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(54) **TRANSDUCER APPARATUS HAVING A MECHANICAL ACOUSTIC FILTER WITH MOVABLE BLOCKING MEMBER**

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H04M 1/03	(2006.01)
H04R 1/08	(2006.01)
H04R 1/22	(2006.01)
H04R 3/00	(2006.01)
H04R 7/04	(2006.01)
H04R 19/00	(2006.01)

(52) **U.S. Cl.**
CPC . ***H04R 1/28*** (2013.01); ***H04M 1/03*** (2013.01); ***H04M 1/035*** (2013.01); ***H04R 1/083*** (2013.01); ***H04R 1/222*** (2013.01); ***H04R 3/00*** (2013.01); *H04R 7/04* (2013.01); *H04R 19/005* (2013.01); *H04R 2201/003* (2013.01); *H04R 2410/07* (2013.01)

(58) **Field of Classification Search**
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See application file for complete search history.

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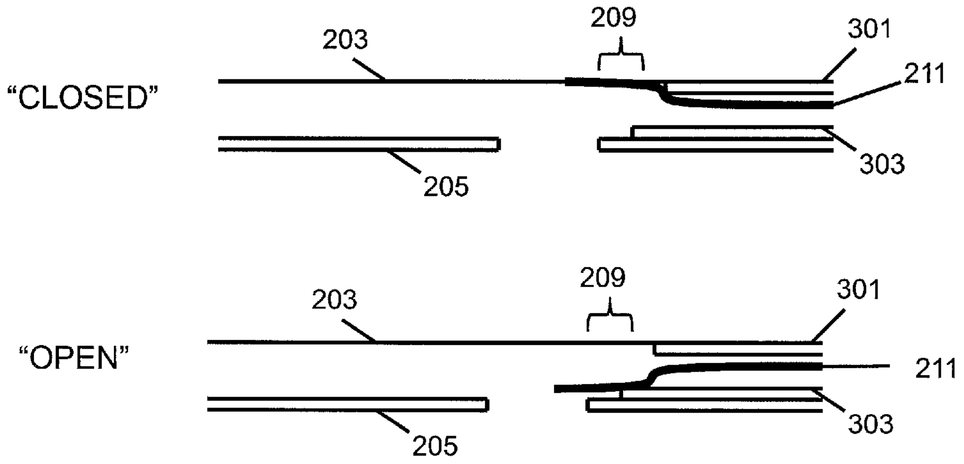
(57) **ABSTRACT**

An acoustic transducer comprising: a mechanical acoustic filter configured to be electrically controllable to change the acoustic properties of the transducer.

13 Claims, 9 Drawing Sheets



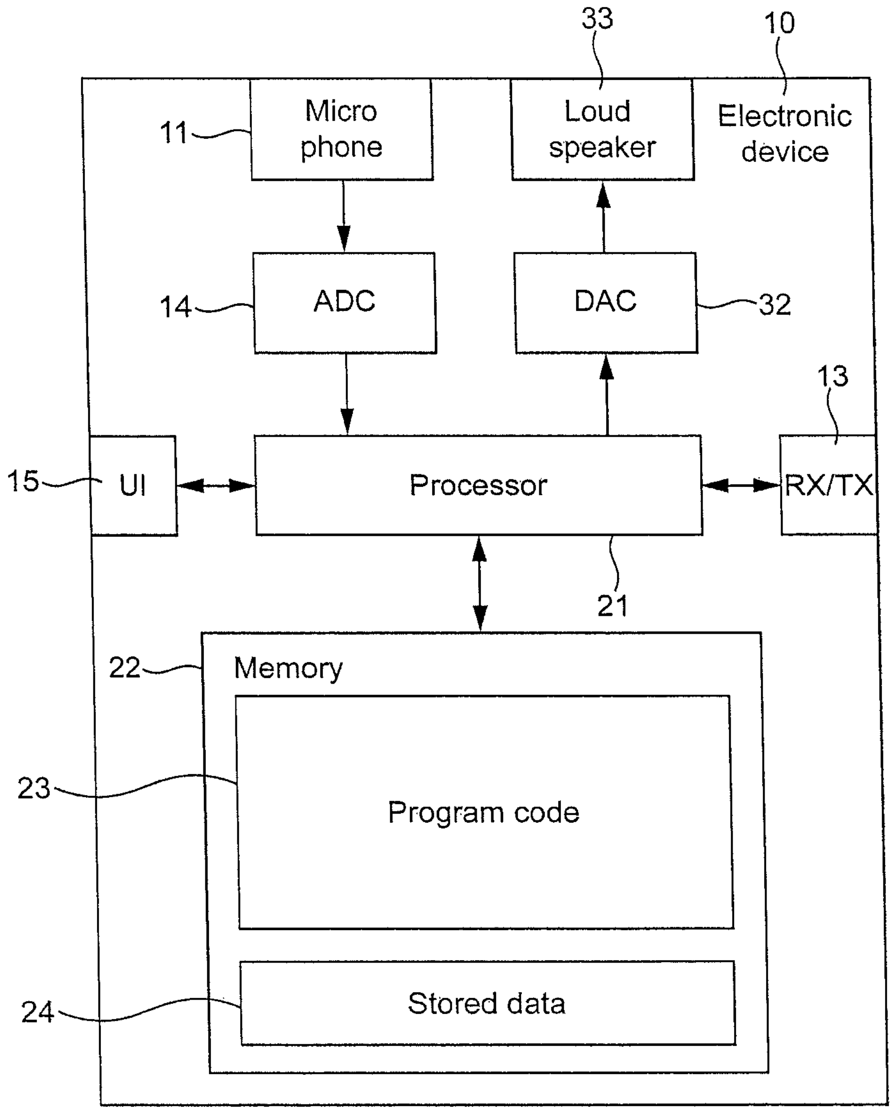
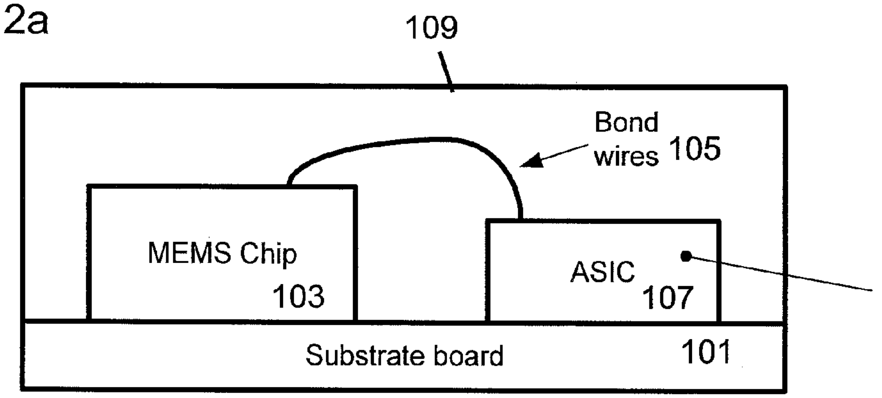

33
10
Micro phone
Loud speaker
Electronic device
11
ADC
DAC
14
32
13
15
UI
Processor
RX/TX
21
22
Memory
23
Program code
24
Stored data

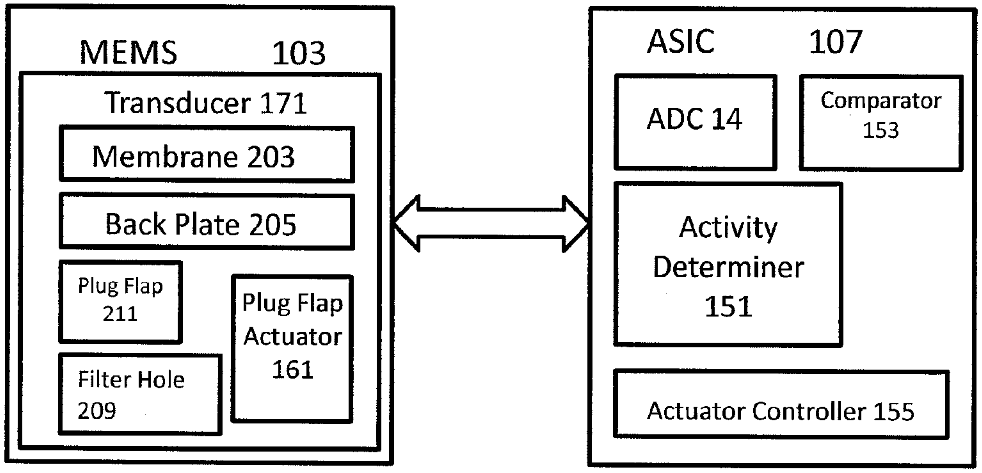
FIG. 1

Figure 2a



The ASIC can include
e.g. the following:
- biasing for the MEMS
microphone element
(back plate)
- preamplifier
- AD converter 14

Figure 2b



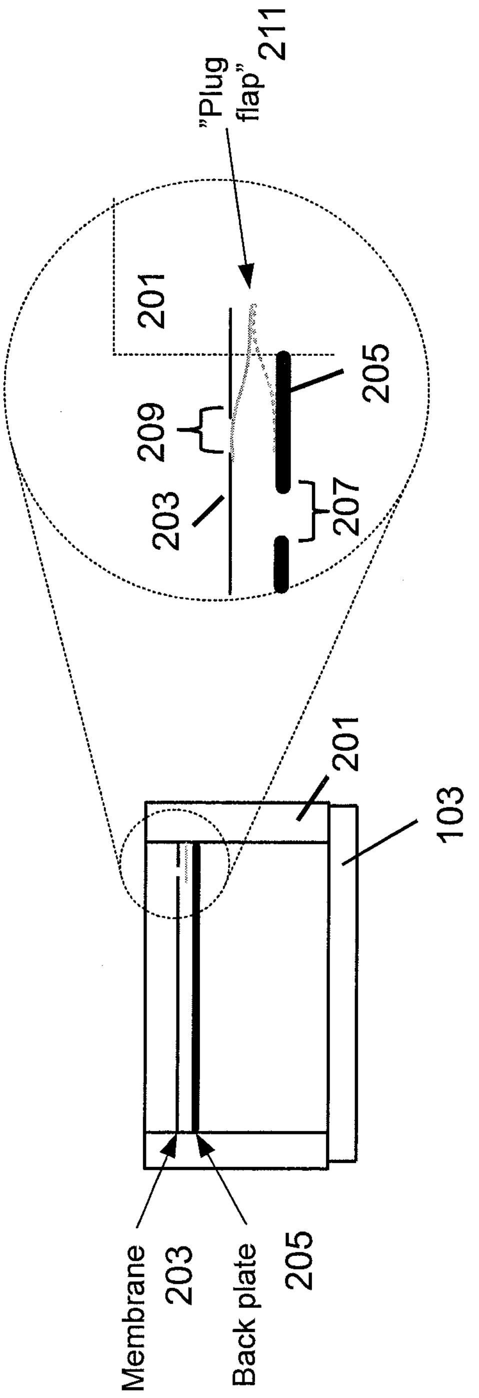
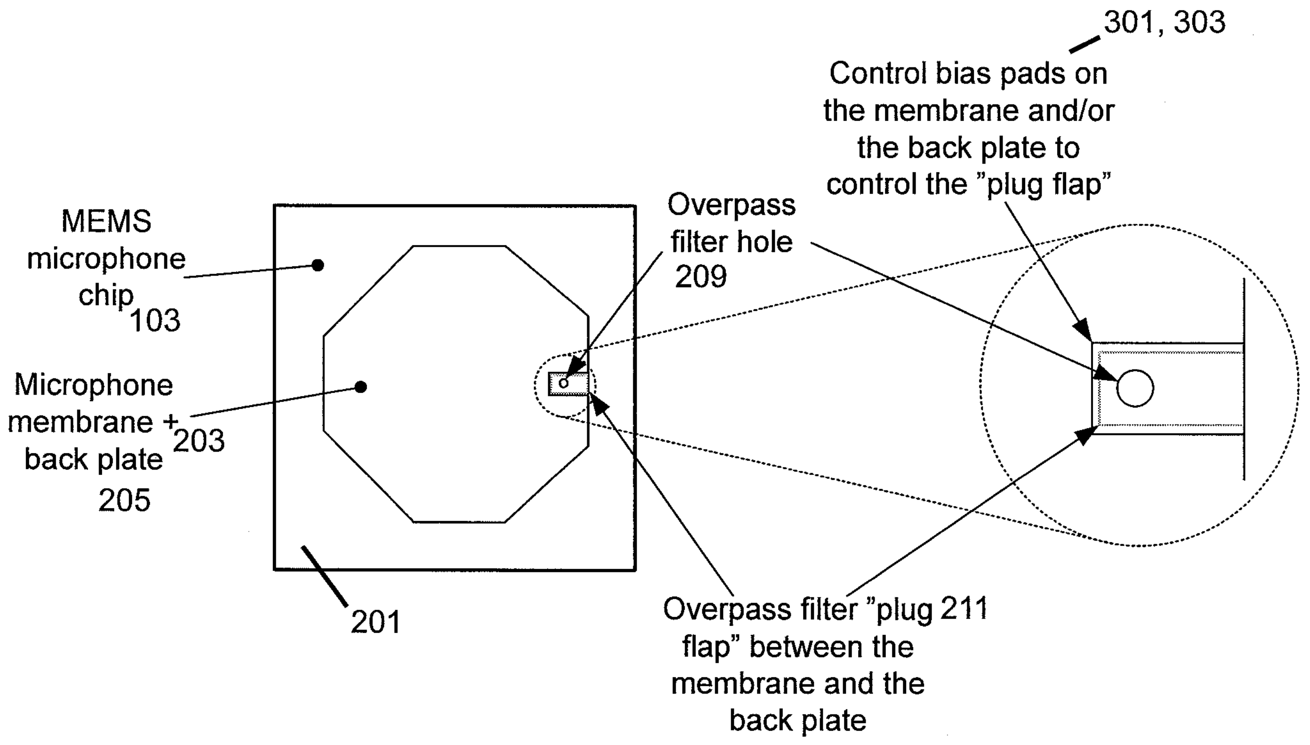

"Plug flap" 211
201
205
209
203
207
201
103
Membrane 203
Back plate 205

Figure 3

Figure 4


MEMS microphone chip 103
Microphone membrane + back plate 205
203
201
Overpass filter hole 209
Control bias pads on the membrane and/or the back plate to control the "plug flap"
301, 303
Overpass filter "plug flap" between the membrane and the back plate
211

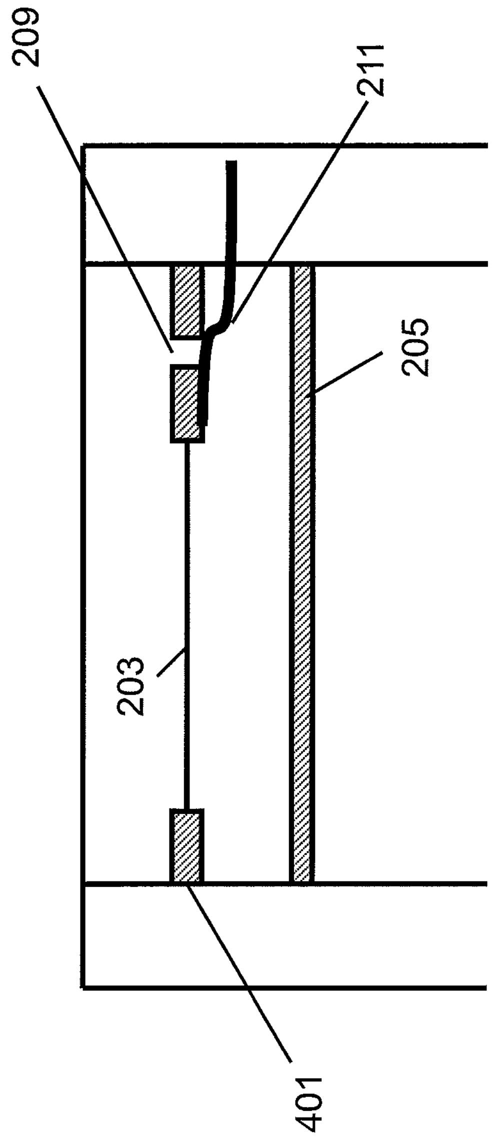
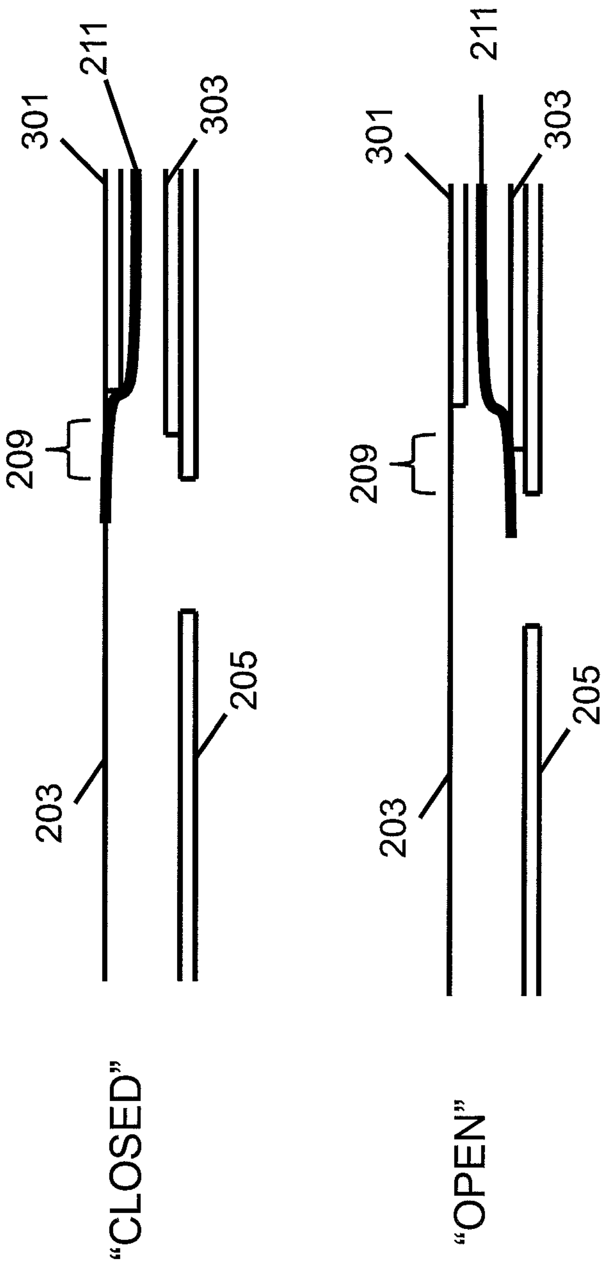


Figure 5

Figure 6



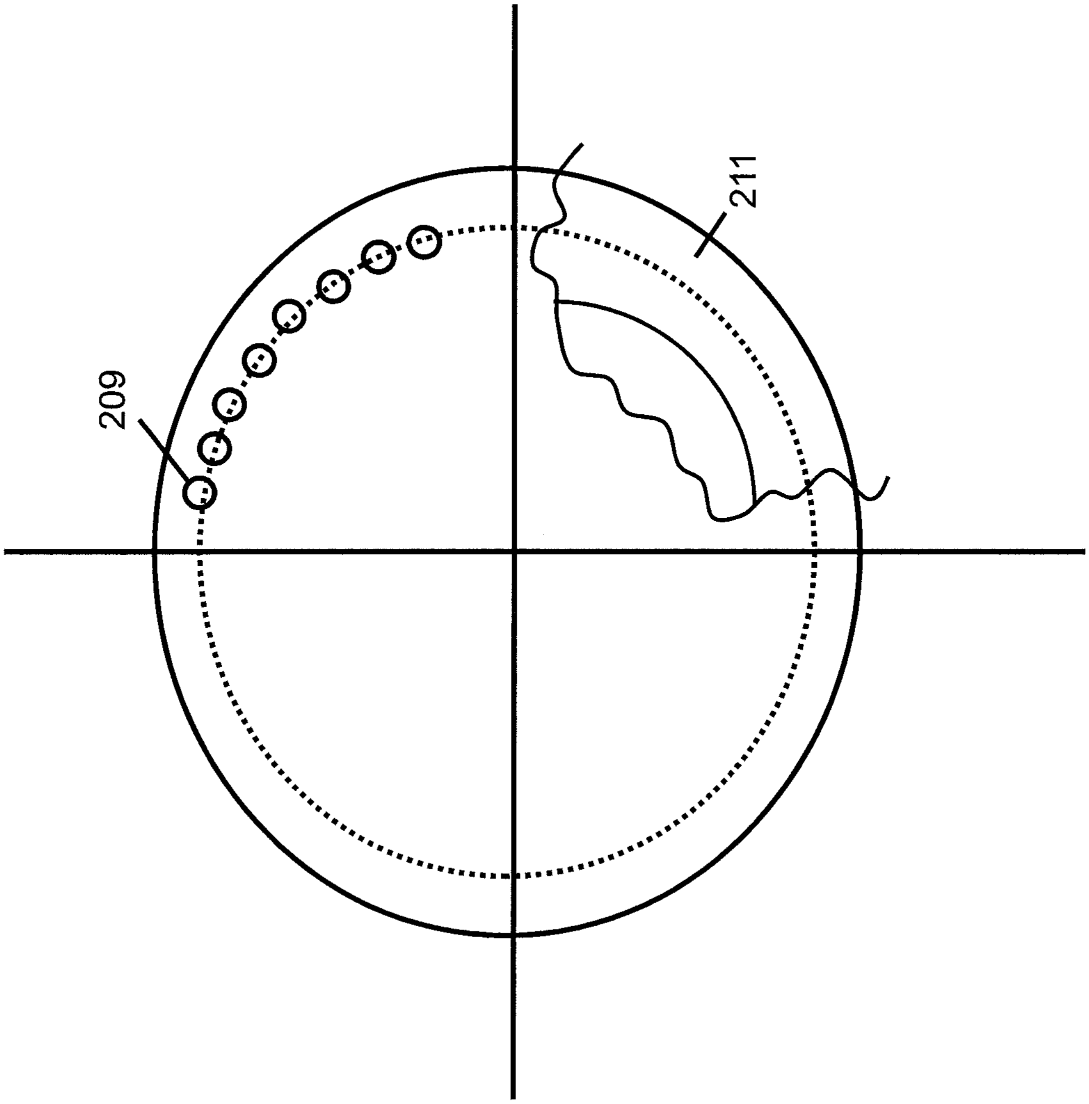
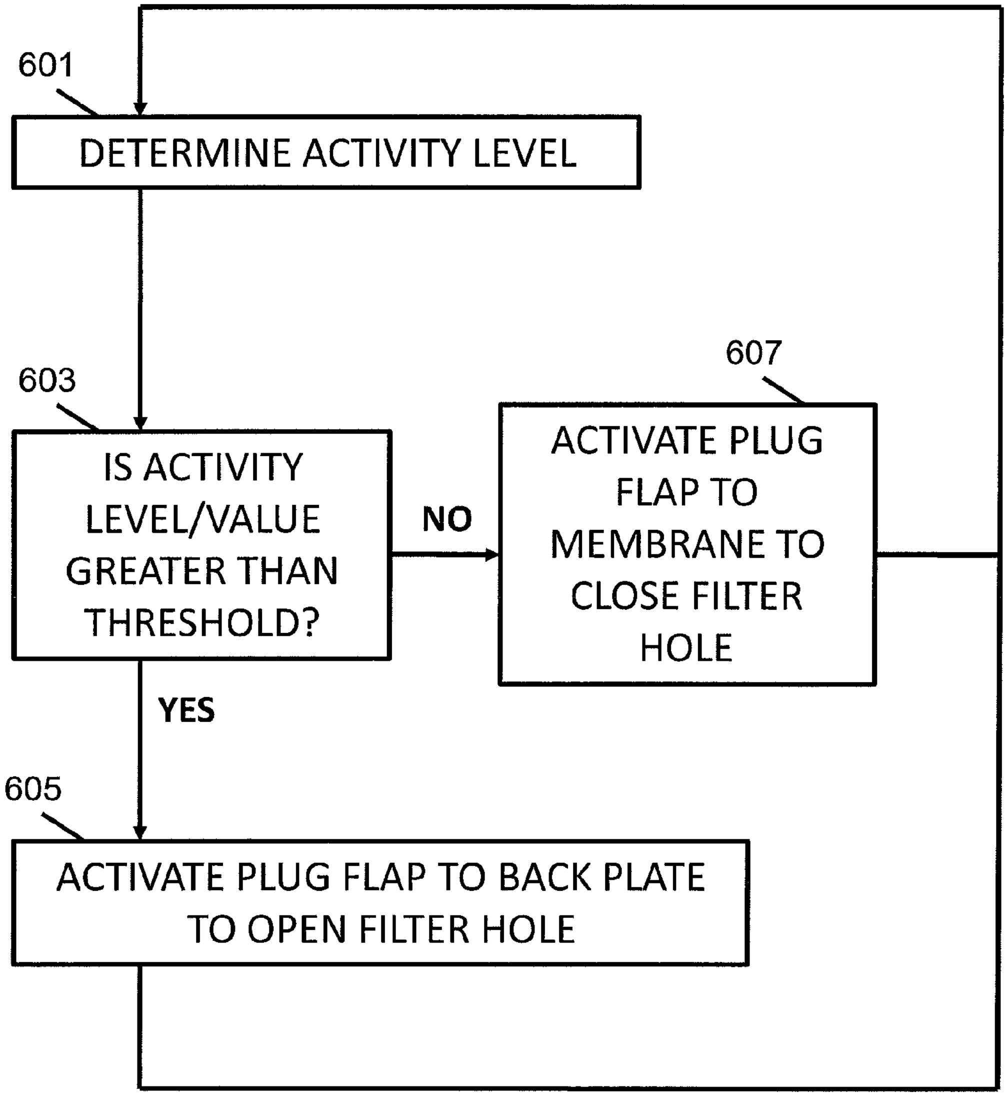


Figure 7

Figure 8


601
DETERMINE ACTIVITY LEVEL
603
IS ACTIVITY LEVEL/VALUE GREATER THAN THRESHOLD?
NO
607
ACTIVATE PLUG FLAP TO MEMBRANE TO CLOSE FILTER HOLE
YES
605
ACTIVATE PLUG FLAP TO BACK PLATE TO OPEN FILTER HOLE

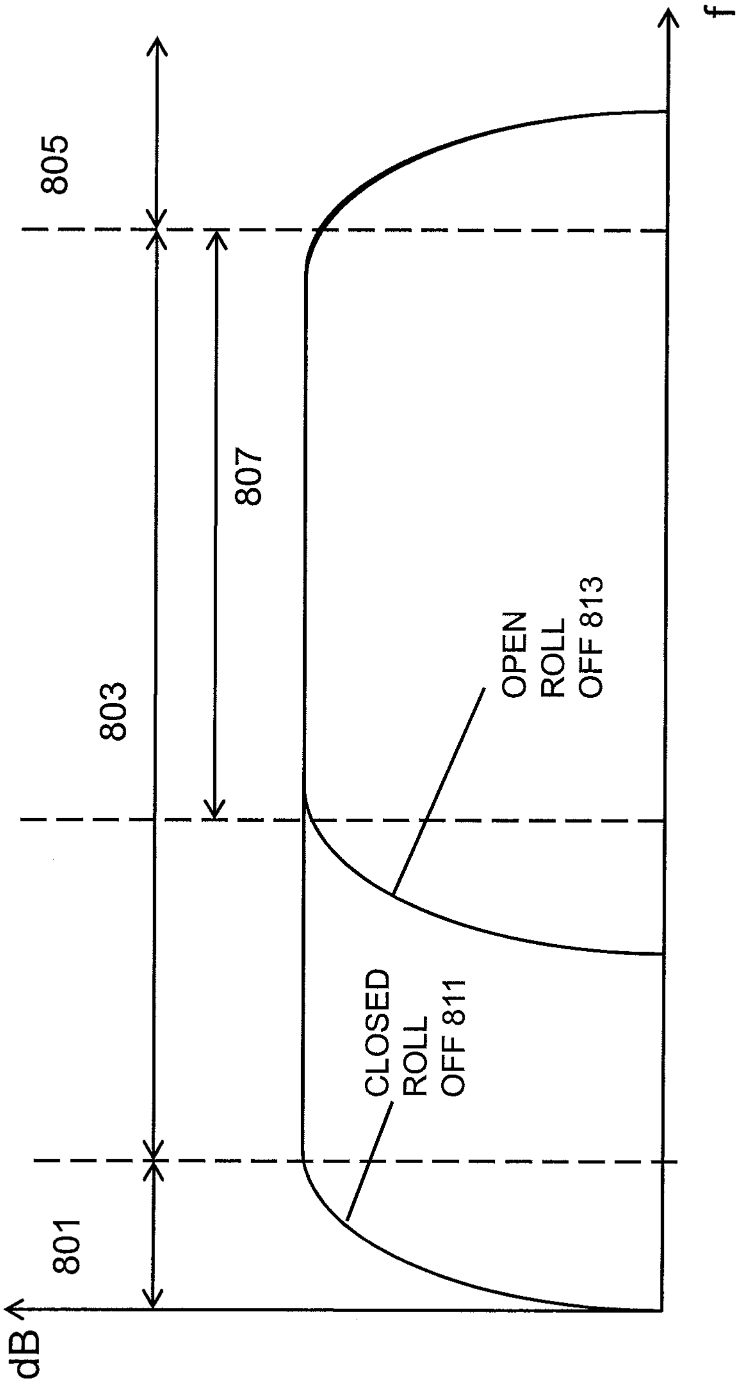


Figure 9

TRANSDUCER APPARATUS HAVING A MECHANICAL ACOUSTIC FILTER WITH MOVABLE BLOCKING MEMBER

RELATED APPLICATION

This application was originally filed as PCT Application No. PCT/IB2011/050817 filed Feb. 25, 2011.

FIELD OF THE APPLICATION

The present invention relates to a transducer apparatus. The invention further relates to, but is not limited to, a transducer apparatus for use in mobile devices.

BACKGROUND OF THE APPLICATION

Many portable devices, for example mobile telephones, contain a number of acoustic transducers, such as microphones, earpieces and speakers. Such transducers are key components in mobile phone audio/acoustic design. Generally, there will be one or more sound channels or back cavities associated with each acoustic transducer. Such sound channels can ensure a certain frequency response is obtained for the transducer, and must be carefully designed as part of the mechanical configuration of the device hardware. Small changes in the size and configuration of the sound channels or cavities can have a large effect on the acoustic properties of the combined transducer/sound channel.

In known acoustic transducer configurations, the mechanical design of the sound channels is fixed at the point of hardware design and manufacture of the device is completed, and cannot be later adapted during use for a specific purpose or desired configuration. Instead, the desired acoustic properties are produced by filtering the electrical signal representing the sound output before the signal is applied to the transducer. Typically, this requires the use of significant processing power, commonly provided by dedicated digital signal processors (DSPs).

Furthermore there is a limit to the modification of the acoustic response of the transducer which can be carried out in the DSP.

An example of the limitations of the mechanical design of typical microphone transducers is that of wind noise. Wind noise is a problem particularly for miniaturised designs such as found in mobile phone where there is no room for mechanical protection of the microphone from wind such as used in broadcast microphones like wind screens or foam protectors. Furthermore filtering out the wind noise from the signal in the electrical domain, not only requires significant processing power in a digital signal processor, but typically produces poor results as the sound pressure levels generated by the wind cause the microphone acoustic element to saturate.

STATEMENT OF THE APPLICATION

This application proceeds from the consideration that the provision of an adjustable acoustic overpass filter may provide suitable wind noise reduction in audio capture environments.

It is an aim of at least some embodiments of the invention to address one or more of these problems.

According to a first aspect there is provided an acoustic transducer comprising: a mechanical acoustic filter configured to be electrically controllable to change the acoustic properties of the transducer.

The mechanical acoustic filter may comprise: at least one filter hole; at least one blocking member configured to be electrically controllable, wherein each at least one blocking member is configured to be selectively seal at least one associated filter hole.

The transducer may comprise a membrane, wherein the at least one filter hole is located in the membrane.

The transducer may comprise a membrane support neighbouring and surrounding the membrane, wherein at least one filter hole is located in the membrane support.

The transducer may comprise a back plate configured to define a volume of air between the membrane and the back plate.

The transducer may be a capacitive transducer and the membrane and back plate are the two plates of the transducer.

The blocking member may comprise a resilient member biased in an open or blocking state.

The acoustic transducer may further comprise a blocking member actuator.

The blocking member actuator may comprise at least one bias member, wherein the at least one bias member is configured to be electrically or electrostatically charged to attract or repel the blocking member.

The blocking member may comprise: an anti-stick coating; and an anti-stick profile.

The acoustic transducer may comprise at least one of: a microphone; and a speaker.

An apparatus may comprise: the acoustic transducer as described herein; and a controller configured to control the mechanical acoustic filter.

The apparatus may further comprise a sensor configured to determine the activity of the acoustic transducer, wherein the controller is further configured to control the mechanical acoustic filter dependent on the sensor activity value.

The controller may be configured to control the mechanical acoustic filter in at least one of: a binary mode of control; a continuous mode of control and a discrete stepwise control.

According to a second aspect of the application there is provided a method comprising: electrically controlling an acoustic transducer mechanical acoustic filter to change the acoustic properties of the transducer.

The acoustic transducer mechanical acoustic filter may comprise: at least one filter hole; and at least one blocking member, wherein electrically controlling an acoustic transducer mechanical acoustic filter may comprise selectively sealing at least one filter hole with a associated blocking member.

The transducer may comprise a membrane, wherein the at least one filter hole is located in the membrane.

The method may comprise locating the at least one filter hole in a membrane support neighbouring and surrounding the membrane.

The transducer may comprise a back plate configured to define a volume of air between the membrane and the back plate.

The transducer may be a capacitive transducer and the membrane and back plate are the two plates of the transducer.

The blocking member may comprise a resilient member, and the method may further comprise biasing the blocking member in an open or blocking state.

The method may further comprise electrically or electrostatically charging at least one blocking member actuator to attract or repel the blocking member.

The method may further comprise: determining the activity of the acoustic transducer; and electrically controlling the acoustic transducer mechanical acoustic filter to change the acoustic properties of the transducer comprises changing the acoustic properties dependent on the activity value of the transducer.

Electrically controlling the acoustic transducer mechanical acoustic filter to change the acoustic properties of the transducer may comprise controlling the mechanical acoustic filter in at least one of: a binary mode of control; a continuous mode of control and a discrete stepwise control.

According to a third aspect of the application there is provided an apparatus comprising electrically controllable mechanical acoustic filter means for changing the acoustic properties of a transducer.

According to a fourth aspect of the application there is provided apparatus comprising at least one processor and at least one memory including computer code, the at least one memory and the computer code configured to with the at least one processor cause the apparatus to at least perform: determining the activity of an acoustic transducer; and electrically controlling an acoustic transducer mechanical acoustic filter to change the acoustic properties of the transducer dependent on the activity value of the transducer.

SUMMARY OF FIGURES

For better understanding of the present invention, reference will now be made by way of example to the accompanying drawings in which:

FIG. **1** shows schematically an electronic device employing embodiments of the invention;

FIG. **2***a* shows schematically the electronic device in further detail;

FIG. **2***b* shows schematically some functional components of the electronic device according to some embodiments;

FIG. **3** shows schematically an example topology for the transducer according to some embodiments;

FIG. **4** shows schematically a further view of the example topology of the transducer according to some embodiments;

FIG. **5** shows schematically a further example topology for the transducer according to some embodiments;

FIG. **6** shows schematically the transducer in detail and the opening and closing of sound channels according to some embodiments;

FIG. **7** shows a further topology for the transducer according to some embodiments;

FIG. **8** shows a flow diagram showing the operation of the transducer; and

FIG. **9** shows schematic example frequency response graphs for the transducer operating with the sound channel open and closed.

DESCRIPTION OF EXAMPLE EMBODIMENTS

The following describes in further detail suitable apparatus and possible mechanisms for the provision of transducers having changeable acoustic properties. In this regard reference is first made to FIG. **1** which shows a schematic block diagram of an exemplary apparatus or electronic device **10**, which may incorporate transducers having changeable acoustic properties according to some embodiments. In the following examples and embodiments the transducer receives or generates an analogue signal which is processed by an associated analogue to digital converter, however it would be understood that in some embodiments the microphone/speaker is an integrated transducer generating digital or receiving digital signals directly. Furthermore in some embodiments the transducer mechanical filter is a pure analogue design, in other words processing is performed in the analogue domain with respect to the mechanical acoustic filter.

The electronic device **10** may for example be a mobile terminal or user equipment of a wireless communication system.

The electronic device **10** comprises a microphone **11**, which is linked via an analogue-to-digital converter (ADC) **14** to a processor **21**. The processor **21** is further linked via a digital-to-analogue (DAC) converter **32** to loudspeakers **33**. The processor **21** is further linked to a transceiver (TX/RX) **13**, to a user interface (UI) **15** and to a memory **22**.

The processor **21** may be configured to execute various program codes. The implemented program codes may comprise encoding code routines. The implemented program codes **23** may further comprise an audio decoding code. The implemented program codes **23** may be stored for example in the memory **22** for retrieval by the processor **21** whenever needed. The memory **22** may further provide a section **24** for storing data.

The user interface **15** may enable a user to input commands to the electronic device **10**, for example via a keypad, and/or to obtain information from the electronic device **10**, for example via a display. The transceiver **13** enables a communication with other electronic devices, for example via a wireless communication network. The transceiver **13** may in some embodiments of the invention be configured to communicate to other electronic devices by a wired connection.

It is to be understood again that the structure of the electronic device **10** could be supplemented and varied in many ways.

A user of the electronic device **10** may use the microphone **11** for inputting speech, or other sound signal, that is to be transmitted to some other electronic device or that is to be stored in the data section **24** of the memory **22**. A corresponding application has been activated to this end by the user via the user interface **15**. This application, which may be run by the processor **21**, causes the processor **21** to execute the encoding code stored in the memory **22**.

The analogue-to-digital converter **14** may convert the input analogue audio signal into a digital audio signal and provides the digital audio signal to the processor **21**.

The processor **21** may then process the digital audio signal in the same way as described with reference to the description hereafter.

The resulting bit stream is provided to the transceiver **13** for transmission to another electronic device. Alternatively, the coded data could be stored in the data section **24** of the memory **22**, for instance for a later transmission or for a later presentation by the same electronic device **10**.

The electronic device **10** may also receive a bit stream with correspondingly encoded data from another electronic device via the transceiver **13**. In this case, the processor **21** may execute the decoding program code stored in the memory **22**. The processor **21** may therefore decode the received data, and provide the decoded data to the digital-to-analogue converter **32**. The digital-to-analogue converter **32** may convert the digital decoded data into analogue audio data and outputs the analogue signal to the loudspeakers **33**. Execution of the decoding program code could be triggered as well by an application that has been called by the user via the user interface **15**.

In some embodiments the loudspeakers **33** may be supplemented with or replaced by a headphone set which may communicate to the electronic device **10** or apparatus wirelessly, for example by a Bluetooth profile to communicate via the transceiver **13**, or using a conventional wired connection.

In some embodiments the hardware integration of the transducers, such as the microphone **11** or the speaker **33**, is in the form of a micro electromechanical system (MEMS) integrated circuit implementation. Although the description herein further details the operation of embodiments of the application with respect to microphone transducers it would be appreciated that the similar apparatus and methods can be employed to speaker operations and/or combined microphone speakers.

With respect to FIG. **2***a* an example of the hardware integration of the transducer is shown within the electronic device or apparatus **10** according to some embodiments. In some embodiments the transducer and in particular the microphone **11** can be implemented as a micro-electromechanical system (MEMS) implemented on an integrated circuit or chip. Although the apparatus and methods described herein relate to a MEMS microphone transducer, any transducer employing a membrane (or surface, or diaphragm) for generating or detecting acoustic waves can implement similar embodiments. For example any suitable condenser microphone can employ a plug flap/filter hole combination as described herein.

The MEMS chip **103** can in some embodiments be mounted physically on the substrate board **101** within the casing **109** of the electronic device or apparatus **10**. The MEMS chip **103** furthermore in some embodiments can be located neighbouring an acoustic portal provided within the casing of the electronic device or apparatus. The acoustic portal is configured to allow acoustic signals to pass 'through' the casing of the apparatus between the transducer and the environment the apparatus is operating in. In some embodiments the acoustic portal can be at least one hole in the casing. The hole can furthermore be covered in some embodiments by a dust or water resistant or proof screen to prevent foreign bodies from entering the device and damaging any components within the apparatus. The MEMS chip **103** can in some embodiments be mechanically and/or electrically fixed on the substrate **101** to prevent movement of the MEMS chip **103** and/or locate the MEMS chip **103** relative to the acoustic portal in the apparatus. In some embodiments the MEMS chip **103** can be mechanically located (mounted) on the substrate board **101** in such a manner that audio waves can pass through the acoustic portal (and in some embodiments sound channels between the casing and the MEMS chip **103**) in the casing **109** to the MEMS chip **103**. In some embodiments the substrate board **101** can itself comprise a sound channel through which the acoustic waves pass through.

With respect to FIG. **2***b*, a schematic view of the MEMS chip **103** is shown.

In some embodiments the MEMS chip comprises a transducer **171**, which is configured in the description herein to be to operate as the microphone **11**. In some embodiments the MEMS chip **103** can comprise further transducers configured to operate as further microphones and/or configured to operate as a loudspeaker **33**. However for clarity the following description describes embodiments of the application having a single transducer/single microphone implementation.

In some embodiments the transducer **171** comprises a membrane **203**, a back plate **205**, a blocking member **211**, a filter hole **209**, and a blocking member actuator **161**.

The membrane **203** can be formed from any suitable material and is configured to move in response to acoustic signals or waves applying a force against the membrane. In some embodiments the membrane can be configured to be mechanically coupled to an actuator such as a moving magnet or moving coil to generate an electrical signal in response to the movement of the membrane. In some other embodiments the membrane is itself electrostatically or electrically charged and causes a change in potential as it moves. For example in some embodiments the membrane **203** is configured to be a mobile capacitor plate relative to a fixed capacitor plate provided by the back plate **205**, electrical couplings to each of the two capacitor plates when charged will produce a varying potential as the membrane moves relative to the back plate.

The filter hole **209** can in some embodiments be implemented in the membrane **203**. In other words, in some embodiments the membrane **203** is manufactured as being incomplete or with a portion of the membrane missing to form the filter hole **209**. In some other embodiments the filter hole **209** can be implemented as a hole or missing or removed portion of the supporting structure which is also impinged by the acoustic waves or signals.

The blocking member, which can also be known as a sealing member, plug or plug flap **211** is configured to be actuated in such a way to permit the opening and closing of the filter hole **209**. Thus in some embodiments the action of the blocking member and the filter hole form a mechanical acoustic filter (or electrically controllable mechanical acoustic filter means for changing the acoustic properties of a transducer) which can be activated when the blocking member **211** opens the filter hole **209** or be deactivated when the blocking member closes or seals the filter hole **209**.

The back plate **205** is a material layer which can in some embodiments underlie the microphone membrane **203** and defines between a 'back volume' or acoustic chamber between the membrane **203** and the back plate **205**. The relative position and form of the back plate **205** can in some embodiments be designed as a compromise between producing a good noise performance and overall size of the transducer as it would be understood that a smaller back volume is preferable to produce a smaller MEMS chip or transducer but producing a less acceptable noise spectrum of the noise floor output by the transducer. In some embodiments the back plate **205** comprises at least one back plate hole. The back plate hole can in some embodiments be further used to tune the response of the transducer and permit the membrane to move more freely. In some other embodiments the back plate hole can be located or formed in any support structure which also forms or defines the acoustic chamber. In some embodiments the back plate hole can be covered or at least partially covered to prevent or reduce foreign bodies entering the acoustic chamber.

The topology of the transducer **171** can be further described in further detail with respect to FIGS. **3** and **4** which show a first example of the filter hole and blocking member forming the mechanical acoustic filter according to some embodiments, FIG. **5** which shows a further example of the filter hole and blocking member arrangement forming a mechanical acoustic filter and FIG. **6** which shows the operation of the filter hole and blocking member in further detail.

With respect to FIGS. **3** and **4**, an example topology of a suitable micro-electromechanical system (MEMS) microphone structure for implementation in some embodiments of the application is shown in elevation and plan view. The MEMS **103** microphone comprises in some embodiments a support frame **201** configured to support elements of the microphone such as the membrane **203** and the back plate **205**. The support frame **201** can in some embodiments for example be part of the external structure of the MEMS chip **103** into or through which a cavity can be machined for implementing the membrane/back plate. The support frame **201** in some embodiments. In the example shown in FIGS. **3** and **4** the support structure is octagonal, but could be circular or can be any suitable shaped structure. Within the support frame **201** of the MEMS chip **103** the microphone membrane **203** can be fixed at its edge and located such that at least a portion of the membrane can move in response to acoustic wave pressure. Also within the support frame **201** of the MEMS chip **103** the back plate **205** can be fixed at the back plate edge and located 'underneath' the membrane, where underneath specifies the direction opposite the impact of the acoustic waves on the membrane **203**. Furthermore the relative location of the microphone membrane **203** and back plate **205** define a 'back volume' or acoustic chamber. The back volume/acoustic chamber can, as described herein, be designed such that the microphone is configured to produce a suitable frequency response.

Although the 'back plate' and back volume as shown in FIG. **3** are orientated below the membrane as the acoustic waves act on the membrane from the upper surface, it would be understood that the orientation of the membrane and the relative positions of the back plate and therefore the back volume can be any suitable direction.

Furthermore as shown in FIGS. **3** and **4**, the membrane **203** has located within itself the filter hole **209**, located near to the edge of the membrane and creating a potential through hole in the membrane linking the back volume to the front volume of the MEMS microphone device. In the example shown in FIG. **3** the filter hole **209** is a circular hole in the membrane however it would be understood that any suitable shape of dimension of hole can be implemented. Furthermore in the examples shown in FIGS. **3** and **4** there is only one filter hole which forms the mechanical acoustic filter however more than a single hole can be implemented.

Furthermore the blocking member **211** can as shown in FIGS. **3** and **4** be configured such that at least a portion of the blocking member **211**, the fixed end, is located or fixed with respect to the support frame **201** and a further portion, a movable end, is able to move relative to the fixed end and be configured to be located in one of at least two positions. A first position for the moveable portion of the blocking member **211** is the blocking member **211** configured to be against the membrane **203** and to form a seal over the filter hole **209** and thus configured to close or block the filter hole **209** as can be seen in FIG. **3** by the solid line representation of the blocking member **211**. The second position for the moveable portion of the blocking member **211** is the blocking member **211** configured to be away from the membrane **203** and therefore does not form a seal over the filter hole **209** and thus opening the filter hole **209** as can be seen in FIG. **3** by the dotted representation of the blocking member **211**.

As can be seen in the example shown in FIG. **4** the blocking member **211** located between the membrane and the back plate is a rectangular strip of material larger than the filter hole and flexible enough such that the moveable portion can move to form the seal over the filter hole **209** (closing the filter hole **209**) and also move away from the filter hole **209** opening the filter hole **209**.

Furthermore with respect to FIG. **4**, the example MEMS microphone shows the blocking member actuator **161** shown in FIG. **2***b*. The blocking member actuator **161** in some embodiments can be a pair of control bias pads **301**, **303**. In such embodiments a first pad **301** can be located on the underside of the microphone membrane **203** and a second pad located on the upperside of the back plate **205**. However it would be understood that in some embodiments at least one of the control bias pads may be located on the opposite sides of the membrane **203** or back plate **305** as the blocking member **211**. The control bias pads **301**, **303** can in some embodiments be activated to attract (or in some embodiments repulse) the blocking member **211**. In some embodiments this can be implemented by the blocking member having a first electrostatic or electrical charge and then charging at least one of the control bias pads with a similar or opposite charge thus respectively repelling or attracting the movable portion of the blocking member **211**.

In some embodiments the back plate **205** can further comprise a back plate hole **207**. The back plate hole **207** is representative of at least one back plate hole attempting to minimise the noise contribution caused by acoustic resistance that effects the air moving between the back plate **205** and the membrane **203**. In other words the air "pumped" by the membrane has an open path to the back volume because of the back plate holes. Thus the holes are configured such that any over or under pressure within the back volume between the membrane **203** and back plate **205** can be equalised via the hole with the volume behind the back plate **205**. In some embodiments the back plate hole **207** can be more than a single hole and be any suitable shape. The location of the back plate hole **207** in the back plate forming a through hole between the back volume between the membrane and back plate and a volume behind the back plate **205** can be in any suitable location. In the example shown in FIG. **3** the representative back plate hole **207** is located close but not directly underneath the filter hole **209**.

In some embodiments, for example in optical sensing microphones, as described herein there can be optionally no back plate and as such the acoustic resistance is caused by the MEMS structure and the acoustic membrane pliability.

With respect to FIG. **5**, a further example topology for the MEMS microphone is shown. In this example topology the membrane **203** is smaller than the MEMS microphone support frame **201** and the membrane is directly supported by the membrane support structure **401** which in turn is fixed to the MEMS microphone support structure. In such embodiments and as shown in FIG. **5** the filter hole **209** can be located within the membrane support structure **401** rather or as well as filter holes located in the membrane.

In such embodiments the blocking member **211** can be configured to operate to form a seal sealing the filter hole **209** when the blocking member **211** is activated to do so, and to open the filter hole **209** located in the membrane support structure **401** when not activated. The use of control bias pads **301**, **303** can in such embodiments be used whereby in some embodiments at least one pad can be located on the underside of the membrane support structure **401**. It would also be understood that any of the other arrangement of actuators discussed herein could also be implemented in such embodiments as shown with respect to the example shown in FIG. **5**.

With respect to FIG. **6** the operation of the mechanical acoustic filter in the transducer according to the examples discussed herein is shown in further detail. As can be seen in the first or 'closed' mode, the membrane **301** with filter hole **209**, is located over and in contact with a first control bias pad **301**, the back plate **205** is located under and in contact with a second control bias pad **303**, and the membrane **203** and back plate define a back volume or acoustic chamber within which is located the blocking member **211**. Furthermore in the first of 'closed' mode the blocking member **211** is configured to be attracted by the first control bias pad **301** located on the underside of the membrane **203** attracting the moveable portion of the blocking member **211** to the underside of the membrane **203** and sealing the filter hole **209**.

FIG. **6** also shows the operation of the mechanical acoustic filter in the transducer in a second or 'open' mode, where the second control bias pad **303** located on the upper side of the back plate **205** is biased (for example by using the opposite electrostatic or electrical charge to the charge stored in the blocking member **211**) attracting the moveable portion of the blocking member away from the filter hole and opening the filter hole.

The above operations shown the actuation of the blocking member by a pull or attractive force, however it would be understood that in some embodiments the actuation of the plug flap could be actuated by the use of a push or repulsive force for example by charging at least one of the bias control pads with the same charge as in the moveable portion of the blocking member. Furthermore in some embodiments the actuation of the blocking member can be performed by a combination pull and push forces.

With respect to FIG. **7** an example of multiple filter hole topology is shown whereby the microphone membrane **203** has located at a radius a plurality of filter holes **209**. Underneath the membrane **203** as shown by the cut away section of FIG. **7** is the blocking member **211** which in this embodiment sample is shown as a continuous strip of material suitable for forming a seal over all of the filter holes or for leaving all of the filter holes in an open state.

In such embodiments the dimension, positioning and the number of filter holes can be designed such that the frequency response of the transducer changes according to a desired amount when the filter holes are operated in the open mode compared to when the filter holes are operated in the closed mode.

Furthermore in some embodiments there can be multiple blocking members which can be independently controlled to close (or open) at least one filter hole each such that the frequency response of the microphone can be selectively tuned.

With respect to FIGS. **2***a* and **2***b* are shown apparatus for controlling the operation of the mechanical acoustic filter within the transducer. For example the apparatus shown in FIG. **2***a* comprises an application specific integrated circuit (ASIC) **107** located on the substrate board **101** with the MEMS chip **103** and coupled to the MEMS chip **103** by a bond wire **105**. The ASIC **107** can in some embodiments be optional with the functionality of the ASIC **107** implemented by other elements such as for example a processor running programs to perform the same functionality, the programs being stored on a memory which can also be used to store data to be processed or processed. In some embodiments the ASIC **107** or at least some elements of the ASIC **107** as described herein can be implemented within the MEMS chip **103**. For example in some embodiments the analogue-to-digital converter **14** can be implemented within the MEMS chip **103**.

With respect to FIG. **2***b* the application specific integrated circuit (ASIC) **107** according to some embodiments of the application is shown in further detail. In such embodiments the ASIC **107** can comprise an analogue-to-digital converter (ADC) **14** which is configured to receive from the microphone (or transducer **171** operating as the microphone) and convert analogue electrical signals into a suitable digital format. In some embodiments the ASIC **107** can further comprise an equaliser. The equaliser can be configured with differing filter settings dependent on the activity of the blocking member and filter hole to assist tune the response of the membrane.

In some embodiments the ASIC **107** can comprise an activity determiner **151**. The power determiner in some embodiments can be configured to receive the digital format signals from the ADC **14** and generate a measure of the microphone activity such as for example the power of the signal. In some other embodiments the activity measurement can be a frequency dependent power spectrum for the microphone signal over a determined window or time period. In such embodiments the ASIC **107** can comprise a time to frequency domain converter such as a fast fourier transform converter or discrete fourier transform converter or any suitable time to frequency domain converter. In some embodiment the ASIC **107** can comprise a filterbank prior to the activity determiner **151** and configured to determine the activity of the microphone output for frequency ranges.

In some embodiments the ASIC **107** can comprise a comparator **153** configured to compare the output of the activity determiner **151** against at least one determined threshold value. The comparator **153** can in some embodiments be a fixed one or be a dynamic comparator configured to be able to vary the threshold values dependent the condition of the MEMS microphone. For example in some embodiments the comparator **153** could vary the threshold values dependent on the age of the microphone, whether the microphone has been damaged or for any suitable reason.

In some embodiments the ASIC **107** can comprise an actuator controller **155**. The actuator controller **155** can in some embodiments receive the output of the comparator **153** and generate a signal to power the blocking member actuator **161** within the MEMS microphone **103**.

The ASIC **107** can in some embodiments comprise further elements of known microphone or audio processing systems such as a processing capability for biasing the MEMS microphone element (in other words generating the charge difference between the membrane and back plate) or a preamplifier (for receiving the analogue audio signal and amplifying the analogue audio signal so that the signal is output a suitable potential range).

With respect to FIG. **8**, an example control mechanism and method is shown for controlling the plug flap and filter hole in an wind noise reduction application for the mechanical acoustic filter in the transducer.

As described herein the MEMS **103** microphone generates, for example in some embodiments by the motion of the membrane relative to the back plate a varying potential dependent on the acoustic waves applying a force to the membrane **203**. The ASIC **107** analogue-to-digital converter **14** can in some embodiments generate a digital representation of the microphone output. Furthermore the activity determiner **151** can in some embodiments generate a representation of the microphone activity. This in some embodiments can comprise the activity determiner **151** being configured to determine the power level for the microphone output by squaring the output values from the ADC **14**. However the activity level can in some embodiments be frequency range dependent, in other words a value representing each frequency bin or range.

The determination of the activity value is shown in FIG. **8** by step **601**.

In some embodiments the activity level can be passed to a comparator **153**. The comparator **153** can in some embodiments compare this activity level or value against at least one determined threshold value. The at least one threshold value can be stored in the ASIC **107** or in a memory. In some embodiments the threshold value can be modified when the transducer is in use, in other words the comparator **153** can "learn" when the transducer is about to saturate or produce a activity level or value indicative of a microphone saturation.

The comparator **153** can output the results of the comparison to the actuator controller **155**.

The operation of determining whether the saturation volume level is greater than a threshold value is shown in FIG. **8** by step **603**.

The actuator controller **155** can then be configured to receive the result from the comparator **153** and output a suitable signal to control the plug flap **211** using the blocking member actuator **161**.

The actuator controller **155** can in some embodiments when the comparator **153** determines that the activity level is less than or equal to the determined threshold value send a signal to the blocking member actuator **161** to move the blocking member **211** to close the filter hole. For example in some embodiments the actuator controller **155** can be configured to pass a voltage level to the blocking member actuator **161** bias plates such that the first control bias pad **301** (located on the underside of the membrane) is charged with a charge opposite to that of the blocking member to attract the blocking member to the membrane surface and seal the filter hole **209**.

The controlling of the actuator to move the blocking member to the membrane to close the filter hole is shown in FIG. **8** by step **607**. Following this control operation the method can in some embodiments pass back to the determination of the activity levels.

The actuator controller **155** can in these embodiments be also configured to when the Comparator determines the activity level is greater than the threshold value send a signal to the blocking member actuator **161** to move the blocking member to open the filter hole. For example in some embodiments the actuator controller **155** can be configured to pass a voltage level to the blocking member actuator second control bias pad **303** (located on the back plate) with a charge opposite to the charge in the blocking member **211** to attract the blocking member away from the surface of the membrane **203** and opening the filter hole **209**.

The controlling of the actuator to move the blocking member away from the membrane to open the filter hole is shown in FIG. **8** by step **605**.

Furthermore as described herein, this operation may be continuous and thus following the control operation the method passes back to a further determination of the activity of the microphone as shown in FIG. **8** by step **601**.

In some embodiments the actuation and deactivation of the blocking member can be controlled or delayed. Thus in such embodiments an attack and/or release time can be implemented such that the actuation from open to sealed hole is controlled by the determined attack time period and the deactivation from sealed to open filter hole is controlled by the determined release time period. These attack and/or release time periods can be chosen in some embodiments to achieve a pleasant sounding transient period.

In some embodiments the blocking member can be configured to be naturally biased in either the filter hole closed or filter hole open modes. For example in some embodiments the blocking member can be naturally biased, for example by use of a resilient or elastic member to seal the filter hole and to be attracted to the back plate when the back plate bias pad is activated. Similarly the blocking member can be naturally biased or located away from the filter hole and be actively biased to seal the filter hole. In some embodiments the actuation can be implemented by means other than a biased pad. For example in some embodiments the microphone membrane can be used as an actuator. In such embodiments the charge of the membrane itself can be sufficient to attract the blocking member. In some embodiments the membrane, back plate, or blocking member itself may be configured such to prevent a permanent latch up, in other words the blocking member is not attached to the membrane such that the actuator cannot open the filter hole. This can be achieved for example by having a membrane surface and/or blocking member surface which has a rough profile and therefore does not allow the blocking member to 'stick' to the membrane.

Furthermore in some embodiments permanent sticking or latch up of blocking members can be achieved by using an anti-stick coating on the blocking member and/or membrane.

In some embodiments where there are multiple filter holes, the filter holes can be implemented as different sizes or shapes and be individually controlled. For example in some embodiments filter holes can be opened and closed in such a manner that a gradual filter response change can be implemented.

As shown in FIG. **9** the operation of the mechanical acoustic filter (the opening and closing of the filter hole) is shown by the frequency response **811** of the transducer when the filter hole is closed. In this example the microphone has a low frequency roll off region **801** below which the microphone does not efficiently detect acoustic waves, a central frequency region **803** which defines a relatively frequency independent response section for the microphone, and a high frequency roll off region **805** which defines an upper roll off frequency region. Furthermore as also shown in FIG. **9** is the frequency response **813** of the transducer when the filter hole is open. By opening the filter hole or operating the transducer in an open hole region the low frequency roll-off region occurs at a higher frequency, and therefore the open central frequency region **807** is smaller than when the filter hole is operated in a closed mode. Where the noise is 'white' or approximates to white noise the amount of noise detected by the microphone is therefore reduced, furthermore where the noise is low frequency specific the tuning of the filter hole mechanical acoustic filter can thus significantly reduce the noise detected whilst removing only a portion of the desired voice or other audio source energy.

It shall be appreciated that the term user equipment is intended to cover any suitable type of wireless user equipment, such as mobile telephones, portable data processing devices or portable web browsers. Furthermore, it will be understood that the term acoustic sound channels is intended to cover sound outlets, channels and cavities, and that such sound channels may be formed integrally with the transducer, or as part of the mechanical integration of the transducer with the device.

In general, the various embodiments of the invention may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. For example, some aspects may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device, although the invention is not limited thereto. While various aspects of the invention may be illustrated and described as block diagrams, flow charts, or using some other pictorial representation, it is well understood that these blocks, apparatus, systems, techniques or methods described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

The embodiments of this invention may be implemented by computer software executable by a data processor of the mobile device, such as in the processor entity, or by hardware, or by a combination of software and hardware. Further in this regard it should be noted that any blocks of the logic flow as in the Figures may represent program steps, or interconnected logic circuits, blocks and functions, or a combination of program steps and logic circuits, blocks and functions. The software may be stored on such physical media as memory chips, or memory blocks implemented within the processor, magnetic media such as hard disk or floppy disks, and optical media such as for example DVD and the data variants thereof, CD.

The memory may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor-based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The data processors may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), application specific integrated circuits (ASIC), gate level circuits and processors based on multi-core processor architecture, as non-limiting examples.

Embodiments of the inventions may be practiced in various components such as integrated circuit modules. The design of integrated circuits is by and large a highly automated process. Complex and powerful software tools are available for converting a logic level design into a semiconductor circuit design ready to be etched and formed on a semiconductor substrate.

Programs, such as those provided by Synopsys, Inc. of Mountain View, Calif. and Cadence Design, of San Jose, Calif. automatically route conductors and locate components on a semiconductor chip using well established rules of design as well as libraries of pre-stored design modules. Once the design for a semiconductor circuit has been completed, the resultant design, in a standardized electronic format (e.g., Opus, GDSII, or the like) may be transmitted to a semiconductor fabrication facility or "fab" for fabrication.

As used in this application, the term 'circuitry' refers to all of the following:

(a) hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry) and

(b) to combinations of circuits and software (and/or firmware), such as: (i) to a combination of processor(s) or (ii) to portions of processor(s)/software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions and

(c) to circuits, such as a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present.

This definition of 'circuitry' applies to all uses of this term in this application, including any claims. As a further example, as used in this application, the term 'circuitry' would also cover an implementation of merely a processor (or multiple processors) or portion of a processor and its (or their) accompanying software and/or firmware. The term 'circuitry' would also cover, for example and if applicable to the particular claim element, a baseband integrated circuit or applications processor integrated circuit for a mobile phone or similar integrated circuit in server, a cellular network device, or other network device.

The foregoing description has provided by way of exemplary and non-limiting examples a full and informative description of the exemplary embodiment of this invention. However, various modifications and adaptations may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the accompanying drawings and the appended claims. However, all such and similar modifications of the teachings of this invention will still fall within the scope of this invention as defined in the appended claims.

The invention claimed is:

1. An acoustic transducer comprising:

a membrane,

a back plate, where the membrane and the back plate form a volume of air therebetween; and

a mechanical acoustic filter configured to be electrically controllable to change acoustic properties of the acoustic transducer,

where the mechanical acoustic filter is formed by having at least one filter hole located in the membrane and/or having at least one filter hole located in a membrane support surrounding the membrane, and having at least one moveable portion of at least one blocking member located within the volume of air, where the at least one blocking member is electrically controllable, and where the at least one movable portion of the at least one blocking member is configured to selectively seal the at least one filter hole.

2. The acoustic transducer as claimed in claim **1**, wherein the transducer is a capacitive transducer comprising the membrane and the back plate.

3. The acoustic transducer as claimed in claim **1**, wherein the at least one blocking member comprises a resilient member biased in an open or blocking state.

4. The acoustic transducer as claimed in claim **1**, further comprising a blocking member actuator.

5. The acoustic transducer as claimed in claim **4**, wherein the blocking member actuator comprises at least one bias member, wherein the at least one bias member is configured to be electrically or electrostatically charged to attract or repel the blocking member.

6. The acoustic transducer as claimed in claim **1**, wherein the blocking member comprises at least one of the following:

an anti-stick coating; and

an anti-stick profile.

7. The acoustic transducer as claimed in claim **1**, wherein the electrically controllable mechanical acoustic filter changes the acoustic properties of the transducer.

8. The acoustic transducer as claimed in claim **1**, wherein the acoustic transducer comprises at least one of:

a microphone; and

a speaker.

9. An apparatus comprising:

the acoustic transducer as claimed in claim **1**; and

a controller configured to control the mechanical acoustic filter.

10. The apparatus as claimed in claim **9**, further comprising a sensor configured to determine activity of the acoustic transducer, wherein the controller is further configured to control the mechanical acoustic filter dependent on a sensor value.

11. The apparatus as claimed in claim **9**, wherein the apparatus determines activity of the acoustic transducer; and

electrically controls the mechanical acoustic filter to change the acoustic properties of the transducer dependent on the activity of the transducer.

12. The apparatus as claimed in claim **9**, wherein the controller is configured to control the mechanical acoustic filter in at least one of:

a binary mode of control;

a continuous mode of control; and

a discrete stepwise control.

13. A method for an acoustic transducer comprising a membrane and a back plate configured to form a volume of air therebetween, the method comprising:

electrically controlling a mechanical acoustic filter to change acoustic properties of the acoustic transducer, wherein the mechanical acoustic filter is formed by having at least one filter hole located in the membrane and/or having at least one filter hole located in a membrane support surrounding the membrane, and having at least one moveable portion of at least one blocking member located within the volume of air, where the at least one blocking member is electrically controllable, and where the at least one movable portion of the at least one blocking member is configured to selectively seal the at least one filter hole, and

where electrically controlling the mechanical acoustic filter comprises electrically controlling the at least one blocking member within the volume of air to selectively seal the at least one filter hole.

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