(54) Title: DIGITALLY CONTROLLED ANALOG CANCELLATION SYSTEM

(57) Abstract

A digitally controlled analog cancellation system containing an analog noise cancellation circuit with a residual microphone (39) with a digital virtual earth controller (40) for optimizing variable parameters employed in the analog cancellation circuit.

DIGITALLY CONTROLLED ANALOG CANCELLATION SYSTEM

This invention relates to the use of a digital signal processor (DSP), or other microprocessor to control various adjustable parameters in an analog active cancellation

5   system. The adjustment of these parameters at calibration time of the system permits the parameters of the analog cancellation system to be matched to the characteristics of the other components used in the system. This adjustment would be necessary when the cancellation electronics are packaged separately from the rest of the cancellation system (e.g. the speakers, microphones, and external gain devices).

10   The example application, (used for illustrative purposes only), is a headset for emergency vehicles. However, this invention relates to any system that would use a digital means to control and adjust the system parameters of an analog cancellation system. In this particular example, the digital system consists of an active noise cancellation controller implementing the "Digital Virtual Earth" algorithm as described in

15   U.S. Patent No. 5,105,377 and incorporated by reference herein. Alternatively, the digital system consists of a general purpose microprocessor and associated input/output circuitry. The analog cancellation electronics consist of a "NoiseBuster" circuit as described in a co-filed U.S. application on September 20, 1993, incorporated by reference herein.

20   Setting of the parameters of the analog cancellation system could be accomplished manually in the factory by trained technical personnel using sophisticated instrumentation, but would not be possible for an average user. Further, preset factory values would preclude the separate packaging of the electronics and the rest of the system.

25   Accordingly, it is an object of this invention to provide a system employing a digital microprocessor to control the parameters of an analog cancellation system in an automated fashion, thus providing superior results over systems with non-adjustable parameters. It is a further object of this invention to improve system flexibility by allowing the cancellation electronics to be packaged separately from the rest of the

30   cancellation system. These and other objects will become apparent when reference is made to the accompanying drawings in which

Figure 1 is a block diagram of a digitally controlled analog filter building block.

Figure 2 is a block diagram of a digitally controlled analog filter.

Figure 3 is a block diagram of a hybrid noise canceling system.

35   Figure 4 is a block diagram of a hybrid noise cancellation system showing the automatic gain setting.

Figure 5 is a block diagram of a hybrid noise cancellation system showing the automatic equalization setting.

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Digitally controlled analog filter building block

One aspect of the present invention will be described with reference to the accompanying Figure 1. The basic building block of the present invention, a digitally controlled analog filter building block 10, is shown consisting of a 16-bit shift register 11
5   connected to the serial port of the microprocessor 12 in the digital system, the output of which gets stored in a 16-bit latch 13. The lower (least significant) bits of this latch are used to set the resistance value of the low pass portion of the filter. This value varies as the digital value sent to the 8-bit C/A 14 is varied. Similarly, the upper (most significant) bits of this latch are used to set the resistance value of the bandpass and highpass portion
10   of the filter. These resistance values vary as the values sent to D/A 15 and D/A 16 vary.

Digitally controlled analog filter

A further aspect of the present invention will be described with reference to the accompanying Figure 2. A complete analog filter is shown utilizing the building block
15   described above (and shown in Figure 1). The complete filter 20 consists of the digitally controlled analog filter building block 10, with the gain of the system being adjusted by the two 8-bit D/A's 21 and 22.

Parameters to be adjusted

20   The example system described contains two different mechanisms which require parametric adjustment to ensure system stability. First, adjustment of the loop gain determines the amount of cancellation achievable by the headset. If the gain setting is too low, there will be too little cancellation. If too high, the system could become unstable resulting in unpleasant or even damaging loud noise at the ear.
25   Second, adjustable equalization of the system permits the transfer function to be "flattened" resulting in maximized stable cancellation. This optimization compensates for variations from unit to unit due to differences in microphones, speakers, and other electronic components. Additionally, variations resulting from components changing with age can be taken into account.
30

Automatic loop gain

Since the loop gain determines the overall cancellation effectiveness of the system, it is the primary parameter of interest. In the example system, the gain of the speaker can vary by as much as 2 dB between units, and the gain of the microphone up
35   to 5 dB between units. The adjustment must therefore have a 10 dB range. If the desired cancellation effectiveness is 12 dB, a variation of 1 dB (20%) in the adjusted loop gain yields a variation of 3 dB in the cancellation effectiveness.

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By way of example this aspect of the present invention will be described with
reference to the accompanying drawings. In Figure 3, the combination of the digital
system is shown combined with the analog cancellation electronics. The system uses an
analog cancellation system 30 with microphone preamplifier 31, cancellation gain 32,
5   equalizers 33, 34, and 35, output amplifier 36, and audio gain 37. System 30 is
connected to controller 40 having analog to digital converter (A/D) and filter 41,
microprocessor 42, parameter setting digital to analog converter (D/A) 43, and output
D/A and filter 44. During calibration of the system, predetermined output would be
generated by the controller 40 and output through the D/A and filter 43 to the output
10   amplifier 36 resulting in a calibration tone at the headset speaker 38. The resulting
output of the residual microphone 39 due to the calibration signal would then be
amplified by the microphone preamplifier 31, and the amplified signal would be used by
the DVE controller to correctly adjust the cancellation gain 32. This cancellation gain 32
would be adjusted by the controller via the parameter setting D/A 43.
15   In the more specific case, this invention could be implemented with the analog
cancellation electronics controlled by a DVE controller consisting of a DVE cancellation
engine, an A/D to acquire the input samples, and a D/A to generate the output samples.
With this specific configuration, the necessary adjustment of the analog system
parameters could easily be made, and the cancellation of the system would be improved
20   even further.

Automatic equalizer setting

In an analog filter, the locations of the poles and zeroes are determined by the
values of the resistors, capacitors, and inductors in the circuit. Since the maximum stable
25   cancellation at any particular loop gain is determined by the flatness and delay in the
equalized loop, the ability to vary the frequency and damping of poles and zeroes in the
filters of the equalizer greatly increases the effectiveness of the active noise cancellation
system.

Again, by way of example this aspect of the present invention will be described
30   with reference to the accompanying drawings. As described previously, and with
reference to Figure 3, the digital system would produce a calibration signal to be used to
adjust the system parameters of the analog cancellation system. During calibration of the
system, predetermined output would be generated by the DVE controller 40 and output
through the D/A and filter 44 to the output amplifier 36 resulting in a calibration tone at
35   the headset speaker 38. In order to set the values of the adjustable equalizer, the digital
system would first set the two EQ2 equalization stages 34 and 35 for a flat response
(since these two stages are strictly used to remove the effects of the analog cancellation
electronics and the audio in from the feedback to the digital processor). The processor

would then iteratively adjust the EQ1 equalization 33 to obtain the desired level of
attenuation in the active band. At the same time, it would avoid a setting which would
cause instability. This dynamic adjustment of the analog electronics ensures that the
cancellation provided by that subsystem is optimized without the need for manual
5   adjustment, and without the need for servicing.

5

Claims

1. A noise cancellation system for canceling unwanted noise, said system comprising

    a first noise canceling electronic means adapted to cancel low
5   frequency noise, and

    a second electronic means,

    said first and second electronic means being connected and implemented in such a way that the second electronic means can optimize the variable parameters employed in the first noise canceling means.

10

2. A hybrid noise cancellation system for canceling unwanted noise, said system comprising

    a first noise canceling electronic means adapted to cancel low
    frequency noise, and

15   a second noise canceling electronic means adapted to cancel periodic noise,

    said first and second noise canceling means being connected and implemented in such a way that the second noise canceling means can optimize the variable parameters employed in the first noise canceling means.

20

3. A system as in claim 2 wherein the first noise canceling means is an analog system means.

4. A system as in claim 3 wherein the analog system contains a digitally controlled
25 analog filter building block comprising a means to acquire a digital input value, a means to latch such acquired digital input value, and a means to adjust the parameters of said analog filter building block.

5. A system as in claim 4 wherein said analog system means is a feedback control
30 system.

6. A system as in claim 4 wherein said analog system means is a feedforward system.

35 7. A system as in claim 3 wherein said second noise canceling electronic means comprises a digital virtual earth system.

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8.   A system as in claim 4 wherein said second noise canceling electronic means
      comprises a digital virtual earth system.

9.   A system as in claim 5 wherein said second noise canceling electronic means
      comprises a digital virtual earth system.

10.   A system as in claim 6 wherein said second noise canceling electronic means
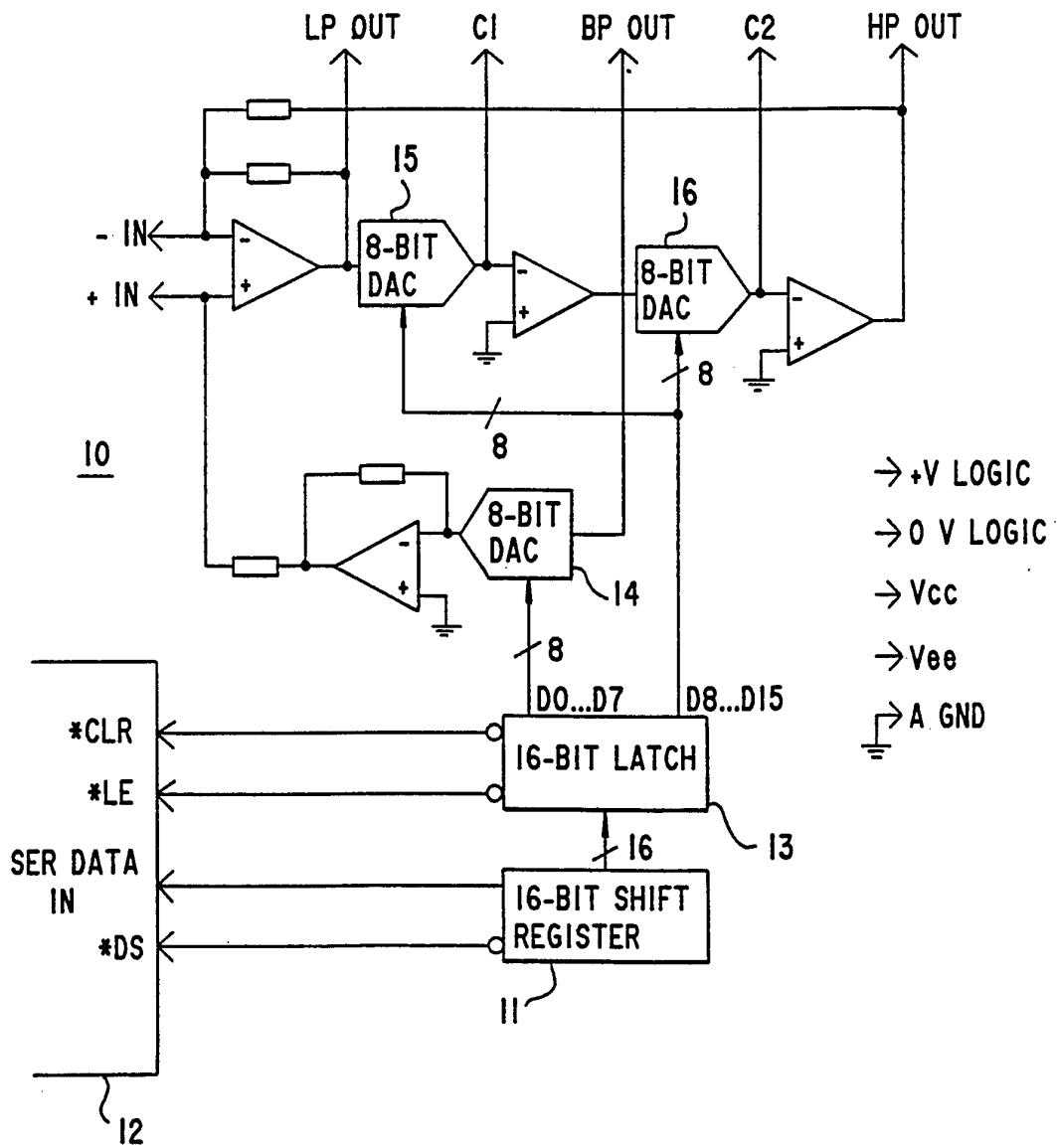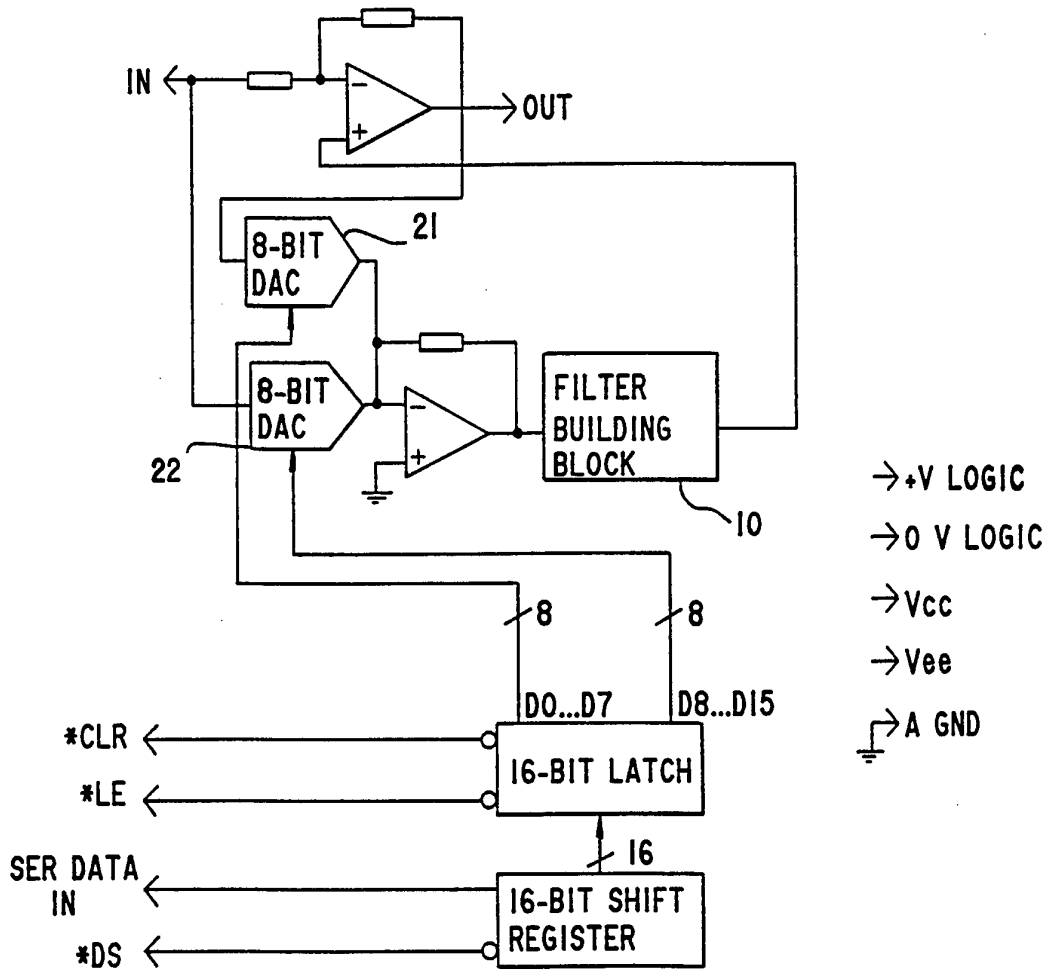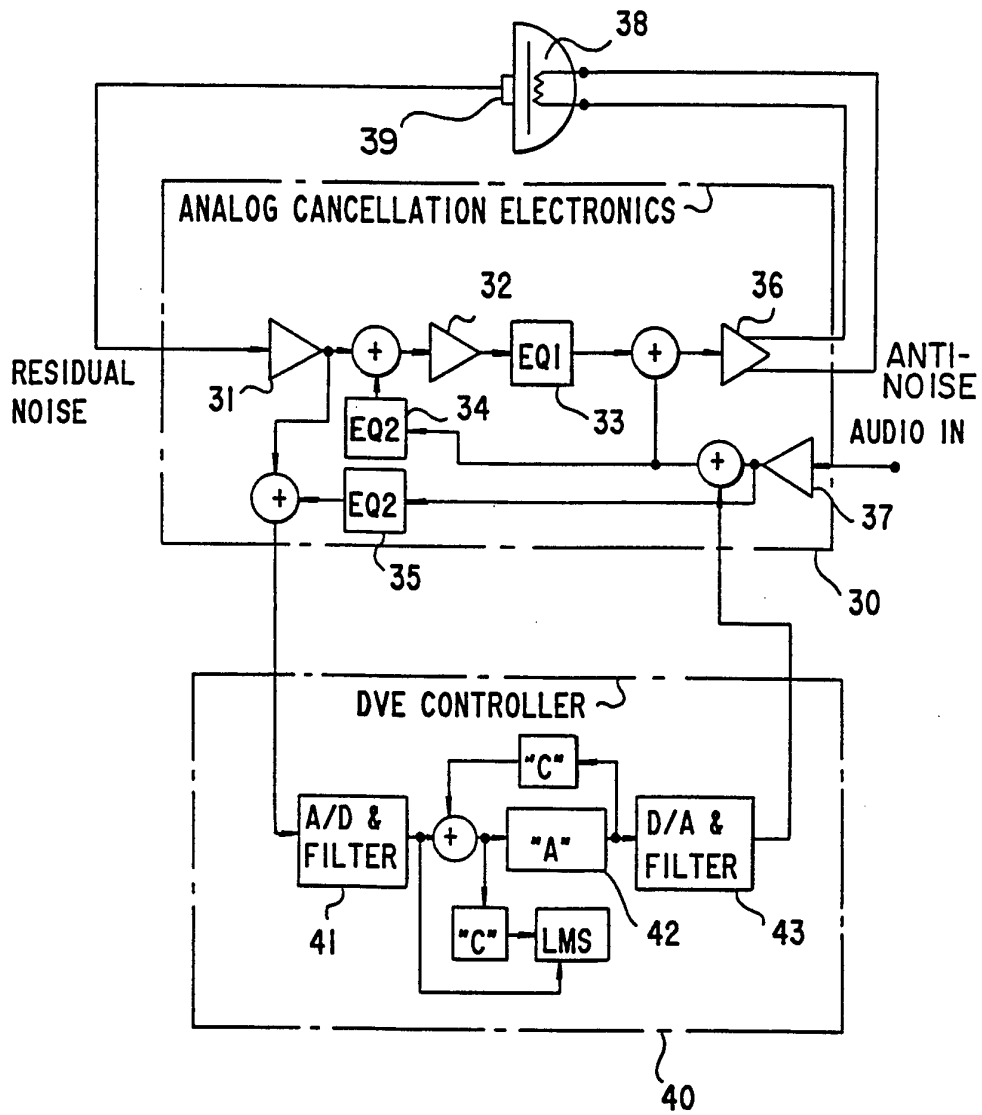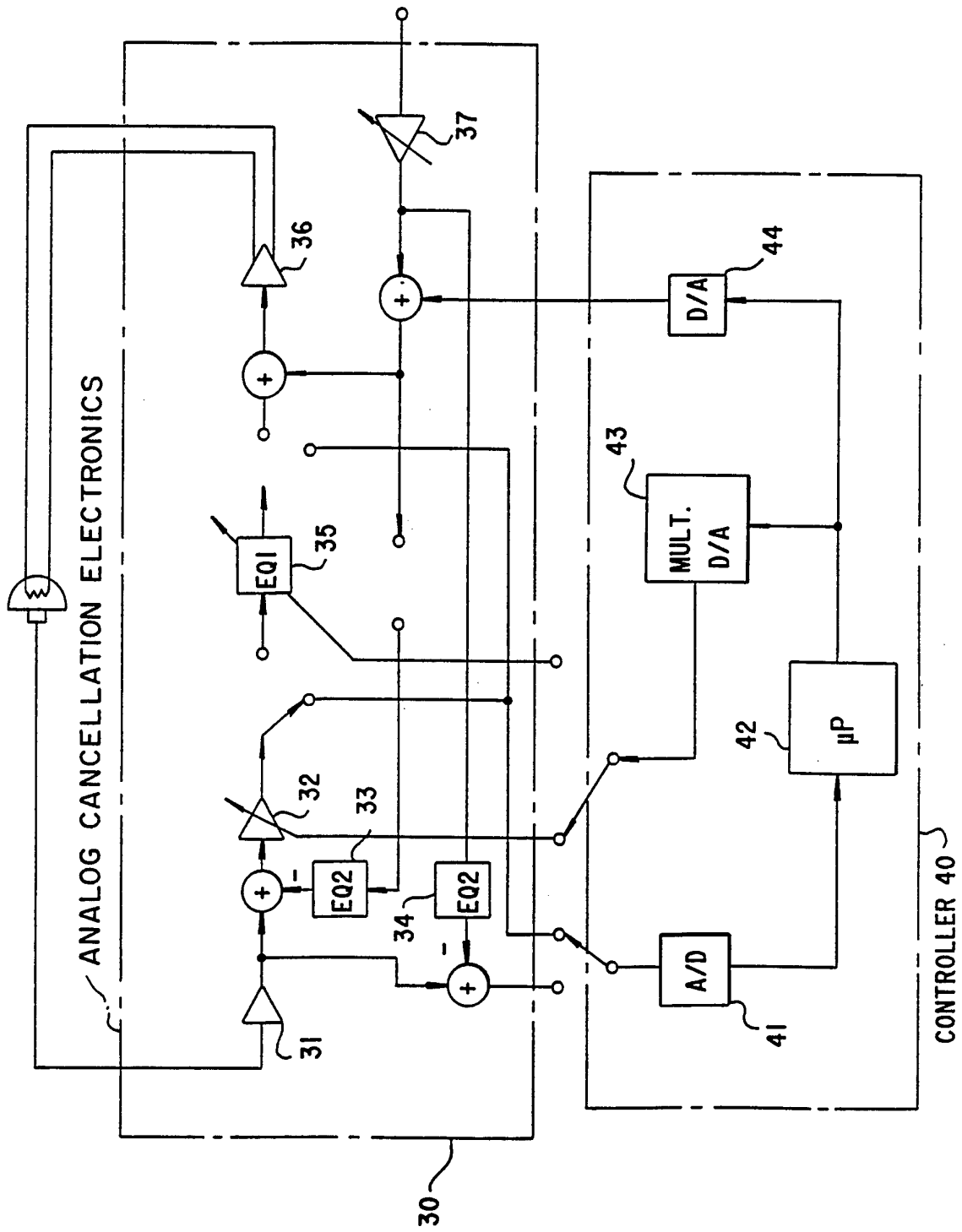   comprises a digital virtual earth system.

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Fig.1

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Fig.2

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Fig.3

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FIG.4

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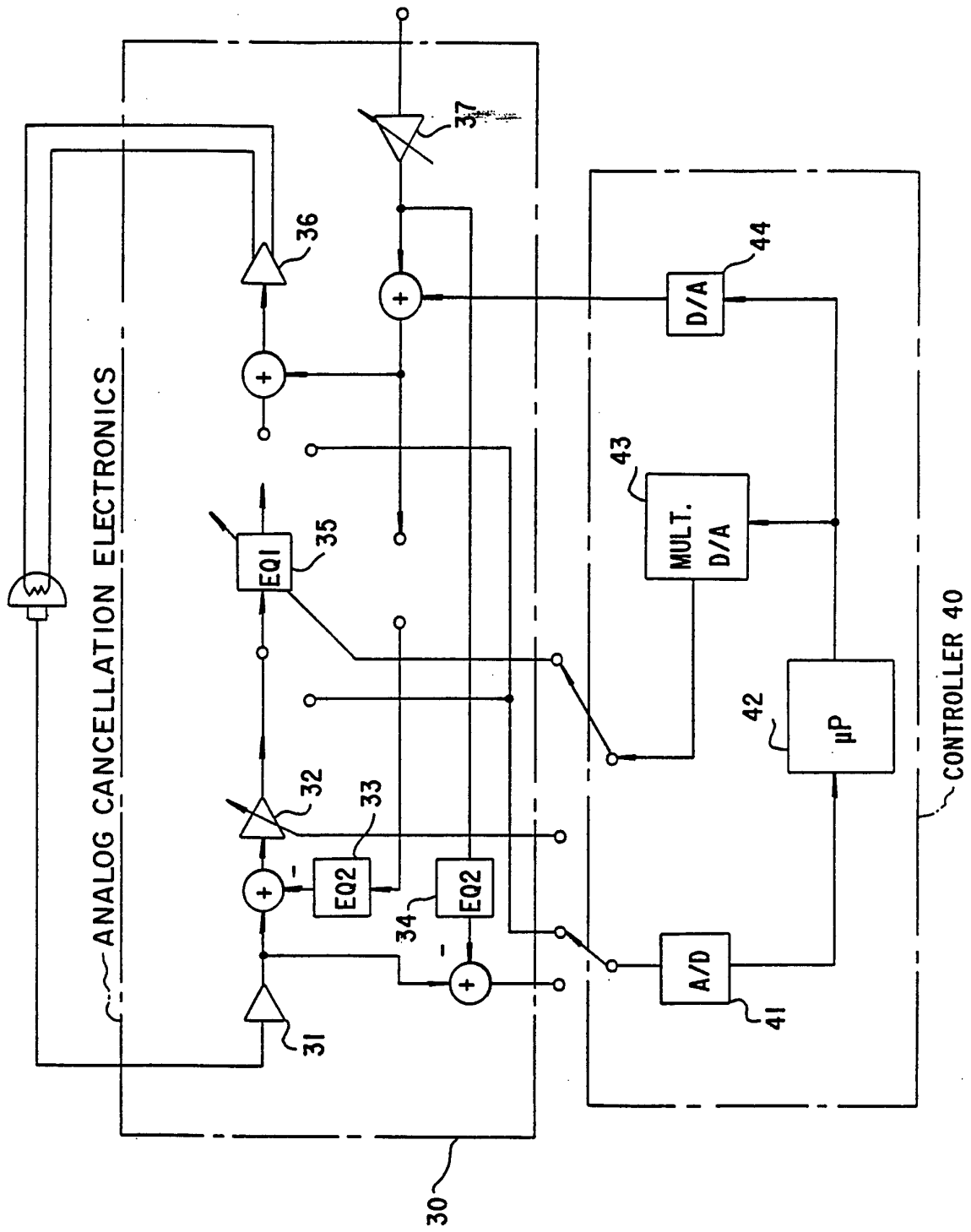
FIG.5

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(5) : H04R 25/00; H04R 25/04
US CL : 381/71
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)
U.S. : 381/71, 94

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 practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 4,837,832 (FANSHEL) 06 June 1989, Abstract, lines 1-2, 15-17, and 19-20	1
A	US, A, 5,140,640 (GRAUPE et al.) 18 August 1992	
A	US, A, 5,146,505 (PFAFF et al.) 08 September 1992	
A	US, A, 5,216,721 (MELTON) 01 June 1993	
A	US, A, 5,259,033 (GOODINGS et al.) 02 November 1993	
A	US, A, 5,321,759 (YUAN) 14 June 1994	
A	US, A, 5,325,437 (DOI et al.) 28 June 1994	

☐ Further documents are listed in the continuation of Box C.   ☐   See patent family annex.

*	Special categories of cited documents:	"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
"A"	document defining the general state of the art which is not considered to be part of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"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	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
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