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(54) Title: **SPEAKER PROTECTION BASED ON OUTPUT SIGNAL ANALYSIS**

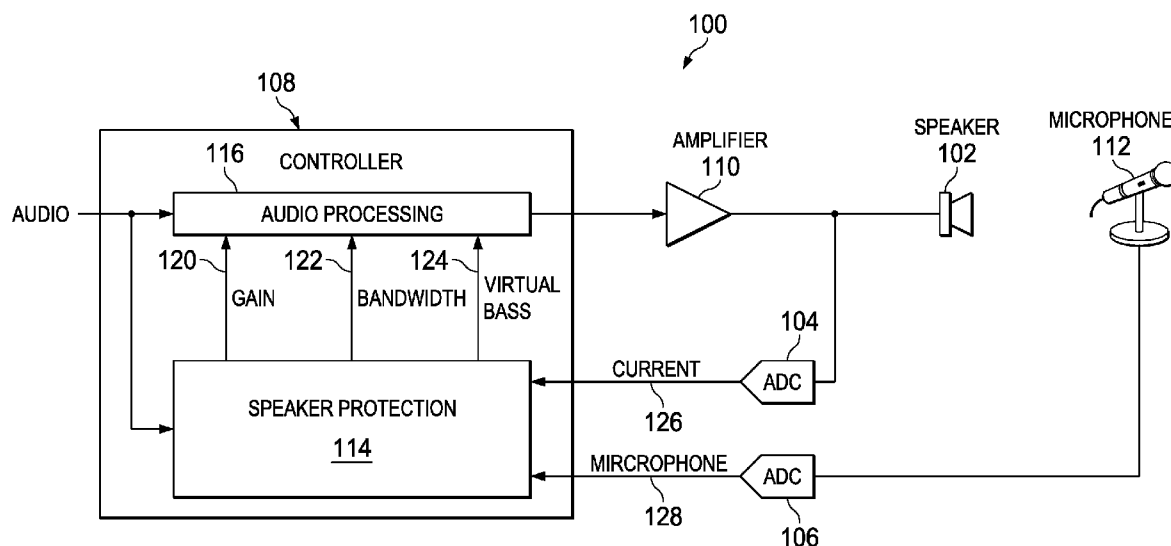


FIG. 1

(57) Abstract: In accordance with embodiments of the present disclosure, a system may include a controller configured to be coupled to an audio speaker, wherein the controller receives an output signal indicative of a physical quantity associated with the audio speaker, compares the output signal to an audio input signal to determine if differences between the output signal and the audio input signal are present indicating at least one of distortion of the output signal, non-linearities of the audio speaker, and overexcursion of the audio speaker, and controls an audio signal communicated from the controller to the audio speaker and based on the audio input signal responsive to determining that differences between the output signal and the audio input signal are present indicating at least one of distortion of the output signal, non-linearities of the audio speaker, and overexcursion of the audio speaker.

UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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SPEAKER PROTECTION BASED ON OUTPUT SIGNAL ANALYSIS

FIELD OF DISCLOSURE

The present disclosure relates in general to audio speakers, and more particularly,
5 to protecting audio speakers from damage.

BACKGROUND

Audio speakers or loudspeakers are ubiquitous on many devices used by
individuals, including televisions, stereo systems, computers, smart phones, and many
10 other consumer devices. Generally speaking, an audio speaker is an electroacoustic
transducer that produces sound in response to an electrical audio signal input.

Given its nature as a mechanical device, an audio speaker may be subject to
damage caused by operation of the speaker, including overheating and/or overexcursion,
in which physical components of the speaker are displaced too far a distance from a
15 resting position. To prevent such damage from happening, speaker systems often include
control systems capable of controlling audio gain, audio bandwidth, and/or other
components of an audio signal to be communicated to an audio speaker.

However, existing approaches to speaker system control have disadvantages. For
example, many such approaches model speaker operation based on measured operating
20 characteristics, but employ linear models. Such linear models may adequately model
small signal behavior, but may not sufficiently model nonlinear effects to a speaker
caused by larger signals.

SUMMARY

25 In accordance with the teachings of the present disclosure, the disadvantages and
problems associated with protecting a speaker from damage have been reduced or
eliminated.

In accordance with embodiments of the present disclosure, a system may include a
controller configured to be coupled to an audio speaker, wherein the controller receives
30 an output signal indicative of a physical quantity associated with the audio speaker,
compares the output signal to an audio input signal to determine if differences between

the output signal and the audio input signal are present indicating at least one of distortion of the output signal, non-linearities of the audio speaker, and overexcursion of the audio speaker, and controls an audio signal communicated from the controller to the audio speaker and based on the audio input signal responsive to determining that differences
5 between the output signal and the audio input signal are present indicating at least one of distortion of the output signal, non-linearities of the audio speaker, and overexcursion of the audio speaker.

In accordance with these and other embodiments of the present disclosure, a method may include receiving an output signal indicative of a physical quantity
10 associated with an audio speaker, comparing the output signal to an audio input signal to determine if differences between the output signal and the audio input signal are present indicating at least one of distortion of the output signal, non-linearities of the audio speaker, and overexcursion of the audio speaker, and controlling an audio signal communicated from the controller to the audio speaker and based on the audio input
15 signal responsive to determining that differences between the output signal and the audio input signal are present indicating at least one of distortion of the output signal, non-linearities of the audio speaker, and overexcursion of the audio speaker.

Technical advantages of the present disclosure may be readily apparent to one skilled in the art from the figures, description and claims included herein. The objects
20 and advantages of the embodiments will be realized and achieved at least by the elements, features, and combinations particularly pointed out in the claims.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the claims set forth in this disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present embodiments and advantages thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings, in which like reference numbers indicate like features,
30 and wherein:

FIGURE 1 illustrates a block diagram of an example system that uses output signal analysis to control operation of an audio speaker, in accordance with embodiments of the present disclosure; and

FIGURE 2 illustrates a flow chart of an example method for controlling operation of an audio speaker based on output signal analysis, in accordance with embodiments of the present disclosure.

DETAILED DESCRIPTION

FIGURE 1 illustrates a block diagram of an example system 100 that employs a controller 108 to control the operation of an audio speaker 102, in accordance with embodiments of the present disclosure. Audio speaker 102 may comprise any suitable electroacoustic transducer that produces sound in response to an electrical audio signal input (e.g., a voltage or current signal). As shown in FIGURE 1, controller 108 may generate such an electrical audio signal input, which may be further amplified by an amplifier 110. In some embodiments, one or more components of system 100 may be integral to a single integrated circuit (IC).

Controller 108 may include any system, device, or apparatus configured to interpret and/or execute program instructions and/or process data, and may include, without limitation, a microprocessor, microcontroller, digital signal processor (DSP), application specific integrated circuit (ASIC), or any other digital or analog circuitry configured to interpret and/or execute program instructions and/or process data. In some embodiments, controller 108 may interpret and/or execute program instructions and/or process data stored in a memory (not explicitly shown) communicatively coupled to controller 108. As shown in FIGURE 1, controller 108 may be configured to perform speaker protection 114 and/or audio processing 116, as described in greater detail below. For example, as shown in FIGURE 1, controller 108 may perform audio processing 116 on a digital input audio signal in order to generate an analog signal to be communicated to amplifier 110.

Amplifier 110 may comprise any system, device, or apparatus configured to amplify a signal received from controller 108, amplify the signal by a predetermined gain, and communicate the amplified signal (e.g., to speaker 102). In some embodiments,

amplifier 110 may comprise a digital amplifier configured to also convert a digital signal output from controller 108 into an analog signal to be communicated to speaker 102.

The audio signal communicated to speaker 102 may be sampled by an analog-to-digital converter 104 configured to detect an analog current flowing through speaker 102, and convert such analog current measurements into digital current signal 126 to be processed by controller 108.

Microphone 112 may comprise any system, device, or apparatus configured to convert sound incident at microphone 112 to an electrical signal, wherein such sound is converted to an electrical signal using a diaphragm or membrane having an electrical capacitance that varies based on sonic vibrations received at the diaphragm or membrane. Microphone 112 may include an electrostatic microphone, a condenser microphone, an electret microphone, a microelectromechanical systems (MEMS) microphone, or any other suitable capacitive microphone.

The electrical signal generated by microphone 112 may be sampled by an analog-to-digital converter 106 configured to convert such analog electrical signal into digital microphone signal 128 to be processed by controller 108.

Based on digital current signal 126 and digital microphone signal 128, controller 108 may perform speaker protection 114. For example, in some embodiments, speaker protection module 114 may compare digital current signal 126 to the digital input audio signal received by controller 108 to determine differences between the two signals indicative of distortion of the current flowing through speaker 102 and/or any non-linearities of speaker 102 that may cause overexcursion. As another example, in these and other embodiments, speaker protection module 114 may compare digital microphone signal 128 to the digital input audio signal received by controller 108 to determine differences between the two signals indicative of distortion of the current flowing through speaker 102 and/or any non-linearities of speaker 102 that may cause overexcursion.

If speaker protection 114 of controller 108 determines from analysis of digital current signal 126 and/or digital microphone signal 128 that distortion, non-linearities, and overexcursion is present, speaker protection 114 may generate one or more control signals, including without limitation control signals for gain 120, bandwidth 122, and virtual bass 124, and such control signals may be used for audio processing 116. As an

example, analysis of digital current signal 126 and/or digital microphone signal 128 by speaker protection 114 may indicate that speaker 102 may generate some distortion and/or non-linearities caused by small overexcursion. In response, speaker protection 114 may control bandwidth 122 in order to filter out lower-frequency components of the audio signal which may reduce displacement of audio speaker 102, while causing virtual bass 124 to virtually add such filtered lower-frequency components to the audio signal. As another example, analysis of digital current signal 126 and/or digital microphone signal 128 by speaker protection 114 may indicate that speaker 102 may generate severe distortion and/or non-linearities caused by large overexcursion. In response, speaker protection 114 may reduce gain 120 in order to reduce the intensity of the audio signal communicated to speaker 102.

FIGURE 2 illustrates a flow chart of an example method 200 for controlling operation of an audio speaker based on output signal analysis, in accordance with embodiments of the present disclosure. According to some embodiments, method 200 may begin at step 202. Teachings of the present disclosure may be implemented in a variety of configurations of system 100. As such, the preferred initialization point for method 200 and the order of the steps comprising method 200 may depend on the implementation chosen.

At step 202, controller 108 may sample a digital output signal indicative of a physical quantity (e.g., current, sound pressure, etc.) of speaker 102. For example, such digital output signal may include a current signal (e.g., current signal 126) or a digital microphone signal (e.g., microphone signal 128), representing a current through a voice coil of speaker 102 or a sound pressure generated by speaker 102 and incident upon microphone 112, respectively.

At step 204, controller 108 may compare the digital output signal to a digital input audio signal. At step 206, controller 108 may, based on such comparison, determine whether differences between the digital output signal and the digital input audio signal indicate distortion of the digital output signal and/or any non-linearities of speaker 102 that may be caused by overexcursion. If differences between the digital output signal and the digital input audio signal indicate of distortion of the digital output signal and/or any

non-linearities of speaker 102 that may be caused by overexcursion, method 200 may proceed to step 208. Otherwise, method 200 may proceed again to step 202.

At step 208, speaker protection 114 may generate one or more control signals, including without limitation control signals for gain 120, bandwidth 122, and virtual bass
5 124, and such control signals may be used for audio processing 116 of the digital input audio signal in order to reduce the detected differences between the digital output signal and the digital input audio signal. After completion of step 208, method 200 may proceed again to step 202.

Although FIGURE 2 discloses a particular number of steps to be taken with
10 respect to method 200, method 200 may be executed with greater or fewer steps than those depicted in FIGURE 2. In addition, although FIGURE 2 discloses a certain order of steps to be taken with respect to method 200, the steps comprising method 200 may be completed in any suitable order.

Method 200 may be implemented using system 100 or any other system operable
15 to implement method 200. In certain embodiments, method 200 may be implemented partially or fully in software and/or firmware embodied in computer-readable media.

This disclosure encompasses all changes, substitutions, variations, alterations, and modifications to the exemplary embodiments herein that a person having ordinary skill in the art would comprehend. Similarly, where appropriate, the appended claims encompass
20 all changes, substitutions, variations, alterations, and modifications to the exemplary embodiments herein that a person having ordinary skill in the art would comprehend. Moreover, reference in the appended claims to an apparatus or system or a component of an apparatus or system being adapted to, arranged to, capable of, configured to, enabled to, operable to, or operative to perform a particular function encompasses that apparatus,
25 system, or component, whether or not it or that particular function is activated, turned on, or unlocked, as long as that apparatus, system, or component is so adapted, arranged, capable, configured, enabled, operable, or operative.

All examples and conditional language recited herein are intended for pedagogical objects to aid the reader in understanding the invention and the concepts contributed by
30 the inventor to furthering the art, and are construed as being without limitation to such specifically recited examples and conditions. Although embodiments of the present

inventions have been described in detail, it should be understood that various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the disclosure.

WHAT IS CLAIMED IS:

1. A system, comprising:

a controller configured to be coupled to an audio speaker, wherein the controller receives an output signal indicative of a physical quantity associated with the audio speaker, compares the output signal to an audio input signal to determine if differences between the output signal and the audio input signal are present indicating at least one of distortion of the output signal, non-linearities of the audio speaker, and overexcursion of the audio speaker, and controls an audio signal communicated from the controller to the audio speaker and based on the audio input signal responsive to determining that differences between the output signal and the audio input signal are present indicating at least one of distortion of the output signal, non-linearities of the audio speaker, and overexcursion of the audio speaker.

2. The system of Claim 1, wherein the controller controls the audio signal communicated from the controller to the audio speaker by controlling at least one of a gain, a bandwidth, and a virtual bass associated with the audio signal.

3. The system of Claim 1, wherein the output signal is indicative of a current flowing through the audio speaker.

20

4. The system of Claim 1, wherein the output signal is indicative of a sound pressure generated by the audio speaker.

5. A method comprising:

receiving an output signal indicative of a physical quantity associated with an audio speaker;

5 comparing the output signal to an audio input signal to determine if differences between the output signal and the audio input signal are present indicating at least one of distortion of the output signal, non-linearities of the audio speaker, and overexcursion of the audio speaker; and

controlling an audio signal communicated from the controller to the audio speaker and based on the audio input signal responsive to determining that differences between
10 the output signal and the audio input signal are present indicating at least one of distortion of the output signal, non-linearities of the audio speaker, and overexcursion of the audio speaker.

6. The method of Claim 5, wherein controlling the audio signal
15 communicated from the controller to the audio speaker comprises controlling at least one of a gain, a bandwidth, and a virtual bass associated with the audio signal.

7. The method of Claim 5, wherein the output signal is indicative of a current
20 flowing through the audio speaker.

8. The method of Claim 5, wherein the output signal is indicative of a sound pressure generated by the audio speaker.

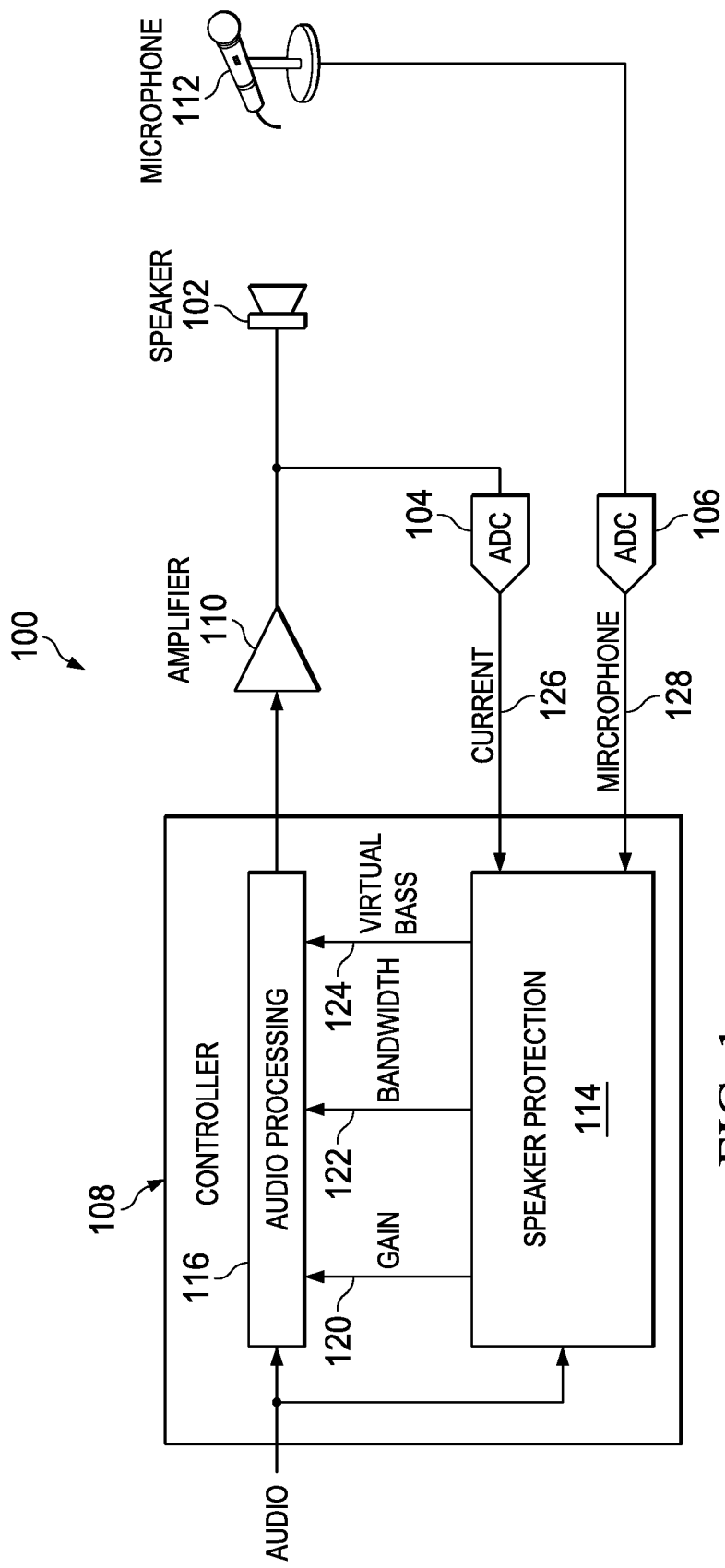


FIG. 1

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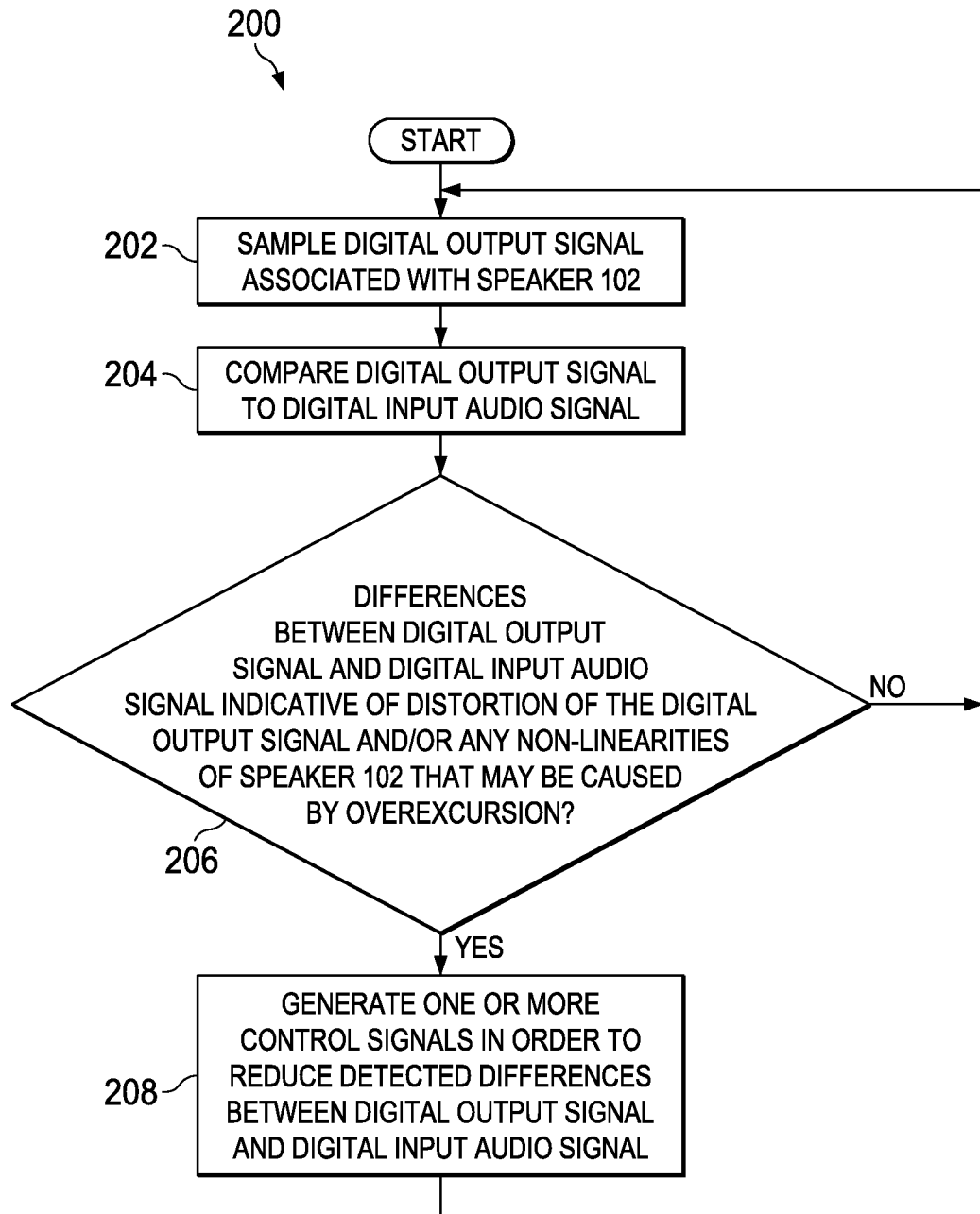


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/039997

A. CLASSIFICATION OF SUBJECT MATTER
 INV. H04R29/00 H04R3/00
 ADD.

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)
 H04R

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014/254805 A1 (SU JIE [US] ET AL) 11 September 2014 (2014-09-11) the whole document	1-8
X	WO 2013/182901 A1 (ACTIWAVE AB [SE]) 12 December 2013 (2013-12-12) the whole document	1,5
X	US 2009/257599 A1 (SAND JENSEN BJORN [DK] ET AL) 15 October 2009 (2009-10-15) page 2, paragraph 30 - page 3, paragraph 50	1,5
X	GB 2 522 449 A (WOLFSON MICROELECTRONICS PLC [GB]) 29 July 2015 (2015-07-29) page 10, line 20 - page 30, line 10	1,5
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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent 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 when the document is taken alone

"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

"&" document member of the same patent family

Date of the actual completion of the international search

3 March 2017

Date of mailing of the international search report

13/03/2017

Name and mailing address of the ISA/

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Coda, Ruggero

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/039997

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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