Fahrzeug (1) nach Anspruch 9 oder 10, wobei der mindestens eine zweite Lautsprecher (22A) mindestens einen eines Front-Lautsprechers und eines Tür-Lautsprechers des Fahrzeugs umfasst.

12. Signalverarbeitungsverfahren für ein Tonsystem (2), wobei das Verfahren die Schritte umfasst von:

- Empfangen mindestens eines Audiosignals (50),
- Erzeugen eines ersten Signals (61) und eines zweiten Signals (62) aus dem mindestens einen empfangenen Audiosignal (50), wobei das erste Signal (61) Signalkomponenten eines ersten Frequenzbereichs des mindestens einen Audiosignals umfasst und das zweite Signal (62) Signalkomponenten eines zweiten Frequenzbereichs des mindestens einen Audiosignals umfasst, wobei der erste Frequenzbereich niedrigere Frequenzen als der zweite Frequenzbereich umfasst und der erste und der zweite Frequenzbereich eine Übergangsfrequenz (fxA) aufweisen,
- Erzeugen eines ersten Ausgangssignals (71) für mindestens einen ersten Lautsprecher (21A) aus dem ersten Signal (61) und eines zweiten Ausgangssignals (72) für mindestens einen zweiten Lautsprecher (22A) aus dem zweiten Signal (62);
- Empfangen eines Laustärkesteuersignals (70), das eine Benutzerlautstärkeeingabe angibt und eine Lautstärke des ersten und des zweiten Ausgangssignals (71, 72) abhängig von der Benutzerlautstärkeeingabe steuert,
- **gekennzeichnet durch** das Bestimmen eines ersten Übergangsfrequenzwerts (fx1) gemäß dem Lautstärkesteuersignal (70) und das Bestimmen eines zweiten Übergangsfrequenzwerts (fx2), wobei das Bestimmen des zweiten Übergangsfrequenzwerts (fx2) eine Berechnung von mindestens einem Leistungswert von Signalkomponenten über mindestens ein Frequenzband des mindestens einen Audiosignals (50) umfasst, und
- Bestimmen der Übergangsfrequenz (fxA) als den ersten Übergangsfrequenzwert (fx1), wenn der erste Übergangsfrequenzwert (fx1) größer als der zweite Übergangsfrequenzwert (fx2) ist, und als den zweiten Übergangsfrequenzwert (fx2), wenn der zweite Übergangsfrequenzwert (fx2) größer als der erste Übergangsfrequenzwert (fx1) ist.

Revendications

1. Appareil de traitement de signaux audio (10) comprenant :

- une partie (11) destinée à l'entrée d'un signal, par laquelle, en état de marche, au moins un signal audio (50) est reçu ;
- une partie (12) destinée à une séparation, couplée à la partie (11) destinée à l'entrée du signal et configurée pour générer un premier signal (61) et un deuxième signal (62) à partir dudit au moins un signal audio reçu (50) ; dans lequel le premier signal (61) comprend des composantes de signal d'une première plage de fréquences dudit au moins un signal audio et le deuxième signal (62) comprend des composantes de signal d'une deuxième plage de fréquences dudit au moins un signal audio, la première plage de fréquences comprenant des fréquences inférieures à celles de la deuxième plage de fréquences, et la première et la deuxième plage de fréquences possédant une fréquence de croisement (fxA) ;
- une première partie (41) faisant office de sortie couplée à la partie (12) destinée à une séparation et conçue pour générer un premier signal de sortie (71) pour au moins un premier haut-parleur (21A) à partir du premier signal (61) ;
- une deuxième partie (42) faisant office de sortie couplée à la partie (12) destinée à une séparation et conçue pour générer un deuxième signal de sortie (72) pour au moins un deuxième haut-parleur (22A) à partir du deuxième signal (62) ;
- une partie (30) destinée à un traitement, couplée à la partie (11) destinée à l'entrée d'un signal et qui reçoit un signal de réglage du volume (70) qui témoigne d'une entrée de volume de la part de l'utilisateur et qui règle un volume du premier et du deuxième signal de sortie (71, 72) en fonction de l'entrée de volume de la part de l'utilisateur ;
- **caractérisé en ce que** la partie (30) destinée à un traitement est configurée pour déterminer une première valeur de fréquence de croisement (fx1) en fonction du signal de réglage du volume (70) et pour déterminer une deuxième valeur de fréquence de croisement (fx2) ; dans lequel la détermination de la deuxième valeur de fréquence de croisement (fx2) comprend un calcul d'au moins une valeur de puissance des composantes du signal sur au moins une bande de fréquences dudit au moins un signal audio (5) ;
- dans lequel la partie (30) destinée à un traitement est configurée pour déterminer la fréquence de croisement (fxA) au titre de la première valeur de fréquence de croisement (fx1) lorsque la première valeur de fréquence de croisement (fx1) est supérieure à la deuxième valeur de fréquence de croisement (fx2) et au titre de la deuxième valeur de fréquence de croisement (fx2) lorsque la deuxième valeur de fréquence de croisement (fx2) est supérieure à la première valeur de fréquence de croisement (fx1).

2. Appareil de traitement de signaux audio (10) selon la revendication 1, dans lequel la détermination de la deuxième valeur de fréquence de croisement (fx2) comprend le fait de :

- calculer des valeurs de puissance des composantes de signaux dudit au moins un signal audio (50) le long d'au moins une bande de fréquences à partir d'un premier niveau de fréquence de la deuxième plage de fréquences jusqu'à une fréquence inférieure de la deuxième plage de fréquences ;
- additionner les valeurs de puissance calculées à partir du premier niveau de fréquence de la deuxième plage de fréquences jusqu'à la fréquence inférieure de la deuxième plage de fréquences ; et déterminer le fait de savoir si une somme des valeurs de puissance calculées additionnées atteint une limite de puissance définie pour ledit au moins un deuxième haut-parleur (22), et ;
- déterminer une valeur de fréquence qui correspond à une valeur de puissance calculée à laquelle la limite de puissance définie est atteinte, au titre de la deuxième valeur de fréquence de croisement (fx2).

3. Appareil de traitement de signaux audio (10) selon l'une quelconque des revendications 1 à 2, dans lequel la détermination de la deuxième valeur de fréquence de croisement (fx2) comprend le fait de :

- mettre en œuvre une analyse d'une bande de n-ième d'octave dans le but de calculer au moins une valeur de puissance dans une bande respective parmi une multitude de bandes de n-ième d'octave de la deuxième plage de fréquences dudit au moins un signal audio (50) à partir d'une première bande de n-ième d'octave de la deuxième plage de fréquences jusqu'à une bande de n-ième d'octave inférieure de la deuxième plage de fréquences ;
- additionner les valeurs de puissance calculées respectives des bandes de n-ième d'octave à partir de la première bande de n-ième d'octave de la deuxième plage de fréquences jusqu'à la bande de n-ième d'octave inférieure de la deuxième plage de fréquences ; et déterminer le fait de savoir si une somme des valeurs de puissance calculées additionnées atteint une limite de puissance définie pour ledit au moins un deuxième haut-parleur (22) ; et
- déterminer une bande la plus basse parmi les bandes de n-ième d'octave à laquelle la somme des valeurs de puissance calculées additionnées atteint la limite de puissance définie ; et déterminer une fréquence de la bande la plus basse parmi les bandes de n-ième d'octave au titre de la deuxième valeur de fréquence de croisement (fx2).

4. Appareil de traitement de signaux audio (10) selon l'une quelconque des revendications 1 à 3, dans lequel la partie (30) destinée à un traitement est configurée pour déterminer une première et une deuxième fréquence de croisement (fxA1, fxA2) à partir d'une valeur choisie parmi la première et la deuxième valeur de fréquence de croisement (fx1, fx2) ; dans lequel la première fréquence de croisement (fxA1) est fournie sous la forme d'une valeur de commande à un filtre passe bas (121) de la partie (12) destinée à une séparation pour la génération du premier signal (61) et la deuxième fréquence de croisement (fxA2) est fournie sous la forme d'une valeur de commande à un filtre passe haut (122) de la partie (12) destinée à une séparation pour la génération du deuxième signal (62).

5. Appareil de traitement de signaux audio (10) selon l'une quelconque des revendications 1 à 4, comprenant en outre une partie (32) réservée au stockage, destinée à la mise en mémoire d'une table de multiples valeurs de fréquences de croisement (X, Y, Z) à de multiples valeurs de signaux de réglage du volume ; dans lequel la partie (30) destinée au traitement est configurée pour déterminer la première valeur de fréquence de croisement (fx1) en fonction d'une des valeurs de fréquences de croisement mises en mémoire (X, Y, Z).

6. Système acoustique (2) comprenant un appareil de traitement de signaux audio (10) selon l'une quelconque des revendications 1 à 5, couplé auxdits au moins un premier et un deuxième haut-parleur (21A, 22A).

7. Système acoustique (2) selon la revendication 6, dans lequel ledit au moins un premier haut-parleur (21A) comprend au moins un haut-parleur pour les basses fréquences et ledit au moins un deuxième haut-parleur (22A) comprend au moins un haut-parleur pour les hautes fréquences.

8. Système acoustique (2) selon la revendication 6 ou 7, dans lequel ledit au moins un premier haut-parleur (21A) comprend au moins un élément choisi parmi : un haut-parleur central, un haut-parleur d'extrêmes graves, un haut-parleur d'ambiance, et ledit au moins un deuxième haut-parleur (22A) comprend au moins un haut-parleur d'aigus.

9. Véhicule (1) comprenant un appareil de traitement de signaux audio (10) selon l'une quelconque des revendications 1 à 5, couplé auxdits au moins un premier et un deuxième haut-parleur (21A, 22A).

10. Véhicule (1) selon la revendication 9, dans lequel ledit au moins un premier haut-parleur (21A) comprend au moins un haut-parleur pour les basses fréquences qui est monté dans le véhicule (1) à un premier endroit, et ledit au moins un deuxième haut-parleur (22A) comprend au moins un haut-parleur pour les hautes fréquences qui est monté dans le véhicule (1) à un deuxième endroit qui est situé à une hauteur supérieure à celle du premier endroit par rapport à un plan de plancher (3) du véhicule.

11. Véhicule (1) selon la revendication 9 ou 10, dans lequel ledit au moins un deuxième haut-parleur (22A) comprend au moins un haut-parleur choisi parmi un haut-parleur avant et un haut-parleur à installer dans une portière du véhicule.

12. Procédé de traitement de signaux destiné à un système acoustique (2), le procédé comprenant les étapes qui comprennent :

- la réception d'au moins un signal audio (50) ;
- la génération d'un premier signal (61) et d'un deuxième signal (62) à partir dudit au moins un signal audio reçu (50) ; dans lequel le premier signal (61) comprend des composantes de signal d'une première plage fréquences dudit au moins un signal audio et le deuxième signal (62) comprend des composantes de signal d'une deuxième plage de fréquences dudit au moins un signal audio, la première plage de fréquences comprenant des fréquences inférieures à celles de la deuxième plage de fréquences et la première et la deuxième plage de fréquences possédant une fréquence de croisement (fxA) ;
- la génération d'un premier signal de sortie (71) pour au moins un premier haut-parleur (21A) à partir du premier signal (61) et d'un deuxième signal de sortie (72) pour au moins un deuxième haut-parleur (22B) à partir du deuxième signal (62) ;
- la réception d'un signal de réglage du volume (70) qui témoigne d'une entrée de volume de la part d'un utilisateur et qui règle un volume du premier et du deuxième signal de sortie (71, 72) en fonction de l'entrée de volume de la part de l'utilisateur ;
- **caractérisé par** le fait de déterminer une première valeur de fréquence de croisement (fx1) en fonction du signal de réglage du volume (70) et pour déterminer une deuxième valeur de fréquence de croisement (fx2) ; dans lequel la détermination de la deuxième valeur de fréquence de croisement (fx2) comprend un calcul d'au moins une valeur de puissance des composantes du signal sur au moins une bande de fréquences dudit au moins un signal audio (50) ; et
- le fait de déterminer la fréquence de croisement (fxA) au titre de la première valeur de fréquence de croisement (fx1) lorsque la première valeur de fréquence de croisement (fx1) est supérieure à la deuxième valeur de fréquence de croisement (fx2) et au titre de la deuxième valeur de fréquence de croisement (fx2) lorsque la deuxième valeur de fréquence de croisement (fx2) est supérieure à la première valeur de fréquence de croisement (fx1).

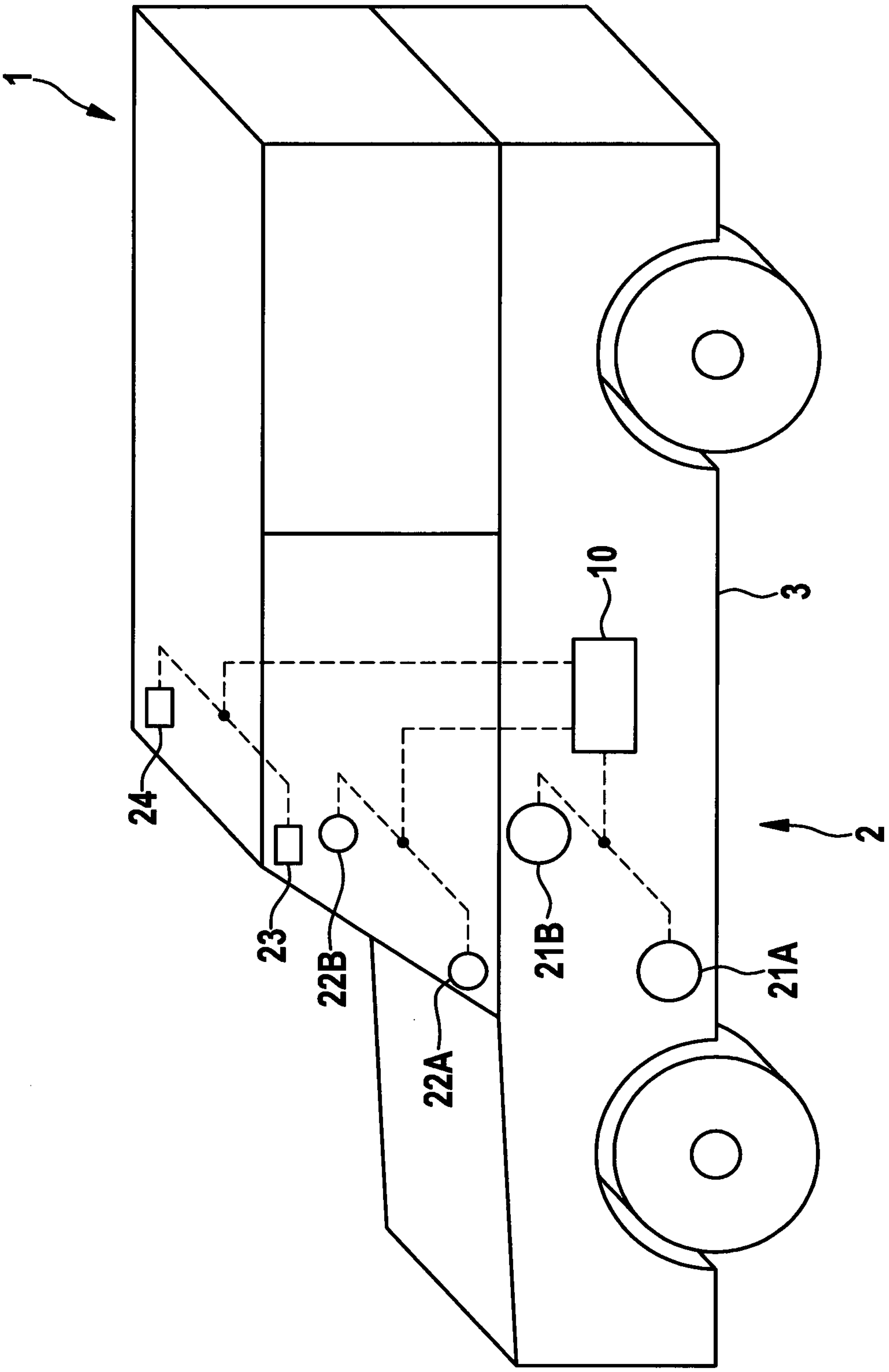
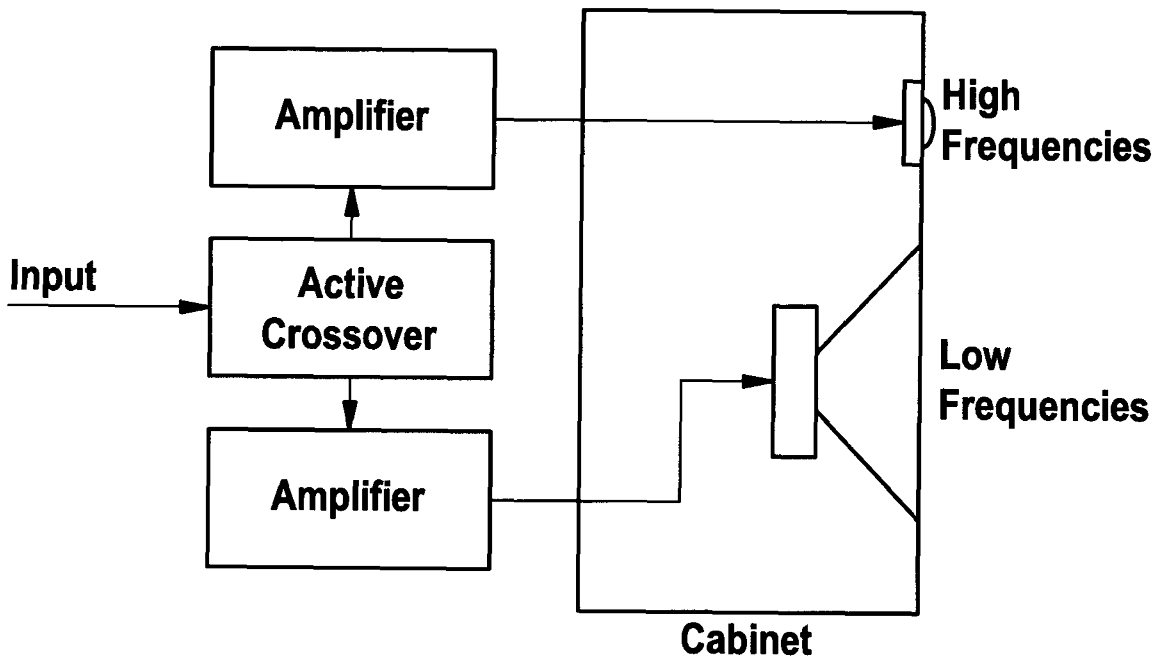


Fig. 1


Amplifier
Input
Active Crossover
Amplifier
High Frequencies
Low Frequencies
Cabinet

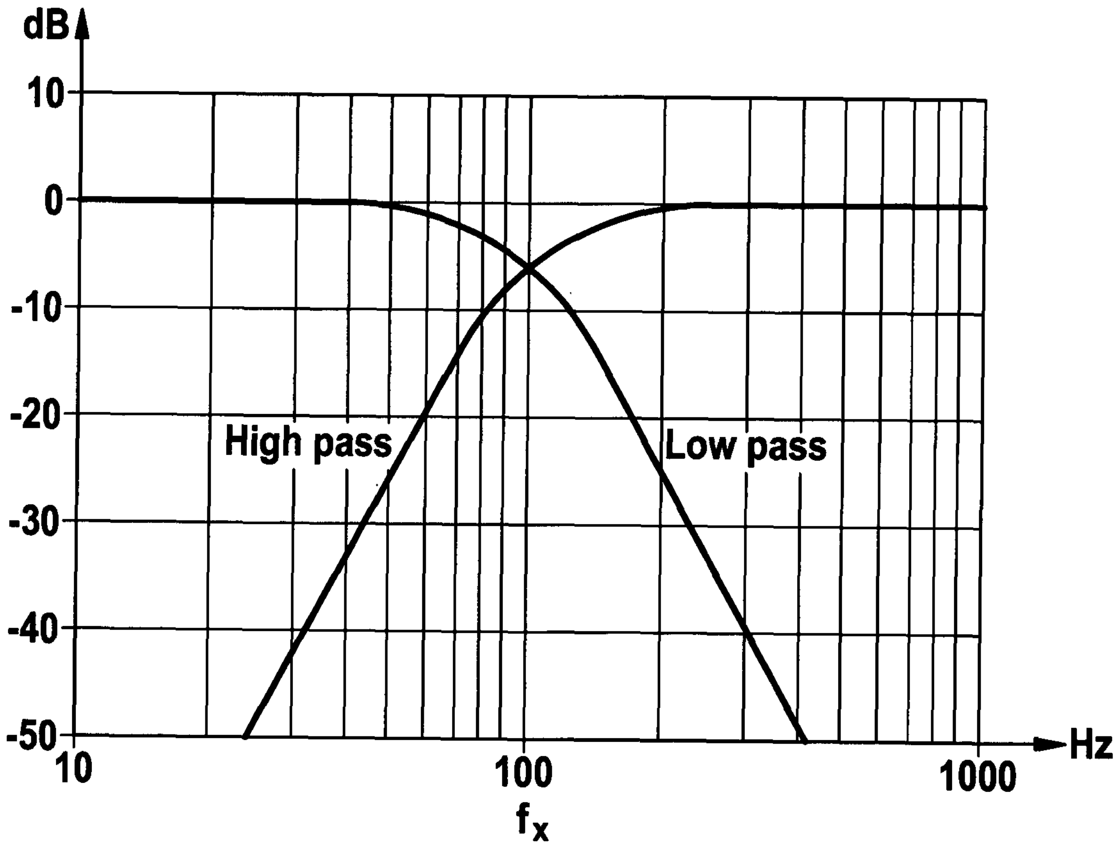

dB
10
0
-10
-20
-30
-40
-50
High pass
Low pass
10
100
1000
Hz
f_x

Fig. 2

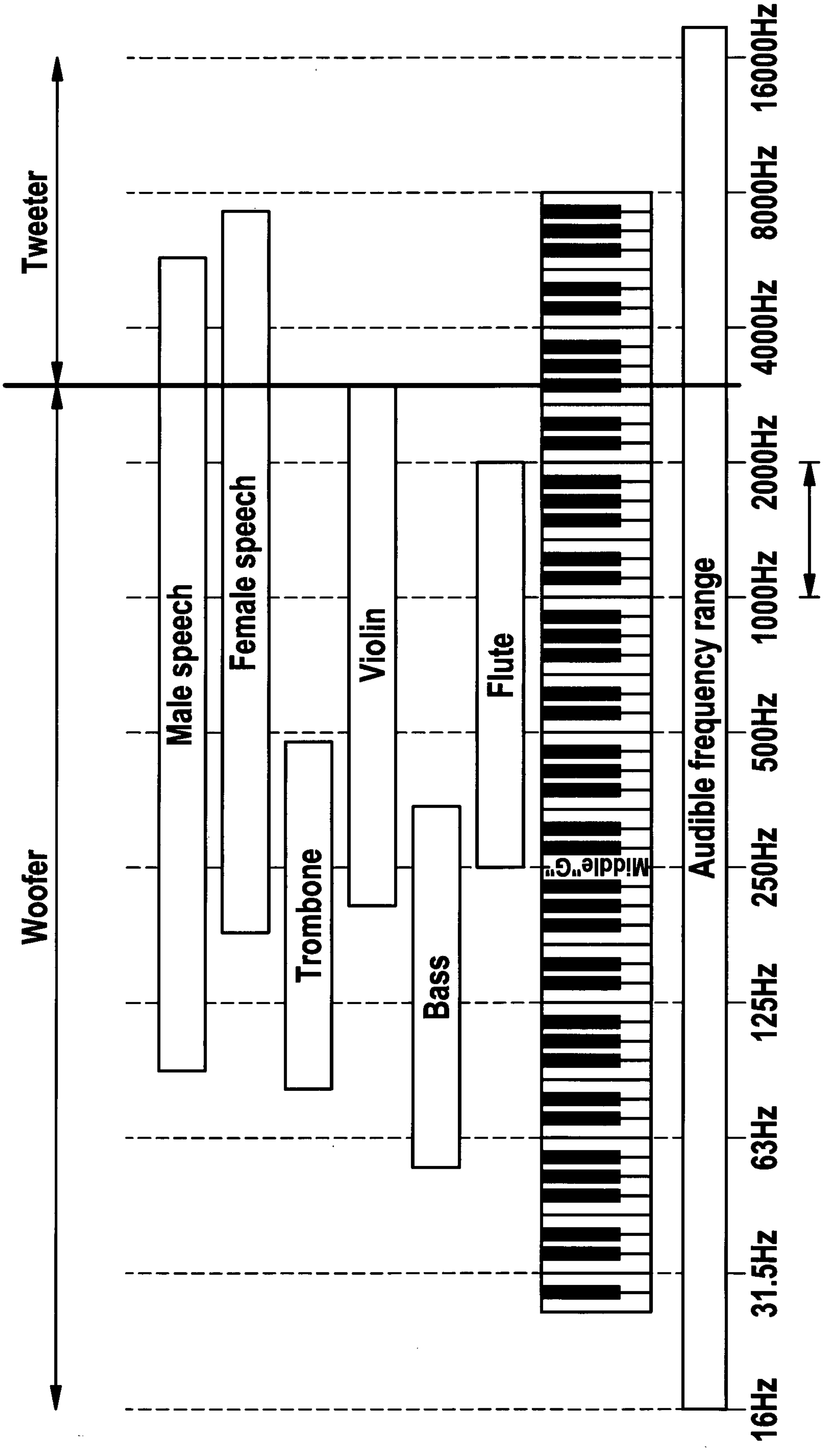

Tweeter
Woofer
Male speech
Female speech
Trombone
Violin
Bass
Flute
Middle"C"
Audible frequency range
1 octave
16Hz
31.5Hz
63Hz
125Hz
250Hz
500Hz
1000Hz
2000Hz
4000Hz
8000Hz
16000Hz

Fig. 3

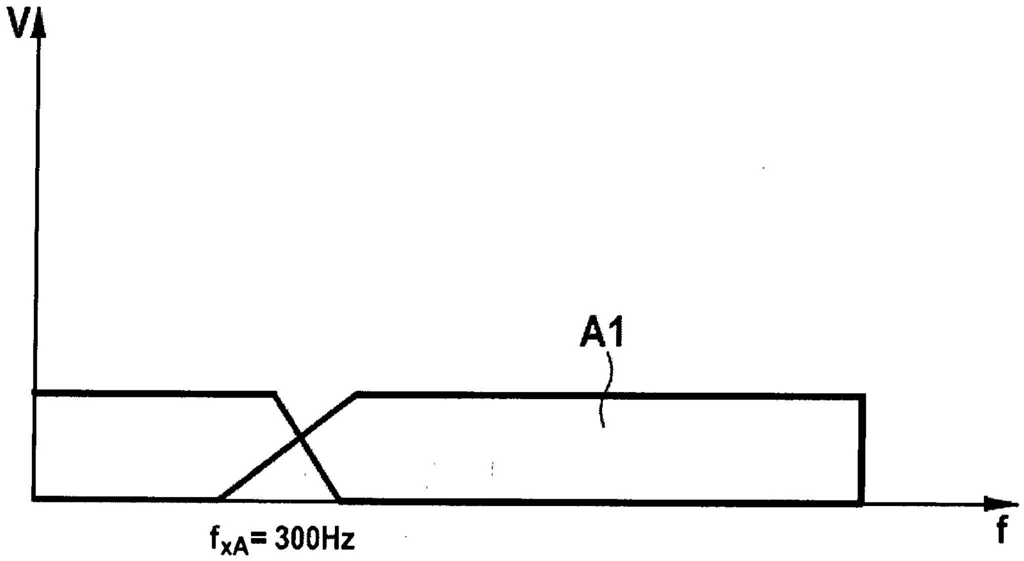


Fig. 4A

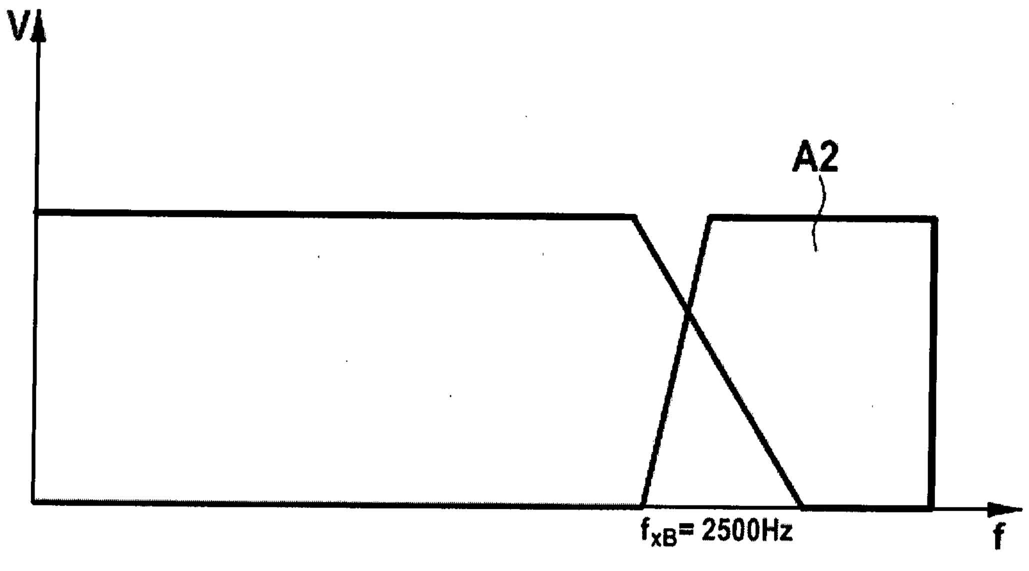


Fig. 4B

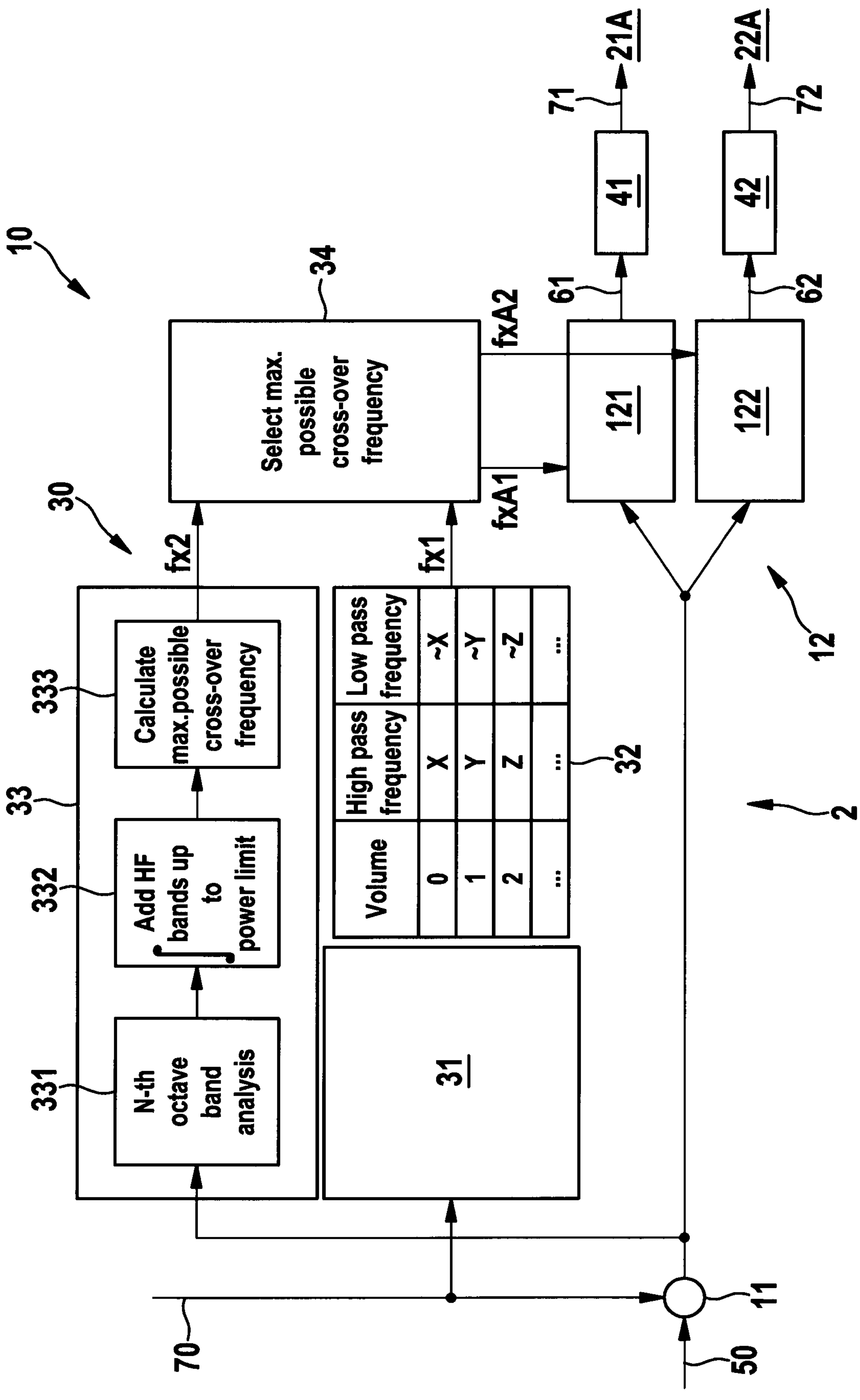

10
30
34
Select max. possible cross-over frequency
fx2
fx1
fxA1
fxA2
121
122
61
62
41
42
71
72
21A
22A
33
331
N-th octave band analysis
332
Add HF bands up to power limit
333
Calculate max.possible cross-over frequency
31
32
Volume
High pass frequency
Low pass frequency
0
X
~X
1
Y
~Y
2
Z
~Z
...
...
...
12
2
11
50
70

Fig. 5

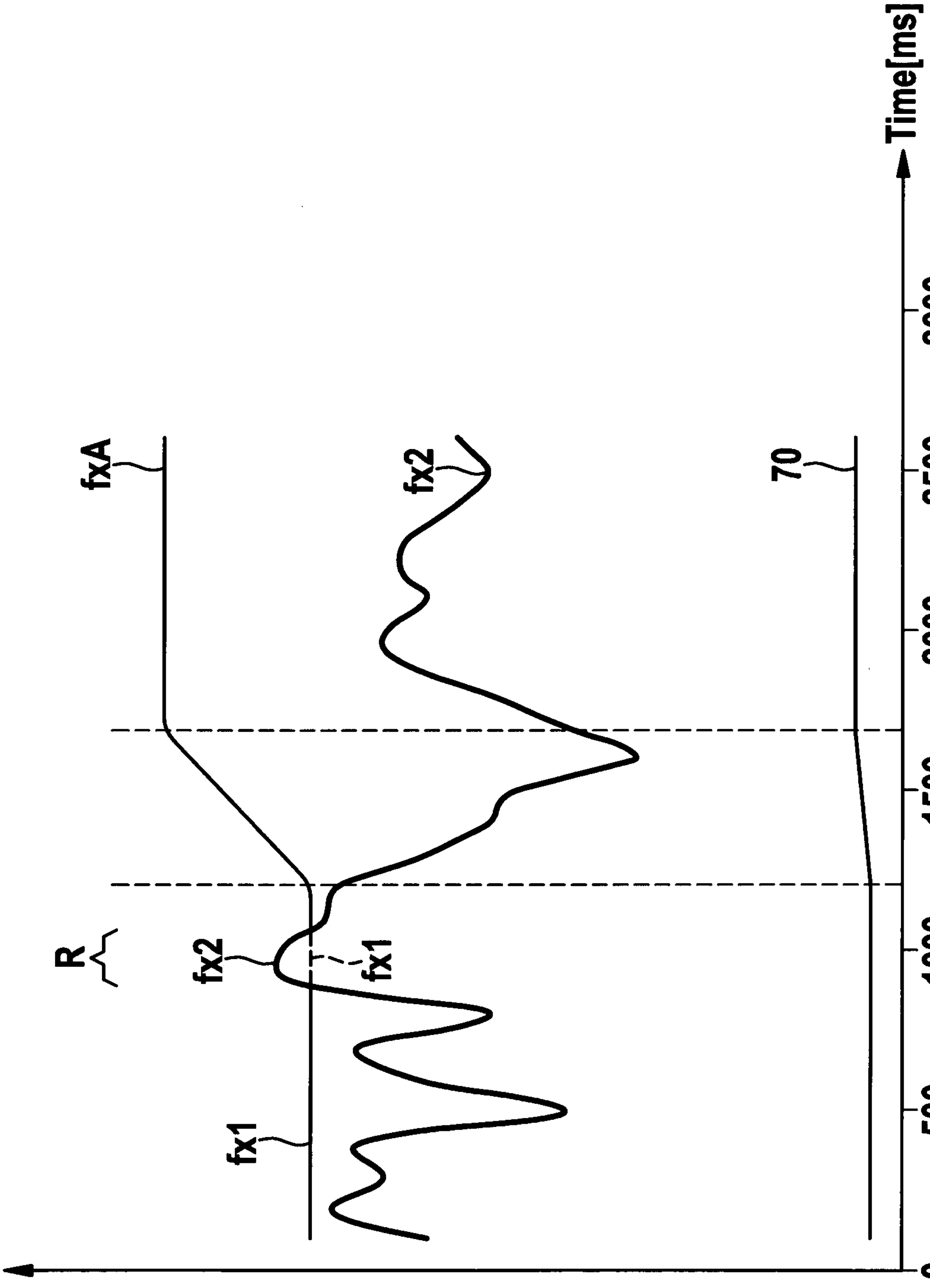


Fig. 6

REFERENCES CITED IN THE DESCRIPTION

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- JP 8033093 A **[0006]**
- US 20140093096 A1 **[0012]**
- GB 2181626 A **[0013]**