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(54) ACOUSTIC SYSTEM

(57) An acoustic system (16) for generating sound comprises a trim part (12), an exciter (18) coupled to the trim part (12) for inducing vibrations to the trim part (12), a sensor (22) measuring temperature and/or a sensor (24) measuring humidity, and a control unit (20) being configured so as to determine control signals for the exciter (18) depending on temperature and/or humidity. The acoustic system (16) is in particular suitable for use in an automotive interior.

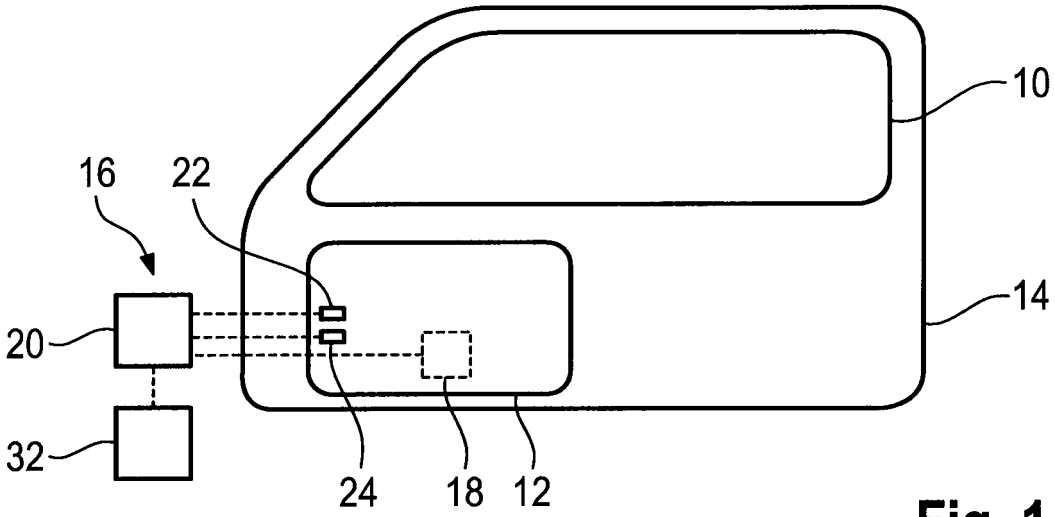

Fig. 1

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Description

[0001] The present invention relates to an acoustic system, in particular to an acoustic system for a vehicle, which comprises a vehicle interior trim panel acting as a loud speaker membrane.

[0002] Standard loudspeakers are integrated into the vehicle and are coupled with an entertainment system in order to output music, telephone conversations etc.

[0003] The integration of the loudspeakers is a challenge for designers and, furthermore, due to limited space assigned to loudspeakers, their minimum volume impedes generating sound waves with low frequencies.

[0004] Therefore, ideas have been created to couple trim panels to electro-mechanical exciters for generating sound. Those exciters are inducing vibrations to the trim part, i.e. the panel, which replaces a loudspeaker membrane. An example for such an acoustic system is presented by EP 1 147 681 A1.

[0005] Contrary to acoustic systems permanently installed in buildings, acoustic systems of vehicles are confronted by high temperature changes and high humidity changes in the seasons of the year, which has an influence on the quality and performance of the acoustic system and the sound created by the system.

[0006] Therefore, it is an object of the present invention to create an acoustic system with improved sound quality.

[0007] This object is achieved by an acoustic system comprising a trim part an exciter coupled to the trim part for inducing vibrations to the trim part so that the trim part emits sound, in particular sound which can be heard by humans, a sensor measuring a temperature and/or a sensor measuring humidity, and a control unit coupled to the exciter and to the sensor measuring a temperature and/or the sensor measuring humidity, the control unit being configured so as to determine control signals for the exciter depending on the measured temperature and/or humidity.

[0008] The acoustic system according to the invention is equipped with a tuning system allowing to tune the sound depending on the actual temperature and/or humidity. Temperature and humidity do influence the sound created by the trim part as both the trim part and the exciter are sensible to temperature and humidity. Their characteristics, in particular their mechanical properties like stiffness, are significantly changing depending on temperature and humidity. The control unit receives data from at least one sensor and tunes the control signals for the exciter depending on temperature and/or humidity so that the acoustic system is insensitive, or at least less sensitive than without the control unit, to the changing environment and compensates sound imperfections based on changes in temperature and/or humidity.

[0009] The trim part may be a plate-shaped panel part having a rigidity. The trim part mainly extends two-dimensionally and can be flat or curved and preferably has a thickness of at least 2 mm.

[0010] The exciter may dynamically bend or deform the trim part or may only move the whole trim part.

[0011] The sensor measuring temperature and/or the sensor measuring humidity are arranged so as to measure the temperature and/or humidity of the trim part and/or the exciter directly or indirectly. Thus, the sensor or sensors are preferably arranged at or in or immediately adjacent to the trim part and/or the exciter. An indirect measurement would, for example, use a sensor distanced from the trim trim part in order to deduct from the measured temperature/humidity of the interior of the vehicle the temperature/humidity of the trim part which could be done by using test results stored in a look-up table.

[0012] If the sensor or sensors are arranged distanced from the trim part and/or the exciter, it will, however, be possible to determine the temperature and/or humidity of the trim part and/or the exciter by measuring methods which allow to deduce or estimate the temperature and/or humidity of the trim part and/or the exciter based on the sensed temperature/humidity at a distance therefrom. The temperature may for example be determined by an infrared camera.

[0013] In order to obtain highest sound quality, the sensor measuring temperature and/or the sensor measuring humidity are/is preferably coupled to the trim part and/or the exciter to directly sense their temperature/humidity.

[0014] The acoustic system according to the present invention may comprise a memory unit for storage of temperature and/or humidity dependent processing parameters. These parameters may be achieved by calibration tests. In those calibration tests, set reference signals are sent to the exciter at reference conditions, i.e. at a reference temperature and a reference humidity. The sound emitted by the trim part is sensed to determine a reference sound result. In a next step, the temperature and/or humidity are/is changed, and the sound emitted is sensed. The control signal is tuned such that the generated, emitted sound is close to or the same as the previous reference sound. The tuning parameters elaborated by the calibration are finally stored in a memory or, alternatively, an algorithm reflecting the tuning is stored in the memory.

[0015] There are several ways to tune the control signals for the exciter.

[0016] The control unit may comprise a processing unit configured to process an audio input signal with processing parameters. Those processing parameters may be provided by the memory unit mentioned above. The processing unit can be a digital signal processor (DSP).

[0017] According to one further option of the present invention, an optional amplifier receiving an input signal from the processing unit provides an output control signal to the exciter which is different from the input signal.

[0018] One variant to tune the control signal comprises at least one digital phase and amplitude filter which is part of the control unit or defines the control unit and processes audio input signals to control signals for the

exciter. Digital phase an amplitude filters are cost-effective devices for processing signals.

[0019] The control unit may include an audio input signal interface via which it receives audio signals from a head unit which can be the entertainment system of a vehicle.

[0020] The control system may be connected to a head unit to receive audio signals therefrom or may be part of the head unit.

[0021] The sensor measuring temperature and/or the sensor measuring humidity can be part of an exciter module comprising the exciter or can be arranged outside the exciter module. One example is to embed the sensor/sensors into the trim part in order to receive genuine data.

[0022] Further features and options of the present invention are presented in the following description together with the enclosed drawings. In the drawings,

- Figure 1 shows an acoustic system according to the present invention arranged in a vehicle interior,
- Figure 2 shows a schematic view of an acoustic system according to a first embodiment of the present invention,
- Figure 3 shows a schematic view of an acoustic system according to a second optional embodiment of the present invention,
- Figure 4 shows a schematic view of an acoustic system according to a third embodiment of the present invention, and
- Figure 5 shows a schematic view of an acoustic system according to a fourth embodiment of the present invention.

[0023] Figure 1 shows a vehicle door having a side window 10 and a trim part 12 which is directly or indirectly attached to a metal frame 14 of the door. Trim part 12 defines the visible interior door panel or a part of the door panel and is a substantially plate-shaped part which can be made of plastics or composite material.

[0024] The visible side of the panel, that is the side facing the vehicle interior, may be covered by a decoration layer, for example a leather skin, a wood veneer, or a plastic film or coating.

[0025] An acoustic system 16 comprises trim part 12, an electrically driven exciter 18 which is mechanically coupled to the rear side of the trim part either by being directly coupled to the trim part or by being indirectly coupled to the trim part via an intermediate mechanical bridge part.

[0026] Acoustic system 16 further comprises a control unit 20 which can be arranged outside the door, for example behind the instrument panel, and which is configured to determine and create control signals for exciter 18.

[0027] A temperature sensor 22 and a humidity sensor 24 are arranged within or in contact with or adjacent to trim part 12 and, preferably, also close to exciter 18. The sensors 22, 24 are electrically coupled to control unit 20.

[0028] Figure 2 shows one embodiment of the acoustic system 16.

[0029] Only to improve the overview, are sensors 22 and 24 depicted distanced from trim part 12. In fact, both sensors 22, 24 are arranged at, in or close to trim part 12 and/or exciter 18 as stated above. Furthermore, sensor 22 may be an infrared sensor so the sensor 22 can be arranged distanced from the trim part 12 which still allows to directly measure the temperature of the trim part 12.

[0030] Control unit 20 may comprise a processing unit 26 in form of a digital signal processor which receives data from sensors 22, 24. Processing unit 26 may be electrically coupled to an exterior memory 28 or may have an embedded memory 28.

[0031] Processing parameters for processing and tuning audio input signals to generate control signals for the exciter 18 depending on temperature and/or humidity, are stored in memory 28.

[0032] Control unit 20 further comprises an audio input signal interface 30 receiving audio signals 31 from a head unit 32 which is also shown in Figure 1.

[0033] Head unit 32 may be the entertainment system or part of the entertainment system of the vehicle. Furthermore, interface 30 is able to receive clock data 33 allowing to synchronize signals and, at the end, sound emitted from trim part 12 with signals and sound emitted from other trim parts or conventional loudspeakers.

[0034] Processing unit 26 is electrically or optically coupled to an amplifier 35 being able to receive input control signals from processing unit 26 and to generate output control signals to exciter 18 to which amplifier 35 is directly connected.

[0035] Interface 30 may be connected to an outer unit for receiving software updates or, more general, information and software 35. The connection to interface 30 can be achieved via cable or via air, i.e. wireless.

[0036] In the following, operation of the acoustic system 16 is explained.

[0037] Memory 28 contains processing parameters which are obtained during calibration of the system as explained above. Parameters may be stored in a lookup table in the memory. Alternatively or additionally, an arithmetic model could be stored in the memory 28 which allows tuning sound emitted by trim part 12 and to process signals.

[0038] Control unit 20 receives audio signals 31 from the head unit 32 via interface 30. Those audio signals are transmitted to processing unit 26 which also receives data from sensors 22 and 24. If the temperature and/or the humidity are different from temperature and/or humidity in the reference conditions for calibration, or if the temperature and/or the humidity values actually sensed

are different from those reference values by a predefined, fixed amount, i.e. 5°C or 5% humidity, so that the acoustic sound emitted by trim part 12 would be significantly different from the sound delivered at reference conditions, processing unit 26 uses the parameters stored in memory 28 to trim and, thus, process the input signals received from interface 30 to control signals sent to amplifier 35.

[0039] The control signals from processing unit 26 define an audio input signal for amplifier 35 which amends these signals in order to provide an audio output signal to exciter 18 which, finally, controls or leads to an actuation of exciter 18 and defines the control signal for exciter 18.

[0040] Due to the coupling of exciter 18 to trim part 12, vibrations are induced to trim part 12 so as to generate and emit sound which can be heard by humans.

[0041] The trim part 12 may be an interior panel, for example a door panel, an instrument panel or a ceiling panel or a part of such panel. An advantage of a vibrating trim part 12 that is only a part of a larger panel is that the acoustic behavior of the acoustic system can be better optimized or adapted to user preferences. The trim part 12 may be configured such that it can be removed and replaced easily.

[0042] The emitted sound usually is between 20 Hz to 20 000 Hz.

[0043] It is to be emphasized that all or some of the mentioned parts of control unit 20 can be embedded in one unit or can be separated and only connected by signal lines or wireless connections.

[0044] In the embodiment according to Figure 3, control unit 20 comprises numerous digital phase and amplitude filters 40, 42, 44 which do amend/process audio signals 31 received from the head unit depending on values for temperature and/or humidity received from sensors 22 and 24. The control signals finally delivered by filters 40, 42, 44 are the control signals for exciter 18.

[0045] A combination of the embodiments according to Figures 2 and 3, not shown in the figures, may comprise a memory 28 according to Figure 2 which contains filters 40, 42 and 44. Thus, lookup tables etc. are not required in this embodiment and are replaced by filters.

[0046] Figures 2 and 3 show embodiments in which audio signals are generated or emitted by head unit 32 which is distanced or separated from control unit 20. However, it is possible to combine control unit 20 and head unit 32 or to embed control unit 20 into head unit 32 as shown in Figures 4 and 5.

[0047] The Figure 4 embodiment is characterized by a head unit 32 which contains memory 28, processing unit 26 and amplifier 35 as explained with respect to Figure 2.

[0048] Temperature and humidity sensors 22 and 24, respectively, are, as an option only, part of an exciter module 50 which comprises exciter 18. Exciter module 50 can be a device which may have an own housing.

[0049] Again, sensors 22 and 24 can each or both be arranged close to both exciter 18 and trim part 12 or can be arranged immediately adjacent to a trim part 12 or partly or fully embedded into trim part 12.

[0050] It is to be emphasized that the present invention is not limited to one temperature and one humidity sensor 22 and 24, respectively. Rather, multiple sensors 22 and 24 may directly or indirectly measure the temperature and/or the humidity of trim part 12, exciter 18 or, if required, the environment, more particular the vehicle interior.

[0051] Operation of the acoustic system according to Figure 4 corresponds to the system according to Figure 2 apart from the fact that the audio signals received by processing unit 26 are generated and processed within head unit 32 as processing unit 26 defines part of head unit 32.

[0052] The embodiment according to Figure 5 substantially corresponds to the embodiment according to Figure 4 apart from temperature sensor 22 and humidity sensor 24 being arranged outside exciter module 50.

[0053] Again, both sensors or one of both sensors 22, 24 can be arranged close to or partly or fully within trim part 12, respectively.

[0054] Trim part 12 can be a part or a portion of the dashboard, of other panel or trim parts, e.g. roof trim or roof ceiling parts. Those trim or panel parts are preferably visible from the vehicle interior. However, the present invention is not limited to an acoustic system within the vehicle interior but can also be used at an outer side of the vehicle, e.g. for generating warning sound for pedestrians necessary for electrical vehicles. Also, sound cancelling systems for cancelling sound of a combustion engine can be provided with the acoustic system according to the present invention.

Claims

1. An acoustic system, comprising a trim part (12), an exciter (18) coupled to the trim part (12) for inducing vibrations to the trim part (12) so that the trim part (12) emits sound, a sensor (22) measuring a temperature and/or a sensor (24) measuring humidity, and a control unit (20) coupled to the exciter (18) and to the sensor (22) measuring a temperature and/or the sensor (24) measuring humidity, the control unit (20) being configured so as to determine control signals for the exciter (18) depending on the measured temperature and/or humidity.

2. The acoustic system according to claim 1, wherein the sensor (22) for measuring temperature and/or the sensor (24) for measuring humidity are arranged so as to measure temperature and/or humidity of the trim part (12) and/or the exciter (18).

3. The acoustic system according to claim 2, wherein the sensor (22) measuring temperature and/or the sensor (24) measuring humidity are coupled to the

trim part (12) and/or the exciter (18).

4. The acoustic system according to any of the preceding claims, wherein a memory unit (28) for storage of temperature and/or humidity dependent processing parameters is provided.

5. The acoustic system according to any of the preceding claims, wherein the control unit (20) comprises a processing unit (26) configured to process an audio input signal with processing parameters, in particular provided by the memory unit (28).

6. The acoustic system according to claim 5, wherein an amplifier (35) receiving audio input signals from the processing unit (26) and for generating control signals to the exciter (18) is provided.

7. The acoustic system according to any of the preceding claims, wherein at least one digital phase and amplitude filter is provided which processes audio input signals to generate control signals for the exciter (18).

8. The acoustic system according to any of the preceding claims, wherein the control unit (20) comprises an audio input signal interface (30).

9. The acoustic system according to any of the preceding claims, wherein the control unit (20) is connected to a head unit (32) to receive audio signals therefrom or is part of a head unit (32).

10. The acoustic system according to any of the preceding claims, wherein the sensor (22) measuring temperature and/or the sensor (24) measuring humidity are part of an or are arranged outside an exciter module (50) comprising the exciter (18).

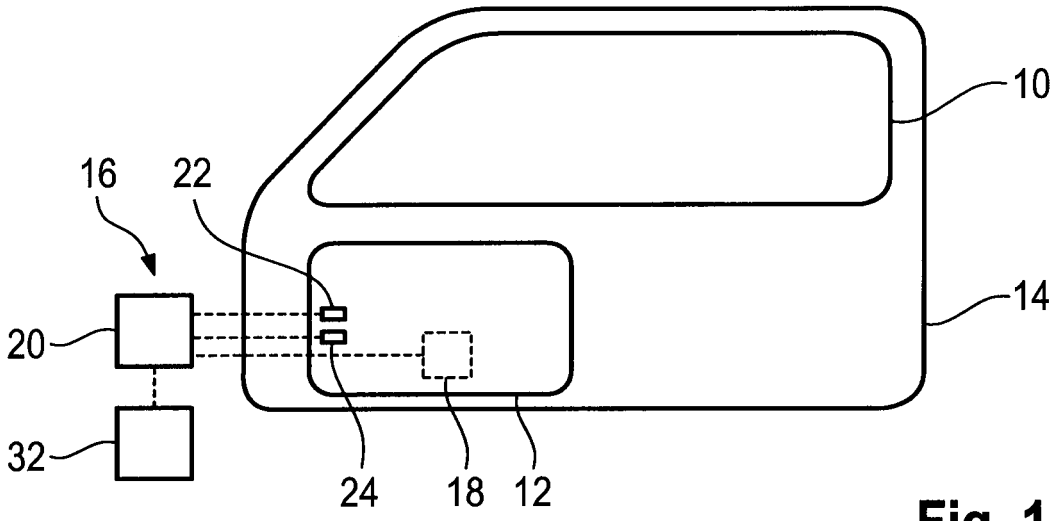
10
16
22
14
20
32
24
18
12

Fig. 1

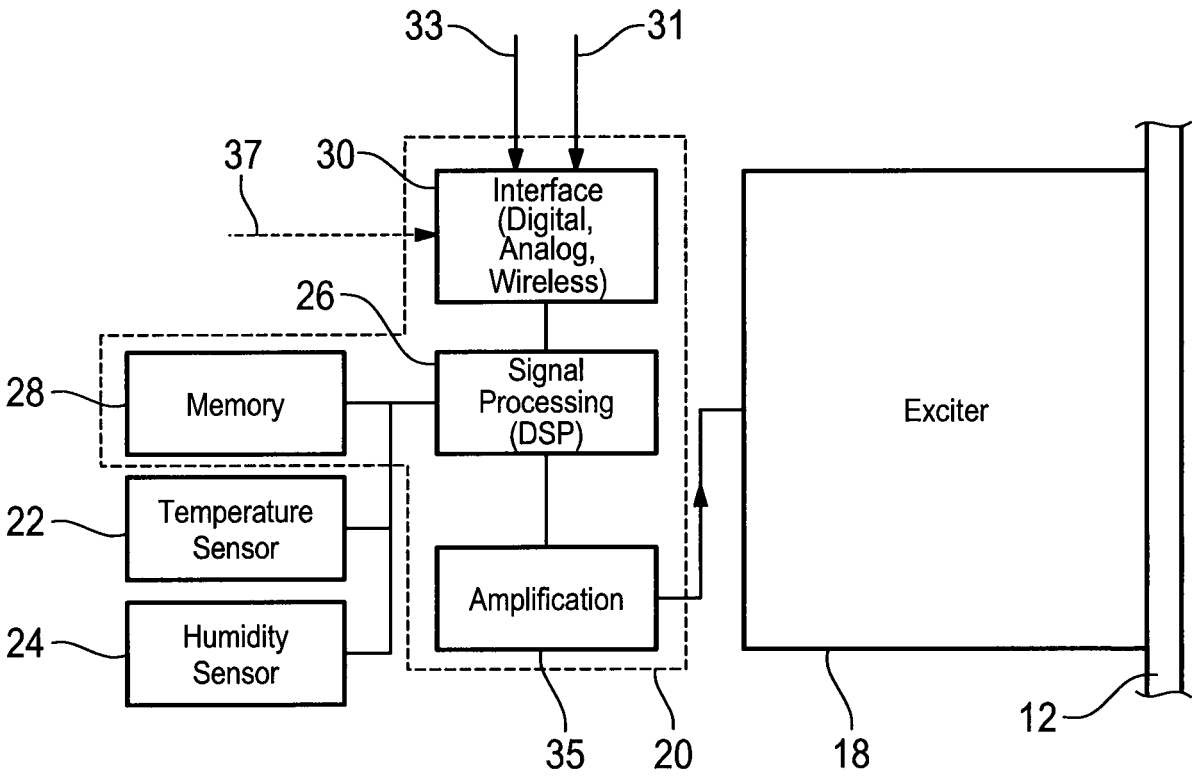
33
31
37
30
Interface (Digital, Analog, Wireless)
26
28
Memory
Signal Processing (DSP)
Exciter
22
Temperature Sensor
Amplification
24
Humidity Sensor
35
20
18
12

Fig. 2

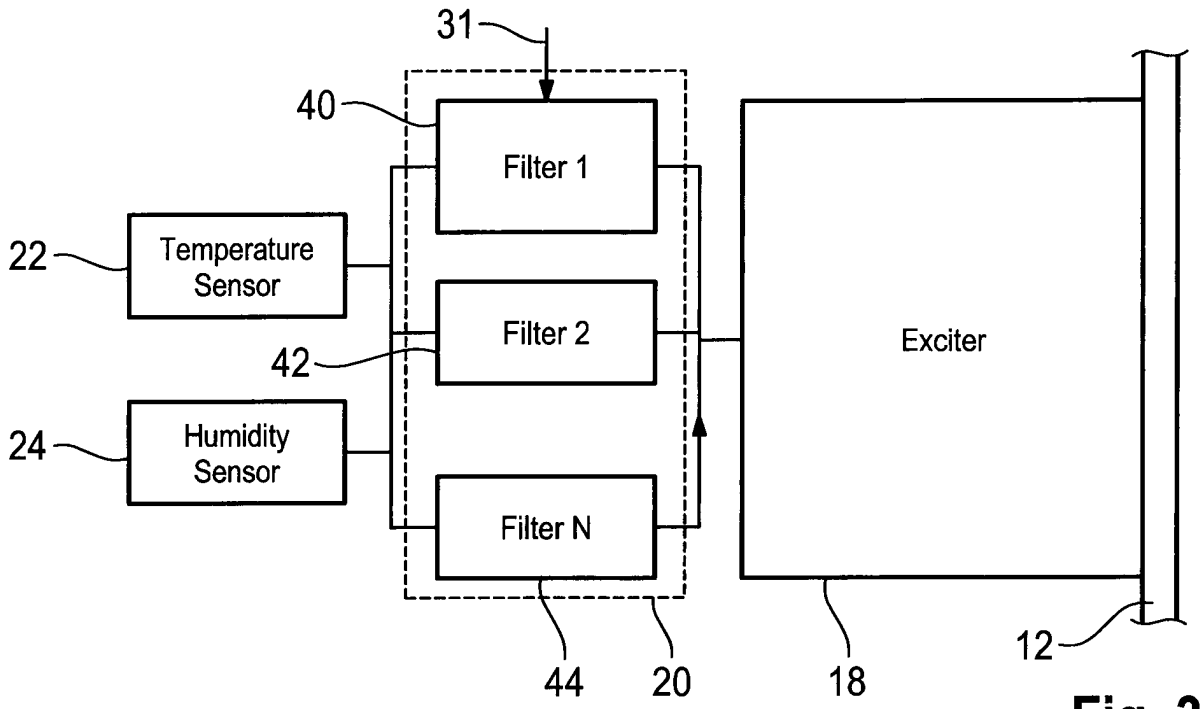
31
40
Filter 1
22
Temperature Sensor
Filter 2
42
Exciter
24
Humidity Sensor
Filter N
44
20
18
12

Fig. 3

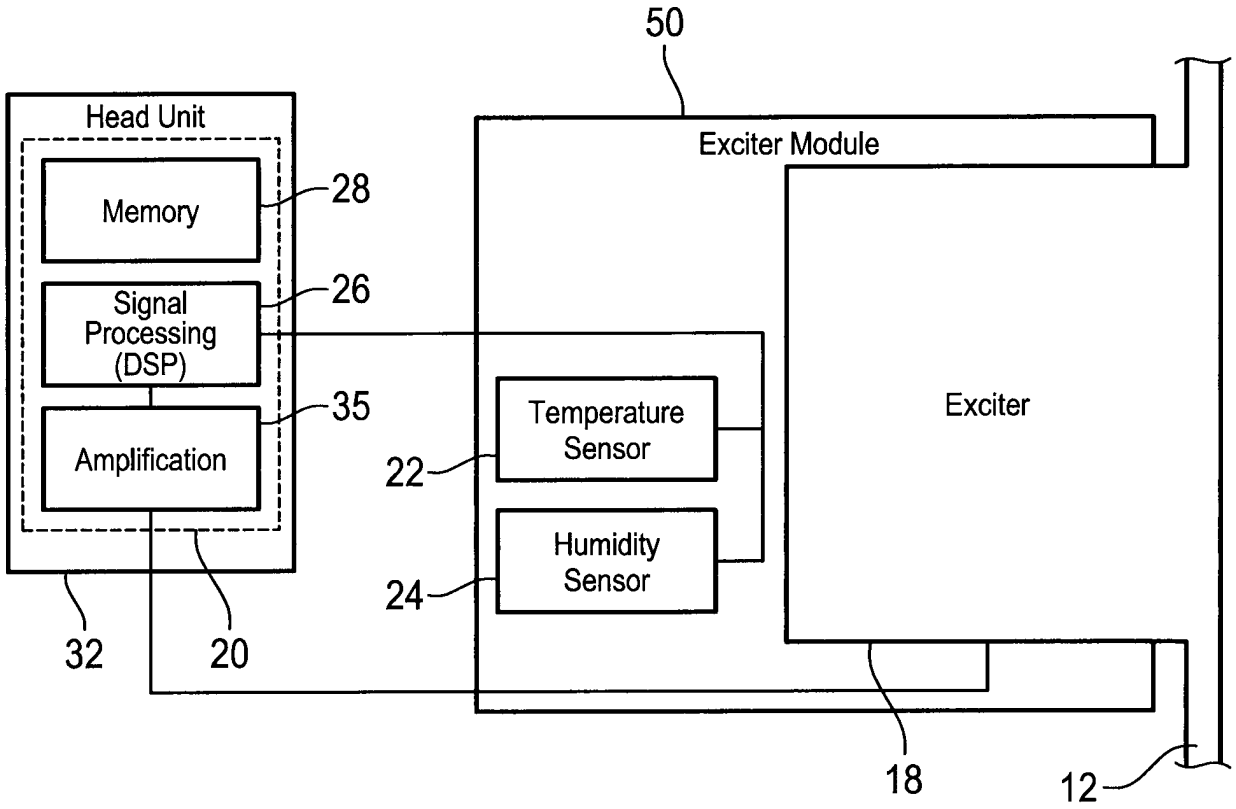
50
Head Unit
Exciter Module
Memory
28
Signal Processing (DSP)
26
Exciter
35
Amplification
Temperature Sensor
22
Humidity Sensor
24
32
20
18
12

Fig. 4

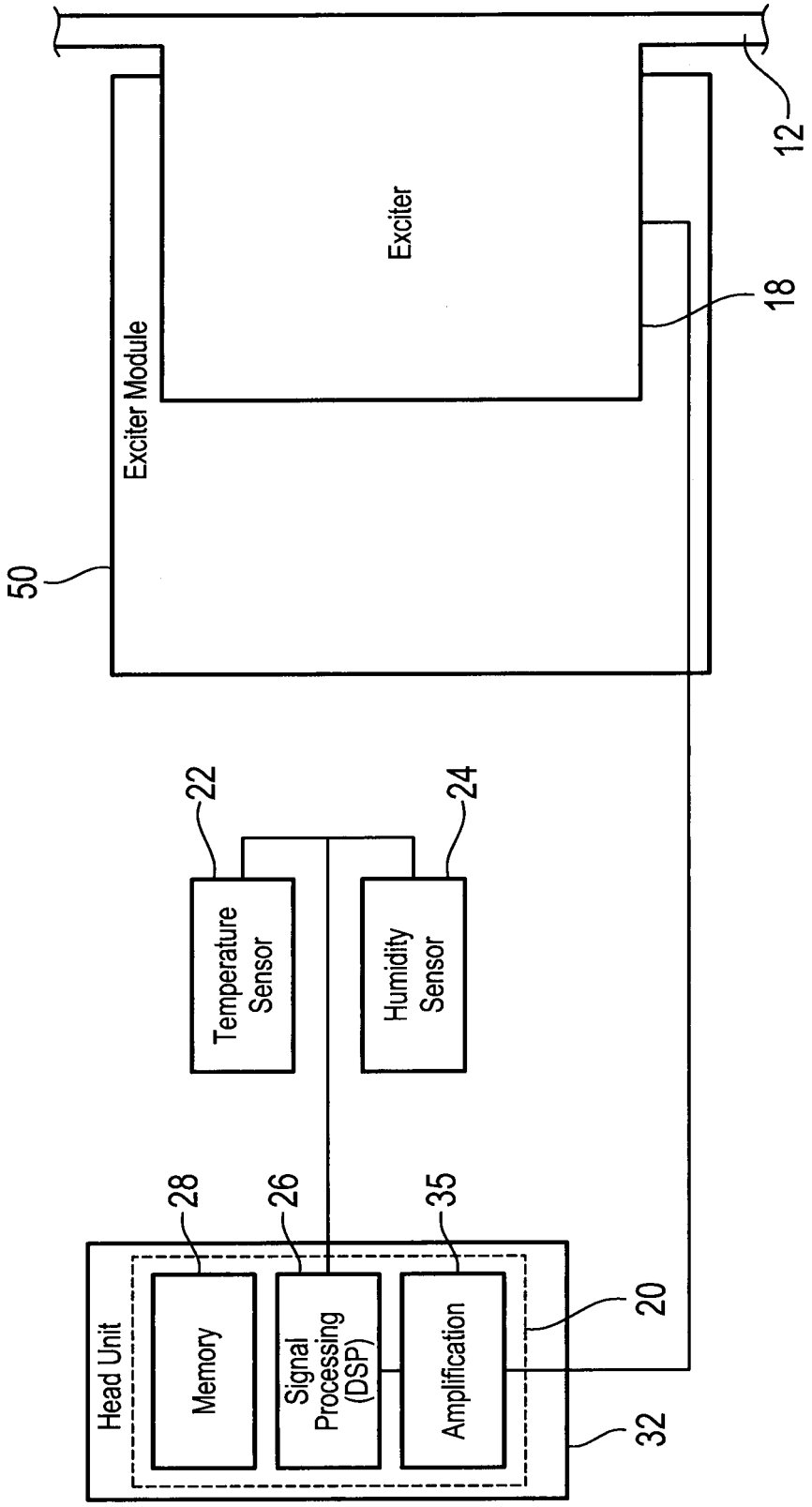
12
Exciter
Exciter Module
18
50
22
24
Temperature Sensor
Humidity Sensor
28
26
35
Head Unit
Memory
Signal Processing (DSP)
Amplification
20
32

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 19 17 7322

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TECHNICAL FIELDS SEARCHED (IPC)

H04R

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	4 November 2019	Fobel, Oliver

CATEGORY OF CITED DOCUMENTS

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