



(11)

EP 4 432 700 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
18.09.2024 Bulletin 2024/38

(51) International Patent Classification (IPC):
H04R 1/24 (2006.01)

(21) Application number: **23162267.1**

(52) Cooperative Patent Classification (CPC):
**H04R 1/24; H04R 1/2811; H04R 9/06; H04R 17/10;
H04R 2499/13**

(22) Date of filing: **16.03.2023**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

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Remarks:
Amended claims in accordance with Rule 137(2)
EPC.

(54) **SOUND GENERATION ASSEMBLY FOR A VEHICLE, VEHICLE, METHOD FOR OPERATING A
SOUND GENERATION ASSEMBLY FOR A VEHICLE, DATA PROCESSING APPARATUS,
COMPUTER PROGRAM, COMPUTER-READABLE STORAGE MEDIUM AND USE**

(57) A sound generation assembly (14) for a vehicle is described. The sound generation assembly (14) comprises a first electroacoustic transducer (22) comprising a piezo actuator (24) and a second electroacoustic transducer (30) comprising a non-metallic diaphragm (32) and an electromagnetic actuator (34) connected thereto. Moreover, the sound generation assembly (14) comprises a control unit (36) being electrically connected to the first electroacoustic transducer (22) and to the second electroacoustic transducer (30). The control unit (36) is configured to provide a first actuation signal (S1) to the

first electroacoustic transducer (22) and a second actuation signal (S2) to the second electroacoustic transducer (30). The first actuation signal (S1) and the second actuation signal (S2) are different and synchronized. Moreover, a vehicle comprising such a sound generation assembly (14) and a method for operating a sound generation assembly (14) are explained. Furthermore, a data processing apparatus (38), a computer program (48) and a computer-readable storage medium (44) are described. Additionally, a use of a sound generation assembly (14) is presented.

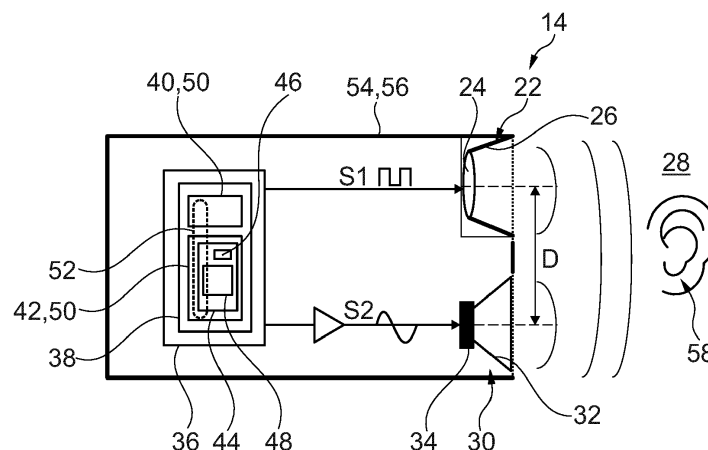


Fig. 2

Description

[0001] The present invention relates to a sound generation assembly for a vehicle.

[0002] Moreover, the present invention is directed to a vehicle comprising such a sound generation assembly.

[0003] Additionally, the present invention relates to a method for operating a sound generation assembly for a vehicle.

[0004] The present invention further is directed to a data processing apparatus, a computer program, and a computer-readable storage medium.

[0005] Furthermore, the present invention relates to a use of a sound generation assembly.

[0006] Vehicles, such as bicycles, scooters, motorcycles, cars, trucks, building machines and buses, use different types of sound generation assemblies depending on the type of the vehicle and the use of the vehicle.

[0007] An electric car may for example use one sound generation assembly as a part of a signal-horn system. Another sound generation assembly may be used as a part of an alarm-horn system. A further sound generation assembly may be used as a part of an acoustic vehicle alerting system (AVAS). The same applies to electric trucks and electric buses.

[0008] Bicycles, scooters, and motorcycles may also comprise a signal-horn system.

[0009] Moreover, any one of the vehicles as mentioned above may comprise a sound generation assembly being configured to generate an acoustic user feedback. Such an acoustic user feedback may be used in connection with locking or unlocking the vehicle. This means that the vehicle is able to issue a sound when being locked or unlocked.

[0010] The fact that vehicles use different sound generation assemblies is due to very different requirements which have to be fulfilled by the different applications needing a sound generation assembly. For example, a sound generation assembly being used as a part of a signal-horn system needs to be able to generate a sound of a certain volume or intensity. The same may apply to a sound generation assembly being used as a part of an alarm-horn system. In contrast thereto, a sound generation assembly being used as a part of an acoustic vehicle alerting system (AVAS) or for generating an acoustic user feedback usually does not need to generate a very loud sound, i.e. a sound of a high volume or high intensity. However, especially in contrast to signal horn systems and alarm-horn systems, these systems need to be able to generate a sound of high quality which shall be perceived by a listener to be pleasant.

[0011] It is an objective of the present invention to simplify such arrangements of different sound generation assemblies. At the same time, the known functionalities shall not be impaired.

[0012] According to a first aspect, there is provided a sound generation assembly for a vehicle. The sound generation assembly comprises a first electroacoustic trans-

ducer comprising a piezo actuator and a second electroacoustic transducer comprising a non-metallic diaphragm and an electromagnetic actuator connected thereto. Moreover, the sound generation assembly comprises a control unit being electrically connected to the first electroacoustic transducer and to the second electroacoustic transducer. The control unit is configured to provide a first actuation signal to the first electroacoustic transducer and a second actuation signal to the second electroacoustic transducer. The first actuation signal and the second actuation signal are different and synchronized. The piezo actuator and, thus, the first electroacoustic transducer is able to produce a comparatively loud, but simple sound. This is due to the fact that a piezo actuator usually is tuned to a predefined frequency or frequency range. When doing so, the piezo actuator requires only a comparatively small amount of electric power. Thus, when comparing the comparatively loud sound, i.e. the sound of relatively high volume or intensity, to the consumption of electric power, the piezo actuator is highly efficient. The second electroacoustic transducer may comprise a standard loudspeaker. Consequently, the second electroacoustic transducer is able to generate a sound of high quality and high variety. However, when being compared to the sound being generated by the first electroacoustic transducer, the sound being generated by the second electroacoustic transducer is less loud, i.e. has a smaller volume or intensity. According to the present invention, the sound being generated by the first electroacoustic transducer and the sound being generated by the second electroacoustic transducer are synchronized. This means that the sound being generated by the first electroacoustic transducer and the sound being generated by the second electroacoustic transducer are acoustically combined such that a listener only perceives the combined sound. The combined sound may be of high quality and, at the same time, of high volume or high intensity. Thus, using the sound generation assembly of the present invention, a sound that is loud and simultaneously perceived to be pleasant may be generated.

[0013] Consequently, the sound generation assembly of the present invention may be used for different applications. For example, the sound generation assembly of the present invention may be used as a common sound generation assembly of at least two out of the group consisting of a signal-horn system, an alarm-horn system, an acoustic vehicle alerting system (AVAS) and an acoustic user feedback generation system. Thus, instead of a plurality of different sound generation assemblies, only one sound generation assembly of the present invention may be needed. Thus, compared to prior art solutions, the sound generation assembly of the present invention is compact and comprises a comparatively low amount of parts. This reduces system complexity.

[0014] A further advantage of the sound generation assembly of the present invention lies in the fact that the second electroacoustic transducer, e.g. comprising a

standard loudspeaker, is able to provide a variety of different sounds. Thus, even though it may be assumed that the first electroacoustic transducer is only able to provide one single type of sound, using the sound generation assembly of the present invention, different combined sounds may be provided by generating different sounds using the second electroacoustic transducer.

[0015] In the present context, the fact that the first actuation signal and the second actuation signal are synchronized means that the first actuation signal and the second actuation signal are provided in a timely coordinated manner. In an example, a signal element of the first actuation signal and a signal element of the second actuation signal corresponding to each other, i.e. being configured to generate sounds that shall be combined, may be generated at the same time. In another example, the signal element of the first actuation signal and the signal element of the second actuation signal may be generated with a predefined timely offset.

[0016] Beyond that, the fact that the first actuation signal and the second actuation signal are different means that the first actuation signal and the second actuation signal originate from different signal sources and/or the first actuation signal and the second actuation signal are of a different type. As has been explained before, the first actuation signal is configured to actuate a piezo actuator which is tuned to a specific frequency or a specific frequency range. Thus, the first actuation signal may be a periodic signal, e.g. a square wave signal. The second actuation signal is configured to actuate the second electroacoustic transducer which may comprise a standard loudspeaker. Consequently, the second actuation signal may be more complex than the first actuation signal. For example, an amplitude and/or a frequency of the second actuation signal may vary over a range which is broad as compared to a range of variation of an amplitude and/or a frequency of the first actuation signal. In a special case, the amplitude and/or the frequency of the first actuation signal is constant, i.e. does not vary.

[0017] According to an example, the control unit comprises a signal generator unit configured to generate the first actuation signal. Additionally, the control unit comprises a data storage unit configured to store an audio file, and a data processing unit being configured to generate the second actuation signal based on the audio file. As has been explained before, for a listener, the sound resulting from the first electroacoustic transducer being operated using the first actuation signal and the second electroacoustic transducer being operated by the second actuation signal is combined. Using the storage unit, an audio file of high quality may be provided in a simple and efficient manner. Thus, high acoustic quality may be ensured for the sound originating from the second electroacoustic transducer and the combined sound. Moreover, different audio files may be stored on the storage unit such that a certain variety of different sounds may be provided in a simple manner.

[0018] According to another example, the piezo actuator is mechanically and acoustically coupled to an acoustic horn. In this context, an acoustic horn is to be understood as a tapering guide for soundwaves. The acoustic horn is configured to provide a match between an acoustic impedance of the piezo actuator and free air of an environment. As a consequence, soundwaves are guided from the piezo actuator to the environment of the sound generation assembly in a highly efficient manner. In other words, the first electroacoustic transducer is able to provide a relatively loud sound, i.e. a sound of high volume or high intensity, while only consuming comparatively little electric power.

[0019] In an example, the first electroacoustic transducer is located in an acoustic nearfield of the second electroacoustic transducer. Additionally or alternatively, the second electroacoustic transducer is located in an acoustic nearfield of the first electroacoustic transducer. In this context, an acoustic near field is to be understood as a region around a source of acoustic waves being characterized by irregular changes between locations with constructive and destructive interference. In contrast thereto, an acoustic farfield is a region remote from the source of acoustic waves where interference effects are negligible. In simplified words, the first electroacoustic transducer is located close to the second electroacoustic transducer and/or the second electroacoustic transducer is located close to the first electroacoustic transducer. This has the effect that a sound originating from the first electroacoustic transducer and a sound originating from the second electroacoustic transducer are perceived by a listener as a combined sound only. In this context, it is assumed that the listener is located in the acoustic farfield of both the first electroacoustic transducer and the second electroacoustic transducer.

[0020] In an example, the distance between a center of the first electroacoustic transducer and the center of the second electroacoustic transducer is 2 cm to 15 cm. Preferably, this distance is 5 cm to 10 cm.

[0021] In a further example, the first electroacoustic transducer and the second electroacoustic transducer are arranged in a common housing. Consequently, the sound generation assembly is structurally simple. This is especially the case when being compared to a solution in which each electroacoustic transducer has its own housing. Relatively few parts are used. Moreover, the common housing renders the sound generation assembly compact.

[0022] In an example, the control unit comprises a control unit housing and the first electroacoustic transducer is located in or on the control unit housing. Such a configuration only needs comparatively few parts and is compact. Additionally, in this configuration, a volume of the control unit housing may be used as a resonance volume being acoustically coupled to the first electroacoustic transducer. This enhances the acoustic quality of a sound being generated by the first electroacoustic transducer and may additionally lead to the fact that the loudness of a sound being generated by the first electroacoustic

transducer may be increased.

[0023] In this context, a resonance frequency of the control unit housing may differ by +/-20% or less from an operational frequency of the first electroacoustic transducer. In other words, the resonance frequency of the control unit housing and the operational frequency of the first electroacoustic transducer are matched. Thus, the control unit housing fulfills an acoustic functionality in connection with the first electroacoustic transducer. This enhances the acoustic quality of a sound being generated by the first electroacoustic transducer and may additionally lead to the fact that the loudness of a sound being generated by the first electroacoustic transducer may be increased.

[0024] According to a second aspect, there is provided a vehicle comprising a sound generation assembly according to the invention. Thus, using the sound generation assembly, the vehicle is able to issue a sound of high quality and at the same time of high volume or high intensity. In other words, the sound is loud and perceived to be pleasant at the same time by a listener. In the vehicle, the sound generation assembly may be used for different applications requiring a comparatively loud sound, a sound of high quality or a comparatively loud sound being of high quality at the same time. For example, the sound generation assembly may be used as a sound generation assembly of a signal-horn system, an alarm-horn system, an acoustic vehicle alerting system (AVAS) or an acoustic user feedback generation system. It is noted that the sound generation assembly may as well be used as a common sound generation assembly of at least two of these systems. Thus, instead of a plurality of different sound generation assemblies, only one sound generation assembly of the present invention may be needed. Thus, compared to prior art solutions, the sound generation assembly of the present invention is compact and comprises a comparatively low amount of parts. This reduces system complexity of the vehicle.

[0025] The vehicle may be a bicycle, especially an electric bicycle, a scooter, a motorcycle, a car, a truck or a bus, in particular an electric car, an electric truck or an electric bus.

[0026] According to a third aspect, there is provided a method for operating a sound generation assembly for a vehicle. The sound generation assembly has a first electroacoustic transducer comprising a piezo actuator and a second electroacoustic transducer comprising a non-metallic diaphragm and an electromagnetic actuator connected thereto. The method comprises:

- providing a first actuation signal to the first electroacoustic transducer and
- providing a second actuation signal to the second electroacoustic transducer, wherein the second actuation signal differs from the first actuation signal and wherein the second actuation signal is synchronized to the first actuation signal.

[0027] Thus, using the method of the present invention, a sound of high quality and at the same time of high volume or high intensity may be generated. Such a sound is loud and may be perceived to be pleasant at the same time. Consequently, the generated sound may be used for different applications requiring a comparatively loud sound, a sound of high quality or a comparatively loud sound being of high quality at the same time. For example, the sound generation assembly may be used as a sound generation assembly of a signal-horn system, an alarm-horn system, an acoustic vehicle alerting system (AVAS) or an acoustic user feedback generation system. It is noted that the sound generation assembly may as well be used as a common sound generation assembly of at least two of these systems.

[0028] It is noted that the method of the present invention may be executed on a sound generation assembly of the present invention. In this context, the method is executed on the control unit, more precisely on a data processing unit of the control unit, of the sound generation assembly of the present invention.

[0029] In an example, the first actuation signal has a higher frequency than the second actuation signal. Thus, the first electroacoustic transducer may be used to generate a sound of higher frequency than the second electroacoustic transducer. Consequently, a combined sound, i.e. the combination of the sound being produced by the first electroacoustic transducer and the second electroacoustic transducer, covers a comparatively large spectrum of frequencies. This is an indicator of high sound quality.

[0030] According to an example, the first actuation signal is configured to cause a sound of a higher volume than the second actuation signal. As has been mentioned before, the first electroacoustic transducer is able to provide a comparatively loud sound in an energy-efficient manner. Consequently a comparatively loud sound may be produced using comparatively little electric power.

[0031] According to a fourth aspect, there is provided a data processing apparatus comprising means for carrying out the method of the invention. Thus, using the data processing apparatus, a sound of high quality and at the same time of high volume or high intensity may be generated. Consequently, the generated sound may be used for different applications requiring a comparatively loud sound, a sound of high quality or a comparatively loud sound being of high quality at the same time. For example, the sound generation assembly may be used as a sound generation assembly of a signal-horn system, an alarm-horn system, an acoustic vehicle alerting system (AVAS) or an acoustic user feedback generation system. It is noted that the sound generation assembly may as well be used as a common sound generation assembly of at least two of these systems.

[0032] According to a fifth aspect, there is provided a computer program comprising instructions which, when the computer program is executed by a computer, cause the computer to carry out the method of the invention.

Thus, using the computer program, a sound of high quality and at the same time of high volume or high intensity may be generated. Consequently, the generated sound may be used for different applications requiring a comparatively loud sound, a sound of high quality or a comparatively loud sound being of high quality at the same time. For example, the sound generation assembly may be used as a sound generation assembly of a signal-horn system, an alarm-horn system, an acoustic vehicle alerting system (AVAS) or an acoustic user feedback generation system. It is noted that the sound generation assembly may as well be used as a common sound generation assembly of at least two of these systems.

[0033] According to a sixth aspect, there is provided a computer-readable storage medium comprising instructions which, when executed by a computer, cause the computer to carry out the method of the invention. Thus, using the computer-readable storage medium, a sound of high quality and at the same time of high volume or high intensity may be generated. Consequently, the generated sound may be used for different applications requiring a comparatively loud sound, a sound of high quality or a comparatively loud sound being of high quality at the same time. For example, the sound generation assembly may be used as a sound generation assembly of a signal-horn system, an alarm-horn system, an acoustic vehicle alerting system (AVAS) or an acoustic user feedback generation system. It is noted that the sound generation assembly may as well be used as a common sound generation assembly of at least two of these systems.

[0034] According to a seventh aspect, there is provided a use of the sound generation assembly of the invention as at least one of a signal-horn for a vehicle, an alarm-horn for a vehicle, a vehicle alerting sound generation assembly and a user feedback sound generation assembly for a vehicle. As has been explained before, the sound generation assembly of the present invention is able to provide a sound of high quality and at the same time of high volume or high intensity. Thus, a sound that is loud and perceived to be pleasant at the same time may be generated. Consequently, the generated sound may be used for different applications requiring a comparatively loud sound, a sound of high quality or a comparatively loud sound being of high quality at the same time. This is structurally simple and efficient.

[0035] These and other aspects of the present invention will become apparent from and elucidated with reference to the examples described hereinafter. Examples of the invention will be described in the following with reference to the following drawings.

Figure 1 shows different examples of vehicles according to the invention comprising a sound generation assembly according to the invention which may be operated using a method according to the invention,

Figure 2 shows the sound generation assembly of Figure 1 in a more detailed view, and

Figure 3 shows an alternative sound generation assembly according to the invention, wherein one electroacoustic transducer is arranged in a control unit housing.

[0036] The Figures are merely schematic representations and serve only to illustrate examples. Identical or equivalent elements are in principle provided with the same reference signs.

[0037] Figure 1 shows four alternative vehicles 10.

[0038] In Figure 1 a), the vehicle 10 is a bicycle which comprises a bicycle frame 12. A sound generation assembly 14 is arranged in the bicycle frame 12. Even though represented as a standard, purely human-powered bicycle, the bicycle can as well be an electric bicycle.

[0039] In Figure 1 b), the vehicle 10 is a motorcycle which comprises a motorcycle frame 16. A sound generation assembly 14 is arranged in the motorcycle frame 16.

[0040] In Figure 1 c), the vehicle 10 is a scooter which comprises a scooter frame 18. A sound generation assembly 14 is arranged in the scooter frame 18.

[0041] In Figure 1 d), the vehicle 10 is a car. A sound generation assembly 14 is arranged in the motor compartment 20 of the car.

[0042] Figure 2 shows the sound generation assembly 14 of all of the exemplary vehicles 10 of Figure 1 in more detail.

[0043] The sound generation assembly 14 comprises a first electroacoustic transducer 22.

[0044] The first electroacoustic transducer 22 comprises a piezo actuator 24 and an acoustic horn 26. The piezo actuator 24 and the acoustic horn 26 are mechanically and acoustically coupled.

[0045] This means that the piezo actuator 24 and the acoustic horn 26 are mechanically connected to one another. Furthermore, a sound being generated by the piezo actuator 24 may be transmitted to an environment 28 via the acoustic horn 26.

[0046] The sound generation assembly 14 additionally comprises a second electroacoustic transducer 30.

[0047] The second electroacoustic transducer 30 comprises a non-metallic diaphragm 32 and an electromagnetic actuator 34 being connected to the non-metallic diaphragm 32.

[0048] Thus, the second electroacoustic transducer 30 may generate a sound and provide the sound to the environment 28 by moving the diaphragm 32 using the electromagnetic actuator 34.

[0049] The sound generation assembly 14 also comprises a control unit 36.

[0050] The control unit 36 comprises a data processing apparatus 38.

[0051] The data processing apparatus 38 comprises a data processing unit 40 and a data storage unit 42.

[0052] The data processing unit 40 is for example a microcontroller.

[0053] The data storage unit 42 comprises a computer-readable storage medium 44.

[0054] The computer-readable storage medium 44 comprising instructions which, when executed by the data processing unit 40 or, more generally speaking a computer, cause the data processing unit 40 or computer to carry out a method for operating the sound generating assembly 14.

[0055] Additionally, at least one audio file 46 is stored on the computer-readable storage medium 44.

[0056] Moreover, on the computer-readable storage medium 44, there is provided a computer program 48.

[0057] Also the computer program 48 comprises instructions which, when the computer program 48 is executed by the data processing unit 40 or, more generally speaking, a computer, cause the computer or the data processing unit 40 to carry out the method for operating the sound generating assembly 14.

[0058] Consequently, the data processing unit 40 and the data storage unit 42 form means 50 for carrying out the method for operating the sound generating assembly 14.

[0059] The control unit 36 is electrically connected to the first electroacoustic transducer 22 and to the second electroacoustic transducer 30.

[0060] Thereby, the control unit 36, more precisely the data processing unit 40, is configured to provide a first actuation signal S1 to the first electroacoustic transducer 22.

[0061] It is understood that, to this end, also an information, e.g. an operational frequency, being stored on the data storage unit 42 may be used.

[0062] Consequently, the data processing unit 40 and the data storage unit 42 form a signal generator unit 52 configured to generate the first actuation signal S1. The first actuation signal S1 is for example a square wave signal of constant amplitude and frequency.

[0063] The control unit 36, more precisely the data processing unit 40, is also configured to provide a second actuation signal S2 to the second electroacoustic transducer 30. The second actuation signal S2 is generated using the data processing unit 40. The second actuation signal S2 is generated based on the audio file 46. Thus, the second actuation signal S2 is a signal having a variable amplitude and variable frequency.

[0064] Due to the fact that the first electroacoustic transducer 22 comprises a piezo actuator 24 and the second electroacoustic transducer 30 comprises an electromagnetic actuator 34 for moving the non-metallic diaphragm 32, the first actuation signal S1 and the second actuation signal S2 are of different types.

[0065] Moreover, the first actuation signal S1 and the second actuation signal S2 are synchronized as will be explained in more detail further below.

[0066] In the example shown in Figure 2, the first electroacoustic transducer 22, the second electroacoustic

transducer 30 and the control unit 36 are arranged in a common housing 54.

[0067] In order not to hinder the sounds being produced by the first electroacoustic transducer 22 and the second electroacoustic transducer 30, the common housing 54 has a grating adjacent to the first electroacoustic transducer 22 and the second electroacoustic transducer 30 respectively.

[0068] The first electroacoustic transducer 22 and the second electroacoustic transducer 30 are arranged such that the first electroacoustic transducer 22 is located in an acoustic nearfield of the second electroacoustic transducer 30. At the same time, the second electroacoustic transducer 30 is located in an acoustic nearfield of the first electroacoustic transducer 22.

[0069] In the present example, this means that a distance D between the center of the first electroacoustic transducer 22 and the center of the second electroacoustic transducer 30 is 8 cm.

[0070] Moreover, a resonance frequency of the common housing 54 is matched to an operational frequency of the first electroacoustic transducer 22.

[0071] This means that the resonance frequency of the common housing 54 differs by +/-20% or less from an operational frequency of the first electroacoustic transducer 22. Thus, the common housing 54 supports the acoustic functionality of the first electroacoustic transducer 22.

[0072] From the perspective of the control unit 36, the common housing 54 is a control unit housing 56. Put otherwise, the first electroacoustic transducer 22 is located in the control unit housing 56 and a resonance frequency of the control unit housing 56 is matched to an operational frequency of the first electroacoustic transducer.

[0073] The sound generation assembly 14 may be operated using a method for operating a sound generation assembly 14 for a vehicle 10.

[0074] According to the method, the first actuation signal S1 is provided to the first electroacoustic transducer 22. As has been mentioned before, the first actuation signal S1 is a square wave signal of constant frequency and amplitude.

[0075] Moreover, the second actuation signal S2 is provided to the second electroacoustic transducer 30.

[0076] As has also been explained before, the second actuation signal S2 is a complex signal of variable frequency and variable amplitude.

[0077] Thus, the second actuation signal S2 differs from the first actuation signal S1.

[0078] Moreover, the second actuation signal S2 and the first actuation signal S1 are synchronized. This means that the first actuation signal S1 and the second actuation signal S2 are provided in a timely coordinated manner.

[0079] This has the effect that a sound being generated by the first electroacoustic transducer 22 and a sound being generated by the second electroacoustic transducer

er 30 are generated in a timely coordinated manner.

[0080] As a consequence thereof, a listener 58 which is represented in Figure 2 by an ear only, only hears a combination of the sound being generated by the first electroacoustic transducer 22 and a sound being generated by the second electroacoustic transducer 30.

[0081] Since in the present example, the first actuation signal S 1 has a higher frequency than the second actuation signal S 2 and the first actuation signal S 1 is configured to cause a sound of a higher volume than the second actuation signal S 2, the combined sound comprises a comparatively broad spectrum of frequencies and is a high-volume sound.

[0082] In other words, the combined sound is loud and of high quality at the same time.

[0083] Figure 3 shows another example of the sound generation assembly 14. In the following, only the differences with respect to the sound generation assembly 14 of Figure 2 will be explained.

[0084] In the example of Figure 3, the first electroacoustic transducer 22 and the control unit 36 are arranged in a common housing which is designated a control unit housing 56. In other words, the first electroacoustic transducer 22 is arranged in the control unit housing 56.

[0085] The second electroacoustic transducer 30 is arranged in a transducer housing 60 which is separate from the control unit housing 56.

[0086] This has the advantage that a volume of the transducer housing 60 which has an effect on the acoustic characteristics of the second electroacoustic transducer 30 may be chosen independently from a volume of the control unit housing 56.

[0087] It is emphasized that also in the example of Figure 3, the distance D between a center of the first electroacoustic transducer 22 and the center of the second electroacoustic transducer 30 is 8 cm as in the example of Figure 2.

[0088] Also the sound generation assembly 14 of Figure 3 may be operated using a method for operating a sound generation assembly 14. Reference is made to the explanations provided in connection with the example of Figure 2.

[0089] In both of the above examples, the sound generation assembly 14 may be used to produce a sound of high volume or high intensity and high quality. Consequently, the sound generation assembly 14 may be used as at least one of a signal-horn for a vehicle, an alarm-horn for a vehicle, a vehicle alerting sound generation assembly and a user feedback sound generation assembly for a vehicle.

[0090] For example, if the vehicle 10 is a bicycle as shown in Figure 1 a), more precisely an electric bicycle, or if the vehicle 10 is a scooter as shown in Figure 1 c) the sound generation assembly 14 may be used as a common sound generation assembly of an alarm-horn and a user feedback sound generation assembly. The user feedback sound generation assembly may for example issue a confirmation sound if the bicycle or the

scooter is locked or unlocked. Moreover, the user feedback sound generation assembly may be used for a find-my-bike functionality or a find-my-scooter functionality.

[0091] In another example, the vehicle 10 may be a motorcycle as shown in Figure 1 b) or a car as shown in Figure 1 d). The motorcycle may be an electric motorcycle and the car may be an electric car.

[0092] In this example the sound generation assembly 14 may be used as a common sound generation assembly of an alarm-horn of an anti-theft system, a signal horn and a vehicle alerting sound generation assembly (AVAS).

[0093] Other variations to the disclosed examples can be understood and effected by those skilled in the art in practicing the claimed disclosure, from the study of the drawings, the disclosure, and the appended claims. In the claims the word "comprising" does not exclude other elements or steps and the indefinite article "a" or "an" does not exclude a plurality. A single processor or other unit may fulfill the functions of several items or steps recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. A computer program may be stored/distributed on a suitable medium such as an optical storage medium or a solid-state medium supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the Internet or other wired or wireless telecommunication systems. Any reference signs in the claims should not be construed as limiting the scope of the claims.

List of Reference Signs

[0094]

10	vehicle
12	bicycle frame
14	sound generation assembly
16	motorcycle frame
18	scooter frame
20	motor compartment
22	first electroacoustic transducer
24	piezo actuator
26	acoustic horn
28	environment
30	second electroacoustic transducer
32	non-metallic diaphragm
34	electromagnetic actuator
36	control unit
38	data processing apparatus
40	data processing unit
42	data storage unit
44	computer-readable storage medium
46	audio file
48	computer program
50	means for carrying out the method for operating the sound generating assembly

52 signal generator unit
 54 common housing
 56 control unit housing
 58 listener
 60 transducer housing

D distance

S1 first actuation signal

S2 second actuation signal

Claims

1. A sound generation assembly (14) for a vehicle (10), comprising

a first electroacoustic transducer (22) comprising a piezo actuator (24),
 a second electroacoustic transducer (30) comprising a non-metallic diaphragm (32) and an electromagnetic actuator (34) connected thereto, and
 a control unit (36) being electrically connected to the first electroacoustic transducer (22) and to the second electroacoustic transducer (30), wherein the control unit (36) is configured to provide a first actuation signal (S1) to the first electroacoustic transducer (22) and a second actuation signal (S2) to the second electroacoustic transducer (30), the first actuation signal (S1) and the second actuation signal (S2) being different and synchronized.

2. The sound generation assembly (14) of claim 1, wherein the control unit (36) comprises a signal generator unit (52) configured to generate the first actuation signal (S1), a data storage unit (42) configured to store an audio file (46), and a data processing unit (40) being configured to generate the second actuation signal (S2) based on the audio file (46).

3. The sound generation assembly (14) of claim 1 or 2, wherein the piezo actuator (24) is mechanically and acoustically coupled to an acoustic horn (26).

4. The sound generation assembly (14) of any one of the preceding claims, wherein the first electroacoustic transducer (22) is located in an acoustic nearfield of the second electroacoustic transducer (30) and/or wherein the second electroacoustic transducer (30) is located in an acoustic nearfield of the first electroacoustic transducer (22).

5. The sound generation assembly (14) of any one of the preceding claims, wherein the first electroacoustic transducer (22) and the second electroacoustic

transducer (30) are arranged in a common housing (54).

6. The sound generation assembly (14) of any one of the preceding claims, wherein the control unit (36) comprises a control unit housing (56) and the first electroacoustic transducer (22) is located in or on the control unit housing (56).

7. The sound generation assembly (14) of claim 6, wherein a resonance frequency of the control unit housing (56) differs by +/-20% or less from an operational frequency of the first electroacoustic transducer (22).

8. A vehicle (10) comprising a sound generation assembly (14) of any one of the preceding claims.

9. A method for operating a sound generation assembly (14) for a vehicle (10), the sound generation assembly (14) having a first electroacoustic transducer (22) comprising a piezo actuator (24) and a second electroacoustic transducer (30) comprising a non-metallic diaphragm (32) and an electromagnetic actuator (34) connected thereto, the method comprising:

- providing a first actuation signal (S1) to the first electroacoustic transducer (22) and
- providing a second actuation signal (S2) to the second electroacoustic transducer (30), wherein the second actuation signal (S2) differs from the first actuation signal (S1) and wherein the second actuation signal (S2) is synchronized to the first actuation signal (S1).

10. The method of claim 9, wherein the first actuation signal (S1) has a higher frequency than the second actuation signal (S2).

11. The method of claim 9 or 10, wherein the first actuation signal (S1) is configured to cause a sound of a higher volume than the second actuation signal (S2).

12. A data processing apparatus (38) comprising means (50) for carrying out the method of any one of claims 9 to 11.

13. A computer program (48) comprising instructions which, when the computer program (48) is executed by a computer, cause the computer to carry out the method of any one of claims 9 to 11.

14. A computer-readable storage medium (44) comprising instructions which, when executed by a computer, cause the computer to carry out the method of any one of claims 9 to 11.

15. A use of the sound generation assembly (14) of any one of claims 1 to 7 as at least one of a signal-horn for a vehicle (10), an alarm-horn for a vehicle (10), a vehicle alerting sound generation assembly and a user feedback sound generation assembly for a vehicle (10).

Amended claims in accordance with Rule 137(2) EPC.

1. A sound generation assembly (14) for a vehicle (10), comprising

a first electroacoustic transducer (22) comprising a piezo actuator (24),
 a second electroacoustic transducer (30) comprising a non-metallic diaphragm (32) and an electromagnetic actuator (34) connected thereto, and
 a control unit (36) being electrically connected to the first electroacoustic transducer (22) and to the second electroacoustic transducer (30),
characterized in that the control unit (36) is configured to provide a first actuation signal (S1) to the first electroacoustic transducer (22) and a second actuation signal (S2) to the second electroacoustic transducer (30), the first actuation signal (S1) and the second actuation signal (S2) being different and synchronized, wherein the first actuation signal (S1) and the second actuation signal (S2) are different **in that** the first actuation signal (S1) and the second actuation signal (S2) originate from different signal sources and/or in that the first actuation signal and the second actuation signal are of a different type.

2. The sound generation assembly (14) of claim 1, wherein the control unit (36) comprises a signal generator unit (52) configured to generate the first actuation signal (S1), a data storage unit (42) configured to store an audio file (46), and a data processing unit (40) being configured to generate the second actuation signal (S2) based on the audio file (46).
3. The sound generation assembly (14) of claim 1 or 2, wherein the piezo actuator (24) is mechanically and acoustically coupled to an acoustic horn (26).
4. The sound generation assembly (14) of any one of the preceding claims, wherein the first electroacoustic transducer (22) is located in an acoustic nearfield of the second electroacoustic transducer (30) and/or wherein the second electroacoustic transducer (30) is located in an acoustic nearfield of the first electroacoustic transducer (22).

5. The sound generation assembly (14) of any one of the preceding claims, wherein the first electroacoustic transducer (22) and the second electroacoustic transducer (30) are arranged in a common housing (54).

6. The sound generation assembly (14) of any one of the preceding claims, wherein the control unit (36) comprises a control unit housing (56) and the first electroacoustic transducer (22) is located in or on the control unit housing (56).

7. The sound generation assembly (14) of claim 6, wherein a resonance frequency of the control unit housing (56) differs by +/-20% or less from an operational frequency of the first electroacoustic transducer (22).

8. A vehicle (10) comprising a sound generation assembly (14) of any one of the preceding claims.

9. A method for operating a sound generation assembly (14) for a vehicle (10), the sound generation assembly (14) having a first electroacoustic transducer (22) comprising a piezo actuator (24) and a second electroacoustic transducer (30) comprising a non-metallic diaphragm (32) and an electromagnetic actuator (34) connected thereto, the method comprising:

- providing a first actuation signal (S1) to the first electroacoustic transducer (22) and
 - providing a second actuation signal (S2) to the second electroacoustic transducer (30), wherein the second actuation signal (S2) differs from the first actuation signal (S1) and wherein the second actuation signal (S2) is synchronized to the first actuation signal (S1), and wherein the first actuation signal (S1) and the second actuation signal (S2) are different in that the first actuation signal (S1) and the second actuation signal (S2) originate from different signal sources and/or in that the first actuation signal and the second actuation signal are of a different type.

10. The method of claim 9, wherein the first actuation signal (S1) has a higher frequency than the second actuation signal (S2).

11. The method of claim 9 or 10, wherein the first actuation signal (S1) is configured to cause a sound of a higher volume than the second actuation signal (S2).

12. A data processing apparatus (38) comprising means (50) for carrying out the method of any one of claims 9 to 11.

13. A computer program (48) comprising instructions

which, when the computer program (48) is executed by a computer, cause the computer to carry out the method of any one of claims 9 to 11.

14. A computer-readable storage medium (44) comprising instructions which, when executed by a computer, cause the computer to carry out the method of any one of claims 9 to 11. 5
15. A use of the sound generation assembly (14) of any one of claims 1 to 7 as at least one of a signal-horn for a vehicle (10), an alarm-horn for a vehicle (10), a vehicle alerting sound generation assembly and a user feedback sound generation assembly for a vehicle (10). 10 15

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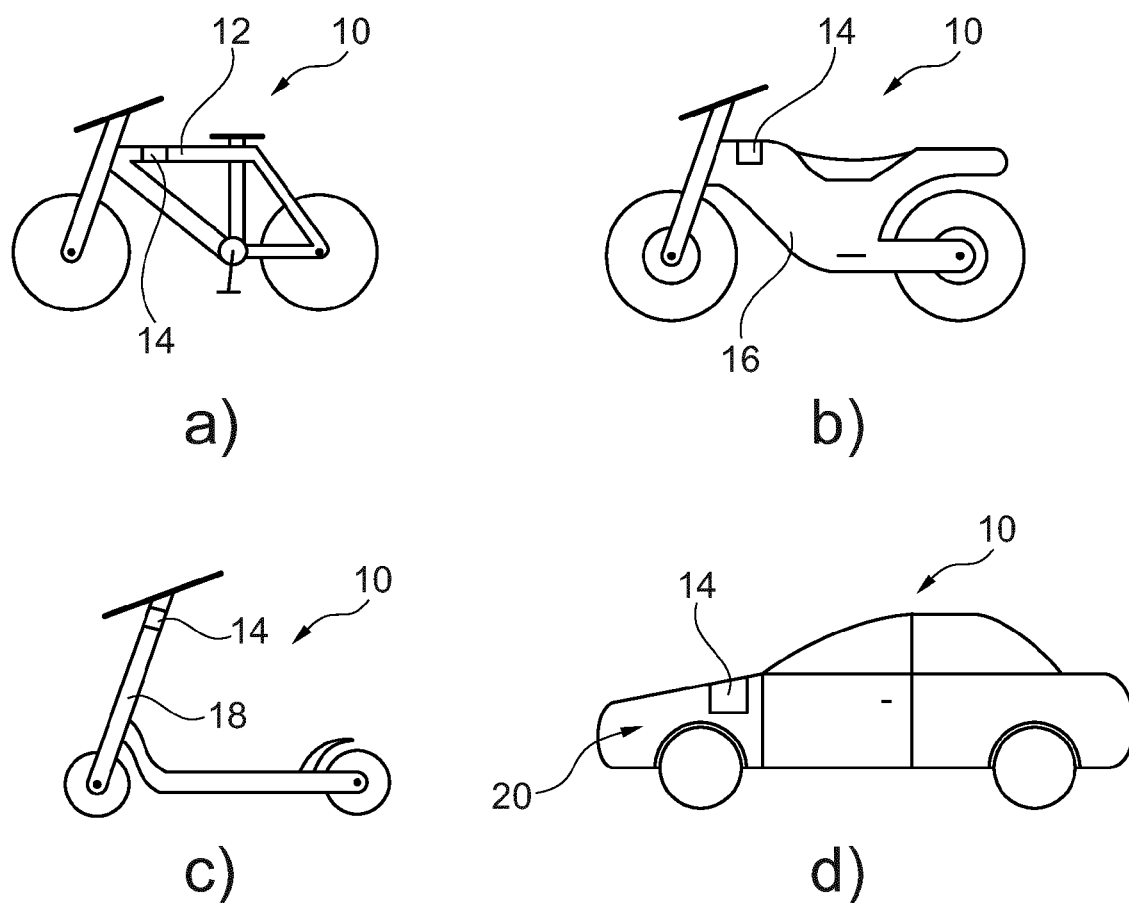


Fig. 1

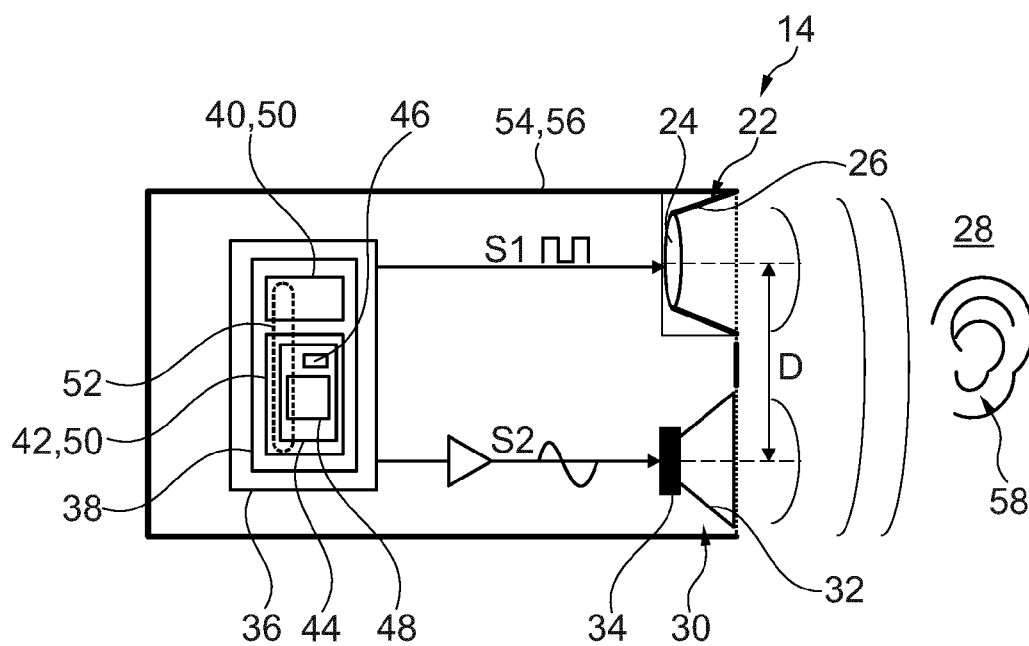


Fig. 2

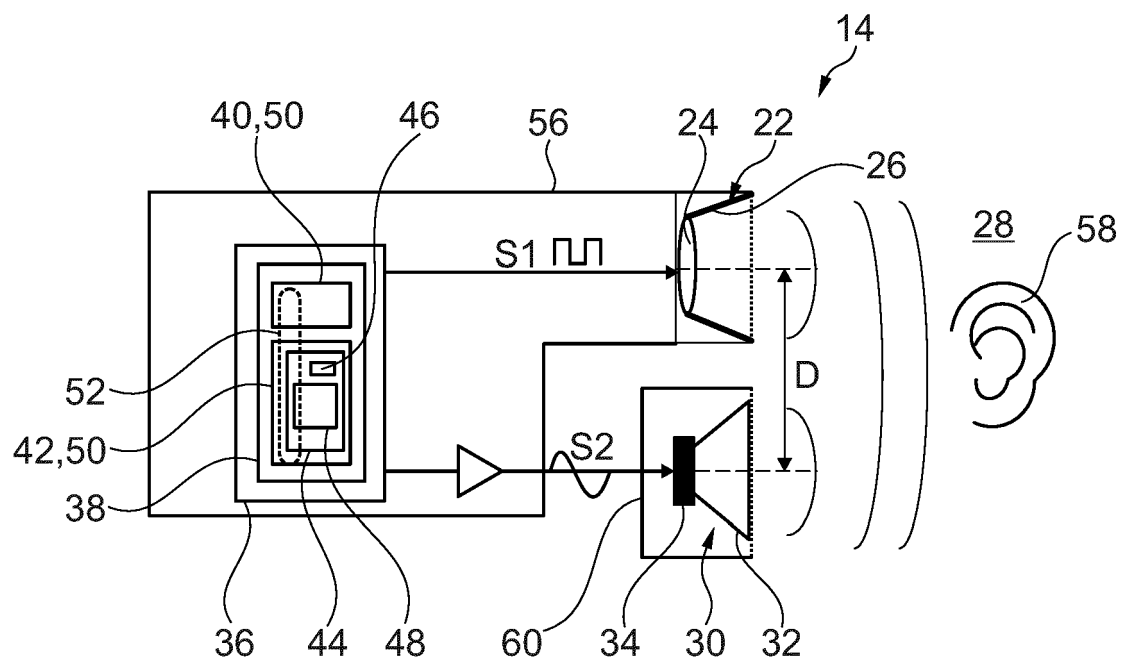


Fig. 3



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Application Number

EP 23 16 2267

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Place of search Munich		Date of completion of the search 6 September 2023	Examiner Moscu, Viorel
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