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A sound and vision generation system

Field of the invention

The present invention relates to a system for the generation of sound and images.

5 Background of Invention

Referring to Fig. 1, a conventional theatre system is shown schematically. It is composed of a VCD player 1 or the like, which sends image data to a projector 2. The projector 2 projects an image onto a viewing screen 3. The
10 VCD player 1 also sends audio signals to a pair of audio speakers 4 for generating stereo sound. The projection screen 3 may be flexible and foldable, and may be suspended from a frame 5 or hung onto a wall (not shown). Currently, in many systems the audio speakers 4 are cone-type electromagnetic speakers disposed on both lateral sides of, or below, the
15 image projection screen. Such an arrangement results in (i) lack of collation between the visual information on the screen and the corresponding audible output, and (i) a large space requirement for accommodating both the screen 3 and the speakers 4.

20 Some efforts have been made to overcome these disadvantages. In this regard, US 5,025,474 discloses a speaker system with an image projection screen, in which a diaphragm carries a screen on its surface. The diaphragm is driven by sixteen driving sources. Each driving source comprises a magnetic circuit composed of a magnet, a top plate and a bottom plate, and a
25 voice coil interposed in the magnetic gap of the magnetic circuit. A cabinet is constructed having a wide opening at one front surface, and the diaphragm stretched over it. The driving sources are arranged spaced apart on the

diaphragm. However, this speaker system has a complicated and bulky configuration, resulting in a high manufacturing cost.

By contrast, US 6,577, 256 discloses a system in which a display device such
5 as a TV set includes a display screen and, spaced from the screen, a number of electro-acoustic transducers.

A similar concept is found in US 5,400,414, in which a transparent
piezoelectric foil is provided, for attachment over the front screen of a display
10 unit such as a TV set. The transparent piezoelectric foil is provided with electrodes which supply audio-frequency signals to it to generate audio-frequency sound. Another similar system is shown in US 6,427,017B1 which again provides a transparent piezoelectric member for attachment over the front of a display device.

15 It is mentioned in US 5,400,414 that the piezoelectric sounder can optionally be attached as a foil over the display surface of a projection-type display device, but is not an attractive possibility because it requires that the sounder is transparent.

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Summary of the Invention

In general terms, the present invention proposes a display unit including a screen member having a front display surface for displaying images, and one or more flexible piezoelectric actuation elements bonded on the rear of the
25 screen member (i.e. on the surface of the screen member opposite the display surface).

The screen member is preferably laminar (i.e. a layer), and may in different embodiments be either flat (planar) or flexed. The piezoelectric actuation

elements are arranged to move the screen member, so that the screen member generates the sound wave.

The invention makes it possible to provide an integrated unit for sound and vision generation in a thin lightweight unit, and without the necessity of
5 providing transparent a sound generation layer.

In contrast to conventional display systems including displays and separate loudspeakers, in embodiments of the present invention the sound and vision are produced at substantially the same location, resulting in improved visual and audible effects.

10 In contrast to the system of US 5400414, the actuator elements of the present invention are not required to be true loudspeakers. This means that the location of the actuator elements on the rear of the screen member does not inhibit the broadcasting of sound in the direction of the viewer, and also that the actuator elements do not have to be as large as in US 5400414 in order to
15 generate low frequency sound.

Preferably, the display unit is used as part of a display system which further includes a projection device arranged to project images onto the display surface. The display system is preferably a one-piece (i.e. integratal) unit.

Brief Description of The Figures

20 Preferred features of the invention will now be described, for the sake of illustration only, with reference to the following figures in which:

Fig. 1 shows schematically a known sound and vision generation system;

Fig. 2, which is composed of Figs. 2(a) to 2(c), shows a speaker/screen
25 system which is first embodiment of the invention;

Fig. 3 shows the application of an alternating voltage across a peizopolymer layer in the embodiment of Fig. 2;

Fig. 4 illustrates the vibration and sound generation produced by the speaker/screen system of Fig. 2;

Fig. 5 shows experimental results of the frequency response of a speaker/screen system as shown in Fig. 2;

5 Fig. 6, which is composed of Figs. 6(a) and 6(b), shows a second embodiment of the invention;

Fig. 7 shows a third embodiment of the invention; and

Fig. 8 shows an amplifier circuit suitable for use in any of the three embodiments of the invention.

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Detailed Description of the embodiments

Referring to Fig. 2, a first embodiment of the invention is shown, which is a display unit having three layers. Fig. 2(a) shows a front view of the display unit, Fig. 2(b) shows an exploded view of the three layers, and Fig. 2(c) is a cross-sectional view in the direction A-A indicated in Fig. 2(a).

The front layer of the display unit is a screen layer 3. The front surface of the screen layer 3 is a display surface, onto which an image can be projected. Adhered to the rear surface of the screen layer 3 is a piezopolymer actuator layer 6. The piezopolymer layer 6 may be a single monolithic sheet, or alternatively composed of a plurality of individual actuator elements. It should be understood that the piezopolymer layer 6 may not be provided over the entire area of the screen layer 3. Instead, one or more layers 6 may be provided spaced-apart in different portions of the screen layer 1.

The piezopolymer may be polyvinylidene fluoride (PVDF) or one of its copolymers, since it has vast dynamic range, high elastic compliance, high dielectric strength and low cost. It is preferred that the piezopolymer layer 6 has a thickness of at least $110\ \mu\text{m}$. Alternatively, the piezopolymer layer 6

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may have a bimorph configuration in which two sheets of piezoelectric film of opposite polarities are adhered together.

On a rear surface of the piezopolymer layer 6 is adhered a protective/sealing layer 7. The protective/sealing layer 7 should be thin and flexible, in particular less stiff than the layers 3, 6 so that it has practically no effect on the mechanical properties of the display unit 1. The layer 7 may extend across the entire rear of the screen layer 3 (i.e. including any areas of the screen layer 3 where the piezopolymer layer 6 is not provided, so that the layers 3 and 7 are in direct contact there), or alternatively only be provided in the areas of the rear surface of the screen layer 3 where the piezopolymer 6 is provided.

The screen system further includes electrodes (not shown) located on the piezopolymer layer 6 for generating electric fields across the piezopolymer 6 when different electrical potentials are applied to the two electrodes. The electrodes may be of any commercial type, such as compliant silver ink or sputtered NiCu alloy.

This is illustrated in Fig. 3, in which an AC voltage source 8 is used to apply different voltages to the electrodes on the respective sides of the screen, so as to produce oscillations of the piezopolymer layer 6 in its d_{31} mode. If the piezopolymer 6 were moving freely this would not produce significant sound wave, since the motion would be planar. However, since the piezoelectric layer 6 is bonded to the flexible screen layer 3, this induces the composite structure to produce a bending motion, which causes sound waves to be generated propagating transverse to the surface of the screen system 1, as shown in Fig. 4. Thus, the flexible viewing screen system 1 serves as the diaphragm of a speaker unit. In other words, the embodiment integrates visual- and audio-generating functions into one thin, flexible, foldable and lightweight unit. Since the screen system 1 provides both sound and image

generation, the two are generated at almost the same location, which results in an improved visual and audio effect.

It is well known that the average actuation capability per unit area of a piezoelectric film actuator is far weaker than that of an electromagnetic actuator. Usually, the maximum output of a piezoelectric film actuator falls into a micro-scale 0.1-100 μ m. This implies that the structural deformation (i.e. displacement) of the viewing screen due to the AC excitation should be essentially invisible to an individual looking at the screen layer 3. In other words, the screen system permits the generation of an image with the same quality as a conventional projection screen. However, it may be ensured that the sound pressure level (SPL) is high enough to produce audible sound by ensuring that the piezopolymer layer 6 has a sufficiently large area, or by providing a large enough number of layers 6 on the rear surface of the screen layer 3 (i.e. with the elements 6 provided in different respective parts of the screen area).

Experimentally we have found that when a piezoelectric film of thickness 100 μ m and an area of 280x280mm² was bonded onto the rear surface of a screen layer 3 having an area of 230x210cm, and a radio signal (demodulated to form an audio frequency signal) was input into the electrodes of the piezoelectric film using an amplifier, the result sounded as if the audible sound radiated from the entire display surface of the screen layer 3, rather than just the location of the piezopolymer actuator 6.

Fig. 5 shows the dynamic characteristics of the screen system, where the horizontal axis indicates frequency and the vertical axis indicates decibel level. The sound quality was found to be acceptable, but a still higher level of sound quality should be obtained when the system is optimised. For example, there may be optimisations of the location and orientation of the actuators 6,

and the number of actuators 6 attached to the screen, since these parameters can modify the frequency response of the screen desirably.

Turning to Fig. 6, a second embodiment of the invention is shown, in perspective view in Fig. 6(a) and in cross-section in Fig. 6(b). In this second embodiment, a display unit 11 is a single integrated unit which may be hung on a wall (not shown) or other support structure. The unit 11 comprises on its front surface a flexible membrane 14 comprising a screen layer 3 onto which images are to be projected and a layer 6 of a piezopolymer. The unit further comprises a support frame 9 having a lattice structure. The frame 9 is shaped such that the unit 11 is much thinner in directions perpendicular to the surface 3 than its dimensions parallel to this plane. The frame 9 includes many chambers 10, which each function as a speaker element. Each chamber 10 further includes one or more elements of a sound absorbing material 19 such as a foam or fibreglass. The sections 12 of the membrane 14 which extend over the respective chambers 10 may have different respective widths in the plane of the membrane 14, and accordingly different respective resonant frequencies. This enhances the ability of the unit 11 to generate sound frequencies in different respective frequency ranges (low, middle or high), analogously to the use in conventional speakers of a combination of woofer, midrange and tweeter electromagnetic speakers to achieve a high fidelity effect.

In the two embodiments described above, the speaker/screen system includes a planar screen layer 3. However, the invention is not limited in this respect, and an alternative speaker/screen system 21 is illustrated in the embodiment of Fig. 7. In this embodiment a thin supporting frame 29 supports a non-planar screen membrane 24 comprising a screen layer 23 having a left portions 27 and a right portion 28 which flex rearwardly. The curved screen membrane 24 is suitable for use in a three-dimensional/dynamic movie

system or the like, in which a curved viewing-screen is commonplace, or for use in a home theatre system. The supporting frame 29 determines the configuration of the membrane 24 in both the planar and non-planar portions of the membrane 24. There is a piezoelectric layer 26 (such as one of PVDF as in the other embodiments) having a high elastic compliance and adhered behind at least one portion of the screen layer 23. Preferably there is a portion of the layer 26 behind at least part of each of these sections 27, 28. The piezoelectric layers 26 cause the sections 27, 28 to vibrate in reaction to an applied AC electric field applied to across the piezopolymer layers 26 by electrodes (not shown), and including an audio signal (e.g. derived from a VCD player). The unit 21 may be hung onto a wall or other support structure.

Alternatively, the wall or other support structure may itself be effectively a portion of the speaker/screen system. For example the wall or other support structure may function as a cover which covers the (otherwise open) rear side of a sounder chamber of the speaker/screen system. Alternatively, the sounder chamber may be contain (e.g. be filled with) sound absorbing materials as discussed above.

In order to obtain a high sound pressure from the embodiments of the invention, a significant driving voltage should be applied to the piezopolymer films 6, 26. Fig. 8 shows schematically the structure of a power amplifier circuit for generating such driving voltages. The circuit includes a transformer 15. An electrical resonance is usually present since the circuit includes an inductance (due to the transformer) and a capacitance (due to the piezopolmer). This resonance may be damped by including an additional resistor 31 and capacitor 33, so that the resonant frequency of the circuit as a whole is far from the audio frequency range of interest.

Although the invention has been described above in relation to a screen onto which images are projected, this too is not a limitation of the invention. In a particularly preferred embodiment the screen layer of the display unit system is replaced by a flexible screen with internal light generation elements (such as OLEDs). The piezopolymer may be bonded onto the rear side of such a pre-formed flexible screen directly. Alternatively, the piezopolymer may be spin-coated and integrated with the flexible screen with internal light generation elements. Such a method is compatible with the fabrication process of the flexible screen with internal light generation elements such as OLEDs.

Furthermore, although the embodiments described above are projection screens (i.e. for mounting in a certain location, and viewing by one or more users), the present concept is applicable also to devices in which the screen is part of a mobile electronic device, such as a wearable computer, MP3 or the like. In such applications, the piezopolymer may optionally be bonded to the surface of a flexible substrate to form a sound resonator.

More generally, many other variants within the scope of the invention exist, as will be clear to a skilled reader.

Claims

1. A display unit including a screen member having a front display surface, one or more piezoelectric elements bonded to the rear surface of the screen member, and electrode means for applying electric signals to the piezoelectric elements whereby the piezoelectric elements actuate the image screen member to generate sound.
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2. A display unit according to claim 1 in which the screen member is laminar and substantially flat.
3. A display unit according to claim 1 in which the screen member is laminar and includes one of more portions at which it flexes.
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4. A display unit according to claim 1, claim 2 or claim 3 in which the screen member is supported by a frame which does not support the screen member in one or more areas, the piezoelectric element or elements being provided in at least part of these areas.
5. A display unit according to claim 4 in which the frame defines chambers covered by the screen member in the forward direction, the chambers including elements of sound absorbing material.
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6. A sound and vision display system including a display unit according to any preceding claim, a projector for projecting images onto the display surface, and an audio system for transmitting electric signals to the electrode means.
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7. A sound and vision display system according to claim 6 in which the display unit, projector and audio system are a one-piece unit.
8. A sound and vision display system according to claim 7 which is a portable consumer device.
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