CIRCUIT ARRANGED FOR ACTIVE NOISE CANCELLATION AND METHOD OF ACTIVE NOISE CANCELLATION

Abstract: The invention relates to a circuit (4), which is arranged for active noise cancellation, and which circuit is arranged for processing a noise signal and which circuit (4) is arranged to provide a canceling signal in dependence on the processed noise signal. The circuit (4) comprises time control means, which time control means are arranged for timing the operation of the active noise cancellation processing.
before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments. For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
Circuit arranged for active noise cancellation and method of active noise cancellation

FIELD OF THE INVENTION

The invention relates to a circuit arranged for active noise cancellation.
The invention further relates to an electronic hearing device and an electronic earplug.
The invention further relates to a method of active noise cancellation.

BACKGROUND OF THE INVENTION

The basic idea of active noise cancellation (ANC) was actually conceived in the 1930s and is generally disclosed in Austrian patent AT 141.998 B. However, only since the advent of modern digital computers active control became truly practical.

ANC works best for sound fields that are spatially simple. A classic example is low-frequency sound waves travelling through a duct, an essentially one-dimensional problem. Active control works best when the wave length is long compared to the dimensions of its surroundings, i.e., low frequencies. In contrary thereto, passive methods tend to work best at high frequencies. Therefore, most active noise control systems combine passive and active techniques to cover a range of frequencies.

The most successful demonstrations of ANC have been for controlling noise in closed spaces such as ducts, vehicle cabins, exhaust pipes and headphones. Active headphones use destructive interference to cancel low-frequency noise while still allowing the wearer to hear mid- and high frequency sounds such as conversation and warning sirens. Those systems typically comprise a pair of earmuffs containing speakers and one or more small circuit boards. Some include a built-in battery pack, and many allow exterior signal inputs such as music or voice communication. Such active headphones are used extensively by for example pilots in helicopter and noisy propeller-driven aircraft.

A further application of ANC are hearing aids where ANC can help to increase speech recognition in an noisy environment. For example, US-6445799 discloses a noise cancellation earpiece having an ear canal which connects a sound processor with a speaker...
and a microphone arranged in close proximity to each other to constitute a closed volume. The sound processor amplifies the ambient sounds received by the microphone to produce processed analog signals. The sound processor also comprise noise cancellation means for producing an inverse noise-signal of noise detected in the ear canal by the microphone. The inverse noise signal is sent to a speaker port so as to be emitted into the ear canal, thereby substantially canceling the ambient noise in the ear canal.

Due to the increasing integration density of integrated circuits also small electronic earplugs which can be used as hearing aid have become an application for ANC. These electronic hearing aid earplugs can be divided in so-called Concha hearing aid, half concha hearing aid or mini-canal hearing aid depending on how much the earplug covers the concha of the user.

However, electronic earplugs can also be used in situations where the user does not want to be disturbed and distracted within a noisy environment or were the user should be prevented from hearing damage by extremely loud sounds like shots or explosions. To increase the low-frequency noise reduction and to facilitate speech recognition in an loud ambience, an ANC functionality can be provided. An example for such an electronic earplug has been developed by Nacre AS, Norway.

Electronic earplugs with ANC functionality reduce noise actively by using a microphone and some electronic circuits for generating an phase-shifted anti-noise signal but also passively reduce noise by damping as they plug the entrance of the ear. Therefore, a possible application of electronic earplugs with ANC functionality is during long-term plane or train travelling. However, since the ANC functionality remains activated once it has been turned on, a user might forget to turn off the ANC functionality although he is wants to be receptive to important acoustic signals like the announcements of the pilot or the train conductor which might be not perceivable for the user due to the activated ANC and the passive sound reduction capability of the earplug. Furthermore, if the user forgets to turn off the ANC functionality, an additional consume of power is created which will exhaust a power supply of the electronic earplug, usually a cell battery, faster than necessary which in turn results in an unexpected shortfall of the electronic earplug. In case of an earplug that is also used as hearing aid, these can lead to a dangerous situation for people with hearing damage.
OBJECT AND SUMMARY OF THE INVENTION

It is an object of the invention to provide a circuit of the type defined in the opening first paragraph and a method of the type defined in the third paragraph in which the disadvantages defined above are avoided.

This object is solved by each feature combination defined in claim 1 and in claim 7.

Further embodiments and advantageous modifications are subject to the depending claims and are herewith entirely incorporated in the description by reference so that repetition of their literally wording can be omitted.

In order to achieve the object defined above, with circuit for ANC according to the invention characteristic features are provided so that a device according to the invention can be characterized in the way defined below, that is:

Circuit for active noise cancellation, which circuit is arranged for processing a noise signal, which noise signal is receivable by the aid of sound receiving means, and which circuit is arranged, in dependence on the processed noise signal, to provide a canceling signal that is intended to be emitted by the aid of sound emitting means for canceling said noise signal, wherein the circuit comprises time control means, which time control means are arranged for timing the operation of the active noise cancellation processing.

The characteristic features according to the invention has the advantage that circuit provides its ANC functionality in a time controlled manner which prevents the user from missing signals due to an unintended active ANC processing and gives him the possibility to activate the ANC functionality for a given time in which he wants not to be receptive to any kind of noisy acoustic signal. A further advantage of the characteristic features according to the invention is that a power consumption due to an unintended active ANC functionality can be avoided which in turn prevents a sudden shortfall of a electronic earplug comprising this circuit.

A further embodiment of the invention according to claim 2 provides the advantage of increased functionality of the circuit for ANC as an alarm clock.

A further embodiment of the invention according to claim 3 provides the advantage of reduced power consumption in situations were no ANC functionality is necessary.

A further embodiment of the invention according to claim 4 provides the
advantage that the user's comfort can be improved as no sudden increase of noise is
generated when the ANC functionality is going to be turned off.

In a further embodiment of the invention according to claim 5, the circuit for
ANC is implemented in an electronic hearing device which improves advantageously the
hearing performance by providing an time-controlled ANC functionality.

In a still further embodiment of the invention according to claim 6, an electronic
earplug with an the circuit for ANC is implemented which improves advantageously the
hearing performance by providing an time-controlled ANC functionality.

In order to achieve the object defined above, with a method according to the
invention characteristic features are provided so that a method according to the invention
can be characterized in the way defined below, that is:

Method of active noise cancellation comprising processing of a noise signal and
providing a canceling signal in dependence on the processed noise signal, wherein
controlling of the processing of said noise signal is performed in a time controlled manner.

The characteristic features according to the invention has the advantage that the
method provides its ANC functionality in a time controlled manner which prevents the user
from missing signals due to an unintended active ANC processing and gives him the
possibility to activate the ANC functionality for a given time in which he wants not to be
receptive to any kind of noisy acoustic signal. A further advantage of the characteristic
features according to the invention is that a power consumption due to an unintended active
ANC functionality can be avoided which in turn prevents a sudden shortfall of a electronic
earplug using this method.

A further embodiment of the invention according to claim 8 provides the
advantage of an additional utility for the user in form of an alarm mode.

A further embodiment of the invention according to claim 9 provides the
advantage of reduced power consumption in situations were no ANC functionality is
necessary.

A further embodiment of the invention according to claim 10 provides the
advantage that the user's comfort can be improved as no sudden increase of noise is
generated when the ANC functionality is going to be turned off.

The aspects defined above and further aspects of the invention are apparent
from the examples of embodiment to be described hereinafter and are explained with
reference to these examples of embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described hereinafter with reference to examples to the embodiment but to which the invention is not limited.

Fig. 1 shows an electronic earplug comprising a circuit for ANC according to an embodiment of the invention.

DESCRIPTION OF EMBODIMENTS

Fig. 1 shows an electronic earplug (8) which is used as concha type hearing aid. The electronic earplug (8) has a hard casing (5), which earplug comprises a cell battery (1) which is rechargeable, a microphone (2) that realizes receiving means for receiving noise signals from the proximity of the earplug, a speaker (3) that realizes sound emitting means for emitting an anti-noise signal according to the principle of ANC and an ANC circuit (4) which performs the ANC processing of the signals received from the microphone (2). The ANC circuit (4) drives the speaker (3) in accordance with the processed signals. The hard casing (5) can be surrounded by a layer of soft slow-recovery foam (6) which is commonly used in passive earplugs. A passive noise reduction circuit may be optional provided in the hard casing (5) or integrated in the ANC circuit (4) for earplugs which have a strong passive attenuation. Such a passive noise reduction circuit shut down the microphone (2) which capture the ambient noise in the case of an excessively loud ambient noise like a shot or a loud scream to prevent the ear of the user from being hurt.

Programmable time control means are integrated in the ANC circuit (4) for time controlled enabling and disabling of the ANC processing or for timing the operation of the active noise cancellation process. Such programmable time control means can be a programmable timer circuit, for example. The time control means disable or enable the ANC according to a time scheme determined by the user. In this way, the user can increase, for example, sleeping comfort in a noisy environment like a plane or a train during long-term travelling.

The ANC circuit (4) is programmable so that different time schemes or timings can be provided. In one case, the user is able to program a time slot for a timer circuit of the ANC circuit. Programming can be done via a docking station where the user connects the
electronic earplug to, for example charge a rechargeable battery of the earplug. For example, if he wants to sleep for two hours and then to be waken up by an alarm. In another case, the user is able to program a certain point in time when he wants to be waken up, for example at 3:00 pm using a clock which can be located in, for example, the docking station, and the timer circuit of the ANC circuit. Also other parameters of the ANC processing as well as of passive noise reduction can be programmed. The docking station includes an interface and a clock so that the user is able to program when he wants the ANC processing to be enabled and disabled.

It has to be noted that programming can also be achieved wireless using mobile phone or a personal digital assistant (PDA) having e.g. the functionality of radio frequency identification (RFID) systems or so called near field communication (NFC) devices. This, of course, requires appropriate interfaces and processing devices to be associated with or to be implemented in the active noise cancellation circuit (4).

To provide an alarm clock function, ANC circuit (4) is able to provide an acoustic alarm signal, which is triggered by the programmable timer circuit at a desired time. The trigger conditions can be programmed by the user and the acoustic alarm signal can be a loud "beep" sound or any other striking sound. Also optical or vibrational alarm signals are conceivable.

Furthermore, a soft wake-up function is provided by the electronic earplug. This is realized by disabling the ANC in a fading manner so that no abrupt increase in noise will shock the user when the ANC functionality is turned off. The parameters of the fading operation of the ANC circuit (4) can also be programmed by the user in order to customize it to his discretion. It can be mentioned that the fading operation can also make use of the time control means, e.g. for smoothly timing the fading-away of the operation of the ANC functionality.

When the ANC is active, a "hiss" like sound can not be avoided which stems from noise of the electronic circuit components. However, although the time control means has enabled the ANC, it is not permanent necessary if the ambient noise level is not constant or stationary. Hence, in some situations, it would therefore increase the comfort of the user if the ANC processing would be disabled which would eliminate the "hiss" sound in the earplug. This would also provide for a lower power consumption of the electronic components of the earplug and therefore contribute to a higher degree of operational
reliability since the battery will be exhausted slower. To detect situations or conditions in which the ANC processing can be disabled without decreasing the comfort of the user, the ANC circuit (4) provides for a clipping functionality, which disables the ANC processing when the level of the noise signal received by the microphone (2) falls below a predetermined threshold.

The electronic earplug of the invention combines passive and active noise reduction to provide the user with attenuation from external noises on a wider spectrum than the passive earplugs, especially at low frequencies.

In a further embodiment of the invention, the ANC processing of the electronic earplug can be manually enabled or disabled by tapping on the microphone (2). Since the microphone (2) is to receive the ambient noise in the proximity of the earplug, it has a direct contact to the external of the ear whereas the rest of the concha type earplug is inserted in the concha. Hence, the microphone (2) is easily reachable for the user. This allows the user to enable or disable the ANC processing at his discretion by simply tapping on the microphone. The tapping signal must be only significant (i.e. sort of code) to be detected, for example two taps within one second for "disable" and three taps in one second for "enable". The successful enabling or disabling can be confirmed by an specific signal, for example a beep sound.

If a disabling tapping signal is detected and the ANC processing is not enabled, the tapping signal must be ignored, and vice versa. This ignoring can also be prompted to the user by a specific sound so that the user can determine if the ANC functionality is active or not. In this way, it is also possible for the user to readily verify the operation mode of the electronic earplug (i.e. ANC functionality enabled or disabled).

The electronic earplug of the invention can be used with any kind of ANC processing architecture. This includes non-adaptive feedforward, non-adaptive feedback and adaptive feedforward ANC processing. It has to be noted that his enumeration is not concluding. If the non-adaptive feedback or the adaptive feedforward ANC processing is used, an additional "error" microphone (7) has to be implemented as shown in fig. 1. This additional "error" microphone (7) provides for a feedback signal for adapting the active noise signal through feedback control.

It has to be appreciated that reference signs within the claims are only given for illustrative purpose and shall not be construed as limiting the scope of the matter for which
protection is sought.

It is to mention that the sound emitting means (3) can be realized by all applicable arrangements based on electrostatic (capacitor), electrodynamic (moving-coil, moving-conductor, coil-driven) or piezoelectric technology. The same statement is valid for the sound receiving means.
CLAIMS

1. Circuit (4) for active noise cancellation, which circuit (4) is arranged for processing a noise signal, which noise signal is receivable by the aid of sound receiving means (2), and which circuit (4) is arranged, in dependence on the processed noise signal, to provide a canceling signal that is intended to be emitted by the aid of sound emitting means (3) for canceling said noise signal, wherein the circuit (4) comprises time control means, which time control means are arranged for timing the operation of the active noise cancellation processing.

2. Circuit (4) according to claim 1, wherein the circuit (4) is arranged to provide an alarm signal triggered by the time control means, which alarm signal is intended to be emitted by the aid of said emitting means (3).

3. Circuit (4) according to claim 1 or to 2, wherein the circuit (4) is arranged to provide a noise signal level depending disabling functionality for disabling the active noise cancellation processing in a case where the noise signal level of the noise signal is below a threshold value.

4. Circuit (4) according to any of the claims 1 to 4, wherein the time control means are arranged for disabling the active noise cancellation processing in a fade-away manner.

5. Electronic hearing device for active noise cancellation comprising a circuit (4) which is arranged for active noise cancellation according to any one of the claims 1 to 4 and sound receiving means (2) for receiving a noise signal, which sound receiving means (2) are arranged for the cooperation with the circuit (4), and sound emitting means (3) for emitting a canceling signal, which sound emitting means (3)
are arranged for the cooperation with the circuit (4).

6. Electronic earplug for active noise cancellation wherein the electronic earplug realizes the electronic hearing device according to claim 5.

7. Method of active noise cancellation comprising processing of a noise signal and providing a canceling signal in dependence on the processed noise signal, wherein controlling of the processing of said noise signal is performed in a time controlled manner.

8. Method according to claim 7, further comprising providing of an alarm signal triggered in accordance to said time controlled manner.

9. Method according to claim 7 or to 8, further comprising disabling of the active noise cancellation processing in a case where the noise signal level of the noise signal drops below a threshold value.

10. Method according to any of the claims 7 to 9, further comprising disabling the active noise cancellation processing in a fade-away manner.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
G10K 11/178

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)
G10K A61F

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 practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X Patent family members are listed in annex.

Date of the actual completion of the international search
17 November 2005

Date of mailing of the international search report
09/12/2005

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