US009398661B2

(12) **United States Patent**
Scapa et al.

(10) **Patent No.: US 9,398,661 B2**
(45) **Date of Patent: Jul. 19, 2016**

(54) **LIGHT AND LIGHT SENSOR**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/837,251**

(22) Filed: **Aug. 27, 2015**

(65) **Prior Publication Data**

US 2015/0366021 A1 Dec. 17, 2015

Related U.S. Application Data

(63) Continuation of application No. 14/555,838, filed on Nov. 28, 2014, which is a continuation of application No. 13/829,069, filed on Mar. 14, 2013, now Pat. No. 8,901,823, which is a continuation-in-part of application No. 13/690,609, filed on Nov. 30, 2012, now Pat. No. 8,946,996, which is a continuation of application No. 12/572,471, filed on Oct. 2, 2009, now Pat. No. 8,324,817.

(60) Provisional application No. 61/108,354, filed on Oct. 24, 2008.

(51) **Int. Cl.**
H05B 33/08 (2006.01)
H05B 37/02 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H05B 33/0848*** (2013.01); ***F21K 9/17*** (2013.01); ***F21V 23/0457*** (2013.01); ***F21V 23/0464*** (2013.01); ***G01J 1/32*** (2013.01); ***H05B 33/08*** (2013.01); ***H05B 33/0803*** (2013.01); ***H05B 33/0851*** (2013.01); ***H05B 33/0854*** (2013.01); ***H05B 33/0884*** (2013.01); ***H05B 37/0218*** (2013.01); *F21S 2/00* (2013.01); *F21S 8/031* (2013.01); *F21S 8/04* (2013.01);
(Continued)

(58) **Field of Classification Search**
USPC 315/119–159
See application file for complete search history.

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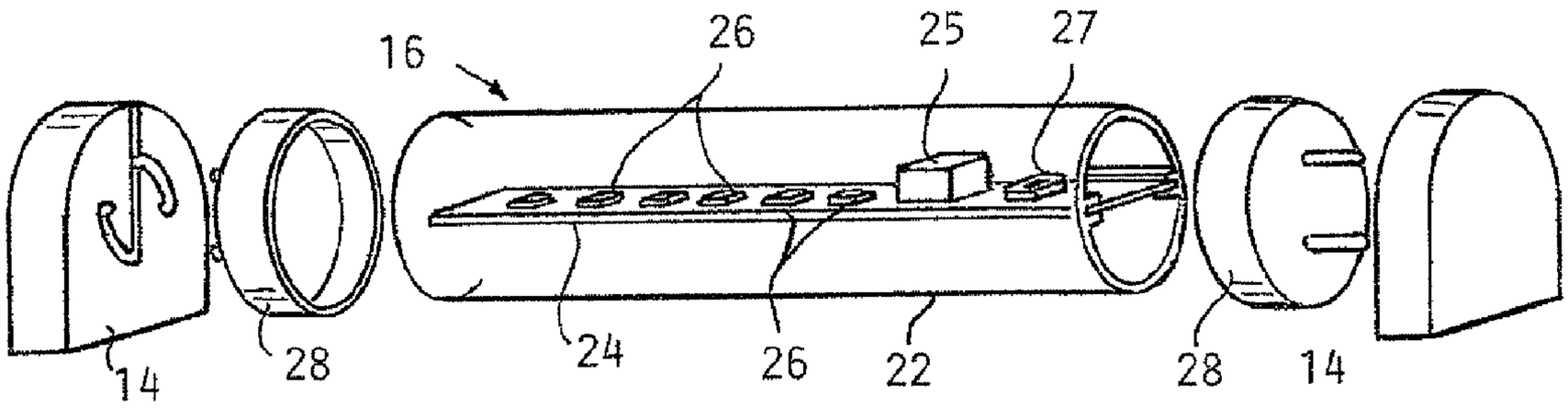
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(57) **ABSTRACT**

An LED-based light includes one or more LEDs, a sensor arranged to detect a brightness level in an area resulting from the combination of light emitted by the LEDs with light from at least one ambient light source other than the LEDs, and operable to output a signal corresponding to the detected brightness level, a controller operable to regulate an amount of power provided to the LEDs in response to the signal, a light transmitting housing for the LEDs, the sensor and the controller and a connector shaped for connection with a light socket disposed at an end of the housing.

19 Claims, 4 Drawing Sheets



(51) **Int. Cl.**

F21K 99/00	(2016.01)
F21V 23/04	(2006.01)
G01J 1/32	(2006.01)
G01J 1/42	(2006.01)
F21Y 101/02	(2006.01)
F21Y 103/00	(2016.01)
F21S 2/00	(2016.01)
F21S 8/00	(2006.01)
F21S 8/04	(2006.01)

(52) **U.S. Cl.**
CPC *F21Y 2101/02* (2013.01); *F21Y 2103/003* (2013.01); *G01J 2001/4252* (2013.01); *Y02B 20/386* (2013.01)

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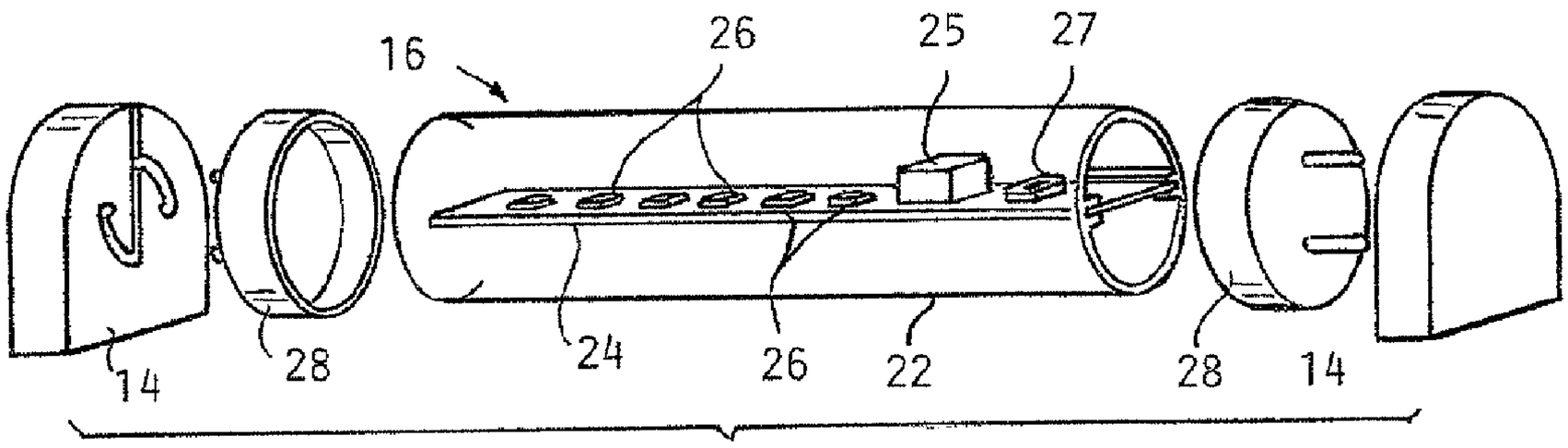


FIG. 1

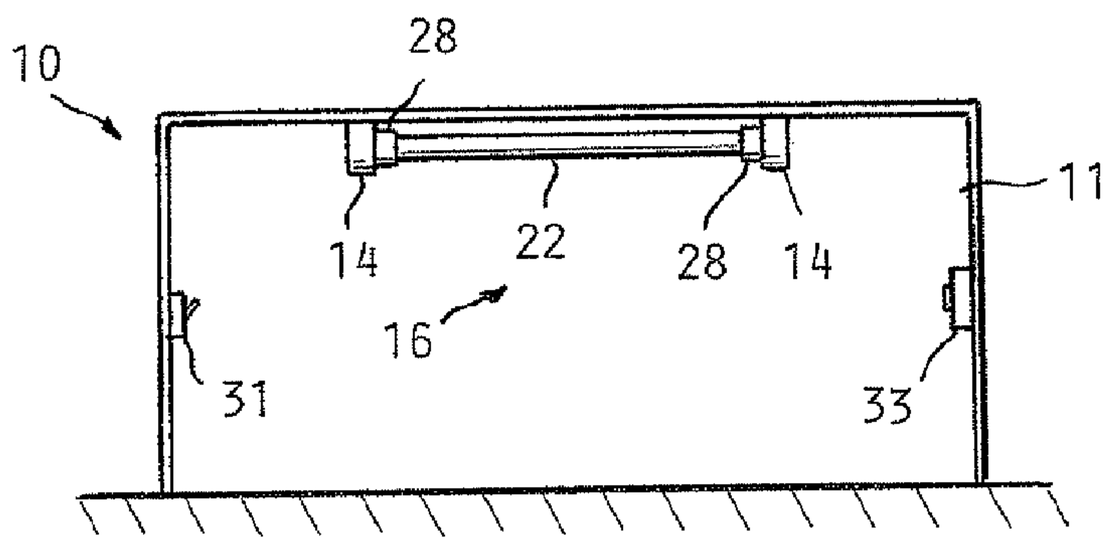


FIG. 2

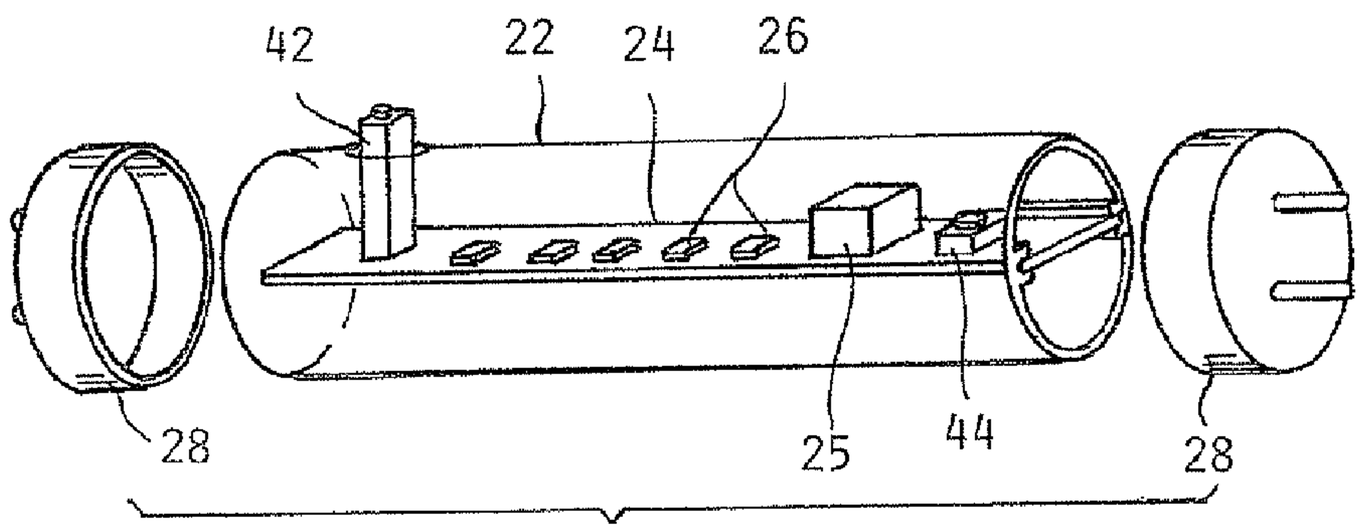
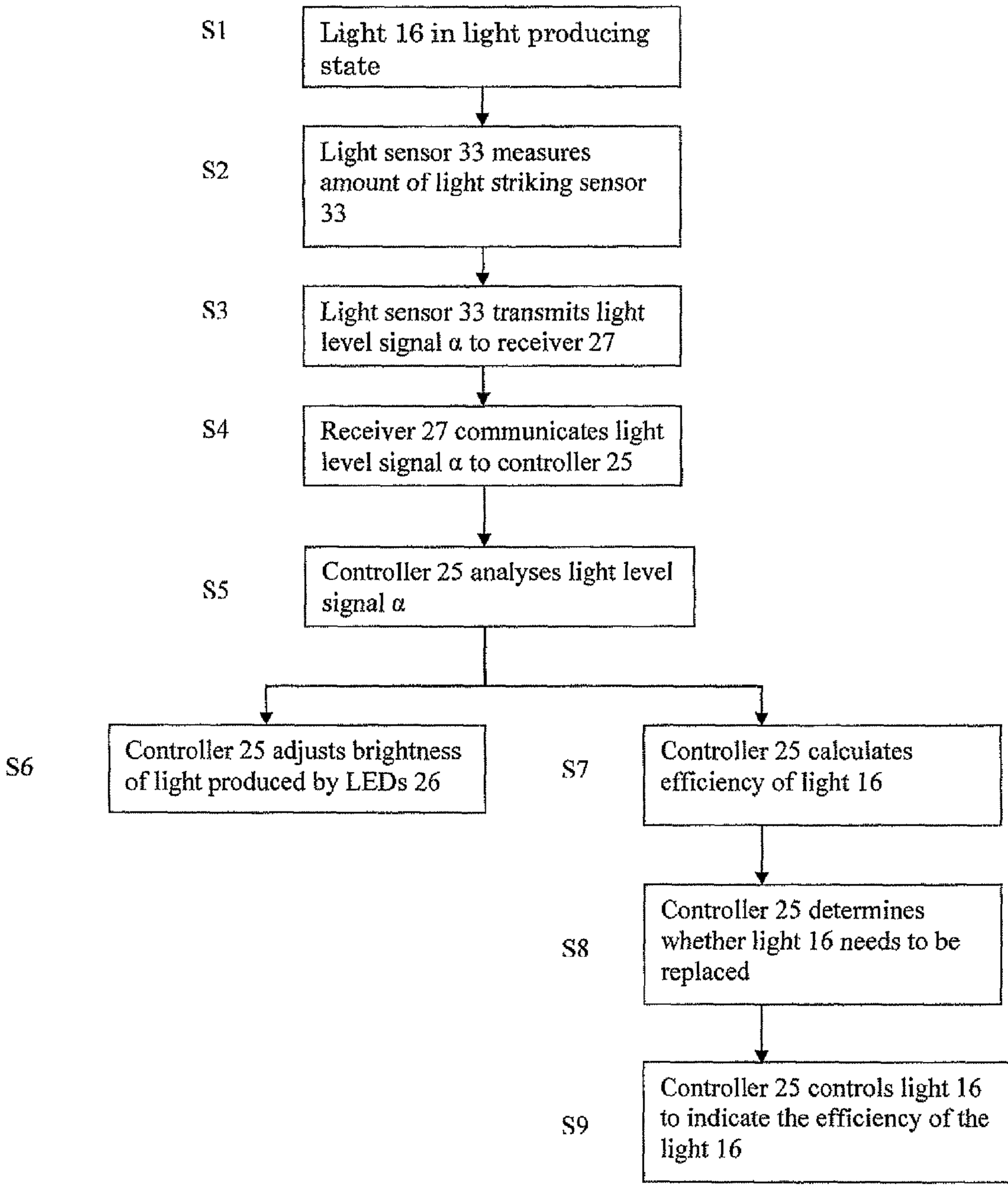


FIG 3

FIG. 4


S1
Light 16 in light producing state
S2
Light sensor 33 measures amount of light striking sensor 33
S3
Light sensor 33 transmits light level signal α to receiver 27
S4
Receiver 27 communicates light level signal α to controller 25
S5
Controller 25 analyses light level signal α
S6
Controller 25 adjusts brightness of light produced by LEDs 26
S7
Controller 25 calculates efficiency of light 16
S8
Controller 25 determines whether light 16 needs to be replaced
S9
Controller 25 controls light 16 to indicate the efficiency of the light 16

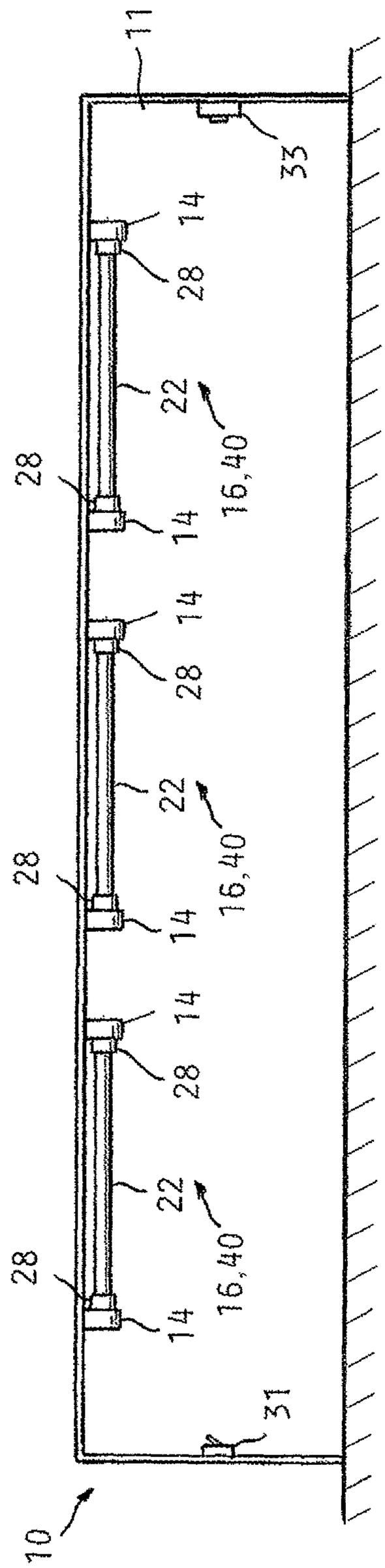
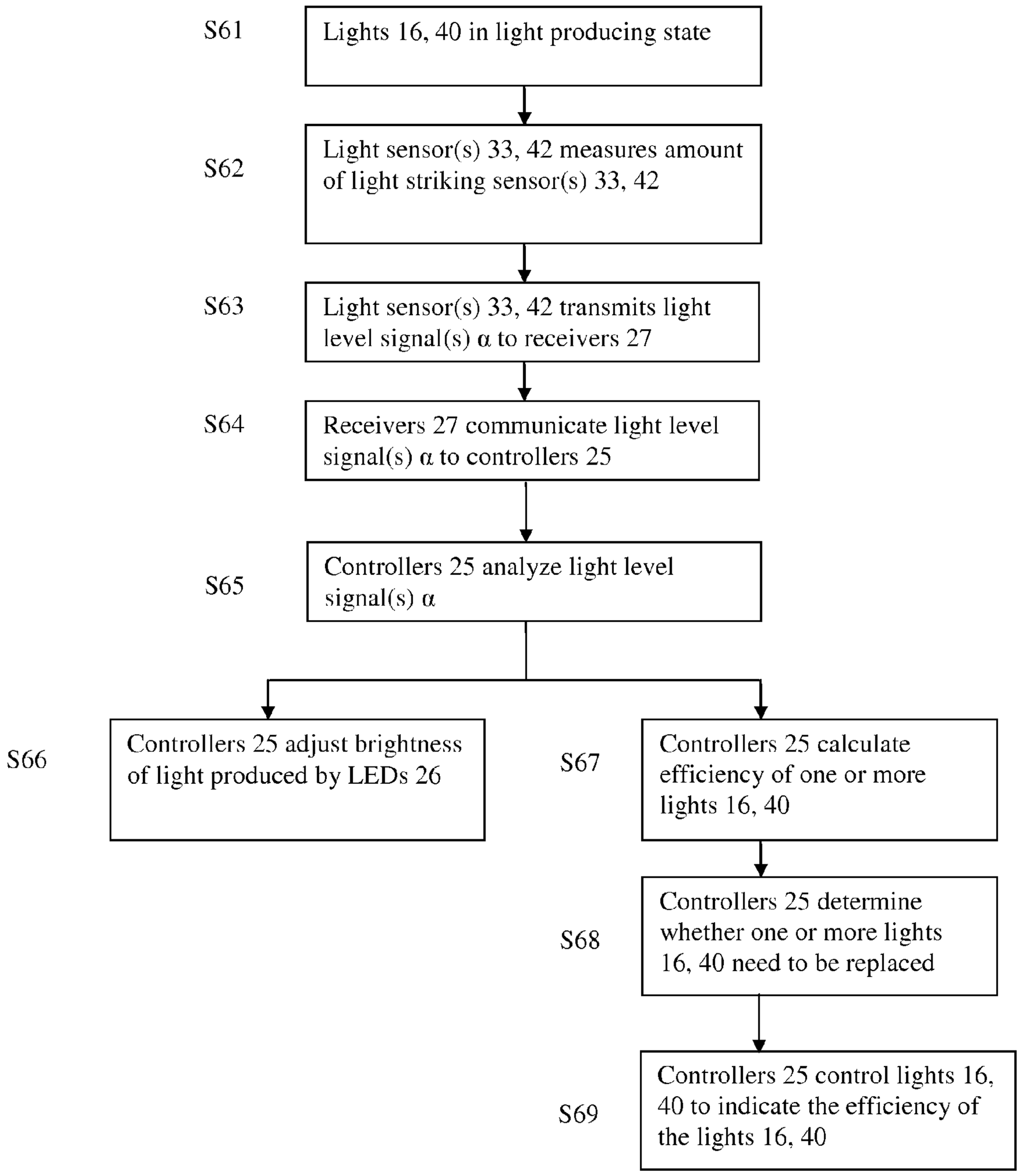

11
33
14
28
22
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16,40
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16,40
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22
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14
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16,40
28
14
22
16,40
31
10

FIG. 5

FIG. 6


S61
Lights 16, 40 in light producing state
S62
Light sensor(s) 33, 42 measures amount of light striking sensor(s) 33, 42
S63
Light sensor(s) 33, 42 transmits light level signal(s) α to receivers 27
S64
Receivers 27 communicate light level signal(s) α to controllers 25
S65
Controllers 25 analyze light level signal(s) α
S66
Controllers 25 adjust brightness of light produced by LEDs 26
S67
Controllers 25 calculate efficiency of one or more lights 16, 40
S68
Controllers 25 determine whether one or more lights 16, 40 need to be replaced
S69
Controllers 25 control lights 16, 40 to indicate the efficiency of the lights 16, 40

LIGHT AND LIGHT SENSOR

STATEMENT OF RELATED CASES

This application is a continuation of U.S. patent application Ser. No. 14/555,838, filed on Nov. 28, 2014, which is a continuation of U.S. patent application Ser. No. 13/829,069, filed on Mar. 14, 2013, and now U.S. Pat. No. 8,901,823, which is a continuation-in-part of U.S. patent application Ser. No. 13/690,609, filed Nov. 30, 2012, now U.S. Pat. No. 8,946,996, which is a continuation of U.S. patent application Ser. No. 12/572,471, filed Oct. 2, 2009, and now U.S. Pat. No. 8,324,817, which claims priority from U.S. Provisional Patent Application Ser. No. 61/108,354 filed Oct. 24, 2008, all of which are hereby incorporated by reference in their entireties.

FIELD

An LED-based light as described herein relates to "smart buildings" that can automatically control lighting in response to various environmental conditions.

BACKGROUND

Lights in buildings are generally controlled by switches, such as wall-mounted switches in the vicinity of one or more lights. The switch can include a dimmer for varying the brightness of one or more lights. However, lights are often left on when not needed, such as when no people are around the lights or when sources of light besides the lights (e.g., sunlight passing through windows and/or skylights) provide sufficient illumination.

SUMMARY

Known smart buildings that can automatically control various environmental characteristics, such as a lighting brightness level, of one or more rooms of a building are typically expensive to manufacture and install. For example, known smart building components typically are not compatible with standard building fixtures, such as conventional fluorescent tube fixtures, and thus can require an electrician to install.

Embodiments of LED-based lights described herein can be used to transform a building with standard fixtures, such as standard fluorescent tube fixtures, into a smart building. Many advantages are offered by the LED-based lights described herein, such as allowing for a low-cost smart building and automatically providing an alert when an efficiency of the LED-based light becomes too low.

In one embodiment, an LED-based light includes one or more LEDs, a sensor arranged to detect a brightness level in an area resulting from the combination of light emitted by the LEDs with light from at least one ambient light source other than the LEDs, and operable to output a signal corresponding to the detected brightness level, a controller operable to regulate an amount of power provided to the LEDs in response to the signal, a light transmitting housing for the LEDs, the sensor and the controller and a connector shaped for connection with a light socket disposed at an end of the housing.

In another embodiment, a system for estimating an efficiency of LEDs in an LED-based light comprises an LED-based light including one or more LEDs, a sensor arranged to detect a brightness level in an area resulting from the light emitted by the LEDs, and operable to output a signal corresponding to the detected brightness level, a light transmitting housing for the LEDs and the sensor, and a connector shaped for connection with a light socket disposed at an end of the housing; and a controller operable to estimate an efficiency of the LEDs at least partially based on a comparison of a brightness level detected by the sensor while the LEDs are operational with a power consumption of the LEDs.

In another embodiment, an LED-based light comprises one or more LEDs, a sensor arranged to detect a brightness level in an area resulting from the light emitted by the LEDs, and operable to output a signal corresponding to the detected brightness level, a controller operable to estimate an efficiency of the LEDs at least partially based on the brightness level detected by the sensor while the LEDs are operational, a transmitter operable to transmit the estimated efficiency of the LEDs, a light transmitting housing for the LEDs, the sensor, the controller and the transmitter and a connector shaped for connection with a light socket disposed at an end of the housing.

These and other embodiments will be described in additional detail hereafter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of an example of an LED light tube;

FIG. **2** is a schematic perspective view of a smart building system;

FIG. **3** is a schematic perspective view of yet another example of an LED light tube;

FIG. **4** is a flowchart illustrating operation of an example of an LED light tube;

FIG. **5** is a schematic perspective view of another example of a smart building system; and

FIG. **6** is a flowchart illustrating operation of multiple LED light tubes.

DESCRIPTION

FIGS. **1-6** are discussed in reference to a light and a light sensor. As shown in FIG. **1**, a light fixture **14** can accept an LED-based light **16**. The light fixture **14** can be designed to accept standard fluorescent tubes, such as a T-5, T-8, or T-12 fluorescent tube, or other standard sized light, such as incandescent bulbs. Alternatively, the fixture **14** can be designed to accept non-standard sized lights, such as lights installed by an electrician.

The LED light tube **16** can include a housing **22**, a circuit board **24**, LEDs **26**, a pair of end caps **28**, a controller **25**, and a receiver **27** as shown in FIG. **1**. The housing **22** as shown in FIG. **1** is a light transmitting cylindrical tube. The housing **22** can be made from polycarbonate, acrylic, glass or another light transmitting material (i.e., the housing **22** can be transparent or translucent). For example, a translucent housing **22** can be made from a composite, such as polycarbonate with particles of a light refracting material interspersed in the polycarbonate. While the illustrated housing **22** is cylindrical, housings having a square, triangular, polygonal, or other cross sectional shape can alternatively be used. Similarly, while the illustrated housing **22** is linear, housings having an alternative shape, e.g., a U-shape or a circular shape can alternatively be used. Additionally, the housing **22** need not be a single piece as shown in FIG. **1**. Instead, another example of a housing can be formed by attaching multiple individual parts, not all of which need be light transmitting. For example, such a housing can include an opaque lower portion and a lens or other transparent cover attached to the lower portion to cover the LEDs **26**. The housing **22** can be manufactured to include light diffusing or refracting properties, such as by

surface roughening or applying a diffusing film to the housing **22**. For compatibility with the fixture **14** as discussed above, the housing **22** can have a length such that the light **16** is approximately 48" long, and the housing **22** can have a 0.625", 1.0", or 1.5" diameter.

The circuit board **24** as illustrated in FIG. **1** is an elongate printed circuit board. Multiple circuit board sections can be joined by bridge connectors to create the circuit board **24**. The circuit board **24** as shown in FIG. **1** is slidably engaged with the housing **22**, though the circuit board **24** can alternatively be clipped, adhered, snap- or friction-fit, screwed or otherwise connected to the housing **22**. For example, the circuit board **24** can be mounted on a heat sink that is attached to the housing **22**. Also, other types of circuit boards may be used, such as a metal core circuit board. Or, instead of a circuit board **24**, other types of electrical connections (e.g., wires) can be used to electrically connect the LEDs **26** to a power source.

The light **16** can include two bi-pin end caps **28** (i.e., each end cap **28** can carry two pins), one at each longitudinal end of the housing **22**, for physically and electrically connecting the light **16** to the fixture **14**. The end caps **28** can be the sole physical connection between the light **16** and the fixture **14**. The end caps **28** can be electrically connected to the circuit board **24** to provide power to the LEDs **26**. Each end cap **28** can include two pins, though two of the total four pins can be "dummy pins" that do not provide an electrical connection. Alternatively, other types of electrical connectors can be used, such as an end cap carrying a single pin. Also, while the end caps **28** are shown as including cup-shaped bodies, the end caps **28** can have a different configuration (e.g., the end caps **28** can be shaped to be press fit into the housing **22**). One or both of the end caps **28** can additionally include electric components, such as a rectifier and filter.

The LEDs **26** can be surface-mount devices of a type available from Nichia, though other types of LEDs can alternatively be used. For example, although surface-mounted LEDs **26** are shown, one or more organic LEDs can be used in place of or in addition thereto. The LEDs **26** can be mounted to the circuit board **24** by solder, a snap-fit connection, or other means. The LEDs **26** can produce white light. However, LEDs that produce blue light, ultra-violet light or other wavelengths of light can be used in place of white light emitting LEDs **26**.

The number of LEDs **26** can be a function of the desired power of the light **16** and the power of the LEDs **26**. For a 48" light, such as the light **16**, the number of LEDs **26** can vary from about five to four hundred such that the light **16** outputs approximately 500 to 3,000 lumens. However, a different number of LEDs **26** can alternatively be used, and the light **16** can output a different amount of lumens. The LEDs **26** can be evenly spaced along the circuit board **24**, and the spacing of the LEDs **26** can be determined based on, for example, the light distribution of each LED **26** and the number of LEDs **26**.

The controller **25** can be mounted on the circuit board **24**, and can include a memory and a CPU for executing a program stored on the memory. That is, the controller **26** can be include a microprocessor or other digital or analog circuit that performs the tasks described herein. The controller **25** can be in communication with the LEDs **26**, the end caps **28**, and the receiver **27** via the circuit board **24**, though the controller **25** can alternatively be in communication with the LEDs **26**, end caps **28**, and/or receiver **27** using wires or another connection. The controller **25** can also be configured to regulate the amount of power provided to the LEDs **26**. That is, the controller **28** can govern the amount of power provided from the end caps **28** to the LEDs **26**. The controller **28** can be in communication with multiple subsets of LEDs **26** (such as individual LEDs **26**) for providing a different amount of power to one or more of the subsets of LEDs **26**. Alternatively, a controller can be external of the light **16**. For example, a controller can be coupled to the fixture **14** to control a light attached to the fixture **14**.

The light **16** can additionally include a receiver **27** mounted on the circuit board **24**. The receiver **27** can be in communication with the controller **25** as mentioned above and with a remote transmitter as is discussed below in greater detail. For example, the receiver **27** can be in communication with the transmitter using a standard wireless protocol (e.g., a radio standard, a cellular standard such as 3G, Bluetooth, or WiFi). The receiver **27** can alternatively be in communication with the transmitter in another manner such as hardwiring or via electric signals sent through the end caps **28**. The receiver **27** can be configured to receive signals from the transmitter, and the receiver **25** can transmit received signals to the controller **25**.

While the light **16** is shown as being compatible with standard sized fluorescent fixtures, an LED-based light having another shape, such as an incandescent bulb or another type of light, can alternatively be used. Also, other types of light sources, such as fluorescent or incandescent based light sources, can be used instead of the LEDs **26**.

As illustrated in FIG. **2**, the fixture **14** can be in a building **11** including a light switch **31** and a light sensor **33**, and the light **16** can be installed in the fixture **14**. The light switch **31** can control whether power is provided to the fixture **14**. However, as is mentioned above and described below in greater detail, the controller **25** can control whether power is provided to the LEDs **26**, in which case the light switch **31** need not be included. Also, if the building **11** is a "smart" building, the controller **25** and switch **31** can be in communication (e.g., via a wired connection, or via a wireless transmitter and a wireless receiver) such that the controller **25** can override the switch **31** to turn on the light **16** even when the switch **31** is in an off position or vice versa.

The light sensor **33** can detect a level of light in an area of the building **11** including the light **16**, such as an amount of light that strikes the sensor **33**. The light sensor **33** can include an integral transmitter for transmitting a light level signal α to the receiver **27**. The light sensor **33** can continuously transmit the signal, or the light sensor **33** can include a controller (e.g., a controller including a memory and a CPU for executing a program stored on the memory) for deciding when to transmit the signal. In addition to the light sensor **33**, other sensors can be in communication with the light **16**. For example, the building **11** can also include a motion sensor, a sensor for determining whether a door is ajar, a sensor for determining when a keypad or other type of lock is actuated, a voice-activated sensor, a clock or calendar, a light sensor for measuring an amount of light in the building **11** other than or including light provided by the light **16** (e.g., an amount of sunlight entering the building **11**), a power supply monitor, and/or another type of sensor.

In operation, as shown by in FIG. **4**, the light **16** produces light in step S**1**. In step S**2** the light sensor **33** can measure the amount of light that strikes the sensor **33**, and the light sensor **33** can transmit the light level signal α to the receiver **27** as shown in step S**3**. The receiver **27** can communicate the light level signal α to the controller **25** as shown in step S**4**.

In step S**5**, the controller **25** can analyze the light level signal α. For example, the controller **25** can estimate a brightness of an area of the building **11** including the light **16**, the controller **25** can compare the light level to a predetermined value (e.g., an amount of light comfortable for an ordinary

person), or can analyze the light level signal α in some other manner. Depending on the light level signal α, the controller **25** can control the light **16** in various ways. For example, as shown in step S**6**, the controller **25** can adjust the brightness of light produced by the LEDs **26**. If the light level signal α indicates the amount of light detected is too high, the controller **25** can dim the LEDs **26** or turn a subset of the LEDs **26** off. Alternatively, if the amount of light is too low, the controller **25** can increase the brightness of the LEDs **26** or turn on a subset of the LEDs **26** that were previously off. Thus, the controller **25** can correct the amount of light provided by the light **16** in response to changes in ambient light, such as if a level of natural light entering the area of the building **11** including the light **16** increases or decreases, or if other lights are turned on or off.

In another example not illustrated, the light **16** can initially not be producing light. The controller **25** can control the light **16** to begin producing light in response to the light level signal α. For example, the light level signal α can indicate that the amount of light in an area of the building **11** is below a predetermined level.

To avoid interference with the light sensor **33** by the light emitted by the LEDs **26**, the light sensor **33** can sense ambient light during a short period, invisible to the eye, when the LEDs **26** are off. This short off period can occur due to line voltage zero-crossing, or a command from the controller **25**.

Therefore, among other advantages, an occupant of the area of the building **11** including the light **16** can avoid having to make an effort to turn on the light.

Returning to FIG. **4**, as another example of operation of the light **16** shown in step S**7**, the light level signal α can be analyzed by the controller **25** to determine an efficiency of the light **16**. For example, the controller **25** can compare the amount of detected light with a reference value, such as an amount of light detected at a previous date if the light **16** includes a clock and/or calendar. The previous date can be a date when conditions such as ambient light conditions were similar, such as a recent day at approximately the same time. The difference between the current amount of light being produced and the previous amount of light being produced can be used to calculate a change in efficiency of the light **16**. The controller **25** can make this efficiency determination without turning the light **16** off, which can be beneficial if the light **16** is in a location such as a stairwell where a lack of light can be dangerous. As an alternative efficiency test, the controller **25** can compare the amount of detected light when the light **16** is on with an amount of light detected when the light **16** is off, with the difference being used to calculate an amount of light produced by the light **16**.

The controller **25** can calculate the efficiency by comparing the amount of light produced by the light **16** with the reference value (e.g., an amount of light produced by the light **16** operating under ideal conditions), or by comparing the amount of light produced by the light **16** with the amount of power consumed by the light **16** (which can be measured with an ammeter and voltmeter, a wattmeter, or another power measuring device either integral with the light **16**, electrically coupled to the fixture **14**, or at another location).

As shown in step S**8**, the controller **25** can also determine whether the light **16** should be replaced. For example, the controller **25** can compare the efficiency of the light **16** with a predetermined value to determine whether the light **16** should be replaced. The predetermined value can be a predetermined efficiency standard, such as the efficiency of the light **16** when new, the efficiency of an ideal light, a maximal output of the light **16**, or some other value.

The controller **25** can also control the light **16** to indicate its efficiency, which can provide notice that the light **16** should be replaced. For example, the controller **25** can control the light **16** to display its efficiency using a digital read-out integral with the light **16**, a bar of light having a length equivalent with the efficiency, or in another manner. Alternatively, the controller **25** can control the light **16** to display when the efficiency of the light **16** is below a predetermined value, such as by illuminating at least one of the LEDs **26** having a different color than surrounding LEDs **26**, by causing at least one of the LEDs **26** to flash, or by controlling the light **16** in some other manner. Once the efficiency of the light **16** drops below the predetermined value, it can be understood that the light **16** should be replaced. Thus, the light **16** can signal to a maintenance worker or other personnel that the light **16** should be replaced.

Another light **40** as shown in FIG. **3** includes the housing **22**, the circuit board **24**, the controller **25**, the LEDs **26**, and the end caps **28** similar to the light **16**. The light **40** can additionally include an integral light level sensor **42** and a transmitter **44**. The light sensor **42** can be mounted on the circuit board **24** to receive power via the end caps **28**, and the light sensor **42** can be in communication with the controller **25** and/or the transmitter **44**. The light level sensor **42** can protrude from the housing **22** as shown in FIG. **3** or otherwise be positioned to sense an amount of light produced by at least some of the LEDs **26** (e.g., the sensor **42** can alternatively be contained within the housing **22**, and one or more reflectors can be included to direct a portion of light toward the sensor **42**). Alternatively, the light level sensor **42** can detect an amount of ambient light. The amount of ambient light can include light produced by the LEDs **26**. The sensor **42** can communicate the light level signal α to the controller **25**.

The transmitter **44** can be mounted on the circuit board **24** for receiving power via the end caps **28**. The transmitter **44** can be in communication with the controller **25** and/or the light sensor **24** for receiving the light level signal α. The transmitter **44** can be configured to transmit the light level signal α to a remote location, such as a smart building control center or another smart building component, or to controllers **25** of other lights **16**, **40**.

With this configuration, the controller **25** in the light **40** can control the LEDs **26** and calculate an efficiency of the light based on the light level signal α as discussed above in reference to the light **16**. The light **40** can also indicate whether the light **40** should be replaced similar to as described above in reference to the light **16**. Additionally, the inclusion of the transmitter **44** allows the light **40** to perform other functions. The transmitter **44** can transmit the light level signal α to the remote location, allowing the light level signal α to be used for controlling another component of a smart building (e.g., window shades, another light, or some other component of a smart building) or for another purpose. For example, the transmitter **44** can transmit an efficiency of the light **40** or an indication that the light **40** should be replaced to the remote location.

The light **40** can also include another sensor, such as a motion detector, in communication with the controller **25** and/or the transmitter **44**. In this case, the controller **25** can take signals other than the light level signal α into consideration in controlling the LEDs **26**. For example, the controller **25** can turn the LEDs **26** off even though the light level sensor **42** detects a low level of light if the motion sensor has not detected movement for a certain amount of time. As a similar example, the controller **25** can turn the LEDs **26** off even though the light level sensor **42** detects a low level of light if

a clock or calendar in communication with the controller **25** indicates the time is not during standard working hours.

As illustrated in FIG. **5**, multiple fixtures **14** can be in the building **11** including the light switch **31** and the light sensor **33**, and multiple of the lights **16** and/or **40** described above can be installed in the fixtures **14**. Each light **16**, **40** may include a controller **25** configured to regulate the amount of power provided to the respective LEDs **26**, as described above. The controllers **25** can be external of the lights **16**, **40**, for example, coupled to a fixture **14** to control a light **16**, **40** attached to the fixture **14**. It will be understood that a controller **25** can be provided that performs the tasks described herein with respect to multiple of the lights **16**, **40**, for example, those installed in a common fixture **14**.

In operation, as shown by in FIG. **6**, one or more of the lights **16**, **40** produce light in step S**61**. In step S**62**, the light sensor **33** can measure the amount of light that strikes the sensor **33**, and transmit a light level signal α to one or more of the lights **16**, **40**. In addition, or in the alternative, if a light **40** is installed, the light sensor **42** of the light **40** can measure the amount of light that strikes the sensor **42**, and transmit a light level signal α. It can therefore be seen that the light level signals α in this example may be generated by a remote sensor **33**, or by a light sensor **42** of a light **40**. Additionally, the light level signals α may be a function of multiple of the lights **16** and/or **40**. Each signal light level signal α may be indicative of the light produced by one light **16**, **40**, multiple lights **16**, **40** or all lights **16**, **40**, and collectively, the light level signals α are indicative of the overall lighting conditions in the building **11**. The light level signal α (or optionally multiple light level signals α of more than one sensor **33**, **42**, depending upon the specific configuration for the building **11**) can be transmitted to one or more of the receivers **27** as shown in step S**63**.

The receivers **27** can communicate the light level signal(s) α to the controllers **25** for processing and analysis as shown in step S**64**. In one example, multiple controllers **25** (e.g., one controller **25** for each light **16**, **40**) may exist in the system. The signal(s) α may be used among the controllers **25** to generate control signals indicative of the desired control for the LEDs **26** of the respective lights **16**, **40** according to the operations described herein. For instance, each of the respective controllers **25** of the lights **16**, **40** may communicatively receive one or more of the signals α for individual analysis, as generally described above, and then control the LEDs **26** of the respective lights **16**, **40**. This analysis and control may be performed collaboratively with respect to the analysis and control of other controllers **25**, for instance. Alternatively, fewer than all of the controllers **25** can be perform certain of the tasks described herein, and can communicate with other controllers **25** of the respective lights **16**, **40** to effect control of the LEDs **26**, for instance, via transmitters **44** and receivers **27**. However, in another example, the lights **16**, **40** need not have individual controllers **25** where, for instance, a controller **25** is external of the lights **16**, **40** and coupled to a fixture **14** common to multiple lights **16**, **40**.

In step S**65**, the one or more light level signals α are analyzed by the controllers **25**. For example, the brightness of an area of the building **11** including the lights **16**, **40** can be estimated, and the light level can be compared to a predetermined value (e.g., an amount of light comfortable for an ordinary person), or the light level signal(s) α can be analyzed in some other manner. The light level signals α may be analyzed to estimate an overall brightness of the area of the building **11**, for example, or could be analyzed to estimate multiple brightness levels within the area. Depending on the light level signal(s) α, the lights **16**, **40** may be controlled in various ways. For example, as shown in step S**66**, the controllers **25** can collectively function to adjust the brightness of light produced by the LEDs **26** of the lights **16**, **40**. With respect to each of the individual lights **16**, **40**, if the amount of light detected is too high, a controller **25** can dim the LEDs **26** or turn a subset of the LEDs **26** off. Alternatively, if the amount of light is too low, a controller **25** can increase the brightness of the LEDs **26** or turn on a subset of the LEDs **26** that were previously off. A control scheme accounting for multiple of the lights **16**, **40** may also cause the LEDs **26** of one or more lights **16**, **40** to be dimmed or brightened, or turned on or off, in accordance with a desired brightness level. Thus, the controllers **25** can collectively correct the amount of light provided by the lights **16**, **40** in response to changes in ambient light, such as if a level of natural light entering the area of the building **11** including the lights **16**, **40** increases or decreases, or if other lights are turned on or off.

In another example not illustrated, one or more of the lights **16**, **40** can initially not be producing light. The controllers **25** can control the light **16**, **40** to begin producing light in response to the light level signal(s) α. For example, the light level signal(s) α can indicate that the amount of light in an area of the building **11** is below a predetermined level.

To avoid interference with the light sensors **33**, **42** by the light emitted by the LEDs **26** of the lights **16**, **40**, the light sensors **33**, **42** can sense ambient light during a short period, invisible to the eye, when the LEDs **26** are off. This short off period can occur due to line voltage zero-crossing, or via commands from the controllers **25**.

Therefore, among other advantages, an occupant of the area of the building **11** including the light **16**, **40** can avoid having to make an effort to turn on the lights.

In FIG. **6**, as another example of operation of the lights **16**, **40** shown in step S**67**, the light level signal(s) α can be analyzed to determine an efficiency of the lights **16**, **40**, either individually or on a collective basis. For example, the controllers **25** can collectively function to compare the amount of detected light with a reference value, such as an amount of light detected at a previous date. The previous date can be a date when conditions such as ambient light conditions were similar, such as a recent day at approximately the same time. The difference between the current amount of light being produced and the previous amount of light being produced can be used to calculate a change in efficiency of the lights **16**, **40**. The controllers **25** can make this efficiency determination without turning the lights **16**, **40** off, which can be beneficial if the lights **16**, **40** are in a location such as a stairwell where a lack of light can be dangerous. As an alternative efficiency test, the controllers **25** can compare the amount of detected light when the lights **16**, **40** are on with an amount of light detected when the lights **16**, **40** are off, with the difference being used to calculate an amount of light produced by the lights **16**, **40**. The controller **25** can calculate the efficiency by comparing the amount of light produced by the lights **16**, **40** with the reference value (e.g., an amount of light produced by the lights **16**, **40** operating under ideal conditions), or by comparing the amount of light produced by the lights **16**, **40** with the amount of power consumed by the light **16**, **40** (which can be measured with an ammeter and voltmeter, a wattmeter, or another power measuring device either integral with the lights **16**, **40**, electrically coupled to the fixtures **14**, or at another location).

It will be understood that the comparisons described above can be completed with respect to individual lights **16**, **40**, for example, or with respect to subsets of lights **16**, **40** or all lights **16**, **40** collectively. Where less than all of the lights **16**, **40** are under consideration, for instance, the output of those lights **16**, **40** may be factored out of the analysis, e.g., by turning the

lights **16**, **40** off or by otherwise accounting for their light output, power consumption, etc.

As shown in step S**68**, the controllers **25** can also determine whether one or more of the lights **16**, **40** should be replaced. For example, the controller **25** can compare the efficiency of the lights **16**, **40** with a predetermined value to determine whether one, some of all of the lights **16**, **40** should be replaced. The predetermined value can be a predetermined efficiency standard, such as the efficiency of the lights **16**, **40** when new, the efficiency of an ideal light, a maximal output of the lights **16**, **40** or some other value. The determination in this step may be made according to individual lights **16**, **40**, for example, or with respect to subsets of lights **16**, **40** or all lights **16**, **40** collectively.

As shown in step S**69**, the controllers **25** can also control the lights **16**, **40** to indicate efficiency, which can provide notice that one, some, or all of the lights **16**, **40** should be replaced. For example, the controllers **25** can control one or more lights **16**, **40** to display efficiency using a digital read-out integral with the lights **16**, **40**, a bar of light having a length equivalent with the efficiency, or in another manner. Alternatively, the controllers **25** can control the lights **16**, **40** to display when the efficiency of the lights **16**, **40** is below a predetermined value, such as by illuminating at least one of the LEDs **26** of a respective light **16**, **40** having a different color than surrounding LEDs **26**, by causing at least one of the LEDs **26** to flash, or by controlling the lights **16**, **40** in some other manner. Once the efficiency one or more lights **16**, **40** drops below a predetermined value, it can be understood that the lights **16**, **40** should be replaced. Thus, the lights **16**, **40** can signal to a maintenance worker or other personnel when one or more of the lights **16**, **40** should be replaced. Once again, it will be understood that the indication of efficiency in this step may be made according to individual lights **16**, **40**, for example, or with respect to subsets of lights **16**, **40** or all lights **16**, **40** collectively.

The above-described embodiments have been described in order to allow easy understanding of the invention and do not limit the invention. On the contrary, the invention is intended to cover various modifications and equivalent arrangements included within the scope of the appended claims, which scope is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structure as is permitted under the law.

What is claimed:

1. An LED-based light, comprising:

one or more LEDs;

a sensor arranged to detect a brightness level in an area resulting from the combination of light emitted by the one or more LEDs with light from at least one ambient light source other than the one or more LEDs, and operable to output a signal corresponding to the detected brightness level;

a controller operable to regulate an amount of power provided to the one or more LEDs in response to the signal and to estimate an efficiency of the one or more LEDs;

a light transmitting housing for the one or more LEDs, the sensor and the controller;

a connector shaped for connection with a light socket disposed at an end of the light transmitting housing; and

a transmitter operable to transmit the estimated efficiency of the one or more LEDs from the controller.

2. The LED-based light of claim **1**, wherein the controller is operable to:

compare the signal to a predetermined value corresponding to a desired brightness level, and

increase an amount of power provided to the one or more LEDs in response to the signal if the comparison shows that the brightness level is less than the desired brightness level to adjust the light produced by the one or more LEDs to achieve the desired brightness level.

3. The LED-based light of claim **1**, wherein the controller is operable to:

compare the signal to a predetermined value corresponding to a desired brightness level, and

decrease an amount of power provided to the one or more LEDs in response to the signal if the comparison shows that the brightness level is more than the desired brightness level to adjust the light produced by the one or more LEDs to achieve the desired brightness level.

4. The LED-based light of claim **1**, wherein the controller is operable to estimate the efficiency of the one or more LEDs at least partially based on a brightness level detected by the sensor while the one or more LEDs are operational.

5. The LED-based light of claim **1**, wherein the controller is operable to estimate the efficiency of the one or more LEDs at least partially based on a comparison of a brightness level detected by the sensor while the one or more LEDs are operational with a reference brightness level.

6. The LED-based light of claim **1**, wherein the controller is operable to estimate the efficiency of the one or more LEDs at least partially based on a comparison of a brightness level detected by the sensor while the one or more LEDs are operational with a power consumption of the one or more LEDs.

7. The LED-based light of claim **1**, wherein the controller is operable to estimate the efficiency of the one or more LEDs, and to activate an alarm when the estimated efficiency of the one or more LEDs is below a predetermined amount.

8. The LED-based light of claim **7**, wherein the alarm includes at least one of an LED that produces colored light, the estimated efficiency of the one or more LEDs on a display, and an LED operated in a flashing pattern.

9. The LED-based light of claim **1**, wherein the transmitter is operable to transmit the brightness level detected by the sensor.

10. The LED-based light of claim **1**, wherein the light transmitting housing is an elongate housing, and the connector is one of a pair of bi-pin connectors disposed at opposing ends of the light transmitting housing.

11. A system for estimating an efficiency of one or more LEDs in an LED-based light, comprising:

an LED-based light including:

one or more LEDs;

a sensor arranged to detect a brightness level in an area resulting from the light emitted by the one or more LEDs, and operable to output a signal corresponding to the detected brightness level;

a light transmitting housing for the one or more LEDs and the sensor; and

a connector shaped for connection with a light socket disposed at an end of the housing; and

a controller operable to estimate the efficiency of the one or more LEDs at least partially based on a comparison of a brightness level detected by the sensor while the one or more LEDs are operational with a power consumption of the one or more LEDs.

12. The system of claim **11**, wherein the controller is operable to activate an alarm when the estimated efficiency of the one or more LEDs is below a predetermined amount.

13. The system of claim **12**, wherein the alarm includes at least one of operating an LED in the LED-based light that produces colored light, displaying the estimated efficiency of

the one or more LEDs on a display, and operating an LED in the LED-based light in a flashing pattern.

14. The system of claim **11**, wherein the controller is housed by the light transmitting housing.

15. The system of claim **11**, wherein the light transmitting housing is an elongate housing, and the connector is one of a pair of bi-pin connectors disposed at opposing ends of the light transmitting housing.

16. The system of claim **11**, further comprising:

another LED-based light including:

one or more second LEDs;

a second sensor arranged to detect a second brightness level in a second area resulting from the light emitted by the one or more second LEDs, and operable to output a second signal corresponding to the second detected brightness level;

a second light transmitting housing for the one or more second LEDs and the second sensor; and

a second connector shaped for connection with a second light socket disposed at an end of the second housing, wherein:

the controller is operable to estimate an efficiency of the system at least partially based on a comparison of brightness levels detected by the sensors of the LED-based light and the other LED-based light while their one or more LEDs are operational with a power consumption of the their one or more LEDs.

17. An LED-based light, comprising:

one or more LEDs;

a sensor arranged to detect a brightness level in an area resulting from the light emitted by the one or more LEDs, and operable to output a signal corresponding to the detected brightness level;

a controller operable to estimate an efficiency of the one or more LEDs at least partially based on the brightness level detected by the sensor while the one or more LEDs are operational;

a transmitter operable to transmit the estimated efficiency of the one or more LEDs;

a light transmitting housing for the one or more LEDs, the sensor, the controller and the transmitter; and

a connector shaped for connection with a light socket disposed at an end of the light transmitting housing.

18. The LED-based light of claim **17**, wherein the controller is operable to estimate the efficiency of the one or more LEDs at least partially based on a comparison of a brightness level detected by the sensor while the one or more LEDs are operational with a power consumption of the one or more LEDs.

19. The LED-based light of claim **17**, wherein the light transmitting housing is an elongate housing, and the connector is one of a pair of bi-pin connectors disposed at opposing ends of the housing.

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