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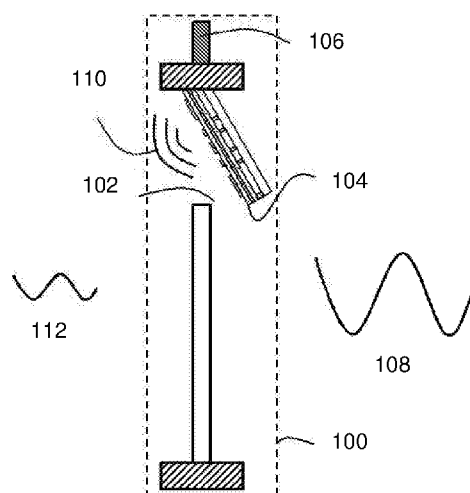


Figure 1

(57) Abstract: A window system, a method of managing noise and a method of installing a noise management system on a window are provided. The window system includes a ventilation channel and a noise management system in or adjacent the ventilation channel. The noise management system includes a multi-cell transparent electroactive film speaker and a control unit connected to the multi-cell transparent electroactive film speaker. The multi-cell transparent electroactive film speaker includes a plurality of individually operable electroactive cells. Each cell includes a respective series of resonance frequencies such that the multi-cell transparent electroactive film speaker is capable of multiple series of resonance frequencies. The control unit is configured to actively detect an incident noise entering the ventilation channel and control at least one cell of the multi-cell transparent electroactive film speaker to generate a corresponding counter noise to substantially cancel the incident noise.

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WINDOW WITH NOISE MANAGEMENT AND RELATED METHODS

FIELD OF INVENTION

[0001] The present invention relates broadly, but not exclusively, to a window system, to a method of managing noise and to a method of installing a noise management system on a window.

BACKGROUND

[0002] The harmful effects of noise pollution are well-recognized. For example, exposure to a high noise level can cause hearing loss. Even at a low noise level, noise disturbance can have a significant negative effect on psychological health and quality of life, and a reduction in working and learning efficiency. Typically, windows provide a main path through which noise enters a building, hence, effectively reducing noise transmission through windows is often important to mitigate noise pollution in an urban area and achieve acoustic comfort in a room.

[0003] A major challenge for reducing noise transmission through a window is that the noise reduction is desired to be effective across the whole window area while the window should still remain transparent and be aesthetically acceptable.

[0004] Conventionally, double-glazed technology is one of the main passive means to reduce noise transmission through window. However, this technology is not satisfactory in low frequency range. Embedding active noise mitigation elements within double glazed windows has led in improved noise mitigation performance at low frequencies. For example, electromagnetic loud-speakers can be embedded within the air gap of the double glazed window. However, such windows are bulky and costly, and not aesthetically acceptable.

[0005] Alternative actuators instead of electromagnetic loud speakers may be discretely installed on the window glass, connected to driver circuits to realize active noise control, particularly for low frequency noise. However, these windows are not able to achieve uniform noise mitigation over the entire area, in addition to

the increased cost, and reduced transparency and aesthetics. The reduction of noise may vary significantly at different locations. Analysis results show that uniform noise mitigation can be achieved only when the length of the window glass pane is less than one-fifth of the wavelength of sound in air (e.g. $0.14 \times 0.14 \text{ m}^2$ for frequencies up to 500 Hz). Such a small window glass is not practical for real applications.

[0006] The aesthetic issues and the uniform noise mitigation over the window area can be partially resolved by replacing the discrete actuators on the window with a transparent piezoelectric film speaker. However, since sound pressure output of a transparent piezoelectric film speaker is significant only at resonance frequencies, the noise mitigation performance of the window is effective only at limited resonance frequencies of the single transparent piezoelectric film speaker.

[0007] In conventional active noise mitigation windows, the primary noise is normally measured by a reference microphone and analyzed and processed using a control system. The control system then generates a driving signal to drive the loud speaker to generate an anti-phase acoustic wave for mitigating the primary noise. To achieve uniform noise mitigation over a large area, several reference microphones and several loud speakers have to be installed on the windows, which can further increase the cost of the window and aggravate the aesthetic issue.

[0008] Furthermore, a common problem of all of the technologies above is the need for the windows to remain closed, hence a lack of natural ventilation. Thus, the air quality indoors may be worsened, while heavy use of air-conditioning systems can lead to more power consumption. Noise mitigation windows with ventilation using localized electromagnetic speakers at the window frame are only effective in the vicinity of the speakers but not over the whole area of the window.

[0009] A need therefore exist to provide a window system that includes noise management and that can address at least some of the above problems.

SUMMARY

[0010] An aspect of the present invention provides a window system comprising a ventilation channel and a noise management system in or adjacent the ventilation

channel. The noise management system comprises a multi-cell transparent electroactive film speaker comprising a plurality of individually operable electroactive cells, wherein each cell includes a respective series of resonance frequencies such that the multi-cell transparent electroactive film speaker is capable of multiple series of resonance frequencies, and a control unit connected to the multi-cell transparent electroactive film speaker. The control unit is configured to actively detect an incident noise entering the ventilation channel and control at least one cell of the multi-cell transparent electroactive film speaker to generate a corresponding counter noise to substantially cancel the incident noise.

[0011] The multi-cell transparent electroactive film speaker may comprise a layered structure comprising a plurality of transparent patterned top electrodes corresponding to the plurality of cells, a transparent electroactive layer disposed below the transparent top electrodes, a transparent bottom electrode layer disposed below the transparent electroactive layer, and a transparent substrate layer disposed below the transparent bottom electrode layer.

[0012] The layered structure may further comprise a transparent grid configured to mechanically secure the individual cells and separate the cells from each other.

[0013] The individual transparent top electrodes may be electrically separated from each other.

[0014] Each cell of the multi-cell transparent electroactive film speaker may comprise a respective size corresponding to its series of resonance frequencies.

[0015] Each cell of the multi-cell transparent electroactive film speaker may comprise a respective geometry corresponding to its series of resonance frequencies.

[0016] The transparent electroactive layer may comprise a transparent piezoelectric material.

[0017] The control unit may comprise a first acoustic sensor to actively detect the incident noise and a second acoustic sensor configured to detect a transmitted noise exiting the ventilation channel, and the control unit may be further configured

to adjust the counter noise generated by the at least one cell based on the detected transmitted noise.

[0018] The control unit may comprise a first acoustic sensor to actively detect the incident noise, and the first acoustic sensor may comprise at least one selected cell of the multi-cell transparent electroactive film speaker.

[0019] The window system may further comprise at least one sash, and the at least one sash may be rotationally adjustable to form the ventilation channel.

[0020] The window system may further comprise at least one sash, and the at least one sash may be translationally adjustable to form the ventilation channel.

[0021] The window system may comprise a first sash and a second sash, and the ventilation channel may be in a space between the first and second sashes.

[0022] Another aspect of the present invention provides a method of managing noise. The method comprises providing, on a window having a ventilation channel, a multi-cell transparent electroactive film speaker and a control unit connected to the multi-cell transparent electroactive film speaker, the multi-cell transparent electroactive film speaker comprising a plurality of individually operable electroactive cells, wherein each cell includes a respective series of resonance frequencies such that the multi-cell transparent electroactive film speaker is capable of multiple series of resonance frequencies. The method further comprises actively detecting, by the control unit, an incident noise entering the ventilation channel, and generating a corresponding counter noise to substantially cancel the incident noise by controlling at least one cell of the multi-cell transparent electroactive film speaker based on the detected incident noise.

[0023] Providing the multi-cell transparent electroactive film speaker may comprise providing a layered structure comprising a plurality of transparent patterned top electrodes corresponding to the plurality of cells, a transparent electroactive layer disposed below the transparent top electrodes, a transparent bottom electrode layer disposed below the transparent electroactive layer, a transparent substrate layer disposed below the transparent bottom electrode layer, and a transparent grid configured to mechanically secure the individual cells and separate the cells from each other.

[0024] The transparent electroactive layer may comprise a transparent piezoelectric material.

[0025] Actively detecting the incident noise may comprise using a first acoustic sensor.

[0026] The method may further comprise detecting a transmitted noise exiting the ventilation channel using a second acoustic sensor, and adjusting the counter noise generated by the at least one cell based on the detected transmitted noise.

[0027] Actively detecting the incident noise may comprise using a first acoustic sensor, and the first acoustic sensor may comprise at least one selected cell of the multi-cell transparent electroactive film speaker.

[0028] Another aspect of the present invention provides a method of installing a noise management system on a window. The method comprises mounting a multi-cell transparent electroactive film speaker in or adjacent a ventilation channel of the window, the multi-cell transparent electroactive film speaker comprising a plurality of individually operable electroactive cells, wherein each cell includes a respective series of resonance frequencies such that the multi-cell transparent electroactive film speaker is capable of multiple series of resonance frequencies. The method further comprises connecting a control unit to the multi-cell transparent electroactive film speaker, the control unit being configured to actively detect an incident noise entering the ventilation channel and control at least one cell of the multi-cell transparent electroactive film speaker to generate a corresponding counter noise to substantially cancel the incident noise.

[0029] Mounting the multi-cell transparent electroactive film speaker may comprise mounting a layered structure comprising a plurality of transparent patterned top electrodes corresponding to the plurality of cells, a transparent electroactive layer disposed below the transparent top electrodes, a transparent bottom electrode layer disposed below the transparent electroactive layer, a transparent substrate layer disposed below the transparent bottom electrode layer, and a transparent grid configured to mechanically secure the individual cells and separate the cells from each other.

[0030] The control unit may comprise a first acoustic sensor, a second acoustic sensor, and a control circuit communicatively coupled to the first and second acoustic sensors.

[0031] The first acoustic sensor may comprise at least one selected cell of the multi-cell transparent electroactive film speaker.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] Embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

[0033] Figure 1 shows a schematic block diagram of a window system according to an example embodiment.

[0034] Figure 2a shows a schematic plan view of a multi-cell transparent electroactive film speaker of the system of Figure 1 according to the example embodiment.

[0035] Figure 2b shows a schematic cross-sectional view of the multi-cell transparent electroactive film speaker of Figure 2a.

[0036] Figure 3 shows the window system of Figure 1 including a block diagram of the control unit according to an example embodiment.

[0037] Figure 4 shows the window system of Figure 1 including a block diagram of the control unit according to an alternate embodiment.

[0038] Figure 5 shows a schematic perspective view of an implementation of the window system of Figure 1.

[0039] Figure 6 shows a schematic side view of another implementation of the window system of Figure 1.

[0040] Figure 7 shows a schematic perspective view of another implementation of the window system of Figure 1.

[0041] Figure 8 shows a schematic top view of another implementation of the window system of Figure 1.

[0042] Figure 9 shows a flow chart of a method of managing noise according to an example embodiment.

[0043] Figure 10 shows flow chart of a method of installing a noise management system on a window according to an example embodiment.

DETAILED DESCRIPTION

[0044] The example embodiments provide a window system having both ventilation and noise management over a broad audio frequency range. The window system comprises a ventilation channel and a noise management system in or adjacent the ventilation channel. The noise management system comprises a multi-cell transparent electroactive film speaker and a control unit connected to the multi-cell transparent electroactive film speaker. The multi-cell transparent electroactive film speaker includes a plurality of individually operable electroactive cells. Each cell includes a respective series of resonance frequencies such that the multi-cell transparent electroactive film speaker is capable of multiple series of resonance frequencies. The control unit is configured to actively detect an incident noise entering the ventilation channel and control at least one cell of the multi-cell transparent electroactive film speaker to generate a corresponding counter noise to cancel the incident noise. The example embodiments also provide a method of managing noise and a method of installing a noise management system on a window.

[0045] The example embodiments will now be described, by way of example only, with reference to the drawings. Like reference numerals and characters in the drawings refer to like elements or equivalents.

[0046] Figure 1 shows a schematic block diagram of a window system 100 according to an example embodiment. The window system 100 comprises a ventilation channel 102, a transparent film speaker 104 having a plurality of individually operable electroactive cells (hereinafter also referred to as a multi-cell transparent electroactive film speaker 104) in the ventilation channel 102 and a control unit 106. As described in further detail below, the multi-cell transparent electroactive film speaker

104 is made up of multiple speaker cells which have varied geometries and/or dimensions, and hence varied resonance frequencies from each other.

[0047] Typically, in operation, an incident (or primary) noise 108 enters the ventilation channel 102 and is detected by the control unit 106. The control unit 106 causes the multi-cell transparent electroactive film speaker 104 to emit a corresponding counter noise 110 to substantially cancel or reduce the incident noise 108. For example, the counter noise 110 is anti-phase to the incident noise 108 (e.g. 180° out of phase) and destructively interferes or interacts with the incident noise 108, such that a transmitted noise 112 exiting the ventilation channel is reduced or minimised. When installed on a building, the window system 100 can help to mitigate noise coming into the building from an outdoor environment.

[0048] Figure 2a and 2b show schematic top view and cross-sectional view, respectively, of the multi-cell transparent electroactive film speaker 104 of the window system 100 according to an example embodiment. The multi-cell transparent electroactive film speaker 104 includes a plurality of transparent patterned top electrodes 202 corresponding to the plurality of speaker cells 204, a transparent electroactive layer 206 disposed below the transparent top electrode electrodes 202, a transparent bottom electrode layer 208 disposed below the transparent electroactive layer 206, and a transparent substrate layer 210 disposed below the bottom electrode layer 208. In some embodiments, the transparent substrate layer 210 can move the neutral line of the structure out of the transparent electroactive layer 206. For example, by forming the transparent substrate layer 210 with the right material and thickness, the magnitude of the vibration excited by the electric field, and hence the sound pressure performance of the multi-cell transparent electroactive film speaker 104, can be significantly improved.

[0049] The multi-cell transparent electroactive film speaker 104 further includes a transparent grid 212. The transparent grid 212 and patterned top electrodes 202 separate the transparent electroactive film speaker 104 into the multiple speaker cells, mechanically and electrically respectively, such that each speaker cell has its own set of resonance frequencies preferably different from the others and can be operated independently.

[0050] As can be seen from Figure 2, the speaker cells 204 have different sizes and geometry, resulting in corresponding different acoustic characteristics. For example, a square speaker cell 204 may exhibit different set of resonance frequencies from a

rectangular speaker cell 204. Similarly, a smaller speaker cell 204 may have different set of resonance frequencies from a larger speaker cell 204. For broadband performance, a wide variety of geometry and sizes may be used. For specific situations, e.g. low frequency noise, these parameters can be adapted accordingly such that the speaker cells are responsive to the desired frequency range.

[0051] The transparent electroactive layer 206 of the multi-cell transparent electroactive film speaker 104 may be fabricated from a transparent piezoelectric polymer with sufficiently high piezoelectric strain coefficients, including but not limited to polyvinylidene fluoride (PVDF), polyvinylidene fluoride–trifluoroethylene (P(VDF-TrFE)), or a transparent electroactive polymer including but not limited to electrets and dielectric elastomers. The transparent top and bottom electrode layers 202, 208 may be fabricated by coating a transparent conductive material including but not limited to indium tin oxide (ITO), carbon nano-tube, carbon nano-bud, graphene, metal nano-wires, poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS), on the transparent electroactive layer 206.

[0052] Figure 3 shows the window system 100 of Figure 1 including a block diagram of the control unit 106 according to an example embodiment. The control unit 106 comprises a first acoustic sensor in the form of at least one reference microphone 302, an analog to digital converter (ADC) 304, a digital signal processing (DSP) unit 306, a digital to analog converter (DAC) 308, a power amplifier 310 and a second acoustic sensor in the form of an error microphone 312. A primary (i.e. incident) noise 108, which is carried by the air flow through the ventilation channel 102, is sensed by the reference microphone 302. The ADC 304 converts the input analog primary noise signal from the reference microphone 302 to digital format data which is processed by the digital signal processing unit 306, based on a digital signal processor or field programmable gate array (FPGA), to generate a suitable digital output signal to be fed to the DAC 308 to produce an analog signal. The analog signal output of DAC 308 is amplified via the power amplifier 310 and fed to the multi-cell transparent electroactive film speaker 104 to generate multiple cancelling (i.e. counter) noise 110 of anti-phase with the primary noise 108 at the various resonance frequencies of individual cells of the multi-cell transparent electroactive film speaker 104. The destructive interaction of the primary noise 108 and the cancelling noise 110 within the ventilation channel 102 results in a reduction of noise transmitted through the window system 100 over a broad audio frequency range.

[0053] Further, in the example embodiments, the analog transmitted noise signal 112, measured by the error microphone 312, is converted by the ADC 304 to digital format data and is analyzed by the digital signal processing unit 306 and compared with the primary noise data to optimize the digital output signal of the digital signal processing unit 306, to adjust the phase as well as sound pressure level of the cancelling noise 110 at individual frequencies. In other words, the control unit 106 includes a feedback loop to optimise or tune the speaker 104.

[0054] Figure 4 shows the window system 100 of Figure 1 including a block diagram of a control unit 400 according to an alternate embodiment. Here, the electroactive layer 206 (Figure 2b) is made of a piezoelectric material and the reference microphones are replaced with one or more sound sensors 402 integrated on a multi-cell transparent piezoelectric film speaker 403 (i.e. a multi-cell transparent electroactive film speaker in which the electroactive layer comprises a piezoelectric material). The sound sensors 402 have the same structure as speaker cells 404 of the multi-cell transparent piezoelectric film speaker 403 and are fabricated on the same transparent piezoelectric film. Due to the piezoelectric effect, the primary noise 108 can generate an electrical signal as the output of the sound sensors 402. The electrical signal is used by the control unit 400 to generate the driving signal to activate the multi-cell transparent piezoelectric film speaker 403 to generate the desired counter noise 110, similar to the operation of the control unit as described in Figure 3.

[0055] It has been noted that sound pressure level of the cancelling noise 110 generated by the multi-cell transparent electroactive film speaker 104 is largest at resonance frequencies of the speaker cells. Due to different sizes and shapes of the speaker cells of the multi-cell transparent electroactive film speaker 104 in the example embodiments, each of the speaker cells possesses a series of resonance frequencies different from the others. As a result, the multi-cell transparent electroactive film speaker 104 has multiple series of resonance frequencies over a broad frequency range. Since the sound pressure is largest at the resonance frequencies, the multi-cell transparent electroactive film speaker 104 has large sound pressure output over a broad frequency range and thus can minimize the transmitted noise over a broad audio frequency range.

[0056] For example, a multi-cell transparent piezoelectric film speaker (i.e. one in which the electroactive layer comprises a piezoelectric material) comprising a 25 μm thick PVDF film and a 75 μm thick polyethylene terephthalate (PET) substrate was simulated and the resonance frequencies of each of the speaker cells were examined.

Six different sizes and geometries of speaker cells were combined to form the multi-cell transparent piezoelectric film speaker having 15 speaker cells in total. Table 1 summarizes the simulation results of frequencies for the first three resonance modes. It has been found that the multi-cell transparent piezoelectric film speaker exhibits multiple resonance frequencies in the range of 69-938 Hz.

Table 1 – Simulation Results of Resonance Frequencies

<i>Speaker Cell Area (mm²)</i>	<i>1st Res. Freq. (Hz)</i>	<i>2nd Res. Freq. (Hz)</i>	<i>3rd Res. Freq. (Hz)</i>
35.0×35.0	69	140	205
35.0×19.5	156	230	320
35.0×17.5	189	242	340
19.5×17.5	249	552	810
35.0×13.0	327	605	886
17.5×13.0	396	657	938

[0057] The window system 100 as described can be implemented in various building designs, either as a complete replacement of a conventional window or as a retrofit or upgrade thereof. While existing solutions are generally against having an opening for air flow, the window system 100 has the advantage of both ventilation and noise management capabilities, and indeed uses the ventilation channel for effective noise management.

[0058] Figure 5 shows a schematic perspective view of an implementation of the window system 100 of Figure 1 in the form of a noise mitigation window 500. In this implementation, the window 500 comprises split lower and upper parts 502, 504. The lower part 502 is the conventional window without ventilation when closed. The upper part 504 of the window 500 has a sash 506 which can be rotationally adjusted to have a certain opening to form a ventilation channel 508. The upper part 504 of the window 500 further comprises a multi-cell transparent piezoelectric film speaker 510 on the sash 506 in the ventilation channel 508 and a control system 512.

[0059] In use, a primary noise 516 enters the ventilation channel 506 with the air flow. The multi-cell transparent piezoelectric film speaker 510 is activated by the control system 512 and generates a broad band cancelling noise 518 over a large area, with anti-phase to the primary noise 516, and results in a reduction of transmitted noise 520 through the window 500.

[0060] Figure 6 shows a schematic side view of another implementation of the window system 100 of Figure 1 in the form of a noise mitigation window 600. Here, the window 600 comprises split upper and lower parts 602, 604. The lower part 604 is the conventional window without ventilation when closed. The upper part 602 has a ventilation channel 606 with a front sash 608 and a rear sash 610. The window 600 further comprises a multi-cell transparent piezoelectric film speaker 612 in the ventilation channel 606 and a control system 614.

[0061] In use, a primary (i.e. incident) noise 618 enters the ventilation channel 606 with the air flow. The multi-cell transparent piezoelectric film speaker 612 is activated by the control system 614 and generates a broad band cancelling noise (i.e. counter noise) 620 over a large area, with anti-phase to the primary noise 618, and results in a reduction of transmitted noise 622 through the window 600.

[0062] Figure 7 shows a schematic perspective view of another implementation of the window system of Figure 1 in the form of a noise mitigation window 700. According to this implementation, the window 700 comprises split upper and lower parts 702, 704. The upper and lower parts 702, 704 each have a ventilation channel with front and rear sashes. For example, the upper part 702 has an upper ventilation channel 706 with upper front sash 708 and upper rear sash 710, while the lower part 704 has a lower ventilation channel 712 with lower front sash 714 and lower rear sash 716. The window 700 further comprises two multi-cell transparent piezoelectric film speakers 718, 720, one (718) in the upper ventilation channel 706 of the upper part 702 and another (720) in the lower ventilation channel 712 of the lower part 704, and a control system 722. Compared to the windows 500 and 600 as described above with reference to Figures 5 and 6 respectively, the noise mitigation window 700 according to this implementation may allow more ventilation as well as effective noise mitigation performance.

[0063] Figure 8 shows a schematic top view of another implementation of the window system of Figure 1 in the form of a noise mitigation window 800. In this implementation, the window 800 comprises a ventilation channel 802 formed between a front sliding sash 804 and a rear sliding sash 806 spaced from and opposite to the front sliding sash 804 in relation to a window frame 808. The window 800 further comprises a multi-cell transparent piezoelectric film speaker 810 mounted on an optional transparent supporting layer 812 in the ventilation channel 802, and a control system 814.

[0064] In use, a primary noise 816 enters the ventilation channel 802 together with the air flow. The multi-cell transparent piezoelectric film speaker 810 is activated by the control system 814 and generates a broadband cancelling noise 818 over a large area, with anti-phase to the primary noise 816, and results in a reduction of transmitted noise 820 through the window 800. Compared to the windows 500, 600 and 700 as described above with reference to Figures 5 to 7, this implementation is suitable for implementation to windows with a slidable (i.e. translationally adjustable) sash. The multi-cell transparent piezoelectric film speaker 810 of this implementation can cover a larger area within the ventilation channel 802 for a more effective interaction between the primary noise 816 and cancelling noise 818.

[0065] Figure 9 shows a flow chart 900 of a method of managing noise according to an example embodiment. At step 902, a multi-cell transparent electroactive film speaker and a control unit connected to the multi-cell transparent electroactive film speaker are provided on a window having a ventilation channel. The multi-cell transparent electroactive film speaker comprises a plurality of individually operable electroactive cells, and each cell includes a respective series of resonance frequencies such that the multi-cell transparent electroactive film speaker is capable of multiple series of resonance frequencies. At step 904, the control unit actively detects an incident noise entering the ventilation channel. At step 906, a corresponding counter noise to substantially cancel the incident noise is generated by controlling at least one cell of the multi-cell transparent electroactive film speaker based on the detected incident noise.

[0066] Figure 10 shows flow chart of a method of installing a noise management system on a window according to an example embodiment. At step 1002, a multi-cell transparent electroactive film speaker is mounted in or adjacent a ventilation channel of the window. The multi-cell transparent electroactive film speaker comprises a plurality of individually operable electroactive cells, and each cell includes a respective series of resonance frequencies such that the multi-cell transparent electroactive film speaker is capable of multiple series of resonance frequencies. At step 1004, a control unit is connected to the multi-cell transparent electroactive film speaker. The control unit is configured to actively detect an incident noise entering the ventilation channel and control at least one cell of the multi-cell transparent electroactive film speaker to generate a corresponding counter noise to substantially cancel the incident noise.

[0067] It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. A window system comprising:
 - a ventilation channel; and
 - a noise management system in or adjacent the ventilation channel, the noise management system comprising:
 - a multi-cell transparent electroactive film speaker comprising a plurality of individually operable electroactive cells, wherein each cell includes a respective series of resonance frequencies such that the multi-cell transparent electroactive film speaker is capable of multiple series of resonance frequencies; and
 - a control unit connected to the multi-cell transparent electroactive film speaker,
 - wherein the control unit is configured to actively detect an incident noise entering the ventilation channel and control at least one cell of the multi-cell transparent electroactive film speaker to generate a corresponding counter noise to substantially cancel the incident noise.
2. The window system as claimed in claim 1, wherein the multi-cell transparent electroactive film speaker comprises a layered structure comprising:
 - a plurality of transparent patterned top electrodes corresponding to the plurality of cells;
 - a transparent electroactive layer disposed below the transparent top electrodes;
 - a transparent bottom electrode layer disposed below the transparent electroactive layer; and
 - a transparent substrate layer disposed below the transparent bottom electrode layer.
3. The window system as claimed in claim 2, wherein the layered structure further comprises a transparent grid configured to mechanically secure the individual cells and separate the cells from each other.
4. The window system as claimed in claim 2 or 3, wherein the individual transparent top electrodes are electrically separated from each other.

5. The window system as claimed in claim 4, wherein each cell of the multi-cell transparent electroactive film speaker comprises a respective size corresponding to its series of resonance frequencies.

6. The window system as claimed in claim 4, wherein each cell of the multi-cell transparent electroactive film speaker comprises a respective geometry corresponding to its series of resonance frequencies.

7. The window system as claimed in any one of claims 2 to 6, wherein the transparent electroactive layer comprises a transparent piezoelectric material.

8. The window system as claimed in claim 1, wherein the control unit comprises a first acoustic sensor to actively detect the incident noise and a second acoustic sensor configured to detect a transmitted noise exiting the ventilation channel, and wherein the control unit is further configured to adjust the counter noise generated by the at least one cell based on the detected transmitted noise.

9. The window system as claimed in claim 1, wherein the control unit comprises a first acoustic sensor to actively detect the incident noise, and wherein the first acoustic sensor comprises at least one selected cell of the multi-cell transparent electroactive film speaker.

10. The window system as claimed in any one of the preceding claims, further comprising at least one sash, wherein the at least one sash is rotationally adjustable to form the ventilation channel.

11. The window system as claimed in any one of claims 1 to 9, further comprising at least one sash, wherein the at least one sash is translationally adjustable to form the ventilation channel.

12. The window system as claimed in claim 10 or 11, comprising a first sash and a second sash, wherein the ventilation channel is in a space between the first and second sashes.

13. A method of managing noise, the method comprising:

providing, on a window having a ventilation channel, a multi-cell transparent electroactive film speaker and a control unit connected to the multi-cell transparent

electroactive film speaker, the multi-cell transparent electroactive film speaker comprising a plurality of individually operable electroactive cells, wherein each cell includes a respective series of resonance frequencies such that the multi-cell transparent electroactive film speaker is capable of multiple series of resonance frequencies;

actively detecting, by the control unit, an incident noise entering the ventilation channel; and

generating a corresponding counter noise to substantially cancel the incident noise by controlling at least one cell of the multi-cell transparent electroactive film speaker based on the detected incident noise.

14. The method as claimed in claim 13, wherein providing the multi-cell transparent electroactive film speaker comprises providing a layered structure comprising:

a plurality of transparent patterned top electrodes corresponding to the plurality of cells;

a transparent electroactive layer disposed below the transparent top electrodes;

a transparent bottom electrode layer disposed below the transparent electroactive layer;

a transparent substrate layer disposed below the transparent bottom electrode layer; and

a transparent grid configured to mechanically secure the individual cells and separate the cells from each other.

15. The method as claimed in claim 14, wherein the transparent electroactive layer comprises a transparent piezoelectric material.

16. The method as claimed in claim 15, wherein actively detecting the incident noise comprises using a first acoustic sensor.

17. The method as claimed in claim 16, further comprising:

detecting a transmitted noise exiting the ventilation channel using a second acoustic sensor; and

adjusting the counter noise generated by the at least one cell based on the detected transmitted noise.

18. The method as claimed in claim 15, wherein actively detecting the incident noise comprises using a first acoustic sensor, the first acoustic sensor comprising at least one selected cell of the multi-cell transparent electroactive film speaker.

19. A method of installing a noise management system on a window, the method comprising:

mounting a multi-cell transparent electroactive film speaker in or adjacent a ventilation channel of the window, the multi-cell transparent electroactive film speaker comprising a plurality of individually operable electroactive cells, wherein each cell includes a respective series of resonance frequencies such that the multi-cell transparent electroactive film speaker is capable of multiple series of resonance frequencies;

connecting a control unit to the multi-cell transparent electroactive film speaker, the control unit being configured to actively detect an incident noise entering the ventilation channel and control at least one cell of the multi-cell transparent electroactive film speaker to generate a corresponding counter noise to substantially cancel the incident noise.

20. The method as claimed in claim 19, wherein mounting the multi-cell transparent electroactive film speaker comprises mounting a layered structure comprising:

a plurality of transparent patterned top electrodes corresponding to the plurality of cells;

a transparent electroactive layer disposed below the transparent top electrodes;

a transparent bottom electrode layer disposed below the transparent electroactive layer;

a transparent substrate layer disposed below the transparent bottom electrode layer; and

a transparent grid configured to mechanically secure the individual cells and separate the cells from each other.

21. The method as claimed in claim 19 or 20, wherein the control unit comprises a first acoustic sensor, a second acoustic sensor, and a control circuit communicatively coupled to the first and second acoustic sensors.

22. The method as claimed in claim 21, wherein the first acoustic sensor comprises at least one selected cell of the multi-cell transparent electroactive film speaker.

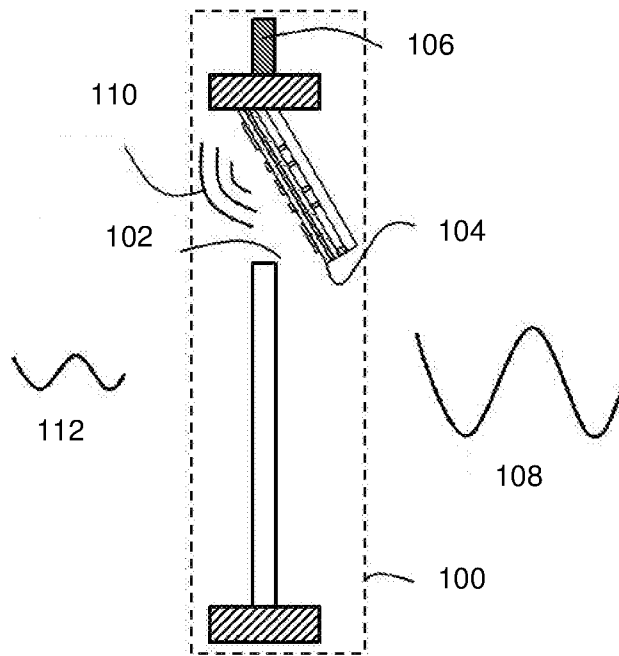


Figure 1

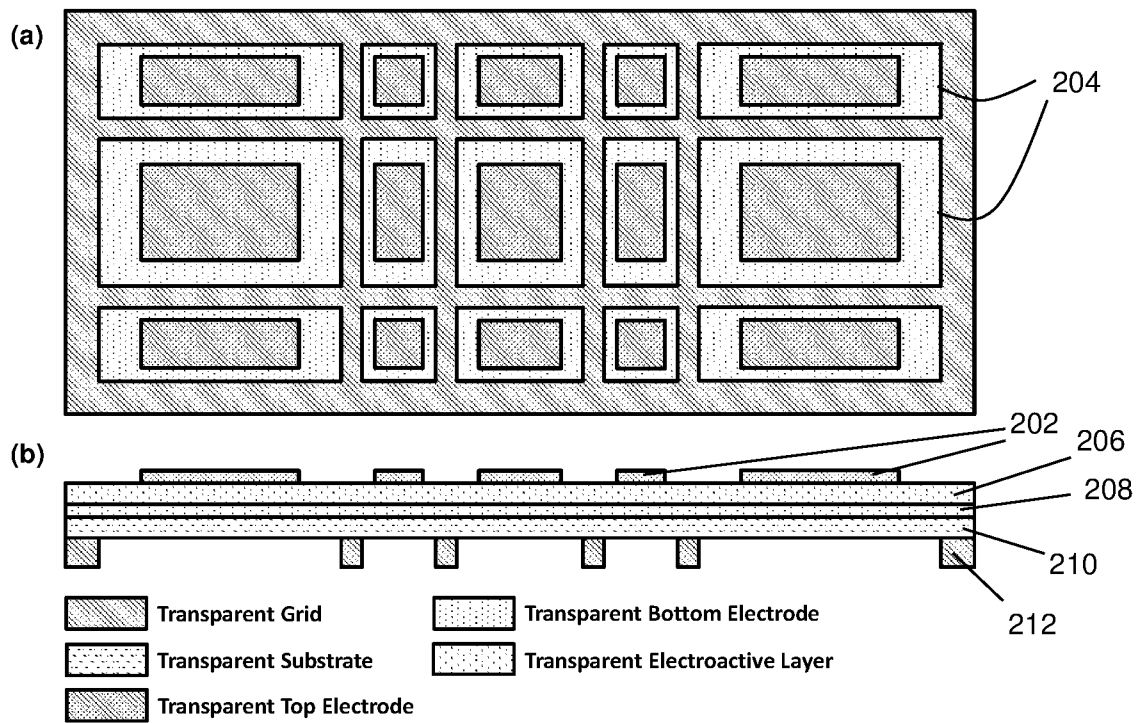


Figure 2

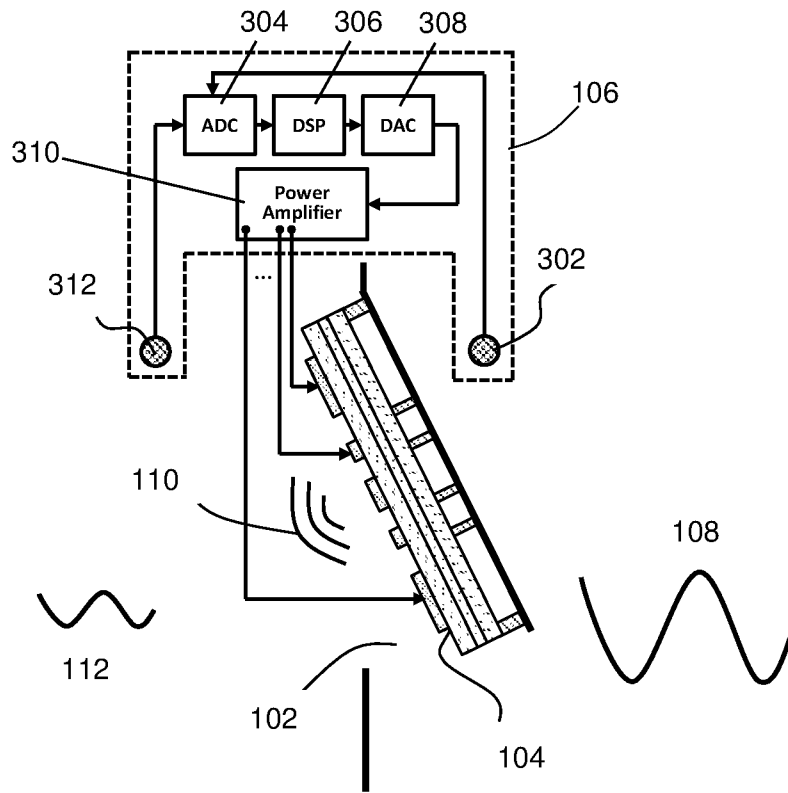


Figure 3

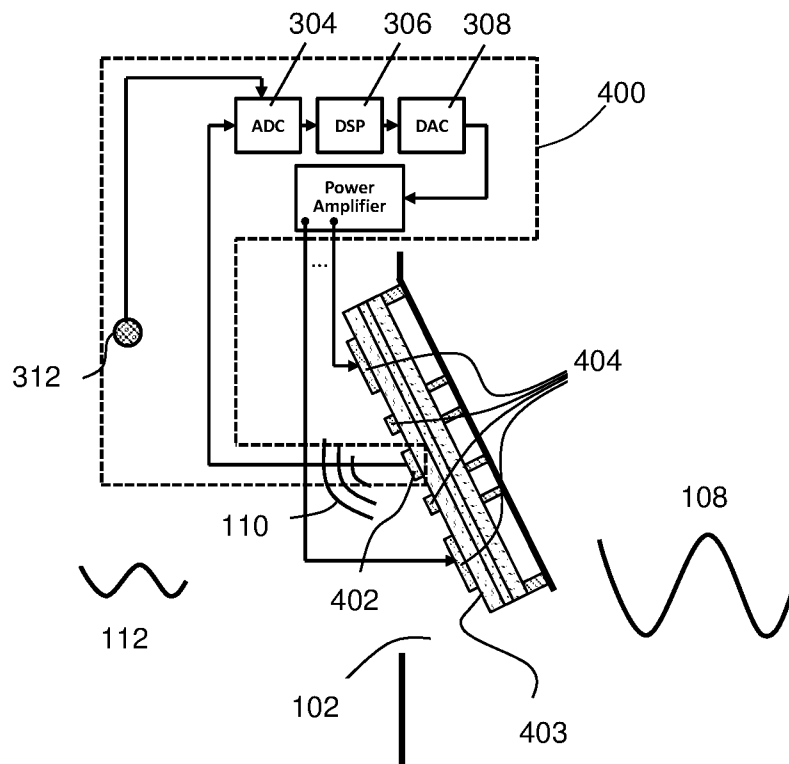


Figure 4

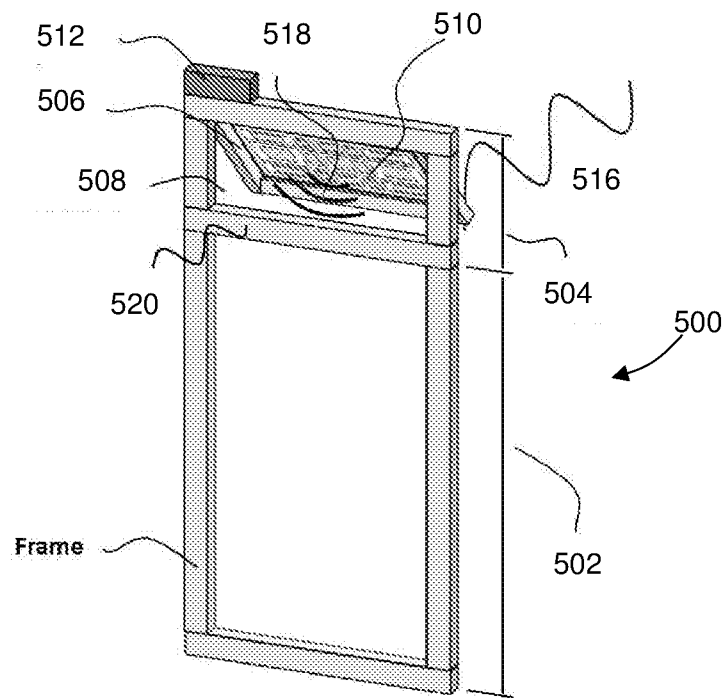


Figure 5

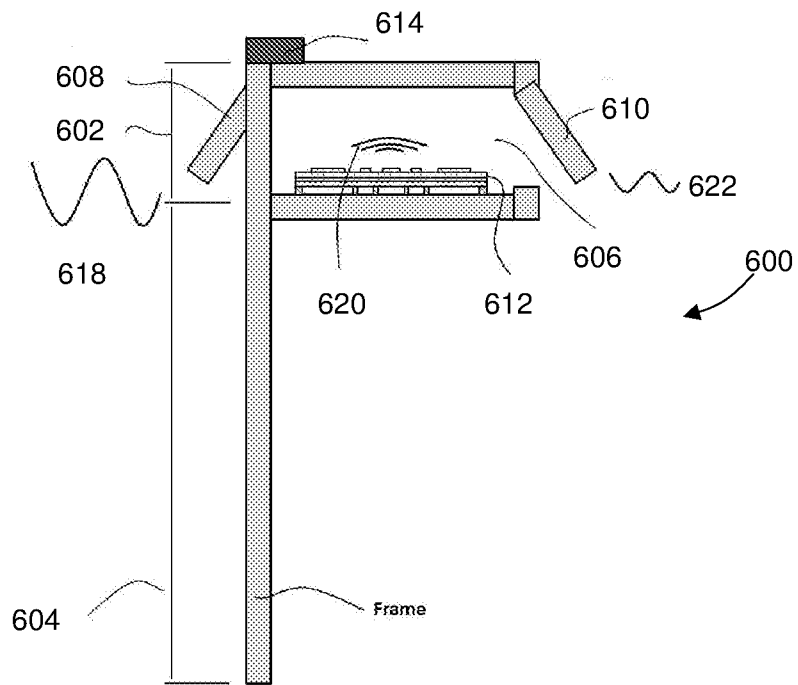


Figure 6

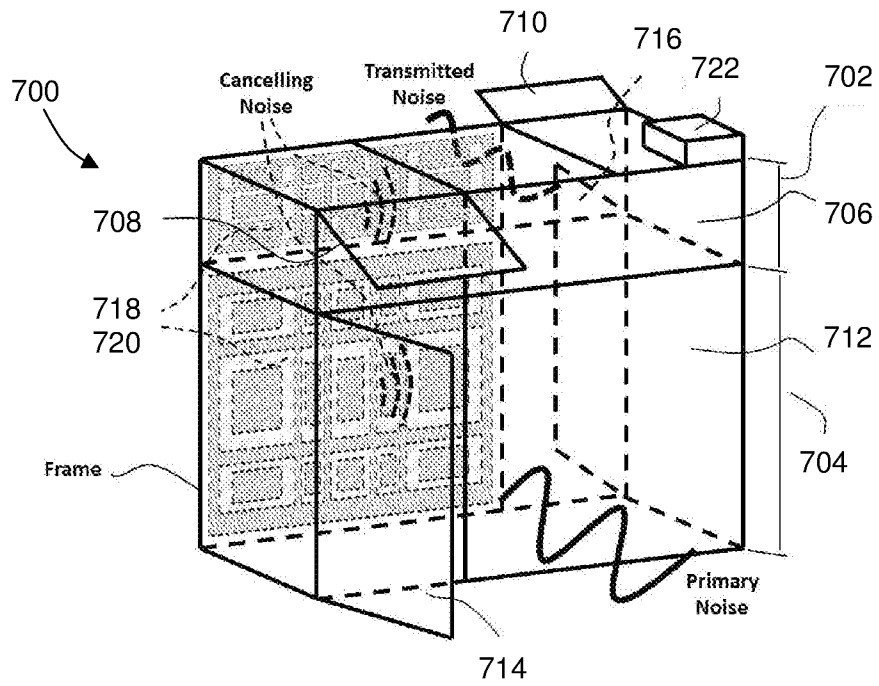


Figure 7

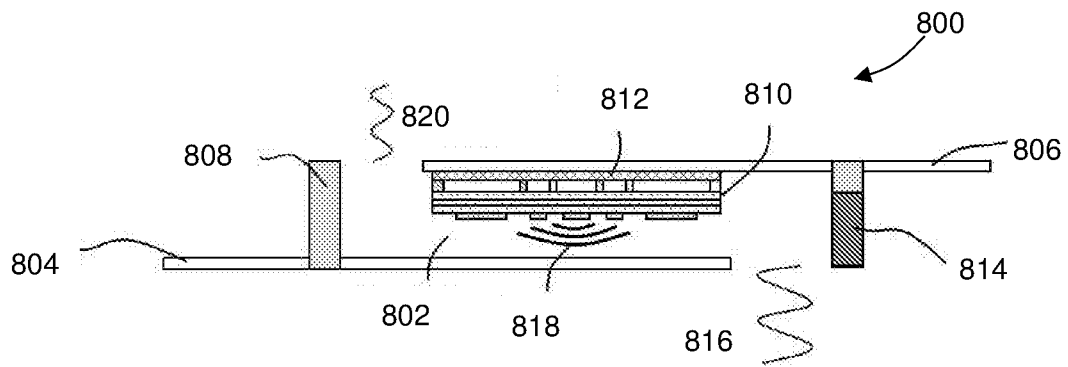


Figure 8

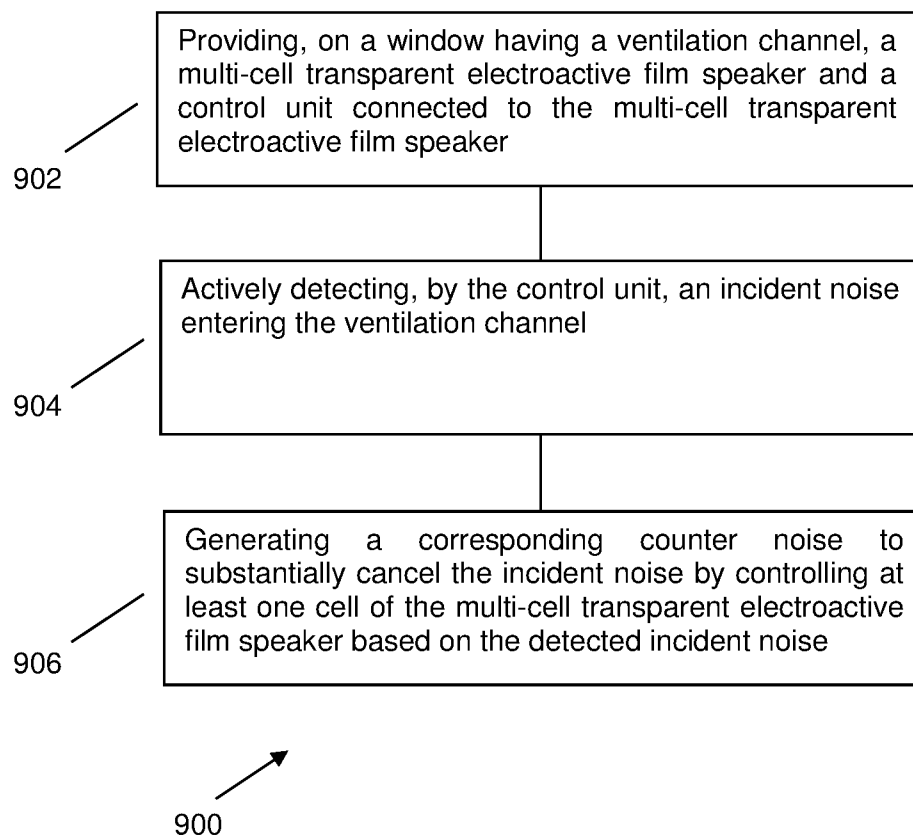


Figure 9

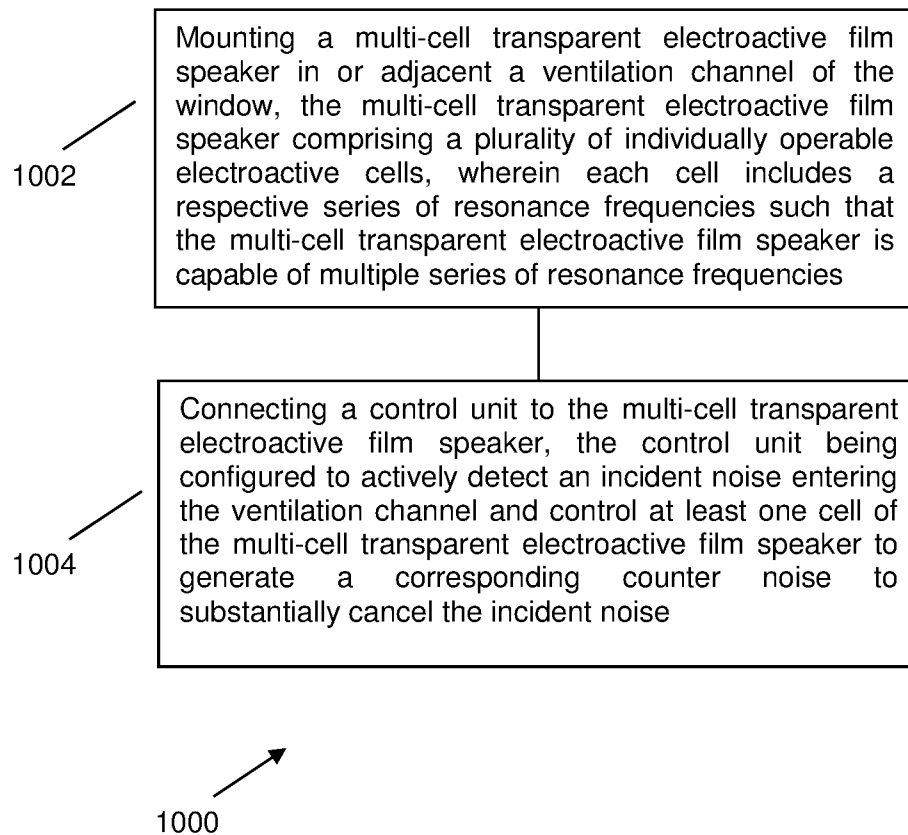


Figure 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2017/050260

A. CLASSIFICATION OF SUBJECT MATTER

See Supplemental Box

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: E06B, H04R, G10K, H04R, B06B

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)

FAMPAT: window, film, speaker, frequencies, ventilation, channel, cancel, noise, 窗, 膜, 压电, 音箱, 声转换, 抵消, 噪音, 通风, 道 and related terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 101881119 A (UNIV NANJING & SHENZHEN GRANDSUN ELECTRONIC CO LTD) 10 November 2010 paragraphs [0007], [0008], figure 1c of the original non-English language document (a machine translation is enclosed only for your reference)	1-22
Y	US 2007/0081681 A1 (YU X. ET AL.) 12 April 2007 paragraphs [0008], [0021], [0026], [0037], [0038], figure 3	1-22
A	DE 10052093 B4 (ANDRÉ J. ET AL.) 24 June 2004 whole document of the machine translation	-
A	US 2014/0117812 A1 (HAJATI A.) 1 May 2014 whole document	-
A	US 2002/0080684 A1 (DONSKOY D. ET AL.) 27 June 2002 whole document	-

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

*Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

06/07/2017

(day/month/year)

Date of mailing of the international search report

12/07/2017

(day/month/year)

Name and mailing address of the ISA/SG



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INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2017/050260**C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5519637 A (MATHUR G.) 21 May 1996 whole document	-

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SG2017/050260

Note: This Annex lists known patent family members relating to the patent documents cited in this International Search Report. This Authority is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 101881119 A	10/11/2010	NONE	
US 2007/0081681 A1	12/04/2007	NONE	
DE 10052093 B4	24/06/2004	NONE	
US 2014/0117812 A1	01/05/2014	CN 104756521 A EP 2912858 A1 JP 2016503312 A KR 20150073964 A WO 2014/066006 A1	01/07/2015 02/09/2015 04/02/2016 01/07/2015 01/05/2014
US 2002/0080684 A1	27/06/2002	AU4322402 A WO 02/48659 A2	24/06/2002 20/06/2002
US 5519637 A	21/05/1996	NONE	

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2017/050260

Supplemental Box

(Classification of Subject Matter)

Int. Cl.

E06B 5/20 (2006.01)

H04R 7/04 (2006.01)

G10K 11/178 (2006.01)

H04R 17/10 (2006.01)

B06B 1/06 (2006.01)