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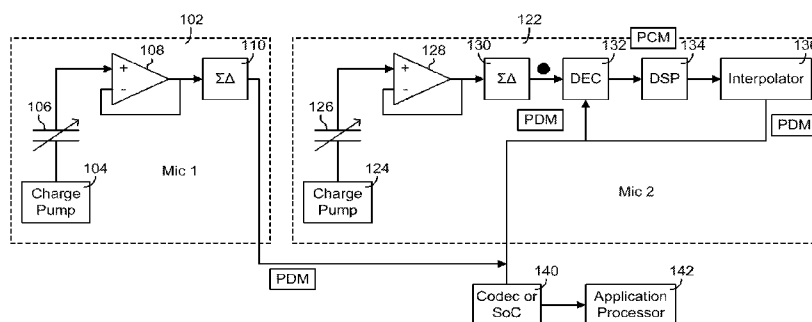
(54) **Title:** INTERFACE FOR MICROPHONE-TO-MICROPHONE COMMUNICATIONS

FIG. 1

(57) **Abstract:** A microphone system includes a first transducer deployed at a first microphone; a second transducer deployed at a second microphone, the first microphone being physically distinct from the second microphone; a decimator deployed at the second microphone that receives first pulse density modulation (PDM) data from the first transducer and second PDM data from the second transducer and decimates and combines the first PDM data and the second PDM data into combined pulse code modulation (PCM) data; and an interpolator deployed at the second microphone for converting the combined PCM data to combined PDM data, and transmits the combined PDM data to an external processing device.



INTERFACE FOR MICROPHONE-TO-MICROPHONE COMMUNICATIONS**CROSS-REFERENCE TO RELATED APPLICATION**

[0001] This patent claims benefit under 35 U.S.C. §119(e) to United States Provisional Application No. 62118252 entitled “Interface for Microphone-to-Microphone Communication” filed February 19, 2015, the content of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] This application relates to microphones and, more specifically, to communications between microphones.

BACKGROUND OF THE INVENTION

[0003] Different types of acoustic devices have been used through the years. One type of device is a microphone and one type of microphone is a microelectromechanical system (MEMS) microphone. A MEMS microphone includes a MEMS die includes a diaphragm and a back plate. The MEMS die is supported by a substrate and enclosed by a housing (e.g., a cup or cover with walls). A port may extend through the substrate (for a bottom port device) or through the top of the housing (for a top port device). In any case, sound energy traverses through the port, moves the diaphragm and creates a changing potential of the back plate, which creates an electrical signal. Microphones are deployed in various types of devices such as personal computers or cellular phones.

[0004] It is sometimes advantageous to utilize two or more microphones. For example, one microphone may be used for sound pick-up in one frequency range, while another microphone may be used for sound pick-up in another frequency range. The microphones are sometimes connected to a codec, which performed processing of the signals from the

microphones. Because of the limitations with the interface between the microphones and the codec, the microphones were unable to communicate with each other.

[0005] The problems of previous approaches have resulted in some user dissatisfaction with these previous approaches.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] For a more complete understanding of the disclosure, reference should be made to the following detailed description and accompanying drawings wherein:

[0007] FIG. 1 comprises a block diagram of a system including two microphones and an interface between the two microphones according to various embodiments of the present invention;

[0008] FIG. 2 comprises a timing diagram showing the operation of the microphone-to-microphone interface shown in FIG. 1 according to various embodiments of the present invention.

[0009] Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity. It will further be appreciated that certain actions and/or steps may be described or depicted in a particular order of occurrence while those skilled in the art will understand that such specificity with respect to sequence is not actually required. It will also be understood that the terms and expressions used herein have the ordinary meaning as is accorded to such terms and expressions with respect to their corresponding respective areas of inquiry and study except where specific meanings have otherwise been set forth herein.

DETAILED DESCRIPTION

[0010] The present approaches provide an interface with microphone-to-microphone communications. In some aspects, a two microphone interface uses a pulse density modulation (PDM) bus. The two microphones share the same clock. The PDM output of the first microphone is transmitted and received by a second microphone on a first clock edge. The second microphone decimates the signals of both microphones and converts these decimated signals into pulse code modulation (PCM) signals, where the signals are processed and converted back to PDM and then a single, combined, and processed output is sent to a codec (or some other external device) on a second clock edge of the clock. The codec will see only the single combined signal (although the codec may receive although not process the signal sent from the first microphone to the second microphone on the first clock edge).

[0011] Referring now to FIG. 1 and FIG. 2, one example of an interface that provides microphone-to-microphone communication is described. A first microphone 102 includes a first charge pump 104, a first micro electro mechanical system (MEMS) transducer 106, a first amplifier 108, and a first sigma delta converter 110.

[0012] A second microphone 122 includes a second charge pump 124, a second micro electro mechanical system (MEMS) transducer 126, a second amplifier 128, a second sigma delta converter 130, a decimator 132, a digital signal processor (DSP) 134, and an interpolator 136. The first MEMS microphone 102 and the second MEMS microphone 122 share a clock 105. The hardware clock that provides the clock signal 105 may be disposed at the codec or system on a chip (SoC) 140 in one example. Other examples are possible.

[0013] The first microphone 102 and the second microphone 122 in some aspects each include a housing that encloses the above-mentioned components. In some examples, each microphone 102, 122 includes a base, on which the components are deployed and a lid or cover that is coupled to the base and that encloses the internal components. Additionally, some of the components (e.g., sigma delta converters, decimators, and amplifiers) may be deployed on an integrated circuit that is disposed on the base.

[0014] The first charge pump 104 and second charge pump 124 provide voltages and/or current to the first MEMS transducer 106 and the second MEMS transducer 126. The first MEMS transducer 106 and the second MEMS transducer 126 convert sound energy into an electrical signal. In these regards, the first MEMS transducer 106 and the second MEMS transducer 126 may include a diaphragm and a charged back plate (with the charge provided by the charge pumps 104 and 124). Sound energy moves the diaphragms to produce an electrical signal. Although MEMS device may be used as transducers 106 and 126, it will also be appreciated that other types of devices such as piezo electrical devices or speakers (being operated as a microphone) may also be deployed.

[0015] The first amplifier 108 and second amplifier 128 amplify the analog signals from the first MEMS transducer 106 and the second MEMS transducer 126. The first sigma delta converter 110 and the second sigma delta converter 130 convert the analog signals into pulse density modulation (PDM) signals.

[0016] The decimator 132 receives signals from the first MEMS transducer 106 and the second MEMS transducer 126 (that have been converted into PDM signals). The decimator 132 converts these PDM signals into to pulse code modulation (PCM) signals for processing by the DSP 134.

[0017] The DSP 134 performs various processing functions on the signals. For example, the DSP 134 may perform noise identification (e.g., identify wind or other types of noise, perform noise suppression (removal), or ultrasonic gesture or activity detection functions. Other examples of processing functions may also be performed by the DSP 134.

[0018] The interpolator 136 converts the PCM signal from the DSP to a PDM signal for transmission to the codec 140. The codec (or system on chip (SoC)) 140 receives the combined signal.

[0019] The first microphone 102 couples to a codec 140 and to the second microphone 122 and to the codec 140. The codec 140 couples to an application processor 142. The purpose of the codec 140 is to convert the PDM signal into PCM data and provide an amplifier for speakers in electronic devices. The application processor 142 is in one aspect a system on a chip

(SoC) designed to support applications running in a mobile operating system environment. In some architectures, the codec 140 is not required and the microphones 102 and 122 may be directly connected to the applications processor 142.

[0020] In one example of the operation of the system of FIG. 1 and now specifically referring to the time line of FIG. 2, the clock 105 has rising edges 107 and falling edges 109. Data 111, 113, 115 is obtained and transmitted from the first microphone 102 (sensed by the first MEMS transducer 106) to the second microphone 122 on the rising edges 107 of the clock 105.

[0021] Data 117, 119, and 121 is obtained from the second MEMS transducer 126 of the second microphone 122 on falling edges 109 of the clock 105. Combined data 131, 133, and 135 is sent from the second microphone 122 to the codec 140 on falling edges 109. The combined data is the processed audio stream from the first microphone 102 and the second microphone 122 combined and processed in the DSP in the second microphone.

[0022] It will be appreciated that there is a time lag between the reception of the data from the first microphone 102 and transmission of the combined data from the second microphone 122. For example, combined data 133 may be the combination of data 111 (from the first microphone 102) and the data 119 (from the second transducer 126 of the second microphone 122).

[0023] It will be appreciated that although in this example data is sent from the first microphone to the second microphone on a rising clock edge and sent from the second microphone to the codec on a second clock edge, that this order may be reversed. Other timing relationships may also be used.

[0024] In this way, the codec 140 receives the combined data from the two microphones 102 and 122. Microphone-to-microphone communications is supported in an efficient and seamless way.

[0025] Preferred embodiments of this invention are described herein, including the best mode known to the inventors for carrying out the invention. It should be understood that the

illustrated embodiments are exemplary only, and should not be taken as limiting the scope of the invention.

WHAT IS CLAIMED IS:

1. A microphone system comprising:
 - a first transducer deployed at a first microphone;
 - a second transducer deployed at a second microphone, the first microphone being physically distinct from the second microphone;
 - a decimator deployed at the second microphone that receives first pulse density modulation (PDM) data from the first transducer and second PDM data from the second transducer and decimates and combines the first PDM data and the second PDM data into combined pulse code modulation (PCM) data;
 - an interpolator deployed at the second microphone, the interpolator being configured to convert the combined PCM data to combined PDM data, and transmit the combined PDM data to an external processing device.
2. The microphone system of claim 1, wherein the first transducer and the second transducer are micro electro mechanical system (MEMS) transducers.
3. The microphone system of claim 2, wherein the first microphone includes a first charge pump and the second microphone includes a second charge pump.
4. The microphone system of claim 1 wherein the first microphone includes a first sigma delta converter and the second microphone includes a second sigma delta converter.

5. The microphone system of claim 1, wherein the first microphone and the second MEMS microphone share a clock.

6. The microphone system of claim 5, wherein the clock is supplied by an external processing device.

7. The microphone system of claim 1, wherein the external processing device is a codec or system on a chip (SoC).

8. The microphone system of claim 1, wherein the decimated PCM data is sent to the external processing device.

9. A microphone comprising:

a housing that encloses:

- a transducer;
- a decimator that is configured to receive first pulse density modulation (PDM) data from the transducer and second PDM data from another transducer external to the housing, such that the decimator decimates and combines the first PDM data and the second PDM data into combined pulse code modulation (PCM) data;
- an interpolator deployed that is configured to convert the combined PCM data to combined PDM data, and transmit the combined PDM data to an external processing device.

10. The microphone of claim 9, wherein the transducer is a micro electro mechanical system (MEMS) transducer.

11. The microphone of claim 9, wherein the microphone includes a charge pump.

12. The microphone of claim 9 wherein the microphone includes a sigma delta converter.

13. The microphone of claim 9, wherein the external processing device is a codec or system on a chip (SoC).

14. The microphone of claim 9, wherein the decimated PCM data is sent to the external processing device.

15. A method of operating a microphone system, the system including a first transducer deployed at a first microphone and a second transducer deployed at a second microphone, the first microphone being physically distinct from the second microphone, the method comprising:

receiving first pulse density modulation (PDM) data from the first transducer and second PDM data from the second transducer;

at a decimator deployed at the second microphone, decimating and combining the first PDM data and the second PDM data into combined pulse code modulation (PCM) data;

at an interpolator deployed at the second microphone, converting the combined PCM data to combined PDM data;

transmitting the combined PDM data to an external processing device.

16. The method of claim 15, wherein the first transducer and the second transducer are micro electro mechanical system (MEMS) transducers.

17. The method of claim 15, wherein the first microphone includes a first charge pump and the second microphone includes a second charge pump.

18. The method of claim 15, comprising sharing a clock between the first microphone and the second MEMS microphone.

19. The method of claim 18, wherein the clock is disposed at the external processing device.

20. The method of claim 15, wherein the external processing device is a codec or system on a chip (SoC).

21. The method of claim 15, wherein the decimated PCM data is sent to the external processing device.

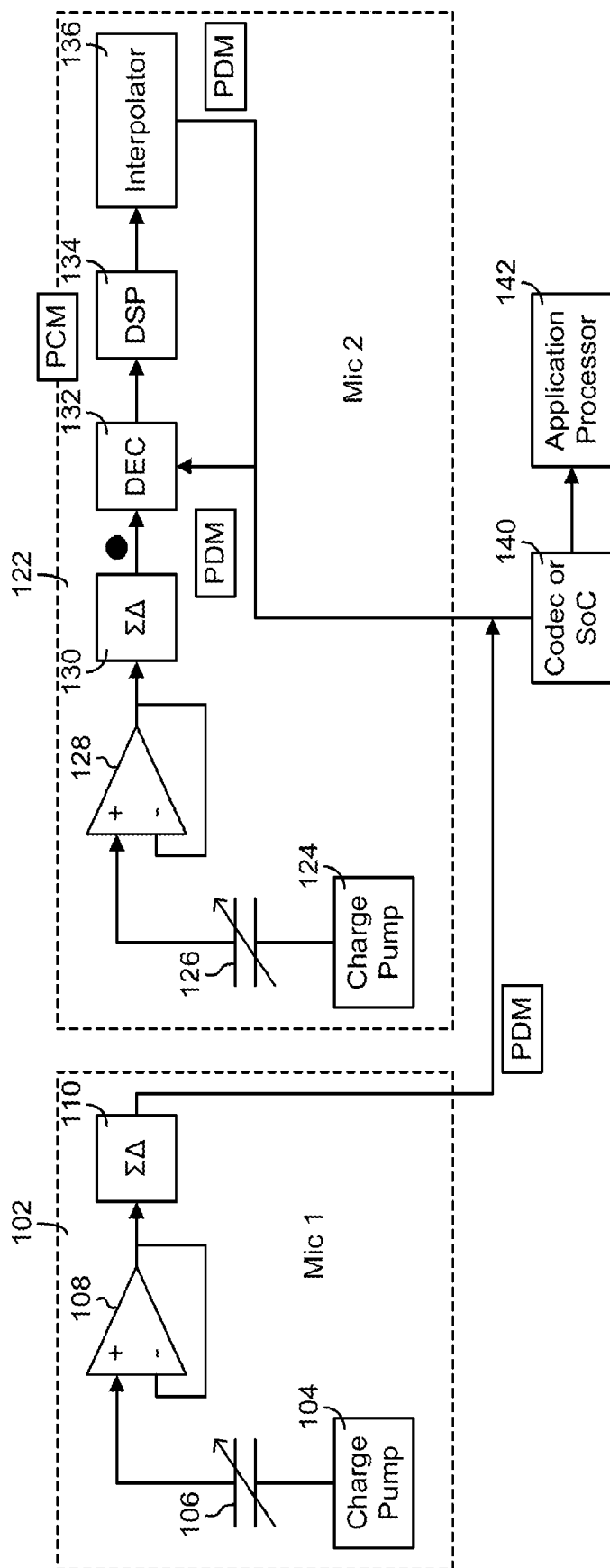


FIG. 1

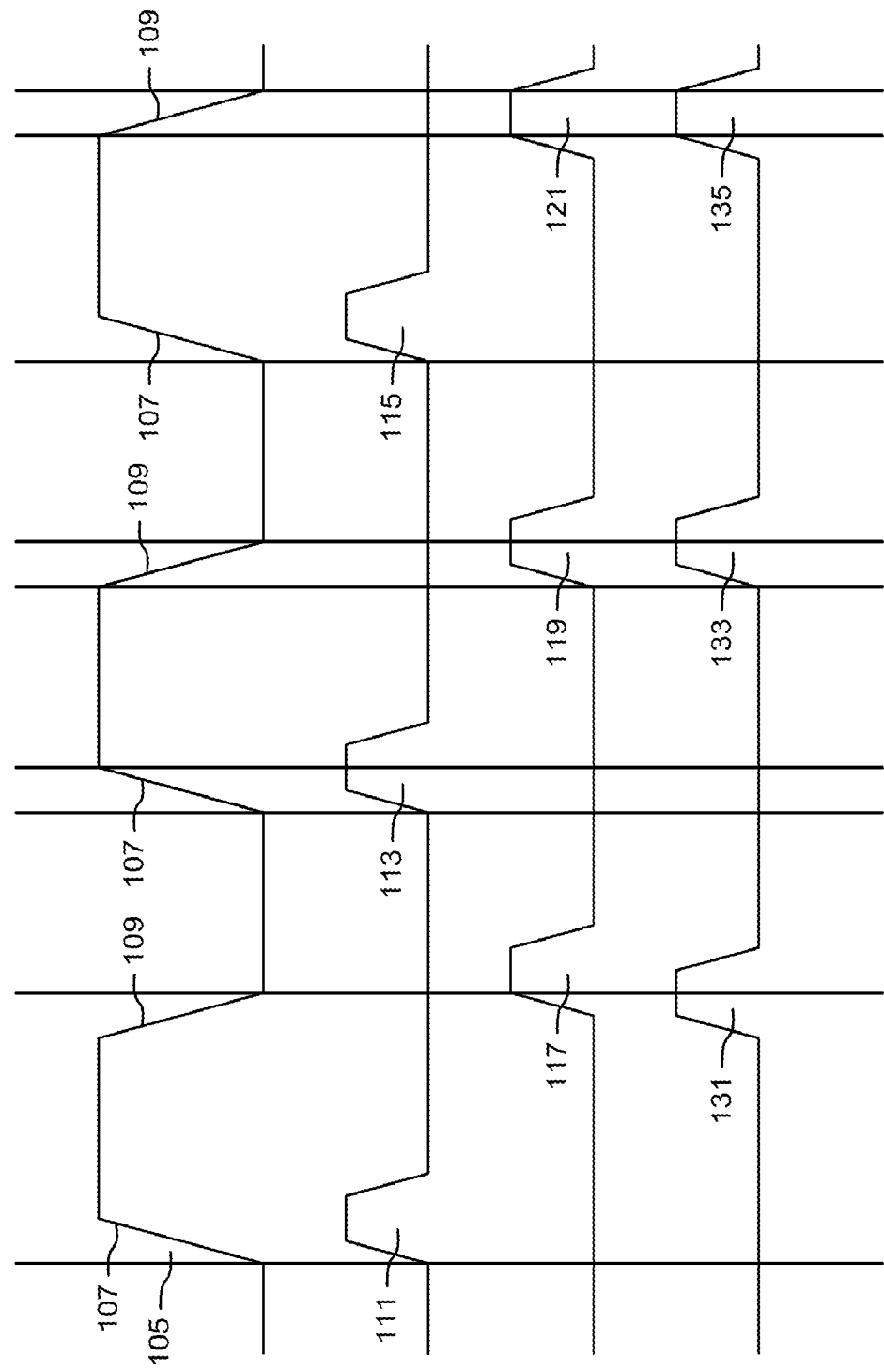


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/016706**A. CLASSIFICATION OF SUBJECT MATTER****H04R 19/04(2006.01)i, H04R 3/00(2006.01)i**

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 19/04; H03M 3/00; H04R 1/02; H04M 9/00; G10K 11/16; H03G 5/00; G10L 19/00; H04R 3/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: microphone, digital, data, pulse, modulation, interpolator, decimator, processor, charge, pump, converter

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 7619551 B1 (LI-TE WU) 17 November 2009 See column 3, line 9 - column 4, line 65 and figures 2-3.	1-21
Y	US 2011-0007907 A1 (HYUN JIN PARK et al.) 13 January 2011 See paragraphs [0144]-[0155] and figures 26-27.	1-21
Y	US 2010-0086146 A1 (SHIH-CHIN GONG et al.) 08 April 2010 See paragraphs [0006], [0066]-[0077] and figures 8-9.	2-3, 10-11, 16-17
A	US 2013-0208915 A1 (DIRK HAMMERSCHMIDT et al.) 15 August 2013 See abstract, paragraphs [0016]-[0028] and figures 1a-3d.	1-21
A	JP 2007-226040 A (AIPHONE CO., LTD.) 06 September 2007 See abstract, paragraphs [0015]-[0035] and figures 1-2.	1-21



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

25 May 2016 (25.05.2016)

Date of mailing of the international search report

26 May 2016 (26.05.2016)

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International Application Division

Korean Intellectual Property Office

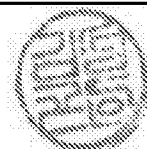
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/016706

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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