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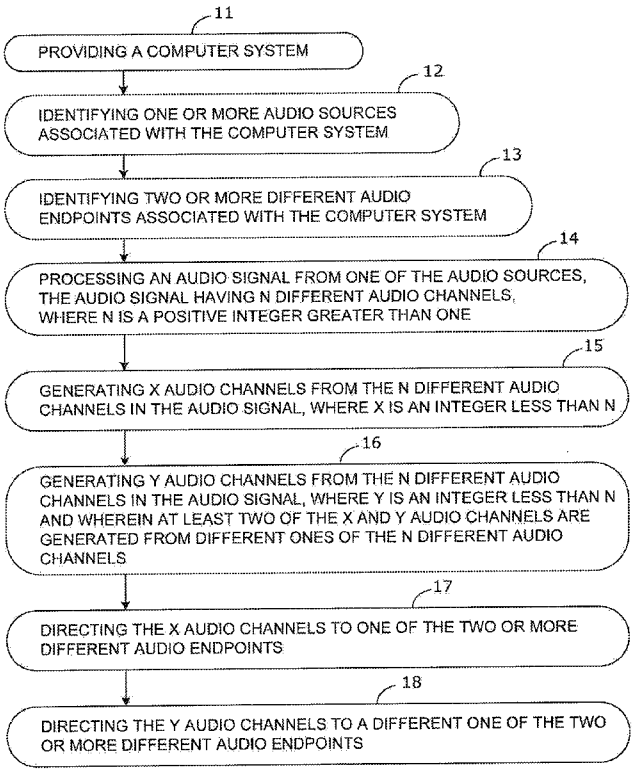


Fig. 1

(57) Abstract: In some embodiments, a computer system may include a processor, a memory coupled to the processor, and two or more different audio output devices associated with the computer system. In some embodiments, an audio driver capable of being loaded in the memory and executed by the processor may be configured to identify one or more audio sources associated with the computer system, identify two or more different audio endpoints associated with the two or more different audio output devices, and process an audio signal from one of the audio sources, the received audio signal having N different audio channels, where N is a positive integer greater than one. In some embodiments, the audio processor may generate X audio channels from the N different audio channels in the audio signal, where X is an integer less than N, generate Y audio channels from the N different audio channels in the audio signal, where Y is an integer less than N and wherein at least two of the X and Y audio channels are generated from different ones of the N different audio channels, direct the X audio channels to one of the two or more different audio endpoints, and direct the Y audio channels to a different one of the two or more different audio endpoints. Other embodiments are disclosed and claimed.

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# APPARATUS AND METHOD FOR AUDIO CLONING AND REDIRECTION

**[0001]** The invention relates to audio cloning and redirection. More particularly, some embodiments of the invention relate to an apparatus and method for audio cloning and redirection in a computer system.

## BACKGROUND AND RELATED ART

**[0002]** Many electronic systems require or benefit from the use of audio devices. In some electronic systems, audio drivers may be provided to manage audio devices.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0003]** According to one aspect of invention, A method of processing an audio signal, comprising:providing a computer system; identifying one or more audio sources associated with the computer system; identifying two or more different audio endpoints associated with the computer system; processing an audio signal from one of the audio sources, the audio signal having N different audio channels, where N is a positive integer greater than one, the processing including: generating X audio channels from the N different audio channels in the audio signal, where X is an integer less than N; generating Y audio channels from the N different audio channels in the audio signal, where Y is an integer less than N and wherein at least two of the X and Y audio channels are generated from different ones of the N different audio channels; directing the X audio channels to one of the two or more different audio endpoints; and directing the Y audio channels to a different one of the two or more different audio endpoints.

**[0004]** According to another aspect of invention, A computer system, comprising: a processor; a memory coupled to the processor; two or more different audio output devices associated with the computer system; and an audio driver capable of being loaded in the memory and executed by the processor to: identify one or more audio sources associated with the computer system; identify two or more different audio endpoints associated with the two or more different audio output devices; process an audio signal from one of the

audio sources, the received audio signal having N different audio channels, where N is a positive integer greater than one, including to: generate X audio channels from the N different audio channels in the audio signal, where X is an integer less than N; generate Y audio channels from the N different audio channels in the audio signal, where Y is an integer less than N and wherein at least two of the X and Y audio channels are generated from different ones of the N different audio channels; direct the X audio channels to one of the two or more different audio endpoints; and direct the Y audio channels to a different one of the two or more different audio endpoints.

**[0005]** According to a further aspect of invention, An audio processor, comprising: a first portion to identify one or more audio sources associated with a computer system; a second portion to identify two or more different audio endpoints associated with two or more different audio output devices; and a third portion to process an audio signal from one of the audio sources, the received audio signal having N different audio channels, where N is a positive integer greater than one, the third portion further to: generate X audio channels from the N different audio channels in the audio signal, where X is an integer less than N; generate Y audio channels from the N different audio channels in the audio signal, where Y is an integer less than N and wherein at least two of the X and Y audio channels are generated from different ones of the N different audio channels; direct the X audio channels to one of the two or more different audio endpoints; and direct the Y audio channels to a different one of the two or more different audio endpoints.

**[0006]** Various features of the invention will be apparent from the following description of preferred embodiments as illustrated in the accompanying drawings, in which like reference numerals generally refer to the same parts throughout the drawings. The drawings are not necessarily to scale, the emphasis instead being placed upon illustrating the principles of the invention.

**[0007]** Fig. 1 is a flow diagram in accordance with some embodiments of the invention.

**[0008]** Fig. 2 is another flow diagram in accordance with some embodiments of the invention.

**[0009]** Fig. 3 is another flow diagram in accordance with some embodiments of the invention.

**[0010]** Fig. 4 is a partial perspective view of a computer system in accordance with some embodiments of the invention.

**[0011]** Fig. 5 is a perspective view of another computer system in accordance with some embodiments of the invention.

**[0012]** Fig. 6 is a perspective view of another computer system in accordance with some embodiments of the invention.

**[0013]** Fig. 7 is a diagram of another computer system in accordance with some embodiments of the invention.

**[0014]** Fig. 8 is a diagram of another computer system in accordance with some embodiments of the invention.

**[0015]** Fig. 9 is a block diagram of an audio processor in accordance with some embodiments of the invention.

**[0016]** Fig. 10 is another block diagram of an audio processor in accordance with some embodiments of the invention.

**[0017]** Fig. 11 is another block diagram of an audio processor in accordance with some embodiments of the invention.

## DESCRIPTION

**[0018]** In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular structures, architectures, interfaces, techniques, etc. in order to provide a thorough understanding of the various aspects of the invention. However, it will be apparent to those skilled in the art having the benefit of the present disclosure that the various aspects of the invention may be practiced in other examples that depart from these specific details. In certain instances, descriptions of well known devices, circuits, and methods are omitted so as not to obscure the description of the present invention with unnecessary detail.

**[0019]** With reference to Figs. 1, some embodiments of the invention may include processing an audio signal by providing a computer system (e.g. at block 11), identifying one or more audio sources associated with the computer system (e.g. at block 12), identifying two or more different audio endpoints associated with the computer system (e.g. at block 13), processing an audio signal from one of the audio sources, the audio

signal having N different audio channels, where N is a positive integer greater than one (e.g. at block 14), the processing including generating X audio channels from the N different audio channels in the audio signal, where X is an integer less than N (e.g. at block 15), generating Y audio channels from the N different audio channels in the audio signal, where Y is an integer less than N and wherein at least two of the X and Y audio channels are generated from different ones of the N different audio channels (e.g. at block 16), directing the X audio channels to one of the two or more different audio endpoints (e.g. at block 17), and directing the Y audio channels to a different one of the two or more different audio endpoints (e.g. at block 18).

**[0020]** For example, in some embodiments generating the X and Y audio channels may involve copying or extracting respective audio channels from the N different audio channels. In other embodiments, generating the X and Y audio channels may involve converting respective audio channels from the N different audio channels. In other embodiments, generating the X and Y audio channels may involve mixing respective audio channels from the N different audio channels. In still other embodiments, generating the X and Y audio channels may involve various combinations of copying, extracting, converting, mixing and / or otherwise processing respective audio channels from the N different audio channels. In some examples, there may be some overlap between the subset of N audio channels used generate the X audio channels and the subset of N audio channels used to generate the Y audio channels.

**[0021]** With reference to Fig. 2, for example, in some embodiments directing the X audio channels may include directing the X audio channels to an audio endpoint associated with an audio amplifier device directly mounted on a motherboard of the computer system (e.g. at block 21), and directing the Y audio channels may include directing the Y audio channels to an audio endpoint associated with an audio output device connected to the computer system by a data bus (e.g. at block 22). For example, the audio amplifier device on the motherboard may be configured to drive one of a headphone output connector and an external audio output connector (e.g. block 23). For example, the audio output device connected to the computer system by a bus may be an add-on audio card (e.g. block 24). For example, in some embodiments the data bus may be a universal serial bus (USB) and the audio output device connected to the computer system by the data bus may include a USB audio device (e.g. block 25).

**[0022]** With reference to Fig. 3, some embodiments of the invention may include providing a user interface which allows a user of the computer system to indicate selected channels of a multi-channel audio signal to be assigned to different audio output devices coupled to the computer system (e.g. block 31). For example, some embodiments of the invention may include providing a graphical user interface on the computer system (e.g. block 32), providing a user-selectable list of audio sources through the graphical user interface (e.g. block 33), providing a user-selectable list of audio endpoints through the graphical user interface (e.g. block 34), and providing a graphical selection mechanism wherein a user can indicate selected channels of an audio signal associated with a selected audio source to assign to different specified audio endpoints (e.g. block 35).

**[0023]** Some embodiments may further include directing the X audio channels to a first specified audio endpoint in accordance with the user selection in the graphical user interface (e.g. block 36) and directing the Y audio channels to a different specified audio endpoints in accordance with the user selection in the graphical user interface (e.g. block 37).

**[0024]** With reference to Fig. 4, a computer system 40 in accordance with some embodiments of the invention may include a processor 41, a memory 42 coupled to the processor 41, two or more different audio output devices 43 and 44 associated with the computer system, and an audio driver capable of being loaded in the memory 42 and executed by the processor 41 to identify one or more audio sources associated with the computer system, identify two or more different audio endpoints associated with the two or more different audio output devices, and process an audio signal from one of the audio sources, the received audio signal having N different audio channels, where N is a positive integer greater than one. The audio driver may also generate X audio channels from the N different audio channels in the audio signal, where X is an integer less than N, generate Y audio channels from the N different audio channels in the audio signal, where Y is an integer less than N and wherein at least two of the X and Y audio channels are generated from different ones of the N different audio channels, direct the X audio channels to one of the two or more different audio endpoints, and direct the Y audio channels to a different one of the two or more different audio endpoints.

**[0025]** For example, in some embodiments of the invention the X audio channels may be directed to an audio endpoint associated with an audio amplifier device 43 mounted on a motherboard 45 of the computer system, and the Y audio channels may be

directed to an audio endpoint associated with an audio output device 44 connected to the computer system 40 by a data bus. For example, the audio amplifier device 43 on the motherboard may be configured to drive a headphone output connector or an external audio output connector 46. For example, the audio output device 44 connected to the computer system by a bus may include an add-on audio card 47. For example, the bus may be a universal serial bus (USB) and the audio output device connected to the computer system by the bus may include a USB audio device. For example, the bus may be a Peripheral Component Interconnect (PCI) bus or a PCI-Express bus and the audio output device may be an audio expansion card.

**[0026]** In some embodiments of the invention, the system 40 may further include a user interface configured to run on the computer system 40 which allows a user of the computer system to indicate selected channels of a multi-channel audio signal to be assigned to different audio output devices 43 and 44 coupled to the computer system 41. For example, the system 40 may include a graphical user interface on the computer system 40, a user-selectable list of audio sources through the graphical user interface, a user-selectable list of audio endpoints through the graphical user interface, and a graphical selection mechanism wherein a user can indicate selected channels of an audio signal associated with a selected audio source to assign to different specified audio endpoints. For example, the X audio channels may be directed to a first specified audio endpoint in accordance with the user selection in the graphical user interface, and the Y audio channels may be directed to a different specified audio endpoint in accordance with the user selection in the graphical user interface.

**[0027]** With reference to Figs. 5 and 6, in some embodiments of the invention, respective portable computer systems may include a display 51, an enclosure 52 housing a processor and memory, a stereo output connector 53 on the enclosure 52, and a pair of speakers 54 integrated with one of the display 51 (e.g. see Fig. 6) and the enclosure 52 (e.g. see Fig. 5). For example, the X audio channels may include at least a front left, a front right and a center channel directed by the audio driver to an audio endpoint associated with the integrated pair of speakers 54. For example, the Y audio channels may include at least one of a rear left and a surround left channel and also at least one of a rear right and a surround right channel directed by the audio driver to an audio endpoint associated with the stereo output connector 53.

**[0028]** Advantageously, some embodiments of the invention may provide a more compelling user experience with only a small amount of extra cost. For example, a user may add a pair of external speakers 65 to their laptop at relatively low cost (e.g. see Fig. 6). Even without adding a specialized audio card, the user may enjoy watching a DVD movie with a 5.1 or 7.1 channel soundtrack by assigning the front left and right channels to the integrated speakers 54, assigning the center channel to be applied equally to the integrated speakers 54 (thus simulating the center speaker with the two front stereo speakers), and assigning the back left and right channels (e.g. for 5.1 sound) and surround left and right channels (e.g. for 7.1 sound) to the stereo output connector (which drives the external speakers 65). At the user's discretion, the low frequency effects (e.g. the LFE or .1) channel may also be assigned to one or both of the external speakers 65. With the external speakers 65 positioned either to the side of the user or slightly behind the user, the cinematic surround sound may be simulated and the user experience may be enhanced.

**[0029]** With reference to Fig. 7, a desktop computer system 70 in accordance with some embodiments of the invention may include a separate display 71 and an enclosure 72 housing a processor and memory. The system 70 may include a stereo output connector 73 on the enclosure 72. The display 71 may include a pair of speakers 74 integrated with the display 71. In some embodiments of the invention, the enclosure 72 may also include an integrated speaker or pair of speakers.

**[0030]** With reference to Fig. 8, an all-in-one desktop computer system 80 in accordance with some embodiments of the invention may include an integrated display 81 and enclosure 82 housing a processor and memory. The system 80 may include a stereo output connector on the enclosure 82 (e.g. on the back of the enclosure 82, not shown). The system 80 may further include a pair of speakers 84 integrated with the enclosure 82 of the all-in-one system 80.

**[0031]** With reference to Fig. 9, in accordance with some embodiments of the invention an audio processor 90 may include a first portion 91 to identify one or more audio sources associated with a computer system, a second portion 92 to identify two or more different audio endpoints associated with two or more different audio output devices, and a third portion 93 to process an audio signal from one of the audio sources, the received audio signal having N different audio channels, where N is a positive integer greater than one. For example, the third portion 93 may generate X audio channels from the N different audio channels in the audio signal, where X is an integer less than N,

generate Y audio channels from the N different audio channels in the audio signal, where Y is an integer less than N and wherein at least two of the X and Y audio channels are generated from different ones of the N different audio channels, direct the X audio channels to one of the two or more different audio endpoints, and direct the Y audio channels to a different one of the two or more different audio endpoints.

**[0032]** For example, in some embodiments of the audio processor the X audio channels may be directed to an audio endpoint associated with an audio amplifier device mounted on a motherboard of the computer system, and the Y audio channels may directed to an audio endpoint associated with an audio output device connected to the computer system by a data bus. For example, the audio amplifier device on the motherboard may be configured to drive a headphone output connector or an external audio output connector, and the audio output device connected to the computer system by a bus may include an add-on audio card.

**[0033]** In some embodiments of the invention, the audio processor may include a user interface configured to run on a computer system which allows a user of the computer system to indicate selected channels of a multi-channel audio signal to be assigned to different audio output devices coupled to the computer system. For example, the audio processor may include a graphical user interface on the computer system, a user-selectable list of audio sources through the graphical user interface, a user-selectable list of audio endpoints through the graphical user interface, and a graphical selection mechanism wherein a user can indicate selected channels of an audio signal associated with a selected audio source to assign to different specified audio endpoints. For example, the X audio channels may be directed to a first specified audio endpoint in accordance with the user selection in the graphical user interface, and the Y audio channels may directed to a different specified audio endpoint in accordance with the user selection in the graphical user interface.

**[0034]** Advantageously, some embodiments of the invention may provide a simple user mode audio driver. For example, the audio driver may implement an audio re-tasking capability at a higher level of the software stack than the kernel driver. Another advantage of some embodiments of the invention is that the audio driver may support a multitude of audio cards. A particular advantage of some embodiments of the invention is that the audio cloning/redirection may not be based

on one audio driver but may be provided across all audio cards and circuits attached to the computer system.

**[0035]** With reference to Fig. 10, in accordance with some embodiments of the invention a first portion of an audio system may include two or more applications (APP) providing respective audio sources. A second portion of the audio system may include two or more audio logical devices corresponding to two or more different audio endpoints (e.g. associated with two or more different physical audio output devices). A third portion of the audio system may include two or more LFX (Local Effects) processors, Global Mixers, and GFX (Global Effects) processors to process an audio signal from one or more of the audio sources. The third portion of the audio system may further include a cloning / redirection data buffer which may be shared among the GFX processors. Respective outputs from the GFX processors may be provided to the audio logical devices.

**[0036]** With reference to Fig. 11, in accordance with some embodiments of the invention a first portion of an audio system may include two or audio streams providing respective audio sources (e.g. a stereo stream, a six channel stream for 5.1 audio, an eight channel stream for 7.1 audio, etc.). A second portion of the audio system may include a port class audio adapter (e.g. Microsoft Windows™ PortCls driver) which supports two or more audio logical devices corresponding to two or more different audio endpoints (e.g. associated with two or more different physical audio output devices). A third portion of the audio system may include two or more LFX processors, a Global Mixer, and GFX processors to process an audio signal from one or more of the audio sources. The third portion of the audio system may further include a shared buffer pool which may be shared among the GFX processors. Respective outputs from the GFX processors may be provided to the PortCls audio adapter.

**[0037]** For example, some embodiments of the invention may utilize a Windows Vista™ APO (Audio Processing Object) architecture to implement a new usage module in the audio driver area. For example, an audio driver according to some embodiments of the invention may be implemented in the APO (one user mode audio driver plug-in module) and support several or all UAA (Universal Audio Architecture) compliant devices attached to the computer system. Advantageously, the audio driver implemented in the APO, according to some embodiments of the invention, may provide re-tasking work (e.g. cloning and / or redirection) across two or more different UAA-compliant audio devices.

**[0038]** Some embodiments of the invention may provide a methodology for cloning and / or redirection of the audio stream between two or more different audio devices / endpoints which comply with the Vista UAA driver. For example, embodiments of the invention may be used to redirect a speaker output to a headphone output and vice versa. For example, embodiments of the invention may also be used to redirect an on-board HD audio output to a USB audio card and vice versa. For example, embodiments of the invention may also be utilized to simulate a multi-channel output across two or more different UAA compliant audio devices, including for example an on-board HD audio device together with a plugged-in USB audio card. For example, some embodiments of the invention may use one speaker jack, one headphone jack and one USB audio card jack to simulate a 5.1 channel output effect.

**[0039]** An example of an embodiment of the invention includes a framework having two associated modules. One module may be implemented as a Vista LFX (Local Effects) APO, which is responsible to generate a uniform audio output to the Microsoft™ Global Mixer (e.g. as a 7.1 channel output). Another module may be implemented as a Vista GFX (Global Effects) APO, which will dump the Global Mixer's output audio stream to a shared buffer or read the audio stream from the shared buffer and then perform a corresponding DSP algorithm (e.g. DownMix) to generate a final audio output.

**[0040]** For example, the framework may be implemented as follows:

1) In the Vista LFX APO (which is application based, that means each audio application will have one LFX APO instance), a corresponding algorithm may be used to do the up-mix on the LFX input and make the LFX output to be 7.1 channels format.

2) In the Vista GFX APO (which is audio endpoint based, that means each audio endpoint, like speaker, headphone, S/PDIF, USB audio and so on will have only one APO instance in the whole system), it will receive the 7.1 channels audio stream from Microsoft Global Mixer.

3) If the APO acts as the source of cloning / redirection, it will put the 7.1 channels buffer to a shared buffer pool. If the APO acts as the sink of cloning / redirection, it may read the 7.1 channels audio stream from shared buffer pool.

4) According to an applied policy, the APO may handle the 7.1 channels audio stream in different manner. For example, if the APO is the full channels sink of cloning / redirection, it will perform the corresponding DSP modules on 7.1 channels stream in the shared buffer pool and generate the audio output stream in its native format, for example 2

channels output for headphone. If the APO is the source sink of cloning, it will still generate the corresponding output with the 7.1 channels input. If the APO is the source sink of redirection, it will generate the SILENT output regardless of its input. If the APO is the partial channels sink of cloning / redirection, it will extract the needed channels output from the shared buffer pool and generate the corresponding output.

**[0041]** The LFX APO module may perform one specific task, namely an UP-Mix task. For example, the up-mix algorithm may be either a padding algorithm or another algorithm like Dolby PLIIx™, among others. The target may be to generate the 7.1 channels or higher audio format stream and try to provide as much information as possible and / or practical from the original stream to be processed by any further cloning / redirection module in the GFX APO.

**[0042]** Following is an example up-mix padding algorithm with the assumption of the output format will be 7.1 channels audio format. For the purpose of this example, the input/output buffer may be considered to be all in the non-interlaced format. Namely, pInBuf[0] pInBuf[1], ... , is for the input buffer first, second, ... channel and likewise for pOutBuf[0], pOutBuf[1], ... , and so on.

1) For each channel in the pInBuf, copy all data from pInBuf[0], pInBuf[1], .. pInBuf[nInChannel] to pOutBuf[0], pOutBuf[1], ... pOutBuf[nChannel];

2) for the pOutBuffer[nChannel], pOutBuffer[nChannel+1], ... pOutBuffer[8], assign the value to be 0.

**[0043]** In the GFX APO module, there may be two basic roles for each GFX module. For example, the role may be either the source of the cloning / redirection or the sink of the cloning / redirection. In some embodiments of the invention, the flow of the source of cloning / redirection may be as follows:

1) Copy the input 7.1 channels audio data to the shared buffer pool. And record its audio format information, include sample frequency, samples per audio frame and so on.

2) If the current setting is the source of cloning, perform other DSP algorithm on the input data and generate the correct sound to underlying module.

3) If the current setting is the source of redirection, the output sound may be set to be SILENT.

**[0044]** In some embodiments of the invention, the flow of the full channels sink of cloning / redirection may be as follows:

1) Check whether the shared buffer pool contains the audio data.

2) If there is data available in the shared buffer, read the 7.1 channels audio date from the shared buffer pool.

3) Check the current audio endpoint capability and its responsibility in the cloning / redirection. Perform corresponding DSP to generate the correct output channels audio output according to current audio endpoint capability. For example, including:

a) If the current audio endpoint is the stereo output (whether stereo speaker or headphone), perform 8-to-2 down-mix to generate final 2-channels output.

b) if the current audio endpoint is the 4-channels output, perform 8-to-4 down-mix to generate the final 4-channels output.

c) If the current audio endpoint is the 5.1 output, perform 8-to-6 down-mix to generate final 6-channels output.

d) If the current audio endpoint is the 7.1 output, pass all 8-channels input to the output.

4) A sample frequency conversion module may be performed on the output of 3) if needed if the audio endpoint output frequency is not same as input audio's sample frequency.

**[0045]** In some embodiments of the invention, the flow of the partial channels sink of cloning / redirection may be as follows:

1) Check the current global audio output format setting (e.g. 5.1 or 7.1 channels output); if it is 5.1 channels output, it will perform 8-to-6 down-mix. For example, pInBuf[FL], pInBuf[FR], pInBuf[FC], pInBuf[LFE], pInBuf[SL], pInBuf[SR] may be used to represent the 5.1 channels data, and pInBuf[BL] and pInBuf[BR] may be used in addition for 7.1 channels data. For example, pInBuf[0], pInBuf[1], ... pInBuf[7] may be used to represent 7.1 channels data in the order of FL, FR, C, LFE, SL, SR, BL, BR and to represent 5.1 channels data in the same order, where pInBuf[6], pInBuf[7] contains all SILENT data.

2) Check the current audio endpoint role in the global audio output and its output capability. For example, a different i by j (i*j) channel-matrix vectors may be used to generate the corresponding audio output.

3) For example, if the output audio endpoint's capability is 2-channels, the channel-matrix vector will be a 2*8 vector and the output pOutBuf may be:

$$(pOutBuf[0], pOutBuf[1]) = (pInBuf[0], pInBuf[1],...pInBuf[7]) \times \begin{pmatrix} a_{00} & a_{01} \\ a_{10} & a_{11} \\ .. & .. \\ a_{70} & a_{71} \end{pmatrix},$$

where $a_{ij}$ will be 0 or 1, and at most one $a_{ij}$ equals to 1 for each row and column

For example, a00 and a11 equals to 1 will means that the current audio endpoint will be used for FL, FR for the final 5.1 or 7.1 channels output.

**[0046]** For example, if the output audio endpoint's capability is 4-channels, the channel-matrix vector will be a 4*8 vector and the output pOutBuf may be:

$$(pOutBuf[0], pOutBuf[1], pOutBuf[2], pOutBuf[3]) =$$

$$(pInBuf[0], pInBuf[1],...pInBuf[7]) \times \begin{pmatrix} a_{00} & a_{01} & a_{02} & a_{03} \\ a_{10} & a_{11} & a_{12} & a_{13} \\ .. & .. & .. & .. \\ a_{70} & a_{71} & a_{72} & a_{73} \end{pmatrix},$$

where $a_{ij}$ will be 0 or 1, and at most one $a_{ij}$ equals to 1 for each row and column

For example, if the $a_{00}$, $a_{11}$, $a_{24}$ and $a_{35}$ equal to 1, the output will be FL, FR, SL and SR of the final 5.1 or 7.1 channels output. If the $a_{62}$, $a_{73}$ equals to 1, the output will be BL and BR of the final 7.1 channels output and in this example, only two speakers have the sound output.

**[0047]** For example, if the output audio endpoint's capability is 6-channels, the channel-matrix vector will be a 6*8 vector and the output pOutBuf may be:

$$(pOutBuf[0], pOutBuf[1], pOutBuf[2], pOutBuf[3], pOutBuf[4], pOutBuf[5]) =$$

$$(pInBuf[0], pInBuf[1],...pInBuf[7]) \times \begin{pmatrix} a_{00} & a_{01} & a_{02} & a_{03} & a_{04} & a_{05} \\ a_{10} & a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\ .. & .. & .. & .. & .. & .. \\ a_{70} & a_{71} & a_{72} & a_{73} & a_{74} & a_{75} \end{pmatrix},$$

where $a_{ij}$ will be 0 or 1, and at most one $a_{ij}$ equals to 1 for each row and column

By setting the value of $a_{ij}$, a different speaker arrangement may be selected to output the different channels of the final output.

**[0048]** Advantageously, in accordance with some embodiments of the invention, by setting different combinations of the channel-matrix vector for different audio endpoints, different cloning effects may be simulated. For example, one USB audio card, one stereo speaker output jack and one headphone output jack may be used to simulate a 5.1 channels output.

**[0049]** Those skilled in the art will appreciate that, given the benefit of the present description, a numerous variety of other circuits and combinations of hardware and / or software may be configured to implement various methods, circuits, and systems in accordance with the embodiments described herein and other embodiments of the invention. The examples of Figs. 1 through 11 are non-limiting examples of suitable embodiments.

**[0050]** For example, in some embodiments of the invention, the audio source's number of audio channels (N) is not necessarily larger than the number of audio channels for the audio end point. For example, in some frameworks, (e.g. as illustrated in Fig, 11 in LFX module), PADDING may be applied to an input audio source to generate an 8-Channel stream or more if needed or desired. For example, if the audio source channel is n (e.g. where $n < N$), after it is processed by LFX module, the generated audio signal may be an audio signal with the N audio channels.

**[0051]** For example, in some embodiments for a full cloning usage, the generated X and Y audio channels may correspond exactly to respective channel capabilities of different audio endpoints. For example, one endpoint may correspond to a USB audio card which has two output channels while another endpoint may correspond to a PCI audio card which can render 5.1 audio outputs. The input audio source may be converted to an X=2 audio channels audio signal and a Y=5.1 audio channels audio signal respectively. The X=2 audio channels audio signal may be directed to one audio endpoint (e.g. the USB audio card) and at the same time, the Y=5.1 audio channels audio signal may be directed to another audio endpoint (e.g. the PCI audio card).

**[0052]** For example, in some embodiments for a full redirection usage, only the X audio channels audio signal may be directed to one audio endpoint or only the Y audio channels audio signal may be directed to another audio endpoint (e.g. in accordance with a user selection from the user interface). For example, in some embodiments for a partial

cloning / redirection usage, just the X audio channels may be extracted from the input N channels audio source and the X audio channels may be directed to one audio endpoint. For example, the other N-X audio channels may be directed to another audio endpoint at the same time (e.g. in accordance with a user selection from the user interface). Advantageously, two low-capability audio endpoints (which can only render X channels and N-X channels audio) may be utilized to simulate a higher-capability audio endpoint.

**[0053]** The foregoing and other aspects of the invention are achieved individually and in combination. The invention should not be construed as requiring two or more of such aspects unless expressly required by a particular claim. Moreover, while the invention has been described in connection with what is presently considered to be the preferred examples, it is to be understood that the invention is not limited to the disclosed examples, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and the scope of the invention.

## CLAIMS

What is claimed is:

1. A method of processing an audio signal, comprising:

providing a computer system;

identifying one or more audio sources associated with the computer system;

identifying two or more different audio endpoints associated with the computer system;

processing an audio signal from one of the audio sources, the audio signal having N different audio channels, where N is a positive integer greater than one, the processing including:

generating X audio channels from the N different audio channels in the audio signal, where X is an integer less than N;

generating Y audio channels from the N different audio channels in the audio signal, where Y is an integer less than N and wherein at least two of the X and Y audio channels are generated from different ones of the N different audio channels;

directing the X audio channels to one of the two or more different audio endpoints; and

directing the Y audio channels to a different one of the two or more different audio endpoints.

2. The method of claim 1, wherein directing the X audio channels comprises directing the X audio channels to an audio endpoint associated with an audio amplifier device directly mounted on a motherboard of the computer system,

and wherein directing the Y audio channels comprises directing the Y audio channels to an audio endpoint associated with an audio output device connected to the computer system by a data bus.

3. The method of claim 2, wherein the audio amplifier device on the motherboard is configured to drive one of a headphone output connector and an external audio output connector.

4. The method of claim 3, wherein the audio output device connected to the computer system by the data bus comprises an add-on audio card.

5. The method of claim 3, wherein the data bus comprises a universal serial bus (USB) and the audio output device connected to the computer system by the data bus comprises a USB audio device.

6. The method of claim 1, further comprising:

providing a user interface which allows a user of the computer system to indicate selected channels of a multi-channel audio signal to be assigned to different audio output devices coupled to the computer system.

7. The method of claim 6, further comprising:

providing a graphical user interface on the computer system;

providing a user-selectable list of audio sources through the graphical user interface;

providing a user-selectable list of audio endpoints through the graphical user interface;

providing a graphical selection mechanism wherein a user can indicate selected channels of an audio signal associated with a selected audio source to assign to different specified audio endpoints;

directing the X audio channels to a first specified audio endpoint in accordance with the user selection in the graphical user interface; and

directing the Y audio channels to a different specified audio endpoints in accordance with the user selection in the graphical user interface.

8. A computer system, comprising:

a processor;

a memory coupled to the processor;

two or more different audio output devices associated with the computer system; and

an audio driver capable of being loaded in the memory and executed by the processor to:

identify one or more audio sources associated with the computer system;

identify two or more different audio endpoints associated with the two or more different audio output devices;

process an audio signal from one of the audio sources, the received audio signal having N different audio channels, where N is a positive integer greater than one, including to:

generate X audio channels from the N different audio channels in the audio signal, where X is an integer less than N;

generate Y audio channels from the N different audio channels in the audio signal, where Y is an integer less than N and wherein at least two of the X and Y audio channels are generated from different ones of the N different audio channels;

direct the X audio channels to one of the two or more different audio endpoints; and

direct the Y audio channels to a different one of the two or more different audio endpoints.

9. The system of claim 8, wherein the X audio channels are directed to an audio endpoint associated with an audio amplifier device mounted on a motherboard of the computer system,

and wherein the Y audio channels are directed to an audio endpoint associated with an audio output device connected to the computer system by a data bus.

10. The system of claim 9, wherein the audio amplifier device on the motherboard is configured to drive one of a headphone output connector and an external audio output connector.

11. The system of claim 10, wherein the audio output device connected to the computer system by the data bus comprises an add-on audio card.

12. The system of claim 10, wherein the data bus comprises a universal serial bus (USB) and the audio output device connected to the computer system by the data bus comprises a USB audio device.

13. The system of claim 8, further comprising:

a user interface configured to run on the computer system which allows a user of the computer system to indicate selected channels of a multi-channel audio signal to be assigned to different audio output devices coupled to the computer system.

14. The system of claim 13, further comprising:

a graphical user interface on the computer system;

a user-selectable list of audio sources through the graphical user interface;

a user-selectable list of audio endpoints through the graphical user interface; and

a graphical selection mechanism wherein a user can indicate selected channels of an audio signal associated with a selected audio source to assign to different specified audio endpoints,

wherein the X audio channels are directed to a first specified audio endpoint in accordance with the user selection in the graphical user interface,

and wherein the Y audio channels are directed to a different specified audio endpoint in accordance with the user selection in the graphical user interface.

15. The system of claim 8, further comprising:

a display;

an enclosure housing the processor and memory;

a stereo output connector on the enclosure; and

a pair of speakers integrated with one of the display and the enclosure,

wherein the X audio channels includes at least a front left, a front right and a center channel directed by the audio driver to an audio endpoint associated with the integrated pair of speakers,

and wherein the Y audio channels includes at least one of a rear left and a surround left channel and also at least one of a rear right and a surround right channel

directed by the audio driver to an audio endpoint associated with the stereo output connector.

16. An audio processor, comprising:

a first portion to identify one or more audio sources associated with a computer system;

a second portion to identify two or more different audio endpoints associated with two or more different audio output devices; and

a third portion to process an audio signal from one of the audio sources, the received audio signal having N different audio channels, where N is a positive integer greater than one, the third portion further to:

generate X audio channels from the N different audio channels in the audio signal, where X is an integer less than N;

generate Y audio channels from the N different audio channels in the audio signal, where Y is an integer less than N and wherein at least two of the X and Y audio channels are generated from different ones of the N different audio channels;

direct the X audio channels to one of the two or more different audio endpoints; and

direct the Y audio channels to a different one of the two or more different audio endpoints.

17. The audio processor of claim 16, wherein the X audio channels are directed to an audio endpoint associated with an audio amplifier device mounted on a motherboard of the computer system,

and wherein the Y audio channels are directed to an audio endpoint associated with an audio output device connected to the computer system by a data bus.

18. The audio processor of claim 17, wherein the audio amplifier device on the motherboard is configured to drive one of a headphone output connector and an external audio output connector, and wherein the audio output device connected to the computer system by the data bus comprises an add-on audio card.

19. The audio processor of claim 16, further comprising:

a user interface configured to run on a computer system which allows a user of the computer system to indicate selected channels of a multi-channel audio signal to be assigned to different audio output devices coupled to the computer system.

20. The audio processor of claim 19, further comprising:

a graphical user interface on the computer system;

a user-selectable list of audio sources through the graphical user interface;

a user-selectable list of audio endpoints through the graphical user interface; and

a graphical selection mechanism wherein a user can indicate selected channels of an audio signal associated with a selected audio source to assign to different specified audio endpoints,

wherein the X audio channels are directed to a first specified audio endpoint in accordance with the user selection in the graphical user interface,

and wherein the Y audio channels are directed to a different specified audio endpoint in accordance with the user selection in the graphical user interface.

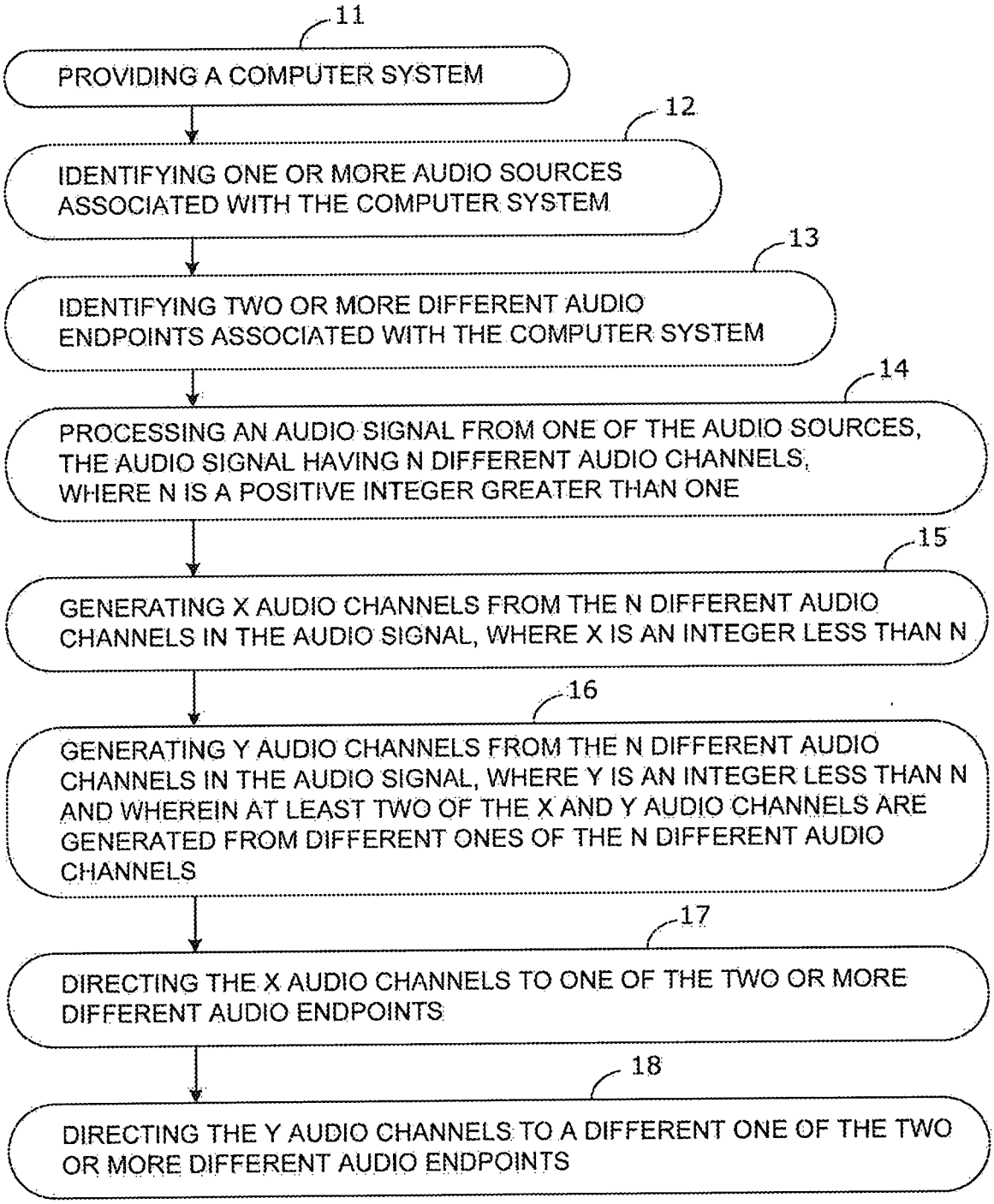
11
PROVIDING A COMPUTER SYSTEM
12
IDENTIFYING ONE OR MORE AUDIO SOURCES ASSOCIATED WITH THE COMPUTER SYSTEM
13
IDENTIFYING TWO OR MORE DIFFERENT AUDIO ENDPOINTS ASSOCIATED WITH THE COMPUTER SYSTEM
14
PROCESSING AN AUDIO SIGNAL FROM ONE OF THE AUDIO SOURCES, THE AUDIO SIGNAL HAVING N DIFFERENT AUDIO CHANNELS, WHERE N IS A POSITIVE INTEGER GREATER THAN ONE
15
GENERATING X AUDIO CHANNELS FROM THE N DIFFERENT AUDIO CHANNELS IN THE AUDIO SIGNAL, WHERE X IS AN INTEGER LESS THAN N
16
GENERATING Y AUDIO CHANNELS FROM THE N DIFFERENT AUDIO CHANNELS IN THE AUDIO SIGNAL, WHERE Y IS AN INTEGER LESS THAN N AND WHEREIN AT LEAST TWO OF THE X AND Y AUDIO CHANNELS ARE GENERATED FROM DIFFERENT ONES OF THE N DIFFERENT AUDIO CHANNELS
17
DIRECTING THE X AUDIO CHANNELS TO ONE OF THE TWO OR MORE DIFFERENT AUDIO ENDPOINTS
18
DIRECTING THE Y AUDIO CHANNELS TO A DIFFERENT ONE OF THE TWO OR MORE DIFFERENT AUDIO ENDPOINTS

Fig. 1

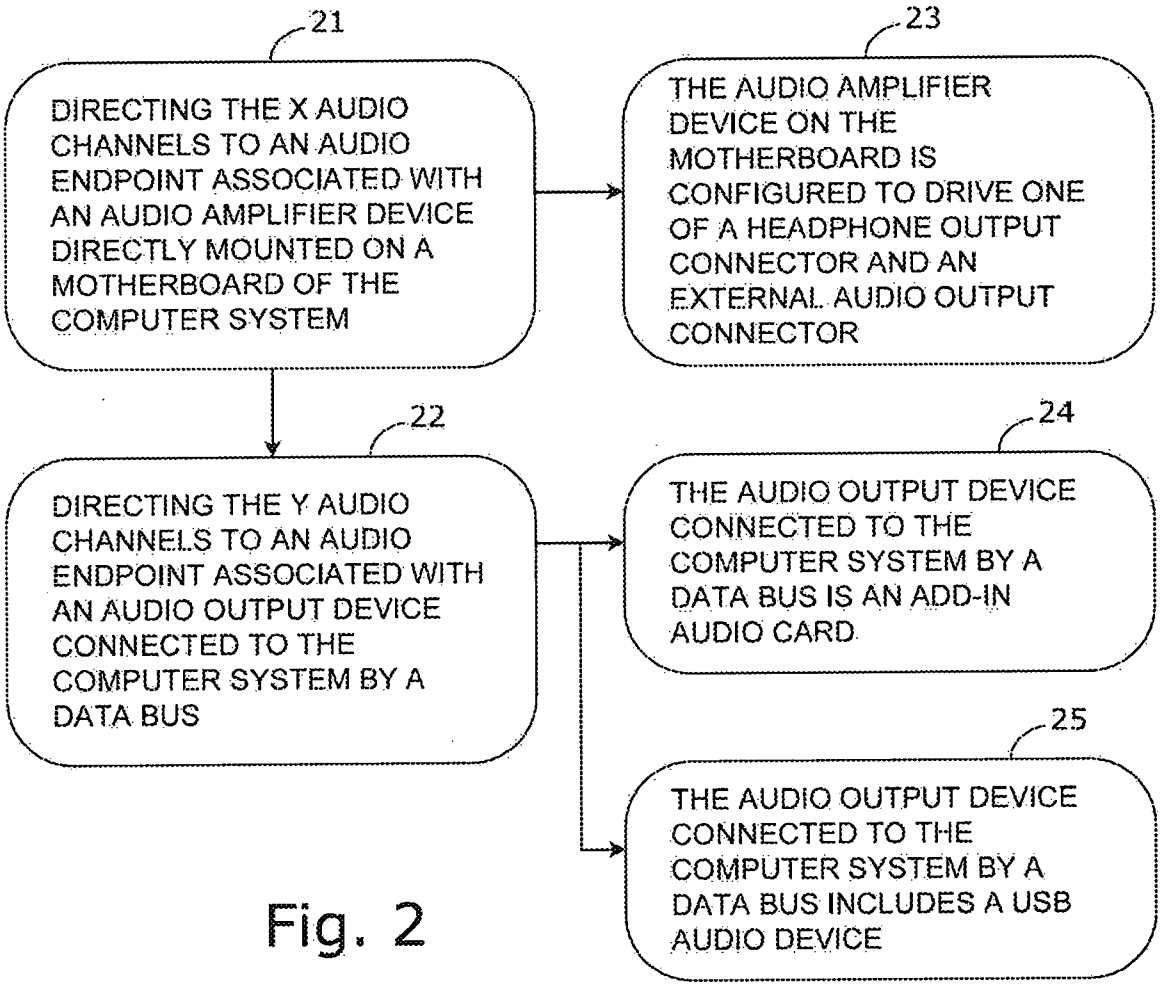
21
DIRECTING THE X AUDIO CHANNELS TO AN AUDIO ENDPOINT ASSOCIATED WITH AN AUDIO AMPLIFIER DEVICE DIRECTLY MOUNTED ON A MOTHERBOARD OF THE COMPUTER SYSTEM
23
THE AUDIO AMPLIFIER DEVICE ON THE MOTHERBOARD IS CONFIGURED TO DRIVE ONE OF A HEADPHONE OUTPUT CONNECTOR AND AN EXTERNAL AUDIO OUTPUT CONNECTOR
22
DIRECTING THE Y AUDIO CHANNELS TO AN AUDIO ENDPOINT ASSOCIATED WITH AN AUDIO OUTPUT DEVICE CONNECTED TO THE COMPUTER SYSTEM BY A DATA BUS
24
THE AUDIO OUTPUT DEVICE CONNECTED TO THE COMPUTER SYSTEM BY A DATA BUS IS AN ADD-IN AUDIO CARD
25
THE AUDIO OUTPUT DEVICE CONNECTED TO THE COMPUTER SYSTEM BY A DATA BUS INCLUDES A USB AUDIO DEVICE

Fig. 2

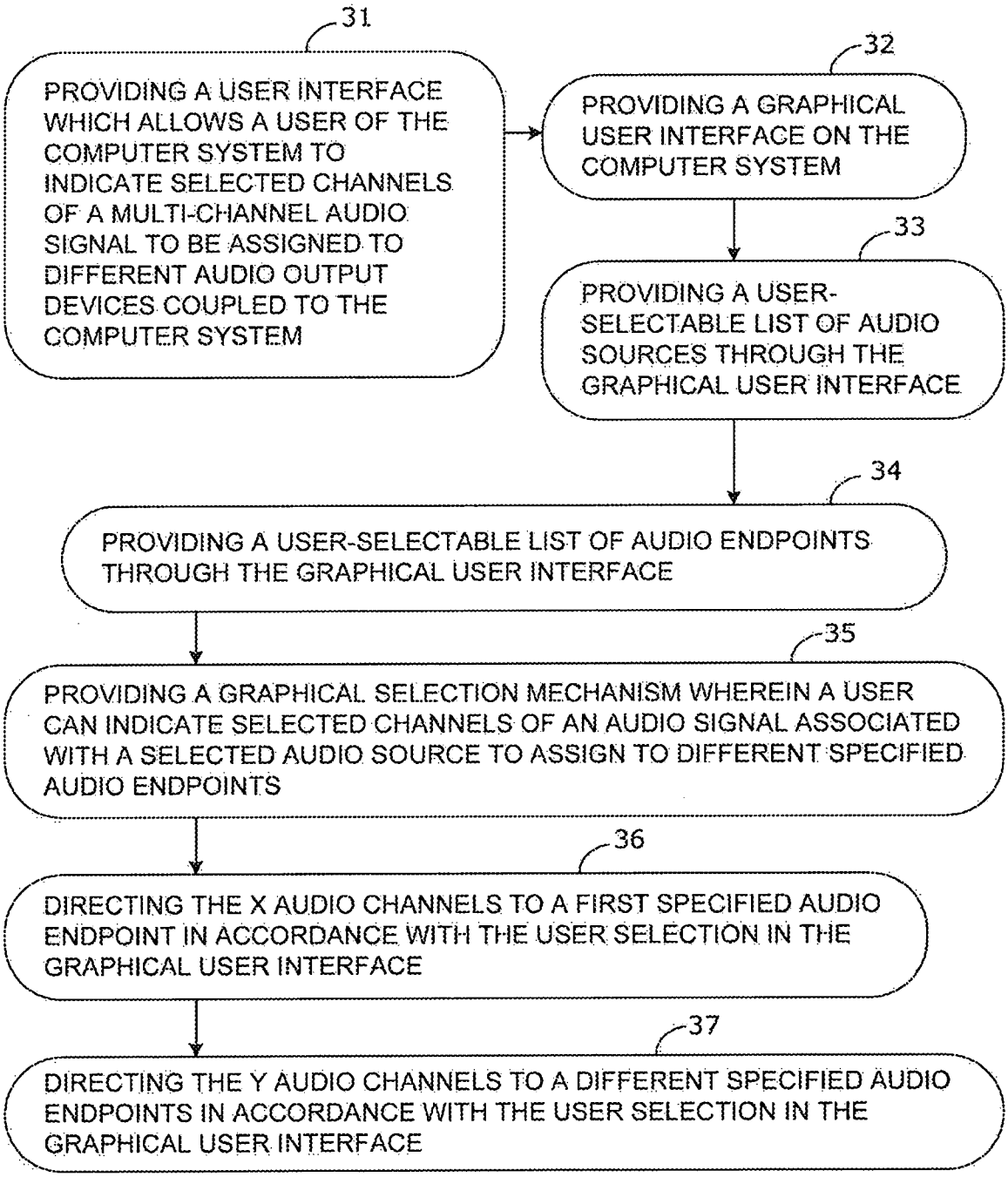
31
PROVIDING A USER INTERFACE WHICH ALLOWS A USER OF THE COMPUTER SYSTEM TO INDICATE SELECTED CHANNELS OF A MULTI-CHANNEL AUDIO SIGNAL TO BE ASSIGNED TO DIFFERENT AUDIO OUTPUT DEVICES COUPLED TO THE COMPUTER SYSTEM
32
PROVIDING A GRAPHICAL USER INTERFACE ON THE COMPUTER SYSTEM
33
PROVIDING A USER-SELECTABLE LIST OF AUDIO SOURCES THROUGH THE GRAPHICAL USER INTERFACE
34
PROVIDING A USER-SELECTABLE LIST OF AUDIO ENDPOINTS THROUGH THE GRAPHICAL USER INTERFACE
35
PROVIDING A GRAPHICAL SELECTION MECHANISM WHEREIN A USER CAN INDICATE SELECTED CHANNELS OF AN AUDIO SIGNAL ASSOCIATED WITH A SELECTED AUDIO SOURCE TO ASSIGN TO DIFFERENT SPECIFIED AUDIO ENDPOINTS
36
DIRECTING THE X AUDIO CHANNELS TO A FIRST SPECIFIED AUDIO ENDPOINT IN ACCORDANCE WITH THE USER SELECTION IN THE GRAPHICAL USER INTERFACE
37
DIRECTING THE Y AUDIO CHANNELS TO A DIFFERENT SPECIFIED AUDIO ENDPOINTS IN ACCORDANCE WITH THE USER SELECTION IN THE GRAPHICAL USER INTERFACE

Fig. 3

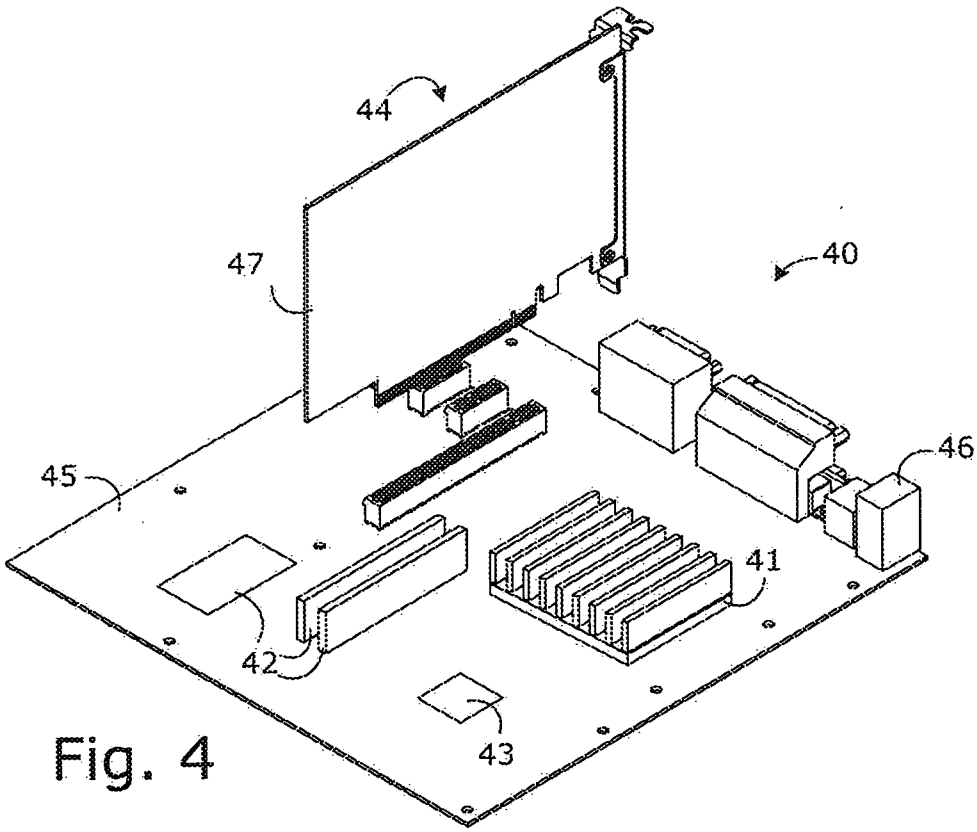


Fig. 4

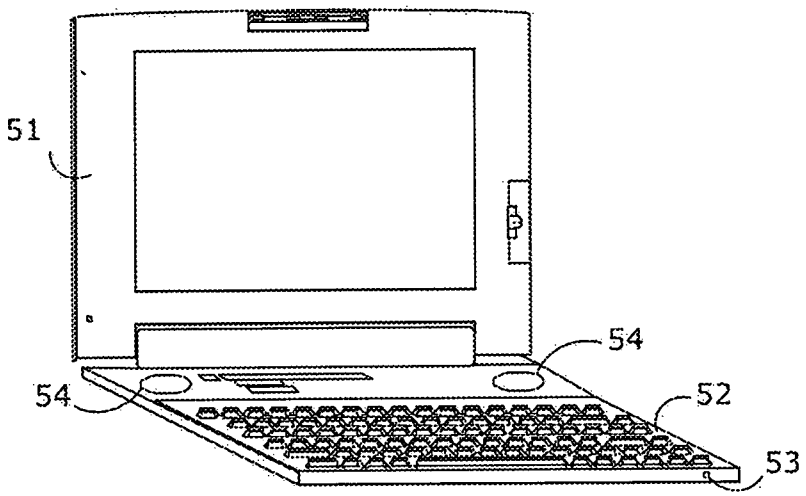


Fig. 5

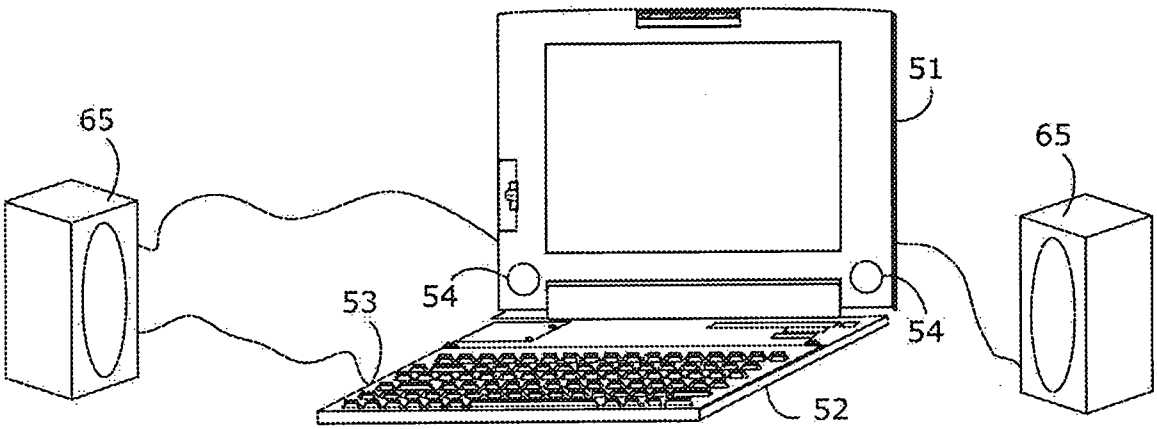


Fig. 6

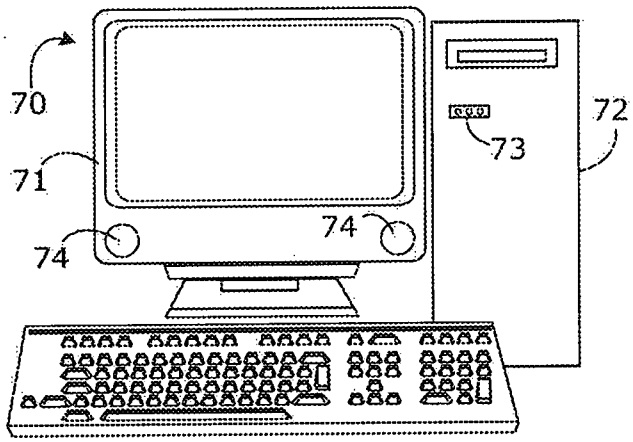


Fig. 7

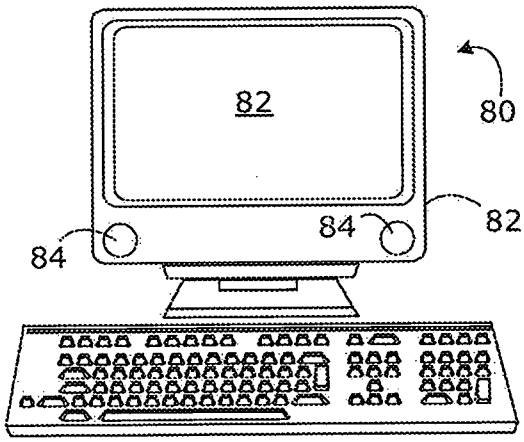


Fig. 8

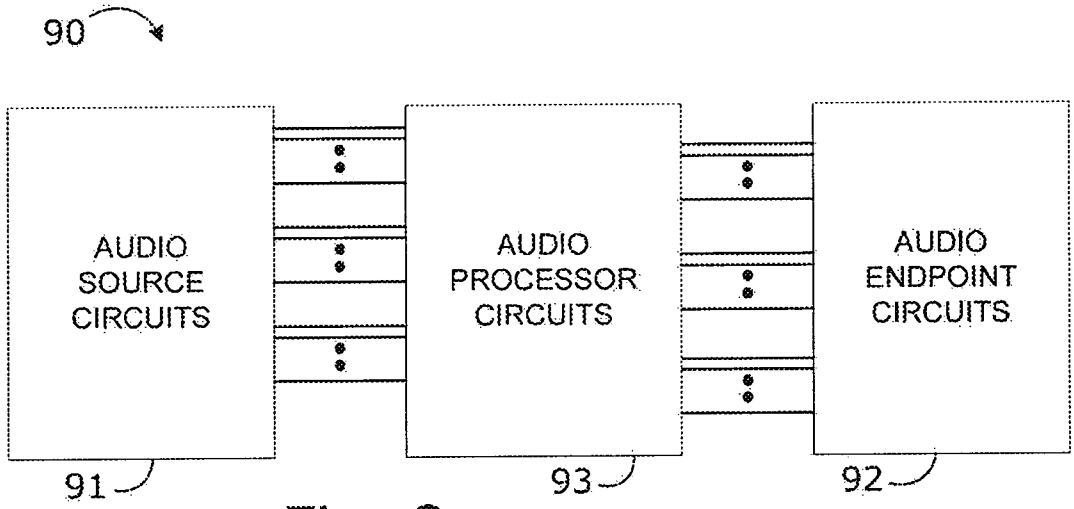
90
AUDIO SOURCE CIRCUITS
AUDIO PROCESSOR CIRCUITS
AUDIO ENDPOINT CIRCUITS
91
93
92

Fig. 9

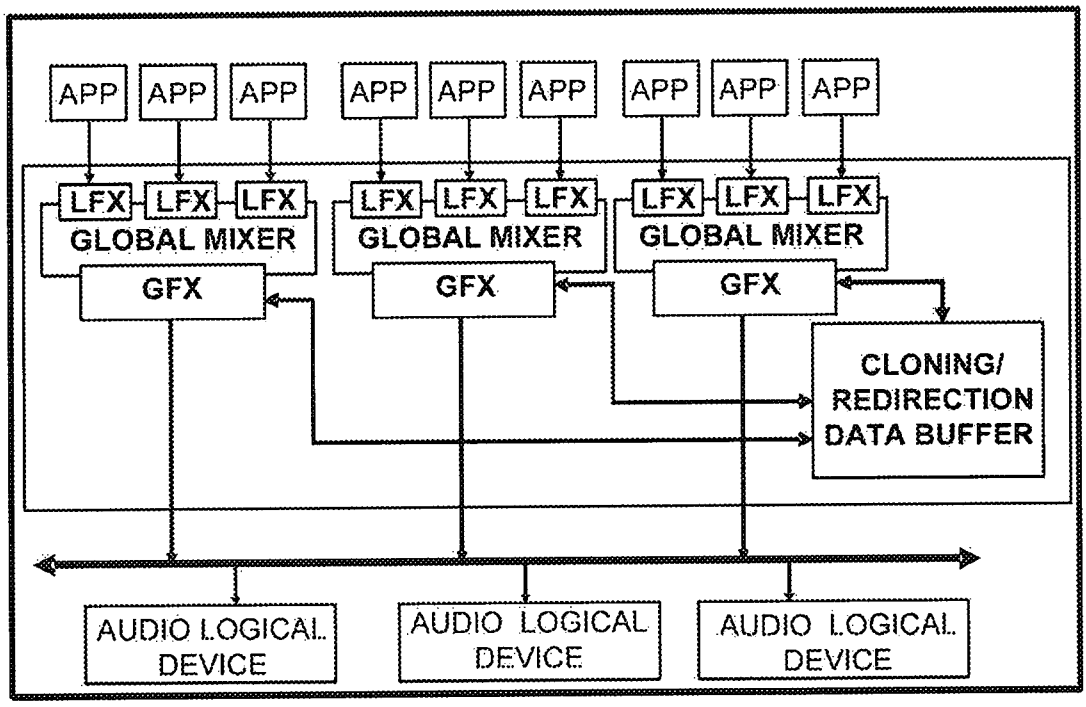
APP
APP
APP
APP
APP
APP
APP
APP
APP
LFX
LFX
LFX
GLOBAL MIXER
GFX
CLONING/ REDIRECTION DATA BUFFER
AUDIO LOGICAL DEVICE
AUDIO LOGICAL DEVICE
AUDIO LOGICAL DEVICE

Fig. 10

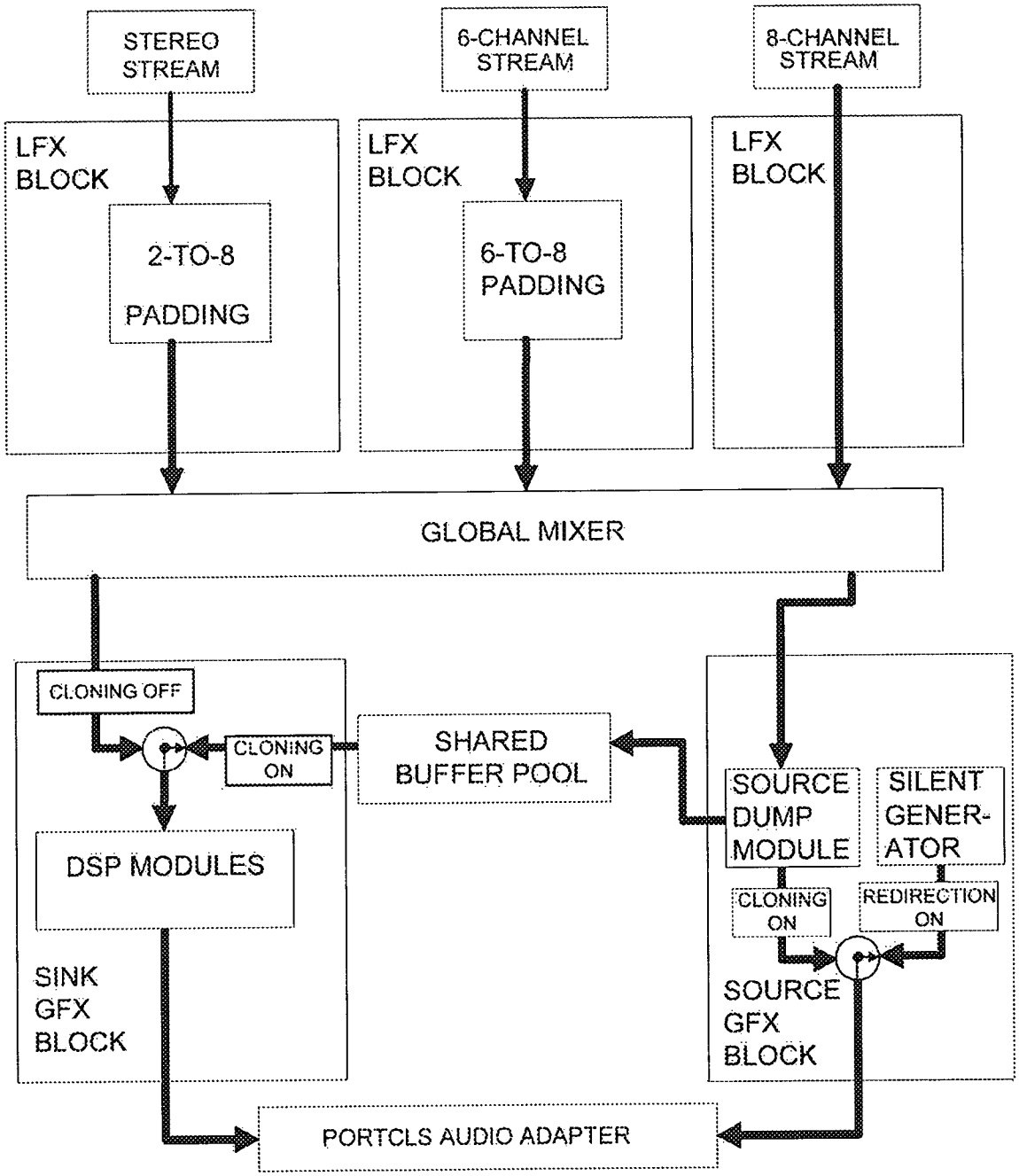
STEREO STREAM
6-CHANNEL STREAM
8-CHANNEL STREAM
LFX BLOCK
2-TO-8 PADDING
LFX BLOCK
6-TO-8 PADDING
LFX BLOCK
GLOBAL MIXER
CLONING OFF
CLONING ON
SHARED BUFFER POOL
DSP MODULES
SINK GFX BLOCK
SOURCE DUMP MODULE
SILENT GENER-ATOR
CLONING ON
REDIRECTION ON
SOURCE GFX BLOCK
PORTCLS AUDIO ADAPTER

Fig. 11

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2008/000988

A. CLASSIFICATION OF SUBJECT MATTER

H04S3/00 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: G06F, H04L, H04S, H04M, H04R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI,EPODOC,PAJ,CNPAT,CNKI,IEEE: (sound w channel) or (sound w track) or track or (audio w channel) or (audio w track), (audio or sound) w card, enhanc+ or amplifier, stereo

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
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| A | CN1451255A, (DIGI-N) DIGITAL THEATER SYSTEMS INC, 22 Oct. 2003(22.10.2003), the whole document | 1-20 |
| A | US2003059066A1, Kohyama et al., 27 Mar. 2003(27.03.2003), the whole document | 1-20 |
| A | CN1532673A, (ZHUS-I) ZHU S, 29 Sep. 2004(29.09.2004), the whole document | 1-20 |

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 26 Aug. 2008(26.08.2008) | **11 Sep. 2008 (11.09.2008)** |
| Name and mailing address of the ISA/CN<br>The State Intellectual Property Office, the P.R.China<br>6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088<br>Facsimile No. 86-10-62019451 | Authorized officer<br>LIU Xu<br>Telephone No. (86-10)62413323 |

Form PCT/ISA/210 (second sheet) (April 2007)

# INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2008/000988

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| | | CN1409580A | 09.04.2003 |
| | | JP3661622B2 | 15.06.2005 |
| | | JP4003424B2 | 07.11.2007 |
| | | US7350156B2 | 25.03.2008 |
| CN1532673A | 29.09.2004 | None | |