Real-Time Acoustic Processor

BACKGROUND

[0001] Active noise cancellation (ANC) may be employed to reduce the amount of ambient noise a user hears when wearing headphones. In ANC, a noise signal is measured and a corresponding an anti-noise signal is produced. The anti-noise signal is an approximation of an inverse signal to the noise signal. The noise signal and the anti-noise signal destructively interfere, which may result in some or all of the ambient noise being removed from the user's ear. Generating an accurate anti-noise signal for high quality ANC requires that the corresponding system react quickly to changes in ambient noise. Latency is detrimental to ANC, because failure to react quickly can result in noise that is not properly canceled out. Further, failure of correction circuits to react quickly may result in erroneous noise amplification, bursts of anti-noise that does not cancel out the noise signal, etc. ANC may be further complicated when music is introduced to the headphones. In some cases, ANC may also be unable to distinguish noise from low frequency music. This may result in erroneous removal of the music signal along with the noise signal.

SUMMARY

[0001A] According to an aspect, there is provided an acoustic processing network, comprising a digital signal processor operating at a first frequency, the digital signal processor configured to receive a noise signal from one or more microphones, at least one microphone being a feed forward microphone, and generate a noise filter based on the noise signal; and a real-time acoustic processor operating at a second frequency higher than the first frequency, the real-time acoustic processor configured to receive the noise signal from the one or more microphones, receive the noise filter from the digital signal processor, generate an anti-noise signal based on the noise signal and the noise filter for use in active noise cancellation, apply an ambient awareness filter to enhance a predetermined frequency band in the noise signal when generating the anti-noise signal, resulting in an enhanced predetermined frequency band, and forward the anti-noise signal with the enhanced predetermined frequency band to a speaker for output to a user, wherein the real-time acoustic processor includes: an adjustable amplifier to amplify the anti-noise signal, and a compressor circuit to

control the adjustable amplifier to mitigate artifacts in the anti-noise signal, ~~and wherein~~ the digital signal processor ~~is further~~ configured to: receive current compression states from the real-time acoustic processor, determine new compression states based on the noise signal and the current compression states, and forward the new compression states to the real-time acoustic processor to support controlling the adjustable amplifier; the real-time acoustic processor including one or more programmable biquadratic filters to implement the noise filter from the digital signal processor and generate the anti-noise signal, and the biquad filters employing one or more poles to amplify portions of a sample of the anti-noise signal, one or more zeros to attenuate portions of the sample of the anti-noise signal, and a filter register to store a quantization of the sample of the anti-noise signal, the biquadratic filters configured to amplify the sample in a first step, prior to quantizing the sample in a second step, and then attenuate the sample in a third step.

{0001B) According to an aspect, there is provided a method for real-time acoustic processing, comprising: receiving a noise signal at a digital signal processor operating at a first frequency, the noise signal received from at least one microphone; generating a noise filter at the digital signal processor based on the noise signal; communicating the noise filter from the digital signal processor to a Real-Time Acoustic Processor operating at a second frequency higher than the first frequency; receiving the noise signal from the microphone at the real-time acoustic processor; generating an anti-noise signal at the real-time acoustic processor based on the noise signal and the noise filter for use in Active Noise Cancellation by configuring one or more programmable biquadratic filters to implement the noise filter from the digital signal processor, the biquadratic filters being configured to amplify a sample of the anti-noise signal in a first step, quantize the sample of the anti-noise signal in a second step, and attenuate the sample of the anti-noise signal in a third step; applying an ambient awareness filter at the real-time acoustic processor to enhance a predetermined frequency band in the noise signal when generating the anti-noise signal, resulting in an enhanced predetermined frequency band; forwarding the anti-noise signal with the enhanced predetermined frequency band to a speaker for output to a user; employing current compression states at the real-time acoustic processor to control an adjustable amplifier to adjust the anti-noise signal; communicating the current compression states from the real-time acoustic processor to the digital signal processor; determining new

compression states at the digital signal processor based on the noise signal and the current compression states, and communicating the new compression states from the digital signal processor to the real-time acoustic processor to support controlling the adjustable amplifier.

[001C] According to an aspect, there is provided a method for real-time acoustic processing, comprising: receiving a noise signal at a digital signal processor operating at a first frequency, the noise signal received from at least one microphone; generating a noise filter at the digital signal processor based on the noise signal; communicating the noise filter from the digital signal processor to a Real-Time Acoustic Processor operating at a second frequency higher than the first frequency; receiving the noise signal from the microphone at the real-time acoustic processor; generating an anti-noise signal at the real-time acoustic processor based on the noise signal and the noise filter for use in active noise cancellation by configuring one or more programmable biquadratic filters to implement the noise filter from the digital signal processor, the biquadratic filters being configured to amplify a sample of the anti-noise signal in a first step, quantize the sample of the anti-noise signal in a second step, and attenuate the sample of the anti-noise signal in a third step; generating an audio signal at the digital signal processor based on audio input; generating an expected output signal at the digital signal processor based on the audio input and a frequency response of an acoustic processing network; communicating the audio signal from the digital signal processor to the real-time acoustic processor; mixing the audio signal with the anti-noise signal at the real-time acoustic processor; setting the expected output signal as a reference point when generating the anti-noise signal to mitigate cancelation of the audio signal by the anti-noise signal; employing current compression states at the real-time acoustic processor to control an adjustable amplifier to adjust the anti-noise signal; communicating the current compression states from the real-time acoustic processor to the digital signal processor; determining new compression states at the digital signal processor based on the noise signal and the current compression states, and communicating the new compression states from the digital signal processor to the real-time acoustic processor to support controlling the adjustable amplifier.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] Aspects, features and advantages of embodiments of the present disclosure will become apparent from the following description of embodiments in reference to the appended drawings in which:

[0003] Fig. 1 is a schematic diagram of an example acoustic processing network.

[0004] Fig. 2 is a schematic diagram of an example Real-Time Acoustic Processor (RAP) input/output (I/O).

[0005] Fig. 3 is a schematic diagram of an example acoustic processing network for compressor state sharing.

[0006] Fig. 4 is a schematic diagram of an example acoustic processing network for audio input equalization.

[0007] Fig. 5 is a schematic diagram of an example RAP architecture.

[0008] Fig. 6 is a schematic diagram of another example RAP architecture.

[0009] Fig. 7 is a schematic diagram of an example programmable topology in a RAP.

[0010] Fig. 8 is a schematic diagram of another example programmable topology in a RAP.

[0011] Fig. 9 is a schematic diagram of a biquad filter structure.

CLAIMS:

We claim:

1. An acoustic processing network, comprising:

a digital signal processor operating at a first frequency, the digital signal processor configured to receive a noise signal from one or more microphones, at least one microphone being a feed forward microphone, and generate a noise filter based on the noise signal; and

a real-time acoustic processor operating at a second frequency higher than the first frequency, the real-time acoustic processor configured to receive the noise signal from the one or more microphones, receive the noise filter from the digital signal processor, generate an anti-noise signal based on the noise signal and the noise filter for use in active noise cancellation, apply an ambient awareness filter to enhance a predetermined frequency band in the noise signal when generating the anti-noise signal, resulting in an enhanced predetermined frequency band, and forward the anti-noise signal with the enhanced predetermined frequency band to a speaker for output to a user, the real-time acoustic processor including an adjustable amplifier to amplify the anti-noise signal, and a compressor circuit to control the adjustable amplifier to mitigate artifacts in the anti-noise signal;

~~wherein~~ the digital signal processor ~~is further~~ configured to receive current compression states from the real-time acoustic processor, determine new compression states based on the noise signal and the current compression states, and forward the new compression states to the real-time acoustic processor to support controlling the adjustable amplifier;

the real-time acoustic processor including one or more programmable biquadratic filters to implement the noise filter from the digital signal processor and generate the anti-noise signal, and the biquad filters employing one or more poles to amplify portions of a sample of the anti-noise signal, one or more zeros to attenuate portions of the sample of the anti-noise signal, and a filter register to store a quantization of the sample of the anti-noise signal, the biquadratic filters configured to amplify the sample in a first step, prior to quantizing the sample in a second step, and then attenuate the sample in a third step.

2. The acoustic processing network of claim 1 wherein the real-time acoustic processor further includes a compression state register to store compression states, the compressor circuit further configured to control the adjustable amplifier based on the compression states.

3. The acoustic processing network of claim 2 wherein the compression states include a peak signal estimate, an instantaneous gain, a target gain, an attack parameter, a release parameter, a decay parameter, a hold parameter, or combinations thereof.

4. The acoustic processing network of claim 2 wherein the compression states include a root mean square of the anti-noise signal.

~~5. The acoustic processing network of claim 1 wherein the real-time acoustic processor includes one or more programmable biquadratic filters to implement the noise filter from the digital signal processor and generate the anti-noise signal.~~

~~6. The acoustic processing network of claim 5 wherein the biquad filters employ one or more poles to amplify portions of a sample of the anti-noise signal, one or more zeros to attenuate portions of the sample of the anti-noise signal, and a filter register to store a quantization of the sample of the anti-noise signal, the biquadratic filters configured to amplify the sample prior to quantizing the sample and then attenuate the sample.~~

~~7~~5. The acoustic processing network of claim 1 wherein a latency between receiving a noise signal sample from the one or more microphones and forwarding a corresponding anti-noise signal sample to the speaker is less than one hundred microseconds.

~~8~~6. The acoustic processing network of claim 1 wherein the digital signal processor is further configured to:

generate an audio signal based on audio input, and

generate an expected output signal based on the audio input and a frequency response of the acoustic processing network, and wherein the real-time acoustic processor is further to:

receive the audio signal from the digital signal processor,

mix the audio signal with the anti-noise signal, and

set the expected output signal as a reference point when generating the anti-noise signal to mitigate cancelation of the audio signal by the anti-noise signal.

~~9~~7. The acoustic processing network of claim 1 wherein the real-time acoustic processor is further configured to forward the anti-noise signal to a digital to analog converter amplifier

controller to support adjusting a digital to analog converter amplifier based on anti-noise signal level.

~~10~~8. A method for real-time acoustic processing, comprising:

receiving a noise signal at a digital signal processor operating at a first frequency, the noise signal received from at least one microphone;

generating a noise filter at the digital signal processor based on the noise signal;

communicating the noise filter from the digital signal processor to a real-time acoustic processor operating at a second frequency higher than the first frequency;

receiving the noise signal from the microphone at the real-time acoustic processor;

generating an anti-noise signal at the real-time acoustic processor based on the noise signal and the noise filter for use in active noise cancellation by configuring one or more programmable biquadratic filters to implement the noise filter from the digital signal processor, the biquadratic filters being configured to amplify a sample of the anti-noise signal in a first step, quantize the sample of the anti-noise signal in a second step, and attenuate the sample of the anti-noise signal in a third step;

applying an ambient awareness filter at the real-time acoustic processor to enhance a predetermined frequency band in the noise signal when generating the anti-noise signal, resulting in an enhanced predetermined frequency band;

forwarding the anti-noise signal with the enhanced predetermined frequency band to a speaker for output to a user;

employing current compression states at the real-time acoustic processor to control an adjustable amplifier to adjust the anti-noise signal;

communicating the current compression states from the real-time acoustic processor to the digital signal processor;

determining new compression states at the digital signal processor based on the noise signal and the current compression states, and

communicating the new compression states from the digital signal processor to the real-time acoustic processor to support controlling the adjustable amplifier.

~~11~~9. The method of claim 10 wherein the current compression states and the new compression states include a peak signal estimate, an instantaneous gain, a target gain, a root mean square of the anti-noise signal or combinations thereof.

~~12. The method of claim 10 wherein the anti-noise signal is generated at the real-time acoustic processor by configuring one or more programmable biquadratic filters to implement the noise filter from the digital signal processor.~~

~~13. The method of claim 12 wherein the biquadratic filters are further configured to amplify a sample of the anti-noise signal, quantize the sample of the anti-noise signal, and attenuate the sample of the anti-noise signal.~~

~~14~~10. The method of claim ~~10~~ 8 further comprising forwarding the anti-noise signal to a digital to analog converter amplifier controller to support adjusting a digital to analog converter amplifier based on anti-noise signal level.

~~15~~11. A method for real-time acoustic processing, comprising:

receiving a noise signal at a digital signal processor operating at a first frequency, the noise signal received from at least one microphone;

generating a noise filter at the digital signal processor based on the noise signal;

communicating the noise filter from the digital signal processor to a real-time acoustic processor operating at a second frequency higher than the first frequency;

receiving the noise signal from the microphone at the real-time acoustic processor;

generating an anti-noise signal at the real-time acoustic processor based on the noise signal and the noise filter for use in active noise cancellation by configuring one or more programmable biquadratic filters to implement the noise filter from the digital signal processor, the biquadratic filters being configured to amplify a sample of the anti-noise signal in a first step, quantize the sample of the anti-noise signal in a second step, and attenuate the sample of the anti-noise signal in a third step;

generating an audio signal at the digital signal processor based on audio input;

generating an expected output signal at the digital signal processor based on the audio input and a frequency response of an acoustic processing network;

communicating the audio signal from the digital signal processor to the real-time acoustic processor;

mixing the audio signal with the anti-noise signal at the real-time acoustic processor;

setting the expected output signal as a reference point when generating the anti-noise signal to mitigate cancelation of the audio signal by the anti-noise signal;

employing current compression states at the real-time acoustic processor to control an adjustable amplifier to adjust the anti-noise signal;

communicating the current compression states from the real-time acoustic processor to the digital signal processor;

determining new compression states at the digital signal processor based on the noise signal and the current compression states, and

communicating the new compression states from the digital signal processor to the real-time acoustic processor to support controlling the adjustable amplifier.