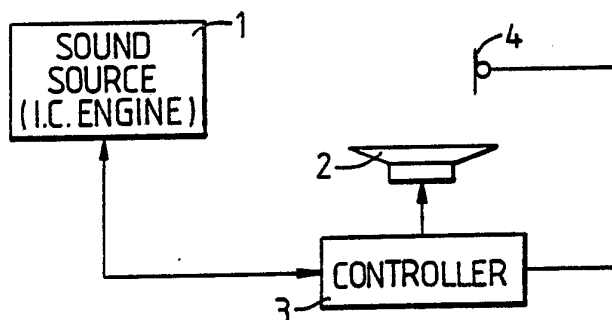




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(21) International Application Number: PCT/GB92/00642 (22) International Filing Date: 9 April 1992 (09.04.92) (30) Priority data: 9107416.1 9 April 1991 (09.04.91) GB (71) Applicant (for all designated States except US): ACTIVE NOISE AND VIBRATION TECHNOLOGIES INC. [US/US]; 3811 East Weir Avenue, Phoenix, AZ 85040 (US). (72) Inventor; and (75) Inventor/Applicant (for US only) : NADIM, Mohammed [GB/GB]; 32 Margaret Road, Colchester, Essex CO1 1RZ (GB). (74) Agents: READ, Matthew, Charles et al.; Venner, Shipley & Co., 368 City Road, London EC1V 2QA (GB).		(81) Designated States: AT (European patent), AU, BE (European patent), CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), GR (European patent), HU, IT (European patent), JP, KR, LU (European patent), MC (European patent), NL (European patent), PL, RO, RU, SE (European patent), US. Published <i>With international search report.</i>

(54) Title: ACTIVE NOISE RECUTION**(57) Abstract**

Primary vibrations (N), e.g. acoustic noise or vibration from a source thereof such as a motor, are cancelled by secondary vibrations (C) produced by an actuator (2) driven by a controller (3) that is responsive to an error signal (E) detected by a detector (4) and representative of the residual or difference between the primary and secondary vibrations. The controller samples the error signal (E) during successive sampling periods determined by a synchronising signal (syn) taken from the motor. The secondary vibrations C_{n+1} for a sampling period $n+1$ are determined as follows: $C_{n+1} = C_n - \mu E_n \text{SGN}[1/\bar{H}]$, where C_n represents the secondary vibrations produced during a preceding sampling period (n); E_n represents the detected error signal for said preceding period n, H represents the transfer coefficient between the actuator (2) and the detector (4) and μ is a scaling factor where $0 \leq \mu \leq 1$. The apparatus is in one embodiment configured as an add-on unit for a personal computer (PC) including circuit board which fits into an expansion slot of the PC.

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ACTIVE NOISE REDUCTION

DESCRIPTION

5

This invention relates to apparatus for cancelling vibrations, which may be gas, liquid or solid-borne, by nulling primary vibrations, at least in part, with specially generated cancelling or secondary vibrations.

10

It has been proposed to cancel repetitive noise produced by e.g. an internal combustion engine, by generating cancellation noise with a controller such that the cancellation noise at least in part cancels the repetitive noise produced by the engine. In order to maintain the amplitude and phase of the cancellation noise in opposition to the noise itself, a detector in the form of a microphone is used to determine the residual noise or error between the cancellation noise and the noise itself. The error signal is used to control the output of the controller in accordance with a predetermined algorithm for maintaining a desired cancellation condition. Also, in order to allow the system to track changes in fundamental frequency of the

20

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noise, a synchronisation sensor is utilised to provide an indication of the fundamental frequency of the noise e.g. from the speed of rotation of the engine. An example of such an arrangement is disclosed in US Patent 4 417 098 (Chaplin et al). The apparatus may operate in a number of different frequencies each comprising a different harmonic of the fundamental frequency so as to produce cancellation over a broad frequency band.

10

The algorithm for the controller operates so that samples of the error signal are compared with one another and the output of the controller is modified in accordance with the algorithm to produce a iterative reduction of the error signal. However, as will be described in more detail hereinafter, the iterative technique utilised has a tendency in conditions close to cancellation, to become unstable as a result of the error signals becoming small, so that the differences between successive error samples can contain a large percentage error that can drive the controller to produce a uncanceled condition.

20

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In accordance with a first aspect of the invention, there is provided improved apparatus for cancelling vibrations wherein the controller is operated in accordance with an improved algorithm that is less
5 prone to drive the apparatus out of the cancelled condition.

In accordance with a second aspect of the invention, there is provided improved noise cancellation apparatus
10 implemented by means of an add-on unit for a personal computer (PC). The apparatus is conveniently embodied as a first circuit board for insertion into the expansion slot of a conventional PC, and a second circuit board driven by the first board and
15 conveniently external to the PC, the second board including an output for a cancellation noise signal, an input for a noise error signal and an input for an external synchronisation signal. Also, software is provided, typically on a floppy disc, to configure the
20 PC processor to perform cancellation in accordance with a predetermined algorithm.

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The apparatus may also include means for producing demonstration noise waveforms to be cancelled. Such waveforms may simulate the noise produced by e.g. a helicopter or a motor vehicle so that the apparatus can be used as a demonstration device for active noise cancellation.

In order that the invention may be more fully understood an embodiment thereof will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a schematic block diagram of an apparatus according to the invention for the active cancellation of repetitive noise from a machine;

Figure 2 is a schematic functional diagram for the signals discussed in relation to Figure 1;

Figure 3 is a schematic block diagram of an example of the invention for use with a personal computer; and

- 5 -

Figure 4 is a more detailed schematic block diagram of first and second circuit boards used in the apparatus of Figure 3.

5 Referring firstly to Figure 1, an active noise reduction apparatus is shown for cancelling noise from a repetitive source such as an internal combustion engine 1. Noise from the engine 1 is cancelled by means of cancellation noise produced by a loudspeaker 2
10 driven by a controller 3. The difference between the noise from the engine 1 and the cancellation noise 2 is detected as an error signal by means of a microphone 4 and the error signal is applied in a feedback loop to the controller so as to control the cancellation noise
15 produced by the loudspeaker in a manner to minimise the error signal.

The controller also receives a synchronisation signal syn from the engine 1 indicative of its fundamental
20 frequency. The synchronisation signal syn is typically produced by means of tachometer and thus comprises a train of pulses at a frequency indicative of the engine's fundamental frequency. It will be appreciated that the signal syn will vary as a function of engine

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speed and thus permits the controller to track the speed variations.

5 The apparatus operates in the frequency domain i.e. cancellation is carried out for a particular frequency harmonic of the signal syn . In practice, cancellation is carried out at a plurality of harmonics so as to achieve cancellation over a broad frequency band. However, for the purposes of this discussion a single
10 harmonic will be considered.

Referring now to Figure 2, in the case of constant repetitive noise from the engine 1, the controller 3 produces an output signal $\bar{C}$ which is received at the
15 microphone 4 after having been modified according to a transfer function $\bar{H}$ dependent upon characteristics of the loudspeaker 2, the microphone 4 and the acoustic environment between the loudspeaker and the microphone. The noise $\bar{N}$ from the engine is for the purpose of this
20 initial discussion assumed to be constant.

The error signal $\bar{E}$ produced by the microphone 4 can thus be expressed as follows:

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$$\bar{E} = \bar{C}\bar{H} + \bar{N} \quad (1)$$

It will be appreciated that since all the variables expressed in equation (1) represent wave functions,
 5 they are actually complex numbers of the form:

$$y = a + ib \text{ where } i = \sqrt{-1} \quad (2)$$

In use of the apparatus, the error signal $\bar{E}$ is
 10 successively sampled at a rate selected to be a predetermined harmonic of the synchronisation signal syn , and a number of successive updates of the error signal are thereby formed.

15 The error signal for successive updates, $n-1$, n , $n+1$ will now be considered for a single harmonic.

For the n th update:

$$20 \quad \bar{E}_n = \bar{C}_n \bar{H} + \bar{N} \quad (3)$$

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For the n-1th update:

$$\bar{E}_{n-1} = \bar{C}_{n-1} \bar{H} + \bar{N} \quad (4)$$

5 For the n+1th update:

$$\bar{E}_{n+1} = \bar{C}_{n+1} \bar{H} + \bar{N} \quad (5)$$

10 Since the noise produced by the engine is repetitive,
it is assumed in the following analysis that the noise
signal $\bar{N}$ produced by the engine is constant for
equations (3), (4) and (5). Similarly, it is
initially assumed for the purpose of this analysis that
the transfer function $\bar{H}$ does not vary significantly
15 between successive updates.

In order to achieve noise cancellation during the n+1th
sample, the controller output $\bar{C}_{n+1}$ should be selected
in such a manner that the error signal $\bar{E}_{n+1}$ becomes
20 zero. Setting $\bar{E}_{n+1}$ to zero in equation (5) yields:

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$$\bar{N} = - \bar{C}_{n+1} \bar{H} \quad (6)$$

By substituting equation (6) into equations (3) and (4)
it can be shown that:

5

$$\bar{C}_{n+1} = \bar{C}_n - \bar{E}_n \frac{(\bar{C}_n - \bar{C}_{n-1})}{(\bar{E}_n - \bar{E}_{n-1})} \quad (7)$$

and

10

$$\bar{H} = \frac{(\bar{E}_n - \bar{E}_{n-1})}{(\bar{C}_n - \bar{C}_{n-1})} \quad (8)$$

From equation (7), it can be seen that noise
cancellation can be achieved by an iterative process in
which the noise output $\bar{C}_{n+1}$ is selected in dependence
upon the values of $\bar{E}$ and $\bar{C}$ utilised for two previous
samplings. In practice, for an adaptive system
converging in a few iterations can result in
significant errors. To overcome this problem a scale
factor $0 < \mu < 1$ is utilised as shown in the following
equation

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$$\bar{C}_{n+1} = \bar{C}_n - \frac{\mu \bar{E}_n (\bar{C}_n - \bar{C}_{n-1})}{(\bar{E}_n - \bar{E}_{n-1})} \quad (9)$$

Whilst iteration according to equation (9) will work
 satisfactorily, a problem remains in that as successive
 values of $\bar{C}$ converge towards the value to produce the
 condition $\bar{E} = 0$ the values of the error samples $\bar{E}_n$ and
 $\bar{E}_{n-1}$ in equation (9) become small so that any spurious
 fluctuations in the values of these error samples will
 produce a very large fluctuation in the value of the
 term $\frac{\mu \bar{E}_n (\bar{C}_n - \bar{C}_{n-1})}{(\bar{E}_n - \bar{E}_{n-1})}$

Thus, in practice, if cancellation is carried out
 according to equation (9) it has a tendency spuriously
 to jump out of the cancelled condition, for example if
 the value of the transfer function $\bar{H}$ varies. By way of
 explanation, if the function $\bar{H}$ according to equation
 (8) is substituted into equation (9) the following
 relationship is provided

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$$\bar{C}_{n+1} = \bar{C}_n - \mu \frac{\bar{E}_n}{\bar{H}} \quad (10)$$

Thus, if the actual value of H varies, the computed
 5 value thereof according to equation (8) no longer holds
 true and a significant error occurs in equation (10).

It might be thought that the solution to this problem
 would be to utilise a constant value of $\bar{H}$ in equation
 10 (10) for successive samples. However, it is to be
 recalled that $\bar{C}$, $\bar{E}$, and $\bar{H}$ are all complex numbers
 having both a modulus and an argument and that the
 resulting combination thereof according to equation
 (10) will be represented by the vector combination of
 15 the signals concerned. Thus, if a constant value of $\bar{H}$
 were utilised the resulting constant argument of $\bar{H}$
 would add in a vector sum in some conditions in such a
 manner as to move away from an iterative convergence
 since the arguments or phase angles of the vectors
 20 concerned would combine in the wrong sense and
 produce a resultant $\mu \frac{\bar{E}_n}{\bar{H}}$ which would combine with $\bar{C}_n$ to
 produce a value of $\bar{C}_{n+1}$ that would tend to move the

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resulting value of $\bar{E}_{n+1}$ into an out of cancellation condition.

In accordance with the present invention, it has been appreciated that much more reliable convergence of the iteration can be achieved if only the vector sign of $\frac{1}{\bar{H}}$ is considered in equation (10). Thus, equation (10)

can be rewritten as follows:

10

$$\bar{C}_{n+1} = \bar{C}_n - \mu \bar{E}_n \cdot \text{SGN} \left[\frac{1}{\bar{H}} \right] \quad (11)$$

It will be appreciated that $\frac{1}{\bar{H}}$ is a complex number and

15

can be expressed as follows:

$$\frac{1}{\bar{H}} = \pm a \pm ib \quad (12)$$

20

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Thus, in accordance with the invention, the term $\frac{1}{\bar{H}}$

is computed in such a manner as to determine the sign of the real and imaginary components a and b shown in
 5 equation (12). The absolute amplitude information of a and b is then discarded and the term $\left[\frac{1}{\bar{H}} \right]$ in equation

(10) is replaced by

10 $(\pm 1 \pm i1)$

wherein the signs for the real and imaginary components are determined in accordance with the actual signs of a and b of equation (12). Accordingly, upon computation
 15 of the term $\mu \bar{E}_n \text{SGN} \left[\frac{1}{\bar{H}} \right]$ the resulting vector will

have a phase in dependence upon the phase of $\frac{1}{\bar{H}}$, so

that the expression will always try to reduce the
 20 error, assuming that μ is selected in such a manner as to produce stable operation. The value of μ can be selected to optimise convergence. Since the absolute value of $\bar{H}$ is no longer incorporated in the vector

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product, spurious variations in the value of $\bar{E}_n$ and $\bar{E}_{n-1}$ will not produce large spurious variations in the expression $\mu \bar{E}_n \text{SGN} \left[\frac{1}{\bar{H}} \right]$.

5

As previously explained in relation to equation (8) when the system moves close to cancellation, $\bar{E}_n$ and $\bar{E}_{n-1}$ both become small and the difference between them becomes prone to spurious errors which can produce very large variations in $\frac{1}{\bar{H}}$. In contrast, in

accordance with the invention, only the sign of $\frac{1}{\bar{H}}$

is considered so that such large amplitude variations cannot occur. If there is an error in $\text{SGN} \left[\frac{1}{\bar{H}} \right]$ the

resulting error is small and the next operation of the iterative process will produce a correction so that convergence will occur.

20

As a practical matter, during start up of the noise cancellation process with large error signals $\bar{E}_n$, both the algorithm of equation (10) and (11) will produce a

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similar result, but as the values of the error signals $\bar{E}_n$ reduce, the potential to get $\frac{1}{\bar{H}}$ wrong

5 becomes more significant which can have a dramatic effect, as previously explained.

An additional problem is that in practice $\bar{H}$ and $\bar{N}$ are not fixed as assumed above, and do actually change with time. $\bar{N}$ changes with engine load and $\bar{H}$ with
 10 frequency. Thus, in practice, it is important to evaluate H in such a manner that the spurious fluctuations in E do not substantially degrade the computation. Thus, the invention has the advantage that by computing the sign of $\frac{1}{\bar{H}}$ any errors in $\bar{E}$ have
 15 minimal effect on the overall cancellation performance.

The invention also embodies an additional advantage that by computing only the sign of $\frac{1}{\bar{H}}$ the speed of
 20 computation can be improved, which is advantageous in terms of processor time. To explain this in more detail, consider the following:

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Let $\nabla \bar{C} = (\bar{C}_n - \bar{C}_{n-1})$, and

$$\nabla \bar{E} = (\bar{E}_n - \bar{E}_{n-1})$$

5 Substituting in equation (8) and inverting:

$$\frac{1}{\bar{H}} = \frac{\nabla \bar{C}}{\nabla \bar{E}}$$

$$10 \quad \text{i.e.} \quad \frac{1}{\bar{H}} = \frac{\nabla \bar{C} \cdot \nabla \bar{E}^*}{\nabla \bar{E} \cdot \nabla \bar{E}^*} \quad (14)$$

where * denotes the complex conjugate.

15 It will be seen that the denominator of equation (14) is a real number and therefore in order to compute the sign of $\frac{1}{\bar{H}}$, it is only necessary to compute the

20 numerator of the equation. It will be appreciated that division performed by a microprocessor is significantly slower than multiplication and the omission of the division step therefore substantially speeds up the computation process.

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The algorithm described above can be implemented by the use of a purpose built controller. However, advantageously, the invention can be embodied in an add-on unit for a personal computer (PC) as will now be described. Referring to Figure 3, a conventional personal computer is shown including a video monitor 5, a keyboard 6, and a disc drive 7, processor circuitry 8 and RAM 9 mounted on a circuit board arrangement 10. In a conventional manner, the circuit board arrangement 10 includes expansion slots which permit additional circuitry to be connected to the system bus (not shown). The expansion slots are shown schematically at 11. In accordance with the invention, a first, internal card 12 is fitted into one of the expansion slots and is connected by a ribbon cable 13 to a second, external card 14. The circuit arrangements for the first and second cards 12, 14 are shown in more detail in Figure 4.

20 The system is arranged to operate generally in the manner shown in Figure 1 wherein the noise cancellation algorithm is performed by means of the processor 8 of the PC. The processor is controlled to operate in accordance with the algorithm by means of software

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from the disc drive 7. Other means of loading software into the computer will be evident to those skilled in the art. Additionally, the system can be used to display an active noise cancellation process without
5 actually cancelling noise produced by a noise source such as the engine 1. Instead, the computer can generate its own noise signal which can be filtered and modified appropriately to simulate noise produced by engines, helicopters and other repetitive noise
10 sources. The simulated noise signal can be fed to a loudspeaker to simulate the presence of the sound source 1. Also, the noise and the resulting cancellation can be displayed on an oscilloscope.

15 Thus, referring in more detail to Figure 4, the second, external board includes an output 15 for simulated noise produced by the PC processor, an output 16 for the cancellation signal $\bar{C}$, an input 17 for the error signal $\bar{E}$, and input 18 for the external
20 synchronisation signal syn and an output 19 for an oscilloscope. The inputs and outputs 15, 16 and 17 are connected through appropriate filters 20, 21, 22, via the cable 13 to the first board 12. The second, external board 14 also includes an internal clock 23

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for generating an internal synchronisation signal *syn* in the event that an external signal is not introduced on input 18. A synchronisation signal select circuit 24 determines whether an internal or external
5 synchronisation signal is fed to the PC.

Considering now the first, internal board 12, it includes edge connections (not shown) providing an interface to the PC bus which is extended across the
10 board by conductive paths shown schematically at 26. The PC data bus is connected to an analog to digital converter 27 in order to receive a digital conversion of the input error signal applied to input 17. The resulting digitised signal is fed to the data bus of
15 the PC for processing in accordance with the aforesaid algorithm. As a result, digital cancellation signals are provided on the data bus which are fed to a dual digital to analog converter 28, which produces analog signals fed to the cancellation output 16 via filter
20 21.

In the event that the PC is used to generate noise to be cancelled for demonstration purposes, the digital noise signals are generated by the processor under the

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control of appropriate software, and are fed to the converter 28 to provide analog signals at output 15 via filter 20.

5 Interrupts from the PC bus are fed to a decoder 29 so as to provide synchronisation pulses at output 19 for controlling an oscilloscope. The synchronisation pulses are produced at a frequency corresponding to a multiple of the fundamental frequency of the input
10 synchronisation pulses derived either from input 18 or from the internal clock 23.

Thus, in operation, noise cancellation signals $\bar{C}$ are developed at output 16 in response to an input error
15 signal $\bar{E}$ applied to input 17 under the control of a program executed by processor 8 in response to software embodying the algorithm, derived from disc drive 7. For demonstration purposes, synthesized noise signals may also be produced at output 15. The system may
20 operate concurrently for a number of different harmonics of the fundamental frequency defined by the sync pulses. The harmonics may be selected by the user in accordance with a menu driven display shown on the video monitor 5. Whilst the system desirably operates

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with the algorithm discussed hereinbefore, it may also be used with other noise cancellation algorithms if desired.

5 Many modifications and variations of the invention will be apparent to those skilled in the art. For example, whilst the algorithm described with reference to equation (11) operates in the frequency domain, it could also be used in a process which operates in the
10 time domain.

Also, whilst in equation (11) the sign of $\left[\frac{1}{\bar{H}} \right]$ is

considered only in terms of the signs of (+1 + i1) the
15 real and imaginary components could also be considered to have zero values as well as + values, so as to increase the range of phase angles considered in the algorithm.

20 Also, the algorithm disclosed with reference to equation (11) can be used to cancel mechanical vibrations rather than acoustic noise as described with reference to Figures 1 and 2. For example, the system

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can be used to attenuate vibrations of a motor such as an electric motor in a domestic appliance. In such a system, a vibration pickup is utilised to sense unwanted motor vibration, and an actuator driven by the controller 3 applies cancelling vibrations to the motor. The system has particular application to a dishwasher.

The algorithm can be run in a single channel as described hereinbefore, or multi-channel systems can be provided with separate algorithms being run in each channel. The system can thus be used for multi-input, multi-output operations. The various channels can be run independently or can be cross-coupled.

Furthermore, in a modification, the syn pulse may be constituted by a single pulse for each motor revolution, and software or hardware may be utilised to produce an appropriate sampling pulse rate signal.

20

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Claims

1. A method of cancelling primary vibrations
5 with secondary vibrations from a source thereof,
comprising utilising detecting means to produce an
error signal as a function of the difference between
the primary and secondary vibrations, sampling the
error signal during successive sampling periods, and
10 producing the secondary vibrations for a particular
sampling period in dependence upon:

(a) the secondary vibrations produced for a preceding
sampling period, and

(b) a term which is a function of the vector product
15 of:

(i) a vector signal which is a function of
the error signal for a preceding period; and
(ii) the sign of a vector signal which is a
function of the transfer coefficient between
20 the source and said detecting means.

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2. A method according to claim 1 wherein the sign of said transfer coefficient vector signal is determined in dependence upon:

- 5 (a) the difference between the secondary vibrations produced for successive preceding sampling periods; and
 (b) the difference between the error signals produced for successive preceding sampling periods.

3. A method according to claim 1 or 2 wherein
 10 said term is scaled by a factor μ where:

$$0 \leq \mu \leq 1$$

4. A method according to claim 3, wherein the secondary vibrations C_{n+1} for a sampling period $n+1$ are
 15 determined as follows:

$$C_{n+1} = C_n - \mu E_n \operatorname{SGN} \left[\frac{1}{H} \right]$$

where C_n represents the secondary vibrations produced
 20 during a preceding sampling period n ; E_n represents the detected error signal for said preceding period n , and H represents said transfer coefficient.

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5. A method according to claim 4 wherein the sign of said transfer coefficient vector signal $\left[\frac{1}{\bar{H}} \right]$

is determined in accordance with the following:

5

$$\text{SGN} \left[\frac{1}{\bar{H}} \right] = \text{SGN} \left[\frac{(C_n - C_{n-1})}{(E_n - E_{n-1})} \right]$$

wherein $n-1$ denotes a sampling period preceding the

10 period n.

6. A method according to claim 5 wherein the sign of said transfer coefficient vector signal is determined in accordance with the following:

15

$$\text{SGN} \left[\frac{1}{\bar{H}} \right] \propto \text{SGN} \nabla C \cdot \nabla E *$$

where $C = (C_n - C_{n-1})$

20 $E = (E_n - E_{n-1})$

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and* denotes the complex conjugate.

7. A method according to any preceding claim including producing a cyclic synchronisation signal having a frequency as a function of a repetitive aspect of the primary vibrations, and performing said sampling of the error signal at least one harmonic of said synchronisation signal.

10 8. An add-on unit for a personal computer (PC) to perform active noise cancellation wherein primary vibrations are at least in part cancelled by secondary vibrations produced by a secondary source and detecting means are utilised to produce error signals as a function of the residual difference between the primary and secondary vibrations, the unit comprising:
15 circuit board means for connection to an expansion slot of the PC
bus connection means on the board means, for forming an
20 electrical connection with a bus of the PC
analog to digital converter means coupled to the bus
connection means for digitising the error signals from the detecting means and supplying the thereby digitised

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signals to the PC bus

digital to analog converter means coupled to the bus
connection for receiving digital cancellation signals
from the PC bus and producing analog cancellation
5 signals to be supplied to the secondary source to
produce said secondary vibrations,

whereby the PC can execute a program to produce said
digital cancellation signals in response to said error
signals.

10

9. A unit according to claim 8 including
synchronisation input means coupled to said bus
connection means, for supplying to the PC bus a cyclic
synchronisation signal of a frequency which
15 characterises a repetitive aspect of the primary
vibrations.

10. A unit according to claim 8 or 9 including
synchronisation signal generator means on said board
20 means for locally producing a synchronisation signal to
be fed to the bus connection means.

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11. A unit according to any one of claims 8 to 10 wherein the circuit board means includes a first circuit card for insertion into the expansion slot, a second circuit card to be disposed externally of the PC, and cable means providing electrical connection
5 between the cards.

12. A unit according to any one of claims 8 to 11 including a noise signal output, and digital to analog
10 to converter means coupled to said bus connection means to supply noise signals to said noise signal output in response to digital signals representative of a simulated noise source generated by said PC.

13. A unit according to any one of claims 8 to 12 including means coupled to said bus connection means for deriving an output for synchronising an
15 oscilloscope.

14. Apparatus configured to perform a
20 cancellation method according to any one of claims 1 to 7.

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15. Apparatus according to claim 14 including a
motor, sensor means for deriving a signal having a
periodicity as a function of the speed of the motor,
detecting means for detecting said difference between
5 the primary and secondary vibrations, controller means
for producing signals representative of said secondary
vibrations for the motor, and actuator means
responsive to said signals to apply said secondary
vibrations to the vicinity of the motor.

10

FIG.1

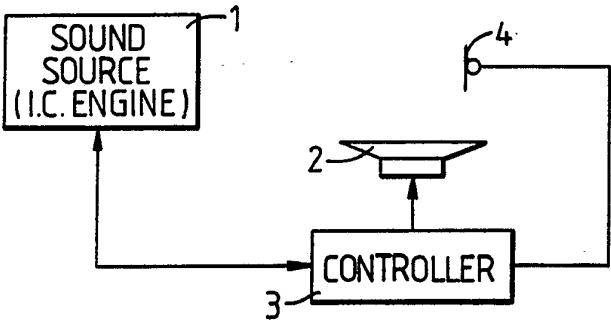


FIG. 2

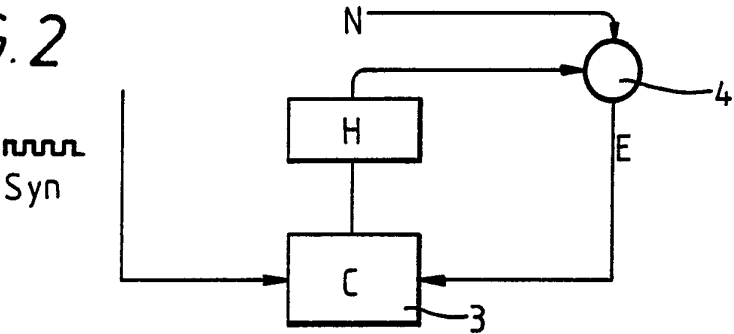
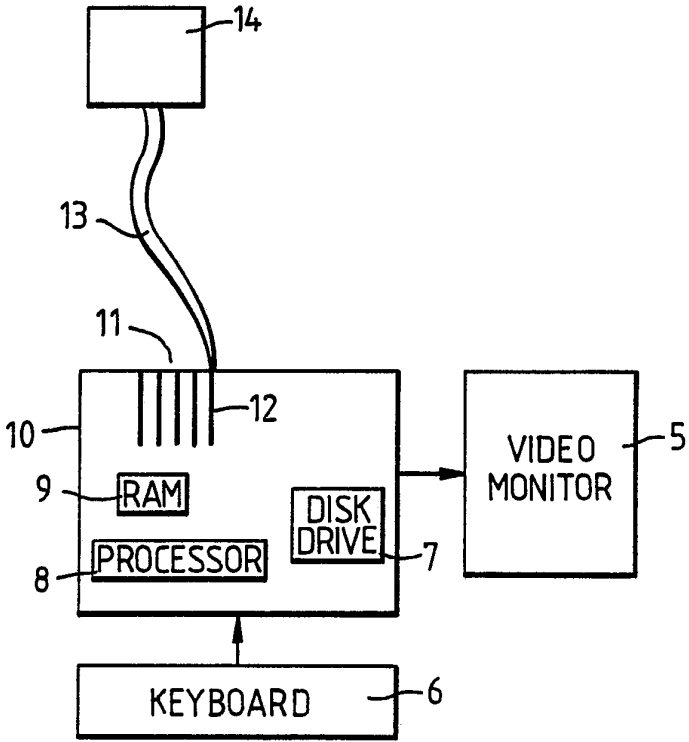
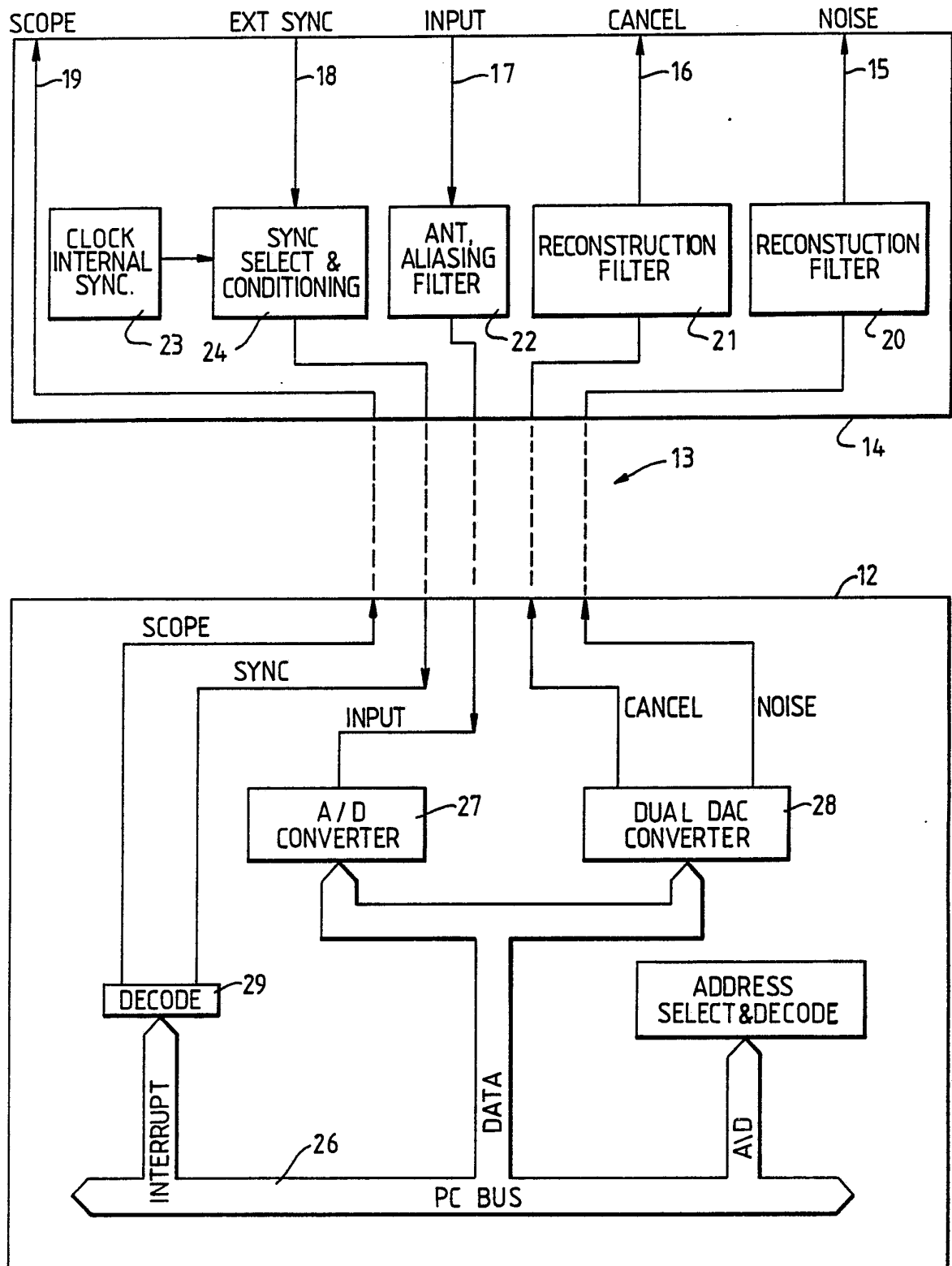


FIG.3

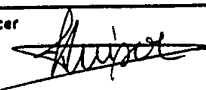


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FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 92/00642

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁴		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC ⁵ : G 10 K 11/16		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
IPC ⁵	G 10 K 11/00	
Documentation Searched other than Minimum Documentation to the extent that such Documents are included in the Fields Searched ⁶		
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁸		
Category ⁹	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
A	US, A, 4 417 098 (CHAPLIN) 22 November 1983 (22.11.83), see abstract; fig. 1-11; claims 1-9 (cited in the application). --	1, 8, 14
A	RESEARCH DISCLOSURE, September 1990, 317 317102 "An Active Noise Controller", page 784 see totality. --	1, 8, 14
A	RESEARCH DISCLOSURE, September 1990, 317 31784 "Active Reduction of Repetitive Noises Using Digital Feedback Control" page 769, see totality. --	1, 8, 14
* Special categories of cited documents: ¹⁴ "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document 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 "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. "Z" document member of the same patent family		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
24 June 1992	10 JUL 1992	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	Mme N. KUIPER 	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, " with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	GB, A, 2 097 629 (NATIONAL RESEARCH DEVELOPMENT CORPORATION) 15 April 1981 (15.04.81), see abstract; fig. 1-6. --	1,8,14
A	EP, A1, 0 335 468 (BIRCH WOOD ACOUSTICS NEDERLAND B.V.) 04 October 1989 (04.10.89), see abstract; fig. 4-6. --	1,8,14
P,A	EP, B1, 0 212 840 (SIEMENS PLESSEY ELECTRONIC SYSTEMS LIMITED) 23 October 1991 (23.10.91), see claims 1-3; fig. 1. ----	1,8,14

ANHANG

ANNEX

ANNEXE

zum internationalen Recherchen-
bericht über die internationale
Patentanmeldung Nr.

to the International Search
Report to the International Patent
Application No.

au rapport de recherche inter-
national relatif à la demande de brevet
international n°

PCT/GB 92/00642 SAE 58287

In diesem Anhang sind die Mitglieder
der Patentfamilien der im obenge-
nannten internationalen Recherchenbericht
angeführten Patentdokumente angegeben.
Diese Angaben dienen nur zur Unter-
richtung und erfolgen ohne Gewähr.

This Annex lists the patent family
members relating to the patent documents
cited in the above-mentioned inter-
national search report. The Office is
in no way liable for these particulars
which are given merely for the purpose
of information.

La présente annexe indique les
membres de la famille de brevets
relatifs aux documents de brevets cités
dans le rapport de recherche inter-
national visée ci-dessus. Les renseigne-
ments fournis sont donnés à titre indica-
tif et n'engagent pas la responsabilité
de l'Office.

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