[0005] One problem the present inventors have recognized is that while ANC headsets improve the listening experiences of users wearing them, they do little or nothing to improve the quality of the signals being transmitted out of the headset to other devices. For example, in many noisy environments, users wearing headsets with their mobile phones are typically required to manually switch their phones to a mute mode to prevent background noise from being transmitted by the phone to other phones and devices. Although this is effective in preventing the unwanted noise transmission, it often leads to gaps in communications as users who muted their phones forget to unmute them when they start speaking again. Moreover, in conference calls with many users manually muting and unmuting, the potential for communications gaps is even greater.

[0006] In attempting to solve the problem, some designers have provided circuitry that monitors the voice mic output and automatically mutes or unmutes based on comparison of the mic output level to one or more thresholds. However, the monitoring circuitry suffers from at least two problems that has inhibited its use in mobile phones. First, it consumes considerable power and thus shortens battery life. Second, the circuitry creates its own communications gaps not only because its slow reaction to speaking stops and starts, but also because it confuses external noises, for example voices of nearby people, with the user voice.

[0007] Accordingly, the present inventors have recognized a need for better ways of reducing transmission of ambient noise through ANC and other types of headsets.

SUMMARY

[0008] To address one or more of these and/or other needs or problems, the present inventors devised, among other things, one or more exemplary systems, kits, methods, devices, assemblies, and/or components for automatically detecting the presence or absence of user speech and operating associated muting or other voice- or speech-dependent functionality. Some examples include a voice mic, at least two control mics, and processing circuitry, with the processing circuitry configured to mute the voice mic based on a relationship of the control mic output signals.

[0008A] In one aspect, the present disclosure refers to an audio processing system comprising, a plurality of inputs to receive a plurality of audio signals, the

plurality of inputs including a first input to receive a first audio signal from a first transducer disposed proximate a first ear of a user, a second input to receive a second audio signal received from a second transducer disposed proximate a second ear of the user, and a third input to receive a third audio signal from a third transducer disposed proximate a vocal region of the user, and processing circuitry coupled to the plurality of inputs and configured to receive the first, second, and third audio signals, to compare speech components of the first audio signal and the second audio signal, to determine whether the speech components are provided by the user based on the comparison, and to provide a voice activity detection signal indicative of whether the speech components are provided by the user.

[0008B] In another aspect, the present disclosure refers to an audio processing system comprising, a plurality of inputs to receive a plurality of audio signals, the plurality of inputs including a first input to receive a first audio signal from a first transducer disposed proximate a first ear of a user, a second input to receive a second audio signal from a second transducer disposed proximate the first ear of the user but farther from the first ear than the first transducer, and a third input to receive a third audio signal from a third transducer disposed proximate a vocal region of the user, and processing circuitry coupled to the plurality of inputs and configured to receive the first, second, and third audio signals, to compare speech components of the first audio signal and the second audio signal, to detect whether the speech components are provided by the user based on the comparison, and to provide a voice activity detection signal indicative whether the speech components are provided by the user.

[0008C] In yet another aspect, the present disclosure refers to a method of processing audio signals comprising, receiving a first audio signal from a first transducer disposed proximate a first ear of a user, receiving a second audio signal from a second transducer disposed one of proximate a second ear of the user, or disposed proximate the first ear of the user but farther from the first ear of the user than the first transducer, receiving a third audio signal from a third transducer disposed proximate a vocal region of the user, comparing speech components of the first audio signal and the second audio signal, determining whether the speech components are provided by the user based on

the comparison, and providing a voice activity detection signal indicative of whether the speech components are provided by the user.

[0009] In a first example, the two control mics, for example a left earpiece mounted mic and a right earpiece mounted mic, are configured for approximately

symmetric acoustic coupling to a user vocal region. The processing circuitry determines whether a user is speaking based on measured temporal symmetry -- for example phase relationship-- of output signals from the two mics, with high symmetry indicative of user speech (arriving at both mics approximately simultaneously) and low symmetry indicative of ambient noise or non-user speech. The two control mics in some variants of the first example are the left and right feedback mics in an ANC headset. Some other variants measure or estimate the phase relationship using complex coherence of the sampled mic outputs, activating the muting circuitry whenever the real part of the complex coherence falls below a threshold value.

[0010] In a second example, the two control mics are configured for assymetric acoustic coupling to the user vocal region, that is, with one mic having superior acoustic coupling to the user vocal region than the other. The processing circuitry is configured to turn the muting on or off based on the relative magnitude or the energy level of the two mic output signals. For example, in some ANC examples, the mic with superior acoustic coupling is the feedback error mic in an ANC earpiece and the other is the feedforward mic. The processing circuitry compares a ratio of feedback error mic output to the feedforward mic output to a threshold in determining whether to turn the muting function on or off. Some variants may use two mics placed on a boom or cord, rather than the ANC control mics.

[0011] The processing circuitry compares a ratio of feedback error mic output to the feedforward mic output to a threshold in determining whether to turn the muting function on or off. Some variants may use two mics placed on a boom or cord, rather than the ANC control mics. More generalized examples use two or more microphones to produce two signals, with a first signal being more closely coupled to user speech than the second, and the second signal being more closely coupled to ambient noise or sound than the first.

[0012] A third example estimates a transfer function that accounts for both the phase and magnitude differences between the signals from two mics, such as the feedback error mic and the feedforward ambient mic. Some variants of this example may lack ANC mic and use other pairs of mics, such as a voice mic and one other mic. The transfer function can be estimated using a variety of methods, such a Kalman filtering or other form of optimal estimator.

[0013] One or more examples also include other features. For example, xom examples include a canceler to cancel music or other audio signals that are output via a loudspeaker within an earpiece associated with one or more of the microphones. Some examples include muting delay and hold functions to reduce risk of muting between spoken words or during short pauses. Still other examples include a buffer memory and look-ahead functionality to ensure timely unmuting of the voice mic and thus avoid partial loss of user speech.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Various embodiments are described herein with reference to the following attached figures (Figs). These figures are annotated with reference numbers for various features and components, and these numbers are used in the following description as a teaching aid, with like numbers referring to the same or similar features and components.

[0015] Fig. 1 is a block diagram of an exemplary headset system or assembly 100 corresponding to one or more embodiments of the present invention.

[0016] Fig. 2 is a block diagram of an exemplary method of operating a user voice activity detector portion of assembly 100, corresponding to one or more embodiments of the present invention.

[0017] Fig. 3 is a conceptual system diagram of one half of a headset system 300 corresponding to one or more embodiments of the present invention.

[0018] Fig. 4 is a block diagram of an generic electroacoustic system having multiple audio transducers and audio input signals, corresponding to one or more embodiments of the invention.

[0019] Fig. 5 is a block diagram of an user voice activity detector corresponding to one or more embodiments of the invention.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENT(S)

[0020] This document, which incorporates drawings and claims, describes one or more specific embodiments of one or more inventions. These embodiments, which are offered not to limit but only to exemplify and teach the invention, are shown and described in sufficient detail to enable those skilled in the art to implement or practice the invention(s).