(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
4 September 2014 (04.09.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/134637 A2

(51) International Patent Classification:
H05B 33/08 (2006.01)

(21) International Application Number:
PCT/ZA2014/000006

(22) International Filing Date:
28 February 2014 (28.02.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

2013/01515	28 February 2013 (28.02.2013)	ZA
2013/01962	15 March 2013 (15.03.2013)	ZA
2013/05446	19 July 2013 (19.07.2013)	ZA

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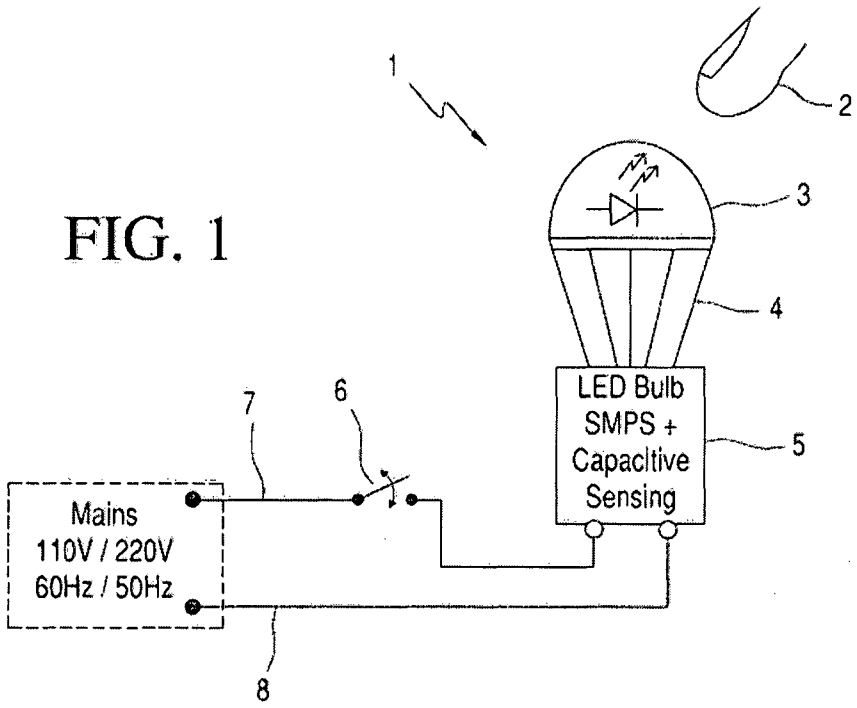
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,

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(54) Title: INTELLIGENT LIGHTING APPARATUS

FIG. 1



(57) Abstract: A light bulb which includes LED's and an integrated circuit controller which, in response to commands and data, operates the LED's within their respective ratings, wherein the commands and data are input by modulating a power line, by proximity or touch events, or by sensing patterns on a display.

WO 2014/134637 A2

TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

INTELLIGENT LIGHTING APPARATUS

BACKGROUND OF THE INVENTION

[0001] Solid state lighting is fast becoming the norm, mainly due to the characteristics of low power consumption relative to light output (efficacy) compared with other light sources, as well as the long lifetime of LED's and LED bulbs. Across the globe, incandescent bulbs are being phased out, often pro-actively through legislation.

[0002] However, even though present state of the art solid state lighting units typically use power supplies with integrated control circuits, the latter do not possess the ability to directly interface with a user. Control of LED bulbs, for example, is done with dedicated control units, often physically removed from the bulb. These either control the power supplied to the bulb, or communicate in some manner, typically via a wireless link, with a power supply driving the bulb or bulbs, allowing the user to change the intensity, colour, colour temperature etc of light being emitted. Having dedicated control units increases cost and complexity of solid state lighting implementations.

[0003] In addition, due to the proliferation of smart phones and tablet computers, users see touch and proximity (prox) gestures as the de facto standard for interfacing with electronic products. This has increasingly resulted in all sorts of products incorporating touch interfaces. Solid state and other lighting units need not be excluded from this trend.

SUMMARY OF THE INVENTION

[0004] The disclosure contained by PCT/ZA2012/000082, entitled *Capacitive Sensing Enabled Switch Mode Power Supply and Data Transfer* is hereby incorporated in its entirety.

[0005] In a first embodiment, the present invention teaches a self-contained lighting unit, for example an LED bulb/lamp such as supplied by Philips or OSRAM that replaces a traditional incandescent globe (e.g. 60W with B22 or E27 connector), for operating HAS directly with alternating current (AC) mains power or direct current (DC) power, which have the ability to sense proximity and/or touch events or gestures in the vicinity of, or directly on said unit, and which may interpret said events or gestures as user instructions to switch said lighting unit on/off, or for configuration setup, or to control or program it, for example, to increase or decrease the amount of light being emitted, and wherein said self-contained lighting unit may incorporate an AC to DC power converter to ensure that power applied to its additional circuitry is at the correct voltage and current levels. Further, as disclosed in PCT/ZA2012/000082, a controller microchip for said power converter, which converter may be a Switch Mode Power Supply (SMPS), may contain sensing circuitry required for said sensing of proximity and/or touch events or gestures, and said sensing circuitry may operate based on the measurement of a change in the capacitance of electrode structures.

[0006] In a second embodiment of the present invention, proximity and/or touch events or gestures in the vicinity of, or directly on said self-contained lighting unit, for example an LED bulb/globe, may be interpreted by said unit as user instructions to change the colour of the light being emitted by said unit.

[0007] According a third embodiment of the present invention, a user may use a swipe gesture on or in the vicinity of an AC mains or DC powered self-contained lighting unit, for example an LED bulb/globe, to place said unit in a mode where the colour of the emitted light may be selected according the disclosed second embodiment. Alternatively, according the present invention, said swipe gesture may be used to place said lighting unit in a Red-Green-Blue (RGB) mode, and the user may use proximity and/or touch events or gestures in the vicinity of, or on said unit to mix RGB colours to attain a preferred emitted light colour.

[0008] The present invention also teaches another embodiment where the colour temperature of the light being emitted by an AC mains or DC powered self-contained lighting unit, for example an LED bulb/globe, may be directly adjusted by a user through proximity and/or touch events or gestures in the vicinity of, or on capacitive sensing electrodes in the bulb base, heat sink structure or on its transparent top, or through the use of discrete switches, for example a pushbutton or buttons contained in or on the base of said bulb. In this embodiment, timing circuitry and counting circuitry may be used to interpret user actions into a desired colour temperature for emitted light. For example, the duration of a proximity and/or touch event or gesture, or switch activation may be used to select a specific colour temperature. Or, a first proximity and/or touch event or gesture or switch activation may be used to start a continuous colour temperature change, and a second proximity and/or touch event or gesture, or switch activation may be used to halt said process at a desired colour temperature. Such selected point will then be stored in non-volatile memory (NVM). Or the number of times that a proximity and/or touch event or gesture, or a switch activation occur within a certain period may be used to select the desired colour temperature of light being emitted by said lighting unit, for example an LED bulb. It

should be clear that according to the present invention, said user may select the colour temperature of light being emitted by said self-contained lighting unit from a number or a continuous range of values by interfacing with said lighting unit in the disclosed manner. For example, a colour temperature similar to that of a traditional incandescent bulb may be selected.

[0009] In the above described embodiment of the present invention, it will be obvious to those schooled in the relevant arts, and it is taught by the present invention, that the disclosed techniques to select a specific colour temperature need not be constrained to this parameter, but may also be used to select the amount of light, or the colour of light being emitted, or the duration of light emission by said lighting unit, for example an LED bulb.

[0010] Yet another embodiment of the present invention is an AC mains or DC powered self-contained lighting unit, for example an LED bulb/globe, which may have a proximity and/or touchslider mechanism incorporated, which may be used to adjust the amount of light, the colour or colour temperature of light being emitted. To enter the mode in which a user may use said slider to adjust said parameters, said lighting unit, for example an LED bulb, may also have the ability to recognize a specific swipe event or gesture by the user on or in the vicinity of the bulb. This could help to reduce the occurrence where a user accidentally engages said slider, especially if it responds to proximity gestures.

~~[0011]~~ According the teachings of the present invention, an embodiment can also be found in an AC mains or DC powered self-contained lighting unit, for example an LED bulb, which has the ability to change the colour temperature of emitted light due to setting of a traditional wall dimmer, for example one that is thyristor based, using a zero-cross (ZC) detect circuit in the bulb, as disclosed by PCT/ZA2012/000082.

[0012] The present invention further teaches an embodiment where an AC mains or DC powered self-contained lighting unit, for example an LED bulb, may have the ability to change the colour temperature of emitted light in response to commands communicated via toggling of a normal mains switch, as disclosed by PCT/ZA2012/000082. Or if the toggling of said mains switch is used to start a dimming process, but the user elects to abort the process, he or she may simply switch the mains switch to the off position for a sufficient period, which will result in the emitted light level being restored to maximum the next time that the lighting unit is powered.

[0013] In another embodiment of the present invention, proximity and/or touch events or gestures in the vicinity of, or on an AC mains or DC powered self-contained lighting unit, for example an LED bulb, may be used to adjust the focus and direction of light being emitted by said bulb. This may be realised by using a plurality of LED's within said bulb, and selectively applying power from a switch mode power supply (SMPS) contained by said bulb to the LED's, based on the location of detected proximity and/or touch events or gestures. For example, if a user proximity and/or touch event or gesture is detected for a certain period on one side of said bulb, the LED's on this side only may be powered. Or if a proximity and/or touch event or gesture is detected for a certain period at the top of said bulb's transparent top, only the LED's in the centre of said bulb may be powered, giving more focussed light.

[0014] To provide an indication of the burn time since the last turn-on event of an AC mains or DC powered self-contained lighting unit, for example an LED bulb, the present invention teaches that an embodiment may be realised where a multicolour, low power LED is located in, for example, the base of said bulb. For example, bulbs may be realised, according to the present invention, where said low power LED

burns green for a first half hour, then changes to amber, and after more than an hour has elapsed since power was applied to said bulb, it turns red. This may assist users in their efforts to conserve energy consumption by raising awareness of the length of time a specific light has been left on. Further, according the present invention, to allow users to view said low power colour LED, said lighting unit may have the ability to detect a proximity and/or touch event or gesture, after which a main light emitting element of said lighting unit is briefly dimmed. For example, a user may wave a hand in front of said lighting unit, resulting in emitted light being dimmed for a brief period, allowing the user to discern the colour of the burn time indication LED. This may be useful if said low power colour LED needs to be oriented, due to one or other constraint, in such a manner that its light is emitted in a direction which is close to that of the main light emitting element, reducing the ease with which it may be observed, due to a swamping effect from said main light emitting element.

[0015] In another embodiment of the present invention, an AC mains or DC powered self-contained lighting unit, for example an LED bulb, may be realised which briefly reduces the amount of light, followed by light level restoration after a specific burn time has elapsed since power was applied to said unit. The amount of dimming during such a flash period may be any value between a maximum, for example no-light emitted, to a minimum, for example only a few percentage points reduction in the amount of light emitted. Such an LED bulb may for example be used in a bed lamp, to help a user go to sleep on time, and not to lose track of time while reading, or to provide an indication of energy usage.

[0016] Yet another embodiment of the present invention may be found in an AC mains or DC powered self-contained lighting unit, for example an LED bulb, which contains an energy store, for example a Li-Ion or Li-Polymer battery, and circuitry to

keep said store fully charged if mains power is applied for a sufficient period. Further, said bulb also contains circuitry to detect, store, and recognise the on/off voltage switching signature of the series mains switch connected to it, said signature detection and recognition based on voltage versus time and/or voltage versus frequency analysis. Such a signature may also be based on the so-called "bounce" characteristics of said switch. If said lighting unit detects a removal of power which is not accompanied by said switching signature, it may deem that said removal is due to a power failure, and utilise the energy stored in said energy store to emit light for a certain period to provide emergency lighting. Typically, the amount of emergency light thus emitted may be significantly lower than that emitted with normal mains power applied, to conserve the energy in said store for as long as possible.

[0017] The above embodiment of the present invention may be further improved by including the ability to sense proximity and/or touch events or gestures in the vicinity of, or on said lighting unit, which may be an LED bulb, and by only providing a Find-In- the- Dark (FITD) indication once a power failure has been detected. Said FITD indication may be an additional, low power LED that intermittently emits a specific colour of light, for example blue, or it may be the intermittent lighting of the LED's used during normal operation, but at a lower light level. As such, the energy store of said lighting unit may be conserved for a longer period after said power failure. To activate said lighting unit, a user only needs to locate it via said FITD, and perform a specific proximity and/or touch event or gesture in the vicinity of, or on the unit, for example touching the top of an LED bulb cover.

[0018] Another possible improvement to the above exemplary embodiment of the present invention may be the use of a dedicated mains monitor that contains one or other transmitter which emits a specific signal when it detects a mains power failure,

with complementary receivers located in AC mains or DC powered self-contained lighting units, for example LED bulbs. Once said lighting units receive said specific signal, they may act by powering a FITD indicator from said energy store, and activating or enabling capacitive sensing circuitry contained by said units. Or said capacitive sensing circuitry may always be powered, irrespective of the mains status, with only depletion of said energy store that causes de-activation of said circuitry. A user may locate said lighting unit in reduced ambient lighting, possibly due to said power failure, via the FITD indicator, and turn said lighting unit on by a proximity and/or touch event or gesture to provide emergency lighting. It is envisaged, according to the present invention, that said mains monitor may have a small enough form factor to fit into a standard two or three prong wall outlet plug, as an example. Thus the mains monitor can be plugged into a standard wall outlet, and may draw very little power, as it nominally only performs a monitoring function, which need not be on a continual basis, for example it may be every 100ms, every second, or even every few seconds. It may also be possible, according the present invention, to use said mains monitor to provide a visible indication to a user that mains power is present. Naturally, this may increase nominal power consumption of said monitor.

[0019] Transmission and reception of said specific signal in the above disclosure may be based on any of a large number of technologies, methods and mediums, according the teachings of the present invention. For example, a radio frequency (RF) transmitter and receiver pair may be used, or a power line communication (PLC) transmitter and receiver pair may be used, or an infra-red (IR) transmitter and receiver pair may be used, or a laser transmitter and receiver pair may be used and so forth. Specific requirements may exist for the use of some of the preceding examples. For instance, if using PLC, a one-wire based system may need to be

used, since mains switches in-line with said lighting units may be open. Or for IR or laser based transmitters and receivers, line of sight may be required. For RF based embodiments, it may be required to network the transmitters and receivers in some manner, to ensure said specific signal reaches all required receivers. For example, a Zigbee™ protocol and hardware solution may be used to establish RF communication between said mains monitor and lighting units, although this may require transmitters and receivers to be changed to transceivers at each node in the network.

[0020] The present invention also teaches that said mains monitor or in fact a dimmer unit may utilize a sensor to measure the ambient light level, and wherein the monitor only transmits said specific signal to said lighting units if ambient light is below a certain level, i.e. if it is dark enough. Alternatively, each lighting unit may have a sensor to measure ambient light level, and wherein said lighting unit only responds to said specific signal from said mains monitor if the ambient light level at the particular lighting unit is low enough. That is, a particular lighting unit will only activate its FITD functionality, for example, if it has received a specific signal from said mains monitor that indicates that a power failure occurred, and if it is dark enough in the vicinity of said lighting unit.

[0021] According to the present invention, an AC mains or DC powered self-contained lighting unit, for example an LED bulb, may also be realised with the ability to use normal mains wiring as capacitive sensing electrodes. Said bulb couples a high-frequency voltage, for example 500kHz or 1MHz, onto the mains wiring back to a mains switch, and utilizes capacitive sensing circuitry to detect significant changes in the capacitance of said wiring. Said capacitance may be either the mutual capacitance between a Live and Neutral conductor, or it may be the self-capacitance

of either the Live or Neutral conductor, or both, to electrical earth. Said detected significant changes may be used to control the amount of light emitted by said bulb, or the colour of emitted light, or the colour temperature of emitted light, or the duration of light emission, with said control which may also be based on timing and counting circuitry of said bulb. For example, it is envisaged that a user may simply hold his or her hand against a wall switch plate for a predetermined period to start a dimming process, which can be halted at the desired light level by removal of the hand, or a brief tap etc.

[0022] In the above embodiments, where toggling of a wall switch or a proximity and/or touch event or gesture is used to control the duration of light emission, for example to start a gradual dimming process, the present invention teaches that each consecutive toggle or proximity and/or touch event or gesture may be used to increase the period until the light emission is zero. That is, toggling or proximity and/or touch events or gestures may be used to select a period, with said emitted light gradually fading to zero during said period. For example, a first toggle or proximity and/or touch event or gesture may be used to set said period to thirty seconds, and a second to set it to five minutes, a third to half an hour and so forth. Clearly the wall switch must be taken through an "OFF – ON" cycle since it must remain ON for the bulb to have any power. In this embodiment a delayed off action is initiated by the OFF/ON toggle sequence. A number of implementations are possible for example after OFF/ON, a) bulb dim to lower power level and x minutes later switch light off, b) slowly fade away to zero light over x minutes.

[0023] In another embodiment of the present invention, a touch or track pad may be used to control a luminaire, for example a desk or bed lamp. It is envisaged that said touch or track pad may be used as input device to enter said luminaire into various

selection modes, using character recognition. For example, a user may trace the letter "P" on said touch or track pad, which will place the luminaire in a Power Level selection mode. Or the letter "A" may be traced, to place said luminaire in an Auto-off Period selection mode. Or the letter "T" may be traced, to place said luminaire in a Colour Temperature selection mode. Once in a particular selection mode, a user may use further tracings of letters or numbers to select a particular value or level, for example tracing a "W" to select a warm colour temperature, or a "C" for a cold colour temperature, or a "1" for power level one, and so forth. The preceding are merely given as examples of how a touch or track pad may be used to control a luminaire according to the present invention, and should not be construed as limiting.

[0024] In PCT/ZA2012/000082, entirely incorporated into the present disclosure, a lamp is taught which has the ability to provide a plurality of emitted light colours, music playback, sound recognition, touch or proximity sensing and the ability to change the colour or amount of emitted light according to detected sound etc. The present invention further teaches a lamp or luminaire that utilizes a lighting unit as disclosed and which has connectivity, enabling said lamp to connect to a smart phone, tablet computer or similar. Said connectivity may be, but is not limited to, in the form of a wireless connection, or a USB connection etc. Said lamp further may have the ability to store and execute applications downloaded from the internet, and transferred to said lamp via said connectivity. It may also be possible for said lamp to directly connect to the internet via said connectivity, obviating the need for an additional device to download said applications. Said applications may result in a large number of different lamp operational schemes. For example, different applications may provide different lighting schemes where colour changes according to elapsed time based on the individual taste of users, or according to sound

detected, or to the time of day, or to the date, or to the season etc. Or said applications may provide different manners of colour mixing etc. The number of possible applications are vast, and cannot be listed here. What is paramount is that the present invention teaches a lamp which may store and execute such downloadable applications, and which have connectivity to receive them from another electronic device.

[0025] The present invention also teaches an alternative to the above intelligent luminaire, in that the lamp or luminaire does not contain a switch mode power supply (SMPS), and does not control a lighting unit, for example an LED bulb, directly, but merely facilitates command input from a user to said lighting unit. For example, an in-line mechanical switch may be toggled to enter commands for said LED bulb. Or a three-position wheel dimmer, as described in US 4,166,236, may be used to enter commands, where a number of sequential selections of the dimmed setting, with the corresponding half-wave rectified voltage, within a certain period, may be interpreted as a certain command, or commands may be embedded as a signal in the power line to the intelligent bulb etc. A switch that is normally closed and which is positioned in parallel to a diode may be used to remove half cycles when pushed to open. A further variation of the switch may be constructed to only momentarily break or open, irrespective of how long or hard the switch is pressed. During the momentarily open state, half cycles are blocked by the diode that now forms the conducting circuit. These removed half cycles are then used for power line communication. The lamp or luminaire may have a low-power reactive or dissipative power supply, for example a so-called cap-dropper supply, which only furnishes enough power to allow minimal user interface (e.g. touch sensing) circuitry and other power line communication circuitry to operate and communicate with said lighting unit, for example an intelligent

LED bulb. User input into said power line communication circuitry may be via mechanical pushbuttons, touch or proximity gestures etc.

[0026] In a variation of the above embodiment, the present invention teaches that said three position wheel dimmer may be replaced by a touch and/or proximity sensing interface device which emulates the functionality of said wheel dimmer. That is, a diode may be selectively switched in series with the AC mains, or may be shorted out, or may be replaced with an open circuit, depending on the touch and/or proximity events or gestures sensed by said interface. The resulting omission of mains half cycles, or parts of the half cycles, or presence or absence of mains cycles in the voltage being applied to said bulb should result in 50% dimmed light emission, full light emission or no light emission by said bulb, respectively. In addition, the present invention also teaches that such omission of mains half cycles, parts of half cycles or presence or absence of full mains cycles for specific pre-determined periods may also be interpreted by said LED bulb as specific commands for dimming, colour change, colour temperature change and so forth

[0027] A low cost touch sensor switch with limited power level selection (dimming) functionality can be constructed in accordance with the present invention. High voltage transistors (BJT's or FET's) or TRIAC's may be used to switch through or block half cycles or parts of an AC supply. In this way limited electromagnetic noise is created due to very small inrush currents and therefore the cost of snubbers and filters required to meet emission standards are reduced. When used in, for example, a normal desk lamp for incandescent bulbs that may later be fitted with LED bulbs a function can be designed in to detect incandescent or LED bulbs and the functions can be adjusted accordingly. For example, a very low duty cycle feature may be present for incandescent bulbs that may not work for LED bulbs and when the

presence of a LED bulb is detected such feature can be disabled. The same principle may be applied to a wall switch dimmer operating with touch and offering proximity detection and backlighting activation upon proximity detection.

[0028] The half cycle to be discarded must be randomly varied in order to statistically balance the load on the mains supply.

[0029] In yet another embodiment of the present invention, a touch control unit which controls a switching element, for example a TRIAC or transistor, to allow or omit complete mains cycles for powering a lighting or an electrical motor load, the latter for example used in a fan with variable speed control, is taught. Cycles or half cycles may be omitted to reduce the amount of power supplied to a given load, for example by omitting every second cycle, only 50% power is supplied. According the present invention, by allowing or omitting complete mains cycles or half cycles from the power applied to said loads, the need for snubber and other circuits required to control switching transients to legally acceptable limits, may be reduced or completely removed, resulting in reduced cost.

[0030] Further, the present invention teaches that a switching element, for example a TRIAC, may be closed near the end of mains half cycles, to supply very little power to a load, for example. By only closing said switching element near the end of the mains half-cycle, small inrush currents are present, due to the low mains voltage level, reducing or obviating the need for Electromagnetic Interference EMI filters. This power may still be enough to power back lighting etc.

[0031] In a further embodiment an AC mains or DC powered self-contained lighting unit may have an ambient light input sensor that may be used to activate the light when the ambient light falls below a certain level or whereby the lighting unit is de-

activated when the ambient light goes above a selected level. The lighting unit may also function as a night light that offers very low level of light automatically when it is dark, even when switched off (by command). The various levels of activation and de-activation may be adjusted in accordance with the teachings of this specification.

[0032] In a specific embodiment the ambient light sensor may be implemented using the capacitive sensing circuitry and charge transfer method used in the integrated circuit controller of the LED light bulb and SMPS. A photo diode may be connected to a capacitive measurement circuit and may be modelled as a capacitor(C) with a variable resistance (R) in parallel. The resistance varies based on the amount of light falling onto it. The R and C form an RC time constant network and if measured at an appropriate frequency the variation in the R will have an effect on the C that is measured by the integrated circuit. A typical surface capacitance (or self) measurement technique will work fine but mutual capacitance measurement can also be used.

[0033] It is advantageous that the ambient light measurement circuit has knowledge about the power level of the light bulb and if or when it is adjusted. An algorithm can be implemented to adjust the switching ON and OFF levels by taking the information about the power and adjustment and time of adjustment into account. For example an ambient light measurement is made when the light bulb is off, and when it is switched on, the same measurement is made and the effect of the light bulb activation can be deducted from this information. I.e. an appropriate level to automatically switch off again can be derived using this information. As such a generic light bulb can be made and every user can set the level of auto activation and de-activation by simply switching the light bulb on at the ambient light level they want. A self-learning system may also be implemented whereby the light bulb will

learn the ambient light levels it is subjected to and find the optimal ambient light levels to activate and de-activated or activate at certain power levels.

[0034] To elaborate on the manner, according to the present invention, by which a user may program or control an AC mains or DC powered self-contained lighting unit, for example an LED or other lighting bulb, as disclosed previously, the following. It is envisaged, for example, that the packaging of said LED bulb may contain instructions whereby set-up or program mode of said bulb is entered by performing a swipe gesture (capacitive or optical), a long proximity and/or touch event or gesture, or a normal proximity and/or touch event or gesture, or other user input mechanism directly into the bulb. Once in program mode, the user may select functionality according the following example:

[0035] One proximity and/or touch event - colour temperature set to blue/cold white.

[0036] Two proximity and/or touch events - colour temperature set to warm white.

[0037] Three proximity and/or touch events - emitted light level set to 100% of maximum.

[0038] Four proximity and/or touch events–emitted light level set to 50% of maximum.

[0039] Five proximity and/or touch events - emitted light level set to 25 % of maximum.

[0040] Six proximity and/or touch events - emitted light level set to 8 % of maximum.

[0041] Seven proximity and/or touch events - bulb is permanently switched on.

[0042] Eight proximity and/or touch events - an 8 hour period is allowed to elapse until an auto off event.

[0043] Nine proximity and/or touch events - a 2 hour period is allowed to elapse until an auto off event.

[0044] Ten proximity and/or touch events - a return to default factory settings occur.

[0045] The following parameters may all be considered for end user configuration: Power level, ON period or auto off period (On period after activation), delayed off period (time to shut off after OFF command), ambient light activation/deactivation levels, colour temperature, colour, night light function ON/OFF, UI option selection.

[0046] Commands may also be transferred by means of light pulses to the ambient light sensor or through power line communications. An IR, Wi-Fi, Blue Tooth or any other type of signal may be used.

[0047] According the present invention, each selection by a user may be confirmed by a number of flashes. If said number of flashes required is a large number, the flashes may be split into groups (for example three), with a perceivable spacing between groups, to make counting easier. Of course the percentages, time periods etc. are all just exemplary and any preferred value, amount, percentage etc. may be chosen. The selection feedback may also be provided via light pipes forming part of the touch sensing or button structures.

[0048] In a further embodiment, a second button, a long touch or proximity or another differentiated gesture may be used to select a specific mode or group of settings. For example, the user may hold said button in, or make said long touch or long proximity, until two flashes occur, which may signify that the LED bulb, for example, is then in a power level selection mode, according the present invention. Or said button may be pressed, or long touch or long proximity made, until three flashes occur, which may signify that said LED bulb is in an auto-off period selection mode.

Advantageously, a much smaller number of button presses, touch events or proximity events may then be used to effect a selection within the selected mode.

[0049] The present invention teaches that if desired, a gradual changing colour may be presented whereby the user may select the desired colour by a proximity and/or touch event or gesture. The colour may be colour temperature for normal (white light) or it may be predominantly white but with a soft colour tint (blue, purple, pink etc.) or it may be a full colour selection within the RGB scheme.

[0050] Embodiments of the present invention where touches need to be made on, or proximity gestures need to be made in the vicinity of the transparent dome of, for example, an LED bulb or other lighting bulb, may be facilitated with a conductive but transparent layer, for example a Polyethylene Terephthalate (PET) film with a coating of Indium Tin Oxide (ITO) or Kodak's PEDOT film.

[0051] As disclosed earlier, the present invention teaches that protection against accidental selection may be facilitated by requiring a swipe action to enter selection activation mode. A further swipe may for example be used to select a group of modes, for example auto-off period or colour temperature modes, and whereas sequential proximity and/or touch events or gestures may be used for further detail selection within the group, according to the present invention. For example diming levels may be chosen in multiples of e.g. 20% or auto off time may be selected in units of 30 minutes.

[0052] According to the present invention, ambient light may also be used as a parameter for selection. For example, the user may set an AC mains or DC powered self-contained lighting unit, for example alighting bulb, into a selection mode in which the level of ambient light where said bulb will automatically switch on or off, may be

adjusted and selected. Said selection mode may be entered according to the preceding disclosure and teachings.

[0053] In the preceding, it should be noted that, according the present invention, selections may be made with proximity and/or touch events or gestures on alternative areas of the AC mains or DC powered self-contained lighting unit, for example an LED bulb, with said areas being isolated from mains, and non-conductive. It is even envisaged that normal pushbuttons may be used to enter selections, said alternative proximity and/or touch areas or push buttons being located within the heat sink structure of said bulb, for example.

[0054] The use of capacitive proximity and/or touch sensing to facilitate user input to control AC mains or DC powered self-contained lighting units, for example lighting bulbs, as taught and disclosed by the present invention, may be especially advantageous for mains lighting applications, as it may provide inherent protection against electric shock. For example, the present invention teaches that part of, or the complete heat sink structure of an LED bulb may be manufactured from plastic with good thermal conductive properties, but which isolates electrically, and wherein said capacitive sensing is performed across the isolation barrier formed by said heat sink plastic.

[0055] Use of light pipes to channel light from light sources, for example, LED's situated on a PCB within a lighting unit, to an external periphery, for example the translucent or semi-translucent dome of an LED bulb, and to provide user guidance via said channelled light, is also hereby taught by the present specification. The light pipe may also be the electrode for capacitive sensing. The light pipe material may have a dielectric constant much higher than air or it may contain conductive material to facilitate better capacitive sensing operation. Further, said light sources, for

example LED's, may be switched on for a brief period, such as after power-on, to provide user guidance. It may also be possible to use said light sources and pipes to provide an indication of elapsed burn time, for example when the product fails within a warranty period, according the present invention.

[0056] The lighting unit may be designed to automatically detect if it is working with a power line communication type dimmer. One configuration selection resulting from such detection is to prevent the lighting unit from being activated by a normal power–on cycle, this means if power is switched off (power failure) and comes back on, the lighting unit will not be activated. Optionally it can be activated if it was activated when the power failed or was switched off. This is also a parameter that may be configurable through the touch sensing user interface feature.

[0057] In yet another exemplary embodiment of the present invention, an AC mains or DC powered self-contained lighting unit, for example an LED bulb, has the ability to be powered and configured from a Universal Serial Bus (USB) port, as is commonly found on computers etc. A dedicated USB connector may be supplied on said lighting unit, which may furnish power at a low DC level, for example 5V, to the bulb, as well as the digital data used for configuration. It is envisaged that a user may use a graphical user interface (GUI) on a personal computer or smart phone to configure the operational parameters of said lighting unit via USB, for example, without placing a limit, the colour, colour temperature, light level to be emitted etc. In an alternative related embodiment, said USB port may be used to only supply power at a low DC level, for example 5V, to said lighting unit, with configuration effected via the touch and/or proximity interface of the unit. For example, a cable may be provided which accepts the lighting unit on one end, and plugs into a USB port at the other. This results in 5V DC being applied to the mains input terminals of said lighting

unit, which may recognise this, and utilise said 5V to power its capacitive sensing and configuration circuitry, along with feedback circuitry, the latter used to provide feedback to said user on configuration status. A user may then configure said lighting unit by performing relevant proximity and/or touch events or gestures, similar to that performed when the lighting unit is powered from mains, and is configured.

[0058] The present invention also teaches that AC mains or DC powered self-contained lighting units, for example LED bulbs, may be configured into masters and slaves, where the configuration selected for a particular master is replicated by its associated slaves, after said configuration is communicated to said slaves in some manner via the one or other communication network. The communication methods thus employed may be quite varied, according the present invention, for example power line communication, radio frequency communication or infra-red based communication, amongst others, may be used. Such an embodiment of the present invention may have the advantage that a user only needs to configure one lighting unit, and as long as that unit is present on said communication network and designated as a master, all other units designated as its associated slaves will replicate its configuration. For example, if a user prefers a certain colour temperature, he/she only needs to select it once, on a master lighting unit, and whenever new lighting units are purchased and installed in a residence or room, for example, these only have to be designated as slaves, which may be a default status, to ensure that all lighting units emit light with the same preferred colour temperature.

[0059] Use of audio output to provide user feedback during configuration or use of an AC mains or DC powered self-contained lighting unit, for example an LED bulb, is taught by the present invention. For example, a controller within said lighting unit may provide a pulse width modulation (PWM) based signal to a buzzer. By varying

the modulation width of said PWM signal, different sounds may be generated by said buzzer. Or the timing base of pulses of PWM signals may be varied to provide said feedback.

[0060] In yet another exemplary embodiment of the present invention, an infra-red (IR) receiver may be present on said lighting units, for example LED bulbs, and used to receive commands for configuration of the lighting unit through adjustment of operational parameters, some of which have been listed during the preceding discourse. It is envisaged that users may utilize devices such as smart phones or TV universal type remote controls as IR transmitters to send the required IR signals to said IR receiver located on said lighting unit, with dedicated lighting unit control applications downloaded to and executed by said phones. Further, if a given smart phone does not have an IR-out port, the audio-out port of said phone may be used to drive an IR transmitter device, wherein said application is used to ensure that the signal provided to said audio-out port is within the constraints of the port, and wherein said IR transmitter device converts the signal received from said port into the signal required by said IR transmitter to communicate said commands successfully to said IR receiver.

[0061] In another related exemplary embodiment, a so-called universal remote may be used to communicate said configuration commands via IR to said IR receiver located on said lighting unit. Such universal remotes are typically used to control a number of devices with one remote, for example a television, set-top box, audio system etc. Devices may normally be added to such a universal remote through dedicated setup and selection buttons, and the use of specific product or product category codes. Once a device is added, it may be controlled by selecting it first via a specific selection button on said remote, for example. Therefore, according the

present invention, a universal remote may be configured that lighting units with IR receivers, as previously disclosed, may be added to said remote. For example, it is envisaged that a user may use said universal remote to adjust his/her audio system, and then use the same remove to adjust operation of a lighting unit as disclosed to suit the music played by said audio system. It should be understood that the receiver on said lighting unit, and the transmitter on said universal remote need not be IR based, but may use any of a large number of alternative communication methods and technologies, for example wireless communication as per RF4CE™ (RF for consumer electronics) or BLE (Bluetooth™ Low Energy).

[0062] In PCT/ZA2012/000082, which is entirely incorporated into the present disclosure, a wall control unit, which may have a touch/proximity sensing interface, is taught which may receive messages from smart utility meters via a wireless interface, and which may then relay said messages to connected lighting units through the omission of mains cycles and/or half-cycles, said omission done through the opening or closing of a solid state switching element at ZC points of the mains voltage. To some extent, such a communication method by said wall control unit emulates the toggling of a mains switch by a user to realize, for example, dimming of a lighting unit connected to said mains switch, with the difference that said toggling will not necessarily occur at the mains ZC points. The present disclosure further augments the above by teaching that said wall control unit may also have the ability to receive messages from, or have full two-way communication with a smart phone, tablet personal computer (PC) or other computers or devices, including other wall control units. Such message reception or two-way communication may, for example, occur wirelessly, and may be based on any of a large number of protocols and methods, for example on Zigbee™, on Zigbee RF4CE™, Bluetooth™, Wi-Fi Direct™,

Blue Tooth Low Energy, ANT and so forth. Said message reception or two-way communication may also be based on some form of power line communication (PLC). Therefore, according the present invention, and as an example, a user may address a particular wall control unit, and the lighting units, or other loads, connected to it via his/her smart phone and an application running on said phone. This may enable the user to configure any of a large number of operational parameters, for example emitted light level, colour, colour temperature, duration and so forth, as listed earlier, for all lighting units connected to said wall control unit, or for an individual lighting unit, from his/her phone. To be clear, the present invention teaches that the communication between said smart phone, as an example, and said wall control unit may take place according to a specific industry standard, which may be wireless based, and the communication between said wall control unit and said lighting units, as exemplary loads, takes place according to the omission of mains cycles and/or half-cycles, part of the AC half cycle or other power line communication method, as disclosed in and taught by PCT/ZA2012/000082, wherein said communication relays configuration commands to said lighting units. This teaching have the advantage of not requiring a wireless transceiver in each lighting unit, and only one receiver or transceiver in said wall control unit. Further, it leverages on the fact that lighting units connected to a wall control unit, or to the traditional wall switch it may replace, are already networked in the sense that they are connected to the same mains wires.

[0063] Further, according to the present invention, a wall control unit as above may have the ability to operate with or without an RF-module present, said module realizing wireless connectivity to a smart phone, tablet PC or other devices, including other wall control units. That is, a wall control unit may operate as disclosed by

PCT/ZA2012/000082 to control operation of connected lighting units through only, as an example, proximity and/or touch events or gestures by a user, without any connectivity to other devices such as a smart phone, tablet PC or other devices, including other wall control units. However, said wall control unit may be able to accept an RF-module, for example via a USB port, wherein said control unit may then have the ability to receive messages from or establish full two-way communication with a smart phone, tablet PC or other devices, including other wall control units. Further, once such connectivity is established for a wall control unit, it may form part of one or other communications network, for example it may be an end node, a concentrator, a master, a slave or a relay station, as is often employed in the art of wireless networking. Such networking may improve the amount of control possible with a single device, such as a smart phone, a tablet PC or a wall control unit, without requiring the increased cost and complexity of having a wireless transceiver in each lighting unit, or other load, whichever is pertinent, and it leverages on the fact that lighting unit, or other loads, are often already networked in some sense through shared mains wires.

[0064] The present invention also teaches a self-contained AC mains or DC powered lighting unit, for example an LED bulb, which may have the ability to recognize the switch type connected between it and the power source, for example whether it is a spring loaded push-to-break (i.e. a push button) or a normal latching type mains switch. According the present invention, a user interface of said lighting unit may be adjusted based on said switch type recognition.

[0065] A self-contained AC mains or DC powered lighting unit, for example an LED bulb, may also be manufactured with components which have not been pre-sorted according to very tight tolerances on component characteristics, or so called

"binning", and wherein different lighting unit operational states are achieved through adjustment of operational parameters during/after manufacture, with said parameter values stored in NVM, for subsequent default use, or for subsequent user access to facilitate a selection of said states, according to the present invention. This may help reduce cost. For example, during manufacture of a lighting unit which embodies the present invention, un-binned LED's may be used, followed by adjustment of emitted light to various colour temperatures, with operational parameter values required for each temperature stored in NVM. Lighting units may then be programmed for default operation in and sold as specific colour temperature units. Or alternatively, a user may select various colour temperatures through proximity and/or touch events or gestures in the vicinity of, or on said lighting unit, as disclosed earlier, all with un-binned, and thus cheaper, LED's, according the present invention.

[0066] It should be understood that in the preceding and following sections of the present disclosure, where reference is made to an LED bulb, this is merely as an example, and the present invention should not be limited to these only, but may also be relevant to a large number of other AC mains or DC powered self-contained lighting units, such as traditional incandescent bulbs, or so called CFL bulbs etc. An LED bulb and LED lamp and LED globe are synonyms and interchangeable words for the same thing (in this specification).

[0067] In the present disclosure, where the term prox or proximity is used, it should be understood to mean, without undue limitation, that no physical contact takes place between a user and a capacitive sensing electrode, or between a user and an overlay material. Correspondingly, where the term touch is used, it should be understood to mean, without undue limitation, that physical contact takes place between a user and said electrode or overlay material above the sensing electrode,

with or without limited air gaps present between the overlay material and the sensing electrode.

[0068] Self-contained AC mains or DC powered lighting units, for example LED bulbs, as disclosed by the present invention may have a form factor similar to, but not limited to that of traditional incandescent, fluorescent tubes or CFL bulbs, for example A19, GU10, PAR38, T5/T8 tubes or A55, and may have bases similar to that traditionally used, for example E10, E14 or E27. This may facilitate the direct replacement of, for example, incandescent bulbs by said lighting units of the present invention.

[0069] The power line data detection mechanism can be an integral part of the switch mode power supply controller. This implementation holds many advantages for SNR (signal to noise) optimisation and for component count reduction. If amplitude or ON/OFF modulation of the mains power is used, the current through the inductor (buck configuration) or transformer primary winding (fly back type configuration) is a good indication of power being available or not. If smoothing is done on the secondary power line, flicker due to the data can be reduced without affecting the data transfers or data transfer rates.

[0070] It is also advantageous to transfer data (ON / OFF) around or after the zero cross points because the capacitors and inductors in the circuit are at low voltage points and thus any discharge times are reduced.

[0071] The implementation of a momentary increase in power level to the LED right after a data bit transferred through zero power (off) is good to counter the possible reduction in light output due to the data bit. In this way flicker due to data transfers can be reduced or essentially removed for practical purposes.

[0072] The trip level of current through the inductor or transformer primary (often referred to as I_sense) may be adjusted for power factor considerations in the troughs or valleys of the mains, it may in general be adjusted for control of the power to the load. The same facility may be used to ensure early and accurate detection of ON/OFF power modulation. It may for example be set very low around the zero cross points of an AC cycle or may be set very high at the maximum voltage level of the AC cycle if data is to be detected there. The trip indicator is then a very good metric of the presence of a low input power (data bit = 0) or not (data bit = 1).

[0073] The power bus to the load (for example over the LED's if the application is a LED light bulb) can also be monitored for a deviation from the norm to detect data transfers. If a low level is reach during the high phase of the AC cycle it clearly indicates an OFF condition in the power supply, and possibly a data bit.

[0074] The data command structure is suitable for many applications that use switch mode power supplies connected to a switch structure or power network. Certainly the new generation of mains LED light bulbs (including GU10 types) or power supplies for MR16 type LED lights can all benefit from this technology. Many parameters may be controlled including but not limited to – colour, colour temperature, light output levels, calibration, time out periods, ambient light levels for activation and deactivation of the light source, night light type functions and many more.

[0075] The prior art holds a number of examples of LED bulbs which utilize an additional, selectable resistive load to enable use of said bulbs with traditional two wire dimmers. In such dimmers, the resistive element of a traditional incandescent bulb allows a power circuit to be completed between live and neutral when the dimmer switching element is open, specifically during the first part of a mains half cycle. As such a voltage potential is formed which can be used to charge an energy

storage element such as a capacitor. The energy thus stored in said storage element may then be used to operate said switching element and dimmer electronics for a period of time (e.g. until the next half cycle). If an LED bulb is retrofitted in the place of said incandescent bulb, the lack of a resistive element between live and neutral prevents the completion of said power circuit during the first part of the mains half cycle, resulting in an in-operable dimmer. Therefore, the prior art teaches LED bulbs circuits wherein an additional resistive load is switched in during a first part of the mains half cycle, allowing said dimmer energy storage element to charge up, thus ensuring compatibility between LED bulb and two wire dimmer.

[0076] According to the present invention, it may be possible to use the above described additional resistive load of a two-wire dimmer compatible LED bulb to transfer data from said bulb to a User Interface Unit (UIU) or to a calibration unit, where such a UIU or calibration unit can operate without charging an energy storage element during every half cycle of the AC mains. By selectively switching said additional resistive load in and out, current flowing in power lines between a UIU and said LED bulb may be modulated according to the control circuit and data present in the bulb. The UIU or calibration unit may measure power line current, and demodulate the data. In such a manner, according the present invention, data may be transferred between an exemplary LED bulb, or another intelligent lighting apparatus, and a UIU or calibration unit.

[0077] Data transferred between an LED bulb, or another intelligent lighting apparatus, and a UIU or calibration unit according to the above teachings may be in response to a request for data from said UIU or calibration unit. For example, it is envisaged that it may be used to investigate warranty claims, where a customer's bulb which failed prematurely is asked for a number of parameters, for example total

burn time. Or a user may use a UIU as disclosed to query a specific bulb on its usage history, to estimate remaining lifetime, to date energy consumption, operating temperature, calibration data and so forth. It is also a mechanism whereby the bulb can acknowledge the receipt of commands, version numbers, model numbers etc.

[0078] The positioning of the data in the AC cycle just past the zero cross is with existing practice and is less likely to cause problems with various equipment and also specifically is less likely to cause a visible alteration in the light output.

[0079] In further embodiments the integrated circuit controller may keep track of the time the bulb is activated, the power level, temperature etc. This information may be used in conjunction with lumen deterioration information from the LED supplier to implement a lumen maintenance algorithm. The performance over time information about a specific LED used in manufacturing may be programmed into NVM in order for the controller IC to work correctly with LED's from various suppliers. For example, in LED A an adjustment of power (higher) of 1% may be required after 1000 hrs whereas an adjustment of 1% is required after 2000 hrs for LED B, in order to keep the light output constant comparable with a new light bulb. This is beneficial when mixing old and new bulbs in an installation. It is important to note that the temperature of operation and power level are also important metrics in implementing a lumen maintenance algorithm. The integrated circuit controller may also measure the temperature of the bulb in order to implement a more sophisticated (and more accurate) lumen maintenance algorithm.

[0080] A number of state of the art and prior art dimmers for incandescent bulb have specific requirements to function properly when connected to LED or other solid-state lighting globes. This is mainly linked to the requirement for working with "Live" only at the dimmer (two wire operation) and also if the switching element is an

SCR (and not a transistor) a holding current is required to keep the SCR on after being activated(fired). Handling these requirements on a generic basis inevitably wastes power in every bulb, even in bulbs not connected to a dimmer. Hence in an embodiment the LED bulb controller may determine if such a dimmer is in the circuit (connected in the power circuit to the bulb) by checking if a holding current is required and if not it can cut down on the wasting of power by the LED bulb by removing the implementation of a holding current in the light bulb. Or the level of holding current may be adjusted to optimise performance.

[0081] This invention also includes the use of an intelligent controller as per the above to implement a light source using HV LED construction (i.e. no SMPS functionality required) but still using the controller for the other functions described in the specification for example the communications, the ambient light sensing, Lumen maintenance or optimised dimmer compatibility functionality and also to switch the correct number of LED's into the circuit that will result in a specific current based on the V in the AC cycle. As the V rises in the cycle more LED's need to be switched in, in order to prevent currents in excess of the LED ratings. And again on the down slope, LED's must be switched out to prevent the current falling too low.

[0082] The controller may also use any of the communication mechanisms disclosed to communicate with an alarm system to activate the bulb when the alarm system detects motion in the room where the bulb is installed. Or the bulb may actually also contain an PIR sensor to check for motion and may communicate detection of motion to the alarm system. Similarly the bulb may function as a smoke detector, with a suitable sensor being part of the bulb circuitry and alert the alarm system with communication when smoke or fire is detected as well as automatically activate the light.

[0083] The controller according to the invention is capable of forming the basis for a very sophisticated but cost effective light bulb. It is a major advantage that even the oldest buildings today are equipped with wiring to allow for light bulbs and control using simple electro mechanical switches (typical wall switches).

[0084] The bulb may be programmed to perform automatic power level adjustment. It is well known that the requirement for a high level of artificial light (e.g. in street lights) is most at dusk and dawn when there is a level of natural sunlight that influences the human eye. Later at night, for example on a moonless night the level of light required from the bulb is much less. Based on ambient light measurements by the bulb controller, the power level of the bulb may be automatically adjusted to save power.

[0085] This bulb may also receive commands to set or reset the light levels for example during an emergency of if overloading of the grid occurs.

[0086] In on broad respect therefore, the invention provides a light bulb which includes LED's and an integrated circuit controller which, in response to commands and data, operates the LED's within their respective ratings, wherein the commands and data are input by modulating a power line, by proximity or touch events, or by sensing patterns on a display.

BRIEF DESCRIPTION OF THE DRAWINGS

[0087] The invention is further described by way of examples with reference to the accompanying drawings in which:

FIGURE 1 shows an exemplary embodiment of the present invention, where an LED bulb incorporates capacitive sensing ability, allowing user configuration via proximity and/or touch;

FIGURE 2 shows an exemplary embodiment of the present invention, where an LED bulb uses a plurality of capacitive sensing electrodes to detect a swipe gesture, and to allow RGB light selection;

FIGURE 3 shows an exemplary embodiment of the present invention, where an LED bulb have dedicated touch areas, or use pushbuttons on the heat sink of said bulb, or on the frontal flange of the bulb, to facilitate user input;

FIGURE 4 shows an exemplary embodiment of the present invention, where an LED bulb use capacitive sensing electrodes to identify swipe gestures, and a slider type structure, to allow a more continuous adjustment of an operating parameter;

FIGURE 5 shows an exemplary embodiment of the present invention, where a luminaire with an LED bulb have a track pad to facilitate user input, and where character recognition is used to determine the parameter that a user wants to adjust;

FIGURE 6 shows an exemplary embodiment of the present invention, where a luminaire with an LED bulb have connectivity, and where applications to be executed by said luminaire may be downloaded from the internet via a number of interfaces;

FIGURE 7 shows an exemplary embodiment of the present invention, where a luminaire utilizes an LED bulb as taught by said invention, and a 100%, 50%, 0% on-cord-dimmer wheel to configure said bulb;

FIGURE 8 shows an exemplary embodiment of the present invention, where a touch sensing device is used to control a series switching element for dimming in such a manner to limit emission of electromagnetic interference;

FIGURE 9 shows an exemplary embodiment of the present invention, where the focus and direction of light being emitted by an LED bulb may be adjusted through proximity and/or touch gestures or events;

FIGURE 10 shows an exemplary embodiment of the present invention, where coloured light emission by dedicated elements are used to provide an indication of bulb burn time since the last power-on event;

FIGURE 11 shows an exemplary embodiment of the present invention, wherein an LED bulb has the ability to detect when a power failure occurred, and to provide FITD functionality and emergency lighting from an integral energy store;

FIGURE 12 shows an exemplary embodiment of the present invention, wherein an LED bulb may use associated mains wiring and switches for capacitive sensing, with said sensing used to control bulb operation;

FIGURE 13 shows an exemplary embodiment of the present invention, wherein a USB link with a smart phone may be used to configure an LED bulb, or a dedicated USB cable may be used to supply 5V to power an LED bulb via its mains contacts, allowing touch and/or proximity gesture or event based configuration;

FIGURE 14 shows an exemplary embodiment of the present invention, wherein LED bulbs are configured into a master and slaves, with the configuration of said master duplicated in its associated slaves;

FIGURE 15 shows an exemplary embodiment of the present invention, where an LED bulb contains an IR receiver, and a smart phone or universal remote may be used to configure operation of said LED bulb;

FIGURE 16 shows an exemplary embodiment of the present invention, where wall control units have connectivity to devices such as a smart phone or a tablet PC;

FIGURE 17 shows a diagram for a switch mode power supply in bucking configuration that can be used for data transfer detection;

FIGURE 18 shows signals that illustrate the effect of the data transfer action;

FIGURE 19 shows an exemplary embodiment of the present invention that allows bi-directional data transfer over the mains power lines to and from an intelligent lighting apparatus;

FIGURE 20 shows a photo diode modelled in its reversed bias condition connected to a self or surface capacitive measurement device; and

FIGURE 21 shows a LED bulb with light sensing elements configured to detect gestures.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0088] In **Figure 1**, an exemplary embodiment of the present invention is illustrated. An LED bulb is shown at **(1)**, with a transparent or semi-transparent dome portion **(3)**, a heat sink **(4)** and a base **(5)**. Said base **(5)** may typically be connected to the utility mains network (AC), with said connection which may be made via a mains switch **(6)**, used to isolate either the live wire **(7)** or the neutral wire **(8)** from said bulb, or both. According the present invention, said LED bulb may have the ability to perform capacitive sensing to implement a user interface, and use such capacitive sensing to detect user touch and/or proximity events or gestures, for example by user finger **(2)**, where said events or gestures are used to, but not limited to, configure said bulb's operational parameters, do function selection or operational mode selection. The parameters that may be adjusted via said capacitive sensing interface, according the present invention, are not limited to the following examples, but may be any one of a large number of parameters: colour of emitted light, the colour temperature of emitted light, the amount of emitted light, the duration of light emission, the period during which gradual fading of emitted light takes place or the period until the occurrence of an auto-off event.

[0089] In a typical embodiment such as that shown by **Figure 1**, the housing (4) and base **(5)** may contain a SMPS (switch mode power supply or voltage converter) to convert mains to the required voltage and current levels, and to control the amount of energy transferred. Further, in step with the disclosure of PCT/ZA2012/000082, a controller microchip for said SMPS may also contain touch sensing circuitry, said sensing based on the measurement of a change in the capacitance of electrode structures. The housing forms a heat sink **(4)**, as is well known in the art, to remove heat due to LED element and other losses, with said LED's contained within dome **(3)**.

[0090] According to the present invention, toggling of mains switch **(6)** may also be used to adjust colour temperature, in addition to the parameters listed by, and according to the manner disclosed in PCT/ZA2012/000082, which is fully incorporated into the present disclosure.

[0091] **Figure 2** shows yet another exemplary embodiment of the present invention at **(9)**, where three electrodes **(10)**, **(11)** and **(12)** in an LED bulbare used for capacitive touch and/or proximity sensing, and to facilitate the ability of said bulb to detect a specific swipe gesture by a user's finger **(2)**, and where said bulb is powered from mains **(13)**. As illustrated, electrodes **(10)**, **(11)** and **(12)** may be located on the top part of heat sink **(4)**, or lower part of dome **(3)**, which may facilitate ease of manufacturing and lower cost. However, the illustrated location is merely given as an example, and should not be construed as limiting. Said swipe gesture may be used as a minimum requirement to enter the LED bulb into an RGB adjustment mode, in which the user may adjust the colour of emitted light to be more red, green or blue. Said adjustment may be done viatouch and/or proximity events or gestures on, or in the vicinity of electrodes **(10)**, **(11)** and/or **(12)**, or with swipe gestures that utilize two

or three of said electrodes. It should be obvious that a large number of proximity, touch and/or swipe schemes or protocols to adjust colour according to the RGB scheme may be contrived that will fall within the spirit and scope of the presently disclosed invention. In addition, it is to be appreciated that any of the large number of relevant operating parameters of LED bulbs, or of other relevant lighting units, such as incandescent bulbs, or CFL bulbs, may also be adjusted, according the present invention, in a manner as described above, for example colour temperature, duration of light emission, period until an auto-off event occurs, power level, delayed switch off (i.e. stay on for a period after user switched off) and so forth. Optical sensing may also be used to detect actions or gestures (Fig 21)

[0092] At **(14)** in **Figure 3**, an exemplary embodiment of the present invention is illustrated where dedicated touch areas or buttons **(15)** and **(16)** are used on the heat sink or between the heat sink structures of an LED bulb to facilitate user input, for example via user finger **(2)**, said input used to configure the bulb's operation. Said buttons may for example also be pushbuttons or may represent a light pipe/channel as the only access for light to a light sensing element inside the housing. By pressing the pushbutton or sealing of the light pipe with a finger, the user may convey selections or commands to the controller. To place the bulb into an adjustment mode, a user may touch area **(15)**, or depress button **(15)**, whichever is relevant, for a certain period. Once said period has elapsed, the entrance into said adjustment mode may be signified to the user via flashing of the light emitted by the bulb. Hereafter, the user may for example touch area **(16)**, or depress button **(16)**, whichever is relevant, to step through the parameter values available for selection. To exit selection mode, said user may touch area **(15)**, or depress button **(15)**, whichever is relevant, for a sufficiently long period, with a flash of the light emitted by

said LED bulb signifying exit. The combination of button presses, number of buttons or sequence is not limited to a single switch or multiple switches, the concept is clear that a switch or switches may be used on the bulb to create a user interface through which configuration and settings of the bulb may be adjusted by the end user.

[0093] At **(17)** in **Figure 3**, an exemplary embodiment similar to the above for a so called GU 10 type of bulb is illustrated. In these types of bulbs, and others, the heat sink **(24)** or body **(25)** of the bulb may not be accessible to the user, due to the bulb being recessed within a flat surface, showing only a flat flange that surrounds LED's, or other lighting elements **(20)**, **(21)**, **(22)** and **(23)**. Therefore, the present invention teaches that dedicated touch areas, switches or buttons **(18)** and **(19)** may be situated in the front flange of said bulb, with exemplary operation as described above. It is to be appreciated that operational parameters that may be adjusted according the manner illustrated by **Figure 3** includes colour of emitted light, colour temperature of emitted light, the amount of emitted light, duration of light emission and the period until occurrence of an auto-off events, amongst others. The buttons may also function as light pipes for low cost LED's mounted on a Printed Circuit Board (PCB) contained by said bulb to assist with guiding the user during setup or configuration. In addition, the above referred touch areas, as illustrated in **Figure 3**, may also be used to sense proximity of a user or an engaging probe.

[0094] **Figure 4** shows yet another exemplary embodiment of the present invention at **(26)** in the form of an LED bulb with capacitive proximity and/or touch sensing electrodes **(27)**, **(28)** and **(29)** contained within dome **(3)** of said bulb, and used to detect permissible swipe gestures of a user finger **(2)**. These swipe gestures, if accepted, may be used to enter said bulb into an adjustment mode, wherein operational parameters as described earlier may be adjusted. Once in adjustment

mode, a user may use a touch and/or proximity slider electrode structure, as illustrated at **(30)** and contained by dome **(3)**, to select a particular value for a given parameter being adjusted. An advantage of using a slider for value selection may be its ability to provide a more continuous selection, and that its use may be fairly intuitive to many users. Further, according the present invention, the slider structure may be realized in a circular structure around the perimeter of dome **(3)**, as illustrated at **(32)**, with electrodes **(27)**, **(28)** and **(29)** that are used for swipe detection being located near the apex of said dome **(3)**, as shown at **(31)**. If colour is adjusted, a colour chart may be positioned on the heat sink or base of a lighting unit to assist with selection. Such an arrangement may provide an extremely intuitive selection interface for users, as a user may turn their fingers along said slider **(32)** as if turning a knob to select a particular parameter value, according the present invention. The capacitive sensing circuitry connected to slider **(32)** may also operate in a manner which does not require absolute positions on said slider, but only monitors relative motion from the positions where a user finger **(2)**, or fingers, first touch down or in the vicinity of which a first proximity gesture or event is detected.

[0095] At **(33)**, an alternative placement for said slider is illustrated, which is on the heat sink **(4)** of said LED bulb, at **(34)**, as an exemplary embodiment of the present invention. Electrodes **(27)**, **(28)** and **(29)**, used for swipe detection, have also been moved to the top part of heat sink **(4)** or lower part of the dome**(3)**, as this may facilitate ease of manufacturing, and thus lower cost.

[0096] In **Figure 5**, another exemplary embodiment of the present invention is presented at **(35)**, in the form of a luminaire or lamp with a touch or track pad **(40)** as user interface. Purely as an example, said luminaire may be a desk lamp, with a base **(38)**, an adjustable stem **(37)** and a lamp head **(36)** which may contain an LED

bulb which may be similar to those taught in the preceding disclosures. Said base **(38)** will typically be connected to the utility mains network **(43)** via a Live wire **(41)** and a Neutral wire **(42)**, and may have a SMPS to convert mains power to relevant voltage and current levels. To interface with said luminaire, a user may perform touch gestures on touch or track pad **(40)** with his/her finger **(2)**, or any other relevant appendage or probe, for example a stylus. A small display **(39)**, for example a low cost LCD display, may be incorporated into base **(38)**, with said display assisting users to visualize their input via touch or track pad **(40)**. For example, in **Figure 5**, the user traced out the letter "P" with his/her finger. This may be interpreted by the luminaire as a command to enter a mode in which said user may select a particular power level. As an example, the user may subsequently trace out a number between 1 and 5 to select a particular power level. Or the letters "h", "m" or "l" may be traced, resulting in high, mid or low power levels respectively. According the teachings of the present invention, a very large number of characters may be used to control said luminaire via said touch or track pad, with the possibility to use a first character to place said luminaire in a particular selection mode, and a second or more characters to make a selection. Alternatively, a user may use touch gestures, for example swipe up/down or left/right to control light level, or make a circular gesture to start a delayed auto-off sequence.

[0097] Another intelligent luminaire that also embodies the present invention is shown at **(44)** in **Figure 6**. Once again, as an example, this may be a desk lamp similar to that described for **Figure 5**. However, the luminaire in **Figure 6** has the ability to connect directly or indirectly to the internet **(52)**. For example, base **(45)** of said lamp may contain circuitry allowing said connection to be a wired or a wireless connection. For a direct connection to the internet **(52)**, said lamp may contain

networking circuitry allowing establishment and use of an Internet Protocol (IP) address. Indirect connections may be made via a large number of portable or fixed computing devices, for example, a tablet computer **(50)** or a smart phone **(46)**, with these connections being either wireless or wired, as illustrated in exemplary manner at **(47)** and **(51)** respectively. Said computing devices, for example smart phone **(46)** or tablet computer **(50)** may in turn connect to the internet **(52)** via any relevant method and hardware as held by the art of internet connectivity. In **Figure 6**, wireless connections **(48)** and **(49)** to the internet **(52)** is shown. According to the present invention, the purpose of said lamp's internet or other connectivity is to facilitate the download of applications by said lamp or to connect via the internet with a home or building automation system or a home alarm system. Applications may then be stored in NVM and executed. For example, different applications may provide different lighting schemes where colour changes according to elapsed time based on individual taste of users, or according to sound detected, or to the time of day, or to the date, or to the season etc. Or said applications may provide different manners of colour mixing. As noted before, the number of possible applications may be quite vast, but if they can be downloaded to a luminaire, and stored and executed by said luminaire, it falls within the teachings of the present invention.

[0098] In **Figure 7**, a luminaire embodiment, for example a desk or bed lamp, of the present invention is shown which utilizes a three state dimmer wheel **(55)** on live wire **(41)** and neutral wire **(42)** to configure operation. The three state dimmer wheel is similar to those that have been commercially available for many years, and to that described in US 4,166,236. Nominally, such dimmers allow three settings, maximum power, 50% power or off. These settings are attained, respectively, by connecting the mains directly to the load, by connecting the mains via a half wave rectifier to the

load, or not connecting the mains to the load. However, according the present invention, such a dimmer wheel may also be used in a different manner to configure the operation of said luminaire at **(53)** which is powered by mains **(43)**. A user may use said dimmer wheel **(55)** to apply 100%, 50% and 0% of mains power in a particular sequence to said luminaire. Either circuitry in base **(54)**, or a lighting unit, for example an LED bulb, similar to that described earlier in the present disclosure, and contained by lamp head **(36)**, may detect said sequence of alternate mains power levels, and interpret it as a particular command, for instance to enter a particular selection mode, whereupon subsequent sequences of 100%, 50% and 0% of mains power being applied are used to select particular values for a given operational parameter. Operational parameters may be any one from a large possible number, a few examples of which are: colour of light emitted, colour temperature of light emitted, the amount of emitted light, the duration of light emission, the period during which a gradual fading of emitted light takes place, the period until the occurrence of an auto-off event or a delayed switch off period (i.e. the lamp stays on for a period after user switched off).Said operational parameter value may then be stored in NVM, and the lamp may use it to adjust its operation, either automatically, of after dimmer wheel **(55)** is used in a particular manner, similar to that described above, to exit said selection mode and to return to normal operation. This is akin to the toggling of a mains switch described in PCT/ZA2012/000082, and referred to earlier in the present disclosure.

[0099] **Figure 8** presents a related exemplary embodiment at **(56)**. Device **(57)** is a touch and/or proximity sensitive dimming device, and may be used to control the amount of power delivered to a load, via terminals **(64)** and **(65)**, which may be a lighting load, for example an LED bulb **(66)**, or any other pertinent load, for example

an incandescent bulb, a motor, a heater element and so forth. Device **(57)** may comprise a power supply **(60)**, which may be, for example, a capacitive dropper type supply, and used to furnish power, which may be a small amount, via interconnects **(58)** and **(61)** to a controller **(62)**. Said controller **(62)** may have the ability to sense user touch and/or proximity gestures via a sense electrode structure **(63)**, and to control series switching element **(59)**, which may be a TRIAC, or other high voltage semiconductor based switches, for example MOSFET's. Device **(57)** may have the ability to accurately sense the ZC points of the AC mains voltage **(43)**, as supplied via interconnects **(41)** and **(42)**. When a relevant touch or proximity gesture (capacitive or light) is sensed, controller **(62)** may control series switching element **(59)** in such a manner that, for example, every second mains half cycle is blocked, with switching of element **(59)** occurring as close as is possible to said ZC points, to minimize electromagnetic interference generation. Such blocking of mains half cycles may result in LED bulb **(66)** only emitting 50% of nominal light. Further, according the present invention, device **(57)** may be instructed by a user via touch and/or proximity events or gestures on or near sensing electrode structure **(63)** to go into an ultra-low power FITD mode, wherein series switching element **(59)** only allows the first or last few per cent of a mains half cycle to be applied to said LED bulb **(66)**, resulting in it being dimly lit, thus performing a FITD function. In such a FITD mode, due to the low value at which said AC mains voltage is being switched, generation of electromagnetic interference should be limited, according to the present invention. Such a FITD mode may also be realized with an incandescent bulb as load, although the voltage and current levels required may be different. The present invention teaches that device **(57)** may have the ability to discern between incandescent and LED bulbs, for example through current versus time and voltage measurements, and adjust said control of series switching element **(59)** accordingly. This may allow a

user to used touch sensitive dimming device **(57)** with either bulb type. Essentially all switching needs to be close to the zero cross point to prevent electromagnetic noise generation. Blocking of two half cycles will remove a full AC power cycle with the advantage of a balanced load on the mains.

[00100] Device **(57)** of **Figure 8** may also be able to send commands over the power line in the form of a string of data bits in accordance with the teachings referencing **Figure 17** and **18**, or receive data in accordance with the teachings referencing **Figure 19**. Device **(57)** may be programmed to work as a normal touch user interface with any CFL, LED or incandescent type bulb designed for direct use with mains (AC) but when used with a LED bulb featuring an intelligent interface according to the teachings of this specification, it may enable the user to transfer commands such as low power, setting output levels, delayed off commands, auto off activation, colour temperature adjustment, calibration information, bulb colour, night light functions and many more. The unit may be provided with power-in sockets or lines and power-out sockets or lines in order to fit it between a normal lamp power cable and a main power socket or line. This may allow touch and other intelligent UI functions to be retrofitted to any standard lamp or product. The smart bulb and the interface unit **(57)** may also exchange data using light sensing with the bulb switching on/off to present a string of data. The off periods may be only a fraction of the AC cycle. See figure 20.

[00101] **Figure 9** shows yet another exemplary embodiment of the present invention. Capacitive sensing electrodes **(70)**, **(71)** and **(72)** are located on the dome of an LED bulb, said bulb being powered from AC mains **(43)**. A user may interface with said LED bulb by performing touch and/or proximity gestures on or in the vicinity of said electrodes, for example with a finger **(2)**. Such interfacing may allow the user to adjust the focus or angle of light being emitted by said bulb. This is done by

selectively powering LED's **(73)** contained by said bulb, with said selective powering depending on the location of user interaction. For example, in a nominal mode, shown at **(66)**, all LED's within said bulb are powered, and light is emitted in as wide a beam as possible. However, if a user performs a touch and/or proximity gesture near the top of said bulb, on or in the vicinity of electrode **(71)**, as shown at **(67)**, this may result in the selective powering of only those LED's **(73)** which are near the centre of a LED array in said bulb, with the emitted light beam becoming more focussed, as illustrated at **(67)**. The present invention also teaches that the amount of power delivered to each LED may be increased as less LED's in said array are powered, to ensure that the perceived emitted light do not decrease significantly as the beam becomes more focussed, for example. Naturally, the amount of power increase possible will be limited by the abilities each LED, the power capability of the SMPS contained, for example, in base **(5)** and the amount of heat transfer possible with heat sink **(4)**. At **(68)** and **(69)** respectively, the adjustment of said LED bulb light beam to the left of right of said bulb through user interaction with capacitive sensing electrodes **(70)** or **(72)** is shown. It is to be appreciated that, according to the present invention, it may be possible to place capacitive sensing electrodes right around the 360° circumference of said LED bulb, allowing the user to adjust said bulbs light beam to be emitted from any point on said circumference.

[00102]According to the present invention, it may also be possible to provide visual feedback on elapsed burn time since the last power-on event to a user through the use of coloured light emission. This may assist users in their efforts to conserve electrical energy consumption by raising awareness and providing an indication of the period that a particular light has been left on. Said coloured light emission may be achieved through the use of dedicated low power, low cost LED's or through the

inclusion of the ability to emit coloured light into the normal high power light emitting devices used by an AC mains or DC powered self-contained lighting unit, for example the LED's of an LED bulb. An exemplary embodiment of this is shown at **(74)** in **Figure 10**. Colour LED **(75)**, which may be low power and low cost, is mounted on heat sink **(4)** of an LED bulb, said bulb powered from AC mains **(43)**, and wherein **(75)** emits a beam of coloured light **(78)**, wherein said beam have different colours to indicate the elapsed burn time since the last power-on event. For example, if the bulb has burned for half an hour, this may be green, if it burned for an hour, LED **(75)** may turn yellow, for two hours it may turn orange and for more than five hours it may turn red. Further, said LED **(75)** need not be continually powered, but may be activated by a touch and/or proximity event or gesture from a user. In addition, the main lighting elements of said LED bulb may be dimmed to a specific level, which may be any level down to a zero percentage of nominal light emission, to allow a user to view the emission of LED **(75)** after said event or gesture. Naturally, the placement of a low power, low cost colour LED need not be constrained to the heat sink **(4)** of said LED bulb, but may be in any suitable location. For example, said LED may also be placed on the base **(5)** of said LED bulb, as is shown at **(76)**, and emit a beam of indicative coloured light **(77)**. Further, said indicative coloured light may also be emitted through dome **(3)** of said LED bulb, either originating from dedicated low cost, low power LED's, or from the nominal high power light emitting devices, as disclosed earlier.

[00103]At **(79)** in **Figure 11**, another exemplary embodiment of the present invention is illustrated. An LED bulb, purely as an example of a self-contained lighting unit, has the ability to recognise the difference between a power failure in the mains network **(43)** and normal removal of power through the opening of an associated switch **(85)**.

Once a power failure has been detected, said bulb may use energy in a store contained by base **(86)**, for example a battery such as Lithium-Ion, Lithium Polymer or Nickel Metal Hydride battery, to provide emergency lighting, or a FITD function. It may also activate capacitive sensing circuitry to enable a user to perform a touch and/or proximity event or gesture on or in the vicinity of a capacitive sensing electrode **(87)**, said event or gesture which may then be used to qualify the activation/deactivation of said emergency lighting, with the latter nominally being at a low level to conserve energy stored in said store, but wherein said user may increase said level though interaction with said capacitive sensing electrode. Further, said LED bulb may also contain an ambient light sensor, for example in its base **(86)**, and only activate said FITD function or emergency lighting if ambient light is at a low enough level. According to the present invention, the ability of said LED bulb to recognise the mentioned difference between a mains power failure and a normal opening of switch **(85)** may be based on its ability to recognise a signature of said switch opening event. For example, a switching waveform between two levels **(80)** and **(81)** over a time period, measured along axis **(82)** is illustrated. Due to inherent characteristics of said switch **(85)**, this waveform will have unique features, for example spikes, oscillatory periods and specific slopes, which may be present every time said switch is opened, i.e. a signature. If said LED bulb monitors the voltage on lines **(83)** and **(84)**, and captures and stores this signature, it may use it to discern between a power failure, when said signature will not be present, and the normal opening of switch **(85)**, when it will be.

[00104] Further, according to the teachings of the present invention, said activation of a FITD function or emergency lighting need not only be based on above disclosed switch signature recognition. An alternative, exemplary embodiment is also shown in

Figure 11. A monitor **(91)** may be realised which monitors mains network **(43)**, either continuously or after specific time intervals, and wherein said monitor also contains an RF-transmitter and antenna **(89)**, with the complimentary receiver and antenna **(90)** contained by an LED bulb, said bulb having an energy store, FITD functionality and capacitive sensing ability, as disclosed before. Said mains monitor **(91)** also contains one or other energy store. Once a power failure occurs on mains network **(43)**, monitor **(91)** may detect it, and transmit a first specific signal to said LED bulb indicating such, using energy from its store. Upon receiving and validating said first specific signal, said LED bulb may activate its FITD functionality, or emergency lighting and/or activate capacitive sensing circuitry, allowing a user to control emergency lighting via interfacing with capacitive sensing electrode **(87)**, as disclosed before. When power is restored to mains network **(43)**, monitor **(91)** may detect this, and transmit a second specific signal to said LED bulb indicating such, which may allow said LED bulb to deactivate its FITD functionality, emergency lighting and/or capacitive sensing circuitry, thus conserving energy stored in said store. The latter is important when the switch connected to said LED bulb is in an open state, implying that the bulb cannot sense on its own when power is restored. Further, it is to be understood that a mains monitor as disclosed need not be constrained to communication with only one self-contained lighting unit, for example an LED bulb, but may communicate the occurrence of a power failure, or power restoration, to a large number of lighting units, and communication need not be one way, that is said monitor and lighting units may have complimentary transceivers, allowing full duplex communication. In other words, a mains monitor as disclosed and a number of lighting units, for example LED bulbs, may form a local communication network. In addition, said mains monitor **(91)** or the base of said LED bulb **(88)** may contain an ambient light sensor. In the case of the ambient light sensor being located

in mains monitor **(91)**, it may use the level of ambient light as a qualifier to decide whether or not said first or second specific signals need to be transmitted to said LED bulb or bulbs. Alternatively, it may transmit the ambient light level to said LED bulb or bulbs, allowing them to use the information as a qualifier to determine whether FITD functionality, emergency lighting and capacitive sensing circuitry should be activated/deactivated. In the case where said ambient lighting sensor is located in said LED bulb, or bulbs, the measured ambient light level may be used in a similar way. However, this case has the advantage that lighting units contained within dark areas, for instance an inner corridor of a house, may activate emergency lighting, and units in lighter areas, for instance close to a window where moonlight shines in, will not necessarily activate emergency lighting, thus not expending stored energy unnecessarily.

[00105] In **Figure 12**, another exemplary embodiment of the present invention is presented at **(93)**. An LED bulb may have the ability to use the normal mains wiring as capacitive sensing electrodes, with capacitive sensing circuitry contained in bulb base **(99)**, for example. For example, a user may use a traditional wall switch **(96)** to apply power from mains network **(43)** to said LED bulb via Live **(97)** and Neutral **(98)** wires. Once said bulb is powered, it may use said capacitive sensing ability via mains wires to detect user touch and/or proximity events or gestures, for example on or in the vicinity of the wall plate of said switch **(96)**. A user may use said events or gestures to control a number of operational parameters of said LED bulb, for example light level, colour of light emitted, colour temperature of light emitted, duration of light emissions, auto-off events, delayed-off events and so forth. Said capacitive sensing by said LED bulb may be based on changes in self-capacitance of a particular wire, for example that of the live wire to earth, illustrated by **(95)** and **(94)**,

or on the change in mutual capacitance between said Live **(97)** wire and said Neutral **(98)** wire.

[00106] The present invention teaches that the configuration of self-contained lighting units, as disclosed, for example LED bulbs, need not require a high voltage supply such as AC mains. For example, in **Figure 13**, an LED bulb **(101)** is illustrated at **(100)**, wherein said bulb has a USB connector **(107)** in its base **(108)**, as well as the ability to receive and use USB signals. This may allow a user, for example, to plug said LED bulb **(101)** into the USB connector **(106)** of his/her smart phone **(105)**, as an exemplary device, via USB cable **(104)**. It is to be appreciated that the USB connector on said LED bulb need not be located in its base **(108)**, but may be in any advantageous or required location, for example in heat sink **(4)**. Said user may then use an application running on said smart phone **(105)** or the capacitive sensing interface of said bulb **(101)** to configure the operation of said bulb, said operational parameters thus selected stored in NVM, and applied when said bulb **(101)** is inserted into a mains socket where mains power is applied to contacts **(102)** and **(103)**.

[00107] In an alternative exemplary embodiment, illustrated at **(109)**, a self-contained lighting unit **(110)**, in this case an LED bulb, has its mains terminals **(112)** and **(114)** directly connected to the +5V and ground lines of a USB port **(117)** of a tablet PC, the latter being solely used as exemplary device, via a dedicated USB cable **(116)**. Said dedicated cable has a normal USB connector on one side, and a special connector **(115)** on the other, said special connector allowing application of the USB +5V and ground signals to the mains terminals of said LED bulb **(110)**. In other words, according the present invention, said LED bulb **(110)** does not contain a dedicated USB connector, but is connected via a special cable **(116)** to a USB port,

with said port furnishing power to said LED bulb. In a typical embodiment, the 5V DC of the USB port will be applied to the rectifying bridge of the SMPS contained by said LED bulb. This will cause some voltage drop, which may result in a voltage such as 3.6V DC being present on the high voltage DC bus of said SMPS. The controller of said SMPS may be configured such that it will utilize such a low DC voltage on the high voltage DC bus to power itself sufficiently to monitor the period during which said low DC voltage is present. If sufficiently long, it may deem this as an indication that a user has connected said bulb to a USB port, and switch in an alternative voltage regulation structure, which may be used to power the capacitive sensing circuitry of said LED bulb, and user feedback circuitry, allowing a user to configure said LED bulb, or other lighting unit, via the capacitive sensing interface, similar to that disclosed earlier.

[00108] In **Figure 14** , another exemplary embodiment of the present invention is presented at **(119)**, where self-contained lighting units, in this case LED bulbs powered from AC mains, are configured into a master **(120)** and slaves **(121)**, **(122)** and **(123)**, and wherein a setting on the master is replicated on said slaves, said setting communicated via communication channels **(124)**, **(125)** and **(126)**, which may use any of the myriad of communication technologies available, for example RF, IR, PLC and so forth. As an example, a user may adjust an operational parameter of master **(120)**, such as the colour temperature of the light being emitted, by performing a touch and/or proximity gesture with finger **(2)**. Master **(120)** may then, either immediately or upon a user command, communicate this setting to all its associated slaves, in this case slaves **(121)**, **(122)** and **(123)**. It is envisaged that a user may use such an embodiment to dim all the lights in a house, for example, to

the same level, for instance after receiving a utility alert that the grid is under pressure, and consumption needs to be reduced.

[00109] Another exemplary embodiment of the present invention which may enable a user to directly configure a self-contained lighting unit, in this case an AC mains powered LED bulb **(128)**, is presented at **(127)** in **Figure 15**. Said bulb contains an IR receiver **(129)**, allowing a user to adjust its operational parameters, as listed and discussed before during the present disclosure, through the use of devices which can transmit relevant IR signals **(130)** and **(134)**, for example a smart phone **(132)** or a universal remote **(133)** respectively. If a smart phone does not have IR transmission capability, an adaptor **(131)** may be utilized, wherein said adaptor plugs into the audio-out port of said phone, for example, and converts audio-out signals into the required IR signals. In this case, an application may be running on said phone which allows a user to select and adjust said bulb operational parameters, and wherein said application then routes data reflecting such selection and adjustment to said audio-out port in a relevant format for reception by adaptor **(131)**. Alternatively, a universal remote **(133)** may be used to adjust the operation of said LED bulb **(128)**, according the present invention. Said remote may be set up in such a manner that LED bulbs may be controlled without interference to other devices also controlled by the remote, and vice versa, as is common with universal remotes. This would require said LED bulb **(128)** to incorporate the necessary firmware required to decode universal remote messages, to avoid unintended control of said bulb. In both cases, that is the use of a smart phone or use of a universal remote, feedback may be provided to said user during lighting unit configuration via visible indicators, such as flashing of emitted light, or via audible indication, for example via a buzzer contained by said LED bulb **(128)**.

[00110] The implementation in Figure **15** may be combined with the implementation of **Figure 21** in that multiple light sensors are used to detect changes in light levels. In an embodiment of an intelligent light the use of two (or more) sensors with a non-overlapping detection area (as per **Figure 21**) can be used to interface with a smart phone. An app (application running on a smart phone or tablet) may be used to program the intelligent smart bulb through the use of visual patterns executing on the screen. For example a sequence of bright and dark lines going back and forth may be used to avoid unintentional programming or calibration. Further metrics may be the direction of movement, the periods between changes in light, the level of light in the sections. This is almost like a bar code where the scanner sensing is now stationary and the bar code is moved back and possibly forth in front of the scanning device. Any of the programmable parameters can be controlled from the outside with your mobile phone, table or computer screen.

[00111] The app discussed above is ideal for configuring the bulbs for a building or home automation system. The setup can be planned on for example a tablet computer, and then a node can be identified in the system and by having the tablet now configure the bulb installed in that position any bulb can easily be paired with the home automation system. This will enable a very simple operation and implementation even though based on a very powerful app and control system. The tablet is now linked to the specific bulb through an address/handle or id with the control system that may be very simple such as an in-line dimmer, which in turn is linked to the internet. A control program running on a computer somewhere, now has control access to the bulb that was paired. The bulb may also be fitted with Wi-Fi, BT, Zigbee or other communication protocols and, once identified like this in a graphical user interface, to make it easier for a non-professional installer (home

owner, house wife) it is linked into the home control system. As an example, the new bulb may be installed in a study. The user will then touch the light identified in the app as the study lamp and indicate configuration. Next the pairing is done. The bulb is thereby correctly brought into the system.

[00112] Figure 16 presents an exemplary embodiment of the present invention which is closely related to the teachings of PCT/ZA2012/000082, the latter being entirely incorporated into the present disclosure. In PCT/ZA2012/000082, a wall control unit for lighting units, for example LED bulbs, is taught, wherein said control unit have a touch/proximity sensing interface, a series switching element and mains ZC detection ability. User commands, entered via said interface, are transmitted to said lighting units by specific omission of mains half cycles or full cycles, which is realised through the opening or closure of said series switching element, with each opening or closing event centred on a mains ZC event. In the embodiment of **Figure 16**, said wall control units **(138)** and **(148)** have connectivity which may allow them to connect to exemplary devices such as a smart phone **(135)** or a tablet PC **(136)**. Said connectivity may be either wired, for example via a USB cable **(137)** that connects to said tablet PC's USB port **(138)**, or wireless, as illustrated by radio waves **(139)** to **(142)** and **(144)**. If wireless connectivity is used by exemplary wall control units of the present invention, any of the myriad of wireless protocols and methods, some of which are listed by the summary of the present disclosure, may be employed. Further, as illustrated by **Figure 16**, said wireless connectivity of said wall control units may be facilitated by antennas **(143)** and **(147)**, and by RF-modules **(145)** and **(146)**, wherein said modules may be an integral part of the wall unit, or a plug-and-play type module, for example which may be simply inserted into a USB port on said wall control unit to realize said wireless connectivity. Exemplary operation of the

network presented in **Figure 16**, said network consisting of smart phone **(135)**, tablet PC **(136)**, wall control unit **(138)**, wall control unit **(148)** and LED bulbs **(150)**, **(151)** and **(152)** are envisaged as follows, according the present invention. A user may plug his/her tablet **(136)** into wall control unit **(138)** via a USB cable **(137)**, and instruct LED bulbs **(151)** and **(152)** to switch on, dim to 50 % of maximum light emission, and change the colour temperature of emitted light to a preferred level. Said instructions are relayed to said LED bulbs via the opening and closing of wall control unit's **(138)** series switching element, performed at mains ZC, to inhibit/allow current flow in wire **(153)**, which is designated as Live-out-1. This may be followed by another user that wants to control all three LED bulbs from his/her smart phone **(135)**. This may be facilitated, according the present invention by said phone connecting wirelessly to either both wall control units **(138)** and **(148)**, or to just one, for example wall control unit **(138)**. In the latter case, wall control unit **(138)** may relay messages from smart phone **(135)** to wall control unit **(148)**. A user may then, for example, instruct all three LED bulbs to switch off within half an hour, with said instruction relayed to LED bulbs **(151)** and **(152)** by wall control unit **(138)**, and relayed to LED bulb **(150)** by wall control unit **(148)**. It should be appreciated that, for example, only the Live-out wire needs to be connected between a particular LED bulb and wall unit, with Neutral shared amongst all connected LED bulbs and wall units, to facilitate both the application of mains power to said LED bulbs, and communication of messages through the disclosed omission of mains cycles or half cycles. This may reduce wiring complexity. Naturally, both a Live-in and Neutral wire needs to be connected to a particular wall unit to supply power for its operation. The operation and functions discussed here with regards to **Figure 16** are closely tied to the disclosures linked to **Figures 20 and 21** wherein a bulb is given an address in terms of where it fits into the system. A number of bulbs may for example be

identified to be activated by scene 1, and only those will react when the scene 1 command is sent.

[00113] In **Figure 17**, yet another exemplary embodiment of the present invention is depicted at **(158)**, wherein data for the control of an LED lighting load **(164)** is modulated onto the mains wiring. According to the teachings of the present invention, mains AC power source **(159)** may be modulated in such a manner by a user interface device **(160)**, said device **(160)** being under user control, and wherein a controller **(169)** for a SMPS can detect said modulation after a rectifying diode bridge **(161)**. In the exemplary embodiment shown, a buck or step-down topology SMPS is used to control the power delivered to LED load **(164)**. This is purely an example used to disclose the present invention more clearly, and any relevant SMPS topology may be used instead. In the buck topology shown, a controller **(169)** monitors the mains rectified voltage at point **(168)**, as well as a signal I_sense, and uses this information to control the current through LED **(164)**, and therefore the power transferred, through variation in the gating signal V_gate applied to switch **(165)**, in this case a MOSFET. When V_gate is at a certain level, switch **(165)** is turned on, and the rectified mains voltage is applied to the series combination of inductor **(163)**, LED **(164)**, switch **(165)**, and sensing resistor **(166)**. This results in current through LED **(164)** steadily increasing, with the ramp rate determined mainly by the value of inductor **(163)**. As current through LED **(164)** and sensing resistor **(166)** increases, the voltage measured by controller **(169)** for I_sense increases accordingly. Once the voltage for I_sense reaches a predetermined trip point, controller **(169)** changes gating signal V_gate in such a manner that switch **(165)** opens. As a result, and due to the inductor **(163)**, current through LED **(164)** and inductor **(163)** commutates to free-wheeling diode **(162)**, thereafter flowing in the loop consisting of **(162)**, **(163)**

and **(164)** and gradually decreasing, with the decline rate determined by the equivalent series resistance in said loop. After a predetermined period, controller **(169)** reactivates switch **(165)**, with the above sequence repeating.

[00114] From the above, it is clear that controller **(169)** can determine when current through sense resistor **(166)**is expected to increase sufficiently to reach said trip level for I_sense, based on the level of the rectified mains voltage measured at **(168)**, or the determination of mains zero-crossing (ZC) points and the use thereof as a time reference. That is, if the rectified mains voltage is above a certain level, or a specific period has elapsed since the last ZC event, controller **(169)** expects I_sense to reach said trip level within a specific period once switch **(165)** has been closed (i.e. conducting). According to the present invention, this information may be used to transfer data from a user interface device **(160)** to controller **(169)** via the power lines connecting power source **(159)**, user interface device **(160)** and rectifying bridge **(161)**, wherein said data is used to control operational parameters of LED lighting load **(164)**, for example the intensity, colour, colour temperature or duration of emitted light.

[00115] To elaborate on the above, reference is made to **Figure 18**. At **(170)**, typical waveforms for the circuit shown in **Figure 17** is presented. It should be noted that the waveforms are of a qualitative nature, and not quantitative, with both time and amplitude axis not too scale. At **(171)**, a typical mains AC waveform for source **(159)** is depicted. If user interface device **(160)** allows this waveform to pass without significant impediment, and it is rectified by diode bridge **(161)**, the waveform applied between reference point **(167)** and **(168)** will typically be as depicted at **(172)**, with a single maximum point in each of the mains half cycles **(176)**, **(177)**, **(178)**, **(179)** and **(180)**. However, if user interface device **(160)** is used to block part of the mains half

cycle voltage, a resultant waveform at **(168)** after bridge **(161)** may be as depicted at **(173)**, with said blocking effected during half cycles **(176)**, **(178)** and **(179)**.The blocking of mains voltage may be facilitated by device **(160)** through the opening of a series switching element, for example. During periods when the mains voltage is blocked, little or no voltage is applied to the series combination of inductor **(163)**, LED **(164)**, switch **(165)** and sense resistor **(166)**, as is evident from the waveform depicted at **(173)**. Consequently, when switch **(165)** is closed, the monitored signal I_sense will not reach said predetermined trip level. This is evident from the waveform presented at **(174)**, with said waveform depicting the envelope of the signal obtained from the trip status of I_sense. In other words, if the envelope at **(174)** is high, I_sense exceeds said trip level, and if it is low, I_sense is below said trip level.

[00116] According to the present invention, the fact that I_sense stays below said trip level when it is expected to reach it, within a certain mains half cycle, may be used to communicate a digital zero to controller **(169)**. Conversely, if I_sense reaches said trip level as expected within a certain mains half-cycle, this may be used to communicate a digital one to controller **(169)**. This is depicted in exemplary manner at **(175)**. For instance, during period **(182)**, the rectified mains voltage is sufficiently high, and I_sense is at or above said trip level, as is evident from the envelope waveform at **(174)**. However, during period **(183)**, user interface device **(160)** block the mains voltage, resulting in I_sense not reaching said trip level. Once device **(160)** allows mains voltage to pass again, I_sense reaches said trip level again, until a ZC point is approached, with said mains voltage falling below a level which allows I_sense to rise to the trip level, as is depicted in period **(184)**. If device **(160)** allows mains voltage to pass with little or no impediment for a complete mains half cycle,

I_sense should reach said trip level as expected, depicted by the envelope in period **(185)**. To clarify, the present invention therefore teaches that the absence of an event where I_sense did not reach a predetermined trip level when it was expected to, said expectation based on mains voltage level or timing information, within a mains half cycle may be interpreted by controller **(169)** as a data bit with value zero, where said data is used for user control of the operational parameters for LED load **(164)**. Conversely, if I_sense reaches said trip level as expected during a mains half cycle, this may interpreted as a data bit with value one by controller **(169)**.

[00117] Furthermore, the present invention teaches that the above disclosed method and means to communicate control data between a user interface device **(160)** and a SMPS controller **(169)** need not be constrained to a single mains voltage blocking event, or the lack thereof, per mains half cycle. Therefore, a large amount of data may be communicated in the disclosed manner, with the only limits being the nominal switching frequency of the SMPS, and the point where the number or repetition rate of mains blocking events by device **(160)** starts to affect the quality of light emitted by LED **(164)** sufficiently as to be unacceptable to users. In this regard, the present invention teaches that more power may be applied to LED **(164)** directly after a mains blocking event, to compensate for the period during which emitted light may have decreased discernibly.

[00118] In addition, the present invention also teaches that sequences of mains voltage blocking events by user interface **(160)** may be used to convey a digital one or zero. In other words, controller **(169)** will only interpret a specific sequence of events where I_sense did not reach said trip level as expected, or the lack thereof, as a digital one or zero.

[00119] According to the present invention, the above disclosed data transfer technique may also be used to transfer calibration data from a calibration controller to controller **(169)** via the power lines, wherein said calibration controller measures operational parameters of an LED bulb, for example, during manufacture, and utilizes this information to calibrate said bulbs operation.

[00120] In **Figure 19**, an exemplary embodiment of the present invention is shown which allows bi-directional data transfer between an intelligent lighting apparatus **(196)**, for example an LED bulb, and another device **(188)**, said data transfer occurring via AC mains power lines **(194)** and **(195)**. Device **(188)** may be a User Interface Unit (UIU), for example a wall control unit which replaces a traditional wall light switch, or it may be a calibration unit used during manufacture of said intelligent lighting apparatus **(196)**. As is evident from **Figure 19**, power is supplied to intelligent lighting apparatus **(196)** from an AC mains source **(187)** via power lines **(192)**, **(193)**, **(194)** and **(195)**. Similar to that disclosed earlier, switch **(197)** may be used by a device **(189)** within device **(188)** to modulate data onto power lines **(194)** and **(195)**, allowing controller **(191)** in intelligent lighting apparatus **(196)**, for example an LED bulb, to receive said data. Device **(189)** may be, for example, a microprocessor or controller.

[00121] In intelligent lighting apparatus **(196)**, for example an LED bulb, an additional resistive load **(203)** is located which may be used to ensure compatibility between said lighting apparatus and a traditional two-wire dimmer, as expounded on during the preceding summary of the present invention. Such an additional resistive load **(203)** may be used to transfer data from intelligent lighting apparatus **(196)** to device **(188)** via power lines **(194)** and **(195)**, according to the present invention. In the example shown, this data transfer may be achieved by the selective opening and

closure of switch **(202)** by controller **(191)**. When switch **(202)** is closed, power is drawn by additional resistive load **(203)** from power supply **(190)** via internal power lines **(204)** and **(206)**. As such, the amount of current flowing in power lines **(194)** and **(195)** between device **(188)** and intelligent lighting apparatus **(196)** should increase accordingly. When controller **(191)** instructs switch **(202)** to open, this increase in line current should fall away abruptly. By monitoring line current, for example as shown at **(198)**, device **(189)**, and therefore device **(188)** may note these abrupt line current changes, and demodulate data which have been modulated by controller **(191)**, and therefore by intelligent lighting apparatus **(196)**, through the control of switch **(202)** onto power lines **(194)** and **(195)**. It should be clarified that said additional resistive load **(203)** need not necessarily be powered from a dedicated power line **(206)** out of power supply **(190)**. For example, it may also be powered from the same internal power line **(205)** that powers controller **(191)**, or it may be powered from a higher voltage bus **(199)** that is used to power light emitting element **(200)**, in this example an LED. The control of switch **(203)** may also be distinct from, or synchronised with, the control of switch **(201)**, the latter used by controller **(191)** to vary the amount of light emitted by apparatus **(196)**. Further, additional resistive load **(203)** need not be powered from a power supply **(190)**, for example an AC to DC converter, but may be placed directly across AC mains power lines **(194)** and **(195)**, according the present invention.

[00122] In **Figure 20** a simplified model for a photo diode **(201)** is shown in a simple circuit connected to a typical charge transfer capacitive measurement circuit. The photo diode has a capacitance **(202)** across the pn junction and a variable resistor **(203)** can be modelled in parallel with the capacitance **(202)**. The capacitance **(202)** can also be supplemented with a discrete capacitance component **(204)** on the

circuit design if a higher C is required for purpose of reducing influence from parasitic capacitance or noise. When no light falls onto the photo diode the resistance **(203)** is very high. This means that the capacitance measurement circuit measures a high capacitance value. However, if light falls on the photo diode the resistance **(203)** becomes less. In effect the charge that is in place on capacitors **(203, 204)** then leaks away to ground through the resistance **(204)**. The more light the lower the resistance **(204)** and the bigger the change in measured capacitance compared to when no light is present. The capacitive measurement circuit for doing the ambient light measurement may be for example the Azoteq IQS127 integrated circuit operating in self capacitance measurement mode.

[00123] In one embodiment the same controller that performs the ambient light measurement also controls the LED power (light output) level and this information is used to implement an algorithm to accurately determine the corresponding light levels when the light bulb is on and when the light bulb is off or in between. Of specific importance is to measure the ambient light in the valleys in applications where there is substantial ripple in the light output due to the ac power cycle in order to minimize the effect of the bulb's own generated light on the ambient light reading.

[00124] Due to the fast response time of the light sensor this facility may also be used to detect user gestures in the bulb when a user affects the light falling on the bulb (shadow effect).Multiple directional ambient light sensors may be used to determine positional information in a gesture application. In **Figure 21** the top end of an LED bulb **(211)** is shown with a heat sink substrate upon which LED's **(213)** are mounted as well as photo diodes **(212)**. There is a transparent cover **(214)** for light emissions as well as for ambient light to reach the photo diodes. The photo diodes may for example be covered with a material that does not let light through apart from

light passing through channels/light pipes **(215)** through which directional light falls onto the photo diodes. This gives directionality to the light sensors and allows for gestures by hand or for using a smart phone **(221)** or tablet running an app to transfer data to the bulb or between the bulb **(211)** and the phone **(221)**. A single optical sensor can be used and a flashing sequence on either side may be used to transfer the data. A sequence of bright sections **(216, 218, 220)** and dark sections **(217, 219)** may be used to mimic a gesture or bar code effect. In this way a bulb may identify and link itself with a control system, or the bulb may be programmed with an address to be identified. For security or robustness, the sequence may be required to move in both directions.

[00125] An optical sensor is also useful to implement other functions such as auto activation as a night light function and to save power by de-activating in daytime. It is also very practical for implementing Lumen maintenance functionality. During manufacturing the Lumen output of the bulb can be measured through the reflected light and a reference can be established. The light output can then be controlled over time to keep at this level by higher power when the light output from the LED's deteriorate. This avoid implementing a specific Lumen maintenance curve or algorithm for different LED's and will of course be more accurate since it reacts to the real and true light output of the LED's. It is not subject to manufacturing differences between LED's or the fact that one bulb may be in a generally much hotter environment than another. And it will not require accurate projections of Lumen lifetime from different manufacturers.

[00126] The light sensor can also be used to measure the light in the valleys (near the zero cross) and compare it with the light output at the peak. The difference may be used as a metric for Lumen maintenance implementation. The contribution from

other light sources at the peak can also be taken into account by measuring light with the optical sensor at the peak position of the AC cycle but without activating the LED's during the measurement period.

CLAIMS

1. An LED light bulb comprising LED's as a light source and an integrated circuit controller for a switch mode power supply to convert AC mains to a DC voltage for driving a configuration of LED's within their specified ratings, wherein the integrated circuit controller is configured to recognize commands and data sent to the light bulb implemented using at least one technology selected from the group comprising:
   a. on/off modulation on a power line,
   b. optical sensing of patterns on a smart phone, tablet or other computer screen.

2. An LED light bulb comprising LED's as a light source and an integrated circuit controller for switching in a configuration of the LED's according to an AC voltage to operate the LED's within their specified ratings, wherein the integrated circuit controller is configured to recognize commands and data sent to the light bulb implemented using at least one of the technologies selected from the group comprising
   a. on/off modulation on a power line,
   b. optical sensing of patterns on a smart phone, tablet or other computer screen.

3. The LED bulb of claim 1 or 2 wherein an optical sensor is also employed to implement a lumen maintenance algorithm.

4. The LED bulb of claim 1 or 2 wherein the bulb transfers data to another device using a flashing sequence.

5. The LED bulb of claim 1 or 2 wherein at least two optical sensors are required for optical data communication.

6. The LED bulb of claim 1 or 2 wherein a sequence of bright and dark lines scrolling across a screen is used in optical data transfer to the bulb and wherein data is embedded in at least some of the parameters in a group of parameters comprising a. scrolling tempo, distance/time between lines, width of lines, direction of scrolling, number of lines.

7. The LED bulb of claim 1 or 2 wherein a device transferring a data to the bulb is part of a graphical user interface for a home or building automation system and is specifically involved with linking the specific bulb being programmed with a node in the graphical user interface.

8. The LED bulb of claim 1 or 2 wherein an optical sensor measurement is made using a charge transfer implementation.

9. The LED bulb of claim 1 or 2 wherein leading and trailing edge dimmer compatibility is implemented such that if no such dimmer is connected in line with the bulb, no power is wasted for compatibility purposes.

10. The LED bulb of claim 1 or 2 wherein an alarm is configured to activate a bulb with a command when motion is sensed in a particular area.

11. The LED bulb of claim 10 wherein addressing between the alarm and the bulb is established using an optical sensor and patterns on a smart phone or tablet screen.

12. The LED bulb of claim 1 or 2 wherein the color temperature of the light is adjusted using a capacitive touch sensing interface on the bulb.

13. The LED bulb of claim 1 or 2 wherein the LED's include RGB LED's and the colour is adjusted using a capacitive touch sensing interface on the bulb or optical data transfer.

14. A light bulb which includes LED's and an integrated circuit controller which, in response to commands and data, operates the LED's within their respective ratings, wherein the commands and data are input by modulating a power line, by proximity or touch events, or by sensing patterns on a display.

FIG. 1

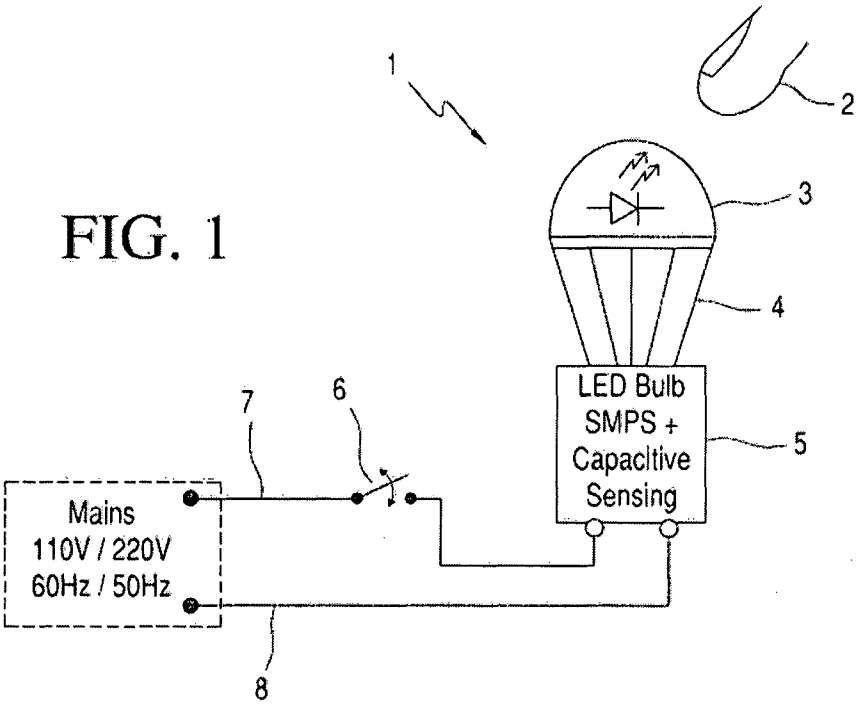
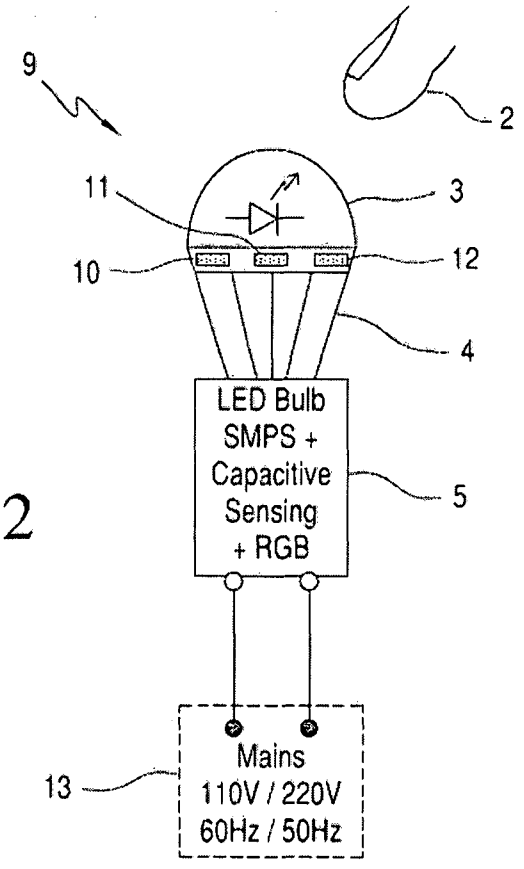

1
2
3
4
LED Bulb
SMPS +
Capacitive
Sensing
5
6
7
Mains
110V / 220V
60Hz / 50Hz
8

FIG. 2


9
2
11
3
10
12
4
LED Bulb
SMPS +
Capacitive
Sensing
+ RGB
5
13
Mains
110V / 220V
60Hz / 50Hz

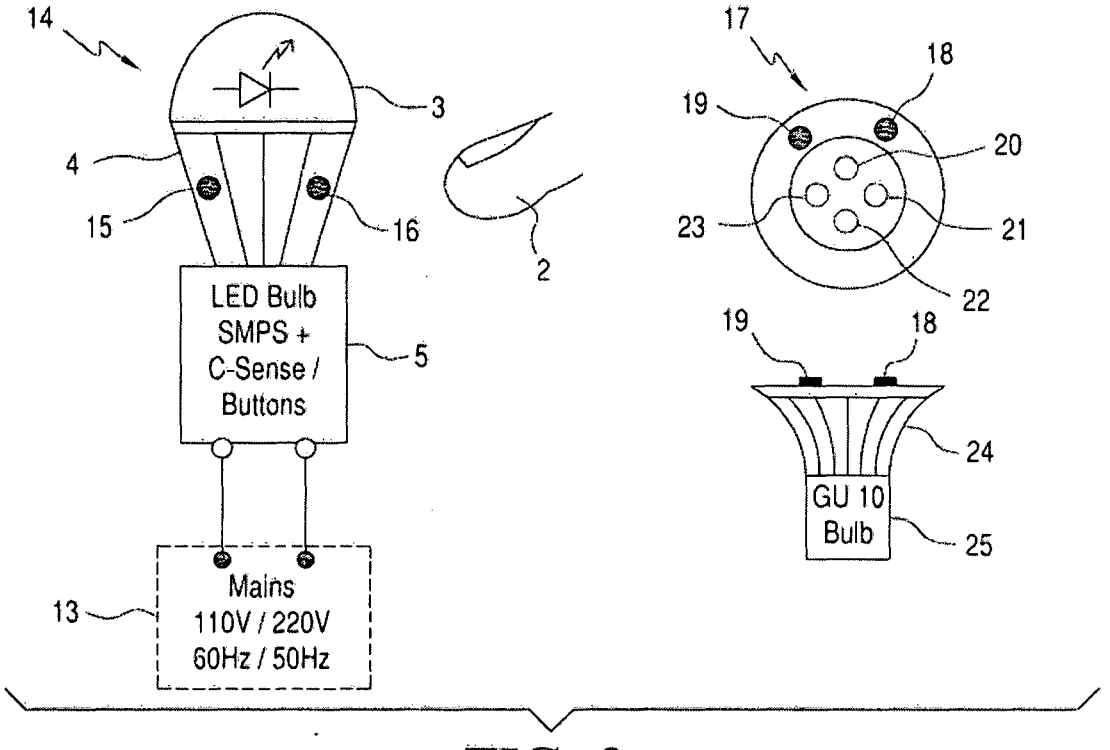

14
3
4
15
16
2
LED Bulb
SMPS +
C-Sense /
Buttons
5
13
Mains
110V / 220V
60Hz / 50Hz
17
18
19
20
23
21
22
19
18
24
GU 10
Bulb
25

FIG. 3

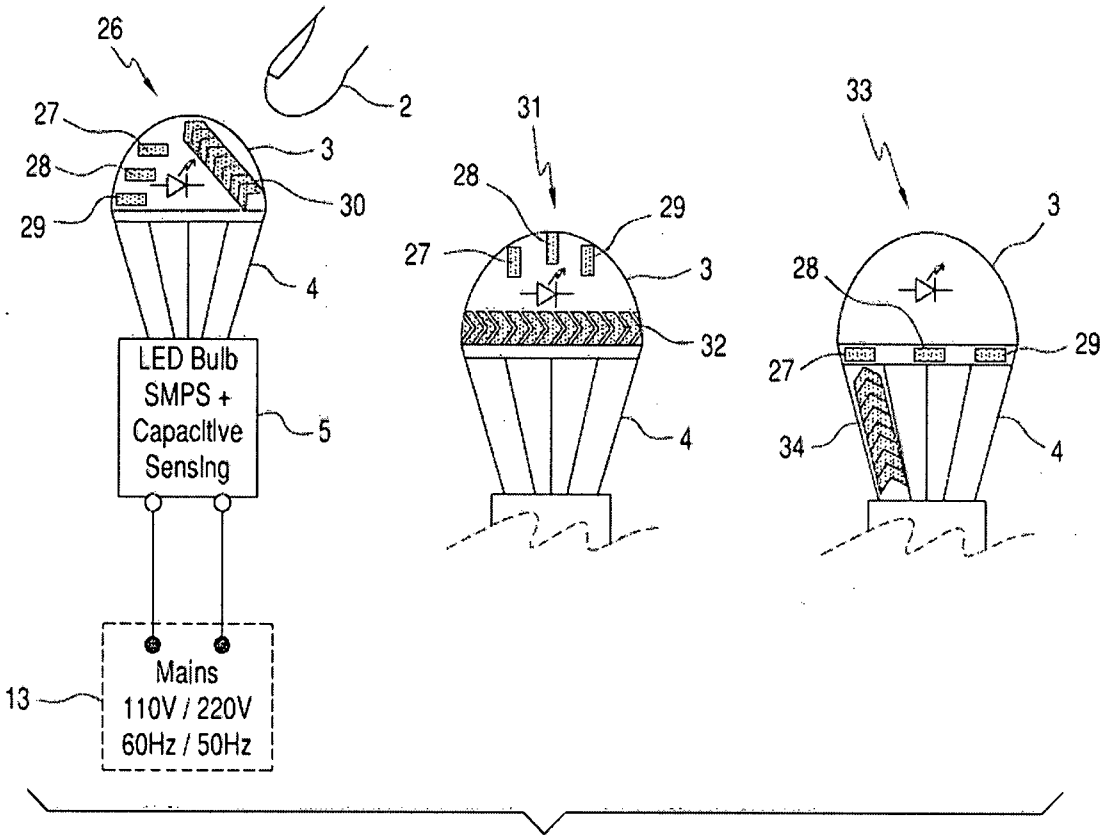

26
2
27
3
28
30
29
4
LED Bulb
SMPS +
Capacitive
Sensing
5
13
Mains
110V / 220V
60Hz / 50Hz
31
28
29
27
3
32
4
33
3
28
29
27
34
4

FIG. 4

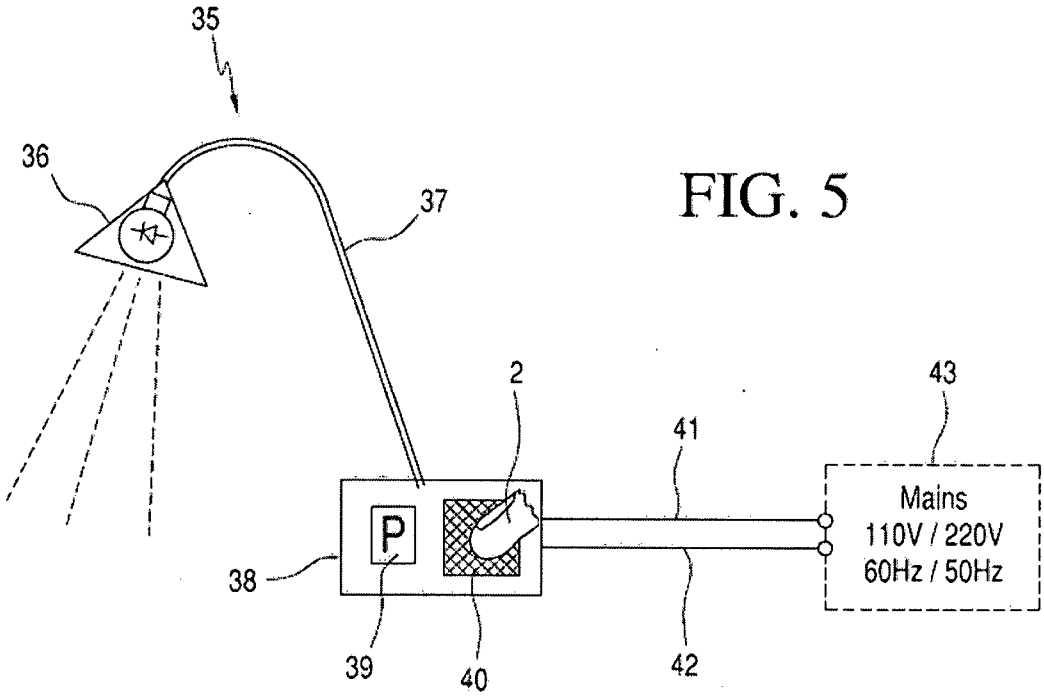
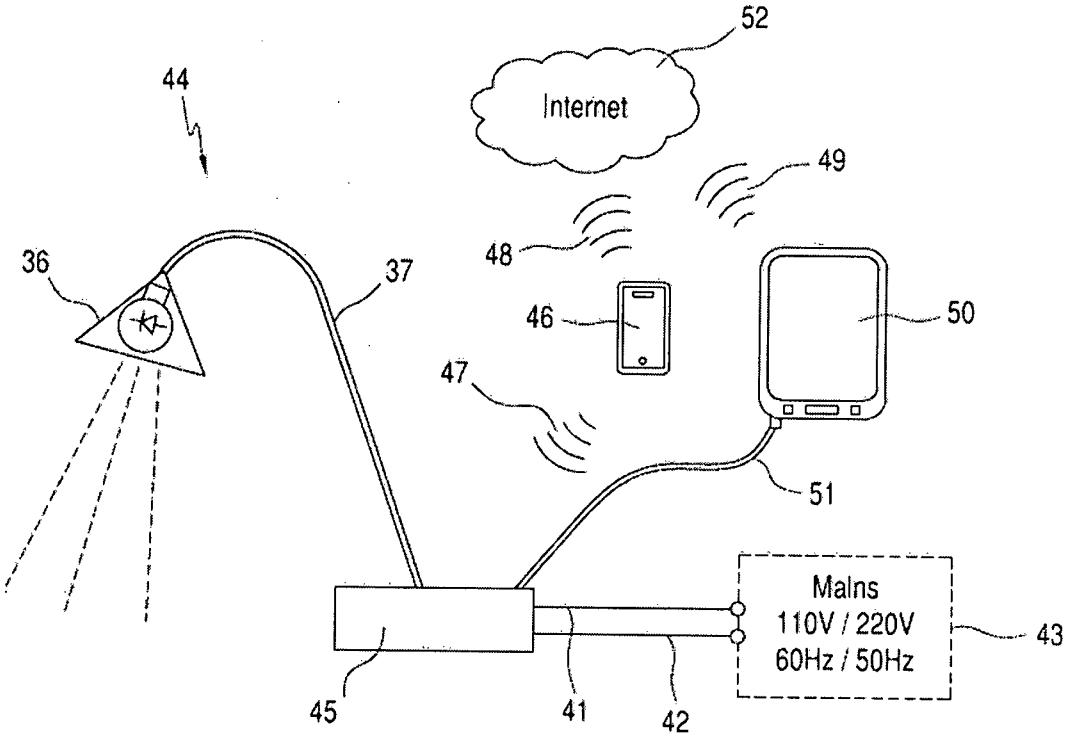

35
36
37
2
43
41
38
P
39
40
42
Mains
110V / 220V
60Hz / 50Hz

FIG. 5

FIG. 6


52
Internet
44
49
48
36
37
46
50
47
51
Mains
110V / 220V
60Hz / 50Hz
43
45
41
42

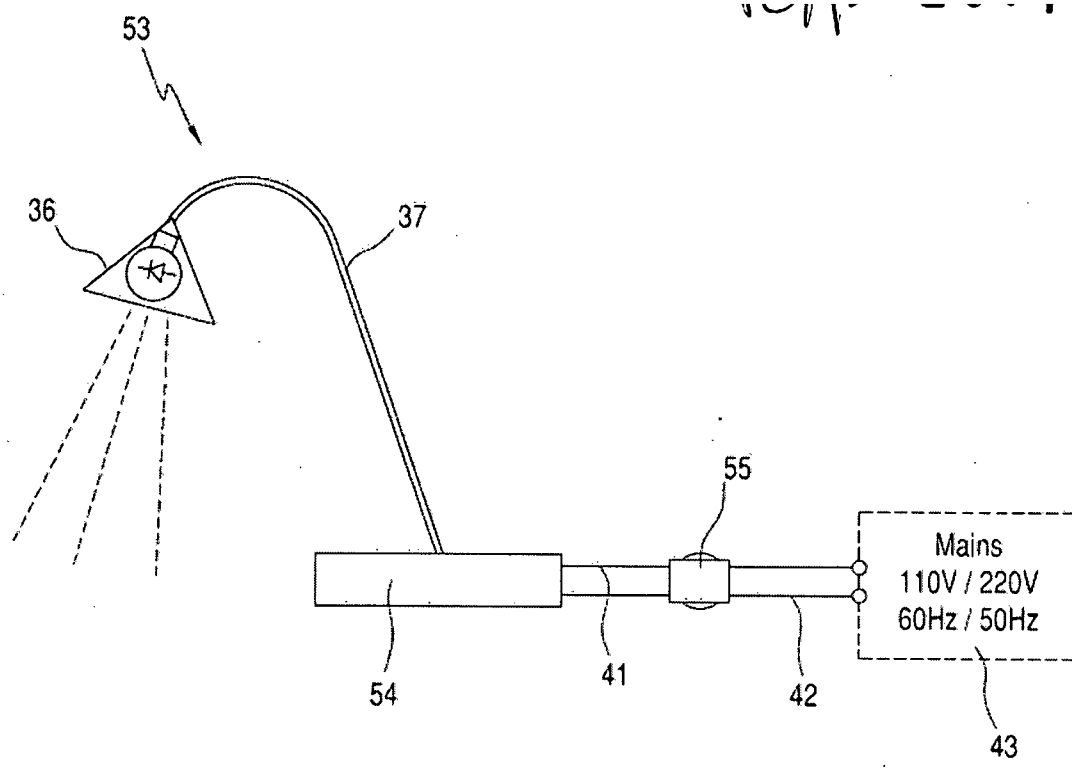

53
36
37
55
Mains
110V / 220V
60Hz / 50Hz
54
41
42
43

FIG. 7

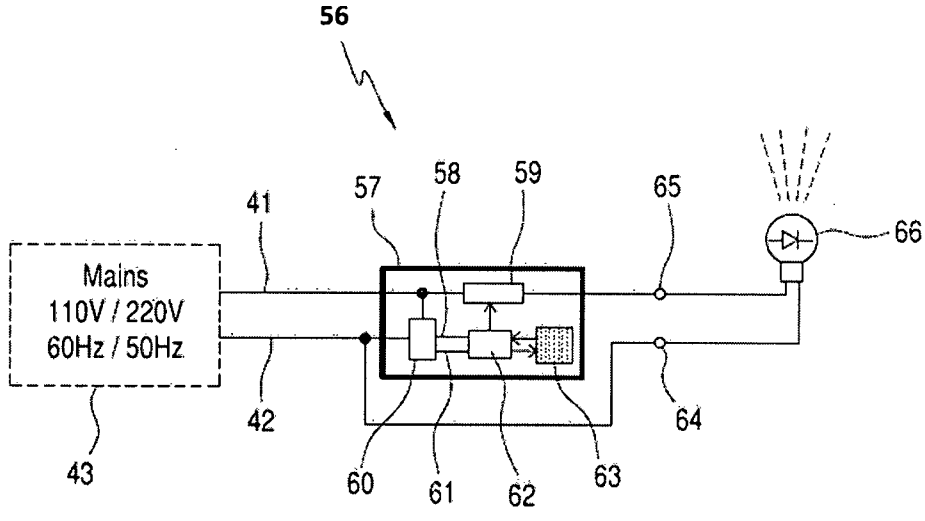

56
41
57
58
59
65
66
Mains
110V / 220V
60Hz / 50Hz
42
64
43
60
61
62
63

FIG. 8

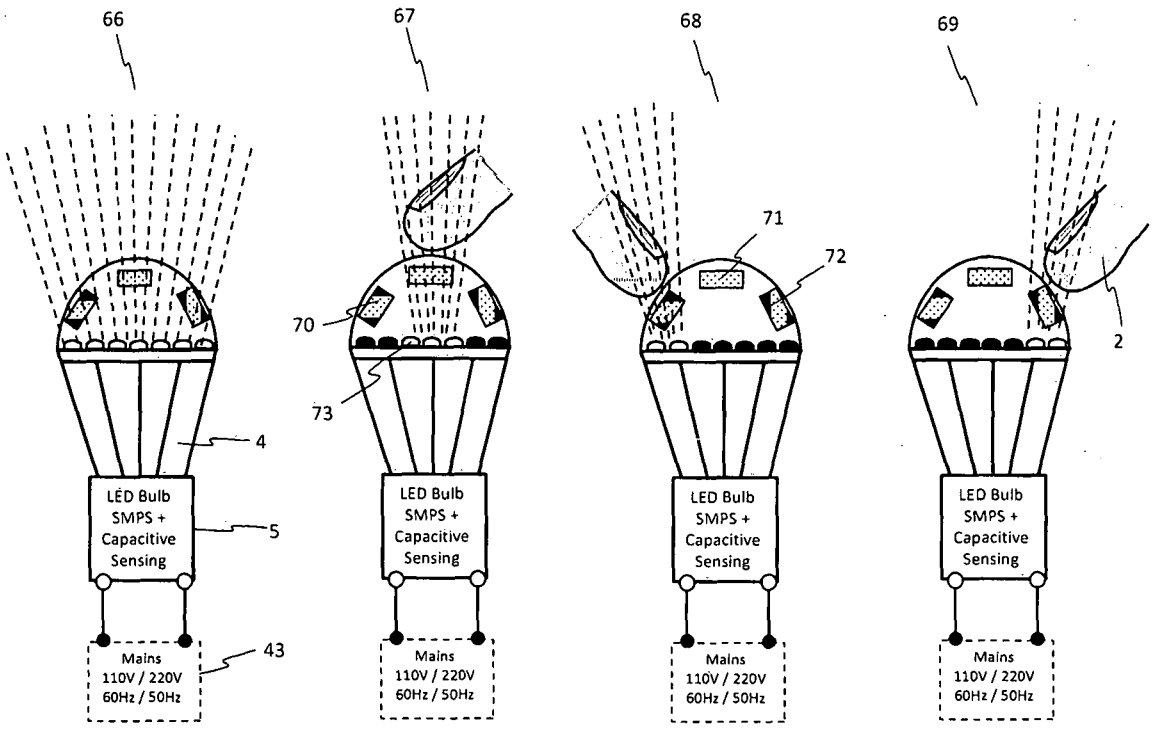


FIGURE 9

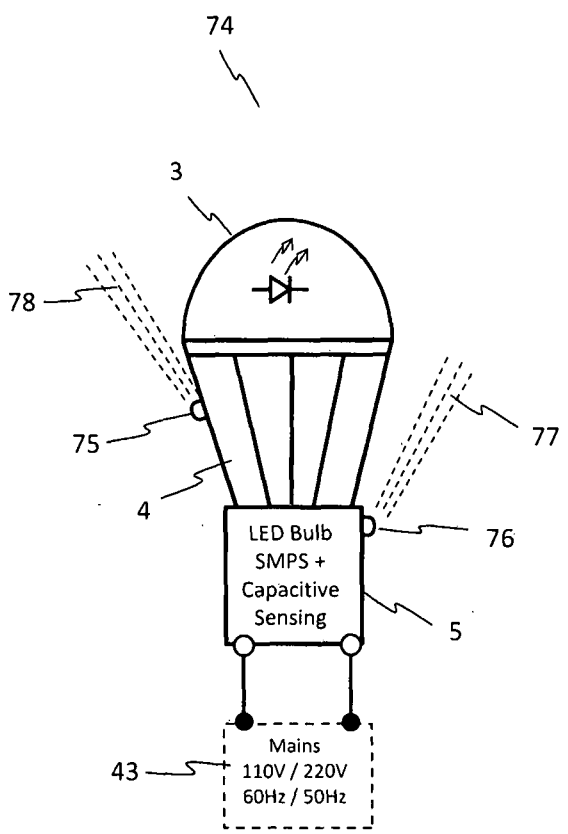


FIGURE 10

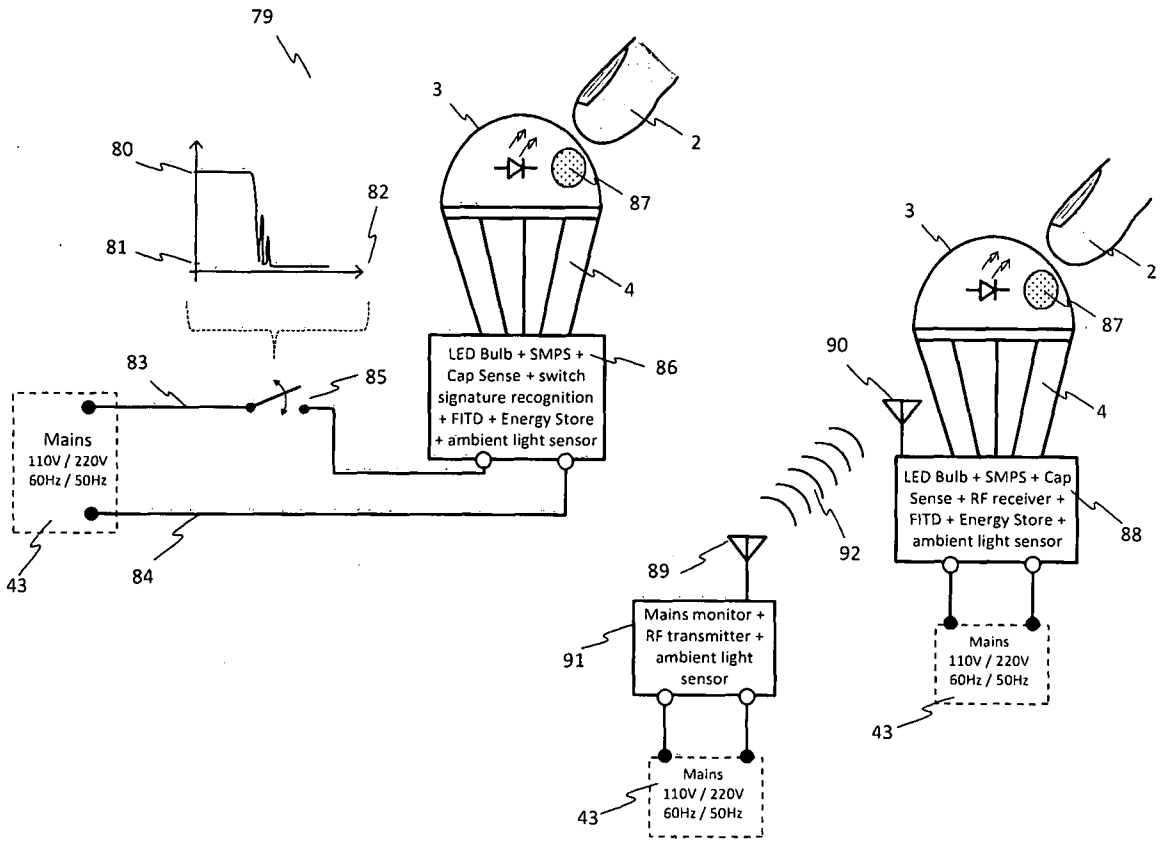


FIGURE 11

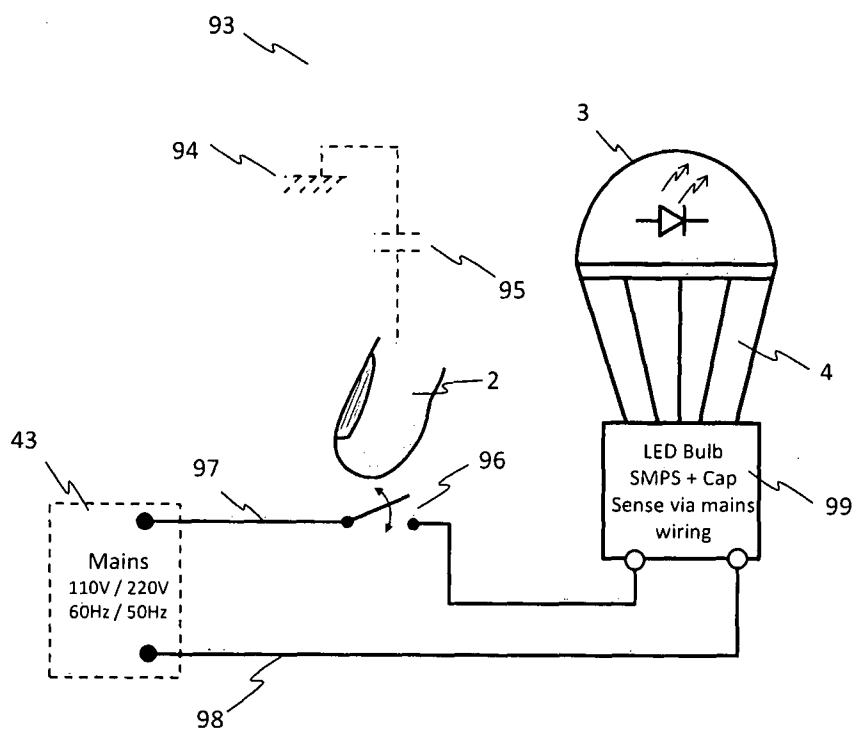


FIGURE 12

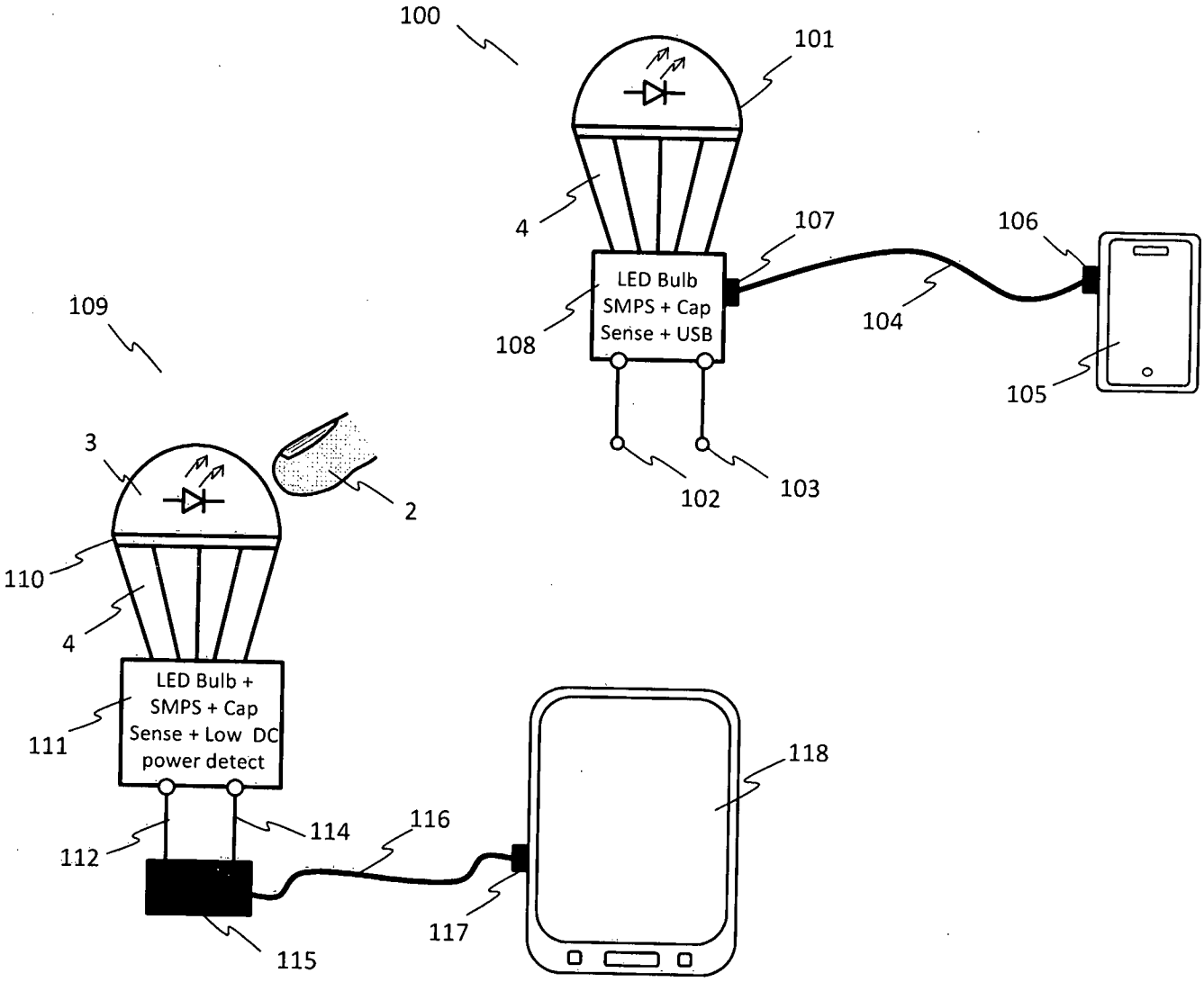

100
101
4
107
106
LED Bulb
SMPS + Cap
Sense + USB
108
104
105
102
103
109
3
2
110
4
LED Bulb +
SMPS + Cap
Sense + Low DC
power detect
111
112
114
116
118
115
117

FIGURE 13

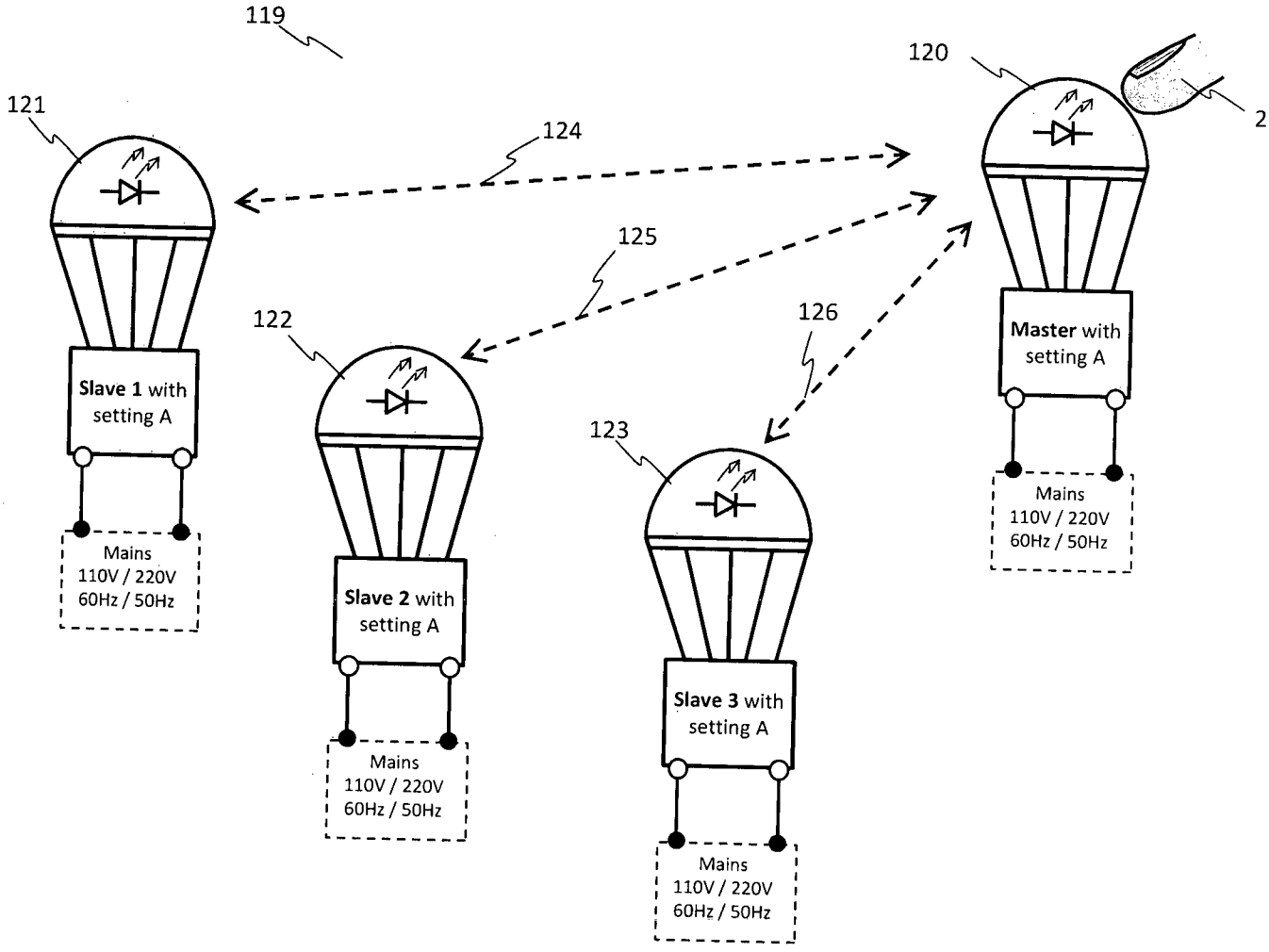

119
120
121
124
2
125
122
126
123
Slave 1 with setting A
Mains 110V / 220V 60Hz / 50Hz
Slave 2 with setting A
Mains 110V / 220V 60Hz / 50Hz
Slave 3 with setting A
Mains 110V / 220V 60Hz / 50Hz
Master with setting A
Mains 110V / 220V 60Hz / 50Hz

FIGURE 14

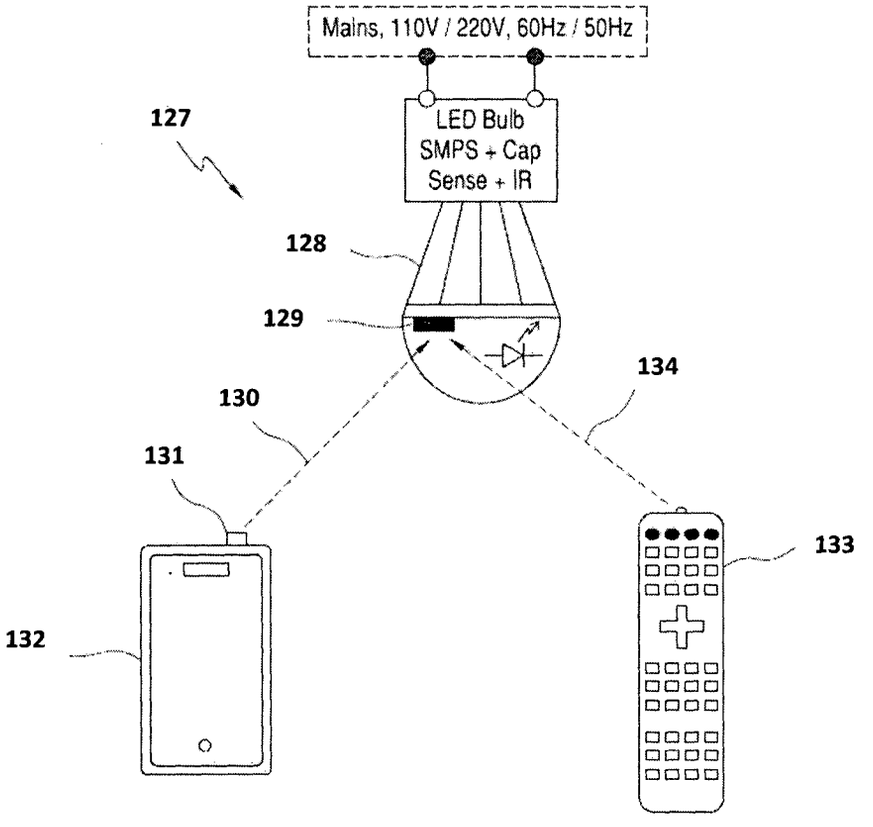

Mains, 110V / 220V, 60Hz / 50Hz
LED Bulb
SMPS + Cap
Sense + IR
127
128
129
130
131
132
133
134

FIG.15

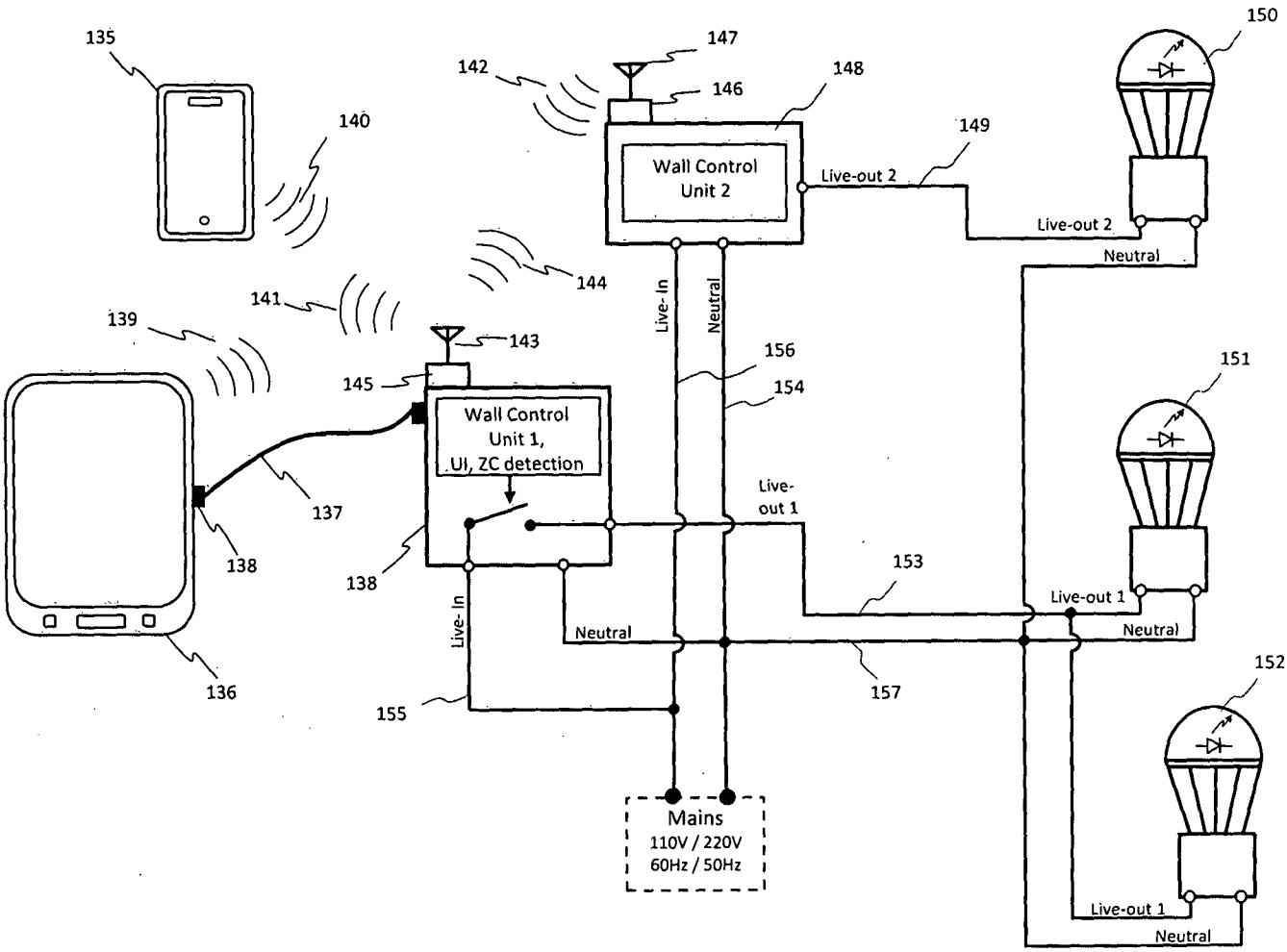

135
140
142
147
146
148
150
149
Wall Control
Unit 2
Live-out 2
Live-out 2
Neutral
144
141
139
143
145
156
154
151
Wall Control
Unit 1,
UI, ZC detection
Live-
out 1
137
138
138
153
Live-out 1
Neutral
Live- In
Neutral
Neutral
157
136
155
152
Mains
110V / 220V
60Hz / 50Hz
Live-out 1
Neutral

FIGURE 16

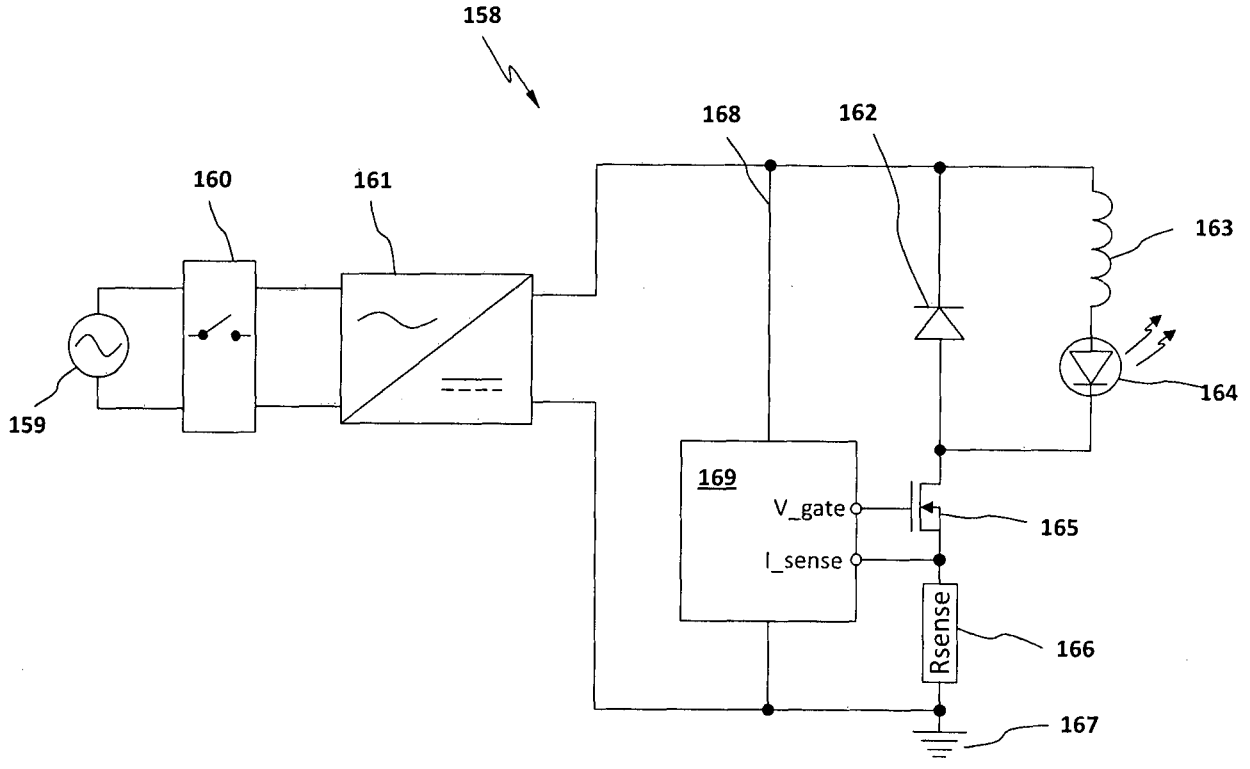

158
168
162
160
161
163
159
164
169
V_gate
165
I_sense
Rsense
166
167

FIG. 17

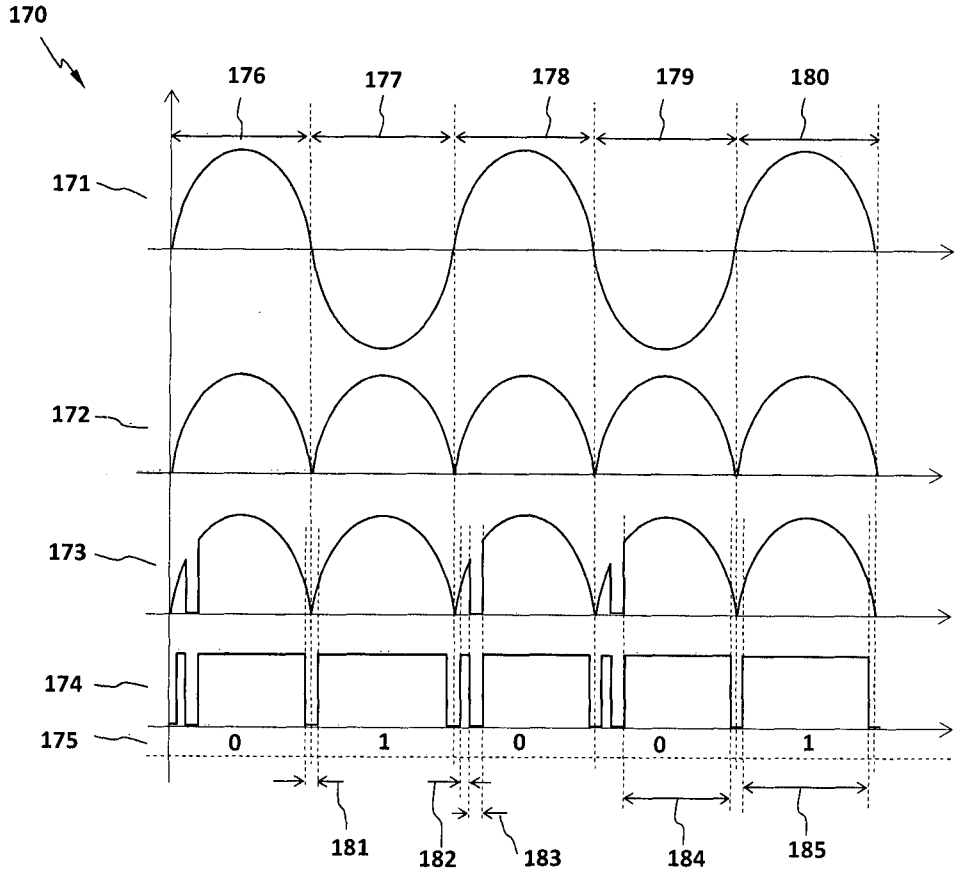

170
176
177
178
179
180
171
172
173
174
175
0
1
0
0
1
181
182
183
184
185

FIG. 18

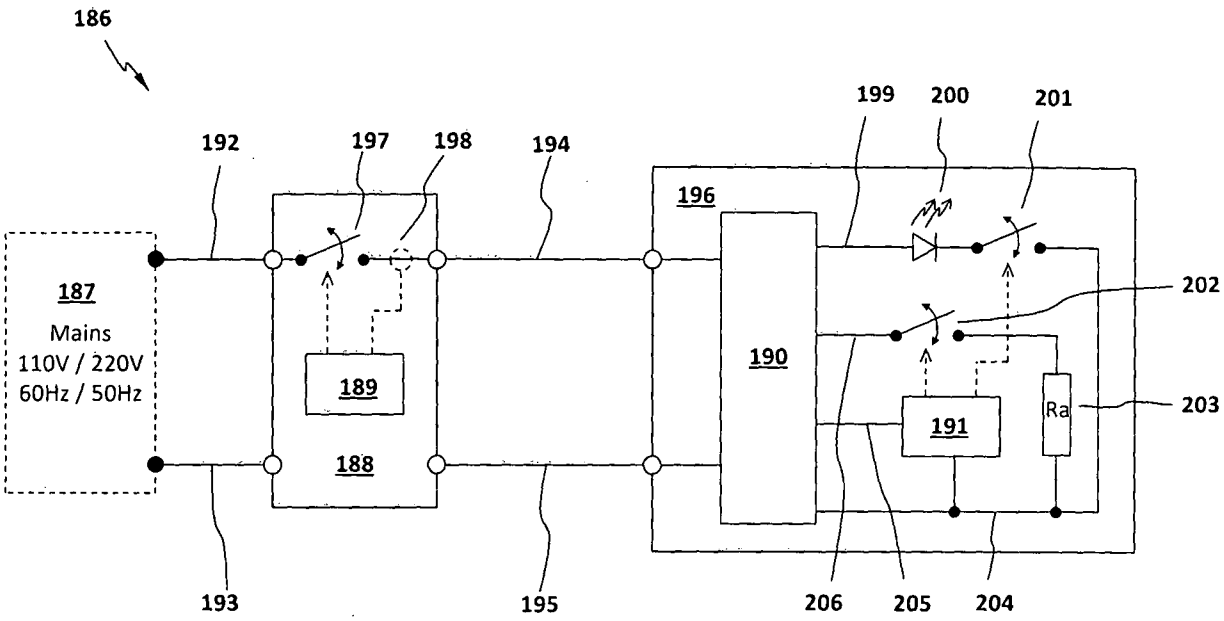

186
192
197
198
194
199
200
201
196
187
Mains
110V / 220V
60Hz / 50Hz
189
188
190
191
Ra
202
203
193
195
206
205
204

FIG. 19

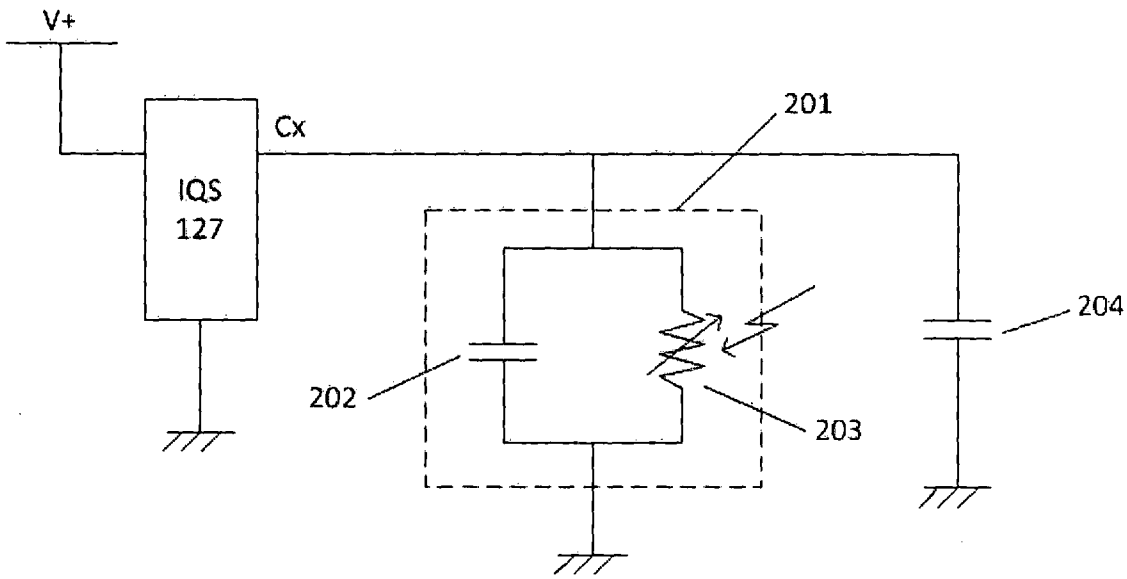

V+
Cx
IQS
127
201
202
203
204

FIG. 20

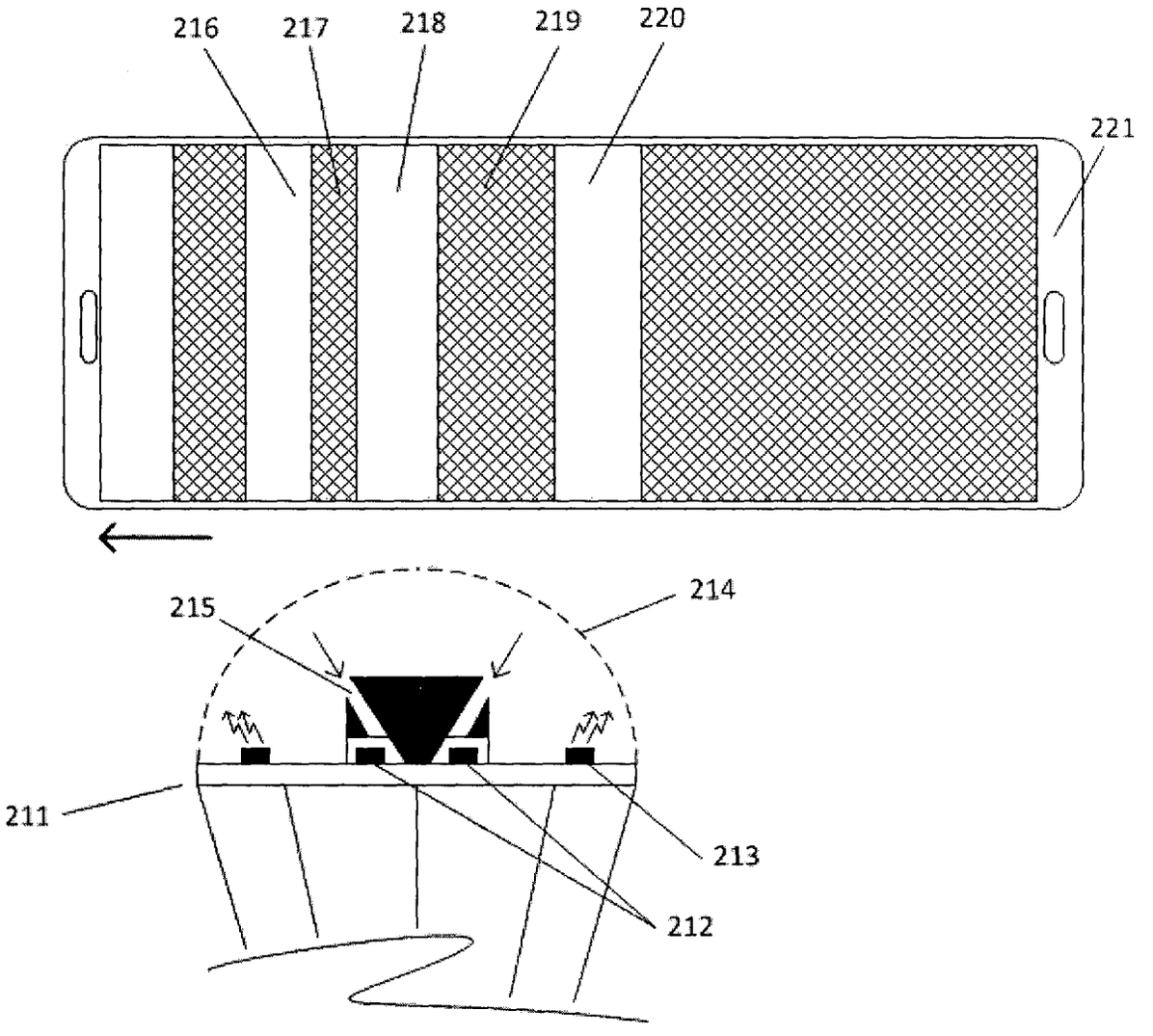


FIG. 21