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PC SURROUND SOUND CIRCUIT

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 60/064,046 filed November 3, 1997, incorporated herein by reference.

BACKGROUND OF THE INVENTION

The present invention relates generally to a PC surround sound circuit, and more particularly to a circuit configured to receive a two-channel input signal from a personal computer and generate a simulated surround sound output, preferably having three or more output channels.

Currently, most PC systems are configured to generate audio output signals having two channels, typically left and right stereo channels. For example, when playing digitally stored audio files, such as MIDI or WAVE files, the PC typically only generates a two channel output. Similarly, when the PC plays audio from CD's, the output again is usually only two channels. Therefore, most PC sound cards and speaker configurations are equipped only to handle two channel audio signals. However, PCs now can handle very complex multimedia applications, including sophisticated video games and movies, which are being developed and recorded on DVD or CD with encoded surround sound audio. Therefore, it is desirable for PC systems to be able to play and handle encoded surround sound applications.

In addition, even though a number of the new computer video games and DVD videos are now being produced with the encoded surround sound scheme, many games and other computer applications are not encoded with the surround sound encoding scheme. However, many users still want to experience the surround sound sensation, even though many of the applications that they are running cannot generate the various surround sound channels. For example, a typical surround

sound encoded application will generate six (6) audio channels, while, as mentioned above, non-encoded applications will only produce audio signals having two (2) channels. Therefore, it is desirable to have a system which can play surround sound encoded applications on a PC in a surround sound environment, as well as have a system which can generate a simulated surround sound signal from a typical two channel PC audio signal. For example, a system which will take the right and left stereo channels of a game, movie, music track or audio file and generate a multi-channel audio output which simulates a surround sound encoded application.

SUMMARY OF THE INVENTION

Accordingly, it is an advantage of the present invention to provide a PC surround sound apparatus which overcomes the shortcomings of the prior art.

Another advantage of the present invention is that a PC surround sound apparatus is configured to play games, movies and other applications which include audio signals encoded with a surround sound encoding scheme.

Yet another advantage of the present invention is that a PC surround sound apparatus can generate a multi-channel simulated surround sound output signal.

Still another advantage of the present invention is that a PC surround sound apparatus can mix an encoded surround sound signal with a simulated surround sound signal generated from two-channel PC signal to create a single multi-channel surround sound output signal.

Still another advantage of the present invention is that a PC surround sound apparatus can generate a multi-channel simulated surround sound output signal which is compatible with all types of PC speaker systems.

The above and other advantages of the present invention are carried out in one form by a PC surround sound apparatus configured to generate a multi-channel simulated surround sound output signal. The PC surround sound apparatus preferably generates the simulated surround sound output signal channels from a PC source signal having two or more

source signal channels. The PC surround sound apparatus preferably comprises an input means for receiving first and second source signal channels. In addition, the apparatus includes a high-pass filter configured to receive the first and second source signal channels from the input means and filter out the low frequencies from the source signal channels, so that only high frequencies are passed to the first and second output signal channels. Finally, the PC surround sound apparatus includes a low-pass filter configured to receive the first and second source signal channels from the input means and filter out the high frequencies from the source signal channels, so that only low frequencies are passed to the third and fourth output signal channels. In accordance with this aspect of the invention, separating the high frequencies of the input channels to the first and second output signal channels, and the low frequencies of the input channels to the third and fourth output signal channels creates the simulated surround sound output signal.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present invention may be derived by referring to the detailed description and claims when considered in connection the Figures, wherein like reference numbers refer to similar items throughout the Figures, and:

Fig. 1 is a diagram of a computer system embodying a PC surround sound circuit;

Fig. 2 is a schematic circuit diagram of a first embodiment of a PC surround sound circuit;

Fig. 3 is a chart showing the relationship between two input signals to the PC surround sound circuit of Fig. 2;

Fig. 4 is a detailed circuit diagram of a second embodiment of a PC surround sound circuit;

Fig. 5 is a flow diagram illustrating a method for generating a simulated surround sound signal; and

Fig. 6 is a flow diagram illustrating a method for generating a simulated surround sound signal and for combining

the simulated surround sound signal with a encoded surround sound signal.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is a circuit or system for generating a multi-channel simulated PC surround sound signal from two or more PC signal channels. While the embodiments of the present invention illustrated in the figures and described herein relate generally to an analog signal processing circuit, one skilled in the art will appreciate that a digital signal processing circuit and/or a software application can be used to implement the present invention. Therefore, the present invention is not limited to the illustrated embodiments.

Referring now to Fig. 1, a computer system 10 is shown embodying a PC surround sound circuit of the present invention. In particular, computer system 10 may comprise any suitable computer system such as a home personal computer system, or other similar computer work station system. Computer system 10 suitably comprises a processing unit 12, a monitor 14, a keyboard 16, a mouse 18, and a plurality of speakers 20-30. As one skilled in the art will appreciate, computer system 10 also may comprise a variety of other computer peripherals not illustrated in Fig. 1.

In accordance with most surround sound systems, computer system 10 preferably comprises six speakers to receive and play a six channel surround sound signal. In accordance with this aspect of the invention, the speaker configuration of computer system 10 preferably comprises a left front speaker 20, a right front speaker 22, a left rear speaker 24, a right rear speaker 26, a center channel speaker 28, and sub-woofer speaker 30. While most surround sound systems currently known in the art have six speakers driven by a six channel surround sound signal, one skilled in the art will appreciate that computer system 10 may comprise any number of speakers and surround sound channels. For example, computer system 10 only may comprise three speakers, such as a left front, a right front and a center channel speaker

configuration. In accordance with this aspect of the invention, computer system 10 only will generate a three channel signal.

Processing unit 12 preferably comprises a processor 32, a memory 34, a storage 36, a surround sound circuit 38, a sound card 40, a floppy drive 42, and an optical drive 44. Processor 32 may comprise any suitable computer processor, such as an Intel X86 processor, a RISC processor, or any other processor currently known in the art.

Similarly, memory 34 may comprise any suitable random access memory device such as SRAM, DRAM, flash memory or the like. In addition, a portion of memory 34 may be configured as cache memory. Storage 36 may comprise any suitable computer storage, such as a hard disc drive, flash memory, or any other suitable computer storage device configured to store application programs, data and the like.

In addition to the typical processor, memory, and storage which is included in most computer systems, processing unit 12 preferably further comprises a surround sound circuit 38 and a sound card 40. As discussed in more detail below, surround sound circuit 38 is configured to generate a simulated surround sound output from a two-channel sound input signal. In addition, surround sound circuit 38 may be configured to receive and decode encoded surround sound signals, and mix encoded surround sound signals with a simulated surround sound signal. Sound card 40 may comprise any suitable PC sound card configured to generate analog sound signals which will drive any of the speakers 20-30. While computer system 12 illustrates surround sound circuit 38 and sound card 40 as separate devices or circuit cards, one skilled in the art will appreciate that surround sound circuit 38 and sound card 40 may be combined into a single circuit configuration or, depending on the configuration of surround sound circuit 38, surround card 40 may be eliminated.

Finally, as illustrated in Fig. 1, processing unit 12 may comprise a floppy drive 42 and/or an optical drive 44. Floppy drive 42 may be any suitable floppy drive such as a 3½" or 5¼" floppy device. In addition, optical drive 44 may

comprise any suitable optical drive, such as a CD or DVD device. As discussed in more detail below, optical drive 44 may be configured to play music, movies, or games which include surround sound encoded sound signals. In accordance with this aspect of the invention, processing unit 12 may include a surround sound decoding circuit (not shown) or, as discussed in more detail below, surround sound circuit 38 may include the encoded surround sound circuit decoding circuitry.

As mentioned briefly above, the functionality of surround sound circuit 38 may be embodied in a software application program rather than an electrical circuit. In such a case, floppy drive 42 or optical drive 44 may be used to load the surround sound application program into computer system 12 and, in particular, into storage 36 and/or memory 34.

Referring now to Fig. 2, a first embodiment of a PC surround sound circuit 100 will be discussed. In particular, PC surround sound circuit 100 preferably comprises a first input 102, a second input 104, an audio signal enhancement circuit 106, a switchable high-pass filter 108, a low-pass filter 110, and a summing or mixing circuit 112. In accordance with this aspect of the invention, inputs 102 and 104 preferably comprise left and right stereo channels from a PC system. For example, inputs 102 and 104 may be inputs from a CD or DVD, or inputs 102 and 104 may comprise audio data channels from a MIDI or WAVE file. Audio signals from a PC typically are in digital form; therefore, if PC surround sound system 100 is an analog signal processing system, inputs 102 and 104 first will pass through a digital to analog converter (not shown) before being processed by system 100.

As illustrated in Fig. 1, inputs 102 and 104 first may pass through a stereo enhancement circuit 106. For example, one type of stereo enhancement circuit 106 may comprise a sound effect circuit configured to generate simulated 3-D sound effect from a two-channel signal. In accordance with one aspect of the invention, stereo enhancement circuit preferably 106 gives inputs 102 and 104 a

3-D or spatial effect by processing signals 102 and 104 in accordance with a specialized function. For example:

$L' = \text{Function}(\text{LINOPL}, \text{LINOPR})$

$R' = \text{Function}(\text{LINOPR}, \text{LINOPL})$

where L' and R' are outputs 114 and 116 of stereo enhancement circuit 106, respectively and LINOPL and LINOPR are inputs 102 and 104, respectively. In addition, stereo enhancement circuit 106 can be enabled or disabled by controlling the state of input signal 118. That is, when input 118 is activated or enabled, stereo enhancement circuit 106 is on, and when input 118 is disabled, stereo enhancement circuit 106 is off. Furthermore, as one skilled in the art will appreciate, PC surround sound circuit 100 may be configured without stereo enhancement circuit 106.

As illustrated in Fig. 2, and discussed briefly above, stereo enhancement circuit 106 generates output signals 114 and 116. Signals 114 and 116 preferably act as input signals into switchable high-pass filter 108 and surround mode selection circuit 120. As one skilled in the art will appreciate, if stereo enhancement circuit 106 is disabled, or if it is eliminated from PC surround sound circuit 100 all together, signals 114 and 116 will be the same as input signals 102 and 104, respectively.

Switchable high-pass filter 108 preferably comprises any suitable filtering circuit configured to filter out the low frequencies from signals 114 and 116. In accordance with this aspect of the invention, high-pass filter 108 preferably filters out all frequencies in the range of about 1.5 KHz and below, allowing the frequencies in the range of about 1.5 KHz and above to pass to first and second simulated surround sound output channels 126 and 128.

Typically, there are about two main types of PC speaker systems currently being sold in the marketplace. The first type generally comprises two front active speakers having the ability to play a relatively full range of audio frequencies. For this type of speaker configuration, the high-pass filter is used to filter out the low frequencies,

allowing the two front speakers to play only the high frequency portions of that signal.

The second type of speaker configuration currently being sold in the PC marketplace generally comprises a single sub-woofer configured to drive two satellite high frequency speakers. With this particular configuration, if we utilize the high-pass filter to filter out the low frequencies, the quality of the sound emanating from the front speakers will be poor because the sub-woofer is a low-frequency output device. To remedy this problem, switchable high-pass filter 108 preferably includes an enabling input signal input 138 (also labeled SPK-MODE) which controls the operation of high-pass filter 108. Thus, when input 138 produces an active state signal, switchable high-pass filter 108 will be on, and only the high frequency portions of signals 114 and 116 will pass to first and second simulated surround sound output channels 126 and 128. Conversely, when input 138 produces an inactive state signal (e.g., no signal) high-pass filter 108 is off, and the full frequency range of signals 114 and 116 will pass to output channels 126 and 128. Accordingly, if a particular PC system has two full frequency front speakers, high-pass filter 108 typically is on, and high-pass filter 108 and low-pass filter 110 are configured to separate different frequency ranges of the input signal channels to front and rear speakers. On the other hand, if a PC system is equipped with the sub-woofer type front speakers, PC surround sound circuit 100 will turn off high-pass filter 108, so that the sound quality from the sub-woofer based speaker configuration is not impeded.

As mentioned briefly above, signals 114 and 116 from stereo enhancement circuit 106 also act as inputs to surround mode selection circuit 120 which acts as the control circuit for the simulated surround sound mode. In accordance with this aspect of the invention, surround mode selection circuit 120 includes an input signal 140 (also labeled CSR-EN) which, when activated, turns on the rear, center and sub-woofer channels of simulated surround circuit 100. For example, as illustrated more clearly in Fig. 3, when input signal 140 is

off, input signal 130 to high-pass filter 108 also is off, disabling the simulated surround sound mode. In this manner, input signal channels 102 and 104 (LINOPL and LINOPR) pass through to first output channel 126 and second output channel 128 without surround mode processing. However, when input signal 140 is activated, the surround sound circuit is on, and rear, center and sub-woofer channels will be active. Accordingly, the output of PC surround sound circuit 100 preferably is a simulated 5.1 channel surround sound output. Moreover, if input signal 140 is on, and input signal 138 is off, the output of surround sound circuit 100 will be a six-channel output, but the user will not experience full frequency separation between the front and rear speakers because high-pass filter 108 is off.

When surround mode selection circuit 120 is on, signals 114 and 116 pass through a low-pass filter 110 which filters out the high frequencies from the signals. The output of low pass filter 110 is a third output channel 130 and a fourth output signal channel 132, which preferably comprise signal frequencies in the range of about 1.5 KHz and below.

As illustrated in Fig. 2, before signals 114 and 116 pass through low-pass filter 110, signals 114 and 116 first may pass through a bass boost circuit 122. Bass boost circuit 122 preferably enhances the low frequency portion of signals 114 and 116 before they pass into the low-pass filter. As one skilled in the art will appreciate, by enhancing the low frequency portion of the signals, the output of low-pass filter 110 also will be enhanced. While the illustrated embodiment in Fig. 2 shows PC surround sound system 100 with bass boost circuit 122, one skilled in the art will appreciate that bass boost circuit 122 may be eliminated from the system without varying from the spirit of the invention.

In addition to passing through base boost circuit 122 and low-pass filter 110, signals 114 and 116 preferably pass to a summing or mixing circuit 112 which sums or mixes signals 114 and 116 into a single signal 142. Signal 142 then preferably passes to fifth and sixth simulated surround sound output signal channels 134 and 136. However, before passing

to channel 136, signal 142 first may pass through a low-pass filter 124.

In accordance with one embodiment of the present invention, first output signal channel 126 and second output signal channel 128 preferably comprise front right and front left output channels; third output signal channel 130 and fourth output signal channel 132 preferably comprise right rear and left rear output channels; fifth output signal channel 134 preferably comprises a center output channel; and sixth output signal channel 136 preferably comprises a sub-woofer output channel. Thus, as mentioned briefly above, when PC surround sound circuit 100 is operating in simulated surround sound mode, the high frequencies of the input channels will be separated to the front speakers while the low frequencies of the input channels will be separated to the back speakers. By performing this frequency separation to the different speaker channels, one will have an impression that the front speakers can extract different information than the rear speakers, the essence of an encoded surround sound system. Therefore, by performing this frequency separation, a multi-channel (preferably six) surround sound system can be simulated from a two channel input.

Referring now to Fig. 4, another embodiment of a PC surround sound circuit 300 is illustrated. Like PC surround sound circuit 100, PC surround sound circuit 300 is configured to receive a two-channel input signal from a PC and generate a multiple-channel surround sound output signal from the two-channel signal. In addition, however, PC surround sound circuit 300 is configured to receive, decode and play multi-channel surround sound encoded signals. For example, PC surround sound circuit 300 can decode and play 5.1 channel surround sound encoded formats, such as the well known surround sound formats like Dolby Stereo Digital (DSD) (TM), Digital Theater Systems (TM), or Sony Dynamic Digital Sound (SDDS) (TM).

For generating a simulated PC surround sound output from a two-channel input source, PC surround sound circuit 300 operates in a similar manner as PC surround sound circuit 100.

In particular, PC surround sound circuit 300 is configured to receive two input channels 102 and 104 from a PC system. As discussed above with reference to Fig. 2 and PC surround sound circuit 100, PC surround sound circuit 300 may comprise a stereo enhancement circuit 106 which spatially enhances input channels 102 and 104 creating signals 114 and 116, respectively. Stereo enhancement circuit 106 can be turned on and/or off by input signal 118. If stereo enhancement circuit 106 is off, signals 114 and 116 will be the same as input channels 102 and 104, respectively. In addition, PC surround sound circuit 300 may be configured without stereo enhancement circuit 106, in which case, signals 114 and 116, also will be the same as input channels 102 and 104, respectively.

In the simulated surround sound mode, signals 114 and 116 are configured to be inputs to switchable high-pass filter 108, surround mode enhancement circuit 302, and multiplexing and mixing circuits 308 and 310. Switchable high-pass filter 108 operates in the same manner as the switchable high-pass filter discussed above with reference to Fig. 2 and PC surround sound circuit 100. Specifically, when the PC system has two front speakers with full frequency or near full frequency capabilities, switchable high-pass filter 108 is activated, so that only the high frequencies from signals 114 and 116 are passed to high-pass filter outputs 126 and 128. Similarly, if the PC system includes a front speaker configuration having a sub-woofer driving two high frequency speakers, it is preferable to deactivate switchable high-pass filter 108, so that the full frequency range of signals 114 and 116 pass through to the sub-woofer and satellite speakers. As one skilled in the art will appreciate, if switchable high-pass filter 108 is active, and only the high frequencies of signals 114 and 116 pass through to the sub-woofer, the sound quality coming from the sub-woofer and satellite speakers driven by the sub-woofer will be degraded significantly.

As illustrated in Fig. 4, before output signals 126 and 128 from switchable high-pass filter 108 pass to first and second surround sound output signal channels 314 and 316, they first pass through mixing and/or multiplexing circuits 304 and

306, respectively. In accordance with this aspect of the invention, if PC surround sound circuit 300 is in the simulated PC surround sound mode, multiplexing circuits 304 and 306 will pass signals 126 and 128 from high-pass filter 108 to output channels 314 and 316. Similarly, as discussed in more detail below, if PC surround sound circuit 300 is in the encoded surround sound mode, multiplexing circuits 304 and 306 will pass the left-front signal 326 and right-front signal 328 (AL and AR, respectively) from the six-channel encoded surround sound input to output channels 314 and 316.

In addition to being inputs to switchable high-pass filter 108, signals 114 and 116 are inputs to surround mode enhancement circuit 302. In accordance with this aspect of the invention, surround mode enhancement circuit 302 preferably comprises an audio enhancement circuit which, when activated, provides additional audio spatial separation for the rear speaker channels. For example, a typical formula for enhancing the rear-channel signals is as follows:

$$L^* = L' - R'$$

$$R^* = R' - L'$$

where L^* and R^* are signals 330 and 332, respectively, and L' and R' comprise signals 114 and 116, respectively.

A user typically will be given the option to activate or deactivate surround mode enhancement circuit 302. In accordance with this aspect of the invention, input 334 is configured to control the operation of sound mode enhancement circuit 302. Thus, if input signal 334 is activated, surround mode enhancement circuit 302 will be on, and if input 334 is deactivated, surround mode enhancement circuit 302 will be off. As one skilled in the art will appreciate, while surround mode enhancement circuit 302 may help improve the surround sound quality of the signal, the audio signal processing of the circuit also may cause the signal to lose some directional qualities. Therefore, some users may not like the effect that surround mode enhancement circuit 302 has on the signal. Thus, the user may be given the option to deactivate surround mode enhancement circuit 302 at his or her choice.

Outputs 330 and 332 from surround mode enhancement circuit 302 preferably are inputs into low-pass filter 110, which is configured to filter out all high frequencies from the signals and pass through only the low frequencies. In addition, before entering low-pass filter 110, signals 330 and 332 first may pass through a bass boost circuit 122 to enhance the low frequency portions of the signal before entering the low-pass filter. PC surround sound circuit 300 may include bass boost circuit 122, or it may be configured without it.

Next, output signals 130 and 132 from low-pass filter 110 pass into a mixing and/or multiplexing circuit 312. If PC surround sound circuit 300 is operating in the simulated surround sound mode, multiplexing circuit 312 will pass signals 130 and 132 through to surround sound output channels 318 and 320, respectively. Similarly, if PC surround sound circuit 300 is operating in the encoded surround sound mode, multiplexing circuit 312 will pass encoded surround sound channels 336 and 338 (also labeled ALS and ARS, respectively) through to output channels 318 and 320..

As discussed in more detail below, it is possible that PC surround sound circuit 300 may operate in a combined simulated and encoded surround sound mode. In such a case, multiplexing and/or mixing circuit 312 preferably will mix signals 130 and 132 with signals 336 and 338 and pass the combined signals through to output channels 318 and 320. In accordance with this aspect of the invention, input signal 340 (DVD-EN) is configured to control the operation of switching circuit 312. For example, depending on the state of input signal 340, circuit 312 will act either as a multiplexer passing signals 130, 132 or signals 336, 338 to output channels 318 and 320, or as a mixer, summing signals 130 and 132 with signals 318 and 320. Also, input signal 342 (SURRND-EN) is used to activate and/or deactivate circuit 310 so as to enable or disable output channels 318 and 320. Thus, when input signal 342 is at an active state, circuit 312 will pass signals to output channels 318 and 320. Similarly, when input signal 342 is at a deactive state, circuit 312 will be off, thus turning off output channels 318 and 320.

As mentioned briefly above, signals 114 and 116 also act as inputs to multiplexing and/or mixing circuits 308 and 310. In accordance with this aspect of the invention, when PC surround sound system 300 is in the simulated surround sound mode, mixing circuit 308 is configured to sum signals 114 and 116, producing surround sound output channel 322. Similarly, mixing circuit 310 is configured to sum signals 114 and 116 to produce surround sound output channel 324. As with PC surround sound circuit 100 in Fig. 2, output channel 324 first may pass through a low-pass filter 124 so that all high frequency portions of the signal are filtered out. Since output channel 324 typically is a sub-woofer channel, the low-pass filter will help enhance the low frequency output of sub-woofer channel 324. PC surround sound circuit 300 may include low-pass filter 124, or it may be configured without it.

Mixing and/or multiplexing circuits 308 and 310 also may include input signal 342 (SURREND-EN) which, as discussed above with reference to circuit 312, may be configured to activate or deactivate output channels 322 and 324. In accordance with this aspect of the invention, if input signal 342 is at a deactive state surround sound output channels 322 and 324 from circuits 308 and 310, respectively, will be off.

As mentioned above, PC surround sound circuit 300 may be configured to play audio signals having surround sound encoding. However, as illustrated in Fig. 4, the encoded surround sound mode input signal into PC surround sound circuit 300 comprises a six channel input signal. Therefore, an encode surround sound signal preferably has been decoded prior to reaching circuit 300. But, as one skilled in the art will appreciate, even though not illustrated, circuit 300 may include circuitry for decoding an encoded surround sound signal prior to processing. For example, circuit 300 may include an AC 3 surround sound decoder. Accordingly, the present invention is not limited to the illustrated embodiment.

When operating PC surround sound circuit 300 in the encoded surround sound mode, circuit 300 preferably comprises six encoded surround sound input channels and six surround

sound output channels. In accordance with this aspect of the invention, the six input channels typically are left front 326, right front 328, left rear 336, right rear 338, center channel 344, and sub-woofer 346. The six-channel output of PC surround sound circuit 300 comprises outputs 314-324, which, in accordance with the preferred embodiment of the invention, comprises left-front, right-front, left-rear, right-rear, center, and sub-woofer channel outputs, respectively. Thus, when operating in the encoded surround sound mode, multiplexing circuits 304 and 306 pass through the front-left 328 and the left-front 326 surround sound input channels to right-front output channel 314 and right-front output channel 316, respectively. Similarly, circuit 312 is configured to pass through the left-rear 338 and the right-rear 336 input channels to left-rear output channel 318 and right-rear output channel 320, respectively.

Finally, in the encoded surround sound mode, circuits 308 and 310 are configured to pass the center-channel input signal 344 to center output channel 322, and the sub-woofer input channel 346 to the sub-woofer output channel 324.

As mentioned briefly above, PC surround sound circuit 300 may be configured to operate in simulated and encoded surround sound modes simultaneously. For example, certain PC applications, such as a video games or movies, may generate some signals from the PC itself (e.g., MIDI or WAVE file data), while other audio and/or video signals may be generated with surround sound encoding from a PC device, such as a DVD or VCD device. In accordance with this aspect of the invention, PC surround sound circuit 300 may receive a two-channel input from the PC, such as input channels 102 and 104, as well as a six-channel surround sound input from the PC or other PC related device, such as a DVD or a VCD device. In this manner, PC surround sound circuit 300 may be configured to receive the two-channel input signal 102 and 104 and create a six-channel simulated surround sound output from the input signal as discussed above. Circuit 300 will then mix the simulated surround sound channels with the six-channel encoded

surround sound input to generate a combined surround sound output.

In accordance with this aspect of the invention, mixing circuit 304 may be configured to mix or sum signal 126 from high-pass filter 106 with the left-front input channel 328 from the encoded surround sound input to produce the left-front surround sound output channel 314. Similarly, circuit 306 may be configured to mix signal 128 from high-pass filter 106 with the right-front surround sound input channel 326 to produce right-front output channel 316. Also, as discussed above, multiplexing and mixing circuit 312 may be configured to add signals 130 and 132 with signals 336 and 338 to produce left-rear output channel 318 and right-rear output channel 320, respectively. Finally, mixing circuit 308 may be configured to add center channel input 344 with mixing signals, 114 and 116 to produce center-channel output 322, and mixing circuit 310 may be configured to sum sub-woofer input channel 346 with signals 114 and 116 to generate sub-woofer output channel 324. In this manner, output channels 314-324 will comprise a combination of the simulated surround sound channels and the encoded surround sound channels.

Referring now to Fig. 5, a flow diagram 500 is shown setting forth a method for generating a simulated surround sound signal from an input signal having two or more signal channels. While the input signal may have more than two channels, the method described herein will refer only to a two-channel signal for ease of understanding. In accordance with one aspect of the present invention, the method for generating a simulated surround sound signal preferably begins by receiving a two-channel input signal (step 502). Next, it is determined whether the input signal is to be spatially enhanced (step 504). In particular, as discussed above, by spatially enhancing the input signal, the signal is given a dimensional or spatial effect, improving the stereo or surround sound quality. If the spatial enhancement aspect of the method is on, the input signal is spatially enhanced (step 506). On the other hand if the spatial enhancement aspect of

method is not on, the signal will by pass step 506 (see path 508).

Next, in accordance with a preferred method of the present invention as illustrated in Fig. 5, it is determined whether the low frequencies from the input signal are to be filtered out for the front speakers (step 510), and whether the surround mode is on, such that the right rear, left rear, center and sub-woofer channels will be generated (step 512).

As discussed above with reference to Figs. 2 and 4, different PC systems may have different front speaker configurations; for example, two full frequency range speakers, or a sub-woofer speaker driving two high-frequency speakers. If the front speaker configuration for the PC system comprises two full frequency speakers, it typically is desirable to filter out the low frequencies from the input signal before passing the signal on to the front speakers. As mentioned above, by dividing the high frequencies of the input signal to the front speakers and the low frequencies of the input signal to the back speakers, it gives the effect of different sound information coming from the different speakers (i.e., a surround sound effect). On the other hand, if the sub-woofer and high frequency speaker configuration is used, it typically is best not to filter out the low frequencies from the input signal. Thus, depending on the front speaker configuration of the system, the low frequencies of the input signal may or may not be filtered out from the signal prior to passing to the front speakers. If filtering is used, the low frequencies are filtered out from the input signal (step 514), and the high frequency portions of the input signal pass to the right and left front speaker channels of the simulated surround sound system (step 516). If filtering is not used, the full frequency range of the input signals pass to the right and left front speakers of the simulated surround sound system (step 518).

Referring now to step 512 in Fig. 5, if the simulated surround sound mode is not on, no rear, center or sub-woofer channels are generated (step 520). On the other hand, if the simulated surround sound mode is on, the rear,

center and sub-woofer channels are generated. In particular, to generate the right and left rear simulated surround sound channels, the high frequencies from the input signal are filtered out (step 522), and only the low frequencies pass to the right and left rear simulated surround sound output channels (step 524). Also, to generate the center and sub-woofer channels, two or more channels of the input signal are summed together into a single channel (step 526), and that single channel passes to both the center and sub-woofer simulated surround sound output channels (step 528). In this manner, a six-channel simulated surround sound output signal is generated from the two-channel input signal.

Referring now to Fig. 6, a flow diagram 600 illustrates a method for generating a simulated surround sound signal from a two channel input signal and for summing the simulated surround sound signal with a six-channel encoded surround sound signal. In particular, the method illustrated in Fig. 6 comprises first generating a simulated surround sound signal in a manner similar to that discussed above with reference to Fig. 5. Specifically, first a two-channel input signal is received (step 602), and the signal is spatially enhanced (step 606). Alternatively, as discussed above, the spatial enhancement aspect of the method may be skipped (path 608).

As discussed above with reference to Fig. 5, depending on the front speaker configuration of the PC system, the low frequencies of the input signal may or may not be filtered out (step 610). If the low frequencies are filtered out, step 614 is processed, otherwise step 614 is skipped. Similarly, as discussed above, if surround sound mode is off (step 612), no rear, center or sub-woofer channels are generated (step 616). However, if the surround sound mode is on, the high frequencies are filtered out of the input signal prior to passing to the right and left rear speakers.

Still referring to Fig. 6, in accordance with one aspect of the present invention, a six-channel encoded surround sound signal may be received and summed or mixed to the simulated surround sound signal. At step 620, it is

determined whether there is a six-channel encoded surround sound input signal. If there is not a six-channel encoded surround sound input signal, the high frequencies from the input signal pass to the right and left front simulated surround sound output channels (step 622), and the low frequencies of the input signal channels pass to the right and left rear simulated surround sound output channels (step 624). As with the method illustrated in Fig. 5 and discussed above, to generate the center and sub-woofer simulated surround sound channels, the two input signal channels are summed together (step 626) and the summed signal passes to both the center and sub-woofer simulated surround sound output channels (step 628).

If a six-channel encoded surround sound input signal is present, the right and left front channels of the encoded surround sound signal are received (step 630), and summed with the right and left front simulated surround sound channels (step 632), generating the right and left front output channels (step 634). Similarly, the right and left rear encoded surround sound channels are received (step 636), and summed with the right and left rear simulated surround sound channels (step 638), generating the right and left rear output channels (step 640). Finally, the center and sub-woofer channels from the six-channel surround sound signal are received (step 642) and summed with the center and sub-woofer simulated surround sound channels (step 644), generating the center and sub-woofer surround sound output channels (step 646).

In conclusion, the present invention provides a novel method and apparatus for generating a PC surround sound output from a two-channel PC input, as well as a system for playing a six-channel surround sound encoded signal from a PC. While a detailed description of presently preferred embodiments of the invention have been given above, various alternatives, modifications, and equivalents will be apparent to those skilled in the art. For example, while embodiments of the present invention are described herein with reference to an analog signal processing circuit, one skilled in the art

will appreciate that a digital signal processing circuit or a software application may be used to create a PC surround sound system.

Therefore, the above-description should not be taken as
5 limiting the scope of the invention which is defined by the
appended claims.

CLAIMS:

1. A personal computer (PC) surround sound simulator apparatus arranged to generate a simulated surround sound output signal, having three or more output signal channels, from a PC source signal having two or more source signal channels, the apparatus comprising:

high-pass filter means configured to receive said two or more source signal channels from a PC and filter out low frequencies of said two or more source signal channels so that only high frequencies are passed to first and second output signal channels; and

low-pass filter means configured to receive said two or more source signal channels from said PC and filter out high frequencies of said two or more source signal channels so that only low frequencies are passed to at least one output signal channel.

2. The apparatus as recited in claim 1, wherein said two or more source signal channels of said source signal comprise right and left stereo signal channels.

3. The apparatus as recited in claim 1, wherein said two or more source signal channels comprise sound signals generated by a MIDI command sound generator.

4. The apparatus as recited in claim 1, wherein said two or more source signal channels comprise WAVE signal channels.

5. The apparatus as recited in claim 1, wherein said at least one output signal channel comprises a third output signal channel and wherein said apparatus further

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comprises a summing circuit for summing said two or more source signal channels into said third output signal channel.

6. The apparatus as recited in claim 1, wherein said at least one output signal channel comprises a third output signal channel and a fourth output signal channel.

7. The apparatus as recited in claim 6, further comprising a summing circuit for summing said two or more source signal channels into a fifth output signal channel and a sixth output signal channel.

8. The apparatus as recited in claim 7, wherein said first output signal channel comprises a right front output signal channel, said second output signal channel comprises a left front output signal channel, said third output signal channel comprises a right rear output signal channel, said fourth output signal channel comprises a left rear output signal channel, said fifth output signal channel comprises a center output signal channel and sixth output signal channel comprises a sub-woofer output signal channel.

9. The apparatus as recited in claim 8, wherein said sub-woofer output signal channel passes through a low-pass filter before passing to a sub-woofer speaker.

10. The apparatus as recited in claim 1, further comprising a first summing circuit for summing said two or more source signal channels into a fifth output signal channel, and a second summing circuit for summing said two or more source signal channels into a sixth output signal channel.

11. The apparatus as recited in claim 10, wherein said fifth output signal channel is a center output signal channel, and said sixth output signal channel is a sub-woofer output signal channel.

12. The apparatus, as recited in claim 1, further comprising an input signal configured to disable the simulated surround sound mode so that the output signal of said apparatus is a two channel output signal.

13. The apparatus as recited in claim 1, wherein said high-pass filter comprises an input signal configured to disable said high-pass filter, so that all frequencies of said two or more source signal channels are passed to said first and said second output signal channels.

14. The apparatus as recited in claim 8, further configured to receive a second source signal having six source signal channels.

15. The apparatus as recited in claim 14, wherein said six source signal channels comprise right front, left front, right rear, left rear, center, and sub-woofer channels.

16. The apparatus as recited in claim 15, further comprising:

a first multiplexer for selecting either said first output signal channel from said high-pass filter or said right front channel of said second source signal to be said first output signal channel of said apparatus;

a second multiplexer for selecting either said second output signal channel from said high-pass filter or said left front signal channel of said second source signal to be said second output signal channel of said apparatus;

a third multiplexer for selecting either said third output signal channel from said low-pass filter or said right rear channel from said second source signal to be said third output signal channel of said apparatus;

a fourth multiplexer for selecting either said fourth output signal channel from said low-pass filter or said left rear channel from said second source signal to be said fourth output signal channel from said apparatus;

a fifth multiplexer for selecting either said fifth output signal channel from said first summing means or said center channel from said second source signal to be said fifth output signal channel; and

a sixth multiplexer for selecting either said sixth output signal channel from said second summing means or said sub-woofer channel from said second source signal to be said sixth output signal channel of said apparatus.

17. The apparatus as recited in claim 16, wherein said first, said second, said third, said fourth, said fifth, and said sixth multiplexers comprise a single twelve-channel to six-channel multiplexer.

18. The apparatus as recited in claim 15, further comprising:

a third summing circuit for summing said first output signal channel from said high-pass filter with said right front channel of said second source signal, creating a summed first output signal channel of said apparatus;

a fourth summing circuit for summing said second output signal channel from said high-pass filter with said left front channel of said second source signal, creating a summed second output signal channel of said apparatus;

a fifth summing circuit for summing said third output signal channel from said low-pass filter with said right rear channel of said second source signal, creating a summed third output signal channel of said apparatus;

a sixth summing circuit for summing said fourth output signal channel from said low-pass filter with said left rear channel of said second source signal, creating a summed fourth output signal channel of said apparatus; and

wherein said first summing circuit is configured to sum said first and said second source signal channels with said center channel of said second source signal, creating a summed fifth output signal channel of said apparatus, and said second summing circuit is configured to sum said first and said second source signal channels with said sub-woofer

channel of said second source signal, creating a summed sixth output signal channel of said apparatus.

19. The apparatus as recited in claim 18, wherein said summed first output signal channel comprises a right front output signal channel, said summed second output signal channel comprises a left front output signal channel, said summed third output signal channel comprises a right rear output signal channel, said summed fourth output signal channel comprises a left rear output signal channel, said summed fifth output signal channel comprises a center output signal channel, and said summed sixth output signal channel comprises a sub-woofer output signal channel.

20. A personal computer (PC) surround sound simulator system arranged to generate and play a simulated surround sound output signal, having three or more output signal channels, from a PC source signal having two or more source signal channels, the system comprising:

a computer comprising a processor and a PC surround sound circuit, said PC surround sound circuit comprising:

high-pass filter means configured to receive said two or more source signal channels from a PC and filter out low frequencies of said two or more source signal channels so that only high frequencies are passed to first and second output signal channels; and

low-pass filter means configured to receive said two or more source signal channels from said PC and filter out high frequencies of said two or more source signal channels so that only low frequencies are passed to at least one output signal channel; the system further comprising:

three or more speakers configured to receive said output signal channels from said surround sound circuit and to play said simulated surround sound signal.

21. The system as recited in claim 20, wherein said two or more source signal channels of said source signal comprise right and left stereo signal channels.

22. The system as recited in claim 20, wherein said two or more source signal channels comprise sound signals generated by a MIDI command sound generator.

23. The system as recited in claim 20, wherein said two or more source signal channels comprise WAVE signal channels.

24. The system as recited in claim 20, wherein said at least one output signal channel comprises a third output signal channel and wherein said surround sound circuit further comprises a summing circuit for summing said two or more source signal channels into said third output signal channel.

25. The system as recited in claim 20, wherein said at least one output signal channel comprises a third output signal channel and a fourth output signal channel.

26. The system as recited in claim 25, wherein said surround sound circuit further comprises a summing circuit for summing said two or more source signal channels into a fifth output signal channel and a sixth output signal channel.

27. The system as recited in claim 26, wherein said first output signal channel comprises a right front output signal channel, said second output signal channel comprises a left front output signal channel, said third output signal channel comprises a right rear output signal channel, said fourth output signal channel comprises a left rear output signal channel, said fifth output signal channel comprises a center output signal channel and sixth output signal channel comprises a sub-woofer output signal channel.

28. The system as recited in claim 27, wherein said sub-woofer output signal channel passes through a low-pass filter before passing to a sub-woofer speaker.

29. The system as recited in claim 20, wherein said surround sound circuit further comprises first summing circuit for summing said two or more source signal channels into a fifth output signal channel, and a second summing circuit for summing said two or more source signal channels into a sixth output signal channel.

30. The system as recited in claim 28, wherein said fifth output signal channel is a center output signal channel, and said sixth output signal channel is a sub-woofer output signal channel.

31. The system as recited in claim 20, wherein said surround sound circuit further comprises an input signal configured to disable the simulated surround sound mode so that the output signal of said system is a two channel output signal.

32. The system as recited in claim 20, wherein said high-pass filter comprises an input signal configured to disable said high-pass filter, so that all frequencies of said two or more source signal channels are passed to said first and said second output signal channels.

33. The system as recited in claim 27, wherein said surround sound circuit is further configured to receive a second source signal having six source signal channels.

34. The system as recited in claim 33, wherein said six source signal channels comprise right front, left front, right rear, left rear, center, and sub-woofer channels.

35. The system as recited in claim 34, wherein said surround sound circuit further comprises:

a first multiplexer for selecting either said first output signal channel from said high-pass filter or said right front channel of said second source signal to be said first output signal channel of said surround sound circuit;

a second multiplexer for selecting either said second output signal channel from said high-pass filter or said left front signal channel of said second source signal to be said second output signal channel of said surround sound circuit;

a third multiplexer for selecting either said third output signal channel from said low-pass filter or said right rear channel from said second source signal to be said third output signal channel of said surround sound circuit;

a fourth multiplexer for selecting either said fourth output signal channel from said low-pass filter or said left rear channel from said second source signal to be said fourth output signal channel from said surround sound circuit;

a fifth multiplexer for selecting either said fifth output signal channel from said first summing means or said center channel from said second source signal to be said fifth output signal channel; and

a sixth multiplexer for selecting either said sixth output signal channel from said second summing means or said sub-woofer channel from said second source signal to be said sixth output signal channel of said surround sound circuit.

36. The system as recited in claim 35, wherein said first, said second, said third, said fourth, said fifth, and said sixth multiplexers comprise a single twelve-channel to six-channel multiplexer.

37. The system as recited in claim 34, wherein said surround sound circuit further comprises:

a third summing circuit for summing said first output signal channel from said high-pass filter with said right front channel of said second source signal, creating a summed first output signal channel of said surround sound circuit;

a fourth summing circuit for summing said second output signal channel from said high-pass filter with said left front channel of said second source signal, creating a summed second output signal channel of said surround sound circuit;

a fifth summing circuit for summing said third output signal channel from said low-pass filter with said right rear channel of said second source signal, creating a summed third output signal channel of said surround sound circuit;

a sixth summing circuit for summing said fourth output signal channel from said low-pass filter with said left rear channel of said second source signal, creating a summed fourth output signal channel of said surround sound circuit; and

wherein said first summing circuit is configured to sum said first and said second source signal channels with said center channel of said second source signal, creating a summed fifth output signal channel of said surround sound circuit, and said second summing circuit is configured to sum said first and said second source signal channels with said sub-woofer channel of said second source signal, creating a summed sixth output signal channel of said surround sound circuit.

38. The system as recited in claim 37, wherein said summed first output signal channel comprises a right front output signal channel, said summed second output signal channel comprises a left front output signal channel, said summed third output signal channel comprises a right rear output signal channel, said summed fourth output signal channel comprises a left rear output signal channel, said summed fifth output signal channel comprises a center output signal channel, and said summed sixth output signal channel comprises a sub-woofer output signal channel.

39. A method for generating a simulated surround sound signal having three or more signal channels from a PC signal having two or more channels, comprising the steps of:

receiving said two or more PC signal channels from a PC;

filtering out low frequencies from said two or more PC signal channels and passing said two or more PC signal channels having only high frequencies to a first set of one or more simulated surround sound signal channels; and

filtering out high frequencies from said two or more channels and passing said two or more channels having only low frequencies to a second set of one or more simulated surround sound signal channels;

wherein separating said high frequencies of said two or more channels to said first set of one or more simulated surround sound signal channels and said low frequencies of said two or more channels to said second set of one or more simulated surround sound signal channels creates the simulated surround sound signal.

40. The method as recited in claim 39, wherein said two or more PC signal channels comprise right and left stereo channels.

41. The method as recited in claim 39, wherein said two or more PC signal channels comprise two sound signals generated by a MIDI command sound generator.

42. The method as recited in claim 39, wherein said two or more PC signal channels comprise two WAVE signal channels.

43. The method as recited in claim 39, wherein said first set of one or more simulated surround sound signal channels comprises a right channel and a left channel.

44. The method as recited in claim 43, wherein said second set of one or more simulated surround sound signal channels comprises a single channel.

45. The method as recited in claim 43, wherein said right and said left channels comprise right front and left front channels, and wherein said second set of one or more simulated surround sound signal channels comprises right rear and left rear channels.

46. The method as recited in claim 39, further comprising the step of mixing said two or more PC signal channels to form a single channel which is passed to a third set of one or more simulated surround sound signal channels.

47. The method as recited in claim 46, wherein said third set of one or more simulated surround sound signal channels comprises a center channel and a sub-woofer channel.

48. The method as recited in claim 47, further comprising the step of filtering out high frequencies from said sub-woofer channel, so that only low frequencies are passed to a sub-woofer speaker.

49. The method as recited in claim 39, wherein said step of filtering out said low frequencies is skipped, so that all frequencies of said two or more PC signal channels are passed to said first set of one or more simulated surround sound signal channels.

50. A method for either playing an encoded surround sound signal having at least three channels or generating a simulated surround sound signal having three or more signal channels from a PC signal having two or more channels, comprising the steps of:

choosing between a simulated surround sound mode and an encoded surround sound mode;

if said simulated surround sound mode is selected, the method further comprises the steps of:

receiving said two or more PC signal channels from a PC;

filtering out low frequencies from said two or more PC signal channels and passing said two or more PC signal channels having only high frequencies to a first set of one or more surround sound output channels; and

filtering out high frequencies from said two or more channels and passing said two or more channels having only low frequencies to a second set of one or more surround sound output channels;

wherein separating said high frequencies of said two or more channels to said first set of one or more surround sound output channels and said low frequencies of said two or more channels to said second set of one or more surround sound output channels creates the simulated surround sound signal;

if said encoded sound mode is selected, the method further comprises the steps of:

passing said at least three encoded surround sound channels to at least three surround sound output channels.

51. The method as recited in claim 50, wherein if said simulated surround mode is selected the method further comprises the step of mixing said two or more PC signal channels to form a single channel which is passed to a third set of one or more surround sound output channels.

52. The method as recited in claim 51, wherein said first set of one or more surround sound output channels comprises a right front channel and a left front channel, said second set of one or more surround sound output channels comprises a right rear channel and a left rear channel, and said third set of one or more surround sound output channels comprises a center channel and a sub-woofer channel.

53. The method as recited in claim 52, further comprising the step of filtering out said high frequencies

from said sub-woofer channel, so that only low frequencies are passed to a sub-woofer speaker.

54. The method as recited in claim 50, wherein said step of filtering out said low frequencies may be skipped, so that all frequencies of said two or more PC signal channels are passed to said first set of one or more surround sound output channels.

55. A method for generating a simulated surround sound signal having at least signal channels S1, S2, S3 and S4 from a PC signal having at least channels PC1 and PC2, and mixing said simulated surround sound signal with an encoded surround sound having at least signal channels E1, E2, E3 and E4 to generate a surround sound signal having at least channels O1, O2, O3 and O4, said method comprising the steps of:

receiving said PC signal channels PC1 and PC2 from a PC;

filtering out low frequencies from said PC signal channels PC1 and PC2, creating filtered PC signal channels PCH1 and PCH2 having only high frequencies;

passing said filtered PC signal channels PCH1 and PCH2 to said signal channels S1 and S2;

filtering out high frequencies from said PC signal channels PC1 and PC2, creating filtered PC signal channels PCL1 and PCL2 having only low frequencies;

passing said filtered PC signal channels PCL1 and PCL2 to said signal channels S3 and S4;

receiving said encoded surround sound signal channels E1, E2, E3 and E4

mixing said simulated surround sound signal channels S1, S2, S3 and S4 with said encoded surround sound signal channels E1, E2, E3 and E4 to generate said surround sound signal output channels O1, O2, O3 and O4.

56. The method as recited in claim 55, further comprising the steps of mixing said PC signal channels PC1 and

PC2 together creating an mixed PC signal channel PCM, and passing said mixed PC signal channel PCM to simulated surround sound signal channels S5 and S6.

57. The method as recited in claim 56, further comprising the step of mixing said simulated surround sound signals S5 and S6 with encoded surround sound signals E5 and E6 to generate surround sound signal output channels O5 and O6.

58. The method as recited in claim 57, wherein surround sound signal channels O1, O2, O3, O4, O5, and O6 comprise right front, left front, right rear, left rear, center, and sub-woofer channels, respectively.

59. The method as recited in claim 58, further comprising the step of passing said simulated surround sound signal channel S6 through a low-pass filter before mixing S6 with encoded surround sound signal channel E6.