US012395786B2

(12) United States Patent
Ye et al.

(10) Patent No.: US 12,395,786 B2
(45) Date of Patent: Aug. 19, 2025

(54) **LOUDSPEAKER**

(71) Applicant: **Harman Becker Automotive Systems GmbH**, Karlsbad (DE)

(72) Inventors: **Xipeng Ye**, SIP.Suzhou (CN); **Xin Liu**, SIP.Suzhou (CN); **Andreas Helmut Pfeffer**, Wenzenbach (DE); **Richard Josef Kralik**, Petershausen (DE)

(73) Assignee: **Harman Becker Automotive Systems GmbH**, Karlsbad-Ittersbach (DE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 212 days.

(21) Appl. No.: **18/080,139**

(22) Filed: **Dec. 13, 2022**

(65) **Prior Publication Data**

US 2023/0217156 A1 Jul. 6, 2023

(30) **Foreign Application Priority Data**

Dec. 30, 2021 (EP) 21218311

(51) **Int. Cl.**
H04R 1/28 (2006.01)
H04R 1/02 (2006.01)
H04R 9/06 (2006.01)

(52) **U.S. Cl.**
CPC ***H04R 1/2834*** (2013.01); ***H04R 1/025*** (2013.01); ***H04R 9/066*** (2013.01); *H04R 2400/11* (2013.01)

(58) **Field of Classification Search**
CPC H04R 1/2834; H04R 1/025; H04R 9/066; H04R 2400/11; H04R 1/2826; H04R 7/20; H04R 7/26; H04R 9/022; H04R 9/06; H04R 2209/026; H04R 2499/13; H04R 1/26; H04R 19/02; H04R 1/021; H04R 1/323; H04R 1/2807; H04R 1/28; H04R 1/227; G06F 3/16
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,805,221	A *	2/1989	Quaas	H04R 1/227	181/171
5,629,502	A	5/1997	Nakano		
8,737,659	B2 *	5/2014	Suzuki	H04R 1/2834	381/337
10,484,788	B1	11/2019	Kudekar		
11,218,797	B2 *	1/2022	Prokisch	H04R 1/2803	
11,849,297	B2 *	12/2023	Tiene	H04R 1/2896	
2004/0105565	A1 *	6/2004	Butters	H04R 1/2834	381/345
2006/0147076	A1 *	7/2006	Hoffmann	H04R 1/345	381/337

(Continued)

FOREIGN PATENT DOCUMENTS

CN	213365496 U *	6/2021	G06F 3/16
EP	1791389 B1	11/2016	

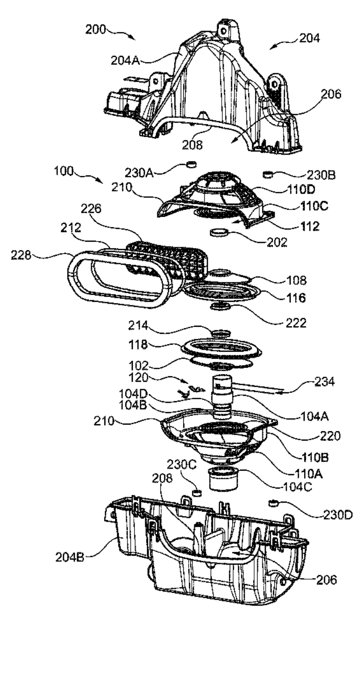
(Continued)

Primary Examiner — Angelica M McKinney
(74) *Attorney, Agent, or Firm* — Angela M. Brunetti

(57) **ABSTRACT**

A loudspeaker comprises a first diaphragm, a second passive diaphragm, and a drive unit coupled to the first diaphragm. The drive unit is configured to drive the first diaphragm in a direction of excursion upon applying electrical energy to the drive unit. The second passive diaphragm is arranged opposing the first diaphragm. The second passive diaphragm is mainly driven by sound waves emitted from the first diaphragm.

18 Claims, 2 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2008/0205682	A1	8/2008	Jenkins	
2009/0316933	A1	12/2009	Koyama	
2013/0195311	A1*	8/2013	Sahyoun	H04R 1/2834 381/398
2017/0013352	A1*	1/2017	Shihuang	H04R 1/323
2018/0270567	A1*	9/2018	Litovsky	H04R 1/26
2020/0068281	A1	2/2020	Chu	
2020/0329301	A1	10/2020	Prokisch	
2022/0225017	A1*	7/2022	Tabata	H04R 1/021
2023/0188895	A1*	6/2023	Tiene	H04R 19/02 381/349

FOREIGN PATENT DOCUMENTS

JP	H10341492	A	12/1998	
WO	WO-2020129262	A1 *	6/2020	H04R 1/28
WO	WO-2020199132	A1 *	10/2020	H04R 1/2807

* cited by examiner

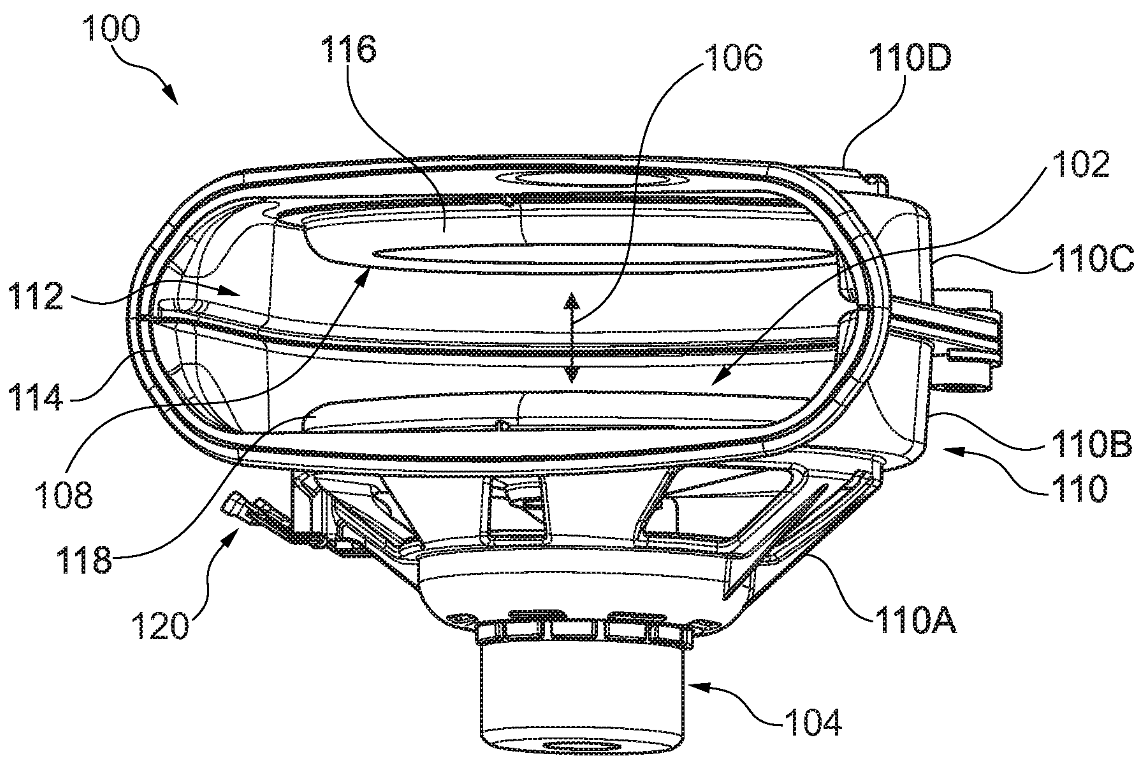


Fig. 1

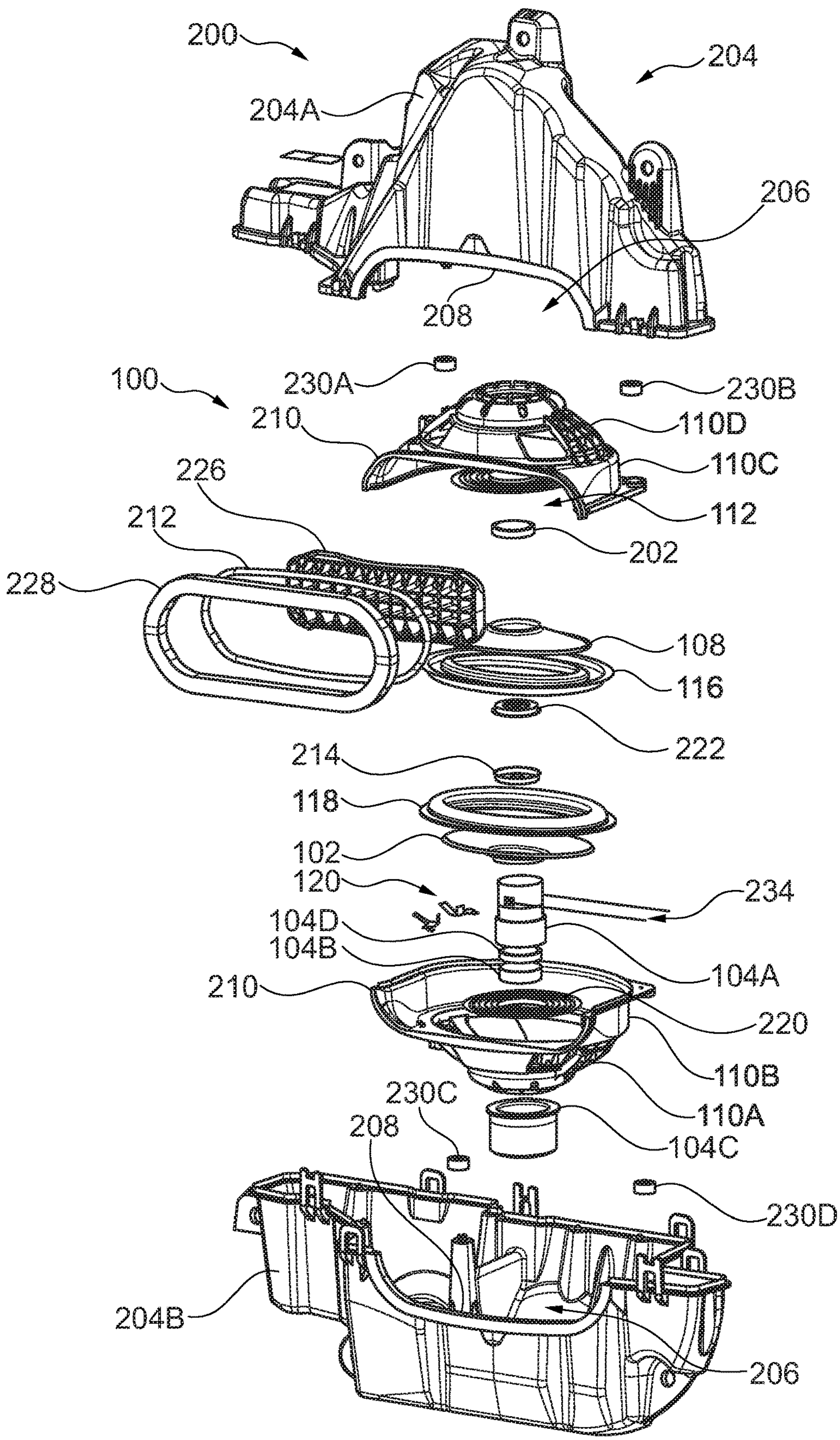

200
204
204A
206
208
100
230A
230B
210
110D
110C
112
226
212
202
228
108
116
222
214
118
102
120
234
104D
104B
104A
210
220
110B
110A
230C
208
104C
230D
204B
206

Fig. 2

LOUDSPEAKER

CROSS REFERENCE

Priority is claimed to application serial no. 21218311.5, filed Dec. 30, 2021 in Europe, the disclosure of which is incorporated in its entirety by reference.

TECHNICAL FIELD

The present disclosure relates to the field of loudspeakers, for example to the field of midrange speakers and bass speakers, so-called woofers, with a compact design.

BACKGROUND ART

Loudspeakers are widely used in various areas, for example in consumer products like radios, television sets, audio players, computers, mobile phones and electronic musical instruments, and commercial applications, for example sound reinforcement in theatres, concert halls, and public address systems. Furthermore, in vehicles, for example planes, ships and cars, loudspeakers are widely used.

A loudspeaker may comprise a diaphragm (also called membrane) which is driven by a drive unit (also called electromagnetic motor system) for generating acoustic waves. The drive unit may comprise for example a magnet, in particular a permanent magnet, and a voice coil coupled to the diaphragm and arranged in a magnetic field provided by the magnet. An outer edge of the diaphragm may be elastically coupled via a suspension (also called surround) to a frame (also called basket) of the loudspeaker. For example, the voice coil may be a coil of wire capable of moving axially in a cylindrical gap containing a concentrated magnetic field produced by the permanent magnet. When an alternating electrical current of for example an electrical audio signal is applied to the voice coil, the voice coil is forced to move back and forth due to the Faraday's law of induction, which causes the diaphragm attached to the voice coil to move back and forth, pushing on the air to create sound waves. The voice coil may be elastically coupled to the frame of the loudspeaker, e.g. via a so called "spider". Arrangement and properties of the magnet and voice coil may affect characteristics of the loudspeaker. Characteristics of a loudspeaker may relate to efficiency, i.e. the sound power output divided by the electrical power input, sensitivity, i.e. the sound pressure level at for example 1 W electrical input measured at 1 meter, linearity or frequency response, maximum acoustic output power, size and weight. Characteristics may be different for different frequencies, for example small loudspeakers may have lower efficiency at low frequencies than large loudspeakers.

In particular in cars a plurality of loudspeakers may be arranged at different locations to provide adequate sound output for each occupant. For example, loudspeakers may be arranged in the dashboard, doors, ceiling, seats and headrests. Small loudspeakers may have better high frequency response. Large loudspeakers and volumes can be advantageous for generating low frequencies. In particular midrange loudspeakers and bass loudspeakers may require large installation space. However, installation space may be sparse in the car.

SUMMARY

In view of the above, there is a need in the art to improve at least some of the above characteristics of a loudspeaker.

For example, there is a need for compact sized light weighted loudspeakers providing high efficiency, in particular at low frequencies.

According to the present disclosure, a loudspeaker as defined in the independent claim is provided. The dependent claims define embodiments.

According to various examples, a loudspeaker comprises a first diaphragm and a drive unit coupled to the first diaphragm. The drive unit is configured to drive the first diaphragm in a direction of excursion upon applying electrical energy to the drive unit. The loudspeaker comprises a second passive diaphragm arranged opposing the first diaphragm. The second diaphragm is on one hand excited by sound waves emitted from the first diaphragm. On the other hand, a main driving force for the second diaphragm may be a pressure difference in a (small) enclosure (in the following also designated as chassis) in which the first and second diaphragms are arranged. An interplay of pressure variation and emitted soundwaves may make such arrangement especially efficient. For example, no drive unit may be associated with the second passive diaphragm, i.e. no drive unit is directly coupled to the second passive diaphragm. However, in other embodiments, at least a voice coil or a carrier of a voice coil may be associated with the second passive diaphragm, i.e. the associated voice coil or carrier may be directly coupled to the second passive diaphragm. However, such associated voice coil may not be energized, for example it may not be electrically connected to electrical components outside the loudspeaker. As a result, the second passive diaphragm is only or at least essentially only driven by sound waves emitted from the first diaphragm. In particular, the second passive diaphragm may not be driven directly by an electromagnetic force. By arranging the second passive diaphragm opposing the first diaphragm, a direction of excursion of the second passive diaphragm may be parallel to the direction of excursion of the first diaphragm.

In various examples, the second passive diaphragm is arranged spaced apart from the first diaphragm. A distance between the second passive diaphragm and the first diaphragm may be at least 10 mm. A distance between the second passive diaphragm and the first diaphragm may be at most 300 mm.

An outer circumference of the first diaphragm may extend in a first plane. An outer circumference of the second passive diaphragm may extend in a second plane. The first plane may be parallel with respect to the second plane, at least essentially parallel. However, in other examples, the first plane may be slightly tilted with respect to the second plane, for example, an angle between the first plane and the second plane may be in a range of up to 5 or 40 degrees. The outer circumference of the first diaphragm may be offset from the outer circumference of the second passive diaphragm along the direction of excursion.

For example, the first diaphragm may have a dome, cone or spherical shape with the base of the dome/cone/spherical shape extending in the first plane perpendicular to the direction of excursion. The second passive diaphragm may also have a dome shape, cone shape or spherical shape with the base of the dome/cone/spherical shape extending in the second plane perpendicular to the direction of excursion. An apex of the dome/cone/spherical shape of the first diaphragm may be outside the area between the first and second planes, and an apex of the dome/cone/spherical shape of the second passive diaphragm may be outside the area between the first and second planes also. I.e., the first diaphragm and the second passive diaphragm may face each other.

The above described shape of the first and second diaphragms is an example only and the first and second diaphragms may have any other shape, for example a conical shape, a flat disk shape, a spherical shape, a dome shape, a horn shape, a funnel shape or a combination thereof. Each of the first and second diaphragms may be made from one piece or assembled from several pieces, which are made of the same material or of different materials.

Furthermore, the second passive diaphragm may be arranged with respect to the first diaphragm such that a projection of the second passive diaphragm along the direction of excursion at least partially overlaps the first diaphragm. For example, dimensions of the outer circumference of the first diaphragm may be the same as dimensions of the outer circumference of the second passive diaphragm, i.e. the first diaphragm and the second passive diaphragm may have the same shape and size. They may be aligned along the direction of excursion such that they face each other.

As a result, a direct and short traveling path for soundwaves emitted by the first diaphragm in the direction of the second passive diaphragm may be established such that the second passive diaphragm may be driven by sound waves emitted by the first diaphragm. Furthermore, the second diaphragm may be driven or excited by pressure variation in the enclosure (chassis) in which the first and second diaphragms are arranged. The second passive diaphragm may in particular oscillate at a resonance frequency thus increasing acoustic output power of the loudspeaker and increasing the efficiency of the loudspeaker assembly. As the second passive diaphragm does not include a drive unit, in particular no magnet assembly, cost, weight and energy consumption may be reduced.

The second passive diaphragm may comprise, at or near a center of the second passive diaphragm, a weight element. For example, the weight element may comprise a ring-shaped element made of plastic and/or metal. The mass of the weight element may adjust a resonance frequency of the second passive diaphragm. A larger mass may lower the resonance frequency, a smaller mass may higher the resonance frequency. The loudspeaker may be installed in a closed enclosure without bass reflex opening, e.g. no bass reflex tube, thus avoiding flow noise at such opening. However, in other examples, the loudspeaker may be installed in an enclosure with a bass reflex opening (bass reflex vent).

In various examples, the loudspeaker comprises a chassis supporting the first diaphragm, the second passive diaphragm and the drive unit. For example, the first diaphragm may be mounted to the chassis via a first elastic surround supporting the first diaphragm in a rest position, and the second passive diaphragm may be mounted to the chassis via a second elastic surround supporting the second passive diaphragm in a rest position. Both, the first diaphragm and the second passive diaphragm, may be movable in the direction of excursion against a restoring force of the first elastic surround and the second elastic surround, respectively.

A usual loudspeaker comprising a single diaphragm may have a so-called basket as chassis for keeping the diaphragm and the drive unit in position. Further components may be provided, for example a surround arranged between an outer circumference of the diaphragm and the basket as well as a so-called spider arranged between a voice coil of the drive unit and the basket. As such, the chassis of the loudspeaker of the present disclosure may be considered as a first basket supporting the first diaphragm via the first elastic surround and the drive unit, and a second basket supporting the second passive diaphragm via the second elastic surround. The first basket and the second basket may be coupled to each other via a wall element extending in the direction of excursion and surrounding an outer circumference of the first and second elastic surrounds.

The chassis may provide a sound outlet aperture. For example, the sound outlet aperture may be formed as a hole in the wall element connecting the first and second baskets. An outer circumference of the sound outlet aperture may extend in a plane parallel to the direction of excursion. In other words, the sound outlet aperture may be arranged perpendicular to the first and second planes of the diaphragms. As a result, the main sound radiation direction of the loudspeaker is perpendicular to the first and second planes in which the first and second diaphragms are arranged.

In further examples, the chassis, the first diaphragm and the second passive diaphragm form a closed surface which circumscribes the sound outlet aperture. In other words, the sound outlet aperture is the only opening for sound radiation. Flow noise at other openings may be avoided. Furthermore, efficient control of the second passive diaphragm by soundwaves emitted by the first diaphragm may be achieved.

According to various examples of, the outer circumference of the first diaphragm has an oval shape. Accordingly, the outcome circumference of the second passive diaphragm may also have an oval shape. Using an oval shape for the first and second diaphragms enables a flat design of the loudspeaker such that the loudspeaker may be used in loudspeaker systems for wall mounting or in a door of a vehicle, e.g. a car, where small dimensions in the direction of sound radiation are desired.

According to further examples, a loudspeaker system is provided. The loudspeaker system comprises a housing and the above described loudspeaker. The housing's design may play an important acoustic role thus determining the resulting sound quality. For example, the housing may provide a sound outlet aperture. The housing may have a closed surface which circumscribes the sound outlet aperture of the housing. An edge of the sound outlet aperture of the housing may be coupled to an edge of the sound outlet aperture of the loudspeaker. As the direction of excursion of the first and second diaphragms is perpendicular to the main direction of sound radiation through the sound outlet aperture, dimensions of the housing in the direction of sound radiation may be small. The housing may have a volume in a range of a few liters, for example 1 to 10 liters, for example a volume of 3 liters.

In some examples, an edge of the sound outlet aperture of the housing may be coupled to an edge of a sound outlet aperture of the loudspeaker via an elastic sealing element providing an airtight sealing between the edge of the sound outlet aperture of the housing and the edge of the sound outlet aperture of the loudspeaker. The airtight sealing in combination with the closed surface of the housing may support that the passive second diaphragm is driven by a pneumatic force generated by the first diaphragm

The loudspeaker may be elastically mounted at the housing. For example, the loudspeaker may be coupled to the housing via rubber grommets and a rubber ring at the sound outlet. The elastic mounting may contribute to avoid clattering noise and resonance noise.

In further examples, the housing is configured to be mountable at a vehicle component, for example at a door interior lining or door panel. As the direction of excursion of the first and second diaphragms is perpendicular to the main direction of sound radiation, requirements concerning a stiffness of the front wall of the housing in which the sound outlet aperture is provided may be low. For example, a vehicle component may form at least a part of the housing, for example the door panel may form at least a part of the front wall surrounding the sound outlet aperture of the loudspeaker. Cost and weight reduction may be achieved.

It is to be understood that the features mentioned above and those described in detail below may be used not only in the described combinations, but also in other combinations or in isolation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** schematically illustrates a perspective view of a loudspeaker according to various examples; and

FIG. **2** schematically illustrates an exploded perspective view of a loudspeaker system according to various examples.

DETAILED DESCRIPTION OF EMBODIMENTS

In the following, embodiments will be described in detail with reference to the accompanying drawings. It is to be understood that the following description of embodiments is not to be taken in a limiting sense. The scope of this disclosure is not intended to be limited by the embodiments described hereinafter or by the drawings, which are taken to be illustrative only.

The drawings are to be regarded as being schematic representations and elements illustrated in the drawings are not necessarily shown to scale. Rather, the various elements are represented such that their function and general purpose become apparent to a person skilled in the art. Any connection or coupling between functional blocks, components, or other physical or functional units shown in the drawings or described herein may also be implemented by an indirect connection or coupling.

Some examples of the present disclosure generally provide for a plurality of mechanical and electrical components. All references to the components and the functionality provided by each are not intended to be limited to encompassing only what is illustrated and described herein. While particular labels may be assigned to the various components disclosed, such labels are not intended to limit the scope of operation for the components. Such components may be combined with each other and/or separated in any manner based on the particular type of implementation that is desired.

FIG. **1** shows a perspective view of a loudspeaker **100**. The loudspeaker **100** comprises a chassis **110** in which a first diaphragm **102** and a second diaphragm **108** are arranged face to face. The chassis **110** may comprise a first basket **110**A at which the first diaphragm **102** is mounted via a first surround **118**. At a second basket **110**D (only partially shown in FIG. **1**) of the chassis **110** the second diaphragm **108** is mounted via a second surround **116**. The chassis **110** may be made of any appropriate material, for example plastics, resin, metal like aluminum or steel or a composite material including carbon or glass fibers.

The first diaphragm **102** is coupled to a drive unit **104** which is mounted at the first basket **110**A. The drive unit **104** is configured to drive the first diaphragm **102** in a direction of excursion **106** upon applying electrical energy to the drive unit **104**. The drive unit **104** may comprise for example a voice coil and a magnet assembly as will be described below in more detail in connection with the FIG. **2**. Electrical energy may be applied to the voice coil via basket terminals **120**. As shown in FIG. **1**, the second diaphragm **108** is arranged opposing the first diaphragm **102** in the direction of excursion **106**. The second diaphragm **108** is not directly driven by any electromagnetic force. The second diaphragm **108** is not directly coupled with any drive unit. Therefore, the second diaphragm **108** is a passive diaphragm which may be driven by sound waves emitted from the first diaphragm and/or by pressure differences inside the chassis **110**. In the following, the second diaphragm **108** will also be called "second passive diaphragm **108**".

A distance between the first and second diaphragms **102**, **108** in the direction of excursion **106** may be in a range of a few centimeters, for example in a range of 1 to 30 cm. The first and second diaphragms **102**, **108** may have a circular or an oval shape. A diameter or length of the first and second diaphragms **102**, **108** may be in a range of 5 to 30 cm. The first and second diaphragms **102**, **108** may have essentially the same dimensions and they may be aligned to each other such that the shape of the second diaphragm **108** may be projected along the direction of excursion **106** on the shape of the first diaphragm **102**.

The first basket **110**A and the second basket **110**D are interconnected to each other via a wall element of the chassis **110**. The wall element may comprise for example a lower wall element **110**B and an upper wall element **110**C. The first basket **110**A and the lower wall element **110**B may be formed as an integrated part. The second basket **110**D and the upper wall element **110**C may be formed as an integrated part. In an assembled state, the lower wall element **110**B and the upper wall element **110**C provide a wall surrounding a space between the first and second diaphragms **102**, **108**, at least partially. The wall elements **110**B and **110**C extend in a circumferential direction around the space between the first and second diaphragms **102**, **108**, and in the direction of excursion **106**. In the wall formed by the wall elements **110**B and **110**C an aperture **112** is provided.

However, the wall elements **110**B and **110**C may be optional and the first basket **110**A and the second basket **110**D may be arranged in a housing (e.g. the housing **204** described below) or coupled by a spacer such that the first diaphragm is arranged opposing the second diaphragm **108**.

As shown in FIG. **1**, the first and second diaphragms **102**, **108** may each have an oval form and the aperture **112** may be provided along the long side of the oval form. For example, a length of the aperture **112** in the direction perpendicular to the direction of excursion **106** may essentially correspond to the length of the oval diaphragms **102**, **108**. A height of the aperture **112** may essentially correspond to the distance between the first and second diaphragms **102**, **108**. An outer circumference **114** of the aperture **112** may extend in a plane parallel to the direction of excursion **106** and parallel to the length of the oval form of the first and second diaphragms **102**, **108**. The aperture **112** may be essentially the only opening to the space between the first and second diaphragms **102**, **108**. In other words, the chassis **110** in combination with the surroundings **116**, **118** and the diaphragms **102**, **108** may essentially enclose the space between the diaphragms **102**, **108** completely, apart from the aperture **112**. Sound generated in the space between the first and second diaphragms **102**, **108**, i.e. the sound generated within the chassis **110**, may be radiated essentially through the aperture **112** only. Thus, the aperture **112** is acting as a sound outlet aperture **112** of the loudspeaker **100**.

When the drive unit **104** is energized with electrical energy, for example an electrical signal representing a sound signal, the first diaphragm **102** is moved back and forth along the direction of excursion **106** thus emitting sound waves. The sound waves may at least partially propagate along the direction of excursion **106** and may be incident on the second passive diaphragm **108**. The sound waves incident on the second passive diaphragm **108** may move the second passive diaphragm **108** along the direction of excursion **106**.

At certain frequencies or frequency ranges resonance may occur such that the sound radiated from the first diaphragm **102** is amplified by the second passive diaphragm **108**, resulting in an increased sound power output at the aperture **112**. In particular, low-frequency performance of the loudspeaker **100** may be improved. Since no drive unit is provided for the second passive diaphragm **108**, additional costs are incurred only for the second passive diaphragm **108**. In addition, the weight of the loudspeaker **100**, i.e. the whole transducer assembly, can be kept low.

FIG. **2** shows an exploded perspective view of a loudspeaker system **200** comprising the above described loudspeaker **100**.

As described above, the loudspeaker **100** comprises the first diaphragm **102** and the second passive diaphragm **108**. Each of the diaphragms **102**, **108** has an oval shape.

The first diaphragm **102** is coupled to the drive unit **104**A-D comprising a voice coil **104**A and a magnet **104**B, i.e. the first diaphragm **102** may be directly controlled by electrical energy provided to the voice coil **104**A. The drive unit **104** may comprise further components, for example a core cap **104**D and a so-called shell pot **104**C which accommodates the magnet **104**B and the voice coil **104**A. Between the shell pot **104**C and the magnet **104**B an annular gap may be formed in which the voice coil **104**A is arranged movably in the direction of excursion **106**. As an alternative, the drive unit **104** may be equipped with a ring neo motor instead of the shell pot **104**C.

The magnet **104**B may comprise a permanent magnet comprising ferromagnetic materials, for example iron, nickel, cobalt and/or neodymium. The magnet **104**B may be a hollow cylindrical magnet, a so-called ring magnet, or a disk-shaped magnet.

The voice coil **104**A may comprise a tubular carrier on which a plurality of coil windings of conductive wire is provided. End sections **234** of the conductive wire are coupled to the basket terminals **120**. The tubular carrier may be made of a non-magnetic material, for example paper, aluminum or plastics, like polyimide, for example Kapton. An inner diameter of the carrier may be larger than an outer diameter of the magnet **104**B. An outer diameter of the coil windings may be smaller than an inner diameter of the shell pot **104**C. The voice coil **104**A is movable in the direction of excursion in the up and down directions in FIGS. **1** and **2**.

A disc-shaped elastic element **220** may be provided between the voice coil **104**A and the first basket **110**A. The elastic element **220**, which is also called "spider", may be configured to allow a movement of the voice coil **104**A in the direction of excursion **106** and to inhibit any movement of the voice coil **104**A perpendicular to the direction of excursion **106**.

Electrical energy may be applied to the voice coil **104**A via basket terminals **120** such that the voice coil **104**A generates a magnetic field which moves the voice coil **104**A together with the first diaphragm **102** in the direction of excursion **106**A upon interaction with a magnetic field from the magnet **104**B. As a result, the first diaphragm **102** can be deflected by energizing the voice coil **104**A.

A center hole of the first diaphragm **102** may be covered with a dust cap **214**.

In FIG. **2**, the second passive diaphragm **108** is arranged above and opposing to the first diaphragm **102**. The second passive diaphragm **108** may have essentially the same shape and dimensions as the first diaphragm **102**. For covering a center opening in the second passive diaphragm **108**, a corresponding dust cap **222** may be provided.

The second passive diaphragm **108** may comprise, at or around a center of the second passive diaphragm **108**, a weight element **202**. The weight element **202** may have a washer or disk shape. The weight element **202** changes the mass of the second passive diaphragm **108**. The resonance frequency of the second passive diaphragm **108** depends on the mass. The mass of the weight element **202** may be selected according to the application of the loudspeaker **100** to provide a required resonance frequency. The weight element **202** may have a mass in the range of a few grams, for example in a range of 1 to 200 grams, for example 18 grams.

The loudspeaker system **200** comprises a housing **204**, in which the loudspeaker **100** is accommodated. The housing **204** may comprise an upper housing part **204**A and a lower housing part **204**B which may be assembled while enclosing the loudspeaker **100**. The assembled housing **204** may be an essentially closed housing with a sound outlet aperture **206**. A part of the sound outlet aperture **206** may be formed in the upper housing part **204**A and another part of the sound outlet aperture **206** may be formed in the lower housing part **204**B. The loudspeaker **100** may be arranged within the housing **204** such that the sound outlet aperture **112** of the loudspeaker **100** is essentially aligned to the sound outlet aperture **206** of the housing **204**, thus forming a common sound outlet aperture **112**/**206**. In detail, an elastic sealing element **212**, for example a ring-shaped rubber sealing, may be provided between an edge **210** of the sound outlet aperture **112** of the loudspeaker **100** and an edge **208** of the sound outlet aperture **206** of the housing **204**. The elastic sealing element **212** may provide an airtight sealing between the edge **208** of the housing **204** and the edge **210** of the loudspeaker **100**. Further support structures for supporting the loudspeaker **100** within the housing **204** may be provided in the housing **204**. Rubber grommets **230**A-D may be provided at contact points between the chassis **110** of the loudspeaker **100** and the housing **204**. As a result, oscillations at the chassis **110** of the loudspeaker **100** may not be conducted to the housing **204** or may at least be significantly attenuated when being conducted to the housing **204**. In the sound outlet aperture **112**/**206**, a touch protection **226** may be provided, for example a grille, to prevent objects from entering the space between the first and second diaphragms **102**, **108**

The housing **204** may be made of any appropriate material, for example plastics, resin, metal like aluminum or steel or a composite material including carbon or glass fibers.

The housing **204** may be installed in a door of a vehicle. In a door panel of the door, an aperture matching to the sound outlet aperture **112**/**206** may be provided. The housing **204** may be arranged such that the sound outlet aperture **112**/**206** is aligned to the aperture in the door panel and a front gasket **228** may be provided between the edge **208** of the aperture **112**/**206** and an edge of the aperture in the door panel. The loudspeaker system **200** may provide a powerful sound, in particular at low frequencies, and requires little installation space only.

The invention claimed is:

1. A loudspeaker, comprising:

a first diaphragm;

a drive unit coupled to the first diaphragm and configured to drive the first diaphragm in a direction of excursion upon applying electrical energy to the drive unit;

a second passive diaphragm arranged opposing the first diaphragm, wherein the second passive diaphragm is mainly driven by sound waves emitted from the first diaphragm;

a housing providing a sound outlet aperture, the housing has a closed surface which circumscribes the sound outlet aperture of the housing, wherein the second passive diaphragm is arranged spaced apart from the first diaphragm, and wherein the sound generated within the housing is radiated through the sound outlet aperture only; and

wherein a main direction of sound radiation is perpendicular to the direction of excursion of the first and second diaphragms.

2. The loudspeaker of claim 1, wherein the second passive diaphragm is not directly driven by an electromagnetic force.

3. The loudspeaker of claim 1, further comprising:

a distance between the second passive diaphragm and the first diaphragm is at least 10 mm, and wherein a height of the sound outlet aperture essentially corresponds to the distance between the second passive diaphragm and the first diaphragm.

4. The loudspeaker of claim 1, further comprising:

a distance between the second passive diaphragm and the first diaphragm is at most 300 mm, and wherein a height of the sound outlet aperture essentially corresponds to the distance between the second passive diaphragm and the first diaphragm.

5. The loudspeaker of claim 1, wherein an outer circumference of the first diaphragm extends in a first plane, an outer circumference of the second passive diaphragm extends in a second plane, and the first plane is parallel with respect to the second plane.

6. The loudspeaker of claim 1, wherein the second passive diaphragm is arranged with respect to the first diaphragm such that a projection of the second passive diaphragm along the direction of excursion at least partially overlaps the first diaphragm.

7. The loudspeaker of claim 1, wherein dimensions of an outer circumference of the first diaphragm are the same as dimensions of an outer circumference of the second passive diaphragm.

8. The loudspeaker of claim 7, wherein the outer circumference of the first diaphragm is offset from the outer circumference of the second passive diaphragm along a direction of excursion.

9. The loudspeaker of claim 1, further comprising a chassis supporting the first diaphragm, the second passive diaphragm, and the drive unit.

10. The loudspeaker of claim 9, wherein the chassis provides a sound outlet aperture that coincides with the sound outlet aperture of the housing, and an outer circumference of the sound outlet aperture extends in a plane parallel to a direction of excursion.

11. The loudspeaker of claim 10, wherein the chassis, the first diaphragm and the second passive diaphragm form a closed surface which circumscribes the sound outlet aperture of the housing.

12. The loudspeaker of claim 9, wherein the second passive diaphragm is mounted to the chassis via an elastic surround supporting the second passive diaphragm in a rest position, and the second passive diaphragm is movable in a direction of excursion against a restoring force of the elastic surround.

13. The loudspeaker of claim 1, wherein an outer circumference of the first diaphragm has an oval shape.

14. The loudspeaker of claim 1, wherein the second passive diaphragm further comprises a weight element at a center of the second passive diaphragm.

15. A loudspeaker system, comprising:

a housing providing a sound outlet aperture, the housing has a closed surface which circumscribes the sound outlet aperture; and

a loudspeaker at the housing, the loudspeaker comprises:

a first diaphragm;

a drive unit coupled to the first diaphragm and configured to drive the first diaphragm in a direction of excursion upon applying electrical energy to the drive unit;

a second passive diaphragm arranged opposing the first diaphragm, wherein the second passive diaphragm is mainly driven by sound waves emitted from the first diaphragm;

wherein the second passive diaphragm is arranged spaced apart from the first diaphragm, and wherein the sound is radiated through the sound outlet aperture only; and

wherein a main direction of sound radiation is perpendicular to the direction of excursion of the first and second diaphragms.

16. The loudspeaker system of claim 15, wherein the loudspeaker is elastically mounted at the housing.

17. The loudspeaker system of claim 15, wherein an edge of the sound outlet aperture of the housing is coupled to an edge of the loudspeaker via an elastic sealing element providing an airtight sealing between the edge of the sound outlet aperture of the housing and the edge of the loudspeaker.

18. The loudspeaker system of claim 15, wherein the housing is configured to be mountable at a vehicle component, and the vehicle component forms at least a part of the housing.

* * * * *