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(54) **LIGHTING DEVICE WITH VIBRATION SENSOR**

(57) The present invention relates to a lighting device having a vibration sensor. The lighting device comprises a housing (5), at least one component (3, 6a, 16) elastically connected to the housing (5) and at least one sensor (4, 12) configured to detect vibrations in an environment of the lighting device (1) by detecting a movement of the at least one component relative (3, 6a, 16) to the housing (5) caused by the vibrations.

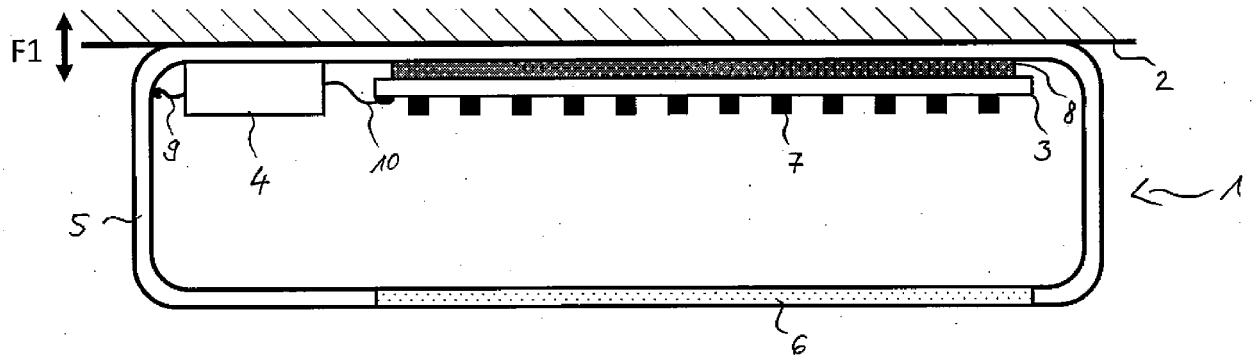

Fig. 1

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Description

[0001] The invention is in the field of lighting equipment. In particular, the invention relates to a lighting device including a sensor for monitoring an environment of the lighting device.

[0002] Sensors are commonly used in lighting equipment to control the lighting equipment based on detected events or changes in their environment. Motion detectors and microphones are used to detect the presence of a person, for example.

[0003] EP 3 220 042 A1 discloses a lighting device (luminaire) comprising a LED module, a cup-shaped reflector for reflecting the light emitted by the diffusor and a passive infrared sensor (PIR sensor) for motion detection, wherein the PIR sensor is mounted on a circuit board of the LED module and a window is integrated into the reflector to guide infrared radiation to the PIR sensor.

[0004] Since the PIR sensor is directed to the open side of the cup-shaped reflector, a person looking into the opening (direct line of sight) can easily see the sensor or its lens. While infrared or PIR-sensors often affect aesthetics of the lighting device, visible microphones, on the other hand, can make a person feel like they are being overheard. Further, additional electronic components are usually required to integrate the sensor function into a luminaire.

[0005] It is an object of the present invention to provide an apparatus and a method, which reduce the above problems. In particular, an object of the present invention is to provide a lighting device with an unobtrusive sensor with low efforts and costs.

[0006] This object is achieved by a lighting device according to the enclosed independent claim 1. Advantageous features of the present invention are defined in the corresponding dependent claims.

[0007] According to the present invention, a lighting device comprises a housing, at least one component elastically connected to the housing and at least one sensor configured to detect vibrations in an environment of the lighting device to be monitored by detecting a movement of the at least one component relative to the housing caused by the vibrations.

[0008] With the present invention, existing components, originally intended/designed only to provide light for illumination, are additionally used to detect vibrations. Since the sensor consists at least in part of components of the lighting device (luminaire), no or few additional components are required to provide the sensor function and the sensor as such is hardly noticed.

[0009] The sensor can be used to detect a vibration that propagates as an acoustic wave (acoustic sound), to detect mechanical shocks and/or to detect structure-borne sound. For example, the lighting device can be mounted on or near a door and the sensor can detect vibrations (mechanical shocks) caused by opening or closing the door. The component is connected to the housing in such a way that the housing and the component react differently in their movements to the vibrations (pressure/acoustic wave, mechanical shocks) acting on the lighting device. This difference is detected by the sensor.

[0010] The signals generated by the sensor can be used for lighting control and/or non-lighting application such as detecting imbalance in a rotating machine, counting passing vehicles, determining the type of vehicle, detecting earthquakes, exposures or a shot from a gun and/or voice control of household appliances.

[0011] The lighting device can comprise an interface configured to output, via cable or radio, signals or information generated by the sensor to another device and/or can comprise a control means configured to control the lighting device based on the signals or information.

[0012] The control means can be configured to generate a control or warn signal based on the vibrations detected by the at least one sensor. Preferably, the control means is configured to detect at least one of a predetermined vibration intensity, a predetermined vibration pattern, a predetermined voice and a predetermined voice command and is configured to generate the control or warn signal when the predetermined vibration intensity, the predetermined vibration pattern, the predetermined voice and/or the predetermined voice command is detected.

[0013] The control or warn signal can be output to the other device instead of or in addition to the sensor signals. In addition or alternatively, the lighting device can comprise a light source controlled by the control means. In addition, the light source can be controlled and powered by an electronic control gear comprising the control means. The control means may contain one or more microcontroller circuits or application specific integrated circuits (ASICs).

[0014] The at least one component can be a circuit board having a ground plane or power plane isolated from the housing and/or isolated from a metal plate connected to the housing. The ground/power plane and the (metallic) housing/metal plate form a parallel-plate capacitor, in which a distance between its plates is affected by the vibrations and the change in capacitance caused by the vibrations is detected by the sensor by, for example, detecting voltage between the ground/power plane and the housing/metal plate. The circuit board can be a component of a LED module or the electronic control gear.

[0015] In addition or alternatively, the at least one component can be a translucent plate that transmits light generated by the lighting device and prevents the ingress of dust and humidity, wherein the at least one sensor is configured to detect light reflected/diverted by the translucent plate. The light reflected/diverted by the translucent plate can be ambient light or emitted from a light source of the lighting device. In addition, the translucent plate can comprise a reflector for reflecting, to the at least one sensor, the light emitted by the light source.

[0016] The component can be a thin foil to easily detect

acoustic sound/speech, wherein the foil closes an opening of the housing and the at least one sensor detects light reflected/diverted by the foil. The light reflected/diverted by the foil can be ambient light or emitted from the light source of the lighting device. Preferably, the housing can comprise a translucent cover, wherein the foil closes an opening in the translucent cover.

[0017] In addition or alternatively, the housing can comprise an opening for pressure equalization.

[0018] A signal generated by the at least one sensor can be output to another lighting device and/or an external control device.

[0019] According to the present invention, a system comprises a plurality of the lighting devices and the control device configured to receive the sensor signals and to control the plurality of the lighting devices based on the received sensor signals.

[0020] At least some of the plurality of the lighting devices can be located in different locations, wherein the control device is configured to determine a point of origin of the vibrations and/or a change of the point of origin based on the received sensor signals and is configured to control the plurality of the lighting devices based on the detected point of origin and/or the detected change.

[0021] According to the present invention, a method for detecting vibrations in an environment of a lighting device comprises a detecting step for detecting a movement of at least one component of the lighting device relative to the housing of the lighting device caused by the vibrations.

[0022] The lighting device can be a downlight luminaire, a luminaire for indoor use (freestanding luminaire, wall-mounted luminaire) or an outdoor luminaire for illuminating streets, roads, paths, buildings, facades or walls.

[0023] Embodiments of the invention are discussed in detail with reference to the enclosed figures, in which

FIG. 1 shows a schematic view of parts of a lighting device according to a first embodiment of the present invention,

FIG. 2 shows a schematic view of parts of a lighting device according to a second embodiment of the present invention,

FIG. 3 shows a schematic view of parts of a lighting device according to a third embodiment of the present invention and

FIG. 4 shows a flowchart of the method according to an embodiment of the present invention.

[0024] In the figures, same reference numbers denote same or equivalent structures. The explanation of structures with same reference numbers in different figures is avoided where deemed possible for sake of conciseness.

[0025] FIG. 1 shows a lighting device 1 according to a first embodiment of the present invention in a sectional view. The lighting device 1 is mounted on a ceiling 2 and comprises a light source 3, an electronic control gear/ballast 4 for the light source 2 and a housing 5, in which the light source 3 and the electronic control gear 4 are disposed. The housing 5 comprises a translucent enclosure part 6 (e.g. transparent cover) through which the light emitted by the light source 3 shines. The light source 3 consists of a plurality of LEDs 7 mounted on a circuit board, wherein the LEDs 7 are connected to the ground and power plane of the circuit board. The circuit board is attached to the housing 5 with a double-sided adhesive pad 8, which is elastic and may have good thermal conductivity to dissipate some of the heat generated by the light source 3 to the metal housing 5.

[0026] The lighting device 1 is configured to detect vibrations indicating, for example, the presence of a person, and to switch on the light for a specified time when such vibrations are detected. The vibrations of the ceiling indicated by the arrow Fi are transmitted to the housing 5 of the lighting device 1, wherein the double-sided adhesive pad 8 dampens the transmission of the vibrations to the circuit board (the light source 3). According to the present invention, the circuit board and the metallic housing 5 form a capacitor, in which a distance between its plates is affected by the vibrations and the change in capacitance caused by the vibrations is detected by the electronic control gear 4. If the housing 1 is not made of metal, a metallic plate (e.g., heat sink) can be attached to the circuit board with the double-sided adhesive pad 8 so that the metallic plate and the circuit board form the capacitor, wherein the metallic plate or the circuit board is mounted on the housing 5.

[0027] The electronic control gear 4 is connected to the metallic housing 5 and the circuit board (the light source 3) by a cable 9 and two cables 10, respectively, and determines the change in capacitance by continuously measuring the voltage between the metallic housing 5 and the ground or power plane of the circuit board, wherein the light is switched on when the voltage or a value derived from it (e.g., by filtering) is greater than or equal to a threshold. Alternatively, the electronic control gear 4 can determine the change in capacitance by determining a change in the resonant frequency of a resonant circuit that includes the capacitor formed by the circuit board and the metallic housing 5, wherein the light is switched on when the change is greater than or equal to a threshold.

[0028] Depending on the design of the lighting device 1, vibrations can reduce the service life of the lighting device 1 or the light source 3. In addition or as an alternative to presence detection, the strength and/or duration of the vibrations can be determined continuously for service life calculation or maintenance planning. The electronic control gear 4 or other internal or external control device can perform the service life calculation and/or the maintenance planning.

[0029] The lighting device 1 shown in FIG. 2 comprises

a sensor 12 configured to also detect vibrations that propagate as acoustic waves and act on the transparent cover 6a of the lighting device 1. The transparent cover 6a is connected to the housing 5 by elastic elements 11 so that it can move in the direction of the arrow F2 when the acoustic waves (e.g., loud sounds) act on the transparent cover 6a and the housing 5 can move relative to the transparent cover 6a when vibrations of the ceiling are transmitted to the housing 5. Alternatively or in addition, the transparent cover 6a may be made of an elastic material.

[0030] A reflector 13 is mounted on the transparent cover 6a to reflect light emitted by the light source 3 to the sensor 12, wherein the light reflected to the sensor 12 depends on the movement/deflection of the transparent cover 6a caused by the vibrations. The sensor 12 detects the reflected light and transmits a sensor signal to the electronic control gear 4 via cables 14. The electronic control gear 4 estimates the vibrations based on the sensor signal and controls the light source 3 based on the estimation. In this way, the electronic control gear 4 can extend the switch-on time by a certain duration when vibrations indicating the presence of a person are detected, wherein a predetermined vibration intensity and/or a predetermined vibration pattern is assigned to the presence. In addition or as an alternative to presence detection, vibrations indicating a dangerous situation can be detected, a warn signal can be transmitted to an output device via cable or radio.

[0031] The lighting device 1 shown in FIG. 3 is configured to detect low intensity acoustic waves/sound, such as speech. The transparent cover 6b of the lighting device 1 shown in FIG. 3 has an opening 15, which is hermetically closed with a foil/film 16. Similar to the reflector 14 shown in FIG. 2, the foil 16 reflects the light emitted by the light source 3 to the sensor 12 and vibrates when the acoustic waves act on the foil 16. Since the foil 16 is lighter and more elastic than the transparent cover 6a, the sensitivity is increased. In order to protect the foil 16, the housing 5 has an opening 17 for pressure equalization.

[0032] In the embodiments shown in FIG. 2 and FIG. 3, light emitted by the light source 3 is reflected to the sensor 12 to reduce the number of components required to provide the sensor function. Alternatively, a separate light source such as a laser or infrared LED can be used to allow detection even when the light source 3 is switched off.

[0033] FIG. 4 shows a very simplistic flowchart showing the single steps performed by the method described in detail above. In step Si, movements of one or more components relative to the housing are detected. In step S2, presence of vibrations, type of vibrations (voice, explosion, shock ...) and/or the information contained in the vibrations (voice information) is determined and a signal assigned to the determined event, type or information is output.

Claims

1. Lighting device, comprising

a housing (5),
at least one component (3, 6a, 16) elastically connected to the housing (5), and
at least one sensor (4, 12) configured to detect vibrations in an environment of the lighting device (1) by detecting a movement of the at least one component (3, 6a, 16) relative to the housing (5) caused by the vibrations.

2. The lighting device according to claim 1, further comprising

a control means (4) configured to generate a control or warn signal based on the vibrations detected by the at least one sensor (4, 12), wherein
the control means (4) is configured to detect at least one of a predetermined vibration intensity, a predetermined vibration pattern, a predetermined voice and a predetermined voice command and is configured to generate the control or warn signal when the predetermined vibration intensity, the predetermined vibration pattern, the predetermined voice and/or the predetermined voice command is detected.

3. The lighting device according to claim 2, further comprising
a light source (3) controlled by the control means (4).

4. The lighting device according to claim 3, wherein
the light source (3) is controlled and powered by an electronic control gear comprising the control means (4).

5. The lighting device according to any one of the preceding claims, wherein

the at least one component (3, 6a, 16) is a circuit board having a ground plane or power plane isolated from the housing (5) and/or isolated from a metal plate connected to the housing (5), and the at least one sensor (6) is configured to detect capacitance between the ground plane or power plane and the housing (5) or metal plate.

6. The lighting device according to claim 5, wherein
the circuit board is a component of a LED module.

7. The lighting device according to any one of the preceding claims, wherein

the at least one component (3, 6a, 16) is a translucent plate (6a), and

the at least one sensor (6) is configured to detect light reflected/diverted by the translucent plate (6a).

8. The lighting device according to claim 7, wherein the translucent plate (6a) comprises a reflector (13) for reflecting, to the at least one sensor (4, 12), light emitted by a light source (3) of the lighting device (1).

9. The lighting device according to any one of the preceding claims, wherein

the at least one component is a foil (16), which closes an opening of the housing (5), and
the at least one sensor (4, 12) is configured to detect light reflected/diverted by the foil (16).

10. The lighting device according to claim 9, wherein

the housing (5) comprises a translucent cover (6b), and
the foil (16) closes an opening in the translucent cover (6b).

11. The lighting device according to any one of the preceding claims, wherein
the housing (5) comprises an opening (17) for pressure equalization.

12. The lighting device according to any one of the preceding claims, further comprising
output means for outputting a sensor signal generated by the at least one sensor (4,12).

13. System comprising

a plurality of the lighting devices (1) according to claim 12, and
a control device configured to receive the sensor signals and to control the plurality of the lighting devices (1) based on the received sensor signals.

14. The lighting device according to claim 13, wherein

at least some of the plurality of the lighting devices (1) are located in different locations, and
the control device is configured to determine a point of origin of the vibrations and/or a change of the point of origin based on the received sensor signals and is configured to control the plurality of the lighting devices (1) based on the detected point of origin and/or the detected change.

15. Method for detecting vibrations in an environment of a lighting device comprising a housing and at least one component elastically connected to the housing, wherein the method comprises the step of:
detecting a movement of the at least one component relative to the housing caused by the vibrations.

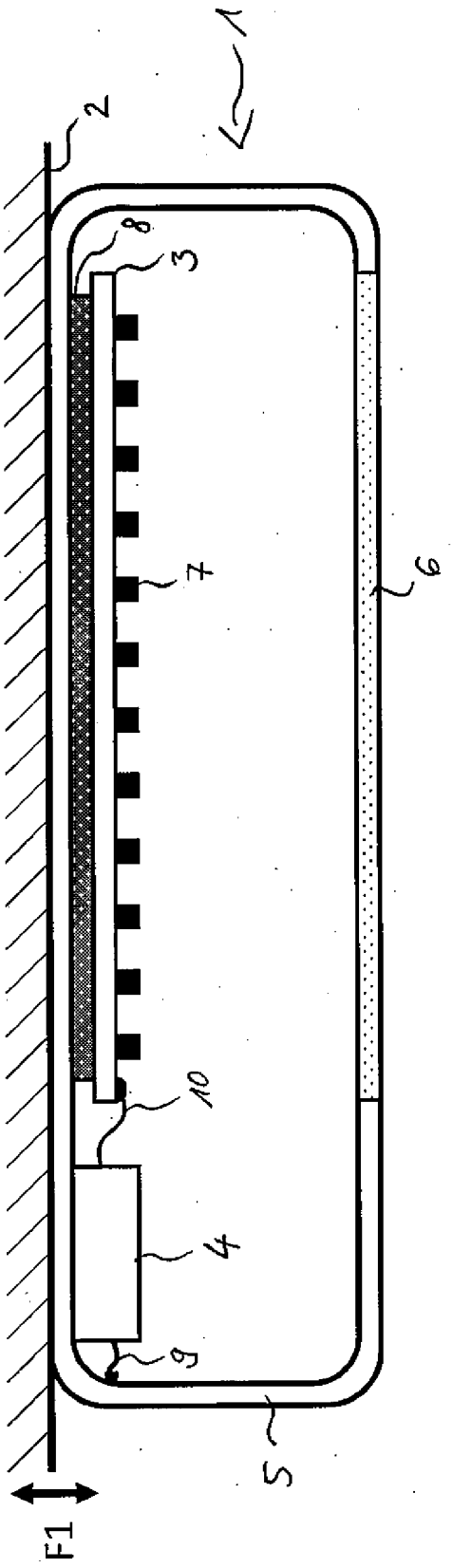

Fig. 1

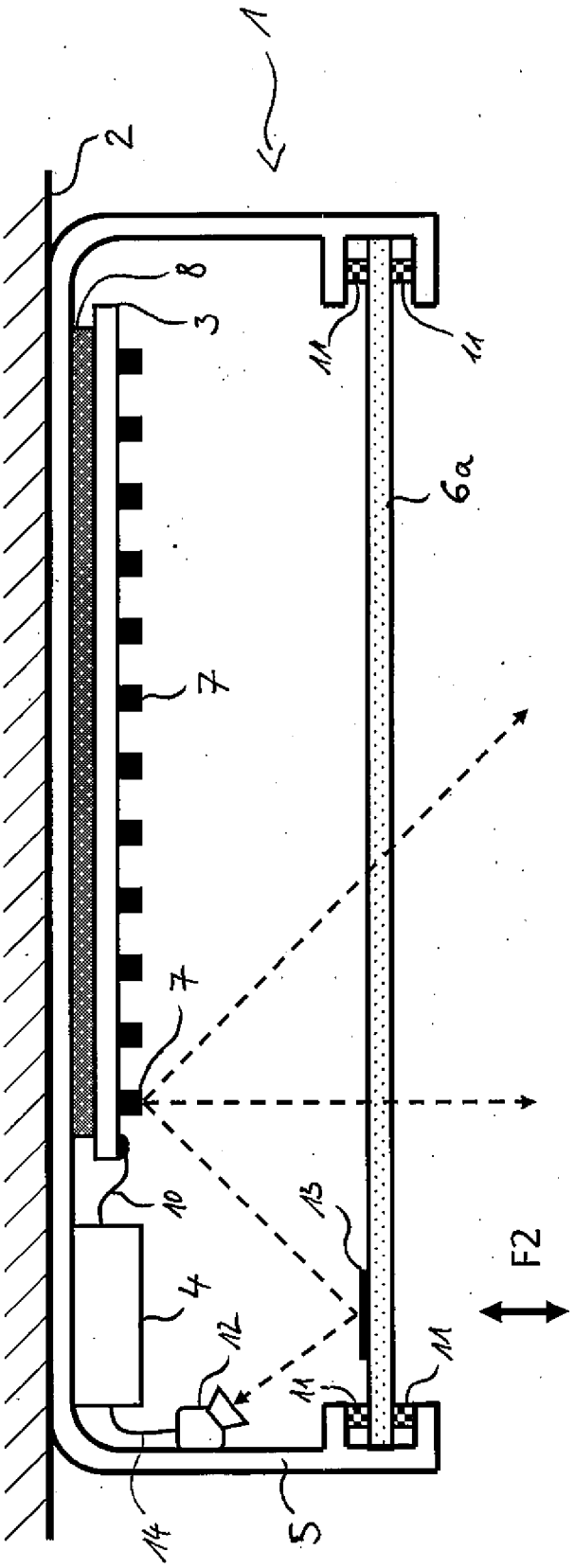

Fig. 2

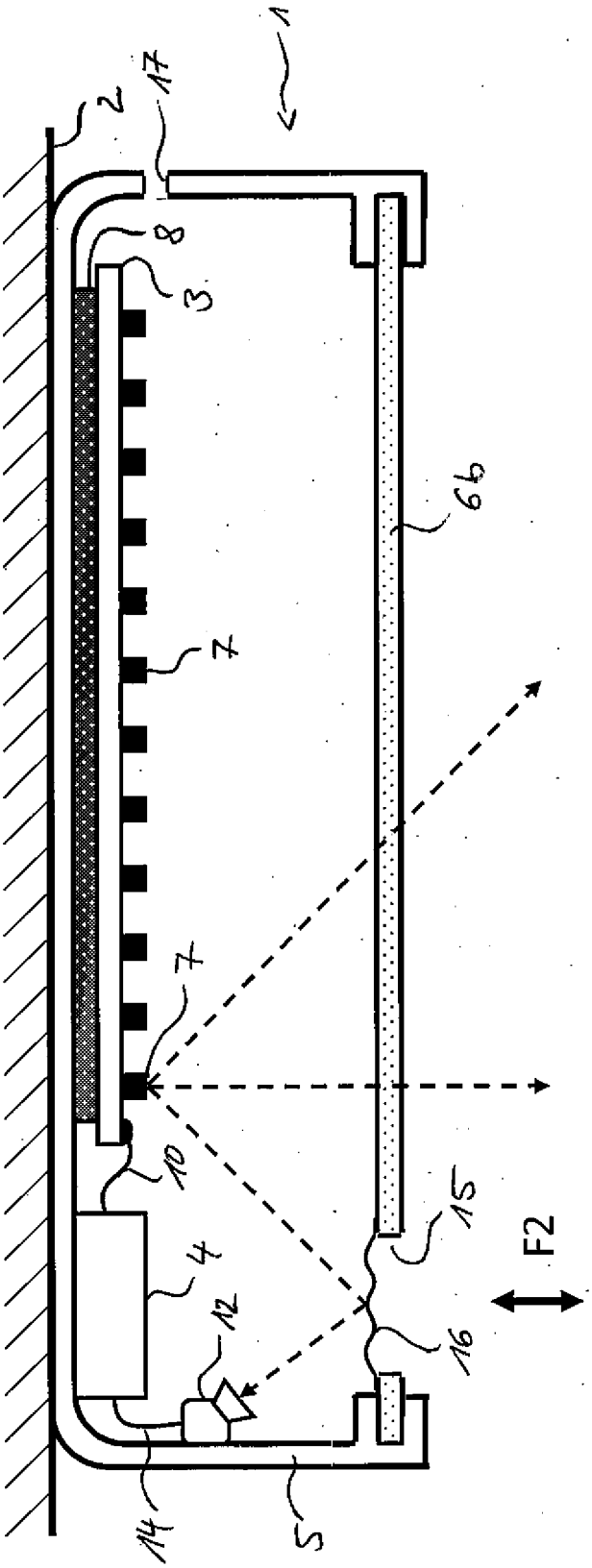

Fig. 3

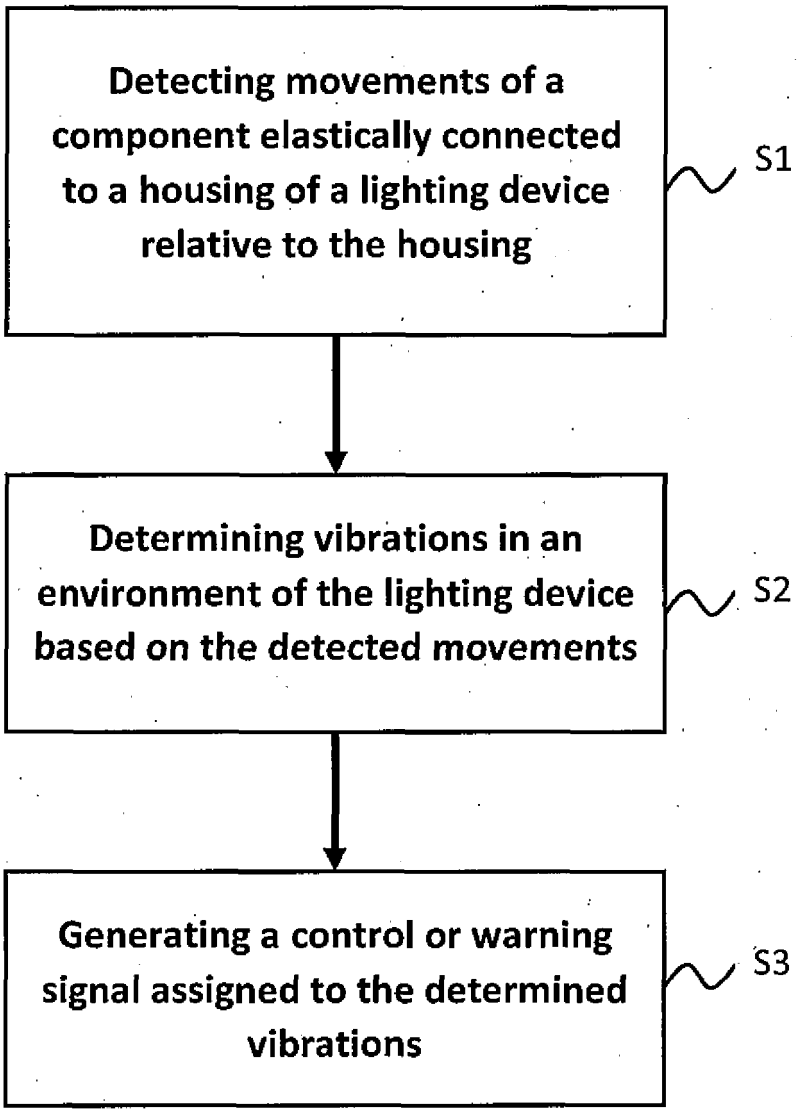
Detecting movements of a component elastically connected to a housing of a lighting device relative to the housing
S1
Determining vibrations in an environment of the lighting device based on the detected movements
S2
Generating a control or warning signal assigned to the determined vibrations
S3

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 22 19 7057

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	10 March 2023	Prévot, Eric

CATEGORY OF CITED DOCUMENTS

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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