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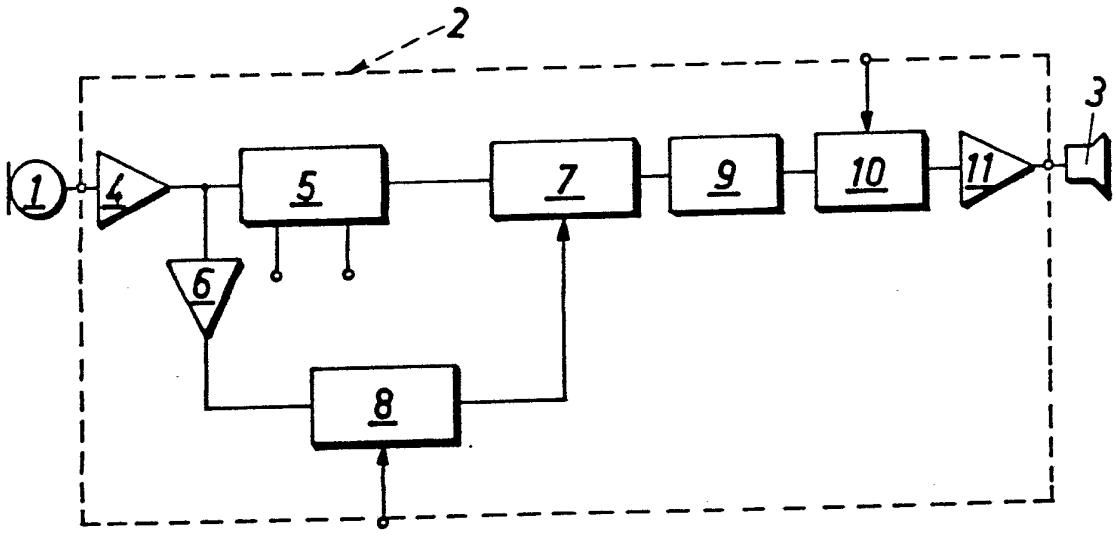
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(57) Abstract

Method and apparatus for damping/eliminating transient sounds, preferably in hearing aids intended for people with impaired hearing or as a noice protection device, whereby the derivative of the incoming sound signal is calculated. The transient eliminator is adapted to discriminate/detect transient sounds in a complex sound signal and thereafter to selectively eliminate/reduce the same. The method is attained in that the mean derivative of the sound signal controls the damping/elimination of damaging/uncomfortable transients occuring in the audio signal. A transient eliminator for performing the method is provided in that a converter (8) is provided in the signal processing unit (2) and adapted to convert the mean derivative/differential delivered from the differentiator (6) into a control signal which is adapted to proportionally control a damper (7) in such a way, that damaging/uncomfortable transient sounds occuring in the sound signal supplied to the microphone (1) will be reduced/eliminated.

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A METHOD AND A DEVICE FOR THE DAMPING OF TRANSIENTS

The present invention relates to a method and a device for the damping/elimination of transients, preferably in hearing aids intended for people with impaired hearing or for noice protection devices, whereby the derivative of the incoming sound signal is calculated.

BACKGROUND OF THE INVENTION AND THE STATE OF THE ART

Nowadays, large resources are spent in industrial enterprises and other place of work for preventing hearing injuries. Paradoxially enough, when it comes to hearing injuries in industrial enterprises, almost all kinds of industrial noice has its significant energy within the frequency range 250-1000 Hz, but a reduction of hearing almost always starts at around 4-6 kHz and is, a normally most pronounced at 6 kHz, independently of whether the hearing injury has been caused for instance by a gun shoot, an explosion or has occured gradually due to extended exposure to a noicy environment.

Transient sounds consist of comparatively short (< 80 ms) sounds caused by one or several correlated sources with intially very high amplitudes and with several transients. Most hearing researches in various types of industrial noice environments especially within the process industry, with a large amount of transients or high peak factors, show serious reductions in hearing despite the fact that the measured dBA-level has been detected so low that there should be no risk of hearing injuries. The opposite thereto, i.e. a high dBA-level but an insignificant reduction of hearing, will be found in environments like sawmills or airplane cockpits where the noice is of the character of "white noice" (caused by many uncorrelated sources), which does not contain transients or high peak factors. The peak factor mentioned above means the maximum instantaneous value divided by the dBA value. The dBA value is the weighted mean energy level at various

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frequencies. The weighing factors are determined by the equal loudness curve related to 40 dB SPL (Sound Pressure Level) and 1000 Hz.

Until 1970, noice measurements and risk norms related thereto have been based upon the dBA-level where the presentation (the pointer) has a time constant of about 35 ms, which approximately corresponds to the time constant of our whole subjective sense of hearing, i.e. one measures what is subjectively experienced (heared) and not that which really causes injuries. The mechanical part of our hearing organs (from the external ear to the basillary membrane) has a considerably shorter time constant, about 20-50 us, which explains that even sounds that are not experienced as especially loud (due to the long integration time in the brain) may mechanically injure the basillary membrane, since the instantaneous amplitudes of oscillations may be very high also if the duration of the sound is so short that it will be experienced as a weak sound. Transients and sounds with high peak factors show the before mentioned characteristics. This means that it is not only the weighed energy mean level of the sound (the dBA-level), but to a higher degree the characteristics of the sound in the time plane, which mirrors the damaging influence a sound can have upon the hearing.

Consequently, the human ear is not designed to tolerate the transient sounds caused by the industrialized world of today. People subjected to a serious reduction in the hearing are usually being prescribed some kind of hearing aid.

A reduction in hearing involves an increased "hearing threshold". However, the "uncomfortability level" remains at the same level as at a normal ear, and in certain cases it may even be at a lower level. This reduces the dynamics (see fig. 5). The shaded area D represents the amplification need for comparatively weak noices. At a given frequency, the arrow A shows the dynamics of a normally hearing ear and the arrow B shows the dynamics at a reduction in hearing where the

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uncomfortability level C also has been slightly lowered. The mean amplification requirement may for instance be 20 dB. This means that, in such a hearing aid, also loud sounds are amplified with 20 dB, which causes serious inconvenience and involves a substantial risk for further damages to the hearing. The result will be that the patient will lower the amplification of the hearing aid, which will result in decreased comprehension of speech. Since it is also a fact that electrical processing of the sound never may give the same comfortability and ability of directional hearing as is the case without a hearing aid (at the same sound pressure), it has been shown that 60-80% of the patients choose to put there hearing aid in a drawer. In modern hearing aids, it has been tried to reduce the problem of the reduced dynamics be means of various compressor systems consisting of for example an AGC (Automatic Gain Control). Psycho-acoustic measurements have shown that although the compressor hearing aids give a better understanding of speach they have a less comfortable sound than a conventional hearing aid without the compressor function. This is due to the fact that the compressors are frequency selective and need a certain integration time (attack time) > 0.5 ms, which causes that the high amplitudes at the beginning of the transient to pass through the hearing aid at a considerably higher amplification than what is acceptable. Furthermore, at low sound levels, the compressor hearing aid produces more noice than a conventional hearing aid. In this connection it should also be noted that the electronics of the output stage will be overloaded at high instantaneous levels, which gives raise to distorsion and also causes resonances in the electronics which extend and amplify transient sounds.

The injurious influence on hearing caused by transients and the uncomfortability experienced by the transients can not be solved be previously known hearing aid technology.

The fact that transients are characterized by very high derivatives has been known for a long time although this

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knowledge is not utilized at the present. The derivative is that quality in the time plane which mirrors what can not be shown by the amplitude spectrum in the frequency plane without the aid of a phace spectrum, which in turn is impossible to measure in practice. Studies have shown that the discrimination between speech and transient sounds will increase by 6-10 dB by derivating the sound signals. By integrating the half or full wave rectified derivative of the sound signal, a further increased ability of discrimination between speech and transient sounds is obtained.

Hearing aids with various forms of transient elimination are previously known. As an example, one such hearing aid is described in the Danish Patent Specification 124439. This publication discloses a hearing aid which comprises apart from a microphone an amplifier and an earphone, an electronic circuit for the differentiation of the incoming signal. This hearing aid has several drawbacks. Among other things, at the detection of a transient it will completely interrupt the sound signal to the ear phone, which will cause new transients to be formed in the "flanks". Echo effects will occur when the ear phone is reconnected due to the fact that the transients causing the interruption have a considerable reverberence (>100 ms). The total lack of sound during the interrupt periods are experienced as uncomfortable. This hearing aid has to be regarded as a primitive design and would not be usable in practice.

Further drawbacks are that a comparatively high threshold value has to be put on the level of the transient signal due to problems of discrimination between the "fundamental tone" in speech (which is of a transient character) and the undesired transients. Furthermore, the hearing aid described only has instantaneous value trigging demanding very rapid comparators which are almost impossible to provid in practice. Finally, it should be pointed out that the damper is not capable of retriggable, but the duration of the sound interruption is determined once and for all and thus may not

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be effected by the occurance of several transients for instance just before the sound is turned on again. This may cause the reverberation to be annoying.

THE OBJECTS AND MAIN CHARACTERISTICS OF THE INVENTION

The object of the present invention is to provide a transient eliminator which eliminates the above-mentioned drawbacks and which is reliable in operation and simple in use. The transient eliminator should, in a manner comfortable to the user, eliminate/reduce damaging/uncomfortable transient sounds but still permit the passage of non-damaging sounds e.g. normal conversation. One method of attaining this is that the mean derivative of the sound signal controls the reduction/elimination of damaging/uncomfortable transients occuring in the sound. An apparatus for attaining the above-mentioned is characterized in that a converter is provided in the signal processing unit and adapted to convert the mean derivative/differential delivered by the differentiator into a control signal which is adapted to proportionally control a damper in such a way, that damaging/uncomfortable transient sounds occuring in the audio signal supplied to the microphone will be reduced/eliminated.

BRIEF DESCRIPTION OF THE DRAWINGS

An embodiment of the invention will be described here below with reference to the accompanying drawings.

Fig. 1 is a block diagram of a transient eliminator according to the invention,
Fig. 2a-c illustrate in more detail various alternatives of a convertor,
fig. 2d is a circuit diagram showing an exmple of an "ideal diod",
Fig. 3 shows an analogue damper,
Fig. 4a-c show signal diagrams,
Fig. 5 is a diagram illustrating the frequency dependency of

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hearing in combination with a reduction of hearing.

DESCRIPTION OF EMBODIMENTS

The transient eliminator according to the invention illustrated diagrammatically in fig. 1 comprises a microphone 1 which converts detected sounds into electrical signals, a signal processing unit 2 for a processing of incoming electrical signals, and an ear phone or loadspeaker 3 for converting the processed electrical signals into sound.

The signal processing unit 2 consists of several circuit parts, most of which are in the form integrated circuits in complementary MOS-technology. This design will guarantee a low power consumption which gives comparatively long periods of operation between changes of battery. Furthermore, this technology is very simple to integrate into small dimensions which is very important in connection with hearing aids. These have to be miniaturized of estetical and practical reasons. The microphone 1 is connected to a first amplifier 4, the output signal of which is supplied, on the one hand, to a delay circuit 5 and , on the other hand to a differentiator 6. The delay circuit 5, which is made in so called CCD-technology (Charge Coupled Devices), will "clock" the information supplied to the input, to the output in relation to the frequency of the internal oscilliator (not shown). To the output of the delay circuit 5 there is connected a damper 5 the damping of which is controlled by a convertor 8. Thus, the delay circuit 5 is adapted to delay the incoming signal to the damper 7, so that a maximum damping may be obtained at the highest passages of the transients. The differentiator 6 is adapted to derivate the incoming sound signal and supply the resulting signal to the converter 8.

The above-mentioned CCD-technology is a combination of analogue and digital technology which makes A/D- and D/A-convertors and memories redundant. This technology involves sampling the analogue signal in an analogue sampling

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chain of a certain frequency. If the signal is taken out after N samples and the clock frequency is f, a delay t_d=N/f will be obtained. Time delays of electrical signals may be attained in various different ways, but in connection with hearing aids sizes and energy consumption have to be considered. It is for this reason that the CCD-technology has been chosen in this embodiment, said technology permitting optional delays from a few us up to several ms.

After the delay circuit 5 and the damper 7 there is provided, on the one hand, a low pass filter (LP-filter) 9, the turn over frequency of which may be set to for instance 10 kHz, and, on the other hand, a signal control unit 10, by means of which the processed signal may be optionally adjusted with respect to tone and volume. An output emplifier 11 is provided between the signal processing unit 10 and the loadspeaker 3.

The convertor 8 shown as a block in fig. 1 is shown in more detail in fig. 2a. In a first embodiment, the convertor comprises a diode 13a connected in serie with a first resistor 14. The diode 13a will rectify the incoming signal and, through its forward voltage drop, will provide a starting threshold for the analogue operation range of the damper 7. Further, a capacitor 15 and a resistor 16 are connected in parallel and connected to chassi ground. When the diod 13a is forwardly polorized, the resistor 14, the resistance of the diode 13a and the capacitor 15 will form an RC-circuit, the time constant of which will be designated hereinafter as τ_{on}. Correspondingly, the resistor 16 and the capacitor 15 will form an RC-circuit with a time constant τ_{off} when the diode 13a is reversely polorized.

The convertor 8 also includes an externally adjustable control circuit 18, by means of which the damper 7 may be disconnected wholly or partially. In certain environments, where disturbing transients are very unusual, e.g. in a lecture hall, it may be of advantage to reduce the influence of the damper 7.

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Fig. 2b and 2c show alternative embodiments, wherein an A/D-convertor 19 is provided in front of the control circuit 18, said A/D-convertor 19 being intended to convert the analogue signal into a digital signal. This digital signal is used for controlling a digitally controlled damper which may be utilized instead of the previously mentioned analogue damper 7. The advantages of using a digitally controlled damper (multiplying DAC) is that it is easily made logarithmic, is easy to integrate and does not necessitate any critical adjustment.

Fig. 2c illustrates a convertor 8 provided with an "ideal diode" 13b and a "true" integrator. An ideal diode 13b may consist of for instance among other things an operational amplifier and two diodes (see fig. 2d). Due to the fact that such an "ideal diode" has a low impedance output, the time constant T_{on} and T_{off} will be approximately equal. This embodiment will not provide the advantages treshold level which will be obtained by using only a common diode.

A damper 7 according to the invention and of analogue type is shown more closely in fig. 3. It comprises and amplifier 20, a resistor 21 and a field effect transistor 22.

Thus, the converter 8 converts the derivative/differential to a control signal which is adapted for the purpose and which controls the damper 7 which will proportionally reduce/eliminate the sound signal/transient. Hereby, the control signal is comprised of the "mean derivative " of the audio signal. By the mean derivative is ment that the derivative is full way or half rectified and supplied to an integrating network. The time constants in the integrating network T_{on} an T_{off} do not need to be equal. In the embodiment here described (fig. 2a, 2b), T_{on} is approximately equal to 1-4 ms and T_{off} is considerably larger, although less than 200 ms (se the broken line B in fig. 4b). In the embodiment according to fig. 2c, $T_{on} = T_{off}$ which is considered as "true" integration. With proportional damping is

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ment here that the damping is a linear or logarithmic function of the potential across the capacitor 15 in fig. 2a-2c. By the inclusion of a time constant T_{on} at "attack" which is equal to the value of the resistance of the diode 13a + the value of the resistor 16 multiplied by the value of the capacitor 15, a very good discrimination between speech and damaging transients is obtained. It has been found that a suitable value of T_{on} is 1-4 ms where at a good discrimination has been obtained between speech and damaging transients. At the same time, large values of T_{on} means that the delay time in the delay circuit 5 has to be increased. This is no problem if a CCD-delay line is used. If only the reduction of very strong transients damaging to hearing were of interest, T_{on} could be made approximately equal to 0 seconds. However, with T_{on} =1-4 ms, the hearing aids will be much more comfortable in use without the need of introducing more electronics.

The "release time", i.e. the diminishing of the damping, which is determined by the time constant T_{off} = the value of the resistor 16 multiplied by the value of the capacitor 15, should be made considerably larger than T_{on}, since otherwise the control signal will contain much ripple. Furthermore, it has been shown that the damping at the end of a transient should be slightly larger than the envelope of the derivative in order to give a comfortable sound picture. When the control signal B has a higher value than the threshold level (indicated at C in fig. 4b), the damping may preferably be at its maximum, for instance 30 dB.

Fig. 4a-c show various diagrams where the vertical axis show signal amplitude and the horisontal axis show time. The curve illustrated in fig. 4a shows a typical example of a derivated speech signal where characteristic transients occur at regular intervals. These transients have a comparatively low amplitude but may still "trigger" a transient eliminator the detection of which occurs only through threshold detection, i.e. even a common level of speech may cause such a hearing aid to interrupt the sound to the ear. The risk of an ordinary

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conversation activating the transient eliminator according to the present invention is very small, since it is the mean value of the derivative signal which controls the damping of the signal.

Fig. 4b illustrates more closely how a transient signal is detected according to the present invention. The broken line B shows the potiential across a capacitor 15 which increases with time upon detection of a transient with several transient periods. It is hereby important that the time constant T_{on} is considerably smaller than the time constant T_{off} so that a sufficiently rapid rise time is obtained.

Fig. 4c shows a composite diagram with three horizontal time axes. This simplifies the comparison of time between the various signals shown. The upper curve diagrammatically illustrates the shape of a transient signal as it might look after having passed through the amplifier 4 in the signal processing unit 2. The middle time axis shows the same signal after time delay in the time delay circuit 5, i.e. the signal supplied to the damper 7. The lower most time axes shows the control signal from the convertor 8 to the damper 7, i.e. the mean derivative of the incoming signal. This clearly shows how the mean derivative of the sound signal will be rapidly increased so that maximum damping will be obtained in the damper 7 when the transient passes. In order to avoid uncomfortable "echo-effects" caused by the reverberation of the transient, the damping signal is allowed to diminish only slowly.

Naturally, the invention is not limited to the embodiment described above, but several alternative embodiments are concievable within the scope of the claims.

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CLAIMS

1. A method of damping/eliminating transient sounds, preferably in hearing aids intended for the people with impaired hearing or for noice protection devices, whereby the derivative of the incoming sound signal is calculated,
c h a r a c t e r i z e d i n,
that the mean derivative of the sound signal controls the damping/elimination of damaging/uncomfortable transients occuring in the sound signal.

2. A transient eliminator for performing the method according to claim 1, i.e. for the damping of transient sounds, preferably intended for hearing aids for the people with impaired hearing or as a noice protection device, and comprising a signal processing unit (2) which consists of i.e. a microphone (1), a differentiator (6), a delay circuit (5) and a loudspeaker (3)
c h a r a c t e r i z e d i n,
that a converter (8) is provided in the signal processing unit (2) and adapted to convert the mean derivative/differential delivered by the differentiator (6) into a control signal which is adapted to proportionally control a damper (7) in such a way, that damaging/uncomfortable transient sounds occuring in the sound signal supplied to the microphone (1) will be reduced/eliminated.

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FIG.1

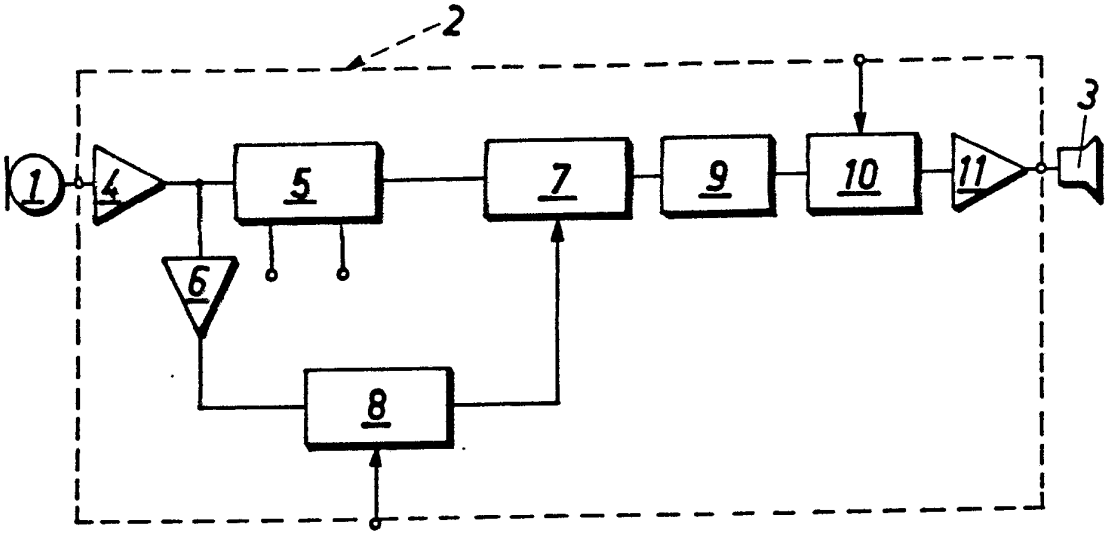


FIG.2a

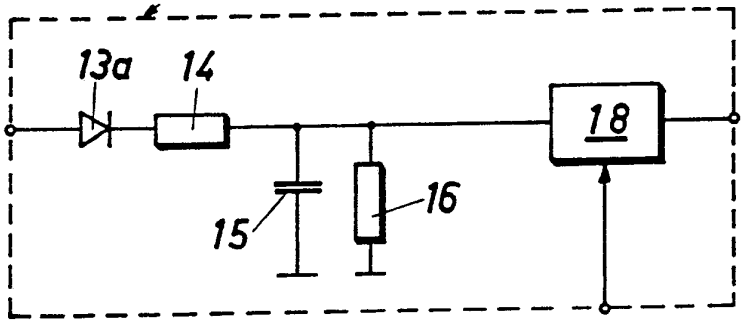


FIG.2b

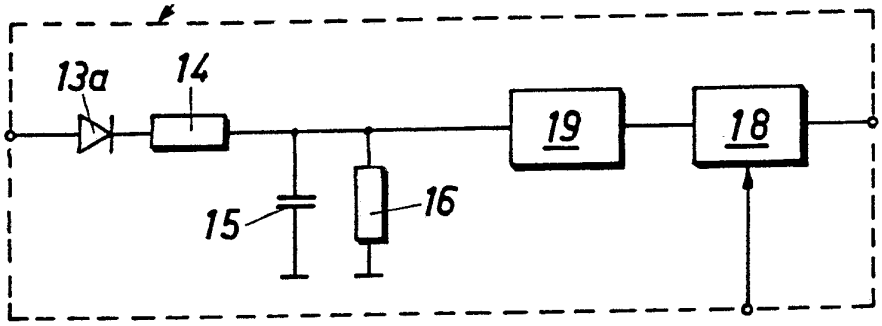
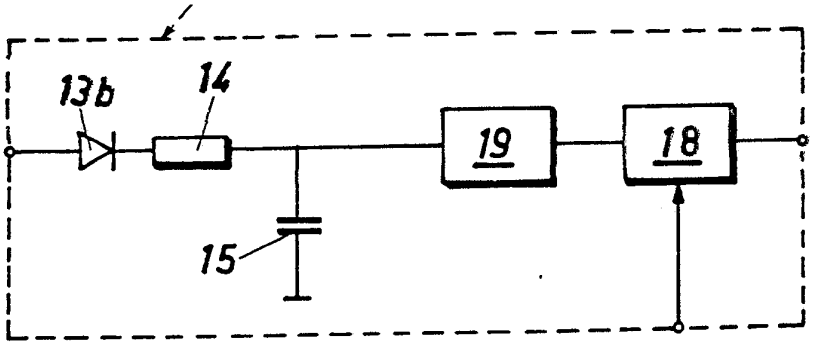


FIG.2c



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FIG.2d

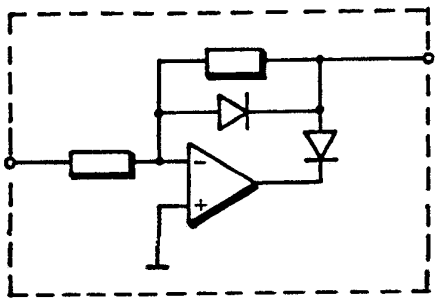


FIG.3

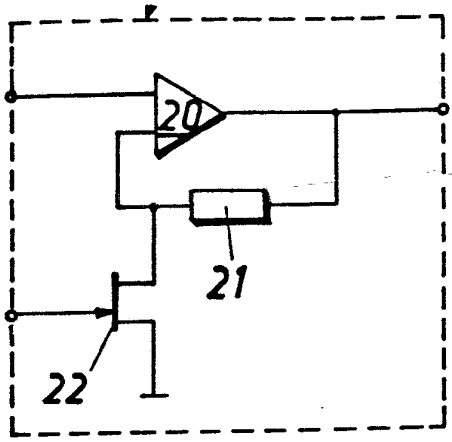


FIG.4a

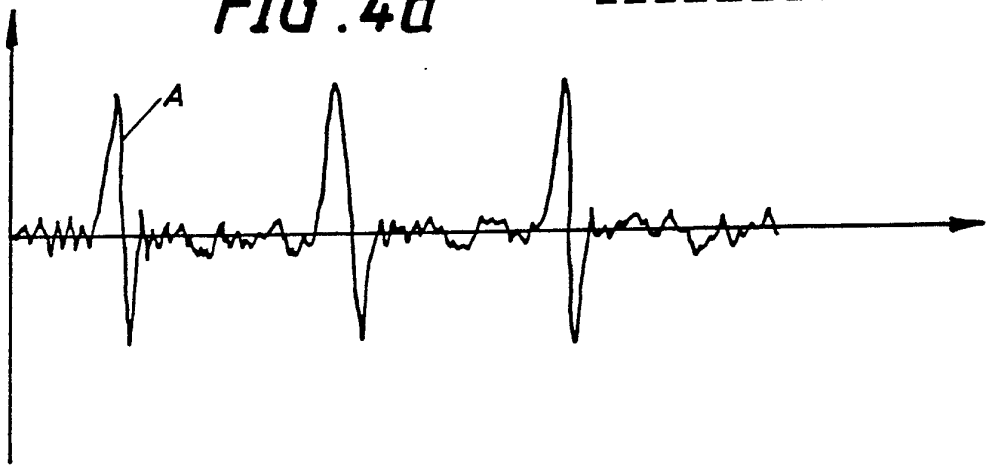
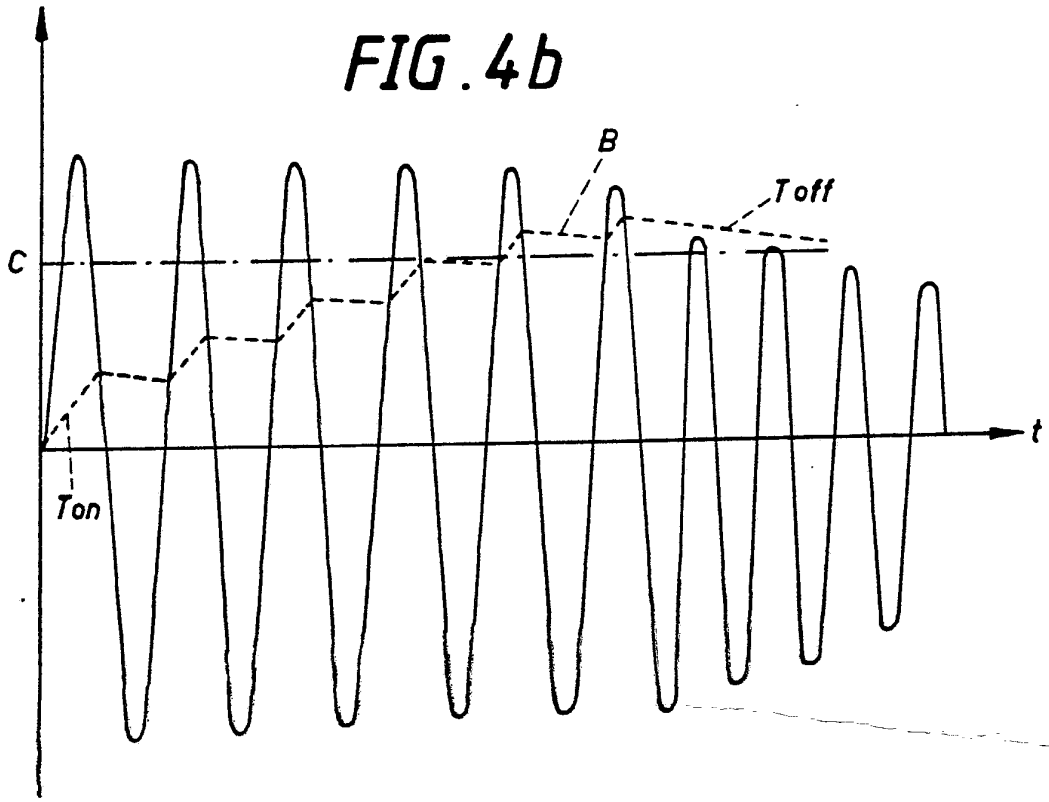


FIG.4b



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FIG. 4c

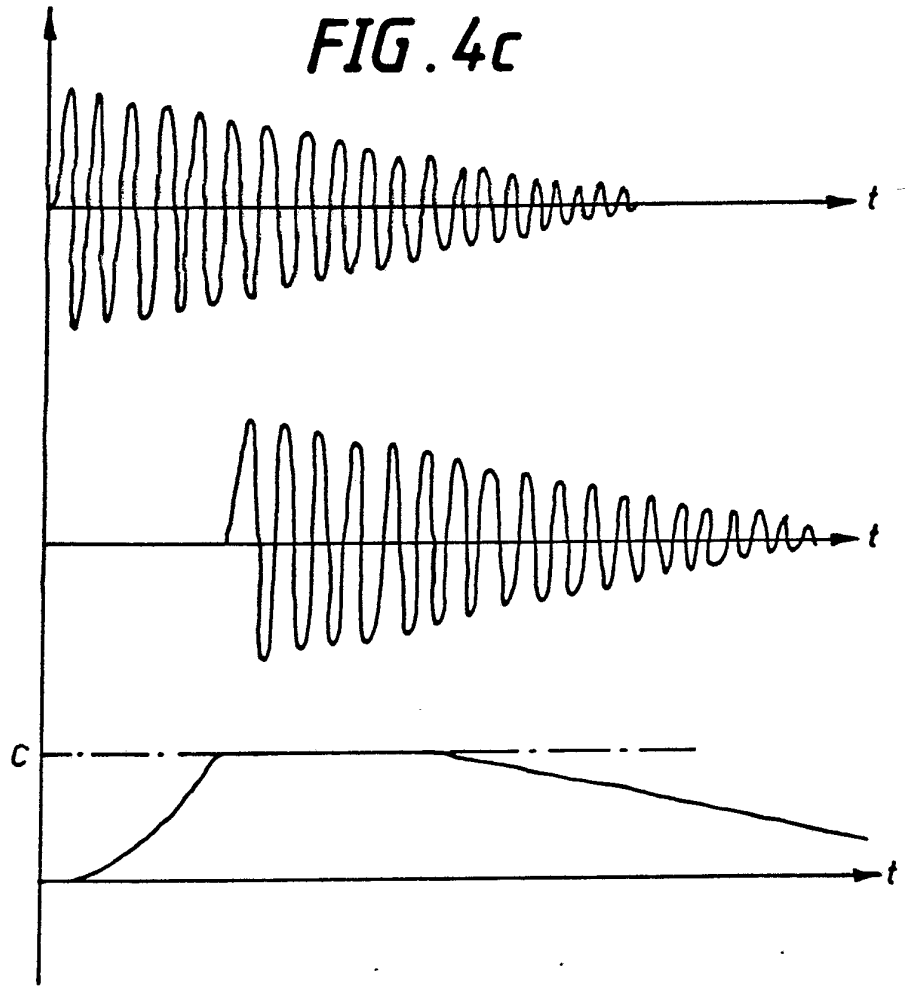
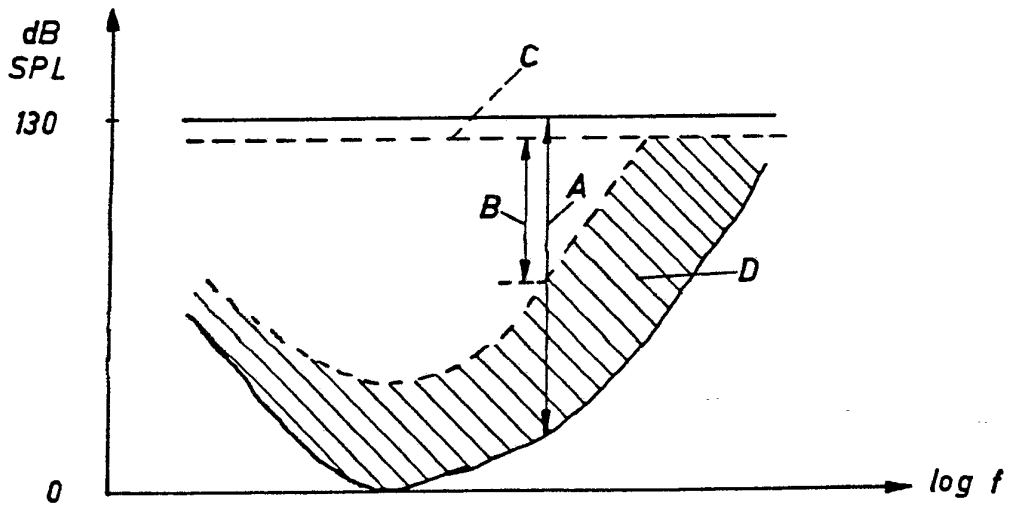


FIG. 5



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INTERNATIONAL SEARCH REPORT

International Application No PCT/SE83/00041

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC 3

H 04 B 1/10

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC 3	H 03 G 11, H 04 B 1/10, 15/00
US Cl	179:1P,107,170; 325:313,319,402,403,473,478,480,482; 330:144,145,149

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category [15]	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	US, A , 3 458 669 (CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE) 29 July 1969 see Fig. 9	1 - 2

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IV. CERTIFICATION

Date of the Actual Completion of the International Search [3]	Date of Mailing of this International Search Report [3]
1983-04-05	1983 -04- 22

International Searching Authority [1]	Signature of Authorized Officer [20]
Swedish Patent Office	Gunnar Hilderot