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(54) **DOWNLIGHT WITH SELECTABLE LUMENS AND CORRELATED COLOR TEMPERATURE**

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See application file for complete search history.

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*F21S 4/00* (2016.01)

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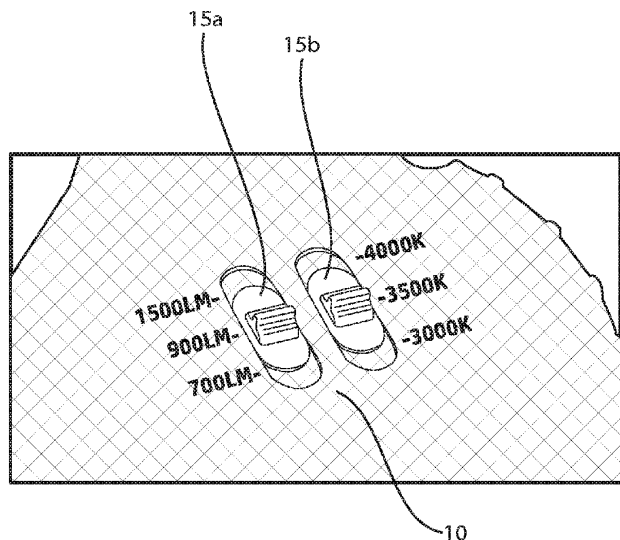
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(57) **ABSTRACT**

A lamp is provided that can have at least one interface on the lamp body for a selectable lumens and selectable correlated color temperature (CCT). In one embodiment, the lamp design includes a housing having a downlight geometry and a light engine including at least one string of light emitting diodes (LEDs), in which the light engine is position to emit light through a light emission end of the housing having the downlight geometry. The lamp also includes at least one first switch for selecting at least one lumen setting for the light emitted by the light engine; and at least one second switch for selecting at least one correlated color temperature. The first and second switch are mounted to the housing.

**18 Claims, 6 Drawing Sheets**



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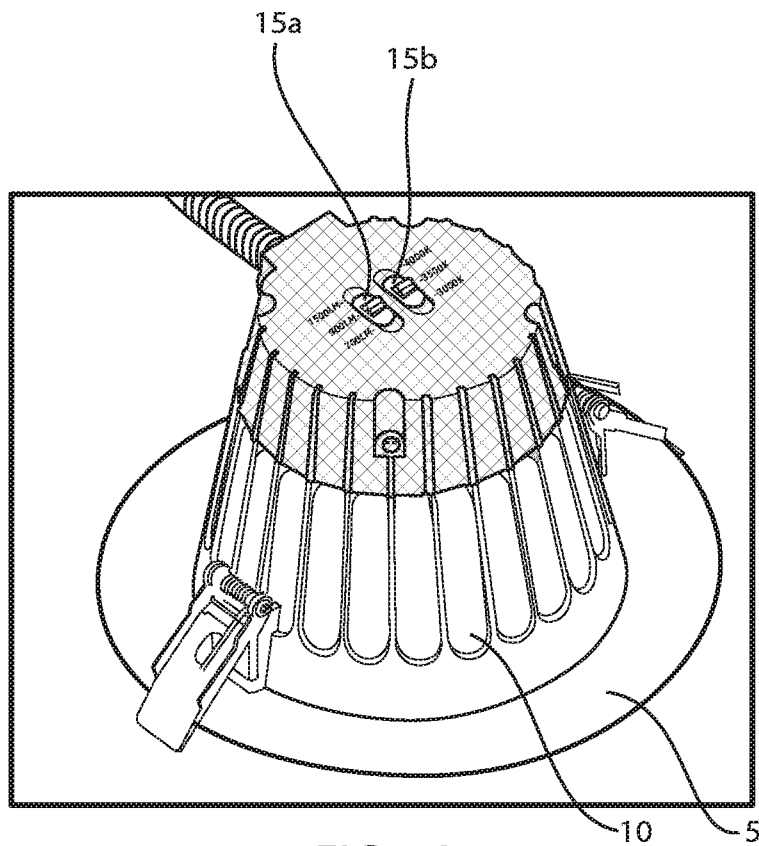


FIG. 1A

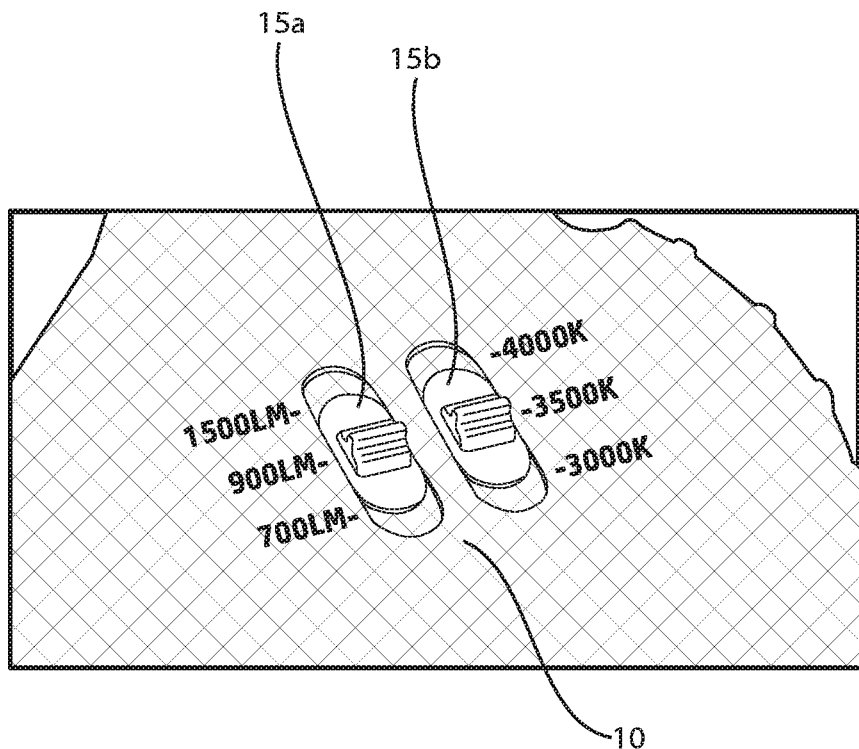


FIG. 1B

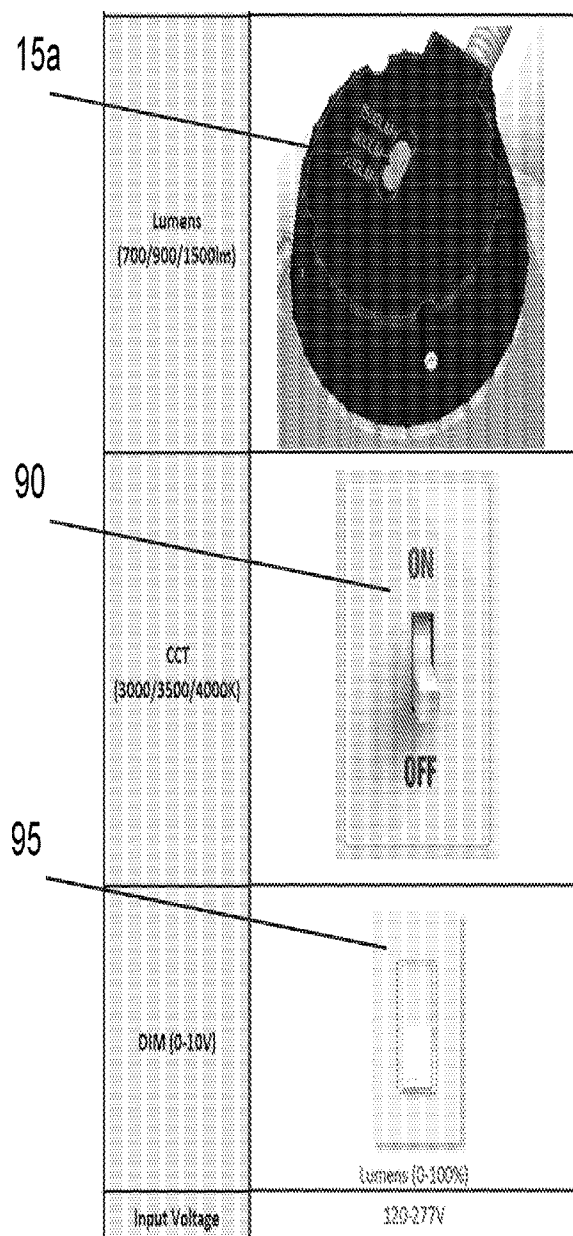


FIG. 2

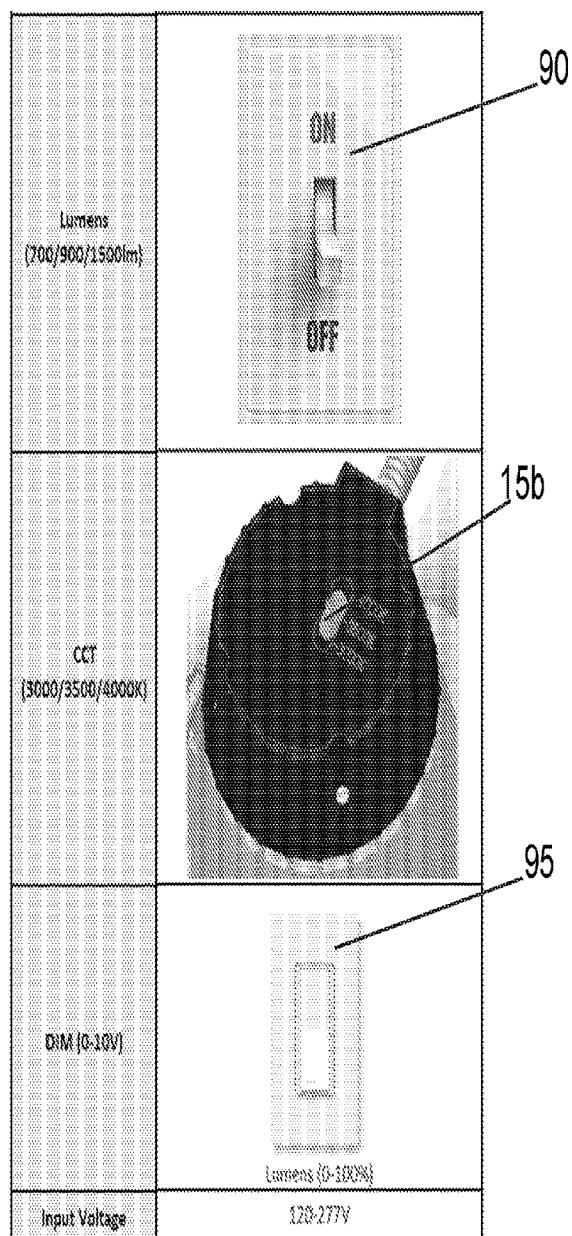


FIG. 3

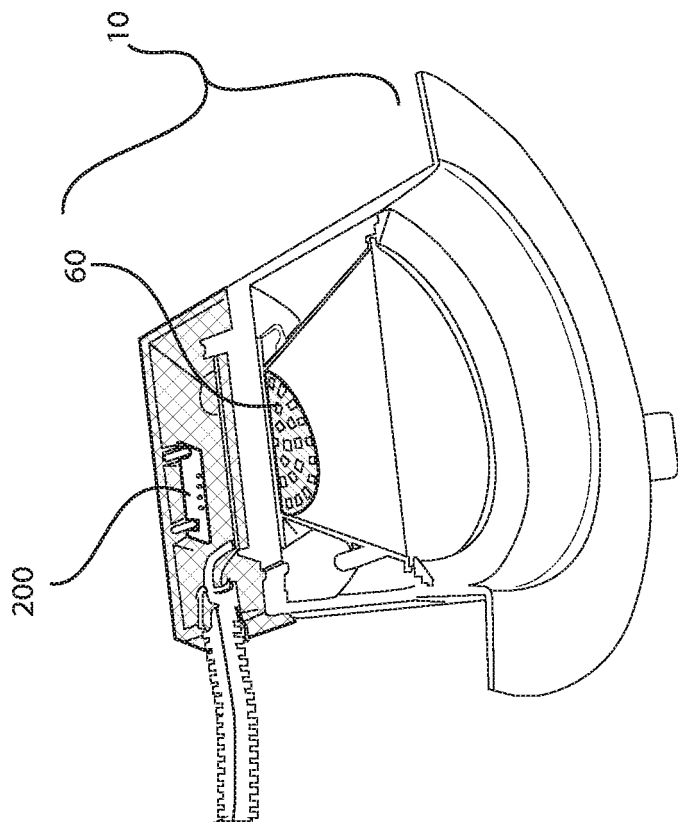


FIG.4B

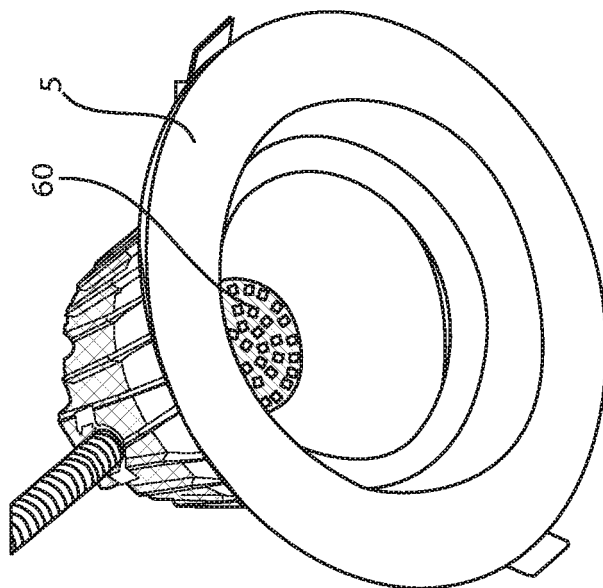


FIG.4A

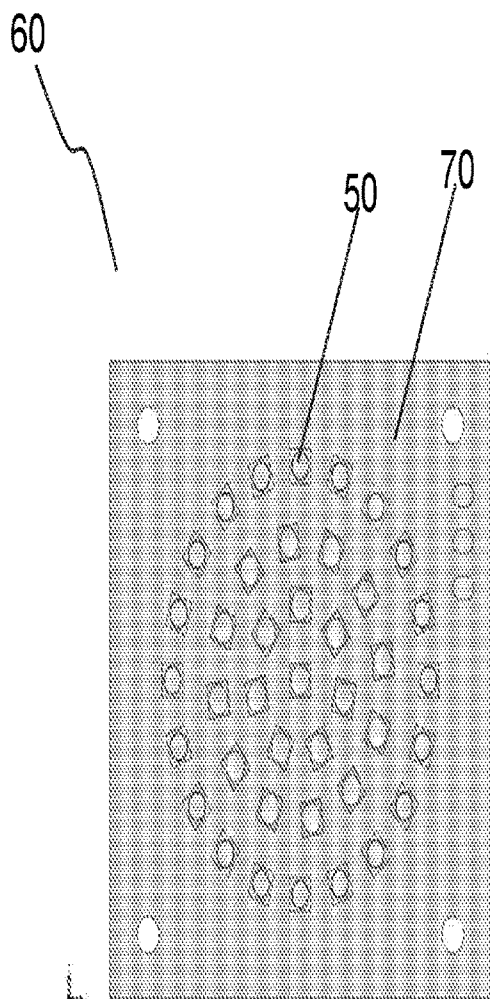


FIG. 5A

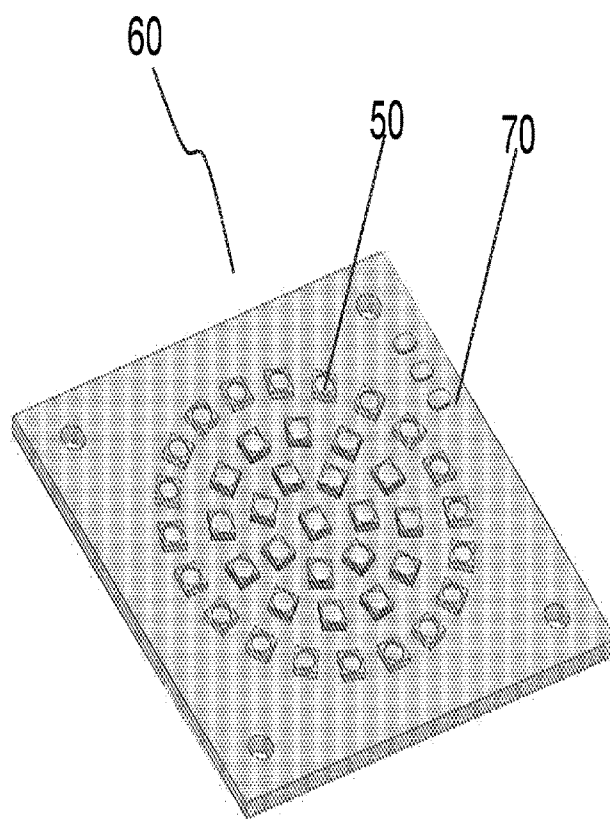


FIG. 5B

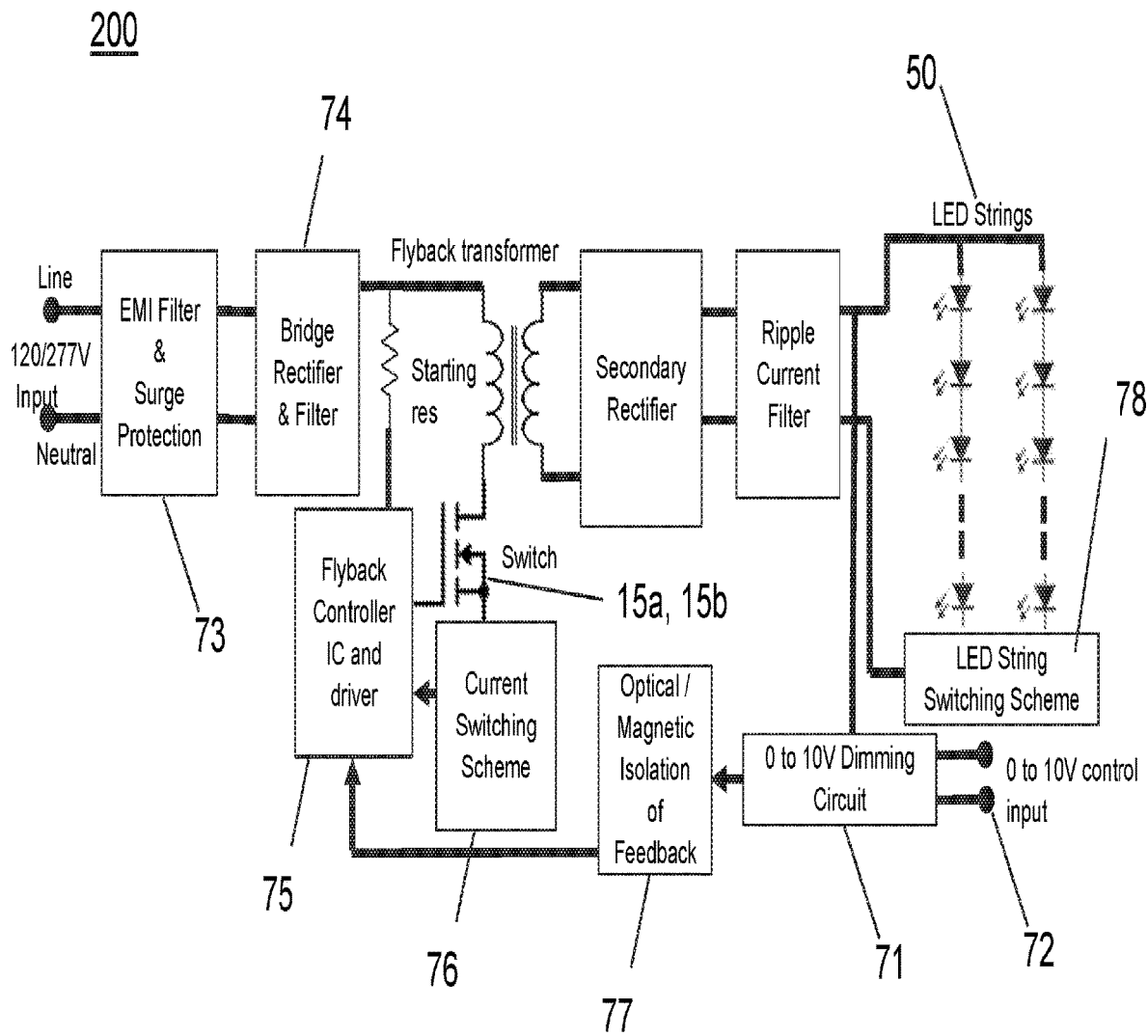


FIG. 6

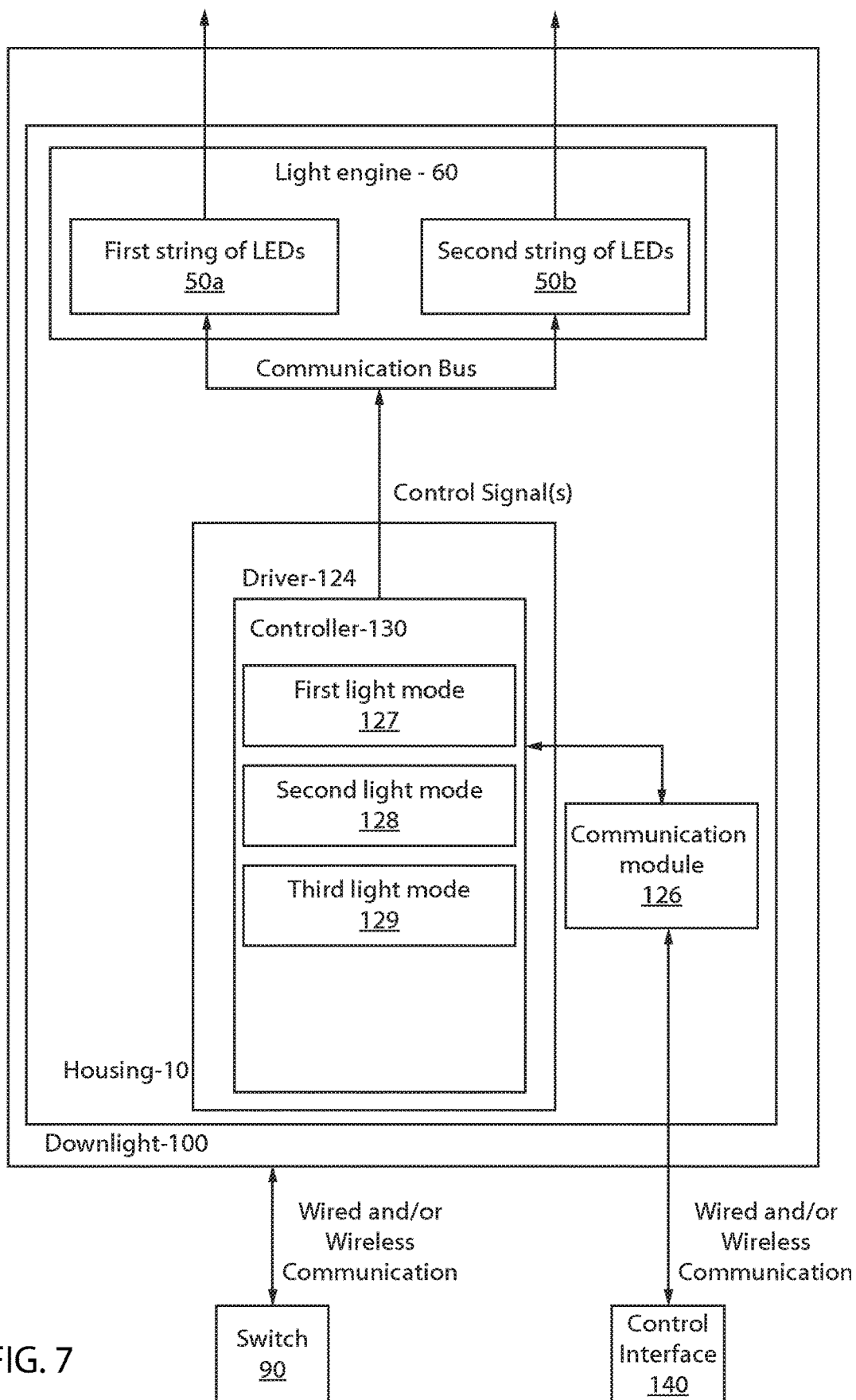


FIG. 7

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# DOWNLIGHT WITH SELECTABLE LUMENS AND CORRELATED COLOR TEMPERATURE

## TECHNICAL FIELD

The present disclosure generally relates to lamp assemblies employing light emitting diodes as the light source.

## BACKGROUND

One of the most common light fixtures is the recessed can downlight (RCD), which is an open-bottom can that contains a light bulb, most commonly an incandescent bulb or a fluorescent bulb. The fixture is typically connected to the power mains at 120 to 277 volts, 50/60 Hz. RCDs are generally installed during the construction of a building before the ceiling material (such as plaster or gypsum board) is applied. Therefore, they are not easily removed or substantially reconfigured during their lifetime. Recently, lighting devices have been developed that make use of light emitting diodes (LEDs) for a variety of lighting applications. Owing to their long lifetime and high energy efficiency, LED lamps are now also designed for replacing traditional incandescent and fluorescent lamps, i.e., for retrofit applications. For such applications, the LED retrofit lamp is typically adapted to fit into the socket of the respective lamp fixture to be retrofitted.

## SUMMARY

In one aspect, a lamp is provided that can have at least one interface on the lamp body for a selectable lumens and selectable correlated color temperature (CCT). In one embodiment, the lamp design includes a housing having a downlight geometry and a light engine including at least one string of light emitting diodes (LEDs), in which the light engine is positioned to emit light through a light emission end of the housing having the downlight geometry. The lamp also includes at least one first switch for selecting at least one lumen setting for the light emitted by the light engine; and at least one second switch for selecting at least one correlated color temperature. The first and second switch are mounted to the housing.

In another embodiment, a lamp is provided that includes a housing having a downlight geometry and a light engine including at least one string of light emitting diodes (LEDs), in which the light engine is positioned to emit light through a light emission end of the housing having the downlight geometry. The lamp also includes at least one first switch for selecting at least one lumen setting for the light emitted by the light engine; and at least one second switch for selecting at least one correlated color temperature. The first and second switch are mounted to the housing. In addition to the light engine being in electrical communication with the first and second switch for selecting settings for correlated color temperature and lumen setting, the light engine may also be in electrical communication with a receiver for receiving setting commands for dimming and intensity of the light being emitted by the lamp.

In another embodiment, a lighting method is provided. The lighting method includes housing a light source including at least one string of light emitting diodes in a body of a lamp having a downlight geometry. The method also includes providing device circuitry that allows for adjustments to lumen settings and correlated color temperature settings through an interface of setting switches fixed to the

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body of the lamp. The method also includes providing a receiver for receiving from a remote switch adjustments to dimming and intensity settings for light emitted by the lamp.

## BRIEF DESCRIPTION OF THE DRAWINGS

The following description will provide details of embodiments with reference to the following figures wherein:

FIG. 1A is a perspective view of lamp design including a housing having a downlight geometry and a light engine including at least one string of light emitting diodes (LEDs), in which the lamp also includes at least one first switch for selecting at least one lumen setting for the light emitted by the light engine, and at least one second switch for selecting at least one correlated color temperature (CCT), in accordance with one embodiment of the present disclosure.

FIG. 1B is a magnified perspective view of the first and second switches for selecting the lumen settings and correlated color temperature (CCT) that is depicted in FIG. 1A, in which the first and second switches are mounted to the housing.

FIG. 2 is a perspective view of lamp design including a housing having a downlight geometry and a light engine including at least one string of light emitting diodes (LEDs), in which the lamp also includes a switch for selecting at least one lumen setting for the light emitted by the light engine fixed to the housing, an "ON"/"OFF" wall switch for selecting at least one correlated color temperature (CCT), and a remote dimmer switch for adjusting the dimming/intensity of the light emitted by the lamp, in accordance with one embodiment of the present disclosure.

FIG. 3 is a perspective view of lamp design including a housing having a downlight geometry and a light engine including at least one string of light emitting diodes (LEDs), in which the lamp also includes a switch for selecting at least one correlated color temperature (CCT) setting for the light emitted by the light engine fixed to the housing, an "ON"/"OFF" wall switch for selecting at least one lumen setting for light emitted by the lamp, and a remote dimmer switch for adjusting the dimming/intensity of the light emitted by the lamp, in accordance with one embodiment of the present disclosure.

FIG. 4A is a perspective view of a downlight geometry lamp that has been tilted to depict the light engine including at least one string of light emitting diodes, in which the lamp design includes at least one first switch for selecting at least one lumen setting for the light emitted by the light engine, and at least one second switch for selecting at least one correlated color temperature (CCT), in accordance with one embodiment of the present disclosure.

FIG. 4B is a cross-sectional view of the lamp design depicted in FIG. 4A.

FIG. 5A is a top down view of a light engine including at least one string of light emitting diodes (LEDs) as used in the lamp designs depicted in FIGS. 1A-4B.

FIG. 5B is a perspective view of the light engine depicted in FIG. 5A.

FIG. 6 is a circuit diagram for the electronics package of one embodiment of the lamp designs that is depicted in FIGS. 1A-4B.

FIG. 7 is a block diagram illustrating a driver for use with the at least one embodiment of the downlights described with reference to FIGS. 1A-6.

## DETAILED DESCRIPTION

Reference in the specification to "one embodiment" or "an embodiment" of the present invention, as well as other

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variations thereof, means that a particular feature, structure, characteristic, and so forth described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, the appearances of the phrase “in one embodiment” or “in an embodiment”, as well as any other variations, appearing in various places throughout the specification are not necessarily all referring to the same embodiment.

In some embodiments, the present disclosure provides a downlight with selectable lumens settings and selectable correlated color temperature (CCT) settings, in which the settings can be selected by switches that are fixed to the body of the downlight. The methods and structures described herein can provide different light output (lumen) levels and different light color levels (CCTs) in a single downlight. In some embodiments, via selectable switch, a lighting designer can adapt the downlight to an application space by selecting appropriate light and color levels. The switch gear for selecting the light levels and/or the light color levels can be either provided on the downlight as selectable switches, or can be provided by a combination of selectable switches on the light housing and a remote wall ON/OFF switch. In some embodiments, the downlights that are described herein provide selectable/switchable light level and light color settings in a single downlight for both new construction and retrofit applications. In some examples, the downlight structures having selectable/switchable light level and light color settings that can include switchgear fixed to the housing (also referred to as body) of the downlight structures offers good flexibility to a lighting designer or specifier for selecting either different light output levels (three light output levels of 700/900/1500 lumens) or the light colors (CCTs of 3000K/3500K/4000K). In some embodiments, the selector switches for selecting the different types of light output level, e.g., lumen levels, and/or different types of light color, e.g., correlated color temperature (CCT) settings, are device mounted on a single unit. The light designs of the present disclosure are suitable for 120-277V applications and can be 0-10V dimmable.

Prior to the lighting structures and methods of the present disclosure, if a lighting designer/user wanted different light levels and/or wanted to use different light color (CCT) the user had to remove the already installed unit and replace it with another unit with desired unit with appropriate light output and/or the light color (CCT). This increased the cost of the installation, i.e., both the system and labor costs.

By employing the methods and structures of the present disclosure, including the downlight having device mounted selector switches for selecting the different types of light output level, e.g., lumen levels, and/or different types of light color, e.g., correlated color temperature (CCT) settings, are on a single unit, a lighting designers can now consider having different light levels in combination with different light colors (CCT) which offers more flexibility without incurring the costs of prior downlights not having selectable light settings. The lamp structures of the present disclosure are now described with greater detail with reference to FIGS. 1A-6.

FIGS. 1A, 1B, 4A and 4B depict one embodiment of a downlight 100 including a light engine having a plurality of solid state light emitters, e.g., light emitting diodes (LEDs) 50. A “downlight”, or recessed light, (also pot light in Canadian English, sometimes can light (for canister light) in American English) is a light fixture that is installed into a hollow opening in a ceiling. When installed it appears to have light shining from a hole in the ceiling, concentrating the light in a downward direction as a broad floodlight or

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narrow spotlight. “Pot light” or “canister light” implies the hole is circular and the lighting fixture is cylindrical, like a pot or canister. Broadly, there are three parts to a downlight fixture: 1) housing, 2) trim and 3) light engine. It is noted that this is not an exclusive list of the elements of a downlight fixture. The trim 5 is the visible portion of the downlight. The trim 5 is the insert that is seen when looking up into the fixture, and also includes the thin lining around the edge of the light. The housing 10 is the fixture itself that is installed inside the ceiling and contains the lamp holder. It is noted that embodiments are contemplated in which the trim 5 and the housing 10 are integrated together in one piece, and there are embodiments in which the trim 5 and the housing 10 are separate components. There are many different types of light engines 60 that can be inserted into recessed lighting fixtures, i.e., downlights 100. In accordance with the embodiments of the present disclosure, the light engines 60 applicable to the methods and structures described herein include solid state emitters, such as light emitting diodes (LEDs) 50.

The housing 10 may be composed of a metal, such as aluminum (Al), which provides for heat dissipation of any heat produced by the light engine 15. In some embodiments, to provide for increased heat dissipation, a plurality of ridges or fin structures may be integrated into the aluminum housing 10. In some embodiments, the housing 10 may also be composed of a plastic, such as polycarbonate. The construction of the housing 10 may fall into one of four categories for downlights that are recognized in North America. For example, the housing may be constructed for IC or “insulation contact” rated new construction housings are attached to the ceiling supports before the ceiling surface is installed. If the area above the ceiling is accessible these fixtures may also be installed from within the attic space. IC housings are typically required wherever insulation will be in direct contact with the housing. Non-IC rated new construction housings are used in the same situations as the IC rated new construction housings, only they require that there be no contact with insulation and at least 3 in (7.6 cm) spacing from insulation. These housings are typically rated up to 150 watts. IC rated remodel housings are used in existing ceilings where insulation will be present and in contact with the fixture. Non-IC rated remodel housings are used for existing ceilings where, no insulation is present. Non-IC rated remodel housings require that there be no contact with insulation and at least 3 in (7.6 cm) spacing from insulation. Sloped-ceiling housings are available for both insulated and non-insulated ceilings that are vaulted. It is noted that the housing 10 of the downlight of the present disclosure may be designed to meet the requirements of any of the aforementioned standards. The housing 10 is typically designed to ensure that no flammable materials come into contact with the hot lighting fixture.

The housing 10 may be dimensioned to be available in various sizes based on the diameter of the circular opening where the downlight 100 is installed. In some examples, the circular opening of the housing 10 may be sized in 4, 5 and 6 inch diameter. It is noted that these dimensions are provided for illustrative purposes only and are not intended to limit the present disclosure. For example, the housing 10 may also have a circular opening in diameters equal to 2 inches or 3 inches. The opening of the housing may also be multi-sided, such as square or rectangular.

In some embodiments, the housing 10 can also be “Air Tight”, which means it will not allow air to escape into the ceiling or attic, thus reducing both heating and cooling costs.

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The trim **5** of the downlight **100** is selected to increase the aesthetic appearance of the lamp. In some embodiments, the trim **5** may be a baffle that is black or white in color. In some embodiments, the trim **5** is made to absorb extra light and create a crisp architectural appearance. There are cone trims which produce a low-brightness aperture. In some embodiment, the trim **5** may be a multiplier that is designed to control the omnidirectional light from the light engine. Lens trim is designed to provide a diffused light and protect the lamp. Lensed trims are normally found in wet locations. The luminous trims combine the diffused quality of lensed trim but with an open down light component. Adjustable trim allows for the adjustment of the light whether it is eyeball style, which protrudes from the trim or gimbal ring style, which adjusts inside the recess.

The light engine (also referred to as light source) is positioned within the housing **10** and orientated to emit light in a direction through opening of the housing **10** at which the trim **5** is positioned. The light engine produces light from solid state emitters.

The term "solid state" refers to light emitted by solid-state electroluminescence, as opposed to incandescent bulbs (which use thermal radiation) or fluorescent tubes, which use a low pressure Hg discharge. Compared to incandescent lighting, solid state lighting creates visible light with reduced heat generation and less energy dissipation. Some examples of solid state light emitters that are suitable for the methods and structures described herein include inorganic semiconductor light-emitting diodes (LEDs), organic light-emitting diodes (OLED), polymer light-emitting diodes (PLED) or combinations thereof. Although the following description describes an embodiment in which the solid state light emitters are provided by light emitting diodes, any of the aforementioned solid state light emitters may be substituted for the LEDs. FIGS. **5A** and **5B** illustrate one example of the light emitting diodes (LEDs) **50** of a light engine **60** that can be utilized within the downlights **100** that are depicted in FIGS. **1A-4B**.

Referring to FIGS. **5A** and **5B**, in some embodiments, the light source (also referred to as light engine) for the downlight **100** is provided by plurality of LEDs **50** that can be mounted to the circuit board **60** by solder, a snap-fit connection, or other engagement mechanisms. In some examples, the LEDs **50** are provided by a plurality of surface mount device (SMD) light emitting diodes (LED).

The circuit board **70** for the light engine **60** may be composed of a metal core printed circuit board (MCPCB). MCPCB uses a thermally conductive dielectric layer to bond circuit layer with base metal (Aluminum or Copper). In some embodiments, the MCPCB use either Al or Cu or a mixture of special alloys as the base material to conduct heat away efficiently from the LEDs thereby keeping them cool to maintain high efficacy. In some other embodiments, the PCB type may be FR4 or CEMI.

It is noted that the number of LEDs **50** on the printed circuit board **70** may vary. For example, the number of LEDs **50** may range from 5 LEDs to 70 LEDs. In another example, the number of LEDs **50** may range from 35 LEDs to 45 LEDs. It is noted that the above examples are provided for illustrative purposes only and are not intended to limit the present disclosure, as any number of LEDs **50** may be present the printed circuit board **70**. In some other examples, the number of LEDs **50** may be equal to 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65 and 70, as well as any range of LEDs **50** with one of the aforementioned examples as a lower limit to the range, and one of the aforementioned examples as an upper limit to the range.

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The LEDs **50** may be arranged as strings on the printed circuit board **70**. When referring to a "string" of LEDs it is meant that each of the LEDs in the string are illuminated at the same time in response to an energizing act, such as the application of electricity from the driving electronics, e.g., driver, in the downlight **100**. The LEDs **50** in a string of LEDs are electrically connected for this purpose. For example, when the a string of LEDs **50** is energized for illumination, all of the LEDs in the string are illuminated. Further, in some embodiments, illuminating the first string of LEDs **50** does not illuminate the LEDs in the second string of LEDs **50**, and vice versa, as they are independently energized by the driving electronics, and not electrically connected. It is also noted that the same LED may be shared by more than one string.

In one example, a first string of LEDs **50** may be illuminated to provide an intensity of light emitted by the light engine **60** for the downlight **100** that is on the order of 500 lumens (LM), a second string of LEDs **50** may be illuminated to provide an intensity of light emitted by the light engine **60** for the downlight **100** that is on the order of 900 lumens (LM); and a third string of LEDs **50** may be illuminated to provide an intensity of light emitted by the light engine **60** for the downlight **100** that is on the order of 1500 lumens (LM).

In another example, a fourth string of LEDs **50** may be illuminated to provide an correlated color temperature (CCT) of light emitted by the light engine **60** for the downlight **100** that is on the order of 2700K, a fifth string of LEDs **50** may be illuminated to provide an correlated color temperature (CCT) of light emitted by the light engine **60** for the downlight **100** that is on the order of 3500K; and a sixth string of LEDs **50** may be illuminated to provide an intensity of light emitted by the light engine **60** for the downlight **100** that is on the order of 4000K.

It is noted that the above examples of LED strings are consistent with the selectable settings for light emitted by the downlight **100** that are depicted in FIGS. **1A** and **1B**. The present disclosure is not limited to only this example, as other lighting characteristics can be assigned to strings of LEDs that can be selected by a user through the interfaces with the downlight **100** that are described herein.

In some embodiments, the LEDs **50** of the lamp **100** are selected to be capable of being adjusted for the color of the light they emit. The term "color" denotes a phenomenon of light or visual perception that can enable one to differentiate objects. Color may describe an aspect of the appearance of objects and light sources in terms of hue, brightness, and saturation. Some examples of colors that may be suitable for use with the method of controlling lighting in accordance with the methods, structures and computer program products described herein can include red (R), orange (O), yellow (Y), green (G), blue (B), indigo (I), violet (V) and combinations thereof, as well as the numerous shades of the aforementioned families of colors. It is noted that the aforementioned colors are provided for illustrative purposes only and are not intended to limit the present disclosure as any distinguishable color may be suitable for the methods, systems and computer program products described herein.

The LEDs **50** of the lamp **100** may also be selected to allow for adjusting the "color temperature" of the light they emit. The color temperature of a light source is the temperature of an ideal black-body radiator that radiates light of a color comparable to that of the light source. Color temperature is a characteristic of visible light that has applications in lighting, photography, videography, publishing, manufacturing, astrophysics, horticulture, and other fields.

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Color temperature is meaningful for light sources that do in fact correspond somewhat closely to the radiation of some black body, i.e., those on a line from reddish/orange via yellow and more or less white to blueish white. Color temperature is conventionally expressed in kelvins, using the symbol K, a unit of measure for absolute temperature. Color temperatures over 5000 K are called “cool colors” (bluish white), while lower color temperatures (2700-3000K) are called “warm colors” (yellowish white through red). “Warm” in this context is an analogy to radiated heat flux of traditional incandescent lighting rather than temperature. The spectral peak of warm-colored light is closer to infrared, and most natural warm-colored light sources emit significant infrared radiation. The LEDs 50 of the lamps provided by the present disclosure in some embodiments can be adjusted from 2000K to 7000K.

The LEDs 50 of the lamp 100 may also be selected to be capable of adjusting the light intensity/dimming of the light they emit. In some examples, dimming or light intensity may be measured using lumen (LM). In some embodiments, the dimming or light intensity adjustment of the LEDs 50 can provide for adjusting lighting between 100 LM to 2000 LM. In another embodiment, dimming or light intensity adjustment of the LEDs 50 can provide for adjusting lighting between 500 LM to 1750 LM. In yet another embodiment, the dimming or light intensity adjustment of the LEDs 50 can provide for adjusting lighting between 700 LM to 1500 LM.

In some embodiments, the LED light engines 60 for the downlight may provide the that downlight be an SMD (Surface Mount Diode) downlight and/or a COB (Chip on Board) downlights. In some embodiments, the LEDs 50 may be selected to be SMD type emitters, in which the SMDs are more efficient than COBs because the light source produces higher lumens per watt, which means that they produce more light with a lower wattage. In some embodiments, the SMD type LEDs 50 can produce a wider beam of light which is spread over a greater area when compared to light engines of COB type LEDs. This means that less material is needed for the heat sink, which in turn means that they are more economical. SMD downlights can be covered with a frosted reflector which hides the LED chip array, and spreads the light evenly. SMD downlights can produce a wide spread of light. In some example, the wide beam angle of the light emitted from SMD downlights means they can be suitable for larger rooms like living rooms, bedrooms, kitchens and bathrooms.

A Chip On Board (COB) LED Downlight consists of a single LED chip, mounted on the downlight, compared to an array of LED's like an SMD. COB LEDs are basically multiple LED chips (typically nine or more) bonded directly to a substrate by the manufacturer to form a single module. The ceramic/aluminum substrate of COB LEDs also acts as a higher efficiency heat transfer medium when coupled to an external heatsink, further lowering the overall operating temperature of the assembly. Since the individual LEDs used in a COB are chips, the chips can be mounted such that they take up less space and the highest potential of the LED chips can be obtained. When the COB LED package is energized, it appears more like a lighting panel than multiple individual lights as would be the case when using several SMD LEDs mounted closely together. In some embodiments, because the single cluster of LED's 50 are mounted in one point, they can require greater cooling, so a heat sink, usually made of aluminum, may be mounted to dissipate the heat.

A light engine of COB type LEDs 50 can provide a more focused light and with the use of reflectors, the light beam

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can be more controlled when compared to a light engine that is composed of SMD LEDs. Chrome reflectors surrounding the diode can be replaced and set at different angles to make the light beam narrower or wider. Due to the narrow beam and with the use of reflectors that are usually clear, COB lights generate crisper and cleaner as there is no frosting on the lenses, which cuts down the clarity of the LED light. Due to the clear lenses, more light can penetrate further which means they perform well in rooms with high ceilings.

It is noted that the above description of the light emitting diodes (LEDs) 50 is provided for illustrative purposes only, and is not intended to limit the present disclosure. For example, In some embodiments, other light sources may either be substituted for the LEDs 50, or used in combination with the LEDs 50, such as organic light-emitting diodes (OLEDs), a polymer light-emitting diode (PLED), and/or a combination of any one or more thereof.

Referring to FIGS. 1A and 1B, in some embodiments, the downlight 100 includes at least one interface on the lamp housing 100 for selecting a lumen setting and for selecting a correlated color temperature (CCT) setting for the light being emitted by the light engine 60 of the downlight 100. In some embodiments, the switch 15a, 15b for selecting each of the settings may be a toggle switch, a pushbutton switch, and/or a selector switch. Toggle switches are actuated by a lever angled in one of two or more positions. Pushbutton switches are two-position devices actuated with a button that is pressed and released. Selector switches are actuated with a rotary knob or lever of some sort to select one of two or more positions. Like the toggle switch, selector switches can either rest in any of their positions or contain spring-return mechanisms for momentary operation. It is noted that the above examples are provided for illustrative purposes only, and are not intended to limit the types of switches that are to be used in accordance with the present disclosure. Any switch used to interrupt the flow of electrons in a circuit can be suitable for use as a switch 15a, 15b for selecting settings for the lumen output of the light emitted by the downlight and/or selecting the correlated color temperature (CCT) of the light emitted by the downlight 100. In one example, a simplest type of switch is one where two electrical conductors are brought in contact with each other by the motion of an actuating mechanism.

Referring to FIGS. 1A and 1B, in one embodiment, the downlight includes a first switch 15a for selecting at least one lumen setting for the light emitted by the light engine 60; and a second switch 15b for selecting at least one correlated color temperature (CCT). In the embodiment that is depicted in FIGS. 1A and 1B, the first switch 15a may be positioned to select a lumen setting from three possible settings, e.g., a first lumen setting of 700 LM, a second lumen setting of 900 LM, and a third lumen setting 1500 LM. In the embodiment that is depicted in FIGS. 1A and 1B, the second switch 15b may be positioned to select a correlated color temperature (CCT) setting from three possible settings, e.g., a first correlated color temperature (CCT) setting of 2700K, a second correlated color temperature (CCT) setting of 3500K, and a third correlated color temperature (CCT) setting 4000K. In the example, that is depicted in FIGS. 1A and 1B, the single downlight offers 9 unique combinations of light levels and color temperature settings.

It is noted that the number of selectable settings provided by the first and second switches 15a, 15b depicted in FIGS. 1A and 1B is provided for illustrative purposes only and is not intended to limit the present disclosure. For example, the number of selectable settings that may be selected using the

first and second switches **15a**, **15b** may be equal to 2, 3, 4, 5, 6, 7, 8, 9 and 10, as well as any range for the number of selectable settings including a lower limit provided by one of the aforementioned examples, and an upper limit provided by one of the aforementioned examples. Further, the values for the selectable settings, e.g., lumen settings and correlated color temperature (CCT) settings, are not limited to those described above and depicted in FIGS. **1A** and **1B**.

For example, the first switch **15a** may select at least one lumen setting, e.g., a set of three lumen settings, selected from 500 LM, 600 LM, 700 LM, 800 LM, 900 LM, 1000 LM, 1100 LM, 1200 LM, 1300 LM, 1400 LM, 1500 LM, 1600 LM, 1700 LM, 1800 LM, 1900 LM and 2000 LM, as well as any range for the lumens associated with the light emitted by the downlight including a lower limit provided by one of the aforementioned examples, and an upper limit provided by one of the aforementioned examples.

For example, the second switch **15b** may select at least one correlated color temperature (CCT) setting selected from 2500K, 2600K, 2700K, 2800K, 2900K, 3000K, 3100K, 3200K, 3300K, 3400K, 3500K, 3600K, 3700K, 3800K, 3900K, 4000K, 4100 K, 4200K, 4300K, 4400K and 4500K, as well as any range for the correlated color temperature (CCT) associated with the light emitted by the downlight including a lower limit provided by one of the aforementioned examples, and an upper limit provided by one of the aforementioned examples.

The first and second switch **15a** **15b** are mounted to the housing **10**. For example, the first and second switch **15a**, **15b** may be mounted to the backside surface of the housing **10**, which is opposite the face of the housing **10** that the trim **5**, in which the trim **5** is present about an opening through which the light emitted from the light engine **60** is directed. The backside surface of the housing **10** is positioned within the ceiling when the downlight **100** is installed. It is not necessary for every embodiment that the first and second switches **15a**, **15b** be mounted to the back surface of the housing **10**. In some embodiments, at least one of the first and second switches **15a**, **15b** may be mounted on the sidewall of the housing **10**, which is the portion of the housing between the back surface of the housing **10**, and the portion of the housing that the trim **5** is mounted to. In other embodiments, at least one of the first and second switches **15a**, **15b** may be mounted to the trim **5**.

In addition to the light engine being in electrical communication with the first and second switch for selecting settings for correlated color temperature and lumen setting, the light engine may also be in electrical communication with a receiver for receiving setting commands for dimming and intensity of the light being emitted by the lamp. In some embodiments, the dimming function may be controlled through a 0-10V dimming wall switch. The 0-10V dimming wall switch is remotely mounted from the housing **10** of the downlight **100**. The 0-10V dimming wall switch communicates with a 0-10V dimming circuit **71** in the electronics package **200** of the downlight **100**.

Referring to FIG. **6**, the 0-10V dimming circuit **71** is in electric communication with a 0-10V dimming input **72** that receives the signal from the 0-10V dimming wall switch. The 0-10V dimming circuit **71** is in electrical communication with the LEDs **50**, i.e., strings of LEDs **50** of the light engine **60**. The 0-10V dimming circuit **71** may be referred to as a 0-10 dimmable LED driver.

In lighting control applications, "0-10" describes the use of an analog controller to adjust the voltage in a 2-wire (+10 VDC and Common) bus connecting the controller to one or more LED drivers equipped with a 0-10 VDC dimming

input. A 0-10V dimmable LED driver includes a power supply circuit that produces approximately 10 VDC for the signal wires and sources an amount of current in order to maintain that voltage. The controlled lighting should scale its output so that at 10 V, the controlled light should be at 100% of its potential output, and at 0 V it should be at the lowest possible dimming level.

A 0-10V LED dimmable driver designs with a control chip. The 0-10V voltage changes, the power supply output current will change. For example, when the 0-10V dimming signal modulates to 0V, the output current will be 0, the brightness of the light will be off; when the 0-10V dimming modulates to maximum 10V, the output current will reach 100% power output, the brightness will be 100%.

The electronics package **200** including the receiver, i.e., input **72**, for the 0-10V wall switch may be mounted within the house **10**, as depicted in FIG. **4B**. In some embodiments, although not depicted in the supplied figures, at least some components of the electronics package **200** may be positioned outside the housing **10** in a remote electronics package.

Referring to FIG. **6**, in some embodiments the electronics package **200** for the downlight **100** may further include: EMI filter and surge protection **73**, bridge rectifier and filter **74**, flyback converter **75**, current switching scheme **76**, optical/magnetic isolation of the feedback **77**, LED strings, **60** and LED string switching scheme **78**.

The EMI filter and surge protection **73** portion of the electronics package **200** includes an EMI filter to filter the high frequency noise generated by the flyback converter from entering the mains input terminals of line and neutral. The surge protector protects the lamp from the surge caused by events such as lightning and disturbances on the mains grid. The Surge protector absorbs the energy and limits the peak voltage to a safe level.

The bridge rectifier and filter **74** portion of the electronics package **200** includes a bridge rectifier that rectifies the AC input voltage into a pulsating DC voltage. The filter filters the high frequency noise.

The flyback converter **75** portion of the electronics package **200** contains the flyback transformer, switch, flyback controller, starting resistor, secondary rectifier and ripple current filter. This section of the electronics package **200** generates the required voltage and current as per the need of the LED strings **50**. This section also provides the necessary isolation between the input and output.

The current switching scheme **76** portion of the electronics package **200** includes the switch **15a** that the user can control the lumen output of the downlight **200**. In some embodiments, this is done by changing the output current of the power supply going into the LEDs. The current switching circuit consists of a network and combination of different values of current sense resistors. Depending on the switch position specific part of the circuit is activated and the sense resistors in that branch circuit determines the current flowing into the power supply output and hence the LEDs **50**. The switching scheme **76** changes the feedback signal into the controller IC **75** based on the position of the switch **15a**. The IC will control the current based on that feedback signal.

The optical/magnetic isolation circuit **77** portion of the electronics package **200** provides electrical isolation of the control signal from the 0 to 10V dimming circuit **71** going into the flyback controller IC. In some instances, this isolation can provide for the safety of the user when installing or operating the 0 to 10V dimmer.

The 0 to 10V dimming circuit **71** of the electronics package **200** accepts the input from the 0 to 10V dimmer and

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generates corresponding signal for the flyback controller IC. This enables the change of output current from power supply going into LEDs to be controlled by the external 0 to 10V dimmer.

The LED string **50** portion of the electronics package **200** includes the circuitry to the number of LEDs, and the number of LED strings. The LED type, e.g., color temperature, can be chosen based on the requirement for the light output characteristics. These LED strings are driven by the voltage and current generated by the flyback converter and they generate the required optical characteristics.

LED string switching scheme **78** portion of the electronics package **200** is a circuit determines which string, i.e., string of LEDs **50**, is operating based on the users' selection of the switch position **15a**, **15b**. Accordingly, it may operate just one string of LEDs **50**, or more than one string of LEDs **50** based on the correlated color temperature (CCT) setting of the switch **15b**. In the example provided in FIGS. 1A and 1B, in which the switch **15b** for selecting the correlated color temperature (CCT) of the downlight **100** has three selectable positions, i.e., three positions for color correlated temperature (CCT) values that are equal to 2700K, 3500K and 4000K. In some examples, each setting that can be selected by the switch **15b** may energize a different LED string of LEDs **50** for each of the three different color correlated temperature (CCT) values. In another embodiment, the lamp interface, i.e., switch **15b**, may offer three light color options (CCTs of 2700K/3500K/4000K), but the design of the light engine **60** may only include two strings of LEDs, e.g., only a first string of LEDs **50** having a correlated color temperature (CCT) of 2700K and second string of LEDs **50** having a correlated color temperature (CCT) of 4000K. In this example, when a user selects the 3500K setting from the switch **15b**, this light color is achieved by mixing light from both the 2700K and 4000K LEDs, which is achieved by the LED string switching scheme.

In one example, to achieve light levels 700 LM, 900 LM and 1500 LM, as well selectable correlated color temperature (CCT) levels of 3000 k, 3500 k, and 4000K, the following LED type and circuit can be employed: 1) the LED type may be lumileds 6V (forward voltage of LEDs) & 1 W LEDs, and 20 LEDs of CCT 3000K in 2 parallel strings of 10 LEDs in series, and 20 LEDs of CCT 4000K in 2 parallel strings of 10 LEDs in series to provide a total quantity of 40 LEDs.

The downlight design depicted in FIGS. 1A, 1B, 4A and 4B is only one embodiment of the present disclosure, and it is not intended that the present disclosure be limited to only this example. For example, in addition to switches being fixed to the housing **10** of the downlight for selecting lighting characteristics, embodiments of the present disclosure combine this capability with lighting controls through toggling of a remote "ON/OFF" switch,

FIG. 2 depicts one embodiment of a lamp design including a housing **10** having a downlight geometry and a light engine **60** including at least one string of light emitting diodes (LEDs), in which the lamp also includes a switch **15a** for selecting at least one lumen setting for the light emitted by the light engine **60** fixed to the housing, an "ON"/"OFF" wall switch **90** for selecting at least one correlated color temperature (CCT), and a remote dimmer switch **95**, i.e., 0-10V dimmer wall switch, for adjusting the dimming/intensity of the light emitted by the lamp. The housing **10**, the light engine **60** (including the LEDs **50**), the switch **15a** and the remote dimmer switch **95** have all been described above for the embodiments described with reference to FIGS. 1A, 1B and 4A-6. The description of those elements

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with reference to FIGS. 1A, 1B and 4A-6 can provide at least one embodiment of these elements for the same structures in FIG. 2. For example, the light levels emitted by the downlight **100**, i.e., lumen values, can be adjusted via the switch **15a** on the back of the unit. In one example, the selectable lumen levels of light may be equal to 700 LM, 900 LM and 1500 LM.

In the embodiment that is depicted in FIG. 2, the correlated color temperature (CCT) of the light being emitted by the downlight may be selecting through a wall ON/OFF switch. In one example, when the light engine **60** is configured to provide for three selectable correlated color temperatures (CCTs), which can include 2700K, 3500K, and 4000K, the light color (CCT) is switched between the three options by flipping the wall ON/OFF switch until the desired CCT is selected.

FIG. 3 depicts one embodiment of a lamp design including a housing **10** having a downlight geometry and a light engine **60** including at least one string of light emitting diodes (LEDs), in which the lamp also includes a switch **15b** for selecting at least one correlated color temperature (CCT) setting for the light emitted by the light engine fixed to the housing, an "ON"/"OFF" wall switch for selecting at least one lumen setting for light emitted by the lamp, and a remote dimmer switch for adjusting the dimming/intensity of the light emitted by the lamp.

The housing **10**, the light engine **60** (including the LEDs **50**), the switch **15b** and the remote dimmer switch **95** have all been described above for the embodiments described with reference to FIGS. 1A, 1B and 4A-6. The description of those elements with reference to FIGS. 1A, 1B and 4A-6 can provide at least one embodiment of these elements for the same structures in FIG. 2. For example, the correlated color temperature (CCT) values for the light emitted by the downlight **100** can be adjusted via the switch **15b** on the back of the unit. In one example, the selectable correlated color temperature (CCT) values of light may be equal to 2700K, 3500K and 4000K.

To provide for switching between light modes, i.e., different settings for light lumens and correlated color temperature of light, being emitted by the downlight using an ON/OFF light switch **90**, as described with reference to FIGS. 2 and 3 the downlight **100** may have to employ a driver **124** having a design similar to that depicted in FIG. 7.

The switch **90** may be in wired or wireless communication with the downlight **100**. In some embodiments, when the downlight **100** is turned on initially by toggling the switch **90** to its ON position, the downlight **100** will enter its first emission mode **127** e.g., a first correlated color temperature of 2700K or a first lumen level of 700 LM. If the downlight **100** is then turned off (by toggling the switch **90** into its off position) and on again (by toggling the switch **90** to its on position) within a specified time window, the downlight **100** can enter the second emission mode **128**, e.g., a second correlated color temperature of 3500K or a second lumen level of 900 LM. If the downlight **100** is thereafter turned off again (by toggling the switch **90** into its off position) and on again (by toggling the switch **90** to its on position) within a specified time window, the downlight **100** can enter the third emission mode **129**, e.g., a third correlated color temperature of 4000K or a third lumen level of 1500 LM. If the downlight **100** is thereafter turned off again (by toggling the switch **90** into its off position) and on again (by toggling the switch **90** to its on position) within a specified time window, the downlight **100** will return to the

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first emission mode **127**, e.g., a first correlated color temperature of 2700K or a first lumen level of 700 LM.

The duration of each of time window for toggling the switch **90** to change lighting modes may be customized, as desired, and in at least some cases may be about 3 seconds or less. For example, in some embodiments, the duration of the time windows may be about 2.5 seconds or less. In another example, the duration of the time windows may be about 2 seconds or less. In yet another example, the duration of each of the time windows may be about 1.5 seconds or less. In some instances, either (or both) the first and second time windows may be user-programmable.

Referring to FIG. 7, in some embodiments, the driver **124** may be a single-channel or multi-channel electronic driver configured to drive the solid state light emitters, e.g., LEDs of the first and second strings of LEDs **50a**, **50b**, utilizing pulse-width modulation (PWM) dimming or any other suitable standard, custom, or proprietary driving techniques. As further shown in FIG. 7, the driver **124** may include a controller **130**. In accordance with some embodiments, the driver **124** may be configured to provide a downlight **100** with a three-mode operation; that is, the driver **124** may provide downlight **100** with: (1) a first emission mode **127** e.g., a first correlated color temperature of 2700K or a first lumen level of 700 LM; (2) a second emission mode **128**, e.g., a second correlated color temperature of 3500K or a second lumen level of 900 LM; and (3) a third emission mode **129**, e.g., a third correlated color temperature of 4000K or a third lumen level of 1500 LM.

In some embodiments, the downlight **100** having the three aforementioned light modes, i.e., first emission mode **127**, a second emission mode **128**, and third emission mode **129** (having settings set depending upon being practiced in the embodiments illustrated in FIG. 2 or 3) depending upon the application to the driver **124** to the embodiments depicted in FIGS. 2 and 3 may be driven by the driver **124** including a controller **130** configured to support mode changing for the lamp **100** based, in part or in whole, on hysteresis. For example, mode changing of the downlight **100** may be based, in part or in whole, on the hysteresis phenomena of a switch **90**, e.g., light switch, in operation toggling between ON and OFF electrical states. In accordance with some embodiments, the output of LEDs for the first and second string of LEDs **50a**, **50b**, and thus the downlight **100** may be electronically controlled by controller **130**. To such ends, the controller **130** may be operatively coupled with the LEDs of the first and second string of LEDs **50a**, **50b** (or light engine **69** more generally), for instance, by a communication bus or other suitable interconnect. In some embodiments, the controller **130** may be configured to communicate with the LEDs, i.e., solid state light emitters, via any one, or combination, of suitable standard, custom, or proprietary wired or wireless digital communications protocol.

In accordance with some embodiments, the first emission mode **127**, the second emission mode **128**, and the third emission mode **129** (having settings set depending upon being practiced in the embodiments illustrated in FIG. 2 or 3) of the controller **130** may be implemented in any suitable standard, custom, or proprietary programming language, such as, for example, C, C++, objective C, JavaScript, or any other suitable instruction set, as will be apparent in light of this disclosure. The module(s) of controller **130** can be encoded, for example, on a machine-readable medium that, when executed by a processor, carries out the functionality of downlight **100**, in part or in whole. The computer-readable medium may be, for example, a hard drive, a compact disk, a memory stick, a server, or any suitable

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non-transitory computer or computing device memory that includes executable instructions, or a plurality or combination of such memories. Some embodiments can be implemented, for instance, with gate-level logic, an application-specific integrated circuit (ASIC) or chip set, or other such purpose-built logic. Some embodiments can be implemented with a microcontroller having input/output capability (e.g., inputs for receiving user inputs; outputs for directing other components) and embedded routines for carrying out device functionality. In a more general sense, the functional modules of controller **130** can be implemented in any one, or combination, of hardware, software, and firmware, as desired for a given target application or end-use.

Moreover, in some embodiments, a given module of controller **130** (or controller **130** more generally) may be programmable to achieve any of the various functions and emissions capabilities desired of downlight **100** for a given target application or end-use. The present disclosure is not intended to be limited only to these example lighting control modules and output signals; as additional and/or different lighting control modules and output signals may be provisioned, as desired for a given target application or end-use.

Further, it is not intended to be limited only to drivers **124** including these specific example controllers **130**. In a more general sense, and in accordance with some other embodiments, controller **130** can be any power supply controller IC or microcontroller having the ability to sense the operation of the input power (e.g., based on the on/off state of switch **90**, discussed below) while maintaining a hysteresis from on-to-off and off-to-on control, with LED string control being provided by controlling the on/off state of the LEDs in the first and second string of LEDs **50a**, **50b**. In some still other cases, controller **130** may be a microcontroller programmed to receive a control input from a wired or wireless source other than, or in addition to, a switch (e.g., such as switch **90**) and accordingly generate a target mode of lighting, e.g. the first emission mode **127**, the second emission mode **128**, and the third emission mode **129** (having settings set depending upon being practiced in the embodiments illustrated in FIG. 2 or 3), by controlling the duty cycle of the first and second string of LEDs **50a**, **50b**.

Returning to FIG. 7, the downlight **100** optionally may include a communication module **126**, which may be configured as a transmitter, a receiver, or both (i.e., a transceiver). In some cases, communication module **126** may be separate and distinct from controller **130** (e.g., as generally shown in FIG. 7), though in some other cases, communication module **126** may be a component of or otherwise integrated with controller **130**. In accordance with some embodiments, controller **130** may be configured to output control signal(s) to the first and second strings of LEDs **50a**, **50b** based, at least in part, on input received from a remote source, such as a control interface **140**. Control interface **140** may be physical, virtual, or a combination thereof and may be configured to communicate with the controller **130** (via intervening communication module **126**), which in turn interprets input received from control interface **140** distributes desired control signal(s) to the first and second strings of LEDs **50a**, **50b** of the light engine **60**.

In some embodiments, the control interface **140** may be employed, in accordance with some embodiments, in changing the emissions modes of downlight **100**. In some embodiments, the control interface **140** interacts with the switch **90**, e.g., over the communications module **126**, as the switch toggles from the ON and Off electrical states, and provides the signal to the driver **124**. The driver **124** receiving the signal from the control interface employing the controller

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**130** sends a signal to illuminate either the string of LEDs **50a**, **50b** to provide the first emission mode **127**, the second emission mode **128**, or the third emission mode **129** (having settings set depending upon being practiced in the embodiments illustrated in FIG. 2 or 3).

To such ends, the communication module **126** and control interface **140** may be configured for wired or wireless communication (or both) utilizing any one, or combination, of suitable means, such as Universal Serial Bus (USB), Ethernet, FireWire, Wi-Fi, Bluetooth, or ZigBee, among others. Optionally, the control interface **140** may be or otherwise employ a touch-sensitive display or surface, such as a touchpad or other device with a touch-based user interface (UI) or graphical UI (GUI), as provided by a computing device, mobile or otherwise. Other suitable configurations for the communication module **126** and the control interface **65** will depend on a given application.

In another aspect, a lighting method is provided. The lighting method includes housing a light source, e.g., light engine **60**, including at least one string of light emitting diodes **50** in a body of a lamp having a downlight geometry. The method also includes providing device circuitry, as depicted in FIGS. 6 and 7, that allows for adjustments to lumen settings and correlated color temperature settings through an interface of setting switches fixed to the body of the lamp. The method also includes providing a receiver for receiving from a remote switch **90**, **95** adjustments to dimming and intensity settings for light emitted by the lamp. Before installing the downlight **100**, based on the application space, the lighting designer may determine the desired light output and the light color needs. Using the light level switch **15a**, and the light color level switch **15b** on the back of the unit, as depicted in FIGS. 1A and 1B, the installer selects appropriate levels for the light output and the light color levels for the downlight **100**. The user may then install the downlight **100**. As needed by the application space, the light levels and/or the light color levels can be changed by uninstalling the unit and adjusting the switches to the desired settings.

It is to be appreciated that the use of any of the following “/”, “and/or”, and “at least one of”, for example, in the cases of “A/B”, “A and/or B” and “at least one of A and B”, is intended to encompass the selection of the first listed option (A) only, or the selection of the second listed option (B) only, or the selection of both options (A and B). As a further example, in the cases of “A, B, and/or C” and “at least one of A, B, and C”, such phrasing is intended to encompass the selection of the first listed option (A) only, or the selection of the second listed option (B) only, or the selection of the third listed option (C) only, or the selection of the first and the second listed options (A and B) only, or the selection of the first and third listed options (A and C) only, or the selection of the second and third listed options (B and C) only, or the selection of all three options (A and B and C). This may be extended, as readily apparent by one of ordinary skill in this and related arts, for as many items listed.

Spatially relative terms, such as “forward”, “back”, “left”, “right”, “clockwise”, “counter clockwise”, “beneath”, “below”, “lower,” “above,” “upper,” and the like, can be used herein for ease of description to describe one element’s or feature’s relationship to another element(s) or feature(s) as illustrated in the FIGs. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the FIGs.

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Having described preferred embodiments of a downlight having selectable lumens settings and selectable correlated color temperature (CCT), it is noted that modifications and variations can be made by persons skilled in the art in light of the above teachings. It is therefore to be understood that changes may be made in the particular embodiments disclosed which are within the scope of the invention as outlined by the appended claims. Having thus described aspects of the invention, with the details and particularity required by the patent laws, what is claimed and desired protected by Letters Patent is set forth in the appended claims.

What is claimed is:

1. A lamp comprising:

a housing having a downlight geometry and a light engine including at least one string of light emitting diodes (LEDs), in which the light engine is positioned to emit light through a light emission end of the housing having the downlight geometry;

an electronics package for the light engine enclosed within the housing, wherein power wiring to the electronics package extends directly through a sidewall portion of the housing;

at least one first switch for selecting at least one lumen setting for the light emitted by the light engine; and

at least one second switch for selecting at least one correlated color temperature, wherein the first and second switch are positioned on the housing, wherein the at least one first switch and the at least one second switch are mounted on an exterior face of a back surface of the housing.

2. The lamp recited in claim 1 further comprising a dimming circuit for dimming the light emitted by the lamp in response to signal from a 0-10V dimming switch.

3. The lamp recited in claim 1, wherein the light emitting diodes are surface mount device (SMD) light emitting diodes (LED).

4. The lamp as recited in claim 1, wherein the light emitting diodes are chip on board (COB) light emitting diodes.

5. The lamp as recited claim 1, wherein the first switch has three selectable settings of 700 LM, 900 LM and 1500 LM.

6. The lamp as recited in claim 1, wherein the second switch has three selectable settings of 2700K, 3500K and 4000K.

7. A lamp comprising:

a housing having a downlight geometry and a light engine including at least one string of light emitting diodes (LEDs), in which the light engine is positioned to emit light through a light emission end of the housing having the downlight geometry;

an electronics package for the light engine enclosed within the housing, wherein power wiring to the electronics package extends directly through a sidewall of the housing;

a switch positioned on the housing for selecting a first setting for the light emitted by the light engine, wherein the switch positioned on the housing for selecting the first setting is mounted on an exterior face of a back surface of the housing; and

a receiver for receiving signal from a remote ON/OFF switch, wherein the signal from the remote ON/OFF switch selects a second setting for light emitted by the light engine, wherein the first and second settings are selected from the group consisting of lumen level, color correlated temperature or a combination thereof.

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8. The lamp recited in claim 7 further comprising a dimming circuit for dimming the light emitted by the lamp in response to signal from a 0-10V dimming switch.

9. The lamp recited in claim 7, wherein the light emitting diodes are surface mount device (SMD) light emitting diodes (LED).

10. The lamp as recited in claim 7, wherein the light emitting diodes are chip on board (COB) light emitting diodes.

11. The lamp as recited claim 7, wherein the switch positioned on the housing has three selectable settings of 700 LM, 900 LM and 1500 LM.

12. The lamp as recited in claim 7, wherein the switch positioned on the housing has three selectable settings of 2700K, 3500K and 4000K.

13. The lamp as recited in claim 7, wherein receiver for receiving signal from the remote ON/OFF switch receives said signal for one of three selectable settings of 700 LM, 900 LM and 1500 LM.

14. The lamp as recited in claim 7, wherein receiver for receiving signal from the remote ON/OFF switch receives said signal for one of three selectable settings of 2700K, 3500K and 4000K.

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15. A lighting method comprising:

housing a light source including at least one string of light emitting diodes in a body of a lamp having a downlight geometry, the housing enclosing an electronics package for the light source, wherein power wiring to the electronics package extends directly through a sidewall of the housing; and

providing device circuitry that allows for adjustments to lumen settings and correlated color temperature settings through an interface of setting switches fixed to the body of the lamp, wherein the setting switches are mounted on an exterior face of a back surface of the body of the lamp.

16. The method recited in claim 15, wherein the method further comprises providing a receiver for receiving from a remote switch adjustments to dimming and intensity settings for light emitted by the lamp.

17. The method recited in claim 15, wherein the light emitting diodes are surface mount device (SMD) light emitting diodes (LED).

18. The method recited in claim 15, wherein the light emitting diodes are chip on board (COB) light emitting diodes.

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