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1 Attorney Docket No. 79326

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3 STATEMENT OF GOVERNMENT INTEREST

4 The invention described herein may be manufactured and used
5 by or for the Government of the United States of America for
6 governmental purposes without the payment of any royalties
7 thereon or therefor.

8
9 BACKGROUND OF THE INVENTION

10 (1) Field Of The Invention

11 The present invention generally relates to an apparatus and
12 method for detecting acoustic signals from a plurality of
13 acoustic signal sensors.

14 (2) Description of the Prior Art

15 Prior art acoustic signal detection devices typically use
16 complex signal processing circuitry which conditions acoustic
17 signals and performs signal processing functions upon such
18 signals, e.g., Fast Fourier Transforms, to extract desired data.
19 Such a device is disclosed in U.S. Patent No. 4,017,859. Other
20 prior art devices measure the cross-spectral density of received
21 acoustic signals to determine the acoustic density in a
22 particular direction. Such a device is disclosed in U.S. Patent
23 No. 4,982,375. Additionally, many prior art devices use complex

1 circuitry to perform phase and magnitude detection and to effect
2 conversion from rectangular to polar coordinates. One such
3 device is described in U.S. Patent No. 4,953,145. Still, other
4 prior art devices utilize circuitry for the generation of
5 frequency tones. For example, U.S. Patent No. 3,588,802 utilizes
6 a mechanical vibrator for exciting a frequency tone that is added
7 to the received acoustic signal. Other prior art devices use a
8 pair of hydrophones wherein each hydrophone is dedicated to
9 receiving particular frequency components of acoustic signals.
10 For example, U.S. Patent No. 4,594,695 discloses a system that
11 utilizes two hydrophones wherein one hydrophone receives a
12 disturbed tracked signal and the other hydrophone receives
13 spurious noises.

14 What is needed is a relatively less complex acoustic signal
15 detection system that provides redundancy whereby the acoustic
16 signal detection system receives and detects acoustic signals
17 from a plurality of acoustic signal sensors (e.g. hydrophones) as
18 long as one of the acoustic signal sensors senses an acoustic
19 signal. Preferably, the redundancy should be realized by the
20 overall design of the acoustic signal detection system so as to
21 substantially increase the probability that acoustic signals
22 sensed by the sensors will still be detected by the acoustic
23 signal detection system even if this system experiences partial

1 component failure. Another desired feature of such an acoustic
2 signal detection system is that it must be relatively simple in
3 construction in order to reduce the costs related to
4 manufacturing, maintenance and repair.

5 Therefore, it is an object of the present invention to
6 provide an apparatus and method for receiving and detecting
7 acoustic signals from a plurality of acoustic signal sensors that
8 fulfills a long-felt need that has not been met by prior art
9 devices and methods.

10 Other objects and advantages of the present invention will
11 be apparent to one of ordinary skill in the art in light of the
12 ensuing description of the present invention.

13 14 SUMMARY OF THE INVENTION

15 The present invention is directed to an apparatus and method
16 for detecting acoustic signals from a plurality of acoustic
17 signal sensors. The apparatus comprises a plurality of acoustic
18 signal detection channels. Each acoustic signal detection
19 channel has an input for receiving acoustic signals from a
20 corresponding acoustic signal sensor. Each acoustic signal
21 detection channel further includes circuitry for (i) amplifying
22 the received acoustic signals, (ii) removing the D.C. components
23 from the amplified acoustic signals, and (iii) removing all

1 frequency components from the amplified acoustic signals which
2 are above a predetermined frequency. The apparatus further
3 comprises circuitry for summing all of the acoustic signals
4 outputted from the acoustic signal detection channels to form a
5 single acoustic signal. The apparatus further comprises
6 additional circuitry for converting the single acoustic signal
7 into a differential signal and outputting the differential signal
8 if at least one acoustic signal sensor senses an acoustic signal
9 and the corresponding acoustic signal detection channel outputs
10 an acoustic signal.

12 BRIEF DESCRIPTION OF THE DRAWINGS

13 The features of the invention are believed to be novel and
14 the elements characteristic of the invention are set forth with
15 particularity in the appended claims. The figures are for
16 illustration purposes only and are not drawn to scale. The
17 invention itself, however, both as to organization and method of
18 operation, may best be understood by reference to the detailed
19 description which follows taken in conjunction with the
20 accompanying drawings in which like reference numerals refer to
21 like parts and in which:

22 FIG. 1 is a block diagram of the apparatus of the present
23 invention; and

FIG. 2 is a diagram, partially in schematic form, showing electrical circuits that are used to realize the apparatus of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, apparatus 10 of the present invention receives acoustic signals from acoustic signal sensors or hydrophones 12 positioned beneath the surface of ocean 14. The acoustic signals originate from noise source 13. Apparatus 10 generally comprises acoustic signal detection channels 15 and 16 and circuit 18. Channel 15 comprises preamplifier 20, filter circuit 22 and amplifier circuit 24. Similarly, channel 16 comprises preamplifier 26, filter circuit 28 and amplifier circuit 30. Channels 15 and 16 are identical in design and construction. The output of each channel 15 and 16 is coupled into circuit 18. Circuit 18 is described in detail in the ensuing description.

Referring to FIGS. 1 and 2, acoustic signals received from hydrophones 12 are inputted into inputs 32 and 34 of apparatus 10. Inputs 32 and 34 are connected to the inputs of preamplifier circuits 20 and 26, respectively. FIG. 2 shows one embodiment of the internal electrical circuitry of channels 15 and 16 and circuit 18. Since channels 15 and 16 are identical in design and

1 construction, only channel 15 is described in detail in the
2 ensuing description. Preamplifier circuit 20 amplifies the low
3 level acoustic signals and removes the D.C. (Direct Current)
4 level from these signals. Preamplifier circuit 20 comprises
5 amplifier U1. Amplifier U1 comprises an operational amplifier
6 having an inverting input, a non-inverting input and an output.
7 In one embodiment, amplifier U1 has the operational
8 characteristics of the commercially available LF147 or LF347
9 operational amplifiers manufactured by National Semiconductor and
10 Texas Instruments. However, it is to be understood that other
11 operational amplifiers having operational characteristics similar
12 to the aforementioned LF147 or LF347 operational amplifiers can
13 also be used. Amplifier U1 includes a terminal for connection to
14 a positive power supply voltage source +Vcc. Amplifier U1 also
15 includes a terminal for connection to a negative power supply
16 voltage source -Vcc. In one embodiment, +Vcc is about +15 VDC
17 and -Vcc is about - 15 VDC.

18 Referring to FIG. 2, resistor R1 is connected between input
19 32 and the non-inverting input of amplifier U1. Resistor R2 is
20 connected between ground potential and the inverting input of
21 amplifier U1. In one embodiment, each resistor R1 and R2 has a
22 resistance of about 249Ω . Diodes D1 and D2 are connected

1 between ground potential and the non-inverting input of amplifier
2 U1. Specifically, the anode of diode D1 is connected to the non-
3 inverting input of amplifier U1 and the cathode is connected to
4 ground potential. The cathode of diode D2 is connected to the
5 non-inverting input of amplifier U1 and the anode is connected to
6 ground potential. Diodes D1 and D2 serve to protect channel 15
7 from high-level voltage spikes and in particular, electromagnetic
8 pulses ("EMP"). Resistor R3 functions as a feedback resistor and
9 is connected between the output and inverting input of amplifier
10 U1. In one embodiment, resistor R3 has a resistance of about
11 1.4K Ω .

12 In a preferred embodiment, preamplifier circuit 20 is
13 configured to provide a gain between about 500 and 1500. In one
14 embodiment, preamplifier circuit 20 provides a gain of about
15 1000. The output of amplifier U1 is coupled to one end of
16 capacitor C1. In one embodiment, capacitor C1 has a capacitance
17 of 0.01 micro-farads. Capacitor C1 prevents the D.C. component
18 of the amplified acoustic signals from entering filter circuit
19 22.

20 Referring to FIGS. 1 and 2, filter circuit 22 functions as a
21 low pass filter. Filter circuit 22 comprises amplifier U2.
22 Amplifier U2 comprises an operational amplifier having an

1 inverting input, a non-inverting input, an output and terminals
2 for connection to +Vcc and -Vcc. In one embodiment, amplifier U2
3 has the operational characteristics of the aforementioned LF347
4 operational amplifier. However, it is to be understood that
5 other operational amplifiers having operational characteristics
6 similar to the LF347 amplifier can also be used. Filter circuit
7 22 further includes resistors R4 and R5 and capacitor C2.
8 Amplifier U2, resistors R4 and R5 and capacitor C2 are connected
9 to form a low pass filter which has a predetermined cut-off
10 frequency F_c . In a preferred embodiment, the cut-off frequency
11 F_c is between about 100 kHz and 300 kHz. In one embodiment,
12 capacitor C2 has a capacitance of 100 picofarads and resistor R5
13 has a resistance of about $10K\Omega$ so as to provide a cut-off
14 frequency F_c of about 160 kHz. However, it is to be understood
15 that the capacitance of capacitor C2 and the resistance of
16 resistor R5 can be chosen so as to provide a different cut-off
17 frequency F_c . In one embodiment, the resistance of resistor R4
18 is about $3.01K\Omega$. The gain of the low pass filter realized by
19 amplifier U2, resistors R4 and R5 and capacitor C2 is represented
20 by the ratio $R5/R4$. Filter circuit 22 further includes resistor
21 R6 which has one end thereof connected to the output of amplifier
22 U2 and the other end connected to resistor R10 which is described

1 in the ensuing description. In one embodiment, resistor R6 has a
2 resistance of about 49.9Ω .

3 Referring to FIG. 2, filter circuit 22 further comprises
4 amplifier U3 and resistors R7 and R8. Amplifier U3 can be
5 realized by the commercially available LM741 operational
6 amplifier, manufactured by several manufacturers including
7 National Semiconductor and Texas Instruments. Amplifier U3 can
8 also be realized by the commercially available LF147 and LF347
9 operational amplifiers which were previously discussed herein.
10 Amplifier U3 and resistors R7 and R8 are connected together to
11 provide an inverting buffer amplifier. Similar to amplifiers U1
12 and U2, amplifier U3 includes terminals for connection to +Vcc
13 and -Vcc. Resistor R7 functions as a feedback resistor and is
14 connected between the output and inverting input of amplifier U3.
15 Resistor R8 is connected between the inverting input of amplifier
16 U3 and the output of amplifier U2. In a preferred embodiment,
17 resistors R7 and R8 have resistances that provide unity gain. In
18 one embodiment, resistors R7 and R8 each have a resistance of
19 $3.01K\Omega$. Filter circuit 22 further includes resistor R9 that is
20 connected between the output of amplifier U3 and one end of
21 resistor R11. In one embodiment, resistor R9 has a resistance of
22 about 49.9Ω .

1 Referring to FIGS. 1 and 2, the output signals of amplifiers
2 U2 and U3 are inputted into amplifier circuit 24. Amplifier
3 circuit 24 comprises amplifier U4, resistors R10, R11, R12, R13
4 and variable resistor or potentiometer R14. Amplifier U4
5 includes an inverting input, a non-inverting input, an output and
6 +Vcc and -Vcc terminals. In one embodiment, amplifier U4 can be
7 realized by the commercially available LM741, LF147 or LF347
8 operational amplifiers previously discussed herein. Amplifier
9 U4, resistors R10, R11, R12, R13 and variable resistor R14 are
10 connected to provide an inverting summing circuit with unity
11 gain. Resistor R10 is connected between one end of resistor R6
12 and the inverting input of amplifier U4. Similarly, resistor R11
13 is connected between one end of resistor R9 and the non-inverting
14 input of amplifier U4. Resistor R12 is a feedback resistor and
15 is connected between the output and inverting input of amplifier
16 U4. In one embodiment, resistors R10, R11 and R12 each have a
17 resistance of about $10K\Omega$. Resistor R13 is connected between the
18 non-inverting input of amplifier U4 and the negative power supply
19 -Vcc. Resistor R13 functions as biasing resistor. In one
20 embodiment, resistor R13 has a resistance of about $9K\Omega$.
21 Variable resistor R14 provides the ability to adjust offset

1 voltages. In one embodiment, variable resistor has a resistance
2 range between about 0Ω and 200Ω .

3 Referring to FIG. 2, amplifier circuit 24 further comprises
4 diodes D3 and D4. Diode D3 is connected between the +Vcc power
5 supply voltage and the +Vcc terminal of amplifier U4 such that
6 diode D3 is forward biased. In this configuration, diode D3
7 blocks current from flowing into the +Vcc power supply voltage
8 source. Similarly, diode D4 is connected between the -Vcc power
9 supply voltage and the -Vcc terminal of amplifier U4 such that
10 diode D4 is forward biased. In this configuration, diode D4
11 blocks current from flowing into the -Vcc power supply voltage
12 source. Amplifier circuit 24 further includes output resistor
13 R15. Resistor R15 is connected between the output of amplifier
14 U4 and the input to amplifier circuit 18. In one embodiment,
15 resistor R15 has a resistance of about $10K\Omega$.

16 Referring to FIGS. 1 and 2, the output of amplifier circuit
17 24 is fed into circuit 18. Circuit 18 comprises two stages. The
18 first stage is a summing circuit which is comprised of amplifier
19 U5 and resistors R17 and R18. In one embodiment, amplifier U5 is
20 configured to have the operating characteristics of the
21 commercially available LF147 operational amplifier previously
22 described herein. However, it is to be understood that amplifier

1 U5 can be configured to have the operational characteristics of
2 the other commercially available operational amplifiers
3 previously described herein. Resistor R15 of circuit 24 is
4 connected between the output of amplifier U4 and the inverting
5 input of amplifier U5. Similarly, the output of circuit 30 is
6 connected to the inverting input of amplifier U5. Resistor R17
7 is a feedback resistor connected between the output and inverting
8 input of amplifier U5. In one embodiment, resistor R17 has a
9 resistance of about $10K\Omega$. Resistor R18 provides offset
10 compensation. In one embodiment, resistor R18 has a resistance
11 value of about $2.5K\Omega$. The output of amplifier U5 is connected
12 to output terminal 36 and is also fed into the second stage of
13 circuit 18. The second stage functions as a differential
14 amplifier and comprises amplifier U6 and resistors R19, R20 and
15 R21. In one embodiment, amplifier U6 is configured as an
16 operational amplifier that has operational characteristics
17 similar to the commercially available LF147 operational
18 amplifier. However, amplifier U6 can also be configured as any
19 of the commercially available operational amplifiers previously
20 described herein. Resistor R19 is connected between the output
21 of amplifier U5 and the inverting input of amplifier U6.
22 Resistor R21 is a feedback resistor and is connected between the

1 inverting input and the output of amplifier U6. In one
2 embodiment, resistors R19 and R21 each have a resistance of about
3 10Ω . Resistor R20 provides offset compensation. In one
4 embodiment, resistor R20 has a resistance of about $2.5K\Omega$. The
5 output of amplifier U6 is connected to output terminal 38.

6 The magnitude of the signal measured between output terminals
7 36 and 38 represents the difference in magnitudes between the
8 acoustic signals outputted from channels 15 and 16. Apparatus 10
9 outputs a signal between terminals 36 and 38 if at least one of
10 hydrophones 12, and the detection channel to which it is
11 connected, are functioning properly. Specifically, apparatus 10
12 outputs a signal between terminals 36 and 38 if at least one of
13 hydrophones 12 senses an acoustic signal and the corresponding
14 acoustic signal detection channel outputs an acoustic signal.
15 Thus, the internal circuitry of apparatus 10 provides built-in
16 redundancy thereby ensuring that acoustic signals are detected
17 even if one of the hydrophones and/or one of the detection
18 channels have failed.

19 Although apparatus 10 has been described as having two
20 detection channels that are connected to the corresponding
21 hydrophones, it is to be understood that apparatus 10 can be

1 configured to have a plurality of detection channels wherein each
2 detection channel is connected to a corresponding hydrophone.

3 Output terminals 36 and 38 can be connected to peripheral
4 electronic analysis equipment such a computer, oscilloscope,
5 video monitor, cathode-ray-tube, liquid-crystal-display, etc.
6 Analog-to-digital conversion circuitry, and driver or buffer
7 circuitry, well known in the art, may be needed to couple the
8 signal outputted at terminals 36 and 38 to the aforementioned
9 analysis equipment.

10 Although the foregoing description is in terms of the
11 resistors and capacitors in apparatus 10 having the stated
12 resistances and capacitances, respectively, it is to be
13 understood that the resistors and capacitors can have different
14 resistance and capacitance values, respectively. It is also to
15 be understood that decoupling capacitors are connected between
16 the +Vcc or -Vcc terminals of all amplifiers and ground potential
17 in a manner well known in the art. Additionally, amplifiers U1,
18 U2, U3, U4, U5 and U6 can also be realized by discrete components
19 such as NPN or PNP transistors, or n-channel or p-channel field
20 effect transistors.

21 In one embodiment, +Vcc is about +15 VDC and -Vcc is about -
22 15 VDC. However, it is to be understood that the circuits
23 described herein can be configured to operate with positive and

negative power supply voltage sources having other magnitudes,
e.g. +12VDC, --12VDC, etc.

Thus, the system of the present invention achieves the
objects set forth above. Specifically, the system of the present
invention:

- a) utilizes a plurality of acoustic signal detection channels
that provide redundancy to ensure that acoustic signals
will be detected in the event of failure of any of the
hydrophones or acoustic signal detection channels;
- b) provides accurate and consistent measurements;
- c) can be implemented with a variety of hardware components;
and
- d) can be implemented at a relatively low cost.

While the present invention has been particularly described,
in conjunction with a specific preferred embodiment, it is
evident that many alternatives, modifications and variations will
be apparent to those skilled in the art in light of the foregoing
description.

1 Attorney Docket No. 79326

2
3 METHOD AND APPARATUS FOR DETECTING ACOUSTIC SIGNALS

4 FROM A PLURALITY OF ACOUSTIC SIGNAL SENSORS

5
6 ABSTRACT OF THE DISCLOSURE

7 An apparatus and method for detecting acoustic signals from a
8 plurality of acoustic signal sensors. The apparatus comprises a
9 plurality of acoustic signal detection channels. Each channel has
10 an input for receiving acoustic signals from a corresponding
11 acoustic signal sensor and includes circuitry for amplifying the
12 received acoustic signals, removing the D.C. components from the
13 amplified acoustic signals and removing all frequency components
14 from the amplified acoustic signals which are above a
15 predetermined frequency. The apparatus further comprises a
16 circuitry for summing all of the acoustic signals outputted from
17 the acoustic signal detection channels to form a single acoustic
18 signal and for converting the single acoustic signal into a
19 differential signal if at least one acoustic signal sensor senses
20 an acoustic signal and its corresponding acoustic signal
21 detection channel outputs an acoustic signal.

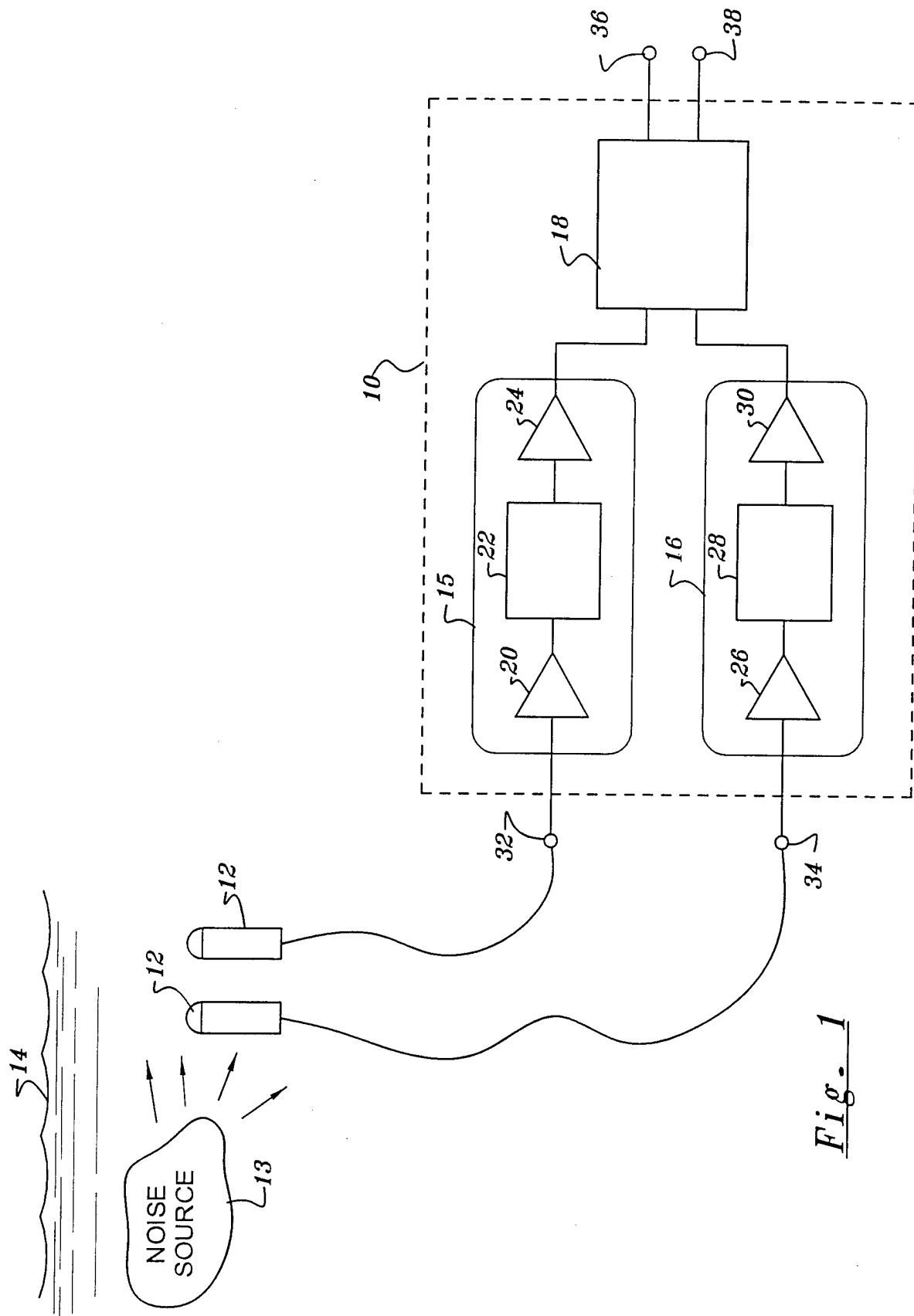


Fig. 1

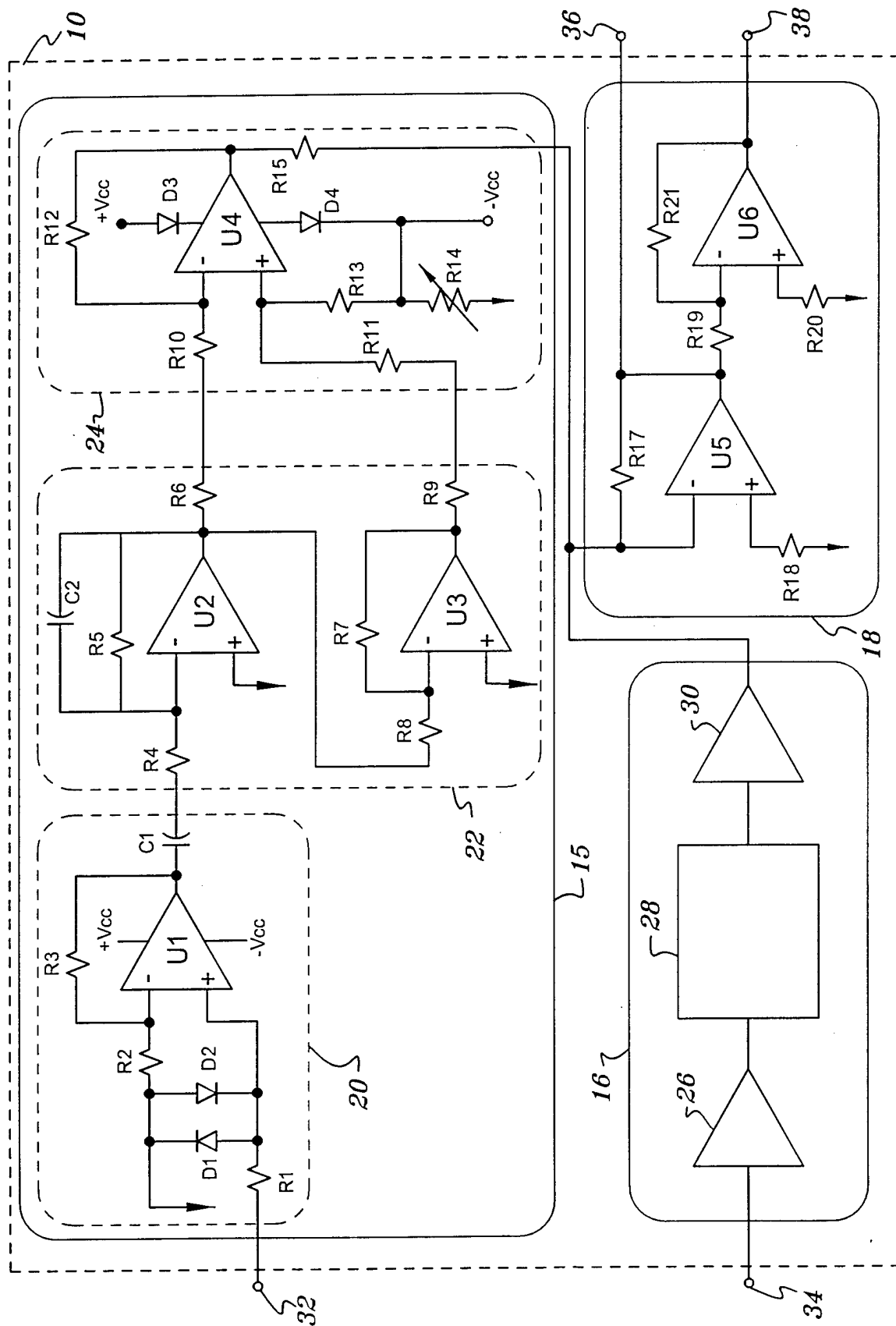


Fig. 2