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(54) **Apparatus for noise active control**

(57) An apparatus for noise active control comprising: a main input (10) for receiving a main signal (11) representative of the acoustic noise present in a predetermined area; a digital signal processor DSP (20) operatively associated with at least said main input (10) for generating, as a function of said main signal (11), a secondary signal (12) for erasure (removal) of said noise; an output (30) operatively associated with said DSP (20) for sending said secondary signal (12) to an electroa-

coustic transducer (2) to convert said secondary signal (12) into an acoustic signal for removal of said noise. The apparatus (1) further comprises an electrically rewritable and non-volatile memory E-EPROM (50) operatively associated with said DSP (20) for storing an operating program and one or more operating parameters depending on which said secondary signal (12) is generated.

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Description

[0001] The present invention relates to an apparatus for noise active control.

[0002] This apparatus applies to all spaces or industrial apparatus in which the requirement of eliminating (or at least greatly reducing) the noise therein present is felt.

[0003] By way of example, cars, earthmovers, sheds for installation of particularly noisy machines, endothermic engine exhausts, etc. can be taken into account.

[0004] It is known that the techniques for noise active control are based on generation of a sound wave substantially identical with, but in phase opposition relative to that present in the region where there is the noise that is wished to be eliminated.

[0005] Practically the two waves that are substantially identical with each other except for phase shift, are caused to be mutually eliminated due to the phenomenon of the acoustic destructive interference.

[0006] To reach this aim, apparatus of known type are provided with one or more inputs generally connected to microphones, vibration transducers or proximity sensors, through which the noise present in the concerned area is detected.

[0007] According to a predetermined algorithm, the detected signal is processed so as to obtain a corresponding erase signal that is admitted to the concerned area by means of suitable outputs, typically connected to electroacoustic transducers (typically loudspeakers).

[0008] A first operating limit of known apparatus is found in the fact that these apparatus are not able to easily adapt themselves to variations in the noise conditions of the space or environment where they operate so that they are not very efficient, of reduced reliability or even unstable if not carefully set up.

[0009] In addition, more generally, apparatus of known type are not designed to work in environments different from each other, exactly due to the fact that it is substantially impossible to update the noise elimination function in a clever manner; therefore there is an important lack of flexibility and adaptability to different types of environments.

[0010] This is mainly due to the fact that the employed algorithms together with the HW architecture for generation of the erase signal, are usually written in the apparatus firmware in such a manner that they cannot be varied and updated based each time on the specific conditions of operation of the apparatus.

[0011] In fact, typically non-rewritable memories are employed, such as ROMs (Read Only Memories) or PROMs (Programmable Read Only Memories).

[0012] The present invention aims at making available an apparatus for noise active control that is able to adapt itself in an optimal manner to the specific conditions at which it has to operate.

[0013] Another aim of the invention is to provide an apparatus characterised by a great flexibility of use so that it can be automatically updated upon variations in

the noise conditions of the area where it is located.

[0014] A further aim of the invention is to make available a stand-alone apparatus, that is independent of external devices (generally PCs) and has a simple structure, reduced manufacturing costs and reduced overall dimensions, so that it can be easily located at the inside of small volumes.

[0015] The foregoing and further aims are substantially achieved by an apparatus for noise active control as disclosed in the appended claims.

[0016] Further features and advantages will become more apparent from the detailed description of a preferred but not exclusive embodiment of an apparatus in accordance with the present invention.

[0017] This description is set out hereinafter with reference to the accompanying Fig. 1, which too has merely exemplary and therefore non-limiting purposes, and in which a block diagram of an apparatus in accordance with the invention is shown.

[0018] With reference to Fig. 1 an apparatus for noise active control in accordance with the invention has been generally denoted by reference numeral 1.

[0019] Apparatus 1 first of all comprises a digital signal processor (DSP) 20 the function of which is to analyse and generate acoustic signals mainly of periodic nature, designed to erase (remove) - or at least reduce - the acoustic noise present in a given region.

[0020] Preferably the DSP (Digital Signal Processor) can be for example of the Harvard architecture type (24-bit fixed point).

[0021] The DSP 20 is operatively associated with a main input 10, through which a main signal 11 representative of the acoustic noise present in said predetermined region is received.

[0022] Practically, the main input 10 can be connected to a microphone 3 or equivalent acoustic detecting device, capable of converting the environmental noise into an electric signal - i.e. the main signal 10; by way of example, a low-cost and high-efficiency electret microphone can be used.

[0023] The predetermined region in which apparatus 1 is designed to operate can be the inside of a vehicle (either a land or a sea vehicle), or the region surrounding particularly noisy industrial machinery.

[0024] The DSP 20 is further operatively associated with an output 30, in turn connected to an electroacoustic transducer 2, consisting of a loudspeaker for example.

[0025] Depending on the main signal 11, the DSP 20 is able to generate a secondary signal 12 to obtain erasure (removal) of the acoustic noise present in said predetermined region.

[0026] The secondary signal 12, through the output 30, is transmitted to transducer 2 so as to generate an acoustic signal for removal of said noise.

[0027] In other words, the acoustic erase signal is quite similar to the acoustic signal defined by the noise, but 180° out of phase relative thereto; in this manner, by exploiting the phenomenon of the acoustic destructive in-

terference, the two acoustic waves partly overlap so that they are mutually erased.

[0028] Apparatus 1 further comprises an electric rewritable and non-volatile memory (EEPROM) 50 operatively associated with the DSP 20 to store one or more operating parameters depending on which the secondary signal 12 is generated; in other words, memory 50 contains the program implementing the different algorithms and the values to be given to a series of coefficients defining the digital filters implemented by the DSP 20 for generation of the secondary signal 12.

[0029] Advantageously, memory 50 is a flash EEPROM (Electrically Erasable Programmable Read Only Memory) having a capacity equal to 128Kb for example.

[0030] As better clarified in the following, memory 50 can be programmed again by the DSP 20 depending on algorithms implemented therein, thus obtaining important advantages both in terms of operating independence of the apparatus (external devices, generally PCs, are not necessary for programming-reprogramming-updating data stored in memory 50), and in terms of adaptability and flexibility in use.

[0031] In order to exploit the chances made available by the rewritable memory 50, the DSP 20 comprises an updating module 21 operatively associated with memory 50 for updating the operating parameters stored therein.

[0032] In this way, apparatus 1 is able both to adapt itself to the acoustic-noise variations that may occur in the space where the apparatus is operating (therefore generating secondary signals designed to compensate for acoustic noise varying in time), and to get ready for correct operation in spaces different from each other under the acoustic point of view.

[0033] In order to activate the updating module 21, the DSP is provided with an activation module 22 connected to an input 40 of apparatus 1 for receiving an auxiliary reference signal 13 as a function of which it is established whether activation of the updating module 21 is to take place or not.

[0034] Preferably, the auxiliary reference signal 13 is a tachometric signal, representative of the acoustic noise generated by an engine 4 mounted on the vehicle on which apparatus 1 is operating; the activation module 22 verifies possible variations of some importance of this tachometric signal 13 (i.e. of the motor speed) and, if necessary, carries out activation of the updating module 21, so that the coefficients stored in memory 50 can be suitably adapted.

[0035] The auxiliary input 40 of apparatus 1 can then be replaced with a tachometric pick-up.

[0036] The auxiliary input 40 allows apparatus 1 to also operate according to algorithms of the feed-forward type, using said auxiliary reference signal 13 as the reference.

[0037] The above description refers to apparatus 1 already in an operating condition and suitably set for acting in the predetermined region.

[0038] In addition to the above, advantageously apparatus 1 is provided to be able to perform a self-learning

step, to be carried out immediately after switching on, or at all events before apparatus 1 becomes operative.

[0039] To this end, the DSP 20 comprises a setting module 23 operatively associated with the main input 30 to detect the transfer function of the preestablished region in a starting step (this transfer function being representative of the acoustic behaviour of the preestablished region) and determine a starting set of operating parameters to be stored in the rewritable memory 50.

[0040] Practically, depending on the transfer function of the preestablished region, the setting module 23 determines a series of starting parameters that will define the starting configuration of the filter by means of which the auxiliary signal 12 is generated.

[0041] Exactly due to the fact that these starting parameters are stored in the rewritable memory 50, the above described updating referring to the updating module 21 is made possible, if and whenever necessary.

[0042] Preferably the setting module 23 is operatively associated with an electroacoustic transducer to emit a preestablished acoustic signal during said starting step; this electroacoustic transducer can advantageously be the same transducer 2 that, during normal operation of apparatus 1, is used for converting the secondary signal 12 into the acoustic erase signal.

[0043] The acoustic signal emitted during the starting step is then "listened again" by the setting module 23 through the main input 10 and microphone 3 connected thereto, in order to enable the starting set of operating parameters to be determined.

[0044] In the preferred embodiment, the apparatus further comprises activation means 70, drivable in particular by a user and operatively associated with said setting module 23 in order to activate the same; through the activation means 70 the user can therefore choose when the self-learning step of the system is to be started.

[0045] The activation means 70 for example comprises a switch in the ON/OFF positions.

[0046] It will be recognised that the self-learning step can be activated each time apparatus 1 has to operate under remarkably different conditions in terms of environmental noise.

[0047] Preferably, apparatus 1 further comprises a signal-conditioning module 80 which is operatively interposed between the DSP 20 and the main input 10 to keep the main signal 11 within predetermined dynamics, i.e. to make the intensity of the useful information about the environmental noise never overcome a predetermined upper saturation threshold and never go below a predetermined lower threshold so as to make this information substantially undetectable.

[0048] Preferably apparatus 1 also comprises a CODEC (combination of Coder and DECoder) 51 operatively associated with the DSP 20; the function of CODEC 51 is mainly to convert the analog signals from the conditioning module 80 into digital signals to be used by the DSP 20, and vice versa, to convert the digital signals generated by the DSP 20 into analog signals to be sent

through output 30, to the electroacoustic transducer 2.

[0049] By way of example, CODEC 51 can be of the Crystall 4218 type, provided with two A/D conversion channels and two D/A conversion channels.

[0050] In the preferred embodiment, apparatus 1 is made up of two boards; a first board 1a on which at least the DSP 20, rewritable memory 50 and, preferably, CODEC are mounted, and a second board 1b on which the conditioning module 80 and/or activation means 70 and, preferably, displaying means to inform the user of the operating conditions of the apparatus are mounted.

[0051] As diagrammatically shown in Fig. 1, each of the two boards 1a, 1b comprises a feeding module 91a, 91b designed to supply each device with the correct electric power.

[0052] In particular, the first feeding module 91a mounted on the first board 1a, feeds the DSP 20 and is connected to the rewritable memory 50 and CODEC 51, while the second feeding module 91b mounted on the second board 1b, feeds the conditioning module 80 and activation means 70 as well as, preferably the displaying means.

[0053] Advantageously, the second feeding module 91b can be directly connected to the electric power of a vehicle on which apparatus 1 is mounted and enables electric power, at 12 V for instance, to be received by the vehicle itself and supplied both to the devices mounted on the second board 1b, and to the first feeding module 91a, so that the latter can suitably feed the devices mounted on the first board 1a.

[0054] By way of example, the second feeding module 91b can output a first 8 V power for the conditioning module 80 and the first feeding module 91a, and a second 5 V power for the activation means 70 and displaying means.

[0055] The two modules 91a, 91b together therefore define a feeding unit 90 capable of feeding all the electric/electronic devices at the inside of apparatus 1 with the correct levels of supply voltage.

[0056] Reference has been hitherto made to a single loudspeaker 3 (the electroacoustic transducer 2) and a single microphone 3 (providing the main signal 11 through the main input 10 of apparatus 1); in any case apparatus 1 is provided to be also used in two-channel systems, having two microphones and two loudspeaker sets governed independently of each other. It is finally to be pointed out, with reference to the DSP 20, that the different modules included therein and above described have been shown separately only for the sake of clarity and for indicating the main functions performed by them in a precise manner; it will be understood that this operating division does not necessarily reflect a corresponding division from the hardware point of view and that the different modules being part of the DSP 20 can be formed with suitable code portions installed in the microprocessor itself.

[0057] The invention achieves important advantages.

[0058] First of all, the apparatus of the invention allows

the acoustic noise present in regions different from each other to be eliminated even under situations involving noise changes in time.

[0059] In addition, the apparatus of the invention due to the above described structural and functional features, is an apparatus of the stand-alone type that does not require further external devices for correct processing of the signals received as an input, and a corresponding generation of efficient erase signals to remove noise.

[0060] Further advantages are represented by the manufacture simplicity, reduced sizes and reduced manufacturing costs characterising the apparatus in accordance with the present invention.

Claims

1. An apparatus for noise active control comprising:

- a main input (10) for receiving a main signal (11) representative of the acoustic noise present in a predetermined area;
- a digital signal processor DSP (20) operatively associated with at least said main input (10) to generate, as a function of said main signal (11), a secondary signal (12) for erasure (removal) of said noise;
- an output (30) operatively associated with said DSP (20) for sending said secondary signal (12) to an electroacoustic transducer (2) to convert said secondary signal (12) into an acoustic signal for removal of said noise,

characterised in that it further comprises a rewritable memory (50) operatively associated with said DSP (20) for storing programs and one or more operating parameters depending on which said secondary signal (12) is generated.

2. An apparatus as claimed in claim 1, **characterised in that** said DSP (20) comprises an updating module (21) operatively associated with said memory (50) for updating said operating parameters.

3. An apparatus as claimed in claim 1 or 2, **characterised in that** it further comprises an auxiliary input (40) for receiving an auxiliary reference signal (13), said DSP (20) further comprising an activation module (22) for activating said updating module (21) as a function of said auxiliary reference signal (13).

4. An apparatus as claimed in anyone of the preceding claims, **characterised in that** said DSP (20) further comprises a setting module (23) operatively associated with said main input (30) for detecting said acoustic noise during a starting step and determining a starting set of operating parameters to be stored in said rewritable memory (50).

5. An apparatus as claimed in claim 4, **characterised in that** said setting module (23) is operatively associated with an electroacoustic transducer for emitting a predetermined acoustic signal during said starting step. 5
6. An apparatus as claimed in anyone of the preceding claims, **characterised in that** it further comprises activation means (70) preferably drivable by a user, and operatively associated with said setting module (23) for activation of the latter. 10
7. An apparatus as claimed in anyone of the preceding claims, **characterised in that** it further comprises a signal conditioning module (80), operatively interposed between said DSP (20) and main input (10) to keep said main signal (11) within predetermined dynamics. 15
8. An apparatus as claimed in anyone of the preceding claims, **characterised in that** it comprises: 20
- a first board (1a) on which at least said DSP (20) and rewritable memory (50) and preferably one or more CODECs are mounted; 25
 - a second board on which said conditioning module (80) and/or said activation means (70) and preferably said displaying means are mounted. 30
9. A system for noise active control, comprising:
- an acoustic-detection device (3) for detecting the acoustic noise present in a predetermined region and generating a corresponding main electric signal (11) representative of said noise; 35
 - an apparatus (1) as claimed in anyone of the preceding claims;
 - an electroacoustic transducer (2) connected to said apparatus (1) for receiving a secondary electric signal (12) therefrom and generating a corresponding acoustic signal for removal of said noise. 40

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FIG 1

