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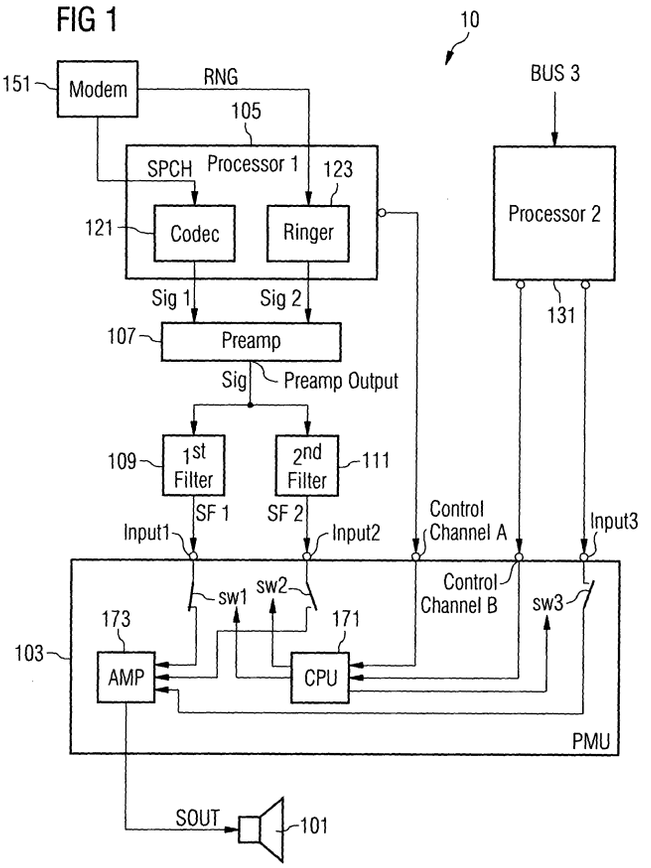
Amended claims in accordance with Rule 86 (2) EPC.

(54) Speaker driving circuit and mobile terminal

(57) A speaker driving circuit (10) for processing an audio signal (SOUT) to be outputted by a loudspeaker (101) having a resonance frequency comprises means (107) for receiving a signal from a signal source (121, 123); a band-pass filter (109) and a high-pass filter (111) for filtering the signal received to a first and a second filtered signal, whereby the band-pass filter (109) has a lower cut-off frequency at or lower than the resonance frequency of the loudspeaker, and the high-pass filter (111) has a cut-off frequency higher than the resonance frequency of the loudspeaker; and means (105) for selecting the first or the second filtered signal for amplifying the filtered signal or for selecting the band-pass filter (109) or the high-pass filter (111).

FIG 1



EP 1 499 157 A1

Description

[0001] Most modern portable electronic devices have relatively small physical dimensions in order to facilitate portability. A perfect example of such a portable electronic device is a mobile terminal, such as a mobile phone which has during the past decade become smaller than ever.

[0002] One consequence of the relatively small size of the devices is that there is much less space available in the device, for example, for the loudspeaker, than in the past.

[0003] The size of the vibrating membrane and properties of other components build up the acoustical characteristics of a loudspeaker. As discussed in German patent application DE 195 48 149 A1, lower frequency tones cause larger membrane movements than tones of higher frequency. Depending on the sound pressure that would be obtained, an overload may even damage the loudspeaker. A solution proposed in DE 195 48 149 A1 is that the loudpeaker is equipped with a high-pass filter, because the vibrations in the membrane are larger at lower frequencies. Similar approach has been presented in EP 1 135 002 A2, where high-pass filtering is used when the volume level exceeds a medium level.

[0004] A problem of using a simple high-pass filter is its adverse effect on the sound quality.

It is an objective of the present invention to bring about a speaker driving circuit, by using which it is possible to output audio signals where the part of the signal spectrum including the resonance frequency of the loudspeaker are either attenuated or not. This can be achieved by using the speaker driving circuit as described in independent patent claim 1. An advantage of such a speaker driving circuit is that some signal types can then be played back by using a higher volume without damaging the loudspeaker than would be possible without the speaker driving circuit.

[0005] Another objective of the present invention is to bring about a mobile terminal comprising such a speaker driving circuit. An advantage of such a mobile terminal is that then in the mobile terminal it is possible to filter the signal to be feed to the loudspeaker in different manners, i.e. to reduce the signal component including frequencies at the resonance frequency of the loudspeaker of the mobile terminal.

[0006] An aspect of the present invention is to use a high-pass filter before outputting a signal representing a ringing tone by a loudspeaker. The high-pass filter has a cut-off frequency at or above a resonance frequency of the loudspeaker. The advantage of such a solution is that the damaging of the loudspeaker can be avoided, and nevertheless the ringing tone can be output with a relatively high volume.

[0007] A further objective of the present invention is to enable the using of some ringing tones without damaging the loudspeaker. This can be achieved by using a high-pass filter before outputting a signal representing a ringing tone by a loudspeaker as descibed in independent patent claim 7.

[0008] Dependent claims describe various embodiments of the present invention.

[0009] In the following, the invention and its preferred embodiments are disclosed in more detail by referring to the examples shown in the accompanying drawings 1 to 4, of which:

Figure 1 shows a speaker driving circuit according to the present invention;

Figure 2 illustrates in more detail the band-pass filter and the high-pass filter;

Figure 3 shows the resulting frequency response of the speaker driving circuit when the band-pass filter is used; and

Figure 4 shows the resulting frequency response of the speaker driving circuit when the high-pass filter is used.

[0010] Figure 1 shows a speaker driving circuit 10 according to the present invention. The speaker driving circuit 10 includes a band-pass filter 109 and a high-pass filter 111. The band-pass filter 109 has cut-off frequencies outside GSM voice band, i.e. at 300 Hz and at 3.4 kHz, and it is mostly used in order to attenuate out-of-band noise caused by the audio front end 103.

[0011] The audio front end 103 includes an amplifier 173 and three inputs (INPUT1, INPUT2, INPUT3). Further there are a first and a second control channel (CONTROL CHANNEL A, CONTROL CHANNEL B) which are used to give input to a central processing unit CPU 171 of the audio front end 103. The CPU 171 operates then responsively to signal obtained through CONTROL CHANNEL A and B three switches SW1, SW2, SW3 used in selecting which INPUT1, INPUT2, and INPUT3 is used for amplifying.

[0012] The output of the amplifier 173 is then connected to a loudspeaker 101 for the reproduction of an audible sound.

[0013] Typically, for a mobile terminal, speech information SPCH is received via a radio modem 151. The modem 151 passes the speech information SPCH received to a processor unit 105. The speech information SPCH is usually coded using some coding, mostly for bandwidth efficiency and error recovery purposes. The speech information SPCH has then to be decoded in a codec 121 which corresponds to a soft- or hard-coded algorithm for obtaining a suitable sampling which can be used for speech reproduction. This signal SIG1 which will be used for speech reproduction will be outputted from the codec 121 to a preamplifier 107.

[0014] If there is a mobile terminating call coming, the mobile network under which the mobile terminal is roaming starts paging the mobile terminal. The mobile termi-

nal then receives a paging signal RNG via the same radio modem 151. This is handled in the processor 105 in a similar manner as the speech information SPCH but instead of passing the paging signal RNG to a codec 121 it activates a ringer 123. The ringer 123 gives a signal SIG2 representing ringing tone which is then further passed to the preamplifier 107.

[0015] The signal SIG2 representing a ringing tone is preferably a signal having a substantially square waveform in the time-voltage space. This corresponds to connecting the output of a voltage source on and off for a short period in the manner usually done in a buzzer. Also other signal forms for the signal SIG2 representing a ringing tone can be used.

[0016] The preamplifier 107 gives from its output (PREAMP OUTPUT) a preamplified signal SIG. Typically, for a mobile terminal there will be generated no signal SIG2 representing a ringing tone when there is an ongoing call so that speech information SIG1 is fed to the preamplifier 107.

[0017] According to one aspect of the present invention, the preamplified signal SIG is passed to the band-pass filter 109 and to the high-pass filter 111. The band-pass filter 109 is connected to a first input INPUT1 and the second high-pass filter is connected to a second input INPUT2 of the audio front end 103. The signal SF1 received from the band-pass filter 109 is different from the signal SF2 received from the high-pass filter 111 in the sense that because now the cut-off frequency of the high-pass filter 111 is above the resonance frequency of the loudspeaker 101.

[0018] The main purpose of the high-pass filter 111 is to remove the lowest frequency part of the signal. This is particularly advantageous when the signal to be amplified in the amplifier 173 is such a signal as the signal SIG2 representing a ringing tone, especially when the ringing tone is created by a buzzer or has otherwise a substantially square waveform in time-voltage space.

[0019] The lowest frequency part carries most energy of the signal. Further, it causes the membrane of the loudspeaker 101 to vibrate too much therefore possibly damaging the loudspeaker especially when the ringer volume is high.

[0020] One reason for the listener'not observing the deterioration of the sound quality can be explained by the results of psychoacoustic theory, also known from the example of the missing fundamental, which was observed by Harvey Fletcher already in 1924. For a sound with harmonic partials to be heard as a musical tone, its spectrum must include three successive harmonics of a common frequency. The pitch is given by that common frequency, whether or not it is present in the musical tone. (Reference on page 58 in Music, cognition, and computerized sounds: an introduction to psychoacoustics, editor Perry R. Cook, ISBN 0-262-03256-2).

[0021] Because the interval relationship of the upper harmonic remains the same regardless of the high-pass filter 111, the tone can still be perceived as having the original pitch.

[0022] In the example of Figure 1 audio front end 103 comprises the switches SW1, SW2 and SW3 used to select the correct input. However, according to another aspect of the present invention, instead of selecting between filtered signals SF1, SF2, i.e. selecting after the band-pass filter 109 and high-pass filter 111, a selection can be made earlier in the signal path. In other words, one can select between the filters 109 and 111.

[0023] In both embodiments, the selection can be made based on the signal type or class. For example, all ringing tones or signals from a specific signal source, such as an FM radio, are all led to the high-pass filter 111 whereas all other signals are led to the band-pass filter 109. Also such a solution where a digital sound processing apparatus is used, based on the low-frequency content of the signal (such as SIG1) the selecting means (SW1, SW2) are operated to select the most suitable high-pass filter.

[0024] The selection can also be made responsively to the state of the portable electronic device. Examples of such states are "ongoing call", and "paging".

[0025] Figure 2 illustrates the band-pass filter 109 and the high-pass filter 111. Both filters 109, 111 are connected to the preamplifier 107 output.

[0026] The band-pass filter 109 is made up by a high-pass filter and a low-pass filter and has resistors R_1, R_5 and R_6, and capacitances C_1, C_2, C_3 and C_4 for selecting the cut-off frequency.

[0027] The high-pass filter 111 has a higher cut-off frequency than the band-pass filter 109. The cut-off frequency is higher than the resonance frequency of the loudspeaker. The high-pass filter 111 comprises resistors R_2, R_3, and R_4, and capacitances C_5 and C_6. Possible values for a loudspeaker 101 (type = SK MS605) used in one mobile terminal model can easily be calculated. A person skilled in the art understands how to modify these values if the loudspeaker 101 is changed to another one.

[0028] Figure 3 shows the resulting frequency response of the speaker driving circuit 10 when the band-pass filter 109 is used; and Figure 4 shows the resulting frequency response of the speaker driving circuit 10 when the high-pass filter 111 is used. One sees readily the effect of the high-pass filtering performed by the high-pass filter 111: the lower part of the voice band of GSM which in Figure 3 was more or less linear is now highly attenuated.

[0029] The band-pass filter 109 and the high-pass filter 111 can be implemented as a digital filter as well. In this case the filtering will most conveniently be performed in the processor unit 105.

[0030] Although the invention has been described above with reference to the examples shown in the appended drawings, it is obvious that the invention is not limited to these but may be modified by those skilled in the art without difference from the scope and the spirit of the invention. Instead of having a GSM terminal, a

CDMA, WCDMA, GPRS, UMTS or any other suitable mobile terminal can be used. In addition to mobile terminals, the invention can be included in any other portable electronic device, such as a portable radio, CD- or MP3 player.

Claims

1. A speaker driving circuit (10) for processing an audio signal (SOUT) to be outputted by a loudspeaker (101) having a resonance frequency, **comprising:**

   - means (107) for receiving a signal from a signal source (121, 123);
   - a band-pass filter (109) and a high-pass filter (111) for filtering the signal received to a first and a second filtered signal, whereby the band-pass filter (109) has a lower cut-off frequency at or lower than the resonance frequency of the loudspeaker, and the high-pass filter (111) has a cut-off frequency higher than the resonance frequency of the loudspeaker; and
   - means (105) for selecting the first or the second filtered signal for amplifying the filtered signal or for selecting the band-pass filter (109) or the high-pass filter (111).

2. A speaker driving circuit (10) of claim 1, **wherein:** said means (105) for selecting the first or the second filtered signal for amplifying the filtered signal or for selecting the band-pass filter (109) or the high-pass filter (111) are adapted to select the first filtered signal for a signal from a first signal source (121) and the second filtered signal for a signal from a second signal source (123).

3. A speaker driving circuit (10) of claim 2, **wherein:** the first signal source (121) is a voice codec and the second signal source (123) is a ringing tone generator.

4. A speaker driving circuit (10) of claim 1, 2, or 3, **wherein:** said means (105) for selecting the first or the second filtered signal for amplifying the filtered signal or for selecting the band-pass filter (109) or the high-pass filter (111) are responsive to a type of the signal received from the signal source (121, 123).

5. A speaker driving circuit (10) of claim 4, **wherein:** at least one of said signal types include a ringing tone.

6. A speaker driving circuit (10) of claim 5, **wherein:** said ringing tone has a substantially square-like waveform in time-voltage space.

7. The use of a high-pass filter (111) before outputting a signal (SIG2) representing a ringing tone by a loudspeaker (101), **characterized in that:** said high-pass filter (111) has a cut-off frequency at or above a resonance frequency of the loudspeaker (101).

8. The use of a high-pass filter (111) according to claim 7, **wherein:** said high-pass filter causes an attenuation of over 3 dB at 300 Hz.

9. The use of a high-pass filter (111) according to claim 7 or 8, **wherein:** said signal (SIG2) has a substantially square waveform in time-voltage space.

10. A mobile terminal **comprising:** a speaker driving circuit (10) according to any one of the claims 1 to 6.

FIG 1

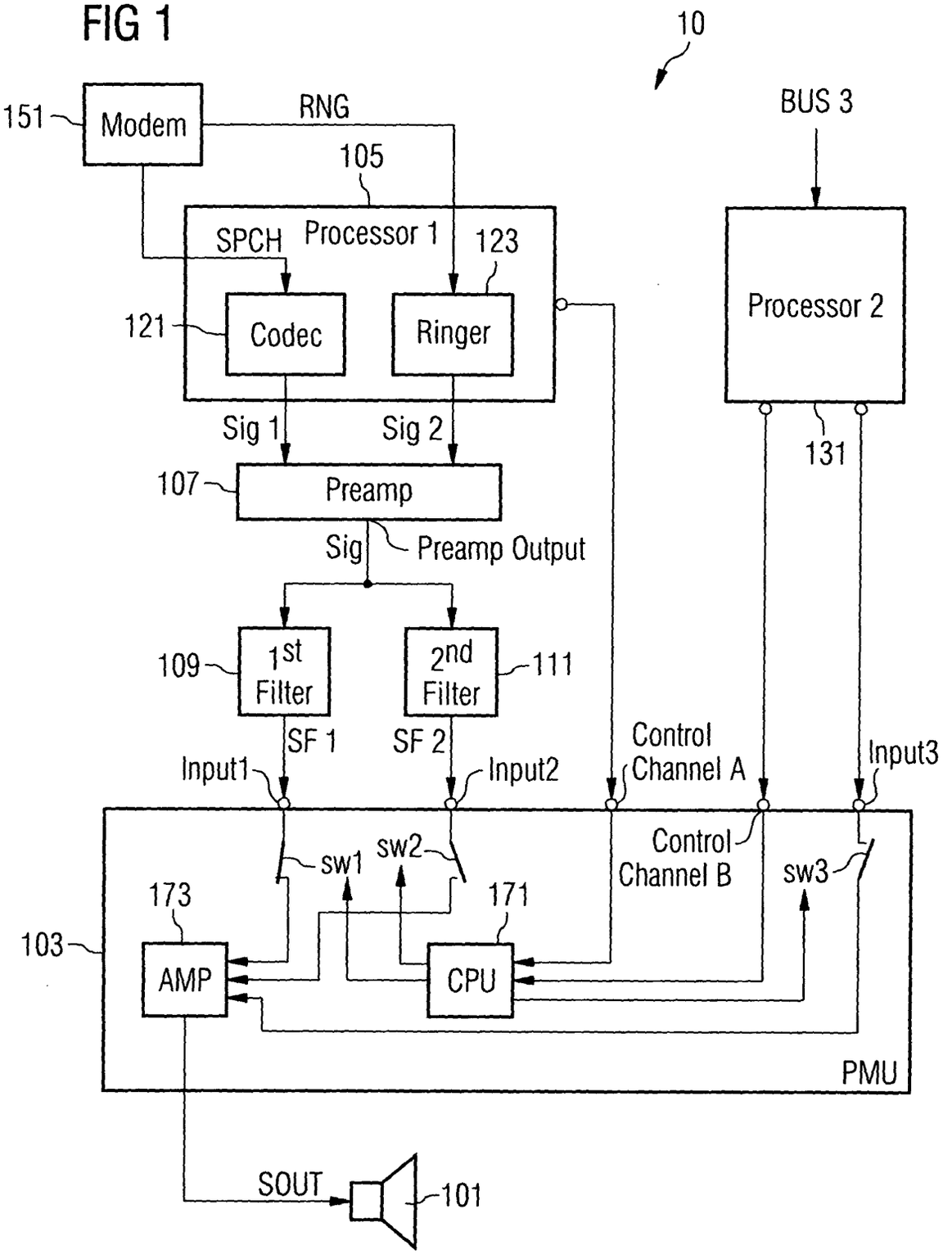

10
151
Modem
RNG
105
BUS 3
SPCH
Processor 1
123
Processor 2
121
Codec
Ringer
Sig 1
Sig 2
131
107
Preamp
Sig
Preamp Output
109
1st Filter
2nd Filter
111
SF 1
SF 2
Control Channel A
Input3
Input1
Input2
Control Channel B
sw1
sw2
sw3
173
171
103
AMP
CPU
PMU
SOUT
101

FIG 2

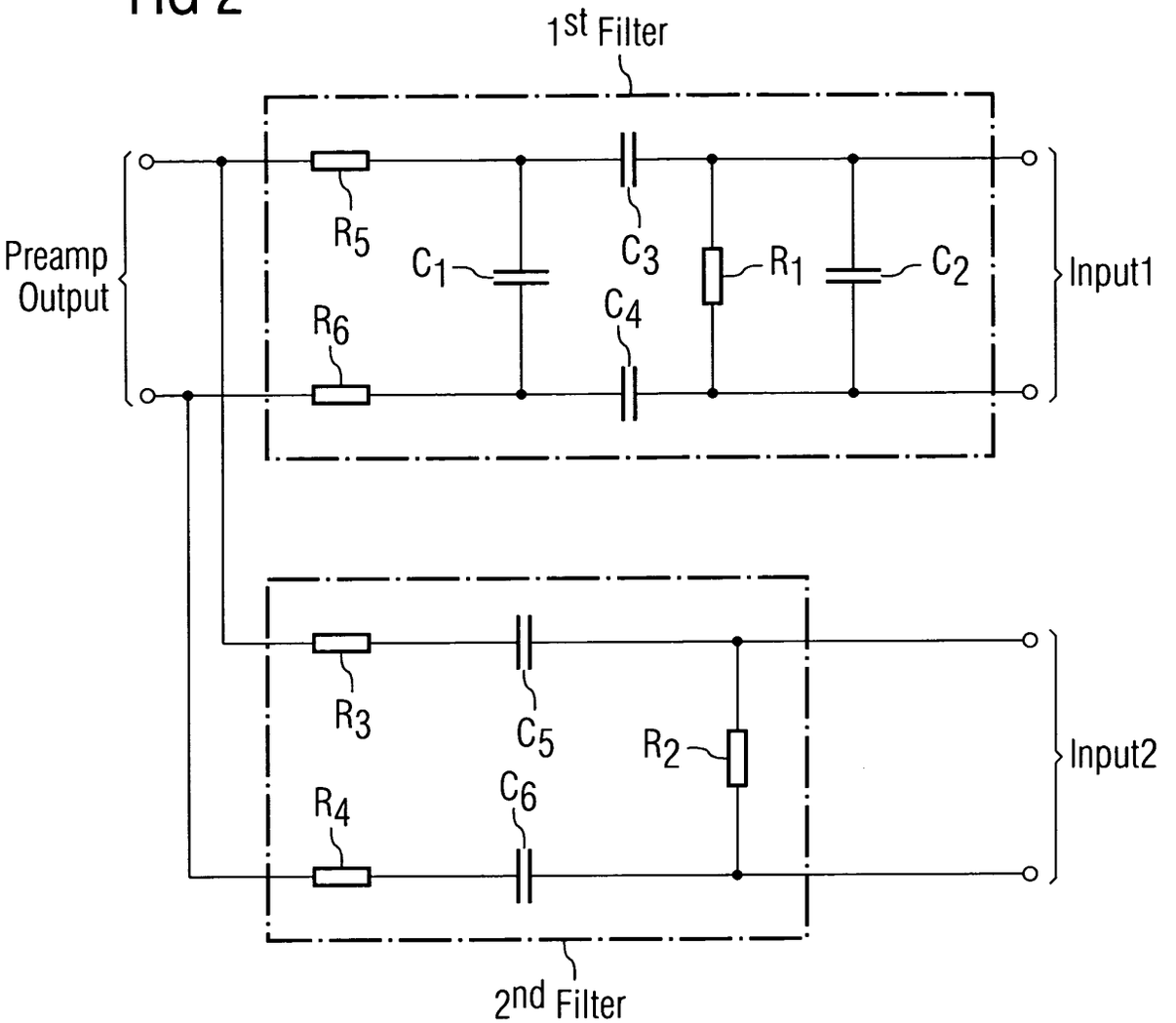
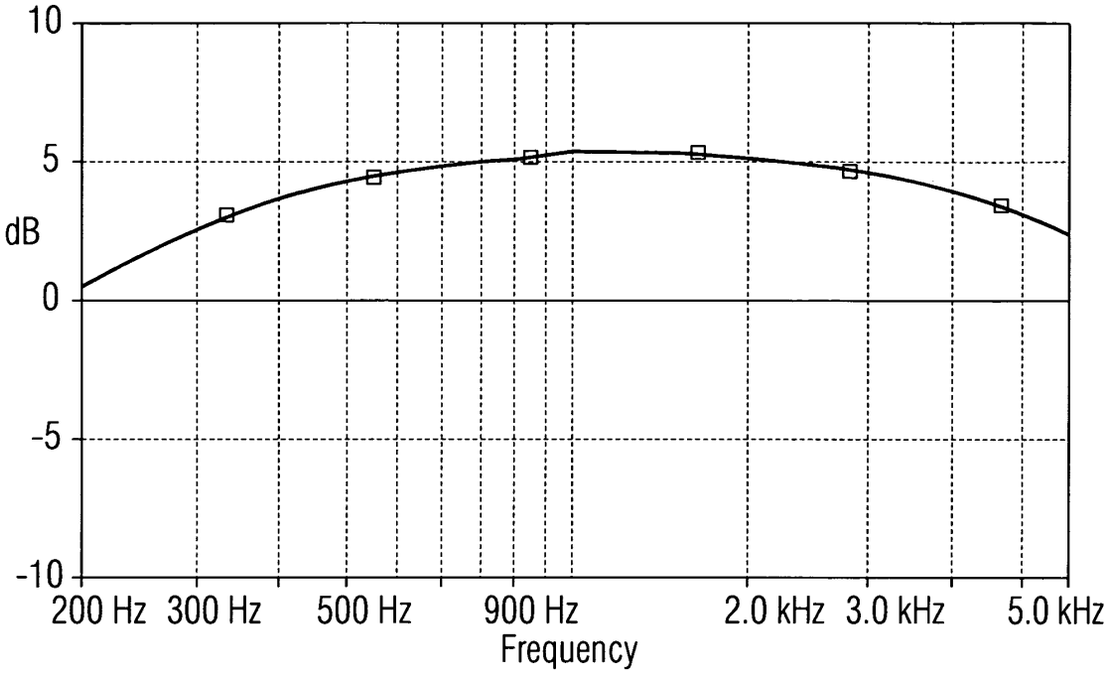
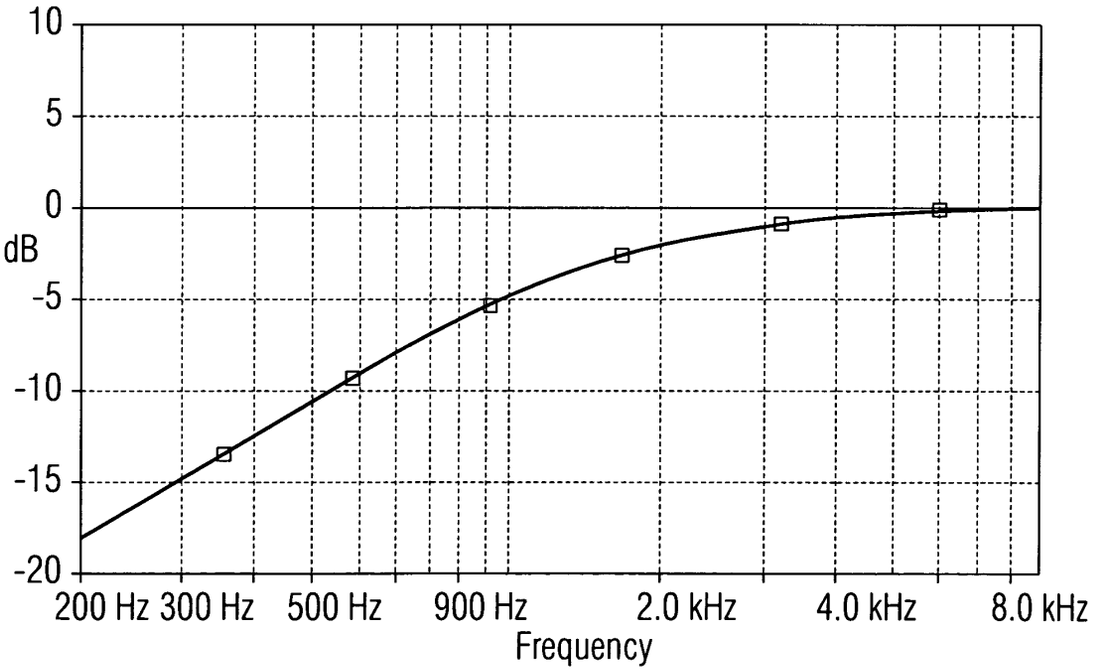

1st Filter
Preamp Output
R5
C1
C3
R1
C2
Input1
R6
C4
R3
C5
R2
Input2
R4
C6
2nd Filter

FIG 3



Simulation of the voice band filter to attenuate out-of-band noise (caused by the audio front and E-GOLD+V3).

FIG 4



Simulation of the HP-filter used to protect the speaker using square wave ringing tones.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 03 01 6331

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A	DE 42 27 601 C (SIEMENS AG) 10 July 1997 (1997-07-10) * abstract; figure 3 *	6,9	
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	14 April 2004	Gerken, S

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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